Parsons Creek Aggregates Project
Hydrogeological Impact Assessment

Prepared for:
Parsons Creek Aggregates

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File # 09-149

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1.0 INTRODUCTION

1.1 Background

The proposed Parsons Creek Resources Aggregates Project (the Project), operated by Parsons Creek Aggregates (PCR), a joint venture of Graymont Western Canada Inc. and Lehigh Hanson Materials Limited, is a quarry that will provide limestone products for construction, environmental and industrial applications.

The Project will be located in Twp 90 R 9 W4M and Twp 90 R 10 W4M (Figure 1.1). The site is located along Highway 63 immediately north from the Fort McMurray Urban Service Area Boundary.

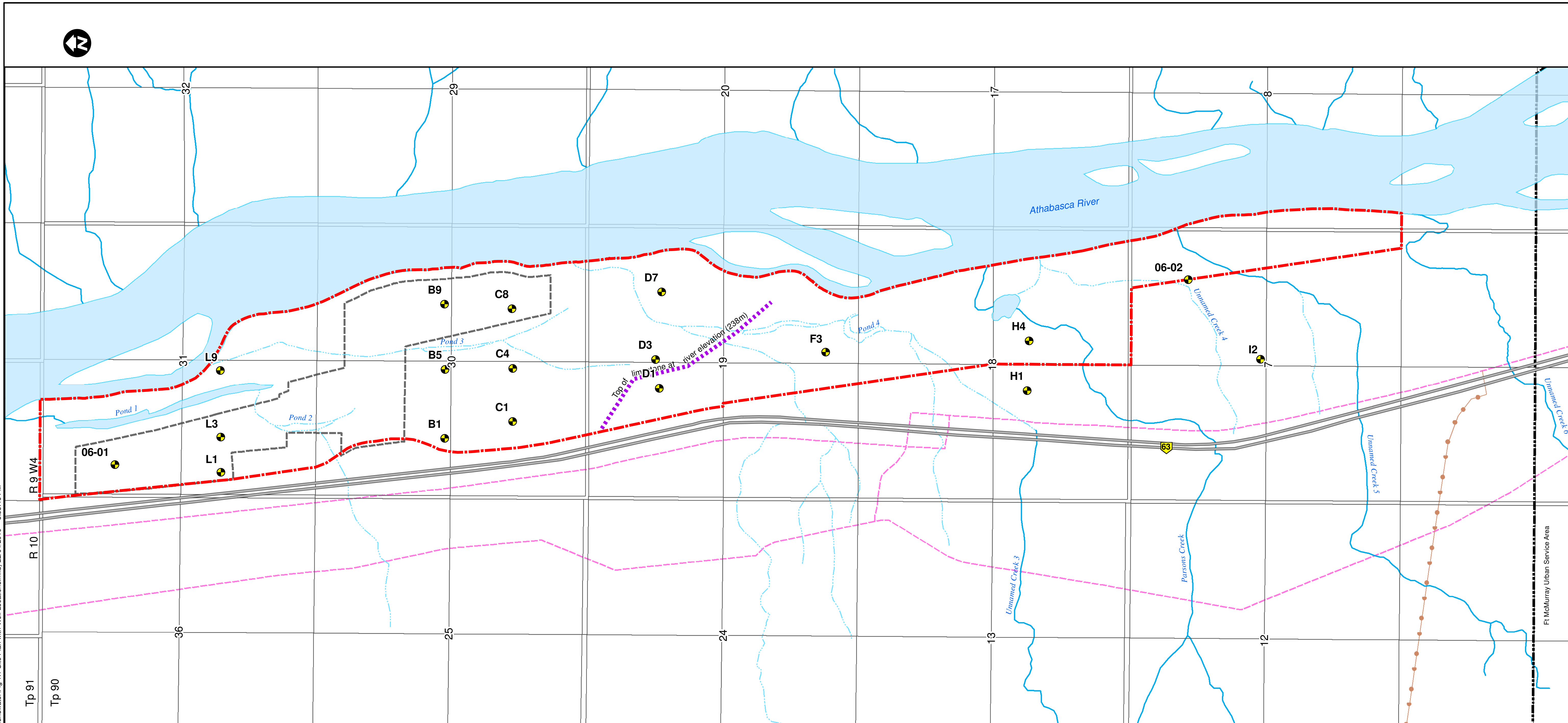
At peak production, the Project will produce 2 million tonnes per year of construction and chemical stone products. Total limestone reserves are estimated to be 55 million tonnes and the Project lifespan is estimated to be at approximately 35 years.

The purpose of this document is to provide:

- A description of the baseline hydrogeological regime.
- An assessment of environmental impacts on the hydrogeological regime.
- An assessment of cumulative effects.

1.2 Topography and Drainage

The site is located on the west bank of the Athabasca River and east of Highway 63 immediately north of Ft. McMurray (Figure 1.1). The site lies in portions of Sections 7, 8, 18, 19, 30 and 31 Twp 90 R 9 W4 and Section 36, Twp 90 R 10 W4.



Legend

- Water Monitoring Well
- Project Area
- Sand & Gravel Operation
- Ft. McMurray Urban Service Boundary
- Permanent Channel
- Intermittent Channel
- Highway
- Powerline
- Pipeline

0 0.25 0.5 1
Kilometres

Parsons Creek Aggregates
a joint venture between Graymont Western Canada Inc. & Lehigh Hanson Materials Limited

PROJECT: **Parsons Creek Aggregates Project**		Millennium EMS Solutions Ltd.	
TITLE: **Site Plan and Well Locations**	DRAWN: PS	FIGURE:	
	CHECKED: DH	**1.1**	
	DATE: Apr 22/10		
	PROJECT: 09-149		

REF: MEMS, Oct 2009

Map Document: (K:\Active Projects 2009\Projects 09-101 to 09-150\09-149 Parsons\Final Docs\Groundwater\Fig 1.1 Site Plan with Well Locations.mxd) 22/04/2010 -- 3:53:46 PM

The land surface rises from an average elevation of 236 m along the Athabasca River on the east to approximately 250 m at the west boundary of the site along Highway 63. Immediately west of Highway 63, the land surface rises abruptly to elevations of approximately 340 m.

The surface water hydrology of the site explained in detail in the Surface Water Hydrology Assessment - Consultant Report #9 in this Application. Notable features of the surface drainage are as follows:

- The site drains generally from west to east.
- There are several permanent drainage courses that enter the property from the west. Few of these drainage courses actually have sufficient flow to have created permanent drainage ways across the site. In many instances, surface water enters the site from the west and infiltrates into the ground before it can completely cross the site.
- Several remnants of former channels of the Athabasca River are present on the site. These are generally located on the east portion of the site and may redirect eastward-flowing water toward the north.
- Levels of the Athabasca River generally range from a normal level of approximately 238 m to as high as 243 m in a 1:100 return-period flood.

1.3 Study Area

The concept of regional and local study areas is frequently applied to environmental impact assessments. The following factors were considered in evaluating study areas for the hydrogeological impact assessment:

- The Project area is bounded on the east by the Athabasca River.
- The Project is bounded on the west by steep bluffs within which the geology changes significantly from recent alluvial deposits to Cretaceous bedrock.
- The Project is bounded on the north by Northlands Forest Products.
- There is a significant setback between the operations and the south boundary of the property.
- The quarry is set in a rock unit of very low hydraulic conductivity.

All of this results in the conclusion that, for the purposes of the hydrogeological assessment and impact statement, there will be no distinction of regional and local study areas.

Hydrogeological impacts will not extend beyond the boundary of the site. The Study Area (SA) will be the boundaries of the Project. Some reference may be made to regional hydrogeology, however this will only be to set appropriate context and not because it is essential to impact statements.

1.4 Quarry Operations

Details of the mine plan are described in Part B of the Environmental Impact Assessment (EIA) report however, the following items are relevant to the hydrogeology:

- Quarrying of the limestone will start at the north end of the area and progress southward:
  - There will be a number of blocks of the quarry that relate to allowing for the preservation of certain water courses; and
  - Several of the blocks will be subdivided to allow for progressive reclamation.
- The quarry may extend to 30 m below ground surface.
- There is abundant sand and gravel which will be removed by PCA prior to limestone quarrying. This aggregate operation has been the subject of another approval process and is not the subject of this impact assessment. Where the sand and gravel pit is present, it will be treated as an existing baseline feature.
- Blasting will take place in the quarry. Ammonium nitrate-fuel oil (ANFO) will be used as a blasting agent.
- Hydrocarbon fuels will be present on site for various purposes. All of these fuels will be stored according to current regulations regarding tankage and berming. Storage of hydrocarbon fuels will be outside of the quarry excavation proper.
- There are no significant masses of chemicals involved in this quarrying operation.
- Hazardous and non-hazardous wastes will be shipped off site for disposal.

2.0 FIELD INSTRUMENTATION

Instrumentation for groundwater monitoring on the site can be divided into observation wells completed in surficial deposits and in the limestone bedrock.

2.1 Surficial Deposits

Table 2.1 presents a summary of the observation wells that were completed in the surficial deposits of the site. Geological logs, details of completion, testing and water chemistry are found in Appendix A. The “geological” logs of many of the holes are oriented to aggregate exploration rather than descriptive geology, but are suitable for hydrogeological interpretation.

Table 2.1 Completion Details of Observation Wells

Surficial Deposits	Ground Surface Elevation (m)	Open Interval (m below ground)	Completion Material	Hydraulic Conductivity (x 10^{-7} m/s)
B1	244.43	4 to 7	Sand	7
B5	241.47	4.2 to 7.2	Sand	20
B9	241.97	4 to 7	Sand/Clay	9
C1	243.89	7 to 8.5	Gravel	7
C4	240.54		Gravel	2
C8	241.74	9 to 10.5	Gravel	
D1	242.57	5.9 to 7.4	Gravel	0.1
D3	241.51	6.7 to 8.2	Gravel	20
D7	242.19	25.1 to 26.6	Gravel	
F3	243.76	6.5 to 8	Gravel	
H1	250.42	6 to 7.5	Gravel	0.7
H4	245.97	2.4 to 3.9	Gravel	30
I2	250.27	15 to 16.5	Gravel	0.5
L1	244.66	4.8 to 7.8	Sand	
L2	243.06	3 to 6	Sand/ Gravel	
L3	241.62	3.85 to 6.85	Gravel	200,000
L4	242.03	1.6 to 4.6	Gravel	
L5	241.82	1.6 to 4.6	Sand/ Gravel	
L6	242.89	1.7 to 4.7	Sand/ Gravel	
L7	242.04	1.6 to 4.6	Sand/ Gravel	
L8	240.20	4.4 to 7.4	Clay	
L9	239.81	4.3 to 7.3	Sand	20
Bedrock Deposits				
06--01-16	241.90	3.4 to 4.9	Limestone	50
06--01-75	241.90	21.3 to 22.9	Limestone	0.02
06--02-26	245.70	6.4 to 7.9	Limestone	300
06--02-75	245.70	21.3 to 22.9	Limestone	1

Twenty-two observation wells were completed in the surficial deposits of the site. Locations of these wells are shown on Figure 1.1. These wells range in depth from 3.9 to 26.6 m and are generally placed near the bottom of the surficial deposits. The length of the open intervals on the observation wells was 1.5 m.

Hydraulic conductivity was estimated in two ways:

- Recovery tests in individual wells; and
- Response to pumping of a test pit along Line “L”.

With one exception, these estimates range from a low of 0.1 x 10^{-7} m/s to a high of 30 x 10^{-7} m/s, these values are lower than what would normally be expected in coarse sand and gravel. The pumping of the test pit resulted in a hydraulic conductivity estimate of 200,000 x 10^{-7} m/s which is much more reasonable for the clean gravel deposit located in that area.

Water levels were measured in these observation wells on several occasions. The elevations of these water levels on the dates of measurement are shown in Table 2.2. Appreciable variation in water levels in the surficial deposits was demonstrated over the period of record.

Table 2.2 Water Levels in Observation Wells

Monitor Well	Date				
	January 18, 2006	April 28, 2006	July 4 & 5, 2006	January 23-27, 2007	May 15, 2007
Surficial Deposits					
B1				243.14	244.40
B5				239.04	239.65
B9				236.52	
C1		243.25			
C4		237.5 (est) *			
C8		236.98			
D1	241.61	---			
D3	238.06	238.03			
D7	243.08	237.13			
F3	238.78	238.99			
H1	248.54	248.78			249.21
H4	245.49	246.01			246.12
I2	246.28	249.32			249.55
L1				239.67	240.86
L2				239.41	240.42
L3				239.35	240.38
L4				239.33	
L5				239.39	
L6				239.32	
L7				239.33	
L8				236.97	
L9				236.31	
Bedrock Deposits					
06--01-16			240.68		241.82
06--01-75			239.28		230.45(est)*
06--02-26			243.23		243.44
06--02-75			243.18		242.99

*(est) = estimated

Water samples were collected from selected observation wells (Appendix A-3).

2.2 Limestone Bedrock

Four observation wells (Table 2.1) were established in the limestone in the bedrock (Figure 1.1). These four wells consisted of two nests of two wells each located near the south and north ends of the site. The completion (Appendix A-1) was done in a single borehole with one well completed and sealed near the top of the limestone and another completed and sealed at a depth of approximately 22 m. The effective sealing of the borehole between the two wells in each borehole is demonstrated by the difference in water chemistry of the pairs of wells (Appendix A-3).

Hydraulic conductivity was estimated through the use of recovery tests in individual wells. These estimates range from a low of 0.02 x 10^{-7} m/s to a high of 300 x 10^{-7} m/s (Table 2.1). The hydraulic conductivity of the limestone was several orders of magnitude lower in the deep wells than in the shallow wells.

Water levels were measured in these observation wells on several occasions. The elevations of these water levels on the dates of measurement are shown in Table 2.2.

Water samples were collected from these observation wells (Appendix A-3).

3.0 BASELINE HYDROGEOLOGY

3.1 Geological Setting

The geology of the site consists of surficial deposits overlying limestone bedrock. This is depicted in Figure B.3.2.2-1 of this application. Generally, these deposits may be described as follows:

- The surficial deposits consist of interbedded gravel, sand, silt and clay. These are interpreted to be alluvial deposits of the Athabasca River. The north half of the site generally contains more gravel and sand while the south half tends to be finer grained with more sand and clay than gravel. The alluvial surficial deposits pinch out against the steep bluffs approximately at the location of Highway 63 just west of the site.
- The bedrock limestone is the Moberly Member of the Waterways Formation and "*consists of interbedded limemudstone, fossiliferous limewackestone to packstone and variously calcareous shale*" (Knox, 2004). The regional dip of the limestone deposits is to the southwest (Hackbarth and Nastasa, 1979).

Thicknesses of the surficial deposits were observed to range from zero at limestone outcrops at the south-eastern end of the site to 27 m at Observation Well D7. The surface of the limestone (Figure 3.1) has the following characteristics:

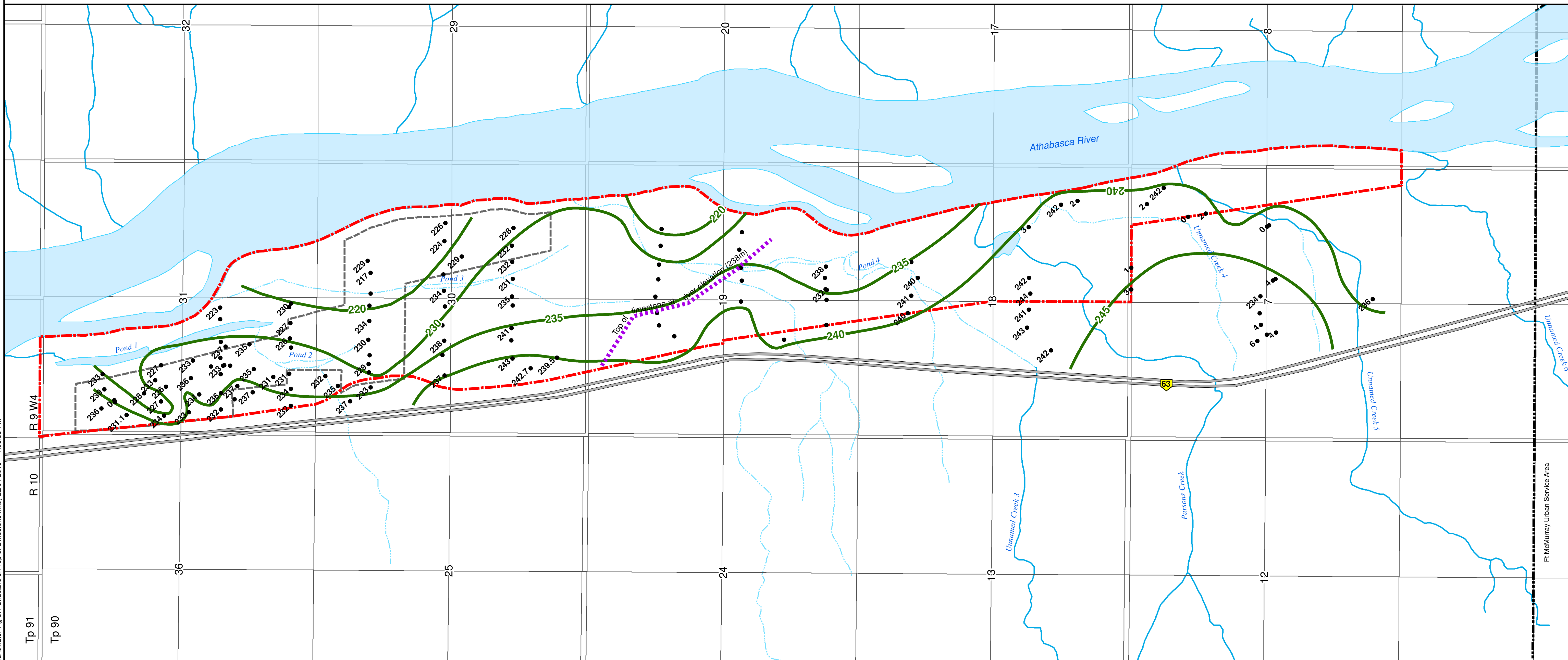
- Elevations in excess of 245 m occur on the south end of the site,
- Lowest elevation of approximately 215 m occurs in the centre of the site at Observation well D7,
- There is a secondary low area below 230 m near the north end of the site,
- Rises above 235 m at the very north end of the site.
- The limestone is at or above normal river level under the southern one-half of the site and is below river level under the northern one-half.

Hackbarth and Nastasa (1979) and McRoberts (2002) presented evidence of a narrow, deep alluvial channel incised below the Athabasca River. The bottom of this channel was determined at elevations ranging from 135 to 182 m from the Suncor Bridge to just north of Fort MacKay. It is reasonable to assume that this channel is present beneath the river east of this site. It is possible that the low elevation of the limestone surface at Observation Well L 9 reflects this feature.

The Recent alluvial deposits of the site pinch out against the bluffs of Cretaceous McMurray Formation (oil sands) immediately to the west. It is not clear in Hackbarth and Nastasa (1979) whether there is “basal water sand” present at Observation Well Site 16. If this unit were present, it would be a thin layer of oil-free sand lying between the limestone and the oil sands of the McMurray Formation.

The geological stratigraphy beneath the bluffs immediately west of Highway 63 is illustrated at Observation Well Site 16 (Hackbarth and Nastasa, 1979) as follows:

- Glacial drift deposits from land surface elevation of 340 m to 312 m;
- Clearwater and McMurray Formations from 312 m to an elevation of 242 m; and
- Top of the limestone at 242 m.



Legend

- Borehole
- Project Area
- Sand & Gravel Operation
- Ft. McMurray Urban Service Boundary
- Surface of Limestone Contour
- Permanent Channel
- Intermittent Channel
- Highway

0 0.25 0.5 1
Kilometres

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PROJECT:
Parsons Creek Aggregates Project

TITLE:
Structure on Top of Limestone

Millennium EMS Solutions Ltd.

DRAWN:	PS
CHECKED:	DH
DATE:	Apr 22/10
PROJECT:	09-149

FIGURE: **3.1**

REF: MEMS, Oct 2009

Map Document: (K:\Active Projects 2009\Projects 09-101 to 09-150\09-149 Parsons\Final Docs\Groundwater\Fig 3.1 Structure on Top of Limestone.mxd) 22/04/2010 -- 4:08:35 PM

3.2 Groundwater Flow

3.2.1 Surficial Deposits

Elevations on the water table are presented on Figure 3.2. The water table slopes west to east toward the Athabasca River. The water table is a subdued replica of the topography.

The general abundance of clay and sand in the south means relatively lower hydraulic conductivity than in the north where sand and gravel predominate and this is reflected in the water table surface. In the south, the water table rises rapidly above the average elevation of the river in response to the generally lower hydraulic conductivity, while in the north the water table is closer to river level due to the higher hydraulic conductivity.

Figure 3.3 presents a cross section of hydrogeological conditions in the north portion of the site (Figure 1.1). Groundwater flow in the surficial materials and the upper layer of the limestone is from west to east toward the Athabasca River. Since the surficial materials pinch out in the west against the oil sands, the source of groundwater recharge in these materials is infiltration of surface flow off the bluffs to the west as well as direct precipitation.

Figure 3.4, located generally along 6,295,000 N (Figure 1.1), presents hydrogeological conditions in the south portion of the site. This section extends from Observation Well Site 16 (Hackbarth and Nastasa, 1979) on the bluffs to Site 06-02 near the river. It shows the pinch-out of the alluvial surficial deposits against the bluffs of oil sand.

Groundwater flow in the alluvial deposits is west to east from the base of the bluffs to the river. Relatively little groundwater will be contributed to the alluvial deposits on the site from the oil sand deposits to the west. If the basal water sands are present beneath the bluffs, then there may be some groundwater contributed from that source however, it would remain relatively low in any event.

Examples of the velocity of groundwater flow are required by the Terms of Reference. Examples for the surficial deposits are presented in Table 3.1. The assumptions of the calculations are provided in the table.

