North American Oil Sands Corporation
A wholly-owned affiliate of StatoilHydro ASA
Upgrader Project

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APPENDICES

5 HYDROGEOLOGY

5.1 Introduction

This section of the EIA describes baseline hydrogeological conditions and identifies components of the Upgrader Project that will potentially affect groundwater from a local and regional perspective.

5.2 Study Area

The hydrogeological study areas are shown on Figure 5.2-1.

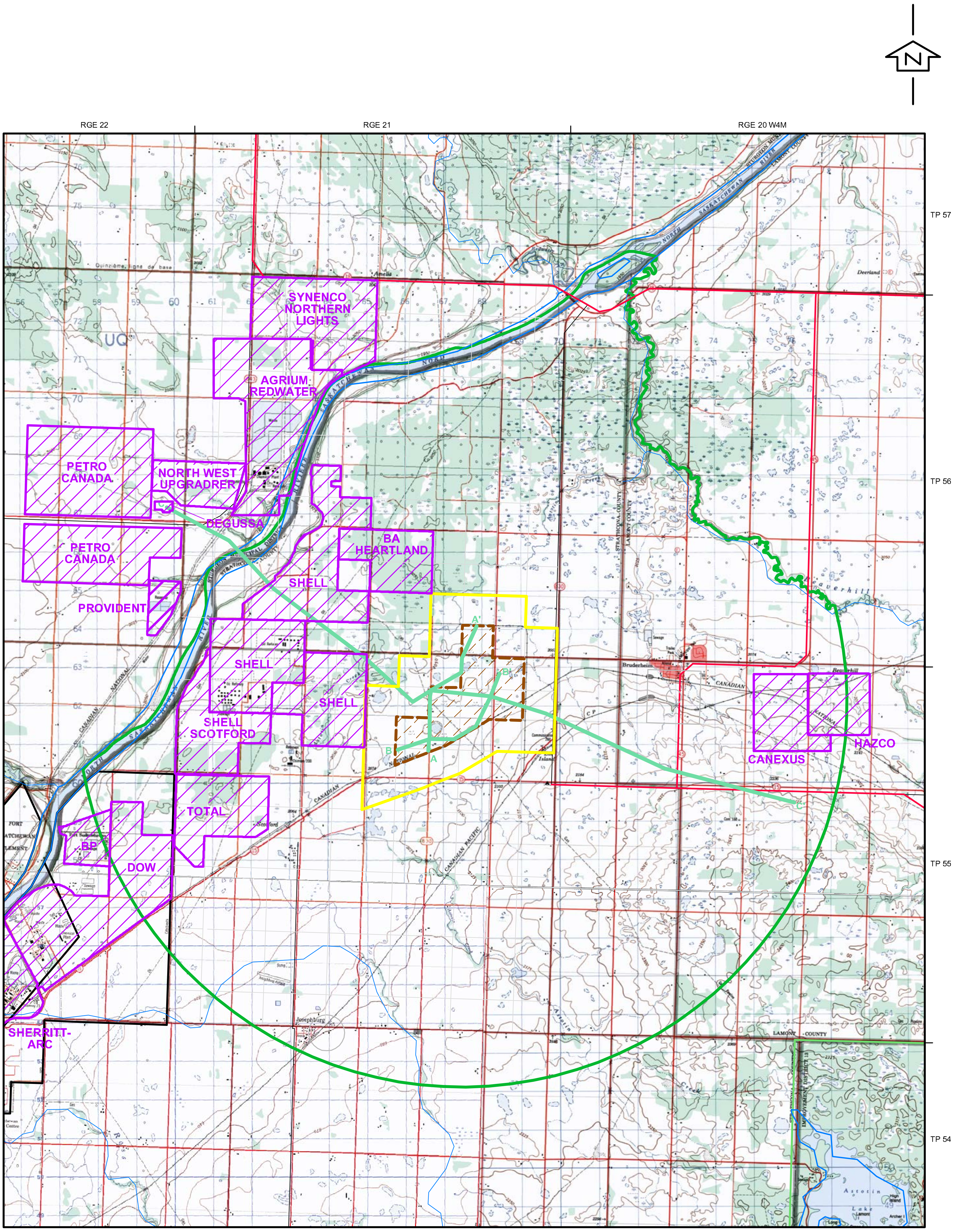
5.2.1 Local Study Area

The Local Study Area (LSA) comprises the North American lands plus an 800 m buffer surrounding the property (Figure 5.2-2). The LSA includes portions of Sections 22, 23, 25, 26, 27, 34, 35 and 36 of Township 55 Range 21 W4M, as well as portions of Sections 1 and 2 of Township 56 Range 21 W4M (Figure 5.2-2).

5.2.2 Regional Study Area

The Regional Study Area (RSA) is bounded to the west and north by the North Saskatchewan River (NSR) and to the north and east by Beaverhill Creek, as these surface waterbodies are interpreted to be shallow groundwater divides (Figure 5.2-1). The southern boundary of the RSA is located approximately 10 km from the centre of the North American lands, and was based on regional topography and the shallow interpreted groundwater flow direction.

*PLOT 1:1 = Letter (P)



NOTE:
ELEVATION CONTOURS: 25ft INTERVALS (10m INTERVALS IN SW PORTION OF MAP AREA)

SCALE 1:100000 kilometres
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LEGEND
🟨 LOCAL STUDY AREA (LSA)
🟩 REGIONAL STUDY AREA (RSA)
▬ ▬ PROPOSED NORTH AMERCIAN UPGRADER
🟪 OTHER EXISTING OR PROPOSED FACILITIES
▬ CROSS-SECTION LINE

REFERENCE MAP:
1:50 000, 83 H/10, 83 H/11, 83 H/14 AND 83 H/15.

Title:

HYDROGEOLOGICAL STUDY AREAS

NORTH AMERICAN
OIL SANDS CORPORATION

Approved: TVD
Revision Date: 07/11/23
File: 6198-SITE-07.DWG
Drawn by: BSW
Checked: RP
Fig. No.: 5.2-1

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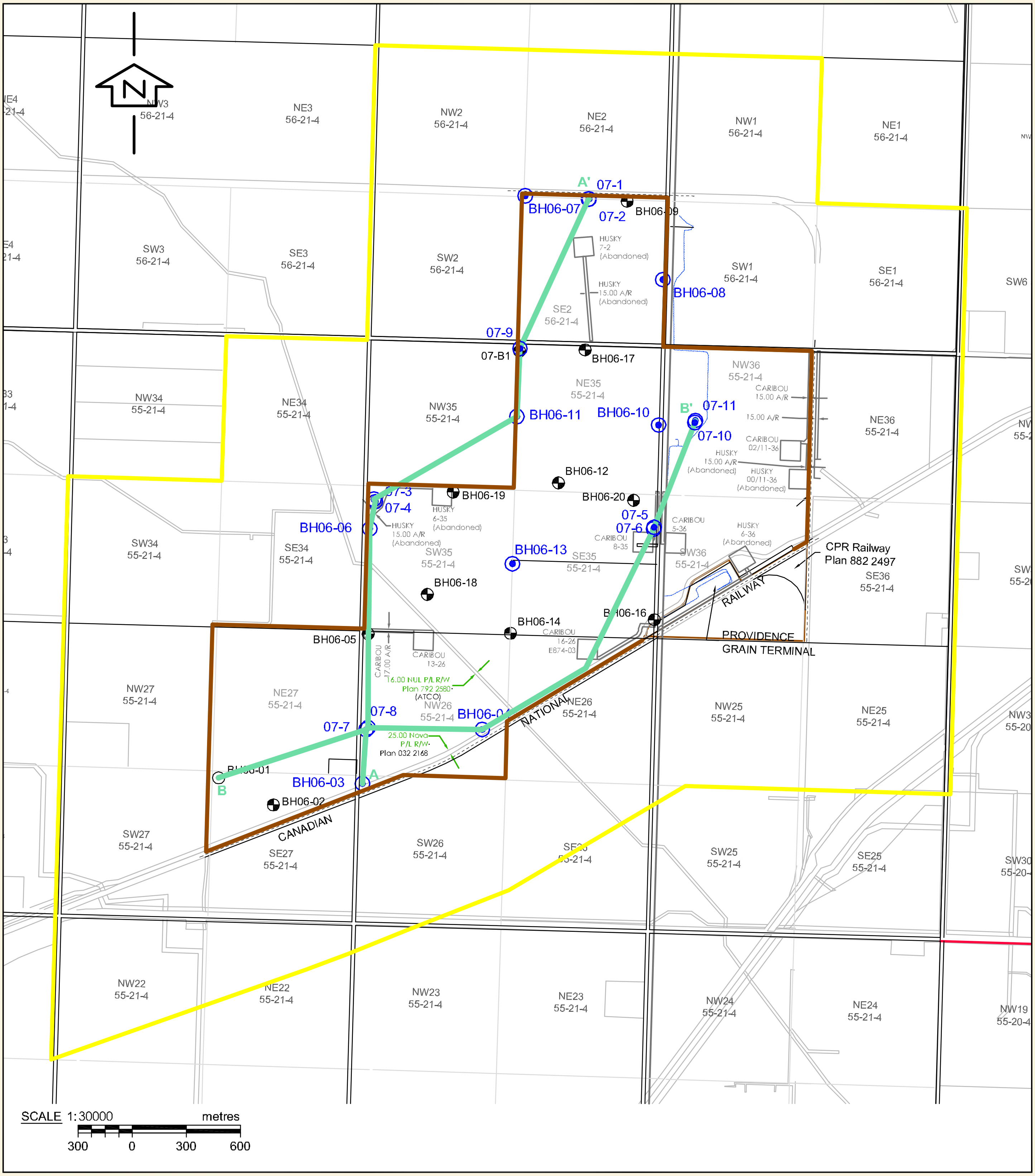
*PLOT 1:1 = Letter (P)



LEGEND

🟨 LOCAL STUDY AREA (LSA)

🟫 NORTH AMERICAN UPGRADER

🟩 CROSS SECTION

◐ BOREHOLE LOCATION

◉ MONITORING WELL LOCATION

Title:

HYDROGEOLOGICAL LOCAL STUDY AREA AND DRILLING LOCATIONS

NORTH AMERICAN OIL SANDS CORPORATION

Approved: TVD	Revision Date: 07/11/11
File: 6198-SITE-07.DWG	

Drawn by: AJG	Checked: RP	Fig. No.: **5.2-2**

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5.3 Issues and Assessment Criteria

Through the construction and operation phases of the Project, components which have the potential to affect groundwater resources include:

- The operation of surface facilities;
- dewatering of excavations during construction of the Upgrader; and
- groundwater withdrawal under the potentially contaminated pond and oily water pond during operation of the Project.

The assessment describes the potential impact to groundwater resources in terms of the following attributes:

- the direction of the impact;
- the geographic extent;
- the magnitude of impact;
- the duration of the impact;
- the confidence in the available information used to make the assessment; and
- the final impact rating.

A detailed description of the criteria for each of the attributes is located in Volume 2, Section 1.

The attributes were used to rank the potential severity of impact to each of the following resources:

- Shallow Overburden Aquifers;
- Lower Sand and Gravel Aquifer;
- Beverly Channel Aquifer; and
- Bedrock Aquifers.

The potential impact to each of the above resources was evaluated with respect to water quality and water levels (hydraulic head). Specific methods used to measure and evaluate the potential impacts to each aquifer (compared to their respective baseline conditions) are discussed in the following subsections.

5.4 Methods

5.4.1 Baseline Conditions

5.4.1.1 Literature Review

An investigation of baseline conditions at the site was conducted by supplementing existing literature with a site-specific hydrogeological investigation. The primary literature sources used for the hydrogeological investigation included the following:

- Environmental Impact Assessment for the BA Energy Inc. Heartland Oil Sands Processing Plant (Bitumen Upgrader) (BA Energy, 2004);
- Regional groundwater study of the Beverly Channel in the Fort Saskatchewan area (Stantec, 2006);
- Water Well Drilling Reports from the Alberta Environment Groundwater Information Centre (GIC, 2006);
- Quaternary stratigraphy of the Edmonton area (Andriashek, 1988);
- Report and map of the hydrogeology of the Edmonton area (Stein, 1976);
- Map of the Quaternary Geology of Central Alberta (Shetsen, 1990); and
- Map of the bedrock geology of Alberta (Hamilton et al., 1998).

5.4.1.2 Site-Specific Investigations

A geotechnical investigation was conducted at the site from November 20 to 26, 2006, and consisted of drilling 20 boreholes and installing 10 monitoring wells. A subsequent hydrogeological field investigation was conducted that consisted of drilling and installing additional monitoring wells and groundwater sampling.

5.4.1.3 Drilling and Installation of Monitoring Wells

Drilling was conducted from March 21 to 26, 2007, with a dual rotary drilling rig. The dual rotary rig is an air rotary rig equipped with a drilling shoe on the drill casing. A total of twelve boreholes were drilled and eleven monitoring wells were installed at six locations. The drilling locations are presented on Figure 5.2-2 and Table 5.4-1.

Table 5.4-1 Hydrogeological Study Drilling Locations

Borehole/Well	Legal Location	Easting (NAD83, Zone 12)	Northing (NAD83, Zone 12)
07-1	SE 02-056-21 W4M	367842.6	5964321.8
07-2	SE 02-056-21 W4M	367838.7	5964321.0
07-3	SW 35-055-21 W4M	366654.8	5962652.7
07-4	SW 35-055-21 W4M	366656.5	5962649.5
07-5	SE 35-055-21 W4M	368201.3	5962501.3
07-6	SE 35-055-21 W4M	368201.1	5962499.8
07-7	NE 26-055-21 W4M	366611.6	5961390.0
07-8	NE 26-055-21 W4M	366613.0	5961391.0
07-9	NE 35-055-21 W4M	367458.4	5963490.2
07-10	NW 36-055-21 W4M	368429.4	5963088.5
07-11	NW 36-055-21 W4M	368429.9	5963091.4
07-B1	NE 35-055-21 W4M	367458.0	5963490.0

All monitoring wells were completed with non-reactive polyvinyl chloride (PVC). In each well, the screen was connected to a solid riser pipe extending above the ground surface. The annular space between the screen and wellbore was backfilled with a filter pack. A bentonite seal was placed above the filter pack, extending to the ground surface in order to prevent the inflow of surface water. A protective metal surface casing with a locking cap was installed over the riser pipe. Completion details are provided in Table 5.4-2.

Table 5.4-2 Monitoring Well Summary

Monitoring Well	Elevation* (masl)			Depth (m)						Hydraulic Conductivity (m/s)	Method	Lithology of Screened Interval
			May 11/07				May 11/07					
	Ground Surface	Top of Casing	Water Level	Ground to Total Drilled	Ground to Top of Screen	Ground to Base of Screen	Top of Casing to Water	Ground to Water	Top of Casing to Product			
07-1	621.42	622.42	615.70	42.1	37.0	41.0	6.72	5.72	ND	---	---	clay, sandstone
07-2	621.42	622.47	617.70	19.3	16.3	19.3	4.77	3.72	ND	---	---	sand
07-3	623.20	624.44	destroyed 2007	31.1	27.1	31.1	---	---	---	---	---	sand, clay
07-4	623.17	624.32	614.61	18.1	15.1	18.1	9.71	8.56	ND	---	---	gravel and sand
07-5	627.65	628.55	620.47	34.3	27.0	30.0	8.08	7.18	ND	9.0E-09	H	sand and silt
07-6	627.62	628.65	620.68	18.7	15.3	18.3	7.97	6.94	ND	9.0E-05	T	gravel and sand
07-7	626.64	627.71	614.27	30.1	26.8	29.8	13.44	12.37	ND	---	---	sand
07-8	626.62	627.59	621.96	11.7	8.7	11.7	5.63	4.66	ND	1.0E-09	H	clay
07-9	624.26	625.22	622.43	12.1	9.1	12.1	2.79	1.83	ND	---	---	clay
07-10	624.66	625.61	620.43	26.1	12.5	15.5	5.18	4.23	ND	---	---	gravel and sand
07-11	624.60	625.54	621.21	11.7	7.7	10.7	4.33	3.39	ND	6.0E-09	H	clay
BH06-01	633.60	634.40	dry	10.4	3.5	5.5	---	---	---	---	---	silt, clayey sandy till
BH06-03	629.40	630.48	614.67	22.6	18.3	19.8	15.81	14.73	ND	---	---	sand, silty clay
BH06-04	628.70	629.75	625.33	10.4	6.6	9.6	4.42	3.37	ND	---	---	silty clay till
BH06-06	625.80	626.85	614.62	19.5	16.2	17.7	12.23	11.18	ND	---	---	sand
BH06-07	623.90	625.11	617.21	16.5	12.8	14.3	7.90	6.69	ND	---	---	silty clay till, sand
BH06-08	621.30	622.48	619.01	10.4	6.7	9.7	3.47	2.29	ND	---	---	clay, silty sand, silty clay till
BH06-10	623.70	624.84	622.00	21.1	8.9	11.9	2.84	1.70	ND	---	---	silty clay till,
BH06-11	624.40	625.51	622.53	10.4	2.4	5.5	2.98	1.87	ND	6.0E-09	H	silty clay till
BH06-13	627.20	628.34	625.81	10.4	3.4	6.4	2.53	1.39	ND	---	---	silty clay till
BH06-15	628.90	629.96	621.46	21.1	18.8	20.3	8.50	7.44	ND	---	---	sand

Notes:

*	- elevations are geodetic.
masl	- metres above sea level.
---	- not available.
ND	- not detected.
TH	- Theis method (1935).
H	- Hvorslev analysis method (1951).

5.4.1.4 Groundwater Sampling

Groundwater sampling was conducted from May 9 to 12, 2007. Static water levels were measured on May 9 and 10. Monitoring wells were purged prior to collecting groundwater samples. Samples were collected on May 11 using dedicated bailers, preserved in ice-filled coolers and transferred to a certified laboratory for analyses.

Field-measured parameters at each monitoring well consisted of temperature, pH, electrical conductivity (EC) and dissolved oxygen (DO). Laboratory analyses included routine parameters, dissolved metals, benzene, toluene, ethylbenzene and xylenes (BTEX), petroleum hydrocarbon (PHC) fraction 1 (F1; C_6-$C_{10,}$ excluding BTEX) and fraction 2 (F2; $C_{>10}$-C_{16}).

In addition, hydraulic response tests were conducted on monitoring wells 07-5, 07-6, 07-8, 07-11 and BH06-11. A description of the methodology and results of the hydraulic response testing are provided in Appendix 5A.

5.4.2 Methods for Impact Assessment

5.4.2.1 Assessment of Potential Impacts to Water Levels

An assessment was completed of potential impacts to water levels due to dewatering of excavations during construction, and groundwater withdrawal during the operational lifetime of the Upgrader. Geotechnical and hydrogeological borehole information, hydraulic heads, hydraulic conductivity estimates and previously published information were referenced for the assessment.

Dewatering of the open excavations may be conducted during construction activities, which could result in a decline in groundwater levels surrounding these excavations. A solution to this problem in one dimension is given in McWhorter and Sunada (1977):

$$s = s_0 \bullet erfc\left[\frac{x}{\sqrt{4\alpha t}}\right]$$

where:

x = distance from the excavation (L)
s = predicted water level change at distance x (L)
s_0 = change in water level at the excavation (L)
erfc = complementary error function
t = time (T)

and:

$$\alpha = \frac{K}{S_s}$$

where:

α = hydraulic diffusivity (L^2/T)
K = the hydraulic conductivity (L/T)
S = specific storage (L^{-1})

The following values were used to determine the maximum impacts resulting from dewatering of excavations during construction of the Upgrader:

- a drawdown at the excavation (s_0) of 6 m;
- a total dewatering time of 180 days (6 months);
- the maximum hydraulic conductivity estimate for the clay till of 6 x 10^{-9} m/s; and
- a specific storage value for the clay till of 1 x 10^{-3} m^{-1} was calculated based on an assumed porosity of 0.15 and a medium-hard clay compressibility of 1 x 10^{-7} m^2/N (Domenico and Schwartz, 1997).

The following values were used to determine the maximum impacts resulting from groundwater withdrawal under the potentially contaminated and oily water ponds:

- a drawdown at the ponds (s_0) of 6.1 m;
- a total dewatering time of 50 years;
- the maximum hydraulic conductivity estimate for the till of 6 x 10^{-9} m/s; and
- a specific storage value for the clay till of 1 x 10^{-3} m^{-1} was calculated based on an assumed porosity of 0.15 and a medium-hard clay compressibility of 1 x 10^{-7} m^2/N (Domenico and Schwartz, 1997).

5.5 Existing Conditions

5.5.1 Topography and Drainage

The Project site lies at an elevation of approximately 625 m above sea level (masl). The topography of the RSA is gently undulating and slopes regionally towards the NSR to the northwest. The highest elevation, of approximately 735 masl, occurs in the southeast portion of the RSA. The lowest elevation, of approximately 594 masl, occurs at the NSR (Figure 5.2-1).

Drainage within the RSA generally flows north towards the NSR. Astotin Creek, located in the northwest corner of the LSA, is the nearest permanent stream to the Project site, and drains into Beaverhill Creek. Topographic contours within the LSA are presented on Figure 5.5-1. Topography within the LSA is gently undulating, and a number of topographical depressions (wetlands) are present.

5.5.2 Regional Geology

The uppermost bedrock geology in the Fort Saskatchewan area consists of Upper Cretaceous deposits. Surficial deposits consist of Quaternary sediments, including fluvial, eolian and lacustrine deposits, as well as glacial tills. The following section provides a regional geological description from oldest to youngest.

A stratigraphic column of the RSA is presented on Figure 5.5-2. Regional cross-section C-C′ indicates the upper bedrock and major surficial deposits underlying the proposed Upgrader site relative to the RSA (Figure 5.5-3). The cross-section line is indicated on Figure 5.2-1. The drilling logs are presented in Appendix 5B.

5.5.3 Bedrock Geology

The upper bedrock geology in most of the RSA consists of the Oldman Formation of the Belly River Group. However, the southeast region of the RSA includes the subcrop edges of the Bearpaw Formation and the Horseshoe Canyon Formation (Figure 5.5-4). A description of the upper bedrock formations is provided below.

A major top of bedrock feature within the RSA is the buried Beverly Channel. The Beverly Channel is a major preglacial buried fluvial channel, with local bedrock relief of up to 60 m and a width of 4 km to 10 km in Strathcona County (Agriculture and Agri-Food Canada, 2001). Locally, the Beverly Channel is interpreted to be 7 km to 8 km wide (Stantec, 2006). The Project site is interpreted to overlie a bedrock terrace adjacent to the Beverly Channel (Figure 5.5-3). Within the LSA, the top of bedrock structure decreases to the northwest towards the buried Beverly Channel.

5.5.3.1 Belly River Group

The Belly River Group consists of the Oldman Formation and the Foremost Formation. Sediments of the Belly River Group are primarily of fluvial origin, consisting of medium to fine-grained sandstone and siltstone, with minor mudstone and coal (Mossop and Shetsen, 1994). The Foremost Formation underlies the Oldman Formation and consists of sandstone and shale units, as well as the McKay and Taber coal zones (Agriculture and Agri-Food Canada, 2001). The Oldman Formation has a maximum thickness of 120 m in the study area, and is composed of sandstone, siltstone, shale and coal. The formation contains three members, identified as the Comrey, Upper Siltstone and Dinosaur Members (Agriculture and Agri-Food Canada, 2001). The regional dip of the Upper Cretaceous beds is approximately 2^{o} to the southwest (Hamilton et al., 1999).

5.5.3.2 Bearpaw Formation

The Bearpaw Formation overlies the Belly River Group, and has a thickness of 80 m to 100 m in the north-central part of Strathcona County (Agriculture and Agri-Food Canada, 2001). Sediments of the Bearpaw Formation are primarily laminated shale and siltstone, with some sandstone beds and lenses of kaolinic claystone (Mossop and Shetsen, 1994).

5.5.3.3 Horseshoe Canyon Formation

The Horseshoe Canyon Formation is part of the Edmonton Group, and overlies the Bearpaw Formation. The Horseshoe Canyon Formation consists of interbedded sandstone, siltstone and mudstone, with up to ten potentially economic coal seams (Mossop and Shetsen, 1994). Within the RSA, only the Lower Horseshoe Canyon Formation is present, which can include coarser-grained sandstone deposits (Agriculture and Agri-Food Canada, 2001).

5.5.4 Surficial Geology

Unconsolidated surficial sediments in the area consist of preglacial, glacial lacustrine, eolian and fluvial deposits (Shetsen, 1990). A map detailing the uppermost Quaternary geology is presented on Figure 5.5-5. Surficial deposits are generally less than 30 m thick in the region, with the exception of the sediments overlying the Beverly Channel, which can reach 50 m in thickness (Agriculture and Agri-Food Canada, 2001). A description of the surficial units within the RSA is presented in the following subsections.

5.5.4.1 Empress Formation

The Empress Formation is defined as all stratified sediments that rest on bedrock and are covered by the first occurrence of glacial till (Andriashek, 1988). These drift sediments consist of "stratified gravel, sand, silt and clay of fluvial, lacustrine and colluvial origin" (Whitaker and Christiansen, 1972), and exist within incised channels and on bedrock terraces. Within the RSA, the Empress Formation is present within the Beverly Channel and on the bedrock terrace to the southeast of the channel. The deposits within the Beverly Channel follow a sedimentary sequence of gravel grading to sand, and finally to silt and clay. The Empress Formation deposits are less than 20 m in thickness (Stantec, 2006). The extent of the Beverly Channel is presented on Figure 5.5-6, as estimated by Stein (1976).

5.5.4.2 Glacial Till

Glacial till deposits are unstratified and unsorted deposits of clay, silt, sand and gravel. These deposits are identified throughout the RSA. The top surface of the glacial till unit is gently to moderately undulating in the region. The thickness of glacial till varies from 0 m to 30 m in the region (Stantec, 2006). Glacial moraine deposits are reported to cover the southeast portion of the RSA, including the south half of the LSA (Figure 5.5-5). Minor sand and gravel deposits are also reported within the glacial till unit.

5.5.4.3 Lacustrine Deposits

A lacustrine clay unit within the RSA has been interpreted as being deposited near the shore of the ancient Lake Edmonton (BA Energy, 2004). The unit is primarily composed of clay and silt, with interspersed sand lenses. The clay unit is generally underlain by glacial till, and has a maximum thickness of greater than 15 m in the RSA (Stantec, 2006). A coarse-grained lacustrine deposit is reported to extend into the northern half of the LSA from the east (Figure 5.5-5).

5.5.4.4 Eolian Deposits

Eolian deposits form the surficial unit in much of the northwest portion of the RSA. The unit consists of loose, fine- to medium-grained sands, with interspersed lacustrine clay layers (Stantec, 2006). These eolian deposits extend into the northwest portion of the LSA (Figure 5.5-5).

5.5.5 Local Geology

The interpretation of the geology at the site is based on borehole records obtained from the geotechnical investigation conducted in the fall of 2006 and the hydrogeological investigation conducted in the spring of 2007. The drilling locations for the hydrogeological and geotechnical investigations are presented on Figure 5.2-2. The geology at the site, from oldest to youngest, consists of:

- Bedrock deposits
    - Sandstone/siltstone/claystone
- Surficial deposits
    - Lower sand and gravel unit
    - Clay till unit
    - Surficial sand unit

Two geologic cross-sections in the LSA are presented on Figures 5.5-7 and 5.5-8. Cross-section A-A′ runs approximately south to north through the site, while cross-section B-B′ runs approximately southwest to northeast through the site. The drilling locations and geological cross-section lines are illustrated on Figure 5.2-2.

5.5.5.1 Bedrock

The upper bedrock encountered during drilling was highly weathered, and was interpreted to underlie directly a sand and gravel unit which was present across the LSA. Ten boreholes were interpreted to be drilled into bedrock.

Based on the drilling program conducted at the site, the depth to bedrock ranged between 14.5 m and 22.3 m below ground surface (bgs). Based on these results, the bedrock elevation ranged from 603.6 masl to 610.2 masl. Bedrock topography within the LSA is presented on Figure 5.5-9, and is generally consistent with that presented in Stantec (2006) and Andriashek (1988).

Bedrock lithology was primarily fine-grained sandstone with interbedded siltstone and claystone (Figures 5.5-7 and 5.5-8). The lithology encountered underlying the site is consistent with descriptions of the Oldman Formation (Agriculture and Agri-Food Canada, 2001).

5.5.5.2 Surficial Sediments

The surficial sediments in the LSA range from 15 m to 23 m in thickness, and are generally consistent with the range reported by Andriashek (1988).

Lower Sand and Gravel

A sand and gravel unit overlies bedrock throughout the LSA. This coarse-grained unit ranged between 1 m and 6 m in thickness, and was observed in all boreholes drilled through the base of the clay till. The gravel and sand unit is interpreted as the Empress Formation. Based on the bedrock elevation, it is interpreted to be located on a bedrock terrace adjacent to the buried Beverly Channel. However, it is not interpreted to be hydrostratigraphically equivalent to the Empress Formation sands and gravels within the Beverly Channel, as indicated on Cross-section C-C′ (Figure 5.5-3). The unit was previously identified as Saskatchewan Sand and Gravels by Stein (1976).

Glacial Till

Glacial till was observed at all borehole locations, and formed the surficial unit at all locations, with the exception of locations in the northern extent of the LSA, where it was overlain by sand. The glacial till at the site was primarily described as clay, with some intervals of silt or sand. Although the till unit was primarily described as a clay, glacial till typically contains approximately equal proportions of clay, silt and sand. The thickness of the till unit ranged from 5.5 m at borehole 07-1, where the glacial till was overlain by the eolian sand, to 23 m at borehole 07-7.

Surficial Sand Unit

A surficial sand unit overlies the clay till at borehole locations BH06-07 and BH06-09, and monitoring well locations 07-1 and 07-2, along the northern extent of the site. This sand is interpreted as being the edge of an eolian sand deposit that extends to the west and north of the site (Figure 5.5-5). The thickness of the sand unit observed on the site was 2.8 m to 5 m.

Sand lenses were also observed in the upper 7 m of the clay till at boreholes BH06-06, BH06-12 and BH06-13, located in Section 35-055-21 W4M. The sand lenses were 0.8 m to 3.5 m thick at these locations, and may be continuous between these locations; however, these sand lenses are located within the glacial till and are not considered to be associated with the eolian sand unit.

5.5.6 Regional Hydrogeology

Groundwater flow in the RSA is interpreted to flow west and north in the direction of the buried Beverly Channel and the NSR. Local variations in this regional flow direction are expected in the shallow subsurface in areas of topographical relief. Within the Beverly Channel, groundwater flow is directed approximately northeast along the buried valley thalweg (Figure 5.5-10). A buried valley tributary was reported by Stein (1976) to transect the LSA, as indicated on Figure 5.5-10. However, no evidence of a buried channel was found during the drilling programs.

The clay and clay till units typically have low permeability, and are interpreted to be aquitards. Groundwater from the clay and clay till units immediately northwest of the LSA is described as a calcium-magnesium/bicarbonate type, with total dissolved solids (TDS) concentrations ranging from 291 mg/L to 783 mg/L (BA Energy, 2004).

Hydraulic conductivity estimates of the surficial sand deposits immediately northwest of the LSA range from 1×10^{-5} m/s to 2×10^{-4} m/s (BA Energy, 2004). Groundwater flow within this unit is expected to flow towards Astotin Creek. Groundwater from within the surficial sand unit was mostly of a calcium-magnesium/bicarbonate type, with TDS concentrations ranging from 217 mg/L to 563 mg/L (BA Energy, 2004).

Previous hydraulic conductivity estimates for Empress Formation sand and gravel deposits within the Beverly Channel range from 2×10^{-4} m/s to 9×10^{-4} m/s as reported by Stantec (2006), and 3×10^{-5} m/s to 4×10^{-4} m/s as reported by Stein (1976). The estimated apparent yield of the Empress Formation ranges from 160 m^3/day to 650 m^3/day (1.9 L/s to 7.5 L/s) where sufficiently thick (BA Energy, 2004). Groundwater within Beverly Channel sand and gravels immediately northwest of the LSA is reported to vary from a sodium/bicarbonate-sulphate to mixed/bicarbonate type (BA Energy, 2004).

The main aquifer units in the Lower Horseshoe Canyon Formation, which subcrops in the southeast portion of the RSA, are fractured coal seams (Agriculture and Agri-Food Canada, 2001). The Bearpaw Formation is considered to be a regional aquitard, based on the predominance of fine-grained sediments, but contains coarser-grained deposits which function as aquifer units. The maximum apparent yield was 98 m^3/day for wells completed in the Bearpaw Formation in Strathcona County (Agriculture and Agri-Food Canada, 2001).

The uppermost 120 m of Belly River Group sediments contain sandstone intervals which are capable of yielding in excess of 1.9 L/s (160 m^3/d). Sandstone and gravel aquifers are present within the LSA, with expected yields of 0.4 L/s to 1.9 L/s (35 m^3/day to 160 m^3/day; Stein, 1976). In the Bruderheim area, the uppermost sandstone intervals of the Belly River Group are reported to have hydraulic conductivity values of 6×10^{-7} to 8×10^{-5} m/s (Stein, 1976). TDS concentrations of groundwater within the Oldman Formation are expected to range between 750 mg/L and 1,500 mg/L (Agriculture and Agri-Food Canada, 2001). Groundwater from aquifer units within the Oldman Formation is typically sodium-bicarbonate type (Agriculture and Agri-Food Canada, 2001).

TDS concentrations in groundwater from upper bedrock formations within the RSA typically range from 500 mg/L to 3,000 mg/L (Agriculture and Agri-Food Canada, 2001). Groundwater from bedrock units in Strathcona County is typically a sodium-bicarbonate or calcium-magnesium-bicarbonate-sulphate type (Agriculture and Agri-Food Canada, 2001).

5.5.7 Local Hydrogeology

5.5.7.1 Hydraulic Conductivity

Hydraulic conductivity tests were conducted at five monitoring wells located at the site. Hydraulic conductivity testing included bail/recovery tests and one pumping test. A description of the methods, results and interpretation are included in Appendix 5A. The results of the testing are presented in Table 5.5-1.

Table 5.5-1 Hydraulic Conductivity Test Results

Monitoring Well	Lithology	Interpretation Method	Hydraulic Conductivity (m/s)
07-5	Sandstone, Siltstone (Oldman Formation)	Hvorslev (1951)	2×10^{-7}
07-6	Gravel, Sand (Empress Formation)	Theis Recovery (Theis, 1935)	8×10^{-5}
07-8	Clay Till	Hvorslev (1951)	1×10^{-9}
07-11	Clay Till	Hvorslev (1951)	6×10^{-9}
BH06-15	Clay Till	Hvorslev (1951)	6×10^{-9}

Testing in the clay till was conducted in three monitoring wells completed at depths ranging from 1.8 m bgs to 11.7 m bgs. Based on the test results, the hydraulic conductivity of the clay till unit is estimated to range from 1×10^{-9} m/s to 6×10^{-9} m/s.

Near-surface sand deposits were observed at boreholes along the north extent and central region of the site. These deposits were largely unsaturated, and no hydraulic conductivity testing was conducted over these intervals. Based on the lithology, the saturated hydraulic conductivity of these sand deposits is expected to be in the order of 10^{-5} m/s to 10^{-4} m/s.

A sand and gravel unit overlying bedrock across the site is interpreted as a bedrock terrace deposit of the Empress Formation. A pumping/recovery test was conducted on monitoring well 07-6. Based on the test results, the hydraulic conductivity of the lower sand and gravel is estimated to be 8×10^{-5} m/s.

The upper bedrock (Oldman Formation) at the site is primarily fine-grained sandstone and siltstone. The hydraulic conductivity of the sandstone/siltstone bedrock underlying the site was estimated to be 2×10^{-7} m/s, based on testing conducted at monitoring well 07-5.

5.5.7.2 Lateral Groundwater Flow

Water levels measured at the site from May 9 to 11, 2007, are presented in Table 5.4-2. The water levels were used to generate piezometric contours for the glacial till, bedrock and lower sand and gravel. These piezometric contours were used to estimate groundwater flow direction in the respective units. Groundwater flow maps for the clay till, bedrock and sand and gravel are presented on Figures 5.5-11, 5.5-12 and 5.5-13, respectively. For each unit, the linear velocity (v_L) was estimated using the relationship between hydraulic conductivity (K), hydraulic gradient (i) and effective porosity (η_e):

$$v_L = \frac{Ki}{\eta_e}$$

Clay Till

Water levels within the clay till varied between 619.01 masl and 625.81 masl. Groundwater flow within the clay till generally flows to the north and west (Figure 5.5-11). However, the groundwater flow patterns illustrated on Figure 5.5-12 are expected to be simplified due to the limited number of data points. Shallow groundwater flow through shallow low-permeability sediments typically follows topography, with the exception of trends observed at topographical depressions. Seasonal water table mounding is expected to occur at topographic depressions where surface water collects (wetlands). These wetlands are commonly the focal points for depression-focused groundwater recharge in the prairie region (Hayashi et al., 1998). Thus, groundwater mounding is expected to occur at topographic depressions, resulting in radial groundwater flow directed away from the depressions.

The maximum horizontal hydraulic gradient within the clay till was estimated to be 0.005 m/m, with flow generally directed towards the north and west. Local gradients may be larger, particularly in areas of focused recharge. Using the maximum estimated hydraulic conductivity of 6×10^{-9} m/s, and assuming an effective porosity of 15% and hydraulic gradient of 0.005 m/m, the linear velocity of groundwater in the clay till is expected to be approximately 0.006 m/y.

Lower Sand and Gravel

Piezometric water levels within the lower sand and gravel unit varied between 614.61 masl and 620.68 masl. The water levels on the site are at least 15 m higher than those observed within the Beverly Channel sands and gravels immediately west of the site, which were less than 600 masl (Stantec, 2006). This fact suggests that there is not direct hydraulic communication between the Empress Formation deposits in the Beverly Channel and those of the bedrock terrace below the site.

Groundwater flow within the lower sand and gravel is directed towards the west, with a hydraulic gradient of approximately 0.004 m/m (Figure 5.5-12). This value falls within the range of hydraulic gradients (0.0005 m/m to 0.005 m/m) observed in the Empress Formation sands and gravels within the Beverly Channel (Stantec, 2006). Groundwater flow within the lower sand and gravel appears to follow bedrock topography, and flows toward the Beverly Channel to the west. Groundwater flow within the Beverly Channel Empress Formation immediately west of the site was directed towards the north, with a gradient of approximately 0.001 m/m (BA Energy, 2004). Assuming a hydraulic conductivity of 8×10^{-5} m/s, and assuming an effective porosity of 30% and hydraulic gradient of 0.004 m/m, the horizontal linear velocity of groundwater in the lower sand and gravel is expected to be approximately 30 m/y to the west.

Bedrock

The lithology of the upper bedrock under the site is primarily fine-grained sandstone and siltstone. At monitoring well 07-1, interbeds of claystone were observed. These intervals are not expected to be regionally continuous (Stein, 1976).

Piezometric water levels within the bedrock (sandstone and siltstone) ranged from 614.27 masl to 621.48 masl. Based on the water levels, groundwater flow is directed towards the west-northwest, with a hydraulic gradient of approximately 0.005 m/m (Figure 5.5-13). Assuming a hydraulic conductivity of 2×10^{-7} m/s, and assuming an effective porosity of 20% and hydraulic gradient of 0.005 m/m, the horizontal velocity of groundwater in the bedrock is expected to be approximately 0.2 m/y to the west-northwest.

5.5.7.3 Vertical Hydraulic Gradients

Nested monitoring well pairs were installed at five locations to determine vertical hydraulic gradients at the site. These wells were installed at various depths and in different units. The water levels were measured from May 9 to 11, 2007, and are summarized in Table 5.4-2. At each location, the water level in the shallower unit was higher than the water level in the deeper unit. This indicates that there is a downward hydraulic gradient in the area which induces downward vertical groundwater flow. This is consistent with the findings of previous investigations (Stantec, 2006). Hydraulic gradients within the clay till can exceed 0.5 m/m due to the low permeability of the material. Groundwater flow within the clay till is expected to be primarily downward, whereas the flow in the lower sand and gravel is expected to be primarily lateral (Figures 5.5-7 and 5.5-8). The vertical hydraulic conductivity estimates for the site are provided in Table 5.5-2.

Nested monitoring well pair 07-10 and 07-11 were completed within the lower sand and gravel (07-10) and clay till (07-11). Assuming hydraulic head changes within the gravel are negligible because of its large hydraulic conductivity, the vertical gradient can be calculated as the difference in hydraulic head between the midpoint of the upper screen and the bottom of the clay till unit. Based on these assumptions, the vertical hydraulic gradient within the clay till is estimated to be 0.24 m/m.

Nested monitoring well pairs 07-1 and 07-2 and 07-5 and 07-6 were completed within the bedrock and the overlying sand and gravel. Like the clay, the assumption can be made that the head changes within the sand and gravel are negligible, so that the majority of the hydraulic head decreases occur within the bedrock units. The vertical hydraulic gradient was greater (0.085 m/m) at nested wells 07-1 and 07-2, where interbedded claystone was present within the bedrock interval, as compared to nested wells 07-5 and 07-6, where the bedrock lithology was sandstone and siltstone.

Table 5.5-2 Vertical Hydraulic Gradients

Monitoring Well Nested Pair	Lithology	Vertical Distance (m)	Hydraulic Head Difference (m)	Vertical Hydraulic Gradient (m/m)
07-1, 07-2	Sandstone, siltstone, claystone	23.5	2.0	0.085
07-5, 07-6	Sandstone, siltstone	8.5	0.21	0.025
07-10, 07-11	Clay till	3.2	0.78	0.24

5.5.8 Groundwater Quality

Groundwater samples were collected from all monitoring wells on May 11, 2007, with the exception of 07-3 (damaged well) and BH06-01 (dry). Field parameter results (temperature, pH, EC and DO) are summarized in Table 5.5-3. The results for routine, indicator and inorganic chemistry are summarized in Table 5.5-4, dissolved metals are summarized in Table 5.5-5 and dissolved hydrocarbons are summarized in Table 5.5-6. The quality control sample results are presented in Appendix 5C. Key results of the groundwater quality characterization are discussed below.

Table 5.5-3 Groundwater Quality Results, Field Measured Parameters

Monitoring Well	Sample Date	Temp °C	Field pH	Field EC* uS/cm	Field DO mg/L
Clay Till					
07-8	May 11/07	7.3	6.8	3,820	3.9
07-8 dup	May 11/07	6.9	6.8	3,820	4.4
07-9	May 11/07	7.0	7.1	1,120	3.2
07-11	May 11/07	6.8	6.7	2,740	5.4
BH06-01	May 11/07	---	---	---	---
BH06-04	May 11/07	7.6	7.0	2,260	7.2
BH06-08	May 11/07	7.3	6.9	3,890	6.4
BH06-11	May 11/07	6.3	7.1	1,830	3.2
BH06-13	May 11/07	5.1	7.3	630	3.7
Sand and Gravel					
07-2	May 11/07	6.0	7.2	800	3.4
07-4	May 11/07	11.1	7.5	830	8.1
07-6	May 11/07	6.9	7.4	730	3.8
07-6 dup	May 11/07	6.2	7.4	730	3.7
07-10	May 11/07	6.3	6.6	1,090	3.0
BH06-03	May 11/07	7.9	7.1	1,480	2.5
BH06-06	May 11/07	7.8	7.2	880	2.7
BH06-07	May 11/07	7.9	6.9	1,100	3.2
BH06-10	May 11/07	7.4	7.0	4,470	6.4
Bedrock					
07-1	May 11/07	6.8	7.4	1,000	2.6
07-3	May 11/07	---	---	---	---
07-5	May 11/07	6.8	8.0	900	3.2
07-7	May 11/07	7.2	7.6	750	2.4
BH06-15	May 11/07	7.5	7.2	1,370	2.4
Detection Limit		**0.1**	**0.1**	**10**	**0.1**
Canadian Drinking Water Guidelines**		**15 $^{(AO)}$**	**6.5-8.5$^{(AO)}$**	**NS**	**NS**

Notes:

---	- not analyzed.
NS	- guideline not specified.
^{AO}	- aesthetic objective.
*	- field EC corrected to 25°C.
**	- Guidelines for Canadian Drinking Water Quality (Health Canada, 2006a).
Italics	- indicate values do not meet Canadian Drinking Water Guidelines.

Table 5.5-4 Groundwater Quality Results - Routine, Indicator and Inorganic Chemistry

Monitoring Well	Sample Date	Lab pH	Lab EC uS/cm	Ca mg/L	Mg mg/L	Na mg/L	K mg/L	Cl mg/L	HCO_3 as $CaCO_3$ mg/L	SO_4 mg/L	NO_2-N mg/L	NO_3-N mg/L	Hardness mg/L	TDS mg/L
Clay Till														
07-8	May 11/07	7.39	3670	621	263	188	14.6	3.6	733	*2,260*	0.003	0.016	2600	*3,710*
07-8 dup	May 11/07	7.26	3690	624	266	192	14.9	3.6	723	*2,270*	<0.003	0.017	2700	*3,730*
07-9	May 11/07	7.67	1140	149	39	56.1	5.3	2.0	662	163	0.007	0.031	530	*741*
07-11	May 11/07	7.48	2660	393	131	102	8.6	5.7	556	*1,390*	<0.003	0.024	1500	*2,300*
BH06-04	May 11/07	7.61	2240	368	155	79.2	9.9	1.4	449	*1,180*	<0.003	0.006	1600	*2,010*
BH06-08	May 11/07	7.53	3740	394	255	*260*	12.7	8.3	653	*2,280*	0.031	0.242	2000	*3,540*
BH06-11	May 11/07	7.71	1840	290	89.3	58.6	6.4	1.5	518	*714*	0.02	*16.6*	1100	*1,490*
BH06-13	May 11/07	7.93	639	86	24.8	13.9	6	2.4	348	39.9	0.063	*11.1*	320	394
Sand and Gravel														
07-2	May 11/07	7.83	825	80.5	22.6	80.4	4.6	5.3	508	70.4	0.009	0.005	290	*516*
07-4	May 11/07	8.06	836	83.2	23.4	73.2	5.5	2.9	439	128	0.005	0.017	300	*532*
07-6	May 11/07	7.92	749	89.2	27.4	56.7	6.5	2.5	437	77.4	0.007	0.037	340	475
07-6 dup	May 11/07	7.66	757	88	25.8	54.1	6.2	2.3	435	78	0.007	0.038	330	469
07-10	May 11/07	7.75	1120	110	33.5	110	5.1	4.5	572	167	0.022	6.62	410	*742*
BH06-03	May 11/07	7.68	1490	210	65	50.7	6.2	1.9	594	445	<0.003	0.009	790	*1,080*
BH06-06	May 11/07	7.94	895	102	27.2	63.4	5	1.2	503	122	<0.003	0.008	370	*571*
BH06-07	May 11/07	7.57	1120	140	52.4	45.5	5.1	1.7	689	133	0.005	0.191	560	*718*
BH06-10	May 11/07	7.78	4340	312	135	*718*	9.7	10.5	503	*2,430*	0.229	5.45	1300	*3890*
Bedrock														
07-1	May 11/07	8.07	1030	39.6	10.5	192	3	2.6	595	102	0.113	0.039	140	*644*
07-5	May 11/07	8.19	937	16.7	3.1	*204*	3.2	7.8	559	66	0.004	0.021	54	*576*
07-7	May 11/07	7.82	768	36.3	8.4	121	3.4	1.4	153	235	0.004	0.009	130	480
BH06-15	May 11/07	7.79	1380	131	30.6	168	7	2.6	632	290	0.024	0.709	450	*946*
Laboratory Detection Limit		**0.01**	**0.02**	**0.1**	**0.1**	**0.1**	**0.3**	**0.5**	**0.5**	**0.1**	**0.003**	**0.003**	**0.5**	**1**
Canadian Drinking Water Guidelines***		**6.5-8.5$^{(AO)}$**	**NS**	**NS**	**NS**	**200$^{(AO)}$**	**NS**	**250$^{(AO)}$**	**NS**	**500$^{(AO)}$**	**1$^{(MAC)}$**	**10$^{(MAC)}$**	**NS**	**500$^{(AO)}$**

Notes:

NS	- not specified.
AO	- aesthetic objective.
MAC	- maximum acceptable concentration based on health effects.
***	- Guidelines for Canadian Drinking Water Quality (Health Canada, 2006a).
Italics	- indicate values do not meet Canadian Drinking Water Guidelines.

Table 5.5-5 Groundwater Quality Results - Dissolved Metals

Monitoring Well	Sample Date	Al mg/L	Sb mg/L	As mg/L	Ba mg/L	Be mg/L	B mg/L	Cd mg/L	Cr mg/L	Co mg/L	Cu mg/L	Fe mg/L	Pb mg/L	Li mg/L
Clay Till														
07-8	May 11/07	<0.04	<0.0002	0.001	0.06	<0.001	0.26	<0.0002	0.01	0.0188	0.0054	0.28	<0.0002	0.49
07-8 dup	May 11/07	<0.04	<0.0002	<0.001	0.06	<0.001	0.26	<0.0002	0.01	0.0191	0.0068	0.30	<0.0002	0.50
07-9	May 11/07	<0.04	<0.0002	0.007	0.06	<0.001	0.25	<0.0002	<0.01	0.0018	0.0010	*0.31*	<0.0002	0.11
07-11	May 11/07	<0.04	<0.0002	<0.001	0.05	<0.001	0.32	0.0002	<0.01	0.0129	0.0035	*0.46*	<0.0002	0.19
BH06-04	May 11/07	<0.04	<0.0002	<0.001	0.03	<0.001	0.16	<0.0002	0.01	0.0044	0.0032	0.17	<0.0002	0.26
BH06-08	May 11/07	<0.04	<0.0002	0.006	0.02	<0.001	0.28	<0.0002	<0.01	0.0041	0.0042	*0.82*	<0.0002	0.43
BH06-11	May 11/07	<0.04	<0.0002	<0.001	0.04	<0.001	0.11	<0.0002	<0.01	0.0009	0.0028	0.07	<0.0002	0.11
BH06-13	May 11/07	<0.04	<0.0002	0.002	0.12	<0.001	0.04	<0.0002	<0.01	0.0008	0.0010	<0.06	<0.0002	0.02
Sand and Gravel														
07-2	May 11/07	<0.04	0.0007	0.002	0.05	<0.001	0.13	<0.0002	<0.01	0.0016	0.0010	*1.66*	<0.0002	0.04
07-4	May 11/07	<0.04	0.0002	0.005	0.07	<0.001	0.13	<0.0002	<0.01	0.0018	0.0023	<0.06	<0.0002	0.07
07-6	May 11/07	<0.04	0.0011	0.003	0.11	<0.001	0.11	<0.0002	<0.01	0.0009	0.0006	*0.37*	<0.0002	0.06
07-6 dup	May 11/07	<0.04	0.0019	0.003	0.09	<0.001	0.11	<0.0002	<0.01	0.0014	0.0016	*0.33*	<0.0002	0.06
07-10	May 11/07	<0.04	<0.0002	0.002	0.06	<0.001	0.16	<0.0002	<0.01	0.0008	0.0020	*0.46*	<0.0002	0.10
BH06-03	May 11/07	<0.04	<0.0002	0.007	0.03	<0.001	0.16	<0.0002	<0.01	0.0009	0.0015	*5.08*	<0.0002	0.09
BH06-06	May 11/07	<0.04	<0.0002	0.009	0.06	<0.001	0.15	<0.0002	<0.01	0.0007	0.0003	*2.67*	<0.0002	0.07
BH06-07	May 11/07	<0.04	<0.0002	<0.001	0.17	<0.001	0.14	<0.0002	<0.01	0.0016	0.0019	<0.06	<0.0002	0.08
BH06-10	May 11/07	<0.04	<0.0002	<0.001	0.01	<0.001	0.20	<0.0002	<0.01	0.0027	0.0042	0.24	<0.0002	0.44
Bedrock														
07-1	May 11/07	<0.04	<0.0002	0.003	0.05	<0.001	0.23	<0.0002	<0.01	0.0007	0.0003	*0.66*	<0.0002	0.06
07-5	May 11/07	0.04	0.0015	0.001	0.06	<0.001	0.28	<0.0002	<0.01	<0.0003	0.0005	<0.06	<0.0002	0.02
07-7	May 11/07	<0.04	0.0008	0.003	0.02	<0.001	0.05	<0.0002	<0.01	<0.0003	0.0009	<0.06	<0.0002	0.07
BH06-15	May 11/07	<0.04	<0.0002	0.001	0.05	<0.001	0.15	<0.0002	<0.01	0.0013	0.0011	*2.75*	<0.0002	0.12
Laboratory Detection Limit		**0.04**	**0.0002**	**0.001**	**0.01**	**0.001**	**0.02**	**0.0002**	**0.01**	**0.0003**	**0.0002**	**0.06**	**0.0002**	**0.02**
Canadian Drinking Water Guidelines**		**NS^^**	**0.006$^{(MAC)}$**	**0.01$^{(MAC)}$***	**1.0$^{(MAC)}$**	**NS**	**5$^{(MAC)}$**	**0.005$^{(MAC)}$**	**0.05$^{(MAC)}$**	**NS**	**1.0$^{(AO)}$**	**0.3$^{(AO)}$**	**0.01$^{(MAC)}$**	**NS**

Notes:

NS	- guideline not specified.
^{AO}	- aesthetic objective.
^{MAC}	- maximum acceptable concentration based on health effects.
*	- Guidelines for Canadian Drinking Water Quality: Guideline Technical Document for Arsenic (Health Canada, 2006b).
**	- Guidelines for Canadian Drinking Water Quality (Health Canada, 2006).
^	- indicates value for Inorganic Mercury.
^^	- guideline applies only to drinking water treatment plants.
Italics	- indicates values do not meet Canadian Drinking Water Guidelines.

Table 5.5-6 Groundwater Quality Results, Dissolved Hydrocarbons

Monitoring Well	Sample Date	Benzene (mg/L)	Toluene (mg/L)	Ethylbenzene (mg/L)	Xylenes (mg/L)	Total BTEX (mg/L)	F1[††] C_6-C_{10} (mg/L)	F2 $C_{>10}$-C_{16} (mg/L)
Clay Till								
07-8	May 11/07	<0.0004	<0.0004	<0.0004	<0.0008	ND	<0.1	<0.12
07-8 dup	May 11/07	<0.0004	<0.0004	<0.0004	<0.0008	ND	<0.1	<0.12
07-9	May 11/07	<0.0004	<0.0004	<0.0004	<0.0008	ND	<0.1	<0.12
07-11	May 11/07	<0.0004	<0.0004	<0.0004	<0.0008	ND	<0.1	<0.12
BH06-04	May 11/07	<0.0004	<0.0004	<0.0004	<0.0008	ND	<0.1	<0.12
BH06-08	May 11/07	<0.0004	<0.0004	<0.0004	<0.0008	ND	<0.1	<0.12
BH06-11	May 11/07	<0.0004	<0.0004	<0.0004	<0.0008	ND	<0.1	<0.12
BH06-13	May 11/07	<0.0004	<0.0004	<0.0004	<0.0008	ND	<0.1	<0.12
Sand and Gravel								
07-2	May 11/07	<0.0004	<0.0004	<0.0004	<0.0008	ND	<0.1	<0.12
07-4	May 11/07	<0.0004	0.0005	<0.0004	<0.0008	0.0005	<0.1	<0.12
07-4	Jun 7/07	<0.0004	<0.0004	<0.0004	<0.0008	ND	---	---
07-6	May 11/07	<0.0004	<0.0004	<0.0004	<0.0008	ND	<0.1	<0.12
07-6 dup	May 11/07	<0.0004	<0.0004	<0.0004	<0.0008	ND	<0.1	<0.12
07-10	May 11/07	<0.0004	<0.0004	<0.0004	<0.0008	ND	<0.1	<0.12
BH06-03	May 11/07	<0.0004	<0.0004	<0.0004	<0.0008	ND	<0.1	<0.12
BH06-06	May 11/07	<0.0004	<0.0004	<0.0004	<0.0008	ND	<0.1	<0.12
BH06-07	May 11/07	<0.0004	<0.0004	<0.0004	<0.0008	ND	<0.1	<0.12
BH06-10	May 11/07	<0.0004	<0.0004	<0.0004	<0.0008	ND	<0.1	<0.12
Bedrock								
07-1	May 11/07	<0.0004	<0.0004	<0.0004	<0.0008	ND	<0.1	<0.12
07-5	May 11/07	<0.0004	0.0008	<0.0004	<0.0008	0.0008	<0.1	<0.12
07-5	Jun 7/07	<0.0004	<0.0004	<0.0004	<0.0008	ND	---	---
07-7	May 11/07	<0.0004	<0.0004	<0.0004	<0.0008	ND	<0.1	<0.12
BH06-15	May 11/07	<0.0004	<0.0004	<0.0004	<0.0008	ND	<0.1	<0.12
Laboratory detection limit		**0.0004**	**0.0004**	**0.0004**	**0.0008**	**-**	**0.1**	**0.12**
Alberta SWQG* - Human Drinking Water - All Soils		**0.005**	**0.024**	**0.0024**	**0.3**	**NS**	**4.6**	**2.1**

Notes:

ND - not detected.

NS - no guideline specified.

* - Alberta Soil and Water Quality Guidelines for Hydrocarbons at Upstream Oil and Gas Facilities (AENV, 2001).

†† - F1 excludes BTEX.

Italics - indicates that values exceed applicable Alberta SWQG.

5.5.8.1 Clay Till

Groundwater quality within the clay till appears to vary between well locations. The temperature of groundwater samples collected from the clay till ranged from 5.1°C to 7.6°C, with temperatures generally increasing with depth. Field pH values ranged from 6.7 to 7.3, indicating that the water is slightly acidic to slightly basic. Laboratory-measured pH values were slightly higher in all samples. This is expected to occur due to the loss of carbon dioxide (CO_2) from the samples, which causes an increase in the pH.

TDS concentrations ranged from 394 mg/L to 3,710 mg/L, and correlated well with both field and laboratory-measured EC values. A good correlation between TDS concentrations and depth within the till was not observed. Major ion concentrations were plotted in a Piper diagram (Figure 5.5-14). Sulphate was the dominant anion in groundwater samples collected from the clay till, with concentrations ranging from 39.9 mg/L to 2,430 mg/L. Five of the seven water samples collected from the clay till exceeded the Canadian Drinking Water Quality (CDWQ) aesthetic objective for sulphate of 500 mg/L (Health Canada, 2006).

In the seven groundwater samples collected from the clay till, carbonate and bicarbonate presence was variable (approximately 20% and 90%), and the relative chloride presence was negligible. Calcium was the dominant cation (approximately 75% to 90%), with some magnesium (approximately 20% to 40%) and sodium (approximately 60% to 80%). Chloride and potassium concentrations were less than 15 mg/L.

Nitrate-nitrogen concentrations exceeded the CDWQ maximum acceptable concentration (MAC) of 10 mg/L in monitoring wells BH06-11 and BH06-13. Both of these monitoring wells are completed at shallow depths (between 2.4 bgs and 6.4 m bgs), and are located in agricultural fields.

Dissolved metal concentrations were relatively consistent within the clay till. The most prevalent metal concentrations in the clay till were silicon (6.0 mg/L to 8.8 mg/L), strontium (0.34 mg/L to 4.45 mg/L) and manganese (0.409 mg/L to 6.010 mg/L).

Dissolved hydrocarbons were not detected in groundwater samples collected from the clay till.

5.5.8.2 Lower Sand and Gravel

The temperature of groundwater samples from the lower sand and gravel ranged from 6.0°C to 11.1°C. The water was slightly acidic to slightly basic, with field pH values ranging from 6.6 to 7.5. Laboratory-measured pH values were slightly higher, ranging from 7.6 to 8.1.

TDS concentrations ranged from 516 mg/L to 3,890 mg/L in the sand and gravel unit. Like the clay, sulphate was the dominant anion in the sand and gravel, with concentrations ranging from 70.4 mg/L to 2,430 mg/L. The highest sulphate and TDS concentrations occurred in BH06-10, which was screened across both the gravel and the clay till; thus, there was likely some influence from groundwater in the clay. Aside from BH06-10, the highest sulphate concentration was 445 mg/L. The groundwater chemistry of the sand and gravel is plotted in the Piper diagram on Figure 5.5-14. In terms of cations, a shift can be observed in the Piper diagram, indicating a greater relative abundance of sodium and a lower relative abundance of calcium and magnesium compared to the clay till. Potassium and chloride concentrations did not exceed 11 mg/L in groundwater samples collected from the lower sand and gravel.

Dissolved metal concentrations were variable within the sand and gravel. The highest concentrations were silicon (3.8 mg/L to 7.6 mg/L), iron (non-detectable to 5.08 mg/L), strontium (0.50 mg/L to 2.54 mg/L) and manganese (0.218 mg/L to 2.390 mg/L).

Dissolved hydrocarbons were not detected in groundwater samples collected from the sand and gravel, with the exception of monitoring well 07-4, which contained a trace concentration of toluene. A confirmatory sample was collected from 07-4 on June 7, 2007, and analyzed for benzene, toluene, ethylbenzene and xylenes (BTEX). The BTEX constituent concentrations in the June 7 sample were non-detectable.

5.5.8.3 Bedrock

The field-measured temperature of groundwater samples collected from bedrock units ranged from 6.8 C to 7.5°C. Field-measured pH values ranged from 7.2 to 8.0, indicating that conditions are slightly more basic compared to the surficial deposits. Laboratory-measured pH values were slightly higher, ranging from 7.8 to 8.2.

TDS concentrations of bedrock groundwater samples ranged from 480 mg/L to 946 mg/L. Sulphate concentrations ranged from 66 mg/L to 290 mg/L, and were generally lower than the surficial deposits. Bicarbonate concentrations were similar in groundwater samples collected from the clay, bedrock and sand and gravel. The groundwater chemistry is plotted in a Piper diagram (Figure 5.5-14). The Piper diagram indicates a shift from the clay till to bedrock in the groundwater chemistry, with decreasing relative abundances of calcium and magnesium, and increasing abundances of sodium. Potassium and chloride concentrations in groundwater samples from bedrock did not exceed 10 mg/L, similar to the overlying units.

Dissolved metal concentrations in bedrock groundwater samples were generally lower than those in the surficial deposits. The highest metal concentrations were silicon (1.5 mg/L to 7.5 mg/L), iron (non-detectable to 2.75 mg/L) and strontium (0.15 mg/L to 1.47 mg/L).

Dissolved hydrocarbon concentrations were non-detectable in bedrock groundwater samples, with the exception of monitoring well 07-5, which had a trace concentration of toluene. A confirmatory sample was collected from 07-5 on June 7, 2007, and analyzed for BTEX. The BTEX constituent concentrations in the June 7 sample were non-detectable.

5.5.9 Existing Groundwater Users

5.5.9.1 Water Wells

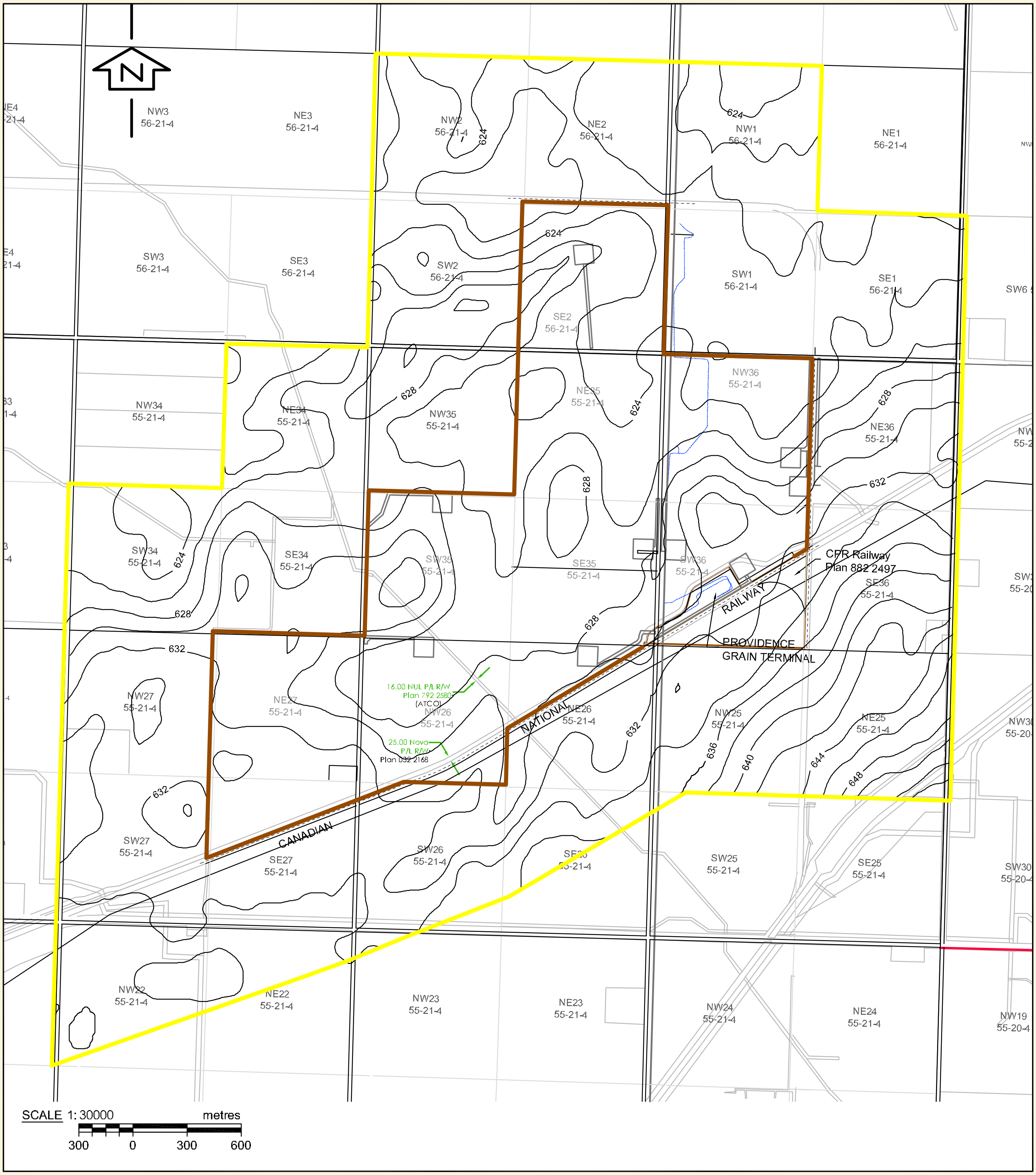
A total of 466 water wells are located within a 7 km radius of the centre of the Project site, according to the Groundwater Information Centre (GIC) database (Figure 5.5-15; Appendix 5D). The majority of these wells (403 wells, or 86% of total) are identified as being used for domestic and/or stock use. Twenty-three wells (5%) are identified as being used for industrial purposes. The remaining water well reports do not identify a well use. The majority of water wells in the RSA with a reported completion depth were completed at depths of less than 50 m bgs, with an average completion depth of 38 m bgs.

Based on the water well search, a total of 51 water wells are located within the LSA. Six of the water wells in the LSA are reported to be located within the Project site. Similar to the RSA, the majority of water wells within the LSA are completed at depths of less than 50 m bgs, with an average completion depth of 35 m bgs.

The locations of potential receptors near the Upgrader site were identified as a part of North American's public consultation program, as described in Volume 1, Section 10.

The receptor locations are indicated on Volume 1, Appendix D2, Figure D2-1. A total of 124 potential receptors were identified in the area surrounding the Upgrader. Of these, 33 receptors were within 1.6 km of the site boundaries, and 91 receptors were between 1.6 km and 5.0 km from the site boundaries.

*PLOT 1:1 = Letter (P)



LEGEND

🟨	LOCAL STUDY AREA (LSA)
🟫	NORTH AMERICAN UPGRADER
– 632 –	GROUND ELEVATION CONTOUR (masl)

Title:

TOPOGRAPHY WITHIN LOCAL STUDY AREA

NORTH AMERICAN
OIL SANDS CORPORATION

Approved: TVD
Revision Date: 07/11/11
File: 6198-SITE-07.DWG
Drawn by: AJG
Checked: RP
Fig. No.: 5.5-1

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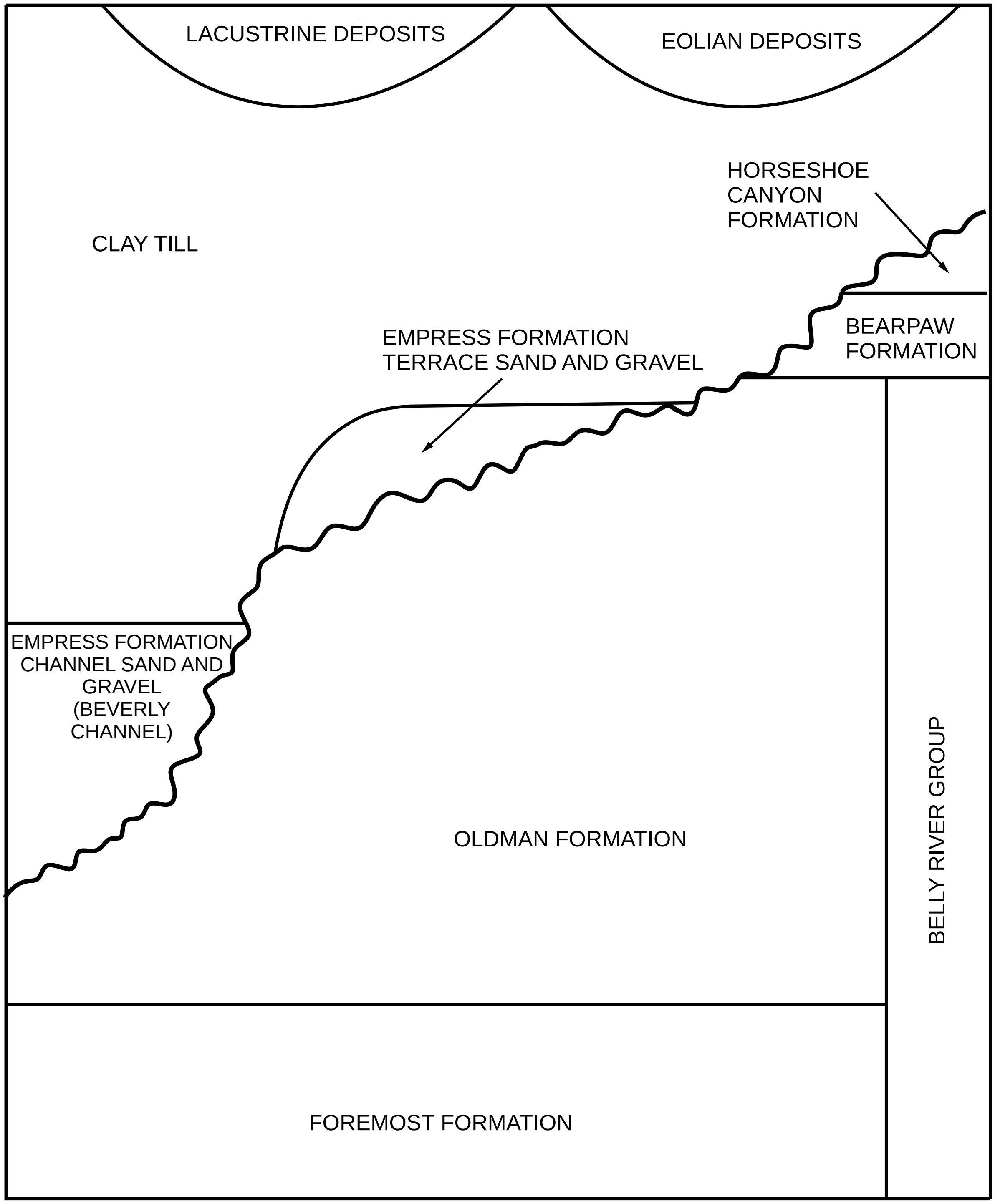


Legend

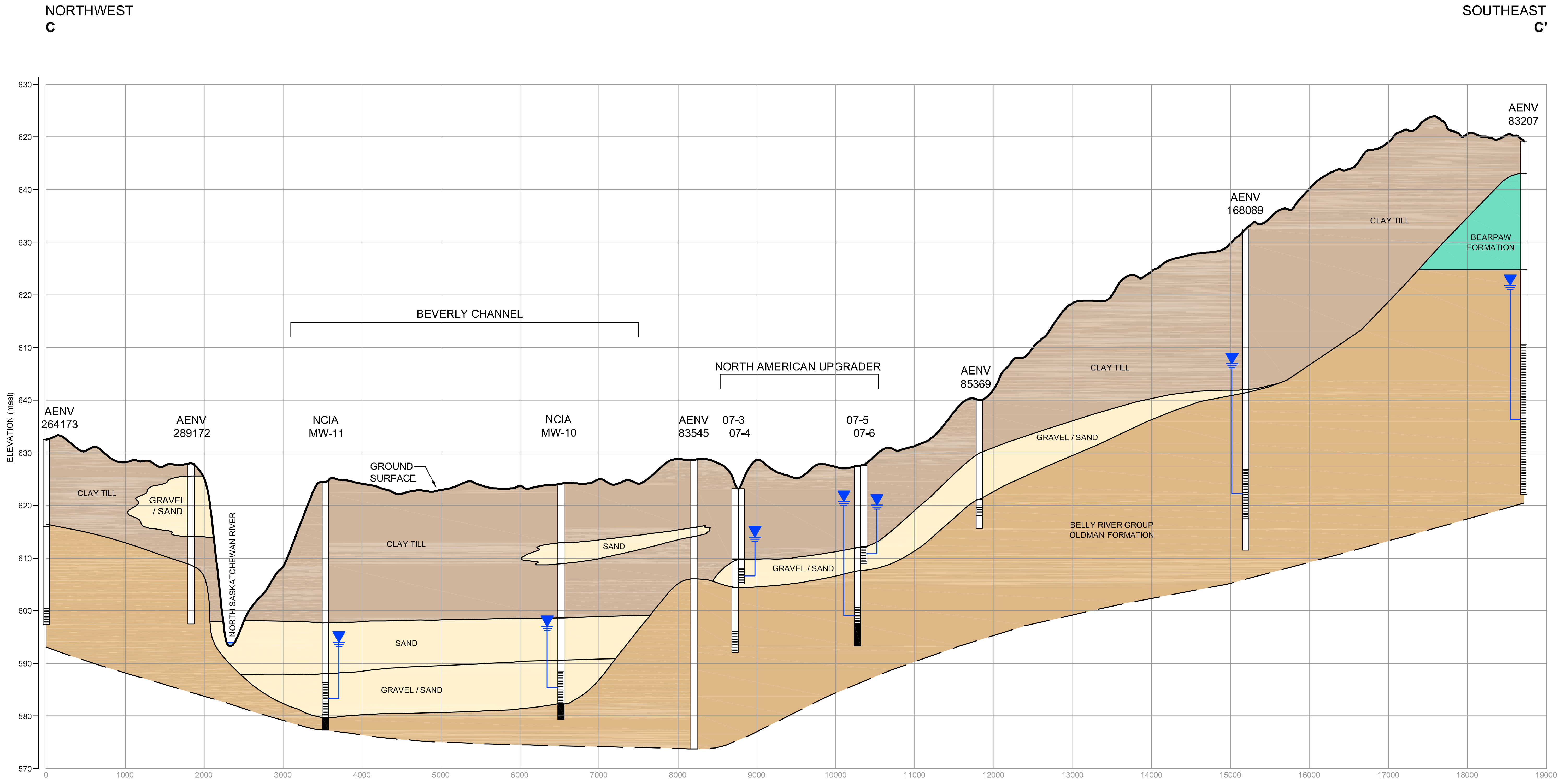
Title:

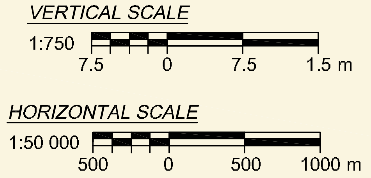
REGIONAL STUDY AREA
STRATIGRAPHIC COLUMN

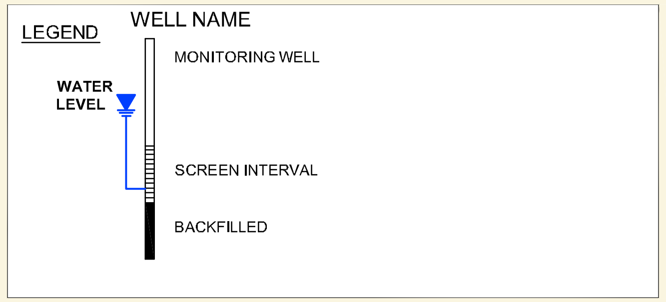
NORTH AMERICAN
OIL SANDS CORPORATION

Approved: TVD
Revision Date: JUNE 2007
File: 6198-StratColumn-07
Drawn By: ZS
Checked: RP
Fig. No. 5.5-2

*PLOT 1:1 = Letter (P)







Title:

CROSS-SECTION
C-C'

NORTH AMERICAN
OIL SANDS CORPORATION

Approved: TVD	Revision Date: 07/11/11
File: 6198-XSEC-07.DWG	

Drawn by: AJG	Checked: RP	Fig. No.: **5.5-3**

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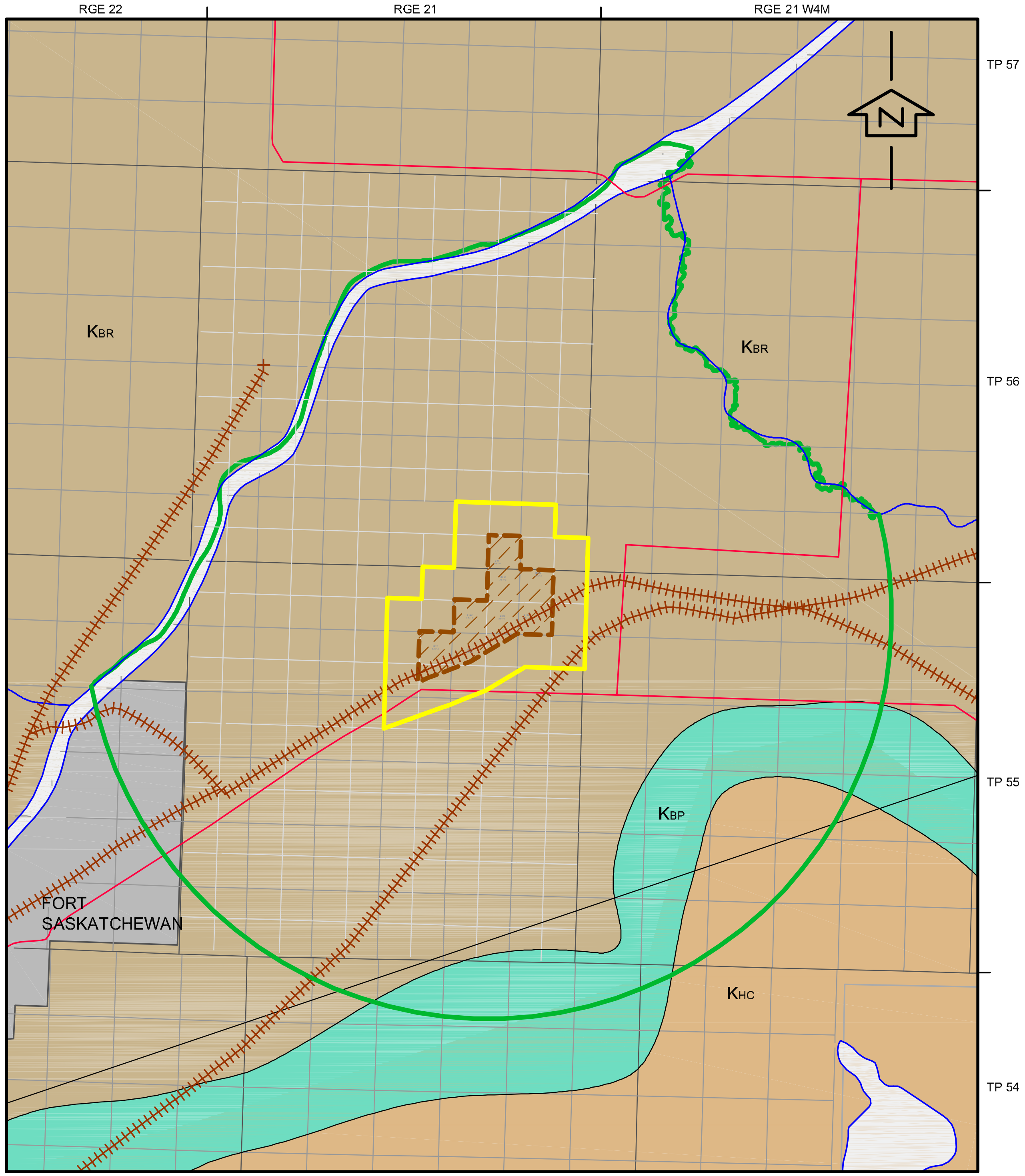


KBR **BELLY RIVER GROUP:** grey to greenish grey, thick-bedded, feldspathic sandstone; grey clayey siltstone, grey and green mudstone; concretionary ironstone beds; nonmarine

KHC **HORSESHOE CANYON FORMATION:** grey, feldspathic, clayey sandstone; grey bentonitic mudstone and carbonaceous shale; concretionary ironstone beds, scattered coal and bentonite beds of variable thickness; minor limestone beds; mainly nonmarine.

KBP **BEARPAW FORMATION:** dark grey blocky shale and silty shale; greenish glauconitic and grey clayey sandstone; thin concretionary ironstone and bentonitic beds; marine

SCALE 1:150000 kilometres

1.5 0 1.5 3

LEGEND

🟨 LOCAL STUDY AREA (LSA)

🟩 REGIONAL STUDY AREA (RSA)

▬ ▬ NORTH AMERICAN UPGRADER

REFERENCE MAP:

1:1 000 000, Hamilton et al, 1999, GEOLOGICAL MAP OF ALBERTA 236D.

Title:

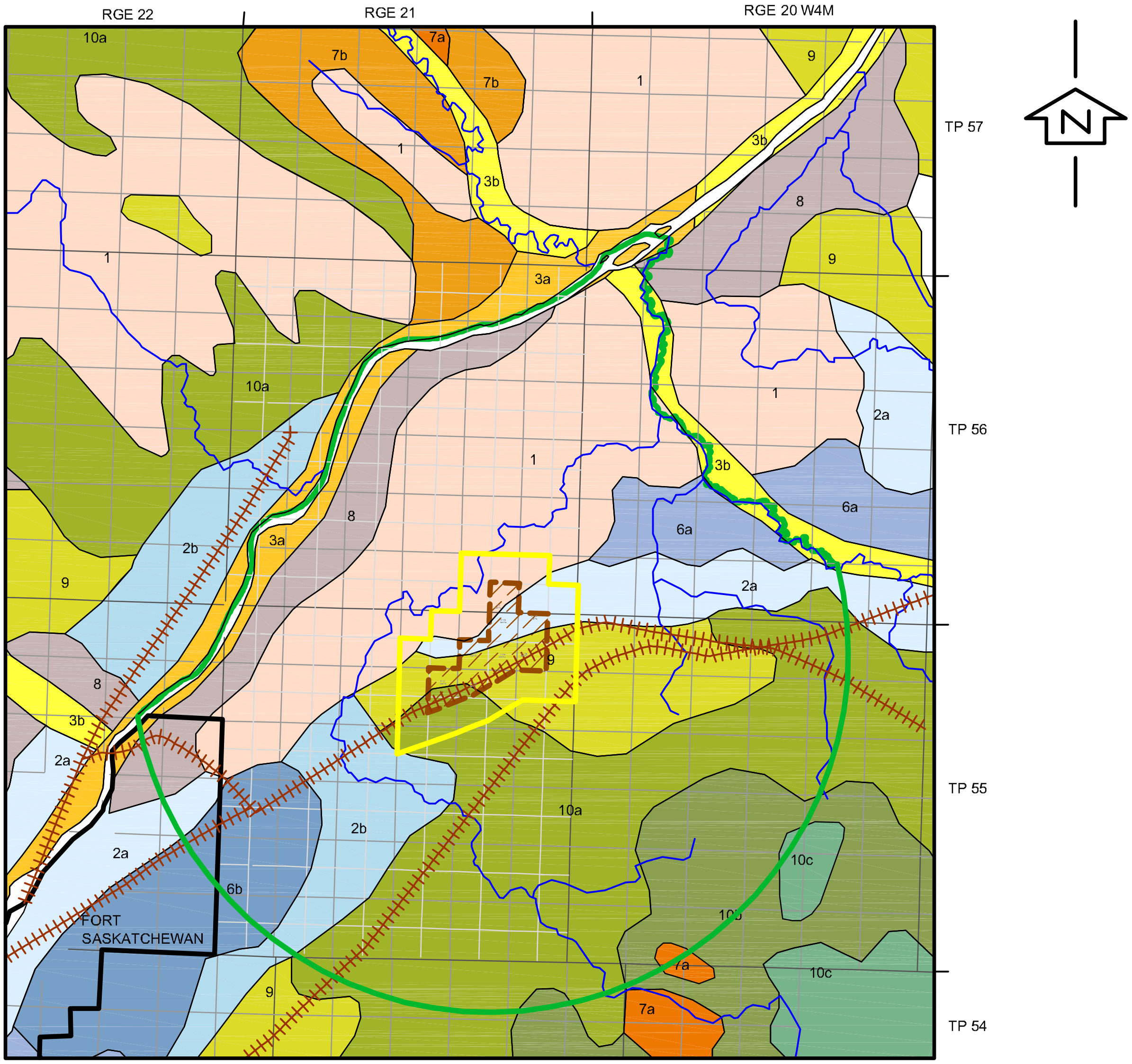
BEDROCK GEOLOGY

NORTH AMERICAN
OIL SANDS CORPORATION

Approved: TVD	Revision Date: 07/11/11
File: 6198-SITE-07.DWG	

Drawn by: AJG	Checked: RP	Fig. No.: **5.5-4**

*PLOT 1:1 = Letter (P)



1 **EOLIAN DEPOSIT:** fine and medium-grained sand and silt; up to 7m thick; longitudinal and parabolic dunes scoured by blowouts; undulating to rolling topography

LACUSTRINE DEPOSIT: sand, silt and clay, with local ice-rafted stones; up to 80m thick; deposited mainly in proglacial lakes, but includes also undifferentiated recent lake sediment; flat to gently undulating topography.

2a Coarse sediment: sand and silt; undulating surface in places mostly by wind.

2b Fine sediment: silt and clay; flat to gently undulating surface.

FLUVIAL DEPOSIT: gravel, sand, silt and clay, includes local till and bedrock exposures; up to 20m thick; present on floors and terraces of river valleys and meltwater channels, and in deltas; flat to gently undulating topography.

3a Coarse sediment: gravel, gravel and sand, fine to coarse-grained sand, minor silt beds.

3b Fine sediment: fine sand, silt and clay, minor gravel beds.

ICE-CONTACT LACUSTRINE DEPOSIT: gravel, sand, silt and clay, local till; up to 20m thick; deposited in supraglacial and ice-walled lakes or in proglacial lakes floored by ice; undulating to hummocky topography

6a Coarse sediment: sand and silt.

6b Fine Sediment: silt and clay.

ICE-CONTACT FLUVIAL DEPOSIT: gravel, sand, silt and clay, local till; up to 25m thick; deposited in ice-walled and supraglacial streams, or in ice-front fans and deltas; undulating to hummocky topography

7a Coarse sediment: gravel, gravel and sand, fine to coarse grained sand

7b Fine sediment: fine sand, silt and clay.

8 **ICE-CONTACT LACUSTRINE AND FLUVIAL DEPOSITS, UNDIVIDED:** gravel, sand , silt and clay, local till; up to 25m thick; deposited in intermittent suraglacial lakes and streams, or at margins of ice-floored proglacial lakes; undulating to hummocky topography.

9 **DRAPED MORAINE:** till of even thickness, with minor amounts of water-sorted material and local bedrock exposures; up to 10m thick; includes local areas of undifferentiated subglacially molded deposit with streamlined features; flat to undulating surface reflecting topography of underlying bedrock and other deposits.

STAGNATION MORAINE: till of uneven thickness, local water-sorted material; up to 30m thick; undulating to hummocky topography reflecting variations in till thicknesses

10a Undulating topography, with local relief generally less than 3m.

10b Hummocky topography moderately to weakly developed, with irregular shaped and poorly defined knobs and kettles; local reliece 3 to 10m.

10c Hummocky topography strongly developed, with generally round, well defined knobs, dimpled knobs, doughnut-shaped hills and kettles; local relief 5 to 20m.

LEGEND

— LOCAL STUDY AREA (LSA)

— REGIONAL STUDY AREA (RSA)

– – NORTH AMERICAN UPGRADER

SCALE 1: 200000 kilometres

2 0 2 4

REFERENCE MAP:
1:500 000, Shetson 1990,QUATERNARY GEOLOGY, CENTRAL ALBERTA.

Title:

SURFICIAL GEOLOGY

NORTH AMERICAN
OIL SANDS CORPORATION

Approved: TVD	Revision Date: 07/11/11
File: 6198-SITE-07.DWG	

Drawn by: AJG	Checked: RP	Fig. No.: 5.5-5

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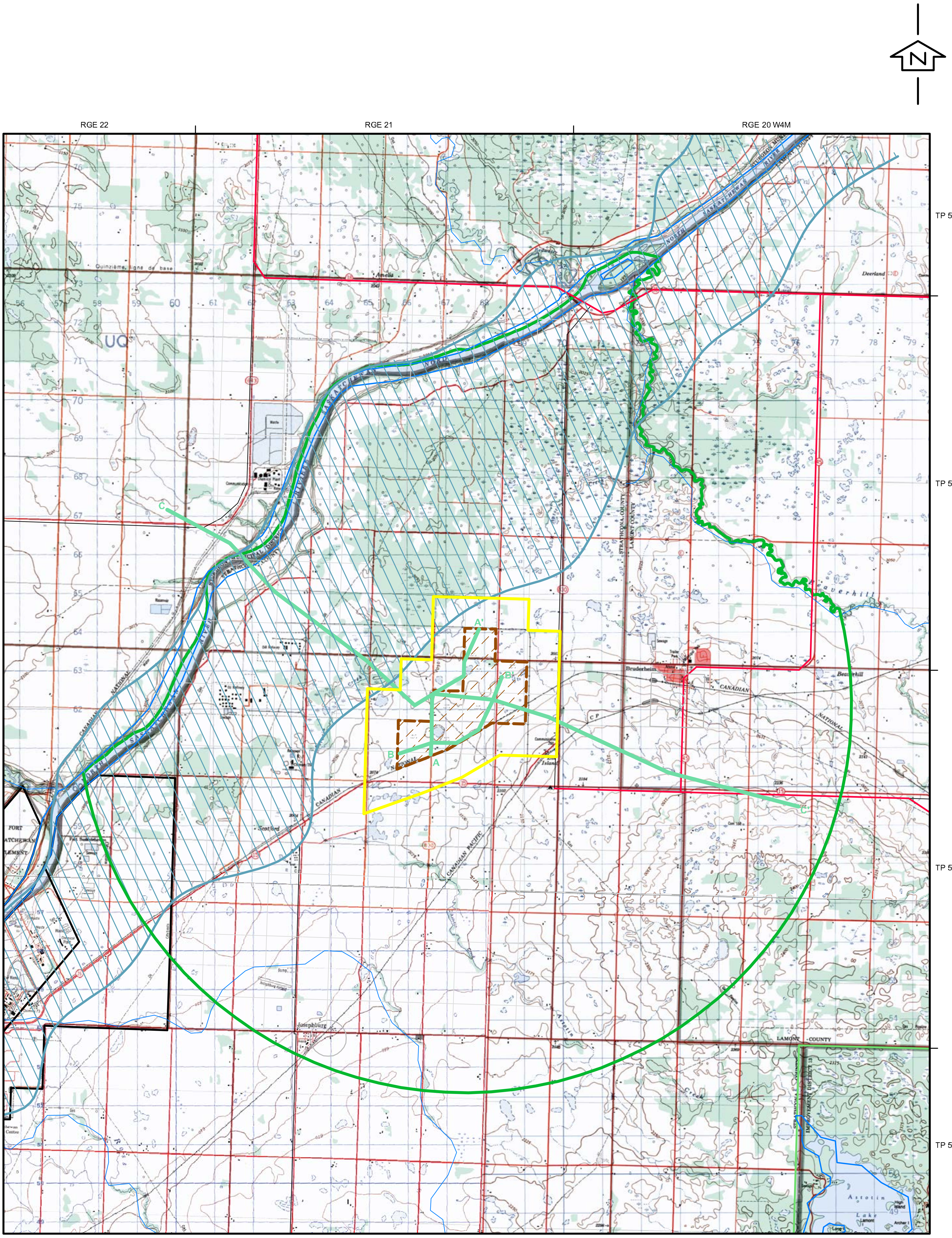


NOTE:
ELEVATION CONTOURS: 25ft INTERVALS (10m INTERVALS IN SW PORTION OF MAP AREA)

BASE MAP:
1:50 000, 83 H/10, 83 H/11, 83 H/14 AND 83 H/15.

REFERENCE MAP FOR BEVERLY CHANNEL:
1:125 000, Stein, 1976, HYDROLOGICAL MAP, EDMONTON AREA (Northeast Segment) ALBERTA,
NTS 83H-NE

SCALE 1:100000 kilometres
\# 0 # #

LEGEND
🟨 LOCAL STUDY AREA (LSA)
🟩 REGIONAL STUDY AREA (RSA)
▬ ▬ NORTH AMERICAN UPGRADER
▬ CROSS-SECTION LINE
▨ BEVERLY CHANNEL AREA

Title:

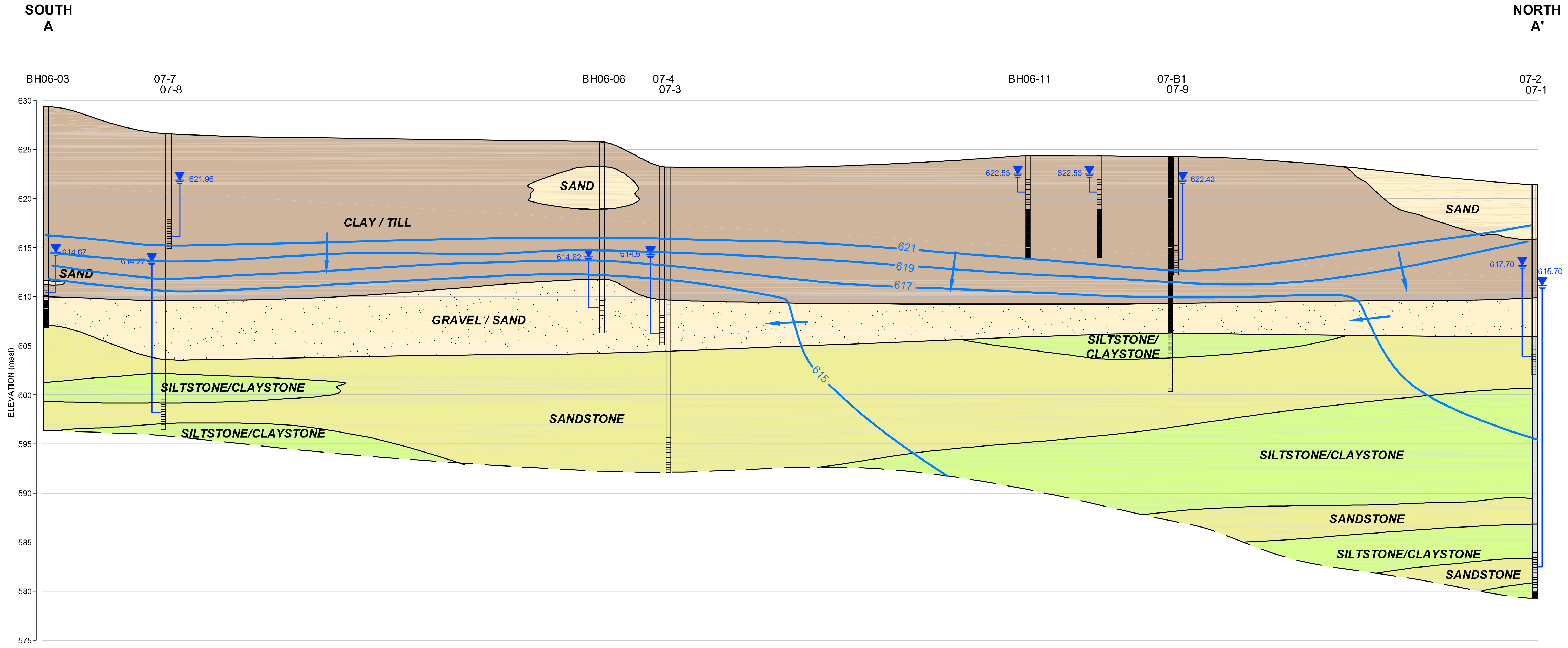
LOCATION OF BEVERLY CHANNEL

NORTH AMERICAN
OIL SANDS CORPORATION

Approved:	Revision Date:
TVD	07/11/11

File: 6198-SITE-07.DWG

Drawn by:	Checked:	Fig. No.:
AJG	RP	**5.5-6**



VERTICAL SCALE

1:400 4 0 4 8 m

HORIZONTAL SCALE

1:10 000 100 0 100 200 m

LEGEND

WELL NAME

WATER LEVEL 614.62	MONITORING WELL
	622.53 MEASURED
	HYDRAULIC HEAD (m)
	DATE
	SCREEN INTERVAL
	BACKFILLED

🟫	CLAY/TILL
🟨	SAND
🟨	GRAVEL/SAND
🟨	SANDSTONE
🟩	SILTSTONE/CLAYSTONE
-619-	HYDRAULIC HEAD CONTOUR (mase)
→	INTERPRETED GROUNDWATER FLOW DIRECTION

Title:

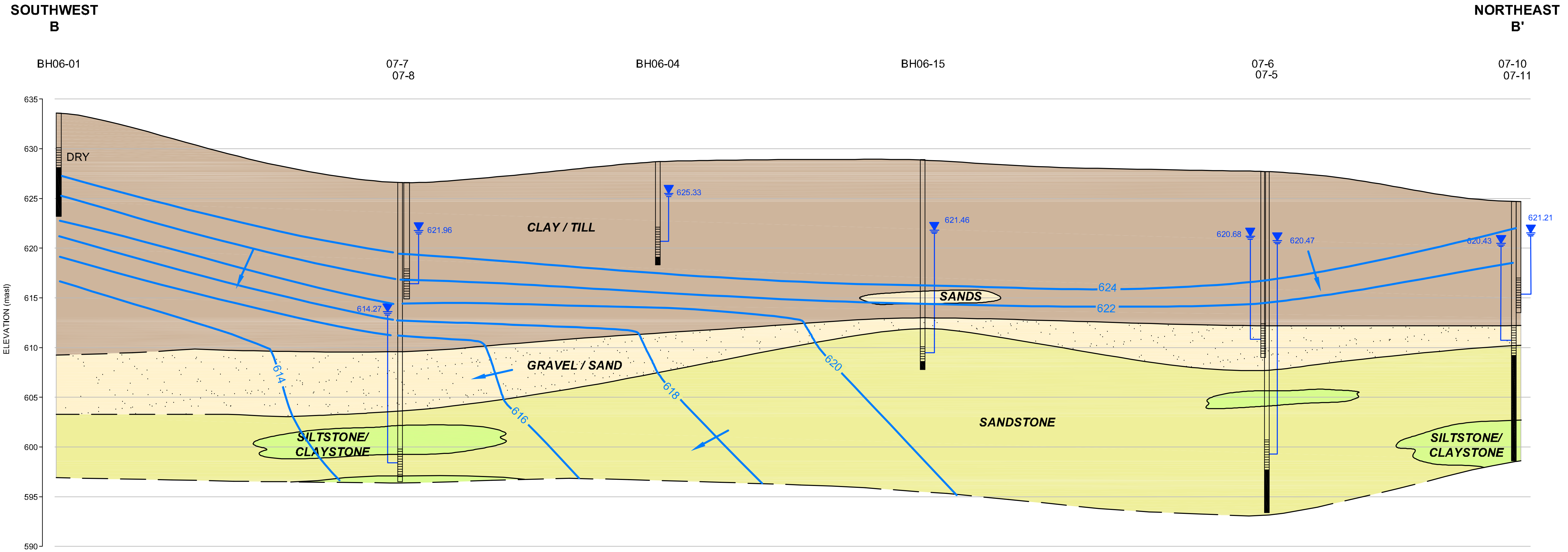
CROSS-SECTION
A-A'

NORTH AMERICAN OIL SANDS CORPORATION

Approved: TVD	Revision Date: 07/11/11

File: 6198-XSEC-07.DWG

Drawn by: AJG	Checked: SR	Fig. No.: **5.5-7**



VERTICAL SCALE
1:400
4 0 4 8 m

HORIZONTAL SCALE
1:10 000
100 0 100 200 m

LEGEND

WELL NAME
MONITORING WELL
WATER LEVEL
621.96
SCREEN INTERVAL
BACKFILLED

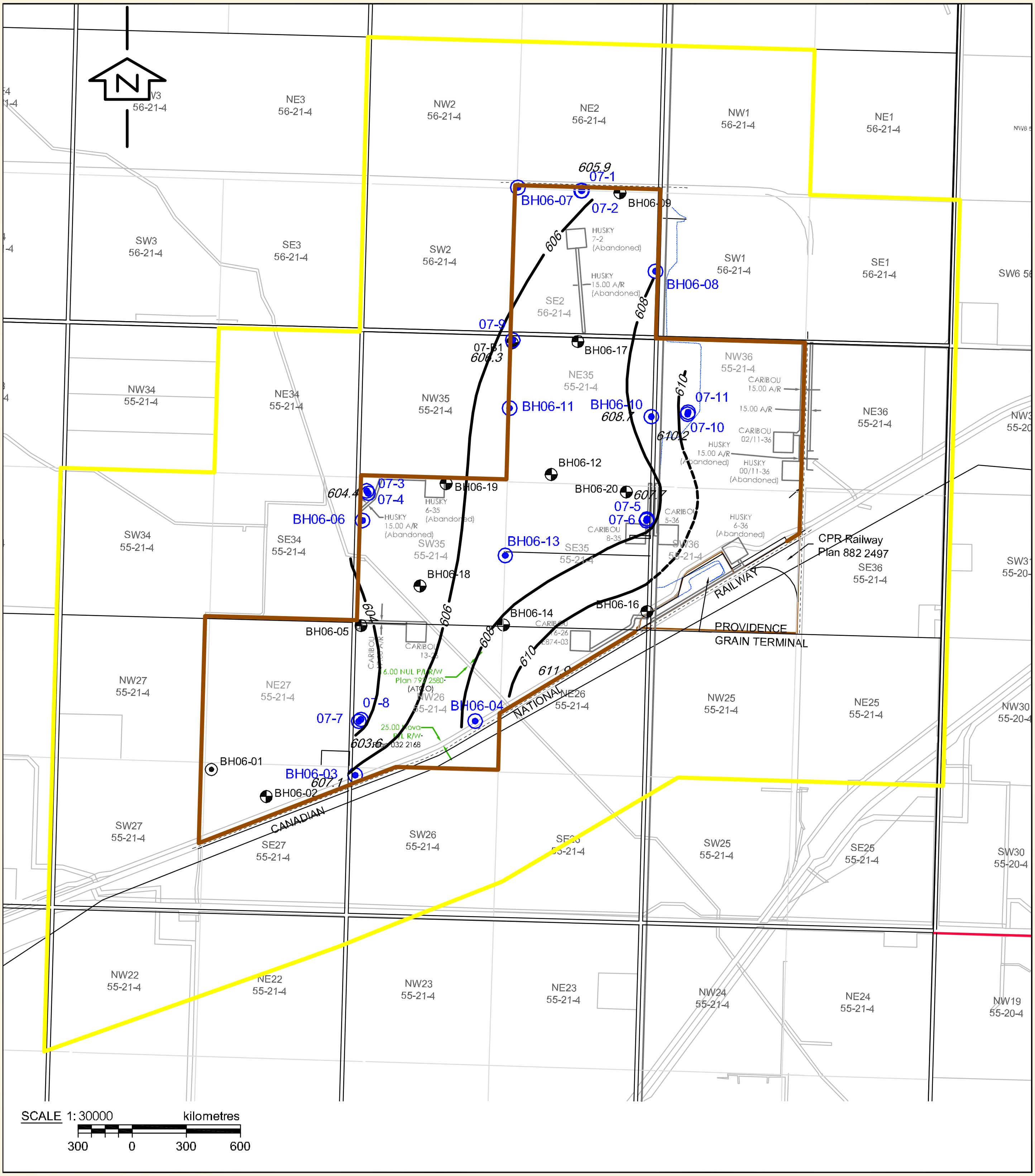
🟫	CLAY/TILL
☐	SAND
☐	GRAVEL/SAND
🟨	SANDSTONE
🟩	SILTSTONE/CLAYSTONE
-619-	HYDRAULIC HEAD CONTOUR (mase)
→	INTERPRETED GROUNDWATER FLOW DIRECTION

Title:

CROSS-SECTION
B-B'

NORTH AMERICAN
OIL SANDS CORPORATION

Approved: TVD	Revision Date: 07/11/11
File: 6198-XSEC-07.DWG	
Drawn by: AJG	Checked: SR
Fig. No.: **5.5-8**	



LEGEND

🟨	LOCAL STUDY AREA (LSA)
🟫	NORTH AMERICAN UPGRADER
610	BEDROCK ELEVATION CONTOUR
◐	BOREHOLE LOCATION
◉	MONITORING WELL LOCATION
607.1	TOP OF BEDROCK ELEVATION (masl)

Title:

BEDROCK TOPOGRAPHY WITHIN THE LSA

NORTH AMERICAN OIL SANDS CORPORATION

Approved: TVD	Revision Date: 07/11/11
File: 6198-SITE-07.DWG	
Drawn by: AJG	Checked: RP
Fig. No.: 5.5-9	

*PLOT 1:1 = Letter (P)

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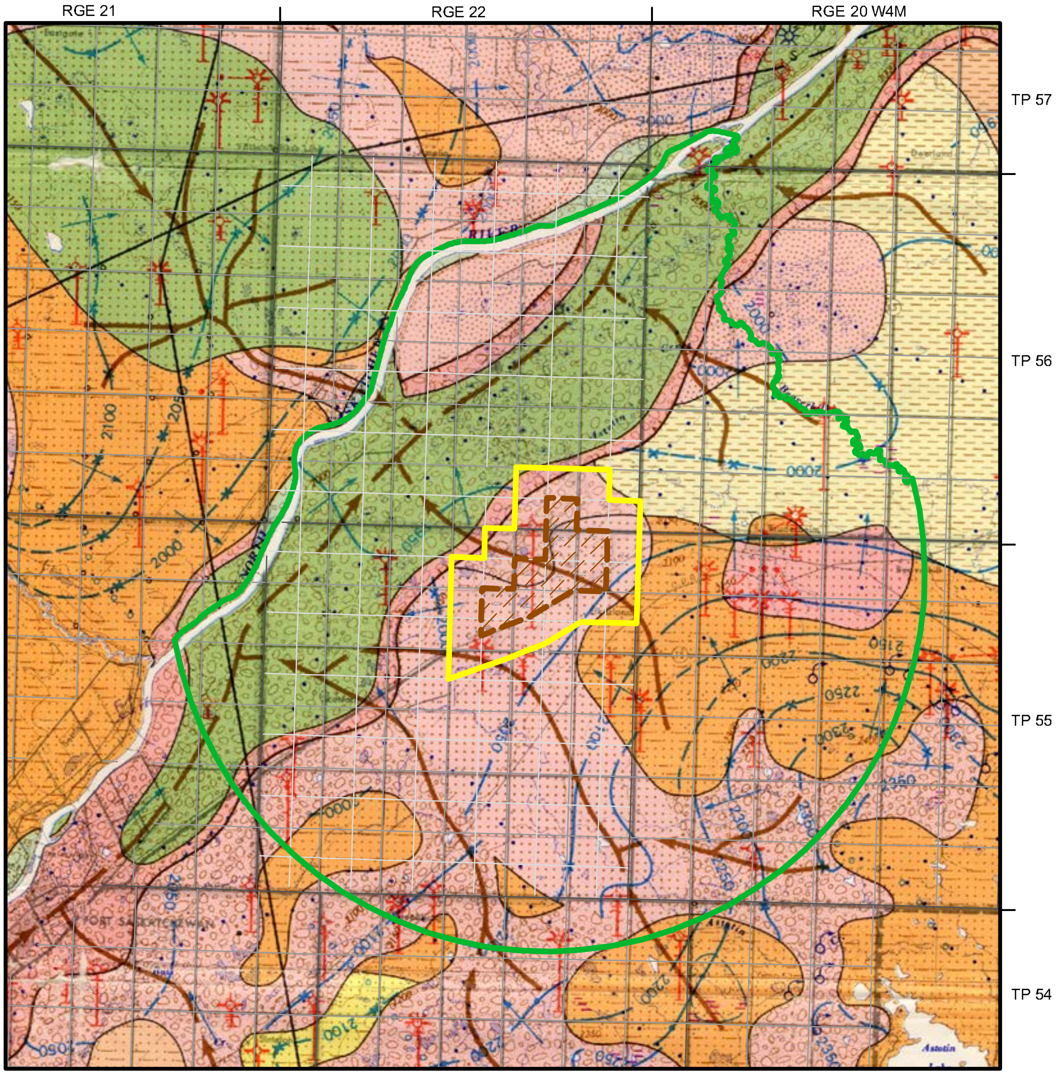


Topography

—3000— Surface contours and elevations in feet

Geology

Geological boundary

Thalweg of buried valley: defined, approximate

Lithology

Sand and Gravel

Sand

Sandstone

Shale

Hydrography

Marsh

Stream, perennial

Stream, intermittent

Surface water divide

Hydrogeology

Spring, flow rate unknown

Upward Flow

Downward Flow

Spring information

Fe iron

S sand

3000 Water table contour (elevation in feet)

3000 Nonpumping water level contour (elevation in feet) and vertical component of groundwater movement

Component of groundwater flow paralell to profile

Ground water divide

Boundary of area of artesian flow

Groundwater Probability

Range of average expected yield of wells (in igpm)

🟩	25-100	🟩
🟥	5-25	🟥
🟧	1-5	🟧
🟨	< 1	🟨

Probable:estimated from quantitative information (pump tests, bail tests, etc.)

Possible: estimated from qualitative information (flow regime, lithology, etc)

Yield boundary

Maximum depth of investigation for yield values on main map

Wells and Other Artificial Works

Depth scale

Feet
0
100
200
300
400

Depth to water

Depth of well or seismic shot hole

Water well, 20 year safe yield calculated from:

- apparent transmissivity
- a good bail test or a short pump test
- a pump test of sufficient length to reflect regional hydraulic conditions

Adjacent wells

Observation well with automatic recorder

ARC Location of Alberta Research Counsil test well

Oil well

Structural test hole

SCALE 1:100000 kilometres

2 0 2 4

LEGEND

LOCAL STUDY AREA (LSA)

REGIONAL STUDY AREA (RSA)

NORTH AMERICAN UPGRADER

REFERENCE MAP:
1:125 000, Stein, 1976, HYDROLOGICAL MAP, EDMONTON AREA (Northeast Segment) ALBERTA, NTS 83H-NE

Title:

REGIONAL HYDROGEOLOGY

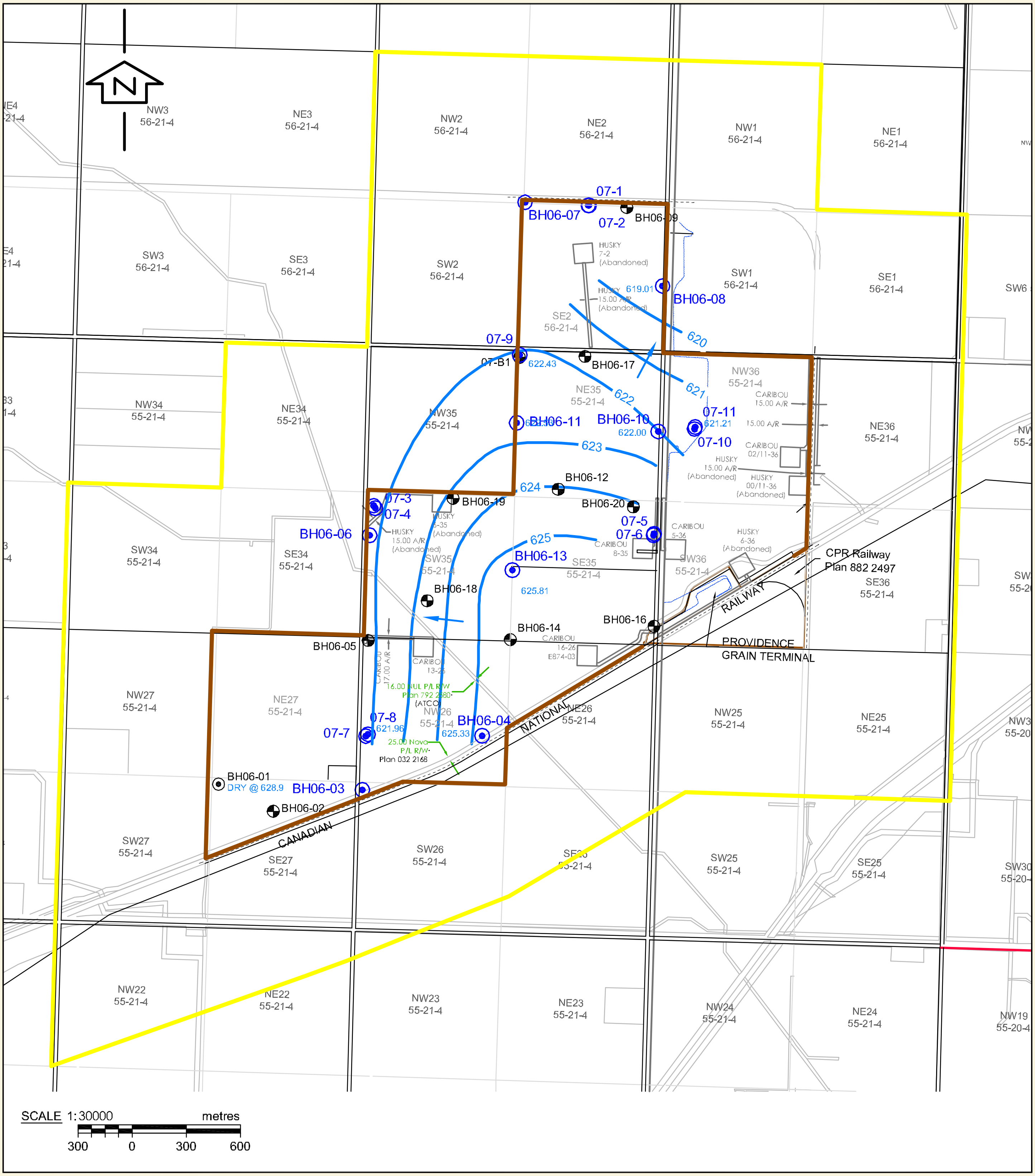
NORTH AMERICAN
OIL SANDS CORPORATION

Approved:	Revision Date:
TVD	07/11/11

File: 6198-SITE-07.DWG

Drawn by:	Checked:	Fig. No.:
AJG	RP	**5.5-10**

*PLOT 1:1 = Letter (P)



LEGEND	
🟨	LOCAL STUDY AREA (LSA)
🟫	NORTH AMERICAN UPGRADER
◐	BOREHOLE LOCATION
◉	MONITORING WELL LOCATION
615	GROUNDWATER CONTOUR (masl)
614.62	GROUNDWATER ELEVATION (masl)
←	DIRECTION OF GROUNDWATER FLOW

Title:

GROUNDWATER FLOW MAP
CLAY TILL
MAY 11, 2007

NORTH AMERICAN
OIL SANDS CORPORATION

Approved: TVD	Revision Date: 07/11/11	
File: 6198-SITE-07.DWG		
Drawn by: AJG	Checked: RP	Fig. No.: **5.5-11**

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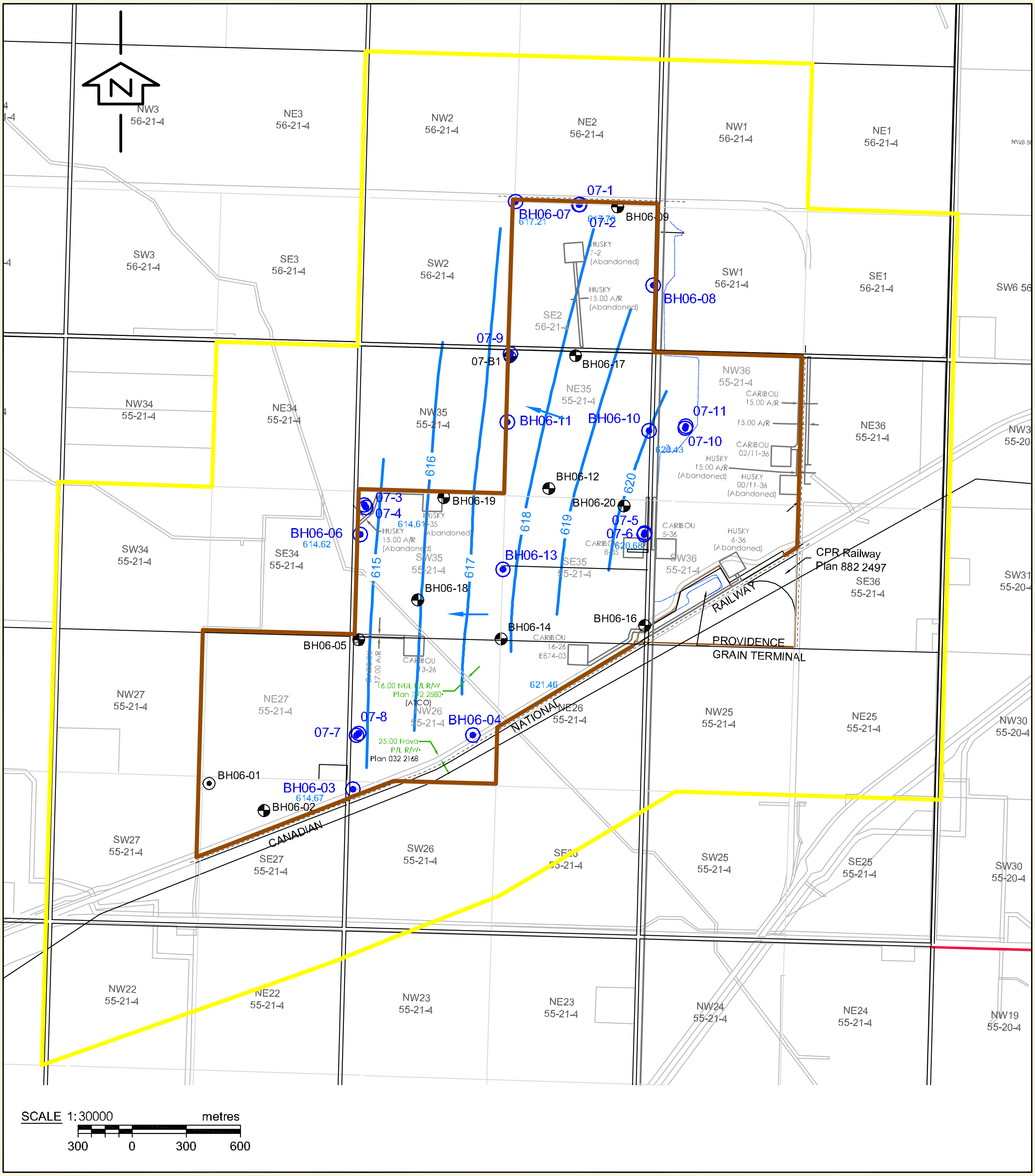
*PLOT 1:1 = Letter (P)



🟨	LOCAL STUDY AREA (LSA)
🟫	NORTH AMERICAN UPGRADER
◐	BOREHOLE LOCATION
◉	MONITORING WELL LOCATION
— 615 —	GROUNDWATER CONTOUR (masl)
614.62	GROUNDWATER ELEVATION (masl)
←	DIRECTION OF GROUNDWATER FLOW

Title:

GROUNDWATER FLOW MAP LOWER SAND AND GRAVEL MAY 11, 2007

NORTH AMERICAN OIL SANDS CORPORATION

Approved: TVD	Revision Date: 07/11/11
File: 6198-SITE-07.DWG	

Drawn by:	Checked:	Fig. No.:
AJG	RP	**5.5-12**

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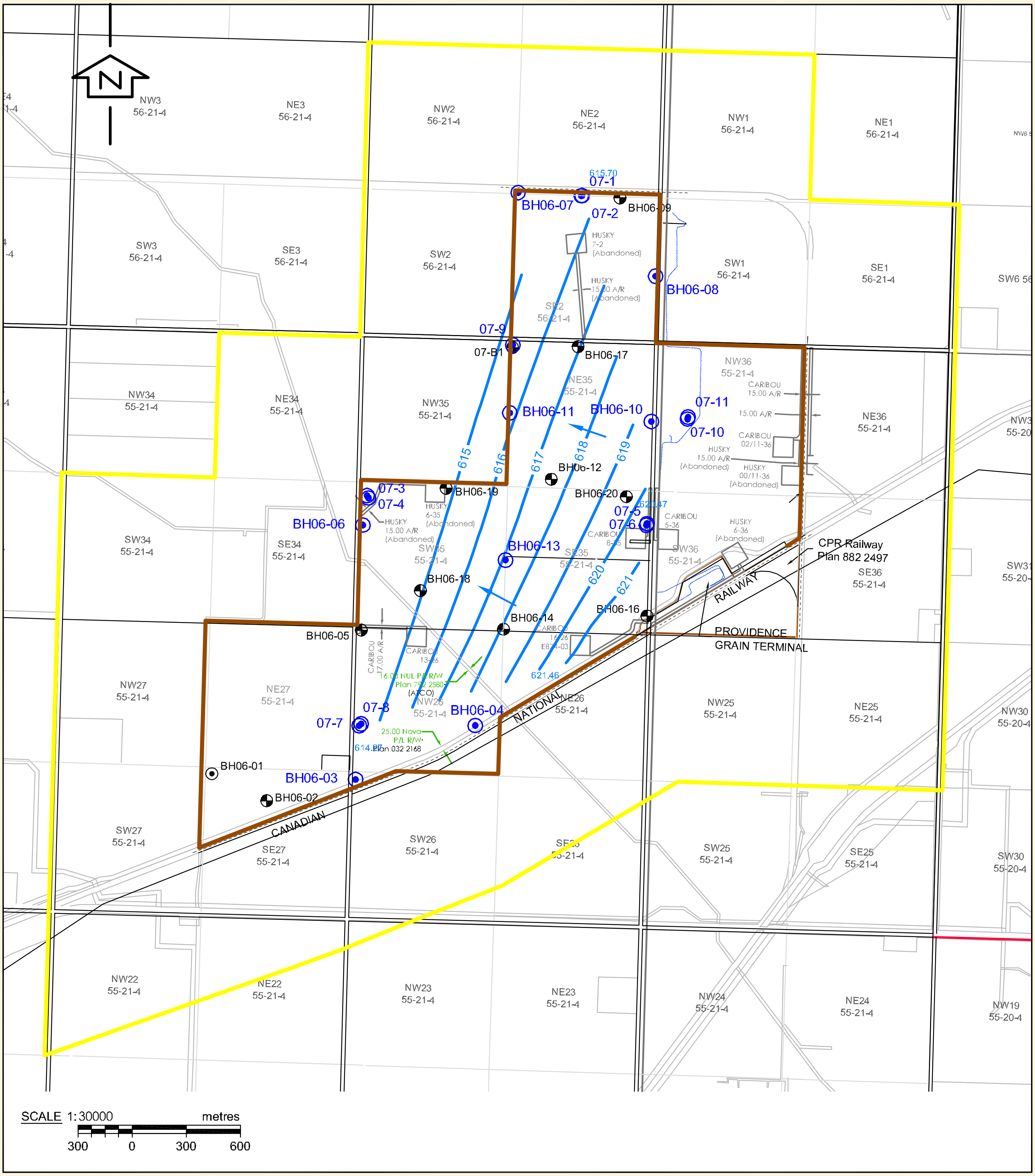
*PLOT 1:1 = Letter (P)



LEGEND

🟨	LOCAL STUDY AREA (LSA)
🟫	NORTH AMERICAN UPGRADER
◐	BOREHOLE LOCATION
◉	MONITORING WELL LOCATION
— 615 —	GROUNDWATER CONTOUR (masl)
614.62	GROUNDWATER ELEVATION (masl)
←	DIRECTION OF GROUNDWATER FLOW

Title:

GROUNDWATER FLOW MAP
BEDROCK
MAY 11, 2007

NORTH AMERICAN
OIL SANDS CORPORATION

Approved: TVD	Revision Date: 07/11/11
File: 6198-SITE-07.DWG	

Drawn by: AJG	Checked: RP	Fig. No.: **5.5-13**

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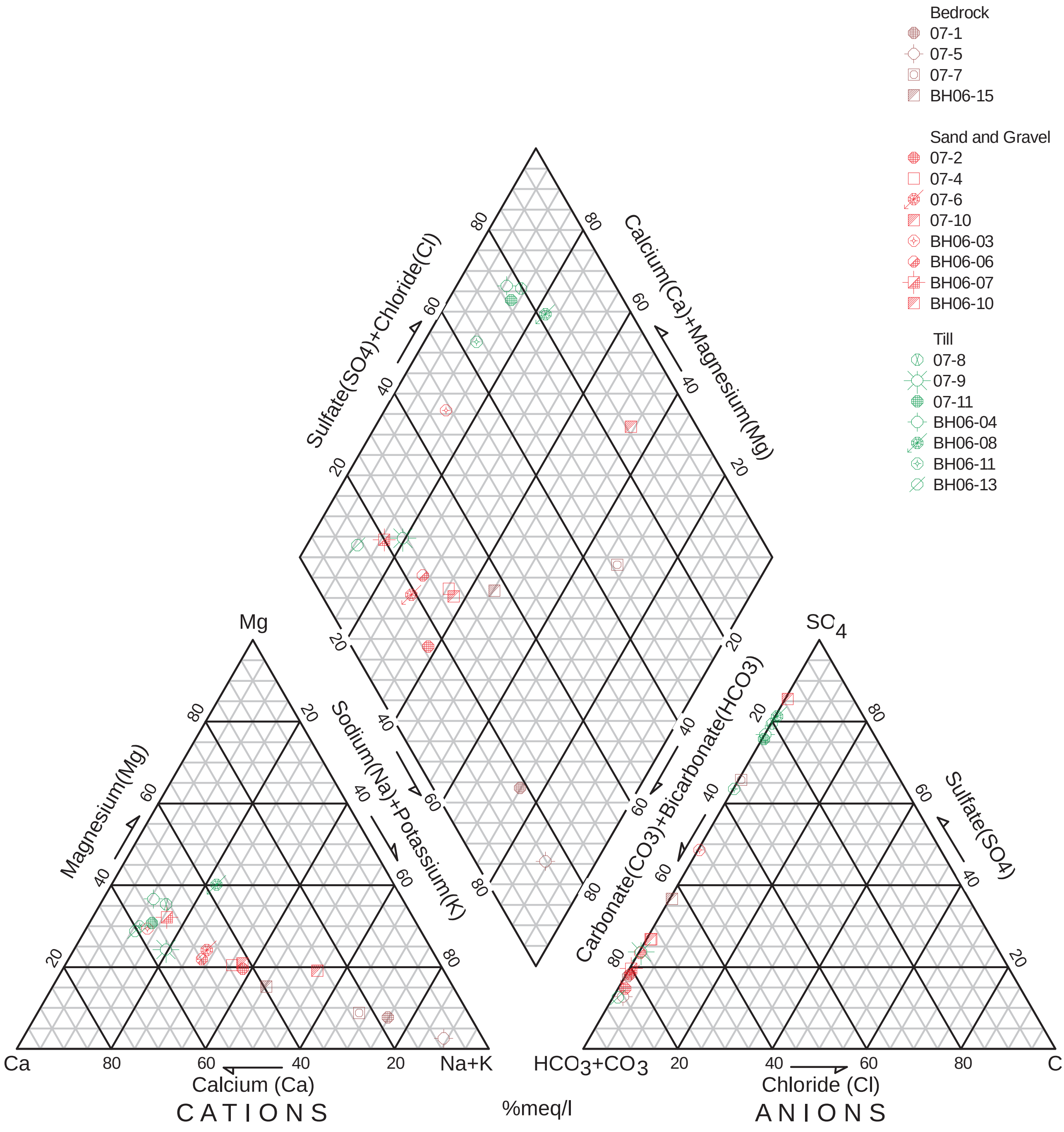

Title:

GROUNDWATER PIPER DIAGRAM

NORTH AMERICAN
OIL SANDS CORPORATION

Approved: DC

Revision Date: 07/05/31

File: 6198-Piper-07.cdr

Drawn by: CZH

Checked: RP

Fig. No.: **5.5-14**

*PLOT 1:1 = Letter (P)

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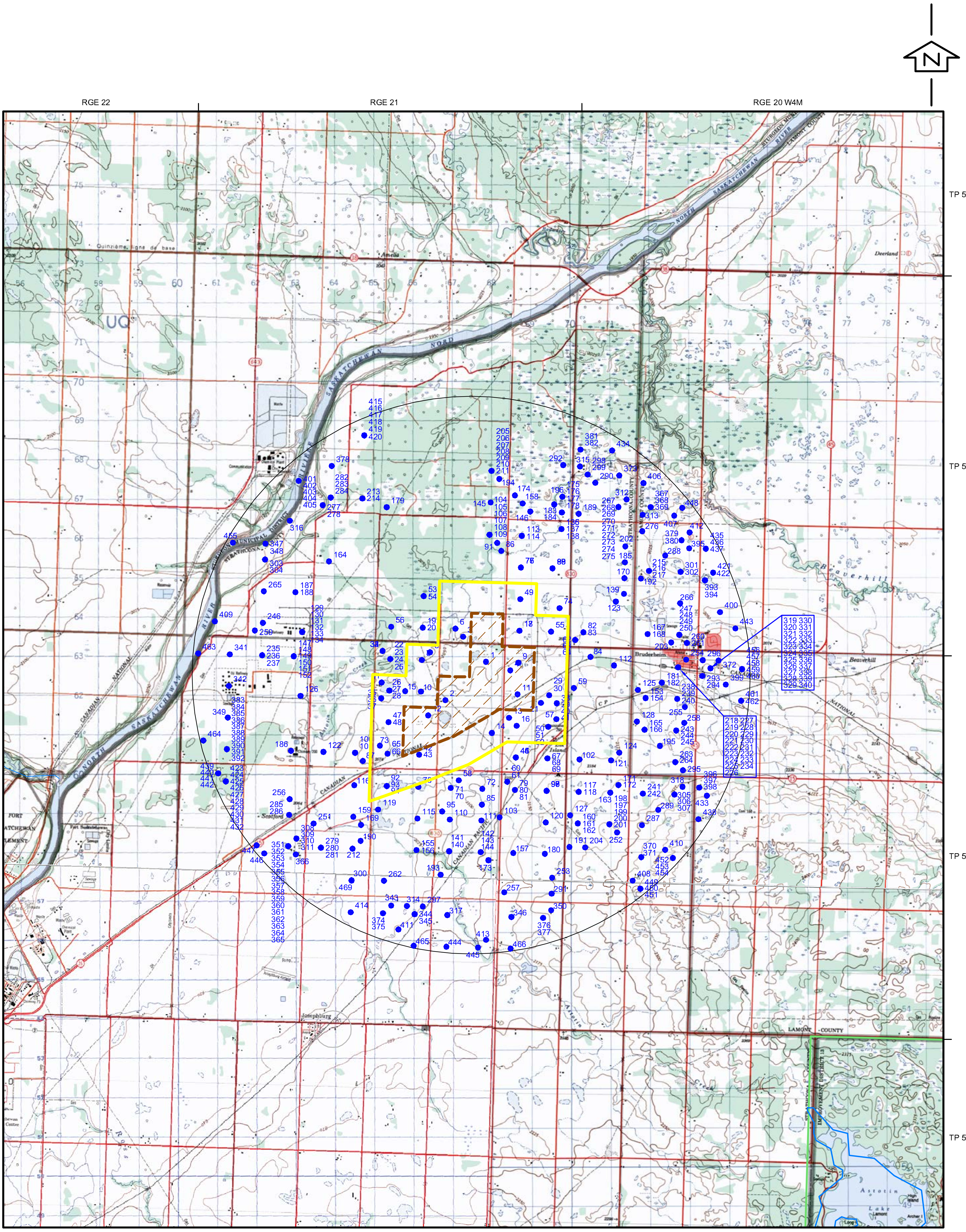


LEGEND

▬ ▬ NORTH AMERICAN UPGRADER

482 ● WATER WELLS (LOCATIONS ARE APPROXIMATE AND NOT FIELD VERIFIED)

REFERENCE MAP:
1:50 000, 83 H/10, 83 H/11, 83 H/14 AND 83 H/15.

SCALE 1:100000 kilometres
1 0 1 2

Title:

WATER WELL LOCATIONS (WITHIN A 7 km RADIUS)

NORTH AMERICAN
OIL SANDS CORPORATION

Approved:	Revision Date:
TVD	07/11/11

File: 6198-SITE-07.DWG

Drawn by:	Checked:	Fig. No.:
AJG	RP	5.5-15

5.6 Impact Assessment and Mitigative Measures

The potential impacts resulting from construction and operation of the Upgrader are described in the following subsections. The potential impacts are evaluated with respect to the following key hydrogeological indicator resources: surficial aquifers within the clay till unit (Shallow Overburden Aquifers), the Lower Sand and Gravel Aquifer, the Beverly Channel Aquifer and Bedrock Aquifers.

5.6.1 Impacts Due to Surface Facilities

Surface disturbance for the Project include Upgrader facilities, tank farms and ponds. Measurable impacts to water levels as a result of the operation of these surface facilities are not expected and are considered neutral, with a prediction confidence of high and a final impact rating of no impact (Table 5.6-1).

Table 5.6-1 Impact Due to Surface Facilities

Key Indicator Resource	Attribute	Direction	Extent	Magnitude	Duration	Frequency	Permanence	Prediction Confidence	Final Impact Rating
Shallow Overburden Aquifers	Water Levels	neutral	n/a	n/a	n/a	n/a	n/a	high	no impact
	Water Quality	negative	local	high	long-term	isolated	reversible in the short to long-term	high	low impact
Lower Sand and Gravel Aquifer	Water Levels	neutral	n/a	n/a	n/a	n/a	n/a	high	no impact
	Water Quality	negative	local	high	long-term	isolated	reversible in the short to long-term	high	low impact
Beverly Channel Aquifer	Water Levels	neutral	n/a	n/a	n/a	n/a	n/a	high	no impact
	Water Quality	neutral	n/a	n/a	n/a	n/a	n/a	high	no impact
Bedrock Aquifers	Water Levels	neutral	n/a	n/a	n/a	n/a	n/a	high	no impact
	Water Quality	negative	local	high	long-term	isolated	reversible in the short to long-term	medium	low impact

Accidental releases from surface facilities such as pipelines, tanks, buildings and ponds all have the potential to impact groundwater quality negatively. The potential risk to receptors depends on the location of the release, the volume of the release, the duration of the release, the nature of materials released and the subsurface hydraulic conditions.

Much of the LSA is covered by organic soils underlain by a clay till unit, with a thickness of 5.5 m to 23 m and a relatively low hydraulic conductivity of 1 x 10^{-9} m/s to 6 x 10^{-9} m/s (Table 5.4-2). The linear velocity of groundwater in the clay till is estimated to be 0.006 m/y. A surficial eolian sand deposit overlies the till at the northern part of the Project site where no facilities are planned for construction. Accidental releases have the potential to impact shallow groundwater quality adversely. North American will implement the following mitigative strategies for the Project:

- Where possible, piping and tanks will be located aboveground to facilitate leak detection (pipeline will be belowground).

- Storage tanks will be protected against leaks using environmental controls such as internal coatings, cathodic protection and secondary containment, in accordance with EUB Directive 055 (EUB, 2001). Leak detection equipment will be installed where appropriate.
- North American will develop contingency plans that will serve as a guide for spill response.
- North American will establish formal asset integrity programs to ensure that equipment quality is managed and maintained.
- North American will require appropriate training for all people whose work may create an impact on the environment.
- Groundwater monitoring will be conducted at processing facilities, tank farms and ponds (Section 5.8) to monitor the effectiveness of the implemented mitigative measures.

Because of these mitigative measures, the depth below ground surface and the low hydraulic conductivity of the overlying till, accidental releases from ground surface pose little threat to the Beverly Channel Aquifer. The direction of impact is considered neutral, with a high prediction confidence and a final impact rating of no impact.

Accidental releases from surface facilities could result in a deterioration of the water quality in the Shallow Overburden, Lower Sand and Gravel and Bedrock Aquifers, and is considered a negative impact. The extent is local, the magnitude is potentially high, the duration is long-term, the frequency is isolated and the permanence is reversible in the short to long-term, depending on the size and nature of the release. The prediction confidence of this assessment is medium to high.

The mitigative measures and groundwater monitoring (Section 5.8) in the vicinity of surface facilities will ensure that any releases will be identified and response measures implemented to minimize impacts. Although potential changes in water quality due to surface facility operations are possible, the final impact rating is considered low because effective industry standard mitigation and monitoring efforts will be implemented for the Project.

5.6.2 Impacts Due to Dewatering of Excavations

Groundwater will not be used for water supply during construction or operation of the Upgrader. Dewatering of excavations may occur during construction of the Upgrader. The depths of the excavations are not expected to extend below the base of the clay till.

Measurable impacts to groundwater quality as a result of dewatering are not expected and are considered neutral, with a prediction confidence of high and a final impact rating of no impact (Table 5.6-2).

Table 5.6-2 Impact Due to Dewatering of Excavations

Key Indicator Resource	Attribute	Direction	Extent	Magnitude	Duration	Frequency	Permanence	Prediction Confidence	Final Impact Rating
Shallow Overburden Aquifers	Water Levels	negative	local	medium	short-term	isolated	reversible in the short-term	high	low impact
	Water Quality	neutral	n/a	n/a	n/a	n/a	n/a	high	no impact
Lower Sand and Gravel Aquifer	Water Levels	negative	local	low	short-term	isolated	reversible in the short-term	medium	negligible impact
	Water Quality	neutral	n/a	n/a	n/a	n/a	n/a	high	no impact
Beverly Channel Aquifer	Water Levels	negative	local	negligible	short-term	isolated	reversible in the short-term	high	negligible impact
	Water Quality	neutral	n/a	n/a	n/a	n/a	n/a	high	no impact
Bedrock Aquifers	Water Levels	negative	local	negligible	short-term	isolated	reversible in the short-term	medium	negligible impact
	Water Quality	neutral	n/a	n/a	n/a	n/a	n/a	high	no impact

The predicted drawdown at distances of 1 m, 2 m, 5 m, 10 m and 20 m from the excavation is presented in Figure 5.6-1. Assuming a conservative required drawdown of 6 m for a period of six months, the measurable drawdown is predicted not to extend beyond 20 m from the excavation (Figure 5.6-1).

Dewatering of the excavations could result in a decrease in the water levels in the Shallow Overburden Aquifers in the vicinity of the excavations, and is considered a negative impact. The extent is local, the magnitude is medium, the duration is short-term, the frequency is isolated and the permanence is reversible in the short-term. The prediction confidence in this assessment is high, and the final impact rating of dewatering on Shallow Overburden Aquifers is low (Table 5.6-2).

Because of thickness and low hydraulic conductivity of the clay till, and the large hydraulic conductivity of the Lower Sand and Gravel Aquifer, dewatering of excavations is expected to have minimal effect on water levels in the Lower Sand and Gravel Aquifer, and a lower magnitude in comparison to the Shallow Overburden Aquifers. The direction of impact is considered negative, with low magnitude, a medium prediction confidence and a final impact rating of negligible (Table 5.6-2).

Based on the low impact to water levels in the Lower Sand and Gravel Aquifer, dewatering of excavations would have no detectable effect on water levels in the Beverly Channel and Bedrock Aquifers. The direction of impact is considered negative, with a medium prediction confidence and a final impact rating of negligible (Table 5.6-2).

5.6.3 Impacts Due to Groundwater Withdrawal Below Ponds

The potentially contaminated pond and oily water pond will be excavated to a working depth of 6.1 m. Liners will be installed in these ponds to prevent infiltration of contaminated water to the groundwater system. If the water table intersects these ponds, groundwater would enter the pond excavation and cause the liners to float. To prevent this, a groundwater tile drainage system will be installed to maintain the water table elevation below the pond bottoms. The drained groundwater will be pumped into the pond system. The depths of the ponds are not expected to extend below the base of the clay till.

Measurable impacts to groundwater quality as a result of groundwater withdrawal are not expected and are considered neutral, with a prediction confidence of high and a final impact rating of no impact (Table 5.6-3).

Table 5.6-3 Impact Due to Groundwater Withdrawal Below Ponds

Key Indicator Resource	Attribute	Direction	Extent	Magnitude	Duration	Frequency	Permanence	Prediction Confidence	Final Impact Rating
Shallow Overburden Aquifers	Water Levels	negative	local	medium	long-term	continuous	reversible in the medium-term	high	low impact
	Water Quality	neutral	n/a	n/a	n/a	n/a	n/a	high	no impact
Lower Sand and Gravel Aquifer	Water Levels	negative	local	low	long-term	continuous	reversible in the short-term	medium	low impact
	Water Quality	neutral	n/a	n/a	n/a	n/a	n/a	high	no impact
Beverly Channel Aquifer	Water Levels	negative	local	negligible	long-term	continuous	reversible in the short-term	high	negligible impact
	Water Quality	neutral	n/a	n/a	n/a	n/a	n/a	high	no impact
Bedrock Aquifers	Water Levels	negative	local	negligible	long-term	continuous	reversible in the short-term	medium	negligible impact
	Water Quality	neutral	n/a	n/a	n/a	n/a	n/a	high	no impact

The predicted drawdown at distances of 5 m, 20 m, 50 m, 100 m and 200 m from the ponds is presented in Figure 5.6-2. Assuming a required drawdown of 6.1 m for a period of 50 years, the measurable drawdown is predicted to be less than 0.4 m at a distance of 100 m from the ponds, and negligible at a distance of 200 m (Figure 5.6-2).

Groundwater withdrawal beneath the potentially contaminated and oily water ponds could result in a decrease in the water levels in the Shallow Overburden Aquifers in the vicinity of the ponds, and is considered a negative impact. The extent is local, the magnitude is medium, the duration is long-term, the frequency is continuous and the permanence is reversible in the medium-term. The prediction confidence in this assessment is high, and the final impact rating of dewatering on Shallow Overburden Aquifers is low (Table 5.6-3).

Because of thickness and low hydraulic conductivity of the clay till, as well as the large hydraulic conductivity of the Lower Sand and Gravel Aquifer, groundwater withdrawal is expected to have minimal effect on water levels in the Lower Sand and Gravel Aquifer, and a lower magnitude in comparison to the Shallow Overburden Aquifers. The direction of impact is considered negative, with low magnitude, a medium prediction confidence and a final impact rating of low (Table 5.6-3).

Based on the low impact to water levels in the Lower Sand and Gravel Aquifer, groundwater withdrawal would have no detectable effect on water levels in the Beverly Channel and Bedrock Aquifers. The direction of impact is considered negative, with a medium prediction confidence and a final impact rating of negligible (Table 5.6-3).

PREDICTED GROUNDWATER LEVEL CHANGES
NORTH AMERICAN UPGRADER EXCAVATIONS

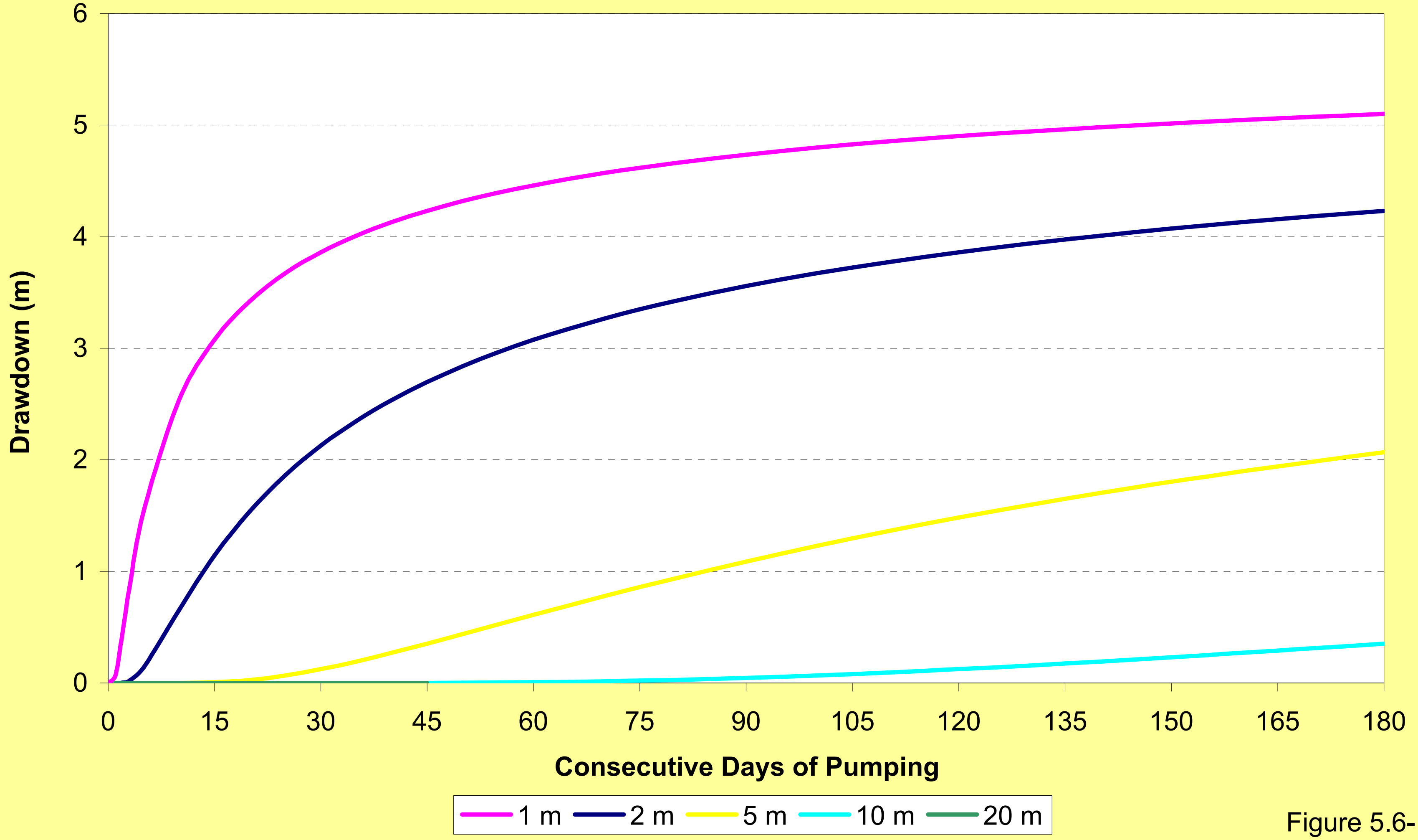


Figure 5.6-1

PREDICTED GROUNDWATER LEVEL CHANGES
NORTH AMERICAN UPGRADER PONDS

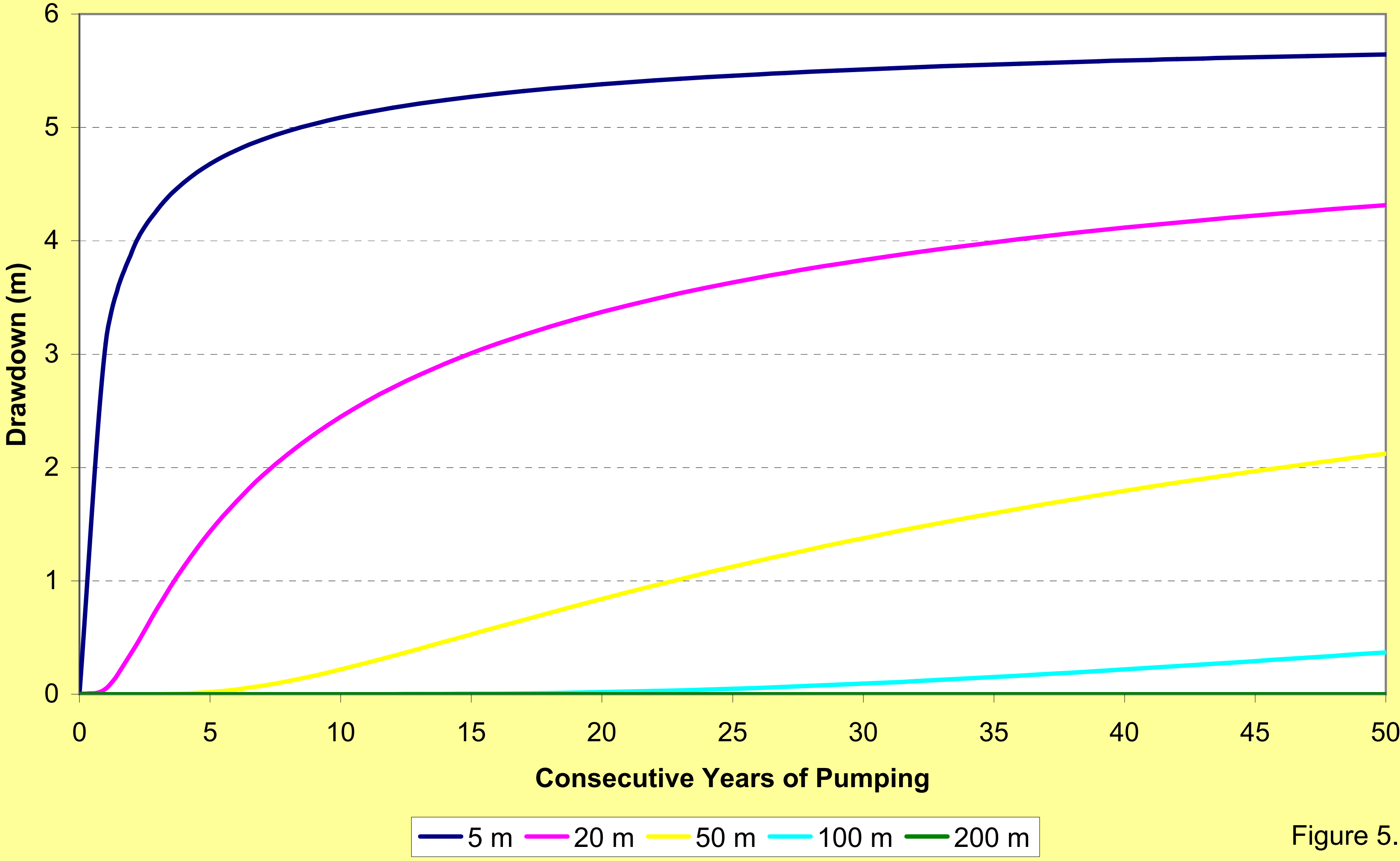


Figure 5.6-2

5.7 Cumulative Effects Assessment

Due to the thickness and low permeability of the surficial clay till unit, impacts to groundwater levels and groundwater quality are expected to be local, and no measurable effects on groundwater are expected to extend outside of the LSA. Temporal and spatial overlaps with existing and future groundwater users in the region are not expected. Thus, no cumulative effects on groundwater quality or groundwater levels are anticipated.

5.8 Follow-up and Monitoring

A groundwater monitoring program will be implemented to monitor groundwater levels, flow conditions and groundwater quality at the Project site. This groundwater monitoring approach will be used to enable early detection of changes in groundwater conditions.

The groundwater monitoring program will include the use of existing monitoring wells, as well as additional monitoring wells that will be installed after the Project facilities have been constructed. The groundwater monitoring network will focus on the water table zone within the clay till unit, to target the most vulnerable zone with respect to potential impacts associated with Project operations, as well as the lower sand and gravel and bedrock. Monitoring wells will be installed adjacent to areas exposed to potential sources of accidental releases, as well as in areas of groundwater withdrawal. At least one on-site monitoring well location will consist of a nested pair, with one well completed at the water table and a second monitoring well completed at a depth of approximately 10 m bgs. At least one monitoring well will be located hydraulically upgradient of the site to serve as a background (control) well. The proposed monitoring well network is presented in Figure 5.8-1.

Groundwater samples will be collected from each monitoring well at least once annually, and analyzed for field parameters, including temperature, pH, EC and DO. Laboratory analyses may include the indicator parameters, which are based on potential impact to groundwater quality associated with heavy oil facilities listed on Table 5.8-1.

Table 5.8-1 Analytical Parameters That May be Used in the Groundwater Monitoring Program

Source of Impact	Routine[1]	Dissolved Metals[2]	DOC	BTEX, F1 and F2[3]	NO_2-NO_3 and NH_4	Amines
Ponds	X	X	X	X		
Amines					X	X
Sulfur	X					
Sodium hydroxide	X					
Fuel			X	X		
Bitumen			X	X		X
Diluent			X	X		
Sour Water	X	X	X	X		
Process Chemicals	X		X			

Notes:

1 Routine water analysis includes EC, pH, total dissolved solids, sodium, potassium, calcium, magnesium, manganese, iron, hydroxide, chloride, carbonate, bicarbonate, sulphate, hardness and alkalinity.

2 Dissolved metals analysis includes aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, lithium, manganese, molybdenum, nickel, phosphorus, selenium, silicon, strontium, sulphur, thallium, tin, titanium, uranium, vanadium, zinc and zirconium.

3 BTEX analysis includes benzene, toluene, ethylbenzene and xylenes, F1 includes hydrocarbon fractions C_5-C_{10} and F2 includes hydrocarbon fractions C_{10}-C_{16}.

In the event that significant changes in groundwater quality are detected, an incident-specific groundwater response plan will be developed and implemented.

