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Joslyn North Mine Project
Environmental Impact Assessment
Hydrogeology

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1.0 INTRODUCTION

Deer Creek Energy Limited (DCEL) has approval on the Joslyn Lease to construct, operate and reclaim Steam Assisted Gravity Drainage (SAGD) activities. As part of the ongoing lease development and expansion, DCEL is now applying to develop the Joslyn North Mine area to add oil sands mining to the development activities.

An important part of understanding the lease hydrogeology was determined when the Phase I (demonstration project) was proposed and approved in 2001. Extensive investigation and review were undertaken which provided the foundation for subsequent work. This subsequent work provided input for the Phase II application and approval. This, in turn led to more investigations that provide the basis for the Phase IIIA application.

As a result of the extensive ongoing investigations, DCEL's understanding of the lease hydrogeology and impacts of the operations continues to grow. This application has the benefit of three previous submissions, which were rigorously reviewed to ensure the groundwater resources were understood. This application will build on this knowledge.

All legal locations in this report are west of the fourth meridian.

This report will provide an understanding of the baseline hydrogeology in the principal development area or local study area (LSA) and the regional study area (RSA) (Figure 2.1) along with the anticipated impacts associated with the Joslyn North Mine project. In addition to the baseline conditions, this report will also consider the application case and the cumulative effects case.

1.1 PHYSICAL SETTING

The project site is located on a plateau between the Birch Mountains, lying to the west, and the Athabasca River lying to the east. The plateau is at an elevation of approximately 340 m near the SAGD activity and drops to an elevation of approximately 230 m at the northeast corner of the lease near the Athabasca River. The plateau slopes gently to the east and drops precipitously into the valley of the Athabasca River.

The Birch Mountains, a major upland feature of north-eastern Alberta, reach elevations of 825 m approximately 40 km northwest of the site.

Joslyn Creek (Figure 2.1) flows eastward in a broad shallow valley just north of the site at an elevation of approximately 260 m. This creek joins the Ells River directly east of the site in T 95 R 11 at an elevation of approximately 240 m. Most of the drop in elevation of the Joslyn Creek occurs just prior to the intersection with the Ells River.

The Ells River meanders within a deep, but narrow, valley approximately 5 km south of the site. At this location, the Ells River is at an elevation of approximately 300 m, which is generally 40 m below the plateau elevation of 340 m. The Ells River flows generally eastward from this point to Section 8-95-11 and then turns northeast to intersect the Athabasca River in Section 3-96-11.

1.2 CLIMATE

Climatic statistics are presented in detail by Northwest Hydraulic Consultants (2005). Mean annual precipitation is shown there to be approximately 435 mm while the mean annual evaporation is estimated at 500 mm. Ozoray et al. (1980) calculated potential evapotranspiration to be approximately 490 mm. Thus, on a mean basis, there is commonly a moisture deficit during the open-water portion of the year.

1.3 STUDY AREAS

The local study area (LSA) is defined as the Joslyn Lease. This area is used for the descriptive assessment based on observational data.

The regional study area (RSA) has been developed for the purposes of groundwater modeling and is defined as follows:

- Horizontally
  - The Athabasca River on the east
  - The Birch Mountains on the west
  - The confluence of the Firebag River with the Athabasca River on the north
  - The confluence of the Muskeg River with the Athabasca River on the south
- Vertically
  - The top of the Devonian limestone underlying the McMurray Formation.

As with the original CNRL model, the domain is defined by the Birch Mountains in the west and the confluences of the Firebag River and the Muskeg River with the Athabasca River in the north and south, respectively.

The rationale for these decisions lies within the hydrogeological framework that will be described subsequently and briefly are:

- The alluvial channel of the Athabasca River is effectively an eastern hydraulic boundary,
- The discontinuous nature of the basal water sands effectively limits the south and west effects of depressurization of that unit,
- Various interactions with CNRL Horizon Project dictate the inclusion of that lease in impact assessment.
- The lack of any evidence in the hydrogeological data that deeper formations contribute in any way to the hydrogeological regime of the lease or the mine.

All referenced figures are presented in Appendix A.

Appendix B contains two sub sections containing hydraulic head and water chemistry information.

2.0 REGIONAL HYDROGEOLOGY

2.1 GEOLOGY

Figure 2.1 presents a plan view of the DCEL Lease that covers both the SAGD and proposed Joslyn North Mine areas. This section covers geological conditions that are important to the hydrogeological interpretation.

2.1.1 Quaternary Geology

DCEL has done extensive investigations of the Quaternary deposits on the lease in search of shallow groundwater supply, aggregate sources and general foundation conditions. These investigations have included the following:

1. Auger Drilling: Since 2003, DCEL has drilled 347 auger holes to bedrock throughout the lease area. The results of this drilling have established the surficial aquifer in the northeast and one possible narrow aquifer at 9-36-94-12 – both at significant distance from SAGD operations. Other than these, there have been no indications of anything other than glacial till in the Quaternary deposits of the western one-half of the lease.
2. EM Survey: DCEL has commissioned 61.5 km of EM survey across the lease in an attempt to locate shallow groundwater supply. This included survey on the west half of the site where SAGD is planned.
3. Airborne EM survey: DCEL has commissioned 493 km of airborne EM across the eastern portion of the lease in an attempt to locate shallow groundwater supply and delineate surface geology. No aquifers were found.
4. Seismic Survey: DCEL has commissioned 60 km of seismic survey across the lease in an attempt to locate shallow groundwater supply. This included survey on the west half of the site where SAGD is planned. No aquifers were found.

Quaternary deposits include aeolian sands in the northeast portion of the lease. These deposits pinch out to the west and are not present in T 95 R 12 north of the Ells River. Glacial till and clay are found at the surface in T 95 R 12 and lie on top of Clearwater or McMurray Formation.

There is little possibility that there are any aquifers in the Quaternary on the western one-half of the lease.

2.1.2 Bedrock Geology

Bachu et al (1993) presented the generalized stratigraphic nomenclature used in north-eastern Alberta. This stratigraphy is presented in Figure 2.2. For purposes of this application, the upper portions of the geological section are of particular interest. They consist of sediments of Quaternary age underlain by Cretaceous shale and sandstone that are, in turn, underlain by Devonian limestone.

There are salt deposits in the Prairie Evaporite Formation that is part of the Elk Point Group underlying the Fort Vermillion Formation. There is abundant evidence that these deposits have been dissolved creating collapse features extending upward to the Devonian surface and that occasionally appear at the present-day surface. Throughout the past 30 years during which hydrogeological investigations of the region have taken place, there has been speculation that this collapse created pathways that would facilitate the movement of saline water to the surface. To date, this remains as speculation without any field evidence of occurrence and hydrogeological significance.

Figure 2.3 presents contours on the Devonian surface on the DCEL lease. The topography of the Devonian exhibits two general features:

1. An upland, generally at or above 240 m elevation, under the south western three-quarters of the lease,
2. In the northeast portion of the lease, the Devonian surface drops down gradually and uniformly from 240 m to 190 m with one substantial sinkhole – known as the “Bitumount Low” - having elevations below 160 m.

There are outcrops of the Devonian east of the southeast portion of the lease near the Fort McKay Settlement.

There is abundant evidence that a major fault is present under the Athabasca River in this area (Hackbarth and Nastasa, 1979). The throw on this fault may have played a large role in the solution of the salt deposits and the subsequent collapse of the overlying limestone deposits.

The McMurray Formation consists of sandstone and shale deposited in a transgressive geological sequence. This sequence was deposited on top of an irregular erosion surface on the Devonian. Because of the various depositional environments in this sequence, the detailed geology of the entire McMurray Formation is quite complicated.

The transgressive nature of the McMurray results in the coarse grained texture of the basal deposits. Where the basal sand is low in bitumen, it tends to be an aquifer and is referred to as the “basal water sand(s)” (BWS). DCEL defines the basal water sand on its lease as basal sands having up to 6 % oil content. The basal water sand tends to be thickest at low points on the Devonian surface. Figure 2.4 presents an isopach map of the thickness of the basal water sand. At this time, the basal water sand appears generally as a series of unconnected lobes under the DCEL lease. Thicknesses are commonly less than 10 m, however up to 20 m has been measured in several places in the eastern and northern portions of the lease.

The Cretaceous Clearwater Formation overlies the McMurray Formation. The Clearwater Formation thins to the east as the land surface declines in elevation. At the east boundary of T95 R12, the Clearwater is commonly absent and Quaternary deposits lie directly on McMurray Formation. A basal Clearwater sandstone or siltstone – the Wabasca Member - is frequently present just above the McMurray Formation west of R 12.

Cretaceous formations younger than the Clearwater are not observed on the DCEL lease.

2.2 REGIONAL HYDROGEOLOGY

A series of piezometers were installed for the purpose of defining hydrogeological conditions on the DCEL lease. The locations of these piezometers are shown on Figure 2.1.

The objective of the piezometers was to provide information on the Quaternary, Clearwater and basal water sands, if they existed, at each selected location. Hydrogeological Cross Sections A-A', B-B' and C-C' (Figures 2.5, 2.6 and 2.7) were developed from these piezometers with reference to other geological interpretations of the lease.

Hydrogeological cross section A-A' (Figure 2.5) runs from the south-western to the north-eastern area of the lease from Section 12-95-13 to Section 2-96-11. Generally, this can be considered to be a dip section that is also approximately parallel to the expected direction of regional groundwater flow. This section demonstrates the gradual east to northeast downward slope of the land surface from approximately 340 m at Site 15-12-95-13 to 260 m at Site 16-3-96-11 and then dropping to approximately 230 m at the Athabasca River. The alluvial valley of the Athabasca River is cut into McMurray Formation – possibly including the basal water sands – just downstream of this location.

The presence of a deep alluvial channel beneath the Athabasca River is shown at the east end of Hydrogeological Cross Section A-A'. This is anticipated to be present based on the following:

- Alberta Research Council Observation Well Site 18 (ARC 1978), that was drilled on an island in the Athabasca River in LSD 7-25-94-11, and encountered Quaternary sand and gravel over Devonian limestone to a depth of 43 m. This places the top of the limestone in this channel at an elevation of 190 m approximately 10 km upstream of the end point of Hydrogeological Cross Section A-A'. The sand and gravel encountered above the limestone was sub-angular fragments of limestone and granite.

- This same situation was observed during foundation drilling for the Fort McKay bridge across the Athabasca River in T 94 R 10 (Hackbarth 1979).

- McRoberts (2002) reported an alluvial channel to an elevation below 180 m at the Suncor site.

The probable intersection of the basal water sands with the alluvial channel deposits of the Athabasca River implies that the water in the basal water sands enters the river through those deposits. It is unlikely that groundwater flow in the basal water sands crosses under the river to the east side.

Hydrogeological cross section B-B' (Figure 2.6) runs generally north to south in the western portion of the lease from Section 1-96-13 to Section 34-94-12. This can be considered to be a strike section that is approximately perpendicular to the inferred direction of groundwater flow. The ground surface along this section does not vary significantly except at the Ells River. The valley of the Ells River, although deep, lies entirely within the Clearwater Formation.

Hydrogeological Cross Section C-C" (Figure 2.7) runs north-south through the center of the mine.

In summary, the cross sections show:

- The Clearwater Formation is present west of approximately Range 11.
- The bitumen-saturated McMurray Formation is present across the entire area.
- The development of the basal water sand is strongly correlated with lows on the Devonian surface.
- These sections emphasize the disconnected nature of the basal water sands.

2.2.1 Groundwater Flow

2.2.1.1 Hydraulic Head

Hydraulic heads tend to be close to the surface in piezometers completed in geological units above the McMurray Formation.

A number of vibrating wire piezometers have been installed in the oil sands at five locations near the north boundary of the DCEL lease. These piezometers are generally in the lower portions of the oil sands and may or may not directly overlie basal water sands. The majority of these piezometers confirm a downward hydraulic gradient toward the basal water sand zone.

The hydraulic head in the basal water sands is typically 20 to 30 m below the head in the overlying Quaternary deposits or Clearwater Formation. This indicates a strong downward hydraulic gradient.

Groundwater flow is generally from west to east. Hydraulic heads drop from approximately 350 m in near-surficial material in the west to 293 m at Site 11-4-96-11 before dropping into the Athabasca River valley. Hydraulic heads observed in the basal water sands drop from 315 m in the west to 240 m in the east.

Figure 2.4 is an interpretation of the pattern of hydraulic heads in the basal water sands. This is based on the hydraulic head values available on the lease and includes no consideration for the distribution of the basal water sand. Considering the limitations the pattern of groundwater flow inferred from this distribution is from southwest to northeast toward the Athabasca River. The probable intersection of the basal water sands with the alluvial channel deposits of the Athabasca River implies that the water in the basal water sands enters the river through those deposits. It is unlikely that groundwater flow in the basal water sands crosses under the river to the east side.

There is only one reliable hydraulic head from the Devonian limestone along these hydrogeological sections. The hydraulic head at 14-36-95-12 (BP-2W) was approximately 282 m in 2004. This was similar to the hydraulic head in the overlying basal water sands.

2.2.1.2 Hydraulic Conductivity

CNRL (2005a) provided extensive current information on the hydraulic conductivity of the bitumen-saturated portion of the McMurray Formation and decided that a horizontal hydraulic conductivity of 2 x 10^{-9}m/s and a vertical hydraulic conductivity of 2 x 10^{-10}m/s were appropriate.

Hydraulic conductivities of the basal water sand under the lease range from 0.2 to 90 x 10^{-6} m/s (Table 2.1).

Table 2.1. Hydraulic Conductivities Measured in the Basal Water Sand

Location	Type of Test	Hydraulic Conductivity (m/s)
14-36-95-12	Injection	90 x 10^{-6}
14-20-95-12	Injection	21 x 10^{-6}
4-16-95-12	Injection	0.9 x 10^{-6}
15-12-95-13	Injection	0.9 x 10^{-6}
5-4-96-11	Injection	50 x 10^{-6}
14-36-95-12 (BP-2WA)	Pump	60 x 10^{-6}
8-15-96-11 (ARC 1-432)	Drill stem	0.2 x 10^{-6}

Assuming an average hydraulic conductivity of 5 x 10^{-5}m/s and the types of regional hydraulic gradients noted on Figure 2.4, the horizontal velocity of movement of a particle in the water of the basal water sand is estimated to be 50 m per year.

The common thickness of the basal water sand ranges zero to 10 metres, which means that the water transmitting capacity of this unit will range over an order of magnitude given constant hydraulic conductivity and hydraulic gradient. The amount of water passing through a 10 m thickness of the zone will be ten times that passing through a one metre thickness. The basal water sands are therefore the routes through which any significant movement of groundwater takes place relative to the oil sands or the Devonian.

Hackbarth and Nastasa (1979) indicated the general lack of hydraulic conductivity in the Devonian formations underlying the McMurray Formation. They presented evidence that the median hydraulic conductivity of the limestone is 1×10^{-8}m/s and that most of the hydraulic conductivities would range between 1×10^{-7} and 1×10^{-10}m/s.

CNRL (2005a) provided extensive updated information on the hydraulic conductivity of the upper Devonian units and decided that a horizontal hydraulic conductivity of 2×10^{-9}m/s and a vertical hydraulic conductivity of 2×10^{-10}m/s were appropriate.

DCEL has reached a similar conclusion to Hackbarth and Nastasa specific to the Joslyn Lease. In a report to the EUB, DCEL (2005) stated the following with respect to the Devonian formations:

- An extensive investigation of lineaments was undertaken in anticipation that this would reveal structural permeability in the Devonian,
- Deer Creek drilled a test hole in 7-4-96-11 in 2004 to a depth of 370 m with the following results;
  - A drill stem test in the Beaverhill Lake Formation at depths of 165 to 175 m suggested low permeability,
  - A drill stem test at depths of 316 to 326 m in the Methy Formation revealed low permeability,
  - A drill stem test at depths of 359 to 369 m in the Granite Wash indicated extremely low permeability.
- CNRL drilled three wells on the Horizon Project lease and failed to locate significant permeability,
- Deer Creek came to the conclusion that there are no permeable zones of any significance in the Devonian underlying the lease.

2.2.2 Groundwater Chemistry

The distribution of total dissolved solids (TDS) in the basal water sands is shown in Figure 2.8. Concentrations in excess of 20,000 mg/L are found in the western portion of the lease and increase to 57,500 mg/L at Site 16-3-96-11 in the northeast. TDS concentrations decline to the southeast where values below 10,000 mg/L are found.

The distribution of TDS in the Quaternary units is shown in Figure 2.9. Concentrations below 500 mg/L are found in the northeast in the dune sand at depths less than 15 m. TDS concentrations above 1,000 mg/L are commonly found in Range 12 and west – approximately coincident with the zero edge of the Clearwater Formation. Natural TDS concentrations above 4,000 mg/L are observed at several locations in Range 12 on the lease.

The hydrogeological sections (Figures 2.5, 2.6 and 2.7) show total dissolved solids (TDS) in water samples collected from various monitoring wells. The following points can be made about TDS and water chemistry:

- Where the Clearwater is present in significant thickness, the TDS in the surficial materials is significantly elevated as compared to where it is thin or absent. Shallow TDS of 2,800 mg/L is observed in Quaternary and Clearwater piezometers at Site 14-20-95-12 – for instance. Ionic make up in the Quaternary is calcium/magnesium sulphate while in the Clearwater Formation it is sodium bicarbonate/sulphate in R 12 (Sites 14-20-95-12 and 14-36-95-12)
- Groundwater is very fresh in the thin aeolian sands at the northeast corner of the lease where there is no Clearwater present. TDS concentrations of 76 to 302 mg/L are observed in Section 4 and 5 – 96-11 where the ionic character of the shallow groundwater is calcium/magnesium bicarbonate.
- The pattern of TDS in the basal water sand shows 18,000 m to 23,000 mg/L in the west declining to 15,000 mg/L and less in the southeast and rising to 58,000 mg/L in the northeast. The ionic character of the basal water sand is sodium chloride with minor bicarbonate in the west changing to sodium chloride but with higher bicarbonate in the southeast.

Samples of water from the piezometers were collected in 2004 and subject to analysis for trace organics and dissolved metals. The organic suite consisted of F1 and F2 hydrocarbons, BTEX and phenols (Appendix B-2). Most of the results were undetectable and none of the detectable results occurred in concentrations that were environmentally significant.

3.0 MINE SITE HYDROGEOLOGY

3.1 GEOLOGY

The footprint of the mine area is shown on Figure 2.1. This section deals with details of the geology that are relevant to the hydrogeological interpretation.

3.1.1 Quaternary Geology

The surficial geology of the mine area is described in Section B.2 of the application. Generally, the north-central portion (sec 32-95-11; Sec 4 and 5-96-11) of the mine area is covered with a layer of sand up to 15 m thick. These sand deposits commonly lie directly on oil sands although outliers of Clearwater Formation may be present. DCEL currently utilizes these sand deposits as a source of groundwater supply for their SAGD operations in the western portions of T 95 R 12.

The western and south-western portions of the mine area consist of clay and till of glacial origin. This material frequently lies on eroded Clearwater Formation. The extensive investigations of the surficial deposits described in Section 2.0 (Regional Hydrogeology) have confirmed the presence of clay and till to the south and west of the mine. There is little likelihood, except as mentioned above, that there are any surficial aquifers present below the mine operations footprint.