Table 3.1 Velocity of Groundwater Flow in Surficial Deposits

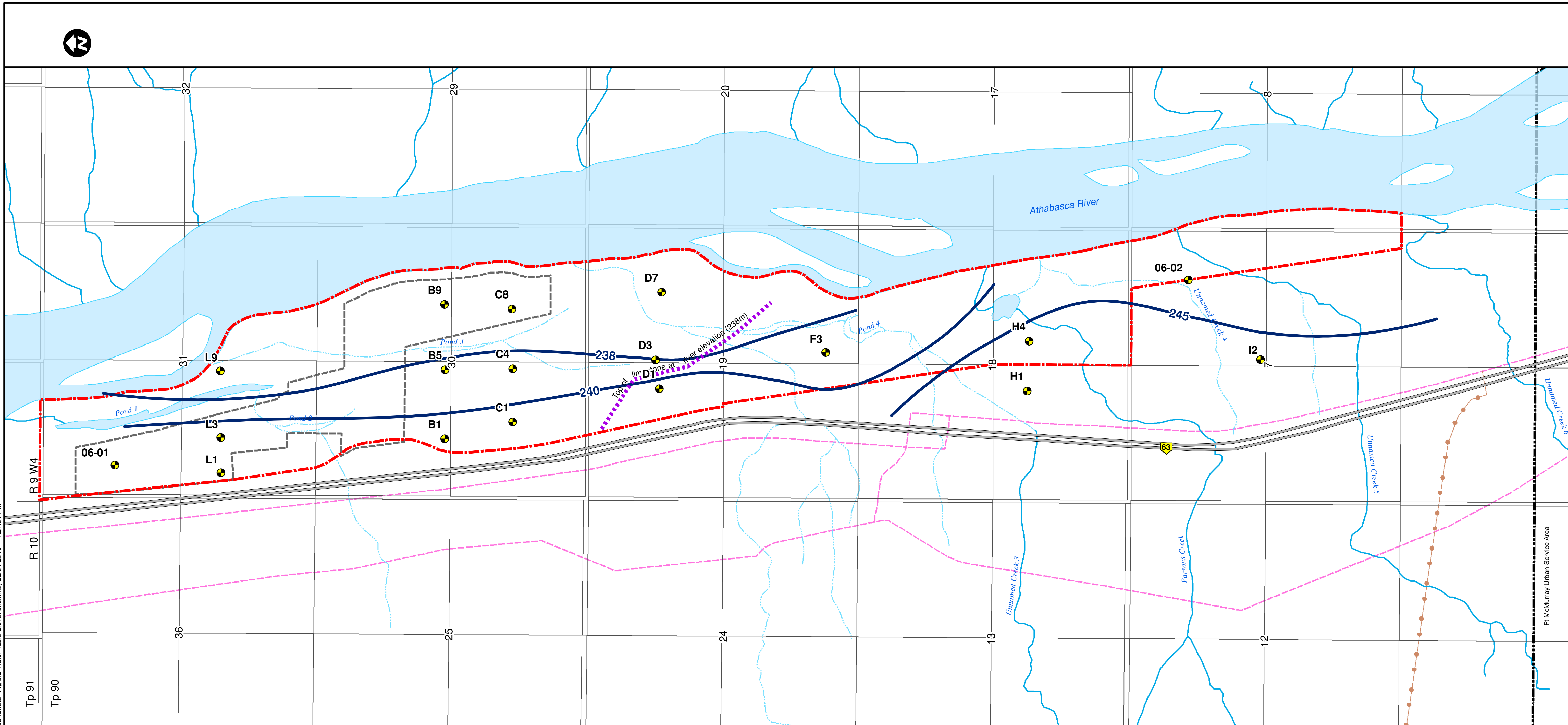
Assumptions	Range of Values	
	Low	High
Hydraulic Gradient (m/m)	8/1000	16/1000
Hydraulic Conductivity (m/s)	0.1×10^{-7}	$200,000 \times 10^{-7}$
Porosity	0.15	0.3
Average Linear Velocity (m/day)	0.0000007	90

*From Table 2.1

Because hydraulic gradients change with time and because of the complex interrelationship of the surficial deposits of gravel, sand, silt and clay, these velocities have little practical meaning for the assessment.

The sources of recharge to groundwater on the site are (in presumed order of importance):

- Surface runoff from the west that moves east, down the bluff, under Highway 63 and subsequently infiltrates on the site;
- Direct precipitation; and
- The Athabasca River – in the sense that its elevation defines the endpoint of the eastward-flowing groundwater – particularly in the north one-half of the site where the alluvial deposits are below river level. If surface runoff and direct precipitation were precluded from entering the site, the groundwater level throughout the site would be approximately equal to river level.



Legend

- Water Monitoring Well
- Project Area
- Sand & Gravel Operation
- Ft. McMurray Urban Service Boundary
- Water Level Contour (m)
- Permanent Channel
- Intermittent Channel
- Highway
- Powerline
- Pipeline

0 0.25 0.5 1
Kilometres

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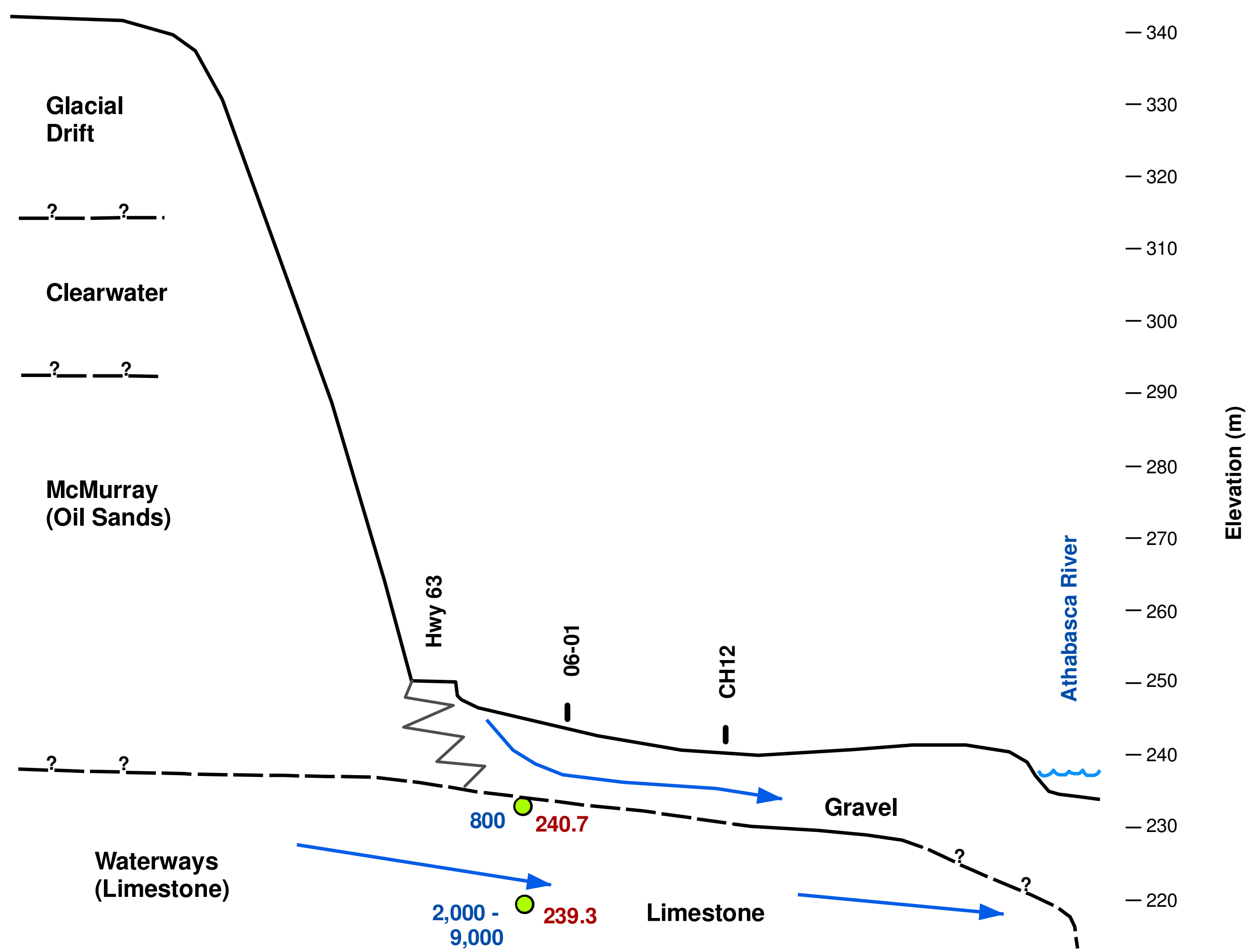
PROJECT: Parsons Creek Aggregates Project		Millennium EMS Solutions Ltd.
TITLE: Water Table Elevations	DRAWN: PS CHECKED: DH DATE: Apr 22/10 PROJECT: 09-149	FIGURE: 3.2

REF: MEMS, Oct 2009

Map Document: (K:\Active Projects 2009\Projects 09-101 to 09-150\09-149 Parsons\Final Docs\Groundwater\Fig 3.2 Water Table Elevations.mxd) 22/04/2010 -- 4:21:51 PM



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Map Document: (K:\Active Projects 2009\Projects 09-101 to 09-150\09-149 Parsons\Final Docs\Groundwater\Fig 3.3 Hydrogeological Cross Section A.mxd) 22/04/2010 -- 4:29:16 PM

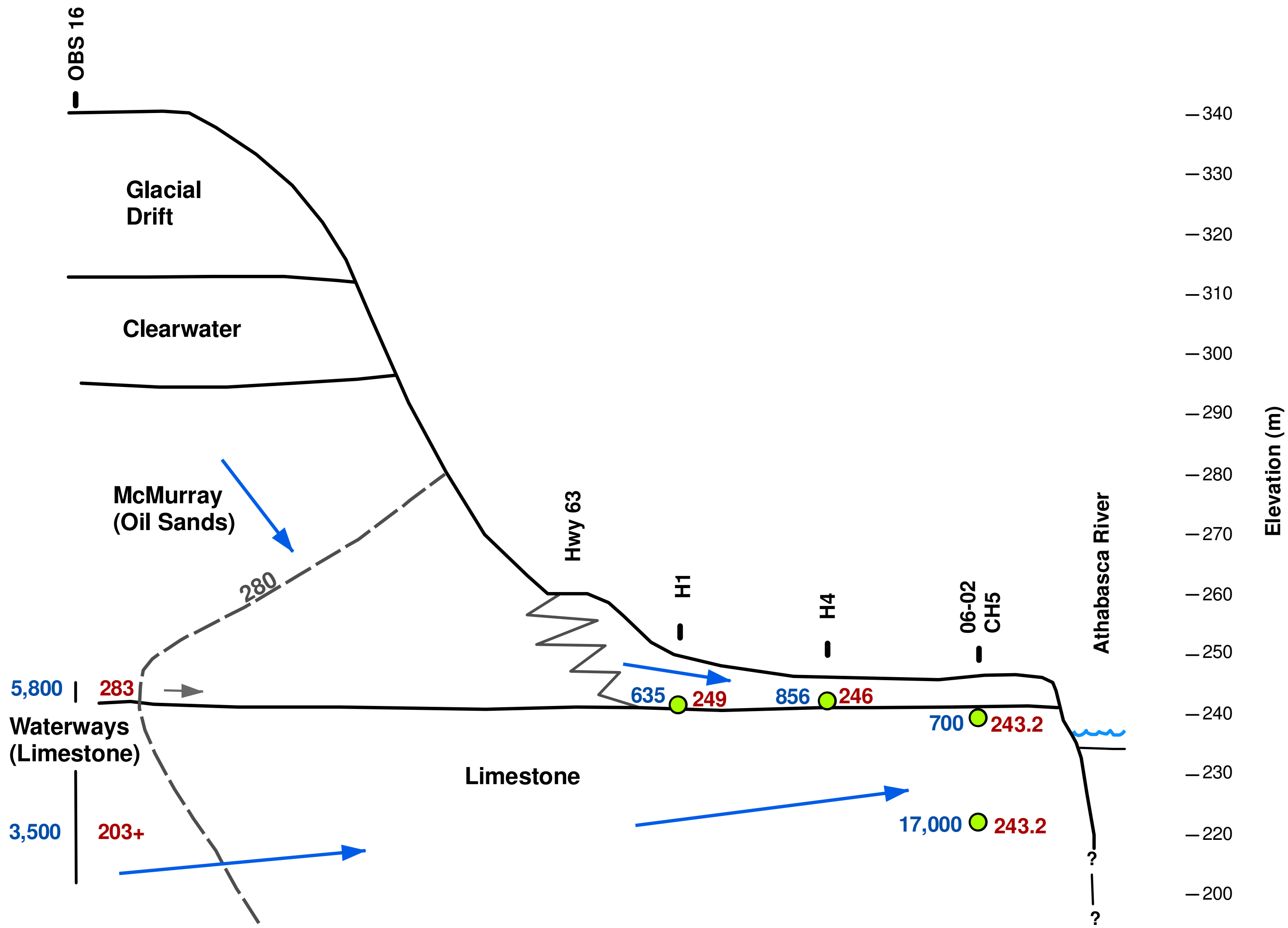
PROJECT: **Parsons Creek Aggregates Project**

Millennium EMS Solutions Ltd.

TITLE: **Hydrogeological Cross-Section A-A' - North**

DRAWN: SL
CHECKED: DH
DATE: Apr 22/10
PROJECT: 09-149

FIGURE: **3.3**



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PROJECT: Parsons Creek Aggregates Project	Millennium EMS Solutions Ltd.	
TITLE: Hydrogeological Cross-Section B-B' - South	DRAWN: SL CHECKED: DH DATE: Apr 22/10 PROJECT: 09-149	FIGURE: 3.4

3.2.2 Limestone Bedrock

Hackbarth and Nastasa (1979) show that groundwater flow in the Devonian limestone in the region is toward the Athabasca River. They indicate that the river is a regional discharge point for groundwater.

Water levels in the four limestone observation wells (Table 2.2) show several features:

- Levels in the deeper of the wells in each nest are above the water level of the Athabasca River.
  - This suggests that water is moving upward from those depths to discharge in the river.
  - Hydraulic conductivities of 0.02 to 1 x 10^{-7} m/s (Table 2.1) indicate that the velocity of water movement is very low.
- Levels in the shallower of the limestone observation wells are above both the Athabasca River and those in the deeper observation well.
  - This suggests that water at the top of the limestone is moving downward to discharge into the river.
  - Hydraulic conductivities 50 to 300 times greater than the deeper limestone observation well indicate that this volume is far more significant than the deeper zone.

Examples of the velocity of groundwater flow are required by the Terms of Reference. Examples for the limestone are presented in Table 3.2. The assumptions of the calculations are provided in the table. In this case however, the knowledge of the parameters is less-well understood compared to those for the surficial deposits. For instance:

- The hydraulic gradient is presumed to be upward toward the Athabasca River at 1 m per m to 1 m per 4 m.
- The porosity of the limestone is known to be low and reasonable assumptions for this porosity have been selected to be 1 to 5 %.

These assumptions result in average linear velocities of 0.01 to 0.05 m/day.

Table 3.2 Velocity of Groundwater Flow in Limestone

Assumptions	Range of Values	
	Low	High
Hydraulic Gradient (m/m)	1/4	1/1
Hydraulic Conductivity* (m/s)	0.2×10^{-7}	1.0×10^{-7}
Porosity	0.01	0.05
Average Linear Velocity (m/day)	0.01	0.05
Discharge	0.00004	0.008

*From Table 2.1

3.3 Groundwater Chemistry

3.3.1 Alluvial Deposits

The chemistry of groundwater in the alluvial deposits (Appendix A-3) is generally dominated by calcium, magnesium and bicarbonate with a TDS in the range of 600 to 900 mg/L. Sodium and chloride are relatively low. TDS were observed to be approximately 1,700 mg/L at Well F2 due to higher concentrations of sodium and chloride as compared to water in alluvium at other locations.

Figure 3.3 shows that the TDS in the surficial materials in the northern portion of the site may be expected to be less than 800 mg/L. Figure 3.4 shows that TDS in the groundwater in the surficial materials in the south portion of the site will be in the 600 to 900 mg/L range. This reflects the general prevalence of clay and silt in the south and sand and gravel in the north.

3.3.2 Limestone Bedrock

The chemistry of groundwater at the top of the bedrock surface (Appendix A-3) is very similar to that in the overlying alluvial deposits. TDS is also in the range of 600 to 900 mg/L however calcium and magnesium are found in lower concentration and sodium and sulphate are relatively higher than in the overlying alluvium. Chloride remains at approximately the same low concentration as that in the overlying alluvium.

Water samples collected 15 to 20 m below the top of the limestone bedrock have a significantly different chemical makeup than do the shallower zones in the limestone. The concentrations of sodium and chloride are significantly higher than the shallow groundwater and TDS is in the range of 2,000 to 27,000 mg/L.

This means that the shallow limestone interacts significantly with the overlying alluvial materials and that there is no interaction with the deeper limestone.

The upward hydraulic gradient drives the saline water in the limestone upward into the Athabasca River. Under the assumptions used in Table 3.2, this means that 0.4 to 8 litres of this saline water is delivered to the Athabasca River each day from each square metre of limestone surface under natural conditions.

3.4 Summary of Hydrogeological Regime

The following observations and conclusions may be presented regarding the hydrogeological regime of the site:

- Groundwater flow is west to east across the alluvial deposits of the site;
- In the southern one-half of the site:
  - The alluvial deposits are above normal river level and will not normally be influenced by changing river levels; and
  - A significant volume of the limestone quarry will also be above river level.
- In the northern one-half of the site:
  - The combination of sand and gravel with high hydraulic conductivity with elevations below river level means that river stage will have a significant direct influence on groundwater levels; and
  - The entire limestone quarry will be below the level of the river.
- Water chemistry in the alluvium and the top of the limestone bedrock has TDS in the range of 600 to 900 mg/L in what is typically a calcium/magnesium/bicarbonate water, however the shallow limestone has some relative enrichment in sulphate. There are no issues with respect to the *Alberta Surface Water Quality Guidelines* (Alberta Environment, 1999); and
- Water chemistry 15 to 20 m below the top of the limestone surface has significantly higher TDS and is characterized as sodium chloride. There will be issues with discharging water with these concentrations.

4.0 IMPACT ASSESSMENT

4.1 Baseline

The project will involve two operations that have distinctly different regulatory constraints:

- Surficial deposits above the limestone will be removed prior to the quarry operation. This removal of surficial deposits will be part of an aggregate extraction operation that will take place in areas 3B, 3C, and 3D (Figure 1.1). Aggregate extraction operations do not require an environmental impact assessment.
- The proposed limestone quarrying operation does require an environmental impact assessment and is the subject of this document.

- In the north, this will take place after the aggregate extraction operations,
- In the central and southern parts of the area, where there are no economic sand and gravel deposits, overburden removal will be part of the quarry operations.

The baseline for the environmental impact assessment with respect to the hydrogeological regime is:

- The exposed limestone surface after aggregate extraction operations are completed and
- The overburden removal and limestone quarrying operations

4.2 Project Components

The purpose of this section is to provide a description of the Project in a manner that focuses on the hydrogeological aspects of the Project and to translate these into statements of potential for environmental impact.

In the case of impacts of “concern”, this section will deal with them by explaining the concern and subsequently dealing with its scientific reality. The issues which lack scientific substance have no probability of an impact and will not be carried forward to the impact statements of Section 5.

In the areas for which there is scientific substance:

- If the probability of occurrence is essentially zero, then there is no probability of impact and this section will provide discussion and explanation of the reason for zero probability and the discussion will then end.
- If there is a probability of occurrence, then the subject will be explained and carried forward to the following impact statement section for discussion of significance.

Table 4.1 lists aspects of construction, operation and closure of the quarry that will involve the following activities which contain hydrogeological aspects. The following section describes each of these aspects in terms of their interaction with the groundwater regime.

Table 4.1 Hydrogeological Aspects of Construction, Operation and Closure			
Aspect	**Construction**	**Operation**	**Closure**
Surface Water Diversion	X	X	X
Overburden Removal and Groundwater Control	X	X	
Quarry Water Control	X	X	X
Water Wells	X	X	X
Blasting	X	X	
Fuel Management	X	X	

4.2.1 Surface Water Diversion

Control of surface water flowing onto the site from the west is an essential aspect of work preliminary to the actual commencement of the aggregate extraction operations as well as the limestone quarry operations. A related aspect is providing for rapid runoff of precipitation falling directly on the site. Both of these activities will have the effect of reducing infiltration of surface water into groundwater and groundwater levels may decline as a consequence. This diversion is a necessary aspect of the aggregate extraction operations and is not the subject of this assessment.

In the central and southern regions of the area there are no sand and gravel deposits and surficial material will be dewatered for removal solely for the purposes of the limestone quarry. This diversion will take place during the construction phase, continue through operations and cease with closure.

This continuing diversion throughout the operational life of the quarry will be necessary to keep water out of the excavation until closure. Environmental impacts that could occur with respect to the relationship of surface water diversion and the hydrogeological regime will be discussed in Section 5.

Surface water diversion takes on a different purpose when the quarry is closed and being reclaimed. At this time, it becomes necessary to control surface water for the purposes of managing the conversion from operations to the desired end land use (i.e., a wetland/land complex).

4.2.2 Overburden Removal and Groundwater Control

As has been described above, a portion of the “overburden” of the limestone quarry operation is sand and gravel that is the focus of the aggregate extraction operations located as shown on Figure 1.1 and is the subject of a different regulatory process.

Sand and clay present in the overburden in the central and southern portions of the area will be removed as part of the quarry construction. Environmental impacts that could occur with respect to the relationship of overburden removal in these areas and the hydrogeological regime will be discussed in Section 5.