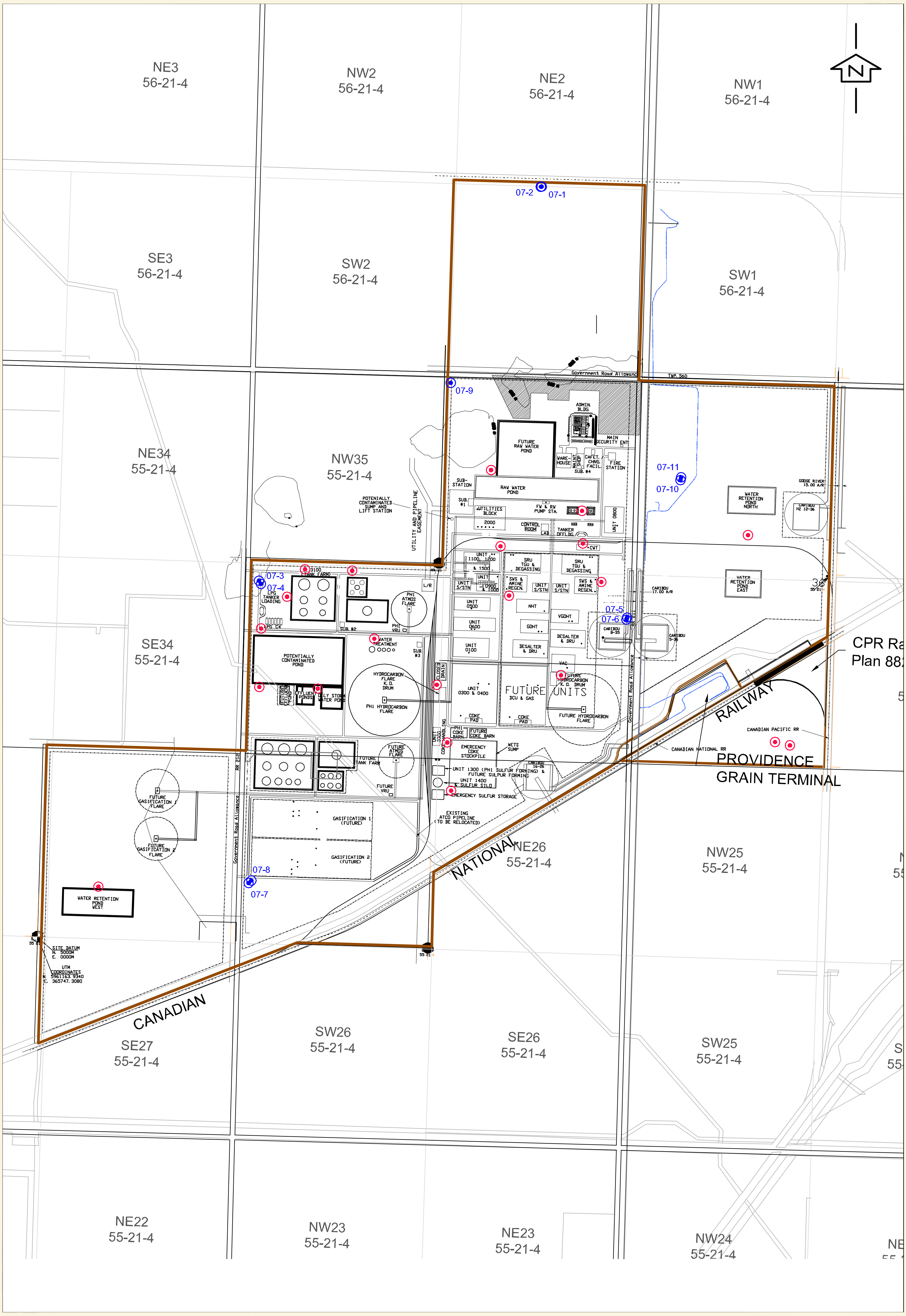
5.8.1 Groundwater Response Plan

In the unlikely event that major changes in groundwater quality are detected as a result of Project operations, an incident-specific response plan will be developed and implemented. Aspects of the plan include:

- conducting confirmatory sampling;
- notifying AENV on confirmation of impact; and
- identifying the source(s) of impact.

Once the source(s) of impact have been identified, a remediation plan and/or site-specific risk management strategy will be developed, based on the nature and concentration of contaminants and potential receptors in the area. The remediation plan and/or risk management strategy will be submitted to AENV for approval, and the remediation plan and/or risk management strategy will be implemented.

*PLOT 1:1 = Letter (P)



SCALE 1:15000 meters
150 0 150 300

LEGEND

▬	NORTH AMERICAN UPGRADER
●	EXISTING MONITORING WELL LOCATION
●	PROPOSED MONITORING WELL LOCATION

Title:

PROPOSED MONITORING WELL NETWORK

NORTH AMERICAN
OIL SANDS CORPORATION

Approved: TVD	Revision Date: 07/11/123
File: 6198-SITE-07.DWG	

Drawn by:	Checked:	Fig. No.:
BSW	RP	5.8-1

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5.9 Summary

The potential impacts of the Project on groundwater were assessed with respect to water levels and water quality for the following: Shallow Overburden Aquifers, Lower Sand and Gravel Aquifer, Beverly Channel Aquifer and Bedrock Aquifers.

Throughout the lifespan of the Project, components which have the potential to affect key indicator resources include:

- the operation of surface facilities;
- dewatering of excavations; and
- withdrawal of shallow groundwater.

All of the above components were given a final impact rating of no impact to low impact.

Groundwater monitoring will be required during the operation phase of the Project to confirm that changes in groundwater levels, groundwater flow direction and/or water quality are consistent with the results of the impact assessment, and to evaluate the environmental performance of operations and engineered structures.

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6 HYDROLOGY

6.1 Introduction

This section describes the hydrology of the area considering the watercourses, waterbodies and wetlands that may be affected by the North American Upgrader Project (the Project). The following includes a description of the existing hydrologic setting within the study areas, identifies potential changes to surface water resources including cumulative effects associated with Project developments, and presents mitigation strategies to minimize or reduce potential environmental effects.

The available local and regional surface flow baseline data, including low, average, and peak flows for key creeks and rivers and typical water level fluctuations are presented. Data and information presented are based upon site specific field surveys conducted in 2006-2007 in the area, relevant historical data available in the region and information from previous studies.

6.2 Study Area

Two study areas were selected to document the hydrologic conditions and assess the hydrologic effects of the Project on a regional basis and a more detailed local level. Figure 6.2-1 shows the hydrology Local Study Area (LSA). The Hydrology Regional Study Area (RSA) is the same as the LSA plus the reach of the North Saskatchewan River (NSR) from the Gold Bar Wastewater Treatment Plant in Edmonton to the Alberta-Saskatchewan border. The Surface Water Quality (Volume 3, Section 7) and Fish and Fish Habitat (Volume 3, Section 8) assessments apply these same study areas.

6.2.1 LSA

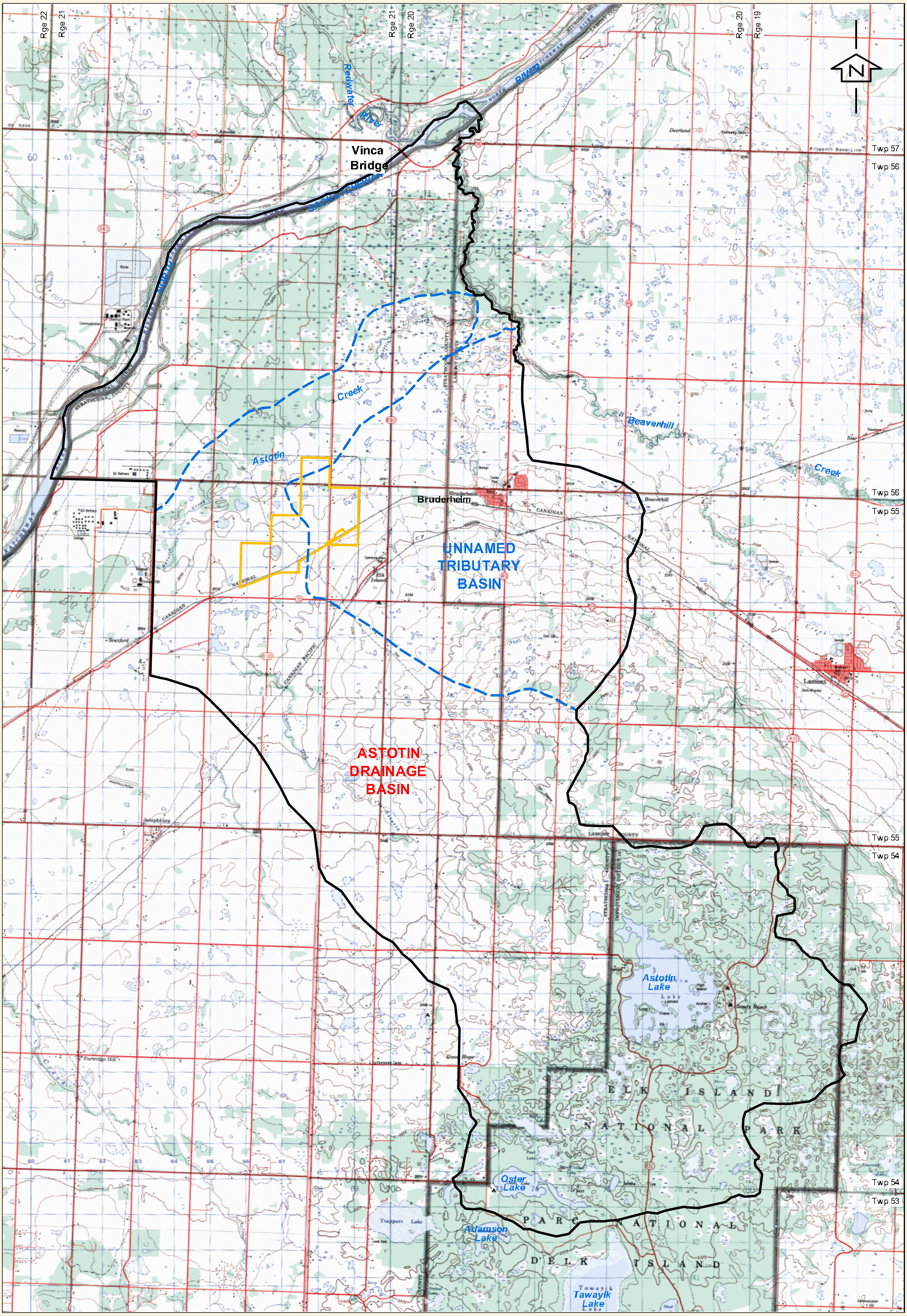
The Hydrology and Fish and Fish Habitat LSA was established to assess the potential for localized effects on water quality, hydrology and fish and fish habitat, and was delineated based on the Project footprint, local drainage basin boundaries and local effects on the NSR. The hydrology LSA includes all Project disturbance activities consisting of the plant area, roads, pipelines and river intake. The hydrology LSA boundaries, as shown in Figure 6.2-1, are defined as follows:

- Astotin Creek watershed boundary to the south;
- Beaverhill Creek to the northeast;
- north-south Range Road 214, which forms the western limit of Astotin Creek watershed; and
- a 15 km reach of the NSR on the north from upstream of the existing Shell Scotford river intake to below the confluence with Beaverhill Creek (approximately 5 km downstream of the proposed river intake and outfall)

The hydrology LSA encompasses 308 km^2. This area includes the Astotin Creek watershed area of 201 km^2. The Astotin Creek watershed extends into Elk Island National Park and includes Astotin and Oster Lakes. The hydrology LSA consists of rolling to near flat Parkland terrain with land slopes ranging from near flat in the Upgrader area to 3% south of Bruderheim. Total relief ranges 140 m, from elevation 730 m in the headwaters of Astotin Creek to the NSR bed at about elevation 590 m. The river valley rises to approximately 617 m with a fragmentary terrace level at about elevation 606 m. Ground level in the Upgrader area ranges about 8 m from elevation 623 m to 631 m.

6.2.2 RSA

The hydrology RSA is defined primarily on the basis of potential impacts of the Project on flows and water levels in the NSR. It defines the study area for the cumulative effects assessment. The Project is expected to have negligible water resources impacts beyond the hydrology RSA. In view of the Alberta-Saskatchewan Apportionment Agreement, the hydrology RSA is extended from the Gold Bar Wastewater Treatment Plant in Edmonton to the Alberta-Saskatchewan border to identify any implications in meeting the 50% apportionment requirement with Saskatchewan. The 60 km stretch of river from Edmonton to the confluence with the Redwater River at Vinca Bridge is the main area of hydrology/water quality assessments. A separate RSA has been defined for the assessment of potential acid input (PAI) to surface water, as discussed in Volume 3, Section 7.



LEGEND

North American Property Boundary
Local Study Area (LSA)
Sub-basin

SCALE 1:100000 kilometres
1 0 1 2

Title:

SURFACE WATER
LOCAL STUDY AREA

NORTH AMERICAN
OIL SANDS CORPORATION

Approved: BE	Revision Date: 07/07/04

File: 6198-SITESW-07.DWG

Drawn by: GDE	Checked: DLC	Fig. No.: 6.2-1

6.3 Issues and Assessment Criteria

Construction and operation of the Project may have the potential to affect the surface water flow regime in watercourses and water levels in waterbodies within the Project and surrounding area. The specific requirements for assessing potential impacts to surface water are identified in the TOR (Volume 1, Appendix A).

Potential surface water quantity impacts may occur as a result of:

- Project water use and return flows from and to the NSR, and
- changes in runoff volumes as a result of changes in land use from agricultural to industrial and related effects during construction and operation of the Project facilities.

The potential impacts of these items are discussed, and where appropriate analyzed for the local sub-basins within the Project area and the NSR. Because variations in stream flow and lake and wetland water levels may affect vegetation, aquatic habitat, wildlife habitat and recreational activities, this assessment attempts to identify if the impact is likely to be measurable, and presents mitigation strategies.

6.4 Methods

The surface water environmental setting is primarily a compilation of existing long-term regional data supplemented with site specific observation of drainage conditions within the Project and surrounding areas, as discussed in the following section. Historical long-term regional data applied to site specific drainage conditions, where appropriate, provide the basis for characterizing the hydrology in the area.

6.4.1 Analyses

Statistical analyses, summaries and comparisons were conducted to describe and predict the variability of climatic and hydrologic conditions relevant to the LSA and RSA. Climatic and hydrological variables analyzed include: temperature, precipitation, evaporation rates, water levels, local and regional stream flows, sediment loading, existing and applied for surface water withdrawal licences, and channel section and geomorphic data.

6.4.2 Existing and Planned Developments

Existing and planned developments are described in Volume 1, Section 1.

6.5 Existing Conditions

6.5.1 Climatic Variables

Climatic variables applied for assessment and design are based upon an average of climatic data and statistics from the Edmonton International Airport and city stations. Specific values applied, sources and how they are applied are as follows:

- Mean Annual Precipitation of 480 mm was used for lake water balance and outflows and was based on data from 1971-2000 climate normals (average of city and airport stations) (Environment Canada, 2001).

- Mean Annual Areal Evapotranspiration of 400 mm was used for annual water balance (average of city and airport stations) (AENV, 2001).
- Mean Annual Lake Evaporation of 665 mm was used for annual lake water balance and outflows (AENV, 2001).
- Maximum 1:25 Year, 24-hour design rainfall of 96.8 mm was used for storm runoff volumes and stormwater pond sizing by the engineering design team. By comparison, the reported 1:25 year, 24 hour rainfall at Edmonton International Airport (AES Canadian Climate Centre, 1984) was only 77.7 mm, based upon data from 1961-1983.
- Maximum 1:25 Year, 15 minute rainfall intensity of 92.8 mm/h (i.e., 23.2 mm in 15 minutes) was used for estimating peak flows for sizing ditches and culverts.

6.5.2 Local Watercourses and Water Bodies

6.5.2.1 Beaverhill Creek

The watersheds and drainage features around the Project area are shown in Figure 6.5-1. The Project area drains into Beaverhill Creek via Astotin Creek and an intermittent unnamed tributary stream.

Beaverhill Creek drains north and west, over a distance of approximately 57 km, ultimately emptying into the NSR where it has a gross drainage area of 2,930 km². Beaverhill Lake with a surface area of 139 km² has a drainage area of 1,970 km² (excluding the lake). Beaverhill Lake significantly controls and reduces downstream flows to the creek and essentially reduces the drainage area of Beaverhill Creek within the hydrology LSA to 960 km².

Beaverhill Creek in the hydrology LSA follows an irregular meander pattern, with an average channel width of approximately 11 m near its mouth. Flows on Beaverhill Creek are strongly affected by beaver activity. A large beaver dam (>2 m in height) located approximately 600 m upstream from the NSR completely impeded the surface flow of the creek in autumn 2006 through the winter 2007. In the period from late April 2007 to early May 2007, the beaver dam washed out due to high runoff. During this period, Beaverhill Creek near its mouth had an average wetted width of 8.5 m, a maximum depth of 0.89 m and a discharge of 1.25 m³/s. Channel substrate was composed of organic fines with occasional areas of large cobbles and boulders.

Beaverhill Creek was gauged for 12 years from 1975-1986 over the March-October season (Water Survey of Canada Station 05EB015, Environment Canada website). These data may therefore provide an indication of runoff rates for Beaverhill Creek's tributaries including Astotin Creek. The mean seasonal (March-October) runoff over the 12-year monitoring period was only 4.4 mm (based on the gross drainage area) or 15.7 mm (excluding the Beaverhill Lake drainage area). The equivalent average flow rate in Beaverhill Creek under either scenario was 0.608 m³/s. By comparison, mean seasonal runoff observed at several other smaller regional gauged streams (Whitemud, West Whitemud, Pointe Aux-Pins, Blackmud, Namepi and Waskatenau Creeks) range from less than 15 mm to over 33 mm and average 28.5 mm. This regional average runoff of 28.5 mm is assumed for annual runoff assessments for the site.

There is commonly no flow in streams in the Project area, including Beaverhill Creek, in the months from July to March. Therefore, no low flow analyses were required for the smaller streams in the hydrology LSA (Astotin and unnamed tributaries).

A regional flood frequency analysis of the gauged small watersheds was conducted to estimate flood flows for the streams in the Project area. The analysis considered effective areas (areas that contribute to runoff during a mean annual flood) and gross drainage areas. Based upon the marginal difference in the results, gross drainage areas versus maximum instantaneous flood discharge relationships were applied to estimate flood flows on the streams in the LSA. The resulting regional flood frequency relationships are shown in Figure 6.5-2. Based upon these relationships and fully excluding the Beaverhill Lake drainage, estimated flood discharges from Beaverhill Creek at its mouth are 11 m^3/s for the mean annual flood and 72 m^3/s at the 1:100 year flood. By comparison, the highest recorded flow in Beaverhill Creek was 78.7 m^3/s on June 26, 1983.

6.5.2.2 Astotin Creek

The southwest portion of the Project area drains west and north to Astotin Creek. This creek flows in a northerly direction from Elk Island National Park, around the west side of the Project and then northeast to its confluence with Beaverhill Creek (Figure 6.5-1). The drainage area of Astotin Creek at its mouth is approximately 200 km^2. Portions of Astotin Creek have been channelized as part of the road ditching on Range Road 214. In this area the creek is a stable, grassed road ditch approximately 0.5 m deep and 6 m wide. Further downstream, below the property, the channel is 10 m wide by 1.6 m deep. The low channel slope at 0.6 m/km is extensively affected by backwater conditions. The channel consists of sandy, silt bed and bank material.

Astotin Creek is not gauged. Astotin Creek flows are regulated by the upstream lakes and wetlands in Elk Island National Park including Astotin Lake that is over 4 km^2 in area. Estimated flows for Astotin Creek at its mouth based upon the regional hydrologic station data are as follows:

- Mean Annual Flow is 0.14 m^3/s;
- Low flows are commonly dry for extended periods;
- Mean Annual Flood is 4.5 m^3/s;
- 1:10 year flood is 13 m^3/s; and
- 1:100 year flood is 30 m^3/s.

6.5.2.3 Unnamed Tributary to Beaverhill Creek

The northeast portion of the Project area drains north into a small slough complex that drains northeast into an intermittent unnamed tributary of Beaverhill Creek. This unnamed tributary has several intermittent and poorly defined tributaries that drain north off of the sloping ground south of Bruderheim. The total drainage area of this unnamed tributary at its mouth is approximately 64 km^2.

This unnamed tributary to Beaverhill Creek stream is poorly defined in many locations. Where it enters Beaverhill Creek, just downstream of Highway 45 crossing, the channel section has a topwidth of approximately 4.5 m. During the May 2007 site observation (a wet post-snowmelt period), this tributary had a wetted width of 2 m, a depth of 0.4 m and an estimated flow of 0.10 m^3/s. Upstream of Highway 45, the creek is significantly affected by grazing cattle causing sloping and eroding banks. The channel bed consists of organic fines and cobbles.

Based upon the regional hydrologic station data, estimated flows in the unnamed tributary at its mouth are as follows:

- Mean Annual Flow is 0.05 m^3/s;
- Low flows (commonly dry for extended periods);
- Mean Annual Flood is 2.2 m^3/s;
- 1:10 year flood is 6.7 m^3/s; and
- 1:100 year flood is 15 m^3/s.

6.5.2.4 Other Watercourses and Waterbodies

Several small sloughs or wetlands ranging from less than 70 m to 300 m in diameter (0.4 ha to 7 ha) are located within the Project area, as indicated in the topographic drainage map in Figure 6.5-1 and the aerial photograph in Figure 6.5-3. A detailed description and classification of these are presented in Vegetation and Wetlands (Volume 4, Section 10).

The main connected sloughs are in the complex in the northern portion of the Project area. These drain into the intermittent unnamed tributary draining to Beaverhill Creek. These are Class IV (Stewart and Kantrud, 1971) semi-permanent ponds. This “North Wetland Complex” is composed of three ponds and has a combined area of 9.36 ha. One of the ponds is present on both sides of Township Road 560. In May 2007, the area was flooded due to snow melt. Measured pond depths on June 26, 2007, when high water levels had receded, were approximately 1 m. These ponds are surrounded by riparian vegetation rings averaging 5 m wide and extending 0.2 m to 0.3 m above the normal water level, suggesting this may be representative of the typical variation in water level in these ponds.

The next largest wetland is a Class III seasonal pond located in the southwest portion of the Project area in NW 26-55-21-W4M. It has a total area of approximately 5.95 ha. The soils around this slough have been cultivated numerous times, resulting in limited riparian vegetation remaining. Satellite photographs of the area dating back to 1979 show a larger wetland area that has receded over the years. This area is now a depression less than 1 m deep with seasonal water typically about 0.3 m deep.

Standing water is present on both sides of the Canadian National Railway (CNR) rail line on the south boundary of the Project area. This area covers up to 3.0 ha on both sides of the rail line. Two culverts under the railway tracks (600 mm and 1,000 mm in diameter) convey water from the upslope area to the south. The total area contributing to runoff south and under the rail line is 1.7 km^2. The drainage path, as indicated in the aerial photograph in Figure 6.5-3, appears to drain north through the Project area to the North Wetland Complex and then to the unnamed tributary. No flow through either culvert was observed during the wet conditions in May 2007 suggesting that any surface flow here is limited to extreme melt and storm events. This runoff will be routed east to drain north via the Range Road 211 drainage ditch.

Other than smaller pothole type depressions and road ditches, there are no other connected drainage paths on the property.

6.5.3 North Saskatchewan River

The raw water supply for the Project is planned to come from the NSR. North American is pursuing alternative sources and supply delivery mechanisms such as the effluent from the City of Edmonton Gold Bar Wastewater Treatment Plant and a regional industrial water treatment and distribution system (Morrison Hershfield, 2007), as discussed in Volume 1, Section 6. For the purposes of assessment, withdrawal from the NSR is proposed at an intake site to be located downstream of the BA Energy/ATCO intake site, as shown in Figure 6.5-1.

Flows have been recorded by Water Survey of Canada (Environment Canada, 2004b) since 1912 (station number 05DF001) where the total basin area is approximately 28,000 km². This gauge site is located approximately 63 km upstream of the proposed intake site. Major inflows between the Edmonton station and the intake site are the Sturgeon River with a drainage area of 3,350 km² and a few minor tributaries that increase the total drainage area at the intake site to approximately 33,000 km². In addition to these inflows, a number of withdrawals and return flows also occur along this reach.

A gauge (05EA001) on the Sturgeon River near Fort Saskatchewan just upstream of the Project indicates the Sturgeon River has a mean March-October discharge into the NSR of 4.2 m^3/s. Assuming the other minor tributaries entering the NSR between the Edmonton gauge and the intake site contribute similar average runoff rates as the Sturgeon River, these may add a further 2 m^3/s to the average flow during the March-October months. Therefore, between the WSC gauge in Edmonton and the intake site, the flow may increase by an average of 6.2 m^3/s (2.7%) during the March-October period. However, due to minimal winter runoff conditions from these tributary watersheds, their relative flow contribution is much less during the winter months and may be considered as negligible.

Withdrawals from this reach, based on current water licences, total 5.6 m^3/s. Assuming all are withdrawing at their maximum licenced rate, which is highly unlikely, the flow during the open water season may therefore be nearly equal at the Project site as at the Edmonton gauge due to the above noted inflows. Because of the limited additional inflows between Edmonton and the Project area during the low flow months, the impacts of withdrawals on both average annual and low winter flow conditions are evaluated by neglecting any inflows between the gauging station at Edmonton and the intake site, as presented in the following sections.

6.5.3.1 Hydrologic Regime

The NSR is regulated by two major multi-purpose (flood control, recreational and flow augmentation) dams. The Brazeau Dam located on the Brazeau River came on line in 1962 and the Bighorn Dam located on the NSR came on line in 1972. Regulation of the NSR has resulted in an increase in low flows and a moderating of peak flows. The annual 7-day low flow is 350% of the unregulated flow, as shown in Figure 6.5-4, from a median of 22.4 m³/s prior to 1961 to a median of 77.8 m³/s after 1972. Because of this flow alteration of the natural hydrologic regime of the NSR, the post-regulation flow conditions (1973-2005) have been considered.

Since regulation in 1972, the gauge on the NSR at Edmonton (WSC 05DF001) has recorded a mean annual flow of 196 m^3/s (234 m^3/s for the open water season of March to October). Figure 6.5-5 presents a summary of the range of historical flows on a monthly and daily basis. The highest flow months are June and July and the lowest monthly flows typically occur in January and February although extreme lows can occur in November, likely in response to freeze-up conditions when water flow goes into the formation of ice. Because of regulation, the range of daily flows, as shown in Figure 6.5-5, are fairly constant with little variation between the minimums, and the upper and lower quartiles. The only major fluctuations occur during large flood events. The lowest flow recorded since regulation was 19.8 m^3/s on November 22, 1977, and the highest was 3,990 m^3/s on July 19, 1986.

Figure 6.5-6 shows daily flow duration curves indicating the percentage of time any given flow is equaled or exceeded in each month. Daily flows rarely drop below 100 m³/s from March to

October and only very rarely drop below 50 m³/s in November and December. These extreme low flows are typically a result of initial freeze-up conditions and the flow recovers after freeze-up and an ice cover layer is established. For example, during the extreme low in 1977 the flow dropped from 88.6 m³/s to 19.8 m³/s in three days and recovered to 85.8 m³/s three days later.

The mean annual flow volume passing by the Edmonton gauge since regulation is approximately 6,170,000 dam^3 (1 dams³ = 1,000 m³). The wettest year was 1990 with a total volume of approximately 9,227,000 dam^3 and the driest was 1975 with a total volume of approximately 4,430,000 dam^3.

High and low flow frequency analyses of the data from 1973-2005 result in similar flood and low flow values, as previously reported (PCOSI, 2006). The estimated 7-day, 1:10 year low flow is 60 m³/s and the 1:100 year maximum instantaneous discharge is 5,760 m³/s. From 1973-2005 there were 50 days when the daily flow was less than 60 m³/s and one 7-day period in 1979 when the flow remained below 60 m³/s. Table 6.5-1 summarizes various statistical flows on the NSR at the Edmonton gauging station for the 1973-2005 period.

The significant flow variation over the day in the NSR should also be noted. This fluctuation is a result of peaking power operations at the dams. Typical flow and water level fluctuations recorded at the Edmonton gauge, as presented in Figure 6.5-7, show that flows may vary by over 50% within a day and levels can vary by 0.6 m within a day due to the flow regulation.

Table 6.5-1 North Saskatchewan River Flow Regime Parameters at Edmonton Station (1973-2005)

Flow Parameter	Flow (m³/s)
Lowest Daily Flow on Record (November)	19.8
Minimum Recorded Monthly Flow (November)	77.5
7Q10 (7-day, 1 in 10 year low flow)	60
7Q2 (7-day, mean annual low flow)	79
Discharge Exceeded 95% of the time	85
Mean November Flow	129
Mean Annual Flow	196
1:2 Year Maximum Instantaneous	815
1:10 Year Maximum Instantaneous	1,990
1:100 Year Maximum Instantaneous	5,760

NSR flows downstream near the Saskatchewan border were monitored at Lea Park (Station 07EF003) from 1959-1971. Although this is a limited period and prior to the Bighorn Dam period, the ten years of overlapping data indicate an average increase in flow of 9.3 m³/s from Edmonton to Lea Park. The next downstream NSR station is near Deer Creek in Saskatchewan. Adjusting for the difference in drainage areas, the 1973-2005 flow data at this station would indicate an average historical increase in flow of about 8 m³/s from Edmonton to the Saskatchewan border.

Total suspended sediment (TSS) data at the gauging station at Edmonton are limited to 121 measurements from 1974-1990. Measured TSS concentrations range from 3 mg/L to 2,460 mg/L. The data correlated with flow predict an average concentration of 43 mg/L at the mean annual flow and a TSS concentration of 800 mg/L at the mean annual flood event. Review of the flow and TSS data suggest TSS concentrations above 500 mg/L are rarely expected to last for periods longer than a week.

6.5.3.2 Channel Regime

The NSR has a stream cut valley with two fragmentary terrace levels in the hydrology LSA reach. The low terraces at the river are about 14 m high on the south and 8 m high on the north. In this reach the NSR is a single meandering, gravel bed channel 160 m to 210 m wide with a mean depth of 1.2 m at the mean annual flow of 196 m^3/s and over 5.6 m at the 1:100 year flood level. The median substrate size is 15 mm based upon sampling upstream and downstream of the hydrology LSA (Shaw and Kellerhalls, 1982). Banks consist of sand and silt that are densely vegetated with willows and shrubs. The overall channel slope is 0.35 m/km based upon regional topographic mapping. However, local channel surveys in the vicinity of the proposed intake indicate a locally steeper gradient at 0.8 m/km.

Review of historical aerial photographs indicates the channel is moderately stable with only minor point bar and bed shifting. The mean channel velocity is 1 m/s at the mean annual flow, increasing to nearly 2.6 m/s at the 1:100 year flood flow. The deepest channel depth, recorded on June 26, 2007 at a flow of approximately 450 m^3/s, was 1.9 m within 20 m of the south bank in the reach just downstream of the existing BA Energy/ATCO intake site. Initial freeze-up has occurred from mid-October to mid-December and averages mid-November. The river becomes ice free starting in early April to early May and averages around mid-April.

6.5.3.3 Existing and Applied Water Withdrawals

Table 6.5-2 includes a summary of existing active licenced surface water withdrawals in the NSR basin based upon the database provided by Alberta Environment (AENV) (Ed Bulgar, pers. comm., 2006). Additional major applications in progress are also included in Table 6.5-2. These include the BA Energy Heartland Upgrader and North West Upgrader that have received regulatory approval although water withdrawal licences are still pending. Other proposed projects currently under review include the Petro-Canada Oil Sands Inc. Sturgeon and Synenco Northern Lights Upgraders and further expansion plans for the Shell Scotford Complex. Differences in the licences in Table 6.5-2 and those reported in previous upgrader EIAs are because licences with expiry dates prior to this report are excluded (e.g., CCS Inc. with a maximum annual withdrawal licence of 2,990 dam^3) and differences in the raw database provided by AENV (e.g., Alberta Ltd. for 2,220 dam^3 was not listed in the database).

Table 6.5-2 North Saskatchewan River Basin Existing and Applied Withdrawal Licences Downstream of Edmonton

Project	Maximum Annual Diversion (dam^3)	Consumptive Use (dam^3)	Losses (dam^3)	Return Flow (dam^3)	Net Withdrawal (dam^3)
Licenced Withdrawals Between Edmonton Gauge and the Project Site					
Agrium Products Inc. – Fort Saskatchewan Fertilizer Plant	3,809	2,476	0	1,333	2,476
Agrium Products Inc. – Redwater Fertilizer Plant	15,647	12,518	1,564	1,564	14,082
BP Canada Energy Company – Fort Saskatchewan Fractionation Plant	2,146	2,146	0	0	2,146
Celanese Canada Inc. – Edmonton Petrochemical Manufacturing Plant	16,038	7,489	0	8,549	7,489
Dow Chemical Inc. – Fort Saskatchewan Chemical Manufacturing Plant	21,493	5,378	16,115	0	21,493
EPCOR	450,220	0	22,511	427,709	22,511
Imperial Oil Ltd. - Strathcona Oil Refinery	9,251	5,499	0	3,752	5,499
Northwest Utilities / ATCO	3,700	3,700	0	0	3,700
Petro-Canada Products – Edmonton Refinery	5,789	1,438	2,912	1,438	4,351
Shell Canada Ltd. - Scotford Complex	20,672	14,963	0	5,708	14,963

Project	Maximum Annual Diversion (dam^3)	Consumptive Use (dam^3)	Losses (dam^3)	Return Flow (dam^3)	Net Withdrawal (dam^3)
Sherritt International Inc. – Fort Saskatchewan Fertilizer Plant	5,154	3,351	0+	1,803	3,351
BA Energy Inc. - Heartland Oil Sands Bitumen Upgrader*	7,570	7,570	0	0	7,570
PCOSI Sturgeon Upgrader*	14,454	11,739	0	2,715	11,739
North West Upgrader*	6,570	2,470	0	4,100	2,470
Synenco Energy - Northern Lights Upgrader*	10,300	2,060	0	8,240	2,060
Shell Canada Ltd. - Scotford Upgrader 2*	39,420	26,280	0	13,140	26,280
Smaller Licences (< 2,000 dam^3/y)	27,101	17,640	4,044	5,417	21,684
Total (dam^3)	**659,334**	**126,719**	**47,147**	**485,469**	**173,865**
Total (m^3/s)	**20.91**	**4.02**	**1.50**	**15.39**	**5.51**
Licenced Withdrawals Between the Project Site and the Alberta Saskatchewan Border					
Alberta Environment	2,220	0	0	2,220	0
Canadian Salt Company Ltd.	12,039	1,204	0	10,835	1,204
City of Lloydminster	11,101	1,110	12	9,979	1,122
Husky Energy Lloydminster	9,955	9,955	0	0	9,955
Murphy Oil Company Ltd.	2,802	2,802	0	0	2,802
Anadarko Canada Corporation (now Canadian Natural Resources Limited)	2,985	2,985	0	0	2,985
Smaller Licences (< 2,000 dam^3/y)	28,246	13,282	10,589	4,376	23,870
Total (dam^3)	**69,349**	**31,338**	**10,601**	**27,410**	**41,939**
Total (m^3/s)	**2.20**	**0.99**	**0.34**	**0.87**	**1.33**
Licenced Withdrawals Between Edmonton Gauge and Alberta Saskatchewan Border					
Total (dam^3)	**728,683**	**158,057**	**57,748**	**512,879**	**215,804**
Total (m^3/s)	**23.11**	**5.01**	**1.83**	**16.26**	**6.84**

Notes:

Maximum Annual Diversion = Consumptive Use + Losses + Return Flow

Examples of Losses are seepage and evaporation.

Net Withdrawal = Consumptive Use + Losses

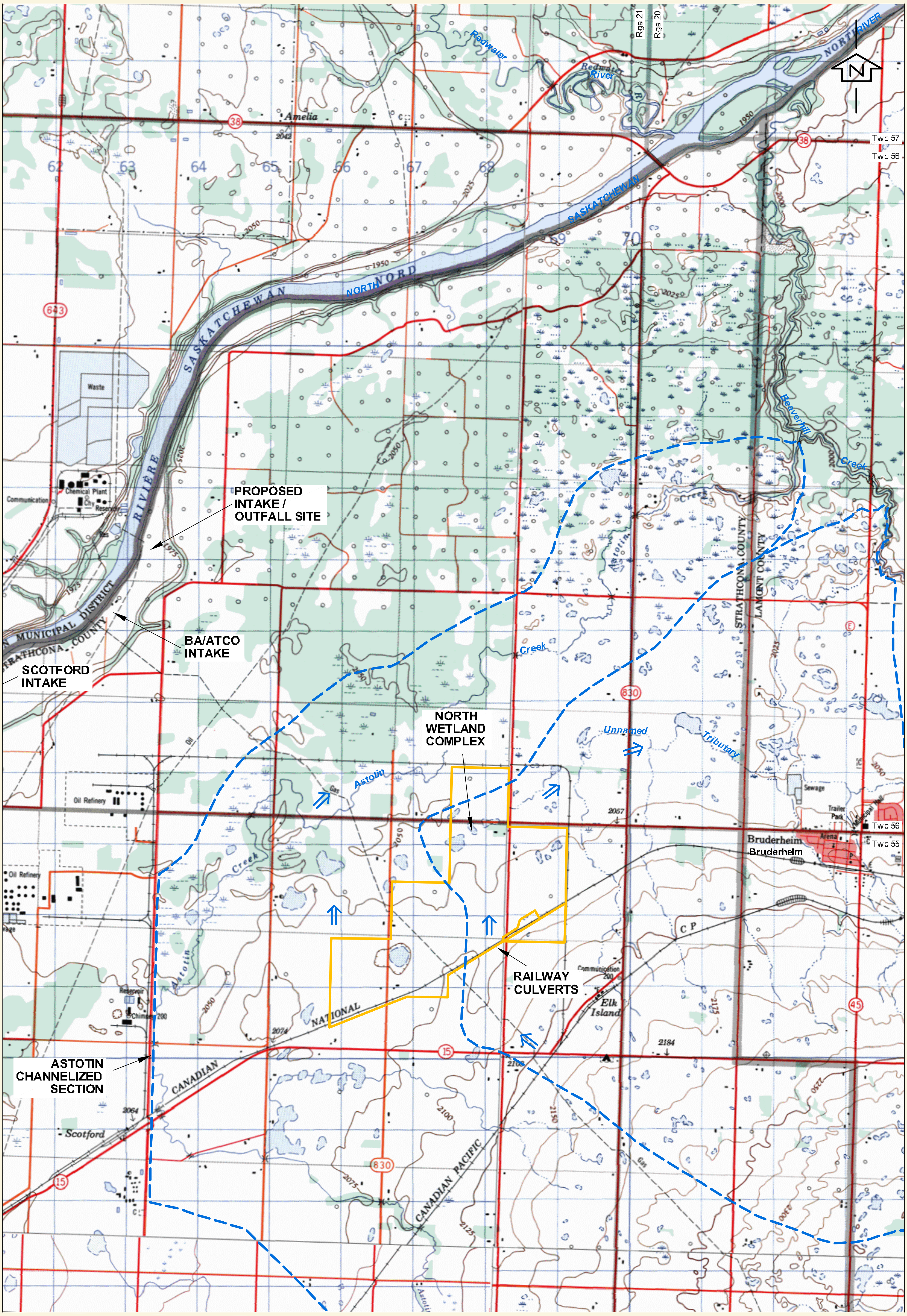
1 dam^3 = 1,000 cubic metres

Sources: AENV, 2006 – EMS database dated November 2006,

* Water Licence Applications pending – BA Energy Inc. Heartland Oil Sands Bitumen Upgrader (BA Energy, 2004), North West Upgrader EIA (North West, 2006), Northern Lights Upgrader EIA (Synenco, 2006), Petro-Canada Oil Sands Inc. Sturgeon Upgrader EIA (PCOSI, 2006), Scotford Upgrader 2 EIA, (Shell Canada Ltd., 2007).

The licenced consumptive use rate from Table 6.5-2 is 3.42 m^3/s plus 1.59 m^3/s from applications under review for a total of 5.01 m^3/s or a total annual volume of 158,057 dam^3.

As a whole, actual total withdrawals and consumptive use are expected to be less than the licenced amounts, although individual amounts may vary substantially from the specific licenced allocations. The North West Upgrader EIA reported that actual consumptive use and losses for the major users totaled approximately 87,400 dam^3 or about 82% of their total licenced amount (North West, 2006). The reported total maximum annual withdrawal for these major users was equivalent to about 91% of their total licenced allocation. These results were reported as based on averages over the 2000-2004 period for the facilities supplying data. Where no actual value was obtained from a major user, the full licenced amounts were assumed. Since this assumption accounted for nearly one-half of the total volume of uses, actual uses may have been less than the percentages given above. A study investigating licence allocations in the NSR basin and estimates of actual uses is currently ongoing (AMEC, 2007 Draft) and may better define actual uses versus allocated amounts.



LEGEND

🟨	North American Property Boundary
▬ ▬	Approximate Basin Divide
⇐	Drainage Direction

25' Contour Interval

SCALE 1: 50000 metres

500 0 500 1000

Title:

LOCAL TOPOGRAPHY AND DRAINAGE FEATURES

NORTH AMERICAN
OIL SANDS CORPORATION

Approved: BE	Revision Date: 07/07/04

File: 6198-SITESW-07.DWG

Drawn by:	Checked:	Fig. No.:
GDE	DLC	6.5-1

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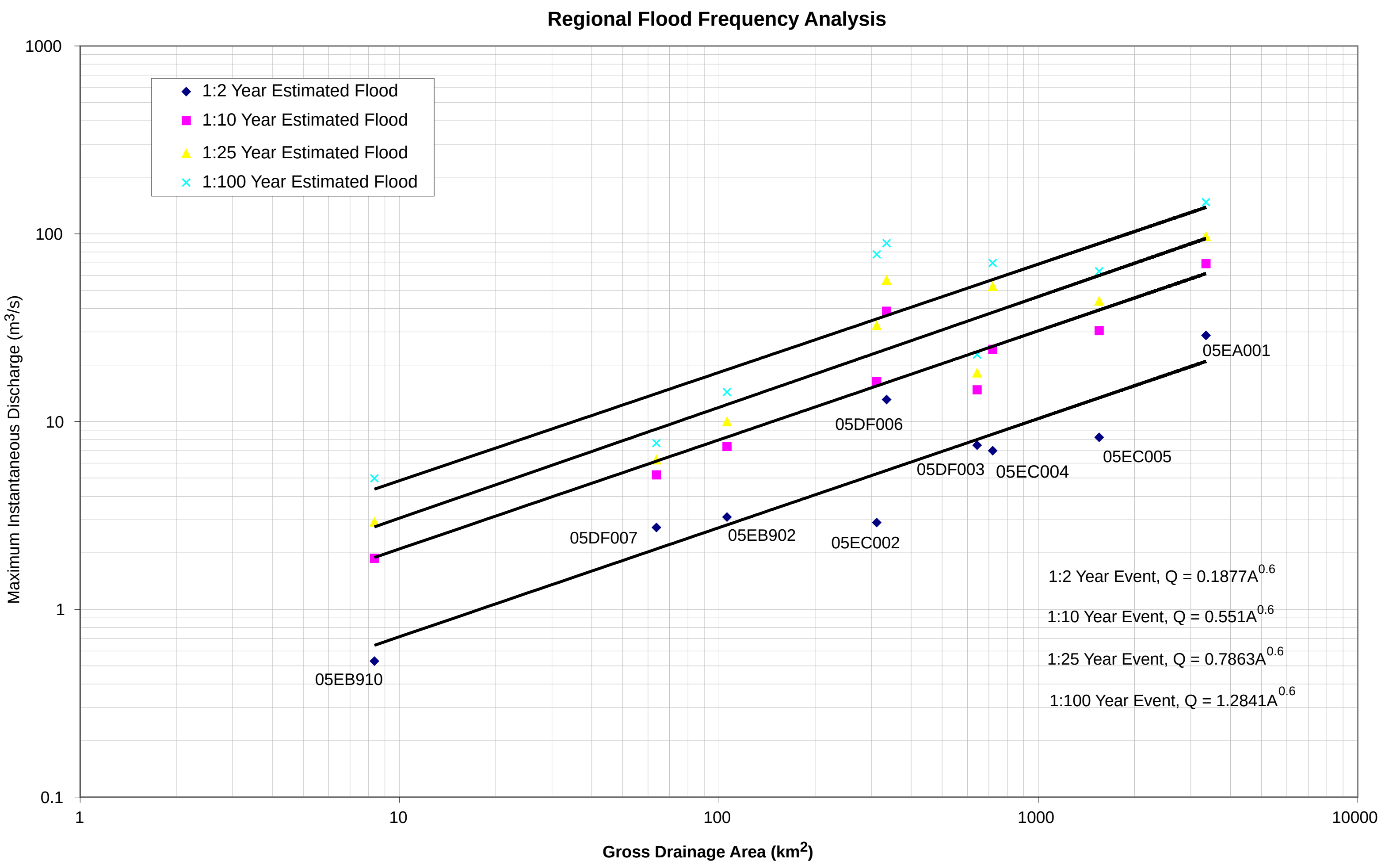


Title:

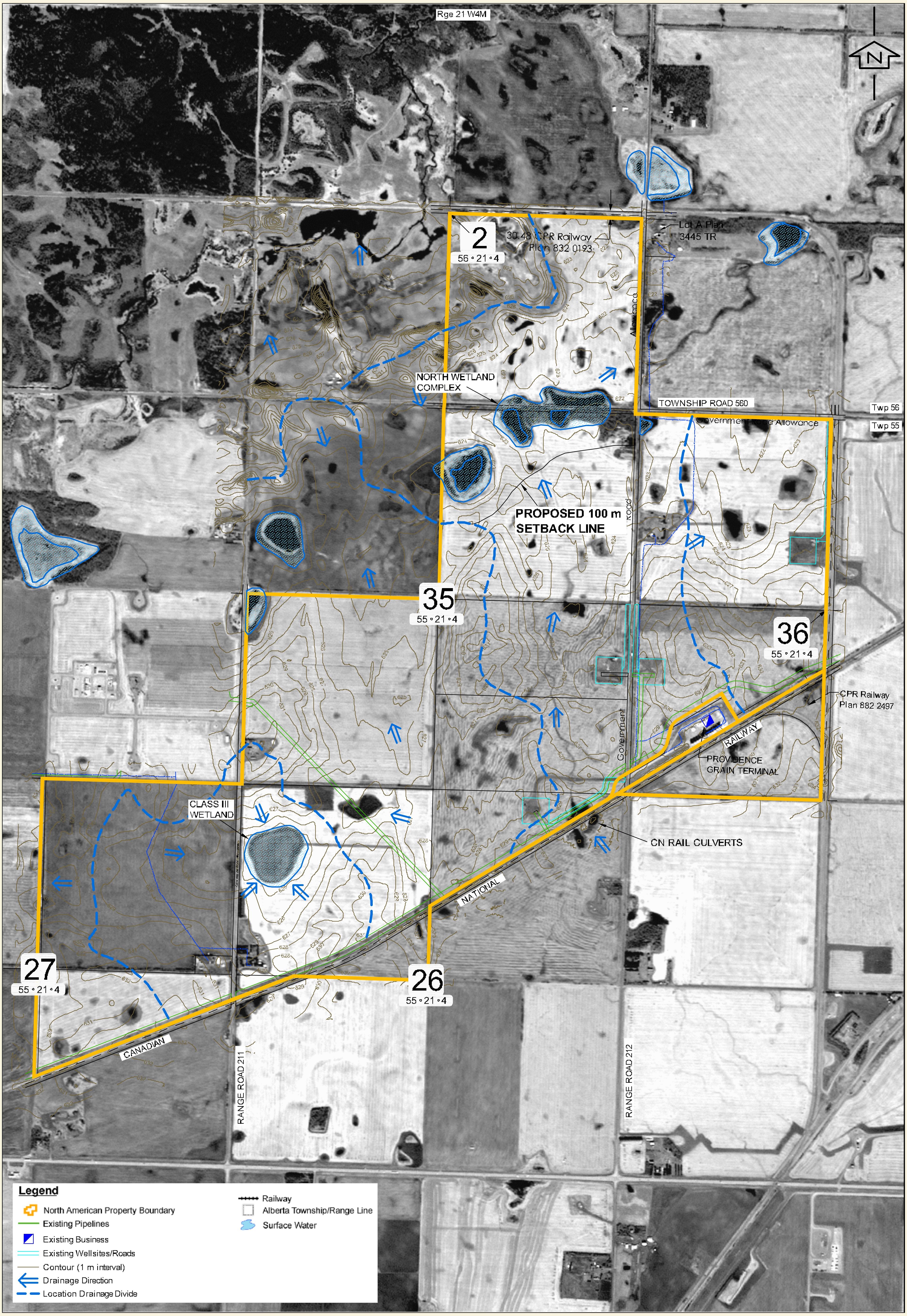
Regional Flood Frequency Analysis

NORTH AMERICAN
OIL SANDS CORPORATION

Approved: DC	Revision Date: 07/05/31

File: 6198-Charts2-07.cdr

Drawn by: BSW	Checked: BE	Fig. No.: **6.5-2**



Legend

- 🟧 North American Property Boundary
- ━ Existing Pipelines
- ◪ Existing Business
- ═ Existing Wellsites/Roads
- ─ Contour (1 m interval)
- ⇐ Drainage Direction
- ╍ Location Drainage Divide
- ┿┿┿ Railway
- ☐ Alberta Township/Range Line
- ▨ Surface Water

REFERENCE: CAN-AM GEOMATICS, 2006.
"NORTH AMERICAN OIL SANDS CORPORATION
PLAN". SCALE: 1:15000

SCALE 1:15000 metres
150 0 150 300

Title:

AERIAL PHOTOGRAPH AND PROPERTY DRAINAGE

NORTH AMERICAN
OIL SANDS CORPORATION

Approved:	Revision Date:
BE	07/07/04

File: 6198-AERIAL-07.DWG

Drawn by:	Checked:	Fig. No.:
GDE	DLC	6.5-3

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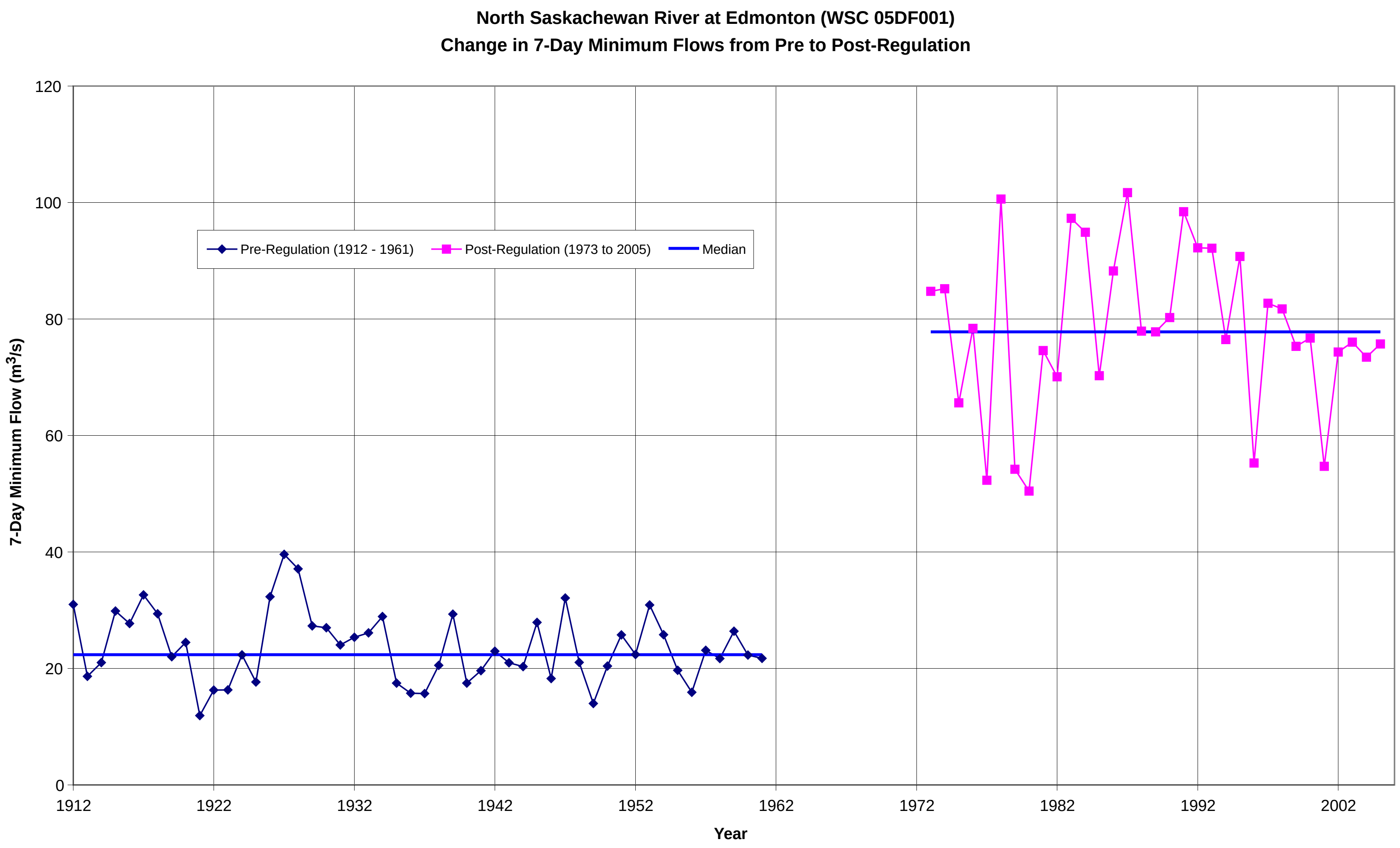


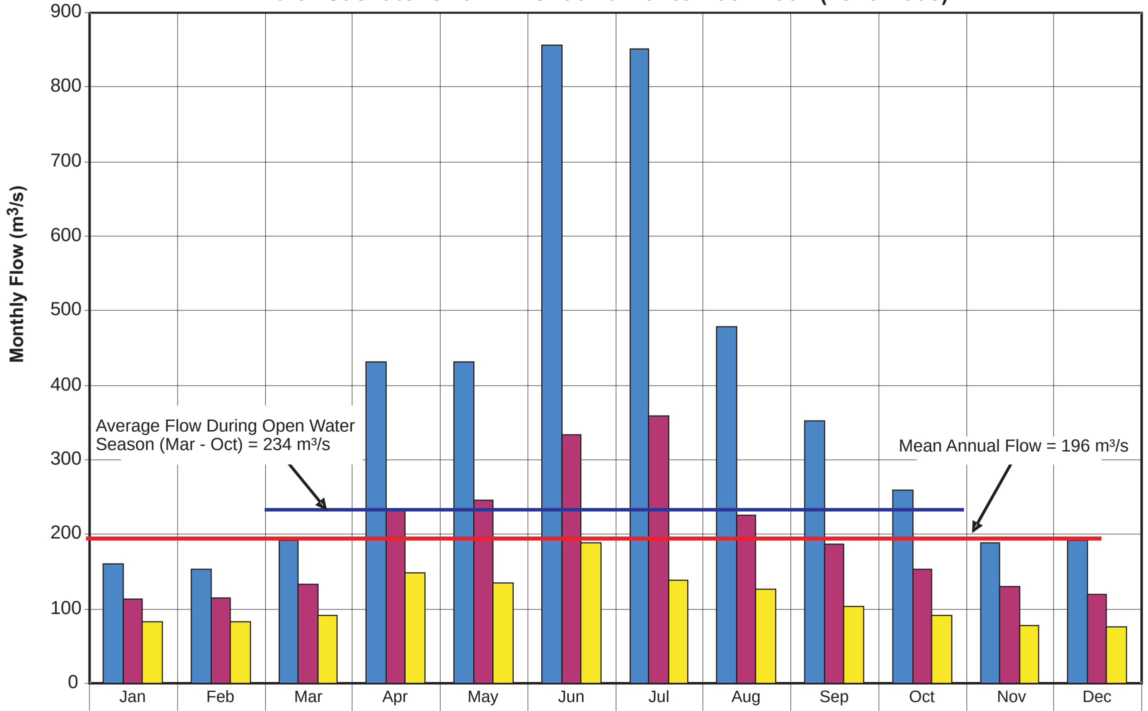
Title:

Changes in 7 Day Minimum Flows from Pre to Post Regulation

NORTH AMERICAN OIL SANDS CORPORATION

Approved: DC		Revision Date: 07/05/31
File: 6198-Charts2-07.cdr		
Drawn by: BSW	Checked: BE	Fig. No.: **6.5-4**

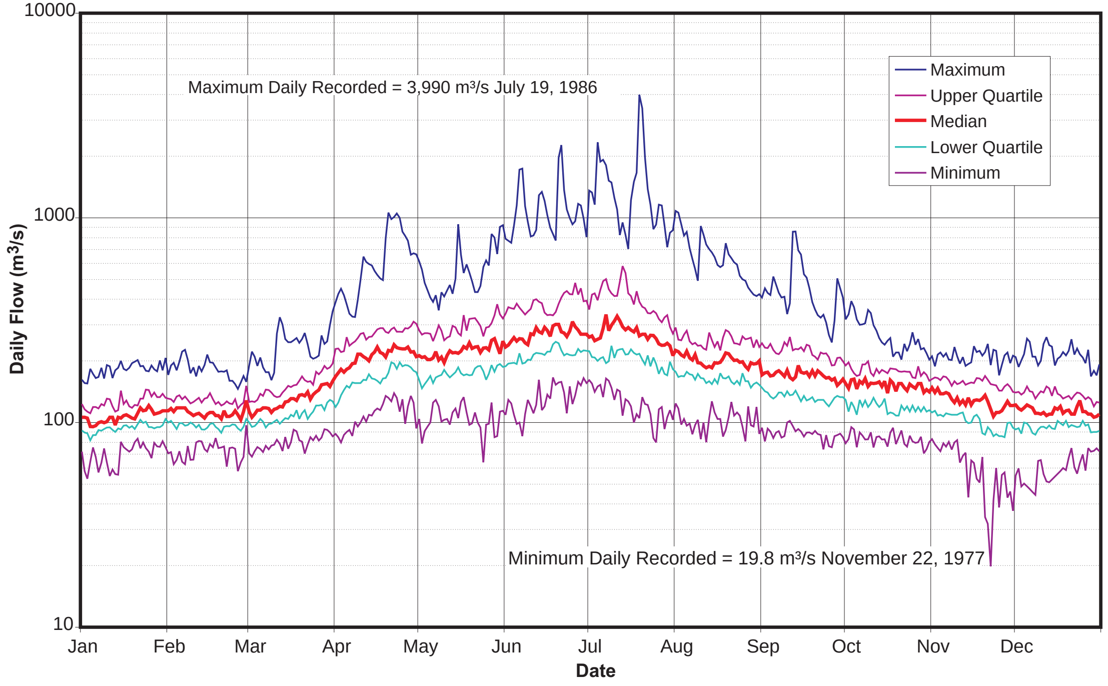
Post-Regulation Monthly Historical Flow
North Saskatchewan River at Edmonton 05DF001 (1973-2005)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
🟦 Maximum Monthly	160	153	192	432	431	857	851	479	353	260	188	192
🟪 Mean Monthly	112.3	114.6	134.0	231.8	245.3	333.1	358.4	225.4	186.8	152.8	129.2	119.2
🟨 Minimum Monthly	82.2	82.2	90.8	149	135	188	138	127	103	91.1	77.5	76

Month

North Saskatchewan River at Edmonton - Historic Range of Daily Discharge, 1973-2005

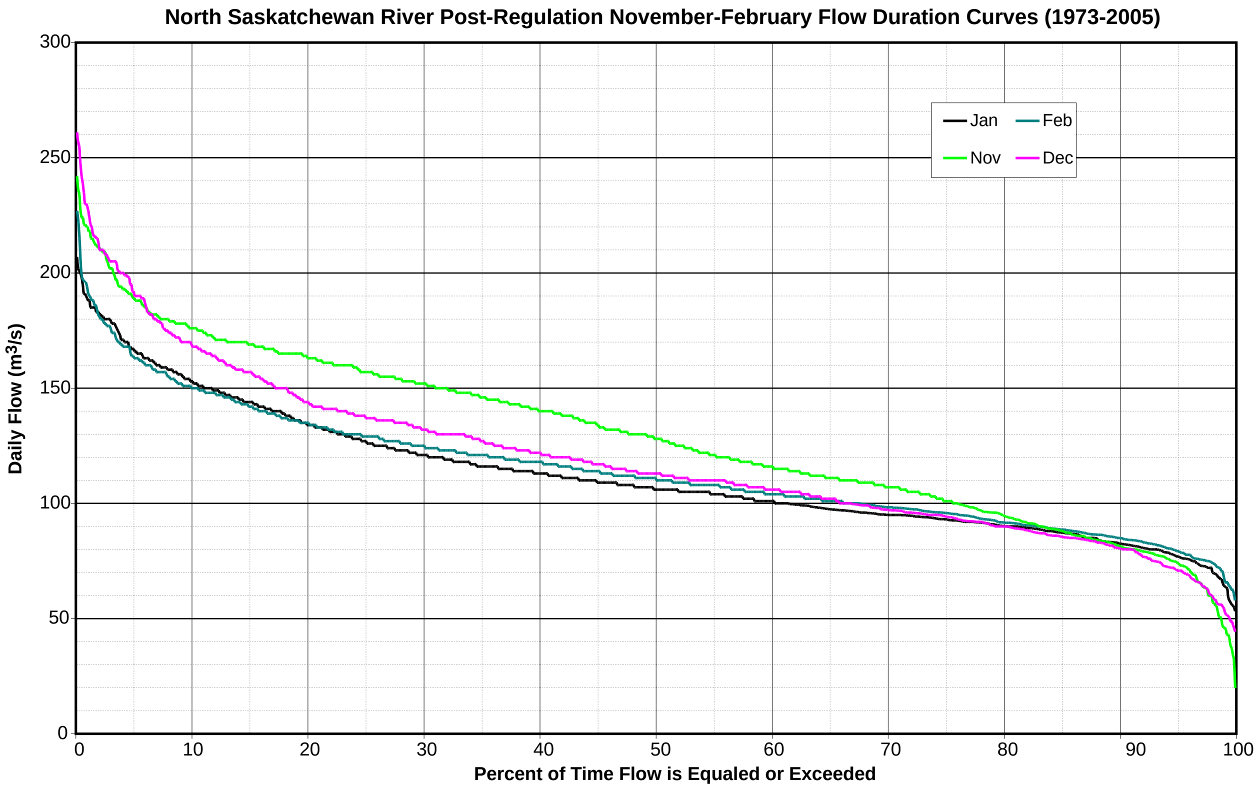


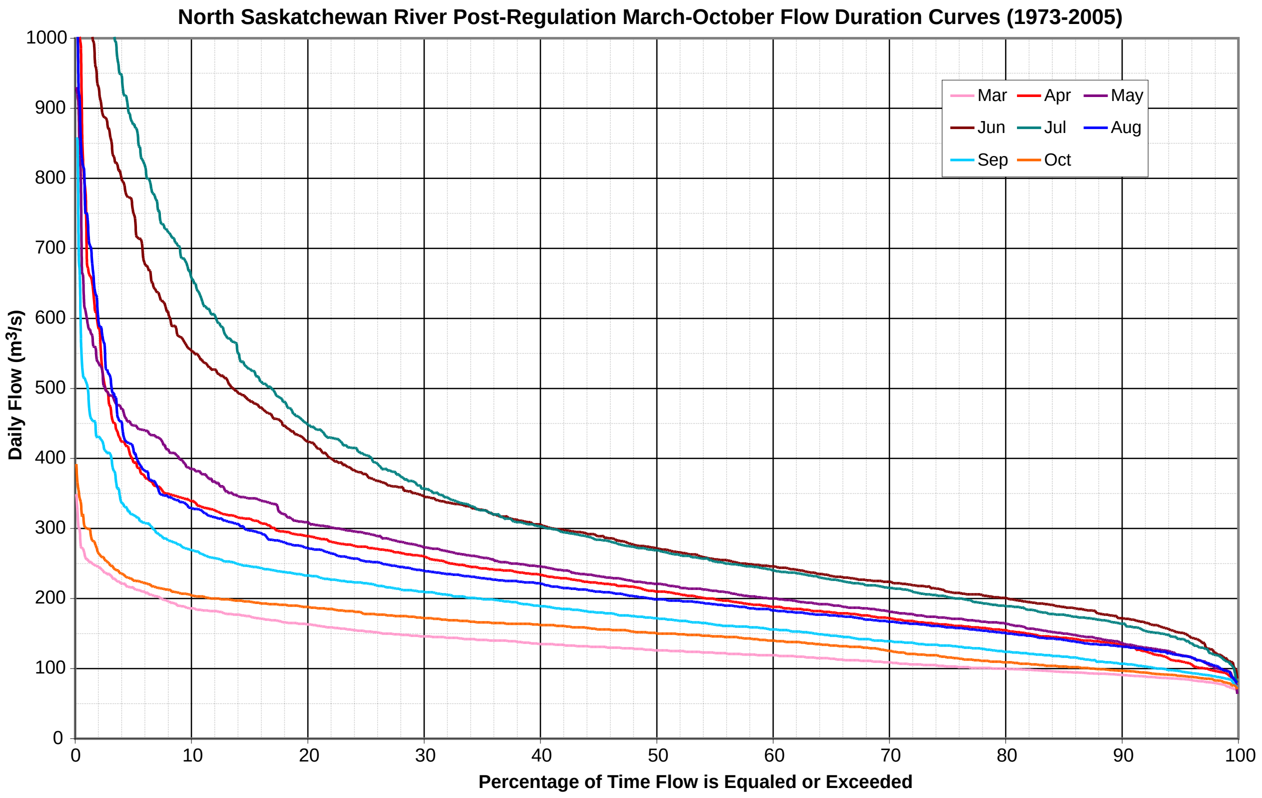
Title:

NORTH SASKATCHEWAN RIVER HISTORIC MONTHLY AND DAILY FLOWS

NORTH AMERICAN
OIL SANDS CORPORATION

Approved: DC
Revision Date: 07/05/31
File: 6198-Charts-07.cdr
Drawn by: BSW
Checked: BE
Fig. No.: **6.5-5**



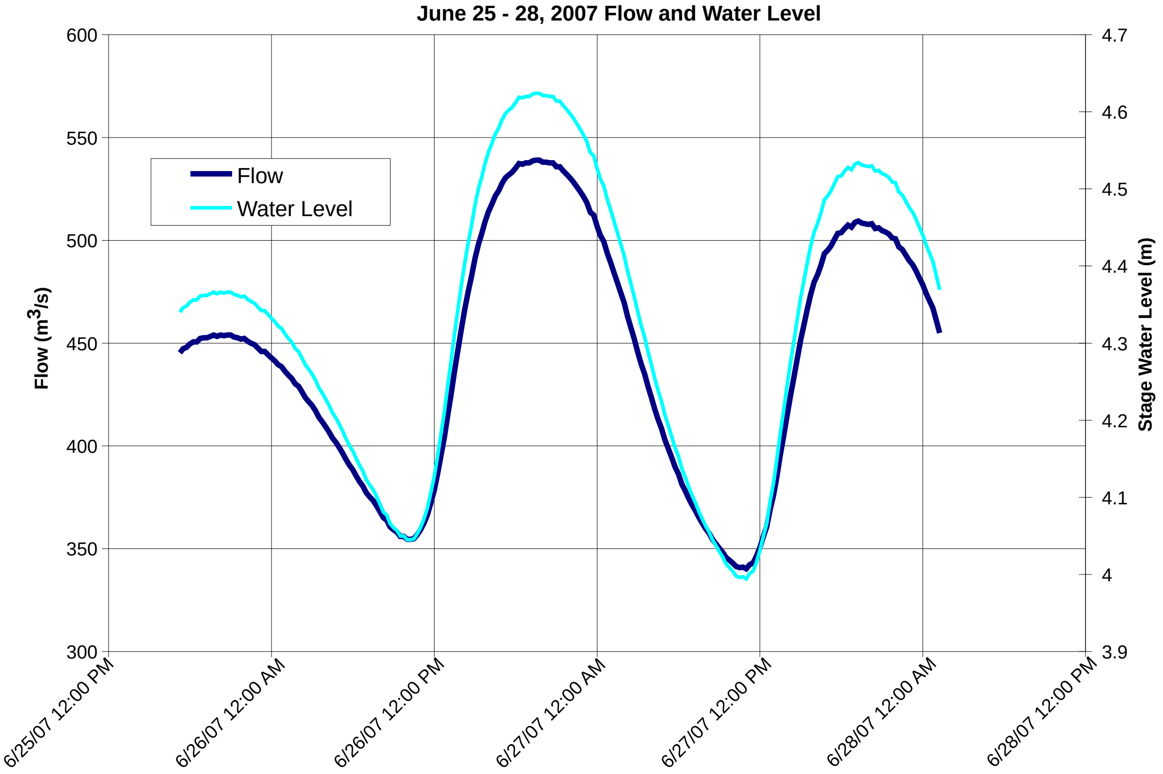


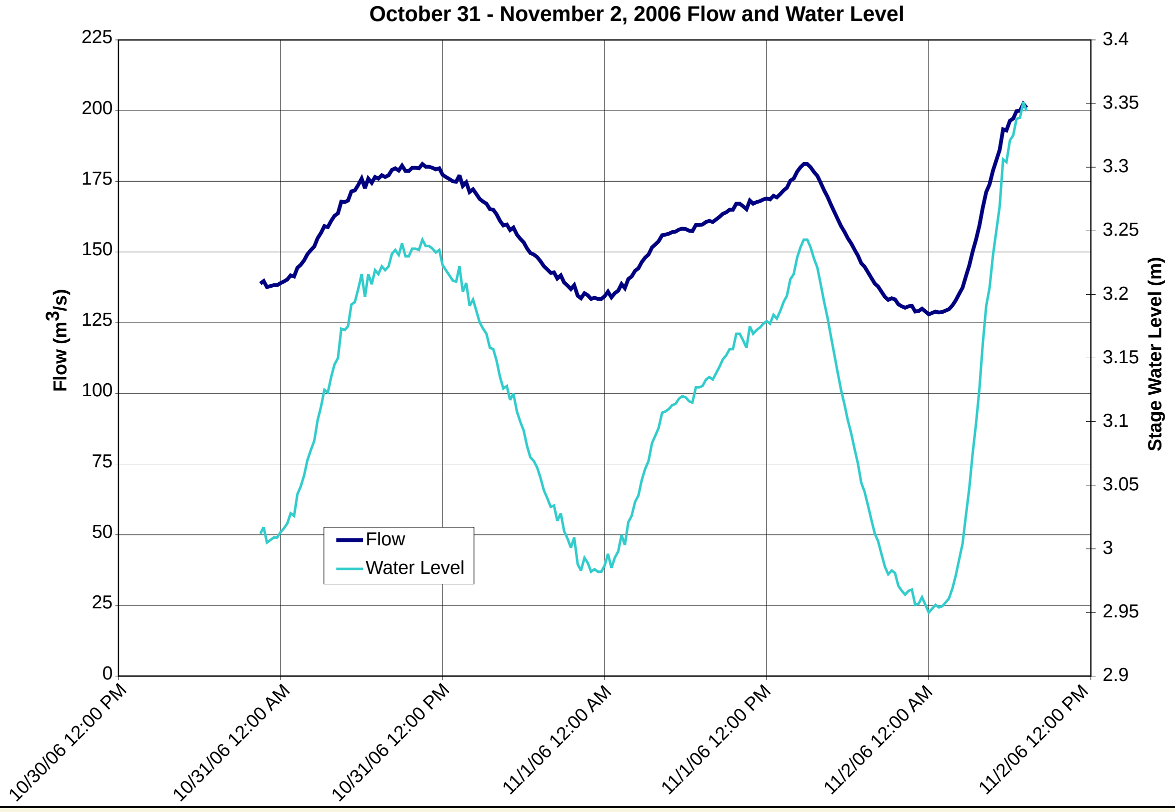
Title:

NORTH SASKATCHEWAN RIVER MONTHLY FLOW DURATION CURVES

NORTH AMERICAN OIL SANDS CORPORATION

Approved: DC
Revision Date: 07/05/31
File: 6198-Charts-07.cdr
Drawn by: BSW
Checked: BE
Fig. No.: **6.5-6**


June 25 - 28, 2007 Flow and Water Level


October 31 - November 2, 2006 Flow and Water Level

Title:

North Saskatchewan River Typical Daily Flow and Water Level Variations

North American Oil Sands Corporation

Approved: DC	Revision Date: 07/05/31

File: 6198-Charts-07.cdr

Drawn by: BSW	Checked: BE	Fig. No.: **6.5-7**

6.6 Impact Assessment and Mitigative Measures

The assessment of potential impacts to hydrology indicators uses the criteria described in Volume 2, Section 1. Final impact ratings, post mitigation, are based on the consolidation of the seven impact assessment criteria (direction, geographic extent, magnitude, duration, frequency of occurrence, permanence and confidence) and professional judgment. Mitigation measures including management of operations and best management practices are provided along with the discussion of impacts.

6.6.1 Upgrader Site Drainage System and Water Management

The water management and site drainage system is shown in Volume 1, Figure 4.3-1. The Upgrader site consists of the main complex and process area in the middle, an administration area to the north located around the raw water pond, and undeveloped construction laydown areas on the east side and in the southwest corner. The water management plan, system design criteria and features are described in more detail in Volume 1, Section 6.5.

Runoff water will be controlled via berms and ditches. It will be contained on site and directed to ponds. The only surface water coming onto the Upgrader site will be from the two previously described culverts under the CN rail line. This local upslope drainage will be isolated from on-site drainage by directing it north along the east side ditch of Range Road 211 to drain to the North Wetland Complex. This redirection of water will maintain part of the natural drainage pattern into the wetlands.

There will be a total of eight engineered ponds within the property boundary, six of which will be for stormwater containment. The pond catchment areas and design storage capacities are identified in Volume 1, Figure 4.3-1. Freeboard in the ponds and backup in the drainage system provides additional storage capacity for extreme storm events in excess of the design. The oily stormwater pond size is based upon 12 hours of fire water storage. It collects drainage from 70% of the process area via catchbasins and an underground stormwater sewer system. The balance of the process area and development area drains to the potentially contaminated pond via the drainage ditch system shown in blue in Volume 1, Figure 4.3-1.

The water from the stormwater ponds that is not contaminated will be sent to the raw water pond as process make-up water. On occasion, if water meets regulatory requirements for release, the three stormwater ponds in the north and east undeveloped areas (admin, northeast and southeast) could have managed releases to enhance and maintain water levels in the wetland area to the north. This may be required, as a portion of the wetlands natural drainage system is captured by these ponds (Figure 6.5-3). After major storms, if ponds are full and water quality sampling indicates that the water meets regulatory requirements for release, the water may be discharged to the NSR via the effluent disposal system. Water that does not meet requirements for process use or release would be treated in the wastewater treatment plant. The total area contained by the drainage system is approximately 400 ha. Applying the regional mean annual runoff rate of 28.5 mm, the average annual volume of water that may be diverted to the stormwater ponds and retained on-site as process make-up water is 114,000 m^3. An application for a *Water Act* licence for diversion of this amount is included in Volume 1, Appendix C.

The following mitigation measures will be implemented as part of the surface water management plan to minimize possible changes to water levels, flows, erosion potential and sediment loading to receiving streams:

- Industrial runoff management facilities consisting of stormwater ponds, berms and drainage ditches will be utilized to collect and contain surface water runoff from the

Project area. These will be designed to provide full containment and use of runoff water in the Upgrader processes. Controlled releases from stormwater runoff ponds (after water quality sampling indicates the water is suitable for release) may be used to maintain the North Wetland Complex.

- The natural low gradient terrain of the Project area means potential erosion concerns will be minimized.
- Culverts will be provided along road alignments. These will be designed and installed to eliminate potential flow restrictions and maintain natural drainage patterns.
- Setback from development near wetlands.
- Best management practices will be used to reduce erosion and provide runoff control during construction of the plant site, roads, drainage ditches and pipelines. These will include: appropriate planning, scheduling and layout of works, installing sediment/runoff retention structures such as silt fences and biotechnical erosion control measures; and maintaining buffers and minimizing disturbances.
- The Upgrader site will be reclaimed by grading and vegetating to restore natural drainage patterns following decommissioning. Further details on reclamation are provided in the Conservation and Reclamation Plan (Volume 1, Section 7).

6.6.2 Raw Water Supply System

The proposed raw water source for the Project is the NSR. Average annual daily raw water demand for the Project is 39,500 m^3/d, and the Phase 1 average demand is 9,500 m^3/d. Recognizing that alternative water supply options are still being investigated, the raw water supply system assessed here will consist of the following features:

- A river intake structure on the south bank of the NSR in the reach immediately downstream of the BA Energy/ATCO intake site, as indicated in Figure 6.5-1. A combined river intake and effluent dispersion pipe system will be constructed along with a pumphouse facility.
- A pipeline from the intake to the Project site which will be addressed in a separate application.
- A pipeline from the Project to the effluent dispersion pipe system, which will be addressed in a separate application.
- A raw water pond, located as shown in Volume 1, Figure 4.3-1; and
- A wastewater treatment plant within the Project, as discussed in Volume 1, Section 6.4.

The raw water pond is sized to provide at least 14 days storage plus 12 hours fire demand storage. This storage capacity will permit short-term shutdowns or reductions in river withdrawals during high sediment load periods, frazil ice periods, or low flow periods where potential future instream flow restrictions might be applied.

Design and construction of the intake will meet or exceed regulatory guidelines and requirements, in particular under the federal *Fisheries Act* and *Navigable Waters Protection Act* and the provincial *Water Act*. Some of these requirements and conceptual design features of the intake structure are as follows:

- The instream portion of the structure will be sized and constructed for the ultimate design water supply rate to eliminate the need for any follow-up instream expansion work.

- A low profile bank intake structure constructed of sheet piling and rock riprap transitions to a concrete walled intake structure is proposed. The structure is expected to project approximately 10 m out into the river and extend as high as the mean annual flood level within the river. The intake is expected to be similar in profile but much larger than the existing BA Energy/ATCO intake. Concrete intake bays will lead back to the main intake pumphouse constructed in line horizontally with the high bank of the river. A modular design concept for the pumphouse facility will be applied for expansion from Phase 1 to the final Project.

- The outer wall of the intake will be angled slightly (about 10 degrees) into the flow to induce local scouring and maintain a sweeping velocity past the vertical intake wall area.

- The screens will have 2.54 mm size openings with a maximum design intake approach velocity of 0.038 m/s. These screens have been designed for exclusion of anguilliform swimming mode fish species such as pike, as per fisheries intake guidelines (DFO, 1995). The design peak summer day withdrawal rate of 62,666 m^3/d results in a minimum required open screen area of 19 m^2. Since these intake screens typically have an open area of 58.5%, the total size of the required screening is 32.6 m^2. These screen dimensions are assumed for preliminary intake sizing; however, detailed designs may alter these dimensions. A series of intake bays will provide moderately uniform intake velocities across the screens.

- Initial field investigations for this reach of the NSR indicate that a reliable scoured depth of 1.8 m may be achieved at minimum flow conditions. With screens set at least 0.3 m above the bed, this means the minimum effective vertical screen height is 1.5 m at low flow. Allowing for the width of walls for bays and structural supports and assuming a spare bay for maintenance, the resulting length of the intake structure will be approximately 27 m. Detailed layout configurations involving angled screens and/or fish bypass systems may be employed to reduce the overall footprint of the intake structure. However, for assessment purposes, a total footprint area of up to 360 m^2 on the river bed is assumed. This includes the upstream and downstream transition areas.

- A protective trash rack may be provided in front of the screens. Either air or water backwashing or self cleaning screens may be used to clear debris and ice. However, cleaning and maintenance issues are expected to be minor. The screen system is designed based upon a minimum flow depth and a maximum design withdrawal rate at the same time, and as such is expected to provide more than adequate over-design for all other operating conditions. It is notable that the average intake rate is about 63% of the peak rate. During Phase 1 only one or two bays in the intake structure may be utilized. In addition, the 14-day storage capacity in the raw water storage pond allows for lengthy reductions in withdrawal rates below the design peak rates or even complete shutdowns in extreme situations such as during flood or ice/debris blockage conditions.

Potable water will be supplied by Strathcona County's expanded distribution system.

6.6.3 Impacts During Construction

A water management and sediment control plan will be developed to provide appropriate isolation and containment of all disturbed area runoff during construction. After topsoil stripping and grading berms, the stormwater ponds and drainage ditches will be among the initial works constructed in order to manage runoff and maintain good drainage conditions during construction. There are no existing defined drainage channels on the site. The only upslope drainage is from the CNR rail culverts at the south. This runoff will be routed east to drain north via the Range Road 211 drainage ditch, as shown in Volume 1, Figure 4.3-1.

Water management and sediment control mitigation measures to be employed during construction will include:

- minimizing the extent of disturbance to developed areas and maintaining a vegetative cover in undeveloped areas including large portions of the laydown areas;
- creating stable topsoil and subsoil stockpiles with maximum 3H:1V side slopes and using sediment control fences until a protective vegetative cover is established;
- using erosion control matting where slopes and soil conditions warrant additional control measures;
- restoring vegetative cover on disturbed areas as soon as practical following completion of construction activities in an area; and
- creating stable low gradient ditches at less than 0.2% grade.

Water during construction will be primarily required for the concrete batch plant, dust suppression and soil compaction and will be provided by stormwater collected from the site and excavation dewatering. Any requirements that exceed the capacity of these supplies will be obtained from the potable water supply until the source water system is constructed.

Instream construction of the water intake structure will be conducted by isolating the area with a cofferdam. Less than 40% of the NSR will be constricted during construction with clean stable rock material placed out around the outside of the cofferdam to control erosion and sediment during construction. The cofferdam will need to accommodate the significant daily water level fluctuations due to the peaking power flow regulation. The effect of the cofferdam on the river water level during construction will be minor compared to these existing fluctuations. Instream construction activities will be limited to the August 1 to April 15 period, which is outside of the Restricted Activity Period (AENV, 2000) for this reach of the NSR.

6.6.4 Impacts During Operations

6.6.4.1 Water Use and Licensing

Daily water use and return flows for Phase 1 (80,000 bpsd production), Gasification 1 at 243,000 bpsd, and the Project (with Gasification 2) at 243,000 bpsd are summarized in Table 6.6-1 for both average and peak water demand conditions. Peak water demands will occur during summer when cooling water requirements are greatest. The demands indicated here include a 15% contingency factor. Water balance details and requirements are presented in Volume 1, Section 5.3.

Table 6.6-1 Phase 1 and Project North Saskatchewan River Raw Water Demands and Return Flows

Development Case	**Raw Water Demand**		**Wastewater Return Flow**	
	Average m³/d (m³/s)	**Peak m³/d (m³/s)**	**Average m³/d (m³/s)**	**Peak m³/d (m³/s)**
Phase 1: 80,000 bpsd	9,500 (0.110)	12,190 (0.141)	4,814 (0.056)	5,352 (0.062)
Gasification 1: 243,000 bpsd	31,158 (0.361)	47,756 (0.553)	4,306 (0.050)	7,646 (0.088)
Project: 243,000 bpsd	39,500 (0.457)	62,666 (0.725)	0	0

A *Water Act* application for an annual raw water volume of 14,417,500 m³ based on the average daily withdrawal rate of 39,500 m³/d is presented in Volume 1, Appendix C.

Measures taken by North American to contribute to the improvement in efficiency and productivity of water use for the Project include water recycle and reuse reclaims of all wastewater through: evaporators, ultrafiltration backwash recycle, stripped sour water recycle and BIOX effluent reuse, stormwater recycle, and recycle of biosolids dewatering filtrate. At the second stage of gasification, a 30% reduction in trim cooling by cooling towers is planned by using aerial cooling. No effluent will be discharged to the river after the second stage of gasification comes on line (referred to as Zero Liquid Discharge [ZLD]). The above measures meet or exceed industry leading water conservation and reuse benchmarks compared to the other upgraders proposed in the AIH. North American will continue to explore technical advancements to further improve water use efficiency over time.

The peak summer day demand of 0.725 m³/s for the Project represents a small percentage of both average and low flow conditions and even the minimum recorded monthly flow in the NSR, as indicated in Table 6.6-2. However, of greater concern is the cumulative effect on NSR flows when combined with other existing and planned projects. These are discussed in the Section 6.7.

Table 6.6-2 Percentage of Project Water Use versus NSR Flows

NSR Flow Condition	**Average Demand (%)**	**Peak Summer Day Demand (%)**
Mean Annual Flow (196 m³/s)	0.23	0.37
1:10 Year, 7-day Low Flow (60 m³/s)	0.76	1.21*
Minimum Recorded Monthly Flow in August (127 m³/s)	0.36	0.57

* Peak demand conditions are not expected to occur during winter low flow conditions.

Potable water demands of 2 m³/h and 3 m³/h for Phase 1 and Project stages, respectively, will be supplied from Strathcona County.

6.6.4.2 Stormwater Management

Site runoff will be managed as discussed above in Section 6.6.1.

Potential runoff from approximately 225 ha of the Astotin Creek basin and 175 ha of the unnamed tributary basin will be intercepted by the stormwater control system on site. However, a portion of these areas are non-effective areas – i.e., they currently do not contribute surface runoff downstream during less than mean annual flood conditions as they drain to local pothole wetlands within the Project boundary. The effective drainage areas intercepted by the Project are estimated at 92 ha in the Astotin Creek basin and 101 ha in the unnamed tributary basin. These effective areas represent approximately 0.5% of the Astotin basin where the runoff would enter Astotin Creek and 1.6% of the total unnamed tributary basin area. More efficiently directing the drainage of the upslope area south of the CNR rail line to the North Wetland Complex, and ultimately the unnamed tributary watershed, somewhat offsets the runoff that is retained within the unnamed tributary watershed. Based upon these small percentage areas, their low natural contribution and the proposed drainage improvements, any impact on downstream flows in the Astotin Creek and unnamed tributary basins are not expected to be detectable. This would apply to all flow regimes (high, low and average).

The Project will result in the loss of Class I and II (ephemeral and temporary pond) wetlands and the Class III seasonal pond in the NW 26-55-21 W4M. The Class IV semi-permanent wetland (North Wetland Complex) on the northwest corner of SW 35-55-21 W4M will remain physically undisturbed. This wetland is already bound by an existing road around its southeast perimeter that limits drainage to it from the Project area. The Project development will decrease the surface drainage area to the North Wetland Complex by up to 25%, resulting in a decrease in runoff and water levels in this wetland. This reduction in runoff will be offset by more efficiently directing the upslope drainage south of the Project area via road ditching to this area.

Monitoring of water levels in the North Wetland Complex will identify when periodic releases from the stormwater ponds may be desirable to sustain and enhance the North Wetland Complex. Opportunities for further enhancement may include establishing greater riparian vegetation buffers around the North Wetland Complex, and setbacks for development.

6.7 Cumulative Effects Assessment

6.7.1 Changes in the Flow in the NSR due to Water Withdrawal

The cumulative effect of withdrawals from the NSR was assessed using the existing and proposed licenced withdrawals indicated in Table 6.5-2 plus the Project. The effect on the mean annual flow is illustrated in Figure 6.7-1. Cumulative licenced withdrawals from downstream of Edmonton to the Alberta – Saskatchewan boundary amount to 743,101 dam³ or a flow rate of 23.56 m³/s, with return flows of 16.26 m³/s, resulting in a net withdrawal rate of 7.30 m³/s. This net withdrawal is 3.7% of the mean annual flow at Edmonton and about 3.6% of the estimated mean annual flow at the Alberta – Saskatchewan border. As noted in Figure 6.7-1, mean annual inflows downstream of Edmonton to the Saskatchewan boundary may amount to approximately 8 m³/s, or more than the total licenced net withdrawals. In the lowest flow year from 1973-2005 (1975), the maximum allocated net withdrawal is equal to 5.2% of the mean annual flow at Edmonton.

The cumulative effect of licenced and proposed licenced withdrawals under low (7Q10) flow conditions is illustrated in Figure 6.7-2. Under this low flow condition, the cumulative net withdrawal from Edmonton to the Saskatchewan boundary (not accounting for any tributary inflows) is 12.0% of the NSR flow.

The cumulative effects of these withdrawals are considered low in view of the following considerations:

- Not all licenced users will withdraw full licenced amounts.
- While peak withdrawal rates may be higher than the licenced annual average rate presented here, these will not all occur at the same time and many peak demands, due to cooling water demands, will generally occur during the higher summer flow periods and not during the 7Q10 low flow period in the winter.

- Downstream inflows further reduce the cumulative effects of withdrawals. In addition, the assessment is based upon the gauging station flows at Edmonton which do not include the return flows from the City of Edmonton.
- The daily fluctuations in flow currently occurring in the NSR are typically much greater than the sum of all net withdrawals.
- Most operations including North American's have storage that would allow for short term cutbacks in withdrawals in the event of future restrictions due to possible instream flow needs during critical low flow periods.
- Flow regulation has substantially increased previous natural low flows in the NSR (the 7-day minimum annual flow has increased from a median of 22.4 m^3/s prior to regulation to 77.8 m^3/s after regulation).
- Flow monitoring accuracy on the NSR is likely in the order of ±5%.

6.7.1.1 Impact of Climate Change During Low Flow Periods

The TOR requests a discussion of the potential hydrologic impact of climate change on the availability of water in the NSR during low flow periods and thus the availability of water for the Project and other users in the future. To gauge the potential effects of climate change on low flows, consideration must be given to a range of complex interrelated factors. These include potential changes in precipitation and evaporation, changes in timing and changes in glacial melt contributions. In addition to these factors, past historical fluctuations and trends can be used as a guide. However, these may be masked by changes in land use (forest cover) and water management and abstractions. All of these factors need to be considered when predicting a seasonal expression of flow. A summary of some issues to consider follows:

- Flow data in the NSR is available from 1912 to present. The recorded annual flow at Edmonton from 1912 to 2002 shows a significant negative trend (at 95% significance criterion) (Seneca, 2004). Although this may be partly due to increasing withdrawals, recently computed naturalized flow data from 1912-2002 (Stantec, 2005) still indicate a strong negative trend over the period of record. (Naturalized means removing the effect of uses and dam operations.) The 1912-2005 naturalized mean annual flow is 214 m^3/s. By comparison, the 1973-2005 post-dam evaluation period indicates a mean annual naturalized flow of approximately 200 m^3/s versus the mean annual recorded flow of 196 m^3/s, as used in this assessment report. The year 1975 was the lowest flow year on record with an estimated naturalized flow of 136.4 m^3/s versus a recorded flow of 140 m^3/s at Edmonton. The lower computed naturalized flow in 1975 implies flows were likely increased this year by reservoir drawdown from the two major dams.
- Current Global Climate Model (GCM) simulations demonstrate significant variability in predicted future changes for both mean temperature and total precipitation on the Canadian prairies and in Alberta (Toyra et al, 2005). Most models appear to indicate that increasing temperatures in Alberta will lead to increased precipitation and increased evaporation and transpiration. The net effect on streamflows is uncertain depending upon whether increased evapotranspiration would exceed any increases in annual precipitation. Canadian studies generally provide indications that the annual volume of runoff may increase in northern regions and decrease in southern regions (Fillion, 2000). The NSR basin sits between these northern and southern regions. For example, several studies in the South Saskatchewan River Basin (SSRB) have predicted lower low flows and drier conditions in southern Alberta. However, the predicted impacts appear to be less severe in central Alberta. Results using scatterplot tools from 31 GCMs for 30-year time periods from 2010-2039 and 2049-2069 (Environment Canada website) forecast a

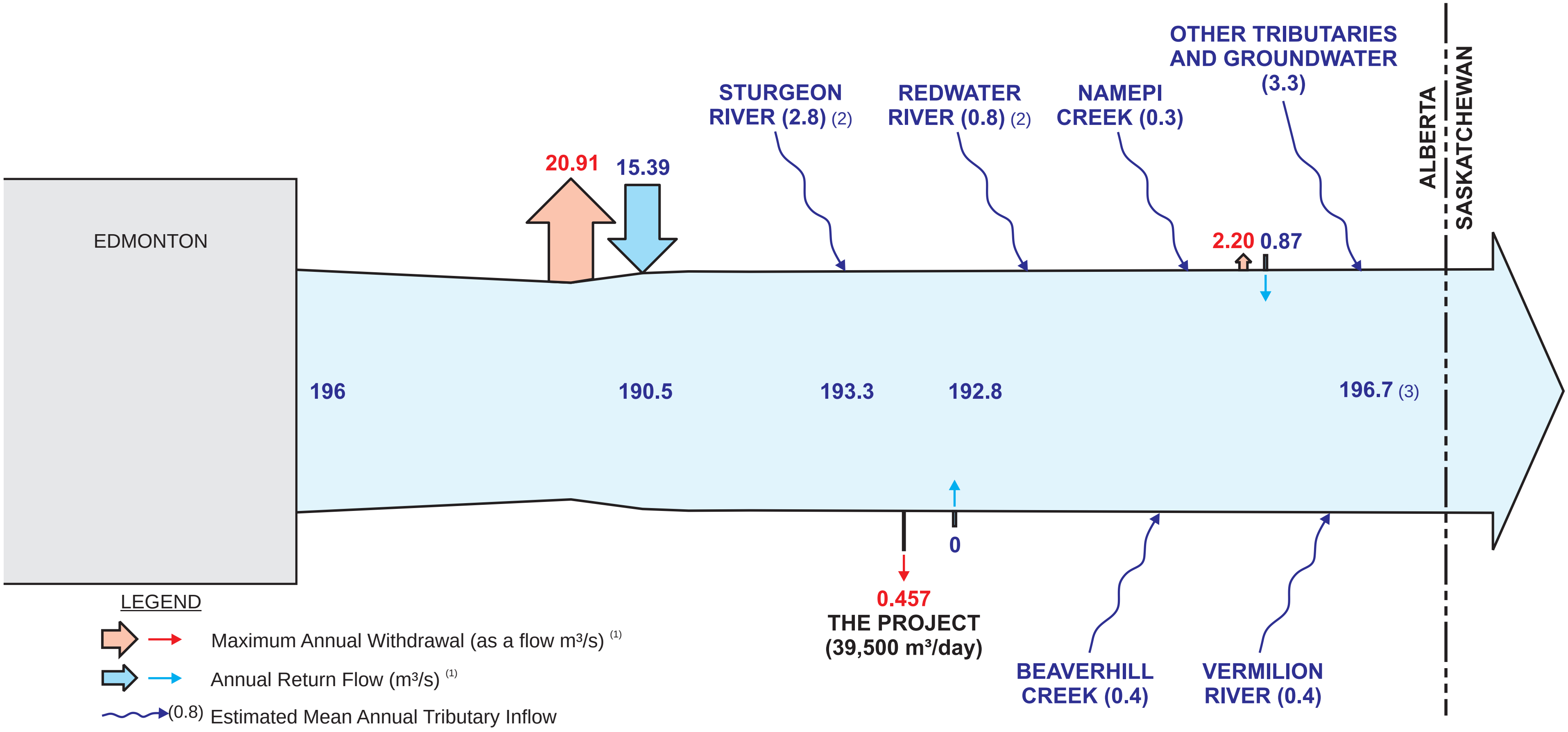
median increase in precipitation from 3.5% to 4.1% (max 13.4% min -10.6%) for the first time period and 7.3% to 7.8% (maximum 19.2% minimum -5.5%) for the second time period with greater increases predicted in the eastern part of the basin. Similar modelling results for predictions of evaporation rates are much more variable and could not be summarized. In addition, modelling of monthly predictions to translate this into low flow periods becomes increasingly speculative.

- "A general increasing trend in precipitation has been projected in the Northern Hemisphere at mid- and high-latitude (particularly during autumn and winter), and there is a general belief that the frequency of heavy rainfall events is likely to increase with global warming due to an intensification of the hydrologic cycle (Hennessay et al., 1997; McGuggie et al., 1999). However precipitation variations associated with climate change over the next 50 years are believed to be small compared to those resulting from natural decadal variability (McCarthy et al., 2001). In light of these considerations, climatic variations as compared to climate change, are expected to play a more decisive role in water resources decisions in the near future than long term gradual climate change" (ASCE, 2006).

- Climate warming results in increased melting of glaciers, although whether a glacier retreats or advances is additionally dependent on snowfall and the dynamic characteristics of the glacier. For the NSR at Edmonton, glaciers covered approximately 1.4% of the total drainage area in 1975. This was reduced to about 1.1% in 1998 (Pietroniro, 2006). At Edmonton, estimates of the proportion of runoff directly from glaciers represents 7.4% of the late summer (August to October) flow and 1.8% of the annual flow (Pietroniro and Nemuth, 2006) in the NSR. However, in low flow years this percentage contribution may be much higher. Assuming double the above contribution to flow in the lowest flow year - 1975 as an illustrative example, and if the glaciers were to fully disappear, the minimum historically recorded flow month in the late summer period (October 1975) could decrease from the 91.1 m^3/s recorded to 77.6 m^3/s. In this scenario, cumulative net consumptive uses downstream of Edmonton would amount to 9.3% of this reduced minimum monthly flow.

- Notwithstanding the scant and sometimes contrasting evidence, the literature highlights concerns that the frequency of severe episodes (droughts and flooding) will increase in the future. Long term low flow investigations to date have primarily relied upon paleoenvironmental studies and tree-ring constructions to define drought patterns and periods (George and Sauchyn, 2006). Evaluation in the context of historical trends needs to be considered. In the past century, droughts in Alberta have had a return period of 30 years to 50 years (Herrington et al., 1997) with severe droughts in the 1930s. Post glacial proxy climate data indicates that the prairies have experienced droughts "far more severe" than during the 1900s (Herrington et al., 1997). However, a 500-year analysis of tree rings on the Canadian prairies concluded that during the last 100 years, "the frequency of droughts…has not been appreciably different from conditions of the preceding four centuries" (Case and MacDonald, 1995).

Drawing conclusions from the literature and available data is difficult at best. Compounding the impact of possible declining annual discharge, as seen in the historic trend, is the need to consider changes in seasonal flows. Late summer flows are expected to decline however late winter flows may slightly increase (Rood, 2006). In addition, the frequency and duration of low flow periods may be expected to increase. In view of the uncertainties, the practice of applying caution in water management is prudent. For the NSR, the use of the substantial flow regulation that is available within the basin combined with potential future restrictions on withdrawals for instream flow needs, and hence the need for short duration offstream storage for the Project, are measures available to address these potential future uncertainties.



NOTE

(1) Includes all existing licenses plus applications plus the project at maximum licenced allocations.

(2) Average annual increase in flow from Edmonton to Alberta - Saskatchewan border = 8 m³/s. Approximate contribution of main tributaries shown in brackets.

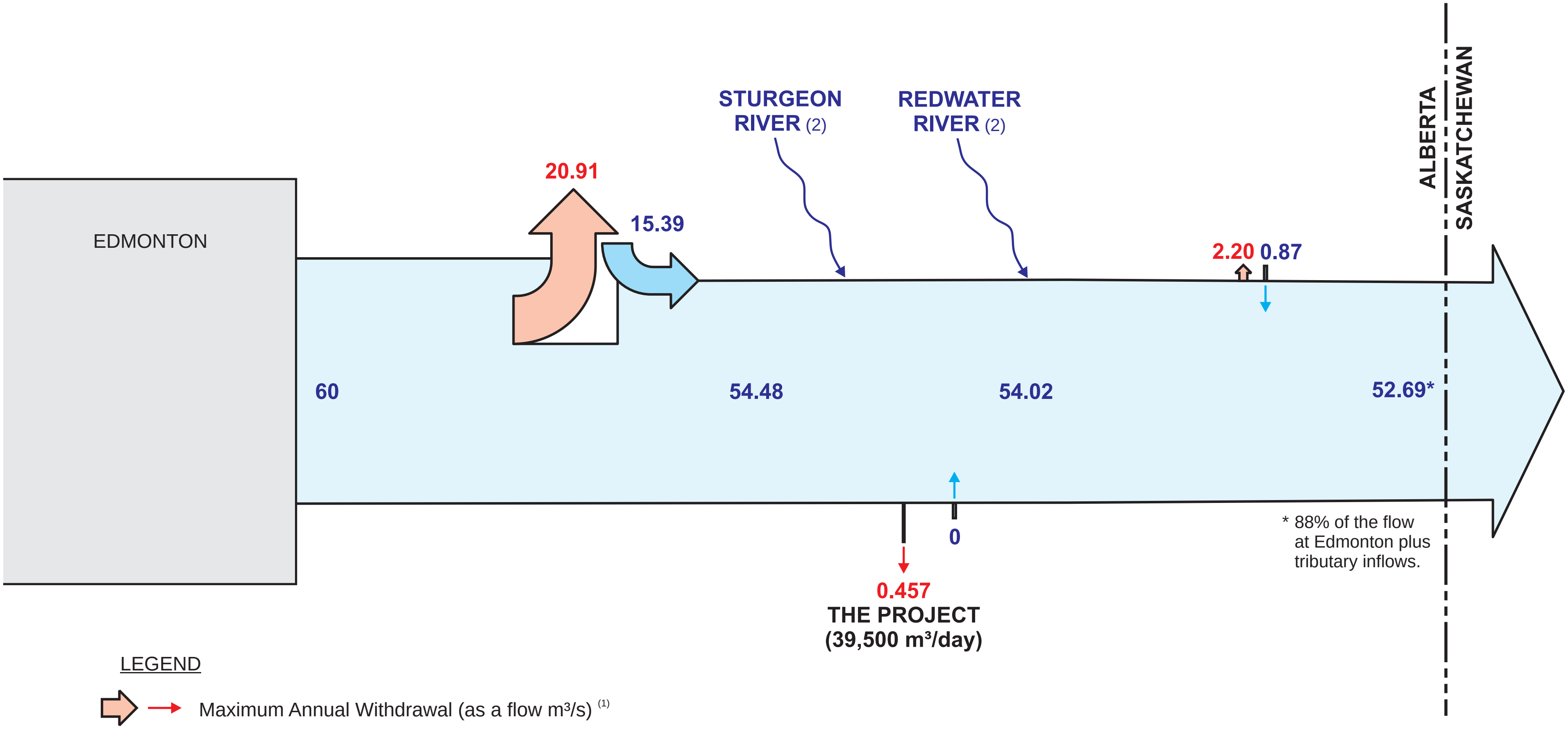
(3) A net increase in flow from Edmonton to the Alberta - Saskatchewan border occurs on average considering all licensed withdrawals and natural inflows.

Title:

NORTH SASKATCHEWAN RIVER CUMULATIVE IMPACT OF WITHDRAWALS AT MEAN ANNUAL FLOW

NORTH AMERICAN OIL SANDS CORPORATION

Approved: LP	Revision Date: 07/03/30	
File: 4455-IMPACT-07.cdr		
Drawn by: GDE	Checked: DC	Fig. No.: **6.7-1**



LEGEND

🡆 → Maximum Annual Withdrawal (as a flow m³/s) (1)

🡆 → Annual Return Flow (m³/s) (1)

NOTE

(1) Includes all existing licenses plus applications plus the project at full build-out.

(2) Additional tributary inflows not included.

Title:

NORTH SASKATCHEWAN RIVER CUMULATIVE IMPACT OF WITHDRAWALS AT 7Q10

NORTH AMERICAN
OIL SANDS CORPORATION

Approved: LP		Revision Date: 07/03/30
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6.8 Follow-up and Monitoring

Hydrologic monitoring conducted as part of operations will consist of the following:

- stormwater pond level monitoring and testing on a regular basis during and following runoff events;
- regular inspections of the drainage system (ditches and culverts) and repair of erosion or blockage issues and
- monitoring of water levels in the North Wetland Complex to ensure natural water levels are being maintained. An assessment of stormwater pond release requirements and timing may be beneficial. A control wetland in an undisturbed drainage area (possibly in Elk Island Park) could be used for comparison purposes.

6.9 Impact Summary

The Project will require water from the NSR. Some local stormwater runoff will be collected from the Project area that is not released back to the environment. Controlled releases of suitable quality runoff water will occur. Cumulative changes anticipated in flows and water levels in the NSR are considered to be minor, and are less than the existing daily fluctuations presently occurring in this reach of the NSR. The Project will not substantially contribute to existing regional cumulative effects on the NSR.

A summary of the hydrologic impacts for the Project are summarized in Table 6.9-1. Comments on each of the evaluation indicators follow.

Temporary / permanent changes in existing drainage patterns, waterbodies and wetlands: This indicator applies to the physical changes in water conveyance and retention areas. There are no defined watercourses in the Project area and no changes in drainage patterns outside of the development area. Wetlands will be removed within the Project area with others enhanced and protected. Any change is considered a net negative impact that is sub-regional in extent (within the Astotin Creek and unnamed tributary watersheds). The magnitude of the impact is low, within acceptable protective standards with no downstream detectable change to runoff rates. The duration is long-term, continuing through construction, Project life and until reclamation is complete. Reclamation can restore the area to pre-Project hydrologic conditions. The level of confidence in this assessment is medium, based upon a good understanding of the cause-effect relationships.

Effect of site runoff management on flows / levels in drainage channels / waterbodies: The retention and use of storm runoff water will have a negative impact that will extend beyond the Project development area to the Astotin and unnamed tributary watersheds. The retention of storm runoff may reduce contributing flows to the North Wetland Complex. The magnitude of the impact is low as any existing contribution of direct surface runoff from the majority of the Project area is small and would not be detectable in the downstream watercourses. The duration is long-term, continuing through construction, Project life and until reclamation is complete. Reclamation of the Project area can restore pre-Project hydrologic conditions. The level of confidence in this assessment is medium, based upon a good understanding of the cause-effect relationships.

Project contribution to cumulative pressures on surface water resources and cumulative impact of water withdrawal on the NSR: These indicators are two separate discussion items stated in the

TOR. They are combined because they have the same evaluation results in terms of impacts in the NSR watershed. Any change or development adds to cumulative pressures on surface water resources. Therefore, this is a negative, regional (NSR watershed) impact that is of medium magnitude because the cumulative magnitude of the water use causes a detectable change in river flow. The duration of the impact is long-term and continuous over the life of the Project. The impact is reversible in the long-term with an end to water uses and site restoration at Project closure. The level of confidence in this assessment is high based upon a good database of flow records on the NSR and a good understanding of current and planned water demands.

The final impact ratings for the above three indicators are rated the same as the magnitude impact ratings.

Table 6.9-1 Hydrologic Impacts for North American Upgrader Project

Indicator	**Direction of Impact**	**Extent of Impact**	**Magnitude of Impact**	**Duration of Impact**	**Frequency of Occurrence of Impact**	**Permanence of Impact**	**Level of Confidence**	**Final Impact Rating**
Temporary / permanent changes in existing drainage patterns, waterbodies and wetlands	Negative	Sub-regional	Low	Long-term	Continuous	Long-term	Medium	Low
Effect of site runoff management on flows / levels in drainage channels / waterbodies	Negative	Sub-regional	Low	Long-term	Continuous	Long-term	Medium	Low
Project contribution to cumulative pressures on surface water resources and Cumulative impact of water withdrawal on the NSR	Negative	Regional	Medium	Long-term	Continuous	Long-term	High	Medium

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7 SURFACE WATER QUALITY

7.1 Introduction

The following sections provide a description of the existing water quality conditions of the creeks, rivers and lakes within the North American Upgrader Project area, and identify potential changes to surface water quality associated with the Project. Mitigative measures to minimize potential environmental effects are presented and residual effects are assessed. In particular, the surface water quality component of the Environmental Impact Assessment (EIA) will address the Terms of Reference (TOR) (Volume 1, Appendix A). These include discussion of:

- water quality characteristics in surface waterbodies within the study areas, their seasonal variation, relationships to flow and other controlling factors and a summary of existing water quality data, including surveys conducted to characterize the water quality;
- the potential Project-related and cumulative impacts of acidifying and other air emissions on surface water quality in the local and regional waterbodies;
- the potential effects of site runoff on water quality in surface waterbodies within the study areas;
- the potential impacts on surface water quality within the study areas due to the change in groundwater movement;
- the potential impacts on surface water quality within the study areas due to spills;
- mitigation plans to minimize these potential effects throughout the Project life;
- a plan and implementation program for the protection of surface water quality, addressing the following:
    - monitoring program for early detection of potential contamination and assistance in remediation planning; and
    - remedial options to be considered for implementation in the event that adverse effects are detected;
- the relative contribution of the Project (after mitigation) to regional cumulative effects on surface water quality; and
- the significant and potential impacts on surface water quality within the study areas resulting from the Project, including site runoff and Project-related wastewater discharges, that may indicate a potential adverse effect or exceedance of the Surface Water Quality Guidelines for Use in Alberta (AENV, 1999) or Canadian Water Quality Guidelines (CCME, 1999-2006 update).

7.2 Spatial Boundaries

Three study areas were selected to document water quality conditions and assess the potential effects of the Project on both the local and regional level. These are shown in Figures 7.2-1 to 7.2-3, and are described in Section 7.2.1 and 7.2.2.

7.2.1 Local Study Area

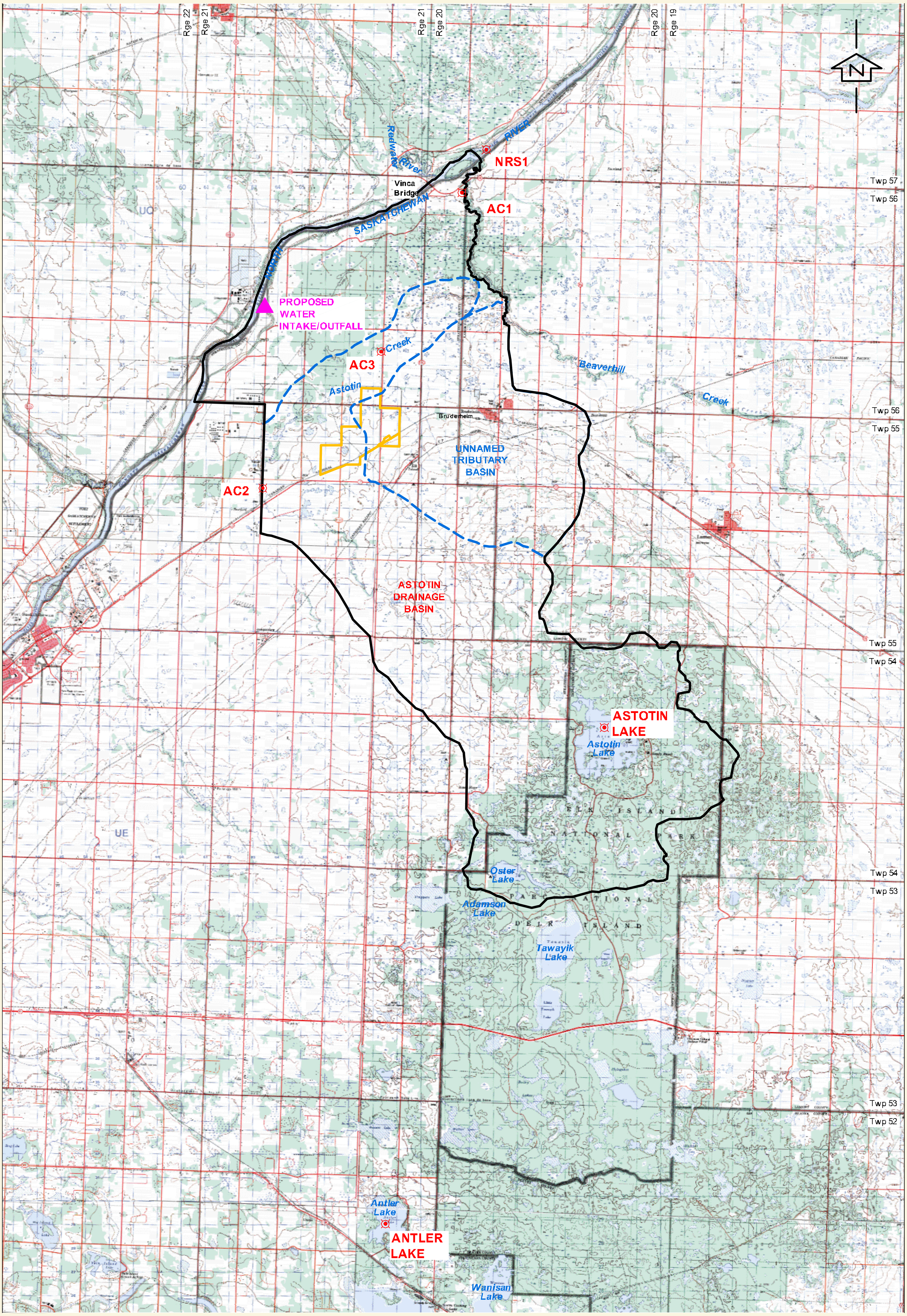
The LSA includes waterbodies and watercourses located within the proposed Project development area, which may be directly or indirectly affected by the Project. The Local Study Area (LSA) (Figure 7.2-1) for the surface water assessment includes the Upgrader site, the catchment basin for Astotin Creek and the catchment basin of an unnamed tributary flowing into Beaverhill Creek. The north end of the LSA follows the North Saskatchewan River (NSR) and includes the proposed locations of the water intake, pump house, outfall and a portion of the NSR within the effluent plume of the proposed effluent outfall (an approximately 5 km stretch downstream of the outfall). A north-central portion of the LSA borders on Beaverhill Creek. This LSA is consistent with that used for the Hydrology and Fish and Fish Habitat assessments (Volume 3, Sections 6 and 8, respectively).

7.2.2 Regional Study Areas

The Regional Study Area (RSA) was selected to identify potential effects of the Project on regional surface water quality associated with changes in flows, runoff, treated effluent discharge and aerial deposition of acidifying substances. In addition, it defines the study area where the cumulative effects assessment will be focused.

Two RSAs are defined. For most surface water issues, the RSA consists of the LSA and a length of the NSR within which the cumulative effects of treated process water discharge to the NSR would likely be measurable. The RSA extends along the NSR from the discharge of the Gold Bar Wastewater Treatment Plant (WWTP) to the confluence with the Redwater River (Figure 7.2-2).

A second RSA, the acidification RSA, for the issue of potential lake acidification from airborne emissions, is defined as that area within the 0.17 keq H^+/ha/y isopleth for the PAI determined for the Cumulative Case by air emissions modelling. This isopleth corresponds to a level of acid input where monitoring and further study are called for (AENV-CASA, 1999; Foster et al., 2001). Because the PAI is largely dominated by the contributions from the City of Edmonton, the analysis in this assessment is concentrated on the eastern portion of the acidification RSA, where the potential effects of the Project would be most apparent (Figure 7.2-3).



LEGEND

🟨	North American Property boundary
▬	Local Study Area (LSA)
- - -	Sub-basin
⊙	Water Sample Location
▲	Proposed Water Intake/Outfall

SCALE 1: 150000 kilometres

2 0 2 3

Title:

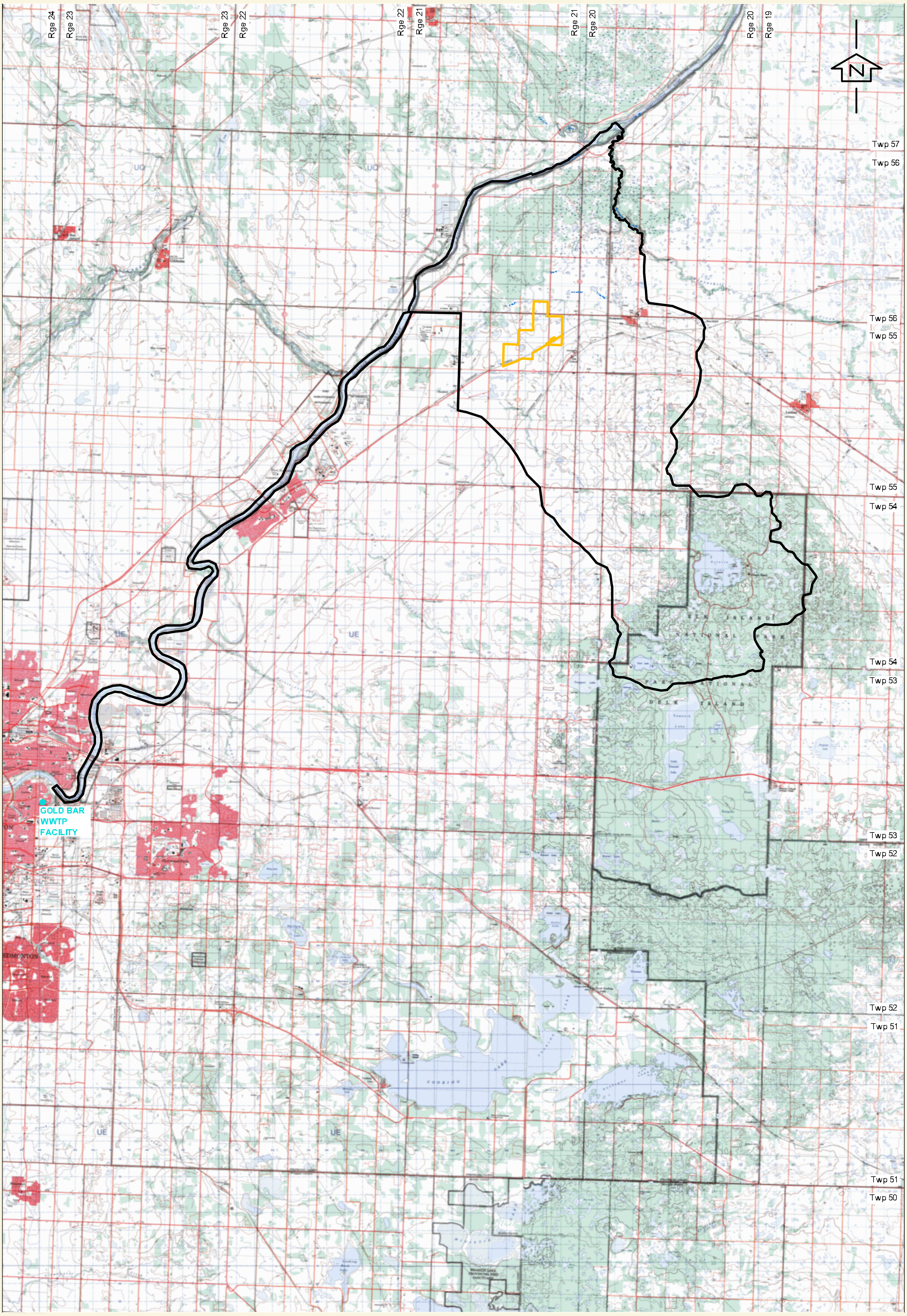
LOCAL STUDY AREA AND FIELD SAMPLING SITES FOR THE NORTH AMERICAN UPGRADER PROJECT

NORTH AMERICAN OIL SANDS CORPORATION

Approved:	Revision Date:
BE	07/11/1

File: 6198-SITESW-07.DWG

Drawn by:	Checked:	Fig. No.:
BSW	DA	7.2-1



LEGEND

North American Property Boundary

Regional Study Area Boundary

SCALE 1: 200000 metres

2000 0 2000 4000

Title:

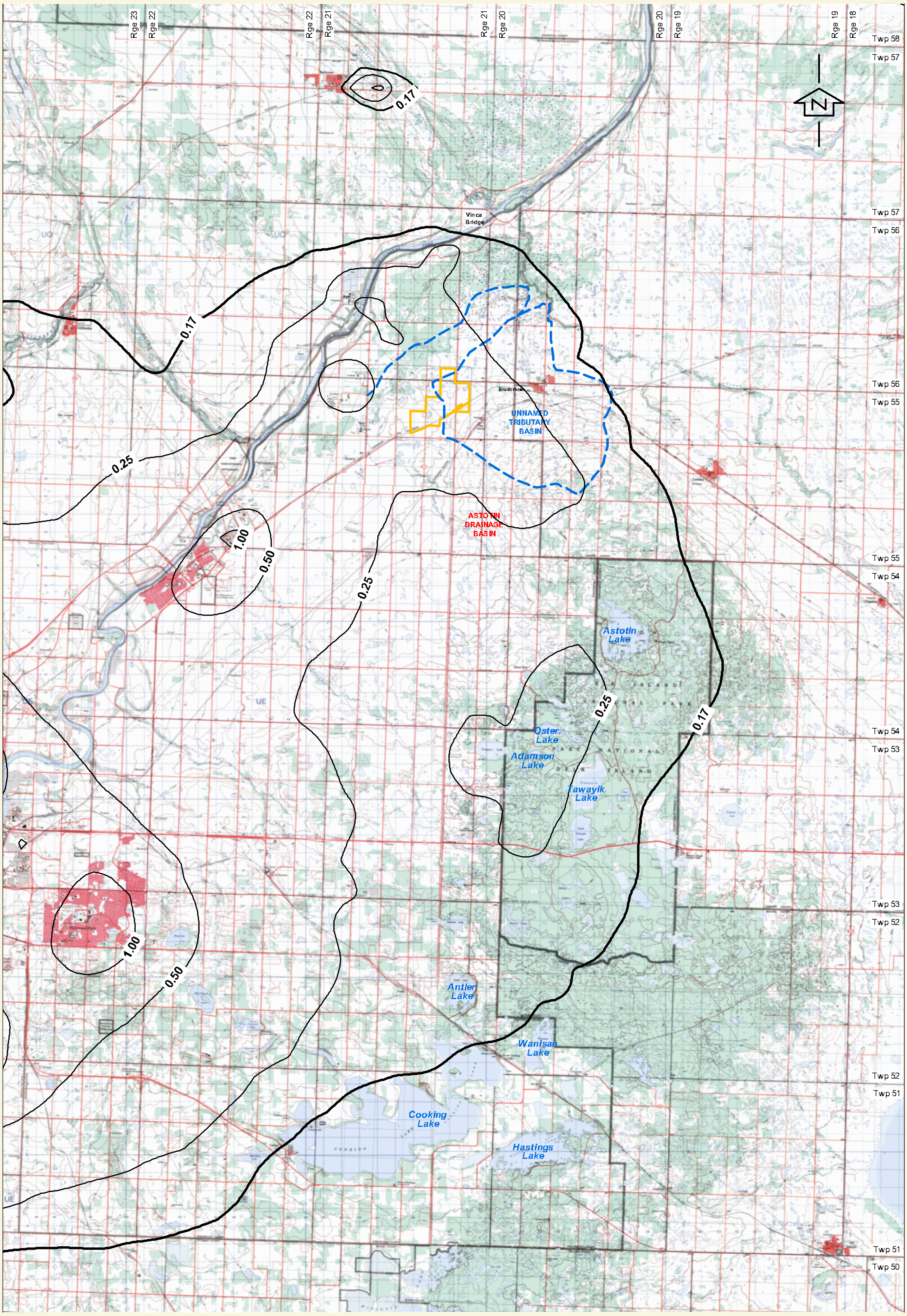
THE REGIONAL STUDY AREA FOR ISSUES RELATED TO PROCESS WATER DISCHARGE

NORTH AMERICAN
OIL SANDS CORPORATION

Approved:	Revision Date:
BE	07/11/01

File: 6198-SITESW-07.DWG

Drawn by:	Checked:	Fig. No.:
BSW	DA	7.2-2



LEGEND

— North American Property Boundary
- - Sub-basin
— Air Isopleth

SCALE 1: 200000 kilometres
2 0 2 4

Title:

THE PAI REGIONAL STUDY FOR NORTH AMERICAN UPGRADER PROJECT

NORTH AMERICAN
OIL SANDS CORPORATION

Approved: BE	Revision Date: 07/11/1

File: 6198-SITESW-07.DWG

Drawn by: BSW	Checked: DA	Fig. No.: 7.2-3

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7.3 Temporal Boundaries

The temporal scope of the EIA reflects the timing and nature of the Project phases, as well as information available on other proposed projects. Project and cumulative effects are assessed for the construction, operations, decommissioning and reclamation and closure phases of the Project. The Project schedule is outlined in Volume 1, Section 1.4.

To establish a baseline timeframe, background conditions were assumed to be those that existed as of May 1, 2007, and include both unpublished data and published data that were readily available.

For this EIA, existing projects are defined as those that have been approved by the EUB and/or AENV. Planned developments include projects that have been publicly disclosed (but not approved) as of May 1, 2007. The projects and developments included within the scope of this assessment are listed in Volume 2, Section 1.

7.4 Issues and Assessment Criteria

Potential water quality issues associated with the Project were identified based on the final TOR prepared by Alberta Environment (AENV) (Volume 1, Appendix A), public input and the professional judgment of the author. Key water quality issues are presented in Table 7.4-1.

Table 7.4-1 Potential Water Quality Issues Associated with the Project

Project Phase	Issue	Comment
Construction	Sediment release to waterbodies	Land clearing, road construction and plant construction could potentially increase sediment in runoff to local waterbodies.
	Changes in surface water quality from dewatering	Construction activities involving excavations could lower shallow water tables and indirectly result in water quality changes in local waterbodies.
Operations	Changes in surface water quality from groundwater suppression	Permanent groundwater suppression under stormwater ponds for liner protection could lower shallow water tables and indirectly result in water quality changes in local waterbodies (see construction impacts above).
	Changes in the water quality of the NSR from release of treated effluent	Discharge of treated process waters could adversely affect the water quality of the NSR.
	Changes in water quality in local waterbodies from the release of stormwater runoff	Release of stormwater runoff from storage ponds could affect the water quality of local waterbodies.
	Changes in water quality in local waterbodies from spills	Spills could affect the water quality of local waterbodies.
	Acidification of local and regional lakes	Increased levels of acidifying air emissions (e.g., nitrogen oxides and sulphur dioxide) from the Upgrader could result in acidification of regional lakes.

7.4.1 Effects Criteria

Residual effects from all water quality issues will be predicted after application of mitigative measures. For most water quality issues, the assessment is based on comparisons between predicted concentrations of specific parameters and published water quality guidelines. These include the Alberta Surface Water Quality Guidelines (ASWQG) and the guidelines published by the Canada Council of Ministers of the Environment (CCME). These water quality guidelines are presented in Table 7.4-2. Consistent with policies outlined in the Canadian Environmental Assessment Act Responsible Authorities Guide (FEARO, 1994), Project-specific effects and cumulative effects will be assessed as outlined in Volume 2, Section 1, except for extent and magnitude.

Extent describes the area within which the effect occurs. It is classified as subregional (one watershed or natural subregion), regional (within the RSA) or extra-regional (effects extend beyond the RSA) effect.

Magnitude describes the size and severity of the effect. Magnitude is classified as negligible (no discernible contribution), low (within acceptable protective standards and/or causes no detectable change to the resource), medium (within acceptable protective standards and/or causes a detectable change to the resource) or high (exceeds protective standards and/or causes a detectable change to the resource beyond the range of tolerance). For surface waters, “protective standards” are assumed to be the applicable water and sediment quality guidelines published by AENV or the CCME. The relevant guidelines are presented with each data summary.

Conclusions for the project effects criteria are based on qualitative and quantitative assessments. Quantitative assessments include the results of measurable predictions or objective comparisons of residual project impacts with established limits (e.g., water quality guidelines, ambient air quality guidelines, environmental objectives, etc.) Qualitative assessments are subjective and take into account professional judgment. This is important when environmental objectives are not available or quantitative predictions are not feasible.

The integration of the various impact ratings results in a final impact rating of no impact, negligible impact, low impact, medium impact or high impact for each potential project effect.

Table 7.4-2 Alberta and Canadian Water Quality Guidelines (mg/L except as noted)

Parameter	Alberta Fresh Water Aquatic Life (Acute)	Alberta Fresh Water Aquatic Life (Chronic)	CCME Guidelines for Protection of Aquatic Life	CCME Protection of Agricultural Water Uses[2]	CCME Recreational Water Quality Guidelines
Routine Parameters					
Total Dissolved Solids				500-3,500	
Total Suspended Solids		<10 mg/L over background value	Clear flow: maximum increase of 25 mg/L for <24 h or 5 mg/L for 1-30 d High flow: maximum increase of 25 mg/L when background between 25 mg/L and 250 mg/L, 10% increase when background is >250 mg/L		
Temperature (°C)		Change of 3°C	Temperature: changes should not alter thermal stratification, exceed maximum weekly average temperature, or exceed short–term exposures to maximum temperature		
pH (pH units)	5.0 (1 day)	6.5-8.5	6.5-9.0		5.0-9.0
Dissolved Oxygen		5-6.5	5.5 -9.5		
Major Ions					
Sodium					
Calcium				100	
Chloride				100-700	
Sulphate				1,000 (livestock)	
Fluoride				1.00-2.00	
Bacteria					
E. coli					200/100 mL
Fecal Coliforms				100 per 100 mL	
Total Metals					
Aluminum			0.1	5	
Antimony					
Arsenic			0.005	0.1/0.025	
Barium					
Beryllium				0.1/0.1	
Boron				0.5-6.0	
Cadmium			0.000047-0.000054	0.0051/0.080	
Chromium			0.0089	0.0049/0.050	
Cobalt				0.050/1.00	
Copper	0.024	0.007	0.002-0.004	0.200-1.00/0.5-5.00	
Iron			0.3	5.00	
Lead			0.001-0.007	0.200/0.100	
Lithium				2.50	
Manganese				0.20 (irrigation only)	
Mercury (total)	0.000013	0.000005	0.0001	0.003 (livestock only)	
Molybdenum			0.073	0.010-0.050	
Nickel			0.11	0.200/1.00	
Selenium			0.001	100 (livestock only)	
Silver			0.0001		
Uranium				0.010/0.200	
Vanadium				0.100/0.100	
Zinc			0.03	1.0-5.0/50.0	

Notes:
Blank cells indicate no guideline.
Sources of information: (AENV, 1999; CCME, 1999-2006 update).
1 Aesthetic objective.
2 Slash indicates difference between irrigation guideline (first number) and livestock guideline (second number).

7.5 Methods

7.5.1 Data Sources for Historic Data Review

Baseline water quality data from the NSR were derived from AENV's water quality database. Data from the following stations were analyzed:

- AENV Station 00AL05EC0005 at Pakan, Alberta; and
- AENV Station 00AL05EB2500 at Vinca Bridge, immediately upstream of the confluence of the NSR and the Redwater River and near the site of the proposed water intake and outfall. The Vinca Bridge station is located within the LSA (Figure 7.2-1).

The Pakan station is part of AENV's Long-Term Monitoring River Network (AENV, 2002a), and is located approximately 54 km downstream of the Project. Data from the Pakan station included the examination of seasonal and flow-related trends in water quality parameters. There were insufficient data available for the Vinca Bridge station to examine these trends.

Analysis of the water quality data from the AENV database involved calculating maximum, minimum, mean and median values. Because of changes in methods and detection limits over the years, only data since 1982 were considered. To calculate statistics on data containing parameters below detection limits, non-detectable values were assumed to be one-half the detection limit. Outlying values for each parameter were identified for the Fort Saskatchewan and Vinca Bridge stations as values greater than the 95th percentile. Over 25 years of monitoring data at the Pakan station were plotted and examined for seasonal trends. Since 2005, improvements in municipal wastewater treatment have resulted in decreases in the median concentrations of certain parameters, including total phosphorus and ammonia. Using the full range of the data in the assessment of Project effects on these parameters makes the assessment more conservative and protective of water quality in the NSR.

Water quality data from recent studies conducted during 2003 and 2004 by the City of Edmonton from the NSR upstream of the confluence with the Sturgeon River were also reviewed (Focus, 2004; 2005). AENV water quality data from 1975 to 1990 from Beaverhill Creek near the confluence with the NSR (AENV Station AB05EB0900) were reviewed. These were the only data available for this waterbody.

7.5.2 Field Program

The field program was designed to characterize water quality in waterbodies and watercourses on and near the Project area. Sampling sites were selected to collect baseline data for locations that may be influenced by potential downstream effects from the Project. These included the transportation of potential contaminants through watercourses or downwind aerial deposition of contaminants in waterbodies.

The field program consisted of four trips to the Project area during 2006 and 2007 to collect water samples during all four seasons. The surface water sampling sites generally correspond to sites assessed in the Fish and Fish Habitat study (Volume 3, Section 8). The site coordinates and sampling dates are summarized in Table 7.5-1. The location of each sampling site, including samples taken as part of the Project water-sampling program and historic data-sampling locations, with the exception of Pakan, are shown in Figure 7.2-1.

Industry standard water quality sampling protocols were followed when handling samples to avoid damage/breakage or contamination (RAMP, 1999; AENV, 2002b). In situ field water quality parameters were measured using a multimeter that was calibrated daily. Field parameters included water temperature, electrical conductivity (EC), pH and dissolved oxygen (DO). Grab samples were collected for laboratory analysis. Samples collected in watercourses were obtained just below the water surface when open water was encountered, and below the ice during the winter. Water samples from lakes were collected at the mid-depth of the deepest location, using a Van Dorn sampler. Sediment samples were taken with a Ponar or Eckman dredge sampler from the upper 0 cm to 15 cm of sediment.

The water samples from each location were analyzed for the following parameters:

- Routine parameters: EC, pH, total dissolved solids (TDS), major cations (sodium, potassium, calcium, magnesium), major anions (chloride, sulphate, carbonate/bicarbonate), total suspended solids (TSS), alkalinity, hardness;
- Nutrients: nitrate, nitrite, total Kjeldahl nitrogen (TKN), ammonia, total phosphorus (TP);
- Total and dissolved metals: aluminum (Al), antimony (Sb), arsenic (As), barium (Ba), beryllium (Be), boron (B), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), iron (Fe), lead (Pb), lithium (Li), magnesium (Mg), manganese (Mn), mercury (Hg), molybdenum (Mo), nickel (Ni), selenium (Se), silicon (Si), silver (Ag), strontium (Sr), thallium (Tl), titanium(Ti), uranium (U), vanadium (V) and zinc (Zn);
- Organics: phenols, total volatile hydrocarbons (F1+BTEX, F2) and polycyclic aromatic hydrocarbons (PAHs). PAHs include naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, acridine, fluoranthene, pyrene, benz[a]anthracene, chrysene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene (b(a)p), indeno[1,2,3-cd]pyrene, dibenz[a,h]anthracene, benzo[g,h,i]perylene, CCME B(a)P calculated equivalent.

The sediment samples were analyzed for total metals, petroleum hydrocarbons (BTEX, F1-F4 fractions) and PAHs. The water and sediment samples were sent to an accredited laboratory for analysis. Mercury samples were sent to a specialized laboratory capable of achieving lower detection limits. The laboratory results are presented in Appendix 7A.

Table 7.5-1 Location of Primary Field Sampling Sites

Station Designation	Sampling Date	UTM (NAD 83, Zone 12)		Description
		Easting	Northing	
AC1	Aug 28, 2006 Oct 24, 2006 Jan 23, 2007 May 1, 2007	371701	5972559	Beaverhill Creek at mouth
AC2	Aug 28, 2006 Oct 23, 2006 Jan 23, 2007 Apr 30, 2007	363312	5960108	Astotin Creek upstream station in road ditch
AC3	Aug 29, 2006 Oct 23, 2006 Jan 23, 2007 Apr 30, 2007	368300	5965864	Astotin Creek downstream
NSR1	Aug 30, 2006 Oct 24, 2006 Jan 23, 2007 May 3, 2007	372727	5974369	NSR downstream of confluence with Redwater River and Beaverhill Creek

Station Designation	Sampling Date	UTM (NAD 83, Zone 12)		Description
		Easting	Northing	
Astotin Lake	Aug 29, 2006 Oct 24, 2006 Jan 24, 2007 May 2, 2007	377690	5950025	in Elk Island National Park
Antler Lake	Aug 29, 2006 Oct 24, 2006 Jan 24, 2007 May 1, 2007	368476	5929118	south of Elk Island National Park

In order to address predicted PAI from Project emissions on regional lakes, six lakes in and near Elk Island National Park were sampled once in the spring (May 1 to May 3, 2007). The locations of these lakes are indicated in Table 7.5-2 and Figure 7.2-3. Lakes were sampled near shore by wading out to a point that was as deep as was feasible. The lakes were not accessible by boat at the time of sampling. Field measurements of dissolved oxygen, pH, EC and temperature were taken with a calibrated multimeter. Water samples were collected and analyzed for routine parameters, nutrients and metals.

Table 7.5-2 Location of Additional Lakes Sampled for Assessing PAI

Lake	Date Sampled	Location (NAD 83, Zone 12)	
		Easting	Northing
Tawayik	May 1, 2007	376218	5942099
Oster	May 2, 2007	372791	5943855
Adamson	May 2, 2007	372906	5942813
Hasting	May 2, 2007	371987	5921185
Wanisan	May 2, 2007	372081	5925512
Cooking	May 3, 2007	370456	5925505

7.5.3 Assessment Methodology

7.5.3.1 Effects of Increase in Sediment Release, Dewatering and Release of Stormwater Runoff

Professional judgment and experience with similar projects were used to assess the potential effects of:

- sediment release during construction;
- dewatering during construction; and
- release of stormwater runoff during operations.

Most of these potential issues are resolved through the appropriate application of standard mitigative measures applied to all current and approved projects.

7.5.3.2 Release of Treated Effluent to the North Saskatchewan River

The effects of the discharge of treated process waters on the NSR were examined in both the LSA and the RSA in the Application Case and Cumulative Case. Concentrations and loadings (kg/d) were calculated for both the average annual and peak summer conditions at 243,000 bpsd with Gasification 1. The peak summer loadings presented in Table 7.5-3 represents the worst-case loading scenario used in the assessment. Development beyond 243,000 bpsd with Gasification 1 will incorporate zero liquid discharge technologies (ZLD) for treatment of all waste streams, which will eliminate loadings to the NSR under normal Upgrader operation. Notable loadings are evident for reduced forms of nitrogen (TKN in particular), chemical oxygen demand (COD) and major ions, including sodium and chloride. The latter parameters contribute to a measurable loading of TDS. Analyses were completed both for the effects of discharge of treated process waters on the LSA and the RSA (cumulative effects).

Table 7.5-3 Predicted Chemical Properties of the Effluent Discharged to the NSR

Parameter	Units	Average Annual Concentration	Average Annual Loading (kg/d)	Peak Summer Concentration	Peak Summer Loading (kg/d)
Flow	m^3/h	179[1]	-	319	-
Flow	m^3/d	4,306	-	7,644	-
TDS	mg/L	1,580	6,803	1,558	11,908
TSS	mg/L	35	151	37	279
Oil and Grease (O&G)	mg/L	0.0	0	0.0	0
Biological Oxygen Demand (BOD)	mg/L	33.0	142	43.5	332
Chemical Oxygen Demand (COD	mg/L	220	947	257	1,961
Total Organic Carbon (TOC)	mg/L	37.0	159	49.8	381
Hardness[1]	mg/L	598	2,575	565	4,320
Alkalinity[1]	mg/L	481	2,071	473	3,614
Na^+	mg/L	216	930	213.3	1,630
K^+	mg/L	11.0	47	16.1	123
Ca^{2+}	mg/L	159	685	150	1,144
Mg^{2+}	mg/L	49.0	211	46.2	353
Fe^{3+}	mg/L	2.0	8.6	1.5	11.6
Cl^-	mg/L	279	1,201	277.9	2,124
SO_4^{2-}	mg/L	184	792	162	1,235
HCO_3^-	mg/L	578	2,489	568	4,339
CO_3^{2-}	mg/L	4.0	17.2	4.2	32.0
OH^-	mg/L	0.1	0.564	0.1	0.724
SiO_2	mg/L	39.0	168	41.3	316
NH_3	mg/L	2.0	8.6	2.3	17.6
NO_3	mg/L	9.0	38.8	10.4	79.8
TKN	mg/L	48.0	207	64.9	496
Total P	mg/L	1.0	4.31	0.5	3.54
Cyanides	mg/L	0.0	0.084	0.1	0.488
Phenols	mg/L	0.012	0.053	0.032	0.242
Sulphides	mg/L	0.004	0.019	0.010	0.077
Aluminum	mg/L	-	-	0.365	2.79
Antimony	mg/L	-	-	0.00004	0.0003
Arsenic	mg/L	-	-	0.0008	0.0061
Beryllium	mg/L	-	-	0.0002	0.0015
Cadmium	mg/L	-	-	0.0004	0.0031
Chromium	mg/L	-	-	0.002	0.0153
Cobalt	mg/L	-	-	0.0006	0.0046
Copper	mg/L	-	-	0.005	0.0382
Iron	mg/L	-	-	1.5	11.5
Lead	mg/L	-	-	0.0045	0.0344
Mercury	mg/L	-	-	0.00004	0.0003
Molybdenum	mg/L	-	-	0.0055	0.0420

Parameter	Units	Average Annual Concentration	Average Annual Loading (kg/d)	Peak Summer Concentration	Peak Summer Loading (kg/d)
Nickel	mg/L	-	-	0.009	0.0688
Selenium	mg/L	-	-	0.0002	0.0015
Titanium	mg/L	-	-	0.0115	0.0879
Vanadium	mg/L	-	-	0.004	0.0306
Zinc	mg/L	-	-	0.04	0.306

Note:

1 Expressed as $CaCO_3$.

Effects of Treated Effluent Discharge on the Local Study Area

The Cornell Mixing Zone Expert System (CORMIX) model was used to examine the dispersion of treated process water discharge and the effects of the discharge on NSR water quality in the LSA for the Application Case. The goal of the dispersion modelling was to predict the geometry and dilution characteristics of the mixing zone so that compliance with water quality regulatory guidelines could be judged. Mixing was examined in both the near-field and the far-field of the mixing zone. The near-field is that region of the effluent plume where dispersion is dominated by the forces of buoyancy and the original momentum of the discharge. The far-field is that region further downstream where mixing is dominated by horizontal buoyant spreading and turbulent mixing. AENV recommends CORMIX for detailed plume analysis of mixing zones in river areas containing sensitive features such as spawning grounds, drinking water intakes or overlapping plumes (AENV, 1995).

The data requirements for the CORMIX model include:

- the wastewater outfall type (submerged single port, multiport diffuser or surface discharge);
- the orientation, depth and configuration of the outfall in the river;
- the effluent flow and temperature;
- ambient water temperature and river flow; and
- bottom bathymetry at and downstream of the discharge (depth, width, bottom slope).

Effluent dispersion was modelled for average flow conditions and low flow ($7Q_{10}$) conditions. The average flow conditions were assumed to be those at the mean annual flow of the NSR (196 m^3/s). The $7Q_{10}$ flow represents the lowest stream flow for seven consecutive days that would be expected to occur once in ten years. The $7Q_{10}$ conditions (60 m^3/s) represent the worst-case scenario where dilution would be at a minimum.

CORMIX assumes channelization of the river within the area of interest; that is, the reduction of the river to a channel of standard width and depth. Bathymetry profiles of the river, taken near the proposed water intake and outfall, were used for this purpose. The modelling parameters are summarized in Section 7.7.5.

Effects of Treated Effluent Discharge on the RSA

The effects of effluent discharge on the RSA were examined by two methods. The first method involved conducting a loading analysis for each parameter to the NSR from all known point sources (municipal and industrial), and calculating the relative contribution of the Project to the total loading of each parameter. The second method was using the Water Quality Analysis Simulation Program (WASP) version 7.2; (Wool et al., 2004) to assess the effects of the proposed effluent discharge on the NSR. The model was applied to two parameters having significant loadings, namely COD and chloride. Chloride represents the discharge of major ions and TDS.

The loading analysis involved the collection of available discharge data for the above parameters in the effluents of known dischargers in the RSA. When available, the loadings were calculated from the individual monitoring data reported by each facility to AENV or collected by AENV in on-site audits. Average values were calculated from the monitoring data and converted to daily loading rates. To calculate background (upstream) loadings in the NSR, concentrations of these parameters upstream of the Gold Bar WWTP were assumed to be the same as those reported at Dawson Bridge (Focus, 2005) in Edmonton during February, when low flow conditions prevailed. For parameters not included in the Focus (2005) report, background concentrations of the NSR were taken from AENV's long-term monitoring station at Devon (AENV, 2002a). Background loadings in the NSR were calculated using the $7Q_{10}$ flow. The loading analysis involved summing the loadings of each parameter to the NSR and determining the relative contribution of the Project to the total loading of that parameter in the RSA.

The WASP model is a dynamic compartment modelling program for aquatic systems that allows the user to predict the water quality responses to natural phenomena and anthropogenic discharges. WASP uses mass balance equations to calculate chemical mass and concentration for defined river segments or reaches along the NSR. The user can specify modelling time steps, the duration of the simulation and the process-affected water loadings from the various facilities in each segment.

The WASP model was configured to simulate water quality within the NSR using 440 surface water segments along the modelled 60 km reach of the RSA. The model was run to predict steady-state conditions. Flows and chemical loadings were kept constant. The model was run under $7Q_{10}$ conditions (60.0 m^3/s), representing a conservative dilution scenario. River hydraulic conditions were approximated using Leopold-Maddock coefficients developed for the NSR (Ray and Dykema, 1991). Dispersion coefficients were assumed constant across the channel at all locations, and a river temperature of 1ºC was applied.

The calibration procedures for the model match those used by an analogous facility, and consisted of adjusting lateral dispersion coefficients so that simulated dye concentrations matched the results of an earlier modelling study by Golder (1995). To verify the performance of the calibrated WASP model for the NSR, the model was applied to simulate recently measured water quality parameters in the NSR.

Effects of Acidifying Emissions on Regional Lakes

The acidification of lakes has been linked in Europe and in eastern North America to the deposition of acidifying emissions from industrial and municipal facilities. Oxides of sulphur and nitrogen (SO_x and NO_x) in these emissions result in the formation of acids that can reduce the acid-neutralization capacity of soils and surface waterbodies, and cause adverse effects on aquatic biota. Acidifying compounds will be emitted from the Upgrader throughout the entire operations phase of the Project.

The RSA for the acidification assessment includes all lands covered by the Cumulative Case 0.17 keq H+/ha/y PAI isopleth (Figure 7.2-3). A level of acid deposition equivalent to 0.17 keq H+/ha/y level triggers increased monitoring of potentially affected waterbodies for acidification (CASA–AENV, 1999; Foster et al., 2001).

A critical load approach to determine the potential effects of acid deposition on regional lakes was recommended for Alberta in the late 1990s by the Target Loading Subgroup of the Clean Air Strategic Alliance (CASA) for median and long-term management of acidic emissions (AENV-CASA, 1999). The critical load of acidity (CL), in units of keq H+/ha/y, is defined as the highest rate of acidic deposition that will not cause adverse biological effects on a lake and its catchment, and is an inherent property of the lake (Nilsson and Grennfelt, 1988). Critical loads of acidity, calculated from steady-state models, have been applied extensively in Northern Europe, where detailed grid maps of lake sensitivity have been produced based on surveys of thousands of lakes (Posch et al., 1995, 1997, 1999; Rhim, 1995; Henriksen et al., 1992; Kamari et al., 1993). In these acidification studies, acid deposition was expressed as the PAI, defined as the total deposition of sulphur and nitrogen species in both wet and dry forms minus the base cations. The PAI, therefore, accounts for the contribution of both sulphate and nitrogen oxides to acid deposition (wet and dry), as well as the acid-neutralizing effects of base cations.

Following the European model, the Target Loading Subgroup of CASA set acid sensitivity grid cells for Alberta of one degree of latitude by one degree of longitude, with critical loads of 0.25 keq H+/ha/y, 0.50 keq H+/ha/y and 1.00 keq H+/ha/y for cells categorized as sensitive, moderately sensitive and of low sensitivity to acidic deposition. Target loads, the environmental management objectives, were similarly set at 0.22 keq H+/ha/y, 0.45 keq H+/ha/y and 0.90 keq H+/ha/y. Monitoring loads were set at 0.17 keq H+/ha/y, 0.35 keq H+/ha/y and 0.70 keq H+/ha/y, respectively. Exceedances of the PAI monitoring loads result in deposition monitoring and studies of receptor sensitivity (Foster et al., 2001; CASA-AENV, 1999).

In most assessments, the Henriksen steady-state model is applied to calculate critical loads for all lakes within the RSA for which water quality data are available. These lake-specific critical loads are then compared to the PAI at each lake modelled during the air quality assessment (Volume 2, Section 2). An exceedance of the critical load implies that the lake has a potential for acidification under this rate of PAI. However, it does not necessarily mean that acidification is a certainty, or that it could happen in the near future.

The Henriksen steady-state model could not be applied to the eight lakes in this study. The Henriksen model assumes that acid neutralizing capacity (ANC), in the form of base cations, is exported to each lake in surface runoff. The runoff, which is one of the terms of the model, is equivalent to the amount of water that would be measured at the lake outflow. Most of the lakes, however, do not have any outflow on a mean annual basis. Hence, there was no measurable runoff. In some cases, when surface evaporation is accounted for, the runoff is actually negative.

7.6 Existing Conditions

The Project is located within the Beaverhill sub-basin of the NSR watershed (NSWA, 2005). This sub-basin is 440,544 ha, and is situated in the Boreal Forest and Parkland natural regions (Volume 4, Section 10). The Project area drains into Beaverhill Creek via Astotin Creek and an intermittent unnamed tributary stream.

7.6.1 Description of Waterbodies and Watercourses within the LSA

Waterbodies within the LSA (Figure 7.2-1) include:

- Astotin Creek;
- Beaverhill Creek.;
- an unnamed creek that flows into Beaverhill Creek;

- a portion of the NSR;
- Astotin and Oster Lakes in Elk Island National Park; and
- several small sloughs/wetlands, some of which are within the lands owned by North American.

Two additional lakes, Antler and Adamson, are outside the LSA but are also described below.

Astotin Creek has a drainage area of approximately 200 km^2. The creek flows in a northerly direction from Elk Island National Park, around the Upgrader site and then northeast to its confluence with Beaverhill Creek. Portions of Astotin Creek have been channelized as a result of the road ditching on Range Road 214. In this area, the creek is a stable, vegetated ditch approximately 0.5 m deep and 6 m wide. Further downstream the channel is 10 m wide by 1.6 m deep, and consists of sandy silt bed and bank material. Astotin Creek is not gauged, and its flows are regulated by the upstream lakes and wetlands in Elk Island National Park, including Astotin Lake.

Beaverhill Creek drains north and west, over a distance of approximately 57 km, ultimately emptying into the NSR. The creek has a gross drainage area of 2,930 km^2 and follows an irregular meander pattern, with an average channel width of approximately 11 m near its mouth. Flows on Beaverhill Creek are strongly affected by beaver activity. A large beaver dam (greater than 2 m in height) located approximately 600 m upstream from the NSR impeded the surface flow in the fall of 2006 through the winter 2007. By early May 2007, high runoff had washed out the beaver dam. At that time, Beaverhill Creek, near its mouth, had a wetted width of 8.5 m, a maximum depth of 0.89 m and a discharge of 1.25 m^3/s. Channel substrate was composed of organic fines, with occasional areas of large cobble and boulder.

The northeast portion of the Upgrader site drains north into a small wetland complex that drains into an intermittent unnamed tributary of Beaverhill Creek. This unnamed creek has several intermittent tributaries that drain towards the north from the elevated area south of Bruderheim. The total drainage area of this creek at its mouth is approximately 64 km^2. A portion of the slope south of the CPR line, approximately 3 km^2 in area, drains under the rail line at the property. This surface water will be routed east towards Range Road 211.

Astotin, Oster and Adamson lakes are very shallow (1 m to 2 m maximum depth) and highly coloured. Astotin, the largest lake, has an area of 5.8 km^2 and a drainage area of 52.2 km^2. Astotin Lake is used extensively for recreational purposes. Oster Lake has an area of 1.1 km^2 and a drainage area of 5.6 km^2. Adamson Lake has an area of 0.43 km ^{2} and a drainage area of 4.3 km^2.

The wetlands within the lands owned by North American are described in detail in the Vegetation and Wetlands section (Volume 4, Section 10). These wetlands were classified based on the categories given in Classification of Natural Ponds and Lakes in the Glaciated Prairie Region (Stewart and Kantrud, 1971). They range in size from 70 m to 300 m in diameter (0.4 ha to 7.0 ha in area) and include:

- Class IV Wetlands: these wetlands form a region to the north of the property that drains into the unnamed creek described above. In this EIA, these are collectively referred to as the North Wetland Complex;
- Class III Wetland: a seasonal pond located in the southwest portion of the property in NW 26-55-21 W4M that is intended to be drained and converted to a stormwater pond;

- Class I/II Wetlands: these are ephemeral and temporary ponds and sloughs that are distributed throughout the Upgrader site area. Some of these ponds contribute to a wetland complex that drains across the Canadian National Railway (CNR) rail line on the south border of the Upgrader site and through an ephemeral draw towards the North Wetland Complex. This drainage will be diverted in ditches along Range Road 211; and

- Ephemeral Draws: these drainage paths are intermittently visible on aerial photographs of the Upgrader site. Surface flow within these draws may be limited to extreme snowmelt and storm events.

7.6.2 Description of Waterbodies/Watercourses in the Regional Study Area

Waterbodies in the RSA include those listed above in the LSA, as well as a section of the NSR from Gold Bar WWTP to a point 20 km downstream of the proposed outfall (Figure 7.2-2).

7.6.2.1 Description of the NSR

The NSR is located about 6.5 km northwest of the Upgrader site. The Sturgeon River is approximately 9 km upstream of the proposed intake structure, and the Redwater River is approximately 11 km downstream near Vinca Bridge (Highway 38). The NSR originates in the Columbia Icefield in Banff and Jasper National Parks, and is regulated by the Bighorn and Brazeau dams in its upper reaches. It flows eastward toward the Saskatchewan border, and has a mean annual discharge at the border that exceeds seven billion cubic metres. The NSR will serve as the main source of water for the Project, and will receive treated runoff and wastewater from the Upgrader during the early stages of the Project. As the Upgrader expands from Phase 1 towards the Project, ZLD treatment of targeted waste streams will be phased in. Eventually, the Project will incorporate ZLD treatment of all waste streams to eliminate effluent discharges to the NSR, and to maximize water recycle.

Many industrial and municipal facilities are located along the NSR and use the NSR for both water supply and effluent discharge. Industrial development in the vicinity of Fort Saskatchewan extends over 194 km^2, from the City of Fort Saskatchewan to the confluence with Redwater River (Alberta's Industrial Heartland website, 2007).

Ongoing monitoring of water quality on the NSR is conducted by AENV at the Devon and Pakan Long-term River Network (LTRN) sampling sites. The Devon site is located between the headwaters of the NSR and Edmonton. Upstream of Devon, the North Saskatchewan River Basin (NSRB) is sparsely populated and dominated by forestry and agricultural activities. In this area, point source inputs are limited to continuous and periodic municipal discharges and some periodic industrial discharges. The Pakan site is located approximately 55 km downstream of the proposed water intake structure near Victoria Settlement.

Flows have been recorded by Water Survey of Canada (WSC) on the NSR at Edmonton since 1912 (station number 05DF001) where the total basin area is approximately 28,000 km^2. This gauge site is located approximately 63 km upstream of the proposed intake site. Major inflows between the Edmonton station and the proposed intake site are the Sturgeon River, with a drainage area of 3,350 km^2 and a few minor tributaries that increase the total drainage area at the intake site to approximately 33,000 km^2. The mean annual flow of the NSR at Edmonton is 196 m^3/s. The highest mean monthly flow occurs in July (359 m^3/s), while the lowest mean monthly flow is observed in January (82.2 m^3/s). The $7Q_{10}$ flow is calculated at 60 m^3/s.

7.6.3 Description of Lakes within the Acidification RSA

The RSA for the acidification issue (Figure 7.2-3) includes a large area encompassed by the 0.17 keq H+/ha/y isopleth for PAI. This isopleth represents a level of PAI where further monitoring is required (CASA-AENV, 1999). Most of the lakes in this region are small prairie sloughs, several hundred metres in diameter, surrounded by agricultural lands. These are usually high pH, hardwater lakes that are not particularly sensitive to acid deposition. These include Antler Lake, Cooking Lake, Big Island and Boag Lakes. Lakes for which water quality data were collected in the field studies include:

- Cooking Lake (area 42.9 km^2);
- Antler Lake (area 2.4 km^2);
- Astotin Lake (area 5.8 km^2);
- Adamson Lake (area 0.42 km^2);
- Wanison Lake (area 2.68 km^2);
- Hastings Lake; (area 8.2 km^2);
- Oster Lake (area 1.05 km^2); and
- Tawayik Lake (area 3.79 km^2).

Most of these lakes, in particular Cooking Lake, have considerable recreational value (e.g., for boating) for the region. Tawayik Lake, Oster Lake, Astotin Lake and Adamson Lake are located within Elk Island National Park.