3.1.2 Bedrock Geology

The bedrock of the mine area consists of discontinuous erosional remnants of Clearwater overlying McMurray Formation. Basal water sands occur as disconnected pods (Figure 2.4) that are present generally on the north, east and south margins of the mine. No significant thickness of basal water sand has been discovered along the eastern margin of the mine paralleling the Ells River and in the central area of the mine.

Devonian limestone underlies the McMurray Formation occurring at elevations of up to 260 m in the south and below 165 m in the northeast (Figure 2.3). An east-west escarpment is apparent in Sections 28, 29, 30-95-11.

3.2 LOCAL HYDROGEOLOGY

3.2.1 Groundwater Flow

Within the Quaternary deposits there is an easterly and downward component to groundwater flow. The easterly component is developed as a result of the topographic slope. The downward component is the result of significantly lower hydraulic heads in the basal water sands as compared to the surficial deposits.

Flow in the basal water sands is northeast across the mine area. Hydraulic heads range from 282 m at 14-36-95-11 to 241 m at 16-3-96-11 (Figure 2.4). Actual movement of water in the basal water sand preferentially follows the presence of that deposit.

3.2.2 Groundwater Chemistry

Water chemistry in the surficial deposits of the mine area may be characterized as generally having less than 1,000 mg/L TDS. In the aeolian sand area located in the north center of the mine the TDS is below 500 mg/L and commonly as low as 100 mg/L.

Water in the basal water sands may be characterized as ranging from 20,000 mg/L at 14-36-95-11 to 57,000 mg/L at 16-3-96-11 (Figure 2.8).

3.2.3 Groundwater / Surface Water Interaction

The interaction of groundwater with surface water bodies on the lease may be examined through a discussion of how the basic water chemistry of such water bodies as Ells River, Joslyn Creek, West Lake and Beaver Pond vary over a typical year. The water chemistry information is discussed in Hatfield (2005).

TDS concentrations are the highest of the year in West Lake, Joslyn Creek and Beaver pond in February (Hatfield 2005). This is a result of groundwater input during the winter and to precipitation influence during other seasons.

The flow in Joslyn Creek varies by several orders of magnitude between winter and other seasons of the year. There is little to no flow in Joslyn Creek during typical winters (nhc 2005).

Thus, a relatively small amount of groundwater of poor quality enters Joslyn Creek (and West Lake and Beaver Pond) during the winter and has a substantial effect on the water chemistry. The amount of this contribution is very small because of the lack of aquifers in the Quaternary.

The TDS in the Ells River however did not show the same pattern as noted above. This river derives its water from Gardiner Lake in the Birch Mountains to the west (nhc 2005).

The Ells River, by contrast, has relatively stable flow regime; varying by only three to 20 times over the course of the year. This is a function of its source in Gardner Lake that sustains flow throughout the year (nhc 2005).

The groundwater contribution to surface water bodies, even during typical base-flow conditions of winter, is insignificant in this area.

4.0 GROUNDWATER MODELLING

4.1 MODEL OVERVIEW

To assist in determining the potential effects of the Joslyn North Mine Project on the local and regional groundwater regime a three-dimensional (3-D) numerical flow model was created. The unconfined aquifer within the surficial sands is located within the footprint of the Joslyn North Mine Project and will be removed as part of mining operations. The model focuses on the only other aquifer identified on lease – the basal water sands aquifer.

The groundwater flow model was generated in Visual MODFLOW Version 4.0. Many of the initial input parameters were based on the basal water sands groundwater model presented in the Hydrogeology Assessment by Canadian Natural Resources Limited (CNRL) for their Horizon Project EIA (2002) and the related Supplemental Information (2003). This model has been accepted in the approval process and, therefore, is considered representative of the basal water sand conditions underlying the CNRL Horizon Lease to the north of DCEL.

Some parameters were further refined with new information from CNRL the DCEL Lease. A full account of the Joslyn Model assumptions and limitations are discussed in Section 4.0.

4.2 JOSLYN MODEL DOMAIN AND BOUNDARY CONDITIONS

The model was created to capture the regional basal water sand distribution to such an extent that boundary conditions would not artificially influence the predicted conditions during mine development. As with the original CNRL model, the domain is defined by the Birch Mountains to the west and the confluences of the Firebag River and the Muskeg River with the Athabasca River in the north and south, respectively. The eastern boundary of the Joslyn model is the Athabasca River, which has been demonstrated to be an effective hydraulic boundary in this area. Figure 4.1 presents a schematic of the model domain.

The vertical distribution of parameters within the model sought to represent the known stratigraphy underlying the area. Four layers with varying hydraulic parameters were defined to represent:

- Layer 1: Quaternary glacial till and clay deposits
- Layer 2: Bedrock from the Clearwater Formation
- Layer 3: Oil sand and basal clays from the McMurray Formation
- Layer 4: Oil sand and basal water sand from the McMurray Formation

The hydraulic properties remained constant within layers 1 through 3; however, layer thickness varied according to topography and the thickness of the respective geologic bodies represented by the model layers. The base of the model was defined as a no-flow boundary and therefore hydraulic properties were not defined. Layer 4 was the only layer to have lateral variations in hydraulic properties. These variations relate to the location of the basal water sand within the McMurray oil sand. The distribution of basal water sand outside of the DCEL Lease is based on the CNRL Horizon Project EIA (2002). Within the DCEL Lease, corrections to the original CNRL basal water sand footprint were made to account for new information gained through DCEL's drilling program. At the interfaces between the original CNRL data and the refined DCEL data, connections between the two distributions were made accordingly. Similar to the CNRL model, the distribution of hydraulic conductivity within the basal water sand was defined by the relative transmissivity caused by variations in sand thickness. At locations where the sand thickness was greater than 5 m, the basal water sand was given a different set of hydraulic properties than where the thickness was between 1 m to 5 m. Large lateral grid spacing in some locations within the model domain did not permit numerical convergence when the refinement of the vertical spacing was less than 5 m. The assignment of the hydraulic conductivity values within basal water sand zones was established through the calibration procedure described in Section 4.3. The distribution of hydraulic conductivity within the basal water sand layer (Layer 4) is shown in Figure 4.2.

The boundary conditions of the Joslyn model are as follows:

- The base of the model is defined by a no-flow boundary that is representative of the underlying Devonian bedrock;
- The top of the model is defined by a constant head boundary that is estimated by topography;
- The east boundary is defined by a constant head boundary that is equivalent to the average stage elevation of the Athabasca River; and
- The north, south and west boundaries are defined by no-flow boundaries.

4.2.1 Basal Boundary Condition

As previously discussed (Section 2.0), there has been speculation that pathways created by Devonian collapse features might facilitate the movement of saline water to the surface. To date, this remains as speculation without any field evidence of occurrence and hydrogeological significance. Therefore, the base of the DCEL Joslyn model presented herein is defined by the contact between the McMurray Formation and Devonian bedrock.

4.2.2 Top Boundary Condition

CNRL presented that the confining units in the Quaternary, Clearwater and McMurray Formations above the basal water sands severely limit the downward movement of surface water to the basal water sands. This assumption continues to be applied to the Joslyn model, where the average thickness of these confining units is 60 m. The head distribution of the groundwater table at the top of the model (layer 1) is therefore entered as a constant head boundary set at the elevation of the surface topography. This boundary was extended over the entire model domain and remained constant during all predictive simulations with the exception of the open pits during mine operation.

4.2.3 East Boundary Condition

The alluvial channel of the Athabasca River is effectively an eastern hydraulic boundary in this area. Northeast of the CNRL Horizon project there is some evidence indicating that oil sand may underlie the Athabasca River, thereby allowing a hydraulic connection below the river through the basal water sand. However, both the distance of this location from the Joslyn Mine and the discontinuity of the basal water sand render this connection insignificant with respect to the proposed Joslyn North Mine. For these reasons, a constant head boundary following the average stage elevation of the Athabasca River (approximately 238 mASL to 232 mASL) has been defined along the entire eastern model boundary.

4.2.4 Perimeter Boundary Condition

The distance of the north, south and west boundaries of the model domain in relation to the proposed mine projects, coupled with the discontinuous nature of the basal water sand pods makes the definition of no-flow conditions along these boundaries insignificant. Any water level drawdown that may be predicted to occur at this boundary during the simulation of basal water sand depressurization is not expected to influence the simulation of depressurization rates at the Joslyn North Mine.

4.3 MODEL CALIBRATION

Although many of the parameters and assumptions of the Joslyn model are identical to the CNRL model (CNRL 2002), a step-by-step calibration procedure was undertaken to account for the changes made. The parameters that were altered during the calibration process included the hydraulic conductivity and specific storage of the basal water sands. Calibration was completed using the following information sources:

- Undisturbed groundwater elevation readings taken from on-site wells;
- Simulated groundwater elevations as presented by CNRL (2002) from both baseline and pumping conditions;
- Simulated depressurization rates as presented by CNRL (2002);
- A long term pump test implemented by CNRL in June 2004.

4.3.1 On-Site Wells

There were 16 piezometers completed on-lease within basal water sand pods at the time of modelling. The baseline measurements from these locations were used to calibrate the model in steady state conditions. The locations of these piezometers are shown in Figure 4.3. The resulting calibration curve for simulated versus measured results is included as Figure 4.4. The resulting hydraulic conductivity of basal water sand with a thickness greater than 5 m was 5×10^{-5} m/s and 6.5×10^{-5} m/s for basal water sand less than 5 m.

4.3.2 Comparison of Simulated Groundwater Elevations: CNRL versus DCEL

The baseline groundwater flow regime that was simulated by CNRL and presented as Figure 4.3-4 (2002) was compared to DCEL's baseline simulations. Particular attention was paid to the CNRL lease, as this was the focus of the 2002 EIA. Although a constant head boundary was not applied at the Athabasca River in the CNRL model, very little variation in groundwater conditions exists near the River between the baseline conditions of the two models (Figure 4.5). The Athabasca River stage elevation seemingly controls the groundwater elevation in this area in both models, either directly through the constant head set in the Joslyn model or indirectly through hydraulic parameters set along the Athabasca River in the CNRL model.

The overall comparison between the two models showed reasonable correlation between baseline conditions, particularly with respect to horizontal flow directions. Within the proposed mine areas (both CNRL and DCEL), the baseline horizontal hydraulic gradients are almost identical between the two models. The horizontal hydraulic gradients to the west (approximately 1 km) of the leases showed considerable variation. This variation is related a simulated block of low permeable material that was inserted in the CNRL model to facilitate calibration. The same calibration technique was not used in the Joslyn model, as the baseline head equipotentials were comparable to measured values without it.

4.3.3 CNRL Simulated Depressurization Rates

In the CNRL Supplemental Information (2003) a table of "Planned Case Basal Water Sands Depressurization Rates (Section 6 Supporting Documents, Part 3, Appendix B, Table 10) was presented. The incremental depressurization rates due to CNRL were predicted for the following time frames:

- 2007 to 2018;
- 2019;
- 2020 to 2027;
- 2028 to 2036;
- 2037 to 2041; and
- 2042 to 2046.

The Joslyn model did not use the exact same time steps as the CNRL model; although a comparison between the two models for dewatering served as another calibration tool.

The Joslyn model was adjusted to include the advancements of the CNRL mine as presented in the Horizon EIA. Likewise, the re-injection locations and schedule presented in CNRL (2002, Table 9) were also entered into the Joslyn model. Table 4.1 compares the results of the Joslyn model to the CNRL model.

Table 4.1 Comparison of CNRL and DCEL Depressurization Rates

		Predicted Depressurization Rates at CNRL (m^3/day)	
CNRL Mining Period*	**Equivalent DCEL Mining Period**	**CNRL Model***	**DCEL Model**
2007 to 2018	2007 to 2015	2,490	2,500
2020 to 2027	2020 to 2025	25,300	24,200
2028 to 2036	2025 to 2035	13,780	16,300
2037 to 2041	2035 to 2040	11,500	13,000

*All CNRL values taken from Section 6 Supporting Documents, Part 3, Appendix B, Table 10 (2003).
Note: The one year time step in 2019 that was presented by CNRL was not included above. The 5-year time steps modeled by DCEL averaged this mine advancement into the 2020 to 2025 time step.

Table 4.1 shows the comparable time steps between the two models. The results indicate there is reasonable correlation between the two models. This calibration step demonstrates the Joslyn model predicts an equivalent regional flux during the CNRL mining operation when compared to the CNRL model.

4.3.4 CNRL Long Term Pump Test

CNRL completed two long term pump tests in 2004 within the basal water sand on Lease 18. Both tests were faced with numerous complications and the resulting data set was difficult to interpret. The test conducted at 4-24-096-12 W4 provided the most uninterrupted and consistent data set. This location is approximately 3 km northeast of the proposed Joslyn North Mine and therefore the data acquired was deemed pertinent to DCEL's basal water sand assessment and provided an additional source of model calibration data.

CNRL's understanding of the basal water sand distribution surrounding the 4-24-96-12 pumping well has been refined in comparison to the original distribution (CNRL 2002). The basis for basal water sand distribution in the Joslyn model was CNRL (2002). Slight variations in drawdown predictions can be expected due to this refinement. Figure 4.6 presents a drawdown map produced by the Joslyn model using the parameters that were applied during the 4-24-96-12 pumping test. These parameters include an average pumping rate of 400 m^3/day for a total of 24 days. The differences between the measured and predicted drawdown measurements are acceptable (Figure 4.6). This calibration step serves to show that the Joslyn model not only predicts regional drawdown within acceptable limits as demonstrated in Section 4.3.3, but that localized drawdown can also be predicted within reasonable limits.

4.3.5 Selection of Hydraulic Parameters

The model calibration that was previously identified assisted in the selection of the hydraulic parameters that were used for the basal water sands. These parameters have been applied for predictive depressurization and injection scenarios and are summarized in Table 4.2. The hydraulic parameters for all other layers are also included in Table 4.2 and are considered representative of the geologic bodies on a regional scale.

Table 4.2 Hydraulic Parameters Applied Within the Joslyn Model

Layer #	Geologic Body	Horizontal Hydraulic Conductivity (m/s)	Vertical Hydraulic Conductivity (m/s)	Specific Storage (1/m)	Effective Porosity
1	Quaternary till and clay	$1x10^{-7}$	$1x10^{-9}$	$1x10^{-6}$	0.25
2	Clearwater bedrock	$1x10^{-8}$	$1x10^{-10}$	$1x10^{-6}$	0.20
3 & 4	McMurray oil sand	$1x10^{-9}$	$1x10^{-10}$	$1x10^{-6}$	0.10
4	McMurray basal water sand	$5x10^{-5}$	$5x10^{-6}$	$5x10^{-6}$	0.30

4.4 MINE DEVELOPMENT

Three groundwater scenarios were assessed using the Joslyn model.

1. Baseline Case – The Joslyn model was originally created to simulate the current baseline case of the basal water sands under steady state conditions. Calibration was achieved for the known hydraulic head distribution and the regional flux.
2. Project Case – The baseline model was modified to include the planned Joslyn mine project. The averaged groundwater diversion and injection activities associated with 5-year mine footprints were entered into the model and the resulting changes in the hydraulic head distribution and regional flux were compared to baseline conditions.
3. Cumulative Case – The baseline model was modified to include both the DCEL Joslyn and CNRL Horizon mine projects. It was judged that the hydraulic barrier provided by the Athabasca River to the east and the discontinuity of the basal water sand to the south of DCEL negate the necessity of including other nearby oil sands mining projects in the cumulative assessment. The averaged groundwater diversion and injection activities associated with 5-year mine footprints were entered into the model and the resulting changes in the hydraulic head distribution and regional flux were compared to baseline conditions.

The simulation of the proposed mine stages was completed using drain boundaries in MODFLOW. These boundaries allow for the water table elevation to be set at the planned base of excavation during each mining stage. Figure 4.7 shows the location and duration of the drains within the model.

Figures 4.9 to 4.14 display the groundwater level changes for the cumulative assessment. As CNRL is actively developing their lease in preparation to begin mining, it is likely that the cumulative assessment is more representative of the impacts to the regional area.

4.4.1 In-Pit Tailings Disposal

The baseline model predicts that recharge into the basal water sand aquifer from the ground surface above the planned mine area is 1 mm/year. During mining, the increased vertical gradient caused by the depressurization of the basal water sand essentially doubles this recharge to 2 mm/year. Table 4.2 demonstrates that the geological bodies overlying the basal water sand have relatively low permeabilities with vertical hydraulic conductivities ranging from $1x10^{-9}$ m/s to $1x10^{-10}$ m/s. DCEL's proposed method of tailings production and disposal are currently not commercially used by Oil Sands operations and the specific hydraulic properties of the end product are unknown. The majority of the tailings material will be filtered (to remove the water) and hauled to disposal areas by trucks as a solid material called "filter cake". This filter cake material will be co-disposed with the Quaternary clay and Clearwater overburden that was originally stripped from surface providing a dry landscape.

This implies that the deposited tailings will have a greater hydraulic conductivity than the original overburden, but that the overall impact on the groundwater regime may be negligible.

A conservative estimate for the vertical hydraulic conductivity of the in-pit tailings is $1x10^{-8}$ m/s. With the tailings material being of similar thickness to the original overburden bedrock material above the basal water sand, the anticipated leakage of surface water into the basal water sand is predicted to increase by one to two orders of magnitude. This increase is deemed insignificant in regards to the groundwater regime for the following reasons:

- Very little basal water sand underlies the proposed in-pit tailing ponds. The majority of tailings will be deposited on a Devonian foundation.
- The tailings are not expected to be saturated prior to deposition; therefore, the hydraulic head that is induced above the basal water sands will be less than baseline conditions.
- Any rise in basal water sand pressure that is related to increased leakage through the tailings will be accounted for during the design of the depressurization well network.
- The baseline water quality within the basal aquifer is currently not potable. Any increase in infiltration from surface into the basal aquifer caused by tailing deposition will not to worsen it.

4.4.2 Injection Wells

Injection wells are planned for the disposal of water produced from depressurization of the basal water sands. There will be no waste liquids included in this water.

The injection rates from CNRL 2003 were also included for the cumulative impact assessment. It is understood that the injection scheme presented in the Horizon EIA was conceptual and may vary significantly during actual mine development. This understanding should also be applied to the injection schedule presented for the Joslyn North Mine project. This injection scheme attempts to account for the disposal of the predicted volumes necessary to achieve depressurization on site. The actual location of injection wells and other potential uses for basal water has not been finalized. Figure 4.8 shows the location of the both the simulated CNRL and DCEL injection wells.

Due to the constant head boundary along the Athabasca River in the Joslyn model, the volume of water that could be injected at CNRL injection wells 3, 4 and 5 was significantly lower than originally presented in CNRL 2003. These wells are located in a large basal water sand body that is not connected to the DCEL Lease, which renders this detail insignificant when calculating DCEL depressurization and injection rates. The prime impact is the volume of water that has the potential to exit or enter the Athabasca River across the entire model domain (Section 4.4.4).

Table 4.3 shows the planned average volumes of water to be injected into the basal water sands based on the current injection scenario. Injection Well #1 is capable of handling the entire volume of depressurization water through 2025. Once mining moves northeast in 2025, Injection Well #1 can no longer be used. It is unlikely that the entire volume of basal water can be re-injected on site after 2025. Approximately 50% of the depressurization water will need to be handled through other means (Section 5.1.5).