4.2.3 Quarry Water Control

The limestone is generally considered to have very low hydraulic conductivity. Large volumes of water are not expected to enter the quarry. The planned water control for in-pit operations will be pumping from sumps within the open pit. Dewatering wells are not anticipated. The water from the in-pit sumps will be transferred to settling ponds where it will mix with precipitation and some surface water. This water will be used for dust control and other process water. Excess water will be released if it meets regulatory requirements.

The groundwater in the limestone is known to have TDS as high as 27,000 mg/L. The impact of a mixture of this and other operational water will be discussed in Section 5.

The aggregate extraction operations will have the effect of removing the surficial materials from this site. The absence of these materials means that they will not contribute to supporting the water levels in the end-pit lakes. The water level in end-pit lakes will be maintained primarily by routing east-flowing water courses through these water bodies. In the south, where the limestone surface is above the level of the Athabasca River, this rerouting will be of major importance. In the north, where the limestone surface is below the level of the river and surficial materials will continue to be present below river level on the east, there will be a larger component of groundwater available (from the east) to the end-pit lakes. In either case, the water entering the end-pit lake(s) is fresh (a combination of surface water and alluvial groundwater) and not saline.

The elevation of the water level in the end-pit lakes will be established to be above that in the underlying limestone. This will mean that salt-bearing water cannot flow into the lakes and that they will remain fresh. The issue of salinity in the end-pit lakes is therefore resolved with respect to groundwater and will not be discussed further.

Dissolution of salt in the Prairie Evaporite Formation along with related karst formation has been observed to varying degrees throughout the general area of the Athabasca oil sands. These features were originally speculated by Intercontinental Engineering (1973) to provide conduits for upward movement of brine. More than thirty years of experience with oil sands mining operations in the area have demonstrated that this situation occurs only infrequently. There is no reason to anticipate these issues on this site. This issue is insignificant and will not be considered further in this assessment.

4.2.4 Local Water Wells

There are no wells in or near this site which produce water for domestic, agricultural or industrial purposes. There is no possibility that the construction, operation or closure of the quarry will have an effect on any water well. Such an impact is therefore insignificant and the topic is not addressed in Section 5.

4.2.5 Blasting

Blasting will take place to break up the limestone in order to excavate it and move it to crushing. It has been demonstrated elsewhere that residual nitrate from blasting materials can have an impact on groundwater (Hackbarth Environmental 1999).

In coal mines in Alberta that use ammonium nitrate explosives to break up overburden in order to excavate coal, it has been observed that nitrate in groundwater emanating from spoil piles can reach temporary concentrations as high as several hundred milligrams per litre. This occurs because of residual and unexploded blasting products in the large masses of spoil materials that remain permanently on site.

There is some possibility of leaching of nitrate and significance needs to be addressed. The impact of the introduction of nitrate into groundwater will be discussed in Section 5.

4.2.6 Fuel Management

Fuel is the only liquid material on site that has implications to groundwater contamination. There are two general sources of possible contamination with fuel:

1. Bulk storage of hydrocarbon fuel; and
2. Fuel in vehicles within the pit.

Fuel spills represent a potential source of impact on groundwater quality and will be discussed in Section 5.

5.0 ENVIRONMENTAL IMPACT STATEMENT

This section provides an environmental impact statement regarding the five aspects of the proposed quarry operation that were brought forward from Section 4.

CEAA (1994) defines an environmental effect as: *"any change that the project may cause in the environment, including any effect of any changed on the health and socio-economic conditions, on physical and cultural heritage, on current use of lands and resources for traditional purposes by aboriginal persons, or on any structure, site or thing that is of historical, archaeological, palaeontological or architectural significance and any change to the project that may be caused by the environment."*

Tilleman (1994) defines environmental impact as; *"the net change, positive or negative, in human health and well-being that results from an environmental effect, including the well-being of the ecosystem on which human survival depends."*

5.1 Surface Water Diversion

There are two aspects of surface water diversion in the central and southern areas that are manifest in the groundwater regime. They are:

- A general lowering of groundwater levels due to the interception of water that would have infiltrated; and
- Lowering of groundwater levels near the diversion ditches.

5.1.1 General Lowering of Groundwater Levels

The major result of surface water diversion will be that water that currently runs onto the site from the west and infiltrates will no longer do so. This will mean a general lowering of groundwater levels within the site – a result that is desired with respect to dewatering of overburden in advance of the quarry. Therefore, this assessment has overlap with Section 5.2 – Overburden Groundwater Control.

The approach to surface water diversion is described in the Surface Water Hydrology Assessment, but will generally have the philosophy of rerouting water that could flow into the quarry pit itself as well as a reasonable distance ahead of the advancing quarry. Diverting years in advance of quarrying is not economically desirable unless physical constraints (such as topography) dictate otherwise. Thus, any effects are not significantly in advance of the quarry operations.

The overburden removal operations immediately in advance of the quarry will be eliminating any groundwater zones that may exist. This is a fundamental aspect of a mining operation. As well, the approved aggregate extraction operations in Sections 30 and 31 will similarly eliminate groundwater zones. This will disrupt groundwater that, under a baseline case, would move east to the Athabasca River. This water will not be lost to the river since the diverted groundwater will simply be moved to a new discharge point relatively close by, but still flowing into the river. The significance of this transfer is discussed in the Surface Water Hydrology Assessment.

It has been noted that the water levels in Pond 1 and monitoring well L-8 demonstrated that there is no direct connection between surface water bodies of the site and groundwater. This is anticipated to be true throughout the site and therefore the lowering of groundwater levels will not draw water from other ponds. The impact of lowered groundwater levels in the overburden will therefore be insignificant to surface water bodies of the site.

5.1.2 Lowering of Groundwater Levels Near Ditches

The main surface water diversion ditches will be located on the west side of the site. In this area, the land surface is higher and the water table is farther below the surface than elsewhere of the site. This means that diversion ditches may not, in fact, intercept groundwater over significant portions of their lengths. Under these circumstances, the impact on groundwater will be insignificant.

Winter icing in the road ditches on the west side of Highway 63 is a significant problem at certain locations. This is due to a combination of surface water and groundwater. To the extent that lowering of groundwater levels does take place near ditches, there may be a significant positive benefit of reducing the conditions that cause icing.

5.2 Overburden Removal and Groundwater Control

As stated in the previous sections, surface water diversion may have the additional effect of lowering groundwater levels within the site. That would be considered a supplemental benefit to the diversion. This section discusses direct activities that might take place intended to reduce groundwater levels in advance of overburden removal.

There are two aspects to control of groundwater in the overburden:

- Lowering the water table so that overburden removal can take place in relatively dry circumstances; and
- Controlling the groundwater discharging from the overburden at the crest of the quarry:
  - This is both a geotechnical and water management issue.

5.2.1 Lowering the Water Table

In the south, where the overburden is relatively thin, it is likely that surface drainage ditches can be extended to the top of the limestone and graded to some lower elevation so as to effect groundwater removal. With thicker overburden as in the mid-portions of the site, the amount of material to be moved to create a continuous ditch may become prohibitive and a series of sumps with pumps and pipelines may need to be utilized in addition to ditches.

It is implicit in a quarry operation that land within the footprint will be significantly disrupted by that operation. The reclamation section of the Application (CR #6, Conservation & Reclamation) deals with the mitigation and the ensuing significance. This section will deal with areas adjacent to the footprint to which impacts may be transmitted by means of the groundwater.

It has been pointed out that surface water bodies on the site appear to be "perched" above the water table. This means that surface water bodies, such as Ponds 1 through 5 that may lie outside of the quarry footprint are not likely to experience significant impact from lowering of groundwater level. Since it is also likely that groundwater control activities, such as dewatering, will route the produced groundwater through these ponds, there may actually be more water in them than was the case prior to quarrying.

It has been shown that groundwater levels are not particularly close to ground surface. It has also been shown that the overburden sediments in the south of the site are relatively fine grained. The fine-grained nature of the sediments means that drawdown of the water table will not be widespread. Combining the depth to groundwater with the limited extent of the effects of lower the water table means that there will be insignificant effects on the availability of groundwater to vegetation outside the footprint of the quarry.

5.2.2 Controlling Groundwater Discharge

Once the overburden has been removed and the limestone surface exposed and ready to quarry, there will be a back-slope of overburden outside the crest of the quarry. The angle of the back-slope will be determined to prevent slumping and will likely have groundwater discharge at the toe. Initially in the quarry life, this water will probably be controlled by pumping, however relatively soon after it will be expedient to allow it to flow over the quarry crest in a controlled manner south of the working face (advancing to the north). Once inside the quarry, the water will be directed to sumps where sediment will settle. The water in the sumps will be released provided that it meets regulatory criteria.

5.3 Quarry Water Control

It is anticipated that water control within the quarry can be done with a series of sumps on the quarry floor. Given the very low hydraulic conductivity of the limestone at depth, there is no anticipation of the need for dewatering wells.

The sumps on the quarry floor will collect a mixture of:

- Seepage from the limestone;
- Seepage from the overburden that has been allowed to run into the quarry; and
- Direct precipitation.

The water in the sumps will be used in operations such as dust suppression and any excess will be pumped to settling ponds from which it will be released providing that it meets accepted water quality guidelines.

It is estimated that the amount of water being pumped from the quarry would average 900 m^3/d – less any amount used in operations. The majority of this volume would come from precipitation. It is further estimated that the TDS in this water would be in the range of 500 to 1,000 mg/L. The impact of release of this water is discussed in Consultant Report #11, Surface Aquatic Resources.

It is not anticipated that large volumes of saline water will enter the quarry. The low hydraulic conductivity of the limestone, coupled with a low hydraulic gradient means that intergranular flow will be insignificant. Precipitation, inflow of water from overburden and other freshwater sources will be more than sufficient to dilute the salt concentration to acceptable concentrations for discharge. The impact will be insignificant.

Open fractures or similar paths for groundwater movement from the limestone are not frequently encountered in the open pit mines to the north of the Project. There is no reason to believe that these openings would occur at the proposed site. If, in the improbable case that such opening(s) were encountered and salt water entered to quarry in significant volumes, the following mitigations might be undertaken:

- Plug the openings to shut off the flow;

- Transport the saline water for disposal off site; and/or
- Shut down the quarry operations.

All of these options have the end point of mitigating the impact of salt water egress into the quarry. Because there is mitigation, the impact is insignificant.

5.4 Blasting

The limestone will be blasted to facilitate excavation. Holes are drilled into the limestone and loaded with ANFO, which consists of ammonium nitrate and a small amount of diesel fuel. The ensuing explosion turns the ammonium nitrate into nitrogenous gas which breaks up the rock. Occasionally, a small number of the blast holes do not ignite and the unexploded ammonium nitrate is incorporated into the broken rock upon excavation (and its explosive properties are lost). This small amount of ammonium nitrate may become available to be leached by water. This phenomenon has been observed in other mines where rock is blasted with ANFO.

Studies at coal mines in Alberta (Hackbarth Environmental 1999) have shown that nitrate can appear in groundwater and surface water associated with dumps of waste rock. These same studies have showed that the residual nitrate is leached out over a period of approximately 10 years after which concentrations decline to previously-observed values.

Some of the limestone in the quarry may not meet specifications and may become waste rock. This will be used for reclamation and may contain diffuse traces of ammonium nitrate that will subsequently be leached by water, thereby raising the nitrate concentration.

All waste rock will remain in the quarry and therefore any elevated nitrate levels will initially appear within water in the pit. This water will report to the sumps and will be pumped out of the quarry.

The presence of nitrate has been shown to be self-mitigating and the impact is therefore insignificant.

5.5 Fuel Management

Liquid hydrocarbon fuels will be present both in bulk and in the various vehicles used in the operations. The bulk fuel will be stored according to existing regulatory requirements. This involves the use of steel double-walled aboveground storage tanks, typically 500 L in capacity, located on the Project site, outside of the quarry proper. The probability of significant leaks from these types of tanks is very low.

The use of hydrocarbon-fuelled vehicles presents a risk of spills and leaks due to accidents or maintenance failures. This risk is higher than the risk of a leak from a double-walled bulk storage tank.

Hydrocarbon fuels are lighter than water and therefore, they float on water. In addition, the hydrodynamic situation around the quarry is that groundwater is flowing towards it, both laterally and vertically through limestone, which has very low hydraulic conductivity. Under these circumstances, there is virtually no probability that a hydrocarbon spill will enter the groundwater system. A spill will either evaporate or flow to a sump on the quarry floor where it can be recovered.

The impact of a hydrocarbon spill or leak on groundwater quality will be insignificant.

6.0 VALUED ENVIRONMENTAL COMPONENTS

Valued environmental components (VECs) for this Project are as follows:

- Movement of groundwater to and from the Athabasca River;
- Surface water quality from saline groundwater; and
- Quality and quantity of groundwater supplies.

The following sections discuss these VECs and relate them to Table 6.1 which summarizes significance.

6.1 Movement of Groundwater to and from the Athabasca River

The quarry will intercept small volumes of water in the limestone that would have discharged into the Athabasca River. This water, along with other water entering the quarry, will be transferred by pumping to the river provided that it meets regulatory guidelines. The impact has no geographical extent and is insignificant.

With the reclamation of the portions of the quarry, groundwater flow in the overburden and limestone will discharge into the wetland and subsequently into the Athabasca River. There is no impact and it is therefore insignificant.

After the Project's quarry operations are completed in the northern portion of the area and reclamation has taken place, the water levels in the wetland will return to original conditions, subject to the influence of end-pit lakes. This will serve to mitigate any impact that the previous aggregate operations might have created with respect flow from the river to the pit.

6.2 Saline Groundwater on Surface Water

This VEC is also discussed in Consultant Report #11, Surface Aquatic Resources.

It has been stated that the flow of saline groundwater from the limestone into the quarry will be small and will mix with freshwater in the pit and result in an insignificant impact. It has been further stated that in the unlikely event that larger volumes of saline water flow enter the pit, the operational choices are as follows:

- Plug the openings to shut off the flow;
- Transport the saline water for disposal off site; and/or
- Shut down the quarry operations.

These mitigations will reduce the volume of saline water such that mixing with make it acceptable for release.

6.3 Quality and Quantity of Groundwater Supplies

There are no users of groundwater who will be impacted by the drawdown associated with this quarry. There is no anticipation of any potential user wishing to draw upon groundwater in the foreseeable future. Impact on quality and quantity of groundwater supplies is non-existent and therefore insignificant.

Table 6.1 Summary of Impact Significance on Valued Environmental Components

Nature of Potential Impact or Effect	Mitigation/ Protection Plan	Type of Impact or Effect	Geographical Extent of Impact or Effect[1]	Duration of Impact or Effect[2]	Frequency of Impact or Effect[3]	Ability for Recovery from Impact or Effect[4]	Magnitude of Impact or Effect[5]	Project Contribution[6]	Confidence Rating[7]	Probability of Impact or Effect Occurrence[8]	Significance[9]
1. Movement of Groundwater to and from the Athabasca River											
Quantity of water in river	none	Project	none	Nil	none	No effect	Nil	none	High	Nil	insignificant
		Residual	none	Nil	none	No effect	Nil	none	High	Nil	insignificant
		Cumulative	none	Nil	none	No effect	Nil	none	High	Nil	insignificant
2. Saline Groundwater on Surface Water											
See surface water quality report	See text	Project	Local	short	isolated	Rev-st	low	none	high	Nil to low	insignificant
		Residual	None	None	None	No effect	Nil	none	high	None	insignificant
		Cumulative	none	none	none	No effect	Nil	none	high	none	insignificant
3. Quality and Quantity of Groundwater Supplies											
Impact on nearby water wells	none	Project	none	Nil	none	No effect	Nil	none	High	Nil	insignificant
		Residual	none	Nil	none	No effect	Nil	none	High	Nil	insignificant
		Cumulative	none	Nil	none	No effect	Nil	none	High	Nil	insignificant

1. Local, Regional, Provincial, National, Global
2. Short, Long, Extended, Residual
3. Continuous, Isolated, Periodic, Occasional, Accidental, Seasonal
4. Reversible in short term, Reversible in long term, Irreversible - rare
5. Nil, Low, Moderate, High
6. Neutral, Positive, Negative
7. Low, Moderate, High
8. Low, Medium, High
9. Insignificant, Significant

7.0 CUMMULATIVE EFFECTS

There is no interaction of the environmental effects on groundwater of this Project or other projects. There are no cumulative effects.

8.0 CLIMATE CHANGE

Climate change scenarios for Ft McMurray are presented in Table 8.1. These are the accepted climatic indices for this EIA.

The indices of direct interest for hydrogeology are precipitation and temperature. Barrow and Yu (2005) have predicted that annual mean temperature in Ft McMurray will rise by 2.4 degrees, from 0.1 to 2.5 degrees C. They further predict that annual precipitation will rise from 473 mm to 525 mm.

While the increase in temperature may indicate an increase in evaporation and evapotranspiration, the concurrent increase in precipitation would tend to off-set that increase. The net result is that any change is indeterminate and will be insignificant to the hydrogeological regime.

The climate change predictions will have no influence on the predictions of significance made in this document.

Table 8.1 Climate Change Scenarios for Ft McMurray

	Baseline	Global Climate Model HadCM3[3]	Difference between Baseline and Model Projection
Emissions Scenario	-	B2 (b)	-
Scenario Type	-	Median	-
30-Year Period	1961-1990	2020s	-
Annual Mean Temperature (°C)	0.1	2.5	+2.4
Annual Precipitation (mm)	473	525	+52 mm
Growing Degree Days Index (DD5)[1]	1311	1781	35%
Annual Moisture Index (AMI)[2]	2.7	3.3	19%

Source: Barrow & Yu (2005)

9.0 MONITORING

A detailed groundwater monitoring program will be required as a condition of any approval resulting from this Application. The purpose of this section is to outline the considerations that will be incorporated into that ensuing program. These considerations are as follows:

- There are no users of groundwater by means of wells or springs within the area of influence;
- The overburden removal in the south and the approved gravel extraction operations will be removing surficial deposits, including any aquifers;
- The operations do not use significant chemicals or produce any contaminants of concern;
- Hydrocarbon fuel storage is anticipated; and
- The limestone is anticipated to have very low hydraulic conductivity coupled with a hydraulic gradient into the pit.

There are few issues that would form the basis of the need for a groundwater monitoring network. In this case, the existing observation wells installed for purposes of this document will be adequate at the outset. Observation wells in the surficial materials and limestone will be measured and sampled for major ion chemistry once per year. Observation well(s) near fuel storage may be considered as appropriate.

10.0 REFERENCES

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APPENDIX A: OBSERVATION WELL INFORMATION

APPENDIX A-1: BOREHOLE LOGS

Project No: 05-051

Borehole No: 0-01

Drill Method:

Client:

Location: 14-1-90-9 4 04 10 011 9

Subsurface Profile	Sample
Ground surface elevation 242.7 m	
Clay	00
River Sand	1
Limestone	0
Limestone	4
Limestone	10
Limestone	
Limestone	914
	10
	119
Limestone	1
	14
Limestone	1
	19
	19
Limestone	14

Depth scale: 00, 10, 0, 0, 40, 0, 0, 0, 0, 90, 100, 110, 10, 10, 140, 10, 10, 10, 10, 190, 00, 10, 0, 0, 40

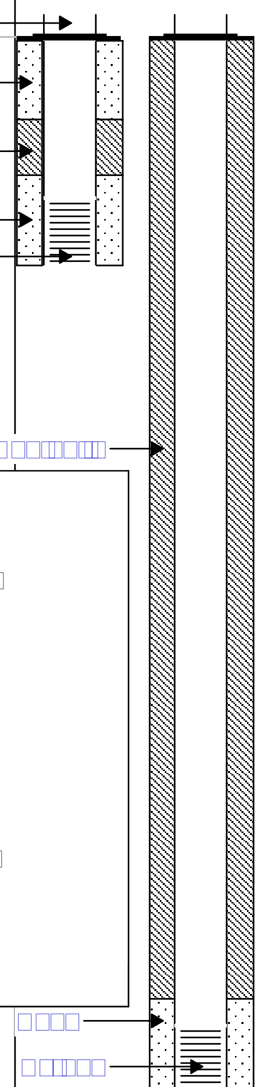
Chart scales: 100, 00, 00, 400; 10, 0, 0, 0, 90

Deep Well (06-01-75)

- 10
- 0 10
- 0 1
- 10 0
- 0
- 4

Shallow Well (06-01-16)

- 0
- 0 0
- 0 1
- 0 1
- 0 1
- 0
- 4 0



Millennium EMS Solutions Ltd.
#208, 4207- 98 Street
Edmonton, AB T6E 5R7

1 0

Project No: 05-051

Borehole No: 0[illegible]-0[illegible]

Drill Method: [illegible]

Client: [illegible]

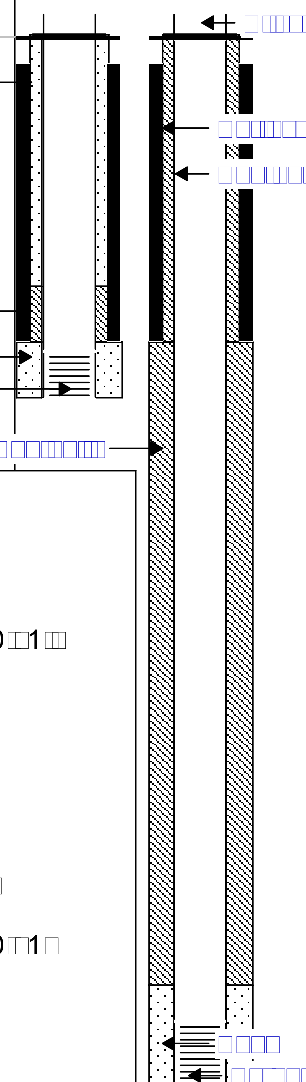
Location: [illegible] 1[illegible]4-[illegible]-90-9[illegible] 4[illegible]4[illegible]4409[illegible]94[illegible]