7.6.4 Historic and Current Water Quality of the North Saskatchewan River

7.6.4.1 Review of Water Quality Studies on the North Saskatchewan River

Water quality in the NSR has been studied extensively over the last 20 years, primarily to document the effects of municipal and industrial discharges within the Edmonton–Fort Saskatchewan region. Water quality studies of the NSR near the Project include Anderson et al. (1986); Shaw et al. (1994); Golder (1995); Mitchell (1998); Focus (2004; 2005); Hebben (2005); Anderson (2005) and information collected as part of Alberta's Water for Life Strategy (AENV, 2007). The results of these studies are summarized below:

- a distinct increase was identified in the concentrations of a number of water quality parameters downstream of Edmonton, including temperature, dissolved oxygen, biochemical and chemical oxygen demand, TSS, EC, DOC, total nitrogen, ammonia, nitrates, total phosphorus, sodium, potassium, chloride, sulphate and several trace metals (zinc, nickel, lead, manganese);
- loading estimates indicate that the main sources of the increases identified in the concentrations of water chemistry variables are the Edmonton WWTPs. Both planktonic and epilithic algae have been stimulated by the increased nutrient loads in this region and have increased markedly downstream. Bacterial forms increased immediately below the Gold Bar WWTP in Edmonton and remain at high levels downstream. The Gold Bar WWTP is the largest point source of contaminants. Compared to this source, the impact

of industrial discharges on water quality has been low. However, increases in chromium, cobalt, nickel and zinc downstream of Edmonton are attributable to a variety of industrial discharges;

- seasonal patterns in water quality include peaks in suspended solids, metals and other related parameters during high-flow periods in spring. These parameters are lowest during low-flow periods in winter. In contrast, concentrations of many dissolved substances are highest during basal flow conditions in winter;
- the discharge of stormwater from Edmonton caused increases in EC, suspended solids, chemical oxygen demand, chromium, lead, nickel, nitrogen, phosphorus and fecal coliforms, that, in some cases, could be detected to the Saskatchewan boundary; and
- the NSR is poorly mixed downstream of Edmonton. Effluents from various sources in Edmonton are not mixed horizontally across the river for 100 km downstream.

Golder Associates Ltd. (1995) completed a joint industrial–municipal study of the NSR in which water quality was simulated using the WASP water quality model for a 60 km study area between Edmonton and the Redwater River under low-flow ($7Q_{10}$) conditions. The simulations suggested that:

- An effluent plume of ammonia would be detectable 20 km downstream of the Gold Bar WWTP, with simulated ammonia concentrations exceeding water quality criteria for much of the length of the study reach. Smaller contributions from the Capital Region WWTP and the Sherritt's Fort Saskatchewan Fertilizer and Metal Manufacturing Plant were barely discernable within the Gold Bar WWTP plume.
- Simulated total phosphorus (TP) would exceed the Alberta chronic water quality objective throughout most of the study reach.
- Of 13 metals simulated in the Golder study, none were predicted to approach water quality guidelines except for aluminum, high values of which are considered a natural phenomenon.
- Additive effects of various constituents could potentially be toxic to aquatic life for approximately 7 km below the Sherritt Fort Saskatchewan Fertilizer and Metal Manufacturing Plant and Dow Chemical's Fort Saskatchewan Chemical Manufacturing Plant.

Studies by Focus in 2003 and 2004 (Focus, 2004; 2005) for the City of Edmonton examined differences in water quality in the NSR during high-flow and low-flow conditions. The findings were:

- During wet weather conditions (high flow after rain events) nutrients (especially phosphorus) and certain metals (aluminum, iron, copper, zinc, mercury, silver, lead) sometimes exceed ASWQ guidelines. Fewer exceedances were observed during dry weather conditions.
- Between 1994 and 2003, TP loading was almost halved, primarily due to improvements in municipal wastewater treatment technology.
- Downstream of wastewater treatment plants, increases in fecal coliform and total coliform counts of more than one order of magnitude were observed in both wet and dry conditions between 1996 and 2004.

The following long-term changes were found to have occurred at Pakan and Devon between 1977 and 2002 (Hebben, 2005):

- Hardness, sodium, magnesium and sulphate have increased at both Devon and Pakan monitoring stations. The NSR at Pakan can be classified as eutrophic according to TP, and algal biomass and mesotrophic according to total nitrogen (TN).
- Total phosphorus (TP), total dissolved phosphorus (TDP), total nitrogen (TN) and total coliforms have decreased at Pakan. These reductions, and reductions in the frequency of guideline exceedances for these parameters, can be attributed to improved wastewater treatment technology.
- TP had the lowest compliance rates of all nutrients assessed at Pakan, followed by TN.

A report by Anderson (2005) examined the nature and extent of pesticide contamination in Alberta's surface waters between 1995 and 2002. The study found that:

- Water quality with respect to pesticide concentrations was rated as "fair" at Pakan and "good" at Devon. All pesticides detected at Pakan were below CCME water quality guidelines.
- Elevated levels of 2,4-D and Lindane in the NSR in the 1970s and early 2000s were attributed to industrial point sources. Detection of these chemicals declined once remedial actions were taken and/or the sources were removed.

7.6.4.2 Summary of Historic Water Quality Data on the NSR

Water quality data for the Pakan station are provided in Tables 7.6-1 and 7.6-2 for January 1982 to April 2006. In general, the waters from the NSR are characterized as well oxygenated; slightly alkaline; high in EC, TDS and alkalinity; dominated by calcium bicarbonate; and relatively high in nutrients (phosphorus and nitrogen). Individual parameters are discussed below. Seasonal changes in water quality parameters from 1999 to 2006 are shown in Figures 7.6-1 and 7.6-2. A brief summary of the water quality parameters follows:

- The pH at Pakan ranged from 6.64 to 9.13, with a median of 8.01. These values are generally well within the guideline range of 6.5 to 9.0. The highest values of pH occur during the periods of high flow in June-July, while the lowest values occur during the low-flow winter months (Figure 7.6-1).
- Dissolved oxygen levels at Pakan ranged from 7.5 mg/L to 15.7 mg/L, with a median concentration of 10.8 mg/L. Dissolved oxygen levels were well above the chronic and acute guideline values. Oxygen levels cycle with the seasons, and are higher when the water temperature is low in winter and lower in the warmer summer months (Figure 7.6-1).
- Conductivity ranged from 220 uS/cm to 461 uS/cm, with a median value of 342 uS/cm (Table 7.6-1). TDS ranged from 139 mg/L to 261 mg/L, with a median value of 342 mg/L. Hardness at Pakan ranged from 100 mg/L to 210 mg/L, with a median value of 166 mg/L. According to the scale published by the Water Quality Association, the water in the NSR is ranked as "hard" (WQA, 2006). All three parameters are highest during periods of base flow in winter and lowest during periods of high flow in June and July during the snowmelt (Figure 7.6-1).

- In order of their importance to the cationic charge, the major cations in the NSR are Ca>Mg>Na>K. Calcium and magnesium together account for 91% of the cationic charge, with the remainder attributable to sodium (9%). Potassium accounted for only 0.8% of the cationic charge. The relative order of importance of the major anions is bicarbonate>sulphate>chloride. Bicarbonate accounts for most (71.8%) of the anionic charge, while sulphate accounts for only 25.7% of the charge. Calcium and magnesium bicarbonates, therefore, represent the principal dissolved species, while calcium/magnesium sulphates and sodium sulphates represent secondary species.

- The alkalinity in the NSR was relatively high, ranging from 1,680 ueq/L to 3,240 ueq/L, with a medium of 2,660 ueq/L. Seasonal cycling of alkalinity follows that of the major ions, and is highest during periods of base flow in winter and lowest during periods of high flow in June and July during the snowmelt (Figure 7.6-1).

- Fecal coliforms at Pakan ranged from non-detectable (<4) to 25,000/100 mL, with a median value of 80/100 mL. There are periodic exceedances of the CCME irrigation guidelines for fecal coliforms (100/100 mL). These exceedances generally occurred in the summer months, with occasional episodes of very high bacterial numbers (Figure 7.6-1). Numbers of *E. coli* ranged from non-detectable (<4) to 8,900/100 mL, with a median number of 30/100 mL. Episodic exceedances were observed for the CCME recreational guidelines (200/100 mL).

- Levels of TSS ranged from 0.2 mg/L to 2,009 mg/L, with a median of 10 mg/L. TSS is elevated during spring runoff during June and early July, when the NSR receives large volumes of runoff from its tributaries, and is lowest during the winter months under basal flow conditions (Figure 7.6-1). TSS is episodic in nature and can peak at extremely high values.

- TP ranged from 0.007 mg/L to 1.15 mg/L, with a median concentration of 0.088 mg/L. Concentrations of TP are greatest during spring runoff (May to July), and least during winter under basal flow conditions (Figure 7.6-1). The high values in spring are likely associated with the high suspended loads often present at this time. Values of total phosphorus are frequently above the Alberta surface water quality guideline of 0.05 mg/L. Levels of TDP were considerably less than TP, and peaks were not as easily related to season or particulate load. TDP at Pakan ranged from 0.002 mg/L to 0.208 mg/L, with a median concentration of 0.044 mg/L.

- Ammonia ranged from 0.005 mg/L to 0.79 mg/L, with a median of 0.190 mg/L. Seasonal cycling of ammonia was evident, with pronounced peaks observed during the low-flow period in winter. Nitrates ranged from non-detectable to 1.57 mg/L, with a median concentration of 0.32 mg/L. As with ammonia, there is a pronounced seasonal cycling of nitrates, with the highest values recorded in the winter (Figure 7.6-1). Levels of ammonia and nitrates never approached the CCME guidelines. As expected in oxygenated waters, nitrite levels were generally low, with a median value of 0.016 mg/L. Occasional exceedances of the CCME guideline (0.060 mg/L) were observed. The elevated values in winter for both ammonia and nitrates reflect reduced uptake by phytoplankton, periphyton and macrophytes during the winter. Sources of ammonia and nitrates include agricultural runoff and discharge from wastewater treatment plants upstream. TKN ranged from 0.025 mg/L to 3.8 mg/L, with a median concentration of 0.56 mg/L. Although less distinct than those observed for nitrates and ammonia, peaks in TKN were also observed during the winter months (Figure 7.6-1).

- Dissolved organic carbon (DOC) ranged from 0.9 mg/L to 27.1 mg/L, with a median of 2.7 mg/L (Table 7.6-1). Total phenolics ranged from non-detectable to 0.044 mg/L, with a non-detectable median value. The majority of the values were less than the detection limit. Over the 22 years of monitoring data, only one value exceeded the CCME guideline (0.004 mg/L).

- Trace metal concentrations were generally low, with a large number of values below detection limits. There were occasional exceedances of CCME guidelines; however, only aluminum had a median concentration exceeding the guideline. Mean values of cadmium and mercury exceeded guidelines, but this was largely an artifact of the convention used to calculate the statistics from the non-detectable measurements, and the fact that the guidelines were generally set below the detection limit. Therefore, any measure of these metals would result in an exceedance. Total aluminum is frequently found to be above guidelines because it is released from suspended particles during sample analysis. Seasonal cycling of aluminum, iron, lead and possible arsenic was evident in the plots, with the highest values occurring during the high-flow period (June-July), coinciding with peaks in TSS (Table 7.5-2).

The effect of significant rain events on the chemistry of the NSR was evident in the reports completed for the City of Edmonton (Focus, 2004; 2005). During rain events, the TSS was noted to increase by two orders of magnitude relative to low-flow, dry conditions. Significant increases were also evident in TP, nitrates, ammonia, fecal coliforms and *E. coli* (Table 7.6-3). The results of the Focus studies emphasize that the variation in water chemistry is affected strongly by both seasonal factors and episodic flow/rain events.

Table 7.6-1 Routine Water Quality Parameters in the NSR at Pakan (1982-2006)

Parameter	Minimum	Maximum	Mean	Median	No.	Guideline Values	
						ASWQ[1]	**CCME[2]**
Routine Parameters (mg/L)							
Total Dissolved Solids	139	261	199	199	133		500-3,500[3]
Conductivity (uS/cm)	220	461	339	342	233		
Total Hardness	100	210	166	165.5	200		
Total Alkalinity (ueq/L)	1,680	3,440	2,647	2,660	222		
Total Suspended Solids	0.2	2009	52	10	263	<10 mg/L increase	See Below[4]
Water Temperature (°C)	-0.4	24.5	8.5	6.42	262	Δ 3 °C	
Lab pH (pH units)	6.64	9.13	8.01	8.01	223	6.5-8.5	5.0-9.0
Dissolved Oxygen (Field)	7.47	15.67	10.66	10.8	123	5.0-6.5	5.5-9.5
Biochemical Oxygen Demand	0.5	5.6	2.2	2	35		
Chemical Oxygen Demand	2.5	43	13.2	11	35		
Major Ions (mg/L)							
Sodium	1.52	18.7	7.85	7.6	227		<200[5]
Magnesium	5	17.4	13.0	13	222		
Calcium	26.8	62.4	44.4	44.1	222		100[3]
Potassium	0.15	6.7	1.37	1.1	221		
Bicarbonate	102.4	209	159.8	161	200		
Chloride	0.5	21.1	3.8	3.3	223		100-700[3]/250[5]
Sulphate	20	64.1	44.5	45.3	222		1,000[3]/<500[5]
Nutrients (mg/L)							
Total Kjeldahl Nitrogen	0.025	3.8	0.62	0.56	257		
Total Ammonia	0.005	0.79	0.23	0.19	237		0.832[6]
Nitrates and Nitrites	0.0015	1.57	0.32	0.32	262		2.94
Nitrite	0.00075	0.15	0.020	0.016	85		0.06
Total Phosphorus	0.007	1.15	0.112	0.088	263	0.05	
Total Dissolved Phosphorus	0.0015	0.208	0.050	0.044	237		
Total Organic Carbon	1.2	17.3	4.1	3	178		
Dissolved Organic Carbon	0.9	27.1	3.5	2.7	249		
Phenolic Material	ND	0.044	0.0013	ND	175	0.005	0.004/0.002[3]
Bacteria (No./100 mL)							
E. coli	ND	8,900	279	30	109	0/100 mL[5]	200/100 mL[7]
Fecal Coliforms	ND	25,000	511	80	251		100/100 mL[3]

Note: Shading represents guideline exceedance.
ND = non-detectable.
N = Number of samples.

1 Alberta Surface Water Quality Guidelines (AENV, 1999).
2 CCME Water Quality Guidelines for Protection of Aquatic Life, unless otherwise indicated (CCME, 1999-2006 update).
3 CCME Protection of Agricultural Water Uses.
4 Clear flow: maximum increase of 25 mg/L for <24 h or 5 mg/L for 1 day to 30 days.
High flow: maximum increase of 25 mg/L when background between 25 mg/L and 250 mg/L, 10% increase when background is >250 mg/L.
5 CCME Drinking Water Guidelines.
6 pH dependent, guideline is for median temperature and pH of NSR.
7 CCME Recreational Water Quality Guidelines.

Table 7.6-2 Total Metals Concentrations in the North Saskatchewan River at Pakan (1982-2006)

Parameter	Minimum	Maximum	Mean	Median	N	Guidelines	
Total Metals (mg/L)						**ASWQG[1]**	**CCME[2]**
Aluminum	ND	29.2	0.70	0.169	240		0.1
Antimony	0.00004	0.0025	0.00018	0.0001	87		
Arsenic	ND	0.02	0.0008	0.00043	136		0.005
Barium	0.0346	0.483	0.080	0.07	138		1[3]
Beryllium	ND	0.006	0.0003	ND	106		
Boron	ND	0.85	0.033	0.02	86		
Cadmium	ND	0.0049	0.0004	ND	202		0.000047[4]
Chromium	ND	0.021	0.0037	0.003	202		0.0089
Cobalt	0.00006	0.0118	0.0008	0.0005	160		
Copper	ND	0.0503	0.0035	0.002	224	0.024-0.03	0.003[4]
Iron	ND	30.3	0.901	0.21	131		0.30
Lead[5]	ND	0.0214	0.0024	0.00119	213		0.004[4]
Lithium	ND	0.301	0.0085	0.00416	82		2.5[6]
Manganese	ND	0.337	0.020	0.006	147		<0.05[3]
Mercury	ND	0.00122	0.000042	ND	197	0.000005	0.000026
Molybdenum	0.0003	0.004	0.0011	0.00108	121		0.073
Nickel	ND	0.0592	0.0054	0.0035	227		0.11[4]
Selenium	ND	0.0035	0.0004	0.0001	133		0.001
Silver	ND	0.002	0.0002	0.00005	130		0.0001
Strontium	0.238	0.552	0.400	0.412	87		
Tin	ND	0.02	0.0010	0.0005	87		
Titanium	0.00025	0.127	0.016	0.003	87		
Uranium	ND	0.04	0.0011	0.0006	87		0.02[3]
Vanadium	ND	0.039	0.0030	0.001	157		
Zinc	0.0005	0.0922	0.0151	0.0109	223		0.03

Notes:
Data from April 2005-Present are from total extractable fraction of metals.
Shaded values indicate guideline exceedances.
N = number of samples.

1 Alberta Surface Water Quality Guidelines–chronic guidelines (AENV, 1999).
2 CCME Water Quality Guidelines for Protection of Aquatic Life, unless otherwise indicated (CCME, 1999-2006 update).
3 CCME Drinking Water Guidelines.
4 At median hardness of the NSR.
5 Data from only 1995–2004.
6 CCME Protection of Agricultural Water Uses.

Table 7.6-3 Comparison of Selected Parameters in the NSR Upstream of the Sturgeon River during Rain Events and Dry Conditions

Parameter	April 30, 2003 Rain Event	September 3, 2003 Dry Conditions	July 3, 2004 Rain Event	September 21, 2004 Dry Conditions	Mean
TSS	411	3.6	349	30	198
N-TKN	1.15	0.534	1.48	0.4	0.89
N-NH3	0.241	0.286	0.27	0.04	0.209
$N\text{-}NO_2+NO_3$	0.09	0.451	0.469	0.069	0.270
TP	0.283	0.083	0.42	0.09	0.219
Fecal Coliforms	50	2	29,973	279	7,576
E. Coli		2	17,330	214	5,849

Source: Focus 2004; 2005.

Water Quality of the NSR within the LSA

The only historic monitoring station in the LSA is an AENV station at Vinca Bridge (Highway 38). Water quality data from this station are presented in Tables 7.6-4 and 7.6-5. These tables include the results of the 2006 and 2007 field sampling at NSR1, a sampling location established as part of this study. NSR1 is located about 2 km downstream of Vinca Bridge. There were 29 sampling events at Vinca Bridge in the AENV database from samples collected between 1984 and 2002. The median values of each parameter at the Pakan long-term monitoring station about 52 km downstream are included in Tables 7.6-4 and 7.6-5 for comparison.

Water quality is similar among samples collected at Vinca Bridge, Pakan and NSR1. This similarity suggests that the seasonal trends evident at Pakan apply as well to those sections of the NSR within the LSA. Higher values of nitrates are evident at Pakan, likely the result of runoff from agricultural lands downstream of Vinca Bridge. Higher median concentrations of TDS, hardness and major ions at NSR1 compared to Vinca Bridge reflect a sampling bias at the latter station, where very few winter samples were collected. These parameters tend to be greatest during the winter. Guideline exceedances were evident for the mean and median values of TP at Vinca, and on May 3, 2007, at NSR1 during the field studies. Guideline exceedances were also observed for the median concentrations of aluminum and cadmium. As above, the exceedances for cadmium are largely an artifact of the low guideline values relative to the detection limit.

Table 7.6-4 Routine Water Quality Parameters at Vinca Bridge, Pakan and NSR1

Parameter	Vinca Bridge					Median Pakan	NSR1 (This Study)				Guidelines	
	N	Min	Max	Mean	Median		Aug 30/06	Oct 26/06	Jan 23/07	May 03/07	ASWQ[1]	CCME[2]
Routine Parameters												
Total Dissolved Solids	12	181	220	197	197	210	198	198	236	194		500-3,500[3]
Conductivity (uS/cm)	15	310	394	349	341	342	328	361	417	349		
Hardness (as $CaCO_3$)	15	150	187	166	166	165.5	170	170	200	160		
Total Alkalinity (ueq/L)	13	2,440	2,900	2,666	2,640	2,660	2,600	2,840	3,060	2,660		
Total Suspended Solids	29	0.5	72	23	11	10	6	7	1	55	<10 mg/L increase	See Below[4]
Temperature (°C)	22	-0.2	23	13	15	6.42	---	5.49	0.03	8.5	Δ 3 °C	
pH (pH units)	15	7.94	8.5	8.2	8.2	8.01	8.43	8.35	8.22	8.24	6.5-8.5	5.0-9.0
Dissolved Oxygen	12	7.5	12.6	10.5	10.6	10.82	---	13.36	15.02	12.6	5.0-6.5	5.5-9.5
Biochemical Oxygen Demand	19	ND	3.2	1.5	1.3	2	---	---	---	---		
Chemical Oxygen Demand						11	---	---	---	---		
Major Ions (mg/L)												
Sodium	14	4	12	7	7	7.6	6.9	8.1	8.2	10.2		<200[5]
Magnesium	12	11	15	13	13	13	14.2	13.3	14.8	12.4		
Calcium	12	42	50	45	45	44.1	44.6	45.6	53.7	43.5		100[3]
Potassium	12	0.7	2.8	1.1	1	1.1	1.2	1.1	1.1	2		
Bicarbonate	12	144	176	161	160	161	152	171	186	162		
Chloride	15	2	5	3	3	3.3	3.5	3.2	3.8	4.4	250[5]	100-700[3]
Sulphate	13	38	54	45	45	45.3	49.5	40.4	60.3	40.6	<500[5]	1000[3]
Nutrients (mg/L)												
Total Kjeldahl Nitrogen	21	0.2	1.1	0.5	0.5	0.56	1.15	0.31	0.42	0.55		
Total Ammonia	17	0.1	0.4	0.2	0.1	0.19	0.05	0.02	0.25	0.09		0.832[6]
Nitrates and Nitrites	12	0.008	0.1	0.04	0.02	0.32	0.11	0.227	0.404	0.143		2.94
Nitrite	12	0.008	0.12	0.04	0.02	0.016	0.014	<0.003	0.008	0.007		0.06
Total Phosphorus	27	0.03	0.1	0.1	0.07	0.088	0.013	0.017	0.012	0.076	0.05	
Total Organic Carbon	11	2	22	5	3	3	---	---	---	---		
Dissolved Organic Carbon	10	0.9	6	3	2	2.7	2.1	3.5	2	6.5		
Phenolic Material	13	ND	0.005	0.002	0.002	0.0005	---	---	---	---	0.005	0.004/0.002[3]
Bacteria (No./100 mL)												
E. coli	9	ND	180	51	30	30	---	---	---	---		200/100 mL[7]
Fecal Coliforms	20	10	10,000	812	163	80	---	---	---	---		100/100 mL[3]

Note: Shaded values indicate guideline exceedance.

1 Alberta Surface Water Quality Guidelines (AENV, 1999).

2 CCME Water Quality Guidelines for Protection of Aquatic Life, unless otherwise indicated (CCME, 1999-2006 update).

3 CCME Protection of Agricultural Water Uses.

4 Clear flow: maximum increase of 25 mg/L for <24 h or 5 mg/L for 1 to 30 day, High flow: maximum increase of 25 mg/L when background is between 25 mg/L and 250 mg/L, 10% increase when background is >250 mg/L.

5 CCME Drinking Water Guidelines.

6 Guideline is pH dependant, based on median temperature and pH of NSR.

7 CCME Recreational Water Quality Guidelines.

Table 7.6-5 Total Metals Concentrations at Vinca Bridge, Pakan and NSR1

Parameter (mg/L)[1]	Vinca Bridge					NSR1 (This Study)				Pakan	Guidelines CCME[2]
	Min	Max	Mean	Median	N	Aug 30/06	Oct 26/06	Jan 23/07	May 03/07	Median	
Aluminum	0.03	2.02	0.46	0.24	17	0.09	0.167	0.082	1.4	0.2	0.1
Antimony	0.00001	0.00013	0.00007	0.000071	8	<0.0002	<0.0002	<0.0002	<0.0002	0.0001	
Arsenic	0.0001	0.001	0.001	0.0006	15	0.0039	<0.0002	<0.0002	0.0007	0.0004	0.005
Barium	0.01	0.09	0.06	0.07	10	0.0687	0.05	0.06	0.07	0.07	1[4]
Beryllium	ND	0.0005	0.0003	0.0004	16	<0.0002	<0.001	<0.001	<0.001	0.0001	
Boron	0.0079	0.0228	0.0158	0.0159	7	0.01	<0.020	<0.020	0.03	0.02	
Cadmium	ND	0.002	0.0004	0.0003	16	0.00001	0.00002	0.00007	0.00009	0.0001	0.000047[5]
Chromium	0.0002	0.007	0.002	0.001	21	<0.001	<0.001	0.001	0.002	0.003	0.0089
Cobalt	ND	0.005	0.0008	0.0005	16	<0.0003	<0.0003	0.0006	0.0011	0.0005	
Copper	ND	0.01	0.002	0.002	18	0.0009	0.0015	0.0018	0.0034	0.002	0.003[5]
Iron	ND	1.01	0.3	0.1	21	0.01	<0.06	<0.06	<0.06	0.2	0.30
Lead	ND	0.003	0.001	0.002	21	<0.0003	<0.0002	<0.0002	0.001	0.001	0.004[5]
Lithium	0.0036	0.0051	0.0045	0.0045	7	<0.004	<0.020	<0.020	<0.020	0.004	2.5[3]
Manganese	0.01	33.9	8.00	0.032	19	<0.004	<0.004	<0.004	<0.004	0.004	<0.05[4]
Mercury (ug/L)	ND	0.2	0.042	0.025	18	<0.0006	<0.0006	<0.0006	0.0023	0.00003	0.026
Molybdenum	ND	0.005	0.001	0.001	16	0.001	0.0009	0.0013	0.001	0.0011	0.073
Nickel	ND	0.01	0.004	0.003	20	0.0025	0.0023	0.0057	0.0059	0.004	0.11[5]
Selenium	ND	0.0009	0.0003	0.00015	16	<0.0002	<0.0002	0.0004	0.0002	0.0001	0.001
Silicon	1.3	3.6	2.3	2.1	5	1.01	1.7	2.3	4.6		
Silver	ND	0.00002	0.00001	ND	7	<0.0001	<0.0001	<0.0001	0.0001	0.00005	0.0001
Strontium	0.346	0.472	0.427	0.449	7	0.432	0.42	0.46	0.35	0.4	
Thallium (ug/L)	ND	0.06	0.026	0.022	7	<0. 2	<0.2	<0.2	<0.2		
Tin	ND	ND	ND	ND	7	<0.001	<0.001	<0.001	<0.001	0.0005	
Titanium	0.0018	0.018	0.0077	0.0035	7	<0.001	0.003	0.005	0.041	0.002	
Uranium	0.00042	0.00065	0.00055	0.00052	7	0.0004	0.0004	0.0006	0.0008	0.0006	0.02[4]
Vanadium	ND	0.006	0.003	0.003	16	<0.001	<0.001	<0.001	0.004	0.001	
Zinc	ND	0.05	0.007	0.004	19	0.0169	0.007	0.032	0.008	0.01	0.03

Note: Shaded values indicate guideline exceedance.
N = Number of samples.
ND= non-detectable.

1 Units in mg/L, unless indicated otherwise.
2 CCME Water Quality Guidelines for Protection of Aquatic Life unless otherwise indicated (CCME, 1999-2006 update).
3 CCME Protection of Agricultural Water Uses.
4 CCME Drinking Water Guidelines.
5 At median hardness.

Figure 7.6-1 Temporal Variability of Water Chemistry in the NSR at Pakan (1999-2006)

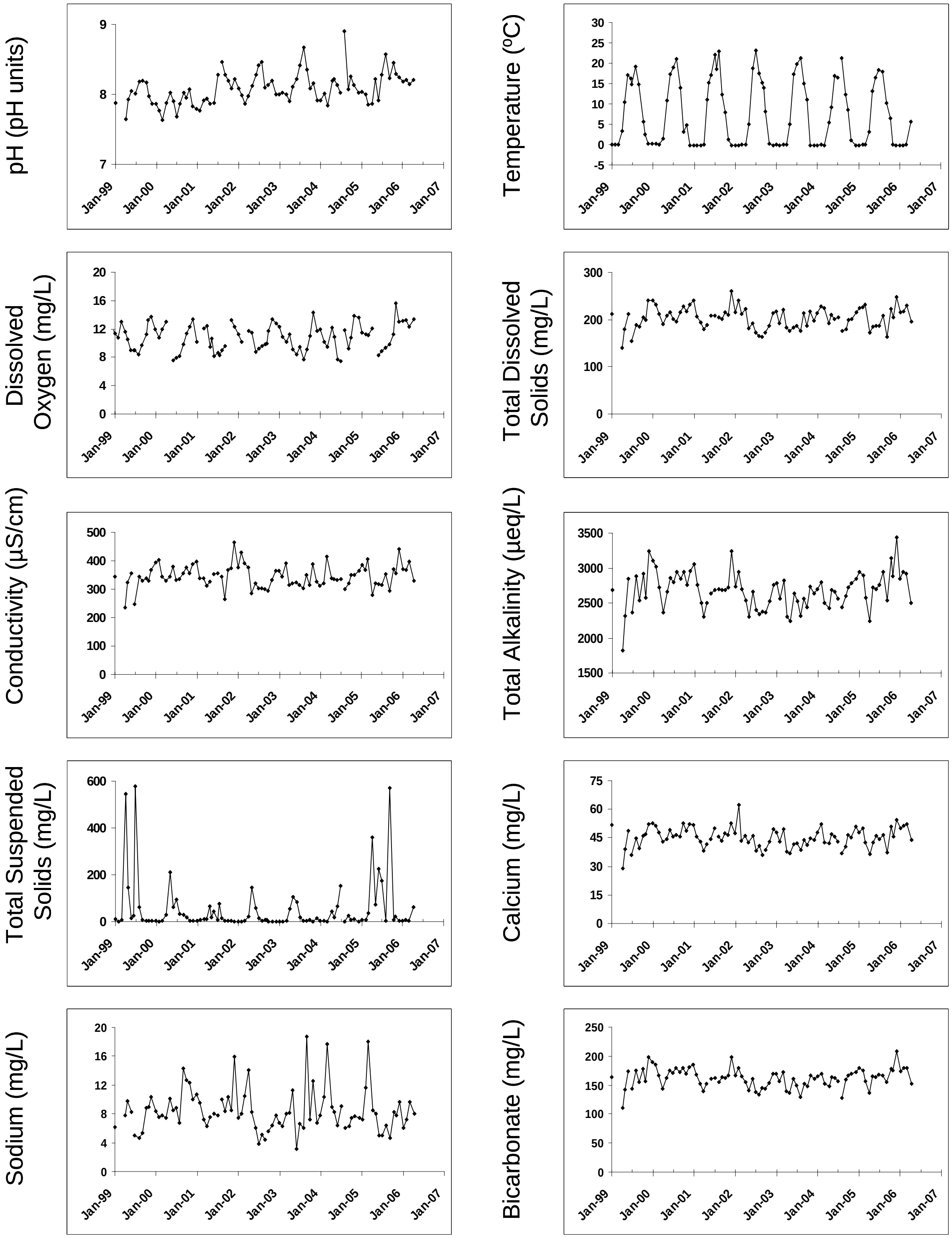
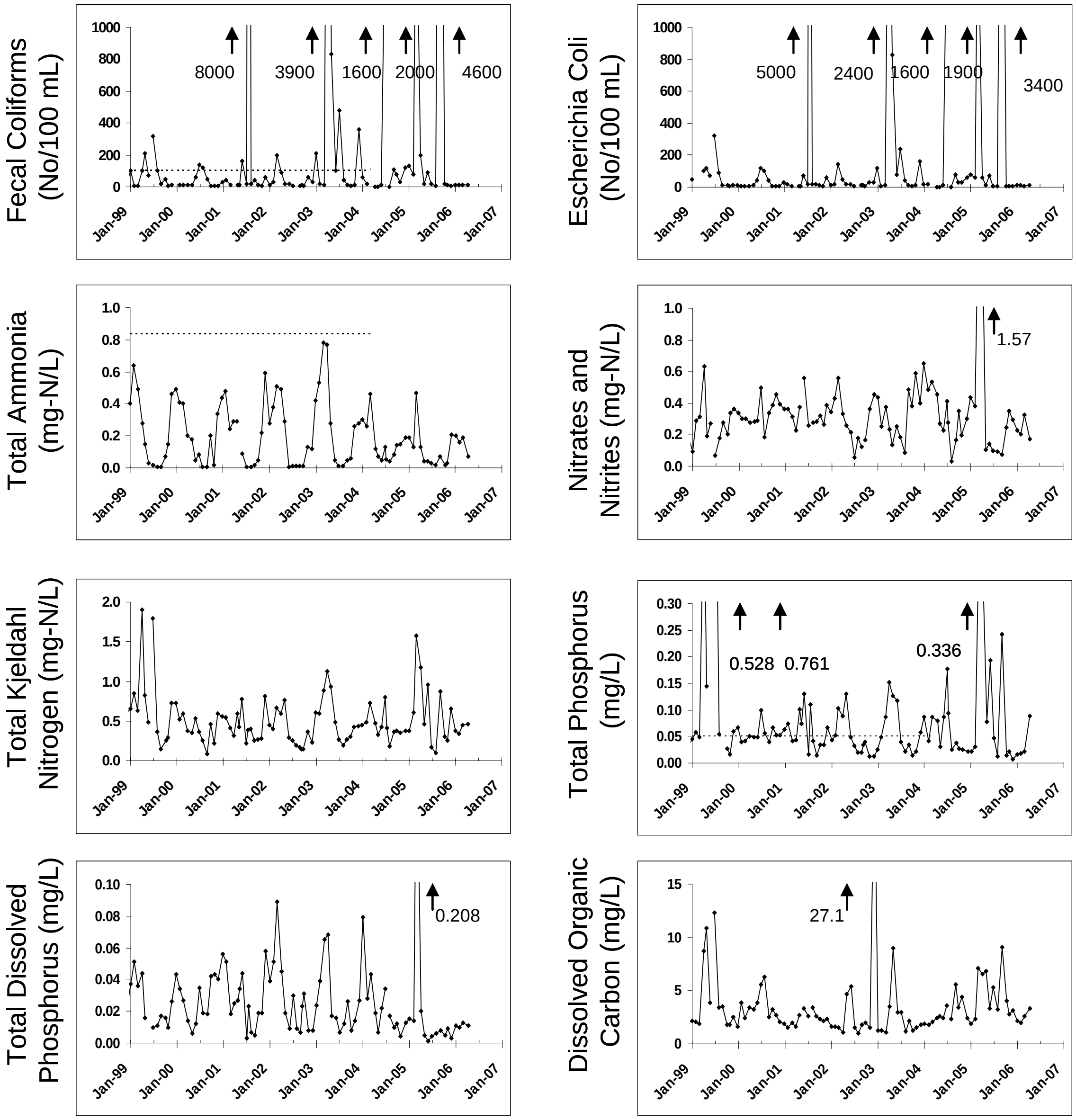
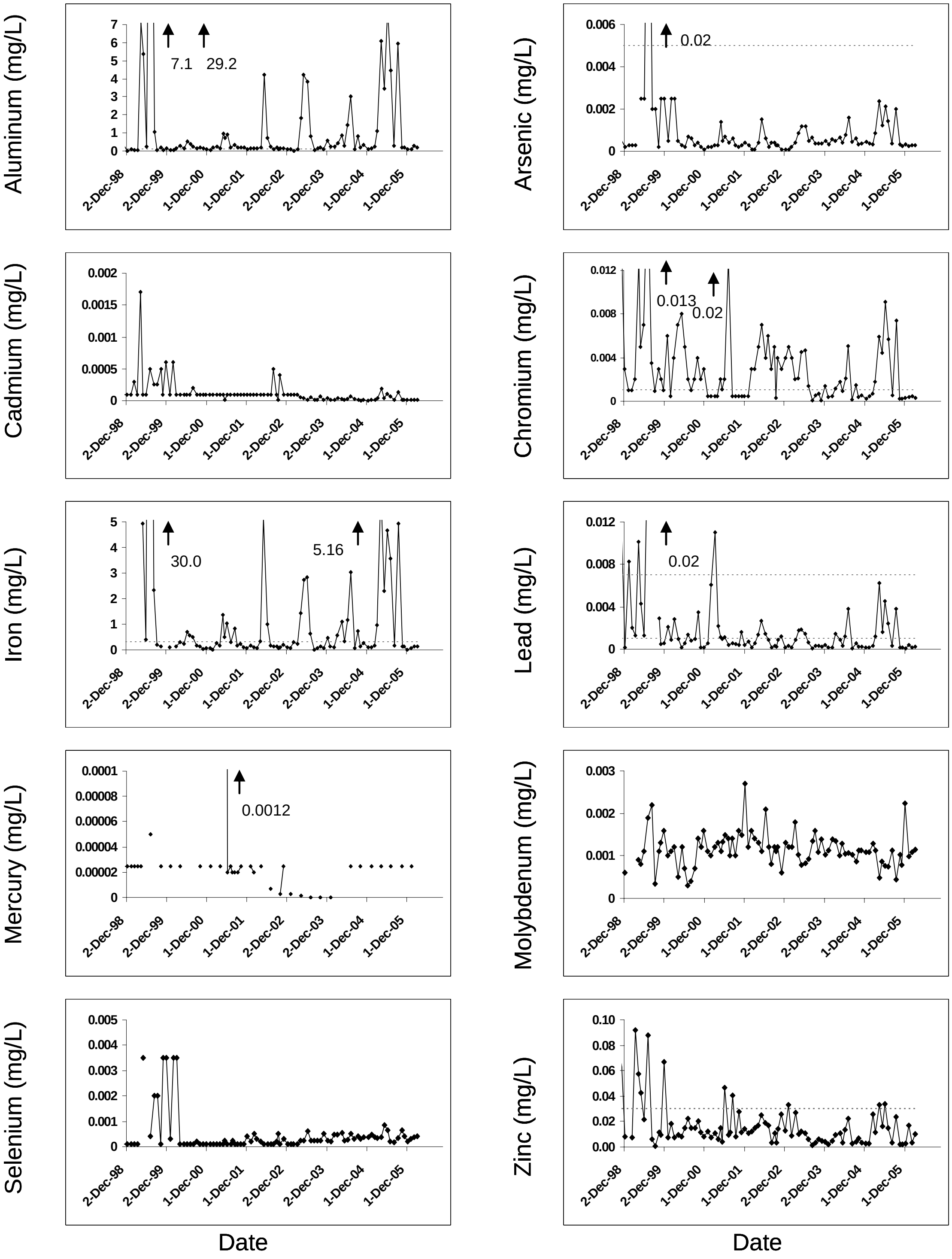


Figure 7.6-1 (continued) Temporal Variability of Water Chemistry in the NSR at Pakan (1999-2006)



Note: Guidelines indicated as dotted lines where available.

Figure 7.6-2 Temporal Variability of Total Trace Metals in the NSR at Pakan (1999-2006)



Note: Guidelines indicated as dotted lines where available Impact Assessment and Mitigative Measures.

7.6.5 Historic Water and Sediment Quality Data of Other Watercourses in the LSA and RSA

7.6.5.1 Beaverhill Creek

The historic data available on Beaverhill Creek and the 2006-2007 field results from this study are presented in Tables 7.6-6 and 7.6-7. Relative to the NSR, Beaverhill Creek is considerably higher in EC, hardness, alkalinity, major ions and nutrients, including TKN, ammonia, nitrates, total phosphorus and phenolics. The high levels of nutrients in Beaverhill Creek are likely the result of intensive agricultural activities in the creek's drainage area. Metals were low in concentration, with isolated exceedances observed for copper, cadmium, iron, aluminum, zinc and manganese (an aesthetic guideline under the CCME drinking water guidelines). As previously noted, the exceedances for cadmium reflect the low guideline value relative to the detection limit, especially in the older data.

7.6.5.2 Water Quality of Regional Lakes

The water quality of eight regional lakes sampled in the field program is summarized in Tables 7.6-8 and 7.6-9. The lakes are typically hard-water lakes with high conductivities, TDS and alkalinity. The phosphorus concentrations were high in most of the lakes, and exceeded the ASWQ guidelines. While nitrates are generally low (below detection) in most lakes, reduced forms of nitrogen attained high levels, with ammonia exceeding CCME guidelines for protection of aquatic life. Low oxygen levels were identified beneath the ice in January in Astotin and Antler Lakes. Metal concentrations in the lakes were almost uniformly low, with few guideline exceedances.

Table 7.6-6 Water Quality in Beaverhill Creek – Routine Parameters

Parameter	Historic Data (AENV) 1975-1990					AC1 (This Study)				Guidelines	
	N	Minimum	Maximum	Mean	Median	Aug 28/06	Oct 25/06	Jan 23/07	May 1/07	ASWQ[1]	CCME[2]
Routine Parameters (mg/L)											
Total Dissolved Solids	12	170	525	345	316	341	396	471	219		500-3500[3]
Conductivity (Lab) (uS/cm)	13	313	1,320	611	520	566	707	836	385		
Total Hardness (as CaCO3)	7	132	503	326	350	210	250	350	110		
Total Alkalinity (ueq/L)	13	1,980	10,400	5,580	5,220	3,800	5,740	7,960	2,460		
Total Suspended Solids	8	240	800	414	350	59	13.0	3.0	38.0	<10 mg/L increase	See Below[4]
Water Temperature (°C)	11	0	21	9.4	7.5	15.55	1.35	0.50	9.74	Δ 3 °C	
Lab pH (pH units)	13	7.5	8.2	8.0	8	8.35	8.30	8.02	8.11	6.5-8.5	5.0-9.0
Dissolved Oxygen (Field)	6	5.6	12.4	7.9	6.7	9.1	8.66	13.5	11.4	5.0-6.5	5.5-9.5
Bioch. Oxygen Demand	11	1.1	10.8	4.0	2.8	--	--	--	--		
Chemical Oxygen Demand	6	21.9	121.2	59.1	54.6	--	--	--	--		
Major Ions (mg/L)											
Sodium	13	11	97	41	39	41.3	49.7	37.9	32.0		<200[5]
Magnesium	13	7	36	20	15	16.4	20.6	24.6	9.0		
Calcium	8	23	142	59	46	58.5	67.4	101	30		100[3]
Potassium	13	2	13.2	6.7	6.2	11.1	11.0	7.0	9.6		
Bicarbonate	2	187	634	410	410	228	350	485	151		
Chloride	13	3	78	20	12	21.6	55.4	29.4	11.6	250[5]	100-700[3]
Sulphate	13	31	117	51	42	77.8	19.5	31.3	51.4	<500[5]	1000[3]
Fluoride	13	0.15	0.53	0.24	0.22	--	--	--	--		
Nutrients (mg/L)											
Total Kjeldahl Nitrogen	12	0.74	6.4	2.19	1.75	0.29	1.44	1.08	1.53		
Total Ammonia	13	0.02	0.98	0.30	0.1	0.04	0.04	0.13	0.25		0.832[6]
Nitrates and Nitrites	14	0.009	0.582	0.228	0.16	<0.003	<0.006	0.010	0.040		2.94
Nitrite	11	0.025	0.17	0.052	0.05	<0.003	<0.006	0.005	0.010		0.06
Total Phosphorus	12	0.065	2.4	0.512	0.29	0.241	0.145	0.056	0.239	0.05	
Total Dissolved Phosphorus	2	0.224	0.765	0.495	0.495	--	--	--	--		
Total Organic Carbon	3	30	48	39	39	--	--	--	--		
Dissolved Organic Carbon	7	24	78	45	42	13.7	18.4	14.1	21.1		
Phenolic Material	14	0.003	0.037	0.0145	0.012	--	--	--	--	0.005	0.004/0.002[3]
Bacteria` (No./100 mL)											
Fecal Coliforms	12	0	110	36	18	--	--	--	--		100/100 mL[3]

Note: Shaded values indicate guideline exceedances.

1 Alberta Surface Water Quality Guidelines (AENV, 1999).

2 CCME Water Quality Guidelines for Protection of Aquatic Life, unless otherwise indicated (CCME, 1999-2006 update).

3 CCME Protection of Agricultural Water Uses.

4 Clear flow: maximum increase of 25 mg/L for <24 h or 5 mg/L for 1 day to 30 day High flow: max increase of 25 mg/L when background between 25 mg/L and 250 mg/L, 10% increase when background is >250 mg/L..

5 CCME Drinking Water Guidelines.

6 Guideline is pH dependant, based on median temperature and pH of NSR.

Table 7.6-7 Water Quality in Beaverhill Creek – Total Metals

Parameter (mg/L)	Historic Data (AENV) 1975-1990					AC1 (This Study)				Guidelines CCME[1]
	Minimum	Maximum	Average	Median	N	Aug 28/06	Oct 25/06	Jan 23/07	May 01/07	
Aluminum (Extractable)	0.06	8.45	1.36	0.14	7	1.86	0.166	0.02	2.03	0.1
Antimony (Total)	--	--	--	--		0.0003	<0.0002	0.0003	0.0002	
Arsenic (Total)	0.0008	0.0035	0.0021	0.0017	5	0.0069	0.0021	0.0016	0.0019	0.005
Barium (Total)	0.087	0.087	0.087	0.087	1	0.165	0.11	0.13	0.08	1[3]
Beryllium (Extractable)	0.0005	0.0005	0.0005	0.0005	6	<0.0002	<0.001	<0.001	<0.001	
Boron (Total)						0.05	0.02	0.03	0.05	
Cadmium (Total)	ND	0.002	0.001	ND	7	0.00006	0.00004	0.00005	0.00009	0.000097[4]
Chromium (Total)	0.003	0.008	0.005	0.005	7	0.003	0.001	0.001	0.003	0.0089
Cobalt (Total)	ND	0.006	0.002	0.003	7	0.0016	0.0008	0.0025	0.0017	
Copper (Total)	ND	0.019	0.008	0.007	7	0.0021	0.0015	0.0015	0.0051	0.004[4]
Iron (Total)	3.91	3.91	3.91	3.91	1	0.07	0.19	0.32	1.15	0.30
Lead (Extractable)	ND	0.031	0.008	0.0035	12	0.0015	0.0003	0.0004	0.0014	0.007[4]
Lithium (Total)	--	--	--	--		0.019	0.02	0.02	<0.02	2.5[2]
Manganese (Total)	0.042	0.284	0.128	0.104	7	0.007	0.38	0.73	0.05	<0.05[3]
Mercury (Total)	ND	0.00005	0.000048	ND	13	0.000015	0.000001	0.000001	0.000005	0.000026
Molybdenum (Dissolved)	0.0005	0.006	0.0026	0.003	7	0.0021	0.0006	0.0006	0.0012	0.073
Nickel (Total)	0.008	0.022	0.012	0.011	7	0.0074	0.0061	0.014	0.0096	0.150[4]
Selenium (Total)	ND	0.0001	0.00009	ND	5	<0.0002	<0.0002	0.0004	0.0005	0.001
Silver (Total)	--	--	--	--		<0.0001	<0.0001	<0.0001	<0.0001	0.0001
Strontium (Total)	--	--	--	--		0.294	0.34	0.43	0.18	
Thallium (Total)	--	--	--	--		<0.0002	<0.0002	<0.0002	<0.0002	
Tin (Total)	--	--	--	--		<0.001	<0.001	<0.001	<0.001	
Titanium (Total)	--	--	--	--		0.029	0.007	0.008	0.038	
Uranium(Total)	--	--	--	--		0.0021	0.0007	0.0008	0.0011	0.02[3]
Vanadium (Total)	ND	0.022	0.008	0.009	7	0.007	<0.001	<0.001	0.006	
Zinc (Total)	0.005	0.055	0.017	0.011	7	0.0149	0.009	0.025	0.012	0.03

Note: Shaded values indicate guideline exceedances.
ND= non-detectable.
N = number of samples.
1 CCME Water Quality Guidelines for Protection of Aquatic Life, unless otherwise indicated (CCME, 1999-2006 update).
2 CCME Protection of Agricultural Water Uses.
3 CCME Drinking Water Guidelines.
4 Guideline is hardness dependant; guideline is based on median hardness.

Table 7.6-8 Water Quality of Lakes in the LSA and RSA – Routine Parameters

Parameter	Study Lakes (Sampled May 01- 03/07)						Astotin Lake (AST4)				Antler Lake (AST5)			
	Oster	Adamson	Hastings	Wanisan	Cooking	Tawayik	Aug 29/06	Oct 24/06	Jan 27/07	May 02/07	Aug 29/06	Oct 25/06	Jan 23/07	May 01/07
Routine Parameters														
Total Dissolved Solids	186	209	626	233	1,230	483	286	281	328	265	271	259	398	218
Conductivity (Lab) (uS/cm)	329	348	1,050	406	1,870	758	485	484	585	461	462	447	715	403
Hardness (as CaCO3)	120	140	280	180	260	180	180	170	200	170	140	130	200	120
Total Alkalinity (ueq/L)	3,020	3,140	5,580	3,000	8,120	4,340	4,600	4,620	5,520	4,300	3,600	3,520	5,600	3,040
Total Suspended Solids	20	55	10	63	50	13	25.0	17.0	4.0	10.0	138	48.0	4.0	18.0
Temperature °C	8.75	9.84	7.41	10.3	9.34	10.2	---	3.48	1.30	5.73	---	4.12	2.94	5.74
pH (pH units)	8.5	9.21	8.6	8.2	9.42	9.1	8.89	8.77	8.49	8.31	9.23	9.20	8.45	8.05
Dissolved Oxygen	12.9		9.32	11.7	11.8	15.5	---	13.7	4.10	8.92	---	16.1	1.85	4.65
Major Ions														
Sodium (Total)	18.5	17.5	107	8.3	329	88.8	35.5	35.6	38.0	30.1	37.6	36.9	53.0	27.3
Magnesium (Total)	14.2	15.9	51.4	18.5	51.7	23.6	31	28.6	32.6	26.4	14.7	14.6	23.3	12.7
Calcium (Total)	22.5	30.9	25.8	38.5	22.4	29.4	21.6	19.5	24.8	22.9	32.3	27.0	41.2	25.3
Potassium (Total)	16.2	16.2	32.2	18.8	49.4	19.5	22.3	22.0	22.8	18.3	29.9	29.2	41.2	21.2
Bicarbonate	175	144	315	184	296	202	241	258	321	258	159	163	329	185
Chloride (Dissolved)	4.1	3.1	18.4	5.3	43.5	6.4	6.3	6.4	7.7	5.7	29.8	28.1	43.3	23.1
Sulphate (Dissolved)	14.6	30.4	217	48.2	499	176	31.5	30.1	35.7	31.4	18.3	17.3	22.6	15.5
Carbonate	4.7	23.4	12.6	<0.5	98	31.1	19.5	11.7	7.8	1.9	30.1	25.4	6.4	<0.5
Nutrients														
Total Kjeldahl Nitrogen	3.49	4.25	3.39	2.93	8.88	3	0.38	3.00	3.39	3.48	4.77	6.25	9.90	4.88
Total Ammonia	0.12	0.08	0.37	0.07	0.12	0.06	0.06	0.05	0.59	0.88	0.15	0.06	2.21	1.05
Nitrates and Nitrites	0.03	<0.003	0.02	<0.003	0.006	<0.003	<0.003	<0.02	0.118	0.010	0.003	<0.003	0.430	0.003
Nitrite (Dissolved)	0.03	<0.003	0.013	<0.003	0.006	<0.003	<0.003	<0.02	0.004	<0.003	<0.003	<0.003	<0.003	<0.003
Total Phosphorus	0.239	0.398	0.071	0.232	0.678	0.168	0.087	0.084	0.048	0.066	0.738	0.383	0.680	0.679
Dissolved Organic Carbon	40.5	40.6	33.7	39.6	80.8	38.5	35.9	36.0	36.0	28.7	71.1	58.1	81.7	40.1

Note: Shaded values indicate ASWQ or CCME guideline exceedances.

Table 7.6-9 Water Quality of Lakes in the LSA and RSA – Total Metals

Parameter	Study Lakes (Sampled May 1 to May 3, 2007)						Astotin Lake					Antler Lake			
	Oster	Adamson	Hastings	Wanisan	Cooking	Tawayik	Aug 29/06	Oct 24/06	Jan 27/07	Jan 27/07	May 02/07	Aug 29/06	Oct 25/06	Jan 23/07	May 01/07
Total Metals (mg/L)															
Aluminum	0.122	0.03	0.023	0.06	0.029	0.008	0.016	0.018	0.016	0.011	0.011	0.278	0.076	0.02	0.004
Antimony	<0.0002	<0.0002	<0.0002	<0.0002	0.0009	<0.0002	0.0005	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Arsenic	0.0003	0.0002	0.0009	0.0004	0.0055	0.0013	<0.002	<0.0002	0.0002	0.0002	0.0002	0.0059	<0.0002	0.0002	0.0003
Barium	0.05	0.05	0.04	0.05	0.02	0.03	0.0643	0.03	0.05	0.05	0.05	0.0828	0.02	0.1	0.05
Beryllium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0002	<0.001	<0.001	<0.001	<0.001	<0.0002	<0.001	<0.001	<0.001
Boron	0.09	0.03	0.11	0.06	0.2	0.08	0.09	0.07	0.09	0.09	0.07	0.08	0.06	0.11	0.07
Cadmium (ug/L)	0.04	0.01	<0.01	0.02	0.04	0.01	0.01	0.02	0.01	0.01	0.02	<0.01	0.08	0.04	<0.01
Chromium	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	0.001	0.001	0.001	0.005	0.001	0.001	0.002	<0.001
Cobalt	0.0004	0.0004	0.0003	0.0005	0.0008	0.0004	<0.0003	<0.0003	0.0004	0.0003	<0.0003	0.0006	0.0006	0.0011	0.0004
Copper	0.0008	0.0008	0.0014	0.0011	0.0028	0.0013	0.0006	0.001	0.001	0.0029	0.0012	0.0008	0.0009	0.001	0.0013
Iron	0.19	0.06	0.08	0.23	0.11	<0.06	0.02	<0.06	<0.06	<0.06	<0.06	0.03	<0.06	0.06	<0.06
Lead	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0003	<0.0002	<0.0002	<0.0002	<0.0002	0.0007	0.0003	0.0003	<0.0002
Lithium	0.03	0.03	0.08	0.02	0.15	0.06	0.049	0.05	0.07	0.07	0.04	0.031	0.03	0.06	<0.020
Manganese	0.107	0.113	0.039	0.061	0.021	0.014	<0.004	<0.004	0.055	0.043	<0.004	<0.004	0.008	0.041	<0.004
Mercury (ug/L)	0.06	0.07	0.08	0.11	0.07	0.08	<0.0006	<0.0006	<0.0006	0.0019	0.0008	0.0011	<0.0006	0.0009	<0.0006
Molybdenum	0.0003	0.0003	0.0003	0.0007	0.0016	0.0006	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.0009	0.0012	0.0016	0.0007
Nickel	0.0031	0.0041	0.0025	0.0037	0.0046	0.0034	0.0015	0.0013	0.0031	0.0029	0.0022	0.0037	0.0027	0.0074	0.0021
Selenium	0.0003	0.0002	0.0002	0.0002	0.0003	0.0002	<0.002	<0.0002	0.0004	0.0004	0.0003	<0.0002	<0.0002	0.0005	0.0004
Silicon	4.4	3.6	2.1	3.2	1.7	4.5	2.17	2.4	3.3	3.3	2.5	8.99	0.3	1.5	2.4
Silver	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	0.0002	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Strontium	0.16	0.19	0.27	0.2	0.22	0.27	0.231	0.22	0.27	0.28	0.2	0.202	0.17	0.28	0.15
Thallium	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.0029	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Tin	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Titanium	0.007	0.006	0.003	0.005	0.006	0.005	0.001	0.002	0.004	0.004	0.002	0.01	0.007	0.007	0.005
Uranium	0.0005	0.0007	0.0008	0.0005	0.0019	0.0005	<0.0004	0.0002	0.0003	0.0003	0.0002	0.0005	0.0007	0.001	0.0003
Vanadium	0.002	0.002	<0.001	0.001	0.004	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	0.002	0.002	<0.001
Zinc	0.009	0.009	0.006	0.008	0.011	0.007	0.0121	0.006	0.017	0.014	0.005	0.0135	0.008	0.014	0.007

Note: Shaded values indicate ASWQ or CCME guideline exceedances.

7.6.5.3 Concentrations of Organic Parameters in Waterbodies in the LSA

Water samples from all six field sampling stations were analyzed for volatile hydrocarbons and PAHs for all four sampling occasions. Volatile hydrocarbons included BTEX and the F1 (C_6-C_{10}) and F2 (C_6-C_{16}) CCME fractions. Detailed results are presented in Appendix 7A. All volatile hydrocarbons were less than detection limits, and there were no guideline exceedances. Detectable PAHs were identified only at the downstream station of Astotin Creek (AC3) for the following parameters: naphthalene, acenaphthene, fluorene, phenanthrene, fluoranthene and pyrene. Levels of naphthalene, fluoranthene and pyrene at this station exceeded the CCME guidelines for protection of aquatic life during the October sampling.

7.6.5.4 Sediment Quality in Waterbodies in the LSA

Sediment concentrations of total metals, total petroleum hydrocarbons and PAHs at the six field stations are summarized in Tables 7.6-10 to 7.6-12. The highest metals concentrations are found in the lake sediments, which represent depositional environments, composed largely of fine particles. Higher metal concentrations are routinely found in finer sediments (Baudo et al., 1990). Exceedances of CCME freshwater sediment quality guidelines were identified for chromium (Astotin Lake, Antler Lake), copper (Astotin Lake) and zinc (Astotin Lake). There were no volatile hydrocarbons (BTEX, C_1-C_6) identified in samples from any of the six field sites. Consistently high concentrations of hydrocarbon fractions F2-F4 were found in Astotin Creek at the downstream station, although there were no guideline exceedances. Exceedances of the CCME Canada-wide standards for petroleum hydrocarbons in soils (F3 fraction) were observed in Astotin and Antler Lakes. Again, these represent depositional environments, and the high values of F3 are likely natural in origin. PAH concentrations were all less than detection limits at all stations, except for the downstream station on Astotin Creek (AC3). A total of 17 PAH species were detected, 13 of which exceeded CCME interim sediment quality guidelines. High sediment PAH concentrations were also seen in water samples for this site. The sources of these PAHs at this station on Astotin Creek are unknown.

Table 7.6-10 Total Metals in Sediments Collected During the 2006-2007 Field Program

Parameter	Units	Beaverhill Cr. AC1 Oct 25/06	Astotin Cr. (Upstream) AC2 Oct 25/06	Astotin Cr. (Downstream) AC3 Oct 25/06	North Saskatchewan River, NSR1 Oct 26/06	Astotin Lake Oct 24/06	Antler Lake Oct 25/06	ISQG[1]
As	mg/kg	2.7	4.2	<0.5	3.1	3	2.3	5.9
Ba	mg/kg	109	177	0.41	94.6	67.6	75	NS
Be	mg/kg	0.31	0.57	<0.02	0.27	0.36	0.36	NS
B	mg/kg	0.6	0.9	1	0.1	6.7	6	NS
Cd	mg/kg	0.35	0.60	<0.02	0.29	0.39	0.44	0.6
Cr	mg/kg	30.2	16.5	<0.1	16.9	45.5	58.2	37.3
Co	mg/kg	4.8	6.53	<0.03	4.13	3.77	3.88	NS
Cu	mg/kg	8.02	15.0	0.03	5.48	301	9.69	37.5
Pb	mg/kg	5.02	11.4	0.02	5.91	9.43	8.07	35
Hg	mg/kg	0.033	<0.2	<0.2	<0.02	0.071	0.034	0.17
Mo	mg/kg	0.37	0.21	<0.02	0.4	1.37	1.46	NS
Ni	mg/kg	21.3	19.6	0.06	15.5	27.7	34.9	NS
Se	mg/kg	<1	<1	<1	<1	<1	<1	NS
Tl	mg/kg	0.1	0.2	<0.02	0.07	0.1	0.1	NS
V	mg/kg	12.8	23.3	<0.1	10.8	15.3	12	NS
Zn	mg/kg	27.9	44.6	0.26	26.5	265	47.6	123
Zr	mg/kg	4.4	9.8	<0.1	4.2	3.2	4.4	NS

Note:
Guideline exceedances are shaded.
NS=no guideline available.

[1] Interim sediment quality guidelines for freshwater (CCME, 1999–2006 update).

Table 7.6-11 Total Petroleum Hydrocarbons in Sediments Collected During the 2006-2007 Field Program

Parameter		Beaverhill Creek AC1 Oct 25/06	Astotin Creek AC2 Oct 25/06	Astotin Creek AC3 Oct 25/06	North Saskatchewan River NSR1 Oct 26/06	Astotin Lake Oct 24/06	Antler Lake Oct 25/06	Laboratory Detection Limit	Guidelines
Benzene	mg/kg	<0.0072	<0.0075	<0.0063	<0.0062	<0.053	<0.065	0.0062	0.073[1] /0.05[2]
Toluene	mg/kg	<0.029	<0.03	<0.025	<0.025	<0.21	<0.26	0.025	0.86[1] /0.1[2]
Ethylbenzene	mg/kg	<0.014	<0.015	0.015	<0.012	<0.11	<0.13	0.012	0.19[1] /0.1[2]
Xylenes	mg/kg	<0.064	<0.067	<0.057	<0.055	<0.47	<0.58	0.055	25[1] /0.1[2]
B[a]P[4]	mg/kg	<0.000016	<0.000017	1.18	<0.000013	<0.00012	<0.00014	0.000013	-
F1 C_6-C_{10}	mg/kg	<12	<12	<12	<12	<12	<12	<12	260[3]
F2 $C_{>10}$-C_{16}	mg/kg	<10	26	193	<10	<80	<100	10	900[3]
F3 $C_{>16}$-C_{34}	mg/kg	378	310	660	<10	1,140	2,490	10	800[3]
F4 $C_{>34}$	mg/kg	181	159	2,180	<20	<200	1,300	20	5,600[3]

Note: Shading represents guideline exceedances.

1 Alberta Soil and Water Quality Guidelines for Hydrocarbons at Upstream Oil and Gas Facilities (AENV, 2001).

2 CCME soil quality guidelines, agricultural land usages (CCME, 1999-2006 update).

3 Canada-wide standards for petroleum hydrocarbons in soil, fine-grain surface soils, ecological soil contact (CCME, 2001).

4 Equivalent benzo[a]pyrene concentration. The Benzo(a)pyrene toxic equivalent is a weighted concentration of total carcinogenic polyaromatic hydrocarbons in a mixture that compensates for the differences in toxicity among the polyaromatic hydrocarbon analogs.

Table 7.6-12 PAHs in Sediment Collected During the 2006-2007 Field Program

Parameter (mg/kg)	Beaverhill Creek (AC1) Oct 25/06	Astotin Creek (AC2) (Upstream) Oct 25/06	Astotin Creek (AC3) (Downstream) Oct 25/06	North Saskatchewan River (NSR1) Oct 26/06	Astotin Lake Oct 24/06	Antler Lake Oct 25/06	CCME Interim Sediment Quality Guidelines
Acenaphthene	<0.0074	<0.0075	2.43	<0.0061	<0.054	<0.065	0.00671
Acenaphthylene	<0.0074	<0.0075	0.0694	<0.0061	<0.054	<0.065	0.00587
Anthracene	<0.0037	<0.0038	0.915	<0.003	<0.027	<0.032	0.0469
Benz[a]anthracene	<0.0074	<0.0075	0.846	<0.0061	<0.054	<0.065	0.0317
Benzo[a]pyrene	<0.0037	<0.0038	0.72	<0.003	<0.027	<0.032	0.0319
Chrysene	<0.0037	<0.0038	0.75	<0.003	<0.027	<0.032	0.0571
Dibenz[a,h]anthracene	<0.0037	<0.0038	0.118	<0.003	<0.027	<0.032	0.00622
Fluoranthene	<0.0037	<0.0038	3.59	<0.003	<0.027	<0.032	0.111
Fluorene	<0.0037	<0.0038	1.73	<0.003	<0.027	<0.032	0.0212
2-Methylnaphthalene	<0.0074	<0.0075	1.2	<0.0061	<0.054	<0.065	0.0202
Naphthalene	<0.0074	<0.0075	6.31	<0.0061	<0.054	<0.065	0.0346
Phenanthrene	<0.0037	0.006	3.98	<0.003	<0.027	<0.032	0.0419
Pyrene	<0.0037	<0.0038	2.63	<0.003	<0.027	<0.032	0.053
Benzo[c]phenanthrene	<0.0037	<0.0038	<0.0032	<0.003	<0.027	<0.032	NS
7,12-dimethybenz[a]anthracene	<0.037	<0.038	<0.032	<0.03	<0.27	<0.32	NS
Benzo[b&j]fluoranthene	<0.0074	<0.0075	1.14	<0.0061	<0.054	<0.065	NS
Benzo[k]fluoranthene	<0.0074	<0.0075	0.344	<0.0061	<0.054	<0.065	NS
Indeno[1,2,3-cd]pyrene	<0.0074	<0.0075	0.486	<0.0061	<0.054	<0.065	NS
Benzo[g,h,i]perylene	<0.0037	<0.0038	0.529	<0.003	<0.027	<0.032	NS
Dibenzo[a,h]pyrene	<0.0074	<0.0075	<0.0064	<0.0061	<0.054	<0.065	NS
Dibenzo[a,i]pyrene	<0.0074	<0.0075	<0.0064	<0.0061	<0.054	<0.065	NS

Shaded values represent exceedances of the CCME Interim Sediment Quality Guidelines for Freshwater (CCME, 1999–2006 update).
NS=no guideline available.

7.7 Impact Assessment and Mitigative Measures

The assessment of potential impacts to surface water quality indicators uses the criteria described in Volume 2, Section 1, with the exception of extent and magnitude which have been revised for this section. Final impact ratings, post mitigation, are based on the consolidation of the seven impact assessment criteria (direction, geographic extent, magnitude, duration, frequency of occurrence, permanence and confidence) and professional judgment. Mitigation measures, including management of operations and best management practices, are provided, along with the discussion of impacts.

More details regarding mitigation measures may be found in the Water Management Plan (Volume 1, Section 6.4).

During construction, potential effects on surface water quality are linked to erosion and sediment loading in local waterbodies, and dewatering.

During plant operations, potential effects on surface water quality are linked to groundwater suppression under the stormwater ponds, wastewater discharge, sediment runoff, releases of process-affected waters and incidental spills. To prevent such effects, engineered protection measures will be a fundamental part of the plant design. In addition, spill response plans and other management procedures will be put in place as described in Volume 1.

7.7.1 Erosion and Sediment Control During Construction

Appropriate design and mitigation measures will be implemented during construction in order to minimize the impacts of the Project on surface water quality. A Water Management and Sediment Control Plan will be developed to provide appropriate isolation and containment of runoff from all disturbed areas. Site grading, berms, stormwater ponds and drainage ditches will be among the initial works constructed to manage runoff during construction. Initial grading and stockpile berms will be used to control runoff temporarily until the ditches and ponds can be completed. There are no defined drainage channels on the site. The only upslope drainage is that from the CNR culverts at the south, which will be diverted to the North Wetland Complex using the Range Road 211 ditch system.

Water management and sediment control mitigation measures to be employed during construction will include:

- minimizing the extent of disturbance to developed areas and maintaining a vegetative cover in undeveloped portions of the site;
- creating stable topsoil and subsoil berms with maximum 3H:1V side slopes and using sediment control fences around them until a vegetation cover is established;
- using erosion control matting where slopes and soil conditions warrant additional control measures;
- restoring vegetation cover on disturbed areas as soon as practical following completion of construction activities in an area; and
- creating stable low gradient ditches at less than 0.2% grade.

Instream construction of the water intake will be conducted by isolating the area with a cofferdam. Less than 40% of the river flow will be constricted during construction, with clean armour material placed around the outside of the cofferdam to control erosion and sediment release during construction. Instream construction activities will be limited to the period of August 1 to April 15 to fall outside of the Restricted Activity Period for this reach of the NSR.

The potential release of sediment during construction will have little effect on the surface water quality of the NSR, Astotin Creek and the unnamed creek. The planned mitigation measures will minimize the movement of sediments off-site. Any suspended sediment loading that might occur during construction would be minimal, occur only occasionally during high rainfall or snowmelt, last a short period and be within the range of natural variability.

The geographic extent of any effect on the tributaries will be localized, and will not produce effects on the water quality of the NSR. The movement of any suspended sediment from the tributaries to the NSR would be undetectable. Once construction is completed, the potential for sedimentation of surface water quality will cease, and the effects will likely revert to baseline conditions.

With mitigation, the residual effects of sediment release on surface water quality will be low in magnitude, short-term in duration and reversible, and will have a low overall environmental consequence.

7.7.2 Dewatering During Construction

During site construction, excavations into the shallow subsoil will be required for the construction of ponds, construction of foundations for aboveground structures and installation of utilities. These excavations may fill with groundwater/seepage that may require removal. The amount of groundwater that could enter an excavation will depend on the size and depth of the excavation below the water table, the permeability of the soil and the length of time that the excavation is left open. Dewatering is generally a temporary requirement associated with construction activities.

The groundwater removed from the excavations will be directed to an on-site holding pond and tested. If the dewatered groundwater quality meets the guidelines for surface water quality (AENV, 1999), the dewatered groundwater will be released to existing drainage control structures (e.g., ditches and stormwater ponds).

Localized dewatering of the Upgrader site during construction will not affect the water quality of Astotin Creek, the unnamed creek or the NSR because of the planned mitigation measures. Therefore, the magnitude of the residual effects is negligible, and the duration and reversibility of the effects are not applicable. There will be no environmental consequence on water quality for dewatering activities. The residual effect of dewatering will not contribute measurably to cumulative effects on surface water quality.

7.7.3 Dewatering During Operations

During operations, dewatering of the shallow subsoil under the stormwater ponds is required to suppress the groundwater table for pond liner protection. The amount of groundwater that may need to removed will depend on the size and depth of the ponds below the water table, the permeability of the soil and the duration of Upgrader operations.

The groundwater removed beneath the stormwater ponds will be directed to the potentially contaminated pond. This water will be managed as part of the stormwater runoff management strategy, and either transferred to the raw water pond, released to the North Wetland Complex or discharged to the effluent pond.

Localized groundwater dewatering beneath the lined stormwater ponds during operations will not affect the water quality of Astotin Creek, the unnamed creek or the NSR because of the planned mitigation measures. Therefore, the magnitude of the residual effects is negligible, and the duration and reversibility of the effects are not applicable. There will be no environmental consequence on water quality for dewatering activities. The residual effect of dewatering will not contribute measurably to cumulative effects on surface water quality.

7.7.4 Wastewater Treatment and Discharge

A treatment facility will be provided on-site to treat the following wastewater streams prior to reuse and/or discharge to the NSR:

- cooling tower blowdown;
- boiler blowdown;
- desalter wash water;
- excess stripped sour water;
- gasification wastewater;
- ultrafiltration backwash;
- reverse osmosis reject;
- groundwater relief;
- ion exchange regeneration waste;
- miscellaneous process waste streams;
- stormwater runoff;
- potentially contaminated stormwater;
- contaminated water; and
- sanitary waste.

7.7.4.1 Wastewater Segregation

The various Upgrader wastewater streams will have varying degrees of water quality, including dissolved solids, oil and grease, biodegradable organics, nitrogen, phosphorus, sulphide, cyanides and phenols. To optimize the efficiency of the wastewater treatment facilities, the wastewater streams will be segregated into “organic” and “high TDS.” The organic waste streams, which typically contain oil and grease and other biodegradable contaminants, will be treated separately from the high TDS waste streams. All the excess treated waste streams not recycled to the Upgrader will be directed to the effluent pond for temporary storage prior to discharge to the NSR.

7.7.4.2 Organic Wastewater Treatment

The organic waste stream, which includes desalter wash water, potentially contaminated stormwater, oily wastewater, and sanitary wastewater, will be treated in the following facilities/processes:

- desalter break tank (initial skim tank for desalter wash water);
- skim tanks;
- dissolved gas flotation;
- membrane bioreactor equalization tank;
- membrane bioreactor; and
- excess biological solids from the bioreactor will be treated with the following processes, prior to off-site disposal that follows AENV licence requirements:
    - aerobic digestion; and
    - digested biosolids dewatering.

7.7.4.3 High TDS Wastewater Treatment

Wastewater streams that have elevated TDS, including boiler and cooling tower blowdowns, excess condensate, reverse osmosis reject and neutralized ion exchange waste will not be treated by the organic wastewater treatment process unless they are contaminated by hydrocarbons. These streams are normally relatively clean, with little or no organics, and typically do not require treatment prior to river discharge.

For Phase 1, all of the high TDS streams will be discharged to the effluent pond, unless contamination is detected. Contaminated high TDS wastewater will be diverted to the wastewater treatment unit for treatment. The concentration of the high TDS streams will be monitored to ensure that adequate dilution is occurring in the effluent pond to maintain TDS within acceptable levels for river discharge.

As the Upgrader expands beyond Phase 1, increased levels of internal recycle will be developed, including ZLD treatment of targeted waste streams. Eventually, the Project will incorporate ZLD treatment of all waste streams to eliminate effluent discharges to the NSR. For Upgrader development beyond Phase 1, North American will introduce the first stage of ZLD treatment, with segregation and ZLD treatment of the reverse osmosis reject and neutralized ion exchange waste streams using an evaporator process. The distillate from this first stage of ZLD treatment will be recycled as boiler feed makeup.

The evaporation process will produce a concentrated brine waste that will be disposed of off-site in a manner approved by regulators. North American is currently investigating potential disposal options, including third-party liquid industrial waste disposal facilities.

7.7.4.4 Raw Water Treatment Waste

The ultrafiltration membrane system used as part of the raw water treatment process will generate a waste stream associated with backwash. This waste stream, which contains suspended solids, will be directed to the head of the raw water pond to allow suspended solids to settle, as well as the recycling of clarified water.

7.7.4.5 Wastewater Discharge

River discharge information is summarized in Table 4.3-2 of Volume 1. There are no waste streams discharged to the NSR for the full Project build-out, since full ZLD is planned. The maximum effluent discharge to the NSR occurs for the case of the Project, excluding Gasification 2 during the summer cooling period.

Treated wastewater will be discharged from the effluent pond to a diffuser in the NSR via a new discharge pipeline. A mulitport, submerged diffuser will provide efficient mixing of the effluent in the river channel. The construction of the in-channel diffuser will require the use of a temporary coffer dam. Construction will be completed in accordance with applicable legislation governing allowable in-stream construction activities. The completed outfall diffuser will not result in permanent alterations or diversions to the NSR. The treated wastewater outfall diffuser would be installed downstream of the proposed raw water intake.

The effluent pond will have sufficient capacity to retain effluent in the event that it does not meet effluent discharge criteria. In such an event, the contaminated effluent will be recycled to the wastewater treatment unit for additional treatment. The discharge from the effluent pond will be continuously monitored for key parameters, including temperature, pH, flow rate and any other parameters specified in the AENV Approval. A composite sampler will be provided to allow daily analyses of the discharge to the NSR.

7.7.5 Effects of Treated Effluent Discharge on the Local Study Area

The CORMIX model was used to examine the dispersion of treated process water discharge and the effects of the discharge on NSR water quality in the LSA (Section 7.5.3.2). The location of the proposed outfall is indicated in Figure 7.7-1. The following mixing zone restrictions outlined in AENV (1995) apply:

- Acute water quality guidelines should be met at end-of-pipe.
- Chronic water quality guidelines should be met before ten times the stream width along the length of the river and one-half the stream width laterally. The stream width in both cases is defined as that width when the river is at the $7Q_{10}$ flow. The $7Q_{10}$ flow is the lowest stream flow for seven consecutive days that would be expected to occur once in ten years. Chronic guidelines include a maximum temperature change above ambient of 3^{o}C.

The point where the guidelines for chronic effects must be met is referred to in the following sections as the chronic boundary within the effluent plume. Effluent mixing was examined in both the near-field and the far-field of the mixing zone.

Effluent and temperature dispersion were modelled at the $7Q_{10}$ flow (60 m^3/s), as well as at mean annual flow of the NSR (196 m^3/s). The effluent chemistry used was that predicted for the Project. The $7Q_{10}$ conditions represent the worst-case scenario, where dilution would be at a minimum. The mean annual flow conditions represent effluent dispersion under average flow conditions in the NSR.

The proposed wastewater outfall was assumed to be a multiport diffuser, 30 cm in diameter, with ten 10 cm ports extending between 8 m and 11 m from the bank of the river at the $7Q_{10}$ flow.

The diffuser was situated just downstream of the intake structure. As reported in the Hydrology section (Volume 3, Section 6), the width of the NSR at the location of the proposed outfall under $7Q_{10}$ conditions is 129 m. This means that chronic guidelines must be met at a point 1.29 km downstream. The width of the NSR under mean annual flow was 183 m. The model parameters are listed in Table 7.7-1. Further details of the inputs to the CORMIX model are presented in the model output in Appendix 7B.

Table 7.7-1 CORMIX Modelling Parameters

Parameter	Average Flow Conditions	$7Q_{10}$ Flow Conditions
River Flow	196 m^3/s	60.0 m^3/s
River Width	183 m	129 m
River Mean Depth	1.9 m	1.00
Effluent Flow	0.0886 m^3/s	0.0886 m^3/s
Effluent Temperature	27°C	24°C
Diameter of Outfall Pipe	0.3 m	0.3 m
Number of Ports	10	10
Diameter of Ports	0.1 m	0.1 m
Distance of Diffuser from Bank	8 m to 11 m	8 m to 11 m

7.7.5.1 Results of CORMIX Modelling

Under both the $7Q_{10}$ and average flow scenarios, the effluent plume follows the right bank of the river, dynamically attaches to this bank and remains attached for at least 20 km downstream. The plume characteristics for both average flow and low-flow scenarios are presented in Table 7.7-2. The near-field, dominated by the forces of buoyancy and momentum, is very short in both cases. At the end of the near-field, the width of the plume is only 2.6 m under $7Q_{10}$ conditions, and about 4.4 m for mean annual flow conditions. Starting with 100% effluent at end-of-pipe, effluent concentrations at the end of the near-field zone are predicted to be 4.2% under $7Q_{10}$ conditions, and 2.3% under average flow conditions.

In the far-field, the plume continues to spread horizontally across the river, although at a relatively slow rate. The plume is fully mixed vertically at about 11.1 m downstream under $7Q_{10}$ conditions, and 27.2 m under average flow conditions. The plume attaches to the right bank at 931 m and 618 m, respectively. At the chronic boundary of the plume, where compliance with chronic guidelines is required, the concentration in the midpoint of the plume is 0.58% effluent for $7Q_{10}$ conditions, and 0.30% for average flow conditions. Mixing is far less efficient under $7Q_{10}$ conditions, which would normally occur during the winter. The widths of the plume at the chronic boundary were 19.4 m under $7Q_{10}$ flow, and 21.1 m under average flow conditions. The temperature differential (Delta T) at the chronic boundary was only 0.12°C under the $7Q_{10}$ flow, and 0.05°C under average flow conditions. Effluent and temperature concentrations in the centre line of the effluent plume and a planar view of the dispersion for the $7Q_{10}$ case are shown in Figure 7.7-1.

Table 7.7-2 Characteristics of the Effluent Plume under $7Q_{10}$ and Average Flow Conditions

Plume Characteristic	Average Flow Conditions (196 m^3/s)	Low Flow Conditions ($7Q_{10}$) (60 m^3/s)
Near Field		
Downstream distance of plume at end of near-field	11 m	6.5 m
Width of plume at end of near-field	4.4 m	2.6 m
Effluent concentration at end of near-field	2.3%	4.2%
Far Field		
Distance downstream that plume is fully mixed vertically	27.2 m	11.1 m
Distance downstream that plume is attached to the right bank	618	931
Effluent concentration at 1.29 km downstream (width at $7Q_{10}$ flow)	0.30%	0.58%
Width of plume at 1.29 km downstream (width at $7Q_{10}$ flow)	21.1 m	19.4 m
Temperature Differential (Delta T) at 1.29 km downstream	0.05	0.12°C

7.7.5.2 Compliance with Mixing Zone Requirements

Predicted effluent concentrations and loadings at end-of-pipe for relevant chemical parameters are presented in Table 7.7-3. The effluent loadings are those predicted for the peak summer day for the Project, and hence represent “worst-case,” or conservative conditions. Column 8 presents the predicted concentrations of these chemical parameters at the chronic boundary of the plume, at 1.29 km downstream of the outfall under $7Q_{10}$ conditions. Table 7.7-3 also includes the background winter (December to February) concentration of each parameter in the NSR and the concentration of each parameter in the river at full mixing (Column 9). Because acute water quality guidelines are met at the end-of-pipe for all parameters for which acute guidelines are available (Table 7.7-3), the first mixing zone requirement is satisfied. The second mixing zone requirement is met for all parameters except TP and TN. For phosphorus, the background concentration in the NSR (0.069 mg/L) already exceeds Alberta’s surface water quality chronic guideline (0.05 mg/L). The concentration of TP at the chronic boundary (0.071 mg/L) is marginally greater than this background value. At full mixing, the concentration of phosphorus is analytically indistinguishable from the background concentration. For TN, the background concentration in the NSR (1.14 mg/L) similarly exceeds the chronic guideline (1.0 mg/L). At the chronic boundary of the plume the predicted concentration of total nitrogen will be 1.38 mg/L. At full mixing, the concentration is predicted to be 1.20 mg/L, which is marginally greater than the upstream concentration and within the seasonal variation in this parameter. Much of the loading of total nitrogen (329 kg/d) is attributable to TKN (283 kg/d). TKN represents reduced forms of nitrogen, including ammonia. As ammonia loading is relatively low (15 kg/d), a large percentage (81%) of the nitrogen loading is attributable to reduced organic forms of nitrogen. Although previous impact assessments for other facilities have concentrated on the Project contribution of ammonia, this does not seem warranted for this Project.

The predicted concentrations of most major chemical parameters at full mixing in the NSR are indistinguishable from background values within the range of analytical error (Table 7.7-3). Exceptions include the major ions sodium and chloride. Incremental increases of 0.3 mg/L are predicted for sodium and 0.4 mg/L for chloride. These incremental increases in the NSR would theoretically be detectable, although they fall within the range of the seasonal variability of each parameter. The predicted increase in TDS (from 218 mg/L upstream to 220 mg/L at full mixing of the discharge) is due to the increase in these major ions.

The residual effects of the discharge of treated effluent on the LSA will be negative in direction, regional in extent, low in magnitude, medium-term in duration, continual in frequency and reversible in the median term. The residual effects will be low in magnitude because the incremental increases in certain water quality parameters attributable to the Project are within acceptable protective standards. The confidence in this prediction is high. The residual effects of the discharge of treated effluent on the NSR have an overall impact rating of low.

Table 7.7-3 Concentrations of Chemical Variables in the North Saskatchewan River Downstream of the Proposed Wastewater Outfall Predicted from the CORMIX Model Under $7Q_{10}$ Flow Conditions

Variable	Units	Effluent Concentration	Loading (kg/d)	Median Winter Concentration of NSR at Pakan	Acute Guideline	Chronic Guideline	Predicted Concentration in Plume at 1.29 km Downstream	Concentration at Full Mixing
BOD	mg/L	43.5	333	1.33			1.6	1.39
COD	mg/L	257	1,965	6			7.5	6.36
TDS	mg/L	1,558	11,909	218			226	220
TOC	mg/L	49.8	381	2.1			2.4	2.17
TSS	mg/L	37	283	2			2.2	2.05
Hardness	mg/L	565	4,319	180			182.2	180
Alkalinity	mg/L	473	3,616	142			143.9	142
Sodium	mg/L	213.3	1,630	7.85			9.0	8.14
Potassium	mg/L	16.1	123	1.1			1.2	1.12
Calcium	mg/L	150	1,147	49.65			50.2	49.7
Magnesium	mg/L	46.2	353	14.2			14.4	14.2
Chloride	mg/L	277.9	2,124	3.6			5.2	4.00
Sulphate	mg/L	162	1,238	51.6			52.2	51.7
Ammonia-N	mg/L	2	15	0.43	8.3	0.832	0.439	0.43
Nitrates-N	mg/L	6	46	0.36		2.94	0.393	0.37
TKN	mg/L	37	283	0.64			0.851	0.69
Total N	mg/L	43	329	1.14		1.0	**1.38**	1.20
Total P	mg/L	0.5	3.82	0.069		0.05	**0.071**	0.070
Cyanides	mg/L	0.1	0.76	ND		0.005	0.0006	0.0001
Sulphides	mg/L	0.01	0.0764	-		0.002	0.0001	ND
Phenols	mg/L	0.032	0.2446	0.001		0.005/0.004	0.0012	0.001
Aluminum	mg/L	0.365	2.7901	0.073		0.1	0.0747	0.073
Antimony	mg/L	0.000043	0.0003	ND			ND	ND
Arsenic	mg/L	0.0008	0.0061	ND		0.005	ND	ND
Beryllium	mg/L	0.0002	0.0015	0.0001			0.0001	0.0001
Cadmium	mg/L	0.0004	0.0031	ND		0.000047	0.000002	ND

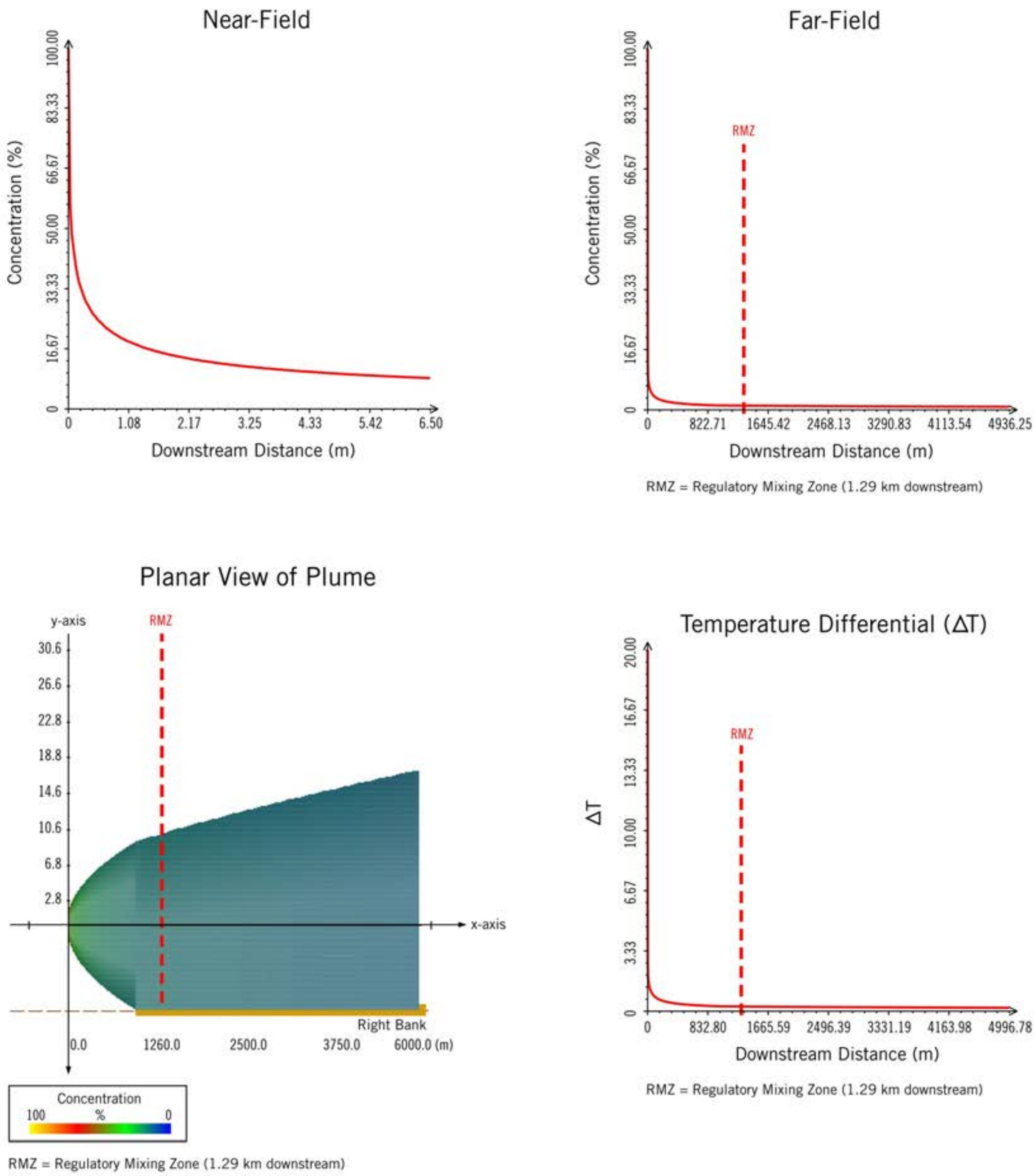
Table 7.7-3 (continued) Concentrations of Chemical Variables in the North Saskatchewan River Downstream of the Proposed Wastewater Outfall Predicted from the CORMIX Model Under $7Q_{10}$ Flow Conditions

Variable	Units	Effluent Concentration	Loading (kg/d)	Median Winter Concentration of NSR at Pakan	Acute Guideline	Chronic Guideline	Predicted Concentration in Plume at 1.29 km Downstream	Concentration at Full Mixing
Chromium	mg/L	0.002	0.0153	ND		0.0089	0.00001	ND
Cobalt	mg/L	0.0006	0.0046	ND			ND	ND
Copper	mg/L	0.005	0.0382	0.001	0.028	0.003	0.0010	0.001
Iron	mg/L	1.5	11.5	0.103		0.3	0.1111	0.105
Lead	mg/L	0.0045	0.0344	0.0009	0.065[2]	0.004	0.0009	0.0009
Mercury	mg/L	0.00004	0.0003	ND	0.013	0.0001	ND	ND
Molybdenum	mg/L	0.0055	0.0420	0.0011		0.073	0.0011	0.0011
Nickel	mg/L	0.009	0.0688	0.0018	0.47[2]	0.11	0.0018	0.0018
Selenium	mg/L	0.0002	0.0015	ND		0.001	ND	ND
Titanium	mg/L	0.0115	0.0879	0.0023			0.0024	0.0023
Vanadium	mg/L	0.004	0.0306	ND		0.1[2]	0.00002	ND
Zinc	mg/L	0.04	0.3058	0.008	0.12	0.03	0.0082	0.008

Notes:

1 CCME Water Quality Guidelines for Protection of Aquatic Life or Alberta Surface Water Quality Guidelines, unless otherwise indicated.
2 U.S. EPA chronic guidelines (2006). These are recommended when CCME or AENV guidelines are lacking.
3 ND = non-detectable.
4 Bold indicates parameters which exceed the chronic guideline at 1.29 km downstream.

Figure 7.7-1 Percent Effluent Concentration and Temperature Differential in the Centreline of the Plume versus Downstream Distance for $7Q_{10}$ Flow Conditions


Near-Field

Far-Field

RMZ = Regulatory Mixing Zone (1.29 km downstream)

Planar View of Plume

RMZ = Regulatory Mixing Zone (1.29 km downstream)

Temperature Differential (ΔT)

RMZ = Regulatory Mixing Zone (1.29 km downstream)

7.7.6 Effects of Effluent Discharge on the Regional Study Area

The effects of effluent discharge on the RSA were examined by two methods. The first method involved conducting a loading analysis of 14 chemical parameters to the NSR from all major point sources (municipal and industrial) in order to calculate the relative contribution of the Project to the total loading of each parameter. The Baseline Case included all existing and approved dischargers, while the Application Case added the proposed discharge for the Project (Table 7.7-4). The Cumulative Case included the addition of two facilities: Petro-Canada Oil Sands Inc.'s Sturgeon Upgrader and Shell Scotford Upgrader Expansion 2. No discharge was reported for BA Energy's Heartland Oil Sands Bitumen Upgrader and the Synenco Northern Lights Upgrader. The second method involved use of the WASP model to assess the effects of the above discharges on the overall water chemistry of the NSR. The model was applied to a selection of the parameters having the highest loadings as determined in the loading analyses. The WASP model is useful for showing the effects of multiple discharges and overlapping plumes within segments of the NSR.

7.7.6.1 Loading Analysis

The loading of 14 effluent parameters for existing and approved dischargers (including the Project) in the RSA is summarized in Table 7.7-5 for the Application Case. The Cumulative Case is presented in Table 7.7-3. In most cases, average daily loading rates were calculated from AENV monitoring data for the most recent five years of data. To calculate background (upstream) loadings in the NSR, concentrations of the 14 parameters upstream of the Gold Bar WWTP reported in Focus (2005) at Dawson Bridge in Edmonton during February during low-flow conditions were used. For parameters not included in the Focus (2005) report, background concentrations of the NSR were taken from AENV's long-term monitoring station at Devon (AENV, 2002a). Background loadings in the NSR were calculated using the $7Q_{10}$ flow. Data from AENV were also used to calculate the loadings attributable to the Sturgeon River. The loading analysis involved summing the loadings of each parameter to the river and determining the relative contribution of the Project to the total loading of that parameter in the RSA.

In the Application Case, the relative contribution of the Project to the total loadings of the 14 parameters ranged from 0.2% for aluminum to 7.6% for COD. The Project is projected to contribute greater than 2% of the load of four parameters:

- COD (7.6%);
- BOD (3.3%);
- sodium (2.6%); and
- chloride (5.3%).

The incremental increases in major ions (sodium, chloride, TDS) downstream of the Project were already noted in the CORMIX effluent dispersion modelling. While the contribution of the Project to ammonia was relatively small (0.7%), the contribution of the Project to all reduced forms of nitrogen, expressed as TKN, is notable and represents about 8.6% of the contribution from Gold Bar WWTP. There were insufficient data to include TKN in the loading analysis or in the WASP modelling below.

The relative contributions of the Project in the Cumulative Case were almost identical to those in the Application Case (Table 7.7-3).

Table 7.7-4 Existing/Approved and Planned Dischargers to the North Saskatchewan River

Discharger	Distance Downstream of Gold Bar WWTP (km)	Existing or Approved Dischargers Used in Application Case[1]	Existing, Approved and Planned Dischargers Used in Cumulative Case[1]
Gold Bar WWTP	0.0	x	x
Imperial Oil - Strathcona Oil Refinery	1.5	x	x
AltaSteel Ltd.	1.5	x	x
Petro-Canada Products' Edmonton Refinery	3.9	x	x
Celanese Canada Inc. – Petrochemical Manufacturing Plant	5.5	x	x
Capital Region WWTP	14.8	x	x
Dow Chemical Canada Inc. Fort Saskatchewan Chemical Manufacturing Plant	35.4	x	x
Air Liquide Canada Inc. – Scotford Cogeneration Power Plant	43	x	x
Shell Canada Refinery	43.6	x	x
Shell Canada Chemical Plant	43.6	x	x
Shell Canada Styrene and MEG Plant	43.6	x	x
Shell Canada Scotford Upgrader	44.2	x	x
Shell Canada Scotford Upgrader Expansion 1	44.2	x	
Shell Canada's Scotford Upgrader 2	44.2		x
Sturgeon Upgrader	47.2		x
Degussa Canada (formerly DuPont) – Gibbons Hydrogen Peroxide Plant	49.1	x	x
North West Upgrading Bitumen Upgrader	49.2	x	
Agrium Products Inc. – Redwater Fertilizer Plant	49.2	x	x

1 Dischargers included in each case are indicated by x.

7.7.6.2 WASP Modelling

Model Set Up

The WASP model is a dynamic compartment modelling program for aquatic systems that allows the user to predict the water quality responses to natural phenomena and anthropogenic discharges. WASP uses mass balance equations to calculate chemical mass and concentration for defined river segments or reaches along the NSR. The user can specify modelling time steps, the duration of the simulation and the process-affected water loadings from the various industries in each segment.

The WASP model was configured to simulate water quality within the NSR in 440 surface water segments along the modelled 60 km reach of the regional study area, from Gold Bar WWTP to the confluence with the Redwater River. The model was run to predict steady-state conditions, with flows and chemical loadings kept constant. The model was run under $7Q_{10}$ conditions (60.0 m^3/s), representing a conservative dilution scenario. River hydraulic conditions were approximated using Leopold-Maddock coefficients developed for the NSR (Ray and Dykema, 1991). Dispersion coefficients were assumed constant across the channel at all locations, and a river temperature of 2ºC was applied. The calibration procedures for the model match those used by an analogous facility, and consisted of adjusting lateral dispersion coefficients so that simulated dye concentrations matched the results of an earlier modelling study by Golder (1995). To verify the performance of the calibrated WASP model for the NSR, the model was applied to simulate recently measured water quality parameters in the NSR. Loadings of the modelled parameters were obtained from the loading analysis described above.

Table 7.7-5 Loading Analysis of Point Sources on the NSR within the Regional Study Area – Application Case

Point Source	Ammonia (kg/d)	Total P (kg/d)	Sulphide (kg/d)	Phenols (kg/d)	COD (kg/d)	BOD (kg/d)	TDS (kg/d)	Sodium (kg/d)	Chloride (kg/d)	Sulphate (kg/d)	Fe (kg/d)	Al (kg/d)	Zn (kg/d)	Ni (kg/d)
NSR Background	72	153	0.511	0.511	2,557	5,115	961,597	14,833	4,399	228,635	2,823	1,228	10.7	3.58
Sturgeon River	50.8	12.6	NA	NA	5,076	165	NA	NA	1,248	NA	NA	NA	NA	NA
Gold Bar WWTP	817	211.5	1.86	NA	9,300	2,523	175,770	28241	21421	48670	21.1	20.2	18.6	4.2
AltaSteel Ltd.	NA	NA	NA	NA	6.72	NA	NA	NA	NA	NA	0.106	0.037	NA	NA
Celanese Canada Inc. – Petrochemical Manufacturing Plant	4.1	NA	NA	NA	261	65.2	NA	NA	NA	NA	NA	NA	NA	NA
Air Liquide Canada – Scotford Cogeneration Power Plant	NA	0.32	NA	NA	116	NA	1601	NA	NA	NA	NA	NA	NA	NA
Imperial Oil - Strathcona Oil Refinery	1.75	NA	0.67	0.13	225	NA	4855	803.4	1390.0	1365	1.2	1.23	0.65	0.010
Petro-Canada Products Edmonton Refinery	2.22	1.12	0.07	0.0169	209	NA	NA	841.2	NA	NA	4.43	3.65	0.40	0.025
Capital Region WWTP	1,052	137	1.425	NA	3571	1478	51,075	7,950.0	5872.5	14,100	8.0	7.35	5.33	1.02
Dow Chemical – Fort Saskatchewan Chemical Manufacturing Plant	2.58	6.23	NA	0.0003	529	81.6	3,789	731.3	263	1,345	0.8	0.79	0.07	0.04
Shell Canada Scotford Refinery	0.880	NA	0.034	0.057	184	NA	2,151	434.2	501.3	675	1.1	NA	NA	NA
Shell Canada Scotford Chemical Plant	NA	NA	NA	NA	NA	22.8	NA	NA	NA	NA	NA	NA	NA	NA
Shell Canada Scotford Styrene and MEG Plant	NA	NA	NA	NA	225	26.7	NA	NA	NA	NA	NA	NA	NA	NA
Shell Canada Scotford Upgrader	2.09	69.6	0.154	0.067	316	30.6	39,816	2712	960	7416	4.3	2.05	0.30	0.04
Shell Scotford Upgrader Expansion 1	33.6	43.2	1.2	0.48	744	192	23,438	1625	576	4442	1.68	9.84	11.9	0.216
Degussa Canada – Gibbons Hydrogen Peroxide Plant	0.081	0.724	NA	NA	12.2	1.7	NA	NA	NA	NA	NA	NA	NA	NA
North West Upgrading Bitumen Upgrader	56.9	2.16	5.7	11.4	513	171	9132	2587	1468	2076	0.72	1.01	2.28	2.28
Agrium Products Inc. - Redwater Fertilizer Plant	10.1	8.4	NA	NA	167	21.0	NA	NA	NA	NA	NA	NA	NA	NA
North American Upgrader Project	15	3.82	0.076	0.24	1965	333	11,909	1,630	2,124	1238	11.5	2.79	0.30	0.07
Total Loadings	2121	650	12	13	25,977	10,226	1,285,133	62,388	40,223	309,963	2878	1276	51	12
Percent of Total Loading Attributable to Project	**0.7**	**0.6**	**0.7**	**1.9**	**7.6**	**3.3**	**0.9**	**2.6**	**5.3**	**0.4**	**0.4**	**0.2**	**0.6**	**0.6**

Data obtained from AENV monitoring data; Data obtained from Regulatory Approvals; Data predicted from EIA; NA=no data available

Table 7.7-6 Loading Analysis of Point Sources on the NSR within the Regional Study Area – Cumulative Case

Point Source	Ammonia (kg/d)	Total P (kg/d)	Sulphide (kg/d)	Phenols (kg/d)	COD (kg/d)	BOD (kg/d)	TDS (kg/d)	Sodium (kg/d)	Chloride (kg/d)	Sulphate (kg/d)	Fe (kg/d)	Al (kg/d)	Zn (kg/d)	Ni (kg/d)
NSR Background	72	153	0.511	0.511	2,557	5,115	961,597	14,833	4399	228635	2823	1228	10.7	3.58
Sturgeon River	50.8	12.6	NA	NA	5,076	165	NA	NA	1248	NA	NA	NA	NA	NA
Gold Bar WWTP	817	211.5	1.86	NA	9,300	2,523	175,770	28,241	21,421	48,670	21.1	20.2	18.6	4.2
AltaSteel Ltd.	NA	NA	NA	NA	6.72	NA	NA	NA	NA	NA	0.106	0.037	NA	NA
Celanese Canada Inc. – Petrochemical Manufacturing Plant	4.1	NA	NA	NA	261	65.2	NA	NA	NA	NA	NA	NA	NA	NA
Air Liquide Canada – Scotford Cogeneration Power Plant	NA	0.32	NA	NA	116	NA	1601	NA	NA	NA	NA	NA	NA	NA
Imperial Oil – Strathcona Oil Refinery	1.75	NA	0.67	0.13	225	NA	4,855	803.4	1,390.0	1,365	1.2	1.23	0.65	0.010
Petro-Canada Products Edmonton Refinery	2.22	1.12	0.07	0.0169	209	NA	NA	841.2	NA	NA	4.43	3.65	0.40	0.025
Capital Region WWTP	1,052	137	1.425	NA	3,571	1,478	51,075	7,950.0	5,872.5	14,100	8.0	7.35	5.33	1.02
Dow Chemical – Fort Saskatchewan Chemical Manufacturing Plant	2.58	6.23	NA	0.0003	529	81.6	3789	731.3	263	1345	0.8	0.79	0.07	0.04
Shell Canada's Scotford Refinery	0.880	NA	0.034	0.057	184	NA	2151	434.2	501.3	675	1.1	NA	NA	NA
Shell Canada Scotford Chemical Plant	NA	NA	NA	NA	NA	22.8	NA	NA	NA	NA	NA	NA	NA	NA
Shell Canada Scotford Styrene and MEG Plant	NA	NA	NA	NA	225	26.7	NA	NA	NA	NA	NA	NA	NA	NA
Shell Canada Scotford Upgrader	2.09	69.6	0.154	0.067	316	30.6	39,816	2,712	960	7,416	4.3	2.05	0.30	0.04
Shell Canada Scotford Upgrader Expansion 1	33.6	43.2	1.2	0.48	744	192	23,438	1,625	576	4,442	1.68	9.84	11.9	0.216
Shell Canada Scotford Upgrader Expansion 2	86.4	57.6	2.19	0.806	1,164	397	86,815	13,582	9,763	32,855	21.3	43.2	5.69	0.75
Degussa (Dupont) – Gibbons Hydrogen Peroxide Plant	0.081	0.724	NA	NA	12.2	1.7	NA	NA	NA	NA	NA	NA	NA	NA
North West Upgrading Bitumen Upgrader	56.9	2.16	5.7	11.4	513	171	9,132	2,587	1,468	2,076	0.72	1.01	2.28	2.28
Agrium Products Inc. – Redwater Fertilizer Plant	10.1	8.4	NA	NA	167	21.0	NA	NA	NA	NA	NA	NA	NA	NA
Sturgeon Upgrader	13.1	2.16	0.072	1.58	168	97	9132	2587	1468	2076	0.72	1.01	0.014	0.014
North American Upgrader Project	15	3.82	0.076	0.24	1,965	333	11,909	1,630	2,124	1,238	11.5	2.79	0.31	0.07
Total Loadings	2220	710	14	15	27309	10,720	1,381,080	78,557	51,454	344,894	2,900	1321	56	12
Percent of Total Loading Attributable to Project	**0.7**	**0.5**	**0.5**	**1.6**	**7.2**	**3.1**	**0.9**	**2.1**	**4.1**	**0.4**	**0.4**	**0.2**	**0.5**	**0.6**

Data obtained from AENV monitoring data; Data obtained from Regulatory Approvals; Data predicted from EIA; NA=no data available

The model was applied to two of the four parameters listed above: chloride and COD. As WASP does not have the algorithms for handling COD, this parameter was run as a conservative compound in WASP's toxicant module, with a small decay constant equivalent to one-tenth of the value normally assigned to carbonaceous BOD (Wool et al., 2004). Chloride was modelled as representing the release of major ions, including sodium (its most common cation) and total dissolved solids. Chloride was also modelled as a conservative compound. Since the contributions of the Project to the loadings of both ammonia and total phosphorus were both quite small (0.7% and 0.6% of the total loads, respectively), these parameters were not modelled in WASP. These two nutrients have been modelled in WASP in previous applications. Initial and boundary (upstream) conditions were assumed to be winter concentrations of COD and chloride reported in Focus (2005) at Dawson Bridge.

Results of WASP Modelling

The results of the loadings on the NSR for the Baseline Case and the Application Case for chloride and COD are presented in the following sections. The plots present pictorially the dispersion of the loadings in Table 7.7-2 and the effects of overlapping plumes from the various point sources. The raw model output is provided in Appendix 7C. The WASP modelling results for the Cumulative Case were very similar to those for the Application Case. Results are included in Appendix 7C.

Chloride

The WASP simulations for chloride are shown in Figures 7.7-1 to 7.7-5. These simulations are representative of the major ion loadings to the NSR, including sodium and TDS. Figure 7.7-1 presents the simulation for the Baseline Case. The background chloride concentration upstream of Gold Bar WWTP is 0.83 mg/L at Dawson Bridge. Immediately downstream of this facility, the concentration rises dramatically to 27.0 mg/L. As suggested in the CORMIX modelling of the proposed effluent discharge from the Project, the effluent plume from Gold Bar WWTP hugs the right bank of the NSR and slowly spreads horizontally across the river. Loadings of chloride from Imperial Oil's Strathcona Oil Refinery at 1.5 km downstream and Petro-Canada's Sturgeon Upgrader 3.9 km downstream are indistinguishable in the large Gold Bar WWTP plume. Another large loading of chloride is evident from Capital Region WWTP at 14.8 km downstream, when the concentration along the right bank rises from 12.5 mg/L to 21.5 mg/L. A small increase in chloride concentration in the NSR is attributable to loading from Dow Chemical's Fort Saskatchewan Chemical Manufacturing Plant 35.4 km downstream. The discharge of the Sturgeon River to the NSR 38 km downstream results in an increase of about 1 mg/L on the left bank. The Shell Canada Scotford Complex, including the Shell Canada Scotford Refinery and the Shell Canada Scotford Upgrader, account for an increase of 3.3 mg/L along the right bank at 44 km downstream. Degussa's Gibbons Hydrogen Peroxide Manufacturing Plant, North West Upgrading's Bitumen Upgrader and Agrium Products' Redwater Fertilizer Plant account for an increase of 2.2 mg/L on the left bank at 49 km downstream. At the end of the WASP simulation, the chloride concentration across the river ranged from 5.65 mg/L to 10.32 mg/L, for an average of 7.33 mg/L. This value is twice the median winter concentration chloride measured at Pakan downstream (3.6 mg/L; Table 7.7-3). The higher predicted values are likely the result of the use of the very low $7Q_{10}$ flow in the model.

Figures 7.7-2 and 7.7-3 present the WASP simulation for the Application Case for the entire RSA, and a small section of the NSR in the vicinity of the Project (close-up view). Under the application scenario, the chloride discharge from the Project at 49 km downstream is evident on the right bank in Figure 7.7-3, and results in a concentration increase along this bank of 2.7 mg/L. At the end of the simulation, 60 km downstream of Gold Bar WWTP, the chloride concentration across the NSR ranged from 5.66 mg/L to11.84 mg/L, for an average concentration of 7.74 mg/L. The difference between the average concentrations of chloride in the NSR attributable to the Project (Application Case–Baseline Case) is 0.41 mg/L. This value is very close to the incremental increase of 0.4 mg/L in chloride predicted from mass balance calculations conducted during the CORMIX dispersion modelling (Table 7.7-3).

Figure 7.7-4 presents the Cumulative Case scenario that includes the contributions of the proposed Sturgeon Upgrader and the Scotford Upgrader Expansion 2. The average concentration of chloride across the NSR at the end of the simulation for this scenario was 7.75 mg/L.

Figure 7.7-5 presents the average chloride concentrations across the NSR as a function of distance downstream for the Baseline, Application and Cumulative Cases. The differences between the baseline and application lines in Figure 7.7-4 indicate the incremental increase in chloride attributable to the Project.

COD

The results of the WASP simulation for COD in the NSR are presented in Figures 7.7-6 to 7.7-10. COD concentrations in the NSR upstream of the Gold Bar WWTP are 0.5 mg/L (Focus, 2005). In the Baseline Case, as a result of the loading of 9,300 kg/d from Gold Bar WWTP, the COD concentration along the left bank of the NSR is predicted to reach 11.6 mg/L. As before, the COD plume from Gold Bar hugs the right bank as it slowly mixes across the river. The COD contributions from AltaSteel Ltd., Imperial Oil's Strathcona Oil Refinery and Celanese Canada's Petrochemical Manufacturing Plant downstream of Gold Bar WWTP are lost in the large Gold Bar plume. A loading of 3,571 kg/d from Capital Region WWTP results in another major increase in COD, to 9.1 mg/L along the right bank. The effects of COD loading from the Sturgeon River at 38.5 km, the Shell Canada Scotford Complex at 44 km downstream, Degussa Gibbons Plant at 49.1 km and Agrium Redwater Fertilizer facilities at 49.2 km downstream are small but evident in the plots. Dilution of the plumes from the various point sources continues downstream until the end of the simulation at Vinca Bridge, when the average river concentration is 1.37 mg/L.

The loading of 1,965 kg/d from the Project in the Application Case is fully visible on the right bank at 49 km downstream (Figures 7.7-7 and 7.7-8). The COD concentration increases by 2.4 mg/L at the point of discharge. At the end of the simulation, 60 km downstream of Gold Bar WWTP, the average river concentration was 1.63 mg/L. The difference between the two average concentrations of COD represents the incremental increase in COD attributable to the Project (0.26 mg/L). This value is again close to the incremental increase of 0.36 mg/L predicted from the mass balance calculations conducted during the CORMIX dispersion modelling (Table 7.6-3). The values predicted during the CORMIX modelling may be higher because the oxidative decay of COD was not taken into account in these calculations, as it was in the WASP model.

Figure 7.7-10 presents the Cumulative Case scenario. The average concentration of COD across the NSR at the end of the simulation for this scenario was 1.78 mg/L.

The effects of the Project on the average river concentrations of COD along the length of the NSR are presented in Figure 7.7-11. This incremental increase in COD attributable to the Project is extremely small and analytically indistinguishable from the Baseline Case.

7.7.6.3 Summary of Residual Effects in the Regional Study Area

The loading analysis and the WASP modelling corroborate the conclusions of the CORMIX analysis on the effects of the proposed effluent discharge on water quality in the NSR. All three analyses indicate that the contribution of the Project to the loading of most parameters to the NSR is extremely small, with final concentrations analytically indistinguishable from baseline concentrations. Incremental increases in major ion concentrations (chloride, sodium and sulphate) are predicted, although no guideline exceedances are anticipated. An incremental increase in reduced forms of nitrogen is also predicted, although insufficient data were available to determine the relative importance of the Project to the overall loading of this parameter to the NSR from all sources. The residual effects of the discharge of treated effluent on the RSA will be negative in direction, regional in extent, low in magnitude, medium-term in duration, continual in frequency and reversible in the medium-term. The residual effects will be low in magnitude because the incremental increases in certain water quality parameters attributable to the Project are within acceptable protective standards (i.e., water quality guidelines; Section 7.4.1). The confidence in this prediction is high. The residual effects of the discharge of treated effluent on the NSR have an overall impact rating of low.

Figure 7.7-2 Predicted Concentrations of Chloride Along the North Saskatchewan River for the Baseline Case

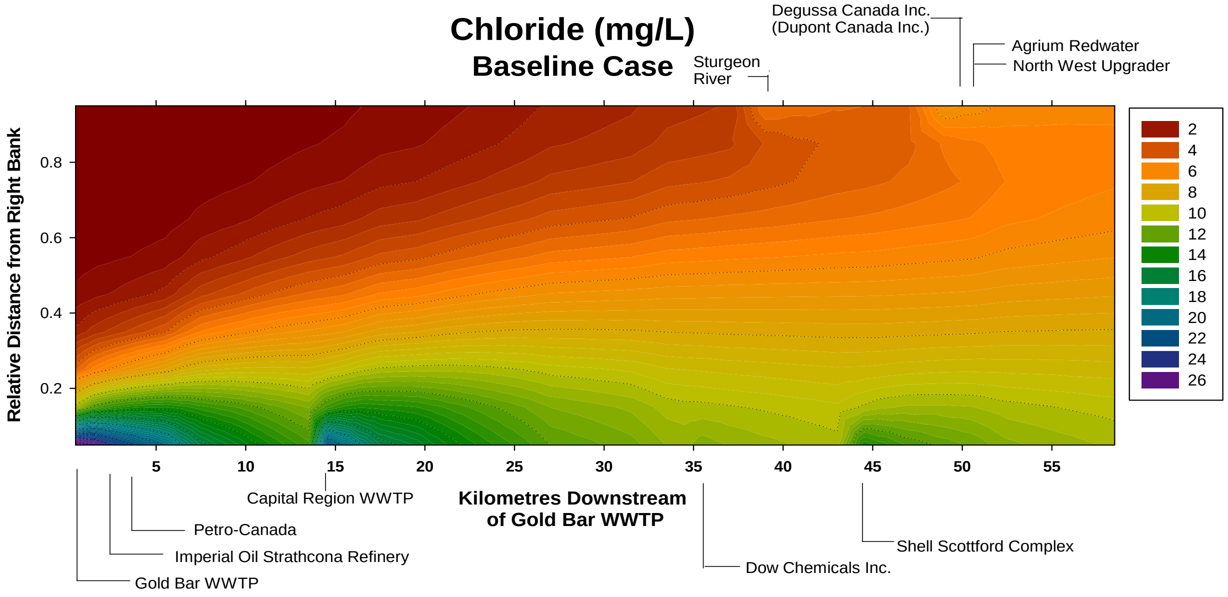


Figure 7.7-3 Predicted Concentrations of Chloride Along the North Saskatchewan River for the Application Case

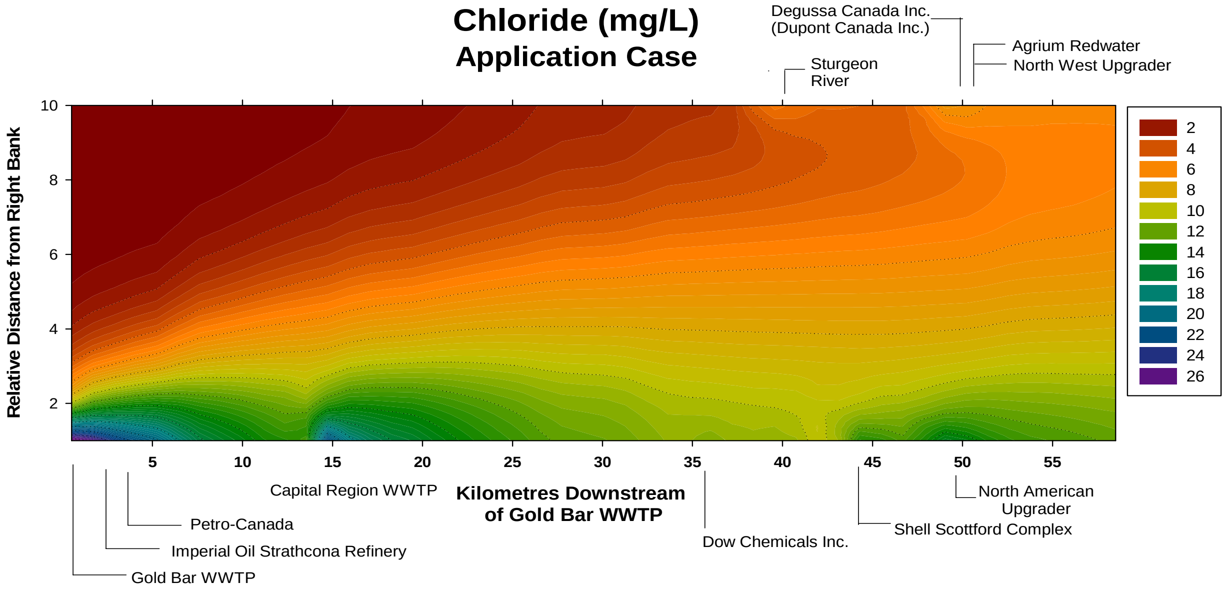


Figure 7.7-4 Predicted Concentrations of Chloride Along the North Saskatchewan River Near the Project for the Application Case (Close-up View)

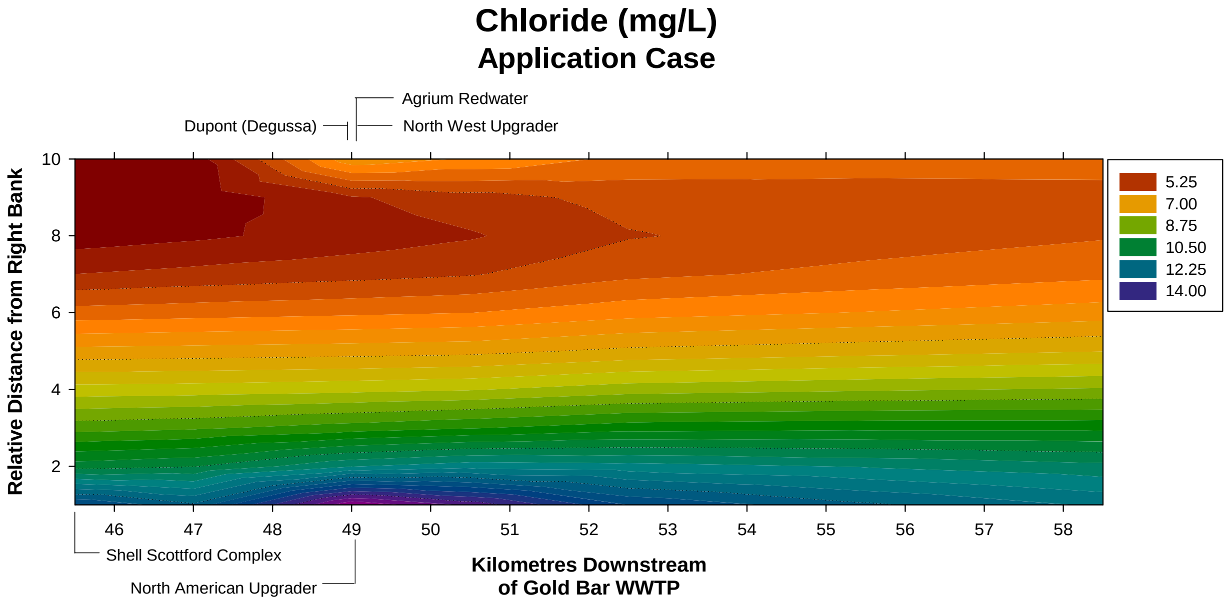

Chloride (mg/L)
Application Case

Figure 7.7-5 Predicted Concentrations of Chloride Along the North Saskatchewan River for the Cumulative Case

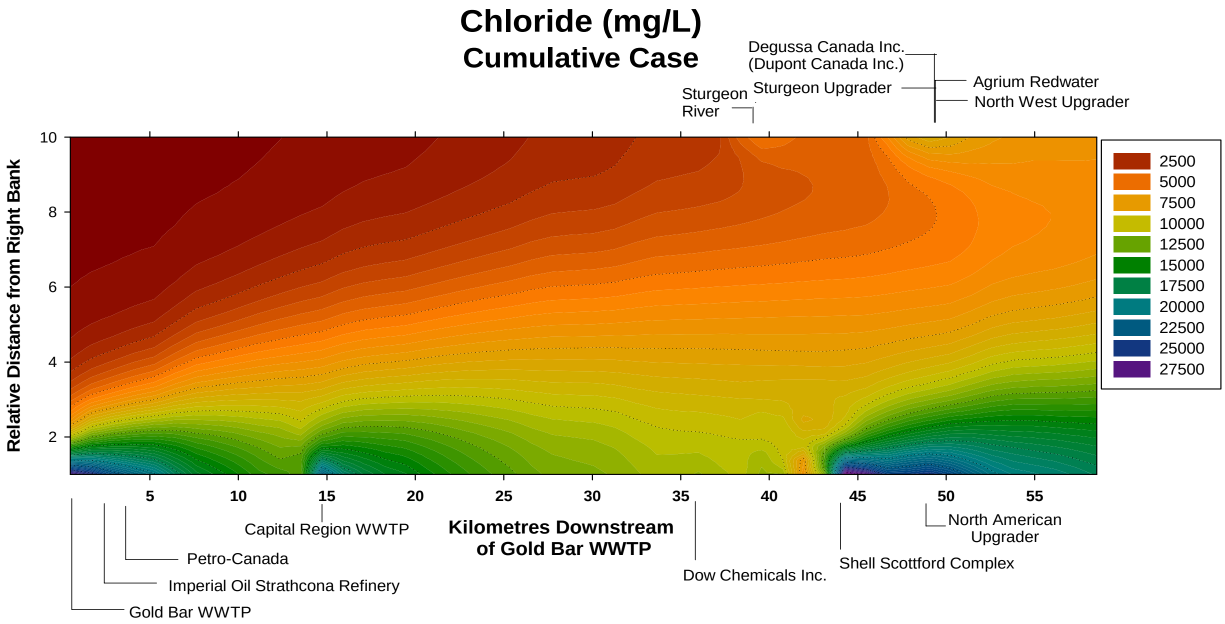

Chloride (mg/L)
Cumulative Case

Figure 7.7-6 **Average Concentration of Chloride Along the North Saskatchewan River Downstream of Gold Bar WWTP**

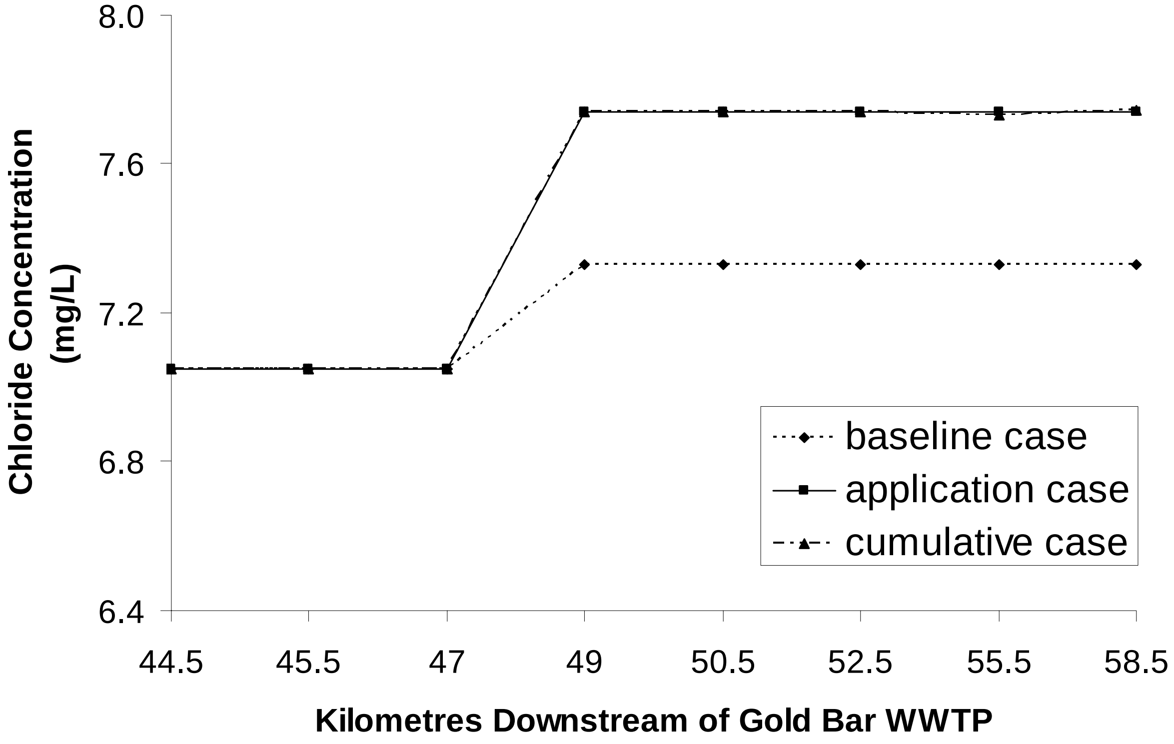


Figure 7.7-7 Predicted Concentrations of COD Along the North Saskatchewan River for the Baseline Case

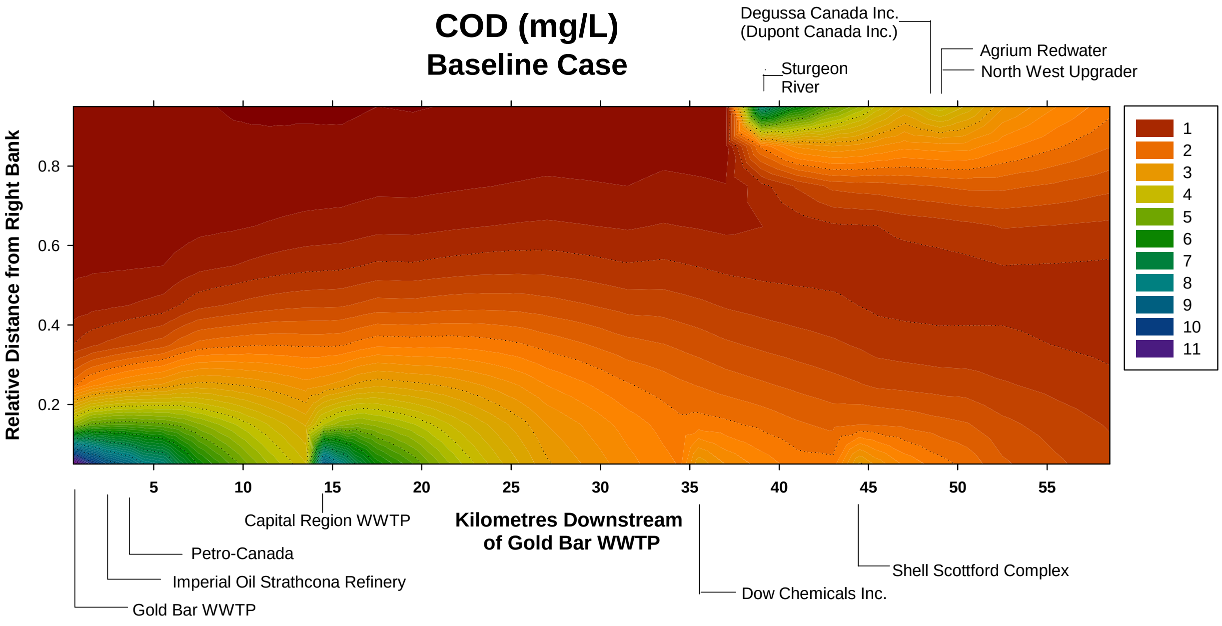


Figure 7.7-8 Predicted Concentrations of COD Along the North Saskatchewan River for the Application Case

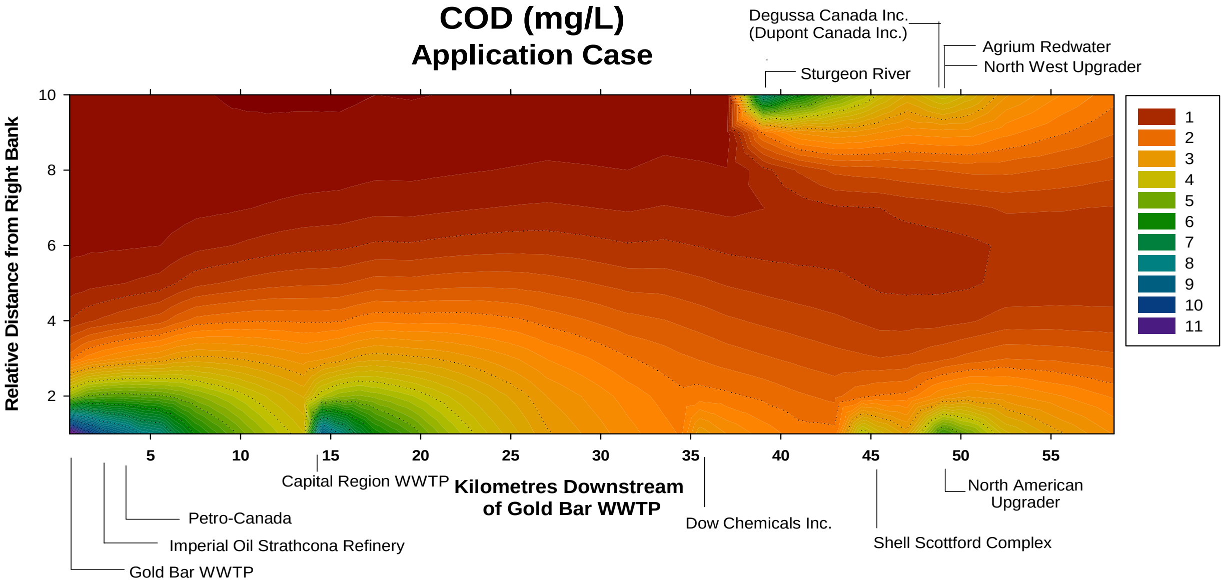


Figure 7.7-9 **Predicted Concentration of COD Along the North Saskatchewan River Near the Project for the Application Case (Close-up View)**

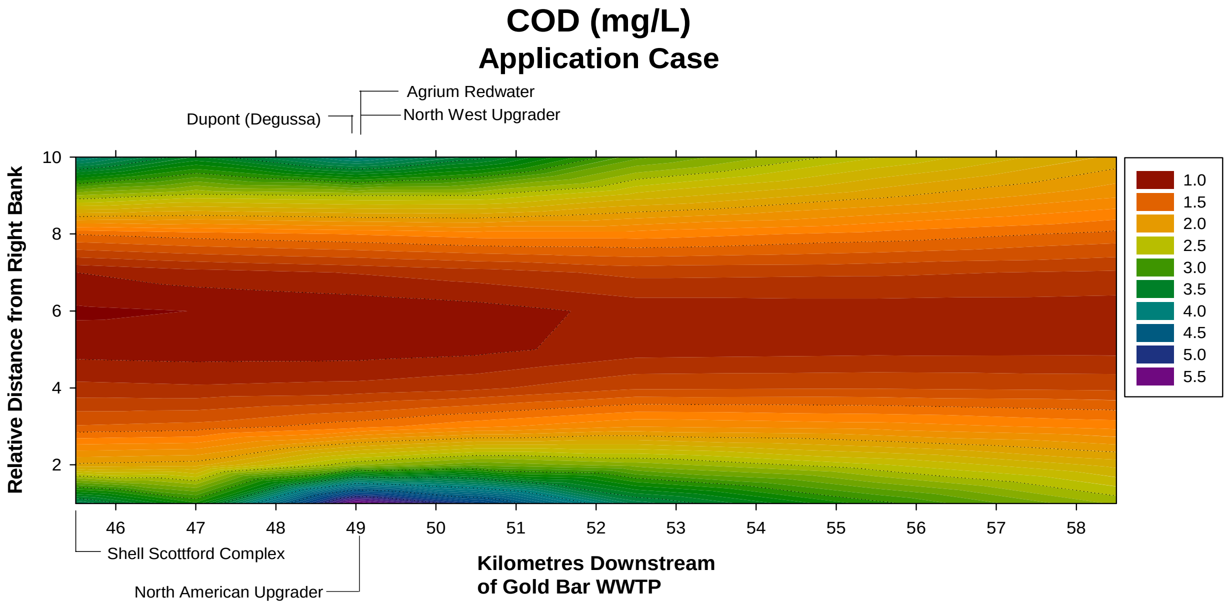


Figure 7.7-10 **Predicted Concentrations of COD Along the North Saskatchewan River for the Cumulative Case**

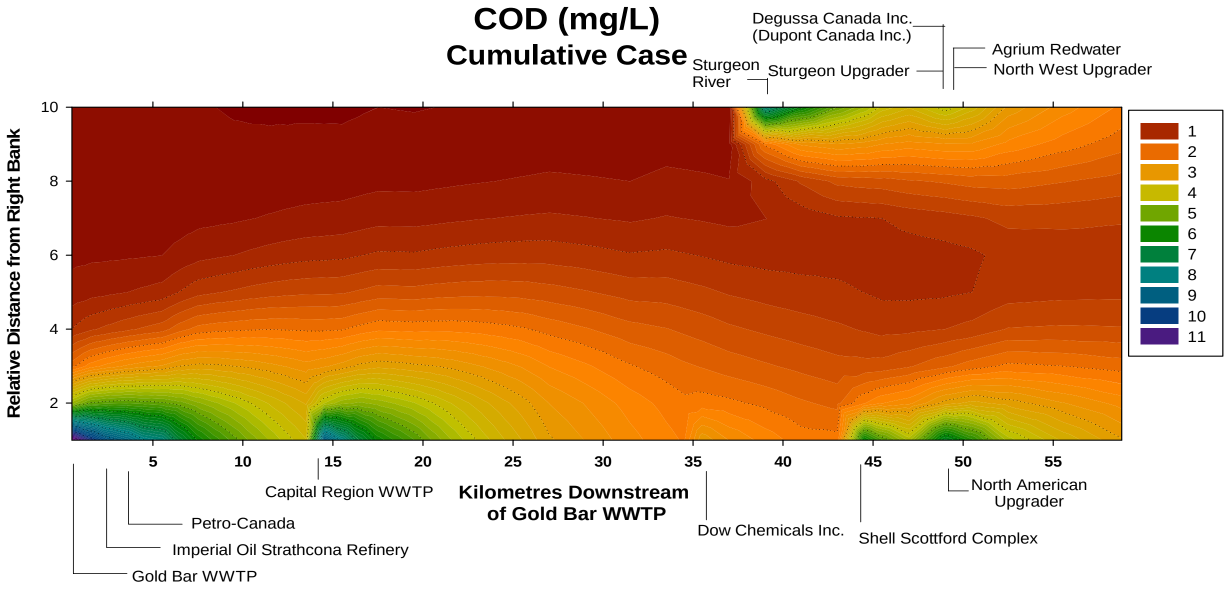
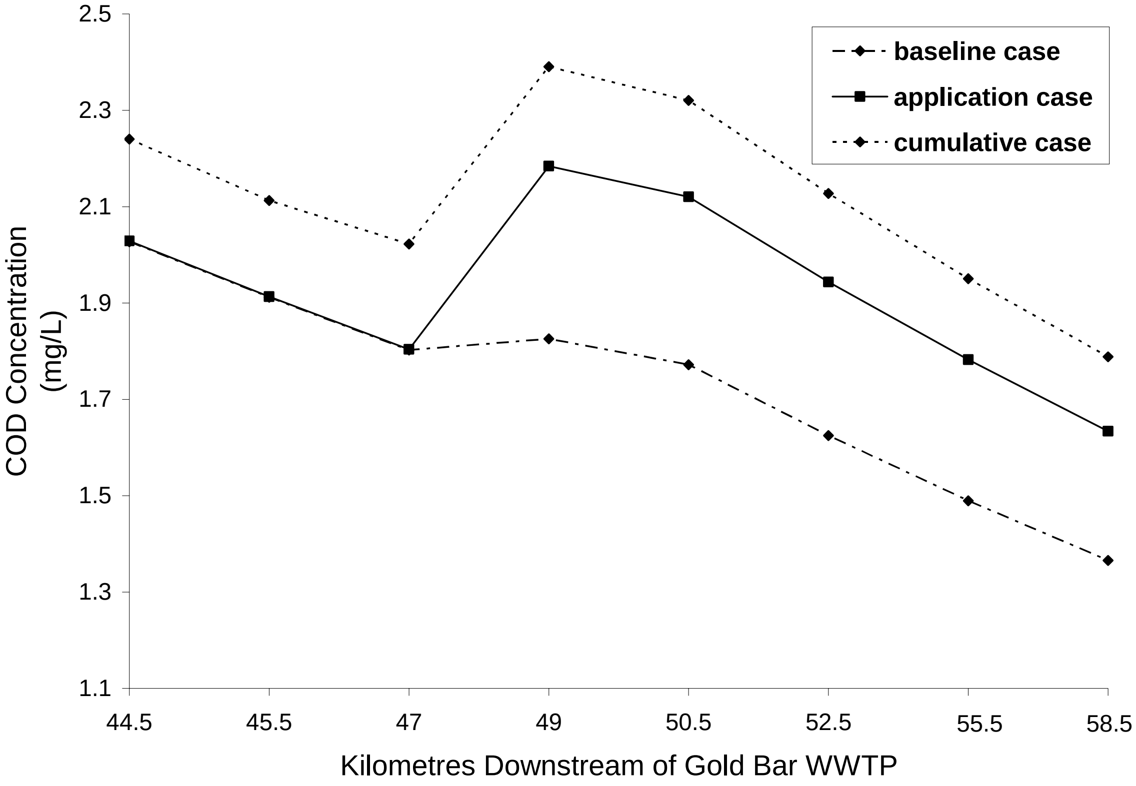


Figure 7.7-11 Average Concentration of COD in the North Saskatchewan River Downstream of Gold Bar WWTP



7.7.6.4 Stormwater Control and Treatment

All surface runoff during both the construction and operations phases will be directed to either the potentially contaminated stormwater pond, the oily stormwater pond or one of four clean stormwater ponds in the undeveloped areas of the site (3) and the administration area (1). The collected stormwater will either be reused within the plant, released to the North Wetland Complex or treated as required and released only when it meets provincial discharge criteria. No surface runoff or process-affected runoff will be directly released to surface waters. Appropriate containment and spill responses will reduce the likelihood for contaminants being released to surface waters.

With the planned mitigations for surface runoff, the likelihood for substantial releases of either sediment or process-related chemicals to surface waters is low. Therefore, only minimal changes to surface water quality are predicted. Suspended sediment concentrations in local surface waters might change measurably, but are expected to remain within natural variation. Therefore, the residual effects of surface runoff on surface water quality will be low in magnitude, medium-term in duration, reversible and will have low environmental consequence. The residual effects from stormwater discharge on surface water quality will have an overall impact rating of low.

Stormwater will be collected and retained on-site through site grading, berms and a network of drains, sewers, ditches and ponds. The stormwater management and site drainage system is shown in Figure 6.6-1 of the Hydrology section (Volume 3, Section 6). The site will be graded, and perimeter berms and ditches constructed, as required, to prevent stormwater runoff from leaving the site by overland flow. The ponds used to temporarily store stormwater collected from the developed areas of the Project site will be lined to prevent accidental contamination to underlying groundwater. In addition, the process areas will be surfaced with concrete and/or asphalt to limit stormwater infiltration in these areas. Stormwater collected on the developed areas of the project site is categorized as either “potentially contaminated stormwater” or “oily stormwater” and will be directed to the appropriate containment pond. Stormwater collected on the undeveloped areas of the site and the administration area is categorized as “clean stormwater,” and will be used to supplement raw water, released to the North Wetland Complex, or transferred to the effluent pond.

Stormwater runoff collected from the coke-handling area will be contained and recycled for coke wetting. Excess runoff from this area will be used for coke-cutting operations. Only under conditions of excessive runoff will stormwater from the coke-handling area be diverted to the oily stormwater pond.

Potentially Contaminated Stormwater

Potentially contaminated stormwater is defined as surface drainage collected from areas of the site that have a low risk of hydrocarbon contamination. These areas generally include portions of the site that are outside the processing areas. The potentially contaminated stormwater will be collected in a series of open ditches that drain to the potentially contaminated stormwater pond. Clean stormwater from the undeveloped Project area and administration areas will be collected in four satellite holding ponds.

Following a storm event, the contents of the potentially contaminated stormwater pond will be sampled for hydrocarbon contamination. Clean stormwater will be directed to either the raw water pond for process use, or to the effluent pond for river discharge. Clean stormwater may also be released periodically to the North Wetland Complex to maintain natural water levels. If it is determined that the stormwater is contaminated, it will be sent to the wastewater treatment unit for treatment. Free-phase hydrocarbon that collects on the surface of the potentially contaminated stormwater pond will be removed using a floating skimmer and vacuum truck.

Clean stormwater retained in the four satellite stormwater holding ponds that meets release criteria will be periodically released to either the raw water pond, effluent pond or North Wetland Complex. Contaminated water from the satellite stormwater ponds will be transferred to the wastewater treatment unit.

Water collected within the bermed area of the tank farm following a storm event will be retained and analyzed for hydrocarbon contamination. Stormwater that meets release criteria will be released to the potentially contaminated stormwater system, and contaminated stormwater discharged to the oily stormwater sewer for treatment.

The potentially contaminated stormwater system is designed to provide stormwater retention for a 1:25-year, 24-hour storm event, plus freeboard. For the 1:25-year storm event, the pond levels will not exceed the invert of inlet sewers or ditches. For storm events that exceed the 1:25-year storm, water will be stored in the ponds above the inlet invert level, resulting in a backwater effect in the sewer and ditches.

Oily Stormwater Treatment

Oily stormwater is defined as water that is collected within processing areas that is at risk of hydrocarbon contamination. Oily stormwater will be collected within the processing areas through a series of catchbasins and underground sewers. The sewer system will include water seals to contain fire within any one catchment.

Oily stormwater collected from the various processing areas will be diverted to the oily stormwater collection hub, which incorporates lift pumps to transfer oily stormwater to the wastewater treatment facility. Oily stormwater in excess of the capacity of these pumps will overflow to the oily stormwater pond for temporary storage. Free-phase hydrocarbon will be retained in the collection hub for removal by vacuum truck, and free-phase hydrocarbon that forms on the surface of the oily stormwater pond will be removed with a floating skimmer and vacuum truck. The contents of the oily stormwater pond will be pumped to the wastewater treatment facility following the storm event. The oily stormwater system is designed to provide storage below the sewer invert for the greater of a 1:25-year storm event, or a fire event.

7.7.6.5 Containment and Collection of Spills

Spills, overfills and stormwater runoff will be contained, treated and disposed of in conformance with regulatory requirements. Product-transfer areas will be paved with concrete and graded, curbed or bermed to contain spills or overfills that might occur during the transfer process. Any spills in the plant will be contained through the stormwater system and routed for treatment. All storage tanks containing hydrocarbons will be protected with a secondary containment system and a leak detection system as per the appropriate provincial guidelines. The residual effects from spills on surface water quality will have an overall impact rating of low.

The water collected in the bermed tank areas will be considered contaminated until tested. Water collected in the bermed area will be held and tested before it is released. The drainage from bermed tank areas will be controlled by a sump and valve located at the low point of the area. Clean stormwater will be released to the potentially contaminated stormwater system, and contaminated stormwater discharged to the oily stormwater sewer for treatment.

Storage Tanks

Various hydrocarbon products from the process units and chemicals necessary for activities such as water treating will be stored in specific tanks. There will be no underground storage tanks. All tanks will meet the CCME Environmental Code of Practice for Aboveground and Underground

Storage Tank Systems Containing Petroleum and Allied Petroleum Products (CCME, 1993) and the AENV Secondary Containment for Aboveground Storage Tanks (AEP, 1997). Secondary containment will be installed in accordance with Alberta Energy and Utilities Board (EUB) Directive 055: Storage Requirements for the Upstream Petroleum Industry (EUB, 2001), and will include the following minimum requirements:

- A synthetic, impervious liner will be placed over the containment area and under the storage tanks. The liner will be 60-mil (0.060 inches or 1.52 mm) thick and will be keyed into the berm walls.
- A leak detection and collection system will be installed under each storage tank. A porous layer, consisting of sand or gravel, or a combination, will be placed over the synthetic liner and under the storage tanks to protect the liner and permit leaks to flow to a collection point in the bermed area. A collection pipe system will be installed in the porous layer and will be easily accessible for visual inspection. Each month the bermed area, storage tanks and visible liners will be inspected for signs of leaks or spills.

Custody transfer meters will be installed on feed and product pipelines for dilbit, diluent, naphtha and gas oil for leak detection and measurement.

Spill Response Procedures

In addition to engineered protection measures to protect against surface water contamination during operations, the following management steps will be taken to address spill readiness and response:

- A comprehensive spill response plan will be developed and implemented that provides for quick spill response, containment and cleanup.
- Appropriate spill control and treatment procedures will be established for each group of chemicals and hydrocarbons used and produced during the upgrading process, including containment, to prevent the spread of the material to other areas and treatment to render materials safe.
- All employees will receive training in spill prevention, control and reporting, and on the sensitivities of the local geography and surface waters to spills.
- Process units will include strategically placed spill kits to assist with spill containment, if required.
- All spills will be reported internally. Spills with volumes above reporting thresholds will be reported to regulators.

7.7.7 Effects of Acidic Emissions on Surface Water Quality in the RSA

The acidification of lakes has been linked in Europe and eastern North America to the deposition of acidifying emissions from industrial and municipal facilities. Oxides of sulphur and nitrogen (SO_x and NO_x) in these emissions result in the formation of acids that can reduce the acid-neutralization capacity of soils and surface waterbodies, and cause adverse effects on aquatic biota. Acidifying compounds will be emitted from the Upgrader throughout the entire operations phase of the Project.

The regional study area for the acidification assessment includes all lands covered by the Cumulative Case 0.17 keq H+/ha/y PAI isopleth (Figure 7.2-3). A level of acid deposition equivalent to 0.17 keq H+/ha/y level triggers increased monitoring of potentially affected waterbodies for acidification (CASA–AENV, 1999; Foster et al., 2001). As the PAI is largely dominated by contributions from the City of Edmonton, the analysis is concentrated on the eastern portion of the region where the potential effects of the Project would be most apparent.

In most assessments, the Henriksen steady-state model is applied to calculate critical loads for all lakes within the RSA for which water quality data are available. These lake-specific critical loads are then compared to the PAI at each lake modelled during the air quality assessment (Volume 2, Section 2). An exceedance of the critical load of acidity of a lake by the PAI implies that there is a potential for acidification of the lake. However, it does not mean that acidification is a certainty, or that it will occur imminently.

The Henriksen steady-state model could not be applied to the eight lakes in this study. The Henriksen model assumes that acid neutralizing capacity (ANC), in the form of base cations, is exported to each lake in surface runoff. The runoff, which is one of the terms of the model, is equivalent to the amount of water that would be measured at the lake outflow. Most of the lakes, however, do not have any outflow on a mean annual basis. Hence, there was no measurable runoff. In some cases, when surface evaporation is accounted for, the runoff is actually negative.

The lakes appear to receive a great deal of their water input from groundwater seepage. This is suggested in the extremely high conductivities and values of ANC for these lakes. The chemistry of the study lakes and the predicted PAI at each lake are presented in Table 7.7-7. The predicted PAI is derived from the air emissions assessment (Volume 2, Section 2). ANC ranged from 3,020 ueq/L in Oster Lake to 8,120 ueq/L in Cooking Lake. These extremely high values for ANC imply that the lakes are highly buffered and resistant to acidification.

The potential for acidification of these lakes between the Baseline Case and the Application Case is considered extremely low for the following reasons:

1. The high ANC of each lake. Lakes as highly buffered as these have a very low risk of acidification.
2. The incremental increase in PAI between Baseline and Application Cases is extremely small, and ranges from 0.003 keq H^+/ha/y to 0.010 keq H^+/ha/y.

The incremental increase in PAI between Application and Cumulative Cases ranges from 0.017 keq H^+/ha/y to 0.113 keq H+/ha/y.

Although a quantitative critical load assessment is not possible, the residual effects of acid emissions on the water quality of regional lakes will be negligible.

Table 7.7-7 Lake Chemistry, Hydrology and Potential Acid Input to Eight Regional Study Lakes

Lake	TDS (mg/L)	Conductivity (uS/cm)	Hardness (mg/L)	ANC (Alkalinity) (ueq/L)	Base Cations (ueq/L)	Lake Area (km^2)	Drainage Area (km^2)	Runoff (m^3/s)	PAI Baseline Case (keq H^+/ha/y)	PAI Application Case (keq H^+/ha/y)	PAI Cumulative Case (keq H^+/ha/y)
Oster	186	329	120	3,020	2,367	1.05	5.6	0	0.304	0.314	0.395
Adamson	209	348	140	3,140	2,603	0.42	4.3	0	0.274	0.282	0.356
Hastings	626	1,050	280	5,580	8,243	8.22	76.4	0	0.111	0.114	0.137
Wanisan	233	406	180	3,000	2,566	2.68	15.7	0	0.148	0.151	0.184
Cooking	1,230	1,870	260	8,120	18,263	42.9	196	0	0.127	0.129	0.146
Tawayik	483	758	180	4,340	6,068	3.79	18.4	0	0.225	0.234	0.308
Astotin	290	504	180	4,760	3,838	5.8	52.2	0	0.213	0.231	0.344
Antler	287	507	148	3,940	3,918	2.4	18.4	0.0004	0.193	0.196	0.223

7.8 Cumulative Effects Assessment

7.8.1 Erosion and Sediment Control

The residual effects of sediment release during construction will not contribute measurably to cumulative effects on surface water quality.

7.8.2 Dewatering

The residual effect of dewatering will not contribute measurably to cumulative effects on surface water quality.

7.8.3 Effects of Effluent Discharge on the LSA and RSA

The residual effects of the discharge of treated effluent on the NSR have an overall impact rating of low.

7.8.4 Surface Water Runoff

Surface runoff will not contribute measurably to cumulative effects on surface water quality.

7.8.5 Spills

Spills will not contribute to cumulative effects on surface water quality.

7.8.6 Acidification of Regional Lakes

PAI will not contribute to acidification of regional lakes.

7.9 Follow-up and Monitoring

Water contained in the stormwater ponds will be monitored before it is discharged to the raw water pond, North Wetland Complex or NSR for comparison to regulatory discharge criteria. Monitoring parameters will include pH, turbidity, TSS, ammonia, TP, cyanide and metals.

The Upgrader final effluent will also be monitored before it is discharged to the NSR to ensure it complies with regulatory discharge criteria. Monitoring will consist of continuous temperature, pH and flow measurements, while other water quality variables will be measured through composite sampling. Parameters to be monitored will include pH, turbidity, TSS, major ions, ammonia, nitrates, TP, cyanide, metals, BOD and COD, and other parameters as directed by AENV. AENV will establish the effluent discharge limits and specific monitoring requirements in the Project Approvals.

7.10 Impact Summary

The summary of residual effects for surface water quality (after mitigation) are presented in Table 7.10-1. The application of the appropriate measures described above during construction and operations is expected to mitigate the potential effects of runoff and sediment release to local waterbodies and the NSR. Effluent recycling will reduce the volume of effluent and the load of the various chemical parameters in the effluent.

The CORMIX modelling of the predicted effluent discharge indicates that AENV's mixing zone regulations will be met in the LSA. No chronic water quality guidelines will be exceeded at the edge of the mixing zone of the proposed treated effluent outfall (1.29 km downstream), with the exception of TP and TN, that are already exceeded upstream of the proposed discharge. These parameters will attain near-background concentrations when the effluent discharge is fully mixed. The increase in TN is due largely to the loading of reduced nitrogen compounds measured as TKN.

Although no guidelines are exceeded, certain major ions, including sodium, chloride and sulphate, are predicted to increase incrementally downstream of the discharge, even after complete mixing. These increments are theoretically measurable, although they fall within the normal seasonal variability of these parameters.

The loading analysis indicated that the Project would contribute almost 7.6% of the COD loading to the NSR. However, the WASP modelling showed that the incremental increase in this parameter would be very small and analytically undetectable.

The release of sediment and surface runoff will have a low impact on local waterbodies. Effluent discharge to the NSR will have a low impact on regional water quality. The effects of dewatering on local waterbodies and the release of acidifying emissions on regional lakes will be negligible. The overall impact of the Project on surface water quality is rated as low.

Table 7.10-1 Summary of Residual Effects for Surface Water Quality

Water Quality Issue	**Direction of Impact**	**Extent of Impact**	**Magnitude of Impact**	**Duration of Impact**	**Frequency of Occurrence of Impact**	**Permanence of Impact**	**Level of Confidence**	**Overall Impact**
Sediment release to waterbodies	negative	local	low	short-term	occasional	reversible	high	low impact
Dewatering	negative	local	negligible	-	-	-	-	negligible impact
Effluent Discharge to the North Saskatchewan River	negative	regional	low	medium-term	continual	reversible	high	low impact
Surface Runoff release	negative	local	low	medium-term	occasional	reversible	high	low impact
Spills	negative	local	low	short-term	-	-	-	low impact
Acidification of Regional Lakes	negative	regional	negligible	-	-	-	-	negligible impact

7.11 Literature Cited

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8 FISH AND FISH HABITAT

8.1 Introduction

The fish and fish habitat section provides an assessment of the fish and fish habitat and benthic invertebrate communities on the North American Project site, as well as in the local and regional study areas directly related to North American's development plans. Field assessments focused on determining presence and absence of fish species in the region, as well as the quality and availability of fish habitat (including the benthic invertebrate community).

In addition to conducting detailed field assessments related to the Project, an assessment of existing historical data related to the area was conducted. The historical data compiled were used to aid in the determination of general fish and fish habitat observed in the region.

The impact assessment for the Project was based upon measured, predicted or reasonably expected changes in some attributes of a selected indicator. Indicators (i.e., fish, benthic invertebrates) were chosen to represent important components of fish and fish habitat. The predicted response of the indicator resources was used to ascertain the level of effects to fish and fish habitat related to the Project. Assessments of potential effects were described in terms of:

- direction (positive or negative effect);
- extent (area of potential change);
- magnitude (amount of change);
- duration (length of time over which change may occur);
- frequency (regularity of impact);
- permanence (reversibility of impact);
- confidence (level of understanding); and
- environmental impact.

A final qualitative impact rating provides guidance as to whether further measures should be considered. Measures including mitigation, monitoring and other means of preventing habitat loss are discussed in detail and relate to potential project activities.

8.2 Study Areas

For the purpose of conducting the assessment of fish and fish habitat related to the Project, a Local Study Area (LSA) and a regional Study Area (RSA) were identified. The study areas were selected to document the aquatic resources as discussed in the Hydrology and Surface Water Quality (Volume 3, Sections 6.2 and 7.2, respectively).