Table 4.3 Proposed DCEL Injection Rates						
Year	**DCEL Independently with Injection (m^3/day)**			***DCEL and CNRL with Injection (m^3/day)**		
Injection Well #	#1	#2	#3	#1	#2	#3
2010-2015	800			200		
2015-2020	1000			700		
2020-2025	1400			900		
2025-2030		900	800		900	800
2030-2037		900	800		1000	900

Refer to Figure 4.8 for injection well locations
* Anticipated volumes when CNRL is also dewatering

4.4.3 Basal Water Sands Depressurization

Two simulations were run for the Joslyn North Mine project independent of potential influence from CNRL. These simulations sought to represent the impacts of the Joslyn North Mine project with and without re-injection into the basal water sands. Depressurization was simulated by lowering the hydraulic head to the base of mine elevations during each specific mine period.

Similar to the independent scenarios described above, two simulations were run to calculate the cumulative impacts of both the proposed Joslyn North Mine project and the planned CNRL Horizon project. The two scenarios represent the predicted depressurization of the basal water sands with and without the inclusion of re-injection.

Table 4.4 lists the simulated average depressurization rates at DCEL that will be necessary for each planned 5-year mine advancement.

Table 4.4 DCEL Basal Water Sand Depressurization Rates				
Year	**DCEL Independently with no Injection (m^3/day)**	**DCEL Independently with Injection (m^3/day)**	**DCEL with CNRL* with no Injection (m^3/day)**	**DCEL with CNRL* with Injection (m^3/day)**
2010-2015	800	800	200	200
2015-2020	1000	1000	500	700
2020-2025	1400	1400	600	900
2025-2030	2900	4000	2700	4400
2030-2037	3000	4200	2500	3600

* CNRL mine advancements and injection rates based on CNRL Horizon Oil Sands Project Supplemental Information - Section 6 Supporting Documents, Part 3, Appendix B.

DCEL Independent Assessment

From 2010 to 2025 the volume of water to be diverted, with or without the simulated injection wells, is expected to remain constant. When mining occurs in the northeast corner of the DCEL Lease (2025 to 2037), the volumes of water are predicted to increase because of injection. It is during this time frame that the water will be injected into basal water sand deposits west of the mine. These deposits are believed to be connected to the basal water sand deposits that are actively being depressurized at the mine (Figures 4.13 and 4.14).

DCEL and CNRL Cumulative Assessment

Table 4.4 shows that in all time frames except one, the predicted diversion by DCEL will decrease when CNRL is dewatering to the north. Table 4.1 predicted the depressurization rates at the CNRL operations independent of DCEL. Table 4.5 compares these values to the incremental depressurization rates proposed by DCEL.

Table 4.5 Incremental Basal Water Sand Depressurization Rates due to the Joslyn North Mine		
Year	**Planned CNRL rates (m^3/day)**	**Incremental rates due to DCEL (m^3/day)**
2007 to 2015	2,490	200
2020 to 2025	25,300	900
2025 to 2035	13,780	3,600 to 4,400
2030 to 2040	11,500	3,600

4.4.4 Influence on the Athabasca River

As presented in Section 4.2.3, the alluvial channel of the Athabasca River is effectively a hydraulic boundary east of the DCEL lease. Northeast of the CNRL Horizon project there is some evidence indicating that oil sand may underlie the Athabasca River, thereby allowing a hydraulic connection below the river through the basal water sand. However, both the distance of this location from the Joslyn North Mine and the discontinuity of the basal water sand render this connection insignificant with respect to the proposed Joslyn North Mine. For these reasons, a constant head boundary following the average stage elevation of the Athabasca River has been defined along the entire eastern model boundary.

The baseline flow from the basal water sands into the Athabasca River is estimated to be 700 m^3/day by the Joslyn model. Four simulations were run in order to assess the potential impacts on flow rates into and out of the Athabasca River:

1. Project Case without Injection – The flux between the basal sand aquifer and the Athabasca River was calculated over the planned 5-year mine advancements. Re-injection was not accounted for in this case, nor was the cumulative influence of CNRL.
2. Project Case with Injection – The flux between the basal sand aquifer and the Athabasca River was calculated during the planned 5-year mine advancements. The calculations included the proposed DCEL injection scheme presented in Table 4.3. The cumulative influence of CNRL was not accounted for in this case.
3. Cumulative Case with Joslyn Model Injection – The flux between the basal sand aquifer and the Athabasca River was calculated during the planned 5-year advancements of both the Joslyn and the CNRL mines. The calculations included the proposed DCEL injection scheme presented in Table 4.3. As explained in Section 4.4.2, the constant head boundary along the Athabasca River in the Joslyn model decreases the total volume of water that can be injected in the CNRL lease. In this scenario, CNRL injection rates are simulated using the maximum injection rates allowable by the Joslyn model (the rates that equalize the elevation of the water table around the injection wells with the elevation of the ground surface).
4. Cumulative Case with CNRL Model Injection – The flux between the basal sand aquifer and the Athabasca River was calculated during the planned 5-year advancements of both the Joslyn and the CNRL mines. In this scenario, CNRL injection rates are simulated using the injection rates presented in Table 9 (CNRL 2003).

Table 4.6 outlines the calculated average changes in the flux between the basal sand aquifer and the Athabasca River during the planned 5-year mine depressurization and injection activities.

Table 4.6 Average Volumes of Water into/out of the Athabasca River				
Year	**DCEL Independently with no Injection (m^3/day)**	**DCEL Independently with Injection (m^3/day)**	**DCEL and CNRL with Injection (DCEL Model) (m^3/day)**	**DCEL and CNRL with Injection (CNRL Model) (m^3/day)**
2010-2015	600	1,400	1,000	1,000
2015-2020	500	1,500	300	24,500
2020-2025	500	1,800	-15,000	-8,700
2025-2030	-1,400	-1,300	-1,000	5,700
2030-2037	-1,400	-1,300	-3,900	2,700

Note: negative values represent water leaving the Athabasca River and positive values represent water entering the Athabasca River.

5.0 ENVIRONMENTAL IMPACT ASSESSMENT

5.1 GENERAL

The purpose of this section is to present a technical discussion of environmental effects of the proposed Joslyn North Mine project on the hydrogeological regime of the area. The methodology used here will be to synthesize the observations on the Joslyn Lease along with regional understanding of the hydrogeology to predict the impacts of the project.

This section will present extensive technical analysis of environmental effects of a hydrogeological nature. Where an effect is identified, a mitigative scheme is presented if appropriate. An evaluation of these effects and their mitigations and any residual effects will be completed according to a common set of guidelines used for environmental assessment.

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 socioeconomic 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 wellbeing of the ecosystem on which human survival depends.*"

Table 5.1 presents a summary of the environmental criteria used in this assessment.

Table 5.1 DCEL Joslyn North Mine Project Evaluation Criteria for Assessing the Significance of the Environmental Impact of the Project

Criteria	Criteria Definition	
Geographic Extent of Impact	Local	Effects occurring mainly within or close proximity to the proposed development area.
	Regional	Effects extending outside of the project boundary to regional surroundings.
	Provincial	Effects extending outside of the regional surroundings, but within provincial boundary.
	National	Effects extending outside of the provincial surroundings, but within national boundary
	Global	Effects extending outside of national boundary.
Duration of Impact	Short	Effects occurring within development phase
	Long	Effects occurring after development and during operation of facility
	Extended	Effects occurring after facility closes but diminishing with time.
	Residual	Effects persisting after facility closes for a long period of time.
Frequency	Continuous	Effects occurring continually over assessment periods.
	Isolated	Effects confined to a specified period (e.g. construction)

Table 5.1 DCEL Joslyn North Mine Project Evaluation Criteria for Assessing the Significance of the Environmental Impact of the Project

Criteria	Criteria Definition	
	Periodic	Effects occurring intermittently but repeatedly over assessment period (e.g. routine maintenance activities).
	Occasional	Effects occurring intermittently and sporadically over assessment period
	Accidental	Effects occurring rarely over assessment period.
	Seasonal	Effects occurring seasonally.
Ability for Recovery	Reversible in short-term	Effects which are reversible and diminish upon cessation of activities.
	Reversible in long-term	Effects which remain after cessation of activities but diminish with time.
	Irreversible - Rare	Effects which are not reversible and do not diminish upon cessation of activities and do not diminish with time.
Magnitude	Nil	No change from background conditions anticipated after mitigation.
	Low	Disturbance predicted to be somewhat above typical background conditions, but well within established or accepted protective standards and normal socio-economic fluctuations, or to cause no detectable change in ecological, social or economic parameters.
	Moderate	Disturbance predicted to be considerably above background conditions but within scientific and socio-economic effects thresholds, or to cause a detectable change in ecological, social or economic parameters within range of natural variability.
	High	Disturbance predicted to exceed established criteria or scientific and socio-economic effects thresholds associated with potential adverse effect, or to cause a detectable change in ecological, social or economic parameters beyond the range of natural variability.
Project Contribution	Neutral	No net benefit or loss to the resource, communities, region or province.
	Positive	Net benefit to the resource, community, region or province.
	Negative	Net loss to the resource, sites; access roads, communities, region or province.
Confidence Rating	Low	Based on incomplete understanding of cause-effect relationships and incomplete data pertinent to study area.
	Moderate	Based on good understanding of cause-effect relationships using data from elsewhere or incomplete understood cause-effect relationship using data pertinent to study area.
	High	Based on good understanding of cause-effect relationships and data pertinent to study.
Probability of Occurrence	Low	unlikely
	Medium	possible or probable
	High	certain

5.2 OVERVIEW OF ISSUES

The activities that may result in environmental impacts have considered both the Joslyn North Mine Project and the CNRL Horizon Project.

Sections 5.3, 5.4 and 5.5 deal with hydrogeological issues that might derive from the construction, operation or reclamation of the plant and mine.

Table 5.2 lists the issues to be discussed and indicates whether they apply to construction, operation and/or reclamation.

Table 5.2. Potential Impact Issues

Issue (discussed in following text)	Discussion Applies to			Considered a "VEC"
	Construction	Operation	Reclamation	
Head Reduction in BWS	X	X	X	NO
Removal of Surficial Aquifer	X	X	--	YES
Diversion of Groundwater from Surface Water	X	X	--	YES
Flow in BWS to/from Athabasca and Ells Rivers	X	X	X	YES
Disposal of Depressurization Water from BWS	X	X	--	NO
Groundwater Contamination	X	X	--	YES
BWS and End Pit Lakes	--	--	X	YES
Dissolution of Salt and Karst Formation	X	X	X	NO
Recycle Pond	X	X	--	NO
Pond 1 Seepage	X	X	X	NO
External Disposal Area Seepage	X	X	X	NO
Waste				NO
Class 2 and 3 Landfills	X	X	X	
Non-hazardous Waste - Solid	X	X	X	
Non-hazardous Waste - Liquid	X	X	X	
Hazardous Waste	X	X	X	
Sewage	X	X	--	

5.2.1 Head Reduction of 50 m in BWS

In order to provide safe conditions for mining it will be necessary to reduce the hydraulic heads in the basal water sands underlying the mine to levels that are below the base of the pit. This will be accomplished through a series of pumping wells that will remove water from the basal water sands and thereby reduce hydraulic heads in that zone.

The environmental issues surrounding this depressurization apply to construction, operations and reclamation. Depressurization of the BWS will be necessary for preparations for mining, during mining and for at least a brief period during reclamation.

As demonstrated in the modelling section of this report, there is substantial interaction between the depressurization effects of CNRL and DCEL until approximately 2025. The modelling also demonstrated that the reductions in hydraulic head will be transmitted primarily through the basal water sand and not where oil sand lies directly on limestone.

The potential environmental issues associated with this head reduction include:

- Reduction in surface water flows
- Impact of other operations

The modelling has shown that the reduction in hydraulic head in the basal water sand will be confined to the basal water sand. The sporadic distribution of the BWS resulted in the prediction that the reductions in hydraulic head will be localized around the depressurization centers and remain within the basal water sand. The presence of a connection to the alluvial channel means that reductions in hydraulic head will not cross the Athabasca River to the east side.

Early in the depressurization process (through the construction phase and into the operations phase) there will be synergies with the Horizon Project since depressurization at that mine will interact with that of DCEL. These synergies will diminish early in the DCEL operations as the Joslyn North Mine moves south (counter clockwise) and the Horizon Mine moves east and then north.

There is a potential that the reductions in hydraulic head in the basal water sand will spread west under the DCEL SAGD operations. This would have a significant adverse effect on that operation and would not be acceptable. (The same concern has been expressed by DCEL with respect to depressurization at the Horizon Project.) This effect would be mitigated by injection of water into the basal water sand in order to re-establish natural hydraulic heads.

The environmental effects during construction and operations of the lowing of hydraulic heads in the basal water sand near the mine are positive with respect to the CNRL and DCEL mines. The impact is significant and positive with respect to the objectives of depressurization.

The environmental effects of lowering the hydraulic heads in the basal water sand near the mine are negative with respect to the DCEL SAGD operations. The probability that this will occur is moderate. Mitigation is possible through water injection and the impact is therefore insignificant.

Under natural conditions, there is a downward hydraulic gradient between the water in the surficial aquifer and that in the basal water sands. Very little water actually moves across the intervening oil sands because of the low hydraulic conductivity. The localized increase in the hydraulic gradient near the depressurization wells will result in an insignificant increase in the volume of flow from the surficial deposits to the basal water sand. There will be no impact on surficial water levels or on vegetation that may depend on those water levels.

The modelling has demonstrated that there is no surficial impact of the basal water sand depressurization. It should also be noted that the effects of depressurization do not extend far enough on the north or west sides of the mine to go beyond the related disturbances of surficial vegetation caused by 1) the Horizon Project, or 2) the DCEL extraction plan and related operations.

At the reclamation stage of the project the hydraulic head in the vicinity of the end-pit lakes will be allowed to rise slowly as the lake(s) fill. The probability that this will occur is high and the impact is insignificant.

5.2.2 Removal of Surficial Aquifer

The surficial sand aquifer is located within the mining areas for both the Joslyn and Horizon Projects. The proposed mining activity of DCEL and the approved activity of CNRL will completely remove the surficial sand aquifer. The sand is a preferred construction material and will be excavated well in advance of actual mining which accelerates the affect on the aquifer. The prime environmental issue associated with the removal of the aquifer is a possible reduction in surface flows.

This is the only source of potable groundwater on the lease and DCEL is the only user. As a result, there are no adverse effects on other users and the impact from that perspective is insignificant.

Removal of the aquifer will have an adverse impact on adjacent ecological systems that derive their water from this aquifer. However, these ecological systems will also be completely disturbed by mining during the course of the project. There is no mitigation possible for this situation and the impact is therefore significant.

A discussion of these ecosystems and their relevance is found in Komex (2005a and 2005 b).

5.2.3 Diversion of Shallow Groundwater from Surface Water Bodies

The modelling has shown that depressurization of the basal water sand will not draw water from shallower groundwater. Therefore the impact of this activity on surface water bodies is insignificant.

Dewatering efforts will be necessary to prevent groundwater in the overburden from entering the mine pit. There is the possibility that this dewatering will create an issue with local surface water bodies.

It has been shown that the groundwater contribution to surface water flow, even during typical base-flow situations such as winter, is very small. This reflects the low hydraulic conductivity of surficial deposits in general throughout the lease. These conditions prevail in the western and southern three-quarters of the lease.

In the north-eastern quarter of the lease, the removal of the surficial sand aquifer has the potential to have some impact on the lower Joslyn Creek and some small tributaries as they are currently located in the mine area during the construction and operations phases. However, the diversion of Joslyn Creek upstream of the mine simply moves that ecosystem to another location during construction and operations. The dewatering will not affect the diverted ecosystem and therefore the impact is insignificant.

At the reclamation phase of the project, Joslyn Creek will be diverted again to flow through end pit lakes and enter the Ells River at the current location. Dewatering will no longer be occurring in this area and there will no longer be diversion of groundwater from surface water. The impact of diversion of groundwater from surface water is therefore insignificant.

5.2.4 BWS flow from/to Athabasca and Ells Rivers

The modelling of reduction in hydraulic head in the basal water sands has been shown to draw water out of the Athabasca River. This modelling has also shown that certain disposal scenarios for the water from the basal water sands may cause movement of groundwater into the river. The following sections discuss the withdrawal from and injection to the BWS as they might impact the Athabasca or Ells Rivers.

Injection to the BWS

From mine start up in 2010 to 2025, the water removed from the BWS for depressurization will be injected back into the BWS in the northeast corner of the lease. This injection has been predicted to cause an increase in the movement of water in the BWS into the Athabasca River. The water to be injected is solely derived from the BWS at other locations. There will be no wastewater from mine, plant or SAGD operations included in this water.

The connection to the Athabasca River is presumed to occur in or north of Section 11-96-11 where the alluvial channel of the river may encounter the BWS. The increase in pressure in the BWS in injection wells located in Section 3 is expected to push naturally-occurring groundwater having approximately 60,000 mg/L TDS into the river through this connection. The water actually being injected into the BWS will not actually move all the way to the river during this 15-year period so the naturally-occurring water will move out in front of the injected water.

It should be noted that the naturally-occurring groundwater having 60,000 mg/L TDS is currently entering the Athabasca River. The difference is that the injection of DCEL will increase the natural rate by up to 1,100 cubic metres per day from 700 cubic metres per day up to a maximum of 1,800 cubic metres per day.

The modelling has predicted that up to 1,100 cubic metres per day of groundwater from the BWS will be pushed into the Athabasca River for the period 2010 to 2025. The following conditions will be applied to assessment of impact:

- The appropriate flow condition for this assessment is the 10-year minimum seven-day average flow (7Q10). This occurs in February and is 108 m^3/s (nhc 2005).
- The TDS in the Athabasca River in winter is typically 250 to 330 mg/L. Winter would represent the worst case with respect to dissolved chemical loading. It must be noted that this TDS already includes all existing natural and anthropogenic upstream sources of dissolved solids.
- The rate of movement of water from the BWS to the river, as a worst case, is 1,100 cubic metres per day (0.013 m^3/s).
- The TDS of the water moving into the Athabasca River is 60,000 mg/L.

The effect on the flow of water in the Athabasca River is adding 0.013 m^3/s to a flow of 108 m^3/s is nil. This is not a measurable difference. There is insignificant impact on the flow.

The net effect of mixing 0.013 m^3/s of water containing TDS of approximately 60,000 mg/L with 108 m^3/s of water containing 330 mg/L would be an increase in TDS downstream of 7 mg/L. This is a theoretical 2 % increase and would not be measurable or significant to the river (Hatfield 2005).

There is no known or hypothesized similar connection to the Ells River. It is unlikely that there will be any impact on the Ells River. Any impact will be insignificant.

Withdrawal from the BWS

After 2025 to mine closure in 2037, water will be withdrawn from the BWS in the northeast and disposed elsewhere. This withdrawal is necessary to reduce hydraulic heads for mine safety. It has been shown that this will cause approximately 1,300 cubic metres per day of water to be removed from the Athabasca River.

The following conditions will be applied to assessment of impact:

- The appropriate flow condition for this type of assessment is the 50-year minimum monthly flow of 95 m^3/s (nhc 2005). This occurs in February.
- The rate of movement of water out of the river and into the BWS, as a worst case, is 1,300 cubic metres per day (0.015 m^3/s).