Subsurface Profile | Sample

Ground surface elevation 246.8 m

Depth	Description	Sample
0[illegible]0	Clay	0[illegible]0[illegible]
1[illegible]0	Clay	
[illegible]0	Sand [illegible]	1[illegible]
[illegible]0	Sand [illegible]	[illegible]0[illegible]
4[illegible]0	Sand [illegible]	4[illegible]
[illegible]0	Sand	[illegible]10[illegible]
[illegible]0	Limestone [illegible]	[illegible]
9[illegible]0		9[illegible]14[illegible]
10[illegible]0		10[illegible]
11[illegible]0		
1[illegible]0	Limestone [illegible]	1[illegible]19[illegible]
14[illegible]0		1[illegible]
1[illegible]0		1[illegible]4[illegible]
1[illegible]0	Limestone [illegible]	1[illegible]
19[illegible]0		1[illegible]9[illegible]
[illegible]0[illegible]0		19[illegible]
[illegible]1[illegible]0	Limestone [illegible]	[illegible]1[illegible]4[illegible]
[illegible]0	[illegible]	[illegible]
[illegible]4[illegible]0		

Scales: 100, [illegible]00, [illegible]00, 400; 10, [illegible]0, [illegible]0, [illegible]0, 90



Deep Well (06-02-75)

- [illegible]0[illegible]
- [illegible]0[illegible]0[illegible]
- [illegible]0[illegible]1[illegible]
- [illegible]0[illegible]0[illegible]
- [illegible]0[illegible]0[illegible]1[illegible]
- [illegible]1[illegible]0[illegible]
- [illegible]4[illegible]4[illegible]

Shallow Well (06-02-26)

- [illegible]9[illegible]
- [illegible]9[illegible]1[illegible]
- [illegible]9[illegible]01[illegible]
- [illegible]01[illegible]49[illegible]
- [illegible]49[illegible]0[illegible]
- [illegible]0[illegible]0[illegible]1[illegible]
- [illegible]1[illegible]
- [illegible]4[illegible]

[illegible]

[illegible]

[illegible]1[illegible]0[illegible]

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Project No: 05-051

Borehole No: □1

Drill Method: □□□□□

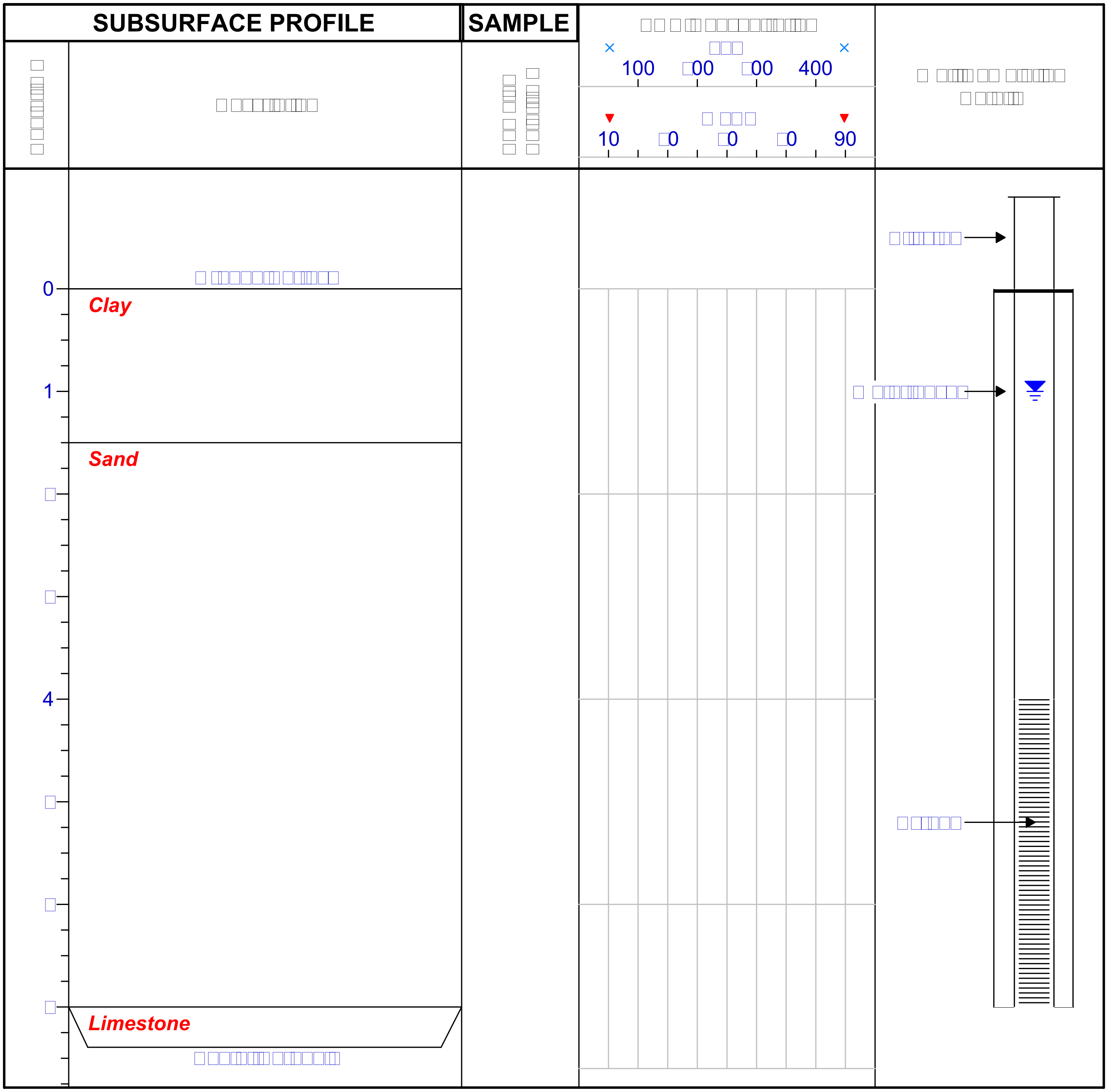
Client: □ □□□□ □□□-□□ □□□□□□□□ □□□□

Location: □□991 □4 □□ □□□□4 □□4 □□□□

Elevation (meters)

-□□□□□□□□ □□□□□□□ □□4 □□41 □□

-□□ □□□□□□□ □□□□□□□□□□ □□44 □4 □□□



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Project No: 05-051

Borehole No:

Drill Method:

Client:

Location: 991 4 0

Elevation (meters)

- 4 0
- 41 4

SUBSURFACE PROFILE		SAMPLE
0	**Clay**	
6	**Sand**	
12.6	**Gravel**	
13	**Limestone**	

Depth scale: 0, 1, 4, 9, 10, 11, 14

Upper scale: 100, 00, 00, 400

Lower scale: 10, 0, 0, 0, 90

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00

Project No: 05-051

Borehole No: [illegible]9

Drill Method: [illegible]

Client: [illegible]

Location: [illegible]991 [illegible]0 [illegible]4 [illegible]4 [illegible]9

Elevation (meters)

- [illegible] 4 [illegible] 0 [illegible]
- [illegible] 41 [illegible] 9 [illegible]

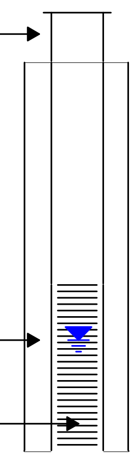
SUBSURFACE PROFILE

Depth (m)	Description
0	Clay
7.3	Sand
8.5	Gravel
12.2	Gravel / Sand
18.3	Limestone

SAMPLE

Scale 1: 100, [illegible]00, [illegible]00, 400

Scale 2: 10, [illegible]0, [illegible]0, [illegible]0, 90



Millennium EMS Solutions Ltd.
#208, 4207-98 Street
Edmonton AB T6E 5R7

[illegible] 00

Project No: 05-051

Borehole No: [illegible]1

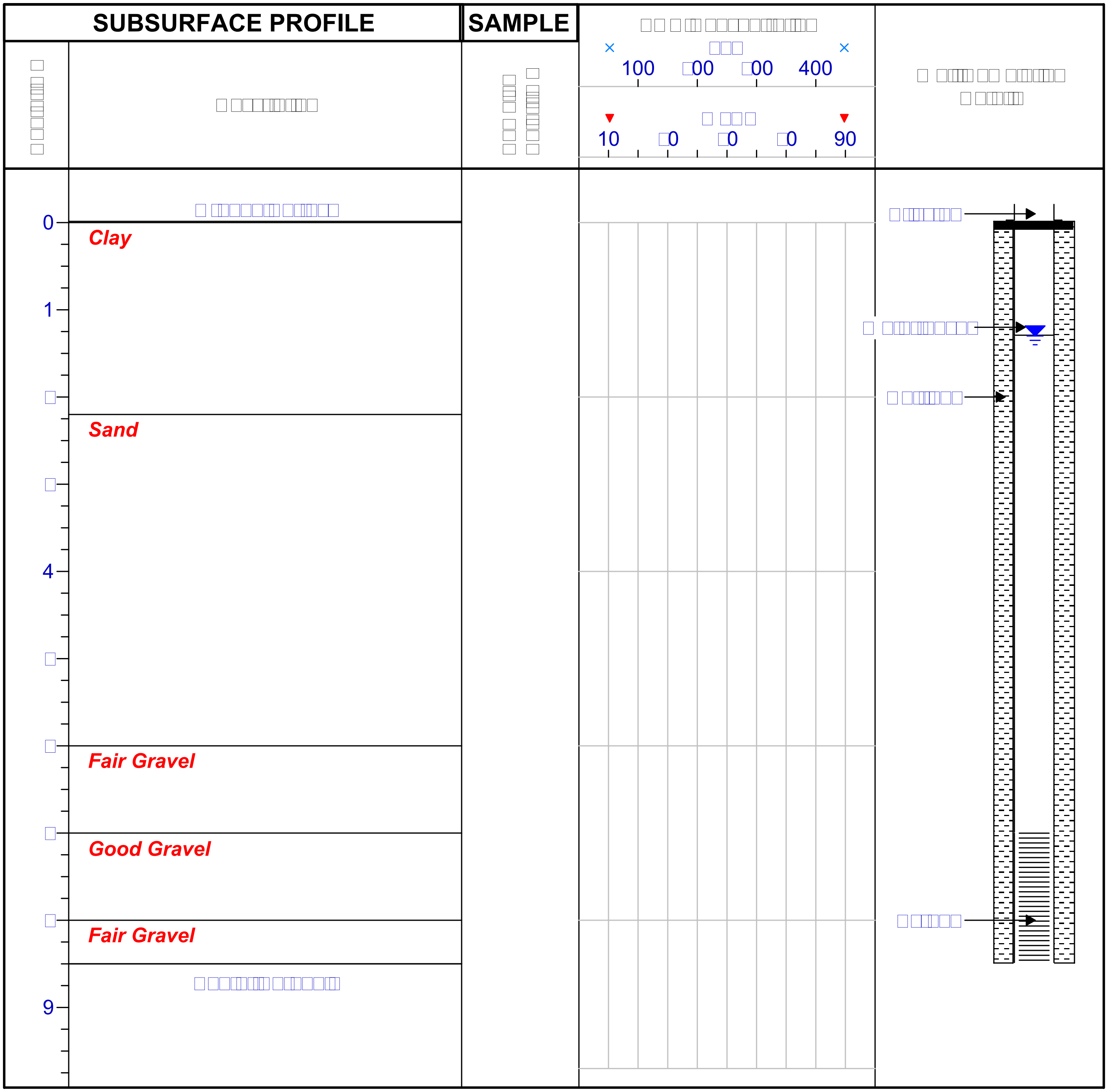
Drill Method: [illegible]

Client: [illegible]

Location: [illegible]9[illegible]00[illegible]4[illegible]

Elevation (meters)

- [illegible] 44 [illegible] 9 [illegible]
- [illegible] 4 [illegible] 9 [illegible]



[illegible]

[illegible]

[illegible] 1 [illegible] 00 [illegible]

Millennium EMS Solutions Ltd.
#208, 4207-98 Street
Edmonton AB T6E 5R7

Project No: 05-051

Borehole No:

Drill Method:

Client:

Location: 9 04 4 4

Elevation (meters)

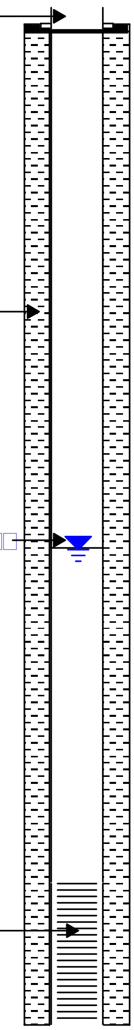
- 4

- 41

SUBSURFACE PROFILE		SAMPLE		
0	*Clay*			
1				
4				
9	*Fair Gravel*			
10				
11	*Limestone*			

Scale: × 100 00 00 400 ×

Scale: ▼ 10 0 0 0 90 ▼



1 00

Millennium EMS Solutions Ltd.
#208, 4207-98 Street
Edmonton AB T6E 5R7

Project No: 05-051

Borehole No: [illegible]1

Drill Method: [illegible]

Client: [illegible]

Location: [illegible]9 [illegible]4 [illegible]4 [illegible]

Elevation (meters)

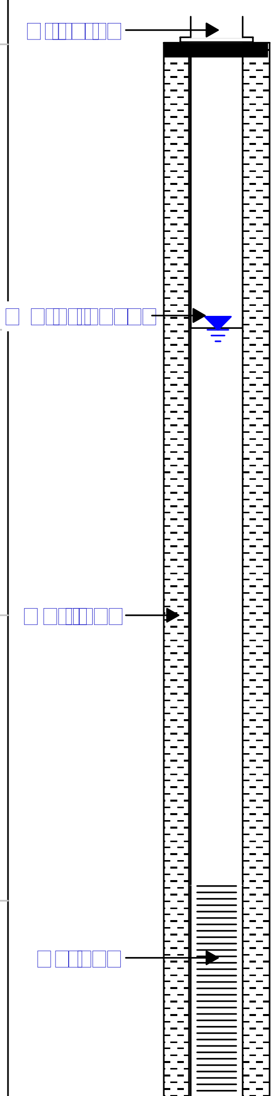
- [illegible]4 [illegible]4 [illegible]
- [illegible]4 [illegible]

SUBSURFACE PROFILE

SAMPLE

Depth (m)	Description
0	Clay
1	
4	Sand
	Poor Gravel

Scale ticks: × 100, [illegible]00, [illegible]00, 400 ×; ▼ 10, [illegible]0, [illegible]0, [illegible]0, 90 ▼



[illegible] 1 [illegible] 00 [illegible]

Millennium EMS Solutions Ltd.
#208, 4207-98 Street
Edmonton AB T6E 5R7

Project No: 05-051

Borehole No: [illegible]

Drill Method: [illegible]

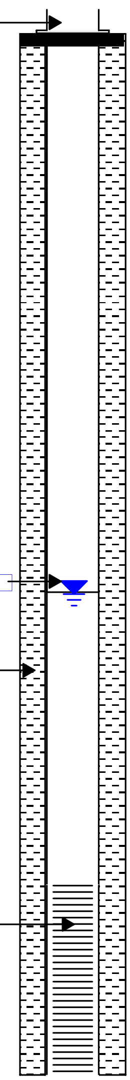
Client: [illegible]

Location: [illegible]

Elevation (meters)

- [illegible] 4 [illegible]
- [illegible] 41 [illegible]

SUBSURFACE PROFILE		SAMPLE		
Depth	Description		100 · 400 / 10 · 90	
	Clay			
	Sand			
	Poor Gravel			
	Fair Gravel			



Millennium EMS Solutions Ltd.
#208, 4207-98 Street
Edmonton AB T6E 5R7

[illegible] 1 [illegible] 00

Project No: 05-051

Borehole No:

Drill Method:

Client:

Location: 9 9 4 4

Elevation (meters)

- 4 0

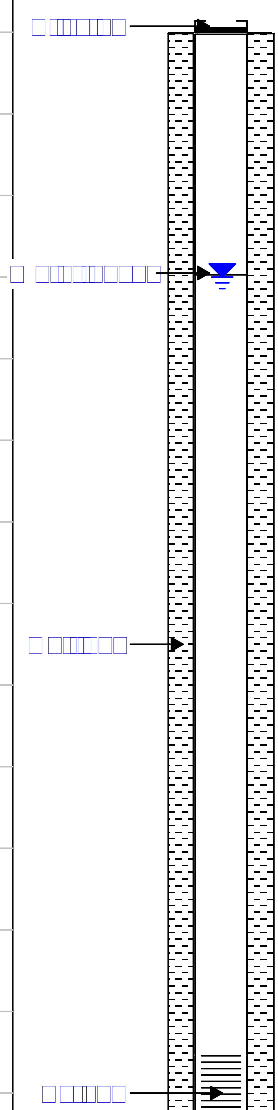
- 4 19

SUBSURFACE PROFILE	SAMPLE

100 00 00 400

10 0 0 0 90

Depth	Soil
0	Clay
5.5	Sand
9.5	Fair Gravel
12	Sand
14.5	Fari Gravel
15.5	Sand
21.5	Good Gravel
27.5	Limestone



Millennium EMS Solutions Ltd.
#208, 4207-98 Street
Edmonton AB T6E 5R7

1 00

Project No: 05-051

Borehole No:

Drill Method:

Client: -

Location: 9 90 4 9 9

Elevation (meters)

- 44

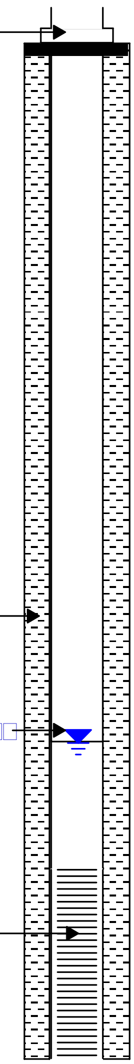
- 4

SUBSURFACE PROFILE	SAMPLE		
		100 00 00 400 / 10 0 0 0 90	

Depth scale: 0, 1, 4

Clay

Poor Gravel



Millennium EMS Solutions Ltd.
#208, 4207-98 Street
Edmonton AB T6E 5R7

1 00

Project No: 05-051

Borehole No: 1

Drill Method:

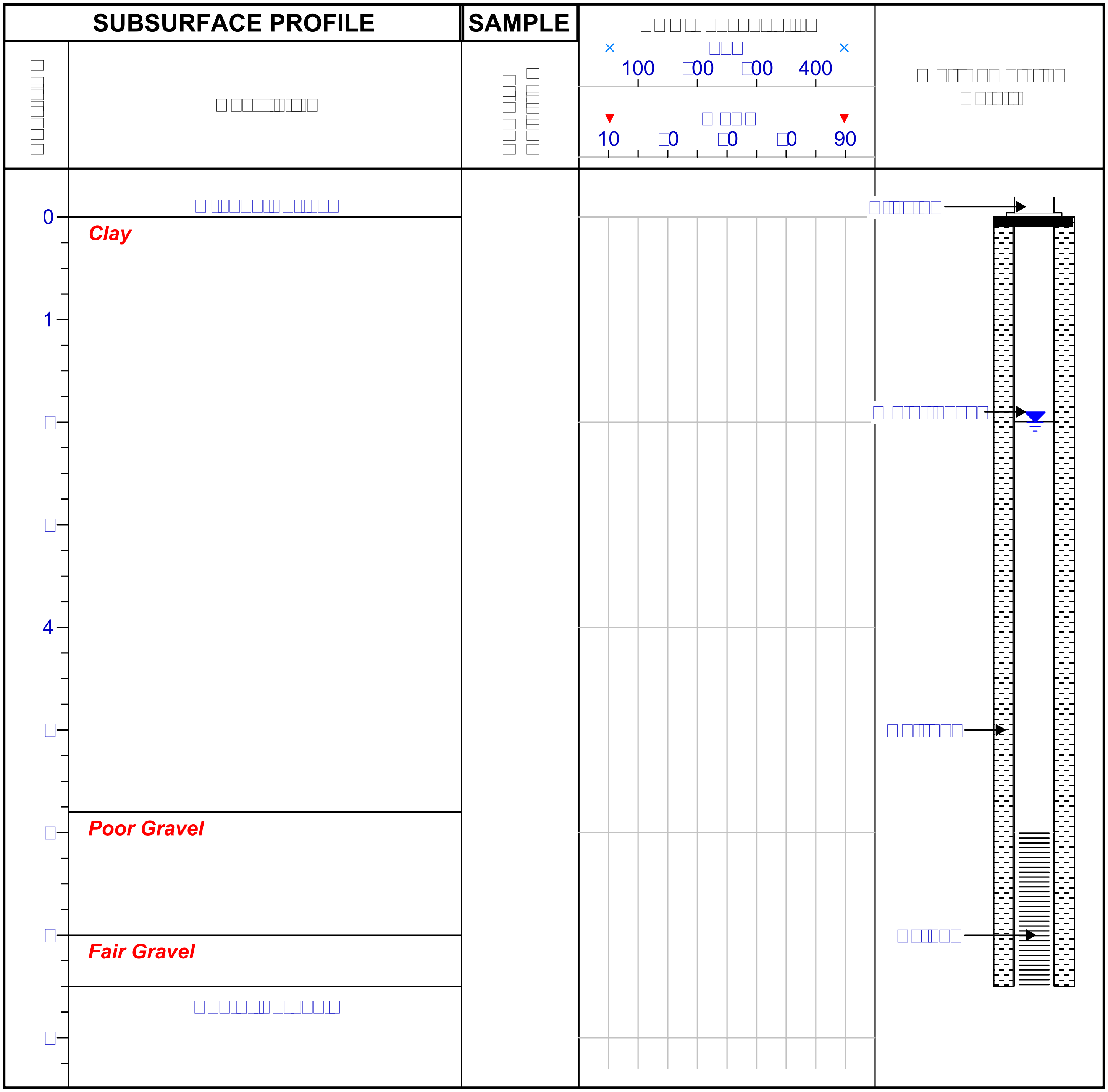
Client:

Location: 9 4 0

Elevation (meters)

- 0

- 0 4



1 00

Millennium EMS Solutions Ltd.
#208, 4207-98 Street
Edmonton AB T6E 5R7

Project No: 05-051

Borehole No: [illegible]4

Drill Method: [illegible]

Client: [illegible]

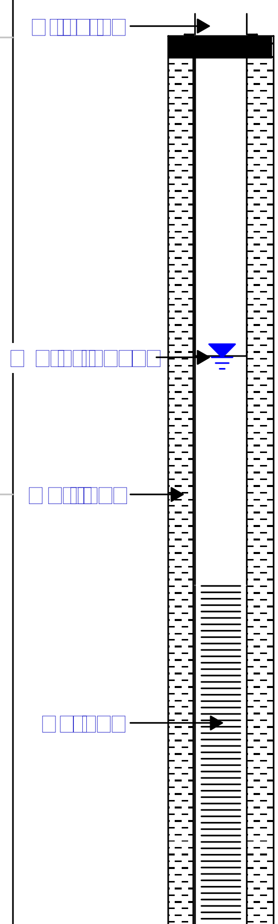
Location: [illegible]9[illegible]4[illegible]404[illegible]

Elevation (meters)

-[illegible]4[illegible]4[illegible]

-[illegible]4[illegible]9[illegible]

SUBSURFACE PROFILE		SAMPLE		
[illegible]	[illegible]	[illegible]	[illegible] 100 [illegible]00 [illegible]00 400 / [illegible] 10 [illegible]0 [illegible]0 [illegible]0 90	[illegible]
0	[illegible]			
	Clay			
1				
[illegible]				
	Poor Gravel			
[illegible]				
4	[illegible]			



[illegible]

[illegible]

[illegible]1[illegible]00[illegible]

Millennium EMS Solutions Ltd.
#208, 4207-98 Street
Edmonton AB T6E 5R7

Project No: 05-051

Borehole No:

Drill Method:

Client:

Location: 94 9 4 9

Elevation (meters)

- 1 49

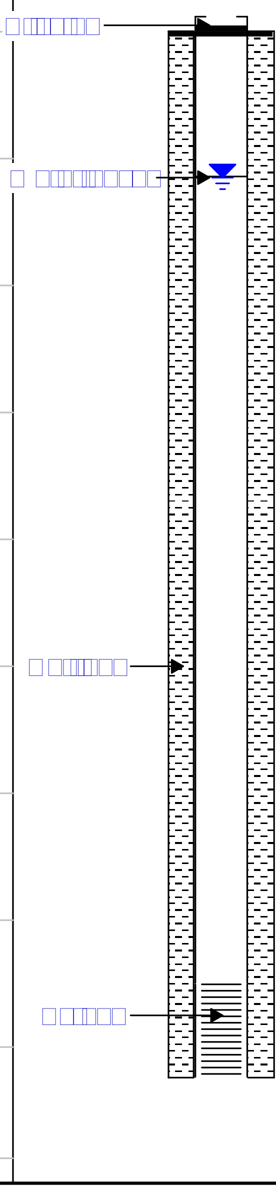
- 0

SUBSURFACE PROFILE	SAMPLE		
		100 00 00 400 / 10 0 0 0 90	

Depth: 0, 1, 4, 9, 10, 11, 1, 1, 14, 1, 1, 1

Clay

Poor Gravel



Millennium EMS Solutions Ltd.
#208, 4207-98 Street
Edmonton AB T6E 5R7

1 00

Project No: 05-051

Borehole No: 1

Drill Method:

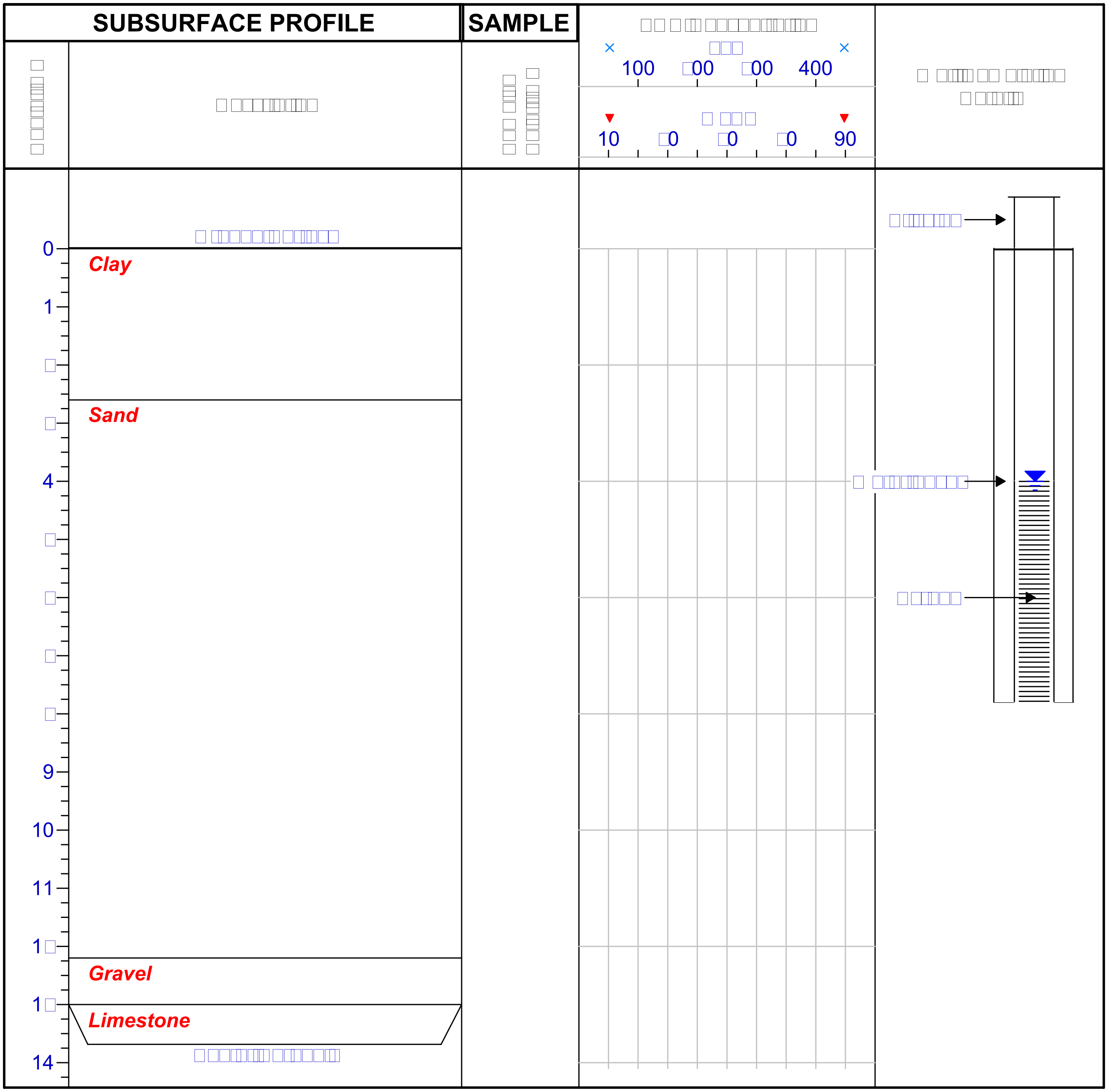
Client:

Location: 00 00 4

Elevation (meters)

- 4 0

- 44



Millennium EMS Solutions Ltd.
#208, 4207-98 Street
Edmonton AB T6E 5R7

Project No: 05-051

Borehole No:

Drill Method:

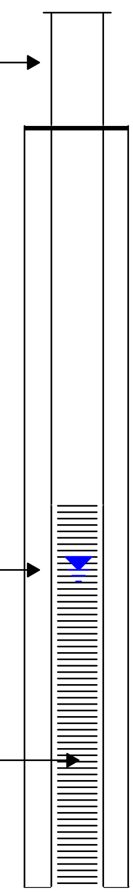
Client:

Location: 0049 4 0

Elevation (meters)

- 44 01
- 4 0

SUBSURFACE PROFILE		SAMPLE		
			100 00 00 400 / 10 0 0 0 90	
0	Soil			
	Clay			
1	Sand			
4				
	Gravel			
	Limestone			



Millennium EMS Solutions Ltd.
#208, 4207-98 Street
Edmonton AB T6E 5R7

00

Project No: 05-051

Borehole No:

Drill Method:

Client:

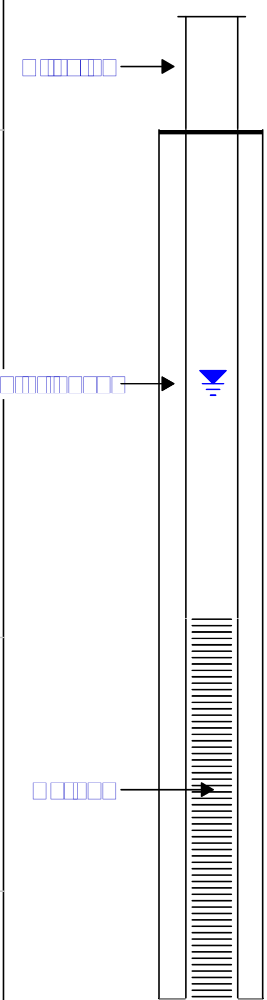
Location: 0049 4 4

Elevation (meters)

- 4

- 41

SUBSURFACE PROFILE		SAMPLE		
			100 00 00 400	
			10 0 0 0 90	
0	***Soil***			
	Clay			
1	***Sand***			
	Gravel			
4				
	Limestone			



4 00

Millennium EMS Solutions Ltd.
#208, 4207-98 Street
Edmonton AB T6E 5R7

Project No: 05-051

Borehole No: [illegible]4

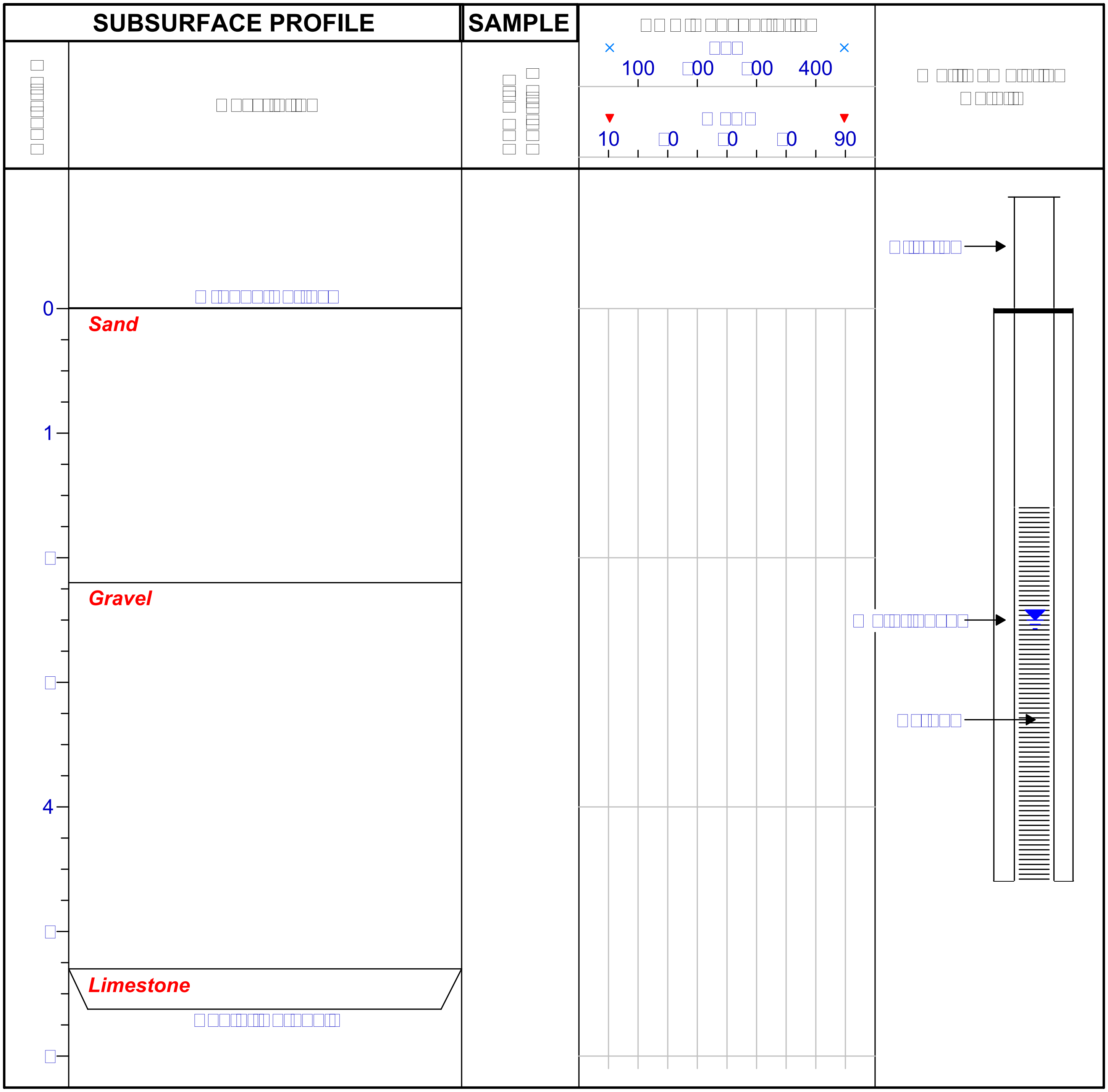
Drill Method: [illegible]

Client: [illegible]

Location: [illegible]00 [illegible]4 [illegible]1 [illegible]

Elevation (meters)

- [illegible] [illegible]4 [illegible]09 [illegible]
- [illegible] [illegible]4 [illegible]0 [illegible]



[illegible]

[illegible]

[illegible]00 [illegible]

Millennium EMS Solutions Ltd.
#208, 4207-98 Street
Edmonton AB T6E 5R7

Project No: 05-051

Borehole No:

Drill Method:

Client:

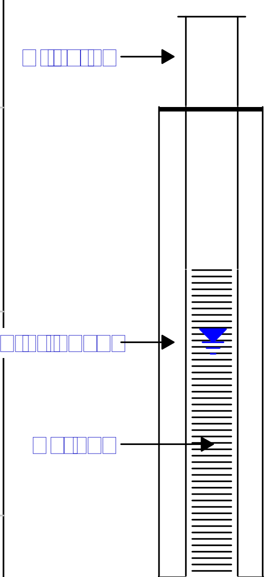
Location: 0044 4 1

Elevation (meters)

- 4 09

- 4 0

SUBSURFACE PROFILE		SAMPLE		
			100 00 00 400 / 10 0 0 0 90	
0	Clay			
1	Sand			
	Gravel			
4				
9				
10	Limestone			



Millennium EMS Solutions Ltd.
#208, 4207-98 Street
Edmonton AB T6E 5R7

00

Project No: 05-051

Borehole No:

Drill Method:

Client:

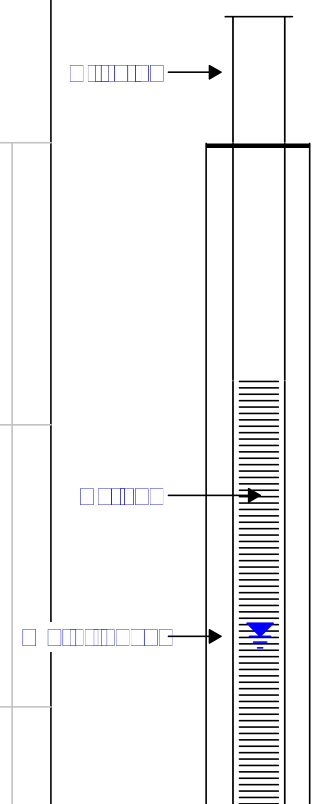
Location: 0049 4 1

Elevation (meters)

- 4 9

- 4 9

SUBSURFACE PROFILE		SAMPLE		
			100 00 00 400 / 10 0 0 0 90	
0	***Clay***			
1	***Sand***			
	Gravel			
4				
	Limestone			



00

Millennium EMS Solutions Ltd.
#208, 4207-98 Street
Edmonton AB T6E 5R7

Project No: 05-051

Borehole No:

Drill Method:

Client:

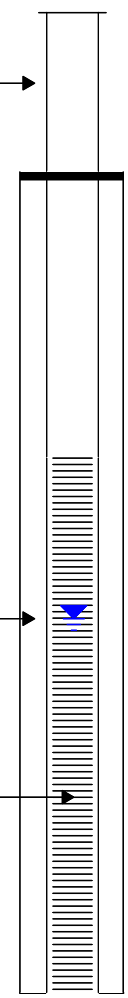
Location: 0049 4 1

Elevation (meters)

- [illegible] 4 09
- [illegible] 4 04

SUBSURFACE PROFILE		SAMPLE		
			100 00 00 400	
			10 0 0 0 90	

Depth	Description
0	*Clay*
1	*Sand*
	Gravel
4	*Limestone*



Millennium EMS Solutions Ltd.
#208, 4207-98 Street
Edmonton AB T6E 5R7

00

Project No: 05-051

Borehole No:

Drill Method:

Client: -

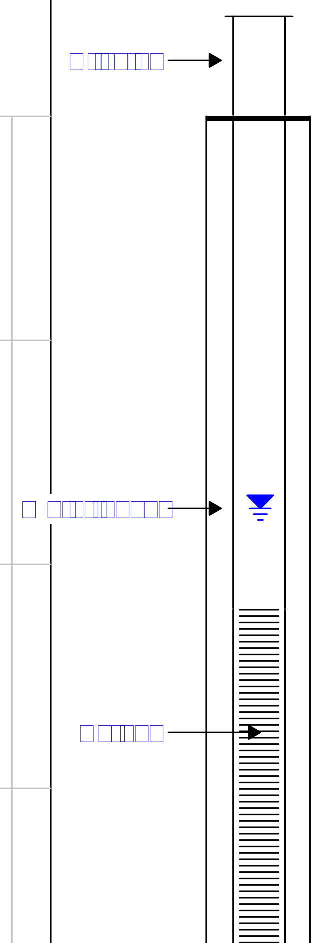
Location: 00499 4 0

Elevation (meters)

- 41 19

- 40 0

SUBSURFACE PROFILE		SAMPLE		
			100 00 00 400	
			10 0 0 0 90	
0	Clay			
1				
4				
	Gravel			
9	Limestone			



Millennium EMS Solutions Ltd.
#208, 4207-98 Street
Edmonton AB T6E 5R7

4 00

Project No: 05-051

Borehole No: 9

Drill Method:

Client: -

Location: 00499 4

Elevation (meters)

- 40

- 9 1

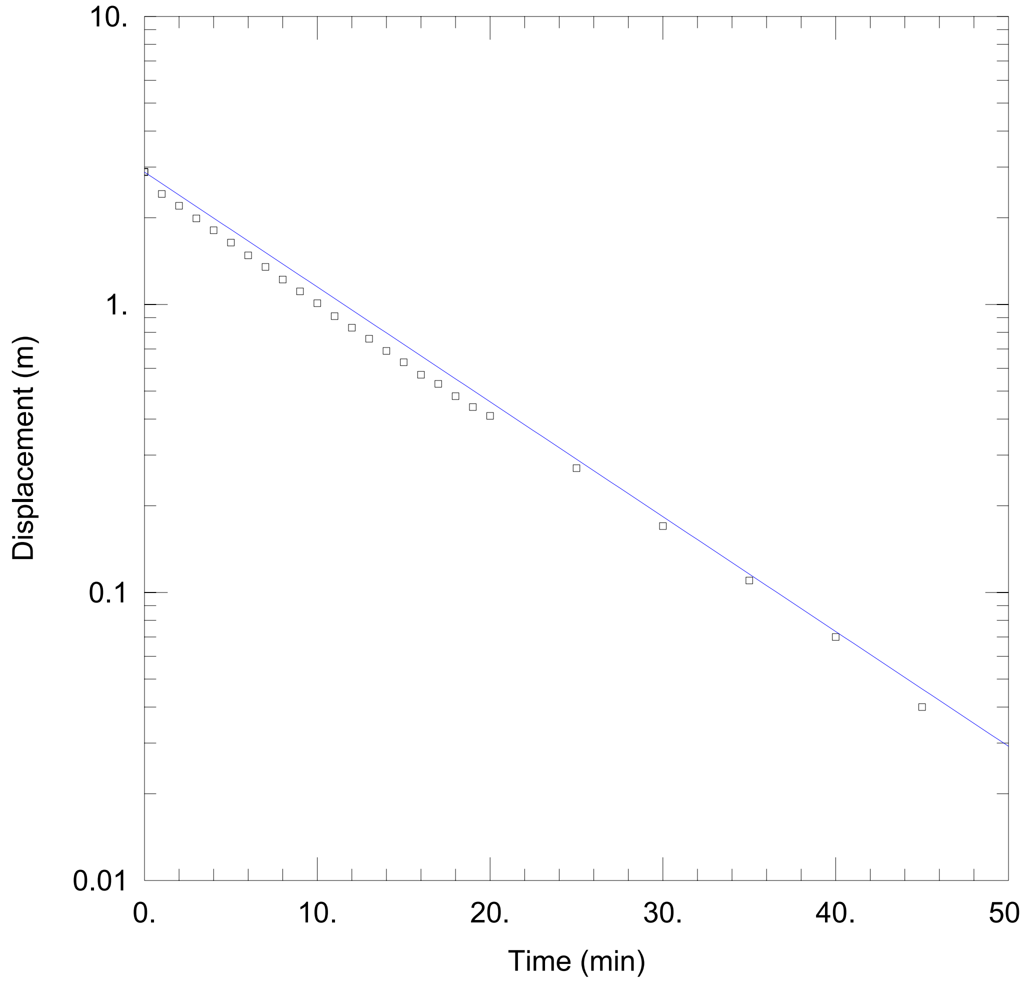
SUBSURFACE PROFILE	SAMPLE	100 / 00 / 00 / 400 10 / 0 / 0 / 0 / 90	
Clay (0)			
Sand (4)			
Gravel			
Gravel (10)			
Sand (14)			
Limestone			

Depth scale: 0, 1, 4, 9, 10, 11, 1, 1, 14, 1, 1, 1

00

Millennium EMS Solutions Ltd.
#208, 4207-98 Street
Edmonton AB T6E 5R7

APPENDIX A-2: HYDRAULIC CONDUCTIVITY TESTING



SLUG TEST - B1

Data Set: I:\...\B1.aqt
Date: 03/26/07 Time: 11:16:15

PROJECT INFORMATION

Company: Graymont
Project: 05-051
Test Date: January 31, 2007

AQUIFER DATA

Saturated Thickness: 5.26 m Anisotropy Ratio (Kz/Kr): 1.