8.2.1 Local Study Areas

The Fish and Fish Habitat and hydrology LSA was established to assess the potential for localized effects on water quality, hydrology and fish and fish habitat, and was delineated based on the Project footprint, local drainage basin boundaries and local effects on the NSR. The fish and fish habitat LSA includes all Project disturbance activities consisting of the plant area, roads, pipelines and river intake. The hydrology LSA boundaries, as shown in Figure 8.2-1, are defined as follows:

- Astotin Creek watershed boundary to the south;
- Beaverhill Creek to the northeast;
- north-south Range Road 214, which forms the western limit of Astotin Creek watershed; and
- a 15 km reach of the NSR on the north from upstream of the existing Shell Canada Scotford Complex river intake to below the confluence with Beaverhill Creek (approximately 5 km downstream of the proposed river intake and outfall)

In order to capture the areas which may be impacted as a result of Project development, the local study area included the Astotin Creek drainage, the lower Beaverhill Creek drainage (downstream of where Astotin Creek enters) and the North Saskatchewan River (NSR). Detailed studies were conducted within these study areas, and the information collected is used to provide a general overview of the waterbodies and watercourses in the entire region.

Astotin Creek/Beaverhill Creek Area

The Astotin Creek/Beaverhill Creek Area (Figure 8.2-1) is delineated by watershed boundaries for Astotin Creek and several tributaries and lakes associated with the Astotin Creek Watershed. A total of three watercourses (Astotin Creek, Beaverhill Creek and one unnamed) and two waterbodies (Astotin Lake and Antler Lake) were visited in 2006/2007 field surveys.

NSR Area

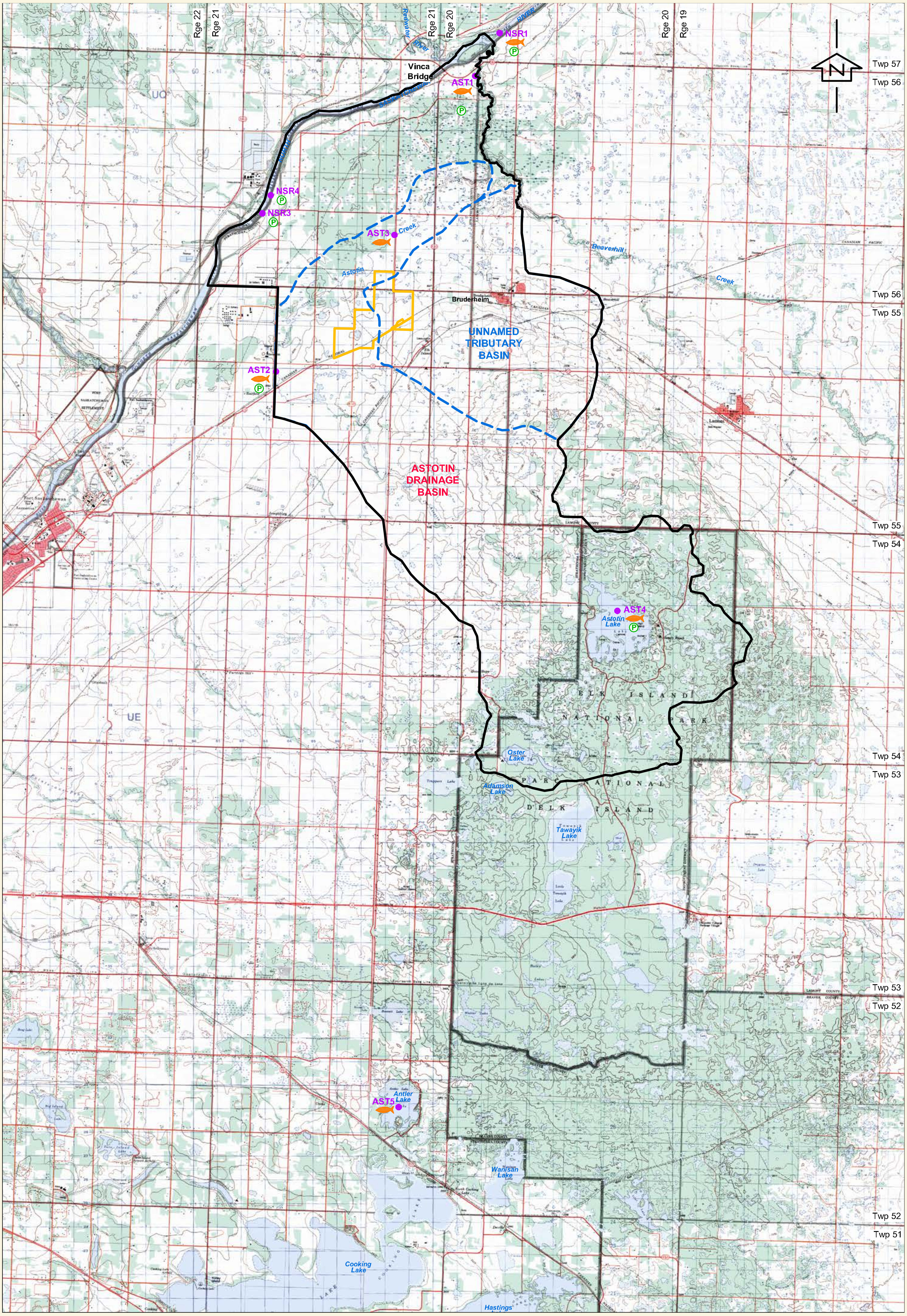
Detailed studies were conducted on a 15 km reach of the NSR from upstream of the existing Shell Canada Scotford Complex river intake to the confluence with Beaverhill Creek, approximately 5 km downstream of the proposed outfall. The outfall location is described in the Hydrology Section (Section 6). The studies were conducted along the south bank of the 10 km reach.

8.2.2 Regional Study Area

The RSA is defined primarily on the basis of potential impacts of the Project on flows and levels in the NSR. It defines the study area where any cumulative effects are expected to occur. In view of the Alberta-Saskatchewan Apportionment Agreement, the RSA is extended from the Gold Bar Waste Water Treatment Plant (WWTP) in Edmonton to the Alberta-Saskatchewan border, to identify any implications in meeting the 50% apportionment requirement with Saskatchewan. The main area of regional aquatic resource assessment includes a 62 km stretch of the NSR from the confluence with Beaverhill Creek downstream of Vinca Bridge to the Saskatchewan/Alberta border. Antler Lake, south of Astotin Lake (Figure 8.2-1) was included in the RSA in order to define the existing fish and fish habitat conditions for that area. The RSA is defined on the basis of potential impacts of the Project on flows and levels in regional rivers, lakes and streams and the likelihood of potential acid input (PAI) and the issue of potential lake acidification and eutrophication.

Consideration was also given to locations where potential for impacts to the surface water/groundwater interactions exists.

*PLOT 1:1 = Letter (P)



LEGEND

- North American Property Boundary
- Local Study Area (LSA)
- Sub-basin
- ● Sample Location
- Fish and Fish Habitat Sample
- Ⓟ Periphyton Sample

SCALE 1:150000 kilometres
1.5 0 1.5 3.0

Title:

FISH AND FISH HABITAT SAMPLING LOCATIONS

NORTH AMERICAN
OIL SANDS CORPORATION

Approved: BE	Revision Date: 07/07/04
File: 6198-SITESW-07.DWG	

Drawn by: GDE	Checked: DLC	Fig. No.: 8.2-1

F:\6198\Drafting\2007\6198-SiteSW-07.dwg - Fish - Saturday, October 20, 2007 1:32:12 PM - Barry Wheeler

8.3 Issues and Assessment Criteria

Activities associated with the Project, including construction, operation and reclamation, have the potential to affect fish and fish habitat in watercourses and waterbodies within the study areas. The aquatic resources assessment considered project activities that might cause direct physical impacts to fish and fish habitat, as well as indirect effects associated with changes to surface water quality and hydrology.

The following key issues for aquatic resources have been identified. They are based on public and regulatory consultations, professional experience and the issues identified with other developments in the Fort Saskatchewan area.

The Project could potentially impact the aquatic resources within the study area in the following ways:

- riparian and instream fish habitat alteration:
    - sedimentation;
    - changes to water flows and levels;
    - riparian habitat degradation; and
    - changes in benthic invertebrate abundance and composition.
- combined industrial disturbance on fish habitat:
    - spill and discharges;
    - changes in surface water pH; and
    - increased access.

These potential effects on fish and fish habitat can ultimately affect fish health and/or fish abundance.

8.4 Methods

The methods used for the fish and fish habitat assessment of watercourses and waterbodies included a review of historical fisheries data and field assessments to evaluate the current baseline conditions of fish habitat and fish community structure. During field assessments, data were collected, using standardized operating procedures, and checked through quality assurance reviews. Results were then analyzed and summarized.

8.4.1 Historical Resources

A review of existing information was conducted to aid in the development of the baseline conditions related to the Project area. The information collected in review came from a number of sources, including existing baseline reports related to similar projects in the area, regional studies, government databases and information contained in current regulatory publications. Several projects in the area have assessed and characterized watercourses and waterbodies with similar characteristics as those captured within the Project area. The data provided in the studies in the Project area were reviewed and used in this assessment where it was deemed relevant (Synenco Energy, 2006; North West, 2006; PCOSI, 2006; Shell, 2005).

Historical information on the fish community associated with the Project area was also acquired from the Alberta Sustainable Resource Development (ASRD) Fisheries Management Information System (FMIS) during consultation with representatives of ASRD (2006) (Table 8.4-1). Sites included in the search consisted of watercourses and waterbodies visited during the sampling program associated with the Project, and waterbodies on or within close proximity to the Project areas.

Additional information related to fish species presence in the area was attained through various sources, including the Alberta Guide to Sportfishing Regulations (ASRD, 2007a; Mitchell, 2007).

Table 8.4-1 Waterbodies and Watercourses Included in a Search of FMIS

Site Name	Aquatic Type	LSD	Section	Township	Range	Meridian
Beaverhill Creek (AST 1)	Watercourse	9	31	56	20	4
Astotin Creek (AST 2)	Watercourse	13	21	55	21	4
Astotin Creek (AST 3)	Watercourse	8	11	56	21	4
Astotin Lake (AST 4)	Waterbody	13	23	54	20	4
Antler Lake (AST 5)	Waterbody	15	14	52	21	4
Astotin Creek (AST 6)	Watercourse	5	32	54	20	4
NSR (NSR 1)	Watercourse	15	5	57	20	4

8.4.2 Species at Risk and of Special Concern

A search of existing databases was conducted to determine the presence of Species at Risk and Species of Special Concern within the vicinity of the Project area. Database inquiries included a search of the Alberta Species at Risk (SARA) (ASRD, 2007b) listings, as well as the lists generated by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (Environment Canada, 2007). Information from these lists was cross-referenced with lists of fish species known to exist in the vicinity of the Project area.

8.4.3 Fish and Fish Habitat Surveys

8.4.3.1 Scope, Timing and Locations of Work

Field surveys were conducted at different times of the year in order to assess the seasonal use of the watercourses and waterbodies by fish species in various life stages. For the purpose of this survey, data were collected from selected study sites within the LSA during summer and fall of 2006 and the winter and spring of 2007. Study sites were selected based on probability of providing fish habitat and potential to support fish communities.

Two waterbodies within the LSA were selected for study, based on their probability of providing fish habitat and supporting fish communities. Representative waterbodies included a relatively shallow lake (Antler Lake), as well as a deeper lake (Astotin Lake), with one or more inlets and/or outlets. Seasonal field studies were conducted at each waterbody to provide data pertaining to the habitat use potential and the fish communities present. Fishing was not conducted in Astotin Lake.

Representative watercourse locations were used to determine typical existing baseline habitat conditions, fish community structure and fish habitat usage within the Project area (Figure 8.2-1 and Table 8.4-2). A total of four watercourse study locations were evaluated during the baseline assessment within the LSA. Of the four study sites, two were located on the mainstem of Astotin Creek, one site was located on Beaverhill Creek and one was located on the NSR.

Within the Project area, Astotin Creek generally flows in a north-northeast direction before flowing to the north into Beaverhill Creek. Beaverhill Creek generally drains in a northwest direction before it flows into the NSR within the LSA. Baseline seasonal sampling examined representative sites for the potential to provide fish habitat and to support fish communities.

8.4.3.2 Field Sampling Methods

Various field sampling techniques were used to assess fish communities and fish habitat in the selected watercourses and waterbodies. Sampling methods were selected for each site based on the most appropriate method for the season and site conditions. The timing of seasonal sampling activities conducted at sampling sites are outlined in Table 8.4-2.

The seasonal baseline field assessments for watercourses included, as appropriate:

- habitat mapping of all relevant instream and bank habitat characteristics, to provide an inventory of available spawning, rearing, feeding and overwintering habitats;
- measurement of average channel dimensions;
- identification of features that may affect fish movement and fish migration potential;
- measurement of stream discharge to help evaluate habitat use potential;
- measurement of water quality parameters (i.e., pH, conductivity, temperature and dissolved oxygen (DO));
- description of riparian vegetation;
- investigation of under-ice habitat and overwintering potential;
- fish inventory, to determine the fish community present; and
- photographs documenting available habitat types and general stream morphology.

The seasonal baseline field assessment of waterbody sites included, as appropriate:

- habitat mapping of the waterbody basin and shoreline characteristics (including distribution of aquatic macrophytes);
- confirmation of basin dimensions and depths;
- examination of inlet and outlet channels to evaluate fish passage potential;
- measurement of water quality parameters (i.e., pH, conductivity, temperature and DO) along a vertical profile or series of profiles at various depths;
- description of riparian vegetation;
- investigation of under-ice habitat and overwintering habitat potential;
- fish inventory to determine the fish community present; and
- photographs documenting available habitat types and general basin morphology.

Details of the various field sampling activities for habitat evaluation and fish sampling techniques are provided below.

8.4.3.3 Habitat Mapping

Habitat mapping was used to provide an inventory of habitats available, and also to detail the location and extent of each stream or lake habitat type within the study reach. The habitat classification system is intended to be ecologically meaningful with respect to describing and cataloging physical habitats in relation to requirements of fish species and their various life stages (spawning, incubation, nursery, rearing, summer feeding, holding, overwintering and migration), and also, to a lesser extent, the relationship between physical habitat and benthic invertebrate productivity, at least with respect to fish food. Detailed habitat maps were generated for each sampling site, where possible. The location and timing of watercourse and waterbody sampling are detailed in Table 8.4-2.

Table 8.4-2 Sampling Site Locations and Seasonal Field Survey Dates

Study Site ID	Sampling Date	UTM (NAD 83-Zone 12)	
		Easting	Northing
AST 1 Figure 8A-2	Aug 28/06 Oct 24/06 Jan 23/07 May 1/07	371701	5972559
AST 2 Figure 8A-3	Aug 28/06 Oct 23/06 Jan 23/07 Apr 30/07	363312	5960108
AST 3 Figure 8A-4	Aug 29/06 Oct 23/06 Jan23/07 April 30/07	368300	5965864
AST 4 Figure 8A-5	Aug 29/06 Oct 24/06 Jan 24/07 May 2/07	377690	5950025
AST 5 Figure 8A-6	Aug 29/06 Oct 24/06 Jan 24/07 May 1/07	368476	5929118
AST 6* Figure 8A-7	May 3/07	372925	5952410
NSR 1 Figure 8A-8	Aug 30/06 Oct 24/06 Jan 23/07 May 3/07	372727	5974369

*Only benthic and periphyton samples were collected at this site.

Waterbodies

Two waterbodies within the study area were selected for detailed assessments, based on their locations and the probability of providing fish habitat and supporting fish communities. Seasonal field studies were conducted at each waterbody to provide baseline data pertaining to the habitat use potential and the fish communities present.

Waterbodies were mapped during open-water season (i.e., spring or summer), when habitat features were most visible. Bathymetric surveys were conducted to determine the extent of the habitat types and to identify shallow littoral zones and deep pelagic zones. Habitat maps were developed to show the location of shoreline characteristics and the distribution of aquatic vegetation.

The physical characteristics recorded for each waterbody included:

- inlet and outlet locations and condition;
- water depths;
- distribution of aquatic macrophytes (submergent, emergent and floating-leaved vegetation);
- shoreline slope and stability;
- riparian vegetation; and
- water quality characteristics (i.e., pH, conductivity, temperature and DO) at varying depths.

The habitat use potential for each waterbody was evaluated based on habitat characteristics, such as the proportions of the available habitat types, water depths, substrate material, vegetation distribution and shoreline development, using the Fish Habitat Manual (Alberta Transportation and Utilities, 2001). Analysis of these types of habitat parameters provides an indication of the potential suitability of the habitats for use by fish species in various stages of life.

Watercourses

A total of four sampling locations were assessed in the study area for fish and fish habitat potential. Two sampling sites were selected on Astotin Creek (AST 2, AST 3), one sampling site was selected on Beaverhill Creek (AST 1) and one site on the NSR (NSR 1).

Representative locations were used to determine typical baseline habitat conditions, fish community structure and fish habitat usage. Watercourses were mapped during open-water season, namely spring or summer, when habitat features were most visible. The location and extent of all instream habitat types and bank characteristics of each watercourse sampling site were mapped to provide an inventory of available habitats. Typical habitat units include riffle, run and pool-type habitats.

The physical characteristics recorded for each sampling site included:

- channel unit type;
- maximum water depth;
- dominant substrate type and size classification;
- channel dimensions, including mean channel width and wetted width;
- debris piles (small and large woody debris);

- cover for fish, including both instream (velocity shelter) and overhead (visual isolation) cover;
- aquatic vegetation;
- water quality characteristics (i.e., pH, conductivity, temperature and DO);
- features that might impede fish movements (i.e., beaver dams);
- bank features, including areas of unstable bank and areas of overhanging vegetation or undercut banks; and
- riparian plant community composition.

At each sampling site, representative photographs were taken to illustrate physical characteristics such as bank conditions, bank profiles, riparian areas, channel characteristics and general terrain layout.

The habitat use potential for study sites was evaluated relative to the habitat requirements of the local fish species and life stages (e.g., spawning, rearing and feeding), the types and proportions of the available channel units, average water depths and substrate material.

Discharge Measurements

Stream discharges were measured at study sites during seasonal sampling activities. Discharge measurements were conducted according to standard industry protocols. Measurements were conducted using a calibrated tagline to determine horizontal stations, and a Pygmy Water Velocity Meter and top setting-wading rod to measure water depth and velocity. The horizontal station distance, water depth and water velocity data were used to calculate the total stream discharge. Measurement of discharge was not possible at some locations due to safety concerns, the lack of measurable flow or the lack of a defined channel. Field discharge measurements were not collected on the NSR.

Water Quality Parameters

Water quality parameters (i.e., water temperature, DO, pH and conductivity) were measured at study sites during seasonal sampling activities. In watercourses and waterbodies, water quality parameters were measured at one or more locations along a vertical profile. Surface water quality and water quality profiles were measured using a YSI 556 Multi-Parameter handheld water quality meter equipped with a 30-m cable.

Overwintering Habitat Assessment

Overwintering habitat assessments evaluated the potential for watercourses and waterbodies to provide habitat for fish throughout the winter season. The assessment was conducted in winter to represent accurately the limiting conditions for fish potentially overwintering in these habitats.

The winter field assessment of watercourse sites included the following:

- measurement of ice thickness and under-ice water depth;
- measurement of water depth and velocity along a transect to determine average depth and velocity;

- measurement of stream discharge, where possible;
- measurement of water quality parameters (i.e., water temperature, DO, pH and conductivity); and
- fisheries inventory to determine fish presence.

The winter field assessment of waterbody sites included the following:

- measurement of ice thickness and under-ice water depth;
- measurement of water quality field parameter profiles (i.e., water temperature, DO, pH and conductivity); and
- fisheries inventory to determine fish presence.

8.4.3.4 Fish Inventory

Fish sampling was conducted at each watercourse and waterbody sampling site to determine the fish communities present. A variety of sampling techniques were used to determine the species and life stages of the fish that use these systems.

Fish sampling techniques employed during field investigations included:

- electrofishing in wadeable watercourses (Smith-Root Type 12b backpack electrofisher);
- baited standard Gee minnow traps;
- baited setlines; and
- test netting (multi-panel gill nets with eight 5.7-m panels with mesh sizes ranging from 25.4 mm to 152.4 mm).

Fish sampling methods were employed as site specific conditions allowed. For detailed sampling techniques and sampling methods used at each site, see Appendix 8A, Figures 8A-1 to 8A-7.

8.4.3.5 Seasonal Sampling

Seasonal sampling of study sites was conducted in an attempt to gather data on fish presence and fish habitat utilization at various times of the year. Some fish species may require different habitat types at different stages of their life cycle. Seasonal habitat assessments provide a representative view of habitat utilization by fish species at various stages in their life cycle. Where conditions permitted, sampling of aquatic environments included minnow trapping, set-lining and electrofishing as outlined in Section 8.4.3.4.

Spring, Summer and Fall Sampling

Minnow trapping, setlines, and backpack electrofishing were used on watercourses to assess fish populations and habitat conditions during open-water seasons. Large multi-panel gill nets were used to sample waterbodies.

Standard Gee-type minnow traps were used to sample for forage fish and juvenile sportfish species. The minnow traps were baited to attract fish and placed in locations suitable for small-bodied species. The traps were set at study sites with sufficient water depths (generally ≥0.4 m) for effective minnow trap sampling to occur.

Backpack electrofishing could not be conducted at any of the sites, as water depth and soft silt substrates contributed to unsafe conditions.

The gill nets used for sampling waterbodies consisted of an eight-panel, 45.6-m net; each panel was 5.7 m in length and 1.8 m in depth, and the panel mesh size ranged from 25.4 mm to 152.4 mm.

Gill net sets were typically set up by placing the gill net perpendicular to the shoreline, while anchoring the bottom of the net to the substrate. Placing the gill net in this configuration increases the opportunity to capture fish species during daily movement between habitats.

Where possible, fish captured were identified and enumerated by species and life stage. Fork length (mm) and body weight (g) were measured for all large species and for a representative sub-sample of small species. If discernable from external examination, sex and state of maturity of captured fish were also recorded. For detailed sampling techniques and sampling methods used at each site, see Appendix 8A, Figures 8A-1 to 8A-7.

Winter Sampling

Fish sampling in winter was conducted at watercourse and waterbody sites as conditions permitted. Observations recorded include ice depth, water depth, water quality and under-ice conditions. Baited minnow traps were used to determine fish presence and assess potential overwintering habitat conditions. These traps were deployed at study sites with sufficient water depths (generally ≥0.4 m). At some locations insufficient water depth did not allow for proper deployment of minnow traps. For detailed sampling techniques and sampling methods used at each site, see Appendix 8A, Figures 8A-1 to 8A-7.

8.4.3.6 Habitat Assessments

Fisheries and Oceans Canada (DFO) defines fish habitat as those parts of the environment “on which fish depend, directly or indirectly, in order to carry out their life processes” (DFO, 1985). Therefore, fish habitat includes the water, water quality and aquatic life in rivers, lakes, canals, streams and oceans, as well as the total surroundings of those waterbodies, including plants and other life forms that interact to make fish life possible. Small streams, ponds, reservoirs, marshes, wetlands, canals, drains, and sometimes even flooded meadows near other waterbodies or watercourses, can provide important habitat for fish, if only on a seasonal basis.

Fish habitat assessments are designed to consider potential migratory corridors, as well as spawning, rearing, feeding and overwintering habitat for fish species that have the potential to exist within the RSA.

Fish use a wide variety of habitat conditions on a year-round or seasonal basis. Typical fish habitat requirements include spawning substrates, physical features providing food, refuge areas providing cover from water flow or predation and migratory corridors to and from overwintering or spawning areas.

Once the presence of fish habitat has been determined, the habitat can be further characterized according to large-bodied/sportfish and forage fish life cycle habitat requirements. The rating of potential habitat is a subjective interpretation of a variety of habitat characteristics based on physical and visual estimates. The habitat rating system is designed to provide a description of existing fish habitat and an indication of potential habitat use.

Physical, chemical and biological characteristics were assessed on a seasonal basis to evaluate the presence of seasonal fish habitat. Habitat characteristics assessed in seasonal surveys included:

- Water quality: pH, conductivity (uS/cm), DO (mg/L) and turbidity;
- Substrate composition: particle sizes and embeddedness, determined via visual estimation or pebble counts;
- Barriers to fish movement: beaver dams, falls, high velocity chutes, perched culverts intermittent flows or very low flow;
- Available instream cover habitats: large organic debris, boulders, instream vegetation, turbidity, deep pools and surface turbulence;
- Available overhead cover habitats: large organic debris, undercut banks and overhanging trees, shrubs or grasses;
- Bank and shoreline characteristics: height, slope, riparian vegetation, percent coverage, percentage of bank that is undercut, erosion potential, presence of riprap, crib walls or other erosion control measures;
- Physical dimensions: mean wetted width, mean wetted depth, mean channel width and mean channel depth;
- Hydrologic condition: discharge (m^3/s), turbulence, watercourse stage (dry, pooled, low, moderate, high, flood);
- Food, cover and reproductive needs; and
- Habitat quantity: a specific habitat condition may be present, but may not be sufficiently represented within the study area.

8.4.3.7 Habitat Rating

Fish require specific habitat conditions to complete successfully critical life cycle stages, such as spawning, rearing, feeding and migration to spawning or overwintering areas.

Spawning habitats are areas of a watercourse or waterbody where fish congregate in order to seek out a mate, nest and reproduce. Rearing habitat refers to the areas that provide young fish the opportunity to hatch, feed and grow into adults. Migratory corridors are areas fish use to reach the habitats they require to carry out life processes. Overwintering habitats consist of areas that provide adequate water quality, habitat features and physical space for fish species to survive for months at a time without crowding into limited deepwater pockets. Available habitat could become overcrowded and/or anoxic (i.e., oxygen deprived) in summer months, resulting in mortalities due to “summer kill.” Similar conditions may occur in winter where water may freeze and result in mortalities due to “winter kill.”

Rating fish habitat requires the assessment of a broad spectrum of conditions. These include water quality, hydraulics, geographic location and physical attributes of the watercourse or waterbody. Habitat characteristics and an in-depth knowledge of the life cycle habitat requirements were used to determine the habitat rating.

Essential habitat requirements of a given fish species can vary between life cycle stages and/or seasonal temperature ranges. Therefore, fish will thrive in different habitats depending on life cycle or seasonal temperature regime.

Fish habitats consist of the areas within a watercourse or waterbody that fish need to carry out successfully one or all of their life processes. The potential utilization of fish habitat can be further described by fish life cycle stage and/or how the fish utilize the existing habitat.

Fish sampling techniques were employed to verify the existence of fish and thereby fish habitat. Fish capture data were used to identify the life cycle stage and species present within the representative assessment area. Historical records of fish habitat utilization, an assessment of existing habitat characteristics and habitat suitability indices were used to determine the habitat potential.

The degree of potential habitat utilization associated with a specific fish life stage may be further characterized as nil, low, medium or high.

A nil habitat rating would characterize an area that does not provide any significant habitat for a specific life cycle stage of a given fish species. A nil rating describes an area where habitat characteristics, such as water quality, were considered inadequate to support aquatic life (CCME, 2006), and/or physical attributes of the area were insufficient to provide for the life cycle requirements of fish species that may exist with the RSA. Nil habitat characteristics would include:

- dry and/or undefined channel;
- no suitable habitat for overwintering, spawning, migration or rearing; and
- not suitable for use as a migratory corridor.

A low habitat rating would indicate an area that provides limited habitat potential for fish life cycle requirements, due to the existence of suboptimal water quality, hydrological or physical conditions limiting the habitat potential. Low habitat characteristics would include:

- unstable banks present and abundant;
- high to moderate scour potential;
- deep pools or evidence of groundwater seepage are nonexistent or limited in abundance;
- flow and depths not generally suited for overwintering habitat;
- size of substrates and cover limiting for rearing activities;
- substrate or macrophytes not suitable for spawning, or not abundant;
- flows or water depth not favourable for spawning;
- flow and depths meet minimal requirements for rearing, but limiting in area;
- flows, water depth and cover habitats not typically suitable for adult holding or feeding; and

- barriers to upstream movement such as seasonal flow, beaver dams, waterfalls or perched culverts exist within the survey area.

A medium habitat rating would characterize habitat conditions that are considered adequate for supporting a given life cycle stage. This rating would include areas that provide sufficient habitat characteristics to satisfy life history requirements. This area would also be considered large enough to accommodate multiple individuals. Medium habitat characteristics would include:

- moderately stable banks;
- medium to low scour potential;
- deep pools, riffles, vegetation, evidence of groundwater seepage and suitable flows observed in moderate abundance;
- size of substrate or macrophytes, flows or water depth suitable for spawning activities;
- water depths, flows, size of substrate and instream or overhead cover adequately suitable for rearing; and
- barriers to upstream migration, such as low seasonal flow, beaver dams, waterfalls or perched culverts, were not observed in the immediate vicinity of the study area, or were not considered a barrier.

A high habitat rating describes habitat conditions considered optimal for one or more stages of a fish life cycle. Habitat characteristics that are rated high would provide ample physical space with optimal habitat condition to satisfy the life history requirements for fish species. This area would not be limiting due to available habitat and physical, chemical or biological characteristics. A high habitat potential area would include:

- stable banks abundant;
- low scour potential;
- deep pools, riffles, vegetation or evidence of groundwater seepage optimal for spawning activities;
- watercourse structure, overhead cover, flow velocities, water depths, size of substrates, instream cover and water quality were considered optimal for spawning, rearing, overwintering or migration activities; and
- barriers to upstream migration, such as low seasonal flow, beaver dams, waterfalls or perched culverts, were not observed in the immediate vicinity of the study area, or were not considered a barrier.

Fish habitats required at a given life cycle stage can vary from species to species, and are best summarized by defining the requirements of large-bodied/sportfish species and small-bodied forage fish species. Large-bodied/sportfish and forage fish species captured within the RSA are represented in Table 8.5-1.

8.4.4 Benthic Invertebrates

Benthic invertebrate samples were collected in the spring of 2007 (May 2 to 5). Benthic samples are generally collected in the fall; however, for this assessment spring sampling was conducted for two reasons; first, to build on previous data collected in the LSA (Synenco Energy, 2006); and secondly, other studies have found that watercourses in the area did not have suitable benthic habitat during base flows in the fall (PCOSI, 2006). Samples were collected at two watercourses and one waterbody in the LSA (Figure 8B-1), with the objective of characterizing the benthic invertebrate community in representative habitat areas. The data were used to describe baseline conditions regarding the availability of food resources for fish, as well as the overall health of the aquatic ecosystem.

Samples were collected in depositional sediments, using a Ponar sampling device with a sampling area of 0.023 m^2, and were field sieved to remove fine sediments using a 250 um Nitex mesh netting. Five replicate samples were collected at each site to account for variability.

A literature review of historical data was completed to obtain background benthic invertebrate data for the study areas (Golder, 1995; PCOSI, 2006; North West, 2006; Synenco Energy, 2006; Shell, 2007).

The benthic invertebrate community was characterized using community variables, including abundance (numbers of organisms per square metre), dominance (the most common taxa at a given site), taxonomic richness (the number of benthic invertebrate taxa) and community composition. The abundance and dominance data among sites were presented graphically. Richness was presented as the total number of taxa (identified to the lowest practical level) among replicates at a site. Major groups of invertebrates were presented in stacked bar graphs to show significant differences in community composition (Appendix 8B provides details).

8.4.5 Periphyton

Periphyton samples were collected in the spring of 2007 (May 1 to 3). Six sampling sites were located in three watercourses in the LSA (Table 8.4-3). Watercourses were sampled in erosional habitat. The objective of collecting periphyton samples was to measure chlorophyll *a*, a biomass estimate of the amount of live algae. Periphyton data are also useful for monitoring environmental change in aquatic habitats.

Table 8.4-3 Periphyton Sampling Site Locations and Field Survey Dates

Watercourse Study Site ID	Sampling Date	UTM (NAD 83-Zone 12)	
		Easting	Northing
AST1	May 1/07	371701	5972559
AST2	April 30/07	363312	5960108
AST6	May 3/07	372925	5952410
NSR1	May 3/07	372823	5974226
NSR3	May 3/07	362836	5966525
NSR4	May 3/07	363182	5967240

8.4.6 Impact Assessment and Mitigative Measures

Potential impacts to aquatic resources in the Project area were assessed in terms of indicator species. Impacts were evaluated in the context of project development and operation and reclamation activities, and include plant facilities, access roads, utility corridors and pipelines.

Two areas of concern for aquatic resources were identified. Riparian and instream habitat loss or alteration, as well as combined industrial disturbance (i.e., effluent discharge, waterbody acidification, spills or releases) on fish habitat. Criteria for evaluating impacts are outlined in Table 8.4-4. Mitigative measures for impacts include management of operations, best management practices for construction and maintenance activities and prevention initiatives.

Table 8.4-4 Assessment Criteria used to Predict Potential Impacts Associated with the North American Upgrader Project

Parameter	Rating	Criteria
Direction of Impact	Positive	Net benefit or gain to indicators or fish habitat.
	Neutral	No net benefit or gain; or benefits and losses are balanced.
	Negative	Net loss or detriment to indicators or fish habitat.
Extent of Impact	Local	Impact to indicators or fish habitat confined to the area directly disturbed by Project facilities.
	Sub-regional	Impact to indicators or fish habitat extends beyond area of direct disturbance but is limited to the LSA.
	Regional	Impact to indicators or fish habitat extends beyond the LSA but is limited to the RSA.
	Extra-regional	Impact to indicators or fish habitat extends beyond the RSA.
Magnitude of impact	Negligible	No discernable impact to indicators or fish habitat.
	Low	Disturbance to indicators or fish habitat predicted to cause no detectable changes greater than that observed in natural variation.
	Medium	Disturbance to indicators or fish habitat predicted to cause a detectable change greater than that observed in natural variation.
	High	Disturbance predicted to cause a detectable change to indicators or fish habitat great enough to impair recovery.
Duration of Impact	Immediate	Impact to indicators or fish habitat that occurs for less than two days.
	Short-term	Impact to indicators or fish habitat that occurs for two days or longer but less than one year.
	Medium-term	Impact to indicators or fish habitat that occurs for one year or longer but less than ten years.
	Long-term	Impact to indicators or fish habitat that occurs for ten years or longer.
Frequency of Occurrence of Impact	Isolated	Impact to indicators fish habitat that occurs during a specified period.
	Occasional	Impact to indicators or fish habitat that occurs intermittently and sporadically over assessment period.
	Regular	Impact to indicators or fish habitat that occurs regularly over assessment period.
	Continuous	Impact to indicators fish habitat that occurs continually over assessment period.
Permanence of Impact	Reversible in short-term	Impact to indicators or fish habitat that can be reversed in less than one year.
	Reversible in medium-term	Impact to indicators or fish habitat that can be reversed in one year or more, but less than ten years.
	Reversible in long-term	Impact to indicators or fish habitat that can be reversed in ten years or more.
	Irreversible	Impact to indicators or fish habitat that is permanent.

Parameter	Rating	Criteria
Level of Confidence	Low	Assessment based on poor understanding of cause-effect relationships and data certainty is unclear (e.g., historical data source, using data from elsewhere, data incomplete, etc)
	Medium	Assessment based on good understanding of cause-effect relationships and data certainty is unclear (e.g., historical data source, using data from elsewhere, data incomplete, etc); or poorly understood cause-effect relationships using data with high certainty.
	High	Assessment based on good understanding of cause-effect relationships and high certainty of data.
Environmental Impact	No impact	Impacts to indicators or fish habitat are not predicted to occur.
	Negligible impact	Impacts to indicators or fish habitat are not discernable above natural background variation.
	Minor impact	Impacts to indicators or fish habitat are low in magnitude, short-, medium- or long-term in duration and restricted to the (local or regional) study area.
	Moderate impact	Impacts to indicators or fish habitat that are medium in magnitude, short-, medium- or long-term in duration and do not extend beyond the regional study area.
	Major impact	Impacts to indicators or fish habitat that are long-term in duration and/or extend beyond the regional study area.

8.4.7 Cumulative Effects Assessment

A Cumulative Effects Assessment (CEA) was conducted to consider the potential impacts associated with the Project in combination with other existing and future projects located within the Project's RSA. The CEA for the Project focused on the effects of water withdrawals from the NSR and potential acidification of lakes in the region.

8.5 Existing Conditions

The existing conditions related to fish and fish habitat within the North American Project area were collected during a series of background data searches, in addition to the seasonal field programs. The information collected is summarized in the following section.

8.5.1 Historical Information

Several assessments of fish habitat and fish species were conducted within the RSA (Synenco Energy, 2006; North West, 2006; PCOSI, 2006; Shell, 2005). These studies, along with an historical data search in FMIS database and existing reference literature (Nelson and Paetz, 1992; Scott and Crossman, 1998), provide a summary of the fish species and habitat in the Astotin Creek, Beaverhill Creek and NSR watersheds.

Table 8.5-1 summarizes the thirty fish species present in the LSA and RSA.

8.5.1.1 NSR and Tributaries

NSR

Watercourses

NSR1 (NSR) – The NSR was sampled in spring of 2006 and the fall of 2004 and 2006 in support of the following Environmental Impact Assessments (EIAs): Petro-Canada Oil Sands Inc. Sturgeon Upgrader EIA (PCOSI, 2006), Synenco Energy Northern Lights Upgrader EIA (Synenco Energy 2006), Shell Canada Scotford Upgrader Expansion EIA (Shell, 2005), and North West Upgrading Bitumen Upgrader Project (North West, 2006). A total of 30 species of fish are known to exist in the LSA or RSA, some of which were captured during sampling. These include burbot, goldeye, mountain whitefish, northern pike, walleye, sauger, mooneye, rainbow trout, lake sturgeon, longnose sucker, white sucker, quillback sucker, shorthead redhorse, silver redhorse, longnose dace, trout perch, emerald shiner and river shiner. White sucker were the most abundant species during both spring and fall sampling. Spawning habitat potential was rated high for all fish species.

AST1 (Beaverhill Creek) – Beaverhill Creek was sampled in spring of 2006 in support of the Synenco Energy Northern Lights Upgrader EIA (Synenco Energy, 2006). A total of four species were captured during sampling. These include goldeye, white sucker, northern pike and longnose sucker. White sucker were the most abundant species during the spring sampling.

AST2, AST3 (Astotin Creek) – Astotin Creek was sampled in spring of 2006 in support of the Synenco Energy Northern Lights Upgrader EIA (Synenco Energy, 2006). Brook stickleback were the only species captured during sampling, and white sucker were observed in the study reach.

Waterbodies

No historical records of fish sampling was identified for Astotin Lake (AST4) or Antler Lake (AST5).

Table 8.5-1 Fish Species Documented During the Present and Previous Studies in or near the North American Upgrader LSA and RSA

Common Name	Scientific Name	Species Code	Occurrence Reported In		Found in Current Study
			LSA	RSA	
Longnose sucker	*Catostomus catostomus*	LNSC	√	√	
White sucker	*Catostomus commersoni*	WHSC	√	√	√
Mountain sucker	*Catostomus platyrhynchus*	MNSC		√	
Quillback	*Carpiodes cyprinus*	QUIL		√	
Shorthead redhorse	*Moxostoma macrolepidotum*	SHRD		√	
Silver redhorse	*Moxostoma anisurum*	SLRD		√	
Longnose dace	*Rhinichthys cataractae*	LNDC		√	
Spottail shiner	*Notropis hudsonius*	SPSH		√	
River shiner	*Notropis blennius*	RVSH		√	
Fathead minnow	*Pimephales promelas*	FTMN		√	
Flathead chub	*Platygobio gracilis*	FLCH		√	
Emerald shiner	*Notropis atherinoides*	EMSH		√	
Northern redbelly dace	*Phoxinus eos*	NRDC		√	
Northern pike	*Esox lucius*	NRPK	√	√	
Burbot	*Lola Iota*	BURB		√	
Brook stickleback	*Culea inconstans*	BRST	√	√	√
Goldeye	*Hiodon alosoides*	GOLD		√	
Mooneye	*Hiodon tergisus*	MOON		√	
Walleye	*Sander vitreus*	WALL	√	√	
Sauger	*Sander canadensis*	SAUG		√	
Iowa darter	*Etheostoma exile*	IWDR		√	
Yellow perch	*Perca flavescens*	YLPR		√	
Lake sturgeon	*Acipenser flavescens*	LKST		√	
Trout-perch	*Percopsis omiscomaycus*	TRPR		√	
Lake chub	*Couesius plumbeus*	LKCH		√	
Bull trout	*Salvelinus confluentus*	BLTR		√	
Brown trout	*Salmo trutta*	BNTR		√	

Common Name	Scientific Name	Species Code	Occurrence Reported In		Found in Current Study
Mountain whitefish	*Prosopium williamsoni*	MNWH		√	
Rainbow trout	*Oncorhynchus mykiss*	RNTR		√	

Source(s): Shell (2005), North West Upgrading (2006), PCOSI (2006), Synenco Energy (2006), FMIS (Fisheries Management Information System) database, as of November 16, 2006 (pers. com. V. Buchwald, ASRD), Nelson and Paetz (1992), Scott and Crossman (1998).

8.5.2 Species at Risk and of Special Concern

Environment Canada maintains an Internet database for all species at risk in Canada (Environment Canada, 2007). Species that "may be at risk" currently require further study to determine whether legal protection under the Alberta *Wildlife Act* (ASRD, 2000) is required, while species that are "sensitive" are not currently at risk but may require future protection to prevent them from becoming at risk. None of these species are currently listed on the Committee on the Status of Endangered Wildlife in Canada website (COSEWIC, 2007). This database lists the following fish species within Alberta and their designation as determined by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC, 2007):

1. Extinct. Banff Longnose Dace (*Rhinichthys cataractae smithi*);
2. Endangered. Lake Sturgeon (*Acipenser fulvescens*); and
3. Threatened. Eastslope sculpin (*Cottus sp.*), shortjaw cisco (*Coregonus zenithicus*), western silvery minnow (*Hybognathus argyritis*) and westslope cutthroat trout (*Oncorhynchus clarkii lewisi*).

Of the identified species, only lake sturgeon is present in the LSA.

Alberta Sustainable Resource Development maintains an Internet database for all species present in provincial waterbodies (ASRD, 2007a). Three species identified in the Alberta Species at Risk Program are known to occur near the RSA. These include the spoonhead sculpin (designated as "may be at risk") and northern redbelly dace and sauger (designated as "sensitive"). Lake sturgeon has recently been designated as "at risk" under the Alberta Species at Risk Program, and as a result, sport fishing for lake sturgeon in the NSR is now limited to "catch and release" (ASRD, 2007b).

8.5.3 Waterbody and Watercourse Assessment Results

Observations recorded during the field surveys of waterbodies and watercourses are presented in Appendix 8A, Figures 8A-1 to 8A-7. These figures provide detailed descriptions of existing conditions and will be used for the purpose of the impact assessment. These figures may also be used as data to support future monitoring programs. The information presented in the figures includes detailed habitat mapping and descriptions, summaries of the recorded surface water quality characteristics, identification of observed fish species and an overall ranking of fish habitat quality. These information categories are further discussed below:

- The habitat map and descriptions provided for each waterbody contain details of existing conditions observed during the four survey seasons. This information includes lakebed composition (shape and substrate composition), the presence and location of inlet and outlet channels, and the presence of potential fish habitat (including depth, cover and vegetation).

- The field water quality data represented in the figures include the temperature (^{o}C), DO (mg/L), pH and conductivity (uS/cm) recorded during the field surveys. Water quality was recorded throughout the water column of the lakes to provide an indication of conditions from the surface to the substrate. Temperature is recorded to determine the suitability of the waterbody to temperature-sensitive species (i.e., coldwater species [optimum temperature less than 18^{o}C, with spawning temperatures less than 15^{o}C] and cool water species [optimum temperatures less than 27^{o}C, with spawning temperatures less than 21^{o}C]; Mitchell and Prepas, 1990). DO levels are recorded in order to determine the waterbody's capacity to sustain fish (i.e., DO levels below 5.6 mg/L were considered to be unsuitable [suboptimum] for sportfish; CCME, 2006; Ford et al., 1995). Recorded pH levels provide an indication of the acidity of the water, and conductivity levels provide an indication of the concentration of ions in the water.

- The fish species section included in the figures provides a breakdown of the species captured or observed during surveys, as well as the methods (baited minnow traps, gill nets, set-lines and angling) and effort required (recorded in hours and minutes) to capture the fish.

- The habitat rankings provided in the figures summarize the overall fish habitat observed for both forage and large-bodied/sportfish species. The rankings were derived using the observations of existing fish habitat and the observed water quality, combined with the presence of fish species observed during field surveys. Rankings are provided for spawning, rearing, feeding and overwintering habitat.

8.5.4 Waterbodies and Watercourses – Baseline Data Summary

For the purpose of the field assessments and the preparation of the baseline data summary, the Project study area was divided into two distinct areas reflecting the two watershed areas that the RSA encompasses. These areas include the following:

- The Astotin Creek/Beaverhill Creek and NSR study areas, which capture the upper, mid and lower regions of Astotin Creek, including Astotin Lake, as well as the lower portion of Beaverhill Creek and the reach of the NSR where Beaverhill Creek enters; and

- Antler Lake study area, which describes the section within the southern region of the regional study area.

The following section outlines the information collected at watercourses during the baseline surveys at each of the outlined study areas.

8.5.4.1 Beaverhill Creek (AST 1)

Beaverhill Creek had no flowing water during the summer, fall and winter surveys, as the channel was dry from just downstream of the study location to the confluence with the NSR. The upper section of Beaverhill Creek was observed to have standing pools of water as a result of existing beaver dams, and would provide limited rearing and feeding habitat use by large-bodied/sportfish and forage fish species. Beaverhill Creek had low to moderate overwintering habitat for both large-bodied/sportfish and forage fish. During the fall fish and fish habitat surveys, white sucker was the only species captured.

A detailed summary of the baseline data collected for AST 1 is presented in Appendix 8A, Figure 8A-1.

8.5.4.2 Astotin Creek (AST 2, AST 3, AST 6)

The locations surveyed for spawning, rearing and feeding in Astotin Creek (AST 2, AST 3) were found to have DO levels below CCME guidelines (<6.5 mg/L) (CCME, 2006), and therefore low habitat potential for large-bodied/sportfish and forage fish species. AST 2 and AST 3 may provide suitable seasonal habitat for fish species tolerant of low DO levels, such as brook stickleback or fathead minnow (Nelson and Paetz, 1992). This watercourse had no potential for overwintering habitat, as it was frozen to the bottom at both sites during the winter survey. Brook stickleback was the only species captured during the fall fish and fish habitat surveys. AST 6 was surveyed in May 2007 for benthic invertebrates only and water quality parameters only. No fishing efforts were completed at AST 6.

A detailed summary of the baseline data collected for the AST 2, AST 3 and AST 6 are presented in Appendix 8A, Figures 8A-2, 8A-4 and 8A-3.

8.5.4.3 Astotin Lake (AST 4)

Astotin Lake was surveyed for spawning, rearing and feeding habitat, and was found to have low habitat potential for large-bodied/sportfish and forage fish species. AST 4 was found to have DO levels below CCME guidelines (<6.5 mg/L) (CCME, 2006). When assessing overwintering habitat potential, it was determined that AST 4 was ranked as low to nil, and can provide suitable habitat for fish species tolerant of low DO levels, such as brook stickleback or fathead minnow (Nelson and Paetz, 1992).

A detailed summary of the baseline data collected for AST 4 is presented in Appendix 8A, Figure 8A-5.

8.5.4.4 Antler Lake (AST 5)

Antler Lake (AST 5) was surveyed for spawning, rearing and feeding habitat and was found to have low habitat potential for large bodied/sport and forage fish species. When assessing overwintering habitat potential it was determined that Antler Lake (AST 5) was ranked as low to nil, as it was found to have DO levels below CCME guidelines (<6.5 mg/L) (CCME, 2006). AST 5 can provide suitable for fish species tolerant of low DO levels, such as brook stickleback or fathead minnow (Nelson and Paetz, 1992); however, no fish were captured during the fish and fish habitat surveys.

A detailed summary of the baseline data collected for AST 5 is presented in Appendix 8A, Figure 8A-6.

8.5.4.5 NSR (NSR 1)

The NSR was determined to have high spawning, rearing and feeding habitat potential for both large-bodied/sportfish and forage fish species. When assessing overwintering habitat potential, it was determined that NSR 1 has high overwintering potential for large-bodied/sportfish and forage fish species. During the fish and fish habitat surveys (fall only), no fish were captured.

A detailed summary of the baseline data collected for NSR 1 is presented in Appendix 8A, Figure 8A-7.

8.5.5 Benthic Invertebrates

Beaver Hill and Astotin creeks

Benthic invertebrate mean total abundances in the Beaver Hill and Astotin creeks ranged from less than 500 organisms/m^2 to greater than 11,000 organisms/m^2. Densities in the two watercourses were similar in 2006 (Synenco Energy, 2006); however, they displayed greater variability in 2007 (Appendix 8B). Total richness appeared to be somewhat higher in Astotin Creek than Beaver Hill Creek during the spring in both 2006 and 2007.

Dominance is a measure of the most common taxa at a site, and higher values generally indicate disturbance or changes to the environment. Often r-selected species are quick to establish large populations after communities of other organisms have collapsed. Dominance was considerably higher in Astotin Creek than Beaver Hill Creek, and was lowest in Astotin Lake, most likely because of a more stable benthic environment.

Community composition of samples collected in the LSA was largely comprised of midges (Chironimidae), aquatic worms (Oligochaeta) and nematodes. The occurrence of large populations of these groups may indicate eutrophication or organic inputs into benthic habitats. This is not uncommon in agricultural areas, as the presence of livestock near watercourses, fertilization of cropland and the breakdown of allocthonous sources of carbon (leaves and terrestrial vegetation) can all contribute to increased organic matter in benthic substrates. Notably, community composition in Astotin Lake was more diverse than in either watercourse.

Differences in community composition between samples collected in 2006 (Synenco Energy, 2006) and samples collected for the project in 2007 suggest that the benthic community may be subject to a variable aquatic environment. Base flows in watercourses in the LSA may be quite low late in the summer and fall, exposing much of the benthic habitat to extreme conditions. For instance, PCOSI (2006) found that there was no flowing water in tributaries in the fall of 2006, and therefore could not collect samples. When habitat changes are excessive, many components of the community are affected and may need to re-establish populations when conditions permit. Depending upon the severity of annual environmental changes, community structure may vary from year to year as populations are restored.

The midge community varied between sampling years in Beaver Hill Creek. In 2006 the community consisted largely of unidentified Chironominae, whereas in 2007 the community was comprised of Chironomini and Tanytarsini (also both in the Chironominae subfamily). Astotin Lake and Astotin Creek communities (in both 2006 and 2007) were largely made up of Tanypodinae and Chironomini.

NSR

Existing benthic invertebrate data in the NSR near the LSA indicate that communities are somewhat variable in this watercourse (Golder, 1995; PCOSI, 2006; North West, 2006; Synenco Energy, 2006; Shell, 2007). Mean total abundances ranged from less than 2,000 organisms/m^2 to greater than 35,000 organisms/m^2 (Appendix 8B). Total richness was also variable in the NSR, ranging from 15 to 46 taxa (identified to lowest practical level).

Most of the studies considered revealed that the benthic invertebrate community was responding to nutrient enrichment. Golder (1995) and PCOSI (2006) suggested that the benthic invertebrate communities showed a change consistent with nutrient enrichment that increased from upstream to downstream. North West (2006) indicated that the proportion of midges and aquatic worms increased from upstream to downstream, which is also indicative of an enrichment effect. Shell (2007) suggested that nutrient effects in the benthic communities were evident at all sites;

however, an upstream to downstream gradient was not observed. Golder (1995) also identified a change in community structure downstream of two chemical plants, which may suggest a toxic effect.

8.5.6 Periphyton

Results for periphyton sampling are summarized in Table 8.5-2.

Table 8.5-2 Periphyton Samples from the LSA

Sample Point	Sample Date	Chlorophyll *a*	Phaeophytin *a*
		mg/m^2	mg/m^2
AST1	May 1/07	nd	nd
		nd	1.14
		nd	1.14
AST2	May 1/07	18.75	8.52
		nd	nd
		19.89	6.82
AST6	May 3/07	3.41	2.84
		30.11	6.25
		5.11	2.84
NSR1	May 3/07	nd	2.27
		0.57	1.14
		1.14	1.14
NSR3	May 3/07	6.82	3.98
		1.14	6.25
		2.84	0.57
NSR4	May 3/07	nd	nd
		nd	nd
		1.70	1.14

nd=below detection limits

8.5.6.1 Chlorophyll *a*

Mean chlorophyll *a* concentrations ranged from non-detectable in Astotin Creek (AST 1) to 30.11 mg/m^2 (AST 6). The highest concentrations in the NSR sites were 6.82 mg/m^2 at NSR 3. A spring survey conducted for Synenco Energy (2006) yielded similar chlorophyll *a* levels, ranging from 14 to 113 mg/m^2.

8.5.6.2 Phaeophytin *a*

Mean phaeophytin *a* concentrations ranged from non-detectable in Astotin Creek (AST 1) to 8.52 mg/m^2 (AST 2). Concentrations in the NSR sites ranged from non-detectable to 6.25 mg/m^2 (NSR 3). A spring survey conducted for Synenco Energy (2006) yielded similar phaeophytin *a* levels, ranging from 4.25 mg/m^2 (Astotin Creek) to 38.4 mg/m^2 in the NSR.

8.6 Impact Assessment and Mitigative Measures

Fish and fish habitat in the North American Project area was assessed in terms of indicator species. Potential impacts to indicators were evaluated in the context of project development, operation and reclamation activities, and include plant facilities, access roads, utility corridors and pipelines. Project activities with the potential to affect aquatic recourses include; first, riparian and instream habitat loss or alteration, including altered flow regimes; and secondly, combined industrial disturbance of fish habitat (i.e. effluent discharge, waterbody acidification, spills or releases). Criteria for evaluating impacts are outlined in Table 8.4-2. Mitigative measures for impacts include management of operations; best management practices for construction and maintenance activities; and prevention initiatives, and they are summarized as they relate to the identified potential impacts.

8.6.1 Indicators

Indicator species depend upon a number of elements in the aquatic environment at various life history stages. They may be affected at various levels (e.g., population abundance, community diversity, health, etc.) when the aquatic environment undergoes change (e.g., effects from industry, over fishing, etc.). Indicators are species (e.g., northern pike) or groups of organisms (e.g., benthic invertebrates) that represent larger groups or processes in the aquatic environment. By acting as surrogates for the larger system, they help to focus the assessment. Specific indicators are chosen because they are able to signal environmental changes that may be caused by certain project-related activities. It is important to choose indicators with relevance to stakeholders, regulators and the aquatic environment.

Environmental changes in aquatic environments are often reflected in alteration to the fish community. Changes to habitat (e.g., substrate, water chemistry, water flow, cover) and food (e.g., macroinvertebrates) may affect fish in ways that include, but are not limited to:

- decreased fish population;
- altered spawning activity;
- altered movement of fish in or out of an area; or
- compromised fish health (e.g., low weight-to-length ratio, lesions, reduced fecundity).

According to recent literature on indicator species, the appropriateness of each indicator to detect environmental change should be assessed, and the natural history of each indicator should be considered to include a variety of indicator responses to detect environmental changes (Karr and Chu, 1999). Fish from different trophic levels (position in the food chain) should be included among the chosen indicators (Shuter and Post, 1990). Generalists (e.g., fish that can eat a variety of food types) tend to do better than specialists (e.g., predators) when environmental changes affect food sources (e.g., macroinvertebrates, algae, small-bodied fish). Small-bodied fish tend to mature rapidly and have a short life span. Consequently, their populations are greatly affected by stressors that affect larval development or fecundity (e.g., changes to pH).

The use of the benthic macroinvertebrate community (benthics, benthic invertebrates) as an indicator has increased in recent years because these communities have attributes that allow them to respond quickly to environmental change. Benthics are short-lived (one generation every two years to more than one generation in a year) and spend most of their lives in a local area. Benthic invertebrates are generally easy to sample, and community attributes (e.g., abundance, diversity, composition) are simple to calculate. Changes in these attributes are also easy to monitor, providing an indication of changes in the aquatic environment.

The following groups were chosen as indicators for the Project study area.

Benthic Macroinvertebrates

Benthic macroinvertebrates generally dwell in natural aquatic habitats. Habitat types tend to support identifiable invertebrate communities (e.g., erosional watercourse communities vs. depositional watercourse communities). A rapid response to environmental change (e.g., sedimentation, water quality) by the invertebrate community is a result of various attributes. These include:

- short life span;
- small territory;
- species with very defined niche requirements; and
- numerous trophic levels.

The role that benthic macroinvertebrates play in the food chain is also important, and is reason for their inclusion in the aquatic assessment. Fish species in northern Alberta generally depend on invertebrates for food during at least one life stage (Scott and Crossman, 1998).

Brook Stickleback

Brook stickleback are a common fish species throughout most of Alberta, and exist in a variety of habitats, including small ponds, lakes and streams with varying velocity and substrate type (Scott and Crossman, 1998). Being tolerant of a wide range of environmental conditions, the brook stickleback can populate many marginal habitats. They are known to tolerate low oxygen levels (Nelson and Paetz, 1992) and high salinity levels, and can survive where other species cannot (Scott and Crossman, 1998). Populations are known to occur in Astotin Creek (Synenco Energy, 2006).

Brook stickleback are predaceous, feeding upon fish eggs, benthic invertebrates and the larvae of various aquatic insects and fishes (Scott and Crossman, 1998). They are also a food source used by larger-bodied fish, including northern pike (Scott and Crossman, 1998). The fish matures in about one year and lives for about two to three breeding seasons.

White Sucker

White sucker is a fish species captured in rivers and lakes in many habitats throughout Alberta, except for high mountainous areas (Scott and Crossman 1998; Nelson and Paetz, 1992). They are generally bottom feeders, with a diet made up primarily of benthic invertebrates, mollusks and algae.

White suckers often favour specific tributaries for spawning, which occurs in Alberta from mid-May through June, when water temperature is about 10ºC. When conditions are right, hundreds of white sucker may migrate from their resident lake to a suitable stream with shallow water and a gravel substrate. White suckers are known to spawn around shoreline areas of lakes. Fecundity is related to size, with females producing an average of 10,000 eggs to 35,000 eggs during a spawning season. The life span is generally between 14 years and 17 years. Although this species is not considered commercially important, it may be captured with sportfish, including northern pike, walleye, yellow perch, lake whitefish, cisco and burbot.

Northern Pike

Northern pike is a popular sportfish captured throughout most of Alberta, except in some high mountainous areas (Nelson and Paetz, 1992). They prefer weedy, clear waters in lakes and marshes, but are also commonly captured in slower rivers and streams. Spawning occurs in early spring, often while ice is still present (Scott and Crossman, 1998). They typically find shallow, marshy locations or flooded grassy areas with ample vegetation to deposit their eggs.

Northern pike generally lie and wait for prey rather than hunt (Scott and Crossman, 1998). They are, however, aggressive and will eat other fish, crustaceans, insects, young muskrats and ducklings. Young of the year have been documented feeding on minnows, suckers, trout-perch and brook stickleback.

8.6.2 Assessment Criteria

Potential fish and fish habitat issues associated with the Project were identified based on the final Terms of Reference (TOR) prepared by AENV (Volume 1, Appendix A) and professional judgment.

8.6.3 Effects on Aquatic Resources

Several potential impacts were identified that could be affected by components of the Project, specifically during the Project's construction and operation phases. Those identified included the potential changes to water quality in local watercourses and waterbodies as a result of sedimentation due to construction activities (which include riparian habitat disturbances); fish habitat alteration and loss due to changes in water levels and flow; fish habitat alteration and loss due to water intake construction; contamination of fish and fish habitat from wastewater discharge and spills; and fish loss due to entrainment at the water intake.

8.6.3.1 Sedimentation

Changes in sedimentation levels in watercourses and waterbodies are often the result of silt and clay particles, originating from the terrestrial environment, being released into the aquatic environment via surface water runoff. Runoff water flowing over a disturbed area collects and transports silt and clay particles that contribute to the sediment loading of surface water. Construction activities in close proximity to watercourses and waterbodies can lead to an increase in the potential for both the disturbance and suspension of sediments in the water column. Construction activities, including land clearing, road, plant and water intake construction, can potentially increase sediment in runoff to local watercourses and waterbodies (i.e., NSR), and may result in changes to fish habitat and fish health.

Environmental Issue

An increase of sediment loading into watercourses and waterbodies can have an impact on the aquatic environment. Sedimentation reduces overall fish habitat quality by filling the interstitial spaces in the gravel, rock or sand, leaving the substrate unsuitable for spawning and/or smothering of fish eggs. Increased turbidity causes many benthic invertebrate species to drift downstream, thereby reducing available food for resident fish populations. Where deposition occurs, benthic invertebrate communities can change from organisms favouring erosional habitat to organisms favouring depositional habitat, thus changing the type of food available for local fish.

An increase of sediment loading into watercourses and waterbodies can also have an impact on the health of fish communities. Fish behavior can be affected by an increase in turbidity; for example, the feeding ability of visual feeder species such as Arctic grayling is reduced. Additionally, some fish species avoid turbid streams (Scott and Crossman, 1998) or move out of the areas with high turbidity; thus they are prevented from using traditional migration routes, feeding areas and spawning habitats. Fine sediments in moving water may act as a scouring agent, resulting in erosion to external gills on some benthic invertebrates (e.g., mayfly species). Sediments may also adhere to fish gills by sticking to mucous, resulting in the irritation of the gill membranes. This condition may then lead to increased infections in the gill tissues and inhibited respiration.

Mitigation

Increases in suspended sediment during land clearing, road construction and plant construction will be prevented by implementing mitigation measures and using best management practices (as described in Volume 3, Section 6.6.3). The effects of an increase in suspended sediment during water intake construction will be reduced by conducting instream activities outside of the Restricted Activity Period for this reach of the NSR (August 1 to April 15), by isolating the work site using a coffer dam and placement of clean armour (to prevent scour/erosion), and by implementing an appropriate construction water management and sediment control plan (Volume 3, Section 6.6.3).

Conclusions

Environmental effects on fish instream habitat due to sedimentation are predicted to be short-term and localized. Environmental impacts on the receiving environments are predicted to be negligible.

8.6.3.2 Water Levels and Flows

Surface water levels and stream flows are important environmental characteristics that, when altered, can affect the quality of fish habitat. Water levels determine the amount of available habitat, and the associated stream flow velocity strongly affects habitat quality (e.g., substrate composition). Development activities within the LSA have the potential to change surface water flow characteristics throughout the lease area. The creation of artificial drainage, straightening or alteration of existing channels and the removal of existing vegetation may increase flows and subsequently alter downstream habitat. However, in Volume 3, Section 6.6.4.2, it was predicted that any impact on downstream flows in the Astotin Creek and unnamed tributary basins are not expected to be detectable. Water withdrawal via the proposed water intake from the NSR has the potential to contribute further to fluctuations in water level.

Changes in surface flow are not always the result of development activities. Natural processes such as beaver activity in the area can also influence local surface water flow patterns. When watercourses associated with small lakes are influenced by beaver activity, changes in waterbody levels can occur. These changes can confound predictions regarding surface water flow dynamics. In addition, altered surface water flow patterns related to beaver activity can strongly affect fish and fish habitat. Beaver dams can restrict the migration of fish between overwintering or rearing areas and habitat suitable for spawning (e.g., headwater streams used by Arctic grayling). Flooding regime alterations can also affect conditions necessary for species like northern pike to spawn. For example, lakes may become impounded and restrict fish movement in and out of available habitats.

Potential Environmental Changes

Shoreline habitat and the littoral zone are considered critical for the health of the aquatic environment, and extend from the shoreline of a lake and continue to depth where sufficient light for plant growth reaches the sediments and lake bottom. The littoral zone is the area where adequate light can penetrate the bottom of the water column and allow for plant growth (Wetzel, 2001), which provides food and cover for many aquatic insects. In turn, many fish species use these areas to gain access to food (smaller fish and invertebrates), for cover and in some cases for spawning habitat (e.g., northern pike). Small decreases in water level at shallow shoreline areas can cause the water's edge to recede, thus eliminating these areas of available habitat. In shallow lakes, a drop in the water level may allow sunlight to penetrate throughout the water column over the extent of the lake and cause an increase in primary productivity, thereby altering lake trophic levels. A drop in water level may also reduce the capacity of some waterbodies to provide overwintering habitat.

Watercourses can be affected by alterations in water levels in ways similar to waterbodies. Decreases in stream flow levels expose substrate at the shoreline and may also decrease shoreline cover. Decreased stream flows result in alterations to pool depths, impacting the fish habitat used for spawning, rearing, feeding, migration and overwintering. Additionally, increased velocities and changes to water volume may result in scouring of stream beds and changes to channel alignments.

Water quality parameters such as temperature, pH, DO and chemical load are important for fish health, and can change as a result of fluctuations in water levels. During the open-water season, changes in water temperature can be a function of water volume and depth. Temperatures in shallow waterbodies tend to fluctuate more rapidly than in deeper waterbodies. Chemical and biological processes (e.g., photosynthesis and respiration) may become more pronounced in lakes with reduced water levels. Fluctuations in pH levels and the oxygen/carbon dioxide ratio may change considerably, potentially affecting fish health. In addition, the chemical load (the amount of a given chemical a waterbody can safely assimilate) decreases as water levels go down.

Benthic invertebrate communities provide an important source of food for a number of fish species, and alteration to stream flows impact these communities. Some benthic invertebrates find the effects of modified stream velocities unfavourable, resulting in decreased food available for fish.

Mitigation

Changes in stream flows and lake levels will be prevented through a number of mitigation measures, implemented during both design and construction activities, as described in Volume 3, Sections 6.7.1 and 6.8. These changes, however, will be very limited and difficult to detect, and the nearest waterbody with fish habitat potential is located well outside the zone of predicted impact. The local waterbodies generally consisted of low-quality fish habitat supporting forage fish tolerant of low DO environments (i.e., brook stickleback) and low overwintering potential (frozen to bottom).

The cumulative effects of withdrawals are considered low in view of the considerations described in Volume 3, Section 6.7.1, including:

- not all licenced users will withdraw their full licenced amounts;
- while peak withdrawal rates may be higher than the licenced annual average rate presented here, these will not all occur at the same time, and many, due to cooling water

demands, will generally occur during the higher summer flow conditions than the 7Q10 low value, which is a winter flow condition;

- downstream inflows further reduce the cumulative effects of withdrawals;
- the daily fluctuations in flow currently occurring on the river are typically much greater than the sum of all net withdrawals;
- flow regulation has substantially increased previous natural low flows in the river (the 7-day minimum annual flow has increased from a median of 22.4 m^3/s prior to regulation to 77.8 m^3/s after regulation); and
- Flow monitoring accuracy on the river is likely in the order of ±5%.

Conclusions

Changes in water levels due to project activities should be isolated and short-term (limited to the duration of the construction period). Environmental impacts on the receiving environments are predicted to be negligible.

8.6.3.3 Riparian Habitat

Riparian zones provide ecosystem features that influence the aquatic habitats that support fish. Riparian areas are characterized as the bank and shoreline features of watercourses and waterbodies, as well as associated vegetation. This includes moist soils and substrates above the waterline, and also trees, shrubs, grasses and forbs growing along the bank. Riparian zones provide several features of fish habitat, including overhanging vegetation, submerged large woody debris and root wads. During periods of spring freshet, flooded areas in the riparian zone may also provide spawning habitat for species, such as the northern pike, that deposit eggs on inundated vegetation. These flooded areas may also provide refuge for various species during periods when stream flows are elevated.

Potential Environmental Changes

Project activities with the greatest potential to impact riparian habitat are associated with construction in the area adjacent to the water intake structure on the NSR. This activity requires the removal of sections of trees and vegetation, as well as the disruption of soil makeup on the banks.

Physical effects resulting from surface water runoff are moderated by vegetative cover in the riparian zones, slowing flow velocity that would otherwise cause stream bank erosion. Shoreline vegetation also acts as a filter for suspended sediments, reducing the sediment loading in watercourses and waterbodies. Additionally, many nutrients are absorbed by vegetation in the riparian zone, thus reducing nutrient loading and the associated effects they may have on trophic structure within the water column.

Alteration to riparian habitat may therefore result in impacts to fish health and fish community structure.

Mitigation

Impacts to riparian habitat will be limited to the areas of localized construction activities in the area adjacent to the water intake structure. With the recommended mitigation activities outlined in Volume 3, Section 6.6.3, disturbed riparian habitat would be restored to conditions consistent with “no net loss” principles. In the unlikely event that the riparian habitat cannot be restored, alternative techniques will be discussed with regulators. Impacts to riparian habitats associated with the North American project are predicted to be short-term and localized. North American is committed to following best management practices to ensure that the impacts to fish and fish habitat will be minimized.

Conclusions

Environmental effects to riparian habitat are predicted to be isolated, short-term and localized, with a low magnitude. Environmental impacts on riparian habitat are predicted to be low as a result of the implementation of best management practices associated with the construction of roads and the water intake structure.

8.6.3.4 Benthic Invertebrate Abundance and Composition

The benthic invertebrate community includes a variety of insects that live on or in the substrates of waterbodies and watercourses. This community of organisms includes the larval and pupal stages of terrestrial adult insects (e.g., mayflies, dragonflies, black flies, midges, etc.), as well as some groups that spend their entire life underwater (e.g., aquatic worms, beetles, nematodes, some crustaceans, snails, etc.). Benthic habitat is typically defined as the interface between sediment and the water column, on the surface of sand, rocks and boulders. Invertebrates living on woody debris, on plant surfaces under the water and within the sediment itself are also included in this group.

Benthic invertebrates play an important role within the aquatic ecosystem. Populations of midges and aquatic worms cause the release of nutrients from sediment that is then available to bacteria, algae and aquatic vegetation for primary production. Organic plant material is broken down and consumed by some benthic organisms, thus continuing the nutrient cycle in the aquatic system. Because many benthic organisms serve as prey for fish, they also provide an important link for energy to be transferred to higher animals (e.g., fish and birds).

Potential Environmental Changes

Benthic invertebrate populations are susceptible to many of the same impacts as fish, including sedimentation, fluctuations in water level, alteration to water quality and general habitat degradation. As the benthic invertebrate community is a source of food for many fish species, changes in their health or population will inevitably affect the fish community. Changes in water levels and flows (Section 8.6.3.2) may result in a reduction of habitat area and changes to overall water quality. Benthic invertebrate community composition is often largely attributed to the effects of water velocity. Increased sedimentation (Section 8.6.3.1) may damage external gills. Project activities with the greatest potential to impact riparian habitat are associated with construction activities in the vicinity of the water intake structure. These activities require the removal of bank vegetation, which may cause increased sedimentation. Emissions-related effects can alter concentrations of major ions in waterbodies and affect pH levels (Section 8.6.4.2). These changes in water quality may impact some sensitive invertebrates. Additionally, land clearing, road construction and plant construction may directly disturb sediments, thereby affecting invertebrates in localized areas.

Mitigation

Construction of site facilities will comply with pertinent legislation and regulatory guidelines and practices. Effects on the benthic invertebrate community associated with the construction and operation of the Project will be alleviated by mitigation described further in Section 8.6.3.1.

Conclusions

Planned mitigation will ensure that construction activities associated with the Project will have a negligible effect on suspended sediment concentrations in receiving streams, lakes, ponds and wetlands. Therefore, impact to the benthic invertebrate community from altered water quality due to the release of sediment is expected to be negligible.

Changes in surface water levels and flows from Project construction and operation activities are predicted to be negligible. Therefore, loss of benthic invertebrate habitat from changes in water levels will be no greater than natural variation.

Small areas of benthic habitat may be altered with the construction in the vicinity of watercourses. However, effects are predicted to be localized and short-term. Once construction with mitigation measures is completed, the benthic community will be able to re-colonize disturbed habitats naturally.

The benthic invertebrate community is not likely to experience many changes from acidification of waterbodies. The lakes in the LSA are well buffered; therefore, the occurrence of acidification in the Project is not likely. Overall, the majority of lakes located within the Project's RSA were found to be well buffered, with concentrations of $CaCO_3$ commonly greater than 100 mg/L (Volume 3, Section 7.5.5.2). If acidification occurs, impacts to benthic invertebrates will be negative and subregional in extent, with medium magnitude. The duration will be long-term, with isolated frequency and long-term permanence. These predictions have been made with moderate confidence. The potential environmental impact to benthic invertebrates is predicted to be moderate under acidifying conditions.

Most activities associated with the Project development, operation and reclamation are conducted with measures to protect the aquatic environment. Where acidification is not a concern, impacts are predicted to be neutral and of negligible magnitude, short-term in duration and occur in occasional frequency. Impacts are expected to be reversible in the medium-term. The overall environmental impact rating for benthic invertebrates is considered to be low impact.

8.6.4 Combined Industrial Disturbance on Fish and Fish Habitat

A number of areas were identified to have the potential to impact fish and fish habitat from combined industrial disturbances associated with the Project (e.g. spills, discharges, changes in pH). The areas of potential impact included spills and wastewater discharges, changes in surface water pH and water intake construction effects on fish habitat.

8.6.4.1 Wastewater Discharge, Stormwater Runoff and Spills

The introduction of toxic or anthropogenic substances into the watercourses and waterbodies in the LSA may result in changes to surface water or groundwater quality. Accidental releases of toxic substances may occur from a variety of activities during construction, operation and reclamation of the Project.

Potential Environmental Changes

Wastewater discharge may result in accumulation of contaminants in higher trophic levels (such as piscivorous sportfish species like northern pike) which could affect the quality of fish relative to human consumption. Human health consumption guidelines exist for mercury, dioxins and furans (ASRD, 2007a). Only mercury will potentially be released in the wastewater discharge. Mercury has the potential to bioaccumulate in sportfish from the consumption of lower trophic levels and sediments, or through water exposure and subsequent uptake across the gills.

Stormwater runoff has the potential to introduce substances into surface waters. Elevated concentrations of foreign substances may result in changes in fish behavior (e.g., predator avoidance, spawning, feeding) and physiology (e.g., respiration, sensory mechanisms). Water quality alterations may also result in adverse affects on fish tissue quality (i.e., chemical burdens, tainting).

Mitigation

Conservative water quality modelling (Volume 3, Section 7 - Surface Water Quality) indicates that Project effluent will not increase the concentration of metals above CCME guidelines for aquatic life (including mercury) in the NSR under the fully mixed condition. The potential for the Project to contribute mercury to the NSR and increase bioaccumulation in sportfish is expected to be low.

During the development and operation phases of the Project, various measures will be taken to minimize the occurrence of spills and upset conditions. Spills will be cleaned up as per the North American emergency response procedures. Additionally, vehicles, machinery and facilities will be maintained in a manner that prevents the introduction of hydrocarbons or other deleterious substances into the environment.

Introducing foreign substances into surface water via stormwater runoff will be mitigated by implementing a stormwater management plan (Volume 1, Section 6 - Hydrology). Stormwater runoff will be collected in retention ponds, where it will be tested and treated (if necessary) to meet AENV guidelines before release into natural areas.

Conclusions

As a result of proposed water treatment plans and conservative water quality modelling, environmental impacts to fish and fish habitat as a result of wastewater discharge are predicted to be low. The collection and treatment of stormwater runoff will prevent any effects to surface water quality. The effects to fish and fish habitat are predicted to be negligible.

8.6.4.2 Changes in pH

The deposition of aerial emissions as a result of industrial activities has the potential to alter the chemistry of surface water in surrounding areas. The primary pollutants associated with aerial depositions include NO_x and SO_2, the precursors to nitric and sulphuric acid, which are the main constituents that may contribute to the acidification of waterbodies and watercourses.

Potential Environmental Changes

The effects of acidification within aquatic communities generally occur as pH levels reach 6.0 to 5.5 (Carbone et al., 1998; Husky, 2003). When pH levels fall below 5.0, impacts to aquatic communities become more severe, at times leading to the extirpation of aquatic species.

Waters with observed alkalinity levels less than 20 mg/L $CaCO_3$ are considered to have a low acid neutralizing capacity and are more susceptible to the effects of acidification (Saffran and Trew, 1996). Waters with alkalinities at higher levels are considered to have a greater buffering capacity from the effects of acidification. Further discussion on surface water acidification from aerial deposition is included in Volume 3, Section 7 - Surface Water Quality.

Based upon the results from Surface Water Quality (Volume 3, Section 7) and Air Quality assessments (Volume 2, Section 2), the lakes within the Astotin Creek study area were determined to be well buffered at baseline (i.e., before Project commencement). Altered pH levels in regional waterbodies resultant from aerial deposition are considered a potential impact to fish and fish habitat. Changes associated with acidification would likely be long-term and, notably, irreversible in the short-term.

Mitigation

As a result of findings from the Surface Water Quality (Volume 3, Section 7) and Air Quality (Volume 2, Section 2) assessments for the Project, acidification from aerial deposition is considered to be unlikely.

Conclusions

The majority of lakes located within the Project's RSA were found to be well buffered, with concentrations of $CaCO_3$ commonly greater than 100 mg/L. The level of environmental impact is projected to be low for the remaining lakes in the RSA. This topic is discussed in detail in Volume 3, Section 7. It is reasonable to predict that the overall impact to fish and fish habitat related to project activities and altered pH will be low.

The environmental effects related to changes in pH associated with acidifying emissions on waterbodies not considered to be sensitive to acidification are predicted to be isolated, short-term and localized, with a negligible magnitude. No environmental impacts resulting from acidifying emissions on these waterbodies are predicted.

8.6.4.3 Water Intake Effects on Fish and Fish Habitat

The construction and operation of an intake on the NSR could affect the fish habitat and water quality in the NSR. The construction of the water intake has the potential to alter the watercourse and deposit sediment. Potential loss of fish may occur due to entrainment at the intake during operation and water withdrawal.

Potential Environmental Changes

Specifically, effects on fish habitat could result from direct disturbance, alteration or loss of productive habitats at the intake location. The proposed intake design is discussed in Volume 3, Section 6.6.2. A total footprint area of up to 450 m^2 on the river bed is assumed.

Instream construction activities could potentially increase deposition of fine sediments downstream of the intake structure (short duration). Increased sedimentation might result in changes to food availability, suitability of spawning or overwintering habitats and alterations to channel morphology and cover habitat. Installation of the coffer dam and isolation activities could result in fish being stranded within the structure, as well as possible mortality.

Stream bed scouring, as a result of instream construction and hydrodynamic influences of the intake structure, could also affect fish habitat.

Entrainment of fry or juvenile fish at the intake could result in a decrease of recruitment levels and an overall decline in the local fish populations.

Mitigation

Because of the potential for erosion and the disturbance of fish habitat associated with the intake structure, the environmental effects are predicted to be low to moderate. Applications to construct the intake structure will be required under the Alberta *Water Act*. In addition, authorizations by DFO under the *Fisheries Act* and Transport Canada under the *Navigable Waters Protection Act* (Canadian Coast Guard, 1994) will also be required.

The intake structure will have a screen to prevent debris from entering the intake pumps and to exclude fish, and will meet the DFO criteria outlined in the "Freshwater Intake End-of-Pipe Fish Screen Guidelines" (DFO, 1995). The intake structure will be designed to draw the amount of water needed for operations, while maintaining water velocities that will not endanger smaller fish or fry by pulling them up against or through the intake screen.

Mitigation of potential impacts related to the construction of the NSR water intake for the Project will be accomplished by constructing the intake according to the guidelines and procedures of Transport Canada under the *Navigable Waters Protection Act*.

Construction scheduling will be completed in consultation with DFO and ASRD to minimize potential impacts of sedimentation and channel alteration on the NSR, and to ensure that activities do not affect fish activities at the intake location. The intake location will be isolated during construction to minimize downstream sediment deposition by:

- minimizing disturbances of stream banks in the immediate area;
- developing and implementing an erosion and sediment control plan before construction, to minimize suspended sediment generation caused by surface water runoff from newly excavated approach slopes and bank areas. Sediment control measures will include appropriate coffer damming, recontouring, revegetation and appropriate use of silt fences; and
- prior to dewatering of the work area, a fish salvage should be undertaken, returning fish to the main channel of NSR, thereby reducing fish mortalities.

A habitat compensation program may be developed to address the temporary disruption of fish habitat during the construction of the intake structure, as well as the loss of 450 m^2 of habitat. Habitat compensation, if required, would be determined through consultations with DFO and ASRD.

The loss of potential fish habitat due to the intake structure footprint will be partially mitigated due to the design of the intake structure (Volume 3, Section 6.6.2). Backwater areas will exist upstream and downstream of the intake, providing a velocity break and cover for local and migrating fish. A detailed description of fish habitat compensation will be discussed in a separate application.

Conclusions

The environmental effects related to water intake construction are predicted to be isolated, short-term and localized, with a negligible magnitude. Environmental impacts resulting from the water intake on fish mortality due to entrainment is predicted to be negligible. Fish habitat loss due to the water intake footprint is expected to be a low-magnitude, medium-term effect.

8.6.4.4 Nutrient Enrichment

Wastewater discharge during operations can contribute nutrients, including phosphorus, nitrogen-containing compounds (including ammonia, nitrate/nitrite and organic nitrogen) and organic carbon. The addition of these components to a waterbody can contribute to eutrophication in a waterbody. The organic carbon content available for decomposition can be measured by two methods. The first is via biochemical oxygen demand (BOD), which is the amount of oxygen consumed during a five-day decomposition of the effluent under laboratory conditions. The other method is by chemical oxygen demand (COD), which provides a faster measure of BOD but is generally much higher.

Under high nutrient loading, the propagation of plant and algal matter can lead to increased decomposition of plant material, thus lowering oxygen levels. Increased bacterial activity associated with BOD may result in oxygen depletion, particularly where re-aeration is limited, such as under ice. Excessive plant and algal growth may cause wide swings in oxygen levels, from supersaturation during daylight hours to depletion at night, when both bacterial decomposition and respiration by plants are at a maximum (Wetzel, 2001).

The loading of BOD, in conjunction with nutrient loading, would be expected to contribute to a reduction in oxygen levels. During the growing season, oxygen levels can decline below saturation at night due to plant and algal respiration, particularly where there is excessive growth of plants and algae. Although no data are available to assess nighttime depletion, a few measurements collected in the early morning do not suggest major overnight declines in oxygen levels. However, oxygen depletion during the growing season depends on many factors and can be highly episodic, so lower levels of oxygen than have been recorded might occasionally occur.

Potential Environmental Changes

The effect of nutrient inputs to aquatic biota is complex and varied. Low levels of organic matter stimulate bacterial activity, and the bacteria, in turn, provide an increased food source to aquatic microorganisms near the base of the food chain. Increased bacterial activity can lower oxygen levels, depending on the amount of BOD. Nitrogen and phosphorus stimulate the growth of algae (both attached and planktonic) and macrophytes when other conditions are suitable for growth, such as light availability and substrate. An increase in primary nutrient production (i.e., phytoplankton) can increase invertebrate and overall aquatic community production, but can also lead to loss of sensitive species and habitat changes (e.g., bare rocks can become covered in algae). Certain types of algae (e.g., blue-green algae) may also produce toxins, and eutrophication may lead to blue-green algal blooms and increased production of algal microtoxins.

Mitigation

Conservative water quality modelling (Volume 3, Section 7) indicates that project effluent may increase the concentration of nutrients above CCME guidelines for aquatic life in the NSR under the fully mixed condition. It is important to note that background levels of nutrients in the NSR, specifically total phosphorus and nitrites, already exceed CCME guidelines (Volume 3, Section 7.6.4.2).

Conclusion

Overall, available information indicates that the LSA does not generally experience substantive oxygen depletion in the open-water season. Environmental impacts on the receiving environments are predicted to be negligible. The potential for the Project to contribute to nutrient enrichment in the NSR is expected to be low, and to last for the duration of the operation phase of the Project.

8.7 Cumulative Effects Assessment

A Cumulative Effects Assessment (CEA) considers the potential impacts associated with the Project in combination with other existing and future projects located within the Project's RSA. Currently, there are a number of projects that exist or have been announced in the RSA. A list of these projects is presented in Volume 2, Section 1.

Impacts to fish and fish habitat are generally predicted to be negligible to low and localized as a result of North American's commitment to adhering to best management practices as they relate to activities in the vicinity of all watercourses and waterbodies. Impact assessments for other projects in the region have also predicted low impacts, localized around each project's intake structure or outfall. As such, the potential fish and fish habitat impacts are not considered to spatially overlap, and therefore no cumulative effects are anticipated.

Cumulative impacts to water quality of the NSR were assessed to be negative in direction, regional in extent, low in magnitude, medium-term in duration, continual in frequency and reversible in medium-term. The effects will be low in magnitude because the incremental increases in certain water quality parameters as a result of the Project are within water quality guidelines (Volume 3, Section 7.7.2). The residual effects of acid emissions on the water quality of regional lakes will be negligible (Volume 3, Section 7.73). Based on the relationship between water quality, fish health and fish habitat, no cumulative effects are predicted for fish.

8.8 Follow-up and Monitoring

North American will adhere to monitoring and mitigation activities during Project development, operation and closure as required.

For construction activities occurring at or near watercourses and waterbodies, appropriate authorizations will be obtained prior to activity commencement. Monitoring and mitigation programs that will be conducted in the LSA in association with the construction activities are further discussed in the mitigation sections outlined in Section 8.6.

8.9 Impact Summary

The fish and fish habitat LSA was delineated based on the Project lease and footprint areas, as well as local drainage basin boundaries. The LSA includes waterbodies and watercourses which may be affected, directly or indirectly, by the Project. The RSA was selected based on potential effects to fish and fish habitat resulting from changes in water flows, levels and quality. In addition, the RSA encompasses the area where the cumulative effects assessment would be focused.

Baseline studies on fish and fish habitat were conducted in 2006 and 2007. Study locations in two waterbodies and three watercourses were selected to characterize fish habitat potential and identify resident fish populations. Historical data sources were reviewed and used to supplement the baseline data collected during field surveys. The overall fish habitat quality observed in the area in both watercourses and waterbodies ranged from low to high. Both forage fish and large-bodied fish species were observed during the field surveys, and included brook stickleback and white sucker.

The fish and fish habitat assessment considered the Project activities that had the potential to cause direct or indirect impact to fish and fish habitat, surface water quality and hydrology. Key issues related to riparian and instream fish habitat alteration and combined industrial disturbance on fish habitat were assessed in relation to the Project. In general, the Project is not expected to have any impacts on fish and fish habitat.

Table 8.9-1 Potential Impacts Associated with the Project

Environmental Impact Associated With Fish And Fish Habitat	**Direction**	**Extent**	**Magnitude**	**Duration**	**Frequency**	**Permanence**	**Confidence**	**Environmental Impact**
Changes to fish habitat through sedimentation	neutral	local	low	Short-term	occasional	reversible in short-term	medium	negligible
Changes to water levels, flows and drainage patterns	neutral	local	low	Short-term	isolated	reversible in short-term	medium	negligible
Riparian habitat degradation	negative	local	low	Short-term	isolated	reversible in medium-term	high	low impact
Changes in benthic invertebrate abundance and composition	neutral	local	low	Short-term	occasional	reversible in medium-term	high	low impact
Effects related to facility and operation spills	neutral	local	low	Short-term	isolated	reversible in medium-term	high	wastewater: low impact runoff: negligible
Acidifying emissions on fish in waterbodies not considered acid sensitive	neutral	local	negligible	Short-term	isolated	Short-term	moderate	no impact
Fish mortality due to operation of water intake	negative	local	negligible	Short-term	isolated	irreversible	high	negligible
Habitat loss due to water intake footprint	negative	local	low	Medium-term	isolated	reversible in the medium-term	high	low impact
Nutrient Enrichment	negative	local	negligible	Medium-term	continuous	reversible in medium-term	high	negligible

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APPENDIX 5A: HYDRAULIC CONDUCTIVITY TESTS

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FIGURES

5A1 SUMMARY

Hydraulic conductivity tests were conducted at monitoring wells installed in surficial and bedrock units between May 10 and 12, 2007. Bail/recovery tests were conducted on three monitoring wells (07-8, 07-11 and BH06-11) completed in the surficial till unit, as well as one monitoring well (07-5) completed in bedrock. In addition, a pumping/recovery test was also conducted at monitoring well 07-6, which is completed in the gravel unit overlying bedrock.

Hvorslev analysis of the bail/recovery test data indicated that the clay/till unit has a hydraulic conductivity ranging between 1 x 10^{-9} m/s and 6 x 10^{-9} m/s, and the siltstone/sandstone bedrock has a hydraulic conductivity of approximately 9 x 10^{-9} m/s. The pumping test data was analyzed using the Theis (1935) forward solution, Theis recovery solution and Cooper-Jacob time-drawdown solution. Based on the results of these analyses, the estimated hydraulic conductivity of the gravel unit is approximately 8 x 10^{-5} m/s. The storativity of the gravel unit was estimated to be 2 x 10^{-3}, based on the Theis forward solution.

5A2 DETAILED PUMPING TEST DESCRIPTION

5A2.1 Well Completion Details

Monitoring well 07-6 is located at UTM easting 368201 and northing 5962500 (NAD 83) on surface lease 08-35-055-21 W4M. The ground elevation is 627.6 m above sea level (masl). The well was drilled to a depth of approximately 34.3 m below ground surface (bgs), and the sand pack extends from 26.2 m bgs to 30.5 m bgs within a unit of fine sandstone and siltstone. Further details regarding the elevation and well completion are summarized in Table 5.4-2.

The static head measurement in monitoring well 07-6 was 620.68 masl.

5A2.2 Pumping Program

The pumping test was completed with a constant pumping rate measured approximately every 10 minutes. The average pumping rate was 0.41 L/s (35 m^3/day), with minor fluctuations of 0.01 L/s. The pumping test lasted 90 minutes, at which time pumping ceased.

5A2.3 Summary of Collected Data

Drawdown in well 07-6 was recorded for 90 minutes during the pumping portion of the test, and for 60 minutes after the cessation of pumping. Drawdown was recorded using a dedicated pressure transducer, as well as with periodic manual measurements using a water level tape. The drawdown is displayed in Figure 5A-1. The pressure transducer was lowered to a depth of approximately 9.5 m below the static water level and 1 m below the pump intake. When the water level was at its static level, the pressure reading exceeded the transducer’s 10 m maximum due to atmospheric pressure. The manual water levels were used to fill the data gaps.

5A2.4 Pumping Analysis

Analysis of the pumping test data was facilitated using Waterloo Hydrogeologic Inc.'s software Aquifer Test Pro 3.5. In order to estimate hydraulic conductivity (K) of the gravel unit, the pumping data was analyzed according to the Theis (1935) forward solution (Figure 5A-2), as well as the Cooper and Jacob (1946) time-drawdown solution (Figure 5A-3).

A transmissivity value of 4.0×10^{-4} m^2/s was calculated for both methods. Given the aquifer thickness of 4.5 m, the hydraulic conductivity for the gravel unit is estimated to be approximately 9×10^{-5} m/s. Based on the Cooper and Jacob (1946) solution, the storativity is estimated to be 2×10^{-3}.

5A2.5 Pumping/Recovery Analysis

Analysis of the pumping and recovery was conducted using the Theis Recovery solution (Figure 5A-4). A transmissivity value of 3.7×10^{-4} m^2/s was calculated using the analysis. Based on an aquifer thickness of 4.5 m, the hydraulic conductivity of the gravel unit is estimated to be 8×10^{-5} m/s. The results for the three methods of pumping test analysis are in relatively good agreement.

5A3 DETAILED BAIL-RECOVERY TEST DESCRIPTION

5A3.1 Well Completion Details

5A3.1.1 Monitoring Well 07-8

Monitoring well 07-8 is located at UTM easting 366613 and northing 5961391 (NAD 83) on surface lease 08-35-055-21 W4M. The ground elevation is 626.6 masl. The well was drilled to a depth of approximately 11.7 m bgs, and the sand pack extends from 8.4 m to 11.7 m bgs within the surficial glacial till unit. Further details regarding the elevation and well completion are summarized in Table 5.4-2.

The static head measurement in monitoring well 07-8 was 621.96 masl.

5A3.1.2 Monitoring Well 07-11

Monitoring well 07-11 is located at UTM easting 368430 and northing 5963091 (NAD 83) on surface lease 10-26-055-21 W4M. The ground elevation is 624.6 masl. The well was drilled to a depth of approximately 11.2 m bgs, and the sand pack extends from 7.4 m bgs to 11.2 m bgs within the glacial till unit. Further details regarding the elevation and well completion are summarized in Table 5.4-2.

The static head measurement in monitoring well 07-11 was 621.21 masl.

5A3.1.3 Monitoring Well BH06-11

Monitoring well BH06-11 is located at UTM easting 367442 and northing 5963118 (NAD 83) on surface lease 15-26-055-21 W4M. The ground elevation is 624.4 masl. The well was drilled to a depth of approximately 11.7 m bgs, and the sand pack extends from 1.8 m to 5.8 m bgs within the glacial till unit. Further details regarding the elevation and well completion are summarized in Table 5.4-2.

The static head measurement in monitoring well BH06-11 was 622.53 masl.

5A3.1.4 Monitoring Well 07-5

Monitoring well 07-5 is located at UTM easting 368201 and northing 5962501 (NAD 83) on surface lease 08-35-055-21 W4M. The ground elevation is 627.7 masl. The well was drilled to a depth of approximately 34.3 m bgs, and the sand pack extends from 26.2 m to 30.5 m bgs within the glacial till unit. Further details regarding the elevation and well completion are summarized in Table 5.4-2.

The static head measurement in monitoring well 07-5 was 620.47 masl.

5A3.2 Bail-Recovery Program

Monitoring wells 07-8, 07-11 and BH06-11 were purged dry with a purge pump on May 10, 2007. Monitoring well 07-5 was purged dry with a Grunfos pump in the morning of May 11, 2007. Recovery was recorded by dedicated pressure transducers installed near the bottom of each well casing. The recovery tests were terminated on May 11, 2007, when the pressure transducers were removed from the wells.

5A3.3 Recovery Analysis

Analysis of the bail-recovery test data was facilitated by Waterloo Hydrogeologic Inc.'s software Aquifer Test Pro 3.5. In order to estimate hydraulic conductivity (K), the bail-recovery data was analyzed according to the Hvorslev (1951) solution. The recovery curves are plotted in Figures 5A-5, 5A-6, 5A-7 and 5A-8.

The estimated hydraulic conductivity of the till was estimated to be 1 x 10^{-9} m/s at monitoring well 07-8, 6 x 10^{-9} m/s at monitoring well 07-11, and 6 x 10^{-9} m/s at monitoring well BH06-11. Based on these results, the hydraulic conductivity of the till appears to be relatively consistent at various locations and depths across the site.

The estimated hydraulic conductivity of the sandstone/siltstone underlying the site is estimated to be 2 x 10^{-7} m/s, based on the bail-recovery test analysis of monitoring well 07-5.

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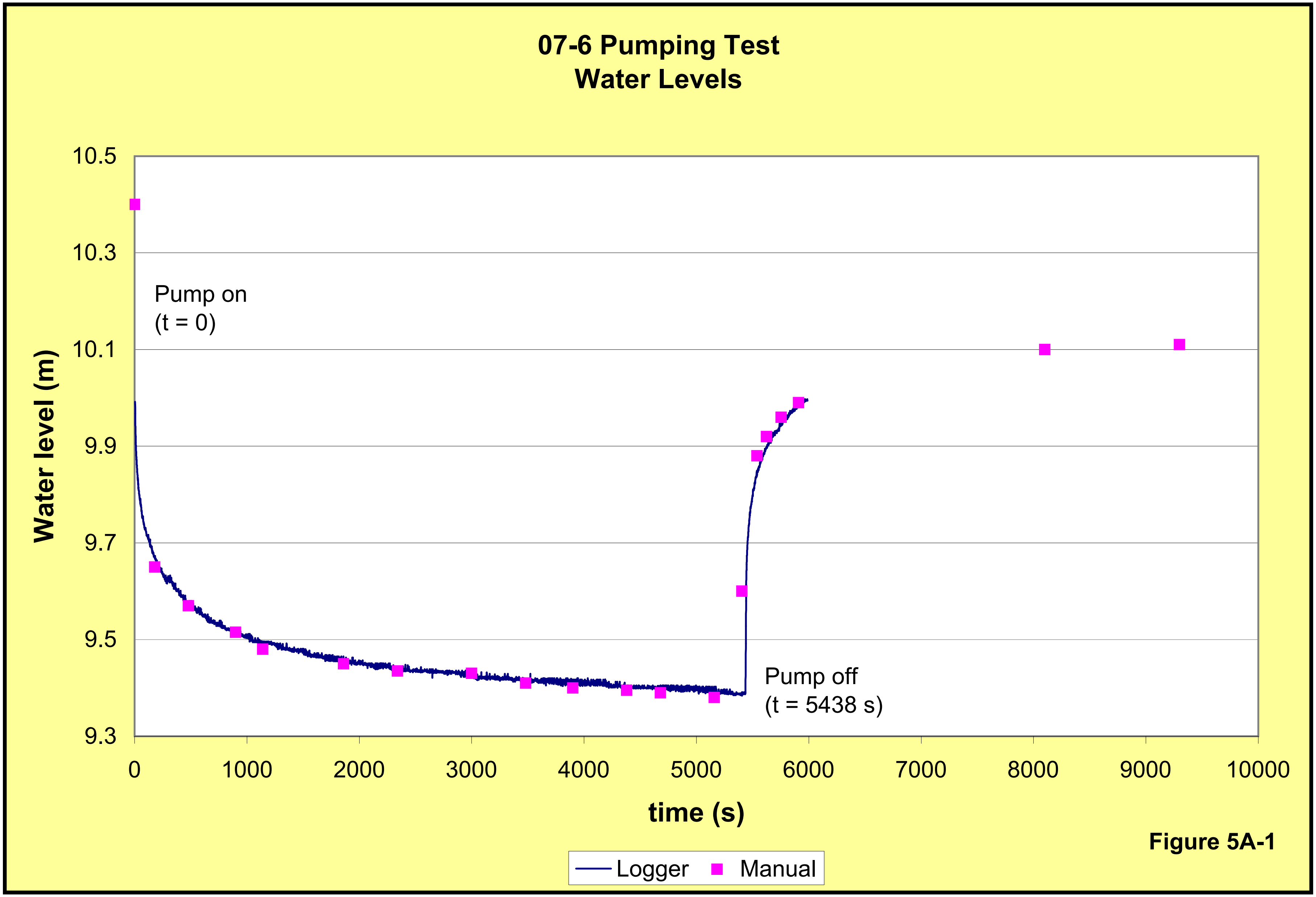
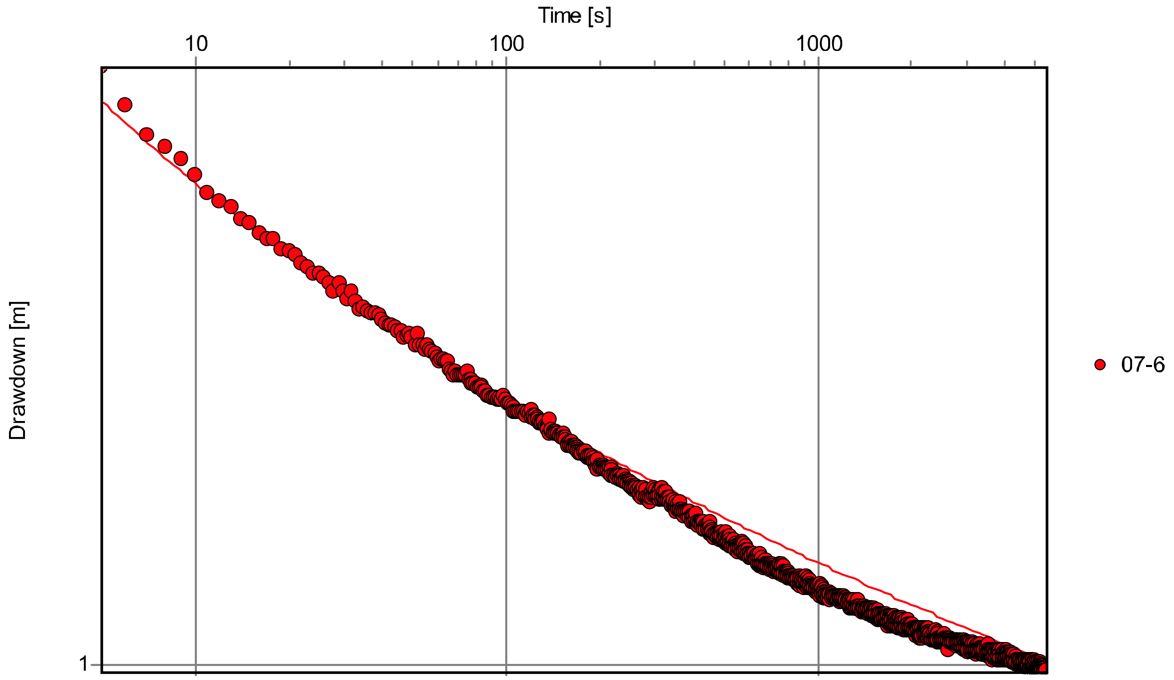

07-6 Pumping Test
Water Levels
Water level (m)
10.5
10.3
10.1
9.9
9.7
9.5
9.3
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
time (s)
Pump on
(t = 0)
Pump off
(t = 5438 s)
Logger
Manual

Figure 5A-1



Pumping Test: 07-6

Analysis Method: Theis (1935) - Forward Solution

Analysis Results:				
	Transmissivity:	4.03E-4 [m²/s]	Mean Error (ME):	2.51E-2
	Storativity:	2.41E-3	Sum of Squares Error (SSE):	4.59E-1
	Conductivity:	8.95E-5 [m/s]	Variance (VAR):	8.44E-5
			Standard Deviation (SDEV):	9.19E-3

Test Details: Saturated Aquifer Thickness: 4.5 m

Pumping Well:	X m	Y m	TOC Elev. m	L m	R m	r m	Q m³/s	Well Screen
07-6	368201.1	5962499.8	628.65		0.1	0.03	0.00041	Fully Penetrating

Title:

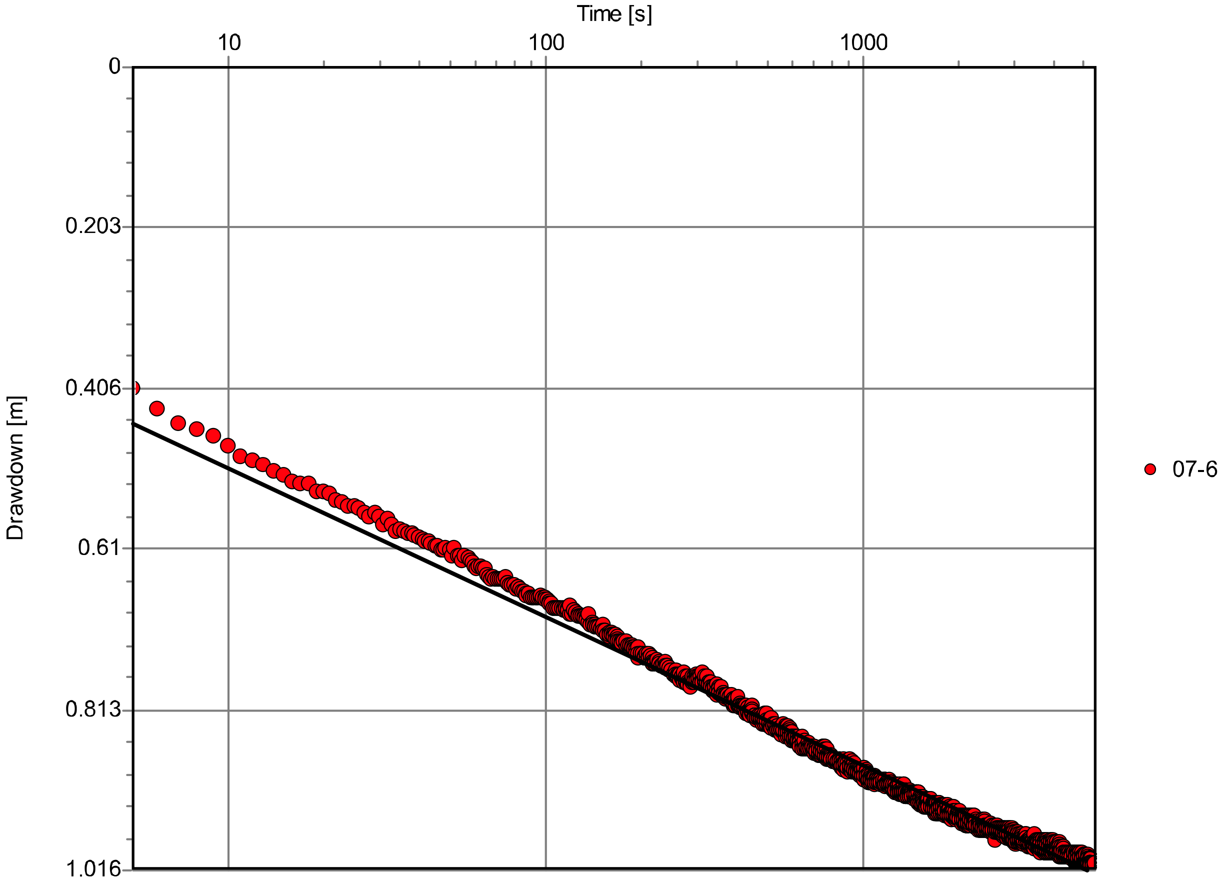
PUMPING TEST 07-6 THEIS
(1935) - FORWARD SOLUTION

NORTH AMERICAN
OIL SANDS CORPORATION

Approved: TVD	Revision Date: JULY, 2007

File:
6198-PumpTest-07

Drawn by: ADF	Checked: RP	Fig. No.: **5A-2**



Pumping Test:	**07-6**			
Analysis Method:	**Cooper-Jacob Time-Drawdown**			
Analysis Results:	Transmissivity:	4.00E-4 [m²/s]	Conductivity:	8.88E-5 [m/s]
Test parameters:	Pumping Well:	07-6	Aquifer Thickness:	4.5 [m]
	Casing radius:	0.025 [m]	Confined Aquifer	
	Screen length:	3.8 [m]		
	Boring radius:	0.097 [m]		
	Discharge Rate:	0.00041 [m³/s]		

Title:

PUMPING TEST 07-6 COOPER-JACOB TIME-DRAWDOWN

NORTH AMERICAN OIL SANDS CORPORATION

Approved: TVD	Revision Date: JULY, 2007	
File: 6198-PumpTest-07		
Drawn by: ADF	Checked: RP	Fig. No.: 5A-3

07-6 Pumping Test
Theis Recovery

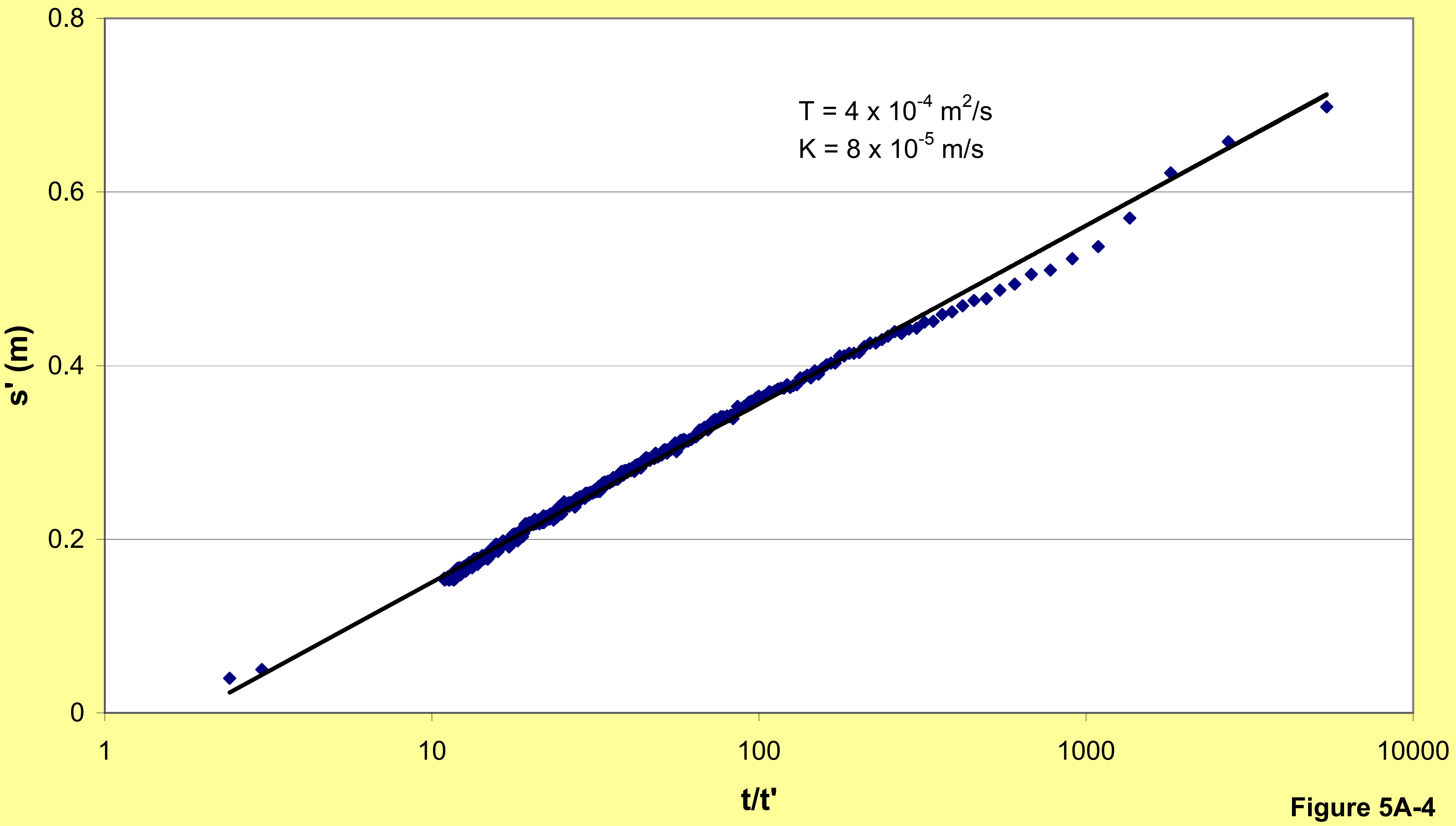
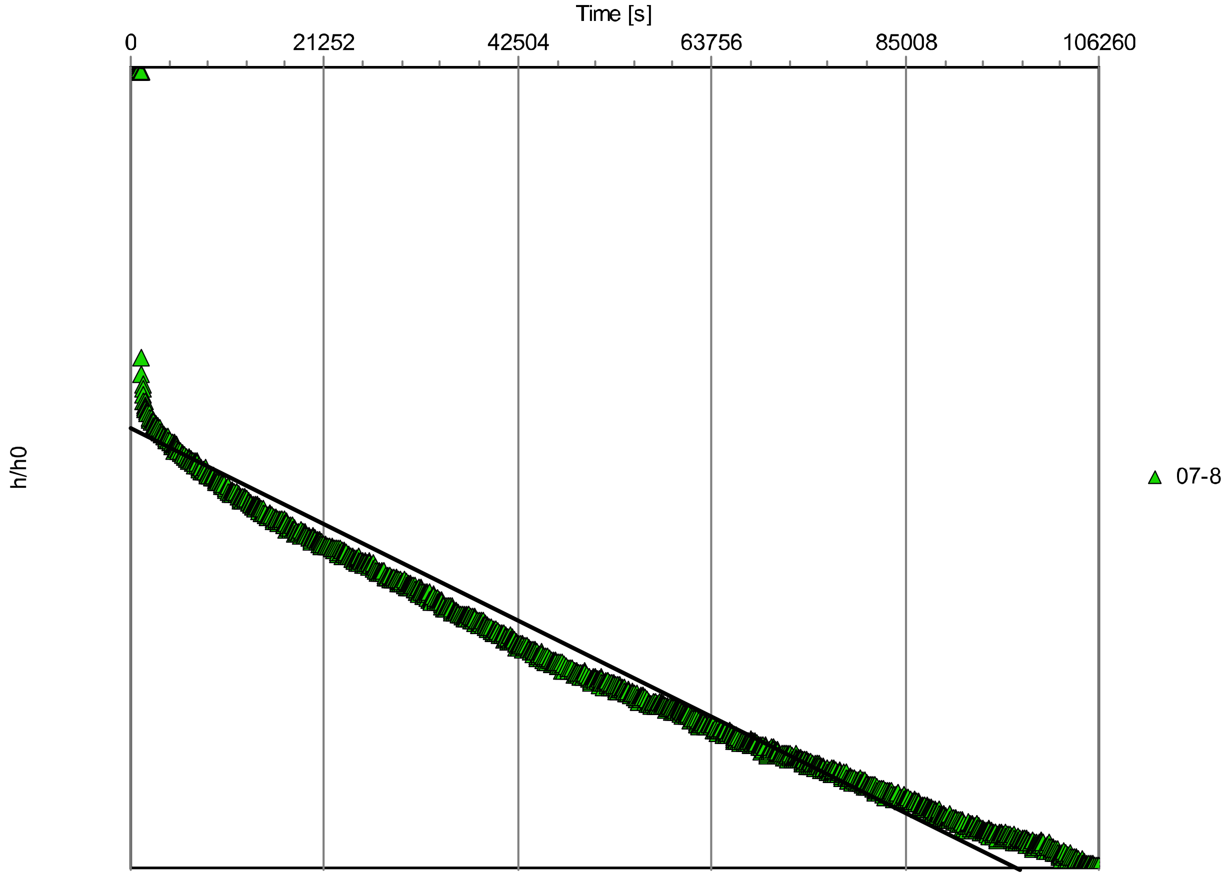


Figure 5A-4



Slug Test: **07-8 Bail-recovery**

Analysis Method: **Hvorslev**

Analysis Results:		Conductivity:	1.21E-9 [m/s]

Test parameters:	Test Well:	07-8	Aquifer Thickness:	3.3 [m]
	Casing radius:	0.025 [m]		
	Screen length:	3.3 [m]		
	Boring radius:	0.097 [m]		

Title:

SLUG TEST 07-8 BAIL-RECOVERY HVORSLEV

NORTH AMERICAN OIL SANDS CORPORATION

Approved: TVD	Revision Date: JULY, 2007	
File: 6198-PumpTest-07		
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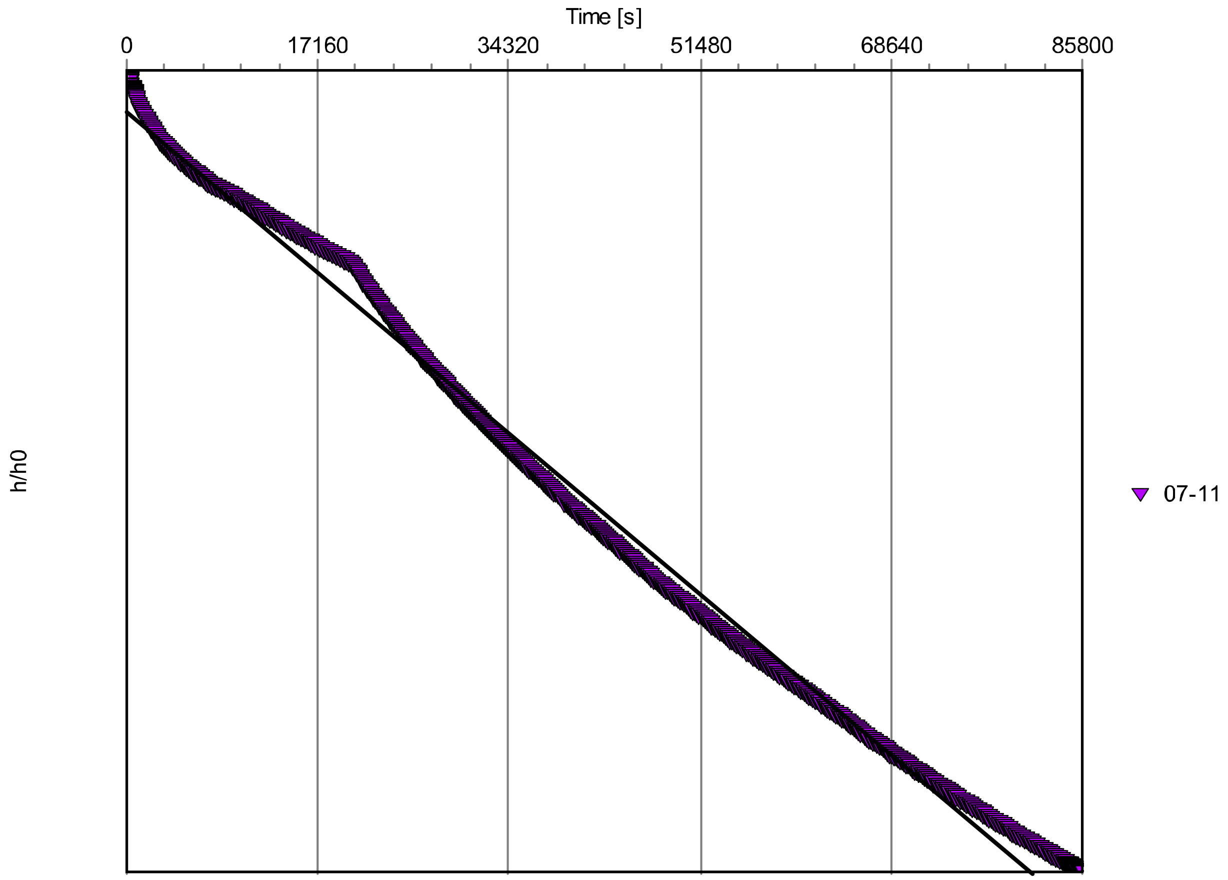


Slug Test: **07-11 Bail-recovery**

Analysis Method: **Hvorslev**

Analysis Results: Conductivity: 6.43E-9 [m/s]

Test parameters:

Test Well: 07-11

Casing radius: 0.025 [m]

Screen length: 3.8 [m]

Boring radius: 0.097 [m]

Aquifer Thickness: 3.8 [m]

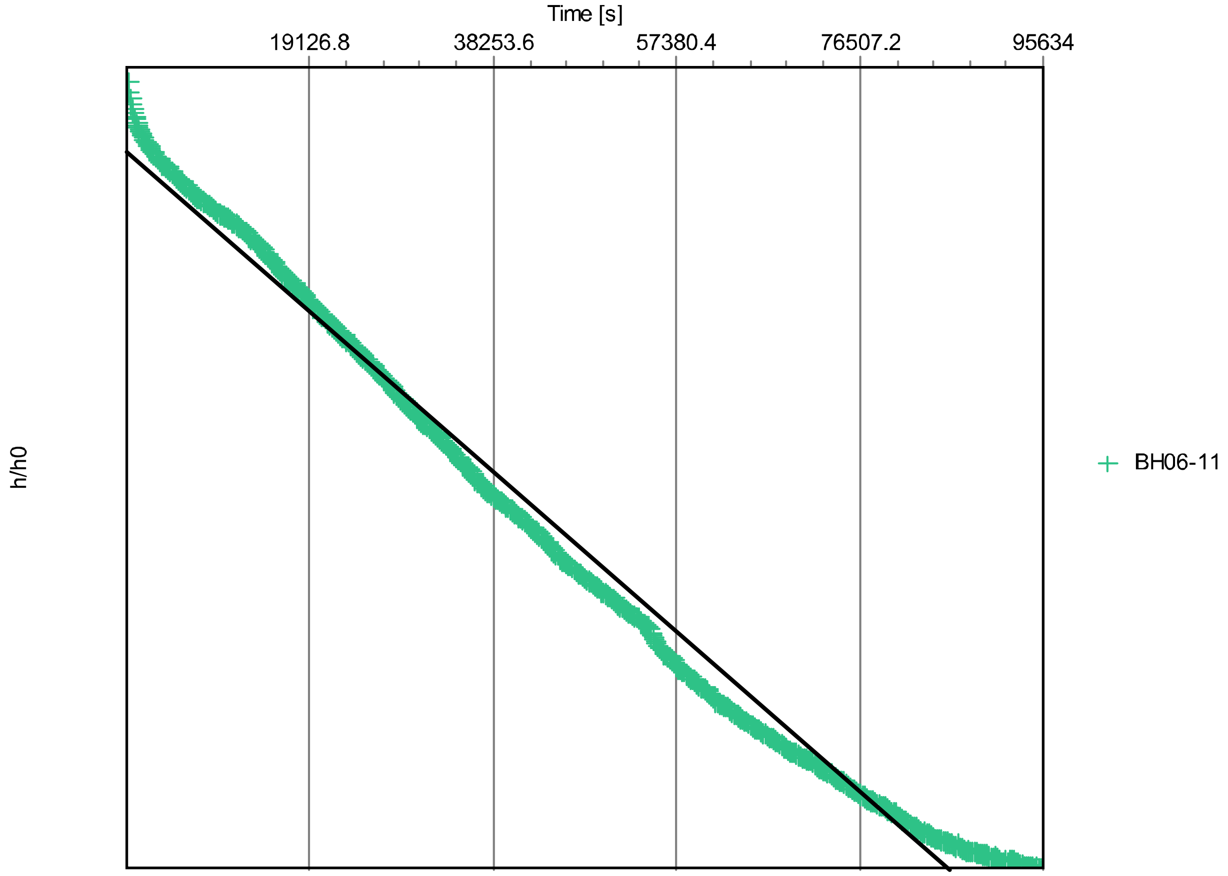
Title:

SLUG TEST 07-11 BAIL
RECOVERY HVORSLEV

NORTH AMERICAN
OIL SANDS CORPORATION

Approved: TVD	Revision Date: JULY, 2007
File: 6198-PumpTest-07	

Drawn by: ADF	Checked: RP	Fig. No.: **5A-6**



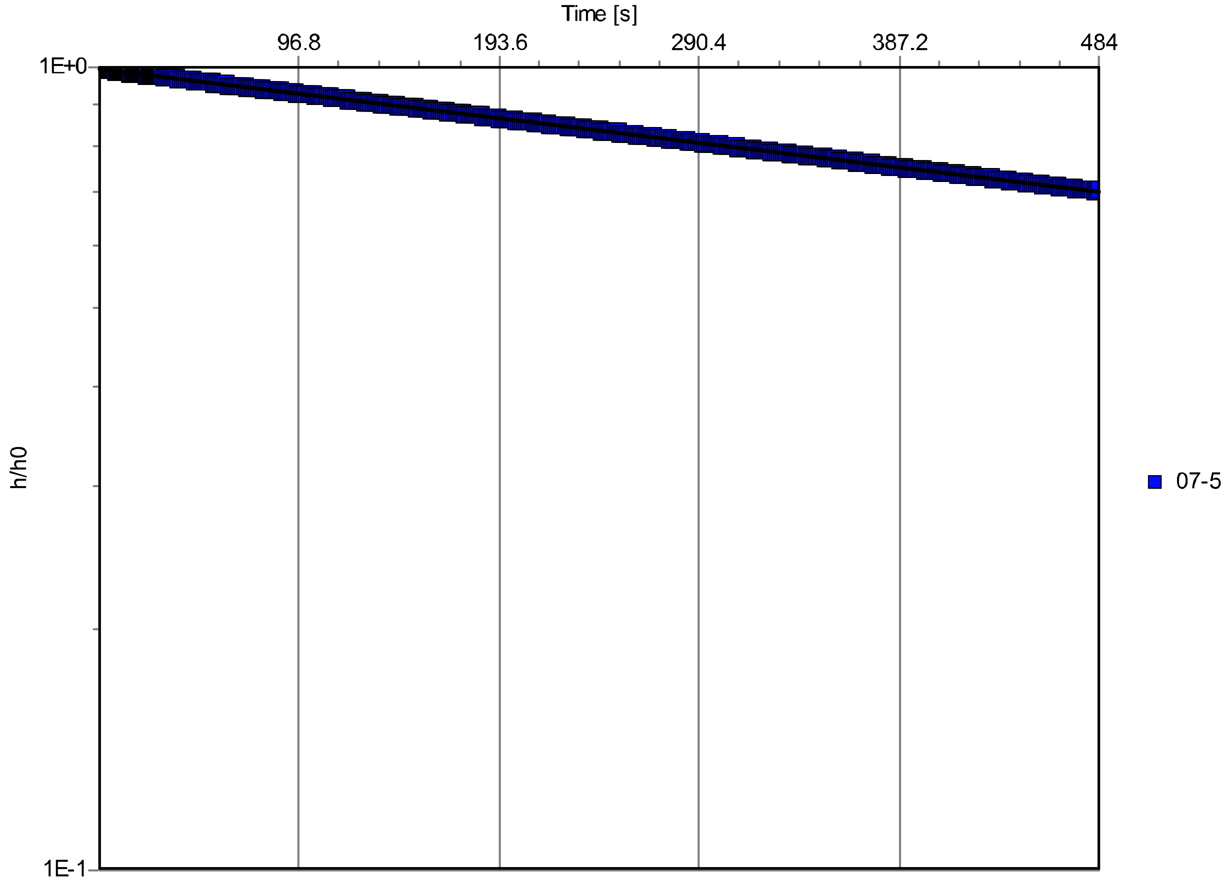
<u>Slug Test:</u>	**BH06-11 Bail-recovery**			
<u>Analysis Method:</u>	**Hvorslev**			
<u>Analysis Results:</u>			Conductivity:	6.34E-9 [m/s]
<u>Test parameters:</u>	Test Well:	BH06-11	Aquifer Thickness:	4 [m]
	Casing radius:	0.025 [m]		
	Screen length:	4 [m]		
	Boring radius:	0.075 [m]		

Title:

SLUG TEST BH06-11 BAIL-RECOVERY HVORSLEV

NORTH AMERICAN
OIL SANDS CORPORATION

Approved: TVD	Revision Date: JULY, 2007	
File: 6198-PumpTest-07		
Drawn by: ADF	Checked: RP	Fig. No.: **5A-7**



Slug Test:	**07-5 Bail-recovery**		
Analysis Method:	**Hvorslev**		

Analysis Results:		Conductivity:	2.01E-7 [m/s]

Test parameters:	Test Well:	07-5	Aquifer Thickness:	4 [m]
	Casing radius:	0.025 [m]		
	Screen length:	4.3 [m]		
	Boring radius:	0.097 [m]		

Title:

SLUG TEST 07-5 BAIL-RECOVERY HVORSLEV

NORTH AMERICAN
OIL SANDS CORPORATION

Approved: TVD	Revision Date: JULY, 2007	
File: 6198-PumpTest-07		
Drawn by: ADF	Checked: RP	Fig. No.: **5A-8**

Geologic Log - USC

Project/Site: **6198-514**

Well/borehole #: **07-1**

Client: **NAOSC**

Logged By: **Tim Van Dijk**

Compiled By: **Jennifer Barbier**

Driller: **Beck**

Drill Equipment: **rotary (air/water)**

Sample Method:

Date: **March 21, 2007**

Start Time: **10:00**

Finish Time: **17:00**

Top of Casing: **622.42m**

Ground Elev: **621.42m**

Top / Base of Sand Pack: **37.6-40.6m**

Screened Interval: **37.0-41.0m**

Screen Size: **0.01"**

Total Depth: **42.1m**

Boring Diameter: **5 1/2" (7 1/4")**

Casing Diameter: **2"**

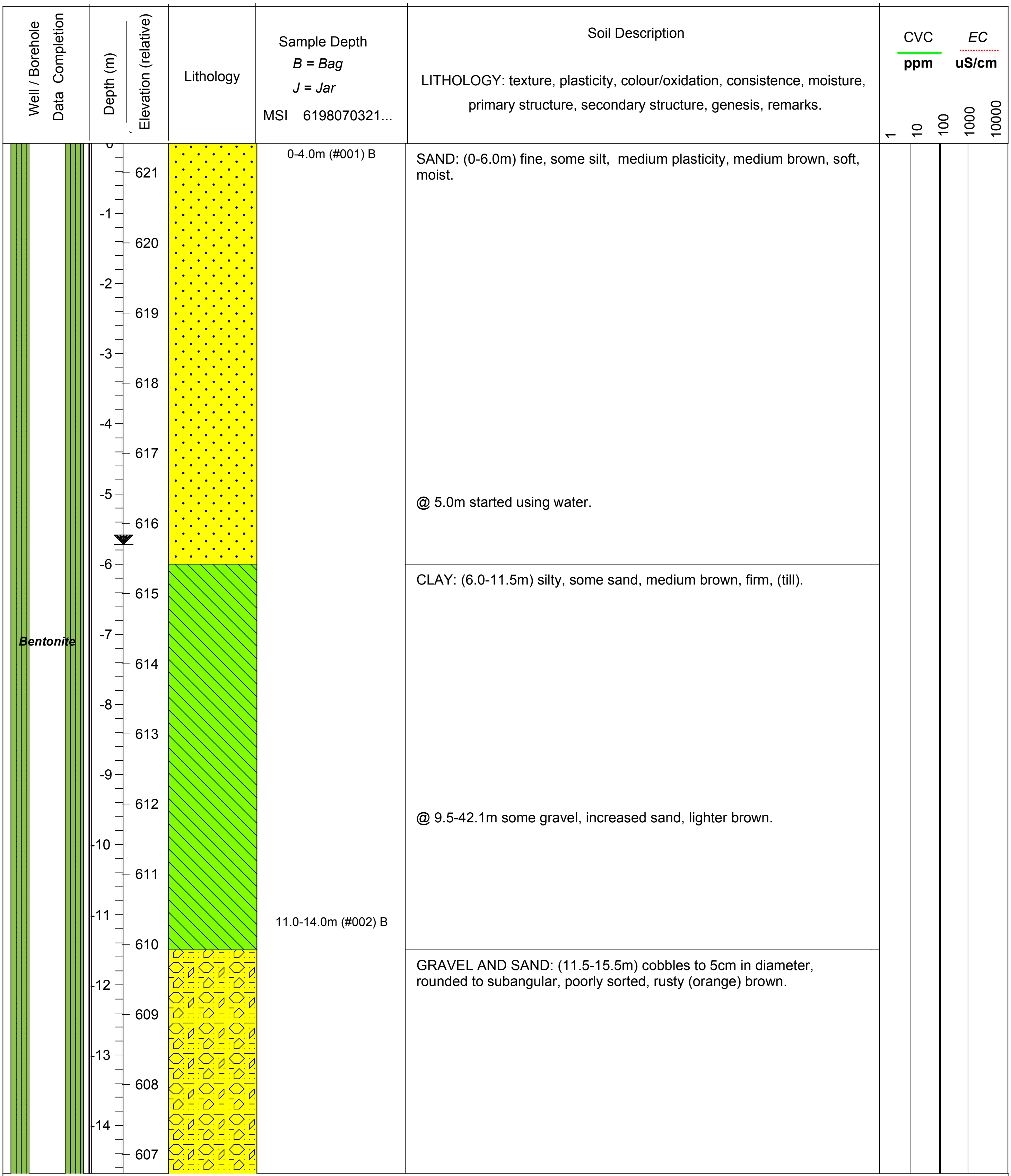
Legal Location: **SE-02-056-21 W4**

Relative Location: **---**

Northing: **5964321.8**

Easting: **367842.6**

Datum/Zone: **Zone 12**



Sample Depth
B = Bag
J = Jar
MSI 6198070321...

0-4.0m (#001) B

11.0-14.0m (#002) B

Soil Description

LITHOLOGY: texture, plasticity, colour/oxidation, consistence, moisture, primary structure, secondary structure, genesis, remarks.

SAND: (0-6.0m) fine, some silt, medium plasticity, medium brown, soft, moist.

@ 5.0m started using water.

CLAY: (6.0-11.5m) silty, some sand, medium brown, firm, (till).

@ 9.5-42.1m some gravel, increased sand, lighter brown.

GRAVEL AND SAND: (11.5-15.5m) cobbles to 5cm in diameter, rounded to subangular, poorly sorted, rusty (orange) brown.

NOTE: Drill bit 5 1/2", casing 7 1/4". No casing shoe (lost by drillers).
NOTE: May 11, 2007 water level - 5.72 m bgs.

Geologic Log - USC

Project/Site: **6198-514**

Well/borehole #: **07-1**

Client: **NAOSC**
Logged By: **Tim Van Dijk**
Compiled By: **Jennifer Barbier**
Driller: **Beck**
Drill Equipment: **rotary (air/water)**

Sample Method:
Date: **March 21, 2007**
Start Time: **10:00**
Finish Time: **17:00**
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Top / Base of Sand Pack: **37.6-40.6m**
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Screen Size: **0.01"**
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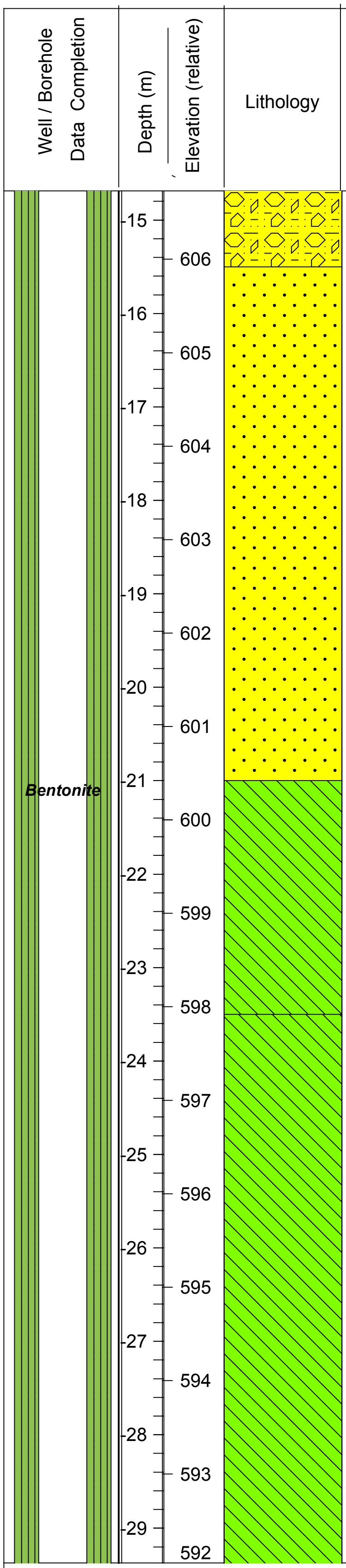
Boring Diameter: **5 1/2" (7 1/4")**
Casing Diameter: **2"**

Legal Location: **SE-02-056-21 W4**
Relative Location: **---**
Northing: **5964321.8**
Easting: **367842.6**
Datum/Zone: **Zone 12**



Sample Depth
B = Bag
J = Jar
MSI 6198070321...

Soil Description

LITHOLOGY: texture, plasticity, colour/oxidation, consistence, moisture, primary structure, secondary structure, genesis, remarks.

SAND: (15.5-21.0m) silty, fine to medium grained, well sorted, grey, some black grained, washes through sieve, (weathered sandstone).

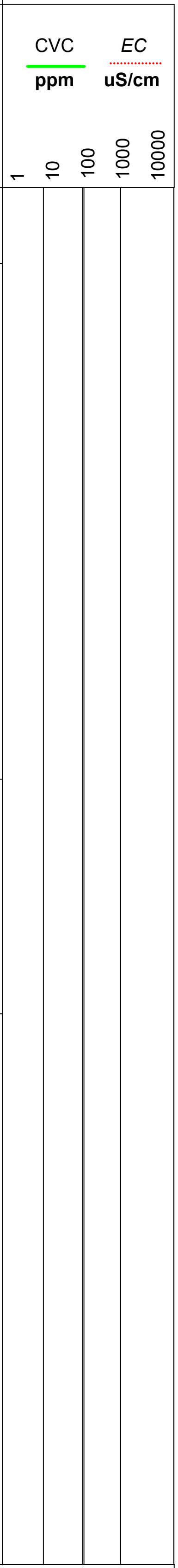
CLAY: (21.0-23.5m) sandy, light brown, hard, homogeneous, (claystone).

CLAY: (23.5-32.0m) silty, light brown, hard, (claystone).

24.0-28.0m (#003) B

@ 24.0m drill with stem only, slow drilling with casing, drill bit chattering.

@ 28.0m some sand.



NOTE: Drill bit 5 1/2", casing 7 1/4". No casing shoe (lost by drillers).
NOTE: May 11, 2007 water level - 5.72 m bgs.

Geologic Log - USC

Project/Site: **6198-514**

Well/borehole #: **07-1**

Client: **NAOSC**

Logged By: **Tim Van Dijk**

Compiled By: **Jennifer Barbier**

Driller: **Beck**

Drill Equipment: **rotary (air/water)**

Sample Method:

Date: **March 21, 2007**

Start Time: **10:00**

Finish Time: **17:00**

Top of Casing: **622.42m**

Ground Elev: **621.42m**

Top / Base of Sand Pack: **37.6-40.6m**

Screened Interval: **37.0-41.0m**

Screen Size: **0.01"**

Total Depth: **42.1m**

Boring Diameter: **5 1/2" (7 1/4")**

Casing Diameter: **2"**

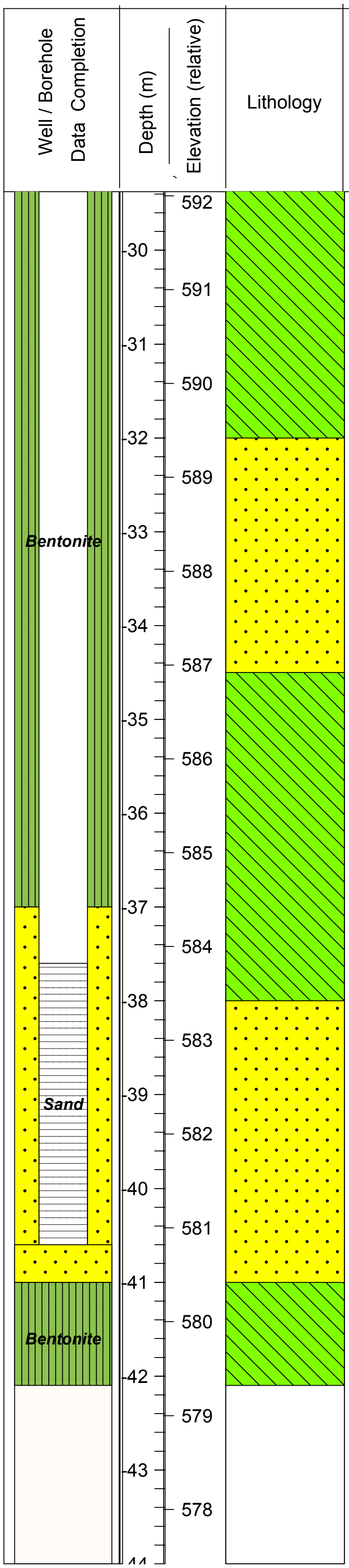
Legal Location: **SE-02-056-21 W4**

Relative Location: **---**

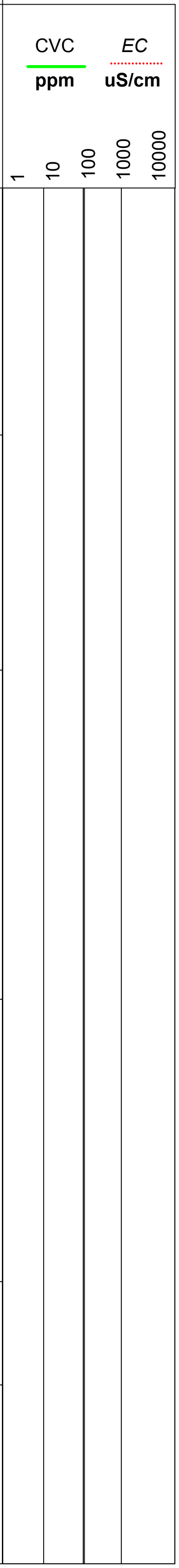
Northing: **5964321.8**

Easting: **367842.6**

Datum/Zone: **Zone 12**



Sample Depth *B = Bag* *J = Jar* MSI 6198070321...	Soil Description LITHOLOGY: texture, plasticity, colour/oxidation, consistence, moisture, primary structure, secondary structure, genesis, remarks.
	SAND: (32.0-34.5m) clayey, fine to medium grained, grey, soft, (sandstone).
35.0-36.0m (#004) B	CLAY: (34.5-38.0m) silty, trace sand, high plasticity, medium brown to grey, (claystone).
	SAND: (38.0-41.0m) medium grained, well sorted, grey, (sandstone). @ 39.0m some gravel.
	CLAY: (41.0-42.1m) silty, non-plastic, light brown, hard, (claystone).
	TD= 42.1m



NOTE: Drill bit 5 1/2", casing 7 1/4". No casing shoe (lost by drillers).
NOTE: May 11, 2007 water level - 5.72 m bgs.

Geologic Log - USC

Project/Site: **6198-514**

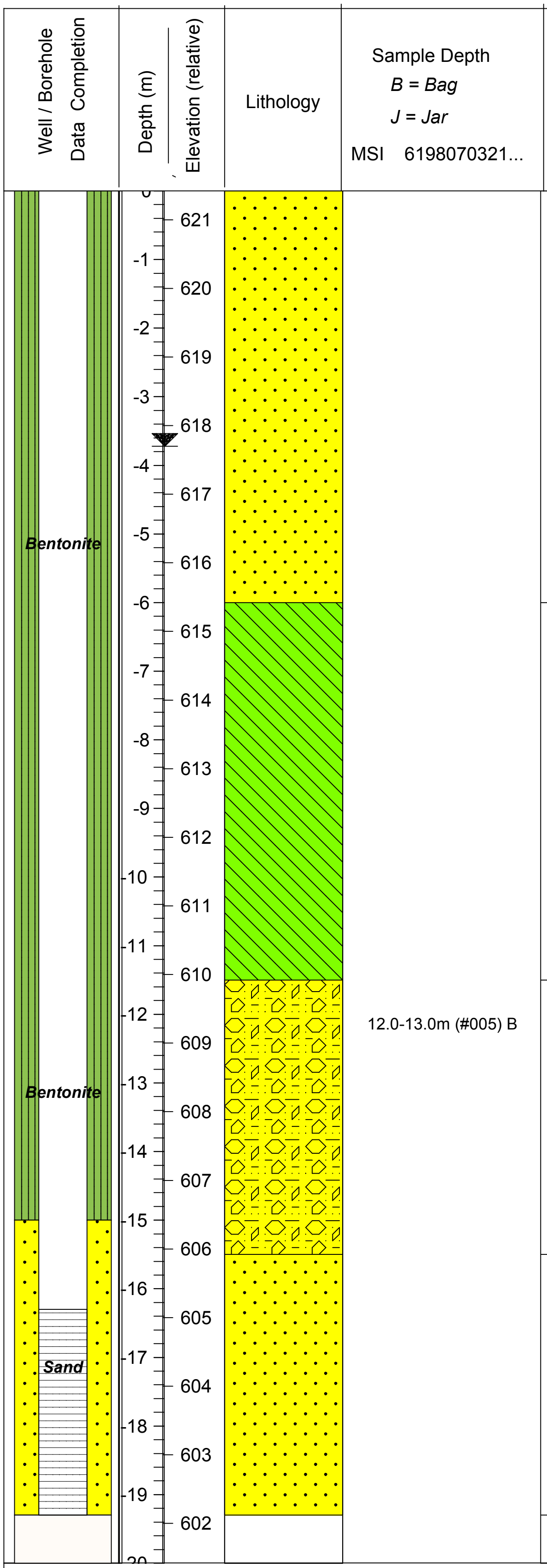
Well/borehole #: **07-2**

Client: **NAOSC**
Logged By: **Tim Van Dijk**
Compiled By: **Jennifer Barbier**
Driller: **Beck**
Drill Equipment: **rotary (air/water)**

Sample Method:
Date: **March 21, 2007**
Start Time: **17:45**
Finish Time: **20:00**
Top of Casing: **622.47m**
Ground Elev: **621.42m**

Top / Base of Sand Pack: **15.0-19.3m**
Screened Interval: **16.3-19.3m**
Screen Size: **0.01"**
Total Depth: **19.3m**
Boring Diameter: **7 1/4"**
Casing Diameter: **2"**

Legal Location: **SE-02-056-21 W4**
Relative Location: **---**
Northing: **5964321.0**
Easting: **367838.7**
Datum/Zone: **Zone 12**



Soil Description

LITHOLOGY: texture, plasticity, colour/oxidation, consistence, moisture, primary structure, secondary structure, genesis, remarks.

SAND: (0-6.0m) fine, some silt, medium plasticity, medium brown, soft, moist.

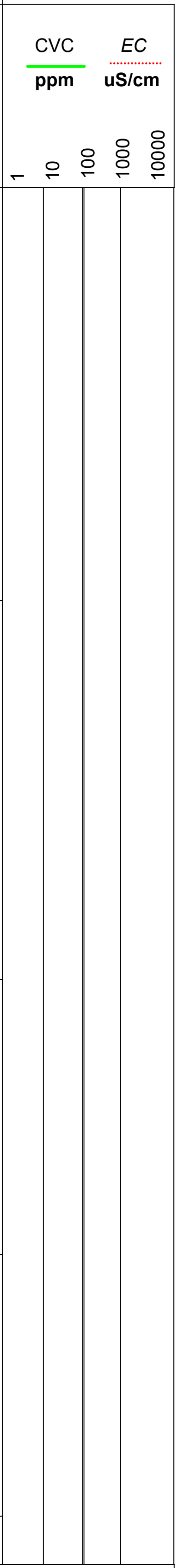
CLAY: (6.0-11.5m) silty, sandy, medium brown, firm.

GRAVEL AND SAND: (11.5-15.5m) cobbles to 5cm in diameter, rounded to subangular, poorly sorted, rusty (orange) brown.

SAND: (15.5-19.3m) silty, fine to medium grained, grey, some black grains, washes through sieve, (sandstone).

@ 17.4m used drill stem only, no casing.

TD= 19.3m



NOTE: May 11, 2007 water level - 3.72m bgs.

Geologic Log - USC

Project/Site: **6198-514**

Well/borehole #: **07-3**

Client: **NAOSC**

Logged By: **T. Van Dijk/S. Salsman**

Compiled By: **Jennifer Barbier**

Driller: **Beck**

Drill Equipment: **rotary (air/water)**

Sample Method:

Date: **March 22, 2007**

Start Time: **9:15**

Finish Time: **13:45**

Top of Casing: **624.44m**

Ground Elev: **623.20m**

Top / Base of Sand Pack: **26.3-31.1m**

Screened Interval: **27.1-31.1m**

Screen Size: **0.01"**

Total Depth: **31.1m**

Boring Diameter: **7 3/4"**

Casing Diameter: **4"**

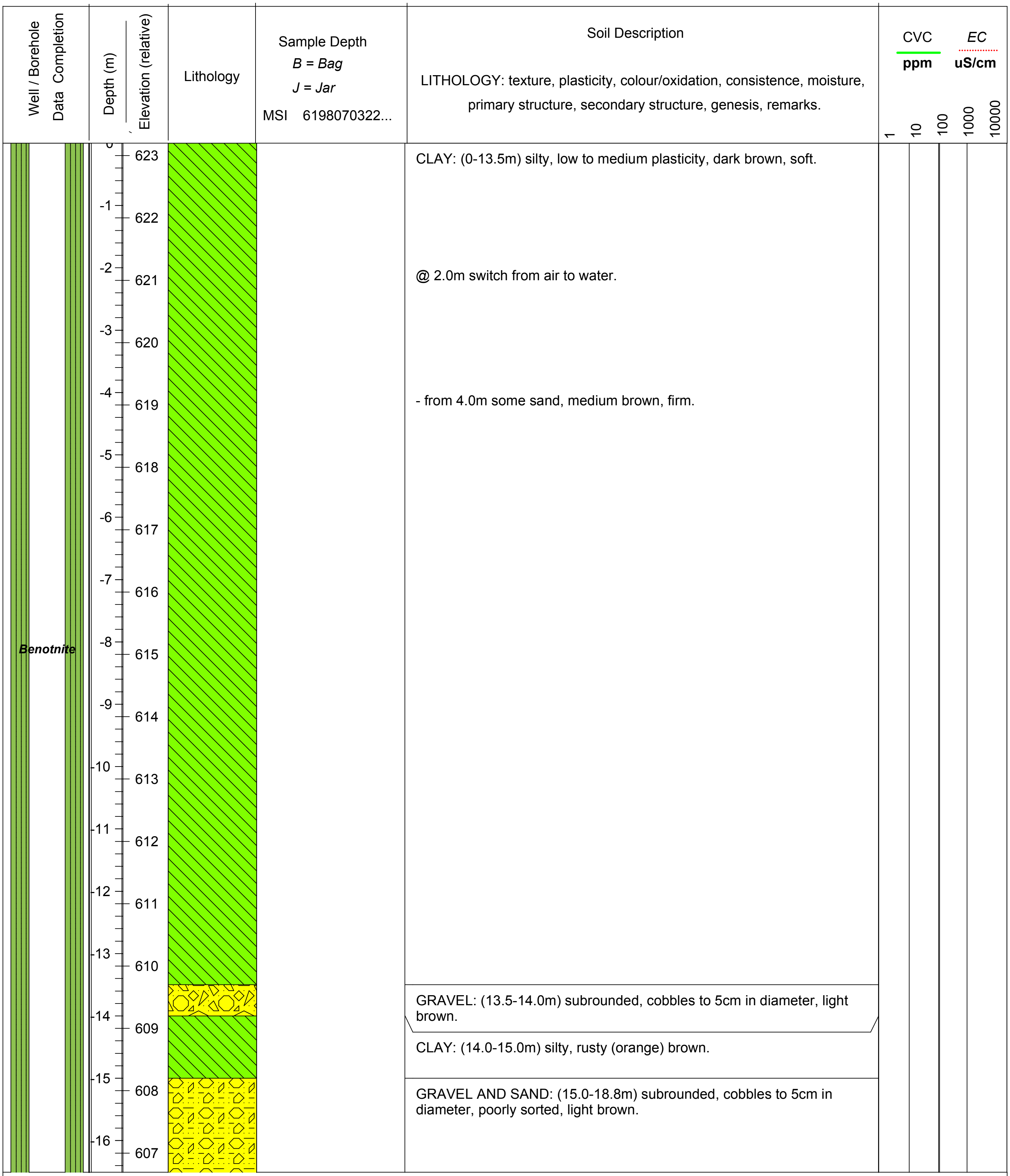
Legal Location: **SW-35-55-21 W4**

Relative Location: **---**

Northing: **5962652.7**

Easting: **366654.8**

Datum/Zone: **Zone 12**



CLAY: (0-13.5m) silty, low to medium plasticity, dark brown, soft.

@ 2.0m switch from air to water.

- from 4.0m some sand, medium brown, firm.

GRAVEL: (13.5-14.0m) subrounded, cobbles to 5cm in diameter, light brown.

CLAY: (14.0-15.0m) silty, rusty (orange) brown.

GRAVEL AND SAND: (15.0-18.8m) subrounded, cobbles to 5cm in diameter, poorly sorted, light brown.

NOTE: After completion, could not get water level past 9.8m BTOC. Well destroyed, likely due to small angular space between P/C and drill casing.

Geologic Log - USC

Project/Site: **6198-514**

Well/borehole #: **07-3**

Client: **NAOSC**

Logged By: **T. Van Dijk/S. Salsman**

Compiled By: **Jennifer Barbier**

Driller: **Beck**

Drill Equipment: **rotary (air/water)**

Sample Method:

Date: **March 22, 2007**

Start Time: **9:15**

Finish Time: **13:45**

Top of Casing: **624.44m**

Ground Elev: **623.20m**

Top / Base of Sand Pack: **26.3-31.1m**

Screened Interval: **27.1-31.1m**

Screen Size: **0.01"**

Total Depth: **31.1m**

Boring Diameter: **7 3/4"**

Casing Diameter: **4"**

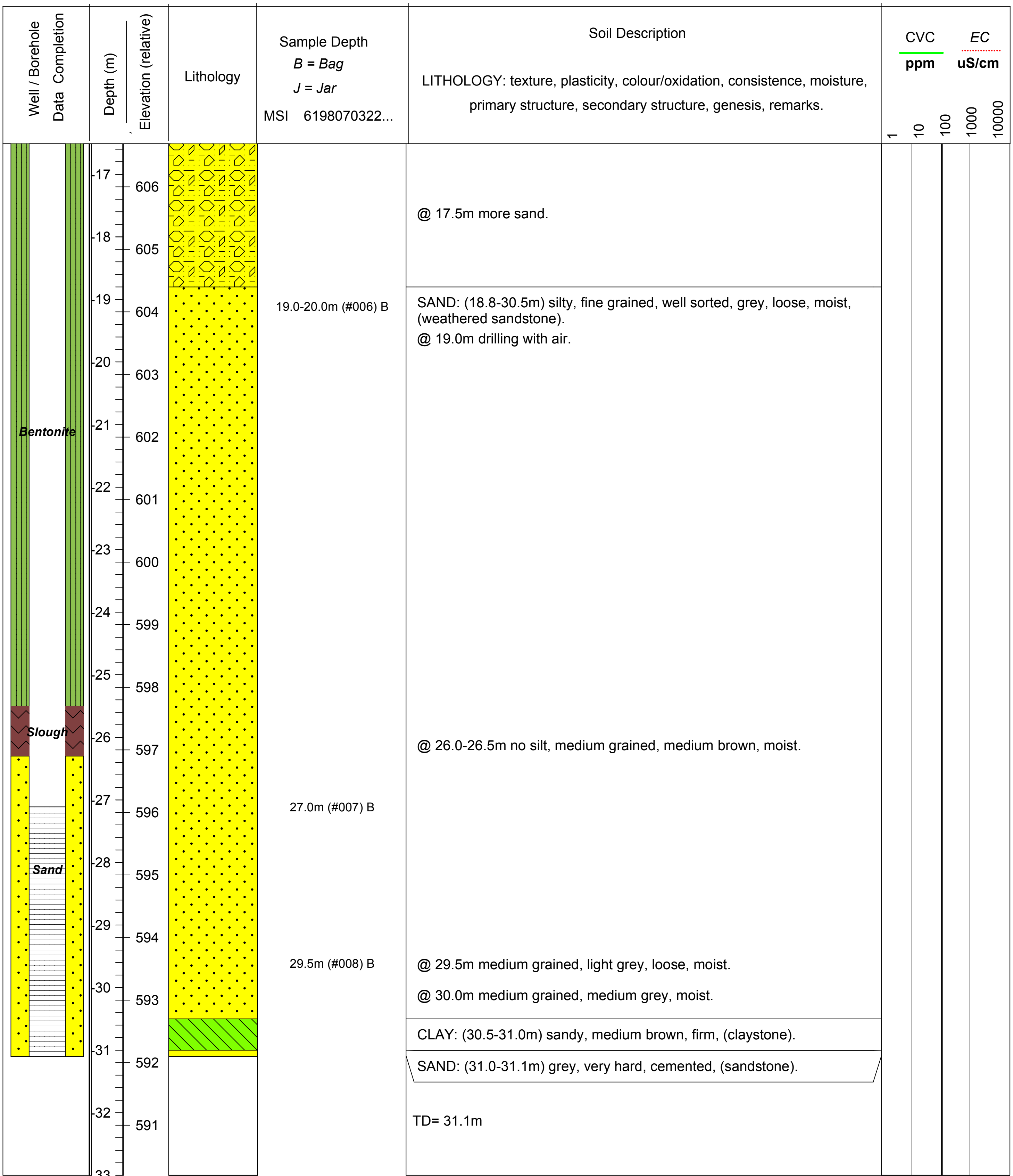
Legal Location: **SW-35-55-21 W4**

Relative Location: **---**

Northing: **5962652.7**

Easting: **366654.8**

Datum/Zone: **Zone 12**



19.0-20.0m (#006) B

27.0m (#007) B

29.5m (#008) B

@ 17.5m more sand.

SAND: (18.8-30.5m) silty, fine grained, well sorted, grey, loose, moist, (weathered sandstone).

@ 19.0m drilling with air.

@ 26.0-26.5m no silt, medium grained, medium brown, moist.

@ 29.5m medium grained, light grey, loose, moist.