The effect on the flow of water in the Athabasca River of a reduction of 0.015 m^3/s from a flow of 95 m^3/s is nil. This is not a measurable difference. There is insignificant impact on the flow.

As the hydraulic heads in the BWS recover after pumping ceases the effect on the Athabasca River will diminish to the current natural condition of 700 cubic metres per day. There will be no residual impacts.

There is no known or hypothesized similar connection to the Ells River. It is unlikely that there will be any impact on the Ells River.

5.2.5 BWS Water Disposal

The volume of water to be pumped to depressurize the mine has been estimated to range up to 4,200 cubic metres per day. This water is expected to have TDS in the range of 15,000 to 57,000 mg/L and therefore cannot be released into local surface water bodies. The disposal of this water represents a potential environmental issue.

It has been shown that injection of BWS water from the depressurization system will take place in the northeast portion of the mine at certain times. The effects of this injection have been discussed with respect to the Athabasca River.

Other disposal options of the depressurization water under consideration include the following:

- Injection back into the BWS between the Horizon and/or Joslyn North Mine in the event that depressurization activities show effects on the SAGD operations of DCEL.
- Injection into hydrocarbon fields located west of the project generally in T 94 R 16.
- Injection into “spent” SAGD chambers.
- Use in operations.

Since depressurization activities will continue through a portion of the filling of the end-pit lakes (Section 5.2.6), there will be the continued need to dispose of this water. The method(s) of disposal will not change from those previously described.

5.2.6 Interaction of BWS with End Pit Lakes

There will be two end-pit lakes created near the end of mining operations. Initially, the pits will be dry due to depressurization and dewatering. The water in the basal water sands beneath the pits is not of appropriate quality that it should mix with surface water. Therefore, at the commencement of filling of these pits with water to form lakes, it will be necessary to undertake activities such that water from the basal water sands does not enter the lakes.

In order to minimize groundwater from the basal water sand from entering the end pit lakes as they fill it will be necessary to keep the hydraulic head below the level of surface water in the pit. This will mean that the groundwater in the basal water sands will not flow into the pit as it fills. Pumping for depressurization of the basal water sands will therefore continue at progressively decreasing rates as the pit(s) fill with surface water.

The final water level in the end-pit lakes will be lower than that which currently exists in the BWS beneath the future location of those pits. It is anticipated that the hydraulic heads in the BWS will return to pre-mining levels at some time after depressurization ceases. The resulting situation will be that there will be a hydraulic gradient upward from the BWS to the overlying end pit lakes. This gradient means that there will be flow of saline water from the BWS to the lakes that at the reclamation phase and in perpetuity. The impact of this flow and others has been considered in determining the water quality of the end pit lakes which has been discussed in Hatfield (2005). The conclusion in that report is that the impact of this flow will not have an adverse effect on water quality and is therefore insignificant.

5.2.7 Issues of Salt Dissolution and Karst Features

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 during depressurization of BWS.

More than thirty years of experience with mining operations in the area have demonstrated that this situation occurs only infrequently. It has been demonstrated in this report that there is no reason to anticipate these issues on the DCEL lease. This issue is insignificant and will not be considered further in this assessment.

5.2.8 Groundwater Contamination

The contamination of groundwater by various compounds and products is potentially an issue. This contamination could take place through leaks and spills of solid and liquid materials stored and used on the site. This section will briefly review the waste and operation water management practices proposed for the project and will subsequently wrap these into an impact assessment.

5.2.8.1 Waste Management Practices

The management of solid and liquid wastes is described in DCEL 2005a, Section B.10. The wastes on the site may be characterized as non-hazardous, hazardous and sewage.

- Non-hazardous wastes in solid form will be disposed in Class 2 or Class 3 landfills that will be constructed on the lease.
- Non-hazardous liquid wastes cannot be placed in the proposed landfills and will be disposed off site through accepted procedures.
- Both liquid and solid hazardous wastes will be shipped off site for disposal by accepted procedures. A storage and transfer station for hazardous wastes will be constructed at one of the landfill sites. These wastes will be shipped from this point for proper disposal.
- Sanitary sewage from the camps and operation facilities will be treated on site. Liquid from the treatment will go to the recycle pond and subsequently be used in the processing plant and/or SAGD plant operations.

5.2.8.2 Operations Water Management

Process-affected water will be collected from the site and will be transferred to the recycle water pond or one of the tailings ponds. This water will be used in the SAGD and/or the processing plant. Other features that contain process-affected water include Pond 1 and the external disposal area.

5.2.8.3 Impact Assessment

It has been shown that the mine and plant sites have hydrogeological conditions that fundamentally preclude significant contamination of groundwater. These conditions include the following:

- Up to several tens of metres of glacial till at the surface having low hydraulic conductivity directly overlying oil sand.
- Approximately 50 m of oil sand having hydraulic conductivity of approximately 1×10^{-9} m/s overlying either BWS or limestone.
- BWS that, while having appreciable hydraulic conductivity, is discontinuous.
- Limestone beneath all of the above units that has been demonstrated to have very low hydraulic conductivity.

Thus, with respect to movement of contaminants in groundwater to some receiving point – notably surface water:

- There is little possibility that contaminants would spread laterally or vertically in the glacial till due to low hydraulic conductivity.

- Even if contaminants were able to pass vertically through the glacial till, they would encounter approximately 50 m of oil sands in which the low hydraulic conductivity would further reduce the possibility of movement to a surface water body.
    - Hydrocarbon contamination, if it were to pass to the oil sands, would likely disappear into the mass of these hydrocarbon deposits.
- In the unlikely event that contamination found it way through the glacial till and the oil sands to the BWS, the discontinuous nature of this deposit would additionally reduce the possibility that contamination would move to surface water bodies.
- The demonstrated low hydraulic conductivity of the limestone underlying the entire plant and mine sites effectively precludes that unit as a route for transmission of contaminants to surface water.

Combining the above with the fact that spill prevention procedures will be in place at the mine and plant sites and considering that there will be a monitoring and response program in effect, the possibility of groundwater contamination is insignificant.

The location of the landfill on the site has tentatively been sited west of the main plant site. Approval for landfills is a rigorous process involving extensive subsurface investigations and the application for these approvals will be made at another time. Under the hydrogeological conditions described on the lease there is an excellent probability appropriate sites can be selected for the Class 2 and 3 landfills.

5.3 VALUED ENVIRONMENTAL COMPONENTS

The purpose of this section is to review the environmental issues of Section 5.2.1 that were identified as “valued environmental components” (VEC) in a format that is accepted practice in these assessments. There are five such VEC’s that relate to hydrogeology in this proposed project and they are identified in Table 5.2. One VEC, BWS and End Pit Lakes, is discussed and evaluated in Hatfield (2005).

Table 5.2 presents the remaining four VEC’s along with eight attributes leading to our assessment of the significance of impact. The following sections build on Section 5.2 for the purposes of assessing impact to these four VEC’s.

5.3.1 Removal of Surficial Aquifer

The surficial aquifer in the northeast portion of the project area will be removed by mining. There will be some cumulative effect of this with the Horizon Project to the north as they will also remove the aquifer. The aquifer is relatively localized and apparently collects and passes water from muskeg in the west to muskeg in the east. The aquifer thins southward such that there is likely little contribution to flow in the lower portion of Joslyn Creek. While there will be irreversible impact, the overall impact is judged to be insignificant. In the context of a completely new landscape for this area, a mitigation plan is not appropriate.

5.3.2 Diversion of Shallow Groundwater from Surface Water

The total operations footprint extends beyond the area of the mine. The mine proper, where drainage of groundwater will take place, is inside the operations footprint. There will be diversions of surface water throughout the operations footprint. The effects of dewatering of the overburden within the pit are not likely to extend outward far enough to influence surface water bodies outside the operations footprint because of the low hydraulic conductivity of the glacial till.

Excavation and dewatering will therefore have an insignificant impact on this situation outside of the operations footprint. There is no expectation of any cumulative effect with any other project in the area.

5.3.3 Flow in BWS to/from the Athabasca River

There is no expectation that planned activities in the BWS will have any effect on the Ells River.

Depressurization of the BWS and re-injection of water into the BWS have been shown to have the possibility of causing movement of water from and to the Athabasca River. The confidence that this will occur is rated as moderate. The extent of impact is regional as it could affect flows or water chemistry downstream. If the impact occurred it would for the duration of the project (long) and would be continuous over that time. There are no residual effects as the impact ends with injection or withdrawal.

On a cumulative basis, the increase in dissolved materials caused by the injection from 2010 to 2025 represents one more small increase to the many upstream anthropogenic increases occurring and planned. It is not a measurable effect in any event and will end in 2025 when injection ceases.

The residual and cumulative effects are insignificant.

5.3.4 Groundwater Contamination

It has been shown that the subsurface conditions in the area are not conducive to the introduction of contaminants into the subsurface nor to their spread. Glacial tills overlying oil sands; both of which have very low hydraulic conductivity, result in this situation. The net effect of these conditions is that groundwater contamination is judged to be insignificant at the project and residual levels.

There is no interaction at the groundwater level of this project with others and therefore no issues with cumulative effects.

Table 5.3. Summary of Impact Significance on Valued Environmental Components

VEC	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. Removal of Surficial Aquifer												
		none	Project	local	residual	continuous	irreversible	low	negative	high	high	insignificant
			Residual	local	residual	continuous	irreversible	low	negative	high	high	insignificant
			Cumulative	local	residual	continuous	irreversible	low	negative	high	high	insignificant
2. Diversion of Groundwater from Surface Water												
		none	Project	local	long	continuous	high	low	negative	high	high	Insignificant
			Residual	local	residual	continuous	high	low	negative	high	high	insignificant
			Cumulative	none	none	none	none	none	none	none	none	insignificant
3. Flow in BWS to/from Athabasca River												
		none	Project	Regional	Long	continuous	high	nil	negative	moderate	low	insignificant
			Residual	None	None	None	None	None	None	None	None	insignificant
			Cumulative	regional	long	continuous	high	nil	negative	low	low	insignificant
4 Groundwater Contamination												
		none	Project	local	Extended	accidental	low	low	negative	moderate	low	insignificant
			Residual	local	extended	isolated	moderate	low	negative	moderate	low	insignificant
			Cumulative	None	None	None	None	None	None	None	None	insignificant
5. BWS and End Pit Lakes												
		See discussion in Hatfield (2005)	Project									
			Residual									
			Cumulative									

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

6.0 CUMULATIVE EFFECTS

The preceding discussions have shown that groundwater impacts are, for the most part, confined to the DCEL lease. There are three areas in which cumulative effects have been identified. This section will examine those areas.

6.1 HEAD REDUCTION OF 50 M IN BWS

Both the Joslyn North Mine and Horizon Projects will need to depressurize the BWS for the purposes of mine safety. These operations will take place in relatively close proximity during the early stages of the Joslyn North Mine Project.

When the operations are in this close proximity the depressurization programs will have cumulative effects. Each depressurization program will influence the other. This has been explored within the groundwater modeling and the effects are mutually beneficial with respect to the mine operations. There should be no conflict between DCEL and CNRL with respect to mine depressurization.

The relationship with the DCEL SAGD operations is quite the opposite however. Decreases in hydraulic head in the BWS, whether they originate from CNRL or DCEL are potentially very damaging to the success of the SAGD operation. The groundwater modeling for the Joslyn North Mine Project did not predict that depressurization from that project would result in the potential for an impact on DCEL SAGD. The DCEL SAGD operations are much closer to CNRL and the impact assessment for the Horizon Project did however predict hydraulic head decline beneath DCEL SAGD operations.

DCEL and CNRL are working together with respect to contingency plans in the event that depressurization from the Horizon Project spreads south under the DCEL SAGD area. DCEL is also working independently on contingency plans in the event that depressurization at the Joslyn North Project spreads west to their SAGD. These mutual and independent plans include:

- Planning of monitoring networks to give warning of impending problems,
- Remedial measures, such as water curtains, to cut off the effects of hydraulic head decline in the BWS.

This issue lies solely between CNRL and DCEL.

6.2 REMOVAL OF SURFICIAL AQUIFER

Both the Joslyn North Mine and Horizon Projects intend to remove the surficial sand aquifer that lies in the northeast quarter of the DCEL lease. This aquifer extends northward into the CNRL lease. This aquifer overlies mineable oil sand on both leases. The removal of this aquifer will be at different times in each of these projects however the end result will be the same. The activities of each company in removing the aquifer will be mutually beneficial in the sense that the groundwater must be drained for excavation to take place.

The cumulative effect is that this aquifer will totally disappear. It is not conceivable that it will be replaced. There is no mitigation plan.

6.3 FLOW IN BWS TO ATHABASCA RIVER

There are two aspects of cumulative effect with respect to the proposal to re-inject water into the basal water sand in the northeast corner of the mine area. They relate to an interaction with the Horizon Project and influence on the Athabasca River.

6.3.1 Interaction with Horizon Project

The Horizon Project plans to depressurize the basal water sand and re-inject it at other places on their lease – just as does the Joslyn North Project. The planned injection of water by DCEL in the northeast corner of the mine area has the potential to be at odds with the depressurization activities of CNRL as their mine advances. The timing of the any conflict will be if the Horizon Mine is in the southeast corner of their lease at the time that Joslyn North Project is using the northeast corner of their lease for injection which appears to be the case.

DCEL and CNRL will need to work together to determine if there is a potential problem and, if so, it's significance.

6.3.2 Influence on Athabasca River

The injection of water from the BWS in the northeast corner of the mine area between 2010 and 2015 has been shown to have moderate probability of increasing the rate of flow of water containing elevated dissolved solids by approximately 1,100 m^3/d. During depressurization activities of DCEL, flow out of the river of 1,300 m^3/d has been predicted. This has been assessed to have insignificant impact on the flow in the river and to have a small effect toward increasing the dissolved solids concentrations in the river downstream.

It has also been shown that the Horizon Project may cause the movement of up to 15,000 and 24,500 m^3/d into and out of the Athabasca River respectively. The effects of this will be 10 to 20 times greater than DCEL.

This situation is a typical cumulative effects situation. An influence, in and of itself, is insignificant but when cumulated with existing and proposed effects the sum may have significance.

Factors to consider are:

- The fact that the impact from DCEL is very small,

- The fact that it is not completely clear that even the small impact will actually take place,
- The fact that the calculated impact already includes other existing impacts upstream of the Joslyn North Mine,
- The fact that the change in dissolved solids will stop when injection ceases in 2025.

Integrating these issues, the assessment is that the cumulative effect is insignificant.

7.0 MONITORING

A network of monitoring wells is already present covering the BWS and the Quaternary deposits of the DCEL lease (Figure 2.1). Both water levels and water chemistry have been collected from the monitoring wells for several years – background conditions to both SAGD and mining are well established. The data collected from this system is presented in Appendix B.

Portions of this system will be used for hydrogeological monitoring that has become a routine part of AEPEA Approvals for industrial projects. This will function as a lease-scale monitoring system.

Current practice in AEPEA Approvals also calls for groundwater monitoring programs for the approved operations. A proposal for such a contamination monitoring system will be part of any ensuing approval. This system will focus on monitoring shallow groundwater since the oil sands lying underneath the plant will act as a barrier for migration of plant-based contaminants to the BWS. Any monitoring program for the plant site may be called upon to address the following features:

- Landfills
- Water containment ponds,
- Process areas,
- Fuel storage areas,
- Outside chemical storage tanks,

A monitoring system for the basal water sand is currently under discussion between DCEL, CNRL and EUB as part of the Phase II license. This system, once agreed and established, will function as the warning system of the DCEL SAGD operations for changes in water pressure in the basal water sand. Mitigation will be planned after an indication of an issue.

Monitoring systems for the interaction of injection to or withdrawal from, the basal water sand is problematic with respect to the Athabasca River. Direct effects within the river are unlikely to be observable within the context of flow volumes and chemistry. As well, there may also be injection of water by CNRL to the north along the river. One possibility would be to plan observation well(s) on one or more of the islands in the Athabasca River northeast of the DCEL lease.

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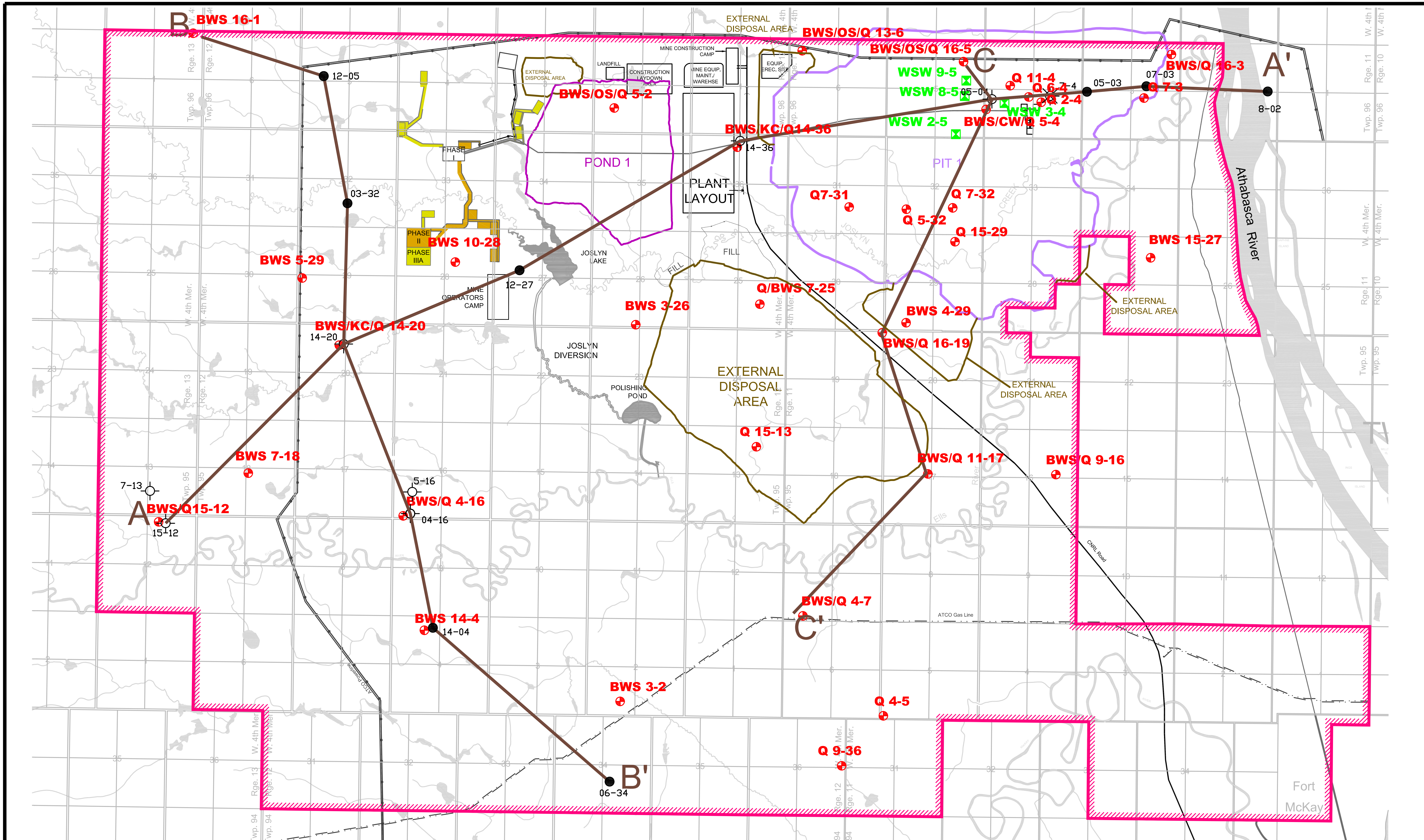
APPENDIX A FIGURES



Deer Creek Energy Limited

Millennium EMS Solutions Ltd.