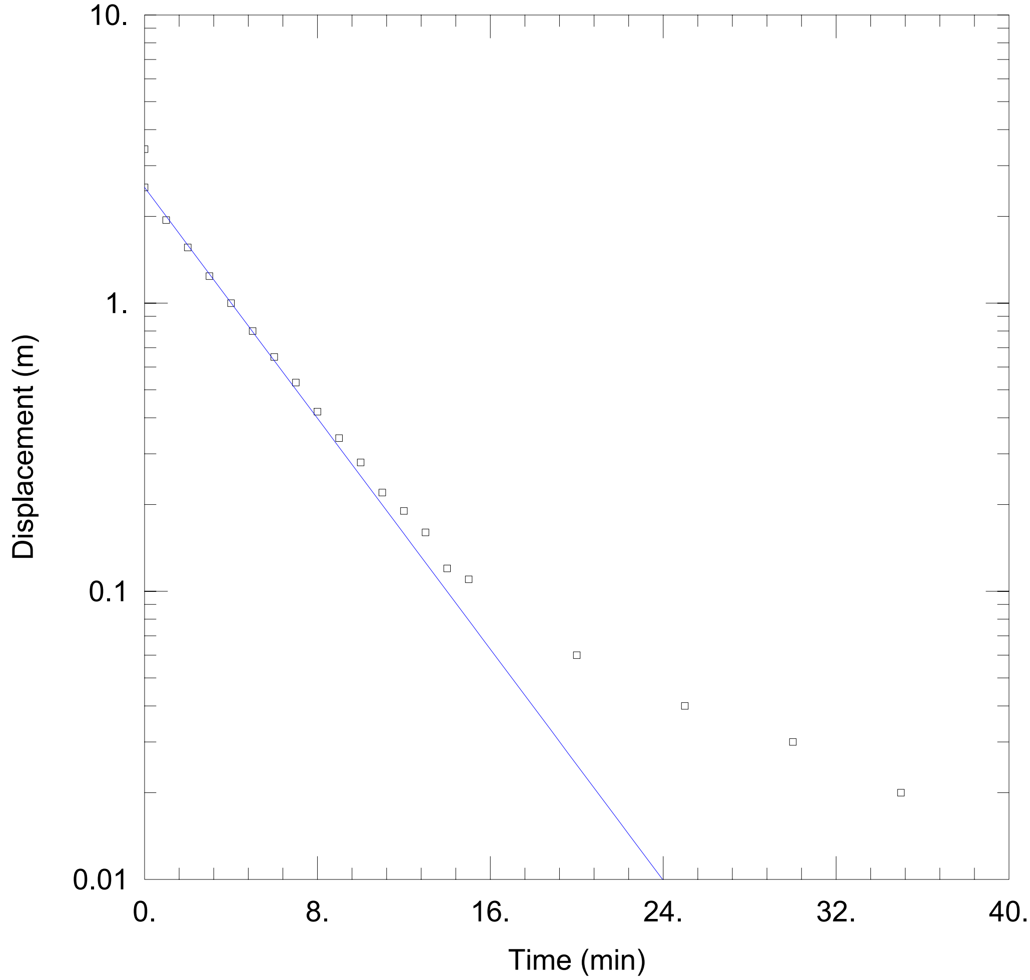
WELL DATA (B1)

Initial Displacement: 2.89 m Static Water Column Height: 2.97 m
Total Well Penetration Depth: 5.26 m Screen Length: 3.05 m
Casing Radius: 0.0254 m Wellbore Radius: 0.0762 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Hvorslev

K = 7.094E-5 cm/sec y0 = 2.88 m



SLUG TEST - B5

Data Set: I:\...\B5.aqt
Date: 03/26/07
Time: 11:15:22

PROJECT INFORMATION

Company: Graymont
Project: 05-051
Test Date: January 31, 2007

AQUIFER DATA

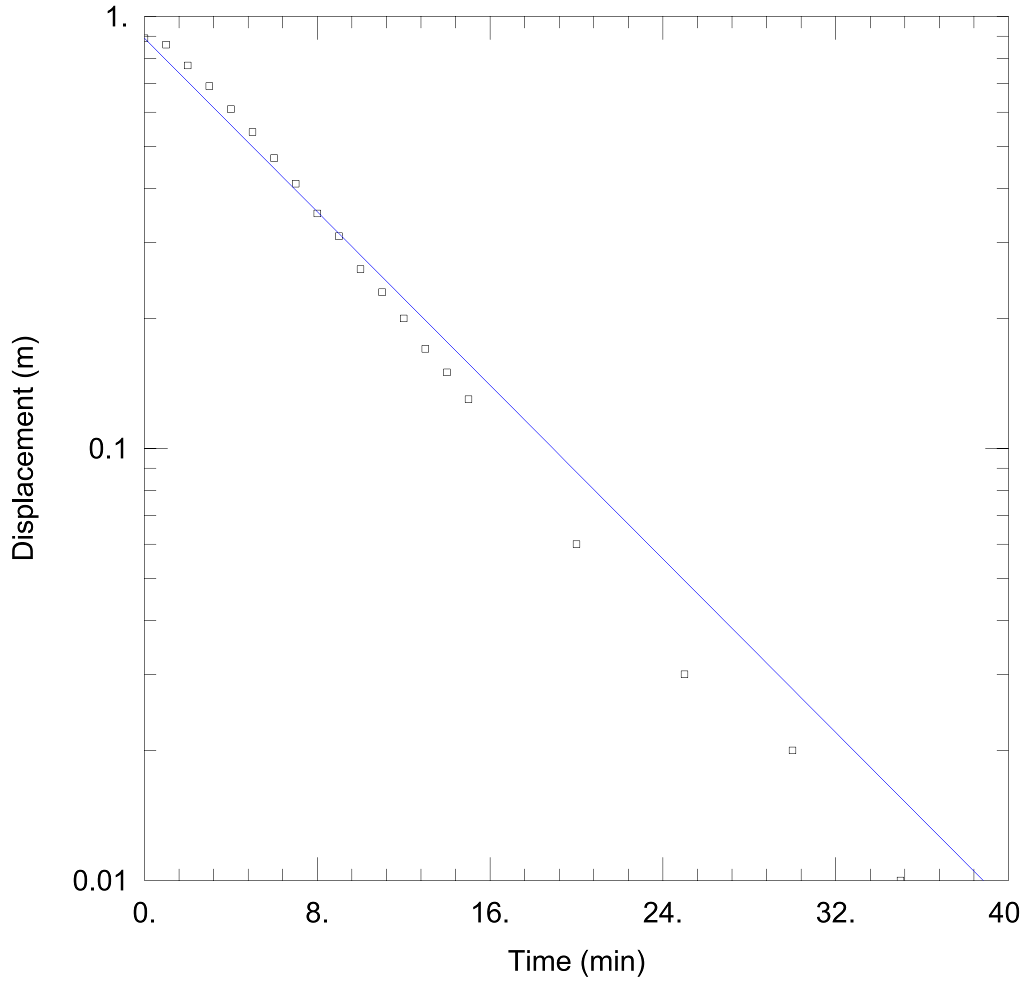
Saturated Thickness: 4.82 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (B5)

Initial Displacement: 3.42 m
Total Well Penetration Depth: 4.82 m
Casing Radius: 0.0254 m
Static Water Column Height: 2.94 m
Screen Length: 3.05 m
Wellbore Radius: 0.0762 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev
K = 0.0001782 cm/sec
y0 = 2.52 m



SLUG TEST - B9

Data Set: I:\...\B9.aqt
Date: 03/26/07
Time: 11:17:01

PROJECT INFORMATION

Company: Graymont
Project: 05-051
Test Date: January 31, 2007

AQUIFER DATA

Saturated Thickness: 1.46 m
Anisotropy Ratio (Kz/Kr): 1.

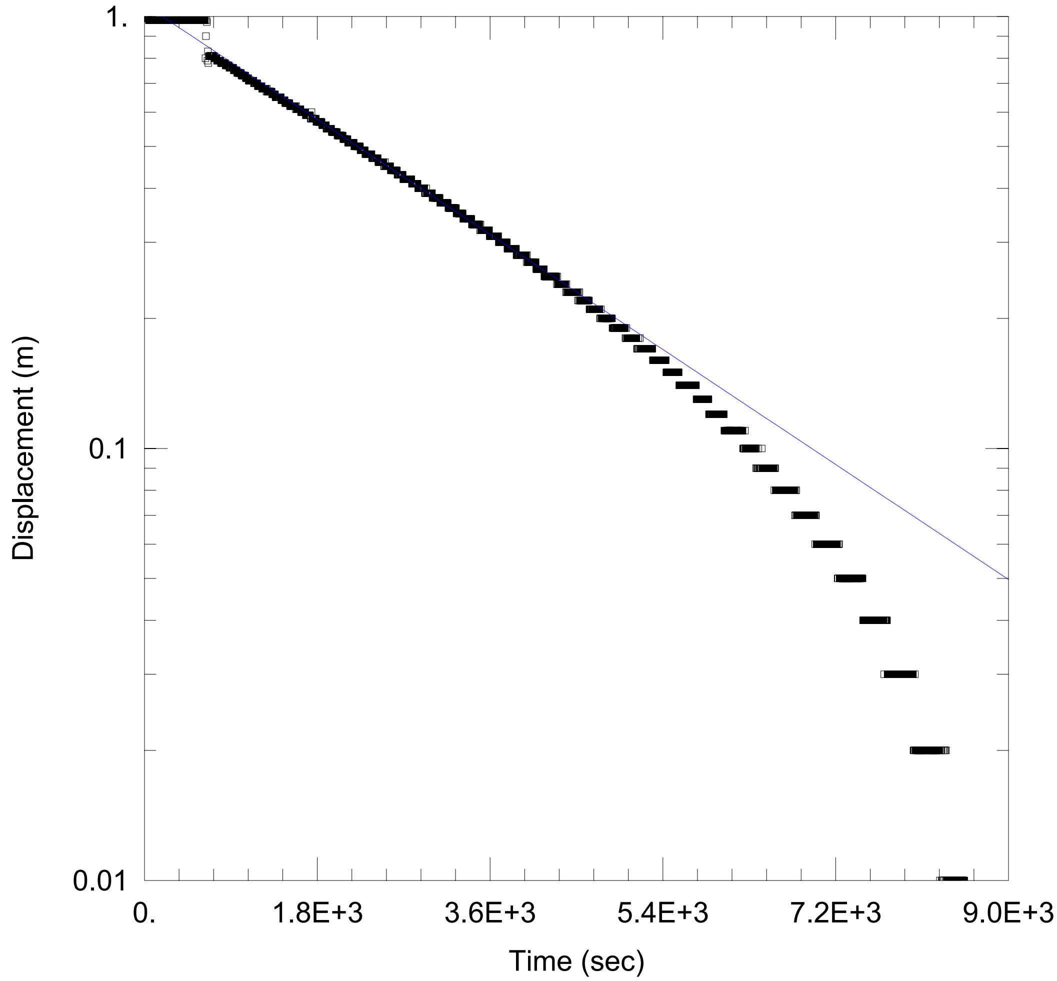
WELL DATA (B9)

Initial Displacement: 6.53 m
Total Well Penetration Depth: 1.46 m
Casing Radius: 0.0254 m
Static Water Column Height: 0.57 m
Screen Length: 3.05 m
Wellbore Radius: 0.0762 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 8.93E-5 cm/sec
y0 = 0.89 m



C1

Data Set: I:\...\C1.aqt
Date: 07/21/06
Time: 08:58:51

PROJECT INFORMATION

Client: Graymont - Parson's Creek
Project: 05-051
Test Well: C1

AQUIFER DATA

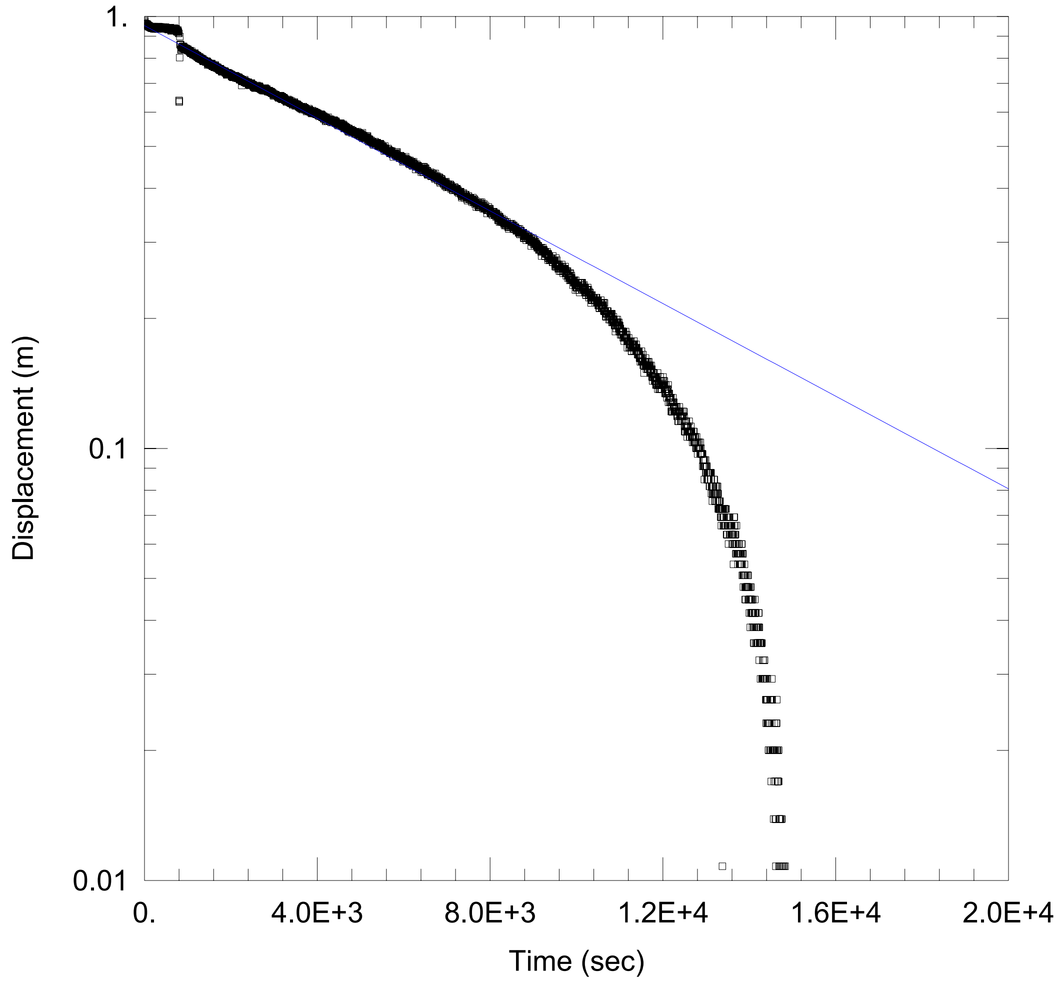
Saturated Thickness: 6.43 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (C1)

Initial Displacement: 5.46 m
Total Well Penetration Depth: 6.43 m
Casing Radius: 0.0508 m
Static Water Column Height: 6.43 m
Screen Length: 3.05 m
Wellbore Radius: 0.0508 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev
K = 6.896E-7 m/sec
y0 = 1.065 m



C4

Data Set: I:\...\C4.aqt
Date: 07/21/06
Time: 09:02:29

AQUIFER DATA

Saturated Thickness: 1.99 m
Anisotropy Ratio (Kz/Kr): 1.

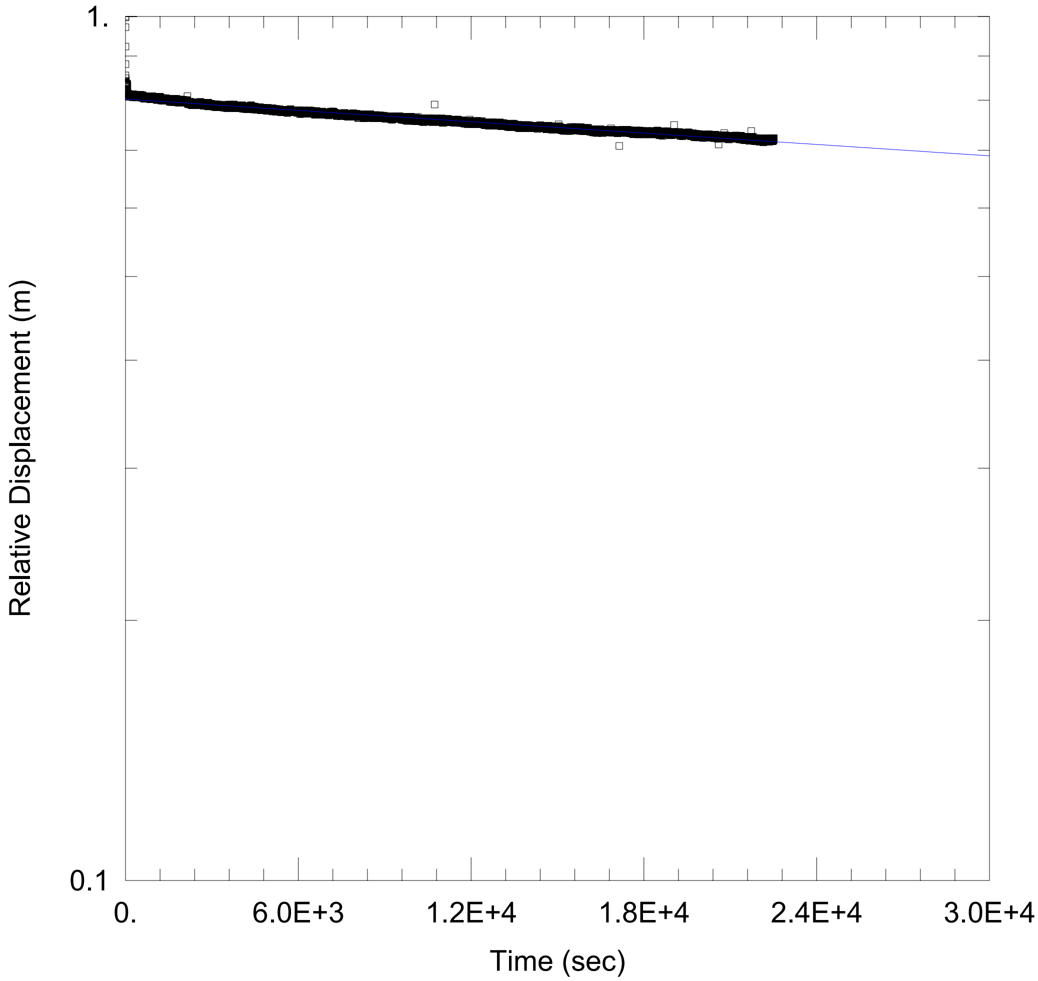
WELL DATA (C4)

Initial Displacement: 1.3 m
Total Well Penetration Depth: 1.99 m
Casing Radius: 0.0508 m
Static Water Column Height: 1.99 m
Screen Length: 3.05 m
Wellbore Radius: 0.0508 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 2.501E-7 m/sec
y0 = 0.9523 m



D1

Data Set: I:\...\D1.aqt
Date: 07/21/06
Time: 09:03:44

PROJECT INFORMATION

Company: MEMS
Client: Graymont
Project: 05-051
Location: Parson's Creek

AQUIFER DATA

Saturated Thickness: 4. m
Anisotropy Ratio (Kz/Kr): 1.