@ 30.0m medium grained, medium grey, moist.

CLAY: (30.5-31.0m) sandy, medium brown, firm, (claystone).

SAND: (31.0-31.1m) grey, very hard, cemented, (sandstone).

TD= 31.1m

NOTE: After completion, could not get water level past 9.8m BTOC. Well destroyed, likely due to small angular space between P/C and drill casing.

Geologic Log - USC

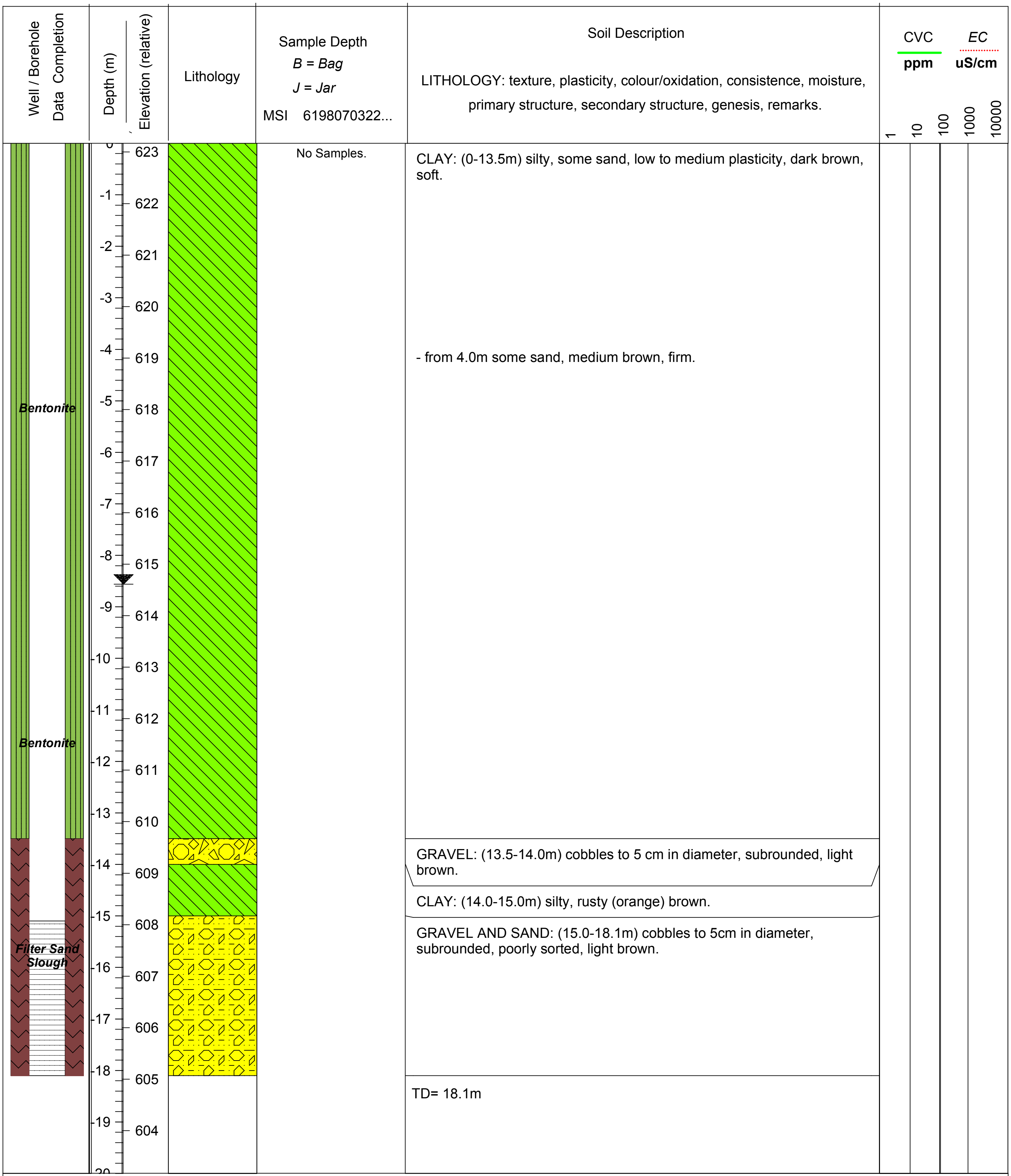
Project/Site: **6198-514**

Well/borehole #: **07-4**
Client: **NAOSC**
Logged By: **T. Van Dijk/S. Salsman**
Compiled By: **Jennifer Barbier**
Driller: **Beck**
Drill Equipment: **rotary (air/water)**

Sample Method:
Date: **March 22, 2007**
Start Time: **14:30**
Finish Time: **16:30**
Top of Casing: **624.32m**
Ground Elev: **623.17m**

Top / Base of Sand Pack: **13.5-18.1m**
Screened Interval: **15.1-18.1m**
Screen Size: **0.01"**
Total Depth: **18.1m**
Boring Diameter: **7 3/4"**
Casing Diameter: **2"**

Legal Location: **SW-35-055-21 W4**
Relative Location: **---**
Northing: **5962649.5**
Easting: **366656.5**
Datum/Zone: **Zone 12**



Sample Depth
B = Bag
J = Jar
MSI 6198070322...

No Samples.

Soil Description

LITHOLOGY: texture, plasticity, colour/oxidation, consistence, moisture, primary structure, secondary structure, genesis, remarks.

CLAY: (0-13.5m) silty, some sand, low to medium plasticity, dark brown, soft.

- from 4.0m some sand, medium brown, firm.

GRAVEL: (13.5-14.0m) cobbles to 5 cm in diameter, subrounded, light brown.

CLAY: (14.0-15.0m) silty, rusty (orange) brown.

GRAVEL AND SAND: (15.0-18.1m) cobbles to 5cm in diameter, subrounded, poorly sorted, light brown.

TD= 18.1m

NOTE: Drilled with water.
NOTE: May 11, 2007 water level - 8.56m bgs.

Geologic Log - USC

Project/Site: **6198-514**

Well/borehole #: **07-5**

Client: **NAOSC**

Logged By: **Tim Van Dijk**

Compiled By: **Jennifer Barbier**

Driller: **Beck**

Drill Equipment: **rotary (air/water)**

Sample Method:

Date: **March 23, 2007**

Start Time: **9:20**

Finish Time: **13:00**

Top of Casing: **628.55m**

Ground Elev: **627.65m**

Top / Base of Sand Pack: **26.2-30.5m**

Screened Interval: **27.0-30.0m**

Screen Size: **0.01"**

Total Depth: **34.3m**

Boring Diameter: **7 3/4"**

Casing Diameter: **2"**

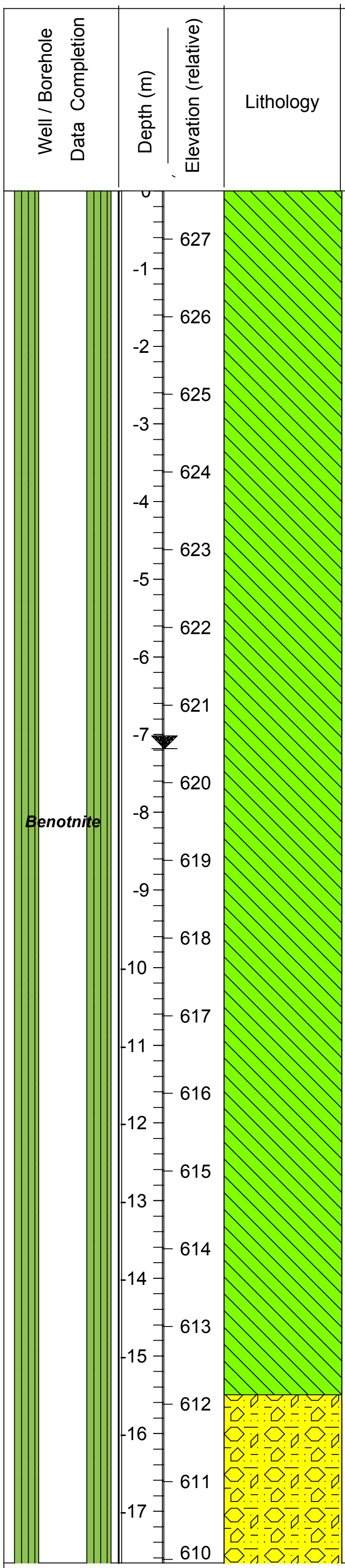
Legal Location: **SE-35-055-21 W4**

Relative Location: **---**

Northing: **5962501.3**

Easting: **368201.3**

Datum/Zone: **Zone 12**



Sample Depth
B = Bag
J = Jar
MSI 6198070323...

Soil Description

LITHOLOGY: texture, plasticity, colour/oxidation, consistence, moisture, primary structure, secondary structure, genesis, remarks.

CLAY: (0-15.5m) silty, medium plasticity, medium brown, soft to firm, moist.

- from 2.5m some sand.

@ 6.5m becomes firm, medium brown to grey.

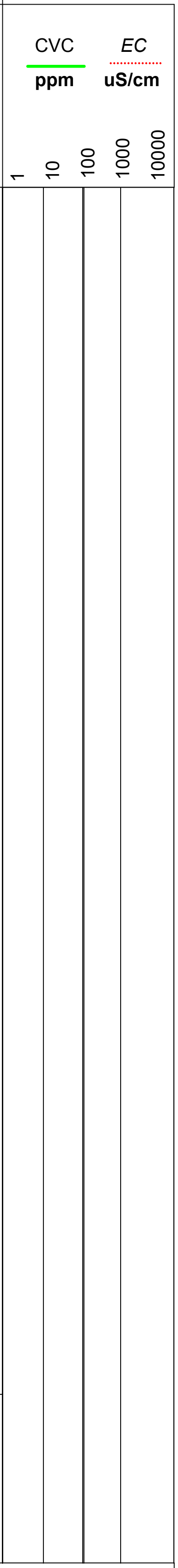
@ 6.5-7.5m some gravel, angular, <3cm in diameter.

GRAVEL AND SAND: (15.5-20.0m) fine to coarse sand, cobbles to 5cm in diameter, subrounded, some silt, rusty brown.

@ 15.5-16.5 sand only.

@ 16.5-17.0m gravel, medium brown.

@ 17.0-17.5m sand, rusty brown.



NOTE: May 11, 2007 water level - 7.18m bgs.

Geologic Log - USC

Project/Site: **6198-514**

Well/borehole #: **07-5**

Client: **NAOSC**

Logged By: **Tim Van Dijk**

Compiled By: **Jennifer Barbier**

Driller: **Beck**

Drill Equipment: **rotary (air/water)**

Sample Method:

Date: **March 23, 2007**

Start Time: **9:20**

Finish Time: **13:00**

Top of Casing: **628.55m**

Ground Elev: **627.65m**

Top / Base of Sand Pack: **26.2-30.5m**

Screened Interval: **27.0-30.0m**

Screen Size: **0.01"**

Total Depth: **34.3m**

Boring Diameter: **7 3/4"**

Casing Diameter: **2"**

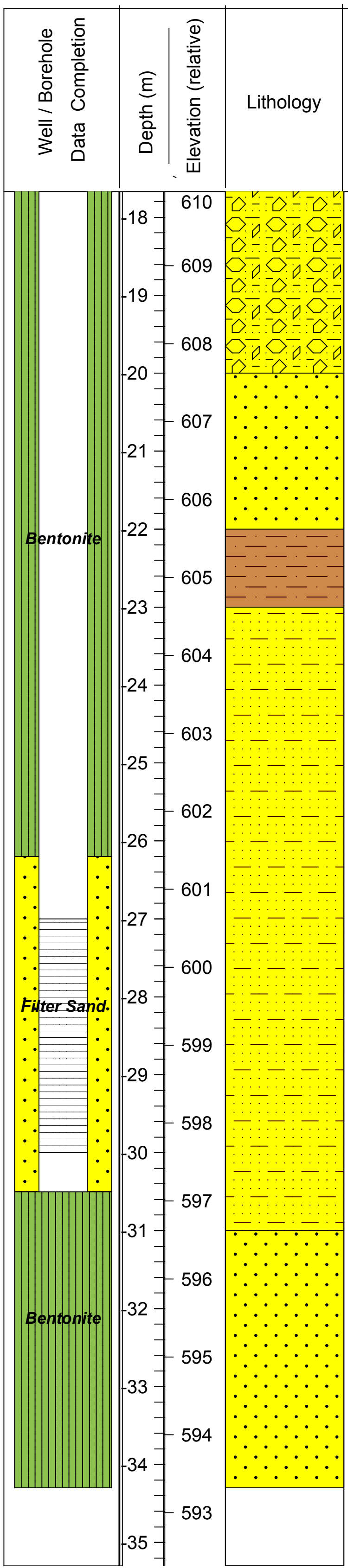
Legal Location: **SE-35-055-21 W4**

Relative Location: **---**

Northing: **5962501.3**

Easting: **368201.3**

Datum/Zone: **Zone 12**



Sample Depth *B = Bag* *J = Jar* MSI 6198070323...	Soil Description LITHOLOGY: texture, plasticity, colour/oxidation, consistence, moisture, primary structure, secondary structure, genesis, remarks.
	@ 17.5-20.0m sand and gravel, medium brown.
	SAND: (20.0-22.0m) silty, fine grained, medium brown, loose powder returns, (weathered sandstone). @ 21.0m some gravel, grey, loose, dry.
	SILT: (22.0-23.0m) some sand, some clay, trace gravel, grey to brown, (siltstone).
24.5m (#009) B 25.5m (#010) B 30.5m (#011) B	SAND AND SILT: (23.0-31.0m) alternating units of sand and silt, well sorted, grey, loose, dry, (sandstone/siltstone). @ 23.5m sand, medium grained, well sorted. @ 24.0m silty sand, grey brown. @ 24.5m moist. @ 25.0m fine sand. @ 26.0m silty fine sand. @ 27.5 some stiff clay (pellets). @ 28.0m fine sand, well sorted. @ 29.0 fine sand, grey brown. @ 29.5m light grey. @ 30.0m using drill stem only, no casing.
	SAND: (31.0-34.3m) grey, hard, dry powder, drill bit chattering, (sandstone).
	TD= 34.3m

CVC ppm — EC uS/cm — 1 10 100 1000 10000

NOTE: May 11, 2007 water level - 7.18m bgs.

Geologic Log - USC

Project/Site: **6198-514**

Well/borehole #: **07-6**

Client: **NAOSC**

Logged By: **Tim Van Dijk**

Compiled By: **Jennifer Barbier**

Driller: **Beck**

Drill Equipment: **rotary (air/water)**

Sample Method:

Date: **March 23, 2007**

Start Time: **14:00**

Finish Time: **17:00**

Top of Casing: **628.65m**

Ground Elev: **627.62m**

Top / Base of Sand Pack: **14.5-18.3m**

Screened Interval: **15.3-18.3m**

Screen Size: **0.01"**

Total Depth: **18.7m**

Boring Diameter: **7 3/4"**

Casing Diameter: **2"**

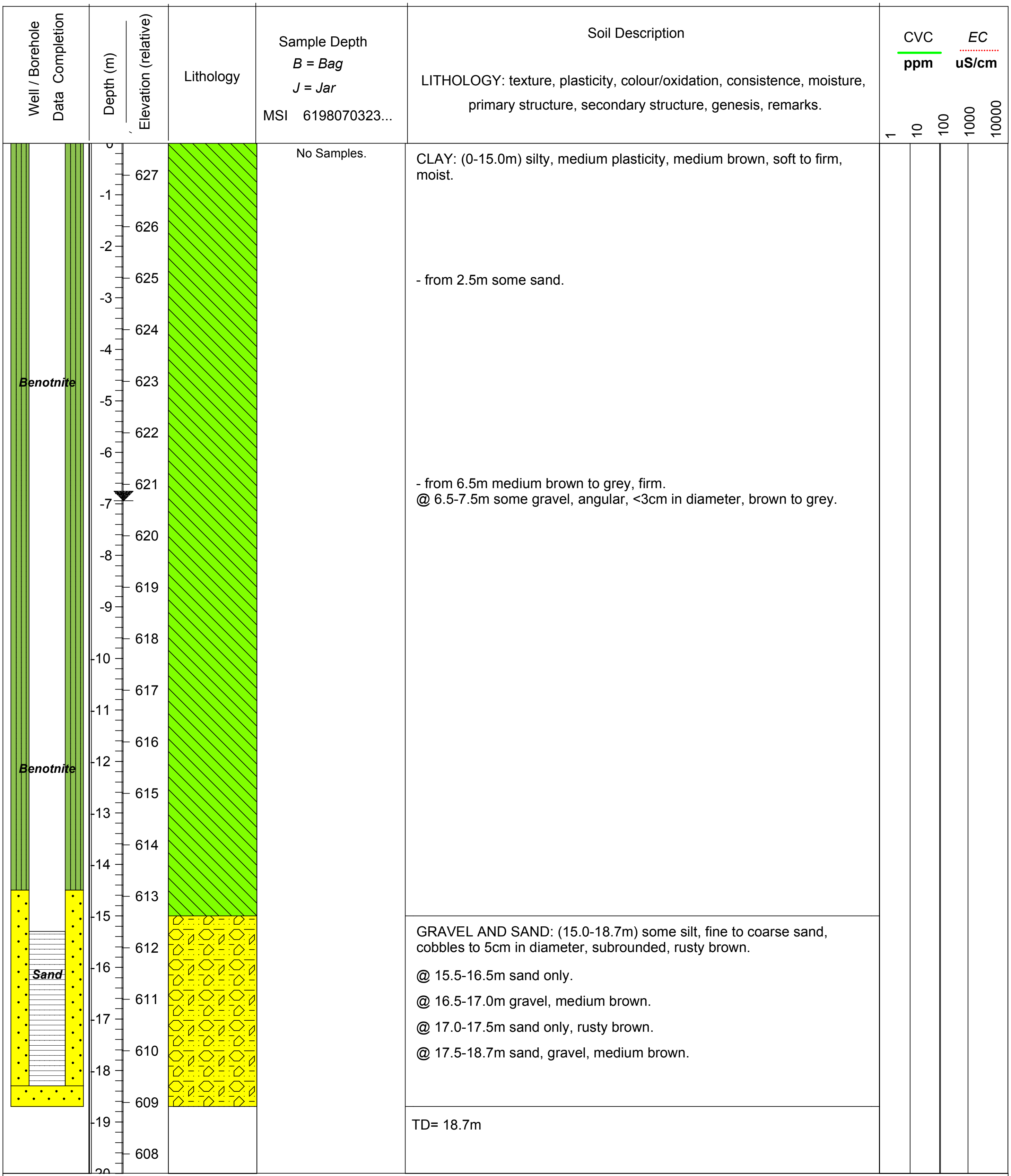
Legal Location: **SE-35-055-21 W4**

Relative Location: **---**

Northing: **5962499.8**

Easting: **368201.1**

Datum/Zone: **Zone 12**



No Samples.

CLAY: (0-15.0m) silty, medium plasticity, medium brown, soft to firm, moist.

- from 2.5m some sand.

- from 6.5m medium brown to grey, firm.
@ 6.5-7.5m some gravel, angular, <3cm in diameter, brown to grey.

GRAVEL AND SAND: (15.0-18.7m) some silt, fine to coarse sand, cobbles to 5cm in diameter, subrounded, rusty brown.

@ 15.5-16.5m sand only.

@ 16.5-17.0m gravel, medium brown.

@ 17.0-17.5m sand only, rusty brown.

@ 17.5-18.7m sand, gravel, medium brown.

TD= 18.7m

NOTE: May 11, 2007 water level - 6.94m bgs.

Geologic Log - USC

Project/Site: **6198-514**

Well/borehole #: **07-7**

Sample Method:

Top / Base of Sand Pack: **24.9-30.1m**

Client: **NAOSC**

Date: **March 24, 2007**

Screened Interval: **26.8-29.8m**

Legal Location: **NE-26-055-21 W4**

Logged By: **Tim Van Dijk**

Start Time: **10:00**

Screen Size: **0.01"**

Relative Location: **---**

Compiled By: **Jennifer Barbier**

Finish Time: **10:30**

Total Depth: **30.1m**

Northing: **5961390.0**

Driller: **Beck**

Top of Casing: **627.71m**

Boring Diameter: **7 3/4"**

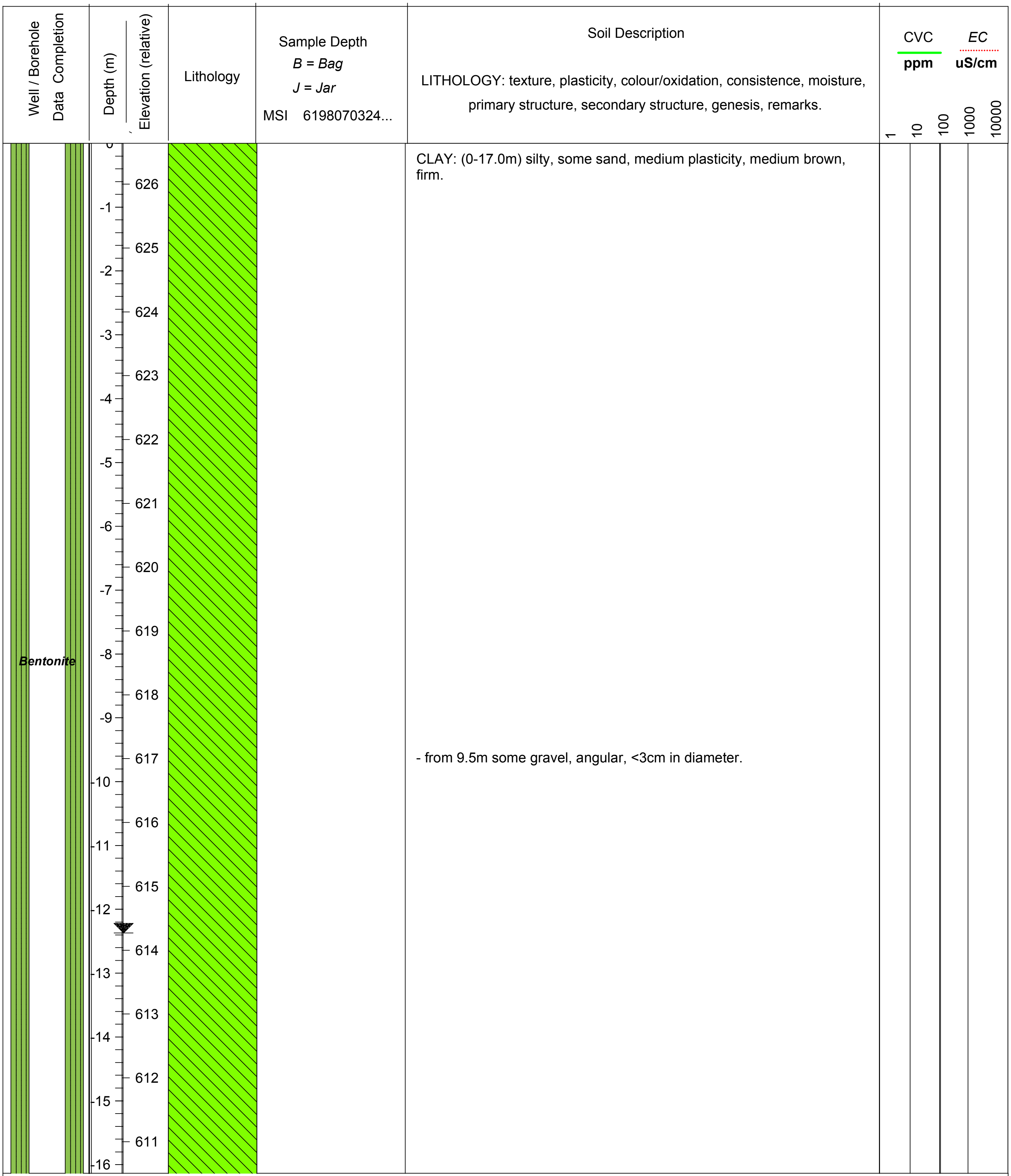
Easting: **366611.6**

Drill Equipment: **rotary (air/water)**

Ground Elev: **626.64m**

Casing Diameter: **2"**

Datum/Zone: **Zone 12**



CLAY: (0-17.0m) silty, some sand, medium plasticity, medium brown, firm.

- from 9.5m some gravel, angular, <3cm in diameter.

NOTE: May 11, 2007 water level - 12.37m bgs.

Geologic Log - USC

Project/Site: **6198-514**

Well/borehole #: **07-7**

Client: **NAOSC**

Logged By: **Tim Van Dijk**

Compiled By: **Jennifer Barbier**

Driller: **Beck**

Drill Equipment: **rotary (air/water)**

Sample Method:

Date: **March 24, 2007**

Start Time: **10:00**

Finish Time: **10:30**

Top of Casing: **627.71m**

Ground Elev: **626.64m**

Top / Base of Sand Pack: **24.9-30.1m**

Screened Interval: **26.8-29.8m**

Screen Size: **0.01"**

Total Depth: **30.1m**

Boring Diameter: **7 3/4"**

Casing Diameter: **2"**

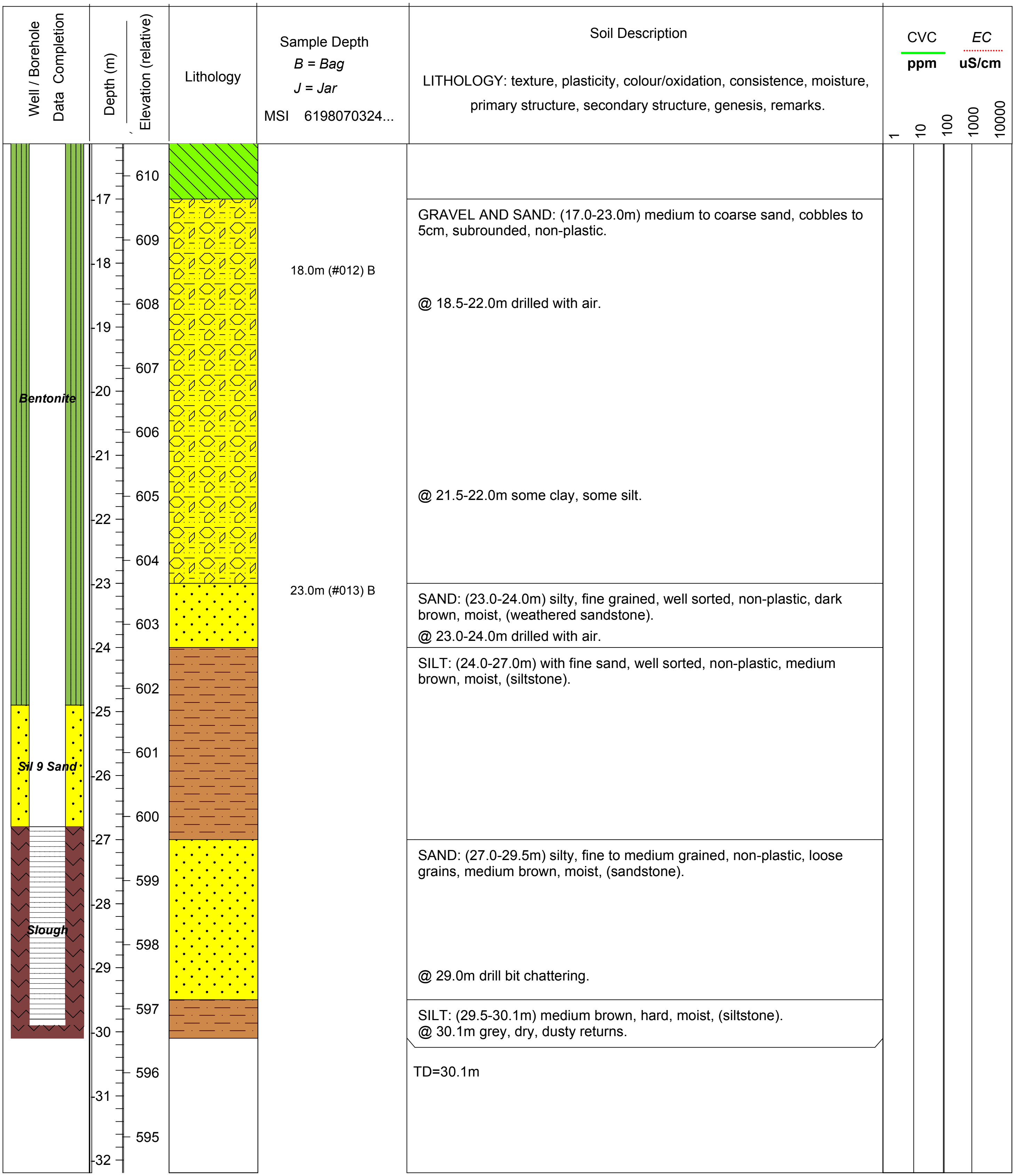
Legal Location: **NE-26-055-21 W4**

Relative Location: **---**

Northing: **5961390.0**

Easting: **366611.6**

Datum/Zone: **Zone 12**



Sample Depth *B = Bag* *J = Jar* MSI 6198070324...	Soil Description LITHOLOGY: texture, plasticity, colour/oxidation, consistence, moisture, primary structure, secondary structure, genesis, remarks.
18.0m (#012) B	GRAVEL AND SAND: (17.0-23.0m) medium to coarse sand, cobbles to 5cm, subrounded, non-plastic. @ 18.5-22.0m drilled with air. @ 21.5-22.0m some clay, some silt.
23.0m (#013) B	SAND: (23.0-24.0m) silty, fine grained, well sorted, non-plastic, dark brown, moist, (weathered sandstone). @ 23.0-24.0m drilled with air.
	SILT: (24.0-27.0m) with fine sand, well sorted, non-plastic, medium brown, moist, (siltstone).
	SAND: (27.0-29.5m) silty, fine to medium grained, non-plastic, loose grains, medium brown, moist, (sandstone). @ 29.0m drill bit chattering.
	SILT: (29.5-30.1m) medium brown, hard, moist, (siltstone). @ 30.1m grey, dry, dusty returns.
	TD=30.1m

NOTE: May 11, 2007 water level - 12.37m bgs.

Geologic Log - USC

Project/Site: **6198-514**

Well/borehole #: **07-8**

Client: **NAOSC**

Logged By: **Tim Van Dijk**

Compiled By: **Jennifer Barbier**

Driller: **Beck**

Drill Equipment: **rotary (air/water)**

Sample Method:

Date: **March 24, 2007**

Start Time: **14:15**

Finish Time: **15:45**

Top of Casing: **627.59m**

Ground Elev: **626.62m**

Top / Base of Sand Pack: **8.4-11.7m**

Screened Interval: **8.7-11.7m**

Screen Size: **0.01"**

Total Depth: **11.7m**

Boring Diameter: **7 3/4"**

Casing Diameter: **2"**

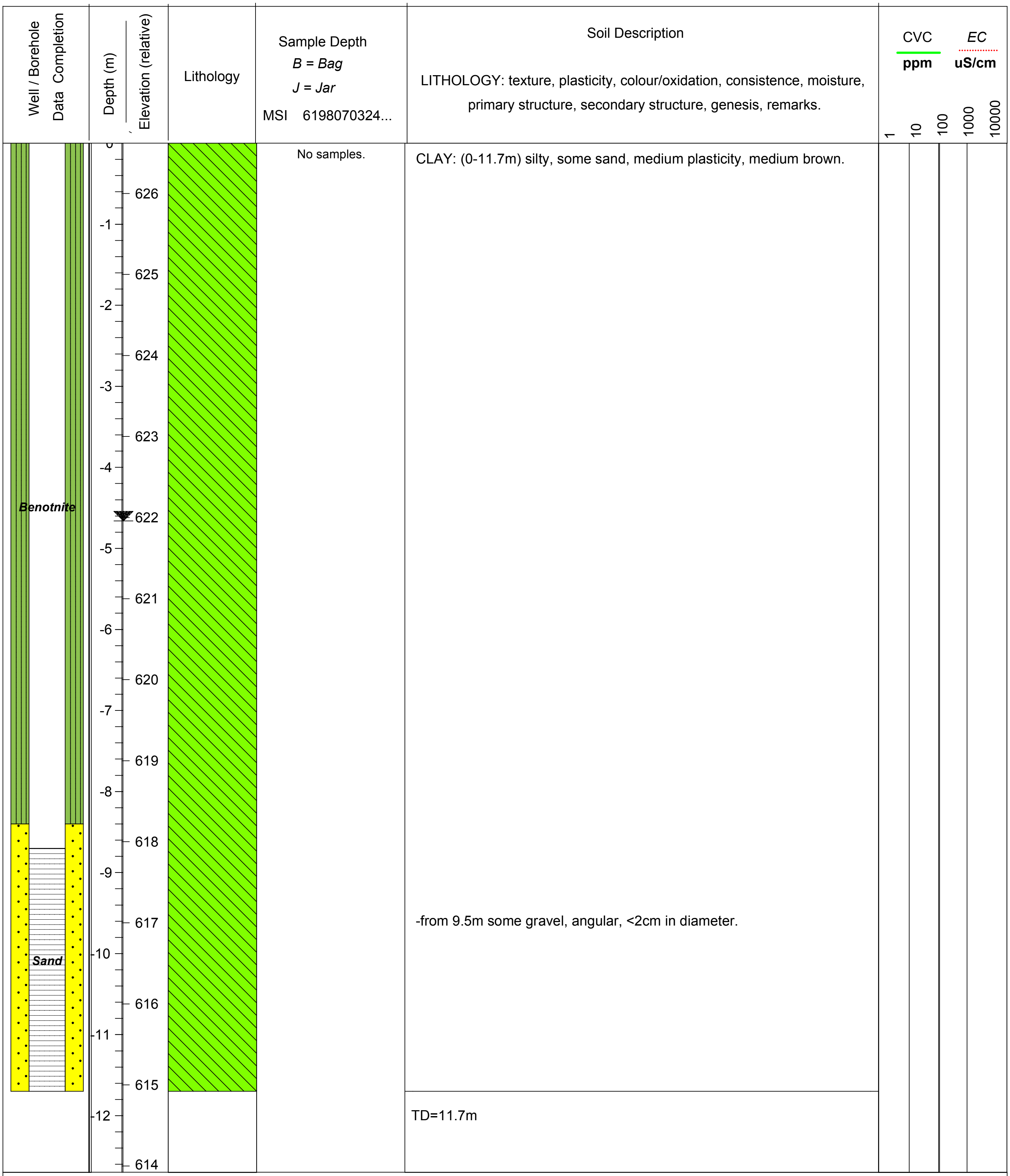
Legal Location: **NE-26-055-21 W4**

Relative Location: **---**

Northing: **5961391.0**

Easting: **366613.0**

Datum/Zone: **Zone 12**



Soil Description

LITHOLOGY: texture, plasticity, colour/oxidation, consistence, moisture, primary structure, secondary structure, genesis, remarks.

No samples.

CLAY: (0-11.7m) silty, some sand, medium plasticity, medium brown.

-from 9.5m some gravel, angular, <2cm in diameter.

TD=11.7m

NOTE: May 11, 2007 water level - 4.66m bgs.

Geologic Log - USC

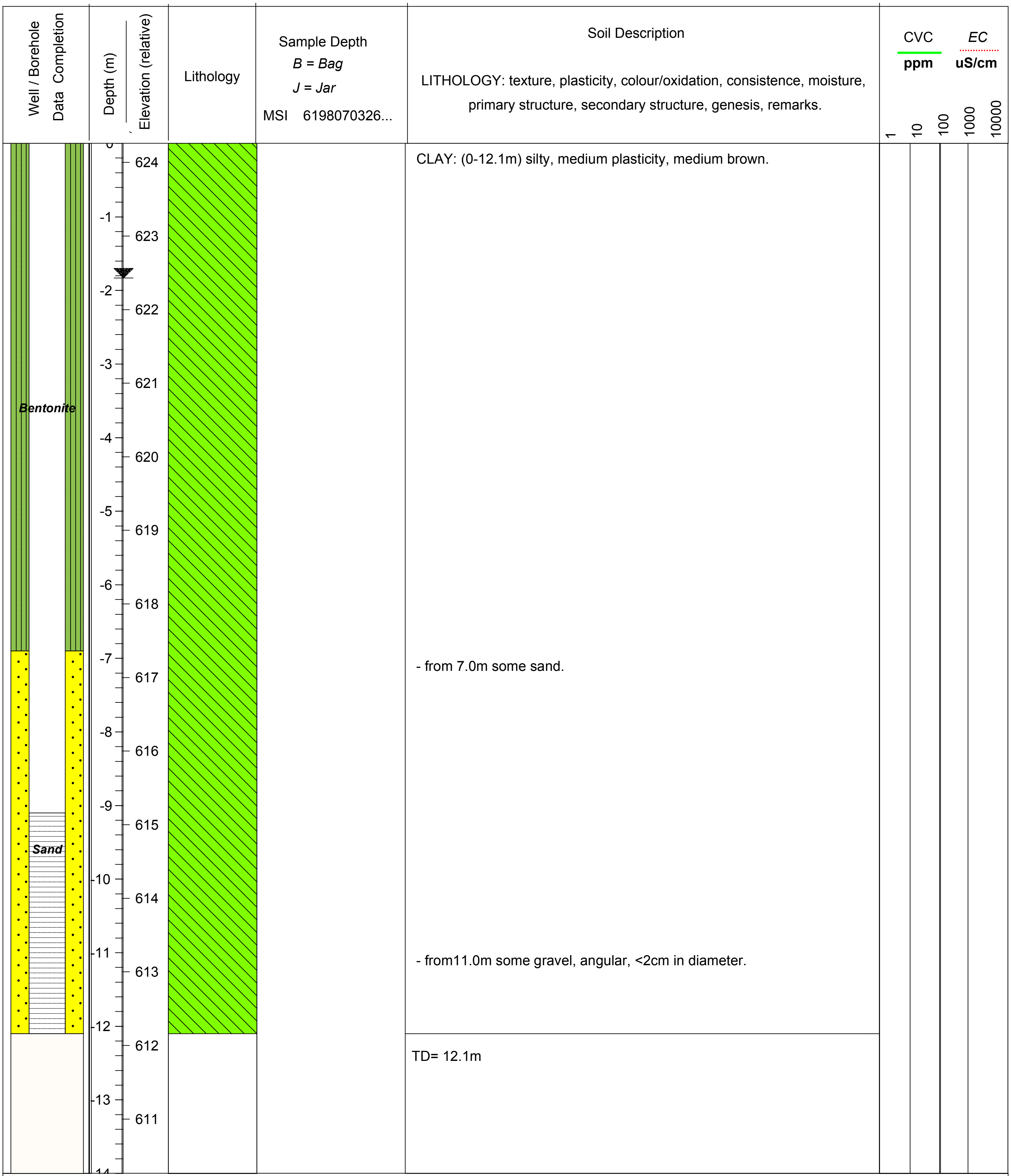
Project/Site: **6198-514**

Well/borehole #: **07-9**
Client: **NAOSC**
Logged By: **Tim Van Dijk**
Compiled By: **Jennifer Barbier**
Driller: **Beck**
Drill Equipment: **rotary (air/water)**

Sample Method:
Date: **March 26, 2007**
Start Time: **11:30**
Finish Time: **13:00**
Top of Casing: **625.22m**
Ground Elev: **624.26m**

Top / Base of Sand Pack: **6.9-12.1m**
Screened Interval: **9.1-12.1m**
Screen Size: **0.01"**
Total Depth: **12.1m**
Boring Diameter: **7 3/4"**
Casing Diameter: **2"**

Legal Location: **NE-35-055-21 W4**
Relative Location: **---**
Northing: **5963490.2**
Easting: **367458.4**
Datum/Zone: **Zone 12**



Soil Description

LITHOLOGY: texture, plasticity, colour/oxidation, consistence, moisture, primary structure, secondary structure, genesis, remarks.

CLAY: (0-12.1m) silty, medium plasticity, medium brown.

- from 7.0m some sand.

- from11.0m some gravel, angular, <2cm in diameter.

TD= 12.1m

NOTE: Drilled with water.
NOTE: May 11, 2007 water level - 1.83m bgs.

Geologic Log - USC

Project/Site: **6198-514**

Well/borehole #: **07-10**

Client: **NAOSC**

Logged By: **Tim Van Dijk**

Compiled By: **Jennifer Barbier**

Driller: **Beck**

Drill Equipment: **rotary (air/water)**

Sample Method:

Date: **March 26, 2007**

Start Time: **13:45**

Finish Time: **17:00**

Top of Casing: **625.61m**

Ground Elev: **624.66m**

Top / Base of Sand Pack: **12.2-16.3m**

Screened Interval: **12.5-15.5m**

Screen Size: **0.01"**

Total Depth: **26.1m**

Boring Diameter: **7 3/4"**

Casing Diameter: **2"**

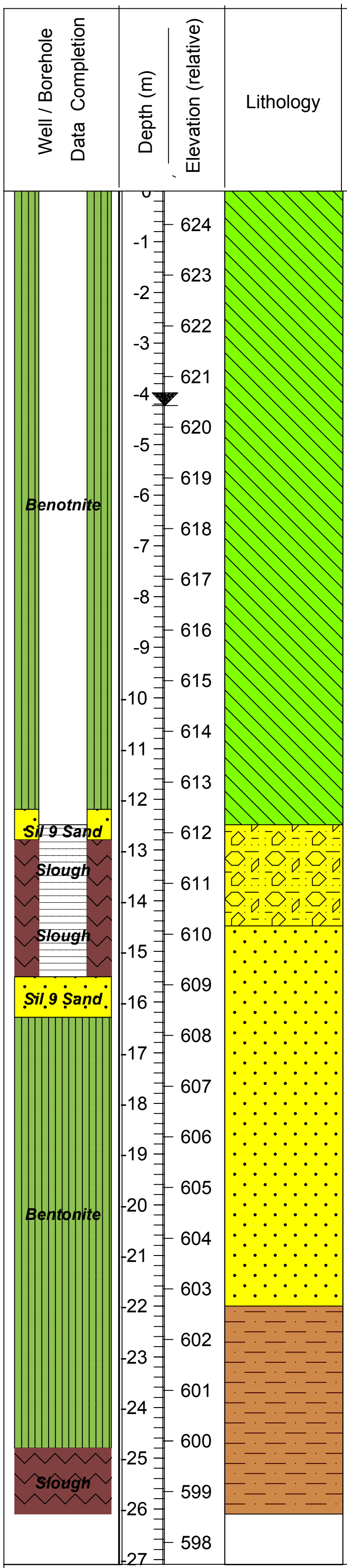
Legal Location: **NW-36-055-21 W4**

Relative Location: **---**

Northing: **5963088.5**

Easting: **368429.4**

Datum/Zone: **Zone 12**



Sample Depth *B = Bag* *J = Jar* MSI 6198070326...	Soil Description LITHOLOGY: texture, plasticity, colour/oxidation, consistence, moisture, primary structure, secondary structure, genesis, remarks.
No samples.	CLAY: (0-12.5m) silty, medium to high plasticity, medium brown, firm. - from 7.0m some sand. - from 11.0m some gravel, angular, <2cm in diameter.
	GRAVEL AND SAND: (12.5-14.5m) medium to coarse sand, poorly sorted, cobbles to 5cm in diameter, subrounded, medium brown.
	SAND: (14.5-22.0m) silty, trace gravel, fine grained, sorted, non-plastic, grey, (weathered sandstone).
	SILT: (22.0-26.1m) well sorted, grey, hard, (siltstone). @ 24.5m some fine sand, medium brown.
	TD=26.1m

CVC ppm — EC uS/cm

1 10 100 1000 10000

NOTE: May 11, 2007 water level - 4.23m bgs.

Geologic Log - USC

Project/Site: **6198-514**

Well/borehole #: **07-11**

Client: **NAOSC**

Logged By: **Tim Van Dijk**

Compiled By: **Jennifer Barbier**

Driller: **Beck**

Drill Equipment: **rotary (air/water)**

Sample Method:

Date: **March 26, 2007**

Start Time: **17:15**

Finish Time: **19:00**

Top of Casing: **---**

Ground Elev: **---**

Top / Base of Sand Pack: **7.4-11.2m**

Screened Interval: **7.7-10.7m**

Screen Size: **0.01"**

Total Depth: **11.7m**

Boring Diameter: **7 3/4"**

Casing Diameter: **2"**

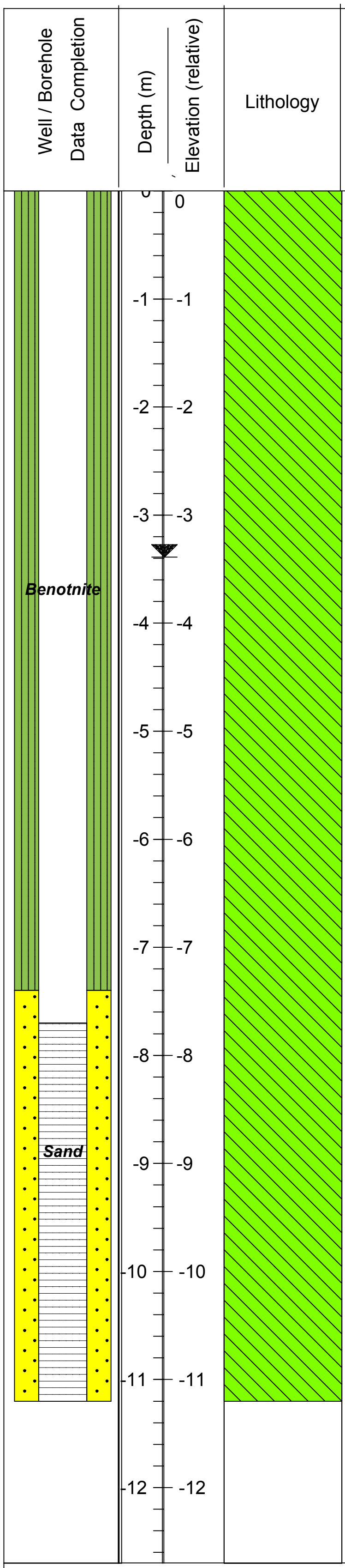
Legal Location: **NW-36-055-21 W4**

Relative Location: **---**

Northing: **5963091.4**

Easting: **368429.9**

Datum/Zone: **Zone 12**



Sample Depth
B = Bag
J = Jar
MSI 6198070326...

No samples.

Soil Description

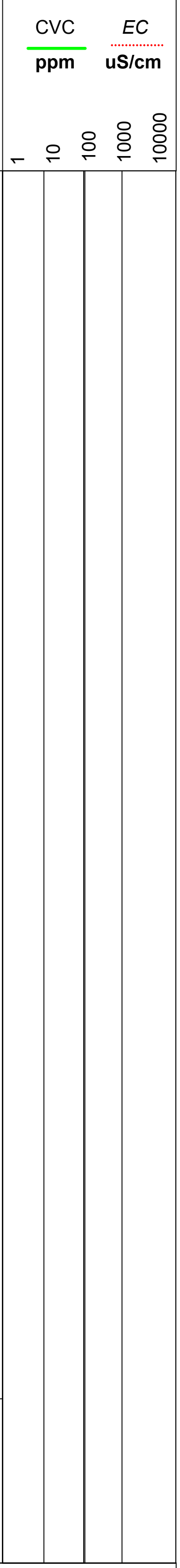
LITHOLOGY: texture, plasticity, colour/oxidation, consistence, moisture, primary structure, secondary structure, genesis, remarks.

CLAY: (0-11.2m) silty, no sand, medium to high plasticity, medium brown.

@ 6.0m becomes sandy, some gravel, angular.

@ 8.0m light brown to grey.

TD= 11.7m



NOTE: May 11, 2007 water level - 3.39m bgs.

Geologic Log - USC

Project/Site: **6198-514**

Well/borehole #: **07-B1**

Client: **NAOSC**

Logged By: **Tim Van Dijk**

Compiled By: **Jennifer Barbier**

Driller: **Beck**

Drill Equipment: **rotary (air/water)**

Sample Method:

Date: **March 26, 2007**

Start Time: **8:45**

Finish Time: **10:45**

Top of Casing: **---**

Ground Elev: **624.3m**

Top / Base of Sand Pack: **---**

Screened Interval: **---**

Screen Size: **---**

Total Depth: **24.0m**

Boring Diameter: **7 3/4"**

Casing Diameter: **---**

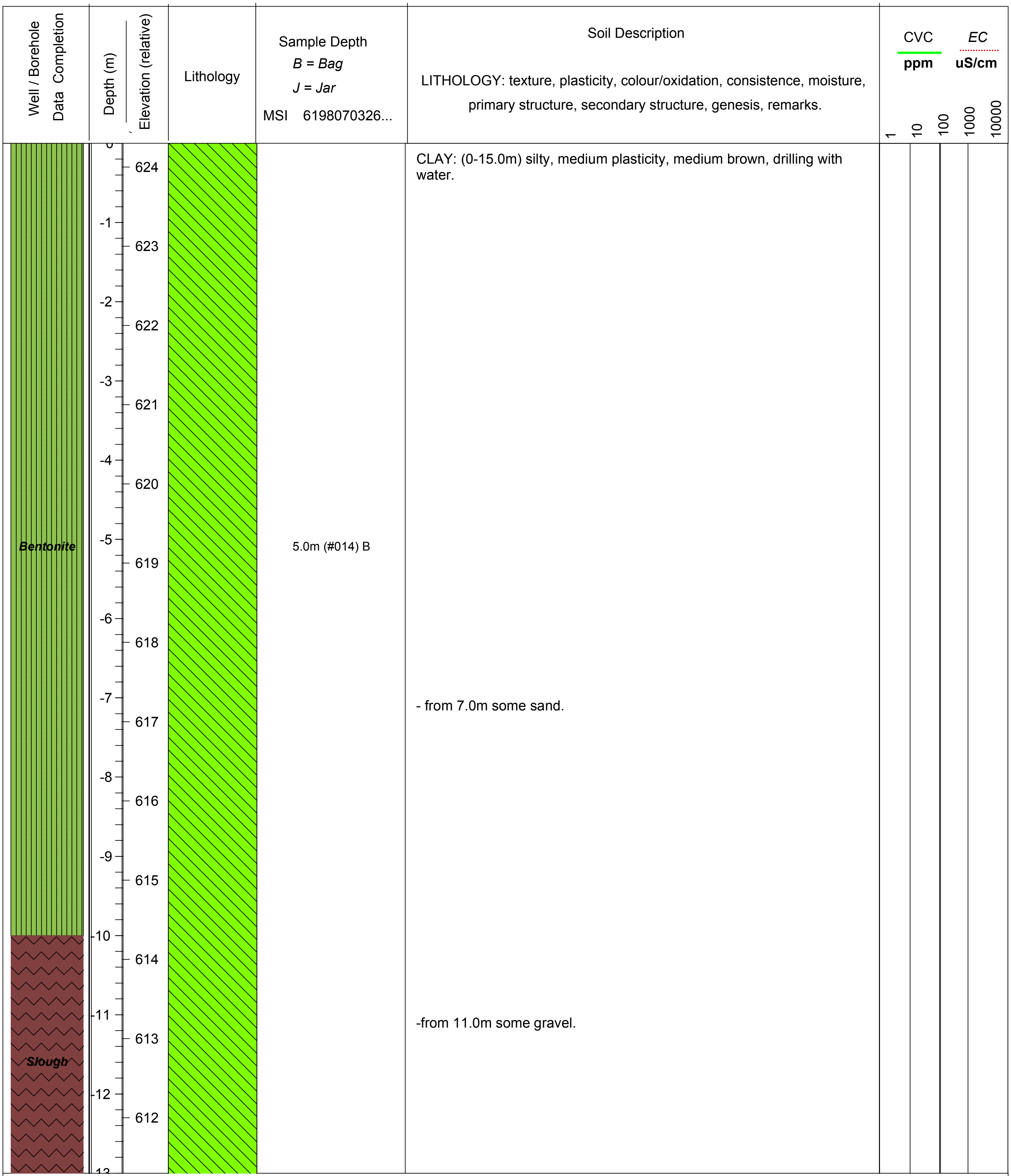
Legal Location: **NE-35-055-21 W4**

Relative Location: **---**

Northing: **5963490.0**

Easting: **367458.0**

Datum/Zone: **Zone 12**



5.0m (#014) B

CLAY: (0-15.0m) silty, medium plasticity, medium brown, drilling with water.

- from 7.0m some sand.

-from 11.0m some gravel.

NOTE:

Geologic Log - USC

Project/Site: **6198-514**

Well/borehole #: **07-B1**

Client: **NAOSC**

Logged By: **Tim Van Dijk**

Compiled By: **Jennifer Barbier**

Driller: **Beck**

Drill Equipment: **rotary (air/water)**

Sample Method:

Date: **March 26, 2007**

Start Time: **8:45**

Finish Time: **10:45**

Top of Casing: **---**

Ground Elev: **624.3m**

Top / Base of Sand Pack: **---**

Screened Interval: **---**

Screen Size: **---**

Total Depth: **24.0m**

Boring Diameter: **7 3/4"**

Casing Diameter: **---**

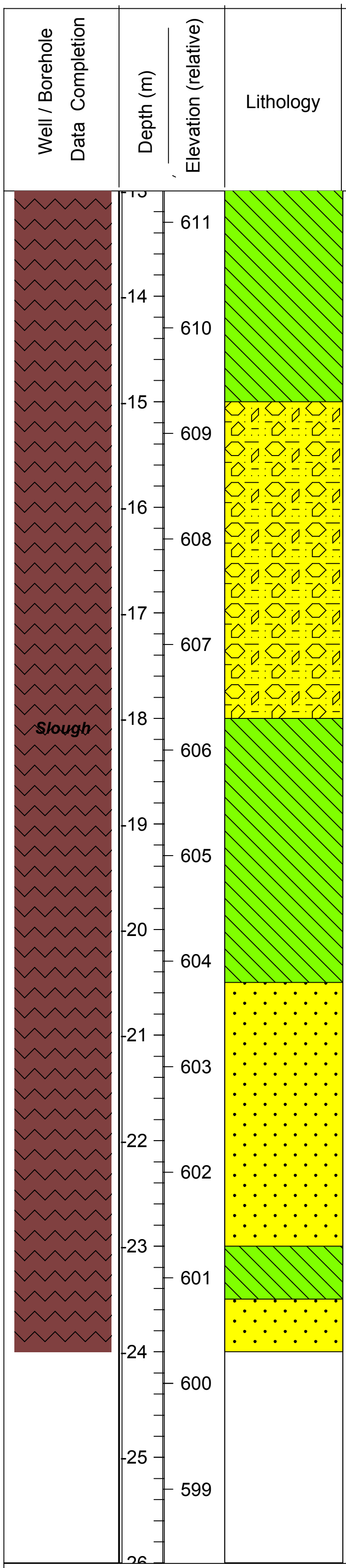
Legal Location: **NE-35-055-21 W4**

Relative Location: **---**

Northing: **5963490.0**

Easting: **367458.0**

Datum/Zone: **Zone 12**



Sample Depth
B = Bag
J = Jar
MSI 6198070326...

Soil Description

LITHOLOGY: texture, plasticity, colour/oxidation, consistence, moisture, primary structure, secondary structure, genesis, remarks.

GRAVEL AND SAND: (15.0-18.0m) medium to coarse sand, cobbles to 5cm in diameter, subrounded, medium brown.

@ 17.0m sand with some gravel

CLAY: (18.0-20.5m) sandy, silty, medium brown, firm, (claystone).

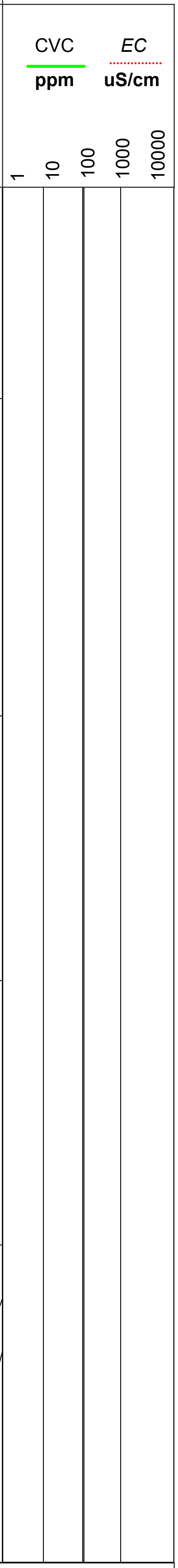
SAND: (20.5-23.0m) medium grained, well sorted, light brown, hard, (sandstone).
@ 20.5-23.0m drilling slower, drill bit chattering.

@ 21.5-23.0m fine grained, well sorted, light brown, hard.

CLAY: (23.0-23.5m) sandy, silty, fine to medium grained sand, poorly sorted, medium grey to brown, hard, (claystone).
@ 23.0-23.5m very slow drilling.

SAND: (23.5-24.0m) silty, fine grained, well sorted, grey hard, (sandstone).

TD= 24.0m



NOTE:

WorleyParsons Komex
resources & energy

Borehole #: BH06-01

Project #: WP0011000

Project Name: Preliminary Geotechnical Investigation-Proposed Upgrader
Client: WorleyParsons (Houston)
Location: Ft. Saskatchewan,AB (27-55-21 W4M,26-55-21 W4M,35-55-21 W4M,2-56-21 W4M)
Drilled by: Mobile Augers
Drill Date: 20 Nov 06
Compiled by: PENB
Northing: -
Easting: -
Elevation: -

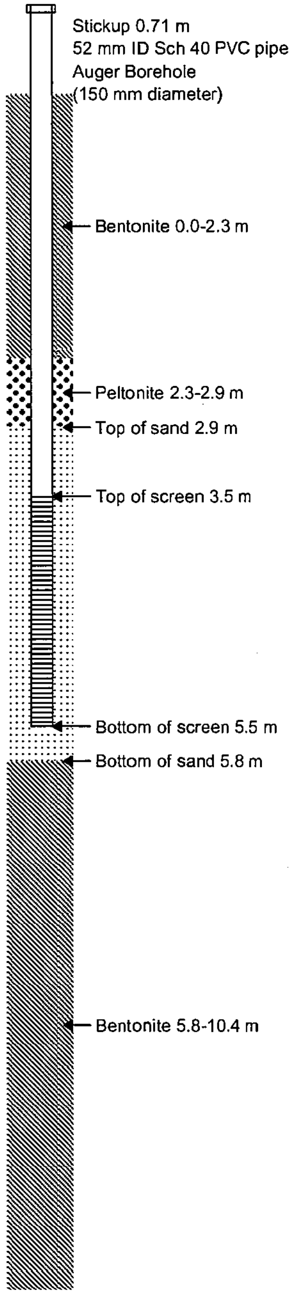
SUBSURFACE PROFILE

Elevation/ Depth	Description
0.0	Ground Surface
0.0 -0.3	***TOPSOIL (TS) (0.0-0.3 m)*** Black, organic.
0.3 -0.8	***SILT (B Horizon)(CL) (0.3-0.8 m)*** Brown, dry to damp, stiff, trace to some clay and sand, low plastic.
0.8 -1.3	***CLAYEY SILT (CL)(0.8-1.3 m)*** Brown, trace white precipiates, damp, very stiff, trace sand, low to medium plastic, trace rootlets.
1.3 -2.8	***SILTY CLAY (TILL) (CL) (1.3-2.8 m)*** Damp, very stiff, low plastic, trace rootlets, some sand, trace oxides, trace of very fine gravel.
2.8 -3.5	***SILTY SAND (SM)(2.8-3.5 m)*** Light brown, damp, very fine, medium dense.
3.5 -4.3	***SILT (SM) (3.5-4.3 m)*** Brown, damp to moist, low plastic, trace sand, trace clay, oxide staining. @ 4.0 m - oxide staining.
4.3 -8.4	***CLAYEY SANDY (TILL) (CL) (4.3-8.4 m)*** Moist, stiff, some silt, low plastic, trace gravel (<25 mm). @ 5.0 m - mostly sand - still till-like structure, free water. @ 6.0 m - increasing clay content, trace to some clay, moist, gravel (<25 mm) can't roll worm-no sloughing of hole. @ 7.8 m - 0.3 m thick silt seams, damp, brown.
8.4 -9.9	***SILTY CLAY (CL)(TILL) (8.4-9.9 m)*** Dark brown with rust colouring (<20mm), damp, hard, low plastic, oxide staining in fractures.
9.9 -10.4	***SILTY CLAY (CI) (9.9-10.4 m)*** Grey, damp, hard, medium plastic, oxide staining, fine sand lenses (moist).
10.4	10.4 m End of Borehole - water level dry on Nov 23, 2006.

SAMPLE

Sample Depth (m)	DCPT / SPT (0 50 100)	Undrained Shear Strength kg/cm² (0 1.25 3.75 5)	Moisture Content % (0 50 100)
0.5-0.8			
0.8-1.3	10	2.25	
1.3-1.6			
2.3-2.8	20	2.25	
2.9-3.2			
3.8-4.3	16	1.50	
5.3-5.8	30	0.75	
6.1-6.4			
6.9-7.4	55	1.63	
7.4-7.7			
8.4-8.9	62	1.63	
9.2-9.5			
9.9-10.4	43		

Well Data



WorleyParsons Komex
resources & energy

Borehole #: BH06-02

Project #: WP0011000

Project Name: Preliminary Geotechnical Investigation-Proposed Upgrader
Client: WorleyParsons (Houston)
Location: Ft. Saskatchewan,AB (27-55-21 W4M,26-55-21 W4M,35-55-21 W4M,2-56-21 W4M)
Drilled by: Mobile Augers
Drill Date: 20 Nov 06
Compiled by: PENB
Northing: -
Easting: -
Elevation: -

SUBSURFACE PROFILE			SAMPLE		DCPT / SPT (0 50 100)	Undrained Shear Strength kg/cm² (0 1.25 3.75 5)	Moisture Content % (0 50 100)	Well Data
Elevation/ Depth	Symbol	Description	Sample Depth (m)	Sample Type				
0.0		Ground Surface						
0.0 -0.6		***TOPSOIL (TS) (0.0-0.6 m)*** Black, organic.						
0.6 -0.9		***SILT (B Horizon) (CL) (0.6-0.9 m)*** Brown, frozen, low plastic, trace to some clay, trace sand.	0.8-1.3		9 ▲	>2.25 ●		
0.9		***SILTY CLAY (TILL) (CL) (0.9-3.8 m)*** Damp, stiff, low plastic, some sand, trace oxidation and precipitates. @ 1.7 m - moist, dark brown.	1.4-1.7					
			2.3-2.8		10 ▲	1.25 ●		
-3.8		between 2.8-3.3 m - thin sand lenses (grey) approximately 2-5 mm thick, throughout, trace of free water in sand.	2.8-3.1					
3.8		3.8 m End of Borehole Dry upon completion.						

WorleyParsons Komex
resources & energy

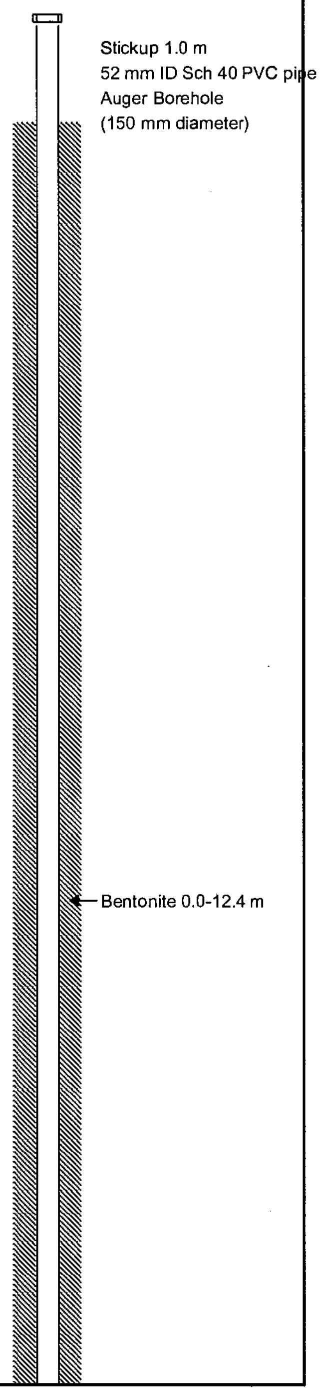
Borehole #: BH06-03

Project #: WP0011000

Project Name: Preliminary Geotechnical Investigation-Proposed Upgrader
Client: WorleyParsons (Houston)
Location: Ft. Saskatchewan,AB (27-55-21 W4M,26-55-21 W4M,35-55-21 W4M,2-56-21 W4M)
Drilled by: Mobile Augers
Drill Date: 20 Nov 06
Compiled by: PENB
Northing: -
Easting: -
Elevation: -

SUBSURFACE PROFILE		SAMPLE	DCPT / SPT (0 50 100)	Undrained Shear Strength kg/cm² (0 1.25 3.75 5)	Moisture Content % (0 50 100)
Elevation/ Depth	Description	Sample Depth (m)			
0.0	Ground Surface				
0.0 -0.5	***TOPSOIL (TS) (0.0-0.5 m)*** Black, frozen, organic.				
0.5 -0.8	***SILTY CLAY (CL) (B Horizon) (0.5-0.8 m)*** Light brown, damp to moist, stiff, low plastic.				
0.8	***SILTY CLAY (CL) (TILL) (0.8-17.8 m)*** Medium brown, damp, very stiff, low plastic, some sand, trace fine rootlets and precipitates and oxides (rootlets to approximately 1.2 m). @ 1.0 m - between 1-1.2 m increased clay, medium plastic. @ 1.2-1.5 m - some sand and gravel (<20 mm),	0.8-1.3	8	2.25	
		1.4-1.7			
		2.3-2.8	10	1.13	
		2.9-3.1			
		3.8-4.2			
	@ 4.2 m - very stiff.	4.2-4.7	17	1.13	
		4.3-4.6			
	@ 5.3 m (CI) - increased clay content, medium plastic.	5.3-5.8	24	1.50	
		6.0-6.3			
	@ 7.0 m (CI) - dark grey.	6.7-7.2	25	1.75	
		8.0-8.3			
		8.4-8.9	28	1.75	
	@ 9.0 m (CI/CH) - medium to high plastic.	9.2-9.5			

Well Data

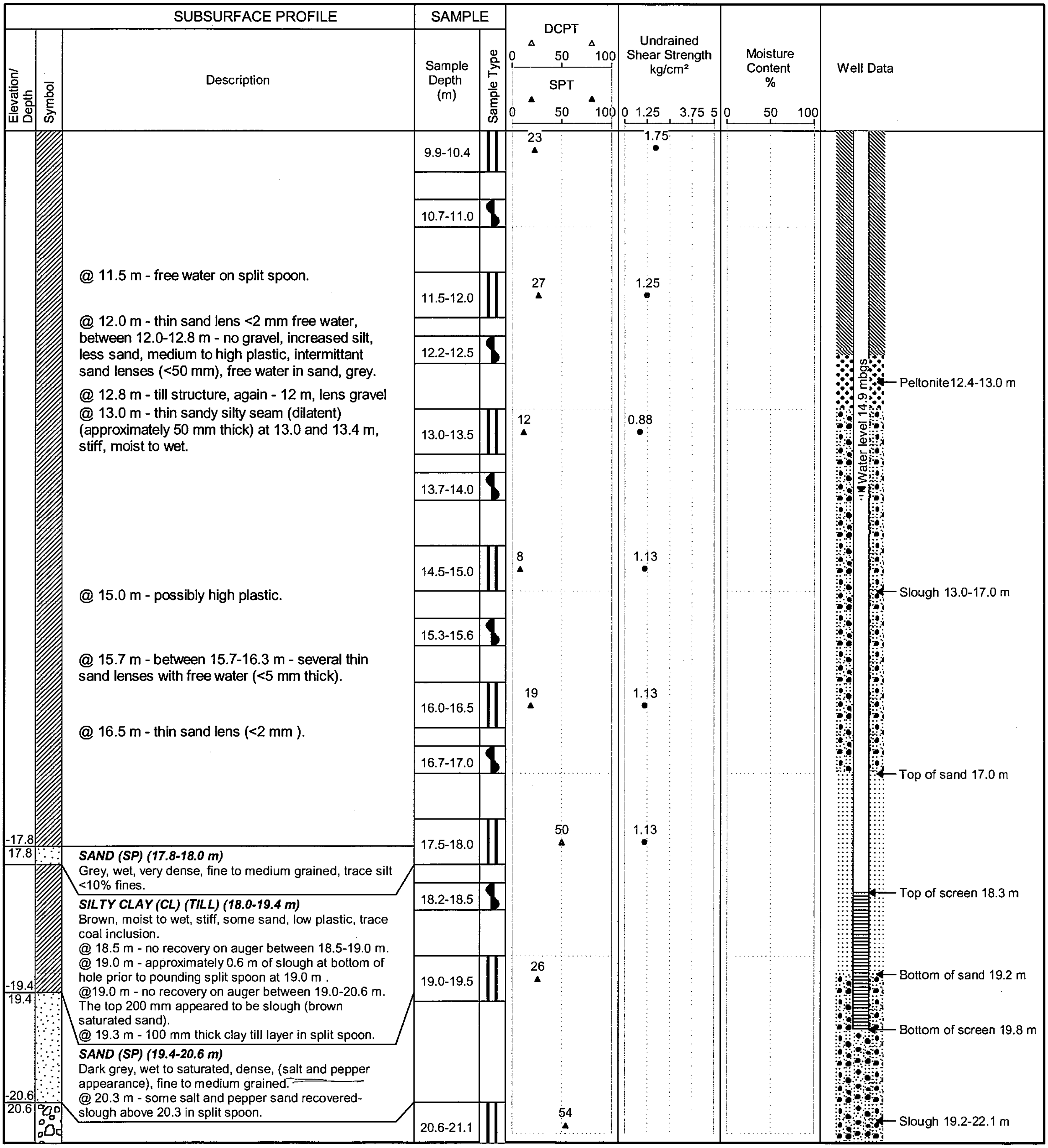


WorleyParsons Komex
resources & energy

Borehole #: BH06-03

Project #: WP0011000

Project Name: Preliminary Geotechnical Investigation-Proposed Upgrader
Client: WorleyParsons (Houston)
Location: Ft. Saskatchewan,AB (27-55-21 W4M,26-55-21 W4M,35-55-21 W4M,2-56-21 W4M)
Drilled by: Mobile Augers
Drill Date: 20 Nov 06
Compiled by: PENB
Northing: -
Easting: -
Elevation: -



@ 11.5 m - free water on split spoon.

@ 12.0 m - thin sand lens <2 mm free water, between 12.0-12.8 m - no gravel, increased silt, less sand, medium to high plastic, intermittant sand lenses (<50 mm), free water in sand, grey.

@ 12.8 m - till structure, again - 12 m, lens gravel

@ 13.0 m - thin sandy silty seam (dilatent) (approximately 50 mm thick) at 13.0 and 13.4 m, stiff, moist to wet.

@ 15.0 m - possibly high plastic.

@ 15.7 m - between 15.7-16.3 m - several thin sand lenses with free water (<5 mm thick).

@ 16.5 m - thin sand lens (<2 mm).

-17.8
17.8

SAND (SP) (17.8-18.0 m)
Grey, wet, very dense, fine to medium grained, trace silt <10% fines.

SILTY CLAY (CL) (TILL) (18.0-19.4 m)
Brown, moist to wet, stiff, some sand, low plastic, trace coal inclusion.
@ 18.5 m - no recovery on auger between 18.5-19.0 m.
@ 19.0 m - approximately 0.6 m of slough at bottom of hole prior to pounding split spoon at 19.0 m .
@19.0 m - no recovery on auger between 19.0-20.6 m. The top 200 mm appeared to be slough (brown saturated sand).
@ 19.3 m - 100 mm thick clay till layer in split spoon.

-19.4
19.4

SAND (SP) (19.4-20.6 m)
Dark grey, wet to saturated, dense, (salt and pepper appearance), fine to medium grained.
@ 20.3 m - some salt and pepper sand recovered-slough above 20.3 in split spoon.

-20.6
20.6

Sample Depth (m)	SPT	Undrained Shear Strength kg/cm²
9.9-10.4	23	1.75
10.7-11.0		
11.5-12.0	27	1.25
12.2-12.5		
13.0-13.5	12	0.88
13.7-14.0		
14.5-15.0	8	1.13
15.3-15.6		
16.0-16.5	19	1.13
16.7-17.0		
17.5-18.0	50	1.13
18.2-18.5		
19.0-19.5	26	
20.6-21.1	54	

WorleyParsons Komex
resources & energy

Borehole #: BH06-03

Project #: WP0011000

Project Name: Preliminary Geotechnical Investigation-Proposed Upgrader
Client: WorleyParsons (Houston)
Location: Ft. Saskatchewan,AB (27-55-21 W4M,26-55-21 W4M,35-55-21 W4M,2-56-21 W4M)
Drilled by: Mobile Augers
Drill Date: 20 Nov 06
Compiled by: PENB
Northing: -
Easting: -
Elevation: -

SUBSURFACE PROFILE			SAMPLE					
Elevation/ Depth	Symbol	Description	Sample Depth (m)	Sample Type	DCPT 0 50 100 / SPT 0 50 100	Undrained Shear Strength kg/cm² 0 1.25 3.75 5	Moisture Content % 0 50 100	Well Data
-22.3 22.3		***GRAVEL (GP) (20.6-22.3 m)*** Dense, some sand, trace silt,(>25 mm) - broken / fractured pieces, subrounded. @ 20.6 m - approximately 0.6 mm of slough in bottom of hole. @ 20.7 m - auger between 20.7-21.1 m - minimal recovery on auger, but gravel contained some larger sizes between 50-75 mm. When dropping rods for split spoon, it pinched at approximately 20.7 m and then with a little effort the rods dropped to bottom of hole.	22.1-22.6		50/150			
-22.6 22.6		***SAND (SP) (22.3-22.6 m)*** Grey, very dense, fine to medium grained, trace silt (<5%). @ 22.6 - wet upon completion. 22.6 m End of Borehole						

Wet upon completion.

2" pipe fell easily to 63' and was pushed to 65'. Dropped tape and got hung up at 47' with water level at approximately 41'. Tried to open a gap at pinche at 47' with 1" pipe which did push through to 63'. Tape still would not fall. Dropped 2.5 bags of 10-20 sand which did not get hung up.
Let hole settle overnight to see what happens.

Note: Piezo - 25 mm diameter pipe lost in hole adjacent to 2" pipe when checking depth of slough, 25mm diameter pipe beckfilled with peltonite.

WPK-Geotech-pz-type3-Shear

WorleyParsons Komex
resources & energy

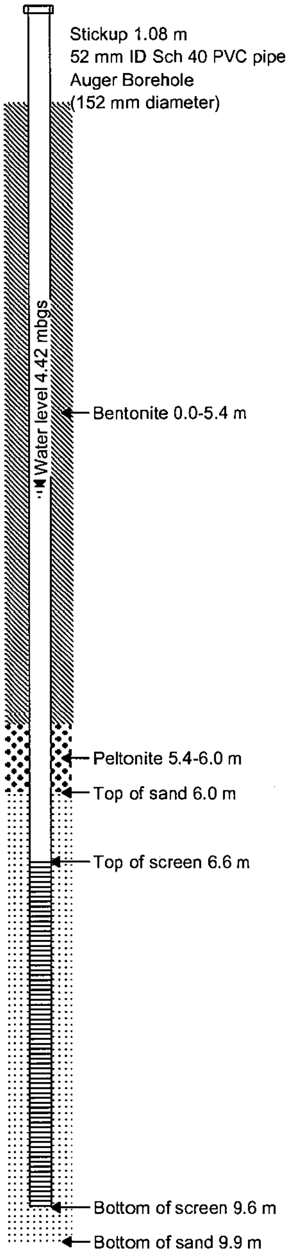
Borehole #: BH06-04

Project #: WP0011000

Project Name: Preliminary Geotechnical Investigation-Proposed Upgrader
Client: WorleyParsons (Houston)
Location: Ft. Saskatchewan,AB (27-55-21 W4M,26-55-21 W4M,35-55-21 W4M,2-56-21 W4M)
Drilled by: Mobile Augers
Drill Date: 21 Nov 06
Compiled by: LEVP
Northing: -
Easting: -
Elevation: -

Elevation/ Depth	Description (SUBSURFACE PROFILE)	Sample Depth (m)	DCPT △ / SPT ▲	Undrained Shear Strength kg/cm²	Moisture Content %
0.0	Ground Surface				
0.0 -0.3	***TOPSOIL (TS) (0.0-0.3 m)***				
0.3	***SILTY CLAY (CL) (B Horizon) (0.3-0.5 m)*** Light brown, damp, firm to stiff, low plasticity.				
	SILTY CLAY(CLICI) (TILL) (0.5-10.4 m) Brown, damp, stiff, low to medium plasticity, precipitates, oxidized particules, some sand.	0.8-1.3	12	2.25	
	@ 1.5 m - trace gravel, 10-40 mm diameter, sub rounded, moist.	1.4-1.7			
		2.3-2.8	11	1.25	
		2.8-3.1			
		3.9-4.3	25		
		4.4-4.7			
	@ 5.3 m - very stiff, dark brown, (below 5.3 m)	5.3-5.8	21	1.38	
		5.9-6.4			
	@ 6.9 m - stiff (below 6.9 m). @ 7.0 m - dark grey, medium plasticity (below 7.0 m).	6.9-7.4	15	0.75	
		7.5-7.8			
	@ 8.4 m - 41 cm recovery in shelby tube.	8.4-8.9			
	@ 9.2 m - thin sand lens, free water.	8.9-9.4	15	0.50	
		9.4-9.7			
-10.4	Wet upon completion.	9.9-10.4	13	0.38	
10.4	10.4 m End of Borehole				

Well Data



WorleyParsons Komex
resources & energy

Borehole #: BH06-05

Project #: WP0011000

Project Name: Preliminary Geotechnical Investigation-Proposed Upgrader
Client: WorleyParsons (Houston)
Location: Ft. Saskatchewan,AB (27-55-21 W4M,26-55-21 W4M,35-55-21 W4M,2-56-21 W4M)
Drilled by: Mobile Augers
Drill Date: 21 Nov 06
Compiled by: LEVP
Northing: -
Easting: -
Elevation: -

SUBSURFACE PROFILE			SAMPLE					
Elevation/ Depth	Symbol	Description	Sample Depth (m)	Sample Type	DCPT △ 0 50 100 / SPT ▲ 0 50 100	Undrained Shear Strength kg/cm² 0 1.25 3.75 5	Moisture Content % 0 50 100	Well Data
0.0		Ground Surface						
0.0 -0.6		***TOPSOIL (TS) (0.0-0.6 m)*** Black, organic.						
0.6	▨	***SILTY CLAY (CL) (B Horizon) (0.6-0.8 m)*** Brown, dry, stiff, some sand, low plasticity.						
	▨	***SILTY CLAY (CL)(0.8-1.7 m)*** Light brown, damp, very stiff, medium to high plasticity, precipitates.	0.8-1.3	‖	12 ▲	>2.25 ●		
-1.7	▨		1.4-1.7	ʃ				
1.7 -2.3	▨	***SILTY CLAY (CL/CI) (TILL) (1.7-2.3 m)*** Medium brown, damp, stiff, low to medium plasticity, oxidized particules, precipitates, some sand.						
2.3	⁘	***SAND (SP) (2.3-3.4 m)*** Light brown, moist to wet, loose to medium dense, fine to medium grained, trace fines (5-10%).	2.3-2.8	‖	13 ▲	1.25 ●		
-3.4	⁘		2.9-3.2	ʃ				
3.4 -4.3	▨	***SILTY CLAY (CL) (TILL) (3.4-4.3 m)*** Medium brown, damp to moist, hard, low to medium plasticity, oxide staining, precipitates, trace of water on spoon.	3.8-4.3	‖	43 ▲			
4.3		4.3 m End of Borehole Dry upon completion.						

WorleyParsons Komex
resources & energy

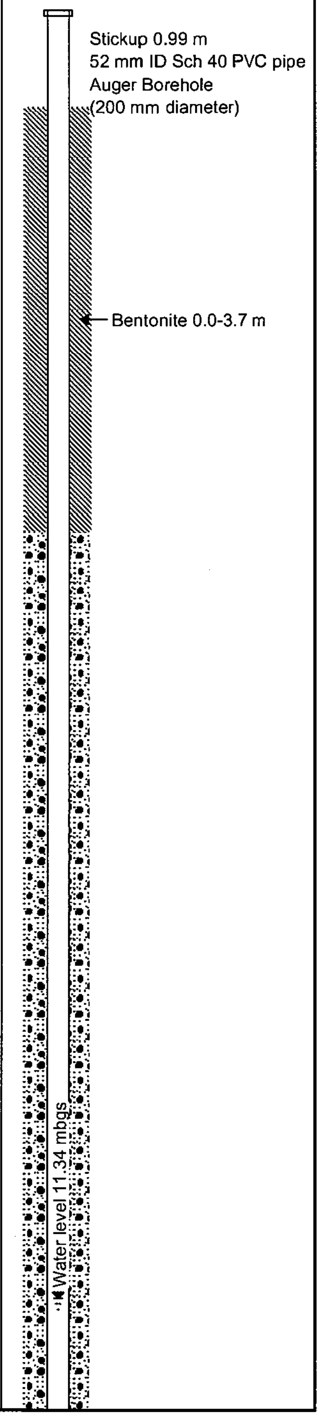
Borehole #: BH06-06

Project #: WP0011000

Project Name: Preliminary Geotechnical Investigation-Proposed Upgrader
Client: WorleyParsons (Houston)
Location: Ft. Saskatchewan,AB (27-55-21 W4M,26-55-21 W4M,35-55-21 W4M,2-56-21 W4M)
Drilled by: Mobile Augers
Drill Date: 21 Nov 06
Compiled by: LEVP
Northing: -
Easting: -
Elevation: -

SUBSURFACE PROFILE		SAMPLE	DCPT △ 0 50 100 / SPT ▲ 0 50 100	Undrained Shear Strength kg/cm² 0 1.25 3.75 5	Moisture Content % 0 50 100
Elevation/ Depth	**Description**	**Sample Depth (m)**			
0.0	Ground Surface				
0.0 -0.4	***TOPSOIL (TS) (0.0-0.35 m)*** Black, organic.				
0.4	***SANDY SILT (SM) (B Horizon) (0.35-0.55 m)*** Light brown, dry to damp, firm to stiff, trace clay, trace organics.				
	SILTY CLAY (CL) (TILL) (0.55-3.2 m) Medium brown, damp, firm to stiff, low to medium plasticity, precipitates, oxide staining, some sand. moist below 0.8 m.	0.8-1.3	8	1.75	
		1.4-1.7			
		2.3-2.8	8	0.63	
-3.2 3.2	***SAND (SP) (3.2-6.7 m)*** Light brown, saturated, loose to medium dense, fine grained, trace to some silt (10-15%). @ 3.8 m - fine to medium grained, dense >10% silt. @ 4.3 m - some silt approximately 15-20% fine grained-silt content varies-flowing sand, high dilatency.	3.2-3.8			
		3.8-4.3	34		
		4.3-4.7			
	@ 5.2 m - no recovery in split spoon between 5.2-5.7 m - switched to hollow stem.	5.2-5.7	20		
-6.7 6.7 -7.0	***SILT (M) (6.7-7.0 m)*** Medium brown, wet to saturated, firm, no-plastic, trace clay, medium dilatency.	6.7-7.2	8	1.25	
7.0	***CLAY (CH) (7.0-9.5 m)*** Dark grey, moist, firm, high plasticity.				
		8.4-8.9	6	0.75	
-9.5 9.5	***SILTY CLAY (CI) (TILL) (9.5-14.0 m)*** Dark grey, damp, very stiff, medium plasticity, some sand, trace gravel, oxidized particules.	10.4-10.9	18	1.38	

Well Data



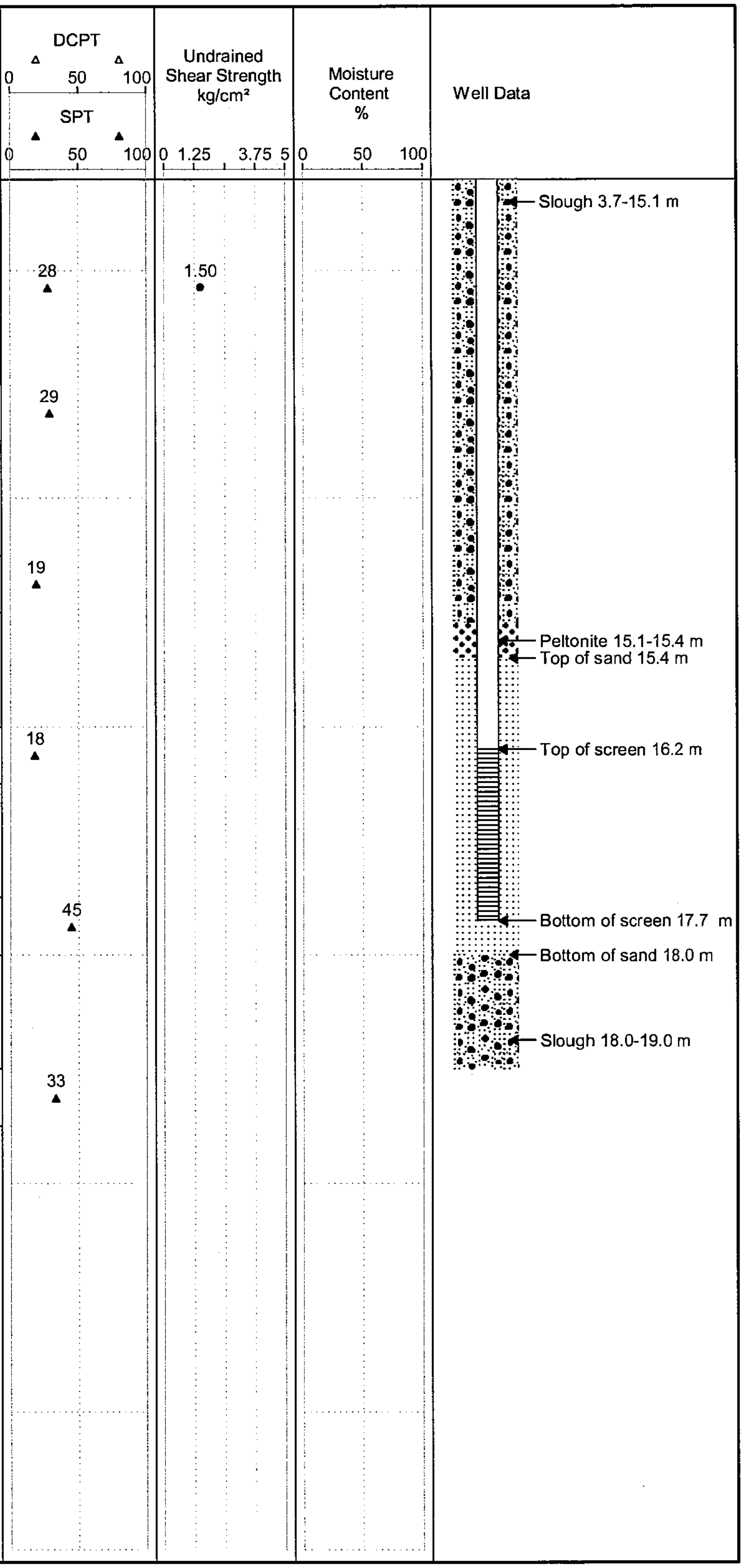
WorleyParsons Komex
resources & energy

Borehole #: BH06-06

Project #: WP0011000

Project Name: Preliminary Geotechnical Investigation-Proposed Upgrader
Client: WorleyParsons (Houston)
Location: Ft. Saskatchewan,AB (27-55-21 W4M,26-55-21 W4M,35-55-21 W4M,2-56-21 W4M)
Drilled by: Mobile Augers
Drill Date: 21 Nov 06
Compiled by: LEVP
Northing: -
Easting: -
Elevation: -

SUBSURFACE PROFILE			SAMPLE	
Elevation/ Depth	Symbol	Description	Sample Depth (m)	Sample Type
	▨		11.4-11.9	
	▨	@ 12.1 m - thin sand lense (>1 cm).	11.9-12.4	
	▨	@ 13.0 m - no recovery on split spoon, pushed a 3" diameter "A" casing to get sample. @ 13.3 m - medium to high plasticity.	13.0-13.5	
-14.0 14.0		***SAND (SP) (14.0-19.5 m)*** Grey, wet, medium dense, trace gravel, fine to medium grained.	14.5-15.0	
		@ 16.2 m trace gravel, approximately 10 mm diameter. @ 16.5 m - thin silt layer, trace clay, some sand, thickness approximately 50 mm.	16.0-16.5	
		@ 17.5 m - no recovery on split spoon, pushed a 3" diameter "A" casing to get sample.	17.5-18.0	
-19.5		@ 19.0 m - increasing gravel content, approximately 25%, approximately 20 mm diameter.	19.0-19.5	
19.5		19.5 m End of Borehole @ 19.5 m - plunger won't reach bottom of hole because of pressure head and sand heave of appximately 1 ft. Filled hollow stem with water to try to push sand down and remove 5 ft. of auger, after pulling auger up to 58 ft. Hole open to 59 ft. Wet upon completion.		



WorleyParsons Komex
resources & energy

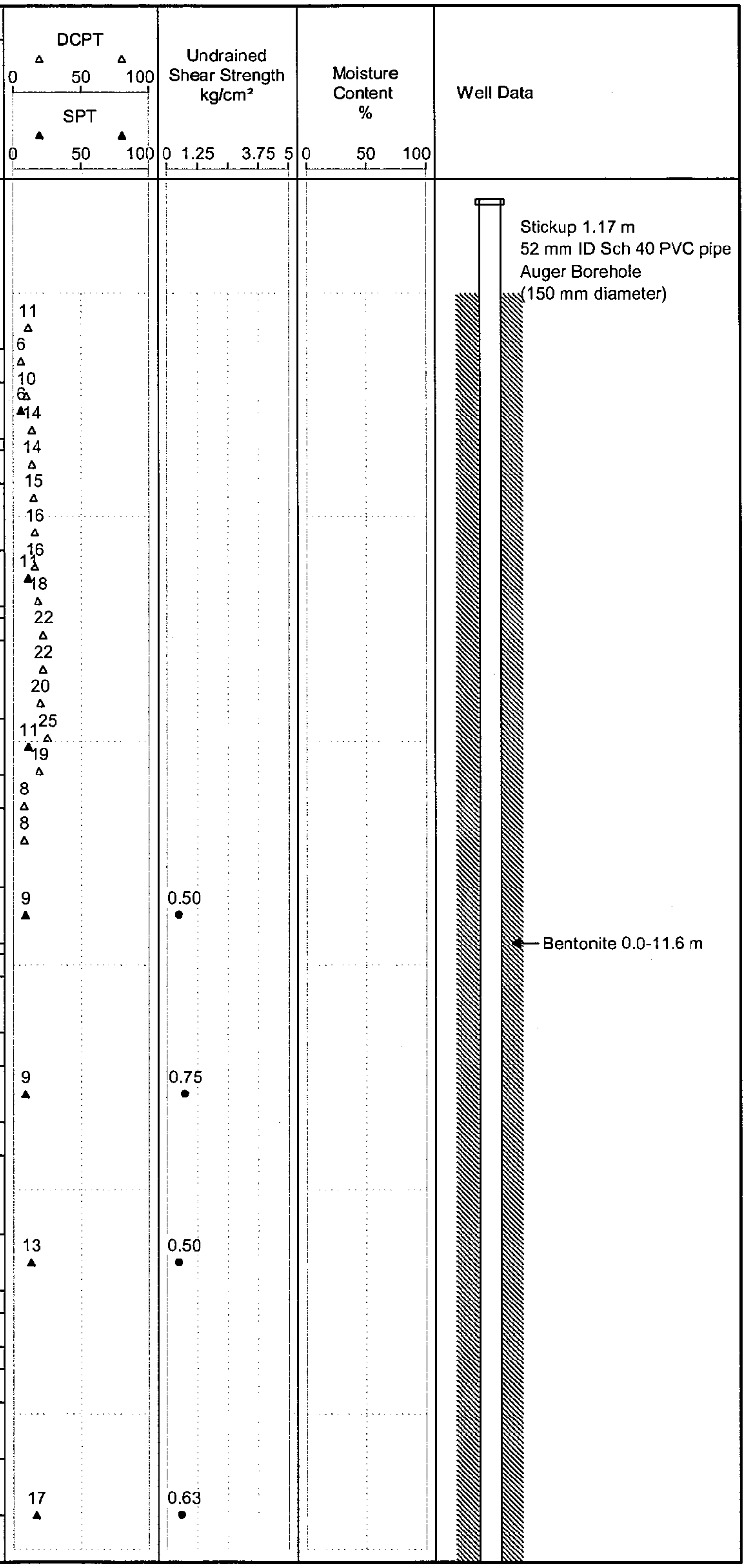
Borehole #: BH06-07

Project #: WP0011000

Project Name: Preliminary Geotechnical Investigation-Proposed Upgrader
Client: WorleyParsons (Houston)
Location: Ft. Saskatchewan,AB (27-55-21 W4M,26-55-21 W4M,35-55-21 W4M,2-56-21 W4M)
Drilled by: Mobile Augers
Drill Date: 22 Nov 06
Compiled by: LEVP
Northing: -
Easting: -
Elevation: -

SUBSURFACE PROFILE / SAMPLE

Elevation/ Depth	Description	Sample Depth (m)
0.0 0.0	Ground Surface	
	TOPSOIL (TS) (0.0-0.15 m) Black, organic.	
	SAND (SP) (0.15-4.2 m) Medium brown, damp, loose, fine grained, trace silt.	0.5-0.8
		0.8-1.3
		1.4-1.7
	@ 2.3 m - loose to medium dense, light brown. (below 2.3 m).	2.3-2.8
		2.9-3.1
-4.2	@ 3.8 m - moist, increasing silt content (approximately 15%) (below 3.8 m).	3.8-4.3
4.2	***SILTY CLAY (CL/CI) (4.2-8.0 m)*** Light brown, moist, firm, low to medium plasticitiy, some sand, trace of small pieces of coal. @ 4.6 m - brown 4.6, oxide staining.	4.3-4.6
		5.3-5.8
	below 5.9 m - medium plasticity.	5.9-6.2
	@ 6.1 m - shelby tube, 45 cm recovery.	6.1-6.6
	@ 6.6 m - medium brown (below 6.6 m).	
	below 6.9 m - trace of high plasticity material (dark grey). @ 7.3 m - thin sand lens 5 mm, free water.	6.9-7.4
-8.0		7.4-7.7
8.0	***CLAY (CI/CH) (8.0-9.6 m)*** Grey, damp, stiff, trace silt, high plasticity.	8.4-8.9
-9.6		9.1-9.4
9.6	***SILTY CLAY (CL/CI) (TILL) (9.6-13.8 m)*** Grey, damp, stiff to very stiff, some sand, trace gravel (approximately 10 mm diameter), low to medium	9.6-9.9
	@ 9.9 m - shelby tube, 45 cm recovery.	9.9-10.4
	below 10.4 m - very stiff.	10.4-10.9



WorleyParsons Komex
resources & energy

Borehole #: BH06-07

Project #: WP0011000

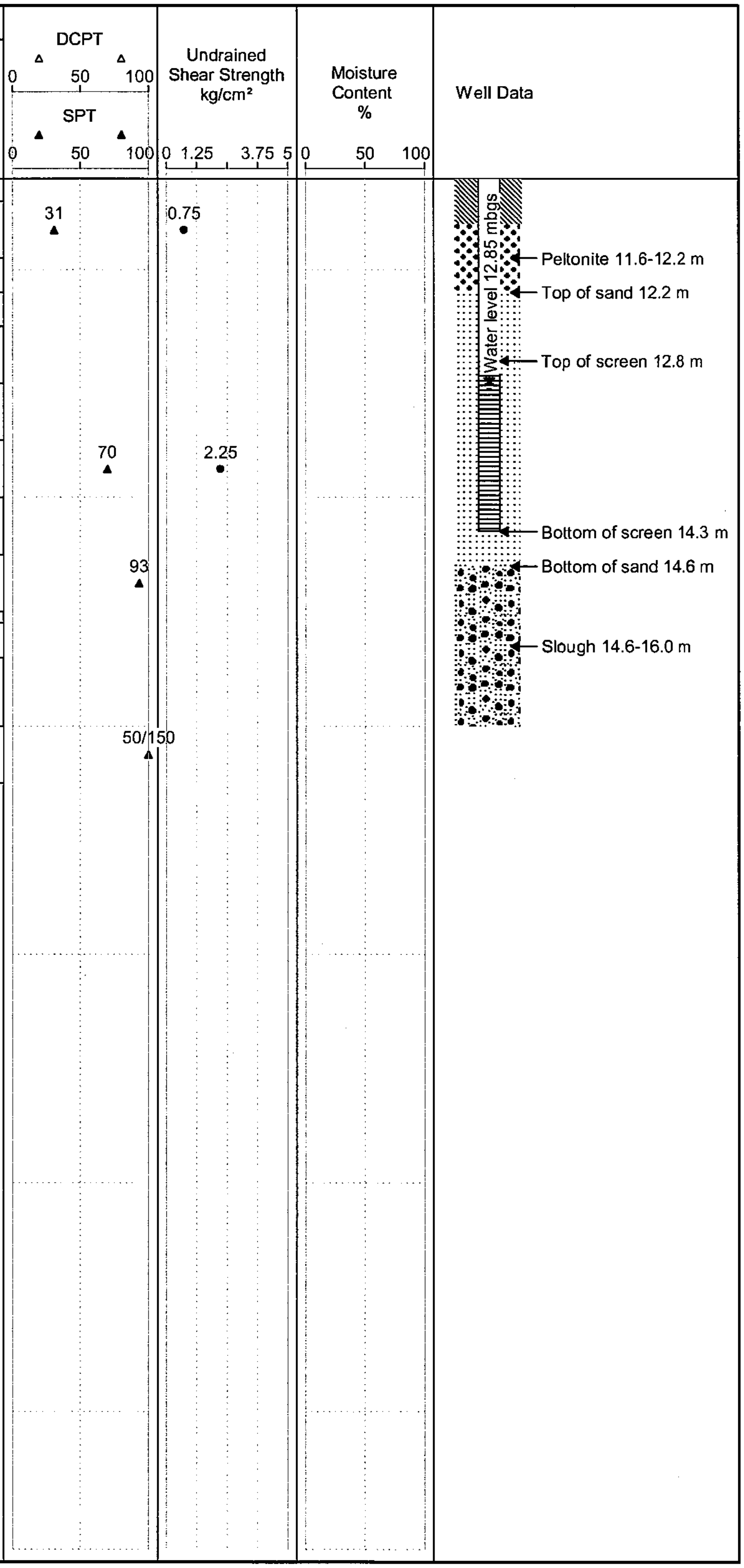
Project Name: Preliminary Geotechnical Investigation-Proposed Upgrader
Client: WorleyParsons (Houston)
Location: Ft. Saskatchewan,AB (27-55-21 W4M,26-55-21 W4M,35-55-21 W4M,2-56-21 W4M)
Drilled by: Mobile Augers
Drill Date: 22 Nov 06
Compiled by: LEVP
Northing: -
Easting: -
Elevation: -

SUBSURFACE PROFILE

Elevation/ Depth	Symbol	Description
-13.8	▨	@ 13.5 m - some gravel (approximately 10%) (approximately 10-20 mm diameter), moist.
13.8 -15.0	⁙	***SAND (SW) (13.8-15.0 m)*** Dark brown,saturated, very dense, some silt, fine to medium grained, trace to some gravel (subrounded, approximately 30 mm diameter).
15.0 -16.5	⁙	***SANDY GRAVEL (GW) (15.0-16.5 m)*** Saturated, subangular, very dense, well-graded. (30mm diameter).
16.5		16.5 m End of Borehole Wet upon completion.

SAMPLE

Sample Depth (m)	Sample Type	SPT	Undrained Shear Strength kg/cm²
11.4-11.9	⦀	31	0.75
12.2-12.5	∿		
13.0-13.5	▮		
13.5-14.0	⦀	70	2.25
14.5-15.0	⦀	93	
15.1-15.4	∿		
16.0-16.5	⦀	50/150	



WPK-Geotech-pz-type3-Shear

WorleyParsons Komex
resources & energy

Borehole #: BH06-08

Project #: WP0011000

Project Name: Preliminary Geotechnical Investigation-Proposed Upgrader
Client: WorleyParsons (Houston)
Location: Ft. Saskatchewan,AB (27-55-21 W4M,26-55-21 W4M,35-55-21 W4M,2-56-21 W4M)
Drilled by: Mobile Augers
Drill Date: 22 Nov 06
Compiled by: LEVP
Northing: -
Easting: -
Elevation: -

SUBSURFACE PROFILE

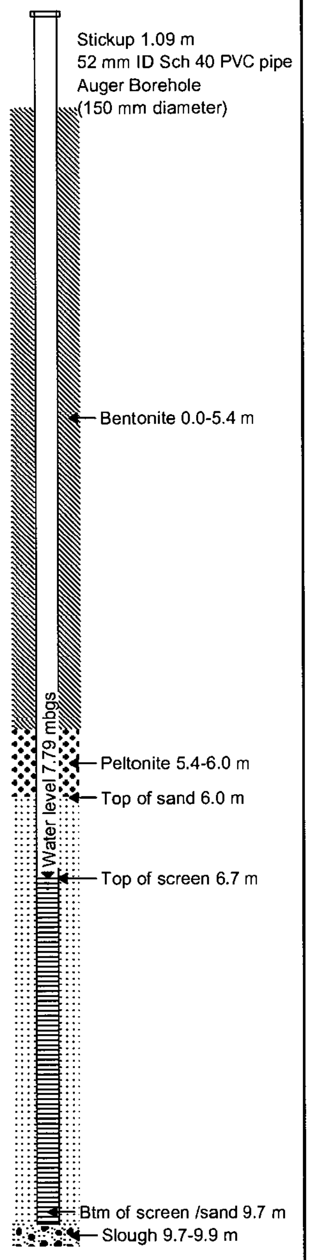
Elevation/ Depth	Description
0.0 0.0	Ground Surface
0.0	***TOPSOIL (TS) (0.0-0.15 m)*** Black, organic.
	SILTY CLAY (CL) (B Horizon) (0.15-0.3 m) Brown, damp, stiff, some sand, low plasticity.
	SILTY CLAY (CL/CI) (0.3-5.7 m) Medium brown with grey mottling, damp, firm, low to medium plasticity, trace sand. below 2.3 m - stiff, trace oxidation staining. @ 4.4 m - increasing clay content and plasticity.
-5.7 5.7	***CLAY (CI/CH) (5.7-8.1 m)*** Grey, damp, stiff, medium to high plasticity, trace silt. below 7.3 m - moist, increasing sand (20%).
-8.1 8.1	***SILTY SAND (SM) (8.1-8.4 m)*** Grey, wet, medium dense, some clay,
-8.4 8.4	***SILTY CLAY (CL/CI) (TILL) (8.4-10.4 m)*** Grey, moist to wet, firm to stiff, low to medium plasticity, some sand. below 9.0 m - trace gravel, subangular <40 mm diameter, increasing stiffness. @ 9.9 m - very stiff to hard, increasing plasticity to medium plasticity.
-10.4 10.4	10.4 m End of Borehole Wet upon completion.

SAMPLE

Sample Depth (m)	SPT	Undrained Shear Strength kg/cm²
0.5-0.8		
0.8-1.3	5	0.75
1.3-1.8		
2.3-2.8	10	0.63
2.8-3.1		
3.8-4.3	13	0.75
4.4-4.7		
5.3-5.8	9	0.63
5.8-6.1		
6.9-7.4	13	0.50
7.4-7.7		
8.4-8.9	4	0.50
9.1-9.4		
9.9-10.4	34	

DCPT: 0 50 100
SPT: 0 50 100
Undrained Shear Strength kg/cm²: 0 1.25 3.75 5
Moisture Content %: 0 50 100

Well Data



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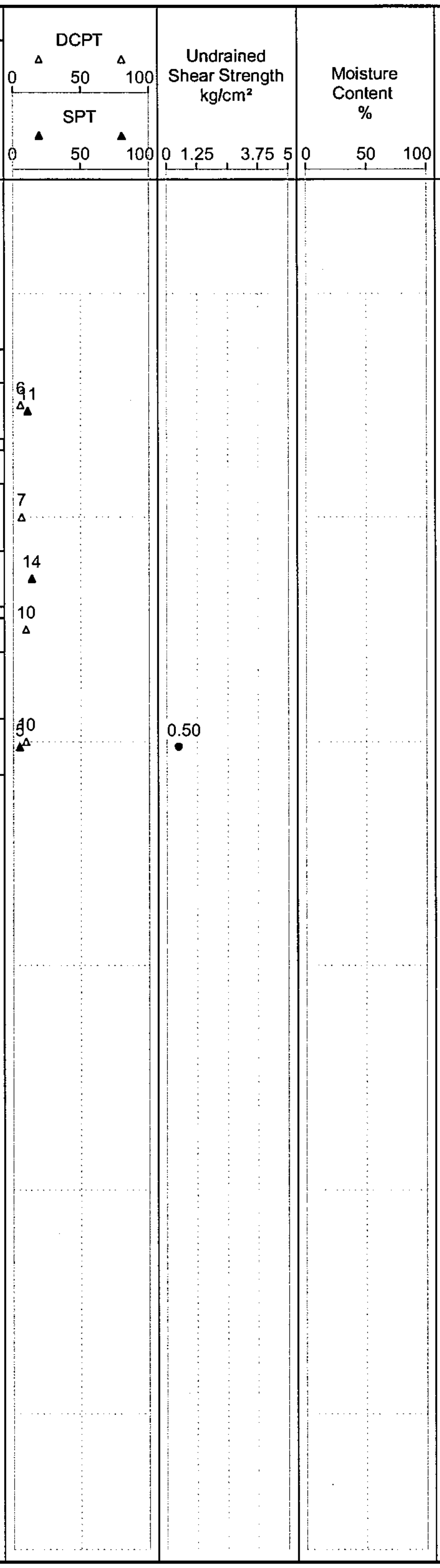
WorleyParsons Komex
resources & energy

Borehole #: BH06-09

Project #: WP0011000

Project Name: Preliminary Geotechnical Investigation-Proposed Upgrader
Client: WorleyParsons (Houston)
Location: Ft. Saskatchewan,AB (27-55-21 W4M,26-55-21 W4M,35-55-21 W4M,2-56-21 W4M)
Drilled by: Mobile Augers
Drill Date: 23 Nov 06
Compiled by: LEVP
Northing: -
Easting: -
Elevation: -

SUBSURFACE PROFILE			SAMPLE		Well Data
Elevation/ Depth	Symbol	Description	Sample Depth (m)	Sample Type	
0.0		Ground Surface			
0.0	~	***TOPSOIL (TS) (0.0-0.15 m)*** Black, organic, frozen.			
	░	***SAND (SP) (0.15-2.8 m)*** Light brown, damp, medium dense, fine grained low dilatency.	0.5-0.8	∫	
	░		0.8-1.3	‖	
	░	below 1.3 m - trace of white particules.	1.4-1.7	∫	
	░	@ 2.3 m - moist (below 2.3 m).	2.3-2.8	‖	
-2.8	░	@ 2.6 m - wet, free water.			
2.8	▨	***SILTY CLAY (CL/CI) (2.8-4.3 m)*** Medium brown, damp, firm, medium to high plasticity.	2.9-3.2	∫	
-4.3	▨	@ 3.8 m - moist (below 3.8 m).	3.8-4.3	‖	
4.3		4.3 m End of Borehole Dry upon completion			



WorleyParsons Komex
resources & energy

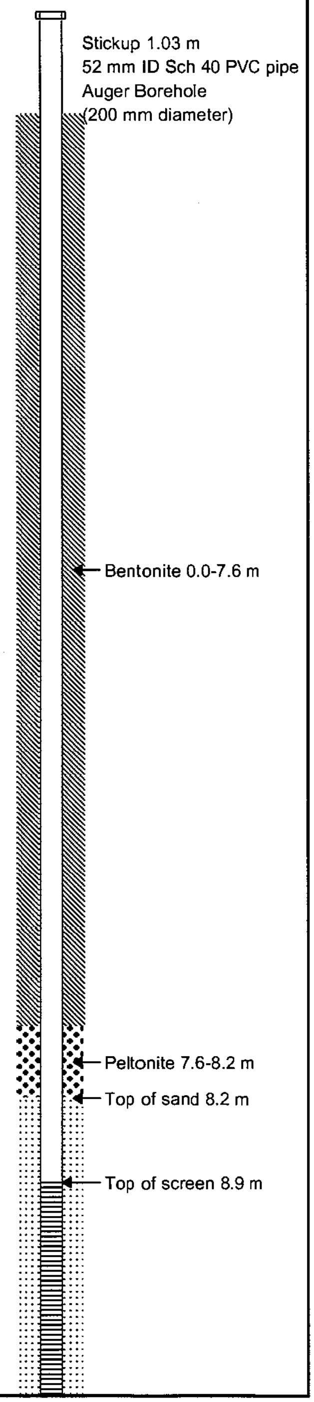
Borehole #: BH06-10

Project #: WP0011000

Project Name: Preliminary Geotechnical Investigation-Proposed Upgrader
Client: WorleyParsons (Houston)
Location: Ft. Saskatchewan, AB (27-55-21 W4M,26-55-21 W4M,35-55-21 W4M,2-56-21 W4M)
Drilled by: Mobile Augers
Drill Date: 23 Nov 06
Compiled by: LEVP
Northing: -
Easting: -
Elevation: -

SUBSURFACE PROFILE			SAMPLE				
Elevation/ Depth	Symbol	Description	Sample Depth (m)	Sample Type	DCPT △ 0 50 100 / SPT ▲ 0 50 100	Undrained Shear Strength kg/cm² 0 1.25 3.75 5	Moisture Content % 0 50 100
0.0		Ground Surface					
0.0 -0.9		***TOPSOIL (TS) (0.0-0.9 m)*** Black, organic.					
0.9		***SILTY CLAY (CL) (0.9-4.2 m)*** Medium brown, damp,firm to stiff, medium to high plasticity, trace sand, precipitates, oxidized particules. below 1.4 m - medium brown, damp, stiff, no sand, medium to high plasticity.	0.8-1.3		7	1.25	
			1.4-1.7				
			2.3-2.8		12	1.25	
			2.8-3.1				
-4.2			3.8-4.3				
4.2		***SILTY CLAY (CL/CI) (TILL) (4.2-11.7 m)*** Medium brown, damp, very stiff, low to medium plasticity, some sand, trace gravel (<30 mm diameter subangular) trace coal, oxidized particules.	4.4-4.7				
		@ 5.1 m - moist, medium to dark brown (below 5.1 m).	5.3-5.8		28	2.25	
			5.8-6.1				
		@ 6.9 m - grey (below 6.9 m), medium plasticity.	6.9-7.4		26	2.00	
			7.4-7.7				
		@ 8.4 m - shelby tube, 48 cm recovery.	8.4-8.9				
			8.9-9.3		27	2.13	
			9.3-9.6				
			9.9-10.4		29	2.00	
		between 10.5 - 11.3 m - increasing sand	10.4-10.7				

Well Data



WPK-Geotech-pz-type3-Shear

WorleyParsons Komex
resources & energy

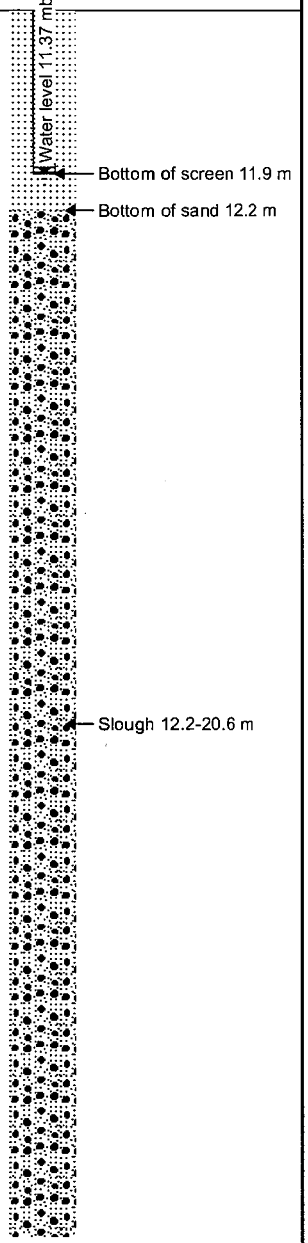
Borehole #: BH06-10

Project #: WP0011000

Project Name: Preliminary Geotechnical Investigation-Proposed Upgrader
Client: WorleyParsons (Houston)
Location: Ft. Saskatchewan, AB (27-55-21 W4M,26-55-21 W4M,35-55-21 W4M,2-56-21 W4M)
Drilled by: Mobile Augers
Drill Date: 23 Nov 06
Compiled by: LEVP
Northing: -
Easting: -
Elevation: -

Elevation/ Depth	Symbol	SUBSURFACE PROFILE: Description	SAMPLE: Sample Depth (m)	SAMPLE: Sample Type	DCPT △ 0 50 100 / SPT ▲ 0 50 100	Undrained Shear Strength kg/cm² 0 1.25 3.75 5	Moisture Content % 0 50 100
			10.4-10.7				
		@ 11.3 m - moist (below 11.3 m).	11.4-11.9		27	2.13	
-11.7 11.7		***GRAVEL-SAND-SILT (GM) (11.7-13.3 m)*** Very dense, subrounded, trace clay, saturated.	12.0-12.3				
			13.0-13.5		66		
-13.3 13.3		***SAND AND GRAVEL (GW) (13.3-15.0 m)*** Brown to grey, saturated, dense, well graded, some silt, some gravel. (<30 mm diameter). Below 14.5 m, (SW) increasing sand content to approximately 65%.	14.5-15.0		23		
-15.0 15.0		***SILTY CLAY (CL) (15.0-19.0 m)*** Grey, moist, very stiff, low plasticity, trace of very fine sand. @ 15.0 m - when driller pulled out split spoon, he noticed waater level approimately 4.0 m below ground surface. @ 16.0 m - slough up to 9.9 m in hole * switched to hollow stem @ 16.0 m.	15.3-15.8				
			16.0-16.5		16	1.00	
		@ 17.5 m - increasing sand content.	17.5-18.0		16	1.00	
-19.0 19.0		***SAND (SP) (19.0-21.1 m)*** Grey, wet to saturated, very dense, high dilatency, fine to medium grained.	19.1-19.6		54		
		@ 19.8 m - some gravel <30 mm diameter, subangular to subrounded.	20.6-21.1		37		
-21.1 21.1		21.1 m End of Borehole Wet upon completion.					

Well Data



WPK-Geotech-pz-type3-Shear

WorleyParsons Komex
resources & energy

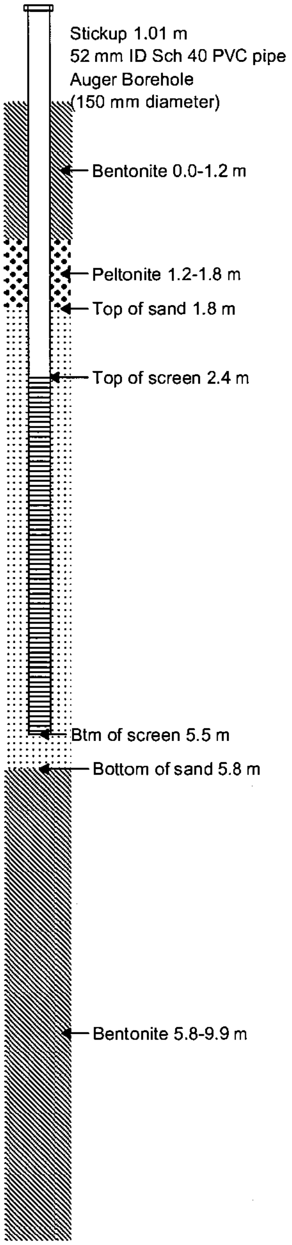
Borehole #: BH06-11

Project #: WP0011000

Project Name: Preliminary Geotechnical Investigation-Proposed Upgrader
Client: WorleyParsons (Houston)
Location: Ft. Saskatchewan, AB (27-55-21 W4M,26-55-21 W4M,35-55-21 W4M, 2-56-21 W4M)
Drilled by: Mobile Augers
Drill Date: 24 Nov 06
Compiled by: LEVP
Northing: -
Easting: -
Elevation: -

SUBSURFACE PROFILE			SAMPLE				
Elevation/ Depth	Symbol	Description	Sample Depth (m)	Sample Type	DCPT 0 50 100 SPT 0 50 100	Undrained Shear Strength kg/cm² 0 1.25 3.75 5	Moisture Content % 0 50 100
0.0		Ground Surface					
0.0 -0.7	≀≀≀	***TOPSOIL (TS) (0.0-0.7 m)*** Black, organic.					
0.7 -1.0	▨	***SILTY CLAY (CL) (B Horizon) (0.7-1.0 m)*** Light brown, dry to damp, firm, some sand, low plasticity, trace of rootlets, oxidized particules, precipitates.	0.8-1.3	‖	6 ▲	0.50 ●	
1.0 -2.6	▨	***SILTY CLAY (CL/CI) (1.0-2.6 m)*** Medium brown, grey mottling, damp, stiff, medium plasticity.	1.4-1.7	∫			
	▨		2.3-2.8	‖	9 ▲	0.75 ●	
2.6	▨	***SILTY CLAY (CL/CI) (TILL) (2.6-10.4 m)*** Medium brown, damp, stiff, some sand, low to medium plasticity, trace gravel (<20 mm diameter), trace coal, oxidized particules.	2.8-3.1	∫			
	▨		3.8-4.3	‖	14 ▲	1.25 ●	
	▨	@ 4.3 m - sand lens approximately 20 mm, free water.	4.4-4.7	∫			
	▨		5.3-5.8	‖	15 ▲	1.75 ●	
	▨	below 5.6 m - moist. below 5.9 m - dark brown to grey, very stiff to hard.	5.9-6.2	∫			
	▨		6.9-7.4	‖	30 ▲	2.00 ●	
	▨	between 7.5-7.8 m - increased plasticity medium to high, no gravel, no sand.	7.5-7.8	∫			
	▨		8.4-8.9	‖	23 ▲	2.13 ●	
	▨		9.1-9.4	∫			
-10.4	▨		9.9-10.4	‖	15 ▲	1.75 ●	
10.4		10.4 m End of Borehole water level dry on 24 Nov 06.					

Well Data



WPK-Geotech-pz-type3-Shear

WorleyParsons Komex
resources & energy

Borehole #: BH06-12

Project #: WP0011000

Project Name: Preliminary Geotechnical Investigation-Proposed Upgrader
Client: WorleyParsons (Houston)
Location: Ft. Saskatchewan, AB (27-55-21 W4M,26-55-21 W4M,35-55-21 W4M,2-56-21 W4M)
Drilled by: Mobile Augers
Drill Date: 24 Nov 06
Compiled by: LEVP
Northing: -
Easting: -
Elevation: -

SUBSURFACE PROFILE			SAMPLE					
Elevation/ Depth	Symbol	Description	Sample Depth (m)	Sample Type	DCPT △ 0 50 100 / SPT ▲ 0 50 100	Undrained Shear Strength kg/cm² 0 1.25 3.75 5	Moisture Content % 0 50 100	Well Data
0.0		Ground Surface						
0.0 -0.5		***TOPSOIL (TS) (0.0-0.5 m)*** .Black, organic, frozen.						
0.5 -0.8		***SILTY SAND (SM) (B Horizon) (0.5-0.8 m)*** Brown, damp, stiff, no plastic, some sand.	0.5-0.8					
0.8 -1.3		***SILT (ML) (0.8-1.3 m)*** Brown, damp, stiff, trace clay, low plasticity.	0.8-1.3		9 ▲ 17 △	1.50 ●		
1.3		***SAND (SW) (1.3-4.3 m)*** Medium brown, damp, medium dense, trace silt, trace clay, fine to medium grained.	1.4-1.7		9 △			
			2.3-2.8		16 ▲			
		below 2.9 m - light brown, no silt, no clay.	2.9-3.1		13 △			
-4.3		@ 3.8 m - dense.	3.8-4.3		11 △ 30 ▲			
4.3		4.3 m End of Borehole Dry upon completion						

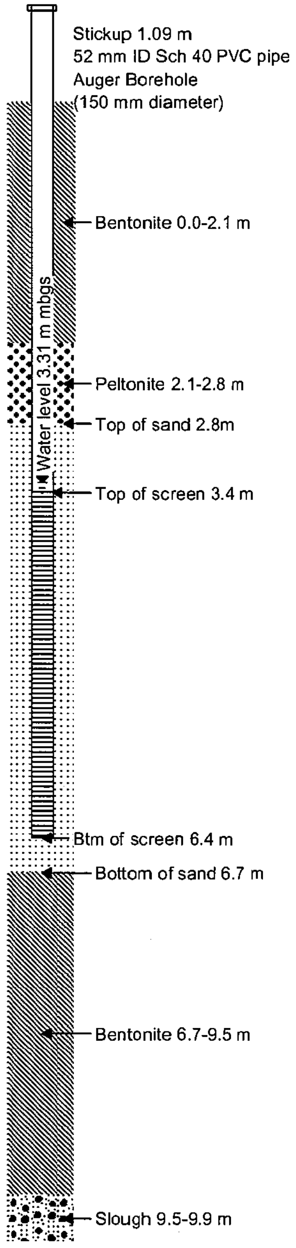
WorleyParsons Komex
resources & energy

Borehole #: BH06-13

Project #: WP0011000

Project Name: Preliminary Geotechnical Investigation-Proposed Upgrader
Client: WorleyParsons (Houston)
Location: Ft. Saskatchewan,AB (27-55-21 W4M,26-55-21 W4M,35-55-21 W4M,2-56-21 W4M)
Drilled by: Mobile Augers
Drill Date: 24 Nov 06
Compiled by: LEVP
Northing: -
Easting: -
Elevation: -

Elevation/ Depth	SUBSURFACE PROFILE Description	SAMPLE Sample Depth (m)	SPT (0 50 100)	Undrained Shear Strength kg/cm² (0 1.25 3.75 5)
0.0	Ground Surface			
0.0 -0.8	***TOPSOIL (TS) (0.0-0.8 m)*** Black, organic.			
0.8	***SILTY CLAY (CL) (B Horizon) (0.8-1.0 m)*** Light brown, damp, firm, low plasticity, some sand, trace rootlets, oxidized particules, precipitates.	0.8-1.3	5	2.00
-1.8	***SAND (SW) (1.0-1.8 m)*** Light brown, damp, loose, medium to fine grained.	1.4-1.7		
1.8	***SILTY CLAY (CI) (1.8-4.1 m)*** Medium brown, grey mottling,damp, stiff, medium plasticity, trace sand, trace of oxidized particules.	2.3-2.8	13	1.50
		2.8-3.1		
-4.1		3.8-4.3	14	2.00
4.1	***SILTY CLAY (CL/CI) (TILL) (4.1-10.4 m)*** Dark brown to grey, moist, stiff to very stiff, medium plasticity, some sand, trace gravel, subangular (<30 mm diameter), oxidized particules.	4.4-4.7		
	@ 4.8 m - thin sand lens approximately 10 mm, free water.	5.3-5.8	18	2.13
		5.9-6.2		
	below 7.2 m - high plasticity, wet, firm to stiff.	6.9-7.4	9	0.75
		7.5-7.8		
		8.4-8.9		
		8.9-9.3	7	0.75
-10.4	below 9.9 m - increasing stiffness, very stiff.	9.9-10.4	19	1.00
10.4	10.4 m End of Borehole			



WorleyParsons Komex
resources & energy

Borehole #: BH06-14

Project #: WP0011000

Project Name: Preliminary Geotechnical Investigation-Proposed Upgrader
Client: WorleyParsons (Houston)
Location: Ft. Saskatchewan,AB (27-55-21 W4M,26-55-21 W4M,35-55-21 W4M,2-56-21 W4M)
Drilled by: Mobile Augers
Drill Date: 25 Nov 06
Compiled by: LEVP
Northing: -
Easting: -
Elevation: -

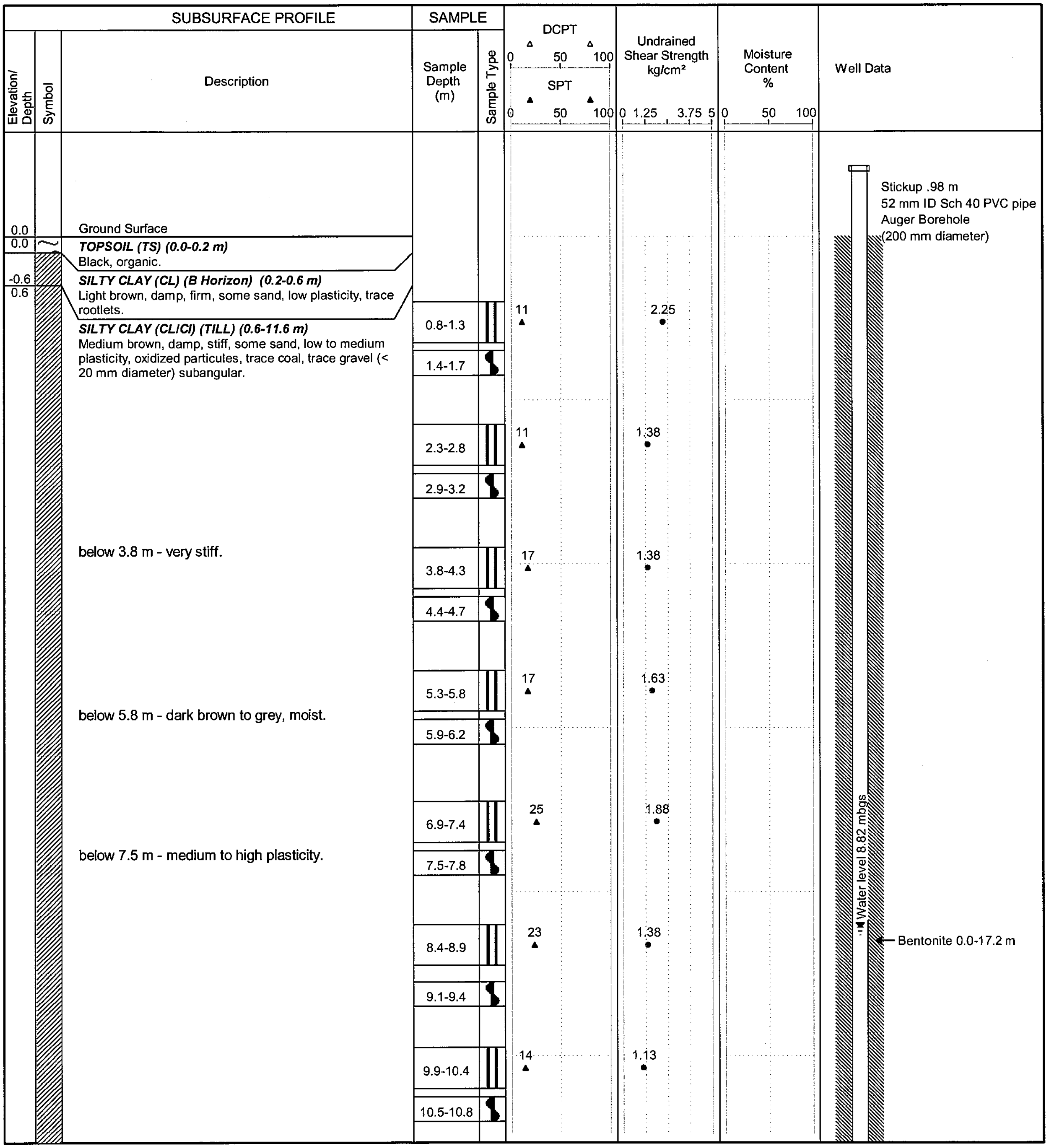
SUBSURFACE PROFILE			SAMPLE					
Elevation/ Depth	Symbol	Description	Sample Depth (m)	Sample Type	DCPT △ 0 50 100 SPT ▲ 0 50 100	Undrained Shear Strength kg/cm² 0 1.25 3.75 5	Moisture Content % 0 50 100	Well Data
0.0		Ground Surface						
0.0 -0.8	∼	***TOPSOIL (TS) (0.0-0.8 m)*** Black, organic.						
0.8 -2.0	▨	***SILTY CLAY (CL/CI) (0.8-2.0 m)*** Medium brown, grey mottling, damp, firm, some sand, low to medium plasticity.	0.8-1.3 1.4-1.7	‖ ∫	7 ▲	1.50 ●		
2.0 -4.3	▨	***SILTY CLAY (CL/CI) (TILL) (2.0-4.3 m)*** Medium brown, damp, stiff, some sand, low to medium plasticity, trace gravel (<20 mm diameter) subangular, trace of oxidized particules.	2.3-2.8 2.8-3.1 3.8-4.3	‖ ∫ ‖	10 ▲ 9 ▲	1.25 ●		
4.3		4.3 m End of Borehole Dry upon completion.						

WorleyParsons Komex
resources & energy

Borehole #: BH06-15

Project #: WP0011000

Project Name: Preliminary Geotechnical Investigation-Proposed Upgrader
Client: WorleyParsons (Houston)
Location: Ft. Saskatchewan,AB (27-55-21 W4M,26-55-21 W4M,35-55-21 W4M,2-56-21 W4M)
Drilled by: Mobile Augers
Drill Date: 25 Nov 06
Compiled by: LEVP
Northing: -
Easting: -
Elevation: -



Elevation/ Depth	Description
0.0	Ground Surface
0.0	***TOPSOIL (TS) (0.0-0.2 m)*** Black, organic.
-0.6	***SILTY CLAY (CL) (B Horizon) (0.2-0.6 m)*** Light brown, damp, firm, some sand, low plasticity, trace rootlets.
0.6	***SILTY CLAY (CL/CI) (TILL) (0.6-11.6 m)*** Medium brown, damp, stiff, some sand, low to medium plasticity, oxidized particules, trace coal, trace gravel (< 20 mm diameter) subangular.
	below 3.8 m - very stiff.
	below 5.8 m - dark brown to grey, moist.
	below 7.5 m - medium to high plasticity.

Sample Depth (m)	SPT	Undrained Shear Strength kg/cm²
0.8-1.3	11	2.25
1.4-1.7		
2.3-2.8	11	1.38
2.9-3.2		
3.8-4.3	17	1.38
4.4-4.7		
5.3-5.8	17	1.63
5.9-6.2		
6.9-7.4	25	1.88
7.5-7.8		
8.4-8.9	23	1.38
9.1-9.4		
9.9-10.4	14	1.13
10.5-10.8		

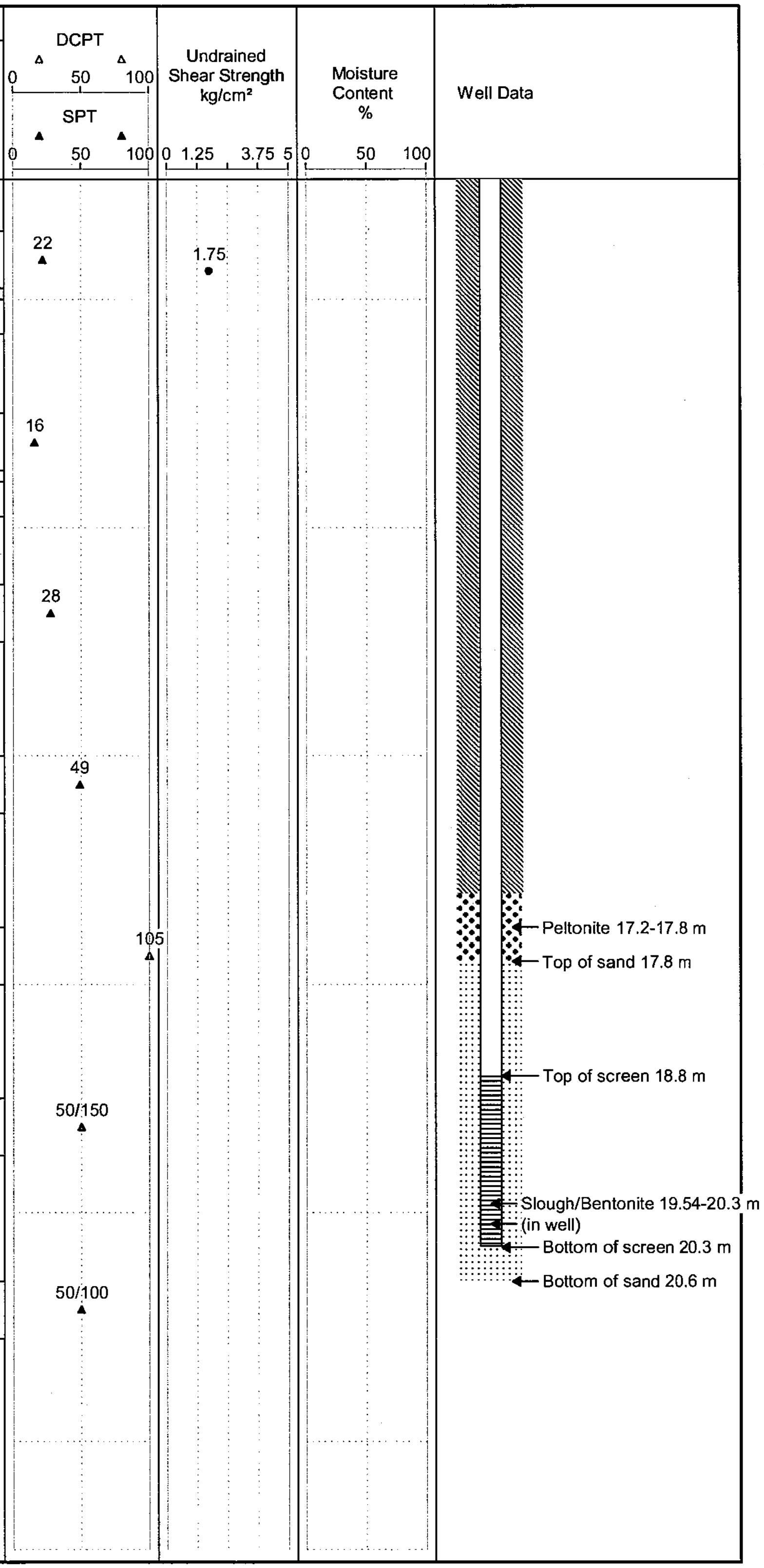
WorleyParsons Komex
resources & energy

Borehole #: BH06-15

Project #: WP0011000

Project Name: Preliminary Geotechnical Investigation-Proposed Upgrader
Client: WorleyParsons (Houston)
Location: Ft. Saskatchewan,AB (27-55-21 W4M,26-55-21 W4M,35-55-21 W4M,2-56-21 W4M)
Drilled by: Mobile Augers
Drill Date: 25 Nov 06
Compiled by: LEVP
Northing: -
Easting: -
Elevation: -

SUBSURFACE PROFILE		SAMPLE
Elevation/ Depth	Description	Sample Depth (m)
-11.6	between 11.1-11.6 m - wet clayey sand, some silt, fine-grained, dark brown.	
11.6 -12.8	***SILTY CLAY (CI/CH) (11.6-12.8*** Grey, moist to wet, very stiff, medium to high plasticity.	11.4-11.9 12.0-12.3
12.8 -13.5	***SILTY SAND (SM) (12.8-13.5 m)*** Dark brown to grey, saturated, medium dense, medium to high dilatency, fine grained.	13.0-13.5
13.5 -15.9	***SILTY CLAY (CI/CH) (TILL) (13.5-15.9 m)*** Dark brown to grey, moist to wet, very stiff, some sand, medium to high plasticity, trace gravel (<20 mm diameter). @ 14.5 m - switched to hollow stem. @ 15.9 m - driller felt gravel.	13.6-13.9 14.5-15.0
15.9 -17.0	***SAND (SW) (15.9-17.0 m)*** Dark brown to grey, saturated, very dense, medium to fine grained, some gravel (<20 mm diameter) subangular, medium dilatency.	16.0-16.5
17.0 -21.1	***SAND (SP) (17.0-21.1 m)*** Grey, moist to wet, very dense, fine-grained. @ 19.0 m - no recovery in split spoon, very dense material, spoon was damaged.	17.5-18.0 19.0-19.5 20.6-21.1
21.1	21.1 m End of Borehole After well completion, service truck ran into well casing, damaged casing and broke 2" pipe approximately 4 ft bgs, well was partly filled with slough and bentonite, well was repaired on 26 Nov 06. Water level shown was measured after well repair. Water level measured on 25 Nov, before well was damaged, was 8.44 mbgs.	



WPK-Geotech-pz-type3-Shear

WorleyParsons Komex
resources & energy

Borehole #: BH06-16

Project #: WP0011000

Project Name: Preliminary Geotechnical Investigation-Proposed Upgrader
Client: WorleyParsons (Houston)
Location: Ft. Saskatchewan,AB (27-55-21 W4M,26-55-21 W4M,35-55-21 W4M,2-56-21 W4M)
Drilled by: Mobile Augers
Drill Date: 26 Nov 06
Compiled by: LEVP
Northing: -
Easting: -
Elevation: -

SUBSURFACE PROFILE			SAMPLE					
Elevation/ Depth	Symbol	Description	Sample Depth (m)	Sample Type	DCPT △ 0 50 100 SPT ▲ 0 50 100	Undrained Shear Strength kg/cm² 0 1.25 3.75 5	Moisture Content % 0 50 100	Well Data
0.0		Ground Surface						
0.0 -0.7	≀	***TOPSOIL (TS) (0.0-0.7 m)*** Black, organic.						
0.7 -2.3	▨	***SILTY CLAY (CL/CI) (0.7-2.3 m)*** Medium brown, damp, stiff, some sand, low to medium plasticity, precipitates, oxidized particules, trace coal.	0.8-1.3	‖	10 ▲	1.75 ●		
			1.4-1.7	⌇				
2.3 -4.3	▨	***SILTY CLAY (CL/CI) (TILL) (2.3-4.3 m)*** Medium brown, damp, stiff, low to medium plasticity, below 2.8 m - trace gravel (<20 mm diameter) subangular.	2.3-2.8	‖	11 ▲	0.88 ●		
			2.8-3.1	⌇				
			3.8-4.3	‖	9 ▲	0.75 ●		
4.3		4.3 m End of Borehole Dry upon completion.						

WPK-Geotech-pz-type3-Shear

WorleyParsons Komex
resources & energy

Borehole #: BH06-17

Project #: WP0011000

Project Name: Preliminary Geotechnical Investigation-Proposed Upgrader
Client: WorleyParsons (Houston)
Location: Ft. Saskatchewan,AB (27-55-21 W4M,26-55-21 W4M,35-55-21 W4M,2-56-21 W4M)
Drilled by: Mobile Augers
Drill Date: 26 Nov 06
Compiled by: LEVP
Northing: -
Easting: -
Elevation: -

SUBSURFACE PROFILE			SAMPLE		DCPT △ 0 50 100 / SPT ▲ 0 50 100	Undrained Shear Strength kg/cm² 0 1.25 3.75 5	Moisture Content % 0 50 100	Well Data
Elevation/ Depth	Symbol	Description	Sample Depth (m)	Sample Type				
0.0		Ground Surface						
0.0 -0.3	~	***TOPSOIL (TS) (0.0-0.3 m)*** Black, organic, frozen.						
0.3 -0.7	▨	***SILTY CLAY (CLICI) (B Horizon) (0.3-0.7 m)*** Dark brown, damp, firm, some sand, low to medium plasticity, rootlets, precipitates, oxidized particules.						
0.7	▨	***SILTY CLAY (CI) (0.7-1.8 m)*** Medium brown, grey mottling, damp, firm, medium plasticity.	0.8-1.3	‖	7 ▲	0.75 ●		
	▨		1.4-1.7	≀				
-1.8	▨							
1.8	▨	***SILTY CLAY (CLICI) (TILL) (1.8-4.3 m)*** Medium brown, moist, stiff, low to medium plasticity, oxidized particules, trace gravel (<20 mm diameter).						
	▨		2.3-2.8	‖	12 ▲	1.13 ●		
	▨		2.8-3.1	≀				
	▨		3.8-4.3	‖	12 ▲			
-4.3	▨							
4.3		4.3 m End of Borehole * Water in the hole when auger @ 0.8 to 2.3 m was removed. Wet upon completion.						

WorleyParsons Komex
resources & energy

Borehole #: BH06-18

Project #: WP0011000

Project Name: Preliminary Geotechnical Investigation-Proposed Upgrader
Client: WorleyParsons (Houston)
Location: Ft. Saskatchewan,AB (27-55-21 W4M,26-55-21 W4M,35-55-21 W4M,2-56-21 W4M)
Drilled by: Mobile Augers
Drill Date: 26 Nov 06
Compiled by: LEVP
Northing: -
Easting: -
Elevation: -

SUBSURFACE PROFILE			SAMPLE					
Elevation/ Depth	Symbol	Description	Sample Depth (m)	Sample Type	DCPT △ 0 50 100 SPT ▲ 0 50 100	Undrained Shear Strength kg/cm² 0 1.25 3.75 5	Moisture Content % 0 50 100	Well Data
0.0		Ground Surface						
0.0 -0.6	∼	***TOPSOIL (TS) (0.0-0.6 m)*** Black, organic, frozen.						
0.6 -0.9	▨	***SILTY CLAY (CL/CI) (B Horizon) (0.6-0.9 m)*** Medium brown, damp, stiff, low to medium plasticity, some sand, rootlets, precipitates.	0.8-1.3	‖	14 ▲	1.88 ●		
0.9 -4.3	▨	***SILTY CLAY (CL/CI) (TILL) (0.9-4.3 m)*** Medium brown, damp, very stiff, some sand, low to medium plasticity, precipitates, oxidized particules, trace coal, trace gravel (<20 mm diameter).	1.4-1.7	≀				
			2.3-2.8	‖	17 ▲	2.25 ●		
			2.8-3.1	≀				
			3.8-4.3	‖	18 ▲			
4.3		4.3 m End of Borehole Dry upon completion.						

WPK-Geotech-pz-type3-Shear

WorleyParsons Komex
resources & energy

Borehole #: Bh06-19

Project #: WP0011000

Project Name: Preliminary Geotechnical Investigation-Proposed Upgrader
Client: WorleyParsons (Houston)
Location: Ft. Saskatchewan,AB (27-55-21 W4M,26-55-21 W4M,35-55-21 W4M,2-56-21 W4M)
Drilled by: Mobile Augers
Drill Date: 26 Nov 06
Compiled by: LEVP
Northing: -
Easting: -
Elevation: -

SUBSURFACE PROFILE			SAMPLE					
Elevation/ Depth	Symbol	Description	Sample Depth (m)	Sample Type	DCPT △ 0 50 100 / SPT ▲ 0 50 100	Undrained Shear Strength kg/cm² 0 1.25 3.75 5	Moisture Content % 0 50 100	Well Data
0.0		Ground Surface						
0.0	~	***TOPSOIL (TS) (0.0-0.15 m)*** Black, organic.						
		SILTY CLAY (CL/CI) (B Horizon) (0.15-0.3 m) Medium brown, damp, firm, some sand, low to medium plasticity, rootlets, precipitates.	0.5-0.8					
		SILTY CLAY (CI) (0.3-4.3 m) Medium brown, grey mottling,damp, stiff, medium plasticity, between 1.1-1.4 m - increasing sand approximately 60%.	0.8-1.3		10 ▲	1.50 ●		
			1.4-1.7					
			2.3-2.8		11 ▲	1.13 ●		
			2.8-3.1					
-4.3			3.8-4.3		12 ▲	1.25 ●		
4.3		4.3 m End of Borehole Dry upon completion.						

WorleyParsons Komex
resources & energy

Borehole #: BH06-20

Project #: WP0011000

Project Name: Preliminary Geotechnical Investigation-Proposed Upgrader
Client: WorleyParsons (Houston)
Location: Ft. Saskatchewan,AB (27-55-21 W4M,26-55-21 W4M,35-55-21 W4M,2-56-21 W4M)
Drilled by: Mobile Augers
Drill Date: 26 Nov 06
Compiled by: LEVP

Northing: -
Easting: -
Elevation: -

SUBSURFACE PROFILE			SAMPLE					
Elevation/ Depth	Symbol	Description	Sample Depth (m)	Sample Type	DCPT ▵ 0 50 100 / SPT ▲ 0 50 100	Undrained Shear Strength kg/cm² 0 1.25 3.75 5	Moisture Content % 0 50 100	Well Data
0.0		Ground Surface						
0.0 -0.5		***TOPSOIL (TS) (0.0-0.5 m)*** Black, organic.						
0.5 -0.8		***SILT (M) (B Horizon) (0.5-0.8 m)*** Medium brown, dry, trace clay, no plasticity, rootlets.						
0.8 -2.8		***SILTY CLAY (CI) (0.8-2.8 m)*** Medium brown, grey mottling,damp, stiff, medium plasticity.	0.8-1.3		12 ▲	1.50 ●		
			1.4-1.7					
			2.3-2.8		8 ▲	0.75 ●		
2.8 -4.3		***SILTY CLAY (TILL) (CL/CI) (2.8-4.3 m)*** Dark brown, damp, stiff, low to medium plasticity, some sand, oxidized particules, trace gravel (<20 mm diameter). below 3.8 m- increasing stiffness, hard.	2.8-3.1					
			3.8-4.3		32 ▲	2.25 ●		
4.3		4.3 m End of Borehole Dry upon completion.						

APPENDIX 5C: QUALITY CONTROL SAMPLE RESULTS

Duplicate samples were submitted to the laboratory to monitor the quality of sampling and analysis. The results of the quality control program are presented in Table 7. Two duplicate sample sets, from wells 07-6 and 07-8, were processed from the May 11, 2007 sampling event. Duplicate groundwater samples were analyzed for field-measured parameters (Table 5C-1), routine and indicator parameters (Table 5C-2), dissolved hydrocarbons (Table 5C-3) and dissolved metals (Table 5C-4).

Reproducibility was evaluated based on the relative percent difference (RPD) calculated for each parameter. The RPD was calculated as follows (APHA, 1998):

$$RPD = \frac{Absolute\ difference\ between\ the\ two\ duplicate\ results}{Mean\ of\ \ the\ two\ duplicate\ results} \times 100$$

Based on Matrix Solutions' experience, RPD values greater than 30 usually indicate poor reproducibility. However, the reproducibility of duplicate analyses at concentrations near the MDL can be poor (Keith, 1992), resulting in RPD values greater than 30. Therefore, RPD values greater than 30 are acceptable if the differences in concentrations of the duplicate analyses are less than approximately 10 times the MDL.

The RPD values were less than 30 for field-measured parameters, routine and indicator parameters, and dissolved hydrocarbons. Therefore, the QC sample results are deemed acceptable for these parameters. In terms of dissolved metals, the RPD values for the sample collected from monitoring well 07-6 exceeded 30 for the laboratory analyses of antimony (53%), cobalt (43%), copper (95%) and zinc (76%). However, the measured concentrations of these metals were near the MDL and the differences in concentrations were less than 10 times the MDL for each result; thus, the reproducibility of these samples is considered acceptable.

REFERENCE

American Public Health Association (APHA), 1998. Standard Methods for the Examination of Water and Wastewater. 20th Edition, American Public Health Association, Washington, D.C.

Keith, L.H., 1992. Environmental Sampling and Analysis, a Practical Guide. Lewis Publishers.