PROJECT

Joslyn North Mine Project

TITLE

Figure 2.1 Deer Creek Energy Lease Area

LEGEND

- DCEL LEASE BOUNDARY
- CNRL ROAD
- PIT LIMITS
- POND 1
- EXTERNAL WASTE DISPOSAL
- OTHER MINE FACILITIES
- HYDROGEOLOGICAL CROSS SECTION
- STAND PIPE
  - BWS-Basal Water Sand
  - OS-Oil Sand
  - KC-Clearwater
  - Q-Quaternary
- WATER SOURCE WELL (BWS)
- DEVONIAN TEST HOLE
- DISPOSAL WELL (BWS)
- GEOLOGICAL DATA POINT

	BY	YY/MM/DD
DRAWN	KY	05/10/31
CHECKED	DH	05/10/31

SCALE : 0m 250 500 750 1000 1250 SCALE IN METRES

ACAD REF.

DRAWING NAME

FIGURE 2.1

PERIOD		STRATIGRAPHY: GROUP	FORMATION	MEMBER	LITHOLOGY
Pleistocene and Recent Deposits					Till, sand, silt, gravel and muskeg
Erosional Unconformity					
Cretaceous	Upper	Colorado	La Biche		Shale
Cretaceous	Upper	Colorado	Dunvegan		Sandstone
Cretaceous	Upper	Colorado	Shaftesbury		Shale
Cretaceous	Lower	Colorado	Pelican		Sandstone
Cretaceous	Lower	Colorado	Joli Fou		Shale
Cretaceous	Lower	Mannville	Grand Rapids		Lithic sand and sandstone
Cretaceous	Lower	Mannville	Clearwater		Shale and siltstone
Cretaceous	Lower	Mannville	McMurray		Oil sand, clays and sands
Erosional Unconformity					
Devonian		Woodbend	Grosmont		Limestone reef
Devonian		Woodbend	Ireton		Shale and shaly limestone
Devonian		Woodbend	Cooking Lake		Limestone reef
Devonian	Upper	Beaverhill Lake	Waterways	Mildred Lake	Calcareous shale
Devonian	Upper	Beaverhill Lake	Waterways	Moberly	Nodular limestone
Devonian	Upper	Beaverhill Lake	Waterways	Moberly	Bloclastic limestone
Devonian	Upper	Beaverhill Lake	Waterways	Moberly	Nodular limestone
Devonian	Upper	Beaverhill Lake	Waterways	Christina	Calcareous shale
Devonian	Upper	Beaverhill Lake	Waterways	Calumet	Carbonate limestone
Devonian	Upper	Beaverhill Lake	Waterways	Firebag	Calcareous shale
Devonian	Upper	Paraconformity			
Devonian	Middle		Slave Point		Anhydrite and dolomite
Devonian	Middle	Paraconformity			
Devonian	Middle	Elk Point	Fort Vermillion		Limestone and dolomite
Devonian	Middle	Elk Point	Watt Mountain		Shale and anhydrite
Devonian	Middle	Elk Point	Prairie Evaporite		Salt and anhydrite
Devonian	Middle	Elk Point	Methyl		Reefal dolomite
Devonian	Middle	Elk Point	McLean River		Dolomite, claystone and evaporite
Devonian			La Loche		Claystone and arkosic sandstone
Erosional Unconformity					

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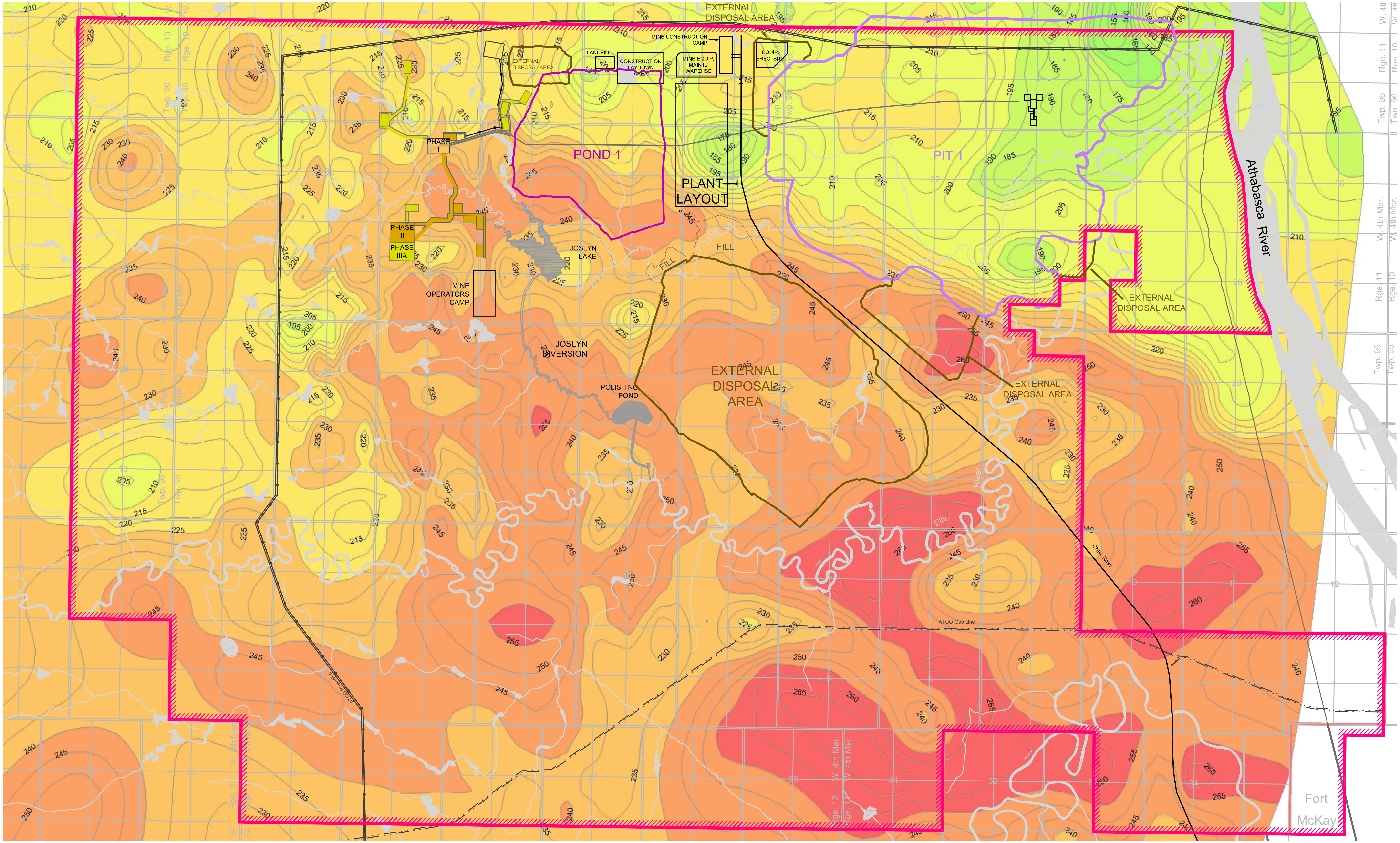
PROJECT	Joslyn North Mine Project		BY	YY/MM/DD	Project No.
		DRAWN	KY	05/10/31	DRAWING NAME
		CHECKED	DH	05/10/31	
TITLE	Figure 2.2. Stratigraphic Nomeclature on DCEL Lease	SCALE :	Not to Scale		FIGURE 2.2



DEER CREEK Energy Limited

Millennium EMS Solutions Ltd.

PROJECT: Joslyn North Mine Project

TITLE: Figure 2.3 Devonian Surface Structure

LEGEND
- DCEL LEASE BOUNDARY
- CNRL ROAD
- PIT LIMITS
- POND 1
- EXTERNAL WASTE DISPOSAL
- OTHER MINE FACILITIES

Elevation (m)
- < 150.0
- 150.1 - 170.0
- 170.1 - 195.0
- 195.1 - 210.0
- 210.1 - 225.0
- 225.1 - 240.0
- 240.1 - 255.0
- > 255

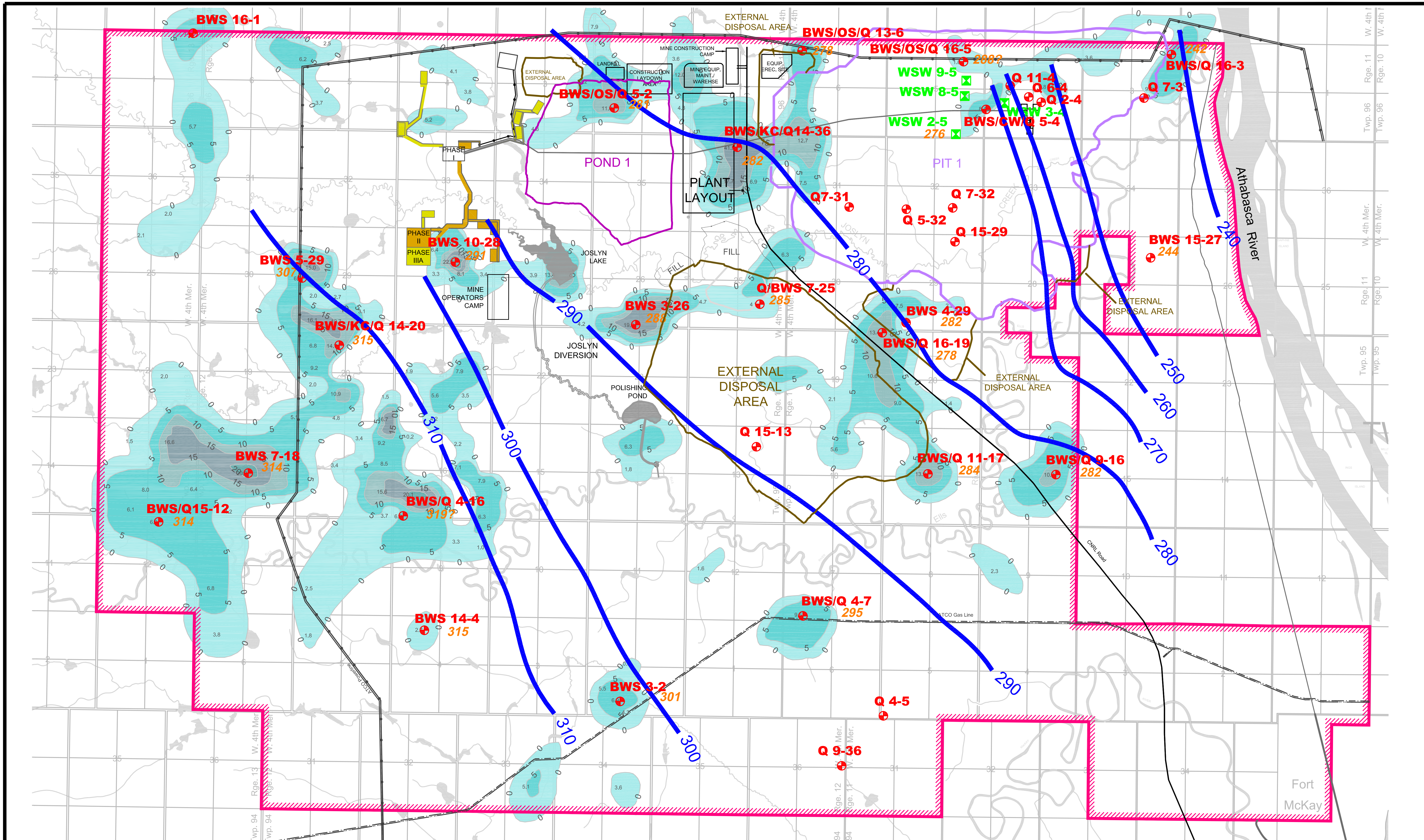
	BY	YY/MM/DD
DRAWN	KY	05/10/31
CHECKED	DH	05/10/31

SCALE: 0m 250 500 750 1000 1250 SCALE IN METRES

ACAD REF.

DRAWING NAME

FIGURE 2.3



DEER CREEK Energy Limited	**Millennium** EMS Solutions Ltd.

PROJECT: Joslyn North Mine Project

TITLE: Figure 2.4 Hydraulic Head and Thickness of the Basal Water Sands

LEGEND
- DCEL LEASE BOUNDARY
- CNRL ROAD
- PIT LIMITS
- POND 1
- EXTERNAL WASTE DISPOSAL
- OTHER MINE FACILITIES
- HYDROGEOLOGICAL CROSS SECTION
- STAND PIPE
  - BWS-Basal Water Sand
  - OS-Oil Sand
  - KC-Clearwater
  - Q-Quaternary
- WATER SOURCE WELL (BWS)
- –320– HYDRAULIC HEAD (m)
- 320 MEASURED HYDRAULIC HEAD

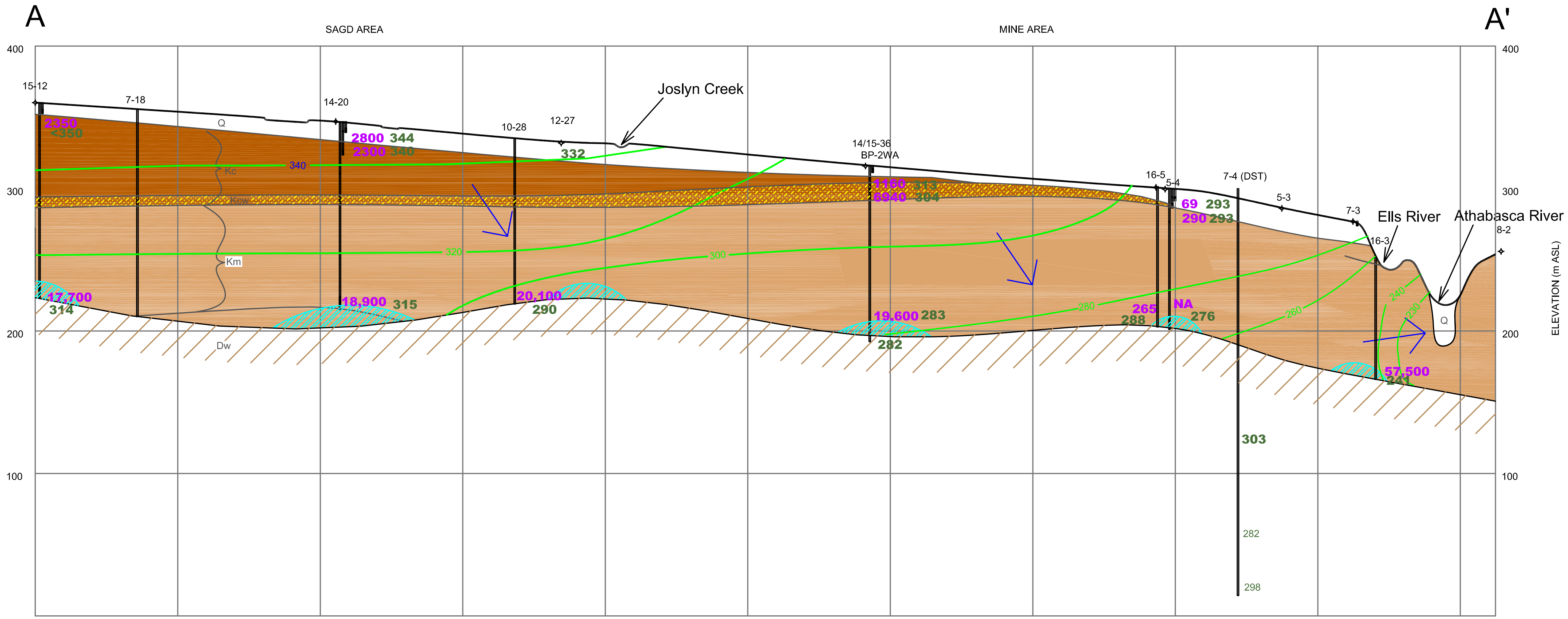
	BY	YY/MM/DD
DRAWN	KY	05/10/31
CHECKED	DH	05/10/31

SCALE: 0m 250 500 750 1000 1250 SCALE IN METRES

ACAD REF.

DRAWING NAME

FIGURE 2.4



PROJECT
Joslyn North Mine Project

TITLE
Figure 2.5. Hydrogeological Cross Section A - A'

LEGEND

- 935 - TDS (mg/L)
- 360 - Hydraulic Head Contour (m)
- 340 - Hydraulic Head Measured (m)
- (244) - Hydraulic Head (m-Freshwater Equiv.)
- 15-12 - Piezometer Site Name
- → - Direction of Groundwater Flow
- — - Geological Boundary
- Q - Quaternary
- Clearwater Formation (Kc)
- Wabasca Member (Kcw)
- McMurray Formation (Km)
- Devonian (Dw)
- Basal Water Sand

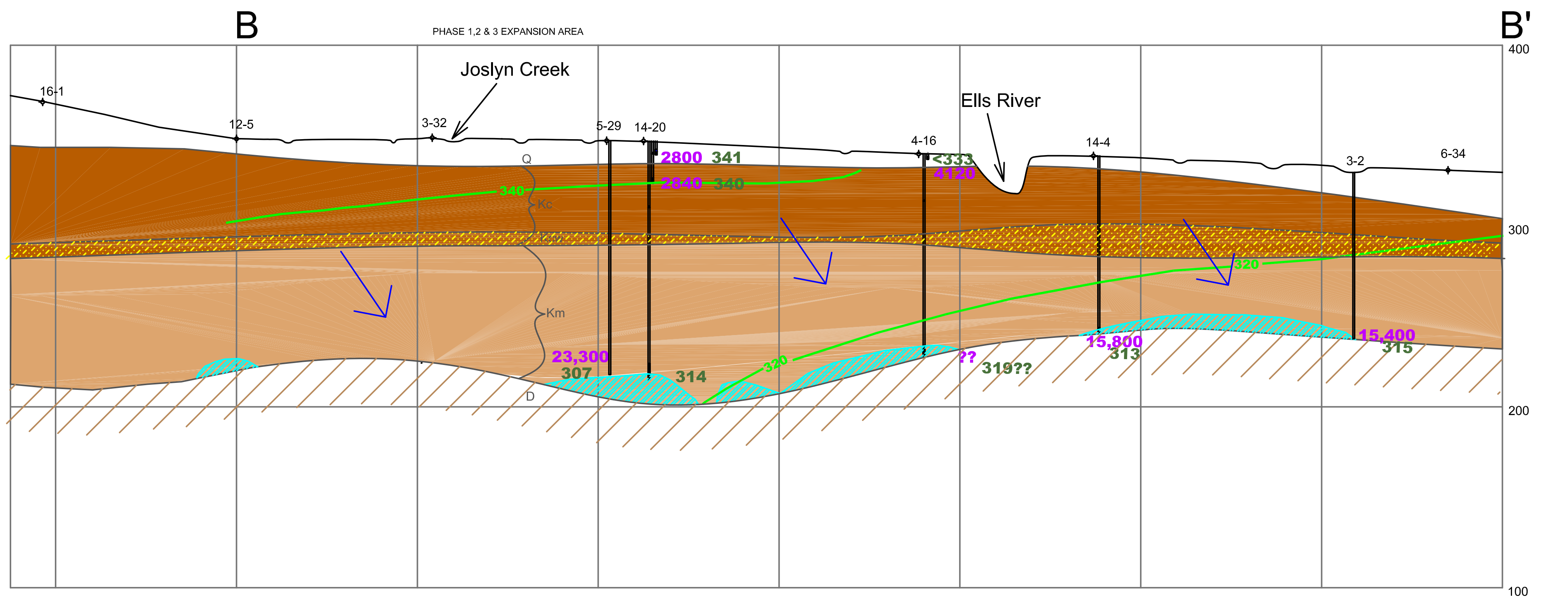
	BY	YY/MM/DD
DRAWN	KY	05/06/16
CHECKED	DH	05/06/16

SCALE : 0.5 0 0.5 1.0 1.5 km

ACAD REF.