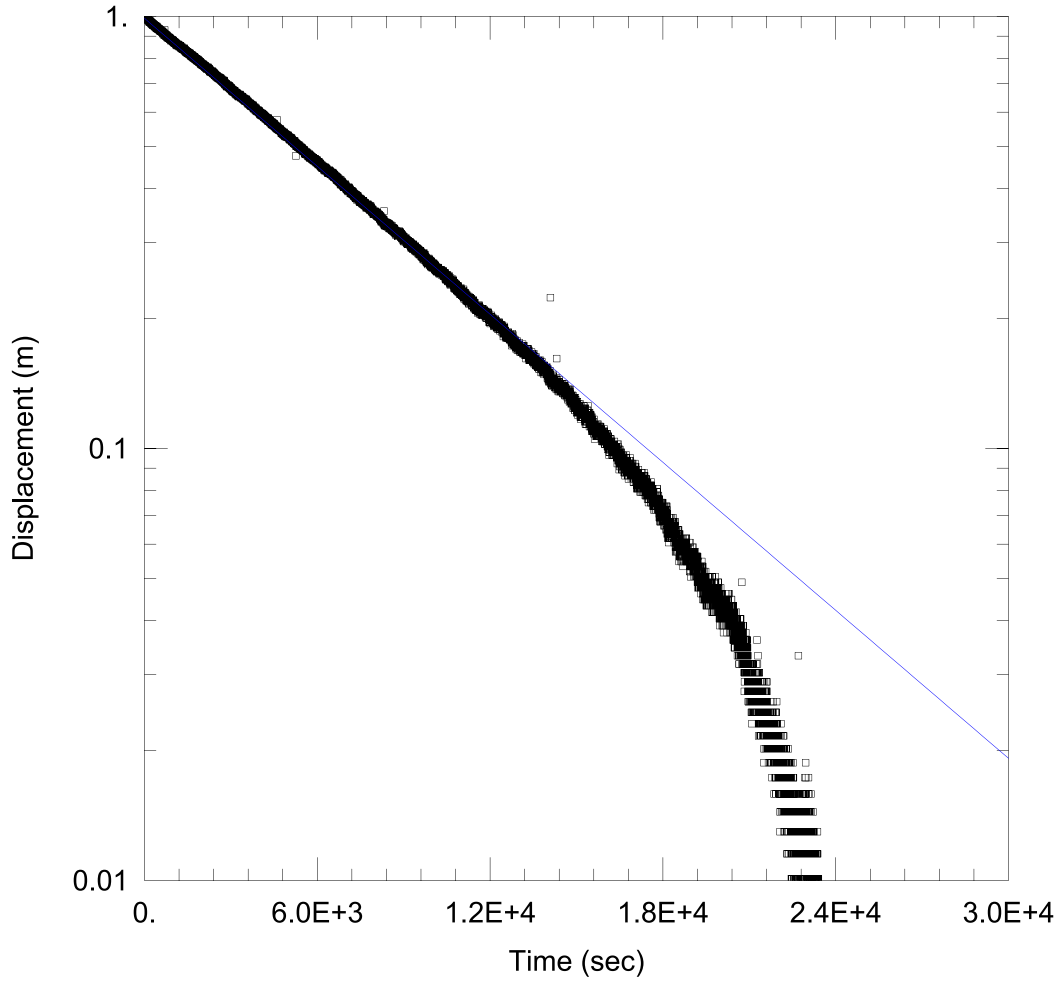
WELL DATA (OW 1)

Initial Displacement: 2.946 m
Total Well Penetration Depth: 5.35 m
Casing Radius: 0.0504 m
Static Water Column Height: 5.35 m
Screen Length: 1.5 m
Wellbore Radius: 0.1 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 1.159E-8 m/sec
y0 = 0.8024 m



WELL TEST ANALYSIS

Data Set: I:\...\D3.aqt
Date: 07/21/06
Time: 10:07:32

AQUIFER DATA

Saturated Thickness: 1. m
Anisotropy Ratio (Kz/Kr): 1.

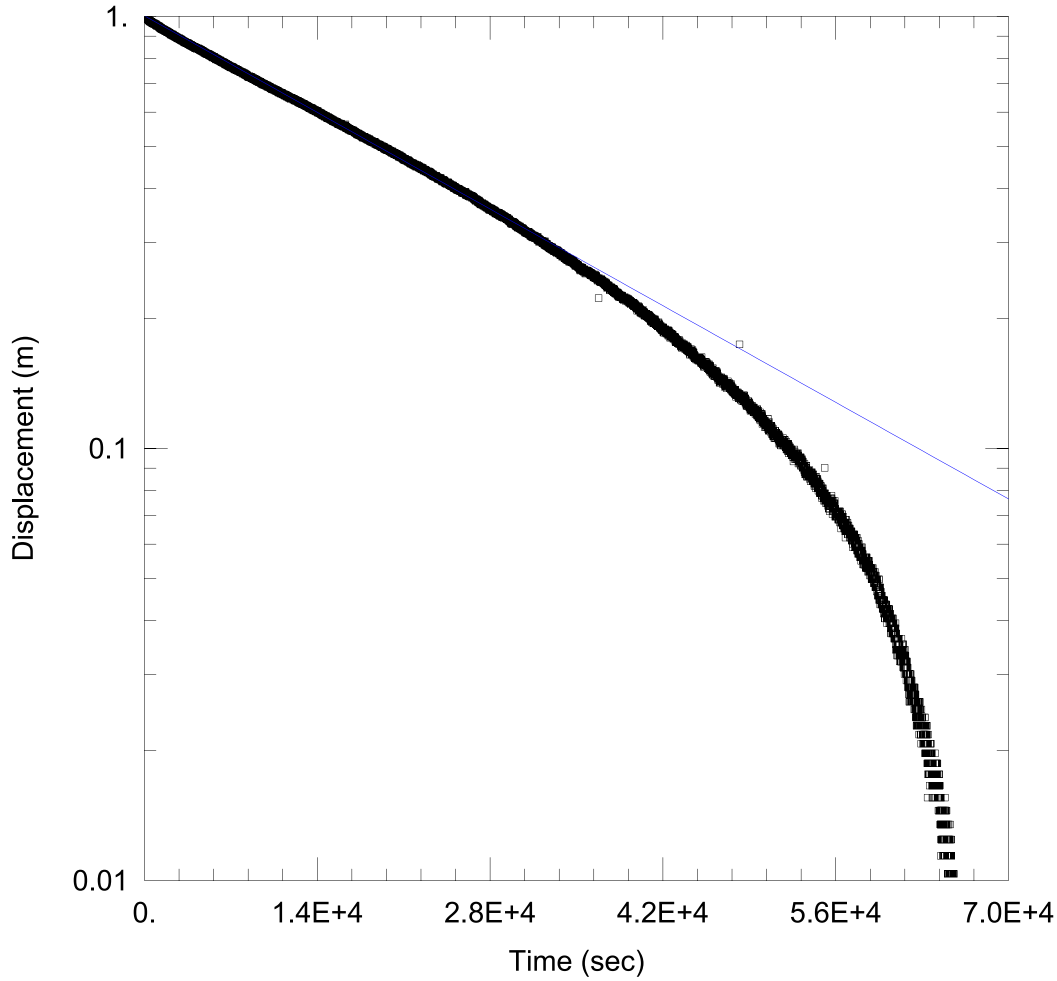
WELL DATA (D3)

Initial Displacement: 1. m
Static Water Column Height: 1. m
Total Well Penetration Depth: 1. m
Screen Length: 1. m
Casing Radius: 0.1 m
Wellbore Radius: 0.1 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 1.971E-6 m/sec
y0 = 0.99 m



H1

Data Set: I:\...\H1.aqt
Date: 07/21/06 Time: 09:05:18

AQUIFER DATA

Saturated Thickness: 5.66 m Anisotropy Ratio (Kz/Kr): 1.

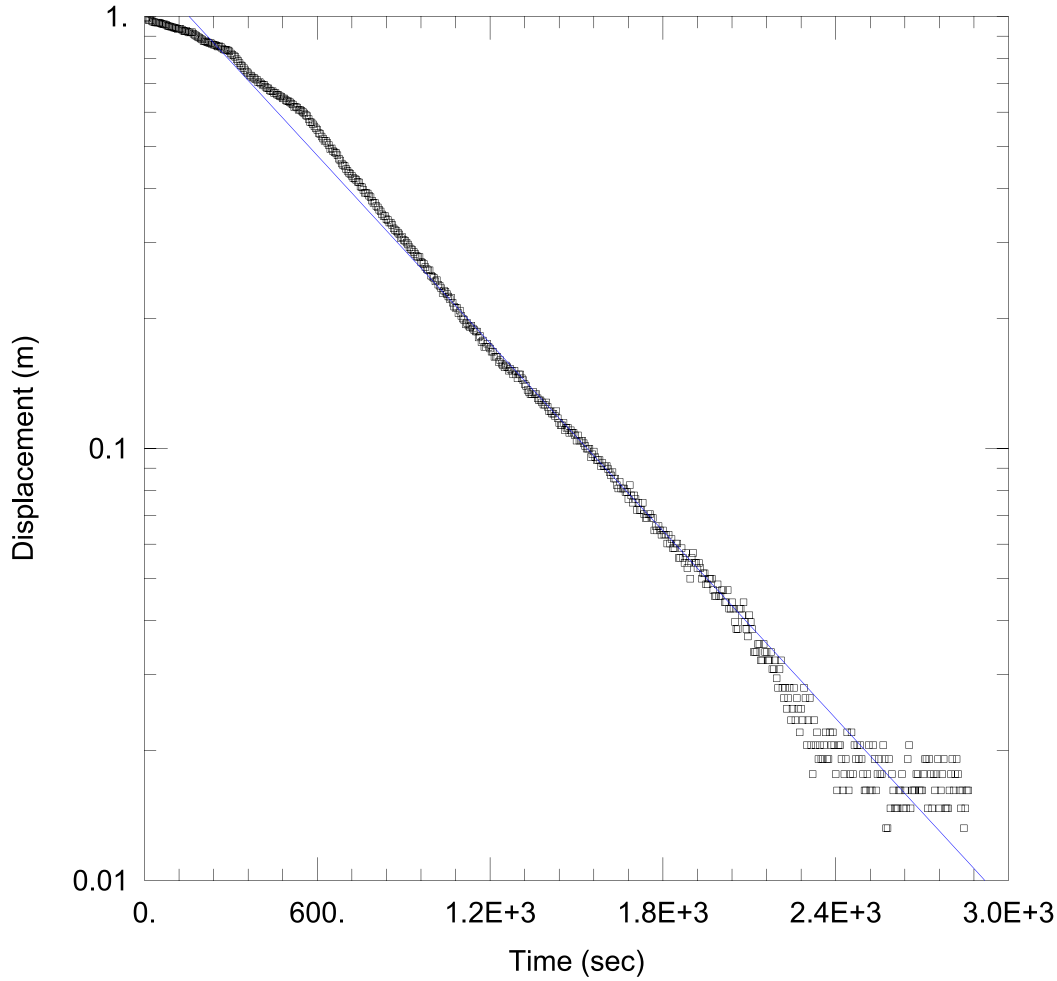
WELL DATA (OW 1)

Initial Displacement: 3.86 m
Total Well Penetration Depth: 5.66 m
Casing Radius: 0.0508 m
Static Water Column Height: 5.66 m
Screen Length: 3.05 m
Wellbore Radius: 0.0508 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Hvorslev

K = 7.453E-8 m/sec y0 = 1.004 m



H4

Data Set: I:\...\H4.aqt
Date: 07/21/06
Time: 09:05:43

AQUIFER DATA

Saturated Thickness: 4.2 m
Anisotropy Ratio (Kz/Kr): 1.

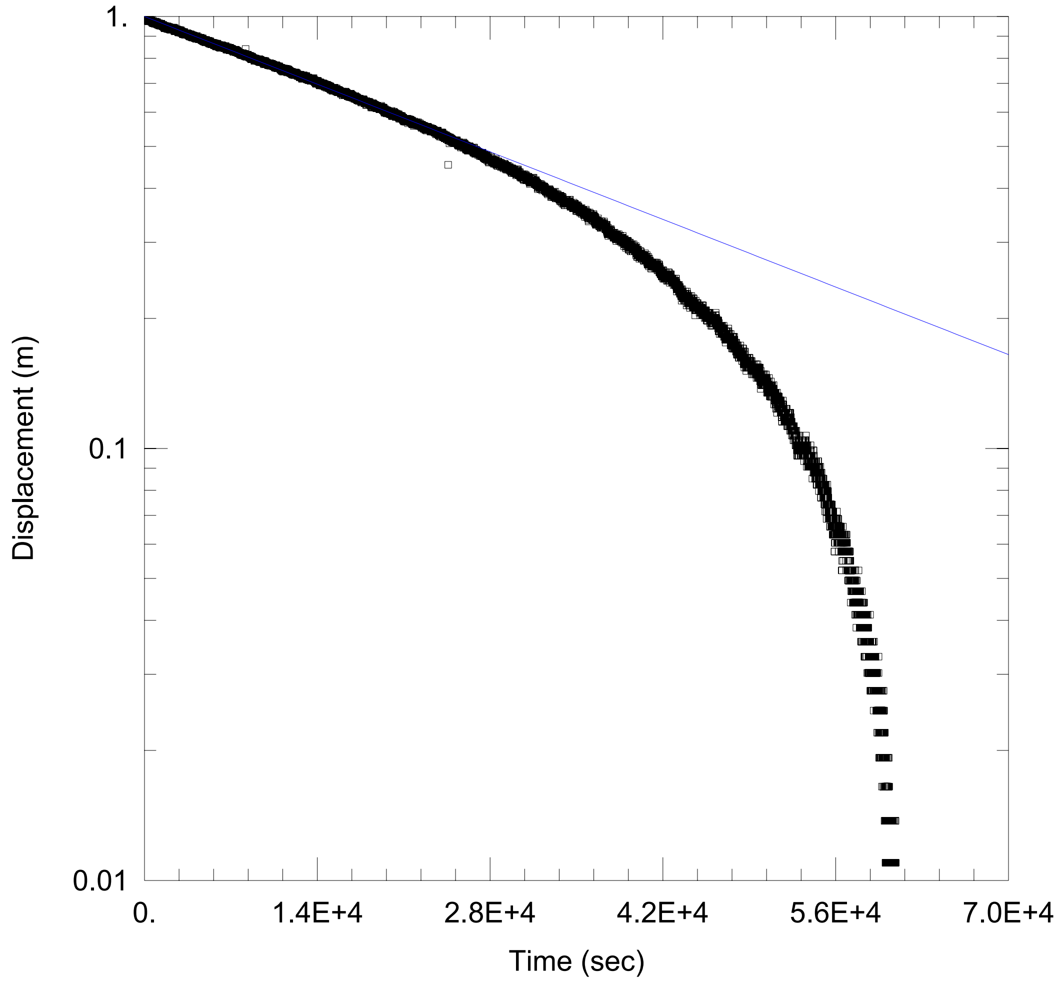
WELL DATA (OW 1)

Initial Displacement: 2.73 m
Total Well Penetration Depth: 4.2 m
Casing Radius: 0.0508 m
Static Water Column Height: 4.2 m
Screen Length: 3.05 m
Wellbore Radius: 0.0508 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 3.376E-6 m/sec
y0 = 1.295 m



I2

Data Set: I:\...\I2.aqt
Date: 07/21/06 Time: 09:06:53

AQUIFER DATA

Saturated Thickness: 5.38 m Anisotropy Ratio (Kz/Kr): 1.

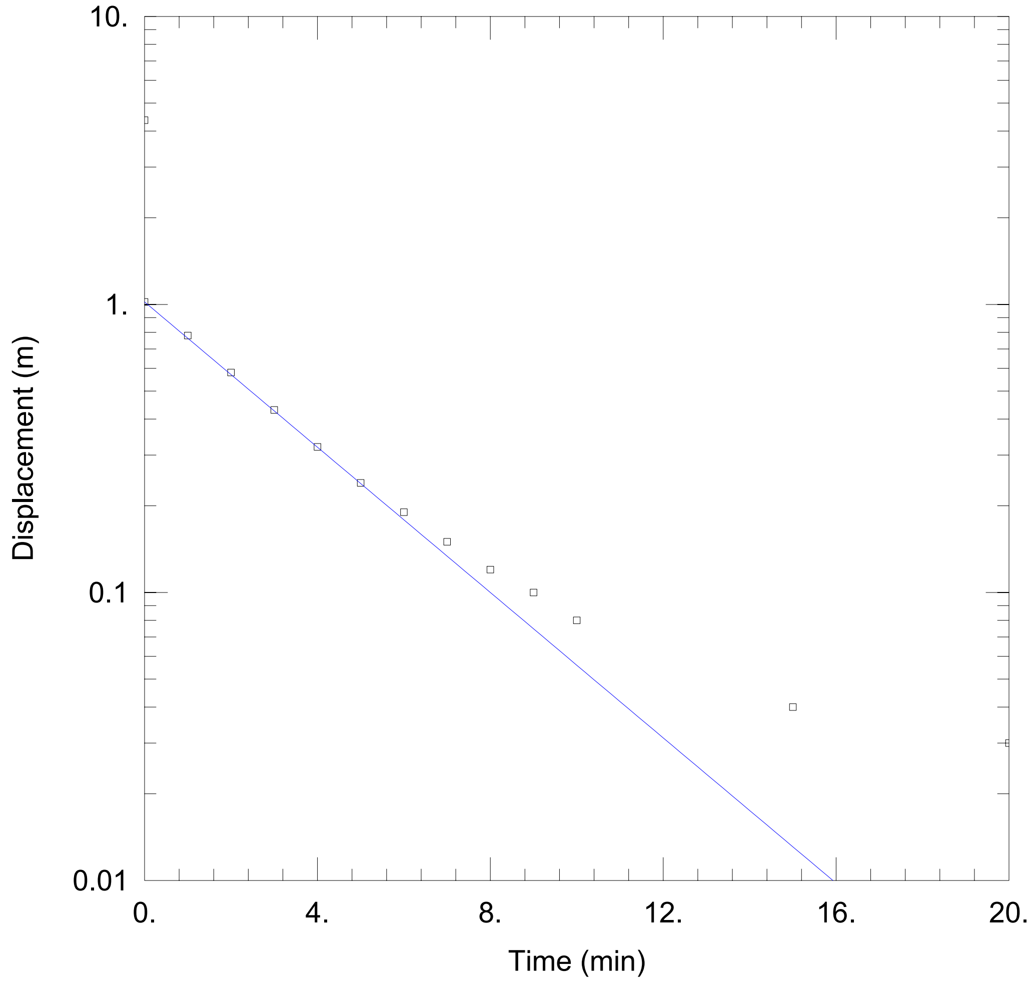
WELL DATA (OW 1)

Initial Displacement: 1.46 m
Total Well Penetration Depth: 5.38 m
Casing Radius: 0.0508 m
Static Water Column Height: 5.38 m
Screen Length: 3.05 m
Wellbore Radius: 0.0508 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Hvorslev

K = 5.216E-8 m/sec y0 = 0.9996 m



SLUG TEST - L9

Data Set: I:\...\L9.aqt
Date: 03/26/07
Time: 11:17:32

PROJECT INFORMATION

Company: Graymont
Project: 05-051
Test Date: January 31, 2007

AQUIFER DATA

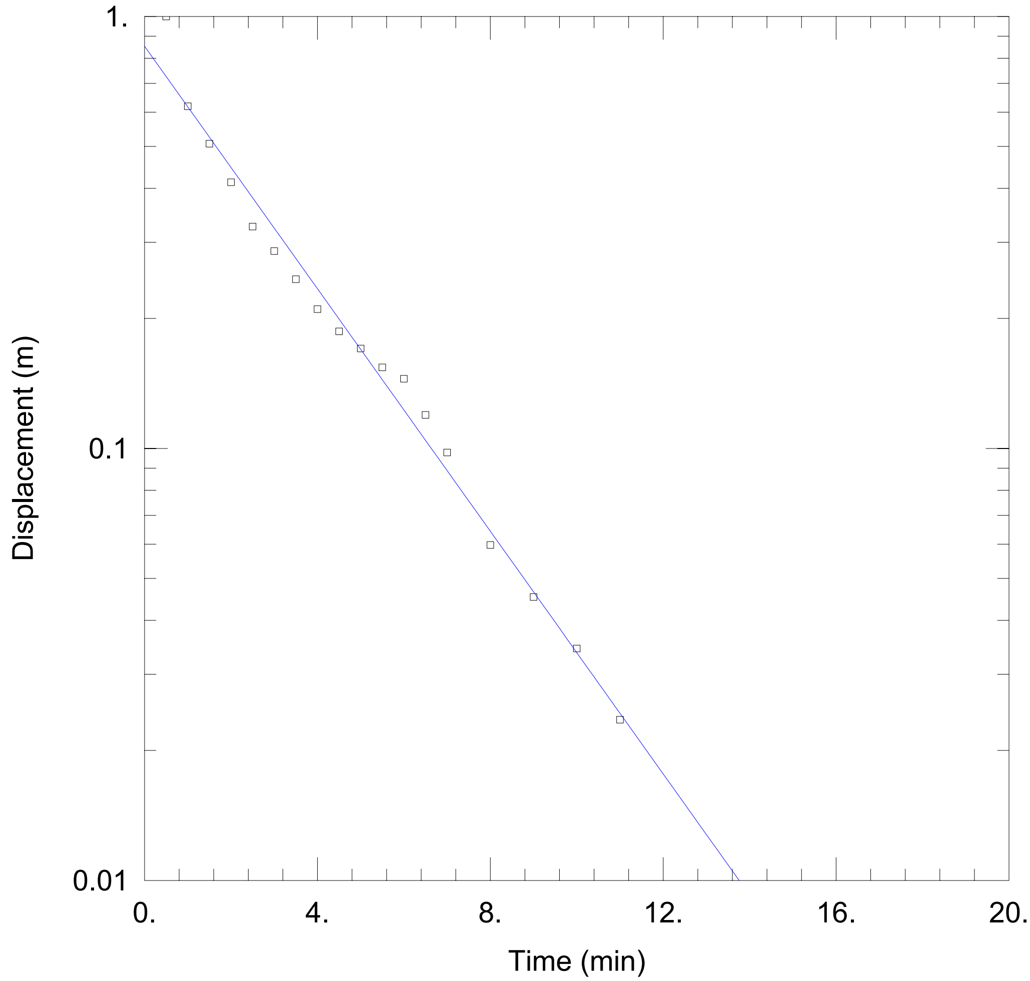
Saturated Thickness: 3.86 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (L9)

Initial Displacement: 4.36 m
Total Well Penetration Depth: 3.86 m
Casing Radius: 0.0254 m
Static Water Column Height: 2.97 m
Screen Length: 3.05 m
Wellbore Radius: 0.0762 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev
K = 0.0002243 cm/sec
y0 = 1.02 m



06-01-16 SLUG TEST

Data Set: I:\...\06-01-16.aqt
Date: 07/21/06 | Time: 09:07:25

PROJECT INFORMATION

Client: Graymont
Project: 05-051
Test Well: 06-01-16
Test Date: July 5, 2006

AQUIFER DATA

Saturated Thickness: 3.61 m | Anisotropy Ratio (Kz/Kr): 1.