TABLE 5C-1. QUALITY CONTROL SAMPLE RESULTS FIELD MEASURED PARAMETERS

North American Oil Sands Corporation

North American Upgrader Site

Monitoring Well	Sample Date	Temp °C	Field pH	Field EC uS/cm	Field DO mg/L
07-6	May 11/07	6.9	7.4	730	3.8
07-6 dup	May 11/07	6.2	7.4	730	3.7
Method Detection Limit		0.1	0.1	10	0.1
Absolute Difference*		0.7	0	0	0.1
Absolute Relative Percent Difference (RPD)		11	0	0	3
07-8	May 11/07	7.3	6.8	3820	3.9
07-8 dup	May 11/07	6.9	6.8	3820	4.4
Method Detection Limit		0.1	0.1	10	0.1
Absolute Difference*		0.4	0	0	0.5
Absolute Relative Percent Difference (RPD)		6	0	0	12

TABLE 5C-2. QUALITY CONTROL SAMPLE RESULTS ROUTINE AND INDICATOR PARAMETERS

North American Oil Sands Corporation

North American Upgrader Site

Monitoring Well	Sample Date	Lab pH	Lab EC uS/cm	Ca mg/L	Mg mg/L	Na mg/L	K mg/L	Cl mg/L	HCO_3 mg/L	SO_4 mg/L	NO_2-N mg/L	NO_3-N mg/L	Hardness mg/L	TDS mg/L
07-6	May 11/07	7.92	749	89.2	27.4	56.7	6.5	2.5	437	77.4	0.007	0.037	340	475
07-6 dup	May 11/07	7.66	757	88.0	25.8	54.1	6.2	2.3	435	78	0.007	0.038	330	469
Method Detection Limit (MDL)		0.01	0.02	0.1	0.1	0.1	0.3	0.5	0.5	0.1	0.003	0.003	0.5	1
Absolute Difference*		0.26	8	1.2	1.6	2.6	0.3	0.2	2	0.6	0	0.001	10	6
Absolute Relative Percent Difference (RPD)		3	1	1	6	5	5	8	0	1	0	3	3	1
07-8	May 11/07	7.39	3670	621	263	188	14.6	3.6	733	2260	0.003	0.016	2600	3710
07-8 dup	May 11/07	7.26	3690	624	266	192	14.9	3.6	723	2270	<0.003	0.017	2700	3730
Method Detection Limit (MDL)		0.01	0.02	0.1	0.1	0.1	0.3	0.5	0.5	0.1	0.003	0.003	0.5	1
Absolute Difference*		0.13	20	3	3	4	0.3	0	10	10	0.00015	0.001	100	20
Absolute Relative Percent Difference (RPD)		2	1	0	1	2	2	0	1	0	5	6	4	1

TABLE 5C-3. QUALITY CONTROL SAMPLE RESULTS DISSOLVED HYDROCARBONS

North American Oil Sands Corporation

North American Upgrader Site

Monitoring Well	Sample Date	Benzene mg/L	Toluene mg/L	Ethylbenzene mg/L	Xylenes mg/L	F1†† C_6-C_{10} mg/L	F2 $C_{>10}$-C_{16} mg/L
07-6	May 11/07	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.12
07-6 dup	May 11/07	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.12
Method Detection Limit (MDL)		0.0004	0.0004	0.0004	0.0008	0.1	0.12
Absolute Difference*		---	---	---	---	---	---
Absolute Relative Percent Difference (RPD)		OK	OK	OK	OK	OK	OK
07-8	May 11/07	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.12
07-8 dup	May 11/07	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.12
Method Detection Limit (MDL)		0.0004	0.0004	0.0004	0.0008	0.1	0.12
Absolute Difference*		---	---	---	---	---	---
Absolute Relative Percent Difference (RPD)		OK	OK	OK	OK	OK	OK

Notes:

* - non-detectable concentrations are assessed at 95% of the detection limit

--- - difference cannot be calculated because both samples yielded non-detectable results

OK - indicates acceptable reproducibility at non-detectable levels

^ - although the RPD is greater than 30, the concentration difference between duplicate analyses is less than approximately 10 times the MDL and, therefore, the reproducibility of the analysis is deemed acceptable

Italics - indicates RPD values greater than 30 and suggests poor reproducibility

TABLE 5C-4. QUALITY CONTROL SAMPLE RESULTS
DISSOLVED METALS

North American Oil Sands Corporation

North American Upgrader Site

Monitoring Well	Sample Date	Al mg/L	Sb mg/L	As mg/L	Ba mg/L	Be mg/L	B mg/L	Cd mg/L	Cr mg/L	Co mg/L	Cu mg/L	Fe mg/L	Pb mg/L	Li mg/L
07-6	May 11/07	<0.04	0.0011	0.003	0.11	<0.001	0.11	<0.0002	<0.01	0.0009	0.0006	0.37	<0.0002	0.06
07-6 dup	May 11/07	<0.04	0.0019	0.003	0.09	<0.001	0.11	<0.0002	<0.01	0.0014	0.0016	0.33	<0.0002	0.06
Method Detection Limit (MDL)		0.04	0.0002	0.001	0.01	0.001	0.02	0.0002	0.01	0.0003	0.0002	0.06	0.0002	0.02
Absolute Difference*		---	0.0008	0.0001	0.02	---	0	---	---	0.0005	0.00103	0.04	---	0
Absolute Relative Percent Difference (RPD)		OK	***53^***	4	20	OK	0	OK	OK	***43^***	***95^***	11	OK	0
07-8	May 11/07	<0.04	<0.0002	0.001	0.06	<0.001	0.26	<0.0002	0.01	0.0188	0.0054	0.28	<0.0002	0.49
07-8 dup	May 11/07	<0.04	<0.0002	<0.001	0.06	<0.001	0.26	<0.0002	0.01	0.0191	0.0068	0.3	<0.0002	0.5
Method Detection Limit (MDL)		0.04	0.0002	0.001	0.01	0.001	0.02	0.0002	0.01	0.0003	0.0002	0.06	0.0002	0.02
Absolute Difference*		---	---	0.00011	0	---	0	---	0	0.0003	0.0014	0.02	---	0.01
Absolute Relative Percent Difference (RPD)		OK	OK	11	0	OK	0	OK	0	2	23	7	OK	2

Monitoring Well	Sample Date	Mn mg/L	Mo mg/L	Ni mg/L	Se mg/L	Si mg/L	Ag mg/L	Sr mg/L	Tl mg/L	Sn mg/L	Ti mg/L	U mg/L	V mg/L	Zn mg/L
07-6	May 11/07	0.22	0.0076	0.0103	<0.001	4.5	<0.0001	0.80	<0.0002	<0.001	0.002	0.0087	<0.001	0.013
07-6 dup	May 11/07	0.218	0.0078	0.0104	<0.001	4.2	<0.0001	0.81	<0.0002	0.001	0.002	0.0082	<0.001	0.029
Method Detection Limit (MDL)		0.004	0.0002	0.0005	0.001	0.1	0.0001	0.02	0.0002	0.001	0.001	0.0001	0.001	0.003
Absolute Difference*		0.002	0.0002	0.0001	---	0.3	---	0.01	---	0.00005	0.00008	0.0005	---	0.016
Absolute Relative Percent Difference (RPD)		1	3	1	OK	7	OK	1	OK	5	4	6	OK	***76^***
07-8	May 11/07	5.95	0.0011	0.108	0.006	8.7	<0.0001	4.35	<0.0002	<0.001	0.02	0.0457	0.031	0.018
07-8 dup	May 11/07	6.01	0.0012	0.107	0.007	8.8	<0.0001	4.45	<0.0002	<0.001	0.02	0.0465	0.03	0.023
Method Detection Limit (MDL)		0.004	0.0002	0.0005	0.001	0.1	0.0001	0.02	0.0002	0.001	0.001	0.0001	0.001	0.003
Absolute Difference*		0.06	1E-04	0.001	0.001	0.1	---	0.1	---	---	0	0.0008	0.001	0.005
Absolute Relative Percent Difference (RPD)		1	9	1	15	1	OK	2	OK	OK	0	2	3	24

Notes:

* - non-detectable concentrations are assessed at 95% of the detection limit

--- - difference cannot be calculated because both samples yielded non-detectable results

OK - indicates acceptable reproducibility at non-detectable levels

^ - although the RPD is greater than 30, the concentration difference between duplicate analyses is less than approximately 10 times the MDL and, therefore, the reproducibility of the analysis is deemed acceptable

Italics - indicates RPD values greater than 30 and suggests poor reproducibility

Table 5D-1. WATER WELLS WITHIN A 7.0km RADIUS
North American Oil Sands Corporation
North American Upgrader Project

Water Well Number (Figure 2)	Well ID*	Location	Well Owner	Distance from Site (km)	Direction from Site	Total Depth (m)	Top of Screen (m)	Bottom of Screen (m)	Bottom of Casing (m)	Depth to Water (m)	Bedrock Depth (m)	Date of Information (dd-mmm-yy)	Type of Work	Proposed Use for Well
1	83564	NE-35-055-21 W4	Charbonneau, Marcel	0.57	---	12.8	---	---	---	4.57	---	---	Domestic	Chemistry
2	83563	04-35-055-21 W4	Berg, R.	0.85	---	30.48	---	---	---		---	1-Jan-26	Domestic & Stock	Federal Well Survey
3	263334	03-02-056-21 W4	Halabey, Alex	1.04	---	118.87	---	---	78.03	21.64	---	9-Jul-65	Domestic	New Well
4	83574	12-36-055-21 W4	Prokopczak, J.	1.05	---	12.19	---	---	---	2.74	---	1-Jan-36	Stock	Federal Well Survey
5	83562	16-34-055-21 W4	Berg, Ron	1.19	---	53.34	---	---	47.24	12.19	---	1-May-82	Stock	New Well
6	263327	SW-02-056-21 W4	Halabey, A	1.29	---	10.66	---	---	---	4.57	---	---	Domestic	Chemistry
7	159197	NE-34-055-21 W4	Berg, Ron	1.29	---	54.86	46.63	52.73	42.37	11.27	---	29-Sep-91	Stock	New Well
8	83561	NE-34-055-21 W4	Berg, Alfred	1.29	---	30.48	28.35	29.87	28.35	9.44	---	5-Jun-68	Domestic	New Well
9	83573	NW-36-055-21 W4	Prokopczak, David	1.29	---	12.19	---	---	---	---	---	---	Domestic	Chemistry
10	83545	SE-34-055-21 W4	Northwestern Utilities	1.29	---	54.86	0.30	54.86	31.09	18.89	---	19-Oct-82	Industrial	New Well
11	83572	SW-36-055-21 W4	United Grain Growers Ltd	1.3	---	39.62	37.80	39.62	37.80	10.05	---	7-Apr-88	Domestic	New Well
12	83504	16-27-055-21 W4	Heinrichs, Ed	1.44	---	26.82	---	---	25.60	17.67	---	5-Jul-74	Stock	New Well
13	83010	13-25-055-21 W4	Hoffman	1.44	---	27.43	---	---	---	---	---	---	Domestic & Stock	Federal Well Survey
14	83497	09-26-055-21 W4	Fluker, R.	1.53	---	13.71	---	---	---	---	---	1-Jan-33	Domestic & Stock	Federal Well Survey
15	83546	SH-34-055-21 W4	Northwestern Utilities	1.68	---	36.57	---	---	---	---	---	---	Industrial	Chemistry
16	167584	NW-25-055-21 W4	Prokopczak, Wm	1.72	---	60.96	---	---	---	---	---	---	Domestic	Chemistry
17	263308	SW-01-056-21 W4	Taron, D.E.	1.73	---	14.02	---	---	---	---	---	---	Domestic	Chemistry
18	263315	SW-01-056-21 W4	Old, R/C	1.73	---	36.57	---	---	---	---	---	---	Domestic	Chemistry
19	263351	SE-03-056-21 W4	Prokopczak, J.	1.73	---	10.66	6.10	10.67	9.75	5.48	---	17-Sep-74	Stock	New Well
20	267241	SE-03-056-21 W4	Prokopczak, L.J.	1.73	---	10.66	4.57	10.67	10.67	6.09	---	10-Oct-74	Stock	New Well
21	83568	02-36-055-21 W4	Shell Oil	1.93	---	15.24	11.89	13.11	---	---	---	18-Nov-80	Industrial	New Well
22	83556	NW-34-055-21 W4	Fisher, George P.	2.07	---	39.62	34.44	35.97	31.70	---	---	1-Oct-70	Domestic	New Well
23	83554	NW-34-055-21 W4	Pickard, Wayne	2.07	---	18.28	---	---	---	5.48	---	---	Domestic	Chemistry
24	83555	NW-34-055-21 W4	Daust, Charlie	2.07	---	42.67	38.10	39.93	36.88	---	---	1-Sep-70	Domestic & Stock	New Well
25	83560	NW-34-055-21 W4	Daoust, C.	2.07	---	42.67	36.58	42.67	36.58	28.95	---	14-Aug-89	Domestic	New Well
26	83550	SW-34-055-21 W4	Radke, Ben	2.07	---	94.48	85.34	94.49	43.28	10.66	---	28-Sep-77	Stock	New Well
27	83548	SW-34-055-21 W4	Radke, James	2.07	---	15.24	---	---	---	4.57	---	---	Domestic	Chemistry
28	83551	SW-34-055-21 W4	Radke	2.07	---	---	---	---	---	---	---	---	Domestic	Chemistry
29	83571	SE-36-055-21 W4	Wiens, Lori	2.08	---	15.24	---	---	---	---	---	---	Domestic	Chemistry
30	83570	SE-36-055-21 W4	Navratil, John	2.08	---	18.28	---	---	---	---	---	---	Domestic	Chemistry
31	83552	05-34-055-21 W4	Radke, J./ R.	2.24	---	35.05	32.00	35.05	32.00	25.90	---	9-Feb-86	Domestic	New Well
32	83559	13-34-055-21 W4	Daoust, C.	2.31	---	42.67	36.58	42.67	36.58	7.62	---	14-Jul-87	Stock	New Well
33	83557	13-34-055-21 W4	Hall'S Auto	2.31	---	36.57	---	---	33.53	27.43	---	9-Sep-81	Stock	New Well
34	83558	13-34-055-21 W4	Daoust, Charles	2.31	---	40.53	---	---	39.93	---	---	19-Oct-78	Stock	New Well
35	83549	04-34-055-21 W4	Radke, Ben	2.31	---	12.19	---	---	12.19	---	---	26-Aug-75	Domestic	New Well
36	83547	04-34-055-21 W4	Radke, Ben	2.31	---	32	---	---	31.39	25.29	---	13-Apr-82	Stock	New Well
37	83553	04-34-055-21 W4	Radke, Ben	2.31	---	14.63	---	---	14.63	8.22	---	6-Nov-81	Stock	New Well
38	83569	01-36-055-21 W4	Shell Oil	2.32	---	30.48	13.11	18.90	13.11	8.83	---	6-Nov-80	Industrial	New Well
39	83566	01-36-055-21 W4	Shell Oil	2.32	---	24.38	20.42	21.95	---	3.35	---	16-Nov-80	Industrial	New Well
40	83565	01-36-055-21 W4	Shell Oil	2.32	---	24.38	17.98	22.56	18.90	3.35	---	15-Nov-80	Industrial	New Well
41	83567	01-36-055-21 W4	Shell Oil	2.32	---	45.72	40.23	41.45	---	33.83	---	17-Nov-80	Industrial	New Well
42	83498	SE-27-055-21 W4	Cholowski, Albert	2.36	---	56.38	40.23	51.21	40.23	18.89	---	30-Nov-62	Stock	New Well
43	90354	SE-27-055-21 W4	Cholowski, Albert	2.36	---	54.86	39.01	42.67	---	20.11	---	1-Aug-72	Domestic	New Well
44	83492	SW-25-055-21 W4	Gabert, Morley	2.36	---	68.58	---	---	---	18.28	---	---	Domestic	Chemistry
45	83493	SW-25-055-21 W4	Olson, W.	2.36	---	31.08	---	---	---	25.60	---	---	Domestic	Chemistry
46	83494	SW-25-055-21 W4	Olson, William M.	2.36	---	39.01	---	---	---	---	---	---	Domestic	Chemistry
47	83502	NW-27-055-21 W4	Millward, Donald	2.36	---	42.67	---	---	---	12.19	---	---	Domestic	Chemistry
48	83503	NW-27-055-21 W4	Millward, Donald	2.36	---	42.67	---	---	---	12.19	---	---	Domestic	Chemistry
49	157040	NW-01-056-21 W4	Cholowski, Tom	2.37	---	10.97	---	---	---	4.57	---	---	Domestic	Chemistry
50	90355	NE-25-055-21 W4	Bertz, Vern	2.37	---	51.81	43.89	45.11	43.89	9.75	---	13-Aug-76	Domestic	New Well

Table 5D-1. WATER WELLS WITHIN A 7.0km RADIUS

North American Oil Sands Corporation
North American Upgrader Project

Water Well Number (Figure 2)	Well ID*	Location	Well Owner	Distance from Site (km)	Direction from Site	Total Depth (m)	Top of Screen (m)	Bottom of Screen (m)	Bottom of Casing (m)	Depth to Water (m)	Bedrock Depth (m)	Date of Information (dd-mmm-yy)	Type of Work	Proposed Use for Well
51	297105	NE-25-055-21 W4	Bartz, Veron	2.37	---	54.86	43.28	49.38	49.38	10.36	---	29-May-01	Domestic & Stock	New Well
52	83496	NE-25-055-21 W4	Bartz, Vern	2.37	---	10.97	---	---	---	---	---	---	Domestic	Chemistry
53	206702	NE-03-056-21 W4	Veltman, Herb	2.37	---	44.19	40.54	42.06	40.54	29.26	---	26-Mar-93	Domestic & Stock	New Well
54	263380	NE-03-056-21 W4	Veltman, H	2.37	---	39.62	---	---	---	24.38	---	---	Domestic	Chemistry
55	263303	SE-01-056-21 W4	Guenette, D	2.37	---	12.19	---	---	---	9.14	---	---	Domestic	Chemistry
56	263375	SW-03-056-21 W4	Hannerman, R	2.37	---	6.4	---	---	---	3.96	---	1-Jan-73	Domestic	Chemistry
57	83495	16-25-055-21 W4	Newman, H.	2.45	---	18.89	---	---	---	7.62	---	1-Jan-30	Domestic & Stock	Federal Well Survey
58	83478	14-23-055-21 W4	Arndt, G.	2.64	---	13.41	---	---	---	---	---	1-Jan-26	Stock	Federal Well Survey
59	83264	05-31-055-20 W4	Sampert, W.	2.67	---	14.93	---	---	---	6.70	---	1-Jan-32	Domestic & Stock	Federal Well Survey
60	83483	13-24-055-21 W4	Kelly, E.	2.83	---	99.06	---	---	---	15.24	---	---	Domestic & Stock	Federal Well Survey
61	83482	13-24-055-21 W4	Fluker, Norman E.	2.83	---	51.81	---	---	49.68	39.62	---	12-Dec-75	Stock	New Well
62	91497	04-06-056-20 W4	Hydrogeological Consult Ltd	2.85	---	7.01	---	---	---	---	---	17-Jul-75	Unknown	Test Hole
63	91495	04-06-056-20 W4	Yaworski, Mike	2.85	---	17.06	---	---	17.07	4.26	---	16-Apr-86	Domestic & Stock	New Well
64	91494	04-06-056-20 W4	Sampert, T.	2.85	---	6.09	---	---	---	---	---	---	Domestic	Federal Well Survey
65	83500	SW-27-055-21 W4	Cholowski, Albert	2.86	---	---	---	---	---	---	---	---	Domestic	Chemistry
66	83501	SW-27-055-21 W4	Chipchase, G.	2.86	---	67.05	---	---	---	---	---	---	Domestic	Chemistry
67	83491	SE-25-055-21 W4	Victor, Robert	2.86	---	18.28	---	---	---	5.48	---	---	Domestic	Chemistry
68	83490	SE-25-055-21 W4	Quartly, C.	2.86	---	24.38	---	---	---	10.66	---	---	Domestic	Chemistry
69	83489	SE-25-055-21 W4	Bondt, Gerard	2.86	---	15.24	---	---	---	9.14	---	---	Domestic	Chemistry
70	153768	NW-23-055-21 W4	Arndt, R.E.	2.86	---	42.67	35.36	36.58	35.36	9.75	---	31-Aug-90	Domestic & Stock	New Well
71	83477	NW-23-055-21 W4	Arndt, Erdman	2.86	---	36.57	35.36	36.58	35.36	9.75	---	2-Jul-68	Domestic & Stock	New Well
72	83479	NE-23-055-21 W4	Wilson, Lloyd	2.86	---	67.05	29.26	59.74	---	16.00	---	21-Dec-87	Domestic	New Well
73	83499	05-27-055-21 W4	Underschultz, A.	2.88	---	30.48	---	---	---	---	---	1-Jan-24	Domestic & Stock	Federal Well Survey
74	261886	09-01-056-21 W4	Schultz, E	2.88	---	4.57	---	---	---	0.03	---	---	Domestic & Stock	Federal Well Survey
75	263699	SW-12-056-21 W4	Olson, R	3.08	---	31.08	---	---	28.96	11.58	---	---	Stock	New Well
76	263707	SW-12-056-21 W4	Gabert, M.	3.08	---	60.96	---	---	0.00	53.34	---	---	Domestic	Chemistry
77	263703	SW-12-056-21 W4	Olsen, R	3.08	---	13.71	---	---	11.89	2.74	---	3-Sep-77	Stock	New Well
78	83473	NE-22-055-21 W4	Chernichan, John	3.09	---	18.28	---	---	---	---	---	---	Domestic	Chemistry
79	299632	NW-24-055-21 W4	Fluker, Norm	3.1	---	21.03	15.24	21.03	---	16.15	---	31-May-01	Domestic	New Well
80	83484	NW-24-055-21 W4	Fluker, Norman	3.1	---	18.28	---	---	18.29	0.00	---	27-Oct-76	Domestic	New Well
81	83485	NW-24-055-21 W4	Fluker, Norman E.	3.1	---	68.58	---	---	---	54.86	---	---	Domestic	Chemistry
82	91496	SW-06-056-20 W4	Thorne, Keith	3.11	---	3.04	---	---	---	---	---	---	Domestic	Chemistry
83	208867	SW-06-056-20 W4	Yaworski, Micheal	3.11	---	16.45	4.57	13.72	---	4.26	---	12-Mar-93	Domestic & Stock	New Well
84	83265	14-31-055-20 W4	Fisher, J.	3.12	---	24.07	---	---	---	---	---	1-Jan-15	Domestic & Stock	Federal Well Survey
85	83480	EH-23-055-21 W4	Wilson, Lloyd	3.26	---	56.38	---	---	---	14.93	---	---	Domestic	Chemistry
86	263661	09-11-056-21 W4	Anuratil, J.	3.31	---	66.44	32.92	37.80	---	---	---	31-Aug-73	Unknown	Unknown
87	83507	01-28-055-21 W4	Alta Agriculture #670H	3.46	---	21.33	---	---	---	---	---	24-Jun-69	Unknown	Test Hole
88	263676	SE-12-056-21 W4	Esch, G	3.48	---	7.92	---	---	---	---	---	---	Domestic	Chemistry
89	263697	SE-12-056-21 W4	Mizera, T.	3.48	---	0	---	---	---	---	---	---	Domestic	Chemistry
90	263683	SE-12-056-21 W4	Esch, G	3.48	---	91.44	79.25	91.44	42.67	27.43	---	5-Nov-81	Domestic	New Well
91	263633	09-11-056-21 W4	Navratil, J	3.49	---	10.66	---	---	---	2.74	---	---	Domestic	Chemistry
92	83471	NW-22-055-21 W4	Larsen, Helen	3.49	---	54.86	---	---	---	---	---	---	Domestic	Chemistry
93	83470	NW-22-055-21 W4	Larsen, Svend	3.49	---	64	---	---	---	48.76	---	---	Domestic	Chemistry
94	83469	NW-22-055-21 W4	Larsen, S.A.	3.49	---	51.81	---	---	37.19	0.00	---	1-Apr-65	Domestic & Stock	New Well
95	83475	05-23-055-21 W4	Penelton, J.	3.49	---	54.86	---	---	---	---	---	1-Jan-26	Stock	Federal Well Survey
96	83488	NE-24-055-21 W4	Alta Transp#Campground	3.5	---	64	---	---	60.66	17.67	---	22-Apr-60	Domestic	New Well
97	169736	NE-24-055-21 W4	Mcintyre, Blaine	3.5	---	73.15	---	---	62.79	21.33	---	27-Sep-92	Domestic	New Well
98	83487	NE-24-055-21 W4	Bruderheim Campground	3.5	---	0	---	---	---	---	---	---	Domestic	Chemistry
99	83486	NE-24-055-21 W4	Alta Transp#Campsite	3.5	---	45.72	---	---	---	---	---	---	Domestic	Chemistry
100	83505	SE-28-055-21 W4	Royce, Sidney	3.5	---	38.7	---	---	---	32.30	---	---	Domestic	Chemistry

Table 5D-1. WATER WELLS WITHIN A 7.0km RADIUS

North American Oil Sands Corporation
North American Upgrader Project

Water Well Number (Figure 2)	Well ID*	Location	Well Owner	Distance from Site (km)	Direction from Site	Total Depth (m)	Top of Screen (m)	Bottom of Screen (m)	Bottom of Casing (m)	Depth to Water (m)	Bedrock Depth (m)	Date of Information (dd-mmm-yy)	Type of Work	Proposed Use for Well
101	83506	SE-28-055-21 W4	Royce, Sidney	3.5	---	24.38	---	---	---	---	---	---	Domestic	Chemistry
102	83263	SW-30-055-20 W4	Schneider, Orvis	3.5	---	7.62	---	---	---	---	---	---	Domestic	Chemistry
103	285788	05-24-055-21 W4	D&R Guenette Farms Ltd	3.65	---	62.48	54.86	59.44	54.86	21.33	---	9-May-96	Domestic & Stock	New Well
104	263640	NE-11-056-21 W4	Andruchow, E	3.66	---	43.28	41.15	42.37	41.15	28.95	---	17-Aug-84	Domestic	New Well
105	263595	NE-11-056-21 W4	Nauratil, J	3.66	---	64.61	---	---	---	33.52	---	---	Domestic	Chemistry
106	263651	NE-11-056-21 W4	Breit, E	3.66	---	17.98	---	---	---	8.22	---	20-Jun-86	Domestic	New Well
107	263645	NE-11-056-21 W4	O'Brien, N	3.66	---	36.57	---	---	---	---	---	---	Domestic	Chemistry
108	263607	NE-11-056-21 W4	Fairweather, B.	3.66	---	37.18	---	---	35.05	35.05	---	1-Aug-73	Stock	New Well
109	263599	NE-11-056-21 W4	Taylor, G J	3.66	---	36.57	---	---	35.05	31.08	---	---	Stock	New Well
110	83476	SW-23-055-21 W4	Brown, George	3.66	---	30.48	---	---	---	---	---	---	Domestic	Chemistry
111	83474	SE-23-055-21 W4	Boyko, Louis	3.66	---	12.19	---	---	---	6.09	---	---	Domestic	Chemistry
112	83266	NE-31-055-20 W4	Hennig, R.	3.69	---	8.53	---	---	---	2.43	---	---	Domestic	Chemistry
113	263710	NW-12-056-21 W4	Gabert, M.	3.83	---	44.19	---	---	42.06	12.19	---	12-Aug-83	Stock	New Well
114	263714	NW-12-056-21 W4	Gabert, M.	3.83	---	33.52	---	---	---	---	---	---	Domestic	Chemistry
115	153167	SE-22-055-21 W4	Poulin, Rodger	3.84	---	48.76	41.15	42.67	42.67	15.24	---	20-Jul-90	Domestic	New Well
116	83467	NE-21-055-21 W4	Scotford Hutterite Colony	4.03	---	76.2	---	---	---	27.43	---	---	Domestic	Chemistry
117	298287	NW-19-055-20 W4		4.03	---	0	---	---	---	---	---	---	Domestic	Old Well-Abandoned
118	292190	NW-19-055-20 W4	Lamprecht, Henry	4.03	---	48.76	36.58	42.67	---	15.84	---	20-Apr-99	Domestic	New Well
119	83468	05-22-055-21 W4	Langhausen, J.	4.1	---	39.01	---	---	---	---	---	1-Jan-15	Domestic & Stock	Federal Well Survey
120	83481	SE-24-055-21 W4	Gabert, Larry	4.18	---	59.43	---	---	57.91	18.89	---	27-Aug-86	Stock	New Well
121	83261	SE-30-055-20 W4	Schneider, J.	4.18	---	36.57	---	---	---	8.83	---	1-Sep-30	Domestic	Well Inventory
122	280650	SW-28-055-21 W4	Visscher, D.	4.18	---	9.14	---	---	---	---	---	---	Domestic	Chemistry
123	91498	NE-06-056-20 W4	Schram, George	4.19	---	91.44	---	---	---	---	---	---	Domestic	Chemistry
124	83262	08-30-055-20 W4	Prochau	4.27	---	6.7	---	---	---	5.18	---	1-Jan-10	Domestic & Stock	Federal Well Survey
125	100870	05-32-055-20 W4	Schwanke, G.	4.29	---	18.28	---	---	---	---	---	1-Jan-19	Domestic & Stock	Federal Well Survey
126	83535	01-32-055-21 W4	Mohr, G.P.	4.33	---	0	---	---	---	---	---	---	Domestic & Stock	Federal Well Survey
127	83179	05-19-055-20 W4	Schultz, R.	4.35	---	18.89	---	---	---	9.75	---	1-Jan-34	Domestic & Stock	Federal Well Survey
128	83255	13-29-055-20 W4	Mashmeyer, K.	4.4	---	67.05	---	---	---	---	---	1-Jan-21	Domestic & Stock	Federal Well Survey
129	263410	01-05-056-21 W4	Can Badger Co Ltd #2	4.41	---	47.24	38.10	41.15	---	24.99	---	6-Apr-82	Monitoring	New Well
130	263417	01-05-056-21 W4	Can Badger Co Ltd #3	4.41	---	60.96	45.72	60.96	45.72	25.60	---	8-Apr-82	Monitoring	New Well
131	263423	01-05-056-21 W4	Can Badger Co Ltd #4	4.41	---	60.96	45.72	60.96	45.42	25.60	---	13-Apr-82	Monitoring	New Well
132	263387	01-05-056-21 W4	Can Badger Co Ltd #7	4.41	---	42.06	39.32	42.06	---	25.60	---	27-Apr-82	Monitoring	New Well
133	263459	01-05-056-21 W4	Can Badger Co Ltd #8	4.41	---	42.67	39.01	40.54	39.01	25.60	---	3-May-82	Monitoring	New Well
134	263465	01-05-056-21 W4	Can Badger Co Ltd #9	4.41	---	42.67	---	---	36.88	25.60	---	5-May-82	Monitoring	New Well
135	263728	16-12-056-21 W4	Bruderheim, Town Of #9-75	4.43	---	42.67	35.66	37.19	35.66	---	---	3-Oct-75	Municipal	New Well
136	263723	16-12-056-21 W4	Bruderheim, Town Of#11-75	4.43	---	42.67	29.26	30.78	29.26	---	---	6-Nov-75	Municipal	New Well
137	263716	16-12-056-21 W4	Bruderheim, Town Of #15-75	4.43	---	42.67	34.14	35.66	34.14	---	---	17-Nov-75		Unknown
138	263729	16-12-056-21 W4	Bruderheim, Town Of#10-75	4.43	---	42.67	33.83	37.19	33.83	24.44	---	4-Nov-75	Municipal	New Well
139	91499	16-06-056-20 W4	Schram, George	4.46	---	67.97	48.77	67.97	28.96	13.71	---	12-Apr-85	Domestic & Stock	New Well
140	83409	NW-14-055-21 W4	Fluker, Randy	4.47	---	80.77	---	---	---	68.58	---	---	Domestic	Chemistry
141	83408	NW-14-055-21 W4	Fluker, Randy	4.47	---	76.2	---	---	---	---	---	---	Domestic	Chemistry
142	167583	NE-14-055-21 W4	Hanes, Raymond/Susan	4.47	---	54.86	---	---	---	---	---	---	Domestic	Chemistry
143	83414	NE-14-055-21 W4	Roesler, Lloyd	4.47	---	64	---	---	---	---	---	---	Domestic	Chemistry
144	83413	NE-14-055-21 W4	Lamarche, Laurier	4.47	---	83.82	44.20	60.96	44.20	15.24	---	30-May-80	Domestic	Deepened
145	263842	SE-14-056-21 W4	Smart, D	4.48	---	3.65	---	---	---	1.82	---	---	Domestic	Chemistry
146	263818	03-13-056-21 W4	Procnaim, R.	4.49	---	4.87	---	---	---	3.04	---	---	Stock	Federal Well Survey
147	83544	NE-32-055-21 W4	Visscher, D.	4.51	---	46.32	---	---	---	32.00	---	---	Domestic	Chemistry
148	83541	NE-32-055-21 W4	Pcl Braun Simons Ltd #Hole1	4.51	---	42.67	40.23	42.67	---	27.43	---	20-Aug-81	Industrial	New Well
149	83539	NE-32-055-21 W4	Pcl Braun Simons Ltd #Well4	4.51	---	41.14	35.05	41.15	41.15	28.95	---	9-Oct-81	Industrial	New Well
150	83542	NE-32-055-21 W4	Pcl Braun Simons Ltd #Hole2	4.51	---	42.67	40.23	42.67	---	27.43	---	2-Sep-81	Industrial	New Well

Table 5D-1. WATER WELLS WITHIN A 7.0km RADIUS
North American Oil Sands Corporation
North American Upgrader Project

Water Well Number (Figure 2)	Well ID*	Location	Well Owner	Distance from Site (km)	Direction from Site	Total Depth (m)	Top of Screen (m)	Bottom of Screen (m)	Bottom of Casing (m)	Depth to Water (m)	Bedrock Depth (m)	Date of Information (dd-mmm-yy)	Type of Work	Proposed Use for Well
151	83540	NE-32-055-21 W4	Pcl Braun Simons Ltd #Hole5	4.51	---	41.14	35.66	41.15	41.15	28.95	---	6-Oct-81	Industrial	New Well
152	83543	NE-32-055-21 W4	Pcl Braun Simons Ltd #Hole3	4.51	---	42.67	40.54	42.67	---	27.43	---	25-Aug-81	Industrial	New Well
153	100869	SW-32-055-20 W4	Fibke, Henry	4.51	---	19.81	---	---	---	10.66	---	---	Domestic	Chemistry
154	83270	SW-32-055-20 W4	Maschmeyer, Loris	4.51	---	47.24	42.37	43.89	20.73	16.55	---	30-Sep-70	Domestic	New Well
155	83418	NE-15-055-21 W4	Anweiler, Sal	4.61	---	91.44	---	---	---	---	---	---	Domestic	Chemistry
156	240752	NE-15-055-21 W4	Alta Env #0297E	4.61	---	24.38	---	---	---	---	---	12-May-69	Unknown	Test Hole
157	83405	NW-13-055-21 W4	Gabert, Ronald D.	4.62	---	60.96	48.77	60.96	44.50	15.84	---	19-Aug-80	Domestic	New Well
158	263820	SW-13-056-21 W4	Prochnau, E.	4.62	---	47.24	35.05	47.24	---	25.90	---	9-May-88	Domestic & Stock	New Well
159	83465	SE-21-055-21 W4	Thomas, Warren	4.63	---	64	---	---	64.01	9.14	---	12-Sep-82	Domestic & Stock	New Well
160	100848	SW-19-055-20 W4	Schultz, Herrmann	4.63	---	45.72	---	---	---	12.19	---	---	Domestic	Chemistry
161	158556	SW-19-055-20 W4	Schultz, H.	4.63	---	53.34	48.77	53.34	43.28	22.70	---	1-Sep-71	Domestic	Deepened
162	158556	SW-19-055-20 W4	Schultz, H.	4.63	---	53.34	48.77	53.34	43.28	12.19	---	1-Sep-71	Domestic	Deepened
163	83181	NE-19-055-20 W4	Duff, Don	4.63	---	---	---	---	---	---	---	---	Domestic	Chemistry
164	263592	SW-09-056-21 W4	Lechenko #3 Drinking Well	4.64	---	---	---	---	---	5.18	---	---	Domestic	Chemistry
165	83254	NW-29-055-20 W4	Hargeshimer, George	4.65	---	50.29	---	---	---	---	---	---	Domestic	Chemistry
166	164853	NW-29-055-20 W4	Hargesheimer, Peter/Adele	4.65	---	34.13	---	---	---	---	---	---	Domestic	Chemistry
167	91491	SW-05-056-20 W4	Mandryk, Jerry	4.66	---	18.28	---	---	---	4.57	---	1-Jan-78	Domestic	Chemistry
168	91492	SW-05-056-20 W4	Burwash, Earl	4.66	---	---	---	---	---	---	---	---	Domestic	Chemistry
169	83464	01-21-055-21 W4	Kribs, Robert	4.67	---	38.1	31.70	36.58	26.82	16.15	---	3-Apr-80	Stock	New Well
170	91501	01-07-056-20 W4	Hydrogeological Consult Ltd	4.68	---	27.43	---	---	---	---	---	17-Jul-75	Unknown	Test Hole
171	83180	16-19-055-20 W4	Duff, Don	4.68	---	30.48	---	---	25.60	12.49	---	1-Nov-73	Stock	New Well
172	83182	16-19-055-20 W4	Kittlitz, C.	4.68	---	18.28	---	---	---	---	---	1-Jan-19	Domestic & Stock	Federal Well Survey
173	83415	09-14-055-21 W4	Fluker, R.	4.69	---	48.76	---	---	---	6.09	---	1-Jan-19	Domestic & Stock	Federal Well Survey
174	263821	05-13-056-21 W4	Bruderheim, Town Of#14-75	4.77	---	48.76	41.76	42.98	41.76	---	---	11-Nov-75	Municipal	New Well
175	263789	01-13-056-21 W4	Bruderheim, Town Of #6A-75	4.8	---	35.66	34.44	35.66	---	25.81	---	16-Jul-75	Municipal & Observation	New Well
176	263738	01-13-056-21 W4	Bruderheim, Town Of#6-75 Pump	4.8	---	43.58	30.78	38.40	---	24.84	---	16-Jul-75	Municipal	New Well
177	263789	01-13-056-21 W4	Bruderheim, Town Of #6A-75	4.8	---	35.66	34.44	35.66	---	25.81	---	16-Jul-75	Municipal & Observation	New Well
178	263738	01-13-056-21 W4	Bruderheim, Town Of#6-75 Pump	4.8	---	43.58	30.78	38.40	---	25.11	---	16-Jul-75	Municipal	New Well
179	263918	04-15-056-21 W4	Seaboard Oil Co #4-15	4.81	---	996.08	---	---	---	---	---	15-Nov-50	Industrial	Oil Exploratory
180	83406	NE-13-055-21 W4	Gabert, Garry	4.89	---	57.91	44.20	54.86	44.20	19.81	---	28-May-79	Domestic	New Well
181	101389	00-32-055-20 W4	Bruderheim #Th 10-75	4.89	---	36.88	---	---	33.83	24.93	---	---	Municipal	Test Hole
182	83288	00-32-055-20 W4	Hofman, Lawrence	4.89	---	6.09	---	---	---	3.04	---	---	Domestic	Chemistry
183	263732	SE-13-056-21 W4	Wagner, J	4.9	---	42.06	---	---	39.93	27.43	---	---	Domestic & Stock	New Well
184	263736	SE-13-056-21 W4	Young, C.S.	4.9	---	7.92	---	---	---	---	---	---	Domestic	Chemistry
185	91500	08-07-056-20 W4	Schram, Elmer	4.91	---	14.63	---	---	14.63	4.87	---	24-Jul-81	Domestic & Stock	New Well
186	83509	SE-29-055-21 W4	Cf Braun Co	4.92	---	45.72	41.76	44.81	---	24.38	---	24-Jun-77	Industrial	New Well
187	263525	NE-05-056-21 W4	Cholowski, R.	4.93	---	6.09	---	---	3.66	3.65	---	---	Domestic	Chemistry
188	263543	NE-05-056-21 W4	Cholowski, R.	4.93	---	4.87	---	---	---	1.21	---	---	Domestic	Chemistry
189	91564	04-18-056-20 W4	Stelter, A.	5	---	---	---	---	---	---	---	---	Domestic	Federal Well Survey
190	83421	16-16-055-21 W4	Manz, A.	5.01	---	14.02	---	---	---	6.09	---	1-Jan-34	Stock	Federal Well Survey
191	83174	13-18-055-20 W4	Schutlz, F.H.	5.02	---	24.38	---	---	---	---	---	---	Domestic	Federal Well Survey
192	91503	04-08-056-20 W4	Riske, E.	5.03	---	7.62	---	---	---	3.04	---	1-Jan-19	Domestic & Stock	Federal Well Survey
193	83407	05-14-055-21 W4	Cantrell, M.	5.09	---	33.52	---	---	---	---	---	---	Domestic & Stock	Federal Well Survey
194	263912	09-14-056-21 W4	Bruderheim, Town Of	5.1	---	49.37	---	---	---	---	---	16-Jul-75	Municipal	New Well
195	83260	00-29-055-20 W4		5.15	---	69.79	---	---	---	---	---	---	Domestic	Chemistry
196	263735	08-13-056-21 W4	Wagner, J	5.16	---	4.87	---	---	---	3.04	---	1-Jan-27	Domestic & Stock	Federal Well Survey
197	161758	SE-19-055-20 W4	Prochnau, Allan#Well 2	5.17	---	19.81	---	---	---	---	---	---	Domestic	Chemistry
198	83176	SE-19-055-20 W4	Prochnau, A.	5.17	---	27.43	---	---	---	19.81	---	---	Domestic	Chemistry
199	83178	SE-19-055-20 W4	Prochnau, Allan	5.17	---	9.14	---	---	---	---	---	---	Domestic	Chemistry
200	295816	SE-19-055-20 W4	Acheson, Bill	5.17	---	61.87	40.23	52.43	---	17.37	---	5-Oct-98	Domestic	New Well

Table 5D-1. WATER WELLS WITHIN A 7.0km RADIUS

North American Oil Sands Corporation
North American Upgrader Project

Water Well Number (Figure 2)	Well ID*	Location	Well Owner	Distance from Site (km)	Direction from Site	Total Depth (m)	Top of Screen (m)	Bottom of Screen (m)	Bottom of Casing (m)	Depth to Water (m)	Bedrock Depth (m)	Date of Information (dd-mmm-yy)	Type of Work	Proposed Use for Well
201	161757	SE-19-055-20 W4	Prochnau, Allan#Well 1	5.17	---	40.84	---	---	---	---	---	---	Domestic	Chemistry
202	91502	09-07-056-20 W4	Driesner, D.	5.17	---	9.14	---	---	---	---	---	---	Domestic	Federal Well Survey
203	91490	02-05-056-20 W4	Arc #Test Hole	5.2	---	103.63	---	---	84.43	---	---	---	Unknown	Test Hole
204	83175	14-18-055-20 W4	Alta Env	5.24	---	20.11	19.51	20.12	19.51	---	---	21-Sep-86	Unknown	Test Hole
205	263877	NE-14-056-21 W4	Hodgson, G	5.28	---	13.41	---	---	13.41	---	---	1-Aug-72	Domestic	New Well
206	263896	NE-14-056-21 W4	Hodgson, G	5.28	---	48.76	42.37	43.89	43.89	21.33	---	4-Nov-88	Domestic & Stock	New Well
207	263887	NE-14-056-21 W4	Percy, G.	5.28	---	48.76	---	---	46.33	27.43	---	17-May-85	Domestic	New Well
208	261833	NE-14-056-21 W4	Hodgson, George	5.28	---	11.27	---	---	11.28	4.87	---	19-Apr-89	Stock	Deepened
209	263883	NE-14-056-21 W4	Percy, G.	5.28	---	11.27	---	---	---	8.22	---	---	Domestic	Chemistry
210	263870	NE-14-056-21 W4	Hodgson, G A	5.28	---	10.66	---	---	---	4.87	---	---	Domestic	Chemistry
211	263910	NE-14-056-21 W4	Smibert, R	5.28	---	---	---	---	---	---	---	---	Domestic	Chemistry
212	83420	NE-16-055-21 W4	Mohr, Gus	5.29	---	51.81	---	---	43.89	13.71	---	23-Apr-65	Domestic & Stock	New Well
213	208911	SE-16-056-21 W4	Henkelman, Percy	5.3	---	11.88	4.57	11.28	---	3.35	---	25-Sep-92	Domestic	New Well
214	169121	SE-16-056-21 W4	Henkelman, P.R.	5.3	---	34.74	---	---	---	---	---	23-Sep-92	Unknown	New Well-Abandoned
215	91504	SW-08-056-20 W4	Schram, Ed	5.31	---	23.77	---	---	---	---	---		Domestic	Chemistry
216	158576	SW-08-056-20 W4	Schram, Edward	5.31	---	21.03	---	---	---	3.65	---	25-Sep-79	Domestic & Stock	New Well
217	100929	SW-08-056-20 W4	Schram, Ed	5.31	---	7.92	---	---	---	3.04	---	---	Domestic	Chemistry
218	83279	NE-32-055-20 W4	Ulmer, J.	5.31	---	7.62	---	---	---	3.04	---	---	Domestic	Chemistry
219	83276	NE-32-055-20 W4	French, N.E.	5.31	---	7.92	---	---	---	4.87	---	---	Domestic	Chemistry
220	83275	NE-32-055-20 W4	Benedict, Don	5.31	---	6.09	---	---	---	2.43	---	---	Domestic	Chemistry
221	83286	NE-32-055-20 W4	Bjorkquist, Bill	5.31	---	---	---	---	---	---	---	---	Domestic	Chemistry
222	83283	NE-32-055-20 W4	Strong, H.A.	5.31	---	8.22	---	---	---	4.87	---	---	Domestic	Chemistry
223	83274	NE-32-055-20 W4	Benedict, Don	5.31	---	7.01	---	---	---	2.74	---	---	Domestic	Chemistry
224	83277	NE-32-055-20 W4	Lukowesky, Peter	5.31	---	7.31	---	---	---	2.74	---	---	Domestic	Chemistry
225	83273	NE-32-055-20 W4	Klose, A.	5.31	---	7.01	---	---	---	2.43	---	---	Domestic	Chemistry
226	280267	NE-32-055-20 W4	Rosnau, E.	5.31	---	6.09	---	---	---	4.26	---	---	Domestic	Chemistry
227	83278	NE-32-055-20 W4	Hennig, R.	5.31	---	8.53	---	---	---	4.26	---	---	Domestic	Chemistry
228	83271	NE-32-055-20 W4	Benedict, D.C.	5.31	---	48.76	---	---	---	9.14	---	---	Domestic	Chemistry
229	83280	NE-32-055-20 W4	Florchuk, Henry	5.31	---	9.14	---	---	---	6.09	---	---	Domestic	Chemistry
230	83281	NE-32-055-20 W4	Klose, Albert	5.31	---	48.76	27.43	48.77	27.43	12.19	---	1-Dec-58	Domestic	New Well
231	83282	NE-32-055-20 W4	Chernyk, Dave	5.31	---	6.7	---	---	6.71	5.18	---	3-Sep-69	Domestic	New Well
232	83285	NE-32-055-20 W4	Loeffelman, Alfred	5.31	---	12.19	---	---	---	---	---	---	Domestic	Chemistry
233	83284	NE-32-055-20 W4	Abercan Ent Ltd	5.31	---	6.09	---	---	---	---	---	---	Domestic	Chemistry
234	83272	NE-32-055-20 W4	Breitzke, David	5.31	---	7.31	---	---	---	3.65	---	---	Domestic	Chemistry
235	83536	NW-32-055-21 W4	Pcl Braun Simons Ltd	5.31	---	39.62	---	---	---	---	---	---	Domestic	Chemistry
236	83537	NW-32-055-21 W4	Pcl Braun Simons Ltd	5.31	---	39.62	---	---	---	---	---	---	Domestic	Chemistry
237	83538	NW-32-055-21 W4	Pcl Braun Simons Ltd	5.31	---	45.72	---	---	---	---	---	---	Domestic	Chemistry
238	83267	SE-32-055-20 W4	Bruderheim, Village Of #3	5.31	---	19.5	15.54	18.59	13.41	5.48	---	3-Sep-70	Municipal	New Well
239	296521	SE-32-055-20 W4	Bruderheim, Town Of	5.31	---	19.5	---	---	13.41	---	---	20-Apr-01	Municipal	Old Well-Abandoned
240	83268	SE-32-055-20 W4	Schultz, T.H.	5.31	---	39.62	---	---	---	20.72	---	---	Domestic	Chemistry
241	83185	NW-20-055-20 W4	Allard, Keith	5.31	---	0	---	---	---	---	---	---	Domestic	Chemistry
242	83184	NW-20-055-20 W4	Prochnau, Elmer	5.31	---	22.86	---	---	---	15.24	---	---	Domestic	Chemistry
243	83256	NE-29-055-20 W4	Maschmeyer, Loris	5.43	---	39.62	---	---	---	---	---	---	Domestic	Chemistry
244	83257	NE-29-055-20 W4	Roloff	5.43	---	42.67	---	---	---	---	---	---	Domestic	Chemistry
245	83259	NE-29-055-20 W4	Heckbert, Joanne	5.43	---	0	---	---	---	---	---	---	Domestic	Chemistry
246	263474	SW-05-056-21 W4	Reed, D	5.44	---	16.76	---	---	---	12.19	---	---	Domestic	Chemistry
247	100927	SE-05-056-20 W4	Rosnau, E.	5.44	---	7.62	---	---	---	2.74	---	---	Domestic	Chemistry
248	100928	SE-05-056-20 W4	Prochnau, Martha	5.44	---	6.09	---	---	---	---	---	---	Domestic	Chemistry
249	159727	SE-05-056-20 W4	Hare, Gerald	5.44	---	6.09	---	---	---	---	---	---	Domestic	Chemistry
250	91488	SE-05-056-20 W4	Pysmeny, Ross	5.44	---	18.28	---	---	---	16.15	---	---	Domestic	Chemistry

Table 5D-1. WATER WELLS WITHIN A 7.0km RADIUS

North American Oil Sands Corporation
North American Upgrader Project

Water Well Number (Figure 2)	Well ID*	Location	Well Owner	Distance from Site (km)	Direction from Site	Total Depth (m)	Top of Screen (m)	Bottom of Screen (m)	Bottom of Casing (m)	Depth to Water (m)	Bedrock Depth (m)	Date of Information (dd-mmm-yy)	Type of Work	Proposed Use for Well
251	83466	04-21-055-21 W4	Wakaryk, Andrew	5.45	---	18.28	---	---	18.29	7.31	---	14-Sep-83	Stock	New Well
252	83177	01-19-055-20 W4	Kittlitz, R.	5.45	---	21.94	---	---	---	---	---	1-Jan-22	Domestic & Stock	Federal Well Survey
253	83402	08-13-055-21 W4	Gabert, A.	5.53	---	13.71	---	---	---	6.09	---	---	Domestic & Stock	Federal Well Survey
254	83287	16-32-055-20 W4	Stewart, M.	5.53	---	10.05	---	---	---	5.48	---	---	Domestic	Chemistry
255	83269	01-32-055-20 W4	Fredriking, E.G.	5.53	---	12.49	---	---	---	---	---	1-Jan-19	Domestic	Federal Well Survey
256	240751	EH-20-055-21 W4	Alta Env/Water Res #0296E	5.54	---	45.11	---	---	---	---	---	12-May-69	Unknown	Test Hole
257	83404	04-13-055-21 W4	Fluker, W.	5.55	---	12.8	---	---	---	4.57	---	1-Jan-13	Domestic & Stock	Federal Well Survey
258	83258	16-29-055-20 W4	Stansky, L.	5.59	---	29.56	---	---	---	---	---	1-Jan-17	Domestic & Stock	Federal Well Survey
259	263484	04-05-056-21 W4	Yarshuk, P	5.6	---	8.53	---	---	8.53	5.48	---	28-Jan-70	Domestic	New Well
260	91489	01-05-056-20 W4	Clonmel #Core Hole	5.6	---	60.96	---	---	---	---	---	---	Industrial	Core Hole
261	297114	01-05-056-20 W4	Alta Infrastructure(Bruderheim	5.6	---	---	---	---	---	---	---	14-Nov-00	Industrial	Old Well-Abandoned
262	83417	SW-15-055-21 W4	Whelan, James	5.63	---	54.86	48.77	54.86	31.09	5.94	---	8-Jun-89	Domestic	New Well
263	83253	SE-29-055-20 W4	Offenberger, Bryan	5.67	---	54.86	---	---	---	---	---	---	Domestic	Chemistry
264	168089	SE-29-055-20 W4	Maschmeyer, L.	5.67	---	60.96	45.72	54.86	54.86	25.60	---	30-Jun-92	Stock	New Well
265	263492	NW-05-056-21 W4	Cholowski, R.	5.68	---	42.67	---	---	28.96	27.43	---	12-Jan-61	Domestic	Old Well-Abandoned
266	91493	NE-05-056-20 W4	Mcbridge, R.	5.68	---	---	---	---	---	---	---	---	Domestic	Chemistry
267	91558	SE-18-056-20 W4	Mclellan, Arthur	5.75	---	5.79	---	---	---	3.65	---	---	Domestic	Chemistry
268	91560	SE-18-056-20 W4	Mclellan, Arthur	5.75	---	15.84	---	---	15.85	6.09	---	9-Aug-78	Domestic & Stock	New Well
269	224564	SE-18-056-20 W4	Mclellan, Art	5.75	---	42.67	35.36	41.45	41.45	21.18	---	9-Oct-93	Domestic	New Well
270	91562	SE-18-056-20 W4	Mclellan, Arthur	5.75	---	67.05	60.96	67.06	51.21	18.28	---	31-Dec-81	Domestic	New Well
271	224564	SE-18-056-20 W4	Mclellan, Art	5.75	---	42.67	35.36	41.45	41.45	21.18	---	9-Oct-93	Domestic	New Well
272	224185	SE-18-056-20 W4	Mclellan, Art	5.75	---	73.15	---	---	---	---	---	8-Oct-93	Observation	Test Hole-Abandoned
273	91561	SE-18-056-20 W4	Mclellan, Arthur L.	5.75	---	33.52	---	---	---	---	---	17-Dec-81	Domestic	New Well
274	297564	SE-18-056-20 W4	Helmer, Muriel/Abner	5.75	---	67.05	---	---	---	24.38	---	7-Oct-00	Domestic	Old Well-Test
275	91559	SE-18-056-20 W4	Mclellan, Arthur	5.75	---	6.7	---	---	---	5.48	---	---	Domestic	Chemistry
276	91505	13-08-056-20 W4	Sampert, Roger	5.75	---	17.67	---	---	17.68	4.26	---	18-Jul-84	Domestic & Stock	New Well
277	263941	04-16-056-21 W4	Kropp, L.	5.76	---	42.67	---	---	38.40	30.02	---	---	Stock	New Well
278	263941	04-16-056-21 W4	Kropp, L.	5.76	---	42.67	---	---	38.40	30.02	---	---	Stock	New Well
279	83419	NW-16-055-21 W4	Krebs, Bernard	5.76	---	56.38	---	---	---	---	---	---	Domestic	Chemistry
280	156870	NW-16-055-21 W4	Krebs, Bernard L.	5.76	---	74.67	---	---	---	21.33	---	---	Domestic	Chemistry
281	154895	NW-16-055-21 W4	Krebs, Bernard L.	5.76	---	48.76	42.67	48.77	42.06	20.42	---	13-Oct-90	Domestic	New Well
282	263924	SW-16-056-21 W4	Kropp, L.	5.78	---	---	---	---	---	---	---	---	Domestic	Spring
283	263933	SW-16-056-21 W4	Bolton School	5.78	---	---	---	---	---	---	---	---	Domestic	Chemistry
284	263959	SW-16-056-21 W4	Marquardt, E	5.78	---	9.14	---	---	---	3.04	---	---	Domestic	Chemistry
285	83462	SE-20-055-21 W4	Cnr#Beamer Spur	5.78	---	99.36	---	---	---	---	---	---	Domestic	Chemistry
286	83463	SE-20-055-21 W4	Cnr#Scotford Yard	5.78	---	---	---	---	---	---	---	---	Domestic	Chemistry
287	83183	SW-20-055-20 W4	Violette, John	5.78	---	39.62	---	---	---	---	---	---	Domestic	Chemistry
288	100931	00-08-056-20 W4	Inkster, Colin	5.86	---	17.06	---	---	---	2.43	---	---	Domestic	Chemistry
289	83188	00-20-055-20 W4	Fluker, David	5.87	---	32.91	---	---	---	---	---	1-Jan-67	Domestic	Chemistry
290	91566	11-18-056-20 W4	Serink, W.	5.89	---	14.93	---	---	14.94	3.04	---	17-Jun-79	Domestic	New Well
291	83403	01-13-055-21 W4	Gabert, Richard	5.89	---	14.63	---	---	---	7.31	---	---	Domestic	Chemistry
292	263828	16-13-056-21 W4	Bruderheim, Town Of#13-75	5.9	---	36.57	31.09	32.31	31.09	---	---	10-Nov-75	Municipal	New Well-Abandoned
293	196474	12-33-055-20 W4	Kroker, G. Patricia/John	5.92	---	9.14	---	---	---	6.09	---	---	Domestic	Chemistry
294	83311	12-33-055-20 W4	Krebs, A.W.	5.92	---	6.4	---	---	---	2.13	---	---	Domestic	Chemistry
295	83252	01-29-055-20 W4	Bisch, B.	5.93	---	48.76	---	---	---	---	---	1-Jan-25	Domestic & Stock	Federal Well Survey
296	83309	13-33-055-20 W4	Thiel, Horst	5.95	---	9.75	---	---	9.75	4.26	---	25-Oct-82	Domestic	New Well
297	83390	16-10-055-21 W4	Mohr, Irwin	5.96	---	55.77	---	---	42.98	18.28	---	9-Jun-83	Stock	New Well
298	91565	NW-18-056-20 W4	Serink, W.	5.97	---	12.19	---	---	12.19	6.09	---	---	Domestic	Chemistry
299	91568	NW-18-056-20 W4	Serink, William	5.97	---	47.24	---	---	---	36.57	---	24-Aug-87	Stock	New Well
300	83656	SE-16-055-21 W4	Rietveld, Leendert	5.98	---	48.15	---	---	---	---	---	---	Domestic	Chemistry

Table 5D-1. WATER WELLS WITHIN A 7.0km RADIUS

North American Oil Sands Corporation
North American Upgrader Project

Water Well Number (Figure 2)	Well ID*	Location	Well Owner	Distance from Site (km)	Direction from Site	Total Depth (m)	Top of Screen (m)	Bottom of Screen (m)	Bottom of Casing (m)	Depth to Water (m)	Bedrock Depth (m)	Date of Information (dd-mmm-yy)	Type of Work	Proposed Use for Well
301	196672	SE-08-056-20 W4	Alexander, Bob	6	---	6.09	---	---	---	---	---	---	Domestic	Chemistry
302	100930	SE-08-056-20 W4	Krause, F.	6	---	9.14	---	---	---	---	---	---	Domestic	Chemistry
303	263579	SW-08-056-21 W4	Maschmeyer, R	6.01	---	24.99	22.86	24.38	---	13.41	---	11-Nov-66	Domestic	New Well
304	263560	SW-08-056-21 W4	Kofluk, D	6.01	---	48.76	---	---	48.77	29.87	---	1-Apr-73	Domestic	New Well
305	100849	NE-20-055-20 W4	Faubert, Al	6.01	---	76.2	70.10	76.20	45.72	45.72	---	5-Jun-74	Domestic	New Well
306	156859	NE-20-055-20 W4	Fluker, Arthur	6.01	---	76.2	---	---	---	---	---	---	Domestic	Chemistry
307	83186	NE-20-055-20 W4	Hopwood, Roger	6.01	---	7.92	---	---	---	4.87	---	---	Domestic	Chemistry
308	83427	16-17-055-21 W4	Scotford Colony	6.03	---	82.29	---	---	72.85	27.43	---	2-Jul-74	Stock	New Well
309	83430	16-17-055-21 W4	Scotford Colony	6.03	---	73.15	71.63	73.15	---	25.29	---	23-Jun-78	Stock	New Well
310	83431	16-17-055-21 W4	Mann, A.A.	6.03	---	85.34	---	---	---	---	---	---	Stock	Federal Well Survey
311	83432	16-17-055-21 W4	Scotford Colony	6.03	---	134.11	---	---	59.74	30.48	---	2-Dec-83	Stock	New Well
312	91563	08-18-056-20 W4	Kaus, A.	6.03	---	4.57	---	---	---	3.35	---	1-Jan-25	Domestic & Stock	Federal Well Survey
313	91556	04-17-056-20 W4	Schram, Barry	6.04	---	42.67	27.43	42.67	27.43	6.09	---	16-Aug-82	Stock	New Well
314	83392	15-10-055-21 W4	Greisling, P.	6.04	---	15.24	---	---	---	13.71	---	---	Domestic & Stock	Federal Well Survey
315	91567	13-18-056-20 W4	Serant, M.	6.05	---	6.7	---	---	---	1.82	---	1-Jan-18	Stock	Federal Well Survey
316	263583	15-08-056-21 W4	Brodie, H.L.	6.07	---	11.58	---	---	---	10.05	---	---	Domestic	Chemistry
317	83396	NW-11-055-21 W4	Rhoades, Ron	6.09	---	54.86	---	---	---	17.37	---	---	Domestic	Chemistry
318	83187	16-20-055-20 W4	Schultz, Adolph	6.1	---	7.62	---	---	---	4.57	---	1-Jan-00	Domestic & Stock	Federal Well Survey
319	83293	NW-33-055-20 W4	Liske, H.	6.13	---	77.72	---	---	---	---	---	---	Domestic	Chemistry
320	83302	NW-33-055-20 W4	Kupsh, B.	6.13	---	6.7	---	---	---	2.74	---	---	Domestic	Chemistry
321	83295	NW-33-055-20 W4	Haur, W.	6.13	---	29.26	---	---	---	---	---	---	Domestic	Chemistry
322	83310	NW-33-055-20 W4	Moravian Church	6.13	---	18.28	---	---	---	---	---	---	Domestic	Chemistry
323	83307	NW-33-055-20 W4	Lilge, A.	6.13	---	3.96	---	---	---	---	---	---	Domestic	Chemistry
324	100871	NW-33-055-20 W4	Thiel, R.	6.13	---	7.31	---	---	---	4.26	---	---	Domestic	Chemistry
325	100872	NW-33-055-20 W4	Thiel, R.	6.13	---	6.7	---	---	---	3.65	---	---	Domestic	Chemistry
326	100873	NW-33-055-20 W4	Theil, Rudolph	6.13	---	6.7	---	---	6.10	4.26	---	---	Domestic	Chemistry
327	83306	NW-33-055-20 W4	Sarjes, Joe	6.13	---	10.66	---	---	10.67	---	---	---	Domestic	Chemistry
328	83305	NW-33-055-20 W4	Loren, Roy	6.13	---	3.96	---	---	---	2.13	---	---	Domestic	Chemistry
329	83303	NW-33-055-20 W4	Lawrence, G.E.	6.13	---	5.48	---	---	---	1.82	---	---	Domestic	Chemistry
330	83301	NW-33-055-20 W4	Frauenfeld, Roy	6.13	---	5.79	---	---	---	2.74	---	---	Domestic	Chemistry
331	83300	NW-33-055-20 W4	Noske, A.	6.13	---	5.18	---	---	---	2.13	---	---	Domestic	Chemistry
332	83299	NW-33-055-20 W4	Jordan, J.R.	6.13	---	6.09	---	---	---	---	---	---	Domestic	Chemistry
333	83298	NW-33-055-20 W4	Kottke, Emil	6.13	---	7.62	---	---	---	4.57	---	---	Domestic	Chemistry
334	83297	NW-33-055-20 W4	Strydnaka, M.	6.13	---	7.01	---	---	---	3.35	---	---	Domestic	Chemistry
335	83296	NW-33-055-20 W4	Loffleman, A.	6.13	---	6.09	---	---	---	2.43	---	---	Domestic	Chemistry
336	256352	NW-33-055-20 W4	Thiel Greenhouses	6.13	---	12.19	9.14	12.19	---	1.79	---	29-Sep-94	Irrigation	New Well
337	83294	NW-33-055-20 W4	Strauss, R.	6.13	---	39.62	---	---	---	---	---	---	Domestic	Chemistry
338	83292	NW-33-055-20 W4	Lutheran House	6.13	---	9.14	---	---	---	---	---	---	Domestic	Chemistry
339	83291	NW-33-055-20 W4	Swartz, M.	6.13	---	64	---	---	---	3.04	---	---	Domestic	Chemistry
340	83304	NW-33-055-20 W4	Hoffman, G.	6.13	---	3.65	---	---	---	1.82	---	---	Domestic	Chemistry
341	83534	NE-31-055-21 W4	Pcl Braun Simons Ltd	6.13	---	39.62	---	---	---	---	---	---	Domestic	Chemistry
342	83533	SE-31-055-21 W4	Pcl Braun Simons Ltd	6.13	---	41.14	---	---	---	---	---	---	Domestic	Chemistry
343	83388	14-10-055-21 W4	Geislinger, Harold	6.15	---	33.52	---	---	---	12.19	---	---	Domestic	Chemistry
344	83391	NE-10-055-21 W4	Mohr, Irwin	6.2	---	76.2	---	---	---	---	---	---	Domestic	Chemistry
345	83389	NE-10-055-21 W4	Mohr, P.	6.2	---	60.96	---	---	59.44	17.98	---	2-Mar-58	Domestic	New Well
346	83399	NW-12-055-21 W4	Gabert, Glen	6.2	---	73.15	60.96	73.15	43.28	16.76	---	25-Sep-86	Domestic	New Well
347	152373	WH-08-056-21 W4	Maschmeyer, Ray	6.21	---	24.99	---	---	24.99	10.66	---	26-Jun-90	Domestic	New Well
348	152372	WH-08-056-21 W4	Maschmeyer, Ray	6.21	---	30.48	---	---	---	---	---	26-Jun-90	Unknown	Dry Hole
349	240750	NE-30-055-21 W4	Alta Env/Water Res #0295E	6.24	---	42.67	---	---	---	---	---	11-May-69	Unknown	Test Hole
350	83400	16-12-055-21 W4	Gabert, S.	6.29	---	71.93	---	---	---	21.33	---	1-Jan-18	Domestic & Stock	Federal Well Survey

Table 5D-1. WATER WELLS WITHIN A 7.0km RADIUS

North American Oil Sands Corporation
North American Upgrader Project

Water Well Number (Figure 2)	Well ID*	Location	Well Owner	Distance from Site (km)	Direction from Site	Total Depth (m)	Top of Screen (m)	Bottom of Screen (m)	Bottom of Casing (m)	Depth to Water (m)	Bedrock Depth (m)	Date of Information (dd-mmm-yy)	Type of Work	Proposed Use for Well
351	83428	NE-17-055-21 W4	Scotford Colony	6.32	---	36.57	---	---	---	21.33	---	---	Domestic	Chemistry
352	220716	NE-17-055-21 W4	Scotford Colony	6.32	---	105.15	---	---	59.13	57.91	---	20-Sep-91	Domestic & Stock	Reconstructed
353	83437	NE-17-055-21 W4	Scotford Colony	6.32	---	0	---	---	---	---	---	---	Domestic & Stock	Chemistry
354	83436	NE-17-055-21 W4	Scotford Hutterite Brethren	6.32	---	79.85	---	---	---	30.48	---	---	Domestic & Stock	Chemistry
355	83435	NE-17-055-21 W4	Scotford Colony	6.32	---	97.53	85.34	97.54	36.58	36.57	---	18-Jun-85	Domestic & Stock	New Well
356	83434	NE-17-055-21 W4	Scotford Colony	6.32	---	21.33	17.68	19.20	17.68	9.14	---	27-Aug-86	Stock	New Well
357	83433	NE-17-055-21 W4	Scotford Colony	6.32	---	109.72	91.44	109.73	27.74	36.57	---	19-Mar-86	Domestic & Stock	Deepened
358	83426	NE-17-055-21 W4	Scotford Hutterite Brethren	6.32	---	79.24	---	---	---	---	---	---	Domestic	Chemistry
359	83425	NE-17-055-21 W4	Scotford Colony	6.32	---	82.29	70.10	82.30	59.13	27.43	---	17-Aug-83	Domestic	New Well
360	83424	NE-17-055-21 W4	Scotford Colony	6.32	---	85.34	73.15	85.34	31.39	28.95	---	7-Dec-83	Stock	New Well
361	167850	NE-17-055-21 W4	Scotford Colony	6.32	---	20.42	12.19	20.42	---	8.53	---	12-Jul-92	Stock	New Well
362	167849	NE-17-055-21 W4	Scotford Colony	6.32	---	14.93	---	---	---	---	---	10-Jul-92	Stock	New Well-Abandoned
363	83433	NE-17-055-21 W4	Scotford Colony	6.32	---	109.72	91.44	109.73	27.74	28.95	---	19-Mar-86	Domestic & Stock	Deepened
364	285787	NE-17-055-21 W4	Hutterian Brethren	6.32	---	18.59	12.19	18.29	18.59	11.09	---	4-Jun-96	Domestic	New Well
365	159190	NE-17-055-21 W4	Scotford Colony#Pump House	6.32	---	82.29	---	---	50.29	30.48	---	28-May-76	Stock	New Well
366	83429	09-17-055-21 W4	Scotford Colony	6.32	---	45.72	---	---	36.27	29.87	---	1-Aug-73	Stock	New Well
367	293774	SW-17-056-20 W4	Schram, Barry	6.32	---	85.34	72.24	80.77	---	17.22	---	17-Oct-99	Domestic	New Well
368	185985	SW-17-056-20 W4	Schram, Barry	6.32	---	67.05	48.77	60.96	27.43	18.59	---	28-Oct-92	Stock	New Well
369	293775	SW-17-056-20 W4	Schram, Barry	6.32	---	123.44	---	---	---	---	---	12-Oct-99	Domestic	Dry Hole-Abandoned
370	83173	NW-17-055-20 W4	Schultz, W.E.	6.33	---	12.8	---	---	---	6.09	---	---	Domestic	Chemistry
371	83168	NW-17-055-20 W4	Werres, Ernest	6.33	---	18.28	---	---	18.29	7.62	---	19-May-78	Stock	New Well
372	83308	14-33-055-20 W4	Boettcher	6.35	---	5.48	---	---	---	2.74	---	1-Jan-22	Domestic & Stock	Federal Well Survey
373	297115	NE-18-056-20 W4	Martin, Bonnie	6.39	---	18.28	---	---	---	7.28	---	7-Oct-00	Domestic	Old Well-Test
374	255797	NW-10-055-21 W4	Echolane Farm Ltd/Rompre, Ben	6.41	---	36.57	29.26	35.05	---	11.70	---	4-Aug-94	Domestic & Stock	New Well
375	83387	NW-10-055-21 W4	Cox, Douglas	6.41	---	27.43	---	---	---	---	---	---	Domestic	Chemistry
376	156869	NE-12-055-21 W4	Gabert, Gordon	6.41	---	76.2	---	---	---	38.10	---	---	Domestic	Chemistry
377	83401	NE-12-055-21 W4	Gabert, J.	6.41	---	68.58	57.91	65.53	48.77	24.38	---	27-May-76	Domestic & Stock	New Well
378	263963	NW-16-056-21 W4	Blenn	6.42	---	6.7	---	---	---	2.43	---	---	Domestic	Chemistry
379	91507	NE-08-056-20 W4	Frey, B.	6.42	---	5.48	---	---	---	1.82	---	---	Domestic	Chemistry
380	100932	NE-08-056-20 W4	Inkster, Colin	6.42	---	19.5	---	---	19.51	0.00	---	14-Jul-73	Domestic	New Well
381	91571	04-19-056-20 W4	Serink, William	6.44	---	45.72	---	---	41.76	0.00	---	8-Jul-77	Stock	New Well
382	91572	04-19-056-20 W4	Serink, Bill	6.44	---	44.19	---	---	44.20	0.00	---	23-Sep-78	Domestic	New Well
383	83510	SE-30-055-21 W4	Waters, Dean	6.45	---	9.75	---	---	---	3.65	---	---	Domestic	Chemistry
384	83517	SE-30-055-21 W4	Woudenburg, Mary	6.45	---	45.72	---	---	---	30.48	---	---	Domestic	Chemistry
385	83511	SE-30-055-21 W4	Docksteader, Ilef	6.45	---	7.62	---	---	---	6.09	---	---	Domestic	Chemistry
386	83514	SE-30-055-21 W4	Ordell, Richard	6.45	---	6.09	---	---	---		---	---	Domestic	Chemistry
387	83515	SE-30-055-21 W4	Godbout, Stan	6.45	---	9.75	3.66	9.75	8.23	3.65	---	20-Aug-75	Stock	New Well
388	83516	SE-30-055-21 W4	Waters, Dean	6.45	---	12.19	---	---	---	4.87	---	---	Domestic	Chemistry
389	83513	SE-30-055-21 W4	Balimore, Wesly	6.45	---	14.32	---	---	14.33	6.70	---	15-Feb-70	Domestic	New Well
390	83512	SE-30-055-21 W4	Harboway, M.	6.45	---	9.14	---	---	---	7.62	---	---	Domestic	Chemistry
391	156871	SE-30-055-21 W4	Honisch, Vernon	6.45	---	9.75	---	---	---	---	---	---	Domestic	Chemistry
392	160666	SE-30-055-21 W4	Sowden, Helen	6.45	---	8.53	---	---	---	---	---	---	Domestic	Chemistry
393	91511	04-09-056-20 W4	Fraunfeld	6.48	---	9.14	---	---	---	---	---	---	Domestic & Stock	Federal Well Survey
394	91510	04-09-056-20 W4	Rosenau, Wes	6.48	---	11.58	---	---	11.58	5.48	---	30-Apr-79	Domestic & Stock	New Well
395	91508	09-08-056-20 W4	Frey, J.	6.48	---	12.19	---	---	0.00	---	---	1-Jan-20	Domestic	Federal Well Survey
396	83195	13-21-055-20 W4	Maschmeyer, Doug	6.49	---	7.62	---	---	7.62	4.57	---	27-May-66	Domestic	New Well
397	83192	13-21-055-20 W4	Maschmeyer, Douglas	6.49	---	70.71	---	---	65.23	41.14	---	18-Jun-68	Domestic & Stock	New Well
398	83194	13-21-055-20 W4	Maschmeyer, Douglas	6.49	---	67.66	---	---	53.04	33.22	---	2-Apr-80	Stock	New Well
399	83313	00-33-055-20 W4	Klasen, Joseph	6.52	---	6.09	---	---	---	---	---	---	Domestic	Chemistry
400	91485	11-04-056-20 W4	Sampert, E.	6.58	---	15.24	---	---	---	---	---	---	Domestic	Federal Well Survey

Table 5D-1. WATER WELLS WITHIN A 7.0km RADIUS

North American Oil Sands Corporation
North American Upgrader Project

Water Well Number (Figure 2)	Well ID*	Location	Well Owner	Distance from Site (km)	Direction from Site	Total Depth (m)	Top of Screen (m)	Bottom of Screen (m)	Bottom of Casing (m)	Depth to Water (m)	Bedrock Depth (m)	Date of Information (dd-mmm-yy)	Type of Work	Proposed Use for Well
401	289177	EH-17-056-21 W4	I.O.L. #4	6.63	---	15.24	---	---	---	---	---	8-Sep-97	Industrial	Test Hole-Abandoned
402	289176	EH-17-056-21 W4	I.O.L. #3	6.63	---	18.28	15.85	17.37	---	---	---	7-Sep-97	Industrial	Test Hole-Abandoned
403	289174	EH-17-056-21 W4	I.O.L. #5	6.63	---	13.41	---	---	---	---	---	8-Sep-97	Industrial	Test Hole-Abandoned
404	289173	EH-17-056-21 W4	I.O.L. #6	6.63	---	15.24	11.89	13.41	---	---	---	9-Sep-97	Industrial	Test Hole-Abandoned
405	289175	EH-17-056-21 W4	I.O.L. #2	6.63	---	14.93	11.89	14.94	---	---	---	6-Sep-97	Industrial	Test Hole-Abandoned
406	91557	12-17-056-20 W4	Hodgson, L.	6.63	---	48.76	39.62	41.45	39.62	20.42	---	4-Jun-84	Stock	New Well
407	91554	02-17-056-20 W4	Sampert, Ray	6.63	---	34.13	---	---	34.14	24.38	---	6-May-81	Domestic	New Well
408	83166	05-17-055-20 W4	Kittlitz, A.C.	6.64	---	14.63	---	---	---	---	---	1-Jan-34	Domestic & Stock	Federal Well Survey
409	281168	SH-06-056-21 W4	Alta Env #0294E	6.64	---	36.57	---	---	---	---	---	11-May-69	Investigation	Test Hole
410	83169	15-17-055-20 W4	Alta Env	6.64	---	15.24	---	---	---	---	---	29-Sep-87	Unknown	Test Hole-Abandoned
411	83393	00-10-055-21 W4	Durand, Real	6.68	---	24.38	---	---	---	---	---	---	Domestic	Chemistry
412	91506	16-08-056-20 W4	Frey, Bert W.	6.7	---	74.98	---	---	---	18.28	---	15-Nov-61	Domestic	New Well
413	83394	08-11-055-21 W4	Lundy, J.	6.7	---	11.27	---	---	---	3.65	---	1-Jan-21	Stock	Federal Well Survey
414	83383	NE-09-055-21 W4	Ede, W.	6.71	---	---	---	---	---	---	---	---	Domestic	Chemistry
415	264203	SE-21-056-21 W4	Debaan, J	6.71	---	57.91	12.80	14.33	12.80	2.43	---	12-Sep-78	Domestic	New Well
416	264180	SE-21-056-21 W4	Debaan, J	6.71	---	54.86	47.55	48.16	46.94	28.95	---	3-Jul-78	Stock	New Well
417	264190	SE-21-056-21 W4	Debaan, J	6.71	---	16.45	---	---	---	---	---	12-May-78	Domestic	New Well-Abandoned
418	290979	SE-21-056-21 W4	Marquardt, Brent	6.71	---	18.28	3.66	16.76	---	3.04	---	14-Jul-98	Domestic	New Well
419	294342	SE-21-056-21 W4	Sooree, Dick	6.71	---	24.38	10.06	23.47	---	3.65	---	8-Aug-98	Domestic	New Well
420	297579	SE-21-056-21 W4	Marquardt, B.	6.71	---	21.03	13.72	---	---	2.74	---	18-Sep-01	Domestic	New Well
421	167679	SW-09-056-20 W4	Holzbouer, Ralph	6.74	---	96.01	47.24	89.92	36.58	13.71	---	9-Mar-92	Stock	New Well
422	91509	SW-09-056-20 W4	Chilkowich, Anthony	6.74	---	15.24	---	---	---	15.24	---	---	Domestic	Chemistry
423	83453	NE-19-055-21 W4	Nebel, Robert	6.75	---	39.01	---	---	---	---	---	---	Domestic	Chemistry
424	83461	NE-19-055-21 W4	Cameron, Ed	6.75	---	50.29	---	---	---	---	---	---	Domestic	Chemistry
425	83460	NE-19-055-21 W4	Doige, J.F.	6.75	---	9.14	---	---	---	5.48	---	---	Domestic	Chemistry
426	83449	NE-19-055-21 W4	Ede, William	6.75	---	39.62	36.58	38.10	---	34.74	---	23-Jul-75	Domestic	New Well
427	298285	NE-19-055-21 W4		6.75	---	---	---	---	---	---	---	---	Unknown	Old Well-Abandoned
428	83451	NE-19-055-21 W4	Ede, W.J.	6.75	---	40.23	34.75	40.23	40.23	28.95	---	10-Oct-81	Domestic	New Well
429	83452	NE-19-055-21 W4	Enos, Al	6.75	---	48.76	---	---	---	---	---	---	Domestic	Chemistry
430	83459	NE-19-055-21 W4	Spruce Hill Hog Ranch	6.75	---	---	---	---	---	---	---	---	Domestic & Stock	Chemistry
431	83458	NE-19-055-21 W4	Nyhuis, Albert	6.75	---	18.28	---	---	---	9.14	---	---	Domestic	Chemistry
432	83450	NE-19-055-21 W4	Olson, Fred	6.75	---	60.96	---	---	---	---	---	---	Domestic	Chemistry
433	83193	NW-21-055-20 W4	Maschmeyer, Doug	6.75	---	97.53	---	---	---	82.29	---	---	Domestic	Chemistry
434	91570	02-19-056-20 W4	Schumak, A.	6.82	---	12.8	---	---	---	1.52	---	---	Domestic & Stock	Federal Well Survey
435	91513	12-09-056-20 W4	Rosenau, Wes	6.84	---	14.63	---	---	14.63	3.65	---	18-Apr-83	Domestic & Stock	New Well
436	91513	12-09-056-20 W4	Rosenau, Wes	6.84	---	14.63	---	---	14.63	---	---	18-Apr-83	Domestic & Stock	New Well
437	91514	12-09-056-20 W4	Rosenau, Wes	6.84	---	9.14	---	---	9.14	---	---	21-Sep-78	Domestic & Stock	New Well
438	83191	05-21-055-20 W4	Fibke, J.	6.86	---	4.87	---	---	---	---	---	1-Jan-14	Domestic & Stock	Federal Well Survey
439	83457	15-19-055-21 W4	Henderson, Garth	6.86	---	12.19	5.49	7.62	6.71	6.70	---	2-Jan-80	Stock	New Well
440	83454	15-19-055-21 W4	Nebel, Robert	6.86	---	7.31	---	---	7.32	3.04	---	10-May-68	Stock	New Well
441	83455	15-19-055-21 W4	Nebel, Robert	6.86	---	11.58	10.06	11.28	10.06	4.57	---	11-May-78	Domestic	New Well
442	83456	15-19-055-21 W4	Henderson, Garth	6.86	---	8.53	1.83	7.92	3.66	1.21	---	7-Jan-80	Stock	New Well
443	91484	07-04-056-20 W4	Taylor Petro	6.88	---	943.96	---	---	---	---	---	24-Mar-49	Industrial	Oil Exploratory
444	83395	SW-11-055-21 W4	Mohr, James	6.89	---	48.76	---	---	---	12.19	---	---	Domestic	Chemistry
445	159888	SE-11-055-21 W4	Johnston, Reg	6.89	---	51.81	---	---	44.81	12.19	---	8-May-65	Domestic	New Well
446	83423	11-17-055-21 W4	Cnr	6.89	---	21.33	20.12	21.34	20.12	---	---	9-Apr-85	Domestic	New Well
447	83422	NW-17-055-21 W4	Scotford Colony	6.91	---	39.62	---	---	38.10	---	---	1-Nov-73	Stock	New Well
448	91555	SE-17-056-20 W4	Sampert, Ray	6.92	---	19.2	4.27	17.37	---	4.87	---	19-Aug-86	Domestic & Stock	New Well
449	83165	SW-17-055-20 W4	Kittlitz, Elmer	6.92	---	74.67	---	---	---	39.62	---	---	Domestic	Chemistry
450	83164	SW-17-055-20 W4	Kittlitz, Adolph	6.92	---	115.82	---	---	---	36.57	---	---	Domestic	Chemistry

Table 5D-1. WATER WELLS WITHIN A 7.0km RADIUS

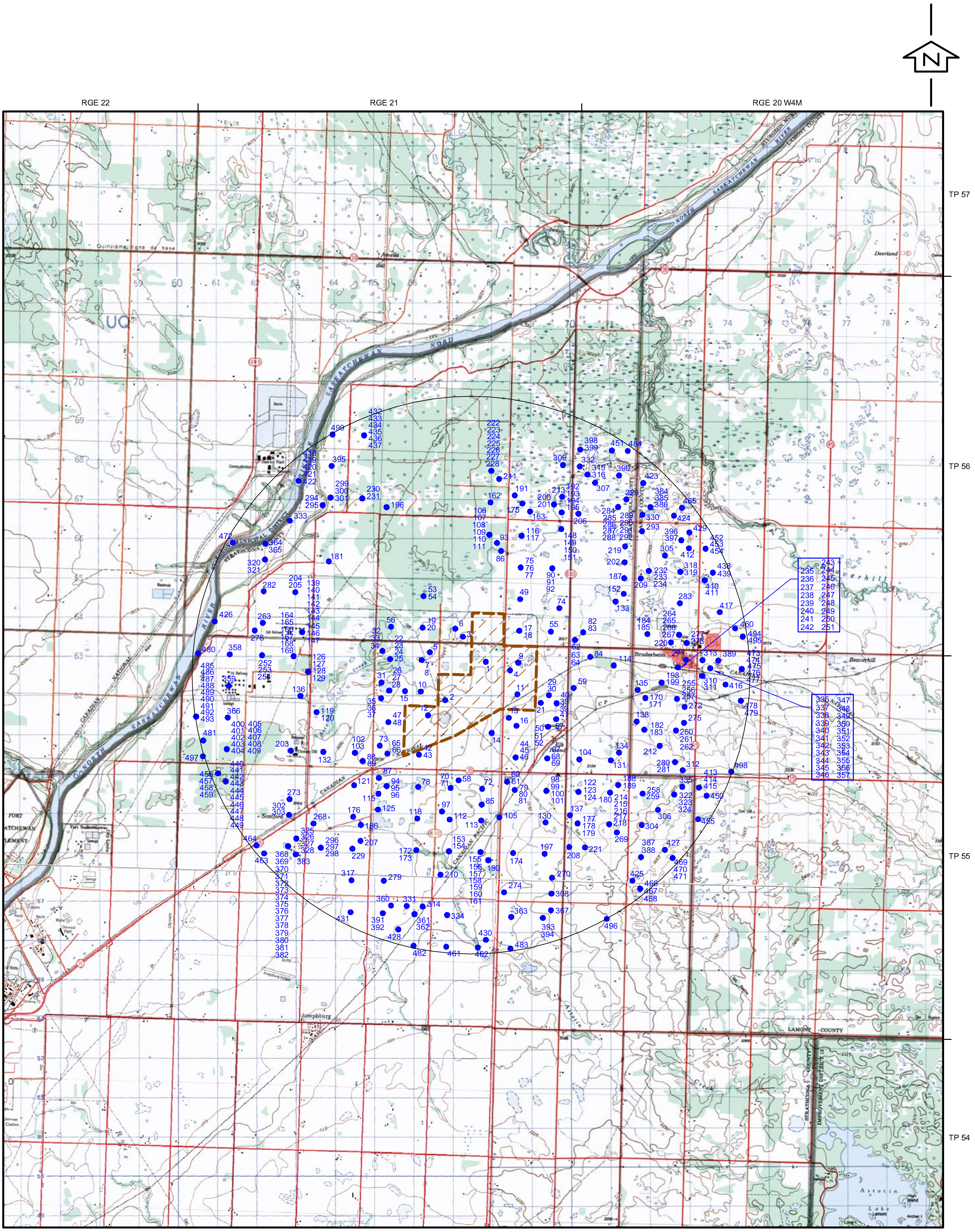
North American Oil Sands Corporation
North American Upgrader Project

Water Well Number (Figure 2)	Well ID*	Location	Well Owner	Distance from Site (km)	Direction from Site	Total Depth (m)	Top of Screen (m)	Bottom of Screen (m)	Bottom of Casing (m)	Depth to Water (m)	Bedrock Depth (m)	Date of Information (dd-mmm-yy)	Type of Work	Proposed Use for Well
451	83167	SW-17-055-20 W4	Kittlitz, Elmer	6.92	---	82.29	73.15	82.30	36.88	33.52	---	2-Dec-83	Domestic & Stock	New Well
452	83170	NE-17-055-20 W4	Fibke, William	6.93	---	27.73	---	---	---	12.19	---	---	Domestic	Chemistry
453	298077	NE-17-055-20 W4	Devry, Pat	6.93	---	74.67	51.82	73.15	35.05	32.91	---	30-Jul-01	Domestic	New Well
454	83172	NE-17-055-20 W4	Schneider, Howard	6.93	---	---	---	---	---	---	---	---	Domestic	Chemistry
455	289172	EH-07-056-21 W4	I.O.L. #1	6.93	---	30.48	---	---	---	---	---	6-Sep-97	Industrial	Test Hole-Abandoned
456	156866	NE-33-055-20 W4	Martinell, Brad (Can Oxy)#5	6.94	---	---	---	---	---	---	---	---	Domestic	Chemistry
457	83312	NE-33-055-20 W4	Gilbert, Thomas	6.94	---	9.14	---	---	---	---	---	---	Domestic	Chemistry
458	90353	NE-33-055-20 W4	Bruderheim, Town Of #Well 1	6.94	---	39.62	26.21	27.74	25.91	4.41	---	23-Jul-70	Municipal	New Well
459	90352	NE-33-055-20 W4	Bruderheim, Town Of #Well 2	6.94	---	38.1	0.00	0.00	24.99	5.18	---	20-Jul-70	Municipal	New Well
460	169169	NE-33-055-20 W4	Marko, Jim/Carol	6.94	---	11.88	---	---	---	---	---	---	Domestic	Chemistry
461	83290	SE-33-055-20 W4	Bruderheim, Village Of #5	6.94	---	36.57	---	---	---	7.92	---	13-Aug-70	Municipal	New Well
462	83289	SE-33-055-20 W4	Bruderheim, Village Of	6.94	---	35.05	---	---	---	5.94	---	3-Sep-70	Municipal	New Well
463	293392	NW-31-055-21 W4	Mckay, Brian	6.94	---	24.38	19.81	21.34	19.81	9.08	---	13-Sep-99	Domestic	New Well
464	83520	06-30-055-21 W4	Moser, Georgette	6.97	---	41.14	39.62	41.15	39.62	27.43	---	8-Aug-84	Domestic	New Well
465	83385	SE-10-055-21 W4	Mckaskill, John	6.99	---	18.28	---	---	---	---	---	---	Domestic	Chemistry
466	83397	SW-12-055-21 W4	Gabird, H.	6.99	---	53.34	---	---	46.63	12.19	---	1-Jan-65	Domestic & Stock	New Well

Notes:

--- - not available

* Alberta Environment, Alberta Groundwater Data on CDROM, Groundwater Information Centre (GIC), 2003; updates from Alberta Environment Groundwater Information Website as available



SCALE 1:100000

1 0 1 2

kilometres

LEGEND

▬ ▬ PROPOSED UPGRADER

482 ● WATER WELLS (LOCATIONS ARE APPROXIMATE AND NOT FIELD VERTIFIED)

REFERENCE MAP:
1:50 000, 83 H/10, 83 H/11, 83 H/14 AND 83 H/15.

Title:

WATER WELL LOCATIONS (WITHIN A 7 km RADIUS)

NORTH AMERICAN
OIL SANDS CORPORATION

Approved:	Revision Date:
TVD	07/05/01

File: 6198-TOPO-07.DWG

Drawn by:	Checked:	Fig. No.:
SC	RP	APP 5D

Appendix 7A - Field Water Quality Data

Antler Lake

EC (uS/cm)					DO (mg/L)				
Depth (m)	Summer	Fall	Winter	Spring	Depth (m)	Summer	Fall	Winter	Spring
0.00	358	438		385	0.00	9.97	16.13		4.88
0.25	358	438		385	0.25	9.7	16.15		4.65
0.50	358	438		385	0.50	9.79	16.13		4.65
0.75	358	438		385	0.75	9.75	16.09		4.35
1.00	358	438		385	1.00	9.63	16.02		4.34
1.25	358	436	694	385	1.25	9.63	15.85	1.85	4.25
1.50	358			385	1.50	9.67			4.23
1.75	358				1.75	9.12			
2.00	374				2.00	3.2			

Astotin Lake

Temperature (°C)					pH				
Depth (m)	Summer	Fall	Winter	Spring	Depth (m)	Summer	Fall	Winter	Spring
0.00	18.75	3.48		5.78	0.00	8.89	8.01		7.56
0.25	18.74	3.47		5.74	0.25	8.88	8.15		7.77
0.50	18.73	3.5		5.73	0.50	8.89	8.2		8.12
0.75	18.73	3.49		5.71	0.75	8.9	8.23		8.19
1.00	18.73	3.49		5.7	1.00	8.9	8.25		8.21
1.25	18.72	3.48	1.3	5.69	1.25	8.91	8.29	6.65	8.23
1.50	18.69	3.48		5.68	1.50	8.9	8.31		8.25
1.75		3.48		5.68	1.75		8.31		8.25
2.00		3.48		5.68	2.00		8.32		8.25
2.25		3.48		5.71	2.25		8.33		8.26
2.50		3.97		5.73	2.50		7.77		8.24
2.75				5.72	2.75				8.25
3.00				5.74	3.00				8.22
3.25				5.75	3.25				8.23
3.50				5.76	3.50				8.22

Astotin Lake - continued

EC (uS/cm)					DO (mg/L)				
Depth (m)	**Summer**	**Fall**	**Winter**	**Spring**	**Depth (m)**	**Summer**	**Fall**	**Winter**	**Spring**
0.00	376	477		456	0.00	8.81	13.7		9.08
0.25	376	468		452	0.25	8.8	13.42		8.92
0.50	376	467		450	0.50	8.71	13.32		8.94
0.75	376	467		451	0.75	8.7	13.25		8.71
1.00	376	467		451	1.00	8.64	13.23		8.62
1.25	377	467	522	452	1.25	8.74	13.14	4.1	8.52
1.50	376	467		452	1.50	8.58	13.12		8.48
1.75		468		453	1.75		13.12		8.44
2.00		468		454	2.00		13		8.39
2.25		468		458	2.25		12.91		8.32
2.50		467		458	2.50		11.63		8.34
2.75				463	2.75				8.07
3.00				463	3.00				7.87
3.25				466	3.25				7.81
3.50				466	3.50				7.66

	Summer	**Fall**	**Winter**	**Spring**
Antler Lake				
• Secchi	.2	-	-	.37
• Turbidity	-	39.36	-	12.62
Astotin Lake				
• Secchi	.5	.48	-	.8
• Turbidity	-	13.71	7.44	7

Appendix 7B -Volatile Hydrocarbons and Polycyclic Aromatic Hydrocarbons in Field Samples

SURFACE WATER QUALITY RESULTS

POLYCYCLIC AROMATIC HYDROCARBONS

Sample	Date	MSI Sample	Naphthalene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Acridine	Fluoranthene	Pyrene	Benz[a]anthracene	Chrysene	Benzo[b&j]fluoranthene	Benzo[k]fluoranthene	Benzo[a]pyrene	Indeno[1,2,3-cd]pyrene	Dibenz[a,h]anthracene	TOTAL PAH
Point		**Number**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
AST1	Aug 28/06	6198060828001	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	ND
Beaverhill Creek-AC1	Oct 25/06	6198061025005	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	ND
AST1	Jan 23/07	6198070123001	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	ND
AST1	May 1/07	6198070501004	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	
AST2	Aug 29/06	6198060829002	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	ND
Beaverhill Creek-AC2	Oct 25/06	6198061025002	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	ND
AST2	Apr 30/07	6198070430001	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	
AST3	Aug 29/06	6198060829003	0.0002	0.00016	0.00006	0.00006	<0.00001	<0.0002	<0.00004	0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	0.0005
Beaverhill Creek-AC3	Oct 25/06	6198061025003	0.00488	0.00078	0.00044	0.00054	<0.00001	<0.0002	0.00012	0.00008	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	0.0068
AST3	Apr 30/07	6198070430002	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	
AST4	Aug 29/06	6198060829004	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	ND
Astotin Lake	Oct 24/06	6198061024001	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	ND
Astotin Lake	Jan 24/07	6198070124004	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	ND
Astotin Lake dup	Jan 24/07	6198070124005	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	ND
AST4	May 2/07	6198070502006	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	ND
AST5	Aug 29/06	6198060829005	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	ND
Antler Lake	Oct 25/06	6198061025004	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	ND
Antler Lake	Jan 23/07	6198070123003	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	0.000029	<0.00001	<0.00005	<0.0001	<0.0001	0.000019	<0.0001	<0.00005	0.000048
AST5	May 1/07	6198070501003	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	ND
AST6	Aug 30/06	6198060830006	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	ND
North Sask River	Oct 26/06	6198061026006	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	ND
North Sask River	Jan 23/07	6198070123002	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	ND

Sample	Date	MSI Sample	Naphthalene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Acridine	Fluoranthene	Pyrene	Benz[a]anthracene	Chrysene	Benzo[b&j]fluoranthene	Benzo[k]fluoranthene	Benzo[a]pyrene	Indeno[1,2,3-cd]pyrene	Dibenz[a,h]anthracene	TOTAL PAH
Point		**Number**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
North Sask River 1	May 3/07	6198070503008	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	ND
North Sask River 1 dup	May 3/07	6198070503009	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	ND
Laboratory detection limit			**0.0001**	**0.0001**	**0.00005**	**0.00005**	**0.0001**	**0.0002**	**0.00004**	**0.00002**	**0.00001**	**0.00005**	**0.0001**	**0.0001**	**0.00001**	**0.0001**	**0.00005**	
Canadian drinking water guidelines**			**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**0.00001**$^{(MAC)}$	**NS**	**NS**	
AENV Freshwater Aquatic Life*			**0.0011^**	**0.0058^**	**0.003^**	**0.0004^**	**0.000012^**	**0.0044^**	**0.00004^**	**0.000025^**	**0.000018^**	**NS**	**NS**	**NS**	**0.000015^**	**NS**	**NS**	
AENV Agriculture - Irrigation*			**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	
AENV Agriculture-Livestock*			**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	

DISSOLVED HYDROCARBONS

Sample	Sample	MSI Sample	Benzene	Toluene	Ethylbenzene	Xylenes	F1[††] C_6-C_{10}	F2 $C_{>10}$-C_{16}	B[a]P
Point	**Date**	**Number**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**μg/L**
AST1	Aug 28/06	6198060828001	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.13	<0.00022
Beaverhill Creek-AC1	Oct 25/06	6198061025005	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.13	<0.00022
AST1	Jan 23/07	6198070123001	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.13	<0.00022
AST1	May 1/07	6198070501004	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.12	<0.00022
AST2	Aug 29/06	6198060829002	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.13	<0.00022
Beaverhill Creek-AC2	Oct 25/06	6198061025002	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.13	<0.00022
AST2	Apr 30/07	6198070430001	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.12	<0.00022
AST3	Aug 29/06	6198060829003	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.13	<0.00022
Beaverhill Creek-AC3	Oct 25/06	6198061025003	<0.0004	0.0015	<0.0004	<0.0008	<0.1	<0.13	<0.00022
AST3	Apr 30/07	6198070430002	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.12	<0.00022
AST4	Aug 29/06	6198060829004	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.13	<0.00022
Astotin Lake	Oct 24/06	6198061024001	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	---	<0.00022
Astotin Lake	Jan 24/07	6198070124004	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.13	<0.00022
Astotin Lake dup	Jan 24/07	6198070124005	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.13	<0.00022
AST4	May 2/07	6198070502006	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.12	<0.00022
AST5	Aug 29/06	6198060829005	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.13	<0.00022
Antler Lake	Oct 25/06	6198061025004	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.13	<0.00022
Antler Lake	Jan 23/07	6198070123003	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.13	0.0187
AST5	May 1/07	6198070501003	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.12	<0.00022
AST6	Aug 30/06	6198060830006	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.13	<0.00022
North Sask River	Oct 26/06	6198061026006	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.13	<0.00022
North Sask River	Jan 23/07	6198070123002	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.13	<0.00022
North Sask River 1	May 3/07	6198070503008	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.12	<0.00022
North Sask River 1 dup	May 3/07	6198070503009	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.12	<0.00022
Laboratory detection limit			**0.0004**	**0.0004**	**0.0004**	**0.0008**	**0.1**	**0.13**	**0.00022**
CCME Water Quality Guidelines - Freshwater**			**0.37**	**0.002**	**0.090**	**NS**	**NS**	**NS**	**NS**

Notes:

B[a]P	- equivalent benzo[a]pyrene concentration
NS	- guideline not specified
**	- Canadian Water Quality Guidelines for the Protection of Aquatic Life (CCME, 1999)
††	- F1 excludes BTEX
Italics	- indicate values do not meet CCME Freshwater Aquatic Life criteria

Appendix 7B - Dissolved Hydrocarbons and PAHs in Water Samples from the 2006-2007 Field Studies

Sample Point	Sample Date	MSI Sample Number	Benzene mg/L	Toluene mg/L	Ethylbenzene mg/L	Xylenes mg/L	F1††C_6-C_{10} mg/L	F2 $C_{>10}$-C_{16} mg/L	B[a]P µg/L
AST1	Aug 28-06	6198060828001	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.13	<0.00022
Beaverhill Creek-AC1	Oct 25-06	6198061025005	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.13	<0.00022
AST1	Jan 23-07	6198070123001	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.13	<0.00022
AST1	May 1-07	6198070501004	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.12	<0.00022
AST2	Aug 29-06	6198060829002	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.13	<0.00022
Beaverhill Creek-AC2	Oct 25-06	6198061025002	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.13	<0.00022
AST2	Apr 30-07	6198070430001	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.12	<0.00022
AST3	Aug 29-06	6198060829003	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.13	<0.00022
Beaverhill Creek-AC3	Oct 25-06	6198061025003	<0.0004	0.0015	<0.0004	<0.0008	<0.1	<0.13	<0.00022
AST3	Apr 30-07	6198070430002	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.12	<0.00022
AST4	Aug 29-06	6198060829004	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.13	<0.00022
Astotin Lake	Oct 24-06	6198061024001	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	---	<0.00022
Astotin Lake	Jan 24-07	6198070124004	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.13	<0.00022
Astotin Lake dup	Jan 24-07	6198070124005	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.13	<0.00022
AST4	May 2-07	6198070502006	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.12	<0.00022
AST5	Aug 29-06	6198060829005	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.13	<0.00022
Antler Lake	Oct 25-06	6198061025004	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.13	<0.00022
Antler Lake	Jan 23-07	6198070123003	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.13	0.0187
AST5	May 1-07	6198070501003	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.12	<0.00022
AST6	Aug 30-06	6198060830006	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.13	<0.00022
North Sask River	Oct 26-06	6198061026006	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.13	<0.00022
North Sask River	Jan 23-07	6198070123002	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.13	<0.00022
North Sask River 1	May 3-07	6198070503008	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.12	<0.00022
North Sask River 1 dup	May 3-07	6198070503009	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.12	<0.00022
Laboratory detection limit			**0.0004**	**0.0004**	**0.0004**	**0.0008**	**0.1**	**0.13**	**0.00022**
CCME Water Quality Guidelines - Freshwater**			**0.37**	**0.002**	**0.090**	**NS**	**NS**	**NS**	**NS**

Notes:

B[a]P	- equivalent benzo[a]pyrene concentration
NS	- guideline not specified
**	- Canadian Water Quality Guidelines for the Protection of Aquatic Life (CCME, 1999)
††	- F1 excludes BTEX
Italics	- indicate values do not meet CCME Freshwater Aquatic Life criteria

Appendix 7B - Dissolved Hydrocarbons and PAHs in Water Samples from the 2006-2007 Field Studies

Sample Point	Date	MSI Sample Number	Naphthalene mg/L	Acenaphthene mg/L	Fluorene mg/L	Phenanthrene mg/L	Anthracene mg/L	Acridine mg/L	Fluoranthene mg/L	Pyrene mg/L	Benz[a]anthracene mg/L	Chrysene mg/L	Benzo[b&j]fluoranthene mg/L	Benzo[k]fluoranthene mg/L	Benzo[a]pyrene mg/L	Indeno[1,2,3-cd]pyrene mg/L	Dibenz[a,h]anthracene mg/L	TOTAL PAH mg/L
AST1	Aug 28-06	6198060828001	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	ND
Beaverhill Creek-AC1	Oct 25-06	6198061025005	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	ND
AST1	Jan 23-07	6198070123001	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	ND
AST1	May 1-07	6198070501004	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	
AST2	Aug 29-06	6198060829002	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	ND
Beaverhill Creek-AC2	Oct 25-06	6198061025002	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	ND
AST2	Apr 30-07	6198070430001	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	
AST3	Aug 29-06	6198060829003	0.0002	0.00016	0.00006	0.00006	<0.00001	<0.0002	<0.00004	0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	0.0005
Beaverhill Creek-AC3	Oct 25-06	6198061025003	0.00488	0.00078	0.00044	0.00054	<0.00001	<0.0002	0.00012	0.00008	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	0.0068
AST3	Apr 30-07	6198070430002	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	
AST4	Aug 29-06	6198060829004	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	ND
Astotin Lake	Oct 24-06	6198061024001	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	ND
Astotin Lake	Jan 24-07	6198070124004	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	ND
Astotin Lake dup	Jan 24-07	6198070124005	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	ND
AST4	May 2-07	6198070502006	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	ND
AST5	Aug 29-06	6198060829005	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	ND
Antler Lake	Oct 25-06	6198061025004	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	ND
Antler Lake	Jan 23-07	6198070123003	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	0.000029	<0.00001	<0.00005	<0.0001	<0.0001	0.000019	<0.0001	<0.00005	0.000048
AST5	May 1-07	6198070501003	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	ND
AST6	Aug 30-06	6198060830006	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	ND
North Sask River	Oct 26-06	6198061026006	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	ND
North Sask River	Jan 23-07	6198070123002	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	ND
North Sask River 1	May 3-07	6198070503008	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	ND
North Sask River 1 dup	May 3-07	6198070503009	<0.0001	<0.0001	<0.00005	<0.00005	<0.00001	<0.0002	<0.00004	<0.00002	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.0001	<0.00005	ND
Laboratory detection limit			**0.0001**	**0.0001**	**0.00005**	**0.00005**	**0.0001**	**0.0002**	**0.00004**	**0.00002**	**0.00001**	**0.00005**	**0.0001**	**0.0001**	**0.00001**	**0.0001**	**0.00005**	**-**
Canadian drinking water guidelines**			**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**0.00001$^{(MAC)}$**	**NS**	**NS**	
AENV Freshwater Aquatic Life*			**0.0011^**	**0.0058^**	**0.003^**	**0.0004^**	**0.000012^**	**0.0044^**	**0.00004^**	**0.000025^**	**0.000018^**	**NS**	**NS**	**NS**	**0.000015^**	**NS**	**NS**	
AENV Agriculture - Irrigation*			**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	
AENV Agriculture-Livestock*			**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	

Notes:

NS - not specified
^{MAC} - maximum acceptable concentration based on health effects
^ - Canadian Water Quality Guidelines for the Protection of Aquatic Life (CCME, 2005)
* - Alberta Environment Surface Water Quality Guidelines for use in Alberta (AENV, 1999)
** - Summary of Guidelines for Canadian Drinking Water Quality (Health Canada, 2004)
Italics - indicates values do not meet drinking water guidelines

Appendix 7C - Results of CORMIX Modelling – $7Q_{10}$ Flow

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 ----------------------------------------------------------------------------
                       CORMIX MIXING ZONE EXPERT SYSTEM
         Subsystem CORMIX2:  Multiport Diffuser Discharges
                        CORMIX Version 5.0GT
                     HYDRO2 Version 5.0.0.0 March 2007
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:   Sturgeon upgrader
 Design case:       7Q10 flows
 FILE NAME:         \\S...\7Q10_run_North American_multiport_10_newflow.prd
 Time stamp:        Wed Oct 31 16:25:27 2007

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =    100.00  AS    =    100.00  QA    =     60.00  ICHREG= 1
 HA    =      1.00  HD    =      1.30
 UA    =      0.600 F     =      0.066 USTAR =0.5449E-01
 UW    =      2.000 UWSTAR=0.2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =  999.9750

DIFFUSER DISCHARGE PARAMETERS (metric units)
 Diffuser type:     DITYPE= alternating_perpendicular
 BANK  =  RIGHT     DISTB =      9.35  YB1   =      8.00  YB2   =     10.70
 LD    =      2.70  NOPEN =   10       SPAC  =      0.30
 D0    =      0.100 A0    =      0.008 H0    =      0.30  SUB0  =      1.00
 Nozzle/port arrangement:   near_vertical_discharge
 GAMMA =     90.00  THETA =     90.00  SIGMA =      0.00  BETA  =     90.00
 U0    =      1.127 Q0    =      0.089       =0.8850E-01
 RHO0  =  997.2973  DRHO0 =0.2678E+01  GP0   =0.2626E-01
 C0    =0.1000E+03  CUNITS=  %
 IPOLL =  1         KS    =0.0000E+00  KD    =0.0000E+00

FLUX VARIABLES - PER UNIT DIFFUSER LENGTH (metric units)
 q0    =0.3278E-01  m0    =0.3693E-01  j0    =0.8607E-03  SIGNJ0=      1.0
 Associated 2-d length scales (meters)
 lQ=B  =      0.029 lM    =      4.08  lm    =      0.10
 lmp   =  99999.00  lbp   =  99999.00  la    =  99999.00

FLUX VARIABLES - ENTIRE DIFFUSER (metric units)
 Q0    =0.8850E-01  M0    =0.9972E-01  J0    =0.2324E-02
 Associated 3-d length scales (meters)
 LQ    =      0.09  LM    =      3.68  Lm    =      0.53  Lb    =      0.01
                                       Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     40.77  FRD0  =     21.99  R     =      1.88  PL    =      2.
 (slot)             (port/nozzle)


FLOW CLASSIFICATION
```

```
 2222222222222222222222222222222222222222222
 2  Flow class (CORMIX2)      =    MU8    2
 2  Applicable layer depth HS =     1.30  2
 2222222222222222222222222222222222222222222

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    =0.1000E+03  CUNITS=  %
 NTOX  =  0
 NSTD  =  0
 REGMZ =  1
 REGSPC=  1         XREG  =   1293.00  WREG  =      0.00  AREG  =      0.00
 XINT  =  20000.00  XMAX  =  20000.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and the diffuser mid-point:
         9.35 m  from the RIGHT bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 200 display intervals per module
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
BEGIN MOD201: DIFFUSER DISCHARGE MODULE

 Due to complex near-field motions:  EQUIVALENT SLOT DIFFUSER (2-D) GEOMETRY

 Profile definitions:
   BV = Gaussian 1/e (37%) half-width, in vertical plane normal to trajectory
   BH = top-hat half-width, in horizontal plane normal to trajectory
   S  = hydrodynamic centerline dilution
   C  = centerline concentration (includes reaction effects, if any)

       X        Y       Z        S       C       BV       BH
      0.00     0.00    0.30     1.0 0.100E+03   0.02     1.35

END OF MOD201: DIFFUSER DISCHARGE MODULE
-----------------------------------------------------------------------------
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BEGIN MOD277: UNSTABLE NEAR-FIELD ZONE OF ALTERNATING PERPENDICULAR DIFFUSER

 Because of the strong ambient current the diffuser plume of this crossflowing
   discharge gets RAPIDLY DEFLECTED.
 A near-field zone is formed that is VERTICALLY FULLY MIXED over the entire
   layer depth.  Full mixing is achieved at a downstream distance of about
   five (5) layer depths.

 Profile definitions:
   BV = layer depth (vertically mixed)
   BH = top-hat half-width, measured horizontally in Y-direction
   S  = hydrodynamic average (bulk) dilution
   C  = average (bulk) concentration (includes reaction effects, if any)

       X        Y       Z        S       C       BV       BH
      0.00     0.00    0.30     1.0 0.100E+03   0.02     1.35
      0.03     0.00    0.30     2.6 0.382E+02   0.03     1.35
      0.06     0.00    0.30     3.3 0.304E+02   0.04     1.35
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   0.10     0.00    0.31     3.8 0.263E+02   0.04     1.35
   0.13     0.00    0.31     4.2 0.236E+02   0.05     1.35
   0.16     0.00    0.31     4.6 0.217E+02   0.06     1.35
   0.19     0.00    0.31     5.0 0.202E+02   0.06     1.35
   0.23     0.00    0.31     5.3 0.189E+02   0.07     1.35
   0.26     0.00    0.31     5.6 0.179E+02   0.07     1.35
   0.29     0.00    0.32     5.9 0.171E+02   0.08     1.35
   0.32     0.00    0.32     6.1 0.164E+02   0.09     1.35
   0.36     0.00    0.32     6.4 0.157E+02   0.09     1.35
   0.39     0.00    0.32     6.6 0.151E+02   0.10     1.35
   0.42     0.00    0.32     6.8 0.146E+02   0.11     1.35
   0.45     0.00    0.32     7.1 0.142E+02   0.11     1.35
   0.49     0.00    0.33     7.3 0.138E+02   0.12     1.35
   0.52     0.00    0.33     7.5 0.134E+02   0.13     1.35
   0.55     0.00    0.33     7.7 0.130E+02   0.13     1.35
   0.59     0.00    0.33     7.9 0.127E+02   0.14     1.35
   0.62     0.00    0.33     8.0 0.124E+02   0.14     1.35
   0.65     0.00    0.34     8.2 0.121E+02   0.15     1.35
   0.68     0.00    0.34     8.4 0.119E+02   0.16     1.35
   0.72     0.00    0.34     8.6 0.116E+02   0.16     1.35
   0.75     0.00    0.34     8.8 0.114E+02   0.17     1.35
   0.78     0.00    0.34     8.9 0.112E+02   0.18     1.35
   0.81     0.00    0.34     9.1 0.110E+02   0.18     1.35
   0.85     0.00    0.35     9.2 0.108E+02   0.19     1.35
   0.88     0.00    0.35     9.4 0.106E+02   0.20     1.35
   0.91     0.00    0.35     9.6 0.105E+02   0.20     1.35
   0.94     0.00    0.35     9.7 0.103E+02   0.21     1.35
   0.98     0.00    0.35     9.9 0.101E+02   0.21     1.35
   1.01     0.00    0.35    10.0 0.100E+02   0.22     1.35
   1.04     0.00    0.36    10.1 0.985E+01   0.23     1.35
   1.07     0.00    0.36    10.3 0.972E+01   0.23     1.35
   1.11     0.00    0.36    10.4 0.959E+01   0.24     1.35
   1.14     0.00    0.36    10.6 0.946E+01   0.25     1.35
   1.17     0.00    0.36    10.7 0.934E+01   0.25     1.35
   1.20     0.00    0.36    10.8 0.923E+01   0.26     1.35
   1.24     0.00    0.37    11.0 0.912E+01   0.27     1.35
   1.27     0.00    0.37    11.1 0.901E+01   0.27     1.35
   1.30     0.00    0.37    11.2 0.891E+01   0.28     1.35
   1.33     0.00    0.37    11.4 0.881E+01   0.28     1.35
   1.37     0.00    0.37    11.5 0.871E+01   0.29     1.35
   1.40     0.00    0.38    11.6 0.862E+01   0.30     1.35
   1.43     0.00    0.38    11.7 0.853E+01   0.30     1.35
   1.46     0.00    0.38    11.8 0.844E+01   0.31     1.35
   1.50     0.00    0.38    12.0 0.836E+01   0.32     1.35
   1.53     0.00    0.38    12.1 0.827E+01   0.32     1.35
   1.56     0.00    0.38    12.2 0.819E+01   0.33     1.35
   1.59     0.00    0.39    12.3 0.812E+01   0.34     1.35
   1.63     0.00    0.39    12.4 0.804E+01   0.34     1.35
   1.66     0.00    0.39    12.5 0.797E+01   0.35     1.35
   1.69     0.00    0.39    12.7 0.790E+01   0.36     1.35
   1.72     0.00    0.39    12.8 0.783E+01   0.36     1.35
   1.76     0.00    0.39    12.9 0.776E+01   0.37     1.35
   1.79     0.00    0.40    13.0 0.770E+01   0.37     1.35
   1.82     0.00    0.40    13.1 0.763E+01   0.38     1.35
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   1.85      0.00     0.40     13.2 0.757E+01   0.39      1.35
   1.89      0.00     0.40     13.3 0.751E+01   0.39      1.35
   1.92      0.00     0.40     13.4 0.745E+01   0.40      1.35
   1.95      0.00     0.41     13.5 0.739E+01   0.41      1.35
   1.98      0.00     0.41     13.6 0.734E+01   0.41      1.35
   2.02      0.00     0.41     13.7 0.728E+01   0.42      1.35
   2.05      0.00     0.41     13.8 0.723E+01   0.43      1.35
   2.08      0.00     0.41     13.9 0.717E+01   0.43      1.35
   2.11      0.00     0.41     14.0 0.712E+01   0.44      1.35
   2.15      0.00     0.42     14.1 0.707E+01   0.44      1.35
   2.18      0.00     0.42     14.2 0.702E+01   0.45      1.35
   2.21      0.00     0.42     14.3 0.698E+01   0.46      1.35
   2.24      0.00     0.42     14.4 0.693E+01   0.46      1.35
   2.28      0.00     0.42     14.5 0.688E+01   0.47      1.35
   2.31      0.00     0.42     14.6 0.684E+01   0.48      1.35
   2.34      0.00     0.43     14.7 0.679E+01   0.48      1.35
   2.37      0.00     0.43     14.8 0.675E+01   0.49      1.35
   2.41      0.00     0.43     14.9 0.671E+01   0.50      1.35
   2.44      0.00     0.43     15.0 0.666E+01   0.50      1.35
   2.47      0.00     0.43     15.1 0.662E+01   0.51      1.35
   2.50      0.00     0.43     15.2 0.658E+01   0.51      1.35
   2.54      0.00     0.44     15.3 0.654E+01   0.52      1.35
   2.57      0.00     0.44     15.4 0.650E+01   0.53      1.35
   2.60      0.00     0.44     15.5 0.647E+01   0.53      1.35
   2.63      0.00     0.44     15.6 0.643E+01   0.54      1.35
   2.67      0.00     0.44     15.6 0.639E+01   0.55      1.35
   2.70      0.00     0.45     15.7 0.636E+01   0.55      1.35
   2.73      0.00     0.45     15.8 0.632E+01   0.56      1.35
   2.76      0.00     0.45     15.9 0.629E+01   0.57      1.35
   2.80      0.00     0.45     16.0 0.625E+01   0.57      1.35
   2.83      0.00     0.45     16.1 0.622E+01   0.58      1.35
   2.86      0.00     0.45     16.2 0.618E+01   0.58      1.35
   2.89      0.00     0.46     16.3 0.615E+01   0.59      1.35
   2.93      0.00     0.46     16.3 0.612E+01   0.60      1.35
   2.96      0.00     0.46     16.4 0.609E+01   0.60      1.35
   2.99      0.00     0.46     16.5 0.606E+01   0.61      1.35
   3.02      0.00     0.46     16.6 0.603E+01   0.62      1.35
   3.06      0.00     0.46     16.7 0.600E+01   0.62      1.35
   3.09      0.00     0.47     16.8 0.597E+01   0.63      1.35
   3.12      0.00     0.47     16.8 0.594E+01   0.64      1.35
   3.15      0.00     0.47     16.9 0.591E+01   0.64      1.35
   3.19      0.00     0.47     17.0 0.588E+01   0.65      1.35
   3.22      0.00     0.47     17.1 0.585E+01   0.66      1.35
   3.25      0.00     0.48     17.2 0.582E+01   0.66      1.35
   3.28      0.00     0.48     17.3 0.580E+01   0.67      1.35
   3.32      0.00     0.48     17.3 0.577E+01   0.67      1.35
   3.35      0.00     0.48     17.4 0.574E+01   0.68      1.35
   3.38      0.00     0.48     17.5 0.572E+01   0.69      1.35
   3.41      0.00     0.48     17.6 0.569E+01   0.69      1.35
   3.45      0.00     0.49     17.7 0.567E+01   0.70      1.35
   3.48      0.00     0.49     17.7 0.564E+01   0.71      1.35
   3.51      0.00     0.49     17.8 0.562E+01   0.71      1.35
   3.54      0.00     0.49     17.9 0.559E+01   0.72      1.35
   3.58      0.00     0.49     18.0 0.557E+01   0.73      1.35
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      3.61     0.00    0.49    18.0 0.554E+01   0.73     1.35
      3.64     0.00    0.50    18.1 0.552E+01   0.74     1.35
      3.67     0.00    0.50    18.2 0.550E+01   0.74     1.35
      3.71     0.00    0.50    18.3 0.547E+01   0.75     1.35
      3.74     0.00    0.50    18.3 0.545E+01   0.76     1.35
      3.77     0.00    0.50    18.4 0.543E+01   0.76     1.35
      3.80     0.00    0.50    18.5 0.541E+01   0.77     1.35
      3.84     0.00    0.51    18.6 0.539E+01   0.78     1.35
      3.87     0.00    0.51    18.6 0.536E+01   0.78     1.35
      3.90     0.00    0.51    18.7 0.534E+01   0.79     1.35
      3.93     0.00    0.51    18.8 0.532E+01   0.80     1.35
      3.97     0.00    0.51    18.9 0.530E+01   0.80     1.35
      4.00     0.00    0.52    18.9 0.528E+01   0.81     1.35
      4.03     0.00    0.52    19.0 0.526E+01   0.81     1.35
      4.06     0.00    0.52    19.1 0.524E+01   0.82     1.35
      4.10     0.00    0.52    19.2 0.522E+01   0.83     1.35
      4.13     0.00    0.52    19.2 0.520E+01   0.83     1.35
      4.16     0.00    0.52    19.3 0.518E+01   0.84     1.35
      4.19     0.00    0.53    19.4 0.516E+01   0.85     1.35
      4.23     0.00    0.53    19.4 0.514E+01   0.85     1.35
      4.26     0.00    0.53    19.5 0.513E+01   0.86     1.35
      4.29     0.00    0.53    19.6 0.511E+01   0.87     1.35
      4.32     0.00    0.53    19.7 0.509E+01   0.87     1.35
      4.36     0.00    0.53    19.7 0.507E+01   0.88     1.35
      4.39     0.00    0.54    19.8 0.505E+01   0.89     1.35
      4.42     0.00    0.54    19.9 0.504E+01   0.89     1.35
      4.45     0.00    0.54    19.9 0.502E+01   0.90     1.35
      4.49     0.00    0.54    20.0 0.500E+01   0.90     1.35
      4.52     0.00    0.54    20.1 0.498E+01   0.91     1.35
      4.55     0.00    0.54    20.1 0.497E+01   0.92     1.35
      4.58     0.00    0.55    20.2 0.495E+01   0.92     1.35
      4.61     0.00    0.55    20.3 0.493E+01   0.93     1.35
      4.65     0.00    0.55    20.3 0.492E+01   0.94     1.35
      4.68     0.00    0.55    20.4 0.490E+01   0.94     1.35
      4.71     0.00    0.55    20.5 0.488E+01   0.95     1.35
      4.74     0.00    0.56    20.5 0.487E+01   0.96     1.35
      4.78     0.00    0.56    20.6 0.485E+01   0.96     1.35
      4.81     0.00    0.56    20.7 0.484E+01   0.97     1.35
      4.84     0.00    0.56    20.7 0.482E+01   0.97     1.35
      4.87     0.00    0.56    20.8 0.481E+01   0.98     1.35
      4.91     0.00    0.56    20.9 0.479E+01   0.99     1.35
      4.94     0.00    0.57    20.9 0.478E+01   0.99     1.35
      4.97     0.00    0.57    21.0 0.476E+01   1.00     1.35
      5.00     0.00    0.57    21.1 0.475E+01   1.01     1.35
      5.04     0.00    0.57    21.1 0.473E+01   1.01     1.35
      5.07     0.00    0.57    21.2 0.472E+01   1.02     1.35
      5.10     0.00    0.57    21.3 0.470E+01   1.03     1.35
      5.13     0.00    0.58    21.3 0.469E+01   1.03     1.35
      5.17     0.00    0.58    21.4 0.467E+01   1.04     1.35
      5.20     0.00    0.58    21.5 0.466E+01   1.04     1.35
      5.23     0.00    0.58    21.5 0.465E+01   1.05     1.35
      5.26     0.00    0.58    21.6 0.463E+01   1.06     1.35
      5.30     0.00    0.59    21.6 0.462E+01   1.06     1.35
      5.33     0.00    0.59    21.7 0.461E+01   1.07     1.35
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      5.36     0.00    0.59    21.8 0.459E+01   1.08     1.35
      5.39     0.00    0.59    21.8 0.458E+01   1.08     1.35
      5.43     0.00    0.59    21.9 0.457E+01   1.09     1.35
      5.46     0.00    0.59    22.0 0.455E+01   1.10     1.35
      5.49     0.00    0.60    22.0 0.454E+01   1.10     1.35
      5.52     0.00    0.60    22.1 0.453E+01   1.11     1.35
      5.56     0.00    0.60    22.1 0.452E+01   1.11     1.35
      5.59     0.00    0.60    22.2 0.450E+01   1.12     1.35
      5.62     0.00    0.60    22.3 0.449E+01   1.13     1.35
      5.65     0.00    0.60    22.3 0.448E+01   1.13     1.35
      5.69     0.00    0.61    22.4 0.447E+01   1.14     1.35
      5.72     0.00    0.61    22.5 0.445E+01   1.15     1.35
      5.75     0.00    0.61    22.5 0.444E+01   1.15     1.35
      5.78     0.00    0.61    22.6 0.443E+01   1.16     1.35
      5.82     0.00    0.61    22.6 0.442E+01   1.17     1.35
      5.85     0.00    0.61    22.7 0.441E+01   1.17     1.35
      5.88     0.00    0.62    22.8 0.439E+01   1.18     1.35
      5.91     0.00    0.62    22.8 0.438E+01   1.19     1.35
      5.95     0.00    0.62    22.9 0.437E+01   1.19     1.35
      5.98     0.00    0.62    22.9 0.436E+01   1.20     1.35
      6.01     0.00    0.62    23.0 0.435E+01   1.20     1.35
      6.04     0.00    0.63    23.1 0.434E+01   1.21     1.35
      6.08     0.00    0.63    23.1 0.433E+01   1.22     1.35
      6.11     0.00    0.63    23.2 0.432E+01   1.22     1.35
      6.14     0.00    0.63    23.2 0.430E+01   1.23     1.35
      6.17     0.00    0.63    23.3 0.429E+01   1.24     1.35
      6.21     0.00    0.63    23.4 0.428E+01   1.24     1.35
      6.24     0.00    0.64    23.4 0.427E+01   1.25     1.35
      6.27     0.00    0.64    23.5 0.426E+01   1.26     1.35
      6.30     0.00    0.64    23.5 0.425E+01   1.26     1.35
      6.34     0.00    0.64    23.6 0.424E+01   1.27     1.35
      6.37     0.00    0.64    23.6 0.423E+01   1.27     1.35
      6.40     0.00    0.64    23.7 0.422E+01   1.28     1.35
      6.43     0.00    0.65    23.8 0.421E+01   1.29     1.35
      6.47     0.00    0.65    23.8 0.420E+01   1.29     1.35
      6.50     0.00    0.65    23.9 0.419E+01   1.30     1.35
 Cumulative travel time =          21.5988 sec
   Plume centerline may exhibit slight discontinuities in transition
     to subsequent far-field module.

END OF MOD277: UNSTABLE NEAR-FIELD ZONE OF ALTERNATING PERPENDICULAR DIFFUSER
-----------------------------------------------------------------------------
** End of NEAR-FIELD REGION (NFR) **
-----------------------------------------------------------------------------
BEGIN MOD241: BUOYANT AMBIENT SPREADING

 Discharge is non-buoyant or weakly buoyant.
   Therefore BUOYANT SPREADING REGIME is ABSENT.

END OF MOD241: BUOYANT AMBIENT SPREADING
-----------------------------------------------------------------------------
 Due to the attachment or proximity of the plume tothe bottom, the bottom
   coordinate for the FAR-FIELD differs from the ambient depth, ZFB = 0 m.
 In a subsequent analysis set "depth at discharge" equal to "ambient depth".
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BEGIN MOD261: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

  Vertical diffusivity (initial value)   = 0.142E-01 m^2/s
  Horizontal diffusivity (initial value) = 0.177E-01 m^2/s

 Profile definitions:
   BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
      = or equal to layer depth, if fully mixed
   BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
        measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
   S  = hydrodynamic centerline dilution
   C  = centerline concentration (includes reaction effects, if any)

 Plume Stage 1 (not bank attached):
       X        Y       Z        S       C       BV       BH      ZU      ZL
      6.50     0.00    1.30    23.9 0.419E+01   1.30     1.35    1.30    0.00
 Plume interacts with BOTTOM.
 The passive diffusion plume becomes VERTICALLY FULLY MIXED within this
   prediction interval.
     11.12     0.00    1.30    26.5 0.377E+01   1.30     1.50    1.30    0.00
     15.74     0.00    1.30    28.9 0.346E+01   1.30     1.64    1.30    0.00
     20.36     0.00    1.30    31.1 0.321E+01   1.30     1.77    1.30    0.00
     24.98     0.00    1.30    33.2 0.301E+01   1.30     1.88    1.30    0.00
     29.60     0.00    1.30    35.1 0.285E+01   1.30     1.99    1.30    0.00
     34.22     0.00    1.30    37.0 0.270E+01   1.30     2.10    1.30    0.00
     38.84     0.00    1.30    38.7 0.258E+01   1.30     2.20    1.30    0.00
     43.46     0.00    1.30    40.4 0.247E+01   1.30     2.29    1.30    0.00
     48.09     0.00    1.30    42.0 0.238E+01   1.30     2.38    1.30    0.00
     52.71     0.00    1.30    43.6 0.229E+01   1.30     2.47    1.30    0.00
     57.33     0.00    1.30    45.1 0.222E+01   1.30     2.56    1.30    0.00
     61.95     0.00    1.30    46.5 0.215E+01   1.30     2.64    1.30    0.00
     66.57     0.00    1.30    47.9 0.209E+01   1.30     2.72    1.30    0.00
     71.19     0.00    1.30    49.3 0.203E+01   1.30     2.80    1.30    0.00
     75.81     0.00    1.30    50.6 0.197E+01   1.30     2.87    1.30    0.00
     80.43     0.00    1.30    51.9 0.193E+01   1.30     2.95    1.30    0.00
     85.05     0.00    1.30    53.2 0.188E+01   1.30     3.02    1.30    0.00
     89.67     0.00    1.30    54.4 0.184E+01   1.30     3.09    1.30    0.00
     94.29     0.00    1.30    55.6 0.180E+01   1.30     3.16    1.30    0.00
     98.91     0.00    1.30    56.8 0.176E+01   1.30     3.22    1.30    0.00
    103.53     0.00    1.30    58.0 0.172E+01   1.30     3.29    1.30    0.00
    108.15     0.00    1.30    59.1 0.169E+01   1.30     3.35    1.30    0.00
    112.77     0.00    1.30    60.2 0.166E+01   1.30     3.42    1.30    0.00
    117.39     0.00    1.30    61.3 0.163E+01   1.30     3.48    1.30    0.00
    122.01     0.00    1.30    62.4 0.160E+01   1.30     3.54    1.30    0.00
    126.64     0.00    1.30    63.5 0.158E+01   1.30     3.60    1.30    0.00
    131.26     0.00    1.30    64.5 0.155E+01   1.30     3.66    1.30    0.00
    135.88     0.00    1.30    65.5 0.153E+01   1.30     3.72    1.30    0.00
    140.50     0.00    1.30    66.5 0.150E+01   1.30     3.77    1.30    0.00
    145.12     0.00    1.30    67.5 0.148E+01   1.30     3.83    1.30    0.00
    149.74     0.00    1.30    68.5 0.146E+01   1.30     3.89    1.30    0.00
    154.36     0.00    1.30    69.5 0.144E+01   1.30     3.94    1.30    0.00
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   158.98      0.00     1.30     70.4 0.142E+01   1.30      3.99     1.30     0.00
   163.60      0.00     1.30     71.3 0.140E+01   1.30      4.05     1.30     0.00
   168.22      0.00     1.30     72.3 0.138E+01   1.30      4.10     1.30     0.00

   172.84      0.00     1.30     73.2 0.137E+01   1.30      4.15     1.30     0.00
   177.46      0.00     1.30     74.1 0.135E+01   1.30      4.20     1.30     0.00
   182.08      0.00     1.30     75.0 0.133E+01   1.30      4.25     1.30     0.00
   186.70      0.00     1.30     75.9 0.132E+01   1.30      4.30     1.30     0.00
   191.32      0.00     1.30     76.7 0.130E+01   1.30      4.35     1.30     0.00
   195.94      0.00     1.30     77.6 0.129E+01   1.30      4.40     1.30     0.00
   200.57      0.00     1.30     78.5 0.127E+01   1.30      4.45     1.30     0.00
   205.19      0.00     1.30     79.3 0.126E+01   1.30      4.50     1.30     0.00
   209.81      0.00     1.30     80.1 0.125E+01   1.30      4.55     1.30     0.00
   214.43      0.00     1.30     81.0 0.124E+01   1.30      4.59     1.30     0.00
   219.05      0.00     1.30     81.8 0.122E+01   1.30      4.64     1.30     0.00
   223.67      0.00     1.30     82.6 0.121E+01   1.30      4.68     1.30     0.00
   228.29      0.00     1.30     83.4 0.120E+01   1.30      4.73     1.30     0.00
   232.91      0.00     1.30     84.2 0.119E+01   1.30      4.78     1.30     0.00
   237.53      0.00     1.30     85.0 0.118E+01   1.30      4.82     1.30     0.00
   242.15      0.00     1.30     85.7 0.117E+01   1.30      4.86     1.30     0.00
   246.77      0.00     1.30     86.5 0.116E+01   1.30      4.91     1.30     0.00
   251.39      0.00     1.30     87.3 0.115E+01   1.30      4.95     1.30     0.00
   256.01      0.00     1.30     88.0 0.114E+01   1.30      4.99     1.30     0.00
   260.63      0.00     1.30     88.8 0.113E+01   1.30      5.04     1.30     0.00
   265.25      0.00     1.30     89.5 0.112E+01   1.30      5.08     1.30     0.00
   269.87      0.00     1.30     90.3 0.111E+01   1.30      5.12     1.30     0.00
   274.49      0.00     1.30     91.0 0.110E+01   1.30      5.16     1.30     0.00
   279.12      0.00     1.30     91.7 0.109E+01   1.30      5.20     1.30     0.00
   283.74      0.00     1.30     92.5 0.108E+01   1.30      5.25     1.30     0.00
   288.36      0.00     1.30     93.2 0.107E+01   1.30      5.29     1.30     0.00
   292.98      0.00     1.30     93.9 0.107E+01   1.30      5.33     1.30     0.00
   297.60      0.00     1.30     94.6 0.106E+01   1.30      5.37     1.30     0.00
   302.22      0.00     1.30     95.3 0.105E+01   1.30      5.41     1.30     0.00
   306.84      0.00     1.30     96.0 0.104E+01   1.30      5.45     1.30     0.00
   311.46      0.00     1.30     96.7 0.103E+01   1.30      5.48     1.30     0.00
   316.08      0.00     1.30     97.4 0.103E+01   1.30      5.52     1.30     0.00
   320.70      0.00     1.30     98.0 0.102E+01   1.30      5.56     1.30     0.00
   325.32      0.00     1.30     98.7 0.101E+01   1.30      5.60     1.30     0.00
   329.94      0.00     1.30     99.4 0.101E+01   1.30      5.64     1.30     0.00
   334.56      0.00     1.30    100.1 0.999E+00   1.30      5.68     1.30     0.00
   339.18      0.00     1.30    100.7 0.993E+00   1.30      5.71     1.30     0.00
   343.80      0.00     1.30    101.4 0.986E+00   1.30      5.75     1.30     0.00
   348.42      0.00     1.30    102.0 0.980E+00   1.30      5.79     1.30     0.00
   353.05      0.00     1.30    102.7 0.974E+00   1.30      5.82     1.30     0.00
   357.67      0.00     1.30    103.3 0.968E+00   1.30      5.86     1.30     0.00
   362.29      0.00     1.30    104.0 0.962E+00   1.30      5.90     1.30     0.00
   366.91      0.00     1.30    104.6 0.956E+00   1.30      5.93     1.30     0.00
   371.53      0.00     1.30    105.2 0.950E+00   1.30      5.97     1.30     0.00
   376.15      0.00     1.30    105.9 0.945E+00   1.30      6.01     1.30     0.00
   380.77      0.00     1.30    106.5 0.939E+00   1.30      6.04     1.30     0.00
   385.39      0.00     1.30    107.1 0.934E+00   1.30      6.08     1.30     0.00
   390.01      0.00     1.30    107.7 0.928E+00   1.30      6.11     1.30     0.00
   394.63      0.00     1.30    108.3 0.923E+00   1.30      6.15     1.30     0.00
   399.25      0.00     1.30    109.0 0.918E+00   1.30      6.18     1.30     0.00
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   403.87      0.00     1.30   109.6 0.913E+00    1.30      6.22     1.30     0.00
   408.49      0.00     1.30   110.2 0.908E+00    1.30      6.25     1.30     0.00
   413.11      0.00     1.30   110.8 0.903E+00    1.30      6.28     1.30     0.00
   417.73      0.00     1.30   111.4 0.898E+00    1.30      6.32     1.30     0.00
   422.35      0.00     1.30   112.0 0.893E+00    1.30      6.35     1.30     0.00
   426.97      0.00     1.30   112.6 0.888E+00    1.30      6.39     1.30     0.00
   431.60      0.00     1.30   113.2 0.884E+00    1.30      6.42     1.30     0.00
   436.22      0.00     1.30   113.7 0.879E+00    1.30      6.45     1.30     0.00
   440.84      0.00     1.30   114.3 0.875E+00    1.30      6.49     1.30     0.00
   445.46      0.00     1.30   114.9 0.870E+00    1.30      6.52     1.30     0.00
   450.08      0.00     1.30   115.5 0.866E+00    1.30      6.55     1.30     0.00
   454.70      0.00     1.30   116.1 0.862E+00    1.30      6.58     1.30     0.00
   459.32      0.00     1.30   116.6 0.857E+00    1.30      6.62     1.30     0.00
   463.94      0.00     1.30   117.2 0.853E+00    1.30      6.65     1.30     0.00
   468.56      0.00     1.30   117.8 0.849E+00    1.30      6.68     1.30     0.00
   473.18      0.00     1.30   118.3 0.845E+00    1.30      6.71     1.30     0.00
   477.80      0.00     1.30   118.9 0.841E+00    1.30      6.74     1.30     0.00
   482.42      0.00     1.30   119.4 0.837E+00    1.30      6.78     1.30     0.00
   487.04      0.00     1.30   120.0 0.833E+00    1.30      6.81     1.30     0.00
   491.66      0.00     1.30   120.5 0.830E+00    1.30      6.84     1.30     0.00
   496.28      0.00     1.30   121.1 0.826E+00    1.30      6.87     1.30     0.00
   500.90      0.00     1.30   121.6 0.822E+00    1.30      6.90     1.30     0.00
   505.53      0.00     1.30   122.2 0.818E+00    1.30      6.93     1.30     0.00
   510.15      0.00     1.30   122.7 0.815E+00    1.30      6.96     1.30     0.00
   514.77      0.00     1.30   123.3 0.811E+00    1.30      6.99     1.30     0.00
   519.39      0.00     1.30   123.8 0.808E+00    1.30      7.02     1.30     0.00
   524.01      0.00     1.30   124.3 0.804E+00    1.30      7.05     1.30     0.00
   528.63      0.00     1.30   124.9 0.801E+00    1.30      7.08     1.30     0.00
   533.25      0.00     1.30   125.4 0.797E+00    1.30      7.11     1.30     0.00
   537.87      0.00     1.30   125.9 0.794E+00    1.30      7.14     1.30     0.00
   542.49      0.00     1.30   126.5 0.791E+00    1.30      7.17     1.30     0.00
   547.11      0.00     1.30   127.0 0.787E+00    1.30      7.20     1.30     0.00
   551.73      0.00     1.30   127.5 0.784E+00    1.30      7.23     1.30     0.00
   556.35      0.00     1.30   128.0 0.781E+00    1.30      7.26     1.30     0.00
   560.97      0.00     1.30   128.6 0.778E+00    1.30      7.29     1.30     0.00
   565.59      0.00     1.30   129.1 0.775E+00    1.30      7.32     1.30     0.00
   570.21      0.00     1.30   129.6 0.772E+00    1.30      7.35     1.30     0.00
   574.83      0.00     1.30   130.1 0.769E+00    1.30      7.38     1.30     0.00
   579.45      0.00     1.30   130.6 0.766E+00    1.30      7.41     1.30     0.00
   584.08      0.00     1.30   131.1 0.763E+00    1.30      7.44     1.30     0.00
   588.70      0.00     1.30   131.6 0.760E+00    1.30      7.47     1.30     0.00
   593.32      0.00     1.30   132.1 0.757E+00    1.30      7.50     1.30     0.00
   597.94      0.00     1.30   132.6 0.754E+00    1.30      7.52     1.30     0.00
   602.56      0.00     1.30   133.1 0.751E+00    1.30      7.55     1.30     0.00
   607.18      0.00     1.30   133.6 0.748E+00    1.30      7.58     1.30     0.00
   611.80      0.00     1.30   134.1 0.746E+00    1.30      7.61     1.30     0.00
   616.42      0.00     1.30   134.6 0.743E+00    1.30      7.64     1.30     0.00
   621.04      0.00     1.30   135.1 0.740E+00    1.30      7.66     1.30     0.00
   625.66      0.00     1.30   135.6 0.737E+00    1.30      7.69     1.30     0.00
   630.28      0.00     1.30   136.1 0.735E+00    1.30      7.72     1.30     0.00
   634.90      0.00     1.30   136.6 0.732E+00    1.30      7.75     1.30     0.00
   639.52      0.00     1.30   137.1 0.730E+00    1.30      7.78     1.30     0.00
   644.14      0.00     1.30   137.5 0.727E+00    1.30      7.80     1.30     0.00
   648.76      0.00     1.30   138.0 0.724E+00    1.30      7.83     1.30     0.00
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   653.38      0.00      1.30    138.5 0.722E+00    1.30       7.86      1.30      0.00
   658.01      0.00      1.30    139.0 0.719E+00    1.30       7.89      1.30      0.00
   662.63      0.00      1.30    139.5 0.717E+00    1.30       7.91      1.30      0.00
   667.25      0.00      1.30    139.9 0.715E+00    1.30       7.94      1.30      0.00
   671.87      0.00      1.30    140.4 0.712E+00    1.30       7.97      1.30      0.00
   676.49      0.00      1.30    140.9 0.710E+00    1.30       7.99      1.30      0.00
   681.11      0.00      1.30    141.4 0.707E+00    1.30       8.02      1.30      0.00
   685.73      0.00      1.30    141.8 0.705E+00    1.30       8.05      1.30      0.00
   690.35      0.00      1.30    142.3 0.703E+00    1.30       8.07      1.30      0.00
   694.97      0.00      1.30    142.8 0.700E+00    1.30       8.10      1.30      0.00
   699.59      0.00      1.30    143.2 0.698E+00    1.30       8.13      1.30      0.00
   704.21      0.00      1.30    143.7 0.696E+00    1.30       8.15      1.30      0.00
   708.83      0.00      1.30    144.2 0.694E+00    1.30       8.18      1.30      0.00
   713.45      0.00      1.30    144.6 0.691E+00    1.30       8.20      1.30      0.00
   718.07      0.00      1.30    145.1 0.689E+00    1.30       8.23      1.30      0.00
   722.69      0.00      1.30    145.5 0.687E+00    1.30       8.26      1.30      0.00
   727.31      0.00      1.30    146.0 0.685E+00    1.30       8.28      1.30      0.00
   731.93      0.00      1.30    146.4 0.683E+00    1.30       8.31      1.30      0.00
   736.56      0.00      1.30    146.9 0.681E+00    1.30       8.33      1.30      0.00
   741.18      0.00      1.30    147.3 0.679E+00    1.30       8.36      1.30      0.00
   745.80      0.00      1.30    147.8 0.677E+00    1.30       8.38      1.30      0.00
   750.42      0.00      1.30    148.2 0.675E+00    1.30       8.41      1.30      0.00
   755.04      0.00      1.30    148.7 0.673E+00    1.30       8.44      1.30      0.00
   759.66      0.00      1.30    149.1 0.670E+00    1.30       8.46      1.30      0.00
   764.28      0.00      1.30    149.6 0.669E+00    1.30       8.49      1.30      0.00
   768.90      0.00      1.30    150.0 0.667E+00    1.30       8.51      1.30      0.00
   773.52      0.00      1.30    150.5 0.665E+00    1.30       8.54      1.30      0.00
   778.14      0.00      1.30    150.9 0.663E+00    1.30       8.56      1.30      0.00
   782.76      0.00      1.30    151.4 0.661E+00    1.30       8.59      1.30      0.00
   787.38      0.00      1.30    151.8 0.659E+00    1.30       8.61      1.30      0.00
   792.00      0.00      1.30    152.2 0.657E+00    1.30       8.64      1.30      0.00
   796.62      0.00      1.30    152.7 0.655E+00    1.30       8.66      1.30      0.00
   801.24      0.00      1.30    153.1 0.653E+00    1.30       8.69      1.30      0.00
   805.86      0.00      1.30    153.5 0.651E+00    1.30       8.71      1.30      0.00
   810.49      0.00      1.30    154.0 0.649E+00    1.30       8.73      1.30      0.00
   815.11      0.00      1.30    154.4 0.648E+00    1.30       8.76      1.30      0.00
   819.73      0.00      1.30    154.8 0.646E+00    1.30       8.78      1.30      0.00
   824.35      0.00      1.30    155.3 0.644E+00    1.30       8.81      1.30      0.00
   828.97      0.00      1.30    155.7 0.642E+00    1.30       8.83      1.30      0.00
   833.59      0.00      1.30    156.1 0.641E+00    1.30       8.86      1.30      0.00
   838.21      0.00      1.30    156.5 0.639E+00    1.30       8.88      1.30      0.00
   842.83      0.00      1.30    157.0 0.637E+00    1.30       8.90      1.30      0.00
   847.45      0.00      1.30    157.4 0.635E+00    1.30       8.93      1.30      0.00
   852.07      0.00      1.30    157.8 0.634E+00    1.30       8.95      1.30      0.00
   856.69      0.00      1.30    158.2 0.632E+00    1.30       8.98      1.30      0.00
   861.31      0.00      1.30    158.6 0.630E+00    1.30       9.00      1.30      0.00
   865.93      0.00      1.30    159.1 0.629E+00    1.30       9.02      1.30      0.00
   870.55      0.00      1.30    159.5 0.627E+00    1.30       9.05      1.30      0.00
   875.17      0.00      1.30    159.9 0.625E+00    1.30       9.07      1.30      0.00
   879.79      0.00      1.30    160.3 0.624E+00    1.30       9.09      1.30      0.00
   884.41      0.00      1.30    160.7 0.622E+00    1.30       9.12      1.30      0.00
   889.04      0.00      1.30    161.1 0.621E+00    1.30       9.14      1.30      0.00
   893.66      0.00      1.30    161.6 0.619E+00    1.30       9.17      1.30      0.00
   898.28      0.00      1.30    162.0 0.617E+00    1.30       9.19      1.30      0.00
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    902.90     0.00    1.30   162.4 0.616E+00   1.30     9.21    1.30    0.00
    907.52     0.00    1.30   162.8 0.614E+00   1.30     9.23    1.30    0.00
    912.14     0.00    1.30   163.2 0.613E+00   1.30     9.26    1.30    0.00
    916.76     0.00    1.30   163.6 0.611E+00   1.30     9.28    1.30    0.00
    921.38     0.00    1.30   164.0 0.610E+00   1.30     9.30    1.30    0.00
    926.00     0.00    1.30   164.4 0.608E+00   1.30     9.33    1.30    0.00
    930.62     0.00    1.30   164.8 0.607E+00   1.30     9.35    1.30    0.00
 Cumulative travel time =        1559.5299 sec

-----------------------------------------------------------------------------
 Plume Stage 2 (bank attached):
       X        Y       Z        S       C        BV       BH      ZU      ZL
    930.62    -9.35    1.30   164.8 0.607E+00   1.30    18.70    1.30    0.00
   1025.97    -9.35    1.30   166.9 0.599E+00   1.30    18.93    1.30    0.00
   1121.31    -9.35    1.30   168.9 0.592E+00   1.30    19.17    1.30    0.00
   1216.66    -9.35    1.30   170.9 0.585E+00   1.30    19.40    1.30    0.00
 ** REGULATORY MIXING ZONE BOUNDARY **
 In this prediction interval the plume DOWNSTREAM distance meets or exceeds
 the regulatory value =  1293.00 m.
 This is the extent of the REGULATORY MIXING ZONE.
   1312.01    -9.35    1.30   172.9 0.578E+00   1.30    19.62    1.30    0.00
   1407.36    -9.35    1.30   174.9 0.572E+00   1.30    19.85    1.30    0.00
   1502.70    -9.35    1.30   176.9 0.565E+00   1.30    20.07    1.30    0.00
   1598.05    -9.35    1.30   178.8 0.559E+00   1.30    20.29    1.30    0.00
   1693.40    -9.35    1.30   180.7 0.553E+00   1.30    20.50    1.30    0.00
   1788.74    -9.35    1.30   182.6 0.548E+00   1.30    20.72    1.30    0.00
   1884.09    -9.35    1.30   184.5 0.542E+00   1.30    20.93    1.30    0.00
   1979.44    -9.35    1.30   186.3 0.537E+00   1.30    21.14    1.30    0.00
   2074.78    -9.35    1.30   188.1 0.532E+00   1.30    21.35    1.30    0.00
   2170.13    -9.35    1.30   190.0 0.526E+00   1.30    21.55    1.30    0.00
   2265.48    -9.35    1.30   191.7 0.522E+00   1.30    21.76    1.30    0.00
   2360.82    -9.35    1.30   193.5 0.517E+00   1.30    21.96    1.30    0.00
   2456.17    -9.35    1.30   195.3 0.512E+00   1.30    22.16    1.30    0.00
   2551.52    -9.35    1.30   197.0 0.508E+00   1.30    22.36    1.30    0.00
   2646.87    -9.35    1.30   198.8 0.503E+00   1.30    22.55    1.30    0.00
   2742.21    -9.35    1.30   200.5 0.499E+00   1.30    22.75    1.30    0.00
   2837.56    -9.35    1.30   202.2 0.495E+00   1.30    22.94    1.30    0.00
   2932.91    -9.35    1.30   203.9 0.490E+00   1.30    23.13    1.30    0.00
   3028.25    -9.35    1.30   205.6 0.486E+00   1.30    23.32    1.30    0.00
   3123.60    -9.35    1.30   207.2 0.483E+00   1.30    23.51    1.30    0.00
   3218.95    -9.35    1.30   208.9 0.479E+00   1.30    23.70    1.30    0.00
   3314.29    -9.35    1.30   210.5 0.475E+00   1.30    23.88    1.30    0.00
   3409.64    -9.35    1.30   212.1 0.471E+00   1.30    24.07    1.30    0.00
   3504.99    -9.35    1.30   213.7 0.468E+00   1.30    24.25    1.30    0.00
   3600.33    -9.35    1.30   215.3 0.464E+00   1.30    24.43    1.30    0.00
   3695.68    -9.35    1.30   216.9 0.461E+00   1.30    24.61    1.30    0.00
   3791.03    -9.35    1.30   218.5 0.458E+00   1.30    24.79    1.30    0.00
   3886.38    -9.35    1.30   220.1 0.454E+00   1.30    24.97    1.30    0.00
   3981.72    -9.35    1.30   221.6 0.451E+00   1.30    25.15    1.30    0.00
   4077.07    -9.35    1.30   223.2 0.448E+00   1.30    25.32    1.30    0.00
   4172.42    -9.35    1.30   224.7 0.445E+00   1.30    25.49    1.30    0.00
   4267.76    -9.35    1.30   226.2 0.442E+00   1.30    25.67    1.30    0.00
   4363.11    -9.35    1.30   227.7 0.439E+00   1.30    25.84    1.30    0.00
   4458.46    -9.35    1.30   229.2 0.436E+00   1.30    26.01    1.30    0.00
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   4553.80     -9.35     1.30   230.7 0.433E+00   1.30     26.18     1.30     0.00
   4649.15     -9.35     1.30   232.2 0.431E+00   1.30     26.35     1.30     0.00
   4744.50     -9.35     1.30   233.7 0.428E+00   1.30     26.51     1.30     0.00
   4839.84     -9.35     1.30   235.1 0.425E+00   1.30     26.68     1.30     0.00
   4935.19     -9.35     1.30   236.6 0.423E+00   1.30     26.84     1.30     0.00
   5030.54     -9.35     1.30   238.0 0.420E+00   1.30     27.01     1.30     0.00
   5125.88     -9.35     1.30   239.5 0.418E+00   1.30     27.17     1.30     0.00
   5221.23     -9.35     1.30   240.9 0.415E+00   1.30     27.33     1.30     0.00
   5316.58     -9.35     1.30   242.3 0.413E+00   1.30     27.49     1.30     0.00
   5411.92     -9.35     1.30   243.7 0.410E+00   1.30     27.65     1.30     0.00
   5507.27     -9.35     1.30   245.1 0.408E+00   1.30     27.81     1.30     0.00
   5602.62     -9.35     1.30   246.5 0.406E+00   1.30     27.97     1.30     0.00
   5697.96     -9.35     1.30   247.9 0.403E+00   1.30     28.13     1.30     0.00
   5793.31     -9.35     1.30   249.3 0.401E+00   1.30     28.29     1.30     0.00
   5888.66     -9.35     1.30   250.7 0.399E+00   1.30     28.44     1.30     0.00
   5984.00     -9.35     1.30   252.0 0.397E+00   1.30     28.60     1.30     0.00
   6079.35     -9.35     1.30   253.4 0.395E+00   1.30     28.75     1.30     0.00
   6174.70     -9.35     1.30   254.7 0.393E+00   1.30     28.90     1.30     0.00
   6270.04     -9.35     1.30   256.1 0.391E+00   1.30     29.06     1.30     0.00
   6365.39     -9.35     1.30   257.4 0.388E+00   1.30     29.21     1.30     0.00
   6460.74     -9.35     1.30   258.7 0.386E+00   1.30     29.36     1.30     0.00
   6556.08     -9.35     1.30   260.1 0.385E+00   1.30     29.51     1.30     0.00
   6651.43     -9.35     1.30   261.4 0.383E+00   1.30     29.66     1.30     0.00
   6746.78     -9.35     1.30   262.7 0.381E+00   1.30     29.81     1.30     0.00
   6842.12     -9.35     1.30   264.0 0.379E+00   1.30     29.95     1.30     0.00
   6937.47     -9.35     1.30   265.3 0.377E+00   1.30     30.10     1.30     0.00
   7032.82     -9.35     1.30   266.6 0.375E+00   1.30     30.25     1.30     0.00
   7128.16     -9.35     1.30   267.9 0.373E+00   1.30     30.39     1.30     0.00
   7223.51     -9.35     1.30   269.1 0.372E+00   1.30     30.54     1.30     0.00
   7318.86     -9.35     1.30   270.4 0.370E+00   1.30     30.68     1.30     0.00
   7414.20     -9.35     1.30   271.7 0.368E+00   1.30     30.82     1.30     0.00
   7509.55     -9.35     1.30   272.9 0.366E+00   1.30     30.97     1.30     0.00
   7604.90     -9.35     1.30   274.2 0.365E+00   1.30     31.11     1.30     0.00
   7700.24     -9.35     1.30   275.4 0.363E+00   1.30     31.25     1.30     0.00
   7795.59     -9.35     1.30   276.7 0.361E+00   1.30     31.39     1.30     0.00
   7890.94     -9.35     1.30   277.9 0.360E+00   1.30     31.53     1.30     0.00
   7986.28     -9.35     1.30   279.1 0.358E+00   1.30     31.67     1.30     0.00
   8081.63     -9.35     1.30   280.4 0.357E+00   1.30     31.81     1.30     0.00
   8176.98     -9.35     1.30   281.6 0.355E+00   1.30     31.95     1.30     0.00
   8272.32     -9.35     1.30   282.8 0.354E+00   1.30     32.09     1.30     0.00
   8367.67     -9.35     1.30   284.0 0.352E+00   1.30     32.23     1.30     0.00
   8463.02     -9.35     1.30   285.2 0.351E+00   1.30     32.36     1.30     0.00
   8558.36     -9.35     1.30   286.4 0.349E+00   1.30     32.50     1.30     0.00
   8653.71     -9.35     1.30   287.6 0.348E+00   1.30     32.63     1.30     0.00
   8749.06     -9.35     1.30   288.8 0.346E+00   1.30     32.77     1.30     0.00
   8844.40     -9.35     1.30   290.0 0.345E+00   1.30     32.90     1.30     0.00
   8939.75     -9.35     1.30   291.2 0.343E+00   1.30     33.04     1.30     0.00
   9035.10     -9.35     1.30   292.4 0.342E+00   1.30     33.17     1.30     0.00
   9130.44     -9.35     1.30   293.5 0.341E+00   1.30     33.30     1.30     0.00
   9225.79     -9.35     1.30   294.7 0.339E+00   1.30     33.44     1.30     0.00
   9321.14     -9.35     1.30   295.9 0.338E+00   1.30     33.57     1.30     0.00
   9416.48     -9.35     1.30   297.0 0.337E+00   1.30     33.70     1.30     0.00
   9511.83     -9.35     1.30   298.2 0.335E+00   1.30     33.83     1.30     0.00
   9607.18     -9.35     1.30   299.3 0.334E+00   1.30     33.96     1.30     0.00
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   9702.52     -9.35     1.30   300.5 0.333E+00    1.30     34.09     1.30     0.00
   9797.87     -9.35     1.30   301.6 0.332E+00    1.30     34.22     1.30     0.00
   9893.22     -9.35     1.30   302.7 0.330E+00    1.30     34.35     1.30     0.00
   9988.56     -9.35     1.30   303.9 0.329E+00    1.30     34.48     1.30     0.00
  10083.91     -9.35     1.30   305.0 0.328E+00    1.30     34.60     1.30     0.00
  10179.26     -9.35     1.30   306.1 0.327E+00    1.30     34.73     1.30     0.00
  10274.60     -9.35     1.30   307.2 0.325E+00    1.30     34.86     1.30     0.00
  10369.95     -9.35     1.30   308.3 0.324E+00    1.30     34.98     1.30     0.00
  10465.30     -9.35     1.30   309.4 0.323E+00    1.30     35.11     1.30     0.00
  10560.64     -9.35     1.30   310.6 0.322E+00    1.30     35.24     1.30     0.00
  10655.99     -9.35     1.30   311.7 0.321E+00    1.30     35.36     1.30     0.00
  10751.34     -9.35     1.30   312.8 0.320E+00    1.30     35.49     1.30     0.00
  10846.68     -9.35     1.30   313.9 0.319E+00    1.30     35.61     1.30     0.00
  10942.03     -9.35     1.30   314.9 0.318E+00    1.30     35.73     1.30     0.00
  11037.38     -9.35     1.30   316.0 0.316E+00    1.30     35.86     1.30     0.00
  11132.72     -9.35     1.30   317.1 0.315E+00    1.30     35.98     1.30     0.00
  11228.07     -9.35     1.30   318.2 0.314E+00    1.30     36.10     1.30     0.00
  11323.42     -9.35     1.30   319.3 0.313E+00    1.30     36.22     1.30     0.00
  11418.76     -9.35     1.30   320.3 0.312E+00    1.30     36.35     1.30     0.00
  11514.11     -9.35     1.30   321.4 0.311E+00    1.30     36.47     1.30     0.00
  11609.46     -9.35     1.30   322.5 0.310E+00    1.30     36.59     1.30     0.00
  11704.80     -9.35     1.30   323.5 0.309E+00    1.30     36.71     1.30     0.00
  11800.15     -9.35     1.30   324.6 0.308E+00    1.30     36.83     1.30     0.00
  11895.50     -9.35     1.30   325.7 0.307E+00    1.30     36.95     1.30     0.00
  11990.84     -9.35     1.30   326.7 0.306E+00    1.30     37.07     1.30     0.00
  12086.19     -9.35     1.30   327.8 0.305E+00    1.30     37.19     1.30     0.00
  12181.54     -9.35     1.30   328.8 0.304E+00    1.30     37.31     1.30     0.00
  12276.88     -9.35     1.30   329.8 0.303E+00    1.30     37.42     1.30     0.00
  12372.23     -9.35     1.30   330.9 0.302E+00    1.30     37.54     1.30     0.00
  12467.58     -9.35     1.30   331.9 0.301E+00    1.30     37.66     1.30     0.00
  12562.92     -9.35     1.30   332.9 0.300E+00    1.30     37.78     1.30     0.00
  12658.27     -9.35     1.30   334.0 0.299E+00    1.30     37.89     1.30     0.00
  12753.62     -9.35     1.30   335.0 0.299E+00    1.30     38.01     1.30     0.00
  12848.96     -9.35     1.30   336.0 0.298E+00    1.30     38.13     1.30     0.00
  12944.31     -9.35     1.30   337.0 0.297E+00    1.30     38.24     1.30     0.00
  13039.66     -9.35     1.30   338.1 0.296E+00    1.30     38.36     1.30     0.00
  13135.00     -9.35     1.30   339.1 0.295E+00    1.30     38.47     1.30     0.00
  13230.35     -9.35     1.30   340.1 0.294E+00    1.30     38.59     1.30     0.00
  13325.70     -9.35     1.30   341.1 0.293E+00    1.30     38.70     1.30     0.00
  13421.04     -9.35     1.30   342.1 0.292E+00    1.30     38.81     1.30     0.00
  13516.39     -9.35     1.30   343.1 0.291E+00    1.30     38.93     1.30     0.00
  13611.74     -9.35     1.30   344.1 0.291E+00    1.30     39.04     1.30     0.00
  13707.08     -9.35     1.30   345.1 0.290E+00    1.30     39.15     1.30     0.00
  13802.43     -9.35     1.30   346.1 0.289E+00    1.30     39.27     1.30     0.00
  13897.78     -9.35     1.30   347.1 0.288E+00    1.30     39.38     1.30     0.00
  13993.12     -9.35     1.30   348.1 0.287E+00    1.30     39.49     1.30     0.00
  14088.47     -9.35     1.30   349.0 0.287E+00    1.30     39.60     1.30     0.00
  14183.82     -9.35     1.30   350.0 0.286E+00    1.30     39.71     1.30     0.00
  14279.16     -9.35     1.30   351.0 0.285E+00    1.30     39.82     1.30     0.00
  14374.51     -9.35     1.30   352.0 0.284E+00    1.30     39.94     1.30     0.00
  14469.86     -9.35     1.30   352.9 0.283E+00    1.30     40.05     1.30     0.00
  14565.20     -9.35     1.30   353.9 0.283E+00    1.30     40.16     1.30     0.00
  14660.55     -9.35     1.30   354.9 0.282E+00    1.30     40.27     1.30     0.00
  14755.90     -9.35     1.30   355.8 0.281E+00    1.30     40.37     1.30     0.00
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  14851.24     -9.35     1.30   356.8 0.280E+00   1.30     40.48     1.30     0.00
  14946.59     -9.35     1.30   357.8 0.280E+00   1.30     40.59     1.30     0.00
  15041.94     -9.35     1.30   358.7 0.279E+00   1.30     40.70     1.30     0.00
  15137.28     -9.35     1.30   359.7 0.278E+00   1.30     40.81     1.30     0.00
  15232.63     -9.35     1.30   360.6 0.277E+00   1.30     40.92     1.30     0.00
  15327.98     -9.35     1.30   361.6 0.277E+00   1.30     41.03     1.30     0.00
  15423.32     -9.35     1.30   362.5 0.276E+00   1.30     41.13     1.30     0.00
  15518.67     -9.35     1.30   363.5 0.275E+00   1.30     41.24     1.30     0.00
  15614.02     -9.35     1.30   364.4 0.274E+00   1.30     41.35     1.30     0.00
  15709.36     -9.35     1.30   365.4 0.274E+00   1.30     41.45     1.30     0.00
  15804.71     -9.35     1.30   366.3 0.273E+00   1.30     41.56     1.30     0.00
  15900.06     -9.35     1.30   367.2 0.272E+00   1.30     41.67     1.30     0.00
  15995.40     -9.35     1.30   368.2 0.272E+00   1.30     41.77     1.30     0.00
  16090.75     -9.35     1.30   369.1 0.271E+00   1.30     41.88     1.30     0.00
  16186.10     -9.35     1.30   370.0 0.270E+00   1.30     41.98     1.30     0.00
  16281.44     -9.35     1.30   370.9 0.270E+00   1.30     42.09     1.30     0.00
  16376.79     -9.35     1.30   371.9 0.269E+00   1.30     42.19     1.30     0.00
  16472.14     -9.35     1.30   372.8 0.268E+00   1.30     42.30     1.30     0.00
  16567.49     -9.35     1.30   373.7 0.268E+00   1.30     42.40     1.30     0.00
  16662.83     -9.35     1.30   374.6 0.267E+00   1.30     42.51     1.30     0.00
  16758.18     -9.35     1.30   375.5 0.266E+00   1.30     42.61     1.30     0.00
  16853.53     -9.35     1.30   376.5 0.266E+00   1.30     42.71     1.30     0.00
  16948.88     -9.35     1.30   377.4 0.265E+00   1.30     42.82     1.30     0.00
  17044.22     -9.35     1.30   378.3 0.264E+00   1.30     42.92     1.30     0.00
  17139.57     -9.35     1.30   379.2 0.264E+00   1.30     43.02     1.30     0.00
  17234.92     -9.35     1.30   380.1 0.263E+00   1.30     43.12     1.30     0.00
  17330.27     -9.35     1.30   381.0 0.262E+00   1.30     43.23     1.30     0.00
  17425.62     -9.35     1.30   381.9 0.262E+00   1.30     43.33     1.30     0.00
  17520.96     -9.35     1.30   382.8 0.261E+00   1.30     43.43     1.30     0.00
  17616.31     -9.35     1.30   383.7 0.261E+00   1.30     43.53     1.30     0.00
  17711.66     -9.35     1.30   384.6 0.260E+00   1.30     43.63     1.30     0.00
  17807.01     -9.35     1.30   385.5 0.259E+00   1.30     43.73     1.30     0.00
  17902.35     -9.35     1.30   386.3 0.259E+00   1.30     43.84     1.30     0.00
  17997.70     -9.35     1.30   387.2 0.258E+00   1.30     43.94     1.30     0.00
  18093.05     -9.35     1.30   388.1 0.258E+00   1.30     44.04     1.30     0.00
  18188.40     -9.35     1.30   389.0 0.257E+00   1.30     44.14     1.30     0.00
  18283.74     -9.35     1.30   389.9 0.256E+00   1.30     44.24     1.30     0.00
  18379.09     -9.35     1.30   390.8 0.256E+00   1.30     44.34     1.30     0.00
  18474.44     -9.35     1.30   391.6 0.255E+00   1.30     44.44     1.30     0.00
  18569.79     -9.35     1.30   392.5 0.255E+00   1.30     44.53     1.30     0.00
  18665.13     -9.35     1.30   393.4 0.254E+00   1.30     44.63     1.30     0.00
  18760.48     -9.35     1.30   394.3 0.254E+00   1.30     44.73     1.30     0.00
  18855.83     -9.35     1.30   395.1 0.253E+00   1.30     44.83     1.30     0.00

  18951.18     -9.35     1.30   396.0 0.253E+00   1.30     44.93     1.30     0.00
  19046.53     -9.35     1.30   396.9 0.252E+00   1.30     45.03     1.30     0.00
  19141.87     -9.35     1.30   397.7 0.251E+00   1.30     45.13     1.30     0.00
  19237.22     -9.35     1.30   398.6 0.251E+00   1.30     45.22     1.30     0.00
  19332.57     -9.35     1.30   399.4 0.250E+00   1.30     45.32     1.30     0.00
  19427.92     -9.35     1.30   400.3 0.250E+00   1.30     45.42     1.30     0.00
  19523.26     -9.35     1.30   401.2 0.249E+00   1.30     45.52     1.30     0.00
  19618.61     -9.35     1.30   402.0 0.249E+00   1.30     45.61     1.30     0.00
  19713.96     -9.35     1.30   402.9 0.248E+00   1.30     45.71     1.30     0.00
  19809.31     -9.35     1.30   403.7 0.248E+00   1.30     45.81     1.30     0.00
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  19904.65    -9.35    1.30   404.6 0.247E+00   1.30    45.90    1.30    0.00
  20000.00    -9.35    1.30   405.4 0.247E+00   1.30    46.00    1.30    0.00
 Cumulative travel time =       33295.0195 sec

 Simulation limit based on maximum specified distance =  20000.00 m.
   This is the REGION OF INTEREST limitation.

END OF MOD261: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT
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-----------------------------------------------------------------------------
CORMIX2: Multiport Diffuser Discharges       End of Prediction File
22222222222222222222222222222222222222222222222222222222222222222222222222222
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Results of CORMIX Modeling – Average Flow

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2222222222222222222222222222222222222222222222222222222222222222222222222222222
                         CORMIX MIXING ZONE EXPERT SYSTEM
         Subsystem CORMIX2:  Multiport Diffuser Discharges
                           CORMIX Version 5.0GT
                        HYDRO2 Version 5.0.0.0 March 2007
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:   Sturgeon upgrader
 Design case:       Avergae flow
 FILE NAME:         \\S...erage_run_North American_multiport_10_newflow.prd
 Time stamp:        Wed Oct 31 16:37:17 2007

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =    160.00  AS    =    304.00  QA    =    196.00  ICHREG= 1
 HA    =      1.90  HD    =      2.20
 UA    =      0.645 F     =      0.053 USTAR =0.5262E-01
 UW    =      2.000 UWSTAR=0.2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =  999.8188

DIFFUSER DISCHARGE PARAMETERS (metric units)
 Diffuser type:     DITYPE= alternating_perpendicular
 BANK  =  RIGHT     DISTB =      9.35  YB1   =      8.00  YB2   =     10.70
 LD    =      2.70  NOPEN =   10       SPAC  =      0.30
 D0    =      0.100 A0    =      0.008 H0    =      0.30  SUB0  =      1.90
 Nozzle/port arrangement:   near_vertical_discharge
 GAMMA =     90.00  THETA =     90.00  SIGMA =      0.00  BETA  =     90.00
 U0    =      1.127 Q0    =      0.089        =0.8850E-01
 RHO0  =  996.5137  DRHO0 =0.3305E+01  GP0   =0.3242E-01
 C0    =0.1000E+03  CUNITS=  %
 IPOLL =  1         KS    =0.0000E+00  KD    =0.0000E+00

FLUX VARIABLES - PER UNIT DIFFUSER LENGTH (metric units)
 q0    =0.3278E-01  m0    =0.3693E-01  j0    =0.1063E-02  SIGNJ0=      1.0
 Associated 2-d length scales (meters)
 lQ=B  =      0.029 lM    =      3.54  lm    =      0.09
 lmp   =  99999.00  lbp   =  99999.00  la    =  99999.00

FLUX VARIABLES - ENTIRE DIFFUSER (metric units)
 Q0    =0.8850E-01  M0    =0.9972E-01  J0    =0.2869E-02
 Associated 3-d length scales (meters)
 LQ    =      0.09  LM    =      3.31  Lm    =      0.49  Lb    =      0.01
                                       Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     36.69  FRD0  =     19.79  R     =      1.75  PL    =      2.
 (slot)             (port/nozzle)


FLOW CLASSIFICATION
 222222222222222222222222222222222222222222
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 2  Flow class (CORMIX2)      =    MU8    2
 2  Applicable layer depth HS =     2.20  2
 222222222222222222222222222222222222222222

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    =0.1000E+03  CUNITS=  %
 NTOX  =  0
 NSTD  =  0
 REGMZ =  1
 REGSPC=  1         XREG  =   1293.00  WREG  =      0.00  AREG  =      0.00
 XINT  =  20000.00  XMAX  =  20000.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and the diffuser mid-point:
         9.35 m  from the RIGHT bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 200 display intervals per module
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
BEGIN MOD201: DIFFUSER DISCHARGE MODULE

 Due to complex near-field motions:  EQUIVALENT SLOT DIFFUSER (2-D) GEOMETRY

 Profile definitions:
   BV = Gaussian 1/e (37%) half-width, in vertical plane normal to trajectory
   BH = top-hat half-width, in horizontal plane normal to trajectory
   S  = hydrodynamic centerline dilution
   C  = centerline concentration (includes reaction effects, if any)

       X        Y       Z        S        C       BV       BH
      0.00     0.00    0.30     1.0 0.100E+03   0.02     1.35

END OF MOD201: DIFFUSER DISCHARGE MODULE
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
BEGIN MOD277: UNSTABLE NEAR-FIELD ZONE OF ALTERNATING PERPENDICULAR DIFFUSER

 Because of the strong ambient current the diffuser plume of this crossflowing
   discharge gets RAPIDLY DEFLECTED.
 A near-field zone is formed that is VERTICALLY FULLY MIXED over the entire
   layer depth.  Full mixing is achieved at a downstream distance of about
   five (5) layer depths.

 Profile definitions:
   BV = layer depth (vertically mixed)
   BH = top-hat half-width, measured horizontally in Y-direction
   S  = hydrodynamic average (bulk) dilution
   C  = average (bulk) concentration (includes reaction effects, if any)

       X        Y       Z        S        C       BV       BH
      0.00     0.00    0.30     1.0 0.100E+03   0.02     1.35
      0.05     0.00    0.30     4.0 0.250E+02   0.03     1.35
      0.11     0.00    0.31     5.2 0.191E+02   0.04     1.35
      0.16     0.00    0.31     6.2 0.161E+02   0.06     1.35
```

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      0.22     0.00    0.32     7.0 0.143E+02   0.07     1.35
      0.28     0.00    0.32     7.7 0.130E+02   0.08     1.35
      0.33     0.00    0.32     8.3 0.120E+02   0.09     1.35
      0.39     0.00    0.33     8.9 0.112E+02   0.10     1.35
      0.44     0.00    0.33     9.5 0.105E+02   0.11     1.35
      0.50     0.00    0.34    10.0 0.100E+02   0.12     1.35
      0.55     0.00    0.34    10.5 0.954E+01   0.13     1.35
      0.61     0.00    0.34    10.9 0.914E+01   0.14     1.35
      0.66     0.00    0.35    11.4 0.878E+01   0.15     1.35
      0.72     0.00    0.35    11.8 0.847E+01   0.16     1.35
      0.77     0.00    0.36    12.2 0.818E+01   0.18     1.35
      0.83     0.00    0.36    12.6 0.793E+01   0.19     1.35
      0.88     0.00    0.36    13.0 0.770E+01   0.20     1.35
      0.94     0.00    0.37    13.4 0.748E+01   0.21     1.35
      0.99     0.00    0.37    13.7 0.729E+01   0.22     1.35
      1.05     0.00    0.38    14.1 0.711E+01   0.23     1.35
      1.10     0.00    0.38    14.4 0.694E+01   0.24     1.35
      1.15     0.00    0.38    14.7 0.678E+01   0.25     1.35
      1.21     0.00    0.39    15.1 0.664E+01   0.26     1.35
      1.26     0.00    0.39    15.4 0.650E+01   0.27     1.35
      1.32     0.00    0.40    15.7 0.637E+01   0.28     1.35
      1.37     0.00    0.40    16.0 0.625E+01   0.30     1.35
      1.43     0.00    0.40    16.3 0.614E+01   0.31     1.35
      1.48     0.00    0.41    16.6 0.603E+01   0.32     1.35
      1.54     0.00    0.41    16.9 0.593E+01   0.33     1.35
      1.59     0.00    0.42    17.1 0.583E+01   0.34     1.35
      1.65     0.00    0.42    17.4 0.574E+01   0.35     1.35
      1.70     0.00    0.42    17.7 0.565E+01   0.36     1.35
      1.76     0.00    0.43    18.0 0.557E+01   0.37     1.35
      1.81     0.00    0.43    18.2 0.549E+01   0.38     1.35
      1.87     0.00    0.44    18.5 0.541E+01   0.39     1.35
      1.92     0.00    0.44    18.7 0.534E+01   0.40     1.35
      1.98     0.00    0.44    19.0 0.527E+01   0.42     1.35
      2.03     0.00    0.45    19.2 0.520E+01   0.43     1.35
      2.09     0.00    0.45    19.5 0.513E+01   0.44     1.35
      2.14     0.00    0.46    19.7 0.507E+01   0.45     1.35
      2.20     0.00    0.46    20.0 0.501E+01   0.46     1.35
      2.25     0.00    0.46    20.2 0.495E+01   0.47     1.35
      2.31     0.00    0.47    20.4 0.489E+01   0.48     1.35
      2.36     0.00    0.47    20.7 0.484E+01   0.49     1.35
      2.42     0.00    0.48    20.9 0.479E+01   0.50     1.35
      2.47     0.00    0.48    21.1 0.474E+01   0.51     1.35
      2.53     0.00    0.48    21.3 0.469E+01   0.52     1.35
      2.58     0.00    0.49    21.6 0.464E+01   0.53     1.35
      2.64     0.00    0.49    21.8 0.459E+01   0.55     1.35
      2.69     0.00    0.50    22.0 0.455E+01   0.56     1.35
      2.75     0.00    0.50    22.2 0.450E+01   0.57     1.35
      2.81     0.00    0.50    22.4 0.446E+01   0.58     1.35
      2.86     0.00    0.51    22.6 0.442E+01   0.59     1.35
      2.92     0.00    0.51    22.8 0.438E+01   0.60     1.35
      2.97     0.00    0.52    23.0 0.434E+01   0.61     1.35
      3.03     0.00    0.52    23.2 0.430E+01   0.62     1.35
      3.08     0.00    0.52    23.4 0.427E+01   0.63     1.35
      3.14     0.00    0.53    23.6 0.423E+01   0.64     1.35
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       3.19      0.00     0.53     23.8 0.419E+01   0.65      1.35
       3.25      0.00     0.54     24.0 0.416E+01   0.67      1.35
       3.30      0.00     0.54     24.2 0.413E+01   0.68      1.35
       3.36      0.00     0.54     24.4 0.409E+01   0.69      1.35
       3.41      0.00     0.55     24.6 0.406E+01   0.70      1.35
       3.47      0.00     0.55     24.8 0.403E+01   0.71      1.35
       3.52      0.00     0.56     25.0 0.400E+01   0.72      1.35
       3.58      0.00     0.56     25.2 0.397E+01   0.73      1.35
       3.63      0.00     0.56     25.4 0.394E+01   0.74      1.35
       3.69      0.00     0.57     25.5 0.391E+01   0.75      1.35
       3.74      0.00     0.57     25.7 0.389E+01   0.76      1.35
       3.80      0.00     0.58     25.9 0.386E+01   0.77      1.35
       3.85      0.00     0.58     26.1 0.383E+01   0.79      1.35
       3.91      0.00     0.58     26.3 0.381E+01   0.80      1.35
       3.96      0.00     0.59     26.4 0.378E+01   0.81      1.35
       4.02      0.00     0.59     26.6 0.376E+01   0.82      1.35
       4.07      0.00     0.60     26.8 0.373E+01   0.83      1.35
       4.13      0.00     0.60     27.0 0.371E+01   0.84      1.35
       4.18      0.00     0.60     27.1 0.368E+01   0.85      1.35
       4.24      0.00     0.61     27.3 0.366E+01   0.86      1.35
       4.29      0.00     0.61     27.5 0.364E+01   0.87      1.35
       4.35      0.00     0.62     27.7 0.362E+01   0.88      1.35
       4.40      0.00     0.62     27.8 0.359E+01   0.89      1.35
       4.45      0.00     0.62     28.0 0.357E+01   0.90      1.35
       4.51      0.00     0.63     28.2 0.355E+01   0.92      1.35
       4.56      0.00     0.63     28.3 0.353E+01   0.93      1.35
       4.62      0.00     0.64     28.5 0.351E+01   0.94      1.35
       4.67      0.00     0.64     28.6 0.349E+01   0.95      1.35
       4.73      0.00     0.64     28.8 0.347E+01   0.96      1.35
       4.78      0.00     0.65     29.0 0.345E+01   0.97      1.35
       4.84      0.00     0.65     29.1 0.343E+01   0.98      1.35
       4.89      0.00     0.66     29.3 0.341E+01   0.99      1.35
       4.95      0.00     0.66     29.4 0.340E+01   1.00      1.35
       5.00      0.00     0.66     29.6 0.338E+01   1.01      1.35
       5.06      0.00     0.67     29.8 0.336E+01   1.02      1.35
       5.11      0.00     0.67     29.9 0.334E+01   1.04      1.35
       5.17      0.00     0.68     30.1 0.333E+01   1.05      1.35
       5.22      0.00     0.68     30.2 0.331E+01   1.06      1.35
       5.28      0.00     0.68     30.4 0.329E+01   1.07      1.35
       5.33      0.00     0.69     30.5 0.327E+01   1.08      1.35
       5.39      0.00     0.69     30.7 0.326E+01   1.09      1.35
       5.44      0.00     0.70     30.8 0.324E+01   1.10      1.35
       5.50      0.00     0.70     31.0 0.323E+01   1.11      1.35
       5.55      0.00     0.70     31.1 0.321E+01   1.12      1.35
       5.61      0.00     0.71     31.3 0.320E+01   1.13      1.35
       5.66      0.00     0.71     31.4 0.318E+01   1.14      1.35
       5.72      0.00     0.72     31.6 0.317E+01   1.16      1.35
       5.77      0.00     0.72     31.7 0.315E+01   1.17      1.35
       5.83      0.00     0.72     31.9 0.314E+01   1.18      1.35
       5.88      0.00     0.73     32.0 0.312E+01   1.19      1.35
       5.94      0.00     0.73     32.2 0.311E+01   1.20      1.35
       5.99      0.00     0.74     32.3 0.310E+01   1.21      1.35
       6.05      0.00     0.74     32.5 0.308E+01   1.22      1.35
       6.10      0.00     0.74     32.6 0.307E+01   1.23      1.35
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        6.16      0.00     0.75     32.7 0.305E+01   1.24      1.35
        6.21      0.00     0.75     32.9 0.304E+01   1.25      1.35
        6.27      0.00     0.76     33.0 0.303E+01   1.26      1.35
        6.32      0.00     0.76     33.2 0.302E+01   1.27      1.35
        6.38      0.00     0.76     33.3 0.300E+01   1.29      1.35
        6.43      0.00     0.77     33.4 0.299E+01   1.30      1.35
        6.49      0.00     0.77     33.6 0.298E+01   1.31      1.35
        6.54      0.00     0.78     33.7 0.297E+01   1.32      1.35
        6.60      0.00     0.78     33.9 0.295E+01   1.33      1.35
        6.65      0.00     0.78     34.0 0.294E+01   1.34      1.35
        6.71      0.00     0.79     34.1 0.293E+01   1.35      1.35
        6.76      0.00     0.79     34.3 0.292E+01   1.36      1.35
        6.82      0.00     0.80     34.4 0.291E+01   1.37      1.35
        6.87      0.00     0.80     34.5 0.290E+01   1.38      1.35
        6.93      0.00     0.80     34.7 0.289E+01   1.39      1.35
        6.98      0.00     0.81     34.8 0.287E+01   1.41      1.35
        7.04      0.00     0.81     34.9 0.286E+01   1.42      1.35
        7.09      0.00     0.82     35.1 0.285E+01   1.43      1.35
        7.15      0.00     0.82     35.2 0.284E+01   1.44      1.35
        7.20      0.00     0.82     35.3 0.283E+01   1.45      1.35
        7.26      0.00     0.83     35.5 0.282E+01   1.46      1.35
        7.31      0.00     0.83     35.6 0.281E+01   1.47      1.35
        7.37      0.00     0.84     35.7 0.280E+01   1.48      1.35
        7.42      0.00     0.84     35.8 0.279E+01   1.49      1.35
        7.48      0.00     0.84     36.0 0.278E+01   1.50      1.35
        7.53      0.00     0.85     36.1 0.277E+01   1.51      1.35
        7.59      0.00     0.85     36.2 0.276E+01   1.53      1.35
        7.64      0.00     0.86     36.4 0.275E+01   1.54      1.35
        7.70      0.00     0.86     36.5 0.274E+01   1.55      1.35
        7.75      0.00     0.86     36.6 0.273E+01   1.56      1.35
        7.81      0.00     0.87     36.7 0.272E+01   1.57      1.35
        7.86      0.00     0.87     36.9 0.271E+01   1.58      1.35
        7.92      0.00     0.88     37.0 0.270E+01   1.59      1.35
        7.97      0.00     0.88     37.1 0.269E+01   1.60      1.35
        8.03      0.00     0.88     37.2 0.269E+01   1.61      1.35
        8.08      0.00     0.89     37.4 0.268E+01   1.62      1.35
        8.14      0.00     0.89     37.5 0.267E+01   1.63      1.35
        8.19      0.00     0.90     37.6 0.266E+01   1.64      1.35
        8.25      0.00     0.90     37.7 0.265E+01   1.66      1.35
        8.30      0.00     0.90     37.8 0.264E+01   1.67      1.35
        8.36      0.00     0.91     38.0 0.263E+01   1.68      1.35
        8.41      0.00     0.91     38.1 0.263E+01   1.69      1.35
        8.47      0.00     0.92     38.2 0.262E+01   1.70      1.35
        8.52      0.00     0.92     38.3 0.261E+01   1.71      1.35
        8.58      0.00     0.92     38.5 0.260E+01   1.72      1.35
        8.63      0.00     0.93     38.6 0.259E+01   1.73      1.35
        8.69      0.00     0.93     38.7 0.258E+01   1.74      1.35
        8.74      0.00     0.94     38.8 0.258E+01   1.75      1.35
        8.80      0.00     0.94     38.9 0.257E+01   1.76      1.35
        8.85      0.00     0.94     39.1 0.256E+01   1.78      1.35
        8.91      0.00     0.95     39.2 0.255E+01   1.79      1.35
        8.96      0.00     0.95     39.3 0.255E+01   1.80      1.35
        9.02      0.00     0.96     39.4 0.254E+01   1.81      1.35
        9.07      0.00     0.96     39.5 0.253E+01   1.82      1.35
```

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      9.13     0.00    0.96    39.6 0.252E+01   1.83     1.35
      9.18     0.00    0.97    39.8 0.252E+01   1.84     1.35
      9.24     0.00    0.97    39.9 0.251E+01   1.85     1.35
      9.29     0.00    0.98    40.0 0.250E+01   1.86     1.35
      9.35     0.00    0.98    40.1 0.249E+01   1.87     1.35
      9.40     0.00    0.98    40.2 0.249E+01   1.88     1.35
      9.46     0.00    0.99    40.3 0.248E+01   1.90     1.35
      9.51     0.00    0.99    40.4 0.247E+01   1.91     1.35
      9.57     0.00    1.00    40.6 0.247E+01   1.92     1.35
      9.62     0.00    1.00    40.7 0.246E+01   1.93     1.35
      9.68     0.00    1.00    40.8 0.245E+01   1.94     1.35
      9.73     0.00    1.01    40.9 0.245E+01   1.95     1.35
      9.79     0.00    1.01    41.0 0.244E+01   1.96     1.35
      9.84     0.00    1.02    41.1 0.243E+01   1.97     1.35
      9.90     0.00    1.02    41.2 0.243E+01   1.98     1.35
      9.95     0.00    1.02    41.3 0.242E+01   1.99     1.35
     10.01     0.00    1.03    41.5 0.241E+01   2.00     1.35
     10.07     0.00    1.03    41.6 0.241E+01   2.01     1.35
     10.12     0.00    1.04    41.7 0.240E+01   2.03     1.35
     10.18     0.00    1.04    41.8 0.239E+01   2.04     1.35
     10.23     0.00    1.04    41.9 0.239E+01   2.05     1.35
     10.29     0.00    1.05    42.0 0.238E+01   2.06     1.35
     10.34     0.00    1.05    42.1 0.237E+01   2.07     1.35
     10.40     0.00    1.06    42.2 0.237E+01   2.08     1.35
     10.45     0.00    1.06    42.3 0.236E+01   2.09     1.35
     10.51     0.00    1.06    42.4 0.236E+01   2.10     1.35
     10.56     0.00    1.07    42.6 0.235E+01   2.11     1.35
     10.62     0.00    1.07    42.7 0.234E+01   2.12     1.35
     10.67     0.00    1.08    42.8 0.234E+01   2.13     1.35
     10.73     0.00    1.08    42.9 0.233E+01   2.15     1.35
     10.78     0.00    1.08    43.0 0.233E+01   2.16     1.35
     10.84     0.00    1.09    43.1 0.232E+01   2.17     1.35
     10.89     0.00    1.09    43.2 0.231E+01   2.18     1.35
     10.95     0.00    1.10    43.3 0.231E+01   2.19     1.35
     11.00     0.00    1.10    43.4 0.230E+01   2.20     1.35
 Cumulative travel time =         34.0160 sec
   Plume centerline may exhibit slight discontinuities in transition
     to subsequent far-field module.

END OF MOD277: UNSTABLE NEAR-FIELD ZONE OF ALTERNATING PERPENDICULAR DIFFUSER
-----------------------------------------------------------------------------
** End of NEAR-FIELD REGION (NFR) **
-----------------------------------------------------------------------------
BEGIN MOD241: BUOYANT AMBIENT SPREADING

 Discharge is non-buoyant or weakly buoyant.
   Therefore BUOYANT SPREADING REGIME is ABSENT.

END OF MOD241: BUOYANT AMBIENT SPREADING
-----------------------------------------------------------------------------
 Due to the attachment or proximity of the plume tothe bottom, the bottom
   coordinate for the FAR-FIELD differs from the ambient depth, ZFB = 0 m.
 In a subsequent analysis set "depth at discharge" equal to "ambient depth".
-----------------------------------------------------------------------------
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BEGIN MOD261: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

  Vertical diffusivity (initial value)   = 0.232E-01 m^2/s
  Horizontal diffusivity (initial value) = 0.289E-01 m^2/s

 The passive diffusion plume is VERTICALLY FULLY MIXED at beginning of region.

 Profile definitions:
   BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
      = or equal to layer depth, if fully mixed
   BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
        measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
   S  = hydrodynamic centerline dilution
   C  = centerline concentration (includes reaction effects, if any)

 Plume Stage 1 (not bank attached):
       X        Y       Z        S       C       BV       BH      ZU      ZL
     11.00     0.00    2.20     43.4 0.230E+01   2.20     1.35    2.20    0.00
     14.04     0.00    2.20     48.2 0.207E+01   2.20     1.50    2.20    0.00
     17.07     0.00    2.20     52.6 0.190E+01   2.20     1.64    2.20    0.00
     20.11     0.00    2.20     56.6 0.177E+01   2.20     1.77    2.20    0.00
     23.14     0.00    2.20     60.4 0.166E+01   2.20     1.88    2.20    0.00
     26.18     0.00    2.20     63.9 0.156E+01   2.20     1.99    2.20    0.00
     29.21     0.00    2.20     67.3 0.149E+01   2.20     2.10    2.20    0.00
     32.25     0.00    2.20     70.4 0.142E+01   2.20     2.20    2.20    0.00
     35.28     0.00    2.20     73.5 0.136E+01   2.20     2.29    2.20    0.00
     38.32     0.00    2.20     76.4 0.131E+01   2.20     2.38    2.20    0.00
     41.35     0.00    2.20     79.3 0.126E+01   2.20     2.47    2.20    0.00
     44.39     0.00    2.20     82.0 0.122E+01   2.20     2.56    2.20    0.00
     47.42     0.00    2.20     84.6 0.118E+01   2.20     2.64    2.20    0.00
     50.46     0.00    2.20     87.2 0.115E+01   2.20     2.72    2.20    0.00
     53.49     0.00    2.20     89.7 0.112E+01   2.20     2.80    2.20    0.00
     56.53     0.00    2.20     92.1 0.109E+01   2.20     2.87    2.20    0.00
     59.56     0.00    2.20     94.4 0.106E+01   2.20     2.95    2.20    0.00
     62.60     0.00    2.20     96.7 0.103E+01   2.20     3.02    2.20    0.00
     65.63     0.00    2.20     99.0 0.101E+01   2.20     3.09    2.20    0.00
     68.67     0.00    2.20    101.2 0.988E+00   2.20     3.16    2.20    0.00
     71.70     0.00    2.20    103.3 0.968E+00   2.20     3.22    2.20    0.00
     74.74     0.00    2.20    105.4 0.948E+00   2.20     3.29    2.20    0.00
     77.77     0.00    2.20    107.5 0.930E+00   2.20     3.35    2.20    0.00
     80.81     0.00    2.20    109.5 0.913E+00   2.20     3.42    2.20    0.00
     83.84     0.00    2.20    111.5 0.897E+00   2.20     3.48    2.20    0.00
     86.88     0.00    2.20    113.5 0.881E+00   2.20     3.54    2.20    0.00
     89.91     0.00    2.20    115.4 0.867E+00   2.20     3.60    2.20    0.00
     92.95     0.00    2.20    117.3 0.853E+00   2.20     3.66    2.20    0.00
     95.99     0.00    2.20    119.1 0.839E+00   2.20     3.72    2.20    0.00
     99.02     0.00    2.20    121.0 0.827E+00   2.20     3.77    2.20    0.00
    102.06     0.00    2.20    122.8 0.814E+00   2.20     3.83    2.20    0.00
    105.09     0.00    2.20    124.6 0.803E+00   2.20     3.89    2.20    0.00
    108.13     0.00    2.20    126.3 0.792E+00   2.20     3.94    2.20    0.00
    111.16     0.00    2.20    128.0 0.781E+00   2.20     3.99    2.20    0.00
    114.20     0.00    2.20    129.7 0.771E+00   2.20     4.05    2.20    0.00
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    117.23     0.00     2.20   131.4 0.761E+00   2.20     4.10     2.20     0.00
    120.27     0.00     2.20   133.1 0.751E+00   2.20     4.15     2.20     0.00
    123.30     0.00     2.20   134.7 0.742E+00   2.20     4.20     2.20     0.00
    126.34     0.00     2.20   136.4 0.733E+00   2.20     4.25     2.20     0.00
    129.37     0.00     2.20   138.0 0.725E+00   2.20     4.30     2.20     0.00
    132.41     0.00     2.20   139.5 0.717E+00   2.20     4.35     2.20     0.00
    135.44     0.00     2.20   141.1 0.709E+00   2.20     4.40     2.20     0.00
    138.48     0.00     2.20   142.7 0.701E+00   2.20     4.45     2.20     0.00
    141.51     0.00     2.20   144.2 0.694E+00   2.20     4.50     2.20     0.00
    144.55     0.00     2.20   145.7 0.686E+00   2.20     4.55     2.20     0.00
    147.58     0.00     2.20   147.2 0.679E+00   2.20     4.59     2.20     0.00
    150.62     0.00     2.20   148.7 0.673E+00   2.20     4.64     2.20     0.00
    153.65     0.00     2.20   150.2 0.666E+00   2.20     4.68     2.20     0.00
    156.69     0.00     2.20   151.6 0.660E+00   2.20     4.73     2.20     0.00
    159.72     0.00     2.20   153.1 0.653E+00   2.20     4.78     2.20     0.00
    162.76     0.00     2.20   154.5 0.647E+00   2.20     4.82     2.20     0.00
    165.79     0.00     2.20   155.9 0.641E+00   2.20     4.86     2.20     0.00
    168.83     0.00     2.20   157.3 0.636E+00   2.20     4.91     2.20     0.00
    171.86     0.00     2.20   158.7 0.630E+00   2.20     4.95     2.20     0.00
    174.90     0.00     2.20   160.1 0.625E+00   2.20     4.99     2.20     0.00
    177.94     0.00     2.20   161.5 0.619E+00   2.20     5.04     2.20     0.00
    180.97     0.00     2.20   162.8 0.614E+00   2.20     5.08     2.20     0.00
    184.01     0.00     2.20   164.2 0.609E+00   2.20     5.12     2.20     0.00
    187.04     0.00     2.20   165.5 0.604E+00   2.20     5.16     2.20     0.00
    190.08     0.00     2.20   166.8 0.599E+00   2.20     5.20     2.20     0.00
    193.11     0.00     2.20   168.1 0.595E+00   2.20     5.25     2.20     0.00
    196.15     0.00     2.20   169.4 0.590E+00   2.20     5.29     2.20     0.00
    199.18     0.00     2.20   170.7 0.586E+00   2.20     5.33     2.20     0.00
    202.22     0.00     2.20   172.0 0.581E+00   2.20     5.37     2.20     0.00
    205.25     0.00     2.20   173.3 0.577E+00   2.20     5.41     2.20     0.00
    208.29     0.00     2.20   174.5 0.573E+00   2.20     5.45     2.20     0.00
    211.32     0.00     2.20   175.8 0.569E+00   2.20     5.48     2.20     0.00
    214.36     0.00     2.20   177.0 0.565E+00   2.20     5.52     2.20     0.00
    217.39     0.00     2.20   178.3 0.561E+00   2.20     5.56     2.20     0.00
    220.43     0.00     2.20   179.5 0.557E+00   2.20     5.60     2.20     0.00
    223.46     0.00     2.20   180.7 0.553E+00   2.20     5.64     2.20     0.00
    226.50     0.00     2.20   181.9 0.550E+00   2.20     5.68     2.20     0.00
    229.53     0.00     2.20   183.1 0.546E+00   2.20     5.71     2.20     0.00
    232.57     0.00     2.20   184.3 0.542E+00   2.20     5.75     2.20     0.00
    235.60     0.00     2.20   185.5 0.539E+00   2.20     5.79     2.20     0.00
    238.64     0.00     2.20   186.7 0.536E+00   2.20     5.82     2.20     0.00
    241.67     0.00     2.20   187.9 0.532E+00   2.20     5.86     2.20     0.00
    244.71     0.00     2.20   189.1 0.529E+00   2.20     5.90     2.20     0.00
    247.74     0.00     2.20   190.2 0.526E+00   2.20     5.93     2.20     0.00
    250.78     0.00     2.20   191.4 0.523E+00   2.20     5.97     2.20     0.00
    253.81     0.00     2.20   192.5 0.519E+00   2.20     6.01     2.20     0.00
    256.85     0.00     2.20   193.7 0.516E+00   2.20     6.04     2.20     0.00
    259.89     0.00     2.20   194.8 0.513E+00   2.20     6.08     2.20     0.00
    262.92     0.00     2.20   195.9 0.510E+00   2.20     6.11     2.20     0.00
    265.96     0.00     2.20   197.0 0.508E+00   2.20     6.15     2.20     0.00
    268.99     0.00     2.20   198.1 0.505E+00   2.20     6.18     2.20     0.00
    272.03     0.00     2.20   199.2 0.502E+00   2.20     6.22     2.20     0.00
    275.06     0.00     2.20   200.3 0.499E+00   2.20     6.25     2.20     0.00
    278.10     0.00     2.20   201.4 0.496E+00   2.20     6.28     2.20     0.00
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281.13	0.00	2.20	202.5	0.494E+00	2.20	6.32	2.20	0.00
284.17	0.00	2.20	203.6	0.491E+00	2.20	6.35	2.20	0.00
287.20	0.00	2.20	204.7	0.489E+00	2.20	6.39	2.20	0.00
290.24	0.00	2.20	205.8	0.486E+00	2.20	6.42	2.20	0.00
293.27	0.00	2.20	206.8	0.483E+00	2.20	6.45	2.20	0.00
296.31	0.00	2.20	207.9	0.481E+00	2.20	6.49	2.20	0.00
299.34	0.00	2.20	208.9	0.479E+00	2.20	6.52	2.20	0.00
302.38	0.00	2.20	210.0	0.476E+00	2.20	6.55	2.20	0.00
305.41	0.00	2.20	211.0	0.474E+00	2.20	6.58	2.20	0.00
308.45	0.00	2.20	212.1	0.472E+00	2.20	6.62	2.20	0.00
311.48	0.00	2.20	213.1	0.469E+00	2.20	6.65	2.20	0.00
314.52	0.00	2.20	214.1	0.467E+00	2.20	6.68	2.20	0.00
317.55	0.00	2.20	215.2	0.465E+00	2.20	6.71	2.20	0.00
320.59	0.00	2.20	216.2	0.463E+00	2.20	6.74	2.20	0.00
323.62	0.00	2.20	217.2	0.460E+00	2.20	6.78	2.20	0.00
326.66	0.00	2.20	218.2	0.458E+00	2.20	6.81	2.20	0.00
329.69	0.00	2.20	219.2	0.456E+00	2.20	6.84	2.20	0.00
332.73	0.00	2.20	220.2	0.454E+00	2.20	6.87	2.20	0.00
335.76	0.00	2.20	221.2	0.452E+00	2.20	6.90	2.20	0.00
338.80	0.00	2.20	222.2	0.450E+00	2.20	6.93	2.20	0.00
341.84	0.00	2.20	223.2	0.448E+00	2.20	6.96	2.20	0.00
344.87	0.00	2.20	224.2	0.446E+00	2.20	6.99	2.20	0.00
347.91	0.00	2.20	225.2	0.444E+00	2.20	7.02	2.20	0.00
350.94	0.00	2.20	226.1	0.442E+00	2.20	7.05	2.20	0.00
353.98	0.00	2.20	227.1	0.440E+00	2.20	7.08	2.20	0.00
357.01	0.00	2.20	228.1	0.438E+00	2.20	7.11	2.20	0.00
360.05	0.00	2.20	229.0	0.437E+00	2.20	7.14	2.20	0.00
363.08	0.00	2.20	230.0	0.435E+00	2.20	7.17	2.20	0.00
366.12	0.00	2.20	230.9	0.433E+00	2.20	7.20	2.20	0.00
369.15	0.00	2.20	231.9	0.431E+00	2.20	7.23	2.20	0.00
372.19	0.00	2.20	232.8	0.429E+00	2.20	7.26	2.20	0.00
375.22	0.00	2.20	233.8	0.428E+00	2.20	7.29	2.20	0.00
378.26	0.00	2.20	234.7	0.426E+00	2.20	7.32	2.20	0.00
381.29	0.00	2.20	235.6	0.424E+00	2.20	7.35	2.20	0.00
384.33	0.00	2.20	236.6	0.423E+00	2.20	7.38	2.20	0.00
387.36	0.00	2.20	237.5	0.421E+00	2.20	7.41	2.20	0.00
390.40	0.00	2.20	238.4	0.419E+00	2.20	7.44	2.20	0.00
393.43	0.00	2.20	239.3	0.418E+00	2.20	7.47	2.20	0.00
396.47	0.00	2.20	240.3	0.416E+00	2.20	7.50	2.20	0.00
399.50	0.00	2.20	241.2	0.415E+00	2.20	7.52	2.20	0.00
402.54	0.00	2.20	242.1	0.413E+00	2.20	7.55	2.20	0.00
405.57	0.00	2.20	243.0	0.412E+00	2.20	7.58	2.20	0.00
408.61	0.00	2.20	243.9	0.410E+00	2.20	7.61	2.20	0.00
411.64	0.00	2.20	244.8	0.408E+00	2.20	7.64	2.20	0.00
414.68	0.00	2.20	245.7	0.407E+00	2.20	7.66	2.20	0.00
417.71	0.00	2.20	246.6	0.406E+00	2.20	7.69	2.20	0.00
420.75	0.00	2.20	247.5	0.404E+00	2.20	7.72	2.20	0.00
423.79	0.00	2.20	248.4	0.403E+00	2.20	7.75	2.20	0.00
426.82	0.00	2.20	249.2	0.401E+00	2.20	7.78	2.20	0.00
429.86	0.00	2.20	250.1	0.400E+00	2.20	7.80	2.20	0.00
432.89	0.00	2.20	251.0	0.398E+00	2.20	7.83	2.20	0.00
435.93	0.00	2.20	251.9	0.397E+00	2.20	7.86	2.20	0.00
438.96	0.00	2.20	252.8	0.396E+00	2.20	7.89	2.20	0.00
442.00	0.00	2.20	253.6	0.394E+00	2.20	7.91	2.20	0.00

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   445.03     0.00     2.20   254.5 0.393E+00   2.20     7.94     2.20     0.00
   448.07     0.00     2.20   255.3 0.392E+00   2.20     7.97     2.20     0.00
   451.10     0.00     2.20   256.2 0.390E+00   2.20     7.99     2.20     0.00
   454.14     0.00     2.20   257.1 0.389E+00   2.20     8.02     2.20     0.00
   457.17     0.00     2.20   257.9 0.388E+00   2.20     8.05     2.20     0.00
   460.21     0.00     2.20   258.8 0.386E+00   2.20     8.07     2.20     0.00
   463.24     0.00     2.20   259.6 0.385E+00   2.20     8.10     2.20     0.00

   466.28     0.00     2.20   260.5 0.384E+00   2.20     8.13     2.20     0.00
   469.31     0.00     2.20   261.3 0.383E+00   2.20     8.15     2.20     0.00
   472.35     0.00     2.20   262.1 0.381E+00   2.20     8.18     2.20     0.00
   475.38     0.00     2.20   263.0 0.380E+00   2.20     8.20     2.20     0.00
   478.42     0.00     2.20   263.8 0.379E+00   2.20     8.23     2.20     0.00
   481.45     0.00     2.20   264.7 0.378E+00   2.20     8.26     2.20     0.00
   484.49     0.00     2.20   265.5 0.377E+00   2.20     8.28     2.20     0.00
   487.52     0.00     2.20   266.3 0.376E+00   2.20     8.31     2.20     0.00
   490.56     0.00     2.20   267.1 0.374E+00   2.20     8.33     2.20     0.00
   493.59     0.00     2.20   268.0 0.373E+00   2.20     8.36     2.20     0.00
   496.63     0.00     2.20   268.8 0.372E+00   2.20     8.38     2.20     0.00
   499.67     0.00     2.20   269.6 0.371E+00   2.20     8.41     2.20     0.00
   502.70     0.00     2.20   270.4 0.370E+00   2.20     8.44     2.20     0.00
   505.74     0.00     2.20   271.2 0.369E+00   2.20     8.46     2.20     0.00
   508.77     0.00     2.20   272.0 0.368E+00   2.20     8.49     2.20     0.00
   511.81     0.00     2.20   272.8 0.367E+00   2.20     8.51     2.20     0.00
   514.84     0.00     2.20   273.6 0.365E+00   2.20     8.54     2.20     0.00
   517.88     0.00     2.20   274.4 0.364E+00   2.20     8.56     2.20     0.00
   520.91     0.00     2.20   275.2 0.363E+00   2.20     8.59     2.20     0.00
   523.95     0.00     2.20   276.0 0.362E+00   2.20     8.61     2.20     0.00
   526.98     0.00     2.20   276.8 0.361E+00   2.20     8.64     2.20     0.00
   530.02     0.00     2.20   277.6 0.360E+00   2.20     8.66     2.20     0.00
   533.05     0.00     2.20   278.4 0.359E+00   2.20     8.69     2.20     0.00
   536.09     0.00     2.20   279.2 0.358E+00   2.20     8.71     2.20     0.00
   539.12     0.00     2.20   280.0 0.357E+00   2.20     8.73     2.20     0.00
   542.16     0.00     2.20   280.8 0.356E+00   2.20     8.76     2.20     0.00
   545.19     0.00     2.20   281.6 0.355E+00   2.20     8.78     2.20     0.00
   548.23     0.00     2.20   282.3 0.354E+00   2.20     8.81     2.20     0.00
   551.26     0.00     2.20   283.1 0.353E+00   2.20     8.83     2.20     0.00
   554.30     0.00     2.20   283.9 0.352E+00   2.20     8.86     2.20     0.00
   557.33     0.00     2.20   284.7 0.351E+00   2.20     8.88     2.20     0.00
   560.37     0.00     2.20   285.4 0.350E+00   2.20     8.90     2.20     0.00
   563.40     0.00     2.20   286.2 0.349E+00   2.20     8.93     2.20     0.00
   566.44     0.00     2.20   287.0 0.348E+00   2.20     8.95     2.20     0.00
   569.47     0.00     2.20   287.7 0.348E+00   2.20     8.98     2.20     0.00
   572.51     0.00     2.20   288.5 0.347E+00   2.20     9.00     2.20     0.00
   575.54     0.00     2.20   289.3 0.346E+00   2.20     9.02     2.20     0.00
   578.58     0.00     2.20   290.0 0.345E+00   2.20     9.05     2.20     0.00
   581.61     0.00     2.20   290.8 0.344E+00   2.20     9.07     2.20     0.00
   584.65     0.00     2.20   291.5 0.343E+00   2.20     9.09     2.20     0.00
   587.68     0.00     2.20   292.3 0.342E+00   2.20     9.12     2.20     0.00
   590.72     0.00     2.20   293.0 0.341E+00   2.20     9.14     2.20     0.00
   593.76     0.00     2.20   293.8 0.340E+00   2.20     9.17     2.20     0.00
   596.79     0.00     2.20   294.5 0.340E+00   2.20     9.19     2.20     0.00
   599.83     0.00     2.20   295.3 0.339E+00   2.20     9.21     2.20     0.00
   602.86     0.00     2.20   296.0 0.338E+00   2.20     9.23     2.20     0.00
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   605.90     0.00    2.20   296.8 0.337E+00   2.20     9.26    2.20    0.00
   608.93     0.00    2.20   297.5 0.336E+00   2.20     9.28    2.20    0.00
   611.97     0.00    2.20   298.2 0.335E+00   2.20     9.30    2.20    0.00
   615.00     0.00    2.20   299.0 0.334E+00   2.20     9.33    2.20    0.00
   618.04     0.00    2.20   299.7 0.334E+00   2.20     9.35    2.20    0.00
 Cumulative travel time =         975.1174 sec

-----------------------------------------------------------------------------
 Plume Stage 2 (bank attached):
      X        Y        Z        S        C       BV       BH      ZU      ZL
   618.04    -9.35    2.20   299.7 0.334E+00   2.20    18.70    2.20    0.00

   714.95    -9.35    2.20   305.5 0.327E+00   2.20    19.06    2.20    0.00
   811.86    -9.35    2.20   311.2 0.321E+00   2.20    19.42    2.20    0.00
   908.77    -9.35    2.20   316.8 0.316E+00   2.20    19.77    2.20    0.00
  1005.68    -9.35    2.20   322.3 0.310E+00   2.20    20.11    2.20    0.00
  1102.59    -9.35    2.20   327.7 0.305E+00   2.20    20.45    2.20    0.00
  1199.49    -9.35    2.20   333.0 0.300E+00   2.20    20.78    2.20    0.00
 ** REGULATORY MIXING ZONE BOUNDARY **
 In this prediction interval the plume DOWNSTREAM distance meets or exceeds
 the regulatory value =  1293.00 m.
 This is the extent of the REGULATORY MIXING ZONE.
  1296.40    -9.35    2.20   338.2 0.296E+00   2.20    21.10    2.20    0.00
  1393.31    -9.35    2.20   343.4 0.291E+00   2.20    21.42    2.20    0.00
  1490.22    -9.35    2.20   348.4 0.287E+00   2.20    21.74    2.20    0.00
  1587.13    -9.35    2.20   353.4 0.283E+00   2.20    22.05    2.20    0.00
  1684.04    -9.35    2.20   358.4 0.279E+00   2.20    22.36    2.20    0.00
  1780.95    -9.35    2.20   363.2 0.275E+00   2.20    22.66    2.20    0.00
  1877.86    -9.35    2.20   368.0 0.272E+00   2.20    22.96    2.20    0.00
  1974.77    -9.35    2.20   372.8 0.268E+00   2.20    23.26    2.20    0.00
  2071.68    -9.35    2.20   377.5 0.265E+00   2.20    23.55    2.20    0.00
  2168.59    -9.35    2.20   382.1 0.262E+00   2.20    23.84    2.20    0.00
  2265.50    -9.35    2.20   386.6 0.259E+00   2.20    24.12    2.20    0.00
  2362.41    -9.35    2.20   391.2 0.256E+00   2.20    24.41    2.20    0.00
  2459.32    -9.35    2.20   395.6 0.253E+00   2.20    24.68    2.20    0.00
  2556.23    -9.35    2.20   400.0 0.250E+00   2.20    24.96    2.20    0.00
  2653.14    -9.35    2.20   404.4 0.247E+00   2.20    25.23    2.20    0.00
  2750.05    -9.35    2.20   408.7 0.245E+00   2.20    25.50    2.20    0.00
  2846.96    -9.35    2.20   413.0 0.242E+00   2.20    25.77    2.20    0.00
  2943.87    -9.35    2.20   417.2 0.240E+00   2.20    26.03    2.20    0.00
  3040.78    -9.35    2.20   421.4 0.237E+00   2.20    26.29    2.20    0.00
  3137.69    -9.35    2.20   425.5 0.235E+00   2.20    26.55    2.20    0.00
  3234.60    -9.35    2.20   429.6 0.233E+00   2.20    26.81    2.20    0.00
  3331.51    -9.35    2.20   433.7 0.231E+00   2.20    27.06    2.20    0.00
  3428.42    -9.35    2.20   437.7 0.228E+00   2.20    27.31    2.20    0.00
  3525.33    -9.35    2.20   441.7 0.226E+00   2.20    27.56    2.20    0.00
  3622.24    -9.35    2.20   445.7 0.224E+00   2.20    27.81    2.20    0.00
  3719.15    -9.35    2.20   449.6 0.222E+00   2.20    28.05    2.20    0.00
  3816.06    -9.35    2.20   453.5 0.221E+00   2.20    28.29    2.20    0.00
  3912.97    -9.35    2.20   457.3 0.219E+00   2.20    28.54    2.20    0.00
  4009.88    -9.35    2.20   461.2 0.217E+00   2.20    28.77    2.20    0.00
  4106.79    -9.35    2.20   465.0 0.215E+00   2.20    29.01    2.20    0.00
  4203.70    -9.35    2.20   468.7 0.213E+00   2.20    29.24    2.20    0.00
  4300.61    -9.35    2.20   472.4 0.212E+00   2.20    29.48    2.20    0.00
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    4397.52     -9.35     2.20    476.1 0.210E+00    2.20     29.71     2.20     0.00
    4494.43     -9.35     2.20    479.8 0.208E+00    2.20     29.94     2.20     0.00
    4591.34     -9.35     2.20    483.5 0.207E+00    2.20     30.16     2.20     0.00
    4688.25     -9.35     2.20    487.1 0.205E+00    2.20     30.39     2.20     0.00
    4785.16     -9.35     2.20    490.7 0.204E+00    2.20     30.61     2.20     0.00
    4882.07     -9.35     2.20    494.2 0.202E+00    2.20     30.84     2.20     0.00
    4978.98     -9.35     2.20    497.8 0.201E+00    2.20     31.06     2.20     0.00
    5075.89     -9.35     2.20    501.3 0.199E+00    2.20     31.28     2.20     0.00

    5172.80     -9.35     2.20    504.8 0.198E+00    2.20     31.49     2.20     0.00
    5269.71     -9.35     2.20    508.2 0.197E+00    2.20     31.71     2.20     0.00
    5366.62     -9.35     2.20    511.7 0.195E+00    2.20     31.93     2.20     0.00
    5463.53     -9.35     2.20    515.1 0.194E+00    2.20     32.14     2.20     0.00
    5560.44     -9.35     2.20    518.5 0.193E+00    2.20     32.35     2.20     0.00
    5657.35     -9.35     2.20    521.9 0.192E+00    2.20     32.56     2.20     0.00
    5754.26     -9.35     2.20    525.2 0.190E+00    2.20     32.77     2.20     0.00
    5851.17     -9.35     2.20    528.5 0.189E+00    2.20     32.98     2.20     0.00
    5948.07     -9.35     2.20    531.9 0.188E+00    2.20     33.18     2.20     0.00
    6044.98     -9.35     2.20    535.1 0.187E+00    2.20     33.39     2.20     0.00
    6141.89     -9.35     2.20    538.4 0.186E+00    2.20     33.59     2.20     0.00
    6238.80     -9.35     2.20    541.7 0.185E+00    2.20     33.80     2.20     0.00
    6335.71     -9.35     2.20    544.9 0.184E+00    2.20     34.00     2.20     0.00
    6432.62     -9.35     2.20    548.1 0.182E+00    2.20     34.20     2.20     0.00
    6529.53     -9.35     2.20    551.3 0.181E+00    2.20     34.40     2.20     0.00
    6626.44     -9.35     2.20    554.5 0.180E+00    2.20     34.60     2.20     0.00
    6723.35     -9.35     2.20    557.6 0.179E+00    2.20     34.79     2.20     0.00
    6820.26     -9.35     2.20    560.8 0.178E+00    2.20     34.99     2.20     0.00
    6917.17     -9.35     2.20    563.9 0.177E+00    2.20     35.18     2.20     0.00
    7014.08     -9.35     2.20    567.0 0.176E+00    2.20     35.38     2.20     0.00
    7110.99     -9.35     2.20    570.1 0.175E+00    2.20     35.57     2.20     0.00
    7207.90     -9.35     2.20    573.1 0.174E+00    2.20     35.76     2.20     0.00
    7304.81     -9.35     2.20    576.2 0.174E+00    2.20     35.95     2.20     0.00
    7401.72     -9.35     2.20    579.2 0.173E+00    2.20     36.14     2.20     0.00
    7498.63     -9.35     2.20    582.3 0.172E+00    2.20     36.33     2.20     0.00
    7595.54     -9.35     2.20    585.3 0.171E+00    2.20     36.52     2.20     0.00
    7692.45     -9.35     2.20    588.3 0.170E+00    2.20     36.70     2.20     0.00
    7789.36     -9.35     2.20    591.2 0.169E+00    2.20     36.89     2.20     0.00
    7886.27     -9.35     2.20    594.2 0.168E+00    2.20     37.07     2.20     0.00
    7983.18     -9.35     2.20    597.1 0.167E+00    2.20     37.26     2.20     0.00
    8080.09     -9.35     2.20    600.1 0.167E+00    2.20     37.44     2.20     0.00
    8177.00     -9.35     2.20    603.0 0.166E+00    2.20     37.62     2.20     0.00
    8273.91     -9.35     2.20    605.9 0.165E+00    2.20     37.80     2.20     0.00
    8370.82     -9.35     2.20    608.8 0.164E+00    2.20     37.98     2.20     0.00
    8467.73     -9.35     2.20    611.7 0.163E+00    2.20     38.16     2.20     0.00
    8564.64     -9.35     2.20    614.5 0.163E+00    2.20     38.34     2.20     0.00
    8661.55     -9.35     2.20    617.4 0.162E+00    2.20     38.52     2.20     0.00
    8758.46     -9.35     2.20    620.2 0.161E+00    2.20     38.70     2.20     0.00
    8855.37     -9.35     2.20    623.0 0.161E+00    2.20     38.87     2.20     0.00
    8952.28     -9.35     2.20    625.8 0.160E+00    2.20     39.05     2.20     0.00
    9049.19     -9.35     2.20    628.6 0.159E+00    2.20     39.22     2.20     0.00
    9146.10     -9.35     2.20    631.4 0.158E+00    2.20     39.40     2.20     0.00
    9243.01     -9.35     2.20    634.2 0.158E+00    2.20     39.57     2.20     0.00
    9339.92     -9.35     2.20    637.0 0.157E+00    2.20     39.74     2.20     0.00
    9436.83     -9.35     2.20    639.7 0.156E+00    2.20     39.91     2.20     0.00
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    9533.74     -9.35     2.20   642.4 0.156E+00   2.20     40.08     2.20     0.00
    9630.65     -9.35     2.20   645.2 0.155E+00   2.20     40.25     2.20     0.00
    9727.56     -9.35     2.20   647.9 0.154E+00   2.20     40.42     2.20     0.00
    9824.47     -9.35     2.20   650.6 0.154E+00   2.20     40.59     2.20     0.00
    9921.38     -9.35     2.20   653.3 0.153E+00   2.20     40.76     2.20     0.00
   10018.29     -9.35     2.20   656.0 0.152E+00   2.20     40.93     2.20     0.00
   10115.20     -9.35     2.20   658.6 0.152E+00   2.20     41.09     2.20     0.00
   10212.11     -9.35     2.20   661.3 0.151E+00   2.20     41.26     2.20     0.00
   10309.02     -9.35     2.20   663.9 0.151E+00   2.20     41.43     2.20     0.00
   10405.93     -9.35     2.20   666.6 0.150E+00   2.20     41.59     2.20     0.00
   10502.84     -9.35     2.20   669.2 0.149E+00   2.20     41.75     2.20     0.00
   10599.75     -9.35     2.20   671.8 0.149E+00   2.20     41.92     2.20     0.00
   10696.66     -9.35     2.20   674.4 0.148E+00   2.20     42.08     2.20     0.00
   10793.57     -9.35     2.20   677.0 0.148E+00   2.20     42.24     2.20     0.00
   10890.48     -9.35     2.20   679.6 0.147E+00   2.20     42.40     2.20     0.00
   10987.39     -9.35     2.20   682.2 0.147E+00   2.20     42.56     2.20     0.00
   11084.30     -9.35     2.20   684.8 0.146E+00   2.20     42.72     2.20     0.00
   11181.21     -9.35     2.20   687.3 0.145E+00   2.20     42.88     2.20     0.00
   11278.12     -9.35     2.20   689.9 0.145E+00   2.20     43.04     2.20     0.00
   11375.03     -9.35     2.20   692.4 0.144E+00   2.20     43.20     2.20     0.00
   11471.94     -9.35     2.20   694.9 0.144E+00   2.20     43.36     2.20     0.00
   11568.85     -9.35     2.20   697.5 0.143E+00   2.20     43.52     2.20     0.00
   11665.76     -9.35     2.20   700.0 0.143E+00   2.20     43.67     2.20     0.00
   11762.67     -9.35     2.20   702.5 0.142E+00   2.20     43.83     2.20     0.00
   11859.58     -9.35     2.20   705.0 0.142E+00   2.20     43.99     2.20     0.00
   11956.49     -9.35     2.20   707.4 0.141E+00   2.20     44.14     2.20     0.00
   12053.40     -9.35     2.20   709.9 0.141E+00   2.20     44.29     2.20     0.00
   12150.31     -9.35     2.20   712.4 0.140E+00   2.20     44.45     2.20     0.00
   12247.22     -9.35     2.20   714.9 0.140E+00   2.20     44.60     2.20     0.00
   12344.13     -9.35     2.20   717.3 0.139E+00   2.20     44.75     2.20     0.00
   12441.04     -9.35     2.20   719.7 0.139E+00   2.20     44.91     2.20     0.00
   12537.95     -9.35     2.20   722.2 0.138E+00   2.20     45.06     2.20     0.00
   12634.86     -9.35     2.20   724.6 0.138E+00   2.20     45.21     2.20     0.00
   12731.77     -9.35     2.20   727.0 0.138E+00   2.20     45.36     2.20     0.00
   12828.68     -9.35     2.20   729.4 0.137E+00   2.20     45.51     2.20     0.00
   12925.59     -9.35     2.20   731.8 0.137E+00   2.20     45.66     2.20     0.00
   13022.50     -9.35     2.20   734.2 0.136E+00   2.20     45.81     2.20     0.00
   13119.42     -9.35     2.20   736.6 0.136E+00   2.20     45.96     2.20     0.00
   13216.33     -9.35     2.20   739.0 0.135E+00   2.20     46.11     2.20     0.00
   13313.24     -9.35     2.20   741.4 0.135E+00   2.20     46.26     2.20     0.00
   13410.15     -9.35     2.20   743.7 0.134E+00   2.20     46.40     2.20     0.00
   13507.06     -9.35     2.20   746.1 0.134E+00   2.20     46.55     2.20     0.00
   13603.97     -9.35     2.20   748.4 0.134E+00   2.20     46.70     2.20     0.00
   13700.88     -9.35     2.20   750.8 0.133E+00   2.20     46.84     2.20     0.00
   13797.79     -9.35     2.20   753.1 0.133E+00   2.20     46.99     2.20     0.00
   13894.70     -9.35     2.20   755.4 0.132E+00   2.20     47.13     2.20     0.00
   13991.61     -9.35     2.20   757.8 0.132E+00   2.20     47.28     2.20     0.00
   14088.52     -9.35     2.20   760.1 0.132E+00   2.20     47.42     2.20     0.00
   14185.43     -9.35     2.20   762.4 0.131E+00   2.20     47.57     2.20     0.00
   14282.34     -9.35     2.20   764.7 0.131E+00   2.20     47.71     2.20     0.00
   14379.25     -9.35     2.20   767.0 0.130E+00   2.20     47.85     2.20     0.00
   14476.16     -9.35     2.20   769.2 0.130E+00   2.20     48.00     2.20     0.00
   14573.07     -9.35     2.20   771.5 0.130E+00   2.20     48.14     2.20     0.00
   14669.98     -9.35     2.20   773.8 0.129E+00   2.20     48.28     2.20     0.00
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  14766.89     -9.35     2.20    776.1 0.129E+00    2.20     48.42     2.20     0.00
  14863.80     -9.35     2.20    778.3 0.128E+00    2.20     48.56     2.20     0.00
  14960.71     -9.35     2.20    780.6 0.128E+00    2.20     48.70     2.20     0.00
  15057.62     -9.35     2.20    782.8 0.128E+00    2.20     48.84     2.20     0.00
  15154.53     -9.35     2.20    785.1 0.127E+00    2.20     48.98     2.20     0.00
  15251.44     -9.35     2.20    787.3 0.127E+00    2.20     49.12     2.20     0.00
  15348.35     -9.35     2.20    789.5 0.127E+00    2.20     49.26     2.20     0.00
  15445.26     -9.35     2.20    791.7 0.126E+00    2.20     49.40     2.20     0.00
  15542.17     -9.35     2.20    793.9 0.126E+00    2.20     49.54     2.20     0.00
  15639.08     -9.35     2.20    796.2 0.126E+00    2.20     49.67     2.20     0.00
  15735.99     -9.35     2.20    798.4 0.125E+00    2.20     49.81     2.20     0.00
  15832.90     -9.35     2.20    800.5 0.125E+00    2.20     49.95     2.20     0.00
  15929.81     -9.35     2.20    802.7 0.125E+00    2.20     50.09     2.20     0.00
  16026.72     -9.35     2.20    804.9 0.124E+00    2.20     50.22     2.20     0.00
  16123.63     -9.35     2.20    807.1 0.124E+00    2.20     50.36     2.20     0.00
  16220.54     -9.35     2.20    809.3 0.124E+00    2.20     50.49     2.20     0.00
  16317.45     -9.35     2.20    811.4 0.123E+00    2.20     50.63     2.20     0.00
  16414.36     -9.35     2.20    813.6 0.123E+00    2.20     50.76     2.20     0.00
  16511.27     -9.35     2.20    815.7 0.123E+00    2.20     50.90     2.20     0.00
  16608.18     -9.35     2.20    817.9 0.122E+00    2.20     51.03     2.20     0.00
  16705.09     -9.35     2.20    820.0 0.122E+00    2.20     51.17     2.20     0.00
  16802.00     -9.35     2.20    822.2 0.122E+00    2.20     51.30     2.20     0.00
  16898.91     -9.35     2.20    824.3 0.121E+00    2.20     51.43     2.20     0.00
  16995.82     -9.35     2.20    826.4 0.121E+00    2.20     51.56     2.20     0.00
  17092.73     -9.35     2.20    828.6 0.121E+00    2.20     51.70     2.20     0.00
  17189.64     -9.35     2.20    830.7 0.120E+00    2.20     51.83     2.20     0.00
  17286.55     -9.35     2.20    832.8 0.120E+00    2.20     51.96     2.20     0.00
  17383.46     -9.35     2.20    834.9 0.120E+00    2.20     52.09     2.20     0.00
  17480.37     -9.35     2.20    837.0 0.119E+00    2.20     52.22     2.20     0.00
  17577.28     -9.35     2.20    839.1 0.119E+00    2.20     52.35     2.20     0.00
  17674.19     -9.35     2.20    841.2 0.119E+00    2.20     52.48     2.20     0.00
  17771.10     -9.35     2.20    843.3 0.119E+00    2.20     52.61     2.20     0.00
  17868.01     -9.35     2.20    845.3 0.118E+00    2.20     52.74     2.20     0.00
  17964.92     -9.35     2.20    847.4 0.118E+00    2.20     52.87     2.20     0.00
  18061.83     -9.35     2.20    849.5 0.118E+00    2.20     53.00     2.20     0.00
  18158.74     -9.35     2.20    851.5 0.117E+00    2.20     53.13     2.20     0.00
  18255.65     -9.35     2.20    853.6 0.117E+00    2.20     53.26     2.20     0.00
  18352.56     -9.35     2.20    855.6 0.117E+00    2.20     53.39     2.20     0.00
  18449.47     -9.35     2.20    857.7 0.117E+00    2.20     53.51     2.20     0.00
  18546.38     -9.35     2.20    859.7 0.116E+00    2.20     53.64     2.20     0.00
  18643.29     -9.35     2.20    861.8 0.116E+00    2.20     53.77     2.20     0.00
  18740.20     -9.35     2.20    863.8 0.116E+00    2.20     53.90     2.20     0.00
  18837.11     -9.35     2.20    865.8 0.115E+00    2.20     54.02     2.20     0.00
  18934.02     -9.35     2.20    867.9 0.115E+00    2.20     54.15     2.20     0.00
  19030.93     -9.35     2.20    869.9 0.115E+00    2.20     54.28     2.20     0.00
  19127.84     -9.35     2.20    871.9 0.115E+00    2.20     54.40     2.20     0.00
  19224.75     -9.35     2.20    873.9 0.114E+00    2.20     54.53     2.20     0.00
  19321.66     -9.35     2.20    875.9 0.114E+00    2.20     54.65     2.20     0.00
  19418.57     -9.35     2.20    877.9 0.114E+00    2.20     54.78     2.20     0.00
  19515.48     -9.35     2.20    879.9 0.114E+00    2.20     54.90     2.20     0.00
  19612.39     -9.35     2.20    881.9 0.113E+00    2.20     55.03     2.20     0.00
  19709.30     -9.35     2.20    883.9 0.113E+00    2.20     55.15     2.20     0.00
  19806.21     -9.35     2.20    885.9 0.113E+00    2.20     55.27     2.20     0.00
  19903.12     -9.35     2.20    887.9 0.113E+00    2.20     55.40     2.20     0.00
```

```
  20000.04    -9.35    2.20   889.8 0.112E+00   2.20    55.52    2.20    0.00
 Cumulative travel time =       31023.3711 sec

 Simulation limit based on maximum specified distance =  20000.00 m.
   This is the REGION OF INTEREST limitation.

END OF MOD261: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
CORMIX2: Multiport Diffuser Discharges       End of Prediction File
22222222222222222222222222222222222222222222222222222222222222222222222222222
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CORMIX Temperature Simulation - 7Q10 flow

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22222222222222222222222222222222222222222222222222222222222222222222222222222
                       CORMIX MIXING ZONE EXPERT SYSTEM
         Subsystem CORMIX2:  Multiport Diffuser Discharges
                         CORMIX Version 5.0GT
                      HYDRO2 Version 5.0.0.0 March 2007
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:   Sturgeon upgrader
 Design case:       7Q10 flows
 FILE NAME:         \\S...run_North American_multiport_10_temp_new flow.prd
 Time stamp:        Wed Oct 31 17:00:56 2007

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =    100.00  AS    =    100.00  QA    =     60.00  ICHREG= 1
 HA    =      1.00  HD    =      1.30
 UA    =      0.600 F     =      0.066 USTAR =0.5449E-01
 UW    =      2.000 UWSTAR=0.2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =  999.9750

DIFFUSER DISCHARGE PARAMETERS (metric units)
 Diffuser type:     DITYPE= alternating_perpendicular
 BANK  =  RIGHT     DISTB =      9.35  YB1   =      8.00  YB2   =     10.70
 LD    =      2.70  NOPEN =   10       SPAC  =      0.30
 D0    =      0.100 A0    =      0.008 H0    =      0.30  SUB0  =      1.00
 Nozzle/port arrangement:   near_vertical_discharge
 GAMMA =     90.00  THETA =     90.00  SIGMA =      0.00  BETA  =     90.00
 U0    =      1.127 Q0    =      0.089       =0.8850E-01
 RHO0  =  997.2973  DRHO0 =0.2678E+01  GP0   =0.2626E-01
 C0    =0.2000E+02  CUNITS=  deg.C
 IPOLL =  3         KS    =0.2388E-05  KD    =0.0000E+00

FLUX VARIABLES - PER UNIT DIFFUSER LENGTH (metric units)
 q0    =0.3278E-01  m0    =0.3693E-01  j0    =0.8607E-03  SIGNJ0=      1.0
 Associated 2-d length scales (meters)
 lQ=B  =      0.029 lM    =      4.08  lm    =      0.10
 lmp   =  99999.00  lbp   =  99999.00  la    =  99999.00

FLUX VARIABLES - ENTIRE DIFFUSER (metric units)
 Q0    =0.8850E-01  M0    =0.9972E-01  J0    =0.2324E-02
 Associated 3-d length scales (meters)
 LQ    =      0.09  LM    =      3.68  Lm    =      0.53  Lb    =      0.01
                                       Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     40.77  FRD0  =     21.99  R     =      1.88  PL    =      2.
 (slot)             (port/nozzle)


FLOW CLASSIFICATION
 222222222222222222222222222222222222222222
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 2  Flow class (CORMIX2)      =    MU8    2
 2  Applicable layer depth HS =     1.30  2
 222222222222222222222222222222222222222222

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    =0.2000E+02  CUNITS=  deg.C
 NTOX  =  0
 NSTD  =  0
 REGMZ =  1
 REGSPC=  1         XREG  =   1293.00  WREG  =      0.00  AREG  =      0.00
 XINT  =  20000.00  XMAX  =  20000.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and the diffuser mid-point:
         9.35 m  from the RIGHT bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 200 display intervals per module

NOTE on dilution/concentration values for this HEATED DISCHARGE (IPOLL=3):
   S  = hydrodynamic dilutions, include buoyancy (heat) loss effects, but
        provided plume has surface contact
   C  = corresponding temperature values (always in "degC"!),
        include heat loss, if any
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
BEGIN MOD201: DIFFUSER DISCHARGE MODULE

 Due to complex near-field motions:  EQUIVALENT SLOT DIFFUSER (2-D) GEOMETRY

 Profile definitions:
   BV = Gaussian 1/e (37%) half-width, in vertical plane normal to trajectory
   BH = top-hat half-width, in horizontal plane normal to trajectory
   S  = hydrodynamic centerline dilution
   C  = centerline concentration (includes reaction effects, if any)

       X        Y       Z        S       C       BV       BH
      0.00     0.00    0.30     1.0 0.200E+02   0.02     1.35

END OF MOD201: DIFFUSER DISCHARGE MODULE
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
BEGIN MOD277: UNSTABLE NEAR-FIELD ZONE OF ALTERNATING PERPENDICULAR DIFFUSER

 Because of the strong ambient current the diffuser plume of this crossflowing
   discharge gets RAPIDLY DEFLECTED.
 A near-field zone is formed that is VERTICALLY FULLY MIXED over the entire
   layer depth.  Full mixing is achieved at a downstream distance of about
   five (5) layer depths.

 Profile definitions:
   BV = layer depth (vertically mixed)
   BH = top-hat half-width, measured horizontally in Y-direction
   S  = hydrodynamic average (bulk) dilution
   C  = average (bulk) concentration (includes reaction effects, if any)
```

```
 X        Y       Z        S       C        BV       BH
0.00     0.00    0.30     1.0 0.200E+02   0.02     1.35
0.03     0.00    0.30     2.6 0.764E+01   0.03     1.35
0.06     0.00    0.30     3.3 0.608E+01   0.04     1.35
0.10     0.00    0.31     3.8 0.526E+01   0.04     1.35
0.13     0.00    0.31     4.2 0.472E+01   0.05     1.35
0.16     0.00    0.31     4.6 0.433E+01   0.06     1.35
0.19     0.00    0.31     5.0 0.403E+01   0.06     1.35
0.23     0.00    0.31     5.3 0.379E+01   0.07     1.35
0.26     0.00    0.31     5.6 0.359E+01   0.07     1.35
0.29     0.00    0.32     5.9 0.342E+01   0.08     1.35
0.32     0.00    0.32     6.1 0.327E+01   0.09     1.35
0.36     0.00    0.32     6.4 0.314E+01   0.09     1.35
0.39     0.00    0.32     6.6 0.303E+01   0.10     1.35
0.42     0.00    0.32     6.8 0.293E+01   0.11     1.35
0.45     0.00    0.32     7.1 0.284E+01   0.11     1.35
0.49     0.00    0.33     7.3 0.275E+01   0.12     1.35
0.52     0.00    0.33     7.5 0.268E+01   0.13     1.35
0.55     0.00    0.33     7.7 0.261E+01   0.13     1.35
0.59     0.00    0.33     7.9 0.254E+01   0.14     1.35
0.62     0.00    0.33     8.0 0.248E+01   0.14     1.35
0.65     0.00    0.34     8.2 0.243E+01   0.15     1.35
0.68     0.00    0.34     8.4 0.238E+01   0.16     1.35
0.72     0.00    0.34     8.6 0.233E+01   0.16     1.35
0.75     0.00    0.34     8.8 0.228E+01   0.17     1.35
0.78     0.00    0.34     8.9 0.224E+01   0.18     1.35
0.81     0.00    0.34     9.1 0.220E+01   0.18     1.35
0.85     0.00    0.35     9.2 0.216E+01   0.19     1.35
0.88     0.00    0.35     9.4 0.213E+01   0.20     1.35
0.91     0.00    0.35     9.6 0.209E+01   0.20     1.35
0.94     0.00    0.35     9.7 0.206E+01   0.21     1.35
0.98     0.00    0.35     9.9 0.203E+01   0.21     1.35
1.01     0.00    0.35    10.0 0.200E+01   0.22     1.35
1.04     0.00    0.36    10.1 0.197E+01   0.23     1.35
1.07     0.00    0.36    10.3 0.194E+01   0.23     1.35
1.11     0.00    0.36    10.4 0.192E+01   0.24     1.35
1.14     0.00    0.36    10.6 0.189E+01   0.25     1.35
1.17     0.00    0.36    10.7 0.187E+01   0.25     1.35
1.20     0.00    0.36    10.8 0.185E+01   0.26     1.35
1.24     0.00    0.37    11.0 0.182E+01   0.27     1.35
1.27     0.00    0.37    11.1 0.180E+01   0.27     1.35
1.30     0.00    0.37    11.2 0.178E+01   0.28     1.35
1.33     0.00    0.37    11.4 0.176E+01   0.28     1.35
1.37     0.00    0.37    11.5 0.174E+01   0.29     1.35
1.40     0.00    0.38    11.6 0.172E+01   0.30     1.35
1.43     0.00    0.38    11.7 0.171E+01   0.30     1.35
1.46     0.00    0.38    11.8 0.169E+01   0.31     1.35
1.50     0.00    0.38    12.0 0.167E+01   0.32     1.35
1.53     0.00    0.38    12.1 0.165E+01   0.32     1.35
1.56     0.00    0.38    12.2 0.164E+01   0.33     1.35
1.59     0.00    0.39    12.3 0.162E+01   0.34     1.35
1.63     0.00    0.39    12.4 0.161E+01   0.34     1.35
1.66     0.00    0.39    12.5 0.159E+01   0.35     1.35
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      1.69     0.00     0.39     12.7 0.158E+01   0.36      1.35
      1.72     0.00     0.39     12.8 0.157E+01   0.36      1.35
      1.76     0.00     0.39     12.9 0.155E+01   0.37      1.35
      1.79     0.00     0.40     13.0 0.154E+01   0.37      1.35
      1.82     0.00     0.40     13.1 0.153E+01   0.38      1.35
      1.85     0.00     0.40     13.2 0.151E+01   0.39      1.35
      1.89     0.00     0.40     13.3 0.150E+01   0.39      1.35
      1.92     0.00     0.40     13.4 0.149E+01   0.40      1.35
      1.95     0.00     0.41     13.5 0.148E+01   0.41      1.35
      1.98     0.00     0.41     13.6 0.147E+01   0.41      1.35
      2.02     0.00     0.41     13.7 0.146E+01   0.42      1.35
      2.05     0.00     0.41     13.8 0.145E+01   0.43      1.35
      2.08     0.00     0.41     13.9 0.143E+01   0.43      1.35
      2.11     0.00     0.41     14.0 0.142E+01   0.44      1.35
      2.15     0.00     0.42     14.1 0.141E+01   0.44      1.35
      2.18     0.00     0.42     14.2 0.140E+01   0.45      1.35
      2.21     0.00     0.42     14.3 0.140E+01   0.46      1.35
      2.24     0.00     0.42     14.4 0.139E+01   0.46      1.35
      2.28     0.00     0.42     14.5 0.138E+01   0.47      1.35
      2.31     0.00     0.42     14.6 0.137E+01   0.48      1.35
      2.34     0.00     0.43     14.7 0.136E+01   0.48      1.35
      2.37     0.00     0.43     14.8 0.135E+01   0.49      1.35
      2.41     0.00     0.43     14.9 0.134E+01   0.50      1.35
      2.44     0.00     0.43     15.0 0.133E+01   0.50      1.35
      2.47     0.00     0.43     15.1 0.132E+01   0.51      1.35
      2.50     0.00     0.43     15.2 0.132E+01   0.51      1.35

      2.54     0.00     0.44     15.3 0.131E+01   0.52      1.35
      2.57     0.00     0.44     15.4 0.130E+01   0.53      1.35
      2.60     0.00     0.44     15.5 0.129E+01   0.53      1.35
      2.63     0.00     0.44     15.6 0.129E+01   0.54      1.35
      2.67     0.00     0.44     15.6 0.128E+01   0.55      1.35
      2.70     0.00     0.45     15.7 0.127E+01   0.55      1.35
      2.73     0.00     0.45     15.8 0.126E+01   0.56      1.35
      2.76     0.00     0.45     15.9 0.126E+01   0.57      1.35
      2.80     0.00     0.45     16.0 0.125E+01   0.57      1.35
      2.83     0.00     0.45     16.1 0.124E+01   0.58      1.35
      2.86     0.00     0.45     16.2 0.124E+01   0.58      1.35
      2.89     0.00     0.46     16.3 0.123E+01   0.59      1.35
      2.93     0.00     0.46     16.3 0.122E+01   0.60      1.35
      2.96     0.00     0.46     16.4 0.122E+01   0.60      1.35
      2.99     0.00     0.46     16.5 0.121E+01   0.61      1.35
      3.02     0.00     0.46     16.6 0.121E+01   0.62      1.35
      3.06     0.00     0.46     16.7 0.120E+01   0.62      1.35
      3.09     0.00     0.47     16.8 0.119E+01   0.63      1.35
      3.12     0.00     0.47     16.8 0.119E+01   0.64      1.35
      3.15     0.00     0.47     16.9 0.118E+01   0.64      1.35
      3.19     0.00     0.47     17.0 0.118E+01   0.65      1.35
      3.22     0.00     0.47     17.1 0.117E+01   0.66      1.35
      3.25     0.00     0.48     17.2 0.116E+01   0.66      1.35
      3.28     0.00     0.48     17.3 0.116E+01   0.67      1.35
      3.32     0.00     0.48     17.3 0.115E+01   0.67      1.35
      3.35     0.00     0.48     17.4 0.115E+01   0.68      1.35
      3.38     0.00     0.48     17.5 0.114E+01   0.69      1.35
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     3.41      0.00     0.48     17.6 0.114E+01   0.69      1.35
     3.45      0.00     0.49     17.7 0.113E+01   0.70      1.35
     3.48      0.00     0.49     17.7 0.113E+01   0.71      1.35
     3.51      0.00     0.49     17.8 0.112E+01   0.71      1.35
     3.54      0.00     0.49     17.9 0.112E+01   0.72      1.35
     3.58      0.00     0.49     18.0 0.111E+01   0.73      1.35
     3.61      0.00     0.49     18.0 0.111E+01   0.73      1.35
     3.64      0.00     0.50     18.1 0.110E+01   0.74      1.35
     3.67      0.00     0.50     18.2 0.110E+01   0.74      1.35
     3.71      0.00     0.50     18.3 0.109E+01   0.75      1.35
     3.74      0.00     0.50     18.3 0.109E+01   0.76      1.35
     3.77      0.00     0.50     18.4 0.109E+01   0.76      1.35
     3.80      0.00     0.50     18.5 0.108E+01   0.77      1.35
     3.84      0.00     0.51     18.6 0.108E+01   0.78      1.35
     3.87      0.00     0.51     18.6 0.107E+01   0.78      1.35
     3.90      0.00     0.51     18.7 0.107E+01   0.79      1.35
     3.93      0.00     0.51     18.8 0.106E+01   0.80      1.35
     3.97      0.00     0.51     18.9 0.106E+01   0.80      1.35
     4.00      0.00     0.52     18.9 0.106E+01   0.81      1.35
     4.03      0.00     0.52     19.0 0.105E+01   0.81      1.35
     4.06      0.00     0.52     19.1 0.105E+01   0.82      1.35
     4.10      0.00     0.52     19.2 0.104E+01   0.83      1.35
     4.13      0.00     0.52     19.2 0.104E+01   0.83      1.35
     4.16      0.00     0.52     19.3 0.104E+01   0.84      1.35
     4.19      0.00     0.53     19.4 0.103E+01   0.85      1.35
     4.23      0.00     0.53     19.4 0.103E+01   0.85      1.35
     4.26      0.00     0.53     19.5 0.103E+01   0.86      1.35
     4.29      0.00     0.53     19.6 0.102E+01   0.87      1.35
     4.32      0.00     0.53     19.7 0.102E+01   0.87      1.35
     4.36      0.00     0.53     19.7 0.101E+01   0.88      1.35
     4.39      0.00     0.54     19.8 0.101E+01   0.89      1.35
     4.42      0.00     0.54     19.9 0.101E+01   0.89      1.35
     4.45      0.00     0.54     19.9 0.100E+01   0.90      1.35
     4.49      0.00     0.54     20.0 0.100E+01   0.90      1.35
     4.52      0.00     0.54     20.1 0.997E+00   0.91      1.35
     4.55      0.00     0.54     20.1 0.993E+00   0.92      1.35
     4.58      0.00     0.55     20.2 0.990E+00   0.92      1.35
     4.61      0.00     0.55     20.3 0.987E+00   0.93      1.35
     4.65      0.00     0.55     20.3 0.983E+00   0.94      1.35
     4.68      0.00     0.55     20.4 0.980E+00   0.94      1.35
     4.71      0.00     0.55     20.5 0.977E+00   0.95      1.35
     4.74      0.00     0.56     20.5 0.974E+00   0.96      1.35
     4.78      0.00     0.56     20.6 0.970E+00   0.96      1.35
     4.81      0.00     0.56     20.7 0.967E+00   0.97      1.35
     4.84      0.00     0.56     20.7 0.964E+00   0.97      1.35
     4.87      0.00     0.56     20.8 0.961E+00   0.98      1.35
     4.91      0.00     0.56     20.9 0.958E+00   0.99      1.35
     4.94      0.00     0.57     20.9 0.955E+00   0.99      1.35
     4.97      0.00     0.57     21.0 0.952E+00   1.00      1.35
     5.00      0.00     0.57     21.1 0.949E+00   1.01      1.35
     5.04      0.00     0.57     21.1 0.946E+00   1.01      1.35
     5.07      0.00     0.57     21.2 0.943E+00   1.02      1.35
     5.10      0.00     0.57     21.3 0.941E+00   1.03      1.35
     5.13      0.00     0.58     21.3 0.938E+00   1.03      1.35
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      5.17     0.00    0.58    21.4 0.935E+00   1.04     1.35
      5.20     0.00    0.58    21.5 0.932E+00   1.04     1.35
      5.23     0.00    0.58    21.5 0.929E+00   1.05     1.35
      5.26     0.00    0.58    21.6 0.927E+00   1.06     1.35
      5.30     0.00    0.59    21.6 0.924E+00   1.06     1.35
      5.33     0.00    0.59    21.7 0.921E+00   1.07     1.35
      5.36     0.00    0.59    21.8 0.919E+00   1.08     1.35
      5.39     0.00    0.59    21.8 0.916E+00   1.08     1.35
      5.43     0.00    0.59    21.9 0.913E+00   1.09     1.35
      5.46     0.00    0.59    22.0 0.911E+00   1.10     1.35
      5.49     0.00    0.60    22.0 0.908E+00   1.10     1.35
      5.52     0.00    0.60    22.1 0.906E+00   1.11     1.35
      5.56     0.00    0.60    22.1 0.903E+00   1.11     1.35
      5.59     0.00    0.60    22.2 0.900E+00   1.12     1.35
      5.62     0.00    0.60    22.3 0.898E+00   1.13     1.35
      5.65     0.00    0.60    22.3 0.896E+00   1.13     1.35
      5.69     0.00    0.61    22.4 0.893E+00   1.14     1.35
      5.72     0.00    0.61    22.5 0.891E+00   1.15     1.35
      5.75     0.00    0.61    22.5 0.888E+00   1.15     1.35
      5.78     0.00    0.61    22.6 0.886E+00   1.16     1.35
      5.82     0.00    0.61    22.6 0.883E+00   1.17     1.35
      5.85     0.00    0.61    22.7 0.881E+00   1.17     1.35
      5.88     0.00    0.62    22.8 0.879E+00   1.18     1.35
      5.91     0.00    0.62    22.8 0.877E+00   1.19     1.35
      5.95     0.00    0.62    22.9 0.874E+00   1.19     1.35
      5.98     0.00    0.62    22.9 0.872E+00   1.20     1.35
      6.01     0.00    0.62    23.0 0.870E+00   1.20     1.35
      6.04     0.00    0.63    23.1 0.867E+00   1.21     1.35
      6.08     0.00    0.63    23.1 0.865E+00   1.22     1.35
      6.11     0.00    0.63    23.2 0.863E+00   1.22     1.35
      6.14     0.00    0.63    23.2 0.861E+00   1.23     1.35
      6.17     0.00    0.63    23.3 0.859E+00   1.24     1.35
      6.21     0.00    0.63    23.4 0.857E+00   1.24     1.35
      6.24     0.00    0.64    23.4 0.854E+00   1.25     1.35
      6.27     0.00    0.64    23.5 0.852E+00   1.26     1.35
      6.30     0.00    0.64    23.5 0.850E+00   1.26     1.35
      6.34     0.00    0.64    23.6 0.848E+00   1.27     1.35
      6.37     0.00    0.64    23.6 0.846E+00   1.27     1.35
      6.40     0.00    0.64    23.7 0.844E+00   1.28     1.35
      6.43     0.00    0.65    23.8 0.842E+00   1.29     1.35
      6.47     0.00    0.65    23.8 0.840E+00   1.29     1.35
      6.50     0.00    0.65    23.9 0.838E+00   1.30     1.35
 Cumulative travel time =          21.5988 sec
   Plume centerline may exhibit slight discontinuities in transition
     to subsequent far-field module.

END OF MOD277: UNSTABLE NEAR-FIELD ZONE OF ALTERNATING PERPENDICULAR DIFFUSER
-----------------------------------------------------------------------------
** End of NEAR-FIELD REGION (NFR) **
-----------------------------------------------------------------------------
BEGIN MOD241: BUOYANT AMBIENT SPREADING

 Discharge is non-buoyant or weakly buoyant.
   Therefore BUOYANT SPREADING REGIME is ABSENT.
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END OF MOD241: BUOYANT AMBIENT SPREADING
-----------------------------------------------------------------------------
 Due to the attachment or proximity of the plume tothe bottom, the bottom
   coordinate for the FAR-FIELD differs from the ambient depth, ZFB = 0 m.
 In a subsequent analysis set "depth at discharge" equal to "ambient depth".
-----------------------------------------------------------------------------
BEGIN MOD261: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

  Vertical diffusivity (initial value)   = 0.142E-01 m^2/s
  Horizontal diffusivity (initial value) = 0.177E-01 m^2/s

 Profile definitions:
   BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
      = or equal to layer depth, if fully mixed
   BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
        measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
   S  = hydrodynamic centerline dilution
   C  = centerline concentration (includes reaction effects, if any)

 Plume Stage 1 (not bank attached):
       X         Y       Z        S       C       BV       BH      ZU      ZL
      6.50     0.00    1.30    23.9 0.838E+00   1.30     1.35    1.30    0.00
 Plume interacts with BOTTOM.
 The passive diffusion plume becomes VERTICALLY FULLY MIXED within this
   prediction interval.
     11.12     0.00    1.30    26.5 0.754E+00   1.30     1.50    1.30    0.00
     15.74     0.00    1.30    28.9 0.692E+00   1.30     1.64    1.30    0.00
     20.36     0.00    1.30    31.1 0.643E+00   1.30     1.77    1.30    0.00
     24.98     0.00    1.30    33.2 0.603E+00   1.30     1.88    1.30    0.00
     29.60     0.00    1.30    35.1 0.569E+00   1.30     1.99    1.30    0.00
     34.22     0.00    1.30    37.0 0.541E+00   1.30     2.10    1.30    0.00
     38.84     0.00    1.30    38.7 0.516E+00   1.30     2.20    1.30    0.00
     43.46     0.00    1.30    40.4 0.495E+00   1.30     2.29    1.30    0.00
     48.09     0.00    1.30    42.0 0.476E+00   1.30     2.38    1.30    0.00
     52.71     0.00    1.30    43.6 0.459E+00   1.30     2.47    1.30    0.00
     57.33     0.00    1.30    45.1 0.444E+00   1.30     2.56    1.30    0.00
     61.95     0.00    1.30    46.5 0.430E+00   1.30     2.64    1.30    0.00
     66.57     0.00    1.30    47.9 0.417E+00   1.30     2.72    1.30    0.00
     71.19     0.00    1.30    49.3 0.406E+00   1.30     2.80    1.30    0.00
     75.81     0.00    1.30    50.6 0.395E+00   1.30     2.87    1.30    0.00
     80.43     0.00    1.30    51.9 0.385E+00   1.30     2.95    1.30    0.00
     85.05     0.00    1.30    53.2 0.376E+00   1.30     3.02    1.30    0.00
     89.67     0.00    1.30    54.4 0.367E+00   1.30     3.09    1.30    0.00
     94.29     0.00    1.30    55.6 0.359E+00   1.30     3.16    1.30    0.00
     98.91     0.00    1.30    56.8 0.352E+00   1.30     3.22    1.30    0.00
    103.53     0.00    1.30    58.0 0.345E+00   1.30     3.29    1.30    0.00
    108.15     0.00    1.30    59.1 0.338E+00   1.30     3.35    1.30    0.00
    112.77     0.00    1.30    60.2 0.332E+00   1.30     3.42    1.30    0.00
    117.39     0.00    1.30    61.3 0.326E+00   1.30     3.48    1.30    0.00
    122.01     0.00    1.30    62.4 0.320E+00   1.30     3.54    1.30    0.00
    126.64     0.00    1.30    63.5 0.315E+00   1.30     3.60    1.30    0.00
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    131.26      0.00     1.30     64.5 0.310E+00   1.30      3.66     1.30     0.00
    135.88      0.00     1.30     65.5 0.305E+00   1.30      3.72     1.30     0.00

    140.50      0.00     1.30     66.5 0.301E+00   1.30      3.77     1.30     0.00
    145.12      0.00     1.30     67.5 0.296E+00   1.30      3.83     1.30     0.00
    149.74      0.00     1.30     68.5 0.292E+00   1.30      3.89     1.30     0.00
    154.36      0.00     1.30     69.5 0.288E+00   1.30      3.94     1.30     0.00
    158.98      0.00     1.30     70.4 0.284E+00   1.30      3.99     1.30     0.00
    163.60      0.00     1.30     71.3 0.280E+00   1.30      4.05     1.30     0.00
    168.22      0.00     1.30     72.3 0.277E+00   1.30      4.10     1.30     0.00
    172.84      0.00     1.30     73.2 0.273E+00   1.30      4.15     1.30     0.00
    177.46      0.00     1.30     74.1 0.270E+00   1.30      4.20     1.30     0.00
    182.08      0.00     1.30     75.0 0.267E+00   1.30      4.25     1.30     0.00
    186.70      0.00     1.30     75.9 0.263E+00   1.30      4.30     1.30     0.00
    191.32      0.00     1.30     76.7 0.260E+00   1.30      4.35     1.30     0.00
    195.94      0.00     1.30     77.6 0.258E+00   1.30      4.40     1.30     0.00
    200.57      0.00     1.30     78.5 0.255E+00   1.30      4.45     1.30     0.00
    205.19      0.00     1.30     79.3 0.252E+00   1.30      4.50     1.30     0.00
    209.81      0.00     1.30     80.1 0.249E+00   1.30      4.55     1.30     0.00
    214.43      0.00     1.30     81.0 0.247E+00   1.30      4.59     1.30     0.00
    219.05      0.00     1.30     81.8 0.244E+00   1.30      4.64     1.30     0.00
    223.67      0.00     1.30     82.6 0.242E+00   1.30      4.68     1.30     0.00
    228.29      0.00     1.30     83.4 0.240E+00   1.30      4.73     1.30     0.00
    232.91      0.00     1.30     84.2 0.237E+00   1.30      4.78     1.30     0.00
    237.53      0.00     1.30     85.0 0.235E+00   1.30      4.82     1.30     0.00
    242.15      0.00     1.30     85.7 0.233E+00   1.30      4.86     1.30     0.00
    246.77      0.00     1.30     86.5 0.231E+00   1.30      4.91     1.30     0.00
    251.39      0.00     1.30     87.3 0.229E+00   1.30      4.95     1.30     0.00
    256.01      0.00     1.30     88.0 0.227E+00   1.30      4.99     1.30     0.00
    260.63      0.00     1.30     88.8 0.225E+00   1.30      5.04     1.30     0.00
    265.25      0.00     1.30     89.5 0.223E+00   1.30      5.08     1.30     0.00
    269.87      0.00     1.30     90.3 0.221E+00   1.30      5.12     1.30     0.00
    274.49      0.00     1.30     91.0 0.220E+00   1.30      5.16     1.30     0.00
    279.12      0.00     1.30     91.7 0.218E+00   1.30      5.20     1.30     0.00
    283.74      0.00     1.30     92.5 0.216E+00   1.30      5.25     1.30     0.00
    288.36      0.00     1.30     93.2 0.214E+00   1.30      5.29     1.30     0.00
    292.98      0.00     1.30     93.9 0.213E+00   1.30      5.33     1.30     0.00
    297.60      0.00     1.30     94.6 0.211E+00   1.30      5.37     1.30     0.00
    302.22      0.00     1.30     95.3 0.210E+00   1.30      5.41     1.30     0.00
    306.84      0.00     1.30     96.0 0.208E+00   1.30      5.45     1.30     0.00
    311.46      0.00     1.30     96.7 0.207E+00   1.30      5.48     1.30     0.00
    316.08      0.00     1.30     97.4 0.205E+00   1.30      5.52     1.30     0.00
    320.70      0.00     1.30     98.0 0.204E+00   1.30      5.56     1.30     0.00
    325.32      0.00     1.30     98.7 0.202E+00   1.30      5.60     1.30     0.00
    329.94      0.00     1.30     99.4 0.201E+00   1.30      5.64     1.30     0.00
    334.56      0.00     1.30    100.1 0.200E+00   1.30      5.68     1.30     0.00
    339.18      0.00     1.30    100.7 0.198E+00   1.30      5.71     1.30     0.00
    343.80      0.00     1.30    101.4 0.197E+00   1.30      5.75     1.30     0.00
    348.42      0.00     1.30    102.0 0.196E+00   1.30      5.79     1.30     0.00
    353.05      0.00     1.30    102.7 0.195E+00   1.30      5.82     1.30     0.00
    357.67      0.00     1.30    103.3 0.193E+00   1.30      5.86     1.30     0.00
    362.29      0.00     1.30    104.0 0.192E+00   1.30      5.90     1.30     0.00
    366.91      0.00     1.30    104.6 0.191E+00   1.30      5.93     1.30     0.00
    371.53      0.00     1.30    105.2 0.190E+00   1.30      5.97     1.30     0.00
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    376.15      0.00     1.30    105.9 0.189E+00    1.30      6.01     1.30     0.00
    380.77      0.00     1.30    106.5 0.188E+00    1.30      6.04     1.30     0.00
    385.39      0.00     1.30    107.1 0.187E+00    1.30      6.08     1.30     0.00
    390.01      0.00     1.30    107.7 0.185E+00    1.30      6.11     1.30     0.00
    394.63      0.00     1.30    108.3 0.184E+00    1.30      6.15     1.30     0.00
    399.25      0.00     1.30    109.0 0.183E+00    1.30      6.18     1.30     0.00
    403.87      0.00     1.30    109.6 0.182E+00    1.30      6.22     1.30     0.00
    408.49      0.00     1.30    110.2 0.181E+00    1.30      6.25     1.30     0.00
    413.11      0.00     1.30    110.8 0.180E+00    1.30      6.28     1.30     0.00
    417.73      0.00     1.30    111.4 0.179E+00    1.30      6.32     1.30     0.00
    422.35      0.00     1.30    112.0 0.178E+00    1.30      6.35     1.30     0.00
    426.97      0.00     1.30    112.6 0.177E+00    1.30      6.39     1.30     0.00
    431.60      0.00     1.30    113.2 0.177E+00    1.30      6.42     1.30     0.00
    436.22      0.00     1.30    113.7 0.176E+00    1.30      6.45     1.30     0.00
    440.84      0.00     1.30    114.3 0.175E+00    1.30      6.49     1.30     0.00
    445.46      0.00     1.30    114.9 0.174E+00    1.30      6.52     1.30     0.00
    450.08      0.00     1.30    115.5 0.173E+00    1.30      6.55     1.30     0.00
    454.70      0.00     1.30    116.1 0.172E+00    1.30      6.58     1.30     0.00
    459.32      0.00     1.30    116.6 0.171E+00    1.30      6.62     1.30     0.00
    463.94      0.00     1.30    117.2 0.170E+00    1.30      6.65     1.30     0.00
    468.56      0.00     1.30    117.8 0.170E+00    1.30      6.68     1.30     0.00
    473.18      0.00     1.30    118.3 0.169E+00    1.30      6.71     1.30     0.00
    477.80      0.00     1.30    118.9 0.168E+00    1.30      6.74     1.30     0.00
    482.42      0.00     1.30    119.4 0.167E+00    1.30      6.78     1.30     0.00
    487.04      0.00     1.30    120.0 0.166E+00    1.30      6.81     1.30     0.00
    491.66      0.00     1.30    120.5 0.166E+00    1.30      6.84     1.30     0.00
    496.28      0.00     1.30    121.1 0.165E+00    1.30      6.87     1.30     0.00
    500.90      0.00     1.30    121.6 0.164E+00    1.30      6.90     1.30     0.00
    505.53      0.00     1.30    122.2 0.163E+00    1.30      6.93     1.30     0.00
    510.15      0.00     1.30    122.7 0.163E+00    1.30      6.96     1.30     0.00
    514.77      0.00     1.30    123.3 0.162E+00    1.30      6.99     1.30     0.00
    519.39      0.00     1.30    123.8 0.161E+00    1.30      7.02     1.30     0.00
    524.01      0.00     1.30    124.3 0.161E+00    1.30      7.05     1.30     0.00
    528.63      0.00     1.30    124.9 0.160E+00    1.30      7.08     1.30     0.00
    533.25      0.00     1.30    125.4 0.159E+00    1.30      7.11     1.30     0.00
    537.87      0.00     1.30    125.9 0.159E+00    1.30      7.14     1.30     0.00
    542.49      0.00     1.30    126.5 0.158E+00    1.30      7.17     1.30     0.00
    547.11      0.00     1.30    127.0 0.157E+00    1.30      7.20     1.30     0.00
    551.73      0.00     1.30    127.5 0.157E+00    1.30      7.23     1.30     0.00
    556.35      0.00     1.30    128.0 0.156E+00    1.30      7.26     1.30     0.00
    560.97      0.00     1.30    128.6 0.155E+00    1.30      7.29     1.30     0.00
    565.59      0.00     1.30    129.1 0.155E+00    1.30      7.32     1.30     0.00
    570.21      0.00     1.30    129.6 0.154E+00    1.30      7.35     1.30     0.00
    574.83      0.00     1.30    130.1 0.153E+00    1.30      7.38     1.30     0.00
    579.45      0.00     1.30    130.6 0.153E+00    1.30      7.41     1.30     0.00
    584.08      0.00     1.30    131.1 0.152E+00    1.30      7.44     1.30     0.00
    588.70      0.00     1.30    131.6 0.152E+00    1.30      7.47     1.30     0.00
    593.32      0.00     1.30    132.1 0.151E+00    1.30      7.50     1.30     0.00
    597.94      0.00     1.30    132.6 0.151E+00    1.30      7.52     1.30     0.00
    602.56      0.00     1.30    133.1 0.150E+00    1.30      7.55     1.30     0.00
    607.18      0.00     1.30    133.6 0.149E+00    1.30      7.58     1.30     0.00
    611.80      0.00     1.30    134.1 0.149E+00    1.30      7.61     1.30     0.00
    616.42      0.00     1.30    134.6 0.148E+00    1.30      7.64     1.30     0.00
    621.04      0.00     1.30    135.1 0.148E+00    1.30      7.66     1.30     0.00
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   625.66      0.00     1.30   135.6 0.147E+00   1.30      7.69     1.30    0.00
   630.28      0.00     1.30   136.1 0.147E+00   1.30      7.72     1.30    0.00
   634.90      0.00     1.30   136.6 0.146E+00   1.30      7.75     1.30    0.00
   639.52      0.00     1.30   137.1 0.146E+00   1.30      7.78     1.30    0.00
   644.14      0.00     1.30   137.5 0.145E+00   1.30      7.80     1.30    0.00
   648.76      0.00     1.30   138.0 0.145E+00   1.30      7.83     1.30    0.00
   653.38      0.00     1.30   138.5 0.144E+00   1.30      7.86     1.30    0.00
   658.01      0.00     1.30   139.0 0.144E+00   1.30      7.89     1.30    0.00
   662.63      0.00     1.30   139.5 0.143E+00   1.30      7.91     1.30    0.00
   667.25      0.00     1.30   139.9 0.143E+00   1.30      7.94     1.30    0.00
   671.87      0.00     1.30   140.4 0.142E+00   1.30      7.97     1.30    0.00
   676.49      0.00     1.30   140.9 0.142E+00   1.30      7.99     1.30    0.00
   681.11      0.00     1.30   141.4 0.141E+00   1.30      8.02     1.30    0.00
   685.73      0.00     1.30   141.8 0.141E+00   1.30      8.05     1.30    0.00
   690.35      0.00     1.30   142.3 0.140E+00   1.30      8.07     1.30    0.00
   694.97      0.00     1.30   142.8 0.140E+00   1.30      8.10     1.30    0.00
   699.59      0.00     1.30   143.2 0.139E+00   1.30      8.13     1.30    0.00
   704.21      0.00     1.30   143.7 0.139E+00   1.30      8.15     1.30    0.00
   708.83      0.00     1.30   144.2 0.138E+00   1.30      8.18     1.30    0.00
   713.45      0.00     1.30   144.6 0.138E+00   1.30      8.20     1.30    0.00
   718.07      0.00     1.30   145.1 0.138E+00   1.30      8.23     1.30    0.00
   722.69      0.00     1.30   145.5 0.137E+00   1.30      8.26     1.30    0.00
   727.31      0.00     1.30   146.0 0.137E+00   1.30      8.28     1.30    0.00
   731.93      0.00     1.30   146.4 0.136E+00   1.30      8.31     1.30    0.00
   736.56      0.00     1.30   146.9 0.136E+00   1.30      8.33     1.30    0.00
   741.18      0.00     1.30   147.3 0.135E+00   1.30      8.36     1.30    0.00
   745.80      0.00     1.30   147.8 0.135E+00   1.30      8.38     1.30    0.00
   750.42      0.00     1.30   148.2 0.135E+00   1.30      8.41     1.30    0.00
   755.04      0.00     1.30   148.7 0.134E+00   1.30      8.44     1.30    0.00
   759.66      0.00     1.30   149.1 0.134E+00   1.30      8.46     1.30    0.00
   764.28      0.00     1.30   149.6 0.133E+00   1.30      8.49     1.30    0.00
   768.90      0.00     1.30   150.0 0.133E+00   1.30      8.51     1.30    0.00
   773.52      0.00     1.30   150.5 0.133E+00   1.30      8.54     1.30    0.00
   778.14      0.00     1.30   150.9 0.132E+00   1.30      8.56     1.30    0.00
   782.76      0.00     1.30   151.4 0.132E+00   1.30      8.59     1.30    0.00
   787.38      0.00     1.30   151.8 0.131E+00   1.30      8.61     1.30    0.00
   792.00      0.00     1.30   152.2 0.131E+00   1.30      8.64     1.30    0.00
   796.62      0.00     1.30   152.7 0.131E+00   1.30      8.66     1.30    0.00
   801.24      0.00     1.30   153.1 0.130E+00   1.30      8.69     1.30    0.00
   805.86      0.00     1.30   153.5 0.130E+00   1.30      8.71     1.30    0.00
   810.49      0.00     1.30   154.0 0.130E+00   1.30      8.73     1.30    0.00
   815.11      0.00     1.30   154.4 0.129E+00   1.30      8.76     1.30    0.00
   819.73      0.00     1.30   154.8 0.129E+00   1.30      8.78     1.30    0.00
   824.35      0.00     1.30   155.3 0.128E+00   1.30      8.81     1.30    0.00
   828.97      0.00     1.30   155.7 0.128E+00   1.30      8.83     1.30    0.00
   833.59      0.00     1.30   156.1 0.128E+00   1.30      8.86     1.30    0.00
   838.21      0.00     1.30   156.5 0.127E+00   1.30      8.88     1.30    0.00
   842.83      0.00     1.30   157.0 0.127E+00   1.30      8.90     1.30    0.00
   847.45      0.00     1.30   157.4 0.127E+00   1.30      8.93     1.30    0.00
   852.07      0.00     1.30   157.8 0.126E+00   1.30      8.95     1.30    0.00
   856.69      0.00     1.30   158.2 0.126E+00   1.30      8.98     1.30    0.00
   861.31      0.00     1.30   158.6 0.126E+00   1.30      9.00     1.30    0.00
   865.93      0.00     1.30   159.1 0.125E+00   1.30      9.02     1.30    0.00
   870.55      0.00     1.30   159.5 0.125E+00   1.30      9.05     1.30    0.00
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   875.17     0.00    1.30   159.9 0.125E+00   1.30     9.07    1.30    0.00
   879.79     0.00    1.30   160.3 0.124E+00   1.30     9.09    1.30    0.00
   884.41     0.00    1.30   160.7 0.124E+00   1.30     9.12    1.30    0.00
   889.04     0.00    1.30   161.1 0.124E+00   1.30     9.14    1.30    0.00
   893.66     0.00    1.30   161.6 0.123E+00   1.30     9.17    1.30    0.00
   898.28     0.00    1.30   162.0 0.123E+00   1.30     9.19    1.30    0.00
   902.90     0.00    1.30   162.4 0.123E+00   1.30     9.21    1.30    0.00
   907.52     0.00    1.30   162.8 0.123E+00   1.30     9.23    1.30    0.00
   912.14     0.00    1.30   163.2 0.122E+00   1.30     9.26    1.30    0.00
   916.76     0.00    1.30   163.6 0.122E+00   1.30     9.28    1.30    0.00
   921.38     0.00    1.30   164.0 0.122E+00   1.30     9.30    1.30    0.00
   926.00     0.00    1.30   164.4 0.121E+00   1.30     9.33    1.30    0.00
   930.62     0.00    1.30   164.8 0.121E+00   1.30     9.35    1.30    0.00
 Cumulative travel time =        1559.5299 sec

-----------------------------------------------------------------------------
 Plume Stage 2 (bank attached):
      X        Y       Z        S        C        BV       BH      ZU      ZL
   930.62    -9.35    1.30   164.8 0.121E+00   1.30    18.70    1.30    0.00
  1025.97    -9.35    1.30   166.9 0.119E+00   1.30    18.93    1.30    0.00
  1121.31    -9.35    1.30   168.9 0.118E+00   1.30    19.17    1.30    0.00
  1216.66    -9.35    1.30   170.9 0.117E+00   1.30    19.40    1.30    0.00
 ** REGULATORY MIXING ZONE BOUNDARY **
 In this prediction interval the plume DOWNSTREAM distance meets or exceeds
 the regulatory value =  1293.00 m.
 This is the extent of the REGULATORY MIXING ZONE.
  1312.01    -9.35    1.30   172.9 0.115E+00   1.30    19.62    1.30    0.00
  1407.36    -9.35    1.30   174.9 0.114E+00   1.30    19.85    1.30    0.00
  1502.70    -9.35    1.30   176.9 0.113E+00   1.30    20.07    1.30    0.00
  1598.05    -9.35    1.30   178.8 0.111E+00   1.30    20.29    1.30    0.00
  1693.40    -9.35    1.30   180.7 0.110E+00   1.30    20.50    1.30    0.00
  1788.74    -9.35    1.30   182.6 0.109E+00   1.30    20.72    1.30    0.00
  1884.09    -9.35    1.30   184.5 0.108E+00   1.30    20.93    1.30    0.00
  1979.44    -9.35    1.30   186.3 0.107E+00   1.30    21.14    1.30    0.00
  2074.78    -9.35    1.30   188.1 0.106E+00   1.30    21.35    1.30    0.00
  2170.13    -9.35    1.30   190.0 0.105E+00   1.30    21.55    1.30    0.00
  2265.48    -9.35    1.30   191.7 0.104E+00   1.30    21.76    1.30    0.00
  2360.82    -9.35    1.30   193.5 0.103E+00   1.30    21.96    1.30    0.00
  2456.17    -9.35    1.30   195.3 0.102E+00   1.30    22.16    1.30    0.00
  2551.52    -9.35    1.30   197.0 0.101E+00   1.30    22.36    1.30    0.00
  2646.87    -9.35    1.30   198.8 0.998E-01   1.30    22.55    1.30    0.00
  2742.21    -9.35    1.30   200.5 0.989E-01   1.30    22.75    1.30    0.00
  2837.56    -9.35    1.30   202.2 0.981E-01   1.30    22.94    1.30    0.00
  2932.91    -9.35    1.30   203.9 0.972E-01   1.30    23.13    1.30    0.00
  3028.25    -9.35    1.30   205.6 0.964E-01   1.30    23.32    1.30    0.00
  3123.60    -9.35    1.30   207.2 0.956E-01   1.30    23.51    1.30    0.00
  3218.95    -9.35    1.30   208.9 0.948E-01   1.30    23.70    1.30    0.00
  3314.29    -9.35    1.30   210.5 0.941E-01   1.30    23.88    1.30    0.00
  3409.64    -9.35    1.30   212.1 0.933E-01   1.30    24.07    1.30    0.00
  3504.99    -9.35    1.30   213.7 0.926E-01   1.30    24.25    1.30    0.00
  3600.33    -9.35    1.30   215.3 0.919E-01   1.30    24.43    1.30    0.00
  3695.68    -9.35    1.30   216.9 0.912E-01   1.30    24.61    1.30    0.00
  3791.03    -9.35    1.30   218.5 0.905E-01   1.30    24.79    1.30    0.00
  3886.38    -9.35    1.30   220.1 0.898E-01   1.30    24.97    1.30    0.00
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   3981.72     -9.35     1.30   221.6 0.892E-01   1.30     25.15     1.30     0.00
   4077.07     -9.35     1.30   223.2 0.885E-01   1.30     25.32     1.30     0.00
   4172.42     -9.35     1.30   224.7 0.879E-01   1.30     25.49     1.30     0.00
   4267.76     -9.35     1.30   226.2 0.873E-01   1.30     25.67     1.30     0.00
   4363.11     -9.35     1.30   227.7 0.867E-01   1.30     25.84     1.30     0.00
   4458.46     -9.35     1.30   229.2 0.861E-01   1.30     26.01     1.30     0.00
   4553.80     -9.35     1.30   230.7 0.855E-01   1.30     26.18     1.30     0.00
   4649.15     -9.35     1.30   232.2 0.849E-01   1.30     26.35     1.30     0.00
   4744.50     -9.35     1.30   233.7 0.844E-01   1.30     26.51     1.30     0.00
   4839.84     -9.35     1.30   235.1 0.838E-01   1.30     26.68     1.30     0.00
   4935.19     -9.35     1.30   236.6 0.833E-01   1.30     26.84     1.30     0.00
   5030.54     -9.35     1.30   238.0 0.827E-01   1.30     27.01     1.30     0.00
   5125.88     -9.35     1.30   239.5 0.822E-01   1.30     27.17     1.30     0.00
   5221.23     -9.35     1.30   240.9 0.817E-01   1.30     27.33     1.30     0.00
   5316.58     -9.35     1.30   242.3 0.812E-01   1.30     27.49     1.30     0.00
   5411.92     -9.35     1.30   243.7 0.807E-01   1.30     27.65     1.30     0.00
   5507.27     -9.35     1.30   245.1 0.802E-01   1.30     27.81     1.30     0.00
   5602.62     -9.35     1.30   246.5 0.798E-01   1.30     27.97     1.30     0.00
   5697.96     -9.35     1.30   247.9 0.793E-01   1.30     28.13     1.30     0.00
   5793.31     -9.35     1.30   249.3 0.788E-01   1.30     28.29     1.30     0.00
   5888.66     -9.35     1.30   250.7 0.784E-01   1.30     28.44     1.30     0.00
   5984.00     -9.35     1.30   252.0 0.779E-01   1.30     28.60     1.30     0.00
   6079.35     -9.35     1.30   253.4 0.775E-01   1.30     28.75     1.30     0.00
   6174.70     -9.35     1.30   254.7 0.770E-01   1.30     28.90     1.30     0.00
   6270.04     -9.35     1.30   256.1 0.766E-01   1.30     29.06     1.30     0.00
   6365.39     -9.35     1.30   257.4 0.762E-01   1.30     29.21     1.30     0.00
   6460.74     -9.35     1.30   258.7 0.758E-01   1.30     29.36     1.30     0.00
   6556.08     -9.35     1.30   260.1 0.754E-01   1.30     29.51     1.30     0.00
   6651.43     -9.35     1.30   261.4 0.750E-01   1.30     29.66     1.30     0.00
   6746.78     -9.35     1.30   262.7 0.746E-01   1.30     29.81     1.30     0.00
   6842.12     -9.35     1.30   264.0 0.742E-01   1.30     29.95     1.30     0.00
   6937.47     -9.35     1.30   265.3 0.738E-01   1.30     30.10     1.30     0.00
   7032.82     -9.35     1.30   266.6 0.734E-01   1.30     30.25     1.30     0.00
   7128.16     -9.35     1.30   267.9 0.731E-01   1.30     30.39     1.30     0.00
   7223.51     -9.35     1.30   269.1 0.727E-01   1.30     30.54     1.30     0.00
   7318.86     -9.35     1.30   270.4 0.723E-01   1.30     30.68     1.30     0.00
   7414.20     -9.35     1.30   271.7 0.720E-01   1.30     30.82     1.30     0.00
   7509.55     -9.35     1.30   272.9 0.716E-01   1.30     30.97     1.30     0.00
   7604.90     -9.35     1.30   274.2 0.713E-01   1.30     31.11     1.30     0.00
   7700.24     -9.35     1.30   275.4 0.709E-01   1.30     31.25     1.30     0.00
   7795.59     -9.35     1.30   276.7 0.706E-01   1.30     31.39     1.30     0.00
   7890.94     -9.35     1.30   277.9 0.702E-01   1.30     31.53     1.30     0.00
   7986.28     -9.35     1.30   279.1 0.699E-01   1.30     31.67     1.30     0.00
   8081.63     -9.35     1.30   280.4 0.696E-01   1.30     31.81     1.30     0.00
   8176.98     -9.35     1.30   281.6 0.693E-01   1.30     31.95     1.30     0.00
   8272.32     -9.35     1.30   282.8 0.690E-01   1.30     32.09     1.30     0.00
   8367.67     -9.35     1.30   284.0 0.686E-01   1.30     32.23     1.30     0.00
   8463.02     -9.35     1.30   285.2 0.683E-01   1.30     32.36     1.30     0.00
   8558.36     -9.35     1.30   286.4 0.680E-01   1.30     32.50     1.30     0.00
   8653.71     -9.35     1.30   287.6 0.677E-01   1.30     32.63     1.30     0.00
   8749.06     -9.35     1.30   288.8 0.674E-01   1.30     32.77     1.30     0.00
   8844.40     -9.35     1.30   290.0 0.671E-01   1.30     32.90     1.30     0.00
   8939.75     -9.35     1.30   291.2 0.668E-01   1.30     33.04     1.30     0.00
   9035.10     -9.35     1.30   292.4 0.665E-01   1.30     33.17     1.30     0.00
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   9130.44     -9.35     1.30    293.5 0.663E-01    1.30     33.30     1.30     0.00
   9225.79     -9.35     1.30    294.7 0.660E-01    1.30     33.44     1.30     0.00
   9321.14     -9.35     1.30    295.9 0.657E-01    1.30     33.57     1.30     0.00
   9416.48     -9.35     1.30    297.0 0.654E-01    1.30     33.70     1.30     0.00
   9511.83     -9.35     1.30    298.2 0.652E-01    1.30     33.83     1.30     0.00
   9607.18     -9.35     1.30    299.3 0.649E-01    1.30     33.96     1.30     0.00
   9702.52     -9.35     1.30    300.5 0.646E-01    1.30     34.09     1.30     0.00
   9797.87     -9.35     1.30    301.6 0.644E-01    1.30     34.22     1.30     0.00
   9893.22     -9.35     1.30    302.7 0.641E-01    1.30     34.35     1.30     0.00
   9988.56     -9.35     1.30    303.9 0.638E-01    1.30     34.48     1.30     0.00
  10083.91     -9.35     1.30    305.0 0.636E-01    1.30     34.60     1.30     0.00
  10179.26     -9.35     1.30    306.1 0.633E-01    1.30     34.73     1.30     0.00
  10274.60     -9.35     1.30    307.2 0.631E-01    1.30     34.86     1.30     0.00
  10369.95     -9.35     1.30    308.3 0.628E-01    1.30     34.98     1.30     0.00
  10465.30     -9.35     1.30    309.4 0.626E-01    1.30     35.11     1.30     0.00
  10560.64     -9.35     1.30    310.6 0.624E-01    1.30     35.24     1.30     0.00
  10655.99     -9.35     1.30    311.7 0.621E-01    1.30     35.36     1.30     0.00
  10751.34     -9.35     1.30    312.8 0.619E-01    1.30     35.49     1.30     0.00
  10846.68     -9.35     1.30    313.9 0.616E-01    1.30     35.61     1.30     0.00
  10942.03     -9.35     1.30    314.9 0.614E-01    1.30     35.73     1.30     0.00
  11037.38     -9.35     1.30    316.0 0.612E-01    1.30     35.86     1.30     0.00
  11132.72     -9.35     1.30    317.1 0.610E-01    1.30     35.98     1.30     0.00
  11228.07     -9.35     1.30    318.2 0.607E-01    1.30     36.10     1.30     0.00
  11323.42     -9.35     1.30    319.3 0.605E-01    1.30     36.22     1.30     0.00
  11418.76     -9.35     1.30    320.3 0.603E-01    1.30     36.35     1.30     0.00
  11514.11     -9.35     1.30    321.4 0.601E-01    1.30     36.47     1.30     0.00
  11609.46     -9.35     1.30    322.5 0.599E-01    1.30     36.59     1.30     0.00
  11704.80     -9.35     1.30    323.5 0.596E-01    1.30     36.71     1.30     0.00
  11800.15     -9.35     1.30    324.6 0.594E-01    1.30     36.83     1.30     0.00
  11895.50     -9.35     1.30    325.7 0.592E-01    1.30     36.95     1.30     0.00
  11990.84     -9.35     1.30    326.7 0.590E-01    1.30     37.07     1.30     0.00
  12086.19     -9.35     1.30    327.8 0.588E-01    1.30     37.19     1.30     0.00
  12181.54     -9.35     1.30    328.8 0.586E-01    1.30     37.31     1.30     0.00
  12276.88     -9.35     1.30    329.8 0.584E-01    1.30     37.42     1.30     0.00
  12372.23     -9.35     1.30    330.9 0.582E-01    1.30     37.54     1.30     0.00
  12467.58     -9.35     1.30    331.9 0.580E-01    1.30     37.66     1.30     0.00
  12562.92     -9.35     1.30    332.9 0.578E-01    1.30     37.78     1.30     0.00
  12658.27     -9.35     1.30    334.0 0.576E-01    1.30     37.89     1.30     0.00
  12753.62     -9.35     1.30    335.0 0.574E-01    1.30     38.01     1.30     0.00
  12848.96     -9.35     1.30    336.0 0.572E-01    1.30     38.13     1.30     0.00
  12944.31     -9.35     1.30    337.0 0.570E-01    1.30     38.24     1.30     0.00
  13039.66     -9.35     1.30    338.1 0.569E-01    1.30     38.36     1.30     0.00
  13135.00     -9.35     1.30    339.1 0.567E-01    1.30     38.47     1.30     0.00
  13230.35     -9.35     1.30    340.1 0.565E-01    1.30     38.59     1.30     0.00
  13325.70     -9.35     1.30    341.1 0.563E-01    1.30     38.70     1.30     0.00
  13421.04     -9.35     1.30    342.1 0.561E-01    1.30     38.81     1.30     0.00
  13516.39     -9.35     1.30    343.1 0.559E-01    1.30     38.93     1.30     0.00
  13611.74     -9.35     1.30    344.1 0.558E-01    1.30     39.04     1.30     0.00
  13707.08     -9.35     1.30    345.1 0.556E-01    1.30     39.15     1.30     0.00
  13802.43     -9.35     1.30    346.1 0.554E-01    1.30     39.27     1.30     0.00
  13897.78     -9.35     1.30    347.1 0.552E-01    1.30     39.38     1.30     0.00
  13993.12     -9.35     1.30    348.1 0.551E-01    1.30     39.49     1.30     0.00
  14088.47     -9.35     1.30    349.0 0.549E-01    1.30     39.60     1.30     0.00
  14183.82     -9.35     1.30    350.0 0.547E-01    1.30     39.71     1.30     0.00
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 14279.16    -9.35    1.30   351.0 0.545E-01   1.30    39.82    1.30    0.00
 14374.51    -9.35    1.30   352.0 0.544E-01   1.30    39.94    1.30    0.00
 14469.86    -9.35    1.30   352.9 0.542E-01   1.30    40.05    1.30    0.00
 14565.20    -9.35    1.30   353.9 0.541E-01   1.30    40.16    1.30    0.00
 14660.55    -9.35    1.30   354.9 0.539E-01   1.30    40.27    1.30    0.00
 14755.90    -9.35    1.30   355.8 0.537E-01   1.30    40.37    1.30    0.00
 14851.24    -9.35    1.30   356.8 0.536E-01   1.30    40.48    1.30    0.00
 14946.59    -9.35    1.30   357.8 0.534E-01   1.30    40.59    1.30    0.00
 15041.94    -9.35    1.30   358.7 0.532E-01   1.30    40.70    1.30    0.00
 15137.28    -9.35    1.30   359.7 0.531E-01   1.30    40.81    1.30    0.00
 15232.63    -9.35    1.30   360.6 0.529E-01   1.30    40.92    1.30    0.00
 15327.98    -9.35    1.30   361.6 0.528E-01   1.30    41.03    1.30    0.00
 15423.32    -9.35    1.30   362.5 0.526E-01   1.30    41.13    1.30    0.00
 15518.67    -9.35    1.30   363.5 0.525E-01   1.30    41.24    1.30    0.00
 15614.02    -9.35    1.30   364.4 0.523E-01   1.30    41.35    1.30    0.00
 15709.36    -9.35    1.30   365.4 0.522E-01   1.30    41.45    1.30    0.00
 15804.71    -9.35    1.30   366.3 0.520E-01   1.30    41.56    1.30    0.00
 15900.06    -9.35    1.30   367.2 0.519E-01   1.30    41.67    1.30    0.00
 15995.40    -9.35    1.30   368.2 0.517E-01   1.30    41.77    1.30    0.00
 16090.75    -9.35    1.30   369.1 0.516E-01   1.30    41.88    1.30    0.00
 16186.10    -9.35    1.30   370.0 0.514E-01   1.30    41.98    1.30    0.00
 16281.44    -9.35    1.30   370.9 0.513E-01   1.30    42.09    1.30    0.00
 16376.79    -9.35    1.30   371.9 0.512E-01   1.30    42.19    1.30    0.00
 16472.14    -9.35    1.30   372.8 0.510E-01   1.30    42.30    1.30    0.00
 16567.49    -9.35    1.30   373.7 0.509E-01   1.30    42.40    1.30    0.00
 16662.83    -9.35    1.30   374.6 0.507E-01   1.30    42.51    1.30    0.00
 16758.18    -9.35    1.30   375.5 0.506E-01   1.30    42.61    1.30    0.00
 16853.53    -9.35    1.30   376.5 0.505E-01   1.30    42.71    1.30    0.00
 16948.88    -9.35    1.30   377.4 0.503E-01   1.30    42.82    1.30    0.00
 17044.22    -9.35    1.30   378.3 0.502E-01   1.30    42.92    1.30    0.00
 17139.57    -9.35    1.30   379.2 0.501E-01   1.30    43.02    1.30    0.00
 17234.92    -9.35    1.30   380.1 0.499E-01   1.30    43.12    1.30    0.00
 17330.27    -9.35    1.30   381.0 0.498E-01   1.30    43.23    1.30    0.00
 17425.62    -9.35    1.30   381.9 0.497E-01   1.30    43.33    1.30    0.00
 17520.96    -9.35    1.30   382.8 0.495E-01   1.30    43.43    1.30    0.00
 17616.31    -9.35    1.30   383.7 0.494E-01   1.30    43.53    1.30    0.00
 17711.66    -9.35    1.30   384.6 0.493E-01   1.30    43.63    1.30    0.00
 17807.01    -9.35    1.30   385.5 0.491E-01   1.30    43.73    1.30    0.00
 17902.35    -9.35    1.30   386.3 0.490E-01   1.30    43.84    1.30    0.00
 17997.70    -9.35    1.30   387.2 0.489E-01   1.30    43.94    1.30    0.00
 18093.05    -9.35    1.30   388.1 0.488E-01   1.30    44.04    1.30    0.00
 18188.40    -9.35    1.30   389.0 0.486E-01   1.30    44.14    1.30    0.00

 18283.74    -9.35    1.30   389.9 0.485E-01   1.30    44.24    1.30    0.00
 18379.09    -9.35    1.30   390.8 0.484E-01   1.30    44.34    1.30    0.00
 18474.44    -9.35    1.30   391.6 0.483E-01   1.30    44.44    1.30    0.00
 18569.79    -9.35    1.30   392.5 0.481E-01   1.30    44.53    1.30    0.00
 18665.13    -9.35    1.30   393.4 0.480E-01   1.30    44.63    1.30    0.00
 18760.48    -9.35    1.30   394.3 0.479E-01   1.30    44.73    1.30    0.00
 18855.83    -9.35    1.30   395.1 0.478E-01   1.30    44.83    1.30    0.00
 18951.18    -9.35    1.30   396.0 0.477E-01   1.30    44.93    1.30    0.00
 19046.53    -9.35    1.30   396.9 0.475E-01   1.30    45.03    1.30    0.00
 19141.87    -9.35    1.30   397.7 0.474E-01   1.30    45.13    1.30    0.00
 19237.22    -9.35    1.30   398.6 0.473E-01   1.30    45.22    1.30    0.00
```

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  19332.57    -9.35    1.30   399.4 0.472E-01   1.30    45.32    1.30    0.00
  19427.92    -9.35    1.30   400.3 0.471E-01   1.30    45.42    1.30    0.00
  19523.26    -9.35    1.30   401.2 0.470E-01   1.30    45.52    1.30    0.00
  19618.61    -9.35    1.30   402.0 0.469E-01   1.30    45.61    1.30    0.00
  19713.96    -9.35    1.30   402.9 0.467E-01   1.30    45.71    1.30    0.00
  19809.31    -9.35    1.30   403.7 0.466E-01   1.30    45.81    1.30    0.00
  19904.65    -9.35    1.30   404.6 0.465E-01   1.30    45.90    1.30    0.00
  20000.00    -9.35    1.30   405.4 0.464E-01   1.30    46.00    1.30    0.00
 Cumulative travel time =       33295.0195 sec

 Simulation limit based on maximum specified distance =  20000.00 m.
   This is the REGION OF INTEREST limitation.

END OF MOD261: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
CORMIX2: Multiport Diffuser Discharges       End of Prediction File
22222222222222222222222222222222222222222222222222222222222222222222222222222
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CORMIX Temperature Simulation - Average Flow

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 22222222222222222222222222222222222222222222222222222222222222222222222222222
                              CORMIX MIXING ZONE EXPERT SYSTEM
          Subsystem CORMIX2:  Multiport Diffuser Discharges
                                CORMIX Version 5.0GT
                             HYDRO2 Version 5.0.0.0 March 2007
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:   Sturgeon upgrader
 Design case:       Avergae flow
 FILE NAME:         \\S...run_North American_multiport_10_temp_new flow.prd
 Time stamp:        Wed Oct 31 17:22:51 2007

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =    160.00  AS    =    304.00  QA    =    196.00  ICHREG= 1
 HA    =      1.90  HD    =      2.20
 UA    =      0.645 F     =      0.053 USTAR =0.5262E-01
 UW    =      2.000 UWSTAR=0.2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =  999.8188

DIFFUSER DISCHARGE PARAMETERS (metric units)
 Diffuser type:     DITYPE= alternating_perpendicular
 BANK  =  RIGHT     DISTB =      9.35  YB1   =      8.00  YB2   =     10.70
 LD    =      2.70  NOPEN =   10       SPAC  =      0.30
 D0    =      0.100 A0    =      0.008 H0    =      0.30  SUB0  =      1.90
 Nozzle/port arrangement:   near_vertical_discharge
 GAMMA =     90.00  THETA =     90.00  SIGMA =      0.00  BETA  =     90.00
 U0    =      1.127 Q0    =      0.089       =0.8850E-01
 RHO0  =  996.5137  DRHO0 =0.3305E+01  GP0   =0.3242E-01
 C0    =0.1850E+02  CUNITS=  deg.C
 IPOLL =  3         KS    =0.2388E-05  KD    =0.0000E+00

FLUX VARIABLES - PER UNIT DIFFUSER LENGTH (metric units)
 q0    =0.3278E-01  m0    =0.3693E-01  j0    =0.1063E-02  SIGNJ0=      1.0
 Associated 2-d length scales (meters)
 lQ=B  =      0.029 lM    =      3.54  lm    =      0.09
 lmp   =  99999.00  lbp   =  99999.00  la    =  99999.00

FLUX VARIABLES - ENTIRE DIFFUSER (metric units)
 Q0    =0.8850E-01  M0    =0.9972E-01  J0    =0.2869E-02
 Associated 3-d length scales (meters)
 LQ    =      0.09  LM    =      3.31  Lm    =      0.49  Lb    =      0.01
                                       Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     36.69  FRD0  =     19.79  R     =      1.75  PL    =      2.
 (slot)             (port/nozzle)


FLOW CLASSIFICATION
 222222222222222222222222222222222222222222
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 2  Flow class (CORMIX2)      =    MU8    2
 2  Applicable layer depth HS =     2.20  2
 222222222222222222222222222222222222222222

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    =0.1850E+02  CUNITS=  deg.C
 NTOX  =  0
 NSTD  =  0
 REGMZ =  1
 REGSPC=  1         XREG  =   1293.00  WREG  =      0.00  AREG  =      0.00
 XINT  =  20000.00  XMAX  =  20000.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and the diffuser mid-point:
         9.35 m  from the RIGHT bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 200 display intervals per module

NOTE on dilution/concentration values for this HEATED DISCHARGE (IPOLL=3):
   S  = hydrodynamic dilutions, include buoyancy (heat) loss effects, but
        provided plume has surface contact
   C  = corresponding temperature values (always in "degC"!),
        include heat loss, if any
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
BEGIN MOD201: DIFFUSER DISCHARGE MODULE

 Due to complex near-field motions:  EQUIVALENT SLOT DIFFUSER (2-D) GEOMETRY

 Profile definitions:
   BV = Gaussian 1/e (37%) half-width, in vertical plane normal to trajectory
   BH = top-hat half-width, in horizontal plane normal to trajectory
   S  = hydrodynamic centerline dilution
   C  = centerline concentration (includes reaction effects, if any)

       X        Y       Z        S       C       BV       BH
      0.00     0.00    0.30     1.0 0.185E+02   0.02     1.35

END OF MOD201: DIFFUSER DISCHARGE MODULE
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
BEGIN MOD277: UNSTABLE NEAR-FIELD ZONE OF ALTERNATING PERPENDICULAR DIFFUSER

 Because of the strong ambient current the diffuser plume of this crossflowing
   discharge gets RAPIDLY DEFLECTED.
 A near-field zone is formed that is VERTICALLY FULLY MIXED over the entire
   layer depth.  Full mixing is achieved at a downstream distance of about
   five (5) layer depths.

 Profile definitions:
   BV = layer depth (vertically mixed)
   BH = top-hat half-width, measured horizontally in Y-direction
   S  = hydrodynamic average (bulk) dilution
   C  = average (bulk) concentration (includes reaction effects, if any)
```

```
  X         Y        Z         S        C        BV        BH
 0.00      0.00     0.30      1.0 0.185E+02   0.02      1.35
 0.05      0.00     0.30      4.0 0.463E+01   0.03      1.35
 0.11      0.00     0.31      5.2 0.353E+01   0.04      1.35
 0.16      0.00     0.31      6.2 0.299E+01   0.06      1.35
 0.22      0.00     0.32      7.0 0.264E+01   0.07      1.35
 0.28      0.00     0.32      7.7 0.240E+01   0.08      1.35
 0.33      0.00     0.32      8.3 0.222E+01   0.09      1.35
 0.39      0.00     0.33      8.9 0.207E+01   0.10      1.35
 0.44      0.00     0.33      9.5 0.195E+01   0.11      1.35
 0.50      0.00     0.34     10.0 0.185E+01   0.12      1.35
 0.55      0.00     0.34     10.5 0.176E+01   0.13      1.35
 0.61      0.00     0.34     10.9 0.169E+01   0.14      1.35
 0.66      0.00     0.35     11.4 0.162E+01   0.15      1.35
 0.72      0.00     0.35     11.8 0.157E+01   0.16      1.35
 0.77      0.00     0.36     12.2 0.151E+01   0.18      1.35
 0.83      0.00     0.36     12.6 0.147E+01   0.19      1.35
 0.88      0.00     0.36     13.0 0.142E+01   0.20      1.35
 0.94      0.00     0.37     13.4 0.138E+01   0.21      1.35
 0.99      0.00     0.37     13.7 0.135E+01   0.22      1.35
 1.05      0.00     0.38     14.1 0.131E+01   0.23      1.35
 1.10      0.00     0.38     14.4 0.128E+01   0.24      1.35
 1.15      0.00     0.38     14.7 0.125E+01   0.25      1.35
 1.21      0.00     0.39     15.1 0.123E+01   0.26      1.35
 1.26      0.00     0.39     15.4 0.120E+01   0.27      1.35
 1.32      0.00     0.40     15.7 0.118E+01   0.28      1.35
 1.37      0.00     0.40     16.0 0.116E+01   0.30      1.35
 1.43      0.00     0.40     16.3 0.114E+01   0.31      1.35
 1.48      0.00     0.41     16.6 0.112E+01   0.32      1.35
 1.54      0.00     0.41     16.9 0.110E+01   0.33      1.35
 1.59      0.00     0.42     17.1 0.108E+01   0.34      1.35
 1.65      0.00     0.42     17.4 0.106E+01   0.35      1.35
 1.70      0.00     0.42     17.7 0.105E+01   0.36      1.35
 1.76      0.00     0.43     18.0 0.103E+01   0.37      1.35
 1.81      0.00     0.43     18.2 0.101E+01   0.38      1.35
 1.87      0.00     0.44     18.5 0.100E+01   0.39      1.35
 1.92      0.00     0.44     18.7 0.987E+00   0.40      1.35
 1.98      0.00     0.44     19.0 0.974E+00   0.42      1.35
 2.03      0.00     0.45     19.2 0.961E+00   0.43      1.35
 2.09      0.00     0.45     19.5 0.949E+00   0.44      1.35
 2.14      0.00     0.46     19.7 0.938E+00   0.45      1.35
 2.20      0.00     0.46     20.0 0.927E+00   0.46      1.35
 2.25      0.00     0.46     20.2 0.916E+00   0.47      1.35
 2.31      0.00     0.47     20.4 0.905E+00   0.48      1.35
 2.36      0.00     0.47     20.7 0.895E+00   0.49      1.35
 2.42      0.00     0.48     20.9 0.886E+00   0.50      1.35
 2.47      0.00     0.48     21.1 0.876E+00   0.51      1.35
 2.53      0.00     0.48     21.3 0.867E+00   0.52      1.35
 2.58      0.00     0.49     21.6 0.858E+00   0.53      1.35
 2.64      0.00     0.49     21.8 0.850E+00   0.55      1.35
 2.69      0.00     0.50     22.0 0.841E+00   0.56      1.35
 2.75      0.00     0.50     22.2 0.833E+00   0.57      1.35
 2.81      0.00     0.50     22.4 0.825E+00   0.58      1.35
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     2.86      0.00     0.51     22.6 0.818E+00   0.59      1.35
     2.92      0.00     0.51     22.8 0.810E+00   0.60      1.35
     2.97      0.00     0.52     23.0 0.803E+00   0.61      1.35
     3.03      0.00     0.52     23.2 0.796E+00   0.62      1.35
     3.08      0.00     0.52     23.4 0.789E+00   0.63      1.35
     3.14      0.00     0.53     23.6 0.783E+00   0.64      1.35
     3.19      0.00     0.53     23.8 0.776E+00   0.65      1.35
     3.25      0.00     0.54     24.0 0.770E+00   0.67      1.35
     3.30      0.00     0.54     24.2 0.764E+00   0.68      1.35
     3.36      0.00     0.54     24.4 0.758E+00   0.69      1.35
     3.41      0.00     0.55     24.6 0.752E+00   0.70      1.35
     3.47      0.00     0.55     24.8 0.746E+00   0.71      1.35
     3.52      0.00     0.56     25.0 0.740E+00   0.72      1.35
     3.58      0.00     0.56     25.2 0.735E+00   0.73      1.35
     3.63      0.00     0.56     25.4 0.729E+00   0.74      1.35
     3.69      0.00     0.57     25.5 0.724E+00   0.75      1.35
     3.74      0.00     0.57     25.7 0.719E+00   0.76      1.35
     3.80      0.00     0.58     25.9 0.714E+00   0.77      1.35
     3.85      0.00     0.58     26.1 0.709E+00   0.79      1.35
     3.91      0.00     0.58     26.3 0.704E+00   0.80      1.35
     3.96      0.00     0.59     26.4 0.700E+00   0.81      1.35
     4.02      0.00     0.59     26.6 0.695E+00   0.82      1.35
     4.07      0.00     0.60     26.8 0.690E+00   0.83      1.35
     4.13      0.00     0.60     27.0 0.686E+00   0.84      1.35
     4.18      0.00     0.60     27.1 0.682E+00   0.85      1.35
     4.24      0.00     0.61     27.3 0.677E+00   0.86      1.35

     4.29      0.00     0.61     27.5 0.673E+00   0.87      1.35
     4.35      0.00     0.62     27.7 0.669E+00   0.88      1.35
     4.40      0.00     0.62     27.8 0.665E+00   0.89      1.35
     4.45      0.00     0.62     28.0 0.661E+00   0.90      1.35
     4.51      0.00     0.63     28.2 0.657E+00   0.92      1.35
     4.56      0.00     0.63     28.3 0.653E+00   0.93      1.35
     4.62      0.00     0.64     28.5 0.649E+00   0.94      1.35
     4.67      0.00     0.64     28.6 0.646E+00   0.95      1.35
     4.73      0.00     0.64     28.8 0.642E+00   0.96      1.35
     4.78      0.00     0.65     29.0 0.639E+00   0.97      1.35
     4.84      0.00     0.65     29.1 0.635E+00   0.98      1.35
     4.89      0.00     0.66     29.3 0.632E+00   0.99      1.35
     4.95      0.00     0.66     29.4 0.628E+00   1.00      1.35
     5.00      0.00     0.66     29.6 0.625E+00   1.01      1.35
     5.06      0.00     0.67     29.8 0.622E+00   1.02      1.35
     5.11      0.00     0.67     29.9 0.618E+00   1.04      1.35
     5.17      0.00     0.68     30.1 0.615E+00   1.05      1.35
     5.22      0.00     0.68     30.2 0.612E+00   1.06      1.35
     5.28      0.00     0.68     30.4 0.609E+00   1.07      1.35
     5.33      0.00     0.69     30.5 0.606E+00   1.08      1.35
     5.39      0.00     0.69     30.7 0.603E+00   1.09      1.35
     5.44      0.00     0.70     30.8 0.600E+00   1.10      1.35
     5.50      0.00     0.70     31.0 0.597E+00   1.11      1.35
     5.55      0.00     0.70     31.1 0.594E+00   1.12      1.35
     5.61      0.00     0.71     31.3 0.591E+00   1.13      1.35
     5.66      0.00     0.71     31.4 0.589E+00   1.14      1.35
     5.72      0.00     0.72     31.6 0.586E+00   1.16      1.35
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      5.77      0.00      0.72      31.7 0.583E+00    1.17      1.35
      5.83      0.00      0.72      31.9 0.580E+00    1.18      1.35
      5.88      0.00      0.73      32.0 0.578E+00    1.19      1.35
      5.94      0.00      0.73      32.2 0.575E+00    1.20      1.35
      5.99      0.00      0.74      32.3 0.573E+00    1.21      1.35
      6.05      0.00      0.74      32.5 0.570E+00    1.22      1.35
      6.10      0.00      0.74      32.6 0.568E+00    1.23      1.35
      6.16      0.00      0.75      32.7 0.565E+00    1.24      1.35
      6.21      0.00      0.75      32.9 0.563E+00    1.25      1.35
      6.27      0.00      0.76      33.0 0.560E+00    1.26      1.35
      6.32      0.00      0.76      33.2 0.558E+00    1.27      1.35
      6.38      0.00      0.76      33.3 0.556E+00    1.29      1.35
      6.43      0.00      0.77      33.4 0.553E+00    1.30      1.35
      6.49      0.00      0.77      33.6 0.551E+00    1.31      1.35
      6.54      0.00      0.78      33.7 0.549E+00    1.32      1.35
      6.60      0.00      0.78      33.9 0.547E+00    1.33      1.35
      6.65      0.00      0.78      34.0 0.544E+00    1.34      1.35
      6.71      0.00      0.79      34.1 0.542E+00    1.35      1.35
      6.76      0.00      0.79      34.3 0.540E+00    1.36      1.35
      6.82      0.00      0.80      34.4 0.538E+00    1.37      1.35
      6.87      0.00      0.80      34.5 0.536E+00    1.38      1.35
      6.93      0.00      0.80      34.7 0.534E+00    1.39      1.35
      6.98      0.00      0.81      34.8 0.532E+00    1.41      1.35
      7.04      0.00      0.81      34.9 0.530E+00    1.42      1.35
      7.09      0.00      0.82      35.1 0.528E+00    1.43      1.35
      7.15      0.00      0.82      35.2 0.526E+00    1.44      1.35
      7.20      0.00      0.82      35.3 0.524E+00    1.45      1.35
      7.26      0.00      0.83      35.5 0.522E+00    1.46      1.35
      7.31      0.00      0.83      35.6 0.520E+00    1.47      1.35
      7.37      0.00      0.84      35.7 0.518E+00    1.48      1.35
      7.42      0.00      0.84      35.8 0.516E+00    1.49      1.35
      7.48      0.00      0.84      36.0 0.514E+00    1.50      1.35
      7.53      0.00      0.85      36.1 0.512E+00    1.51      1.35
      7.59      0.00      0.85      36.2 0.511E+00    1.53      1.35
      7.64      0.00      0.86      36.4 0.509E+00    1.54      1.35
      7.70      0.00      0.86      36.5 0.507E+00    1.55      1.35
      7.75      0.00      0.86      36.6 0.505E+00    1.56      1.35
      7.81      0.00      0.87      36.7 0.504E+00    1.57      1.35
      7.86      0.00      0.87      36.9 0.502E+00    1.58      1.35
      7.92      0.00      0.88      37.0 0.500E+00    1.59      1.35
      7.97      0.00      0.88      37.1 0.499E+00    1.60      1.35
      8.03      0.00      0.88      37.2 0.497E+00    1.61      1.35
      8.08      0.00      0.89      37.4 0.495E+00    1.62      1.35
      8.14      0.00      0.89      37.5 0.494E+00    1.63      1.35
      8.19      0.00      0.90      37.6 0.492E+00    1.64      1.35
      8.25      0.00      0.90      37.7 0.490E+00    1.66      1.35
      8.30      0.00      0.90      37.8 0.489E+00    1.67      1.35
      8.36      0.00      0.91      38.0 0.487E+00    1.68      1.35
      8.41      0.00      0.91      38.1 0.486E+00    1.69      1.35
      8.47      0.00      0.92      38.2 0.484E+00    1.70      1.35
      8.52      0.00      0.92      38.3 0.483E+00    1.71      1.35
      8.58      0.00      0.92      38.5 0.481E+00    1.72      1.35
      8.63      0.00      0.93      38.6 0.480E+00    1.73      1.35
      8.69      0.00      0.93      38.7 0.478E+00    1.74      1.35
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      8.74     0.00    0.94    38.8 0.477E+00   1.75     1.35
      8.80     0.00    0.94    38.9 0.475E+00   1.76     1.35
      8.85     0.00    0.94    39.1 0.474E+00   1.78     1.35
      8.91     0.00    0.95    39.2 0.472E+00   1.79     1.35
      8.96     0.00    0.95    39.3 0.471E+00   1.80     1.35
      9.02     0.00    0.96    39.4 0.470E+00   1.81     1.35
      9.07     0.00    0.96    39.5 0.468E+00   1.82     1.35
      9.13     0.00    0.96    39.6 0.467E+00   1.83     1.35
      9.18     0.00    0.97    39.8 0.465E+00   1.84     1.35
      9.24     0.00    0.97    39.9 0.464E+00   1.85     1.35
      9.29     0.00    0.98    40.0 0.463E+00   1.86     1.35
      9.35     0.00    0.98    40.1 0.461E+00   1.87     1.35
      9.40     0.00    0.98    40.2 0.460E+00   1.88     1.35
      9.46     0.00    0.99    40.3 0.459E+00   1.90     1.35
      9.51     0.00    0.99    40.4 0.457E+00   1.91     1.35
      9.57     0.00    1.00    40.6 0.456E+00   1.92     1.35
      9.62     0.00    1.00    40.7 0.455E+00   1.93     1.35
      9.68     0.00    1.00    40.8 0.454E+00   1.94     1.35
      9.73     0.00    1.01    40.9 0.452E+00   1.95     1.35
      9.79     0.00    1.01    41.0 0.451E+00   1.96     1.35
      9.84     0.00    1.02    41.1 0.450E+00   1.97     1.35
      9.90     0.00    1.02    41.2 0.449E+00   1.98     1.35
      9.95     0.00    1.02    41.3 0.447E+00   1.99     1.35
     10.01     0.00    1.03    41.5 0.446E+00   2.00     1.35
     10.07     0.00    1.03    41.6 0.445E+00   2.01     1.35
     10.12     0.00    1.04    41.7 0.444E+00   2.03     1.35
     10.18     0.00    1.04    41.8 0.443E+00   2.04     1.35
     10.23     0.00    1.04    41.9 0.442E+00   2.05     1.35
     10.29     0.00    1.05    42.0 0.440E+00   2.06     1.35
     10.34     0.00    1.05    42.1 0.439E+00   2.07     1.35
     10.40     0.00    1.06    42.2 0.438E+00   2.08     1.35
     10.45     0.00    1.06    42.3 0.437E+00   2.09     1.35
     10.51     0.00    1.06    42.4 0.436E+00   2.10     1.35
     10.56     0.00    1.07    42.6 0.435E+00   2.11     1.35
     10.62     0.00    1.07    42.7 0.434E+00   2.12     1.35
     10.67     0.00    1.08    42.8 0.433E+00   2.13     1.35
     10.73     0.00    1.08    42.9 0.431E+00   2.15     1.35
     10.78     0.00    1.08    43.0 0.430E+00   2.16     1.35
     10.84     0.00    1.09    43.1 0.429E+00   2.17     1.35
     10.89     0.00    1.09    43.2 0.428E+00   2.18     1.35
     10.95     0.00    1.10    43.3 0.427E+00   2.19     1.35
     11.00     0.00    1.10    43.4 0.426E+00   2.20     1.35
 Cumulative travel time =          34.0160 sec
   Plume centerline may exhibit slight discontinuities in transition
     to subsequent far-field module.

END OF MOD277: UNSTABLE NEAR-FIELD ZONE OF ALTERNATING PERPENDICULAR DIFFUSER
-----------------------------------------------------------------------------
** End of NEAR-FIELD REGION (NFR) **
-----------------------------------------------------------------------------
BEGIN MOD241: BUOYANT AMBIENT SPREADING

 Discharge is non-buoyant or weakly buoyant.
   Therefore BUOYANT SPREADING REGIME is ABSENT.
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END OF MOD241: BUOYANT AMBIENT SPREADING
-----------------------------------------------------------------------------
 Due to the attachment or proximity of the plume tothe bottom, the bottom
   coordinate for the FAR-FIELD differs from the ambient depth, ZFB = 0 m.
 In a subsequent analysis set "depth at discharge" equal to "ambient depth".
-----------------------------------------------------------------------------
BEGIN MOD261: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

  Vertical diffusivity (initial value)   = 0.232E-01 m^2/s
  Horizontal diffusivity (initial value) = 0.289E-01 m^2/s

 The passive diffusion plume is VERTICALLY FULLY MIXED at beginning of region.

 Profile definitions:
   BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
      = or equal to layer depth, if fully mixed
   BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
        measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
   S  = hydrodynamic centerline dilution
   C  = centerline concentration (includes reaction effects, if any)

 Plume Stage 1 (not bank attached):
       X        Y       Z        S       C       BV       BH      ZU      ZL
     11.00     0.00    2.20    43.4 0.426E+00   2.20     1.35    2.20    0.00
     14.04     0.00    2.20    48.2 0.384E+00   2.20     1.50    2.20    0.00
     17.07     0.00    2.20    52.6 0.352E+00   2.20     1.64    2.20    0.00
     20.11     0.00    2.20    56.6 0.327E+00   2.20     1.77    2.20    0.00
     23.14     0.00    2.20    60.4 0.306E+00   2.20     1.88    2.20    0.00
     26.18     0.00    2.20    63.9 0.290E+00   2.20     1.99    2.20    0.00
     29.21     0.00    2.20    67.3 0.275E+00   2.20     2.10    2.20    0.00
     32.25     0.00    2.20    70.4 0.263E+00   2.20     2.20    2.20    0.00
     35.28     0.00    2.20    73.5 0.252E+00   2.20     2.29    2.20    0.00
     38.32     0.00    2.20    76.4 0.242E+00   2.20     2.38    2.20    0.00
     41.35     0.00    2.20    79.3 0.233E+00   2.20     2.47    2.20    0.00
     44.39     0.00    2.20    82.0 0.226E+00   2.20     2.56    2.20    0.00
     47.42     0.00    2.20    84.6 0.219E+00   2.20     2.64    2.20    0.00
     50.46     0.00    2.20    87.2 0.212E+00   2.20     2.72    2.20    0.00
     53.49     0.00    2.20    89.7 0.206E+00   2.20     2.80    2.20    0.00
     56.53     0.00    2.20    92.1 0.201E+00   2.20     2.87    2.20    0.00
     59.56     0.00    2.20    94.4 0.196E+00   2.20     2.95    2.20    0.00
     62.60     0.00    2.20    96.7 0.191E+00   2.20     3.02    2.20    0.00
     65.63     0.00    2.20    99.0 0.187E+00   2.20     3.09    2.20    0.00
     68.67     0.00    2.20   101.2 0.183E+00   2.20     3.16    2.20    0.00
     71.70     0.00    2.20   103.3 0.179E+00   2.20     3.22    2.20    0.00
     74.74     0.00    2.20   105.4 0.175E+00   2.20     3.29    2.20    0.00
     77.77     0.00    2.20   107.5 0.172E+00   2.20     3.35    2.20    0.00
     80.81     0.00    2.20   109.5 0.169E+00   2.20     3.42    2.20    0.00
     83.84     0.00    2.20   111.5 0.166E+00   2.20     3.48    2.20    0.00
     86.88     0.00    2.20   113.5 0.163E+00   2.20     3.54    2.20    0.00
     89.91     0.00    2.20   115.4 0.160E+00   2.20     3.60    2.20    0.00
     92.95     0.00    2.20   117.3 0.158E+00   2.20     3.66    2.20    0.00
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   95.99     0.00     2.20   119.1 0.155E+00   2.20     3.72     2.20     0.00
   99.02     0.00     2.20   121.0 0.153E+00   2.20     3.77     2.20     0.00
  102.06     0.00     2.20   122.8 0.151E+00   2.20     3.83     2.20     0.00
  105.09     0.00     2.20   124.6 0.148E+00   2.20     3.89     2.20     0.00
  108.13     0.00     2.20   126.3 0.146E+00   2.20     3.94     2.20     0.00
  111.16     0.00     2.20   128.0 0.144E+00   2.20     3.99     2.20     0.00
  114.20     0.00     2.20   129.7 0.143E+00   2.20     4.05     2.20     0.00
  117.23     0.00     2.20   131.4 0.141E+00   2.20     4.10     2.20     0.00
  120.27     0.00     2.20   133.1 0.139E+00   2.20     4.15     2.20     0.00
  123.30     0.00     2.20   134.7 0.137E+00   2.20     4.20     2.20     0.00
  126.34     0.00     2.20   136.4 0.136E+00   2.20     4.25     2.20     0.00
  129.37     0.00     2.20   138.0 0.134E+00   2.20     4.30     2.20     0.00
  132.41     0.00     2.20   139.5 0.133E+00   2.20     4.35     2.20     0.00
  135.44     0.00     2.20   141.1 0.131E+00   2.20     4.40     2.20     0.00
  138.48     0.00     2.20   142.7 0.130E+00   2.20     4.45     2.20     0.00
  141.51     0.00     2.20   144.2 0.128E+00   2.20     4.50     2.20     0.00
  144.55     0.00     2.20   145.7 0.127E+00   2.20     4.55     2.20     0.00
  147.58     0.00     2.20   147.2 0.126E+00   2.20     4.59     2.20     0.00
  150.62     0.00     2.20   148.7 0.124E+00   2.20     4.64     2.20     0.00
  153.65     0.00     2.20   150.2 0.123E+00   2.20     4.68     2.20     0.00
  156.69     0.00     2.20   151.6 0.122E+00   2.20     4.73     2.20     0.00
  159.72     0.00     2.20   153.1 0.121E+00   2.20     4.78     2.20     0.00
  162.76     0.00     2.20   154.5 0.120E+00   2.20     4.82     2.20     0.00
  165.79     0.00     2.20   155.9 0.119E+00   2.20     4.86     2.20     0.00
  168.83     0.00     2.20   157.3 0.118E+00   2.20     4.91     2.20     0.00
  171.86     0.00     2.20   158.7 0.117E+00   2.20     4.95     2.20     0.00
  174.90     0.00     2.20   160.1 0.116E+00   2.20     4.99     2.20     0.00
  177.94     0.00     2.20   161.5 0.115E+00   2.20     5.04     2.20     0.00
  180.97     0.00     2.20   162.8 0.114E+00   2.20     5.08     2.20     0.00
  184.01     0.00     2.20   164.2 0.113E+00   2.20     5.12     2.20     0.00
  187.04     0.00     2.20   165.5 0.112E+00   2.20     5.16     2.20     0.00
  190.08     0.00     2.20   166.8 0.111E+00   2.20     5.20     2.20     0.00
  193.11     0.00     2.20   168.1 0.110E+00   2.20     5.25     2.20     0.00
  196.15     0.00     2.20   169.4 0.109E+00   2.20     5.29     2.20     0.00
  199.18     0.00     2.20   170.7 0.108E+00   2.20     5.33     2.20     0.00
  202.22     0.00     2.20   172.0 0.108E+00   2.20     5.37     2.20     0.00
  205.25     0.00     2.20   173.3 0.107E+00   2.20     5.41     2.20     0.00
  208.29     0.00     2.20   174.5 0.106E+00   2.20     5.45     2.20     0.00
  211.32     0.00     2.20   175.8 0.105E+00   2.20     5.48     2.20     0.00
  214.36     0.00     2.20   177.0 0.104E+00   2.20     5.52     2.20     0.00
  217.39     0.00     2.20   178.3 0.104E+00   2.20     5.56     2.20     0.00
  220.43     0.00     2.20   179.5 0.103E+00   2.20     5.60     2.20     0.00
  223.46     0.00     2.20   180.7 0.102E+00   2.20     5.64     2.20     0.00
  226.50     0.00     2.20   181.9 0.102E+00   2.20     5.68     2.20     0.00
  229.53     0.00     2.20   183.1 0.101E+00   2.20     5.71     2.20     0.00
  232.57     0.00     2.20   184.3 0.100E+00   2.20     5.75     2.20     0.00
  235.60     0.00     2.20   185.5 0.997E-01   2.20     5.79     2.20     0.00
  238.64     0.00     2.20   186.7 0.990E-01   2.20     5.82     2.20     0.00
  241.67     0.00     2.20   187.9 0.984E-01   2.20     5.86     2.20     0.00
  244.71     0.00     2.20   189.1 0.978E-01   2.20     5.90     2.20     0.00
  247.74     0.00     2.20   190.2 0.972E-01   2.20     5.93     2.20     0.00
  250.78     0.00     2.20   191.4 0.966E-01   2.20     5.97     2.20     0.00
  253.81     0.00     2.20   192.5 0.961E-01   2.20     6.01     2.20     0.00
  256.85     0.00     2.20   193.7 0.955E-01   2.20     6.04     2.20     0.00
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   259.89      0.00     2.20   194.8 0.949E-01   2.20      6.08     2.20     0.00
   262.92      0.00     2.20   195.9 0.944E-01   2.20      6.11     2.20     0.00
   265.96      0.00     2.20   197.0 0.939E-01   2.20      6.15     2.20     0.00
   268.99      0.00     2.20   198.1 0.933E-01   2.20      6.18     2.20     0.00
   272.03      0.00     2.20   199.2 0.928E-01   2.20      6.22     2.20     0.00
   275.06      0.00     2.20   200.3 0.923E-01   2.20      6.25     2.20     0.00
   278.10      0.00     2.20   201.4 0.918E-01   2.20      6.28     2.20     0.00
   281.13      0.00     2.20   202.5 0.913E-01   2.20      6.32     2.20     0.00
   284.17      0.00     2.20   203.6 0.908E-01   2.20      6.35     2.20     0.00
   287.20      0.00     2.20   204.7 0.903E-01   2.20      6.39     2.20     0.00
   290.24      0.00     2.20   205.8 0.899E-01   2.20      6.42     2.20     0.00
   293.27      0.00     2.20   206.8 0.894E-01   2.20      6.45     2.20     0.00
   296.31      0.00     2.20   207.9 0.889E-01   2.20      6.49     2.20     0.00
   299.34      0.00     2.20   208.9 0.885E-01   2.20      6.52     2.20     0.00
   302.38      0.00     2.20   210.0 0.881E-01   2.20      6.55     2.20     0.00
   305.41      0.00     2.20   211.0 0.876E-01   2.20      6.58     2.20     0.00
   308.45      0.00     2.20   212.1 0.872E-01   2.20      6.62     2.20     0.00
   311.48      0.00     2.20   213.1 0.868E-01   2.20      6.65     2.20     0.00
   314.52      0.00     2.20   214.1 0.863E-01   2.20      6.68     2.20     0.00
   317.55      0.00     2.20   215.2 0.859E-01   2.20      6.71     2.20     0.00
   320.59      0.00     2.20   216.2 0.855E-01   2.20      6.74     2.20     0.00
   323.62      0.00     2.20   217.2 0.851E-01   2.20      6.78     2.20     0.00
   326.66      0.00     2.20   218.2 0.847E-01   2.20      6.81     2.20     0.00
   329.69      0.00     2.20   219.2 0.843E-01   2.20      6.84     2.20     0.00
   332.73      0.00     2.20   220.2 0.840E-01   2.20      6.87     2.20     0.00
   335.76      0.00     2.20   221.2 0.836E-01   2.20      6.90     2.20     0.00
   338.80      0.00     2.20   222.2 0.832E-01   2.20      6.93     2.20     0.00
   341.84      0.00     2.20   223.2 0.828E-01   2.20      6.96     2.20     0.00
   344.87      0.00     2.20   224.2 0.825E-01   2.20      6.99     2.20     0.00
   347.91      0.00     2.20   225.2 0.821E-01   2.20      7.02     2.20     0.00
   350.94      0.00     2.20   226.1 0.818E-01   2.20      7.05     2.20     0.00
   353.98      0.00     2.20   227.1 0.814E-01   2.20      7.08     2.20     0.00
   357.01      0.00     2.20   228.1 0.811E-01   2.20      7.11     2.20     0.00
   360.05      0.00     2.20   229.0 0.807E-01   2.20      7.14     2.20     0.00
   363.08      0.00     2.20   230.0 0.804E-01   2.20      7.17     2.20     0.00
   366.12      0.00     2.20   230.9 0.801E-01   2.20      7.20     2.20     0.00
   369.15      0.00     2.20   231.9 0.797E-01   2.20      7.23     2.20     0.00
   372.19      0.00     2.20   232.8 0.794E-01   2.20      7.26     2.20     0.00
   375.22      0.00     2.20   233.8 0.791E-01   2.20      7.29     2.20     0.00
   378.26      0.00     2.20   234.7 0.788E-01   2.20      7.32     2.20     0.00
   381.29      0.00     2.20   235.6 0.785E-01   2.20      7.35     2.20     0.00
   384.33      0.00     2.20   236.6 0.781E-01   2.20      7.38     2.20     0.00
   387.36      0.00     2.20   237.5 0.778E-01   2.20      7.41     2.20     0.00
   390.40      0.00     2.20   238.4 0.775E-01   2.20      7.44     2.20     0.00
   393.43      0.00     2.20   239.3 0.772E-01   2.20      7.47     2.20     0.00
   396.47      0.00     2.20   240.3 0.769E-01   2.20      7.50     2.20     0.00
   399.50      0.00     2.20   241.2 0.767E-01   2.20      7.52     2.20     0.00
   402.54      0.00     2.20   242.1 0.764E-01   2.20      7.55     2.20     0.00
   405.57      0.00     2.20   243.0 0.761E-01   2.20      7.58     2.20     0.00
   408.61      0.00     2.20   243.9 0.758E-01   2.20      7.61     2.20     0.00
   411.64      0.00     2.20   244.8 0.755E-01   2.20      7.64     2.20     0.00
   414.68      0.00     2.20   245.7 0.752E-01   2.20      7.66     2.20     0.00
   417.71      0.00     2.20   246.6 0.750E-01   2.20      7.69     2.20     0.00
   420.75      0.00     2.20   247.5 0.747E-01   2.20      7.72     2.20     0.00
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   423.79      0.00     2.20   248.4 0.744E-01   2.20      7.75     2.20     0.00
   426.82      0.00     2.20   249.2 0.742E-01   2.20      7.78     2.20     0.00
   429.86      0.00     2.20   250.1 0.739E-01   2.20      7.80     2.20     0.00
   432.89      0.00     2.20   251.0 0.737E-01   2.20      7.83     2.20     0.00
   435.93      0.00     2.20   251.9 0.734E-01   2.20      7.86     2.20     0.00
   438.96      0.00     2.20   252.8 0.731E-01   2.20      7.89     2.20     0.00
   442.00      0.00     2.20   253.6 0.729E-01   2.20      7.91     2.20     0.00

   445.03      0.00     2.20   254.5 0.726E-01   2.20      7.94     2.20     0.00
   448.07      0.00     2.20   255.3 0.724E-01   2.20      7.97     2.20     0.00
   451.10      0.00     2.20   256.2 0.722E-01   2.20      7.99     2.20     0.00
   454.14      0.00     2.20   257.1 0.719E-01   2.20      8.02     2.20     0.00
   457.17      0.00     2.20   257.9 0.717E-01   2.20      8.05     2.20     0.00
   460.21      0.00     2.20   258.8 0.714E-01   2.20      8.07     2.20     0.00
   463.24      0.00     2.20   259.6 0.712E-01   2.20      8.10     2.20     0.00
   466.28      0.00     2.20   260.5 0.710E-01   2.20      8.13     2.20     0.00
   469.31      0.00     2.20   261.3 0.707E-01   2.20      8.15     2.20     0.00
   472.35      0.00     2.20   262.1 0.705E-01   2.20      8.18     2.20     0.00
   475.38      0.00     2.20   263.0 0.703E-01   2.20      8.20     2.20     0.00
   478.42      0.00     2.20   263.8 0.701E-01   2.20      8.23     2.20     0.00
   481.45      0.00     2.20   264.7 0.698E-01   2.20      8.26     2.20     0.00
   484.49      0.00     2.20   265.5 0.696E-01   2.20      8.28     2.20     0.00
   487.52      0.00     2.20   266.3 0.694E-01   2.20      8.31     2.20     0.00
   490.56      0.00     2.20   267.1 0.692E-01   2.20      8.33     2.20     0.00
   493.59      0.00     2.20   268.0 0.690E-01   2.20      8.36     2.20     0.00
   496.63      0.00     2.20   268.8 0.688E-01   2.20      8.38     2.20     0.00
   499.67      0.00     2.20   269.6 0.686E-01   2.20      8.41     2.20     0.00
   502.70      0.00     2.20   270.4 0.684E-01   2.20      8.44     2.20     0.00
   505.74      0.00     2.20   271.2 0.682E-01   2.20      8.46     2.20     0.00
   508.77      0.00     2.20   272.0 0.680E-01   2.20      8.49     2.20     0.00
   511.81      0.00     2.20   272.8 0.678E-01   2.20      8.51     2.20     0.00
   514.84      0.00     2.20   273.6 0.676E-01   2.20      8.54     2.20     0.00
   517.88      0.00     2.20   274.4 0.674E-01   2.20      8.56     2.20     0.00
   520.91      0.00     2.20   275.2 0.672E-01   2.20      8.59     2.20     0.00
   523.95      0.00     2.20   276.0 0.670E-01   2.20      8.61     2.20     0.00
   526.98      0.00     2.20   276.8 0.668E-01   2.20      8.64     2.20     0.00
   530.02      0.00     2.20   277.6 0.666E-01   2.20      8.66     2.20     0.00
   533.05      0.00     2.20   278.4 0.664E-01   2.20      8.69     2.20     0.00
   536.09      0.00     2.20   279.2 0.662E-01   2.20      8.71     2.20     0.00
   539.12      0.00     2.20   280.0 0.660E-01   2.20      8.73     2.20     0.00
   542.16      0.00     2.20   280.8 0.658E-01   2.20      8.76     2.20     0.00
   545.19      0.00     2.20   281.6 0.656E-01   2.20      8.78     2.20     0.00
   548.23      0.00     2.20   282.3 0.655E-01   2.20      8.81     2.20     0.00
   551.26      0.00     2.20   283.1 0.653E-01   2.20      8.83     2.20     0.00
   554.30      0.00     2.20   283.9 0.651E-01   2.20      8.86     2.20     0.00
   557.33      0.00     2.20   284.7 0.649E-01   2.20      8.88     2.20     0.00
   560.37      0.00     2.20   285.4 0.648E-01   2.20      8.90     2.20     0.00
   563.40      0.00     2.20   286.2 0.646E-01   2.20      8.93     2.20     0.00
   566.44      0.00     2.20   287.0 0.644E-01   2.20      8.95     2.20     0.00
   569.47      0.00     2.20   287.7 0.642E-01   2.20      8.98     2.20     0.00
   572.51      0.00     2.20   288.5 0.641E-01   2.20      9.00     2.20     0.00
   575.54      0.00     2.20   289.3 0.639E-01   2.20      9.02     2.20     0.00
   578.58      0.00     2.20   290.0 0.637E-01   2.20      9.05     2.20     0.00
   581.61      0.00     2.20   290.8 0.636E-01   2.20      9.07     2.20     0.00
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    584.65     0.00    2.20   291.5 0.634E-01   2.20     9.09    2.20    0.00
    587.68     0.00    2.20   292.3 0.632E-01   2.20     9.12    2.20    0.00
    590.72     0.00    2.20   293.0 0.631E-01   2.20     9.14    2.20    0.00
    593.76     0.00    2.20   293.8 0.629E-01   2.20     9.17    2.20    0.00
    596.79     0.00    2.20   294.5 0.627E-01   2.20     9.19    2.20    0.00
    599.83     0.00    2.20   295.3 0.626E-01   2.20     9.21    2.20    0.00
    602.86     0.00    2.20   296.0 0.624E-01   2.20     9.23    2.20    0.00
    605.90     0.00    2.20   296.8 0.623E-01   2.20     9.26    2.20    0.00
    608.93     0.00    2.20   297.5 0.621E-01   2.20     9.28    2.20    0.00
    611.97     0.00    2.20   298.2 0.620E-01   2.20     9.30    2.20    0.00
    615.00     0.00    2.20   299.0 0.618E-01   2.20     9.33    2.20    0.00
    618.04     0.00    2.20   299.7 0.617E-01   2.20     9.35    2.20    0.00
 Cumulative travel time =         975.1174 sec

-----------------------------------------------------------------------------
 Plume Stage 2 (bank attached):
      X        Y       Z        S        C       BV       BH      ZU      ZL
    618.04    -9.35    2.20   299.7 0.617E-01   2.20    18.70    2.20    0.00
    714.95    -9.35    2.20   305.5 0.605E-01   2.20    19.06    2.20    0.00
    811.86    -9.35    2.20   311.2 0.594E-01   2.20    19.42    2.20    0.00
    908.77    -9.35    2.20   316.8 0.583E-01   2.20    19.77    2.20    0.00
   1005.68    -9.35    2.20   322.3 0.573E-01   2.20    20.11    2.20    0.00
   1102.59    -9.35    2.20   327.7 0.564E-01   2.20    20.45    2.20    0.00
   1199.49    -9.35    2.20   333.0 0.554E-01   2.20    20.78    2.20    0.00
 ** REGULATORY MIXING ZONE BOUNDARY **
 In this prediction interval the plume DOWNSTREAM distance meets or exceeds
 the regulatory value =  1293.00 m.
 This is the extent of the REGULATORY MIXING ZONE.
   1296.40    -9.35    2.20   338.2 0.546E-01   2.20    21.10    2.20    0.00
   1393.31    -9.35    2.20   343.4 0.538E-01   2.20    21.42    2.20    0.00
   1490.22    -9.35    2.20   348.4 0.530E-01   2.20    21.74    2.20    0.00
   1587.13    -9.35    2.20   353.4 0.522E-01   2.20    22.05    2.20    0.00
   1684.04    -9.35    2.20   358.4 0.515E-01   2.20    22.36    2.20    0.00
   1780.95    -9.35    2.20   363.2 0.508E-01   2.20    22.66    2.20    0.00
   1877.86    -9.35    2.20   368.0 0.501E-01   2.20    22.96    2.20    0.00
   1974.77    -9.35    2.20   372.8 0.495E-01   2.20    23.26    2.20    0.00
   2071.68    -9.35    2.20   377.5 0.488E-01   2.20    23.55    2.20    0.00
   2168.59    -9.35    2.20   382.1 0.482E-01   2.20    23.84    2.20    0.00
   2265.50    -9.35    2.20   386.6 0.477E-01   2.20    24.12    2.20    0.00
   2362.41    -9.35    2.20   391.2 0.471E-01   2.20    24.41    2.20    0.00
   2459.32    -9.35    2.20   395.6 0.466E-01   2.20    24.68    2.20    0.00
   2556.23    -9.35    2.20   400.0 0.460E-01   2.20    24.96    2.20    0.00
   2653.14    -9.35    2.20   404.4 0.455E-01   2.20    25.23    2.20    0.00
   2750.05    -9.35    2.20   408.7 0.451E-01   2.20    25.50    2.20    0.00
   2846.96    -9.35    2.20   413.0 0.446E-01   2.20    25.77    2.20    0.00
   2943.87    -9.35    2.20   417.2 0.441E-01   2.20    26.03    2.20    0.00
   3040.78    -9.35    2.20   421.4 0.437E-01   2.20    26.29    2.20    0.00
   3137.69    -9.35    2.20   425.5 0.432E-01   2.20    26.55    2.20    0.00
   3234.60    -9.35    2.20   429.6 0.428E-01   2.20    26.81    2.20    0.00
   3331.51    -9.35    2.20   433.7 0.424E-01   2.20    27.06    2.20    0.00
   3428.42    -9.35    2.20   437.7 0.420E-01   2.20    27.31    2.20    0.00
   3525.33    -9.35    2.20   441.7 0.416E-01   2.20    27.56    2.20    0.00
   3622.24    -9.35    2.20   445.7 0.413E-01   2.20    27.81    2.20    0.00
   3719.15    -9.35    2.20   449.6 0.409E-01   2.20    28.05    2.20    0.00
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   3816.06     -9.35     2.20    453.5 0.405E-01    2.20     28.29     2.20     0.00
   3912.97     -9.35     2.20    457.3 0.402E-01    2.20     28.54     2.20     0.00
   4009.88     -9.35     2.20    461.2 0.398E-01    2.20     28.77     2.20     0.00
   4106.79     -9.35     2.20    465.0 0.395E-01    2.20     29.01     2.20     0.00
   4203.70     -9.35     2.20    468.7 0.392E-01    2.20     29.24     2.20     0.00
   4300.61     -9.35     2.20    472.4 0.389E-01    2.20     29.48     2.20     0.00
   4397.52     -9.35     2.20    476.1 0.386E-01    2.20     29.71     2.20     0.00

   4494.43     -9.35     2.20    479.8 0.383E-01    2.20     29.94     2.20     0.00
   4591.34     -9.35     2.20    483.5 0.380E-01    2.20     30.16     2.20     0.00
   4688.25     -9.35     2.20    487.1 0.377E-01    2.20     30.39     2.20     0.00
   4785.16     -9.35     2.20    490.7 0.374E-01    2.20     30.61     2.20     0.00
   4882.07     -9.35     2.20    494.2 0.371E-01    2.20     30.84     2.20     0.00
   4978.98     -9.35     2.20    497.8 0.369E-01    2.20     31.06     2.20     0.00
   5075.89     -9.35     2.20    501.3 0.366E-01    2.20     31.28     2.20     0.00
   5172.80     -9.35     2.20    504.8 0.363E-01    2.20     31.49     2.20     0.00
   5269.71     -9.35     2.20    508.2 0.361E-01    2.20     31.71     2.20     0.00
   5366.62     -9.35     2.20    511.7 0.358E-01    2.20     31.93     2.20     0.00
   5463.53     -9.35     2.20    515.1 0.356E-01    2.20     32.14     2.20     0.00
   5560.44     -9.35     2.20    518.5 0.353E-01    2.20     32.35     2.20     0.00
   5657.35     -9.35     2.20    521.9 0.351E-01    2.20     32.56     2.20     0.00
   5754.26     -9.35     2.20    525.2 0.349E-01    2.20     32.77     2.20     0.00
   5851.17     -9.35     2.20    528.5 0.347E-01    2.20     32.98     2.20     0.00
   5948.07     -9.35     2.20    531.9 0.344E-01    2.20     33.18     2.20     0.00
   6044.98     -9.35     2.20    535.1 0.342E-01    2.20     33.39     2.20     0.00
   6141.89     -9.35     2.20    538.4 0.340E-01    2.20     33.59     2.20     0.00
   6238.80     -9.35     2.20    541.7 0.338E-01    2.20     33.80     2.20     0.00
   6335.71     -9.35     2.20    544.9 0.336E-01    2.20     34.00     2.20     0.00
   6432.62     -9.35     2.20    548.1 0.334E-01    2.20     34.20     2.20     0.00
   6529.53     -9.35     2.20    551.3 0.332E-01    2.20     34.40     2.20     0.00
   6626.44     -9.35     2.20    554.5 0.330E-01    2.20     34.60     2.20     0.00
   6723.35     -9.35     2.20    557.6 0.328E-01    2.20     34.79     2.20     0.00
   6820.26     -9.35     2.20    560.8 0.326E-01    2.20     34.99     2.20     0.00
   6917.17     -9.35     2.20    563.9 0.324E-01    2.20     35.18     2.20     0.00
   7014.08     -9.35     2.20    567.0 0.322E-01    2.20     35.38     2.20     0.00
   7110.99     -9.35     2.20    570.1 0.321E-01    2.20     35.57     2.20     0.00
   7207.90     -9.35     2.20    573.1 0.319E-01    2.20     35.76     2.20     0.00
   7304.81     -9.35     2.20    576.2 0.317E-01    2.20     35.95     2.20     0.00
   7401.72     -9.35     2.20    579.2 0.315E-01    2.20     36.14     2.20     0.00
   7498.63     -9.35     2.20    582.3 0.314E-01    2.20     36.33     2.20     0.00
   7595.54     -9.35     2.20    585.3 0.312E-01    2.20     36.52     2.20     0.00
   7692.45     -9.35     2.20    588.3 0.310E-01    2.20     36.70     2.20     0.00
   7789.36     -9.35     2.20    591.2 0.309E-01    2.20     36.89     2.20     0.00
   7886.27     -9.35     2.20    594.2 0.307E-01    2.20     37.07     2.20     0.00
   7983.18     -9.35     2.20    597.1 0.306E-01    2.20     37.26     2.20     0.00
   8080.09     -9.35     2.20    600.1 0.304E-01    2.20     37.44     2.20     0.00
   8177.00     -9.35     2.20    603.0 0.303E-01    2.20     37.62     2.20     0.00
   8273.91     -9.35     2.20    605.9 0.301E-01    2.20     37.80     2.20     0.00
   8370.82     -9.35     2.20    608.8 0.300E-01    2.20     37.98     2.20     0.00
   8467.73     -9.35     2.20    611.7 0.298E-01    2.20     38.16     2.20     0.00
   8564.64     -9.35     2.20    614.5 0.297E-01    2.20     38.34     2.20     0.00
   8661.55     -9.35     2.20    617.4 0.295E-01    2.20     38.52     2.20     0.00
   8758.46     -9.35     2.20    620.2 0.294E-01    2.20     38.70     2.20     0.00
   8855.37     -9.35     2.20    623.0 0.293E-01    2.20     38.87     2.20     0.00
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   8952.28     -9.35     2.20    625.8 0.291E-01    2.20     39.05     2.20     0.00
   9049.19     -9.35     2.20    628.6 0.290E-01    2.20     39.22     2.20     0.00
   9146.10     -9.35     2.20    631.4 0.289E-01    2.20     39.40     2.20     0.00
   9243.01     -9.35     2.20    634.2 0.287E-01    2.20     39.57     2.20     0.00
   9339.92     -9.35     2.20    637.0 0.286E-01    2.20     39.74     2.20     0.00
   9436.83     -9.35     2.20    639.7 0.285E-01    2.20     39.91     2.20     0.00
   9533.74     -9.35     2.20    642.4 0.283E-01    2.20     40.08     2.20     0.00
   9630.65     -9.35     2.20    645.2 0.282E-01    2.20     40.25     2.20     0.00
   9727.56     -9.35     2.20    647.9 0.281E-01    2.20     40.42     2.20     0.00
   9824.47     -9.35     2.20    650.6 0.280E-01    2.20     40.59     2.20     0.00
   9921.38     -9.35     2.20    653.3 0.279E-01    2.20     40.76     2.20     0.00
  10018.29     -9.35     2.20    656.0 0.277E-01    2.20     40.93     2.20     0.00
  10115.20     -9.35     2.20    658.6 0.276E-01    2.20     41.09     2.20     0.00
  10212.11     -9.35     2.20    661.3 0.275E-01    2.20     41.26     2.20     0.00
  10309.02     -9.35     2.20    663.9 0.274E-01    2.20     41.43     2.20     0.00
  10405.93     -9.35     2.20    666.6 0.273E-01    2.20     41.59     2.20     0.00
  10502.84     -9.35     2.20    669.2 0.272E-01    2.20     41.75     2.20     0.00
  10599.75     -9.35     2.20    671.8 0.271E-01    2.20     41.92     2.20     0.00
  10696.66     -9.35     2.20    674.4 0.269E-01    2.20     42.08     2.20     0.00
  10793.57     -9.35     2.20    677.0 0.268E-01    2.20     42.24     2.20     0.00
  10890.48     -9.35     2.20    679.6 0.267E-01    2.20     42.40     2.20     0.00
  10987.39     -9.35     2.20    682.2 0.266E-01    2.20     42.56     2.20     0.00
  11084.30     -9.35     2.20    684.8 0.265E-01    2.20     42.72     2.20     0.00
  11181.21     -9.35     2.20    687.3 0.264E-01    2.20     42.88     2.20     0.00
  11278.12     -9.35     2.20    689.9 0.263E-01    2.20     43.04     2.20     0.00
  11375.03     -9.35     2.20    692.4 0.262E-01    2.20     43.20     2.20     0.00
  11471.94     -9.35     2.20    694.9 0.261E-01    2.20     43.36     2.20     0.00
  11568.85     -9.35     2.20    697.5 0.260E-01    2.20     43.52     2.20     0.00
  11665.76     -9.35     2.20    700.0 0.259E-01    2.20     43.67     2.20     0.00
  11762.67     -9.35     2.20    702.5 0.258E-01    2.20     43.83     2.20     0.00
  11859.58     -9.35     2.20    705.0 0.257E-01    2.20     43.99     2.20     0.00
  11956.49     -9.35     2.20    707.4 0.256E-01    2.20     44.14     2.20     0.00
  12053.40     -9.35     2.20    709.9 0.255E-01    2.20     44.29     2.20     0.00
  12150.31     -9.35     2.20    712.4 0.254E-01    2.20     44.45     2.20     0.00
  12247.22     -9.35     2.20    714.9 0.254E-01    2.20     44.60     2.20     0.00
  12344.13     -9.35     2.20    717.3 0.253E-01    2.20     44.75     2.20     0.00
  12441.04     -9.35     2.20    719.7 0.252E-01    2.20     44.91     2.20     0.00
  12537.95     -9.35     2.20    722.2 0.251E-01    2.20     45.06     2.20     0.00
  12634.86     -9.35     2.20    724.6 0.250E-01    2.20     45.21     2.20     0.00
  12731.77     -9.35     2.20    727.0 0.249E-01    2.20     45.36     2.20     0.00
  12828.68     -9.35     2.20    729.4 0.248E-01    2.20     45.51     2.20     0.00
  12925.59     -9.35     2.20    731.8 0.247E-01    2.20     45.66     2.20     0.00
  13022.50     -9.35     2.20    734.2 0.247E-01    2.20     45.81     2.20     0.00
  13119.42     -9.35     2.20    736.6 0.246E-01    2.20     45.96     2.20     0.00
  13216.33     -9.35     2.20    739.0 0.245E-01    2.20     46.11     2.20     0.00
  13313.24     -9.35     2.20    741.4 0.244E-01    2.20     46.26     2.20     0.00
  13410.15     -9.35     2.20    743.7 0.243E-01    2.20     46.40     2.20     0.00
  13507.06     -9.35     2.20    746.1 0.242E-01    2.20     46.55     2.20     0.00
  13603.97     -9.35     2.20    748.4 0.242E-01    2.20     46.70     2.20     0.00
  13700.88     -9.35     2.20    750.8 0.241E-01    2.20     46.84     2.20     0.00
  13797.79     -9.35     2.20    753.1 0.240E-01    2.20     46.99     2.20     0.00
  13894.70     -9.35     2.20    755.4 0.239E-01    2.20     47.13     2.20     0.00
  13991.61     -9.35     2.20    757.8 0.238E-01    2.20     47.28     2.20     0.00
  14088.52     -9.35     2.20    760.1 0.238E-01    2.20     47.42     2.20     0.00
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  14185.43     -9.35     2.20    762.4 0.237E-01    2.20     47.57     2.20     0.00
  14282.34     -9.35     2.20    764.7 0.236E-01    2.20     47.71     2.20     0.00
  14379.25     -9.35     2.20    767.0 0.235E-01    2.20     47.85     2.20     0.00
  14476.16     -9.35     2.20    769.2 0.235E-01    2.20     48.00     2.20     0.00
  14573.07     -9.35     2.20    771.5 0.234E-01    2.20     48.14     2.20     0.00
  14669.98     -9.35     2.20    773.8 0.233E-01    2.20     48.28     2.20     0.00
  14766.89     -9.35     2.20    776.1 0.233E-01    2.20     48.42     2.20     0.00
  14863.80     -9.35     2.20    778.3 0.232E-01    2.20     48.56     2.20     0.00
  14960.71     -9.35     2.20    780.6 0.231E-01    2.20     48.70     2.20     0.00
  15057.62     -9.35     2.20    782.8 0.230E-01    2.20     48.84     2.20     0.00
  15154.53     -9.35     2.20    785.1 0.230E-01    2.20     48.98     2.20     0.00
  15251.44     -9.35     2.20    787.3 0.229E-01    2.20     49.12     2.20     0.00
  15348.35     -9.35     2.20    789.5 0.228E-01    2.20     49.26     2.20     0.00
  15445.26     -9.35     2.20    791.7 0.228E-01    2.20     49.40     2.20     0.00
  15542.17     -9.35     2.20    793.9 0.227E-01    2.20     49.54     2.20     0.00
  15639.08     -9.35     2.20    796.2 0.226E-01    2.20     49.67     2.20     0.00
  15735.99     -9.35     2.20    798.4 0.226E-01    2.20     49.81     2.20     0.00
  15832.90     -9.35     2.20    800.5 0.225E-01    2.20     49.95     2.20     0.00
  15929.81     -9.35     2.20    802.7 0.224E-01    2.20     50.09     2.20     0.00
  16026.72     -9.35     2.20    804.9 0.224E-01    2.20     50.22     2.20     0.00
  16123.63     -9.35     2.20    807.1 0.223E-01    2.20     50.36     2.20     0.00
  16220.54     -9.35     2.20    809.3 0.222E-01    2.20     50.49     2.20     0.00
  16317.45     -9.35     2.20    811.4 0.222E-01    2.20     50.63     2.20     0.00
  16414.36     -9.35     2.20    813.6 0.221E-01    2.20     50.76     2.20     0.00
  16511.27     -9.35     2.20    815.7 0.221E-01    2.20     50.90     2.20     0.00
  16608.18     -9.35     2.20    817.9 0.220E-01    2.20     51.03     2.20     0.00
  16705.09     -9.35     2.20    820.0 0.219E-01    2.20     51.17     2.20     0.00
  16802.00     -9.35     2.20    822.2 0.219E-01    2.20     51.30     2.20     0.00
  16898.91     -9.35     2.20    824.3 0.218E-01    2.20     51.43     2.20     0.00
  16995.82     -9.35     2.20    826.4 0.218E-01    2.20     51.56     2.20     0.00
  17092.73     -9.35     2.20    828.6 0.217E-01    2.20     51.70     2.20     0.00
  17189.64     -9.35     2.20    830.7 0.216E-01    2.20     51.83     2.20     0.00
  17286.55     -9.35     2.20    832.8 0.216E-01    2.20     51.96     2.20     0.00
  17383.46     -9.35     2.20    834.9 0.215E-01    2.20     52.09     2.20     0.00
  17480.37     -9.35     2.20    837.0 0.215E-01    2.20     52.22     2.20     0.00
  17577.28     -9.35     2.20    839.1 0.214E-01    2.20     52.35     2.20     0.00
  17674.19     -9.35     2.20    841.2 0.213E-01    2.20     52.48     2.20     0.00
  17771.10     -9.35     2.20    843.3 0.213E-01    2.20     52.61     2.20     0.00
  17868.01     -9.35     2.20    845.3 0.212E-01    2.20     52.74     2.20     0.00
  17964.92     -9.35     2.20    847.4 0.212E-01    2.20     52.87     2.20     0.00
  18061.83     -9.35     2.20    849.5 0.211E-01    2.20     53.00     2.20     0.00
  18158.74     -9.35     2.20    851.5 0.211E-01    2.20     53.13     2.20     0.00
  18255.65     -9.35     2.20    853.6 0.210E-01    2.20     53.26     2.20     0.00
  18352.56     -9.35     2.20    855.6 0.210E-01    2.20     53.39     2.20     0.00
  18449.47     -9.35     2.20    857.7 0.209E-01    2.20     53.51     2.20     0.00
  18546.38     -9.35     2.20    859.7 0.209E-01    2.20     53.64     2.20     0.00
  18643.29     -9.35     2.20    861.8 0.208E-01    2.20     53.77     2.20     0.00
  18740.20     -9.35     2.20    863.8 0.208E-01    2.20     53.90     2.20     0.00
  18837.11     -9.35     2.20    865.8 0.207E-01    2.20     54.02     2.20     0.00
  18934.02     -9.35     2.20    867.9 0.206E-01    2.20     54.15     2.20     0.00
  19030.93     -9.35     2.20    869.9 0.206E-01    2.20     54.28     2.20     0.00
  19127.84     -9.35     2.20    871.9 0.205E-01    2.20     54.40     2.20     0.00
  19224.75     -9.35     2.20    873.9 0.205E-01    2.20     54.53     2.20     0.00
  19321.66     -9.35     2.20    875.9 0.204E-01    2.20     54.65     2.20     0.00
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  19418.57    -9.35    2.20   877.9 0.204E-01   2.20    54.78    2.20    0.00
  19515.48    -9.35    2.20   879.9 0.203E-01   2.20    54.90    2.20    0.00
  19612.39    -9.35    2.20   881.9 0.203E-01   2.20    55.03    2.20    0.00
  19709.30    -9.35    2.20   883.9 0.202E-01   2.20    55.15    2.20    0.00
  19806.21    -9.35    2.20   885.9 0.202E-01   2.20    55.27    2.20    0.00
  19903.12    -9.35    2.20   887.9 0.202E-01   2.20    55.40    2.20    0.00
  20000.04    -9.35    2.20   889.8 0.201E-01   2.20    55.52    2.20    0.00
 Cumulative travel time =       31023.3711 sec

 Simulation limit based on maximum specified distance =  20000.00 m.
   This is the REGION OF INTEREST limitation.

END OF MOD261: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT
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CORMIX2: Multiport Diffuser Discharges       End of Prediction File
22222222222222222222222222222222222222222222222222222222222222222222222222222
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Appendix 7D - WASP Results - Chloride Base Case

	Distance Downstream																					
Relative Distance from Right Bank	**0.5**	**1.5**	**2.5**	**3.5**	**4.5**	**5.5**	**6.5**	**7.5**	**8.5**	**9.5**	**10.5**	**11.5**	**12.5**	**13.5**	**14.5**	**15.5**	**16.5**	**17.5**	**18.5**	**19.5**	**20.5**	**21.5**
1	27.03896	25.98364	23.98927	22.36388	21.01696	19.88356	17.85016	16.32229	15.54375	14.87251	14.16252	13.55016	13.01513	12.54251	21.45971	19.71515	17.79449	16.43229	15.95698	15.53681	14.84782	14.26713
2	10.41535	12.28283	13.0204	13.42437	13.60906	13.64999	13.37675	12.96104	12.68917	12.41132	12.07204	11.74713	11.43981	11.15096	12.61974	13.31854	13.56911	13.43549	13.3429	13.22595	12.95312	12.67027
3	4.335628	5.429506	6.108233	6.706793	7.216995	7.641643	8.302232	8.685243	8.837801	8.931385	8.982599	8.987461	8.959643	8.90896	9.165334	9.484266	9.895006	10.14475	10.21965	10.27191	10.3082	10.29561
4	2.112107	2.587089	2.929105	3.281332	3.631083	3.968892	4.681046	5.252105	5.545855	5.794644	6.043994	6.242152	6.397608	6.517769	6.651013	6.819455	7.124562	7.403473	7.508462	7.605335	7.763127	7.88638
5	1.298908	1.486285	1.631081	1.793137	1.968819	2.15411	2.626613	3.07531	3.331019	3.570152	3.839607	4.080328	4.293325	4.480403	4.625283	4.772289	5.025364	5.275817	5.374749	5.471601	5.652001	5.81611
6	1.001509	1.072536	1.129445	1.196262	1.27281	1.358453	1.611693	1.885654	2.053794	2.222493	2.428626	2.627317	2.816217	2.993903	3.130802	3.26417	3.482947	3.699175	3.785195	3.870589	4.036997	4.197156
7	0.892773	0.919223	0.940821	0.966892	0.997821	1.03384	1.153905	1.298717	1.393093	1.493413	1.624602	1.75935	1.895324	2.030599	2.138296	2.245078	2.421846	2.598243	2.668769	2.739259	2.879635	3.01866
8	0.853087	0.862899	0.87099	0.880914	0.892946	0.907342	0.960265	1.03037	1.078446	1.132177	1.206861	1.288147	1.374802	1.465617	1.540693	1.61753	1.749645	1.885392	1.940249	1.995643	2.108316	2.222492
9	0.838799	0.842554	0.845667	0.84952	0.854256	0.860026	0.883056	0.916256	0.940083	0.967965	1.009029	1.05629	1.109437	1.168041	1.21837	1.271723	1.368102	1.471189	1.513453	1.556705	1.646856	1.74032
10	0.834189	0.835981	0.83747	0.839324	0.84162	0.844451	0.856515	0.875183	0.88909	0.905991	0.932113	0.963593	1.000567	1.043023	1.080596	1.121551	1.198597	1.283781	1.319114	1.355665	1.433314	1.515181

	Distance Downstream																					
Relative Distance from Right Bank	**22.5**	**23.5**	**24.5**	**25.5**	**27**	**29**	**31.5**	**33.5**	**34.5**	**35.5**	**37**	**39**	**41**	**43**	**44.5**	**45.5**	**47**	**49**	**50.5**	**52.5**	**55.5**	**58.5**
1	13.76693	13.32855	12.93901	12.58899	12.00231	11.733	11.37274	10.77744	10.68147	11.02703	10.76607	10.54458	10.34971	10.17401	13.48651	13.00027	12.32745	11.83325	11.53138	10.91841	10.59068	10.31729
2	12.39141	12.12304	11.86781	11.62649	11.19567	10.99247	10.71235	10.23175	10.15376	10.13735	10.04851	9.935566	9.813894	9.690914	10.09087	10.32609	10.47727	10.4743	10.42453	10.16928	9.989922	9.816146
3	10.24908	10.17953	10.09479	10.00038	9.796692	9.693193	9.538494	9.245521	9.197188	9.157491	9.086717	9.01603	8.943553	8.869703	8.895165	8.945733	9.042913	9.107256	9.135271	9.10823	9.060413	8.996494
4	7.978791	8.044794	8.088777	8.114698	8.11768	8.109376	8.081099	7.990746	7.974862	7.959366	7.930372	7.902183	7.873975	7.845482	7.839655	7.843658	7.87588	7.917231	7.948781	8.014181	8.043317	8.059733
5	5.962655	6.091609	6.203755	6.300333	6.442805	6.502801	6.571939	6.653153	6.665211	6.676056	6.69433	6.710854	6.726866	6.742943	6.752176	6.763674	6.797496	6.840963	6.877997	7.000118	7.079714	7.153147
6	4.349537	4.493071	4.627154	4.751576	4.963848	5.061255	5.189569	5.390012	5.42192	5.452424	5.508583	5.565002	5.623828	5.684654	5.715558	5.747004	5.812162	5.884267	5.943026	6.13534	6.262078	6.381228
7	3.155482	3.289271	3.419301	3.544998	3.776785	3.887619	4.042481	4.310616	4.354164	4.396602	4.477311	4.57434	4.682598	4.793679	4.848985	4.903366	5.00605	5.125898	5.223535	5.505636	5.676835	5.827789
8	2.337698	2.453398	2.569042	2.684098	2.908438	3.018797	3.179345	3.477016	3.525959	3.574228	3.668029	3.850545	4.039115	4.208215	4.286677	4.358901	4.482355	4.697152	4.862066	5.22075	5.405498	5.551134
9	1.836737	1.93571	2.036814	2.139611	2.34857	2.453478	2.610568	2.916283	2.966965	3.017349	3.116718	3.628691	3.914236	4.087815	4.155992	4.211748	4.298197	4.859135	5.105309	5.37428	5.472902	5.541518
10	1.600928	1.690202	1.782631	1.877824	2.076029	2.176677	2.329808	2.635793	2.68674	2.7376	2.838693	4.814781	4.574625	4.444799	4.400355	4.371327	4.351815	6.563736	6.25121	5.85658	5.72115	5.657737
															7.047195	7.047177	7.047159	7.330319	7.33031	7.330281	7.330251	7.330221

Appendix 7D - WASP Results - Chloride Application Case

Distance Downstream

Relative Distance from Right Bank	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5	19.5	20.5	21.5
1	27.03896	25.98364	23.98927	22.36388	21.01696	19.88356	17.85016	16.32229	15.54375	14.87251	14.16252	13.55016	13.01513	12.54251	21.45971	19.71515	17.79449	16.43229	15.95698	15.53681	14.84782	14.26713
2	10.41535	12.28283	13.0204	13.42437	13.60906	13.64999	13.37675	12.96104	12.68917	12.41132	12.07204	11.74713	11.43981	11.15096	12.61974	13.31854	13.56911	13.43549	13.3429	13.22595	12.95312	12.67027
3	4.335628	5.429506	6.108233	6.706793	7.216995	7.641643	8.302232	8.685243	8.837801	8.931385	8.982599	8.987461	8.959643	8.90896	9.165334	9.484266	9.895006	10.14475	10.21965	10.27191	10.3082	10.29561
4	2.112107	2.587089	2.929105	3.281332	3.631083	3.968892	4.681046	5.252105	5.545855	5.794644	6.043994	6.242152	6.397608	6.517769	6.651013	6.819455	7.124562	7.403473	7.508462	7.605335	7.763127	7.88638
5	1.298908	1.486285	1.631081	1.793137	1.968819	2.15411	2.626613	3.07531	3.331019	3.570152	3.839607	4.080328	4.293325	4.480403	4.625283	4.772289	5.025364	5.275817	5.374749	5.471601	5.652001	5.81611
6	1.001509	1.072536	1.129445	1.196262	1.27281	1.358453	1.611693	1.885654	2.053794	2.222493	2.428626	2.627317	2.816217	2.993903	3.130802	3.26417	3.482947	3.699175	3.785195	3.870589	4.036997	4.197156
7	0.892773	0.919223	0.940821	0.966892	0.997821	1.03384	1.153905	1.298717	1.393093	1.493413	1.624602	1.75935	1.895324	2.030599	2.138296	2.245078	2.421846	2.598243	2.668769	2.739259	2.879635	3.01866
8	0.853087	0.862899	0.87099	0.880914	0.892946	0.907342	0.960265	1.03037	1.078446	1.132177	1.206861	1.288147	1.374802	1.465617	1.540693	1.61753	1.749645	1.885392	1.940249	1.995643	2.108316	2.222492
9	0.838799	0.842554	0.845667	0.84952	0.854256	0.860026	0.883056	0.916256	0.940083	0.967965	1.009029	1.05629	1.109437	1.168041	1.21837	1.271723	1.368102	1.471189	1.513453	1.556705	1.646856	1.74032
10	0.834189	0.835981	0.83747	0.839324	0.84162	0.844451	0.856515	0.875183	0.88909	0.905991	0.932113	0.963593	1.000567	1.043023	1.080596	1.121551	1.198597	1.283781	1.319114	1.355665	1.433314	1.515181

Distance Downstream

Relative Distance from Right Bank	22.5	23.5	24.5	25.5	27	29	31.5	33.5	34.5	35.5	37	39	41	43	44.5	45.5	47	49	50.5	52.5	55.5	58.5
1	13.76693	13.32855	12.93901	12.58899	12.00231	11.733	11.37274	10.77744	10.68147	11.02703	10.76607	10.54458	10.34971	10.17401	13.48651	13.00027	12.32745	15.02586	14.25135	12.94106	12.31551	11.83759
2	12.39141	12.12304	11.86781	11.62649	11.19567	10.99247	10.71235	10.23175	10.15376	10.13735	10.04851	9.935566	9.813894	9.690914	10.09087	10.32609	10.47727	11.17919	11.41153	11.33965	11.16875	10.96147
3	10.24908	10.17953	10.09479	10.00038	9.796692	9.693193	9.538494	9.245521	9.197188	9.157491	9.086717	9.01603	8.943553	8.869703	8.895165	8.945733	9.042913	9.262888	9.423651	9.650439	9.708753	9.705414
4	7.978791	8.044794	8.088777	8.114698	8.11768	8.109376	8.081099	7.990746	7.974862	7.959366	7.930372	7.902183	7.873975	7.845482	7.839655	7.843658	7.87588	7.951594	8.025296	8.238465	8.355742	8.443316
5	5.962655	6.091609	6.203755	6.300333	6.442805	6.502801	6.571939	6.653153	6.665211	6.676056	6.69433	6.710854	6.726866	6.742943	6.752176	6.763674	6.797496	6.84855	6.897233	7.087083	7.217817	7.341848
6	4.349537	4.493071	4.627154	4.751576	4.963848	5.061255	5.189569	5.390012	5.42192	5.452424	5.508583	5.565002	5.623828	5.684654	5.715558	5.747004	5.812162	5.885942	5.947701	6.167764	6.319609	6.467809
7	3.155482	3.289271	3.419301	3.544998	3.776785	3.887619	4.042481	4.310616	4.354164	4.396602	4.477311	4.57434	4.682598	4.793679	4.848985	4.903366	5.00605	5.126268	5.224644	5.517438	5.699821	5.865509
8	2.337698	2.453398	2.569042	2.684098	2.908438	3.018797	3.179345	3.477016	3.525959	3.574228	3.668029	3.850545	4.039115	4.208215	4.286677	4.358901	4.482355	4.697234	4.862326	5.224995	5.414443	5.567009
9	1.836737	1.93571	2.036814	2.139611	2.34857	2.453478	2.610568	2.916283	2.966965	3.017349	3.116718	3.628691	3.914236	4.087815	4.155992	4.211748	4.298197	4.859153	5.105369	5.375842	5.476427	5.548253
10	1.600928	1.690202	1.782631	1.877824	2.076029	2.176677	2.329808	2.635793	2.68674	2.7376	2.838693	4.814781	4.574625	4.444799	4.400355	4.371327	4.351815	6.563741	6.251228	5.857292	5.722855	5.661217

Appendix 7D - WASP Results - Chloride Future

Distance Downstream (km)

Relative Distance from Right Bank	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5	19.5	20.5	21.5
1	27.03896	25.98364	23.98927	22.36388	21.01696	19.88356	17.85016	16.32229	15.54375	14.87251	14.16252	13.55016	13.01513	12.54251	21.45971	19.71515	17.79449	16.43229	15.95698	15.53681	14.84782	14.26713
2	10.41535	12.28283	13.0204	13.42437	13.60906	13.64999	13.37675	12.96104	12.68917	12.41132	12.07204	11.74713	11.43981	11.15096	12.61974	13.31854	13.56911	13.43549	13.3429	13.22595	12.95312	12.67027
3	4.335628	5.429506	6.108233	6.706793	7.216995	7.641643	8.302232	8.685243	8.837801	8.931385	8.982599	8.987461	8.959643	8.90896	9.165334	9.484266	9.895006	10.14475	10.21965	10.27191	10.3082	10.29561
4	2.112107	2.587089	2.929105	3.281332	3.631083	3.968892	4.681046	5.252105	5.545855	5.794644	6.043994	6.242152	6.397608	6.517769	6.651013	6.819455	7.124562	7.403473	7.508462	7.605335	7.763127	7.88638
5	1.298908	1.486285	1.631081	1.793137	1.968819	2.15411	2.626613	3.07531	3.331019	3.570152	3.839607	4.080328	4.293325	4.480403	4.625283	4.772289	5.025364	5.275817	5.374749	5.471601	5.652001	5.81611
6	1.001509	1.072536	1.129445	1.196262	1.27281	1.358453	1.611693	1.885654	2.053794	2.222493	2.428626	2.627317	2.816217	2.993903	3.130802	3.26417	3.482947	3.699175	3.785195	3.870589	4.036997	4.197156
7	0.892773	0.919223	0.940821	0.966892	0.997821	1.03384	1.153905	1.298717	1.393093	1.493413	1.624602	1.75935	1.895324	2.030599	2.138296	2.245078	2.421846	2.598243	2.668769	2.739259	2.879635	3.01866
8	0.853087	0.862899	0.87099	0.880914	0.892946	0.907342	0.960265	1.03037	1.078446	1.132177	1.206861	1.288147	1.374802	1.465617	1.540693	1.61753	1.749645	1.885392	1.940249	1.995643	2.108316	2.222492
9	0.838799	0.842554	0.845667	0.84952	0.854256	0.860026	0.883056	0.916256	0.940083	0.967965	1.009029	1.05629	1.109437	1.168041	1.21837	1.271723	1.368102	1.471189	1.513453	1.556705	1.646856	1.74032
10	0.834189	0.835981	0.83747	0.839324	0.84162	0.844451	0.856515	0.875183	0.88909	0.905991	0.932113	0.963593	1.000567	1.043023	1.080596	1.121551	1.198597	1.283781	1.319114	1.355665	1.433314	1.515181

Distance Downstream (km)

Relative Distance from Right Bank	22.5	23.5	24.5	25.5	27	29	31.5	33.5	34.5	35.5	37	39	41	43	44.5	45.5	47	49	50.5	52.5	55.5	58.5
1	13.76693	13.32855	12.93901	12.58899	12.00231	11.733	11.37274	10.77744	10.68147	11.02703	10.76607	10.54458	10.34971	10.17401	13.48651	13.00027	12.32745	15.02586	14.25135	12.94106	5.661217	5.722855
2	12.39141	12.12304	11.86781	11.62649	11.19567	10.99247	10.71235	10.23175	10.15376	10.13735	10.04851	9.935566	9.813894	9.690914	10.09087	10.32609	10.47727	11.17919	11.41153	11.33965	12.31551	11.83759
3	10.24908	10.17953	10.09479	10.00038	9.796692	9.693193	9.538494	9.245521	9.197188	9.157491	9.086717	9.01603	8.943553	8.869703	8.895165	8.945733	9.042913	9.262888	9.423651	9.650439	11.16875	10.96147
4	7.978791	8.044794	8.088777	8.114698	8.11768	8.109376	8.081099	7.990746	7.974862	7.959366	7.930372	7.902183	7.873975	7.845482	7.839655	7.843658	7.87588	7.951594	8.025296	8.238465	9.708753	9.705414
5	5.962655	6.091609	6.203755	6.300333	6.442805	6.502801	6.571939	6.653153	6.665211	6.676056	6.69433	6.710854	6.726866	6.742943	6.752176	6.763674	6.797496	6.84855	6.897233	7.087083	8.355742	8.443316
6	4.349537	4.493071	4.627154	4.751576	4.963848	5.061255	5.189569	5.390012	5.42192	5.452424	5.508583	5.565002	5.623828	5.684654	5.715558	5.747004	5.812162	5.885942	5.947701	6.167764	7.217817	7.341848
7	3.155482	3.289271	3.419301	3.544998	3.776785	3.887619	4.042481	4.310616	4.354164	4.396602	4.477311	4.57434	4.682598	4.793679	4.848985	4.903366	5.00605	5.126268	5.224644	5.517438	6.319609	6.467809
8	2.337698	2.453398	2.569042	2.684098	2.908438	3.018797	3.179345	3.477016	3.525959	3.574228	3.668029	3.850545	4.039115	4.208215	4.286677	4.358901	4.482355	4.697234	4.862326	5.224995	5.699821	5.865509
9	1.836737	1.93571	2.036814	2.139611	2.34857	2.453478	2.610568	2.916283	2.966965	3.017349	3.116718	3.628691	3.914236	4.087815	4.155992	4.211748	4.298197	4.859153	5.105369	5.375842	5.414443	5.567009
10	1.600928	1.690202	1.782631	1.877824	2.076029	2.176677	2.329808	2.635793	2.68674	2.7376	2.838693	4.814781	4.574625	4.444799	4.400355	4.371327	4.351815	6.563741	6.251228	5.857292	5.476427	5.548253
															7.047195	7.047177	7.047159	7.740042	7.740032	7.740002	7.733809	7.746107

Appendix 7D - WASP Results - COD Base Case

Distance Downstream

Relative Distance from Right Bank	**0.5**	**1.5**	**2.5**	**3.5**	**4.5**	**5.5**	**6.5**	**7.5**	**8.5**	**9.5**	**10.5**	**11.5**	**12.5**	**13.5**	**14.5**	**15.5**	**16.5**	**17.5**	**18.5**	**19.5**	**20.5**	**21.5**
1	11.61808	10.31459	9.282662	8.768726	8.002707	7.776535	6.734806	5.956183	5.497274	5.100338	4.710826	4.373122	4.07651	3.81319	9.091752	7.926995	6.759499	5.936646	5.554021	5.214793	4.788157	4.428906
2	4.500618	5.0398	5.150874	5.183031	5.120571	5.056809	4.89103	4.639444	4.424118	4.210407	3.983362	3.768138	3.566112	3.377368	4.196687	4.535112	4.640677	4.521303	4.373285	4.216326	4.013073	3.80926
3	1.933536	2.300793	2.486646	2.636204	2.746518	2.827401	3.007916	3.077857	3.051959	3.003698	2.942034	2.864935	2.778367	2.686504	2.771103	2.886955	3.06282	3.144118	3.105782	3.05582	3.012756	2.94589
4	1.007657	1.163498	1.258167	1.350376	1.435974	1.513076	1.722036	1.874895	1.923223	1.953067	1.981086	1.989795	1.983101	1.964351	1.962959	1.983674	2.07562	2.154949	2.143959	2.128736	2.14454	2.143607
5	0.673718	0.726622	0.759619	0.796282	0.835037	0.874453	1.010424	1.132947	1.184926	1.228407	1.27902	1.317462	1.344687	1.361886	1.367351	1.376282	1.428784	1.483664	1.478261	1.471962	1.498116	1.517013
6	0.553279	0.564292	0.568885	0.576267	0.586127	0.598048	0.665168	0.73592	0.768596	0.79938	0.839859	0.875619	0.90616	0.931321	0.943387	0.95423	0.992502	1.031814	1.028695	1.025353	1.048193	1.068535
7	0.509851	0.504907	0.498023	0.492695	0.488927	0.486668	0.511829	0.543504	0.557297	0.571853	0.594665	0.617031	0.63824	0.657759	0.668262	0.677733	0.706443	0.735093	0.733063	0.730888	0.748247	0.764852
8	0.494218	0.483379	0.472125	0.461759	0.452313	0.443807	0.447891	0.45693	0.458363	0.461105	0.469587	0.479236	0.489593	0.500235	0.505742	0.511106	0.530542	0.550305	0.548181	0.546019	0.558256	0.570433
9	0.488662	0.475702	0.462852	0.450603	0.438971	0.427971	0.422734	0.420639	0.415504	0.411536	0.411291	0.412523	0.415029	0.418587	0.419486	0.420815	0.432698	0.445602	0.442787	0.44007	0.448342	0.456936
10	0.486889	0.473248	0.459882	0.447017	0.434658	0.422811	0.414177	0.40772	0.399887	0.393045	0.388893	0.386167	0.384798	0.384681	0.383039	0.382057	0.389779	0.39893	0.395557	0.392366	0.398457	0.405069

Distance Downstream

Relative Distance from Right Bank	**22.5**	**23.5**	**24.5**	**25.5**	**27**	**29**	**31.5**	**33.5**	**34.5**	**35.5**	**37**	**39**	**41**	**43**	**44.5**	**45.5**	**47**	**49**	**50.5**	**52.5**	**55.5**	**58.5**
1	4.119812	3.84934	3.60948	3.394488	3.036339	2.79255	2.476696	2.264849	2.176683	2.950955	2.594234	2.318658	2.095277	2.073822	3.057911	2.72236	2.358253	2.081673	1.936062	1.635749	1.435632	1.270845
2	3.612392	3.425634	3.250014	3.085528	2.796372	2.586565	2.309536	2.133435	2.053783	2.091377	2.044705	1.946446	1.829453	1.744371	1.795595	1.782356	1.749168	1.667289	1.616811	1.450063	1.307514	1.180092
3	2.863972	2.773201	2.677851	2.580811	2.39135	2.233791	2.018595	1.899731	1.83437	1.786393	1.706893	1.627733	1.546155	1.471054	1.412265	1.362385	1.339718	1.305029	1.291733	1.22135	1.135511	1.051995
4	2.128433	2.10176	2.066155	2.023843	1.924676	1.819239	1.668852	1.609724	1.560549	1.514634	1.434327	1.362041	1.29566	1.235863	1.175345	1.121241	1.090745	1.064415	1.061122	1.04203	0.994987	0.945749
5	1.528159	1.531743	1.528361	1.518814	1.481692	1.417294	1.320946	1.310137	1.275797	1.242241	1.179465	1.124086	1.078099	1.041772	0.996524	0.955479	0.939315	0.928423	0.936091	0.954913	0.933694	0.906522
6	1.085613	1.098955	1.108358	1.11383	1.110877	1.073965	1.016094	1.036957	1.014359	0.991892	0.948129	0.92079	0.913377	0.921042	0.900304	0.881782	0.89965	0.916882	0.942966	0.996674	0.988782	0.968242
7	0.780306	0.794245	0.806382	0.816514	0.828378	0.807746	0.774134	0.811645	0.797331	0.782937	0.75413	0.795445	0.880174	0.974571	0.989482	0.999515	1.058742	1.105219	1.15003	1.214582	1.193846	1.153333
8	0.582384	0.593916	0.604834	0.614959	0.631077	0.619126	0.5993	0.643215	0.634183	0.625024	0.60633	0.916012	1.226356	1.449771	1.489793	1.50489	1.556794	1.605178	1.648912	1.646054	1.559448	1.455967
9	0.465756	0.474689	0.483608	0.492383	0.508418	0.500608	0.48779	0.532869	0.526834	0.520682	0.507964	2.040544	2.629946	2.780476	2.705762	2.593861	2.456492	2.505153	2.490972	2.256537	2.025625	1.811029
10	0.412114	0.419498	0.427123	0.434882	0.450086	0.443873	0.433904	0.478616	0.473909	0.469102	0.459104	7.719043	6.091782	4.987568	4.410805	3.93016	3.386971	3.955585	3.557225	2.830682	2.405353	2.073858
															1.893378	1.785403	1.683585	1.713485	1.663192	1.524863	1.398039	1.281763

Appendix 7D - WASP Results - COD Application Case

Distance Downstream

Relative Distance from Right Bank	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5	19.5	20.5	21.5
1	11.61808	10.31459	9.282662	8.768726	8.002707	7.776535	6.734806	5.956183	5.497274	5.100338	4.710826	4.373122	4.07651	3.81319	9.091752	7.926995	6.759499	5.936646	5.554021	5.214793	4.788157	4.428906
2	4.500618	5.0398	5.150874	5.183031	5.120571	5.056809	4.89103	4.639444	4.424118	4.210407	3.983362	3.768138	3.566112	3.377368	4.196687	4.535112	4.640677	4.521303	4.373285	4.216326	4.013073	3.80926
3	1.933536	2.300793	2.486646	2.636204	2.746518	2.827401	3.007916	3.077857	3.051959	3.003698	2.942034	2.864935	2.778367	2.686504	2.771103	2.886955	3.06282	3.144118	3.105782	3.05582	3.012756	2.94589
4	1.007657	1.163498	1.258167	1.350376	1.435974	1.513076	1.722036	1.874895	1.923223	1.953067	1.981086	1.989795	1.983101	1.964351	1.962959	1.983674	2.07562	2.154949	2.143959	2.128736	2.14454	2.143607
5	0.673718	0.726622	0.759619	0.796282	0.835037	0.874453	1.010424	1.132947	1.184926	1.228407	1.27902	1.317462	1.344687	1.361886	1.367351	1.376282	1.428784	1.483664	1.478261	1.471962	1.498116	1.517013
6	0.553279	0.564292	0.568885	0.576267	0.586127	0.598048	0.665168	0.73592	0.768596	0.79938	0.839859	0.875619	0.90616	0.931321	0.943387	0.95423	0.992502	1.031814	1.028695	1.025353	1.048193	1.068535
7	0.509851	0.504907	0.498023	0.492695	0.488927	0.486668	0.511829	0.543504	0.557297	0.571853	0.594665	0.617031	0.63824	0.657759	0.668262	0.677733	0.706443	0.735093	0.733063	0.730888	0.748247	0.764852
8	0.494218	0.483379	0.472125	0.461759	0.452313	0.443807	0.447891	0.45693	0.458363	0.461105	0.469587	0.479236	0.489593	0.500235	0.505742	0.511106	0.530542	0.550305	0.548181	0.546019	0.558256	0.570433
9	0.488662	0.475702	0.462852	0.450603	0.438971	0.427971	0.422734	0.420639	0.415504	0.411536	0.411291	0.412523	0.415029	0.418587	0.419486	0.420815	0.432698	0.445602	0.442787	0.44007	0.448342	0.456936
10	0.486889	0.473248	0.459882	0.447017	0.434658	0.422811	0.414177	0.40772	0.399887	0.393045	0.388893	0.386167	0.384798	0.384681	0.383039	0.382057	0.389779	0.39893	0.395557	0.392366	0.398457	0.405069

Distance Downstream

Relative Distance from Right Bank	22.5	23.5	24.5	25.5	27	29	31.5	33.5	34.5	35.5	37	39	41	43	44.5	45.5	47	49	50.5	52.5	55.5	58.5
1	4.119812	3.84934	3.60948	3.394488	3.036339	2.79255	2.476696	2.264849	2.176683	2.950955	2.594234	2.318658	2.095277	2.073822	4.235552	3.705244	3.127294	5.519198	4.81507	3.65848	3.040165	2.580292
2	3.612392	3.425634	3.250014	3.085528	2.796372	2.586565	2.309536	2.133435	2.053783	2.091377	2.044705	1.946446	1.829453	1.744371	1.94848	2.02099	2.058033	2.590944	2.767139	2.6505	2.412199	2.166326
3	2.863972	2.773201	2.677851	2.580811	2.39135	2.233791	2.018595	1.899731	1.83437	1.786393	1.706893	1.627733	1.546155	1.471054	1.432113	1.407781	1.432922	1.5591	1.672064	1.793834	1.748531	1.661881
4	2.128433	2.10176	2.066155	2.023843	1.924676	1.819239	1.668852	1.609724	1.560549	1.514634	1.434327	1.362041	1.29566	1.235863	1.177921	1.129005	1.11526	1.133544	1.176575	1.284887	1.292606	1.274967
5	1.528159	1.531743	1.528361	1.518814	1.481692	1.417294	1.320946	1.310137	1.275797	1.242241	1.179465	1.124086	1.078099	1.041772	0.996859	0.95673	0.945283	0.946789	0.969322	1.050783	1.06581	1.067759
6	1.085613	1.098955	1.108358	1.11383	1.110877	1.073965	1.016094	1.036957	1.014359	0.991892	0.948129	0.92079	0.913377	0.921042	0.900347	0.881976	0.901036	0.921638	0.952163	1.032749	1.043822	1.041707
7	0.780306	0.794245	0.806382	0.816514	0.828378	0.807746	0.774134	0.811645	0.797331	0.782937	0.75413	0.795445	0.880174	0.974571	0.989488	0.999544	1.059055	1.106422	1.152497	1.227715	1.215737	1.185027
8	0.582384	0.593916	0.604834	0.614959	0.631077	0.619126	0.5993	0.643215	0.634183	0.625024	0.60633	0.916012	1.226356	1.449771	1.489794	1.504895	1.556863	1.605476	1.649557	1.650739	1.567887	1.469131
9	0.465756	0.474689	0.483608	0.492383	0.508418	0.500608	0.48779	0.532869	0.526834	0.520682	0.507964	2.040544	2.629946	2.780476	2.705762	2.593862	2.456507	2.505227	2.49114	2.258229	2.028898	1.816515
10	0.412114	0.419498	0.427123	0.434882	0.450086	0.443873	0.433904	0.478616	0.473909	0.469102	0.459104	7.719043	6.091782	4.987568	4.410805	3.93016	3.386975	3.955606	3.557276	2.831435	2.406904	2.076635
															2.028712	1.913019	1.803923	2.184394	2.12028	1.943935	1.782256	1.634024

Appendix 7D - WASP Results - COD Future Case

Distance Downstream

Relative Distance from Right Bank	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5	19.5	20.5	21.5
1	11.61808	10.31459	9.282662	8.768726	8.002707	7.776535	6.734806	5.956183	5.497274	5.100338	4.710826	4.373122	4.07651	3.81319	9.091752	7.926995	6.759499	5.936646	5.554021	5.214793	4.788157	4.428906
2	4.500618	5.0398	5.150874	5.183031	5.120571	5.056809	4.89103	4.639444	4.424118	4.210407	3.983362	3.768138	3.566112	3.377368	4.196687	4.535112	4.640677	4.521303	4.373285	4.216326	4.013073	3.80926
3	1.933536	2.300793	2.486646	2.636204	2.746518	2.827401	3.007916	3.077857	3.051959	3.003698	2.942034	2.864935	2.778367	2.686504	2.771103	2.886955	3.06282	3.144118	3.105782	3.05582	3.012756	2.94589
4	1.007657	1.163498	1.258167	1.350376	1.435974	1.513076	1.722036	1.874895	1.923223	1.953067	1.981086	1.989795	1.983101	1.964351	1.962959	1.983674	2.07562	2.154949	2.143959	2.128736	2.14454	2.143607
5	0.673718	0.726622	0.759619	0.796282	0.835037	0.874453	1.010424	1.132947	1.184926	1.228407	1.27902	1.317462	1.344687	1.361886	1.367351	1.376282	1.428784	1.483664	1.478261	1.471962	1.498116	1.517013
6	0.553279	0.564292	0.568885	0.576267	0.586127	0.598048	0.665168	0.73592	0.768596	0.79938	0.839859	0.875619	0.90616	0.931321	0.943387	0.95423	0.992502	1.031814	1.028695	1.025353	1.048193	1.068535
7	0.509851	0.504907	0.498023	0.492695	0.488927	0.486668	0.511829	0.543504	0.557297	0.571853	0.594665	0.617031	0.63824	0.657759	0.668262	0.677733	0.706443	0.735093	0.733063	0.730888	0.748247	0.764852
8	0.494218	0.483379	0.472125	0.461759	0.452313	0.443807	0.447891	0.45693	0.458363	0.461105	0.469587	0.479236	0.489593	0.500235	0.505742	0.511106	0.530542	0.550305	0.548181	0.546019	0.558256	0.570433
9	0.488662	0.475702	0.462852	0.450603	0.438971	0.427971	0.422734	0.420639	0.415504	0.411536	0.411291	0.412523	0.415029	0.418587	0.419486	0.420815	0.432698	0.445602	0.442787	0.44007	0.448342	0.456936
10	0.486889	0.473248	0.459882	0.447017	0.434658	0.422811	0.414177	0.40772	0.399887	0.393045	0.388893	0.386167	0.384798	0.384681	0.383039	0.382057	0.389779	0.39893	0.395557	0.392366	0.398457	0.405069

Distance Downstream

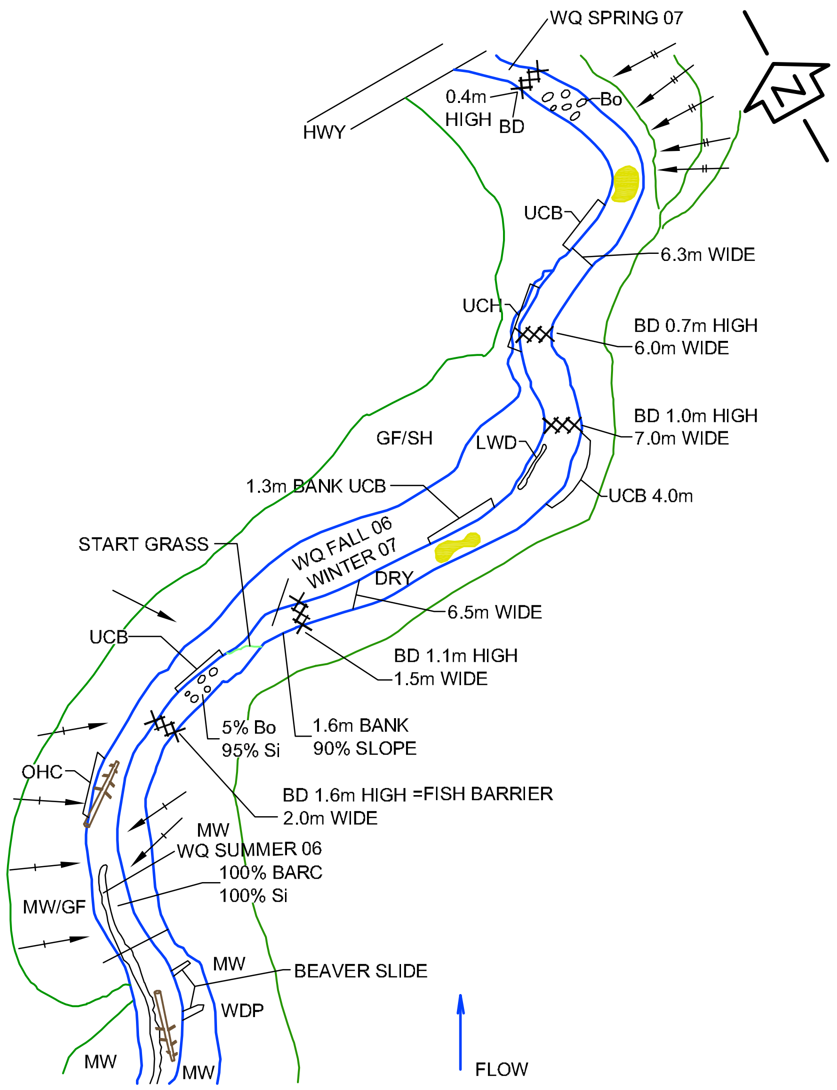
Relative Distance from Right Bank	22.5	23.5	24.5	25.5	27	29	31.5	33.5	34.5	35.5	37	39	41	43	44.5	45.5	47	49	50.5	52.5	55.5	58.5
1	4.119812	3.84934	3.60948	3.394488	3.036339	2.79255	2.476696	2.264849	2.176683	2.950955	2.594234	2.318658	2.095277	2.073822	6.078	5.242984	4.330467	6.492609	5.668969	4.302203	3.56901	3.022709
2	3.612392	3.425634	3.250014	3.085528	2.796372	2.586565	2.309536	2.133435	2.053783	2.091377	2.044705	1.946446	1.829453	1.744371	2.18767	2.39434	2.541264	3.099615	3.277449	3.10867	2.818346	2.52383
3	2.863972	2.773201	2.677851	2.580811	2.39135	2.233791	2.018595	1.899731	1.83437	1.786393	1.706893	1.627733	1.546155	1.471054	1.463165	1.478802	1.578746	1.757551	1.901342	2.053495	2.004109	1.90471
4	2.128433	2.10176	2.066155	2.023843	1.924676	1.819239	1.668852	1.609724	1.560549	1.514634	1.434327	1.362041	1.29566	1.235863	1.181953	1.141153	1.153637	1.199477	1.263267	1.411944	1.432603	1.420112
5	1.528159	1.531743	1.528361	1.518814	1.481692	1.417294	1.320946	1.310137	1.275797	1.242241	1.179465	1.124086	1.078099	1.041772	0.997382	0.958687	0.954725	0.96693	0.999143	1.108645	1.137212	1.148775
6	1.085613	1.098955	1.108358	1.11383	1.110877	1.073965	1.016094	1.036957	1.014359	0.991892	0.948129	0.92079	0.913377	0.921042	0.900415	0.88228	0.903696	0.928753	0.963905	1.062091	1.083308	1.089674
7	0.780306	0.794245	0.806382	0.816514	0.828378	0.807746	0.774134	0.811645	0.797331	0.782937	0.75413	0.795445	0.880174	0.974571	0.989496	0.99959	1.061856	1.113942	1.16443	1.253287	1.248454	1.223451
8	0.582384	0.593916	0.604834	0.614959	0.631077	0.619126	0.5993	0.643215	0.634183	0.625024	0.60633	0.916012	1.226356	1.449771	1.489795	1.504901	1.567847	1.627633	1.679185	1.692045	1.612372	1.514862
9	0.465756	0.474689	0.483608	0.492383	0.508418	0.500608	0.48779	0.532869	0.526834	0.520682	0.507964	2.040544	2.629946	2.780476	2.705762	2.593863	2.507687	2.576428	2.569141	2.334125	2.098376	1.879444
10	0.412114	0.419498	0.427123	0.434882	0.450086	0.443873	0.433904	0.478616	0.473909	0.469102	0.459104	7.719043	6.091782	4.987568	4.410805	3.93016	3.627606	4.142751	3.717233	2.94776	2.501163	2.155223
															2.240444	2.112676	2.022753	2.390569	2.320407	2.127427	1.950495	1.788279

LEGEND

Ba	BARE GROUND
Bd	BEDROCK
Bo	BOULDER
L.Bo	LARGE BOULDER
Co	COBBLE
S.Co	SMALL COBBLE
L.Co	LARGE COBBLE
Gr	GRAVEL
S.Gr	SMALL GRAVEL
L.Gr	LARGE GRAVEL
┬┬┬┬	ESCARPMENT
Sa	SAND
Si	SILT
Or	ORGANIC MATERIAL
LWD	LARGE WOODY DEBRIS
BL	BEAVER LODGE
BD	BEAVER DAM
EM	EMERGENT MACROPHYTES
SM	SUBMERGENT MACROPHYTES
FM	FLOATING MACROPHYTES
IV	INSTREAM VEGETATION
TV	TERRESTIAL VEGETATION
	DEADFALL
RW	ROOTWAD
SH	SHRUB
MF	MIXEDWOOD FOREST
CF	CONIFEROUS FOREST
DF	DECIDUOUS FOREST
SE	SEDGES
GF	GRASS/FORBES
MO	MOSS
MT	MINNOW TRAP
UCB	UNDERCUT BANK
OHC	OVERHEAD COVER
OHV	OVERHANGING VEGETATION
ISC	INSTREAM COVER
INV	INUNDATED VEGETATION
USB	UNSTABLE BANK
BW	BACKWATER
IP	IMPOUNDMENT POND
SN	SNYE
CH	CHUTE
CA	CASCADE
→	SHALLOW SLOPE
→	MODERATE SLOPE
→	MODERATELY STEEP SLOPE
→	STEEP SLOPE
→	FLOW DIRECTION
RA	RAPIDS
RF	RIFFLE
R1	CLASS 1 RUN
R2	CLASS 2 RUN
R3	CLASS 3 RUN
P1	CLASS 1 POOL
P2	CLASS 2 POOL
P3	CLASS 3 POOL
FL	FLAT
FA	FALLS
▼	WATER DEPTH
T1	TRANSECT

AQUATIC HABITAT MAP

NOT TO SCALE



FISHERIES COLLECTION DATA

Sampling Season	Angling		Minnow Trap		Electrofishing	
	Fish Captured	Effort (h)	Fish Captured	Effort (h)	Fish Captured	Effort (sec.)
Summer	--	--	--	--	--	--
Spring	--	--	8 WHSC	23.33	--	--
Summer	--	--	0	19.00	--	--
Fall	--	--	0	22.17	--	--
Total	**0**	**0**	**8 WHSC**	**64.50**	**--**	**--**

Note(s):
'--' = method not used during this survey.
WHSC - White Sucker

PHOTO 1. No flowing water (August 2006)

PHOTO 2. Flooded beaver dam (October 2006)

AST 1 (Beaverhill Creek)

AST 1 was located on Beaverhill Creek, which followed an irregular meander pattern, with an average channel width of approximately 11 m. The watercourse was located in a mature deciduous forest with primarily tall grasses and willows bordering the banks of the watercourse. The habitat in the study area included runs and pools created by beaver activity. Substrate was composed of organic fines with occasional areas of large cobble and boulder. The watercourse only contained flowing water during the spring survey and was not flowing during the summer, fall, and winter surveys. AST1 provided low spawning, rearing and feeding habitat potential for forage fish species, and low spawning, rearing, and feeding habitat potential for large bodied/sport fish species. Overwintering habitat was low-moderate for both forage and large bodied/sport fish species due to shallow water depth below the ice.

PHOTO 3. High flow conditions (May 2007)

WATER QUALITY

Sampling Date	Water Depth (m)	Discharge (m^3/s)	Temperature (°C)	Dissolved Oxygen (mg/L)	Conductivity (µS/cm)	pH (units)	Turbidity (NTU)
28-Aug-06	0.11	0.00	15.55	9.10	550	8.17	48.00
24-Oct-06	0.35	0.00	1.35	8.66	729	6.97	14.00
22-Jan-07	0.40	0.00	0.50	13.50	731	5.32	--
1-May-07	0.89	1.25	9.74	11.38	371	6.94	48.34

Note(s):
'--' = not sampled

AENV Guideline: 6.5 - 9 (pH) **AENV, 1999**
AENV Guideline: minimum 5.0 mg/L (Dissolved Oxygen) **CCME, 2002**

HABITAT POTENTIAL RANKING

Fish Habitat Potential	Large Bodied/ Sport Fish	Forage Fish
Overwintering	Low-Moderate	Low-Moderate
Spawning	Low	Low
Rearing	Low	Low
Feeding	Low	Low

Title:

NORTH AMERICAN
FISHERIES BASELINE
AST 1
WATERCOURSE DATA

NORTH AMERICAN
OIL SANDS CORPORATION

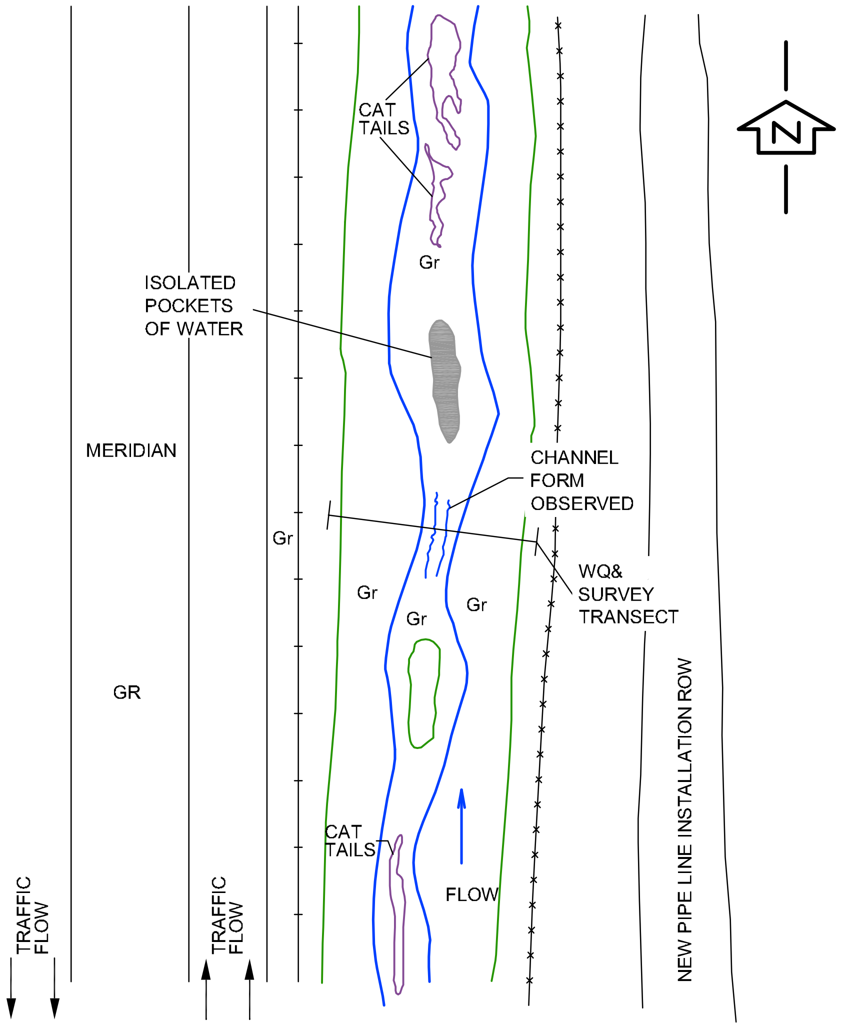
Approved:
Revision Date:
File: 6198-HABITAT-07-WB
Drawn by: ADF
Checked: CJS
Fig. No.: 8A-1

LEGEND

Ba	BARE GROUND
Bd	BEDROCK
Bo	BOULDER
L.Bo	LARGE BOULDER
Co	COBBLE
S.Co	SMALL COBBLE
L.Co	LARGE COBBLE
Gr	GRAVEL
S.Gr	SMALL GRAVEL
L.Gr	LARGE GRAVEL
┬┬┬┬	ESCARPMENT
Sa	SAND
Si	SILT
Or	ORGANIC MATERIAL
LWD	LARGE WOODY DEBRIS
BL	BEAVER LODGE
BD	BEAVER DAM
EM	EMERGENT MACROPHYTES
SM	SUBMERGENT MACROPHYTES
FM	FLOATING MACROPHYTES
IV	INSTREAM VEGETATION
TV	TERRESTIAL VEGETATION
⇹	DEADFALL
RW	ROOTWAD
SH	SHRUB
MF	MIXEDWOOD FOREST
CF	CONIFEROUS FOREST
DF	DECIDUOUS FOREST
SE	SEDGES
GF	GRASS/FORBES
MO	MOSS
MT	MINNOW TRAP
UCB	UNDERCUT BANK
OHC	OVERHEAD COVER
OHV	OVERHANGING VEGETATION
ISC	INSTREAM COVER
INV	INUNDATED VEGETATION
USB	UNSTABLE BANK
BW	BACKWATER
IP	IMPOUNDMENT POND
SN	SNYE
CH	CHUTE
CA	CASCADE
→	SHALLOW SLOPE
─┼→	MODERATE SLOPE
─┼┼→	MODERATELY STEEP SLOPE
─┼┼┼→	STEEP SLOPE
→	FLOW DIRECTION
RA	RAPIDS
RF	RIFFLE
R1	CLASS 1 RUN
R2	CLASS 2 RUN
R3	CLASS 3 RUN
P1	CLASS 1 POOL
P2	CLASS 2 POOL
P3	CLASS 3 POOL
FL	FLAT
FA	FALLS
▼	WATER DEPTH
T1	TRANSECT

AQUATIC HABITAT MAP

NOT TO SCALE



FISHERIES COLLECTION DATA

	Angling		Minnow Trap		Electrofishing	
Sampling Season	**Fish Captured**	**Effort (h)**	**Fish Captured**	**Effort (h)**	**Fish Captured**	**Effort (sec.)**
Summer	--	--	--	--	--	--
Fall	--	--	466 BRST	22.30	--	--
Winter	--	--	--	--	--	--
Spring	--	--	0*	19.50	--	--
Total	--	--	**466 BRST**	**41.80**	--	--

Note(s):
'--' = method not used during this survey.
BRST - Brook stickleback
* - no fish were caught, however one tiger salamander was caught in the trap.

PHOTO 1. Spring conditions (May 2007)

AST 2 (Astotin Creek)

AST 2 was located on Astotin Creek, which followed an irregular meander pattern, with an average channel width of approximately 1.8 m. The watercourse was located to the east of a secondary highway, adjacent to an open field (agricultural) featuring an oil and gas pipeline right-of-way . The banks of the watercourse were bordered by tall grasses. The watercourse only contained flowing water during the spring survey and was not flowing during the summer and fall surveys. AST2 provided low spawning, rearing and feeding habitat potential for forage fish species, and low spawning, rearing, and feeding habitat potential for large bodied/sport fish species. Overwintering habitat was nil for both forage and large bodied/sport fish species as the watercourse was frozen to the bottom at the time of the survey.

PHOTO 2. Brook stickleback (Culea *inconstans*) (October 2006)

PHOTO 3. Pooled water, looking downstream (October 2007)

SURFACE WATER QUALITY

Sampling Date	Water Depth (m)	Discharge (m^3/s)	Temperature (°C)	Dissolved Oxygen (mg/L)	Conductivity (µS/cm)	pH (units)	Turbidity (NTU)
29-Aug-06	0.30	0.00	14.21	2.93	1292	7.07	4.79
23-Oct-06	0.45	0.00	4.89	10.47	1893	6.79	11.74
23-Jan-07	FROZEN TO BOTTOM						
30-Apr-07	0.22	–	12.64	14.93	544	7.79	1.45

Note(s):
'–' = not surveyed

AENV Guideline: 6.5 - 9 (pH) **AENV, 1999**
AENV Guideline: minimum 5.0 mg/L (Dissolved Oxygen) **CCME, 2002**

HABITAT POTENTIAL RANKING

Fish Habitat Potential	Large Bodied/ Sport Fish	Forage Fish
Overwintering	Nil	Nil
Spawning	Low	Low
Rearing	Low	Low
Feeding	Low	Low

Title:
NORTH AMERICAN
FISHERIES BASELINE
AST 2
WATERCOURSE DATA

NORTH AMERICAN OIL SANDS CORPORATION

Approved:	Revision Date:
File: 6198-HABITAT-07-WB	

Drawn by:	Checked:	Fig. No.:
ADF	CJS	8A-2

LEGEND

	Ba	BARE GROUND
	Bd	BEDROCK
	Bo	BOULDER
	L.Bo	LARGE BOULDER
	Co	COBBLE
	S.Co	SMALL COBBLE
	L.Co	LARGE COBBLE
	Gr	GRAVEL
	S.Gr	SMALL GRAVEL
	L.Gr	LARGE GRAVEL
┬┬┬		ESCARPMENT
●	Sa	SAND
●	Si	SILT
●	Or	ORGANIC MATERIAL
	LWD	LARGE WOODY DEBRIS
✸	BL	BEAVER LODGE
✕✕✕	BD	BEAVER DAM
●	EM	EMERGENT MACROPHYTES
●	SM	SUBMERGENT MACROPHYTES
⊛	FM	FLOATING MACROPHYTES
●	IV	INSTREAM VEGETATION
▨	TV	TERRESTIAL VEGETATION
⟶		DEADFALL
⊕	RW	ROOTWAD
●	SH	SHRUB
	MF	MIXEDWOOD FOREST
	CF	CONIFEROUS FOREST
	DF	DECIDUOUS FOREST
	SE	SEDGES
	GF	GRASS/FORBES
	MO	MOSS
Ⓜ	MT	MINNOW TRAP
	UCB	UNDERCUT BANK
	OHC	OVERHEAD COVER
	OHV	OVERHANGING VEGETATION
	ISC	INSTREAM COVER
	INV	INUNDATED VEGETATION
----	USB	UNSTABLE BANK
	BW	BACKWATER
	IP	IMPOUNDMENT POND
	SN	SNYE
	CH	CHUTE
	CA	CASCADE
⟶		SHALLOW SLOPE
─┼─►		MODERATE SLOPE
─╫─►		MODERATELY STEEP SLOPE
─╫┼─►		STEEP SLOPE
─►		FLOW DIRECTION
	RA	RAPIDS
	RF	RIFFLE
	R1	CLASS 1 RUN
	R2	CLASS 2 RUN
	R3	CLASS 3 RUN
	P1	CLASS 1 POOL
	P2	CLASS 2 POOL
	P3	CLASS 3 POOL
	FL	FLAT
	FA	FALLS
▼		WATER DEPTH
	T1	TRANSECT

AQUATIC HABITAT MAP

NOT TO SCALE

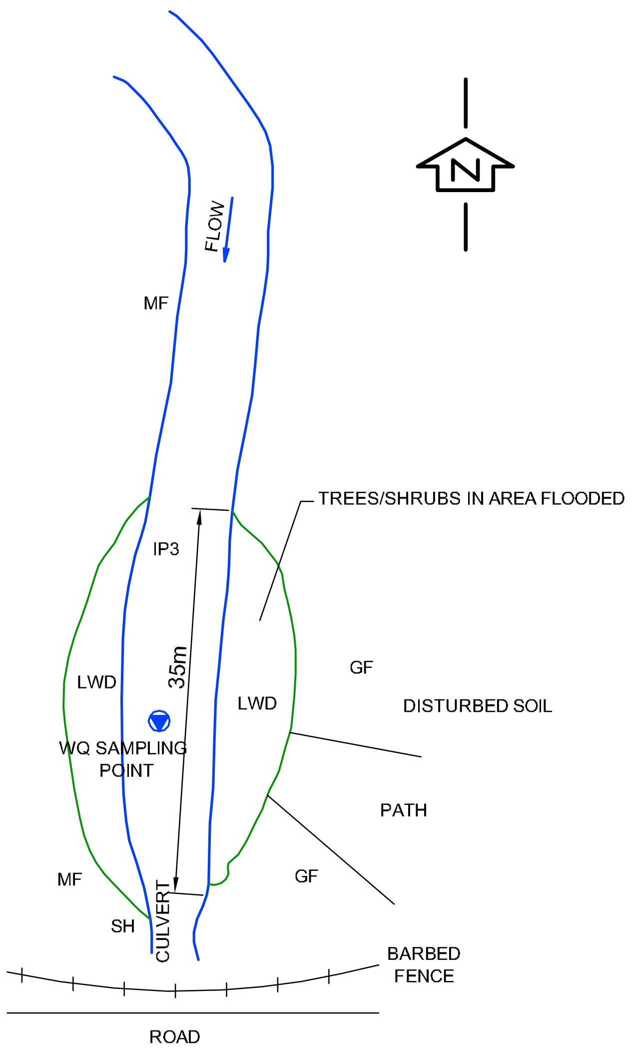


PHOTO 1. Culvert and road crossing at the upstream section of the study reach (May 2007)

PHOTO 2. Large woody debris and representative of bank habitat (May 2007)

PHOTO 3. Flooded area in downstream section of the study reach (May 2007)

WATER QUALITY TABLE

Sampling Date	Water Depth (m)	Discharge (m3/s)	Temperature (°C)	Dissolved Oxygen (mg/L)	Conductivity (µS/cm)	pH (units)	Turbidity (NTU)
3-May-07	0.30	--	9.15	9.25	468	6.91	5.50

Note(s):
'--' = not measured

Title:

NORTH AMERICAN FISHERIES BASELINE
AST 6
WATERCOURSE DATA

NORTH AMERICAN
OIL SANDS CORPORATION

Approved:	Revision Date:

File: 6198-HABITAT-07-WB

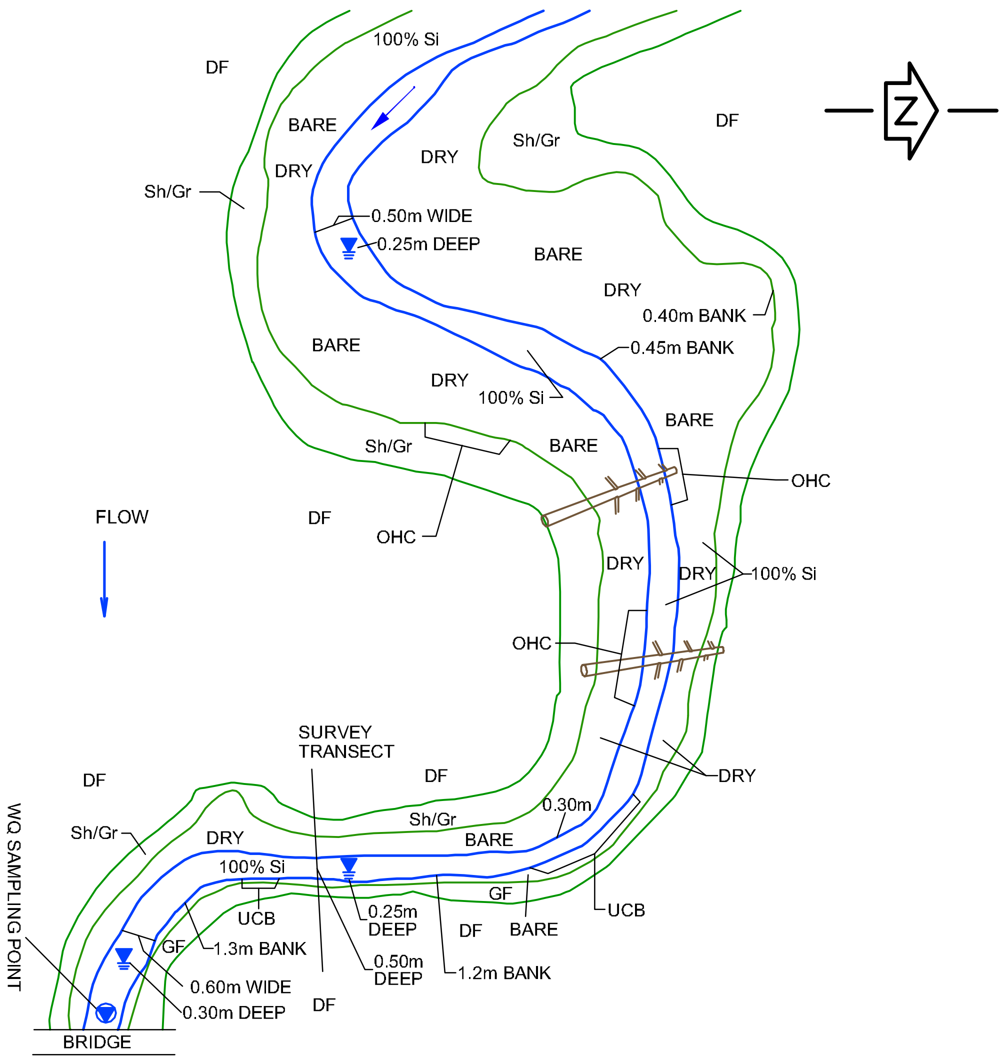
Drawn by:	Checked:	Fig. No.:
ADF	CJS	8A-3

LEGEND

Ba	BARE GROUND
Bd	BEDROCK
Bo	BOULDER
L.Bo	LARGE BOULDER
Co	COBBLE
S.Co	SMALL COBBLE
L.Co	LARGE COBBLE
Gr	GRAVEL
S.Gr	SMALL GRAVEL
L.Gr	LARGE GRAVEL
┬┬┬┬	ESCARPMENT
Sa	SAND
Si	SILT
Or	ORGANIC MATERIAL
LWD	LARGE WOODY DEBRIS
BL	BEAVER LODGE
BD	BEAVER DAM
EM	EMERGENT MACROPHYTES
SM	SUBMERGENT MACROPHYTES
FM	FLOATING MACROPHYTES
IV	INSTREAM VEGETATION
TV	TERRESTIAL VEGETATION
	DEADFALL
RW	ROOTWAD
SH	SHRUB
MF	MIXEDWOOD FOREST
CF	CONIFEROUS FOREST
DF	DECIDUOUS FOREST
SE	SEDGES
GF	GRASS/FORBES
MO	MOSS
MT	MINNOW TRAP
UCB	UNDERCUT BANK
OHC	OVERHEAD COVER
OHV	OVERHANGING VEGETATION
ISC	INSTREAM COVER
INV	INUNDATED VEGETATION
USB	UNSTABLE BANK
BW	BACKWATER
IP	IMPOUNDMENT POND
SN	SNYE
CH	CHUTE
CA	CASCADE
→	SHALLOW SLOPE
→	MODERATE SLOPE
→	MODERATELY STEEP SLOPE
→	STEEP SLOPE
→	FLOW DIRECTION
RA	RAPIDS
RF	RIFFLE
R1	CLASS 1 RUN
R2	CLASS 2 RUN
R3	CLASS 3 RUN
P1	CLASS 1 POOL
P2	CLASS 2 POOL
P3	CLASS 3 POOL
FL	FLAT
FA	FALLS
▼	WATER DEPTH
T1	TRANSECT

AQUATIC HABITAT MAP

NOT TO SCALE



FISHERIES COLLECTION DATA

	Angling		Minnow Trap		Electrofishing	
Sampling Season	Fish Captured	Effort (h)	Fish Captured	Effort (h)	Fish Captured	Effort (sec.)
Summer	--	--	--	--	--	--
Fall	--	--	0	22.75	--	--
Winter	--	--	--	--	--	--
Spring	--	--	0	22.25	--	--
Total	**0**	**0**	**0**	**45.00**	--	--

Note(s):

'--' = method not used during this survey.

PHOTO 1. No flowing water during the fall survey (October 2006)

PHOTO 2. Beaver dam downstream section of the study reach (May 2007)

AST 3 (Astotin Creek)

AST 3 was located on Astotin Creek, which followed an irregular meander pattern, with an average channel width of approximately 5.4 m. The watercourse was located adjacent to agricultural land with primarily tall grasses and willows bordering the banks of the watercourse. The habitat in the study area was extremely variable and included only shallow pockets of non-flowing water during the summer, fall, and winter surveys. Deeper runs and pools created by beaver activity were observed during the spring survey. Substrate was composed entirely of organic fines. AST3 provided low spawning, rearing and feeding habitat potential for forage fish species, and low spawning, rearing, and feeding habitat potential for large bodied/sport fish species. Overwintering habitat was nil for both forage and large bodied/sport fish species as the watercourse was frozen to the bottom at the time of the survey.

PHOTO 3. Spring conditions (May 2007)

SURFACE WATER QUALITY PROFILE

Sampling Date	Water Depth (m)	Discharge (m3/s)	Temperature (°C)	Dissolved Oxygen (mg/L)	Conductivity (µS/cm)	pH (units)	Turbidity (NTU)
29-Aug-06	0.25	0.00	13.36	0.92	622	7.09	--
23-Oct-06	0.30	0.00	2.00	0.88	1679	6.70	192.40
23-Jan-07	FROZEN TO BOTTOM						
30-Apr-07	0.95	0.28	11.77	6.11	471	6.61	0.38

Note(s):

'--' = not sampled

AENV Guideline: 6.5 - 9 (pH) **AENV, 1999**

AENV Guideline: minimum 5.0 mg/L (Dissolved Oxygen) **CCME, 2002**

HABITAT POTENTIAL RANKING

Fish Habitat Potential	Large Bodied/ Sport Fish	Forage Fish
Overwintering	Nil	Nil
Spawning	Low	Low
Rearing	Low	Low
Feeding	Low	Low

Title:

NORTH AMERICAN
FISHERIES BASELINE
AST 3
WATERCOURSE DATA

NORTH AMERICAN
OIL SANDS CORPORATION

Approved:
Revision Date:
File: 6198-HABITAT-07-WB
Drawn by: ADF
Checked: CJS
Fig. No.: 8A-4

LEGEND

Ba	BARE GROUND
Bd	BEDROCK
Bo	BOULDER
L.Bo	LARGE BOULDER
Co	COBBLE
S.Co	SMALL COBBLE
L.Co	LARGE COBBLE
Gr	GRAVEL
S.Gr	SMALL GRAVEL
L.Gr	LARGE GRAVEL
┬┬┬┬	ESCARPMENT
Sa	SAND
Si	SILT
Or	ORGANIC MATERIAL
LWD	LARGE WOODY DEBRIS
BL	BEAVER LODGE
BD	BEAVER DAM
EM	EMERGENT MACROPHYTES
SM	SUBMERGENT MACROPHYTES
FM	FLOATING MACROPHYTES
IV	INSTREAM VEGETATION
TV	TERRESTIAL VEGETATION
	DEADFALL
RW	ROOTWAD
SH	SHRUB
MF	MIXEDWOOD FOREST
CF	CONIFEROUS FOREST
DF	DECIDUOUS FOREST
SE	SEDGES
GF	GRASS/FORBES
MO	MOSS
MT	MINNOW TRAP
UCB	UNDERCUT BANK
OHC	OVERHEAD COVER
OHV	OVERHANGING VEGETATION
ISC	INSTREAM COVER
INV	INUNDATED VEGETATION
USB	UNSTABLE BANK
BW	BACKWATER
IP	IMPOUNDMENT POND
SN	SNYE
CH	CHUTE
CA	CASCADE
───►	SHALLOW SLOPE
─┼─►	MODERATE SLOPE
─┼┼─►	MODERATELY STEEP SLOPE
─┼┼┼─►	STEEP SLOPE
───►	FLOW DIRECTION
RA	RAPIDS
RF	RIFFLE
R1	CLASS 1 RUN
R2	CLASS 2 RUN
R3	CLASS 3 RUN
P1	CLASS 1 POOL
P2	CLASS 2 POOL
P3	CLASS 3 POOL
FL	FLAT
FA	FALLS
▼	WATER DEPTH
T1	TRANSECT

AQUATIC HABITAT MAP

NOT TO SCALE

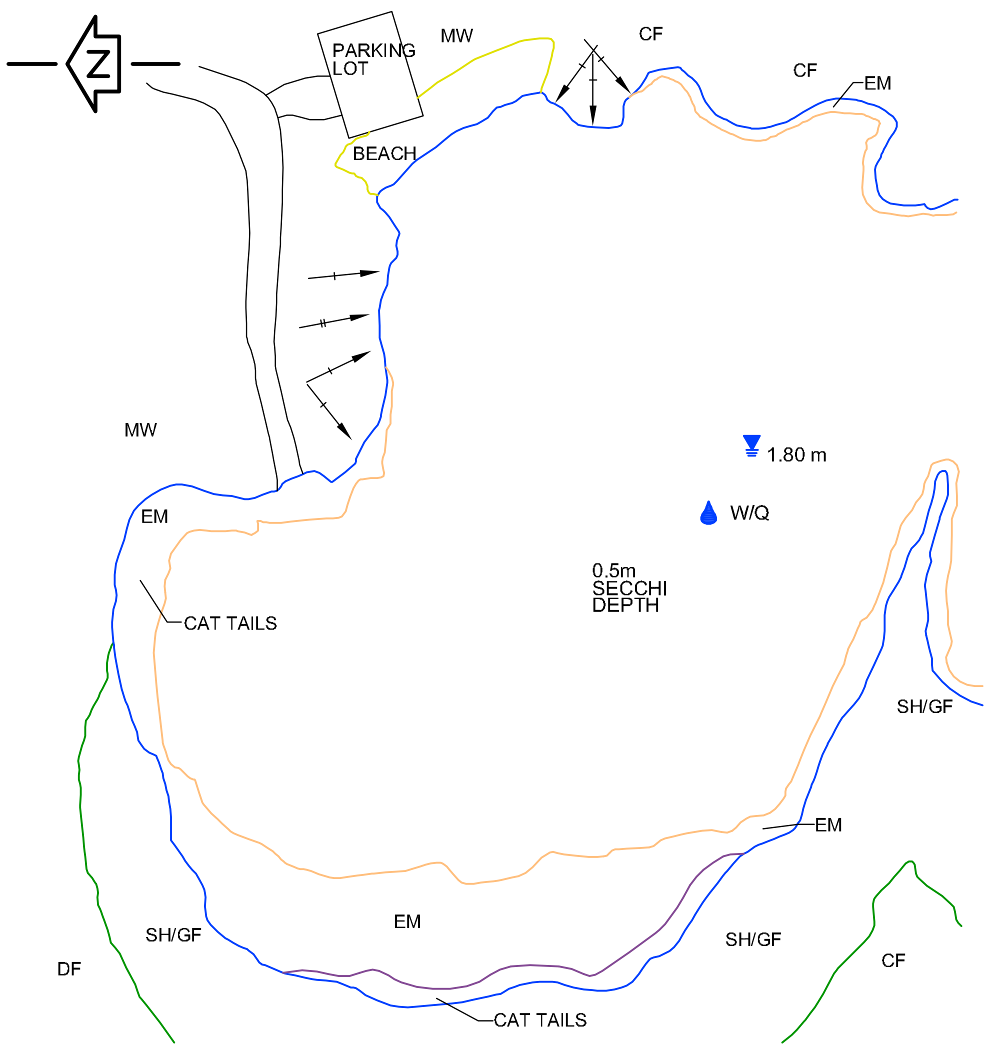


PHOTO 1. Shoreline habitat representative of Astotin Lake (August 2006)

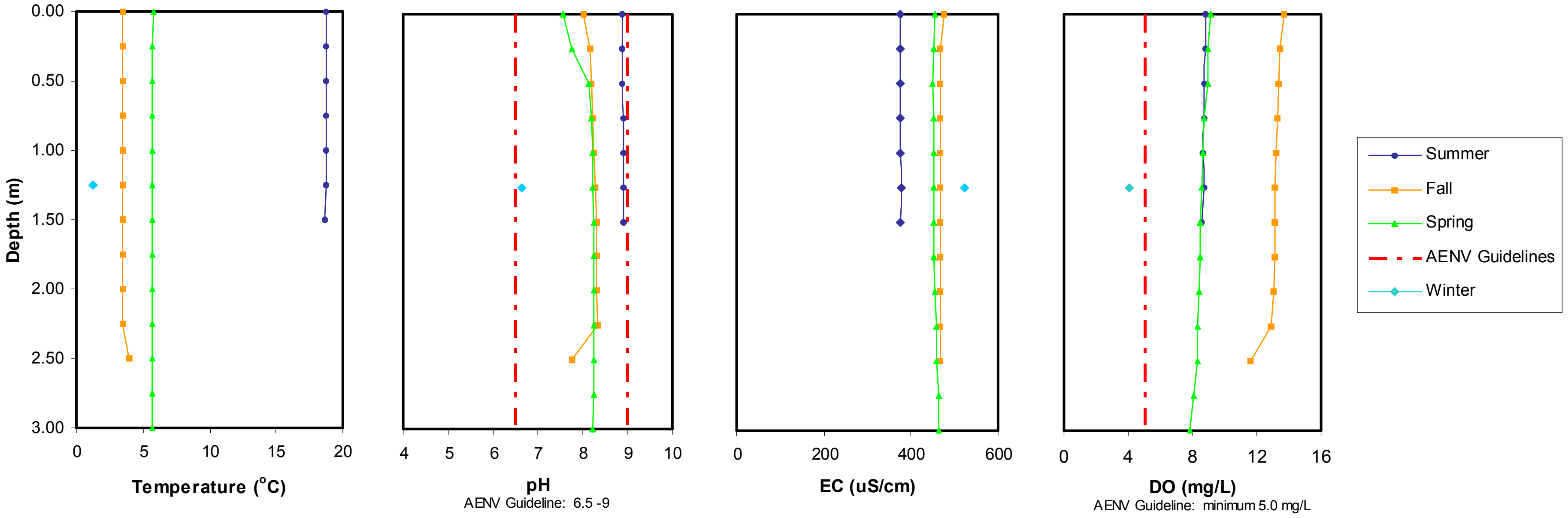
PHOTO 2. East shoreline along public beach, Astotin Lake.

PHOTO 3. Northeast bay shoreline, Astotin Lake.

AST 4 (Astotin Lake)

AST 4 was located in the Astotin Creek watershed and drains into Astotin Creek through a northwest outlet. The waterbody surface area was approximately 6.0 km² and observed depths were approximately 3.5 m. The euphotic zone extended to approximately 22% of the depth of the waterbody (secchi depth x = 0.8 m) and turbidity was low (x = 7.06 NTU). Vegetation surrounding the waterbody consisted primarily of coniferous black spruce forest with aspen and willow and grasses in shoreline areas. The shoreline of the lake was comprised of grasses, sedges and forbs with some isolated sections of cobble and bolder. Substrate consisted of silt, and aquatic vegetation was present in the form of aquatic grasses, sedges and water lilies. Based on low winter dissolved oxygen levels, overwintering potential for sport and forage fish was low. Spawning rearing and feeding potential for forage fish and sport fish species was moderate. Although the observed dissolved oxygen was below guidelines in the winter, it is likely this waterbody could support fish species more resilient to low dissolved oxygen conditions such as brook stickleback.

ASTOTIN LAKE WATER QUALITY PROFILE



HABITAT POTENTIAL RANKING

Fish Habitat Potential	Large Bodied/Sport Fish	Forage Fish
Overwintering	Nil	Nil
Spawning	Low	Low
Rearing	Low	Low
Feeding	Low	Low

Title:

NORTH AMERICAN
FISHERIES BASELINE
AST 4
WATERBODY DATA

NORTH AMERICAN OIL SANDS CORPORATION

Approved:
Revision Date:
File: 6198-HABITAT-07-WB
Drawn by: ADF
Checked: CJS
Fig. No.: 8A-5

LEGEND

Ba	BARE GROUND
Bd	BEDROCK
Bo	BOULDER
L.Bo	LARGE BOULDER
Co	COBBLE
S.Co	SMALL COBBLE
L.Co	LARGE COBBLE
Gr	GRAVEL
S.Gr	SMALL GRAVEL
L.Gr	LARGE GRAVEL
	ESCARPMENT
Sa	SAND
Si	SILT
Or	ORGANIC MATERIAL
LWD	LARGE WOODY DEBRIS
BL	BEAVER LODGE
BD	BEAVER DAM
EM	EMERGENT MACROPHYTES
SM	SUBMERGENT MACROPHYTES
FM	FLOATING MACROPHYTES
IV	INSTREAM VEGETATION
TV	TERRESTIAL VEGETATION
	DEADFALL
RW	ROOTWAD
SH	SHRUB
MF	MIXEDWOOD FOREST
CF	CONIFEROUS FOREST
DF	DECIDUOUS FOREST
SE	SEDGES
GF	GRASS/FORBES
MO	MOSS
MT	MINNOW TRAP
UCB	UNDERCUT BANK
OHC	OVERHEAD COVER
OHV	OVERHANGING VEGETATION
ISC	INSTREAM COVER
INV	INUNDATED VEGETATION
USB	UNSTABLE BANK
BW	BACKWATER
IP	IMPOUNDMENT POND
SN	SNYE
CH	CHUTE
CA	CASCADE
	SHALLOW SLOPE
	MODERATE SLOPE
	MODERATELY STEEP SLOPE
	STEEP SLOPE
	FLOW DIRECTION
RA	RAPIDS
RF	RIFFLE
R1	CLASS 1 RUN
R2	CLASS 2 RUN
R3	CLASS 3 RUN
P1	CLASS 1 POOL
P2	CLASS 2 POOL
P3	CLASS 3 POOL
FL	FLAT
FA	FALLS
▼	WATER DEPTH
T1	TRANSECT

AQUATIC HABITAT MAP

NOT TO SCALE

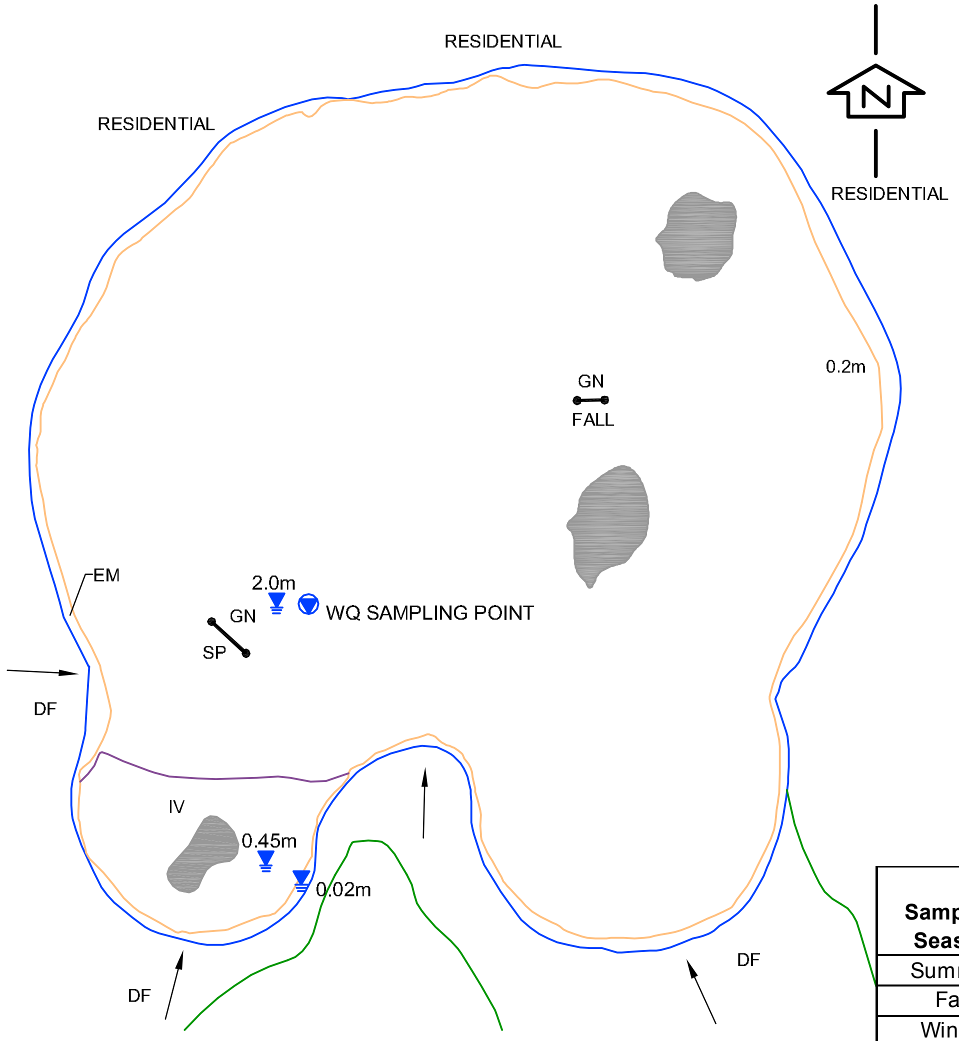


PHOTO 1. Habitat representative of the east shoreline, Antler Lake.

PHOTO 2. Shoreline and aquatic vegetation representative of Antler Lake.

AST 5 (Antler Lake)

AST 5 was located on the South border of the RSA and drains into Cooking Lake through a southeast outlet. AST5 is surrounded partly by a residential community. The waterbody surface area was approximately 2.3 km² and observed depths were approximately 2.0 m. The euphotic zone extended to approximately 25% of the depth of the waterbody (secchi depth x = 0.2 to 0.4 m) and turbidity was low to moderate (12.62 to 39.36 NTU). Vegetation surrounding the waterbody consisted primarily of deciduous forest with grasses and willow in shoreline areas.

PHOTO 3. Shoreline representative of the south shoreline, Antler Lake.

ANTLER LAKE FISHERIES COLLECTION DATA

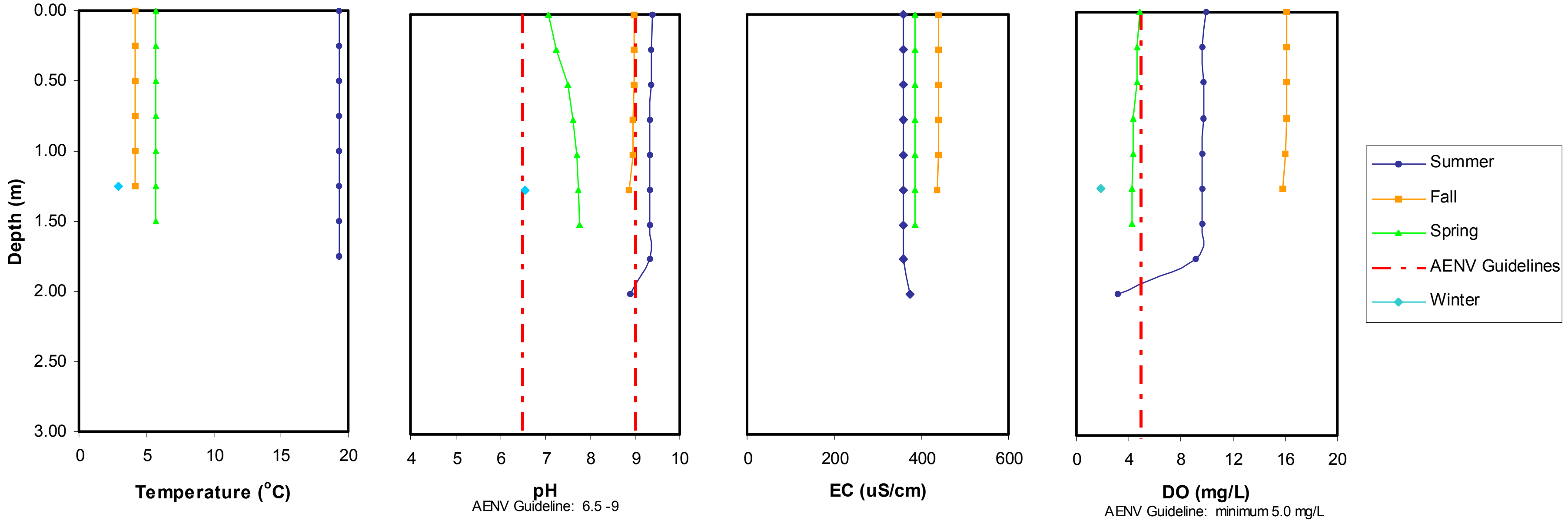
Sampling Season	Angling		Minnow Trap		Gill Nets	
	Fish Captured	Effort (h)	Fish Captured	Effort (h)	Fish Captured	Effort (h)
Summer	--	--	--	--	--	--
Fall	--	--	0	22.75	0	22.75
Winter	--	--	0	17	--	--
Spring	--	--	0	23.5	0	23.25
Total	**--**	**--**	**0**	**63.25**	**0**	**46**

Note(s):
'--' = method not used during this survey

HABITAT POTENTIAL RANKING

Fish Habitat Potential	Large Bodied/Sport Fish	Forage Fish
Overwintering	Nil	Nil
Spawning	Low	Low
Rearing	Low	Low
Feeding	Low	Low

ANTLER LAKE WATER QUALITY PROFILE



Title:

NORTH AMERICAN
FISHERIES BASELINE
AST 5
WATERBODY DATA

NORTH AMERICAN
OIL SANDS CORPORATION

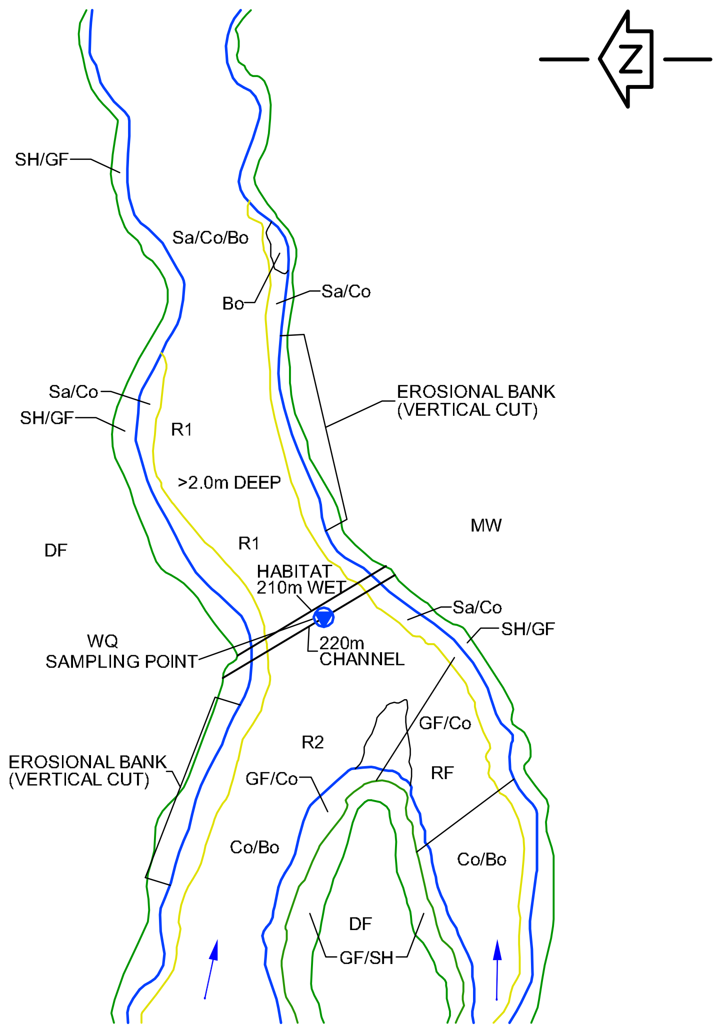
Approved:	Revision Date:
File: 6198-HABITAT-07-WB	
Drawn by: ADF	Checked: CJS
Fig. No.: 8A-6	

LEGEND

Ba	BARE GROUND
Bd	BEDROCK
Bo	BOULDER
L.Bo	LARGE BOULDER
Co	COBBLE
S.Co	SMALL COBBLE
L.Co	LARGE COBBLE
Gr	GRAVEL
S.Gr	SMALL GRAVEL
L.Gr	LARGE GRAVEL
	ESCARPMENT
Sa	SAND
Si	SILT
Or	ORGANIC MATERIAL
LWD	LARGE WOODY DEBRIS
BL	BEAVER LODGE
BD	BEAVER DAM
EM	EMERGENT MACROPHYTES
SM	SUBMERGENT MACROPHYTES
FM	FLOATING MACROPHYTES
IV	INSTREAM VEGETATION
TV	TERRESTIAL VEGETATION
	DEADFALL
RW	ROOTWAD
SH	SHRUB
MF	MIXEDWOOD FOREST
CF	CONIFEROUS FOREST
DF	DECIDUOUS FOREST
SE	SEDGES
GF	GRASS/FORBES
MO	MOSS
MT	MINNOW TRAP
UCB	UNDERCUT BANK
OHC	OVERHEAD COVER
OHV	OVERHANGING VEGETATION
ISC	INSTREAM COVER
INV	INUNDATED VEGETATION
USB	UNSTABLE BANK
BW	BACKWATER
IP	IMPOUNDMENT POND
SN	SNYE
CH	CHUTE
CA	CASCADE
	SHALLOW SLOPE
	MODERATE SLOPE
	MODERATELY STEEP SLOPE
	STEEP SLOPE
	FLOW DIRECTION
RA	RAPIDS
RF	RIFFLE
R1	CLASS 1 RUN
R2	CLASS 2 RUN
R3	CLASS 3 RUN
P1	CLASS 1 POOL
P2	CLASS 2 POOL
P3	CLASS 3 POOL
FL	FLAT
FA	FALLS
▼	WATER DEPTH
T1	TRANSECT

AQUATIC HABITAT MAP

NOT TO SCALE



FISHERIES COLLECTION DATA

	Angling		Minnow Trap		Electrofishing	
Sampling Season	Fish Captured	Effort (h)	Fish Captured	Effort (h)	Fish Captured	Effort (sec.)
Summer	--	--	--	--	--	--
Fall	--	--	0	41.25	--	--
Winter	--	--	--	--	--	--
Spring	--	--	--	--	--	--
Total	**0**	**0**	**0**	**41.25**	**--**	**--**

Note(s):
'--' = method not used during this survey.

PHOTO 1. North Saskatchewan River, downstream of split channel (October 2006)

PHOTO 2. Right downstream bank of the North Saskatchewan River (May 2007)

NSR 1 (North Saskatchewan River)

NSR 1 was located on the North Saskatchewan River, downstream of the confluence with Beaverhill Creek. The watercourse was located within a mixture of agriculture and industrial land use, with deciduous forest, shrubs, and tall grasses bordering the banks of the river. The habitat in the study area consisted of deep runs (>2.0 m depth) and riffle with an average channel width of 220 m. Substrate in the run habitat was composed of sand, cobble, and boulder; substrate in the riffle habitat was composed of gravel and cobble. NSR1 provided high spawning, rearing, feeding, and overwintering habitat potential for both forage and large bodied/sport fish species.

PHOTO 3. North Saskatchewan River, downstream of split channel (May 2007)

SURFACE WATER QUALITY PROFILE

Sampling Date	Water Depth (m)	Discharge (m^3/s)	Temperature (°C)	Dissolved Oxygen (mg/L)	Conductivity (µS/cm)	pH (units)	Turbidity (NTU)
30-Aug-06	--	N/A	17.99	8.15	273	7.66	3.19
24-Oct-06	0.30	N/A	5.49	13.36	337	7.22	3.23
23-Jan-06	1.16	N/A	0.03	15.02	362	6.65	--
3-May-07	--	N/A	5.80	12.60	312	7.38	38.38

Note(s):
'--' = not sampled

AENV Guideline: 6.5 - 9 (pH) **AENV, 1999**
AENV Guideline: minimum 5.0 mg/L (Dissolved Oxygen) **CCME, 2002**

HABITAT POTENTIAL RANKING

Fish Habitat Potential	Large Bodied/ Sport fish	Forage Fish
Overwintering	High	High
Spawning	High	High
Rearing	High	High
Feeding	High	High

Title:
NORTH AMERICAN FISHERIES BASELINE
NSR 1
WATERCOURSE DATA

NORTH AMERICAN OIL SANDS CORPORATION

Approved:
Revision Date:
File: 6198-HABITAT-07-WB
Drawn by: ADF
Checked: CJS
Fig. No.: 8A-7

APPENDIX 8B: BENTHIC INVERTEBRATES

TABLE OF CONTENTS

TABLES

FIGURES

8B1 INTRODUCTION

Benthic invertebrate samples were collected to assist in characterization of the aquatic habitat in the LSA. Benthic invertebrates can be used to help develop a trophic level understanding of aquatic habitats. Because they respond to environmental variation, they also indicate when aquatic habitats undergo change.

8B2 METHODOLOGY

Benthic invertebrate samples were collected in the Spring of 2007 (May 2 to 5). Benthic samples are generally collected in the fall; however, for this assessment spring sampling was conducted for two reasons. First, to build on previous data collected in the LSA (Synenco, 2006) and second, other studies have found that watercourses in the area did not have suitable benthic habitat during base flows in the fall (Petro-Canada Oil Sands Inc., 2006). Samples were collected on two watercourses and one waterbody in the LSA (Figure 8B-1), with the objective of characterizing the benthic invertebrate community in representative habitat areas. The data were used to describe baseline conditions regarding the availability of food resources for fish and the overall health of the aquatic ecosystem.

8B2.1 Field Sampling

Sampling points were randomly chosen in representative habitat at each of the sampling sites in the selected watercourse or waterbody. Sampling was conducted during the spring, similar to Synenco (2006). Samples were collected in depositional sediments using a Ponar sampling with a sampling area of 0.023 m^2 and were field sieved to remove fine sediments using a 250 um Nitex mesh netting. Five replicate samples were collected at each site to account for variability.

8B2.1.1 Sample Handling

Benthic invertebrate samples were preserved in 85 percent ethyl alcohol and stored in properly labelled and sealed containers. Samples were then stored and shipped in plastic coolers to prevent damage. Identification and enumeration of samples was handled by Enviro-Test Laboratories in Winnipeg, Manitoba. Chain of custody forms were used to track samples and prevent against loss or misidentification.

8B2.1.2 Supporting Data

Supporting habitat information was collected at each sampling site to help understand the variation in benthic invertebrate community structure among different sampling sites. Supporting data collected at each site included:

- exact site location (easting and northing using Global Positioning System [GPS], NAD 83, UTM 12);
- water depth;
- water velocity (Marsh-McBirney Model 2000 current velocity meter);
- bankfull and wetted channel width (measuring tape);
- water quality parameters (temperature, dissolved oxygen (DO), conductance and pH using a field calibrated Quanta Hydrolab multi-meter); and

- general description of the sampling area (e.g., macrophytes, riparian habitat, sediment characteristics).

8B2.2 Laboratory Methods

Benthic invertebrate samples were sorted, identified and enumerated by Enviro-Test Laboratories in Winnipeg, Manitoba.

Each replicate sample was sieved using 500 um and 250 um radial sieves to divide replicate samples into fine and coarse fractions. The radial sieve was divided into one eighth or one quarter portions and used to sub-sample each fraction. Coarse and fine fractions were sub-sampled to the same proportion (both to ⅛ or both to ¼). Sub-samples were then transferred to a Petri dish for sorting. Benthic invertebrates were removed with the aid of a zoom stereo-microscope at 20 to 40 power (Enviro-Test, personal communication).

Invertebrates were identified to the lowest practical taxon (genus for amphipods, leeches, oligochaetes, aquatic mites, insects and molluscs; major group for nematodes, ostracods, zooplankton [in this classification, “major group” is defined as a grouping of like organisms at the class or order level where lower level identification is impractical and the information does not contribute to study objectives]). Damaged and immature specimens were identified to the lowest practical level that condition allowed. Laboratory data are presented as numbers of organisms per sample in Table 8B-1.

8B2.2.1 Laboratory Quality Assurance

Laboratory procedures were conducted by trained individuals and were consistent with methods approved by other monitoring programs (e.g., AENV, 1990; Environment Canada, 2002). Sorting efficiency was calculated as follows:

$$\%E = \frac{N_r}{(N_i + N_r)} \times 100$$

where:

$\%E$ is the calculated sorting efficiency;

N_r is the number of organisms found in a sample during resorting; and

N_i is the number of organisms found during initial sorting.

Sorting efficiency was calculated to be greater than 90 percent.

Benthic invertebrate abundance data were tallied on laboratory data sheets and transferred to an electronic format. Electronic data were then validated through comparison with the laboratory data sheets.

Table 8B-1 Abundances of Organisms Collected in Benthic Invertebrate Samples from the North American Upgrader Project, Spring 2007 (presented as number of organisms per sample)

				Beaverhill Creek (AST 1)					**Astotin Creek (AST 6)**					**Astotin Lake (AST 4)**				
Major Group	**Order**	**Family**	**Genus/species**	**A**	**B**	**C**	**D**	**E**	**A**	**B**	**C**	**D**	**E**	**A**	**B**	**C**	**D**	**E**
Nematoda	-	-	i/d	1	10	3	0	1	32	0	8	24	0	8	24	24	80	32
Oligochaeta	-	Lumbriculidae	*Lumbriculus* sp	0	0	0	0	0	0	0	0	24	0	0	0	0	0	0
	-	Naididae	*Nais* sp	0	1	3	0	0	0	0	0	0	0	0	0	0	0	8
	-		*Pristina* sp	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
	-	Tubificidae	i/d	0	9	0	1	2	688	0	64	96	112	8	8	88	144	0
Annelida	Hirudinea	Erpobdellidae	*Erpobdella punctata*	0	0	0	0	0	0	0	0	0	0	16	0	32	16	24
		Hirudinidae	*Molibdella grandis*	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0
		Lumbricidae	*Eiseniella* sp	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0
Pelecypoda	Sphaeriacea	Sphaeridae	*Sphaerium* sp	0	1	0	0	0	0	8	0	0	0	0	0	0	0	0
Arachnoidea	Hydracarina	-	i/d	0	0	0	0	0	8	0	8	0	0	0	0	0	0	0
		Arrenuridae	*Arrenurus* sp	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0
		Protziidae	*Calonyx* sp	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0
		Unionicolidae	*Unionicola* sp	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0
		Limnesiidae	*Tyrellia* sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
	Hydryphantidae	Diplodontidae	*Diplodontus* sp	0	0	0	0	0	0	0	0	0	0	0	8	16	16	8
Crustacea	Copepoda	Harpacticidae	i/d	0	0	0	0	0	0	0	0	0	0	0	0	16	0	8
	Ostrocoda	-	i/d	0	2	0	0	0	0	0	8	0	0	0	0	0	0	0
	Amphipoda	Hyalellidae	*Hyalella azteca*	0	0	0	0	0	0	0	0	0	0	24	16	8	8	0
Insecta	Collembola	-	i/d	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0
		Isotomidae	*Isotomurus* sp	0	0	0	0	0	8	0	0	0	8	0	0	0	0	0
	Ephemeroptera	Caenidae	*Caenis* sp	0	0	0	0	0	0	0	0	0	0	8	8	24	0	8
	Odonata-Zygoptera	Coenagrionidae	*Enallagma* sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
	Trichoptera	Phryganeidae	*Agrypnia* sp	0	0	0	0	0	0	0	0	0	0	8	16	0	0	8
	Coleoptera	-	i/d	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	Coleoptera	Elmidae	*Dubiraphia* sp	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0
	Diptera	-	i/d	0	0	0	0	0	40	0	0	8	0	0	0	0	0	0
		Ceratopogonidae	i/d	2	3	0	0	0	0	0	0	0	8	48	112	48	16	8
		Chironomidae	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Chironimini	i/d	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0
			Chiromomus sp	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0
			Cryptochironomus sp	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
			Dicrotendipes sp	0	2	0	0	0	0	0	0	0	0	0	56	8	24	16
			Endochironomus sp	0	0	1	1	0	0	0	0	0	0	0	0	8	0	32
			Glyptotendipes sp	2	2	1	1	0	0	0	0	0	0	0	0	0	0	0
			Phaenopsectra sp	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0

Major Group	Order	Family	Genus/species	Beaverhill Creek (AST 1)					Astotin Creek (AST 6)					Astotin Lake (AST 4)				
				A	**B**	**C**	**D**	**E**	**A**	**B**	**C**	**D**	**E**	**A**	**B**	**C**	**D**	**E**
		Tanytarsini	*Cladotanytarsus* sp	0	0	0	0	0	0	0	0	0	0	0	0	8	8	8
			Tanytarsus sp	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
		Orthocladinae	i/d	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
			Psectocladius sp	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0
		Tanypodinae	*Procladius* sp	0	0	0	0	0	0	0	8	0	32	24	32	72	32	0
		Dolichopodidae	i/d	0	0	0	0	1	0	0	0	8	0	0	0	0	0	0
		Empidiae	i/d	0	0	0	0	0	40	0	0	16	0	0	0	0	0	0
		Empidiae	*Hemerodromia* sp	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
		Psychodidae	*Pericoma* sp	0	0	0	0	0	0	0	0	0	0	8	0	0	0	32
		Psychodidae	*Psychoda* sp	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0
		Tipulidae	*Ormosia* sp	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0
Total				**5**	**35**	**9**	**4**	**5**	**832**	**32**	**120**	**192**	**168**	**152**	**296**	**360**	**344**	**216**

8B2.3 Data Analysis

A literature review of historic data was completed to obtain background benthic invertebrate data for the study areas (Golder, 1995; Petro-Canada Oil Sands Inc., 2006; North West, 2006; Synenco, 2006; Shell, 2007). Data were evaluated for suitability of inclusion with Project data (e.g., comparability of mesh sieve sizes and sampling equipment; season when samples were collected). Historical data that were included aided in providing a regional context to evaluate data collected for the Project.

The benthic invertebrate data were graphed and inspected for outliers and potential errors and taxonomic names were checked. Non-benthic invertebrates including terrestrial insects, adults and pupa were removed from the data set. Any incorrect data were removed or corrected.

Data files were kept electronically and systematically processed. Each series of steps was saved on subsequent worksheets in Microsoft Excel® files to allow calculation checks and validation of the results.

The benthic invertebrate community was characterized using community variables, including abundance (numbers of organisms per square metre), dominance (the most common taxa at a given site), taxonomic richness (the number of benthic invertebrate taxa) and community composition. The abundance and dominance data among sites were presented graphically. Richness was presented as the total number of taxa (identified to the lowest practical level) among replicates at a site. Major groups of invertebrates were presented in stacked bar graphs to show significant differences in community composition.

8B3 RESULTS

8B3.1 Habitat

Benthic invertebrate samples were collected between May 2 and 5, 2007 (Figure 8B-1). Samples were collected at two watercourse locations (Beaver Hill Creek [AST 1] and Astotin Creek [AST 6]) and in one waterbody (Astotin Lake [AST 4]). Watercourses were relatively small with mean depths between 0.4 m and 0.5 m. Stream flows in both watercourses were slow. Benthic invertebrate samples at AST4 were collected in the littoral zone at a mean depth of 0.4 m.

Water quality among the sampling sites was variable (Table 8B-2). Water temperatures in the watercourses were just above 9ºC; water temperature in Astotin Lake was slightly lower. The pH levels among all sampling sites ranged from 6.4 to 6.9. Conductance among sites ranged between 374 uS/cm and 542 uS/cm; the highest level was observed in Astotin Lake. Dissolved oxygen concentrations were variable. Concentrations in the watercourses were high enough to be protective of aquatic life (AENV, 1999); however, DO in Astotin Lake was considerably lower. Turbidity was high at Beaver Hill Creek but lower in Astotin Creek and Astotin Lake.

Table 8B-2 Habitat Parameters at Benthic Invertebrates Sampling Sites in the LSA

Parameter	Beaver Hill Creek (AST 1)	Astotin Creek (AST 6)	Astotin Lake (AST 4)
Northing (Nad 83)	5972753	5952410	5949489
Easting (Nad 83)	371888	372925	379032
Date	02-May-07	03-May-07	02-May-07
Macrophyte Cover (%)	10	45	90
Algae Cover (%)	40	15	50

Parameter	Beaver Hill Creek (AST 1)	Astotin Creek (AST 6)	Astotin Lake (AST 4)
Conductance (µS/cm)	374	468	542
Temperature (°C)	9.65	9.15	6.82
Dissolved Oxygen (mg/L)	11.09	9.25	4.87
pH	6.40	6.91	6.57
Turbidity	43.42	5.5	11.71
Mean sample depth (m)	0.4	0.5	0.4
Mean stream velocity (m/s)	0.07	nm	--

Note(s):
nm non-measurable
-- not applicable

8B3.2 Benthic Invertebrates in the LSA

Benthic invertebrate mean total abundances in Beaver Hill and Astotin creeks ranged from less than 500 organisms/m^2 to greater than 11,000 organisms/m^2. Densities in the two watercourses were similar in 2006 (Synenco, 2006); however, displayed greater variability in 2007 (Figure 8B-2). Total Richness appeared to be somewhat higher in Astotin Creek than Beaver Hill Creek during the spring in both 2006 and 2007 (Tables 8B-3, 8B-4 and 8B-5).

Table 8B-3 Benthic Invertebrates in Samples Collected in Beaver Hill Creek (AST1)

Major Group	Family	Genus/species	Mean	SE	Percent of total Abundance
Nematoda	-	i/d	129.0	78.1	25.9
Oligochaeta	Tubificidae	i/d	103.2	72.7	20.7
Diptera	Chironimini	Glyptotendipes sp	51.6	16.1	10.3
Diptera	Ceratopogonidae	i/d	43.0	27.2	8.6
Oligochaeta	Naididae	Nais sp	34.4	25.1	6.9
Diptera	Tanytarsini	Tanytarsus sp	25.8	25.8	5.2
Oligochaeta	Naididae	Pristina sp	17.2	10.5	3.4
Ostrocoda	-	i/d	17.2	17.2	3.4
Diptera	Chironimini	Dicrotendipes sp	17.2	17.2	3.4
Diptera	Chironimini	Endochironomus sp	17.2	10.5	3.4
Pelecypoda	Sphaeridae	Sphaerium sp	8.6	8.6	1.7
Coleoptera	-	i/d	8.6	8.6	1.7
Diptera	Chironimini	Cryptochironomus sp	8.6	8.6	1.7
Diptera	Dolichopodidae	i/d	8.6	8.6	1.7
Diptera	Empidiae	Hemerodromia sp	8.6	8.6	1.7
Mean total abundance			499	254	
Total Richness (lowest practical level)			15		

Notes(s):
SE Standard Error
i/d immature or damaged specimen
- not identified to that level

Table 8B-4 Benthic Invertebrates in Samples Collected in Astotin Creek (AST6)

Major Group	Family	Genus/species	Mean	SE	Percent of total Abundance
Oligochaeta	Tubificidae	i/d	8,256.0	5,395.4	71.4
Nematoda	-	i/d	550.4	279.5	4.8
Diptera	Empidiae	i/d	481.6	337.0	4.2
Diptera	-	i/d	412.8	333.5	3.6
Diptera	Tanypodinae	Procladius sp	344.0	266.5	3.0
Oligochaeta	Lumbriculidae	Lumbriculus sp	206.4	206.4	1.8
Hydracarina	-	i/d	137.6	84.3	1.2
Collembola	-	i/d	137.6	137.6	1.2
Collembola	Isotomidae	Isotomurus sp	137.6	84.3	1.2
Hirudinea	Lumbricidae	Eiseniella sp	68.8	68.8	0.6
Pelecypoda	Sphaeridae	Sphaerium sp	68.8	68.8	0.6
Hydracarina	Protziidae	Calonyx sp	68.8	68.8	0.6
Hydracarina	Unionicolidae	Unionicola sp	68.8	68.8	0.6
Ostrocoda	-	i/d	68.8	68.8	0.6
Coleoptera	Elmidae	Dubiraphia sp	68.8	68.8	0.6
Diptera	Ceratopogonidae	i/d	68.8	68.8	0.6
Diptera	Chironimini	i/d	68.8	68.8	0.6
Diptera	Chironimini	Chiromomus sp	68.8	68.8	0.6
Diptera	Orthocladinae	Psectocladius sp	68.8	68.8	0.6
Diptera	Dolichopodidae	i/d	68.8	68.8	0.6
Diptera	Psychodidae	Psychoda sp	68.8	68.8	0.6
Diptera	Tipulidae	Ormosia sp	68.8	68.8	0.6
Mean total abundance			11,558	6,168	
Total Richness (lowest practical level)			18		

Notes(s):
SE Standard Error
i/d immature or damaged specimen
- not identified to that level

Dominance is a measure of the most common taxa at a site and higher values tend to indicate disturbance or alteration to the environment. Often r-selected species are quick to establish large populations after communities of other organisms have collapsed. Dominance was considerably higher in Astotin Creek than Beaver Hill Creek and was the lowest in Astotin Lake, most likely because of a more stable benthic environment (Figure 8B-2).

Table 8B-5 Benthic Invertebrates in Samples Collected in Astotin Lake (AST4)

Major Group	Family	Genus/species	Mean	SE	Percent of Total Abundance
Oligochaeta	Tubificidae	i/d	2,132.8	1,227.8	18.1
Diptera	Ceratopogonidae	i/d	1,995.2	787.5	17.0
Nematoda	-	i/d	1,444.8	526.2	12.3
Diptera	Tanypodinae	Procladius sp	1,376.0	498.5	11.7
Diptera	Chironimini	Dicrotendipes sp	894.4	415.7	7.6
Hirudinea	Erpobdellidae	Erpobdella punctata	756.8	228.2	6.4
Amphipoda	Hyalellidae	Hyalella azteca	481.6	175.4	4.1
Hydryphantidae	Diplodontidae	Diplodontus sp	412.8	128.7	3.5
Ephemeroptera	Caenidae	Caenis sp	412.8	168.5	3.5

Major Group	Family	Genus/species	Mean	SE	Percent of Total Abundance
Diptera	Chironimini	Endochironomus sp	344.0	266.5	2.9
Diptera	Psychodidae	Pericoma sp	344.0	266.5	2.9
Trichoptera	Phryganeidae	Agrypnia sp	275.2	128.7	2.3
Copepoda	Harpacticidae	i/d	206.4	137.6	1.8
Diptera	Tanytarsini	Cladotanytarsus sp	206.4	84.3	1.8
Oligochaeta	Naididae	Nais sp	68.8	68.8	0.6
Hirudinea	Hirudinidae	Molibdella grandis	68.8	68.8	0.6
Hydracarina	Arrenuridae	Arrenurus sp	68.8	68.8	0.6
Hydracirina	Limnesiidae	Tyrellia sp	68.8	68.8	0.6
Odonata-Zygoptera	Coenagrionidae	Enallagma sp	68.8	68.8	0.6
Diptera	Chironimini	Phaenopsectra sp	68.8	68.8	0.6
Diptera	Orthocladinae	i/d	68.8	68.8	0.6
Mean total abundance			11,765	1,694	
Total Richness (lowest practical level)			21		

Notes(s):
SE Standard Error
i/d immature or damaged specimen
- not identified to that level

Community composition of samples collected in the LSA was largely comprised of midges (Chironimidae), aquatic worms (Oligochaeta) and nematodes (Figure 8B-3). The occurrence of large populations of these groups may indicate eutriphication or organic inputs into benthic habitats. This is not uncommon in agricultural areas, as the presence of livestock near watercourses, fertilization of cropland and the breakdown of allocthonous sources of carbon (leaves and terrestrial vegetation) can all contribute to increased organic matter in benthic substrates. Notably, community composition in Astotin Lake was more diverse than either watercourse (Figure 8B-3).

Differences in community composition between samples collected in 2006 (Synenco, 2006) and samples collected for the project in 2007 suggest the benthic community may be subject to a variable aquatic environment. Base flows in watercourses in the LSA may be quite low late in the summer and fall, exposing much of the benthic habitat to extreme conditions. For instance, Petro-Canada Oil Sands Inc. (2006) found that there was no flowing water in tributaries in the fall of 2006 and therefore could not collect samples. When habitat changes are excessive, many components of the community are affected and may need to re-establish populations when conditions permit. Depending upon the severity of annual environmental changes, community structure may vary from year to year as populations are restored.

The midge community varied between sampling years in Beaver Hill Creek (Figure 8B-3). In 2006 the community consisted largely of unidentified Chironominae, whereas, in 2007 the community was comprised of Chironomini and Tanytarsini (also both in the Chironominae subfamily). Astotin Lake and Astotin Creek communities (in both 2006 and 2007) were largely made up of Tanypodinae and Chironomini.

8B3.3 North Saskatchewan River

Existing benthic invertebrate data in the North Saskatchewan River (NSR) near the LSA indicate that communities are somewhat variable in this watercourse (Golder, 1995; Petro-Canada Oil Sands Inc., 2006; Northwest, 2006; Synenco, 2006; Shell, 2007). Mean total abundances ranged from less than 2,000 organisms/m^2 to greater than 35,000 organisms/m^2 (Table 8B-6). Total richness was also variable in the NSR, ranging from 15 taxa to 46 taxa (identified to lowest practical level).

Table 8B-6 Existing Benthic Invertebrate Data in the NSR near the LSA

Parameter	Golder (1995)		Petro-Canada (Fort Hills) (2006)	North West (2006)	Synenco (2006)	Shell (2006)
	Fall 1992	**Fall 1993**	**Fall 2006**	**Fall 2004**	**Spring 2006**	**Early summer 2006**
Total Abundance (#/m^2)	1,900-32,300	2,600-20,200	7,300-25,300	12,300-35,700	5,500-26,700	20,400-28,700
Total Richness (lowest practical level)	15-25	18-33	35-38	23-46	16-39	6-8$^{(a)}$

Notes(s)

(a) reported as mean richness

Most of the studies considered revealed that the benthic invertebrate community was responding to nutrient enrichment. Golder (1995) and Petro-Canada Oil Sands Inc. (2006) suggested that the benthic invertebrate communities showed a change consistent with nutrient enrichment that increased from upstream to downstream. North West (2006) indicated that the proportion of midges and aquatic worms increased from upstream to downstream, which is also indicative of an enrichment effect. Shell (2007) suggested that nutrient effects in the benthic communities were evident at all sites; however, an upstream to downstream gradient was not observed. Golder (1995) also identified a change in community structure downstream of two chemical plants which may suggest a toxic effect.

8B4 REFERENCES

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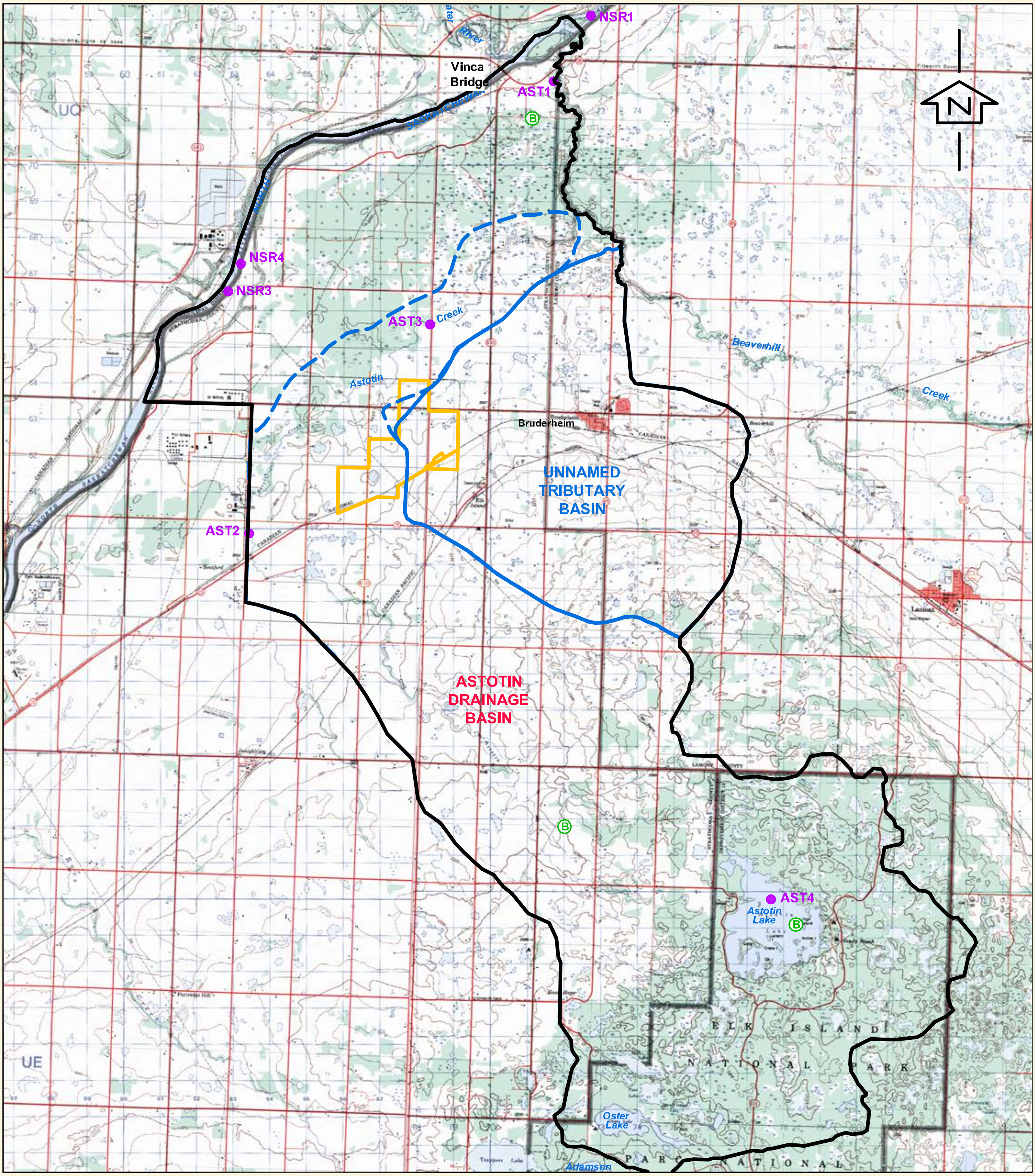


LEGEND

- North American Property Boundary
- Local Study Area (LSA)
- Sub-basin
- Sub-basin
- Ⓑ Benthics Sample

SCALE 1:150000 kilometres

1.5 0 1.5 3.0

Title:

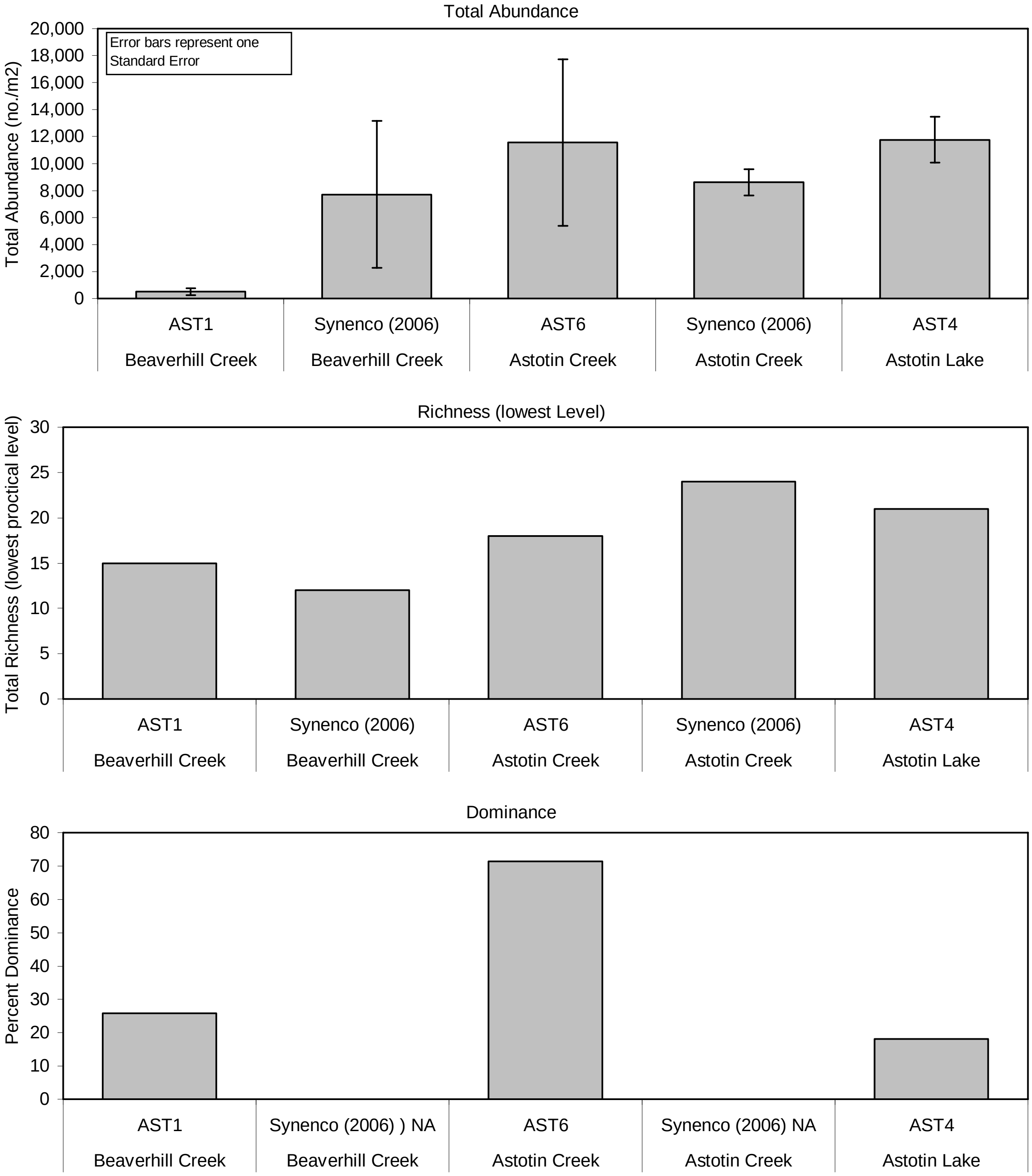
BENTHIC INVERTEBRATE SAMPLING SITES IN THE LSA

NORTH AMERICAN OIL SANDS CORPORATION

Approved: BE	Revision Date: 07/09/04
File: 6198-SITESW-07.DWG	

Drawn by: CZH	Checked: DLC	Fig. No.: 8B-1

Figure 8B-2 Benthic Invertebrate Mean Total Abundance, Total Richness and Dominance in Samples Collected in the North American Upgrader LSA



Note(s)
NA – data not available

Figure 8B-3 Benthic Invertebrate Community Composition and Chironomidae Composition in Samples Collected in the North American Upgrader LSA