DRAWING NAME

FIGURE 2.5



PROJECT	Joslyn North Mine Project
TITLE	Figure 2.6. Hydrogeological Cross Section B - B'

Deer Creek Energy Limited

Millennium EMS Solutions Ltd.

LEGEND

- 935 - TDS (mg/L)
- 350 - Hydraulic Head Contour (m)
- 340 - Hydraulic Head Measured (m)
- (244) - Hydraulic Head (m-Freshwater Equiv.)
- 15-12 - Piezometer Site Name
- → - Direction of Groundwater Flow
- — - Geological Boundary
- Q - Quaternary
- Clearwater Formation (Kc)
- Wabasca Member (Kcw)
- McMurray Formation (Km)
- Devonian (Dw)
- Basal Water Sand

	BY	YY/MM/DD
DRAWN	KY	05/06/16
CHECKED	DH	05/06/16

SCALE : 0.5 0 0.5 1.0 1.5 km

ACAD REF.

DRAWING NAME

FIGURE 2.6

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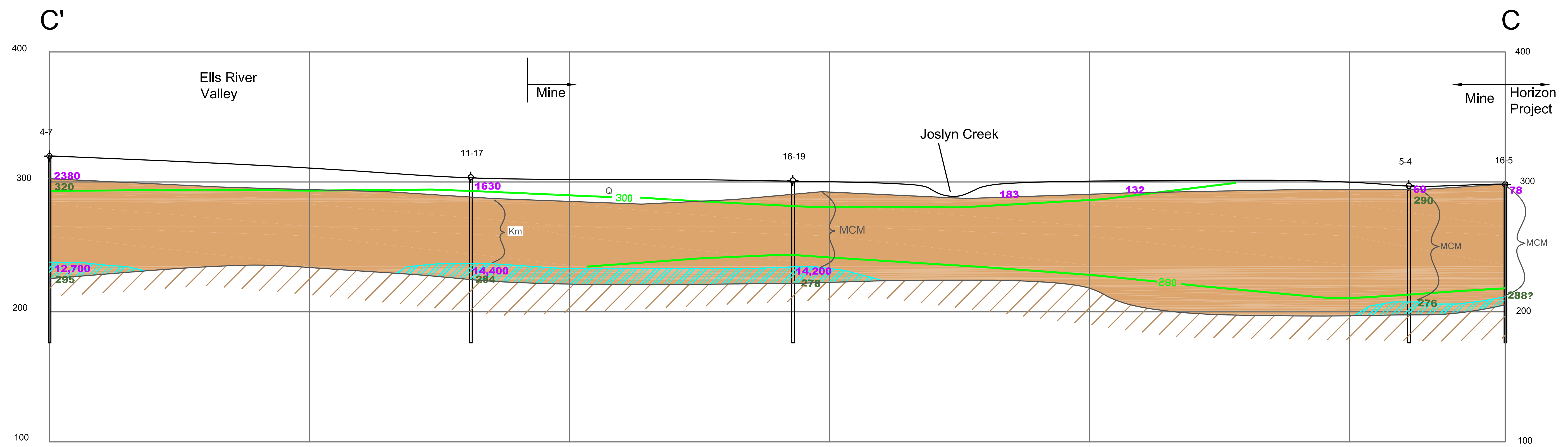


DEER CREEK Energy Limited

Millennium EMS Solutions Ltd.

PROJECT

Joslyn North Mine Project

TITLE

Figure 2.7. Hydrogeological Cross Section C - C'

LEGEND

935 - TDS (mg/L)
350 - Hydraulic Head Contour (m)
340 - Hydraulic Head Measured (m)
(244) - Hydraulic Head (m-Freshwater Equiv.)
15-12 - Piezometer Site Name
→ - Direction of Groundwater Flow
— - Geological Boundary
Q - Quaternary
- Clearwater Formation (Kc)
- Wabasca Member (Kcw)
- McMurray Formation (Km)
- Devonian (Dw)
- Basal Water Sand

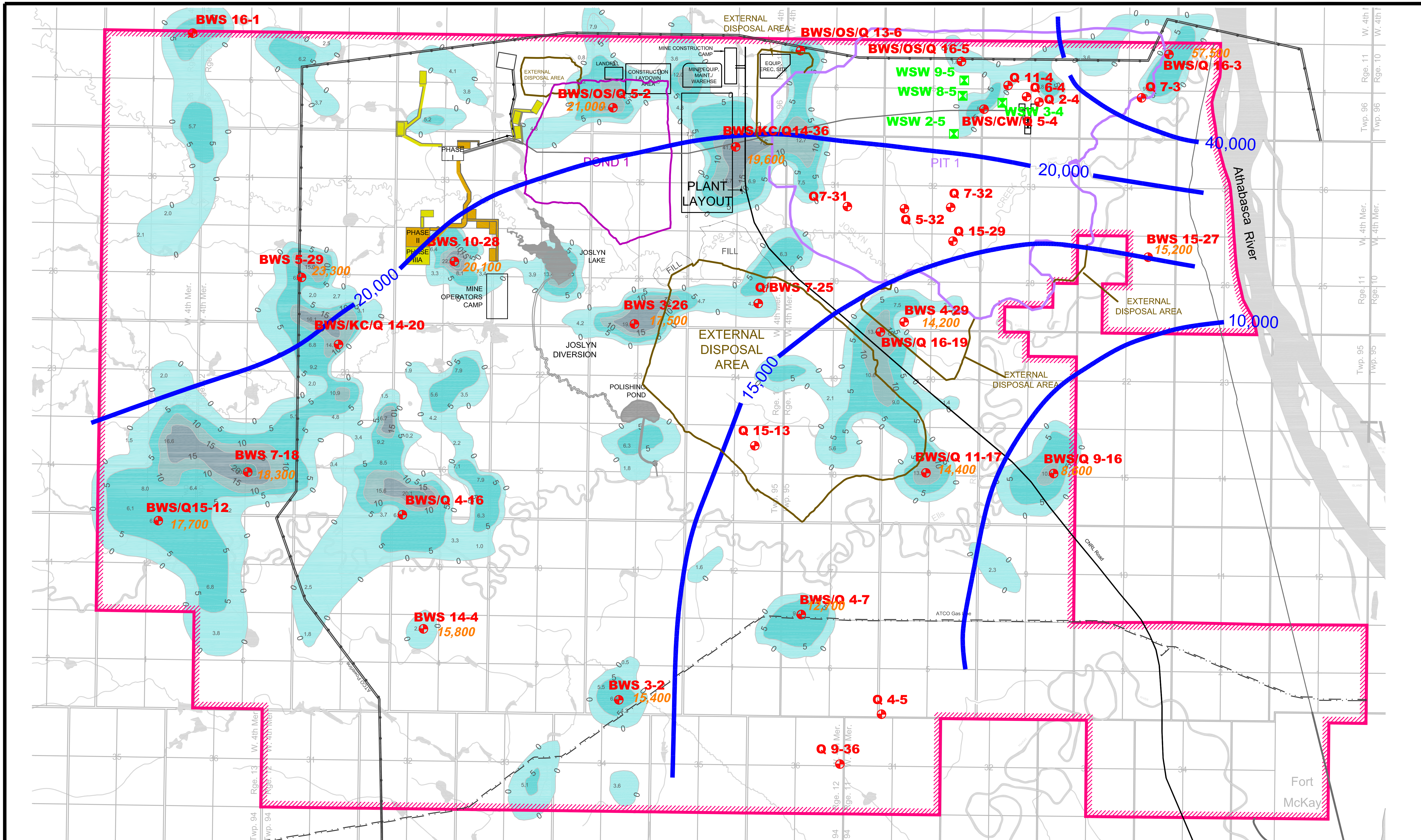
	BY	YY/MM/DD
DRAWN	KY	05/06/16
CHECKED	DH	05/06/16

SCALE : 0.25 0 0.25 0.50 0.75 km

ACAD REF.

DRAWING NAME

FIGURE 2.7



DEER CREEK Energy Limited	Millennium EMS Solutions Ltd.	PROJECT: Joslyn North Mine Project	
		TITLE: Figure 2.8 TDS in the Basal Water Sands	

LEGEND
- DCEL LEASE BOUNDARY
- CNRL ROAD
- PIT LIMITS
- POND 1
- EXTERNAL WASTE DISPOSAL
- OTHER MINE FACILITIES
- HYDROGEOLOGICAL CROSS SECTION
- STAND PIPE
  - BWS-Basal Water Sand
  - OS-Oil Sand
  - KC-Clearwater
  - Q-Quaternary
- WATER SOURCE WELL (BWS)
- –10,000– TOTAL DISSOLVED SOLIDS (mg/L)
- 320 MEASURED VALUE TOTAL DISOLVED SOLIDS (mg/L)

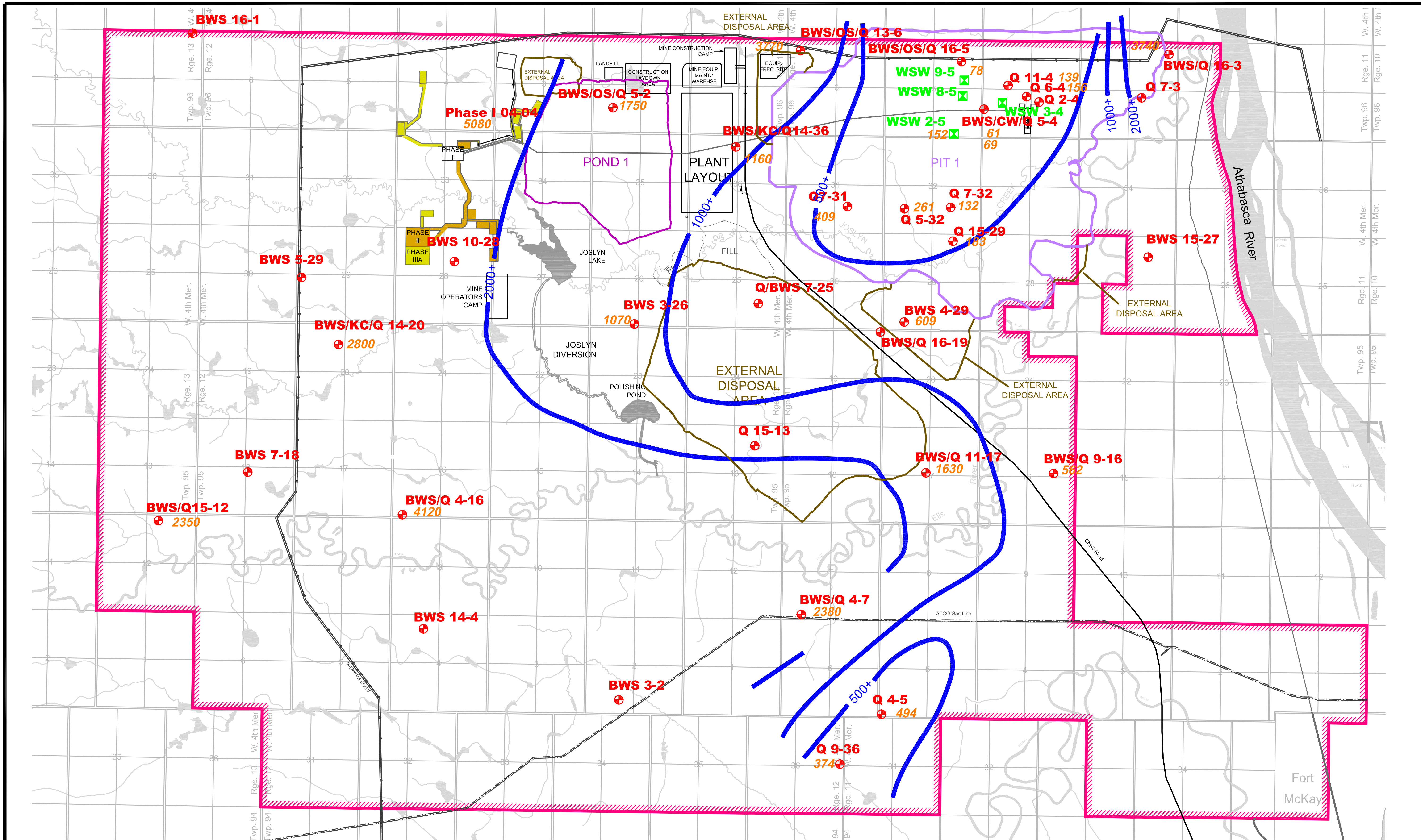
	BY	YY/MM/DD
DRAWN	KY	05/10/31
CHECKED	DH	05/10/31

SCALE : 0m 250 500 750 1000 1250 SCALE IN METRES

ACAD REF.

DRAWING NAME

FIGURE 2.8



PROJECT	Joslyn North Mine Project
TITLE	Figure 2.9 TDS in the Quaternary Units

DEER CREEK Energy Limited

Millennium EMS Solutions Ltd.

LEGEND
- DCEL LEASE BOUNDARY
- CNRL ROAD
- PIT LIMITS
- POND 1
- EXTERNAL WASTE DISPOSAL
- OTHER MINE FACILITIES
- HYDROGEOLOGICAL CROSS SECTION
- STAND PIPE
  - BWS-Basal Water Sand
  - OS-Oil Sand
  - KC-Clearwater
  - Q-Quaternary
- WATER SOURCE WELL (BWS)
- 500+ TOTAL DISOLVED SOLIDS (mg/L)
- 320 MEASURED VALUE TOTAL DISOLVED SOLIDS (mg/L)

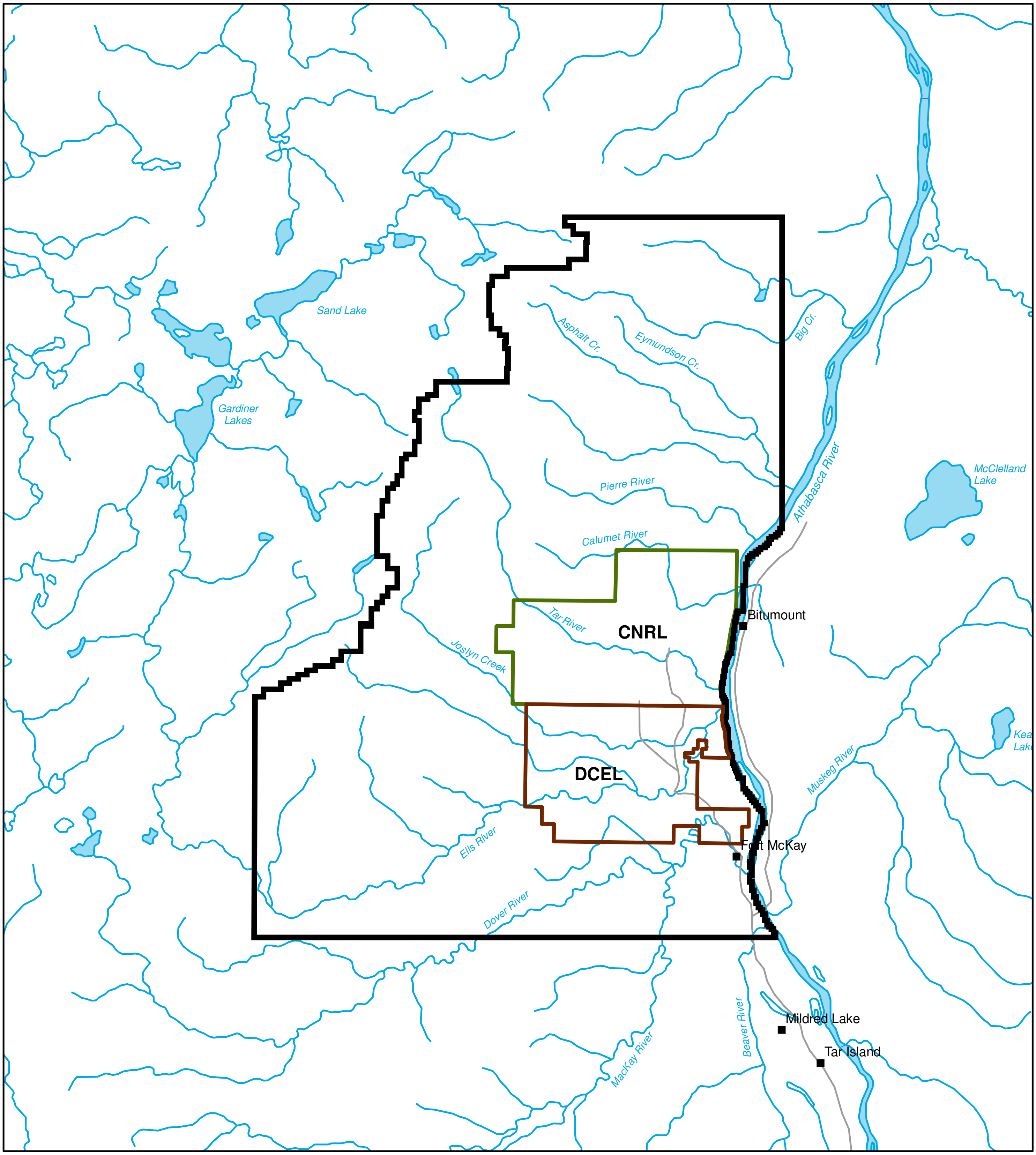
	BY	YY/MM/DD
DRAWN	KY	05/10/31
CHECKED	DH	05/10/31

SCALE : 0m 250 500 750 1000 1250 SCALE IN METRES

ACAD REF.

DRAWING NAME

FIGURE 2.9



Model Domain

DEER CREEK Energy Limited

Millennium EMS Solutions Ltd.

PROJECT

Joslyn North Mine Project

TITLE

Figure 4.1 Basal Water Sands Groundwater Model Domain

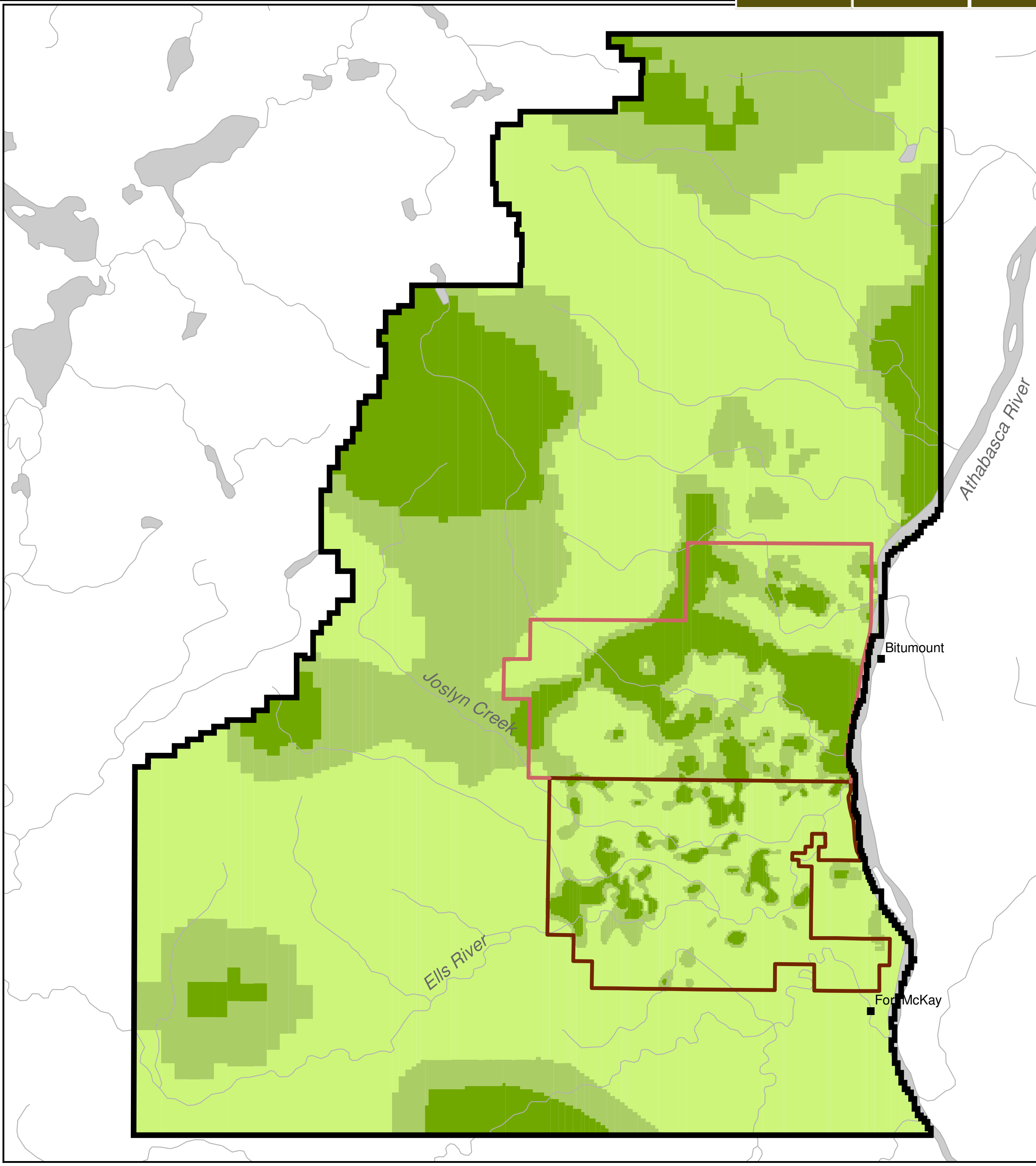
	BY	DATE
DRAWN	PS	18Oct05
CHECKED	SB	18Oct05

SCALE 1:500,000

PROJECTION: UTM Zone 12 NAD83

DRAWING NAME Fig 1 Model Domain

FIGURE 4.1



Conductivity (m/s)

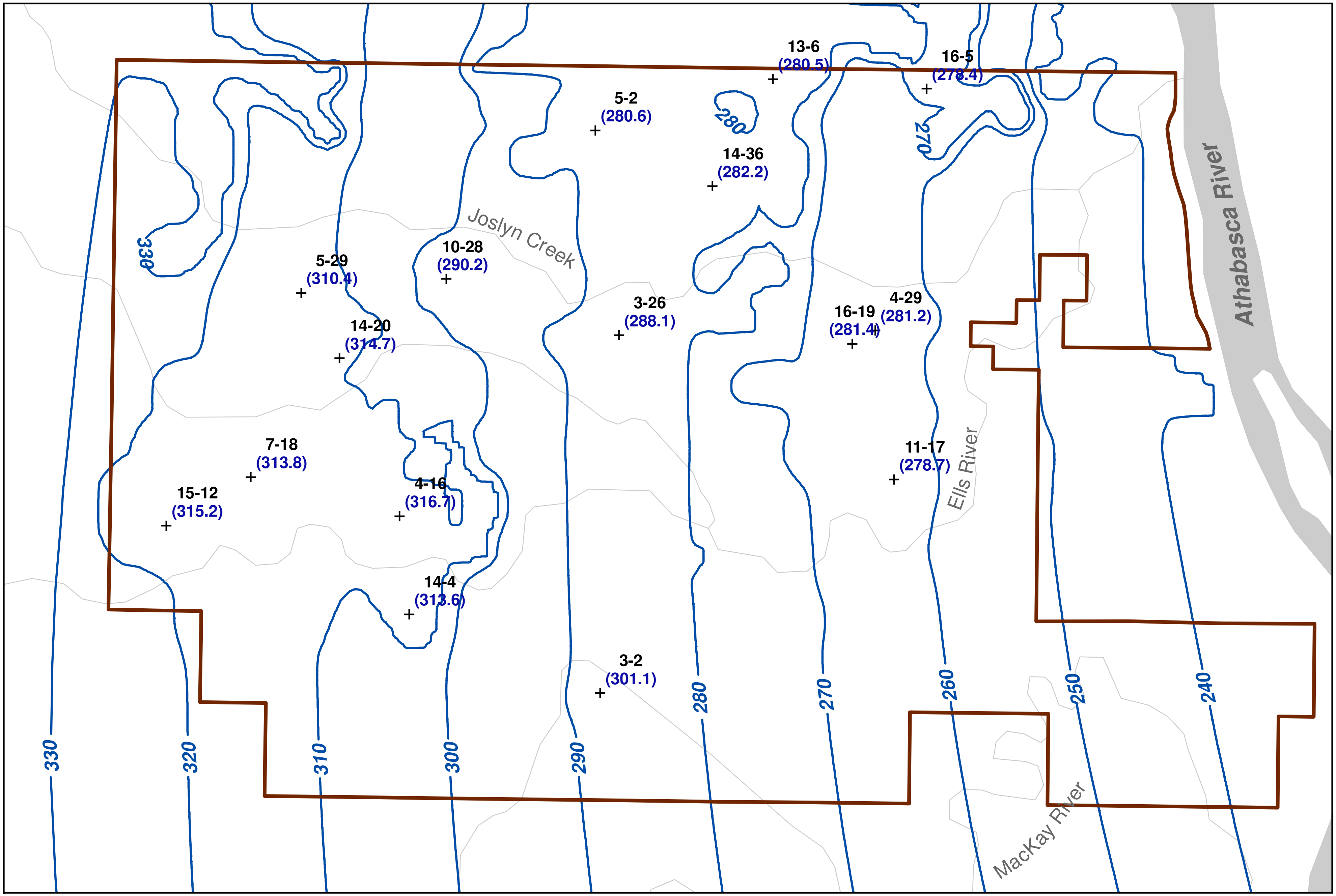
- $K_h = 1 \times 10^{-9}$
- $K_h = 6.5 \times 10^{-5}$
- $K_h = 5 \times 10^{-5}$

- Model Domain
- CNRL Lease Boundary
- DCEL Lease Boundary

Deer Creek Energy Limited

Millennium EMS Solutions Ltd.

PROJECT		BY	DATE	PROJECTION:
Joslyn North Mine Project	DRAWN	PS	18Oct05	UTM Zone 12 NAD83
	CHECKED	SB	18Oct05	DRAWING NAME: Fig 2 Conductivity Distribution
TITLE: **Figure 4.2 Basal Water Sands Hydraulic Conductivity Distribution (Layer 5)**	SCALE 1:330,000 (0 – 4 – 8 Kilometres)			FIGURE **4.2**



DEER CREEK Energy Limited

Millennium EMS Solutions Ltd.

PROJECT

Joslyn North Mine Project

TITLE

Figure 4.3. Simulated Baseline Groundwater Elevations in the Basal Water Sands on Lease

LEGEND

+ 3-2 (301.1) Basal Water Sand Observation Well; Basal Water Measured Elevation (spring 2004) mASL

—280— Simulated Basal Water Elevation (mASL)

—— DCEL Lease Boundary

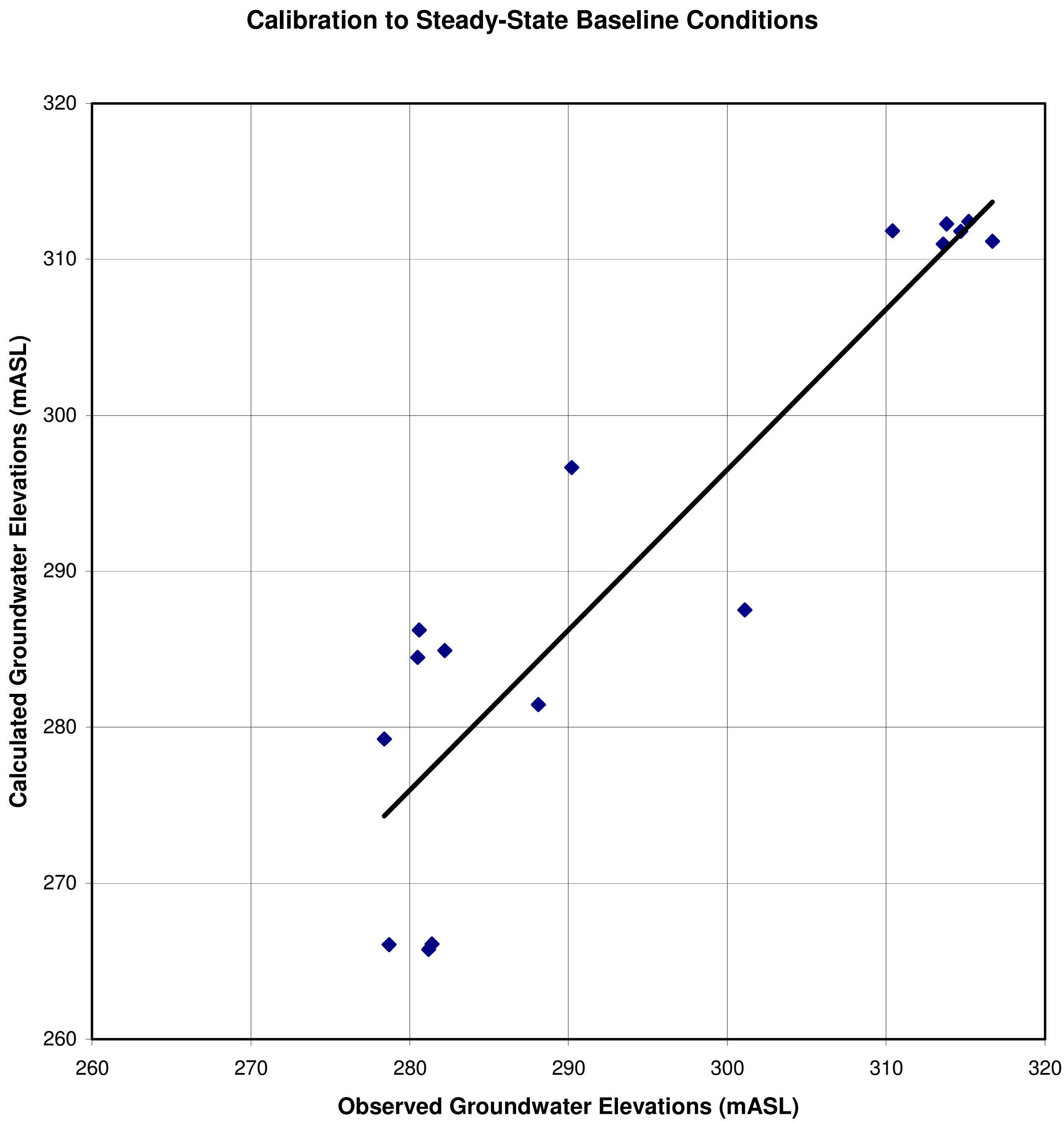
	BY	DATE
DRAWN	PS	18Oct05
CHECKED	SB	18Oct05

SCALE: 1:90,000

PROJECTION: UTM Zone 12 NAD83

DRAWING NAME: Fig 3 Sim baseline

FIGURE: 4.3



DEER CREEK Energy Limited	PROJECT: Joslyn North Mine Project		BY	DATE	PROJECTION:
		DRAWN	PS	18Oct05	DRAWING NAME: Fig 4 Calibration
		CHECKED	SB	18Oct05	
Millennium EMS Solutions Ltd.	TITLE: Figure 4.4. Calibration of Baseline Basal Water Sand Groundwater Model	SCALE			FIGURE: 4.4

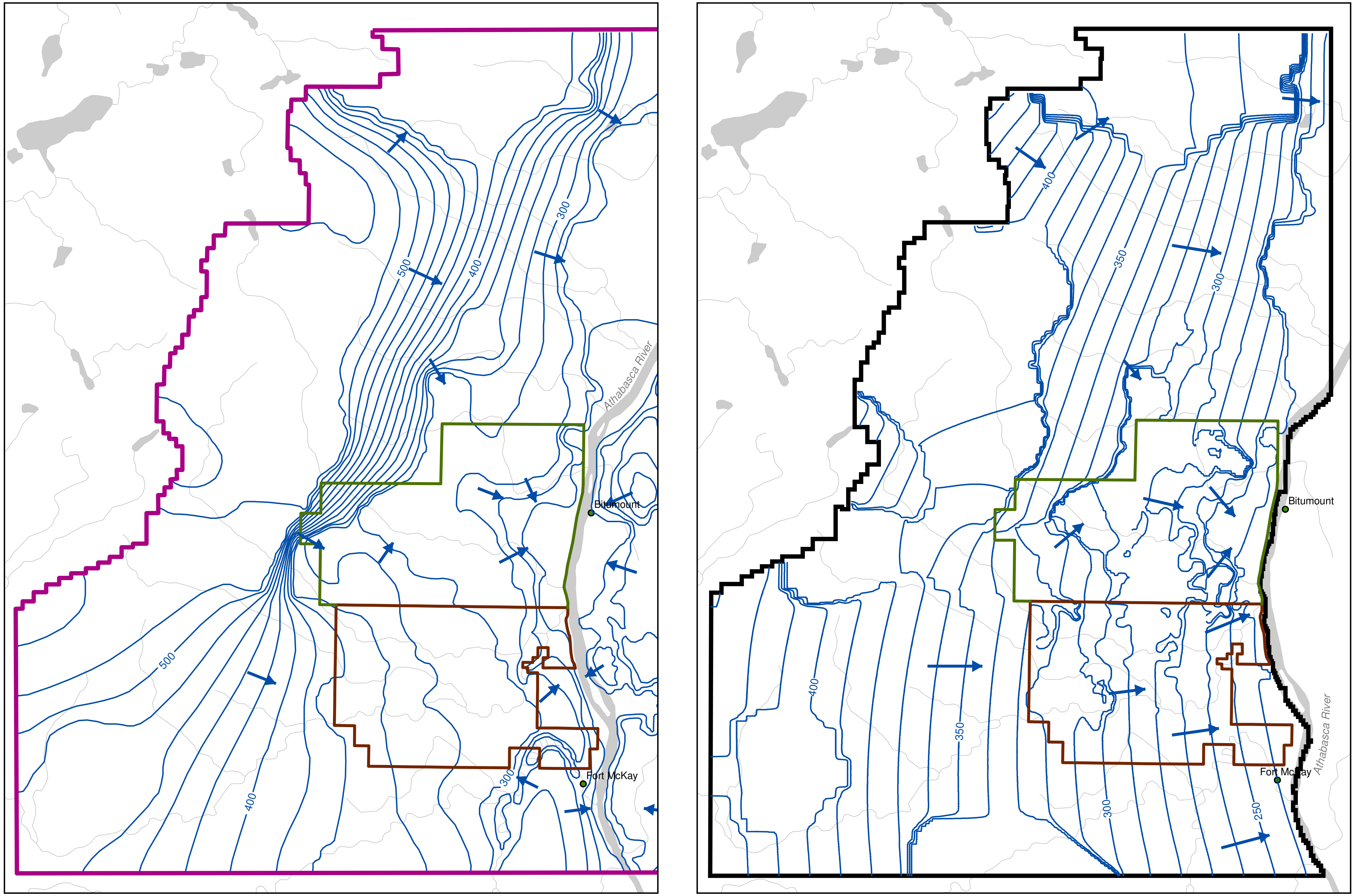


Figure recreated from Canadian Natural Resources Limited Horizon Project - Environmental Impact Assessment, June 2002. Volume 5, Section 4 Hydrogeology Assessment, Figure 4.5-12.

Deer Creek Energy Limited

Millennium EMS Solutions Ltd.

PROJECT

Joslyn North Mine Project

TITLE

Figure 4.5. Simulated Groundwater Elevations and Flow Directions in the Basal Water Sands (Baseline Conditions)

LEGEND

- Approximate Groundwater Flow Direction
- Simulated Groundwater Elevations (mASL)
- CNRL Model Domain
- DCEL Model Domain
- CNRL Lease Boundary
- DCEL Lease Boundary

	DRAWN	DATE
DRAWN	PS	18Oct05
CHECKED	SB	18Oct05

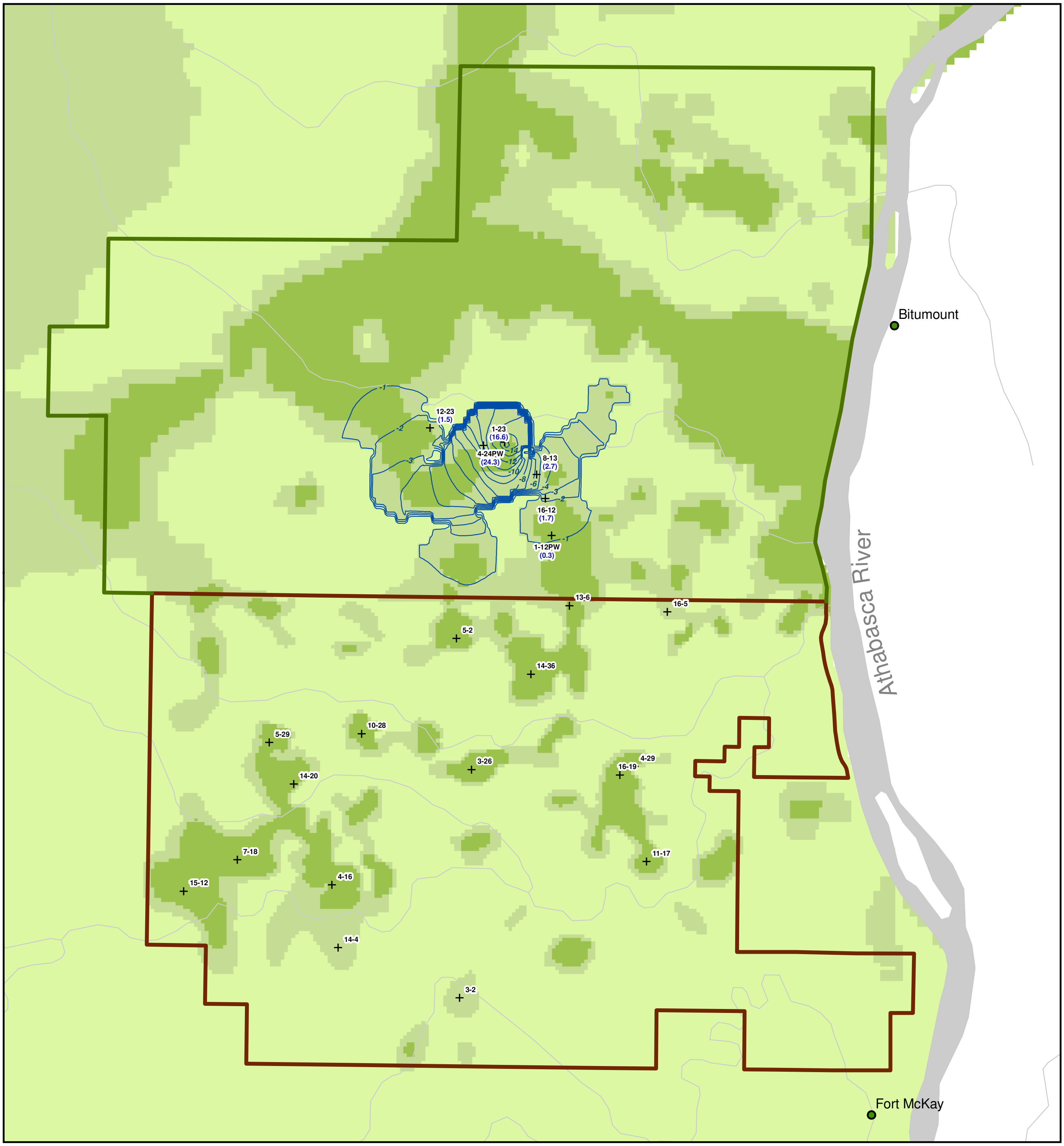
SCALE 1:330,000

0 2.5 5 10 Kilometres

PROJECTION UTM Zone 12 NAD 83

DRAWING NAME Fig 5 Baseline BWS

FIGURE 4.5



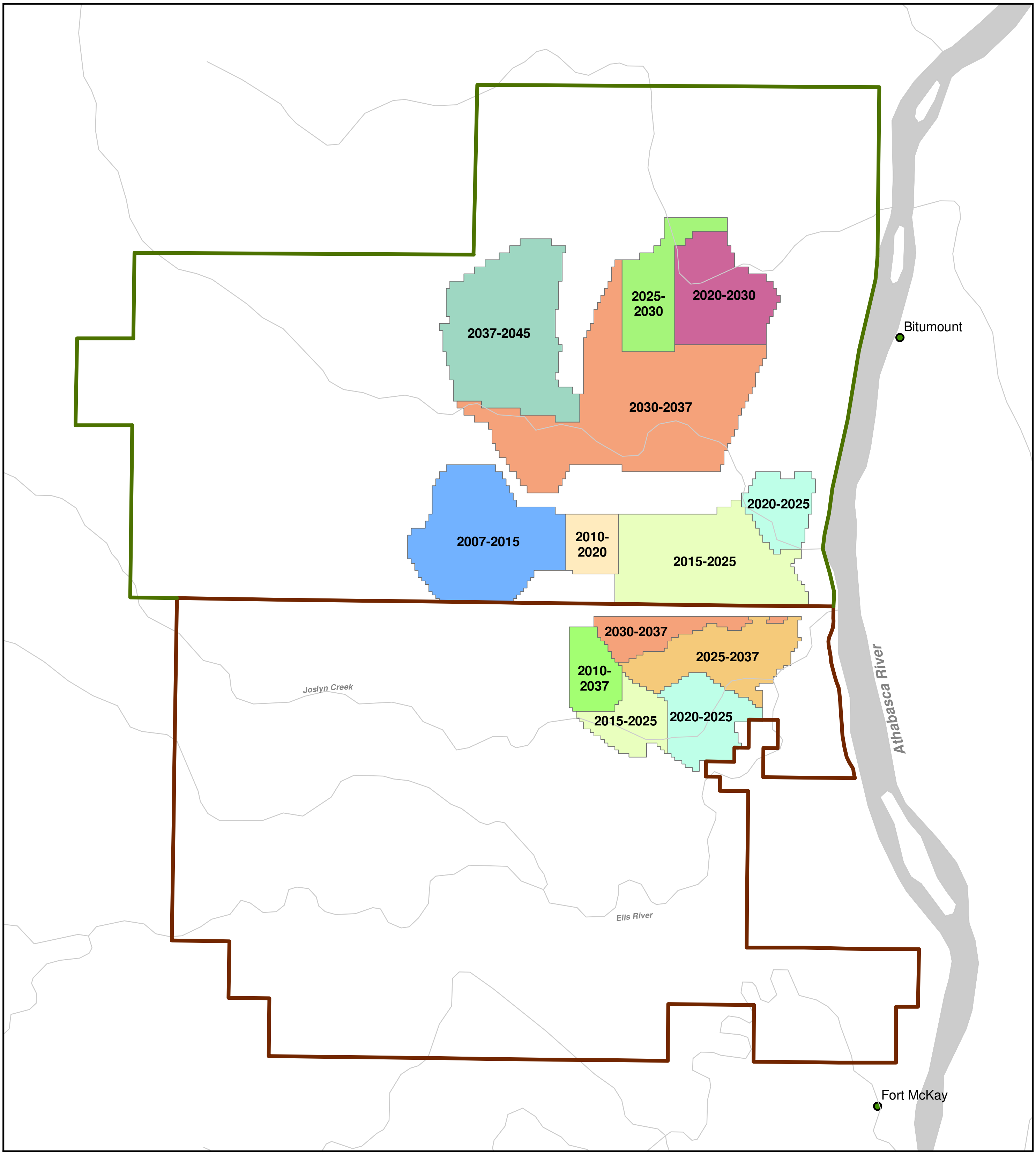
Reference: Observations from 2004 Winter Hydrogeological Field Program.
Canadian National Horizon Project Townships 96 and 97, Ranges 11-13 W4M.
Prepared by: Matrix Solutions Inc., November 2004.

+ 14-4 - Basal Water Sand Observation Well
(2.7) - Observed Drawdown after 24 days (m)
— 2 — Simulated Drawdown contours (m)
CNRL Lease Boundary
DCEL Lease Boundary

Conductivity (m/s)

- $K_h = 1 \times 10^{-9}$
- $K_h = 6.5 \times 10^{-5}$
- $K_h = 5 \times 10^{-5}$

Deer Creek Energy Limited	PROJECT **Joslyn North Mine Project**		BY / DATE DRAWN PS 18Oct05 CHECKED SB 18Oct05	PROJECTION: UTM Zone 12 NAD83 DRAWING NAME Fig 6 Pump Test
Millennium EMS Solutions Ltd.	TITLE **Figure 4.6. CNRL 4-24 Pump Test (400^{3}m /d for 24 days)**	N	SCALE 1:150,000 0 1 2 4 Kilometers	FIGURE **4.6**



Deer Creek Energy Limited

Millennium EMS Solutions Ltd.

PROJECT		BY	DATE	PROJECTION:
Joslyn North Mine Project	DRAWN	PS	18Oct05	UTM Zone 12 NAD83
	CHECKED	SB	18Oct05	DRAWING NAME: Fig 7 Mine Pit Advancement
TITLE: Figure 4.7. Simulated Mine Pit Advancements	SCALE	1:150,000 (0 1 2 4 Kilometers)		FIGURE: 4.7

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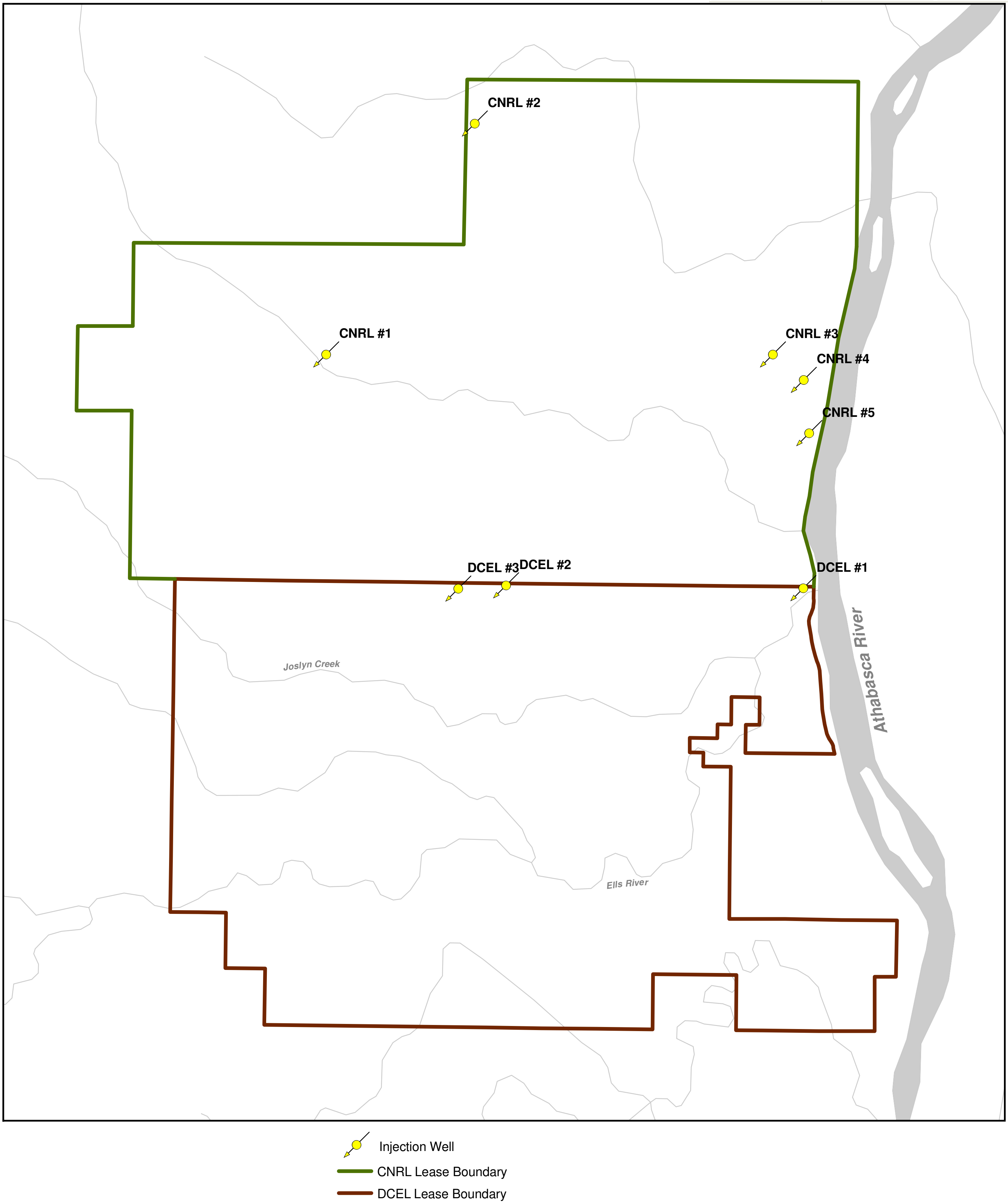
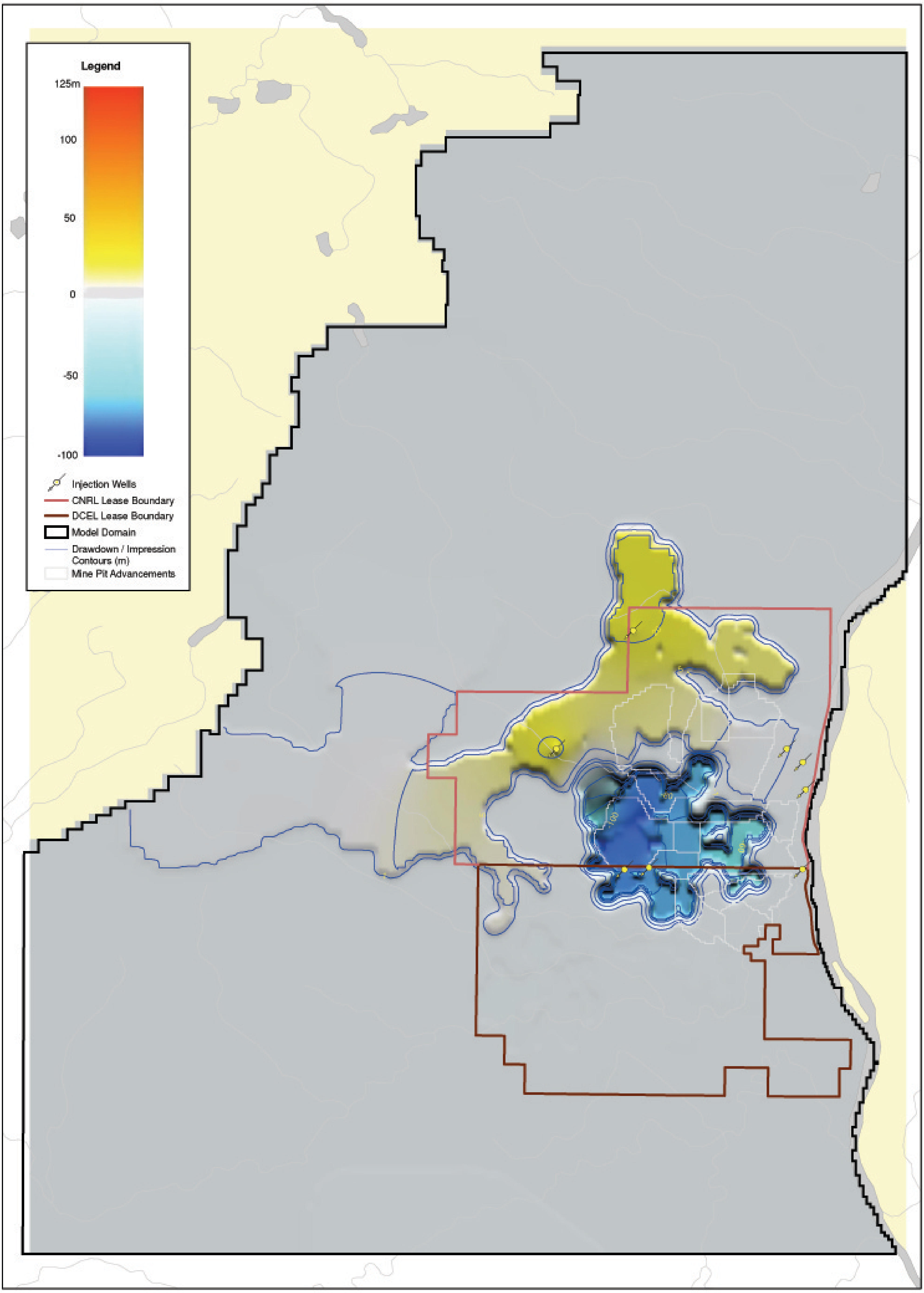
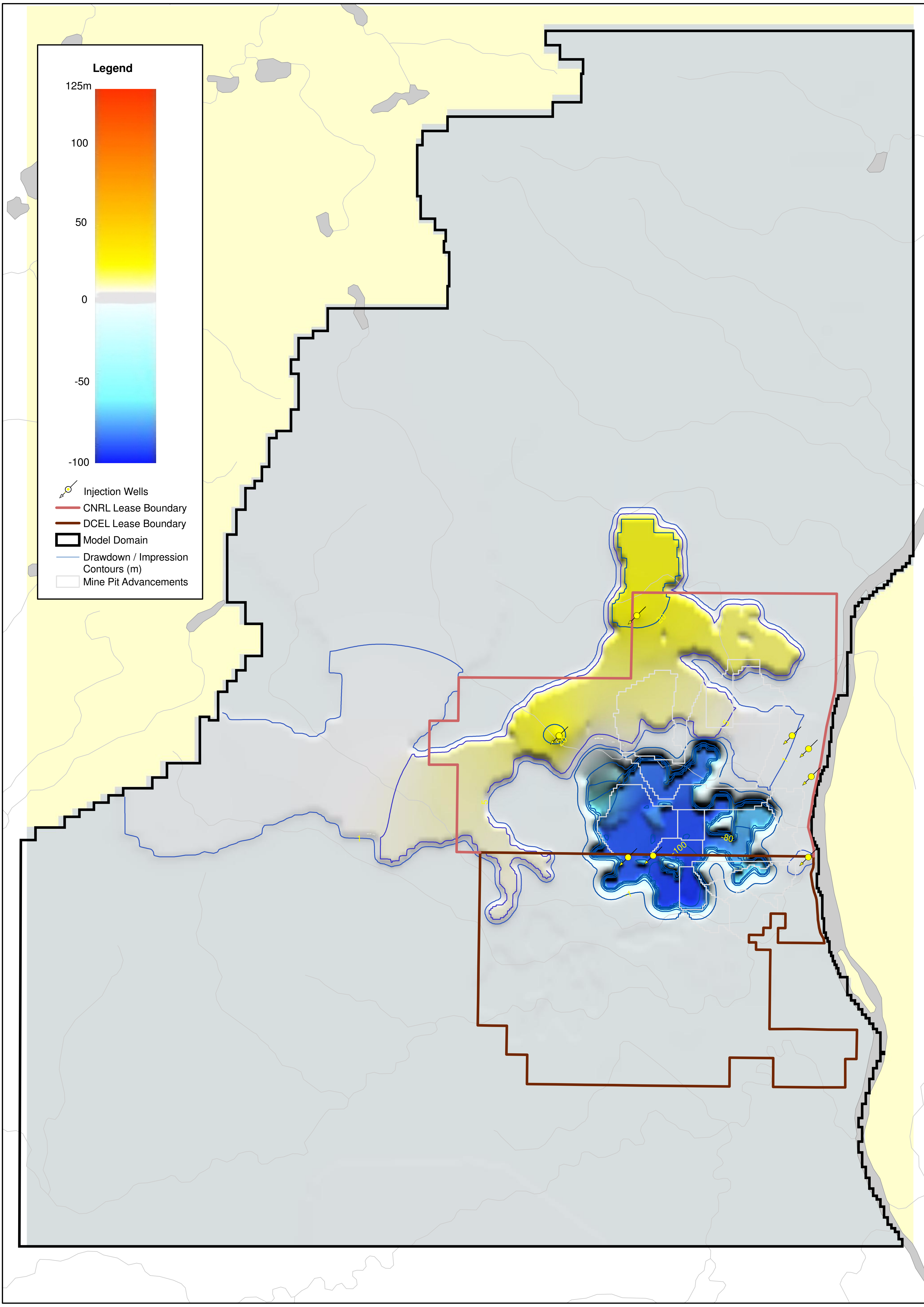