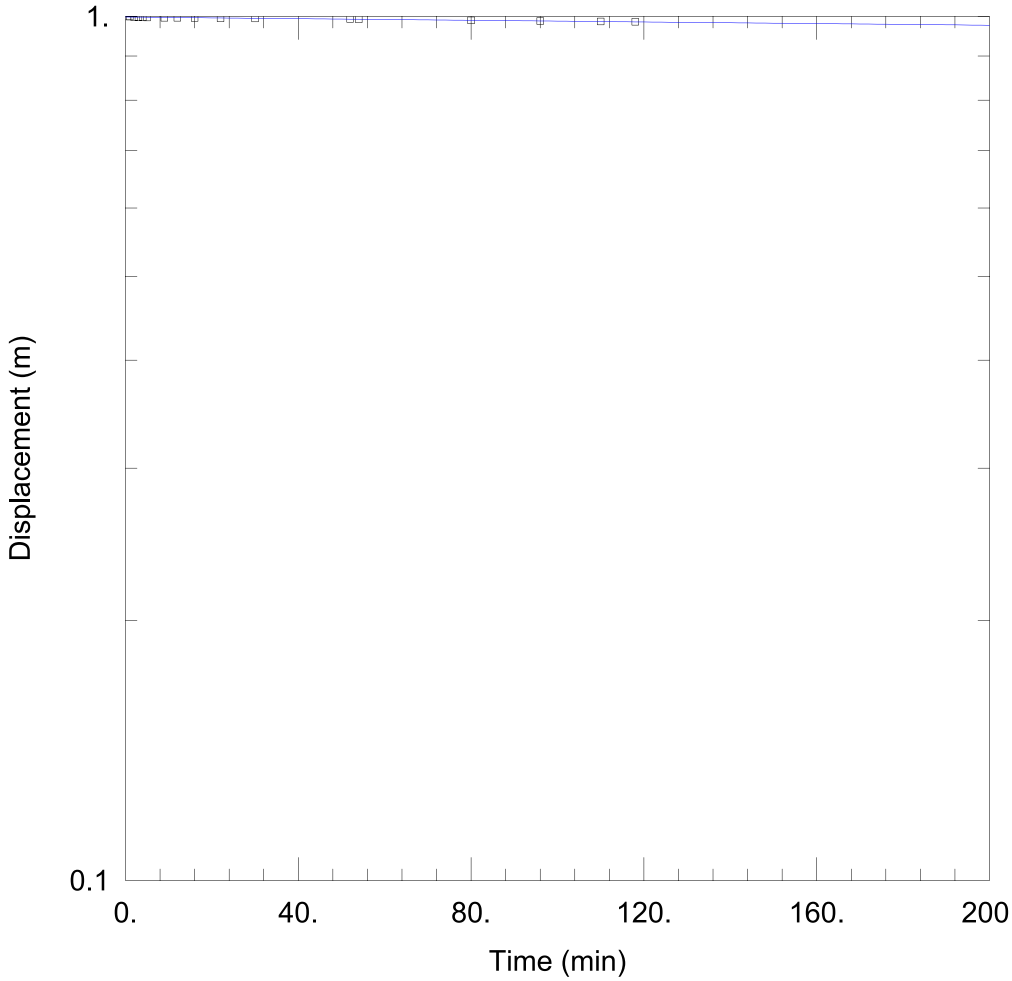
WELL DATA (06-01-16)

Initial Displacement: 2.76 m | Static Water Column Height: 3.61 m
Total Well Penetration Depth: 3.61 m | Screen Length: 1.524 m
Casing Radius: 0.0254 m | Wellbore Radius: 0.0254 m

SOLUTION

Aquifer Model: Unconfined | Solution Method: Hvorslev

K = 5.457E-6 m/sec | y0 = 0.8531 m



06-01-75 SLUG TEST

Data Set: I:\...\06-01-75.aqt
Date: 07/21/06 Time: 09:08:29

PROJECT INFORMATION

Company: Millennium EMS Solutions
Client: Graymont
Project: 05-051
Test Well: 06-01-75
Test Date: July 5,2006

AQUIFER DATA

Saturated Thickness: 20.38 m Anisotropy Ratio (Kz/Kr): 1.

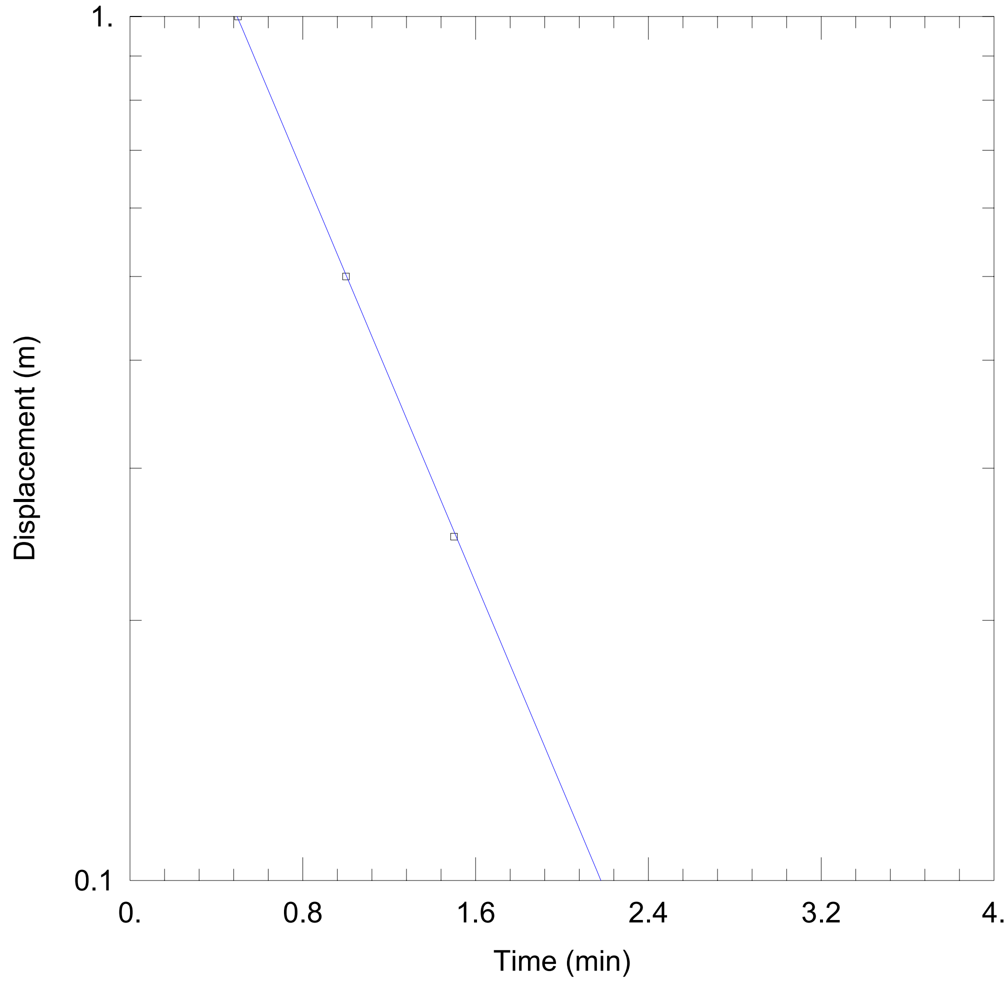
WELL DATA (06-01-75)

Initial Displacement: 5.245 m
Total Well Penetration Depth: 20.38 m
Casing Radius: 0.0254 m
Static Water Column Height: 20.38 m
Screen Length: 1.524 m
Wellbore Radius: 0.0254 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Hvorslev

K = 1.842E-9 m/sec y0 = 0.9983 m



06-02-26 SLUG TEST

Data Set: I:\...\06-02-26.aqt
Date: 07/21/06
Time: 09:20:09

PROJECT INFORMATION

Company: Millennium EMS Solutions
Client: Graymont
Project: 05-051
Test Well: 06-02-26
Test Date: July 4, 2006

AQUIFER DATA

Saturated Thickness: 5.15 m
Anisotropy Ratio (Kz/Kr): 1.

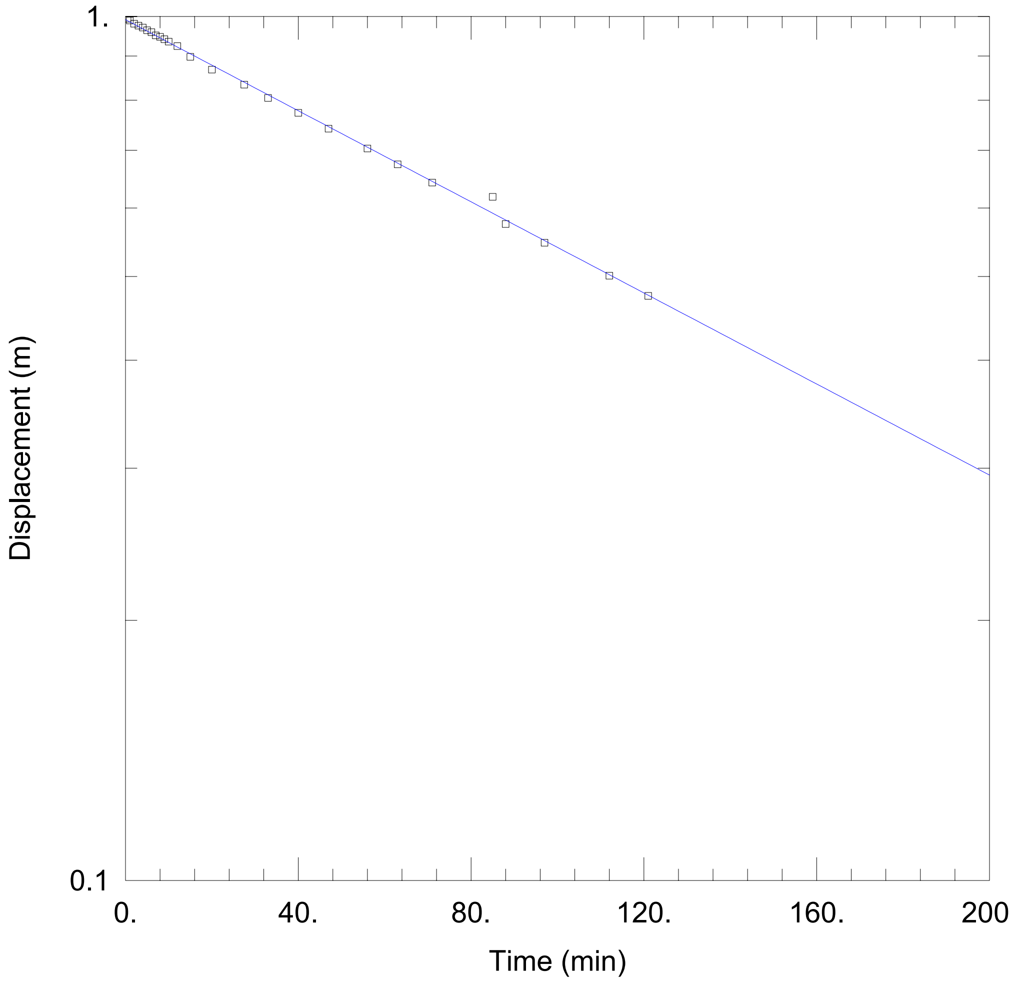
WELL DATA (06-02-26)

Initial Displacement: 0.04 m
Total Well Penetration Depth: 5.15 m
Casing Radius: 0.0254 m
Static Water Column Height: 5.15 m
Screen Length: 0.9144 m
Wellbore Radius: 0.0254 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 3.438E-5 m/sec
y0 = 1.97 m



06-02-75 SLUG TEST

Data Set: I:\...\06-02-75.aqt
Date: 07/21/06
Time: 09:20:50

PROJECT INFORMATION

Company: Millennium EMS Solutions
Client: Graymont
Project: 05-051
Test Well: 06-02-75
Test Date: July 4, 2006

AQUIFER DATA

Saturated Thickness: 20.41 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (06-02-75)

Initial Displacement: 4.99 m
Static Water Column Height: 20.41 m
Total Well Penetration Depth: 20.41 m
Screen Length: 1.524 m
Casing Radius: 0.0254 m
Wellbore Radius: 0.0254 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 1.025E-7 m/sec
y0 = 0.9914 m

APPENDIX A-3: WATER CHEMISTRY

	Surficial Deposits									
Well ID>>>	**B1**		**B5**		**B9**	**C1**		**C4**		**C8**
Date Sampled>>>	26-Jan-07	15-May-07	26-Jan-07	15-May-07	26-Jan-07	3-Feb-06	11-Oct-06	3-Feb-06	11-Oct-06	11-Oct-06
Parameters										
Calcium (Ca)	53.3	229.0	61.7	161.0	85.8	110	94.8	120	82.1	199
Magnesium (Mg)	35.1	102.0	17.1	46.9	18.1	25.6	33.8	27	22.3	38.2
Sodium (Na)	277	653	29	69	27	77	269	67	117	41
Potassium (K)	3.2	6.9	2.9	5.2	3.2	1.8	2.1	3.8	4.7	4.5
Carbonate (CO_3)	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Bicarbonate (HCO_3)	527	1,560	239	522	320	456	663	523	512	518
Sulphate (SO4)	10.2	32.0	41.3	95.7	50.9	68.9	64.1	37.6	53.8	197
Chloride (Cl)	306	791	45	132	23	62	232	52	38	39
Total Dissolved Solids	944	2,580	315	767	368	570	1,020	565	570	774
Conductivity	1,740	3,700	594	1,190	649	949	1,760	944	959	1,170
pH	7.60	7.70	7.80	7.70	7.60	7.5	8.2	7.7	8.3	8.1
Nitrate (N)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	0.2	0	0.2

	Surficial deposits						
Well ID>>>	**D1**		**D3**		**D7**	**F3**	
Date Sampled>>>	19-Jan-06	11-Oct-06	19-Jan-06	11-Oct-06	11-Oct-06	19-Jan-06	11-Oct-06
Parameters							
Calcium (Ca)	103	108	127	133	180	123	107
Magnesium (Mg)	38	40	24.8	28.8	36.5	59.4	35.4
Sodium (Na)	155	148	76	53	47	487	13
Potassium (K)	4	3.7	2.7	2.5	3.5	3.9	3.6
Carbonate (CO_3)	<5	<5	<5	<5	<5	<5	<5
Bicarbonate (HCO_3)	409	580	488	537	551	911	434
Sulphate (SO4)	43.5	12.3	119	67	97.3	73.2	87.9
Chloride (Cl)	206	169	62	69	70	512	14
Total Dissolved Solids	751	766	654	617	706	1,710	475
Conductivity	1,110	1,380	1,140	1,100	1,160	2,680	852
pH	8	8.2	7.9	8.1	8.1	7.9	8.2
Nitrate (N)	<0.1	<0.1	0.5	<0.1	<0.1	<0.1	<0.1

	Surficial Deposits											
Well ID>>>	**H1**			**H4**			**I2**		**L1**	**Test Pit**		**L9**
Date Sampled>>>	19-Jan-06	11-Oct-06	15-May-07	19-Jan-06	11-Oct-06	15-May-07	11-Oct-06	15-May-07	26-Jan-07	27-Jan-07	28-Jan-07	26-Jan-07
Parameters												
Calcium (Ca)	106	105	113	82.7	80.2	81.6	105	101	92.7	54.8	88.3	68.8
Magnesium (Mg)	38.6	42.1	40.4	28.2	31	19.1	57.9	52.9	28.2	22	20.7	20.5
Sodium (Na)	88	57	84	213	221	179	469	516	36	33	37	21
Potassium (K)	2.1	1.5	3	4	3.8	13.6	3.8	5.1	1.8	2.5	2.6	2.7
Carbonate (CO_3)	<5	<5	<5	<5	9	<5	6	<5	<5	<5	<5	<5
Bicarbonate (HCO_3)	568	556	589	721	598	629	892	989	273	261	399	284
Sulphate (SO4)	46.7	48.2	59.2	32	29.8	56.5	51.6	38.9	124	69.6	57.5	31.6
Chloride (Cl)	74	10	40	141	173	133	529	541	32	10	27	14
Total Dissolved Solids	635	537	629	856	843	792	1,660	1,740	451	322	430	300
Conductivity	1,110	901	1,030	1,670	1,460	1,370	2,830	2,700	720	493	799	533
pH	7.8	8.2	7.7	8	8.4	7.9	8.3	7.9	7.7	7.9	7.9	7.6
Nitrate (N)	<0.1	<0.1	<0.1	<0.1	0.3	0.1	0.1	<0.1	0.4	0.3	0.2	0.3

	Limestone						
Well ID>>>	**06--01--16**				**06--01--75**		
Date Sampled>>>	17-Jun-06	5-Jul-06	11-Oct-06	15-May-07	11-Oct-06	15-May-07	14-Aug-07
Parameters							
Calcium (Ca)	48.8	80.6	92	87.9	120	165	172
Magnesium (Mg)	16.1	28.3	33.1	30.1	62.8	125	132
Sodium (Na)	252	184	119	135	2,100	4,240	4,150
Potassium (K)	5.2	4	2.3	4.5	15.5	28.3	26
Carbonate (CO_3)	<5	<5	5	<5	<5	<5	<6
Bicarbonate (HCO_3)	518	588	492	595	863	1240	1260
Sulphate (SO4)	210	133	79.5	81.7	1,480	2040	2280
Chloride (Cl)	44	60	74	88	2,190	5,150	4,300
Total Dissolved Solids	844	780	647	720	6,480	12,400	11,700
Conductivity	1,210	1,230	1,080	1,040	9,460	15,800	17,100
pH	8.1	7.9	8.4	7.8	8.2	7.6	7.4
Nitrate (N)	3	0.3	<0.1	0.1	17.2	8.8	3.94

	Limestone							
Well ID>>>	**06--02-26**				**06-02--75**			
Date Sampled>>>	17-Jun-06	4-Jul-06	11-Oct-06	15-May-07	4-Jul-06	11-Oct-06	15-May-07	14-Aug-07
Parameters								
Calcium (Ca)	56.7	79.7	73.4	68.7	173	244	225	172
Magnesium (Mg)	15.8	20.1	20.4	18.4	194	300	313	132
Sodium (Na)	197	147	163	217	6,280	9,640	10,400	4,150
Potassium (K)	2.9	1.6	1.9	4.1	35.8	46.2	71.3	26
Carbonate (CO_3)	<5	<5	8	<5	<5	*<5*	*<5*	*<6*
Bicarbonate (HCO_3)	447	497	476	572	1,050	1,190	1,460	1260
Sulphate (SO4)	122	54.4	65.8	91	337	78.8	244	2280
Chloride (Cl)	77	75	87	100	9,430	15,900	15,200	4,300
Total Dissolved Solids	699	623	655	781	17,000	26,800	27,200	11,700
Conductivity	1,050	1,020	1,100	1,210	26,400	41,300	39,700	17,100
pH	8	7.9	8.4	7.9	7.8	8	7.4	7.44
Nitrate (N)	1.6	0.1	0.2	0.1	6.4	0.8	0.9	3.94

APPENDIX B: CONCURRENCE TO TERMS OF REFERENCE

TOR No.	Requirements	Comment	Reference Section in this Report
5.6.5	**Groundwater**		
Describe the groundwater regime in the Study Area(s), using map(s), cross section(s) and/or other drawings as appropriate. Discuss the following:			
a)	the lithology, stratigraphic and structural continuity, thickness, hydraulic properties, major groundwater features (aquifers, aquitards, aquicludes), groundwater flow direction and velocity, and groundwater quality of the geologic units in the Study Area(s);		**Section 3**
b)	historical and current hydrogeological investigations, including methodology and results;	**None current**	**Section 3**
c)	the potential for hydraulic connection between geological zones affected by the Project (e.g., quarry zones, groundwater production and the land surface);	**Very low potential**	**Sections 4 & 5**
d)	parameters to be used as indicators of potential aquifer contamination;	**Major ions hydrocarbons**	**Section 8**
e)	the potential for changes in the groundwater regime and the effects of these changes that may arise from the Project, including:		
i)	changes in groundwater quality, vertical gradients and aquifer recharge rates;		**Sections 4 & 5**
ii)	changes resulting from any proposed diversion;		**Sections 4 & 5**
iii)	an inventory of all groundwater users (field verified survey), and potential water use conflicts and proposed resolutions;	**No users**	**Sections 4 & 5**
iv)	the effect(s) of groundwater withdrawal and/or surficial dewatering and their implications for other environmental resources, including habitat diversity and quantity, surface water quality and quantity, vegetation, wetlands and soil saturation;		**Sections 4 & 5**
f)	the inter-relationship of the groundwater to the surface water and the potential for impacts on water quality and quantity due to recharge from and discharge to local waterbodies and wetlands; and		**Sections 4 & 5**
g)	a conceptual plan and implementation program for the protection of groundwater resources, including the following:		
i)	the early detection of potential contamination and remediation planning;		**Section 9**
ii)	groundwater remediation options in the event that adverse effects are detected; and		**Section 9**
iii)	monitoring the sustainability of groundwater production or dewatering effects.		**Section 9**

APPENDIX C: AUTHENTICATION

AUTHENTICATION

Form: MEMS-APEGGA-BS

The Engineering, Geological and Geophysical Professions Act (the Act) of Alberta requires that engineering, geological or geophysical work be authenticated by the application of:

- The professional seal or stamp of the individual member responsible for preparing the work **and**
- The corporate permit number or stamp of the company employing the responsible individual member.

This section identifies those portions of this report that fall under the Act and will be authenticated in compliance with the Act.

The report entitled "*Parsons Creek Resources Project Hydrogeological Impact Assessment"* meets the definition of engineering or geology within the Act and is authenticated with APEGGA Permit to Practice Number P07002 and the professional stamp applied below:

Millennium EMS Solutions Ltd. provides the same level of quality assurance to our clients throughout this report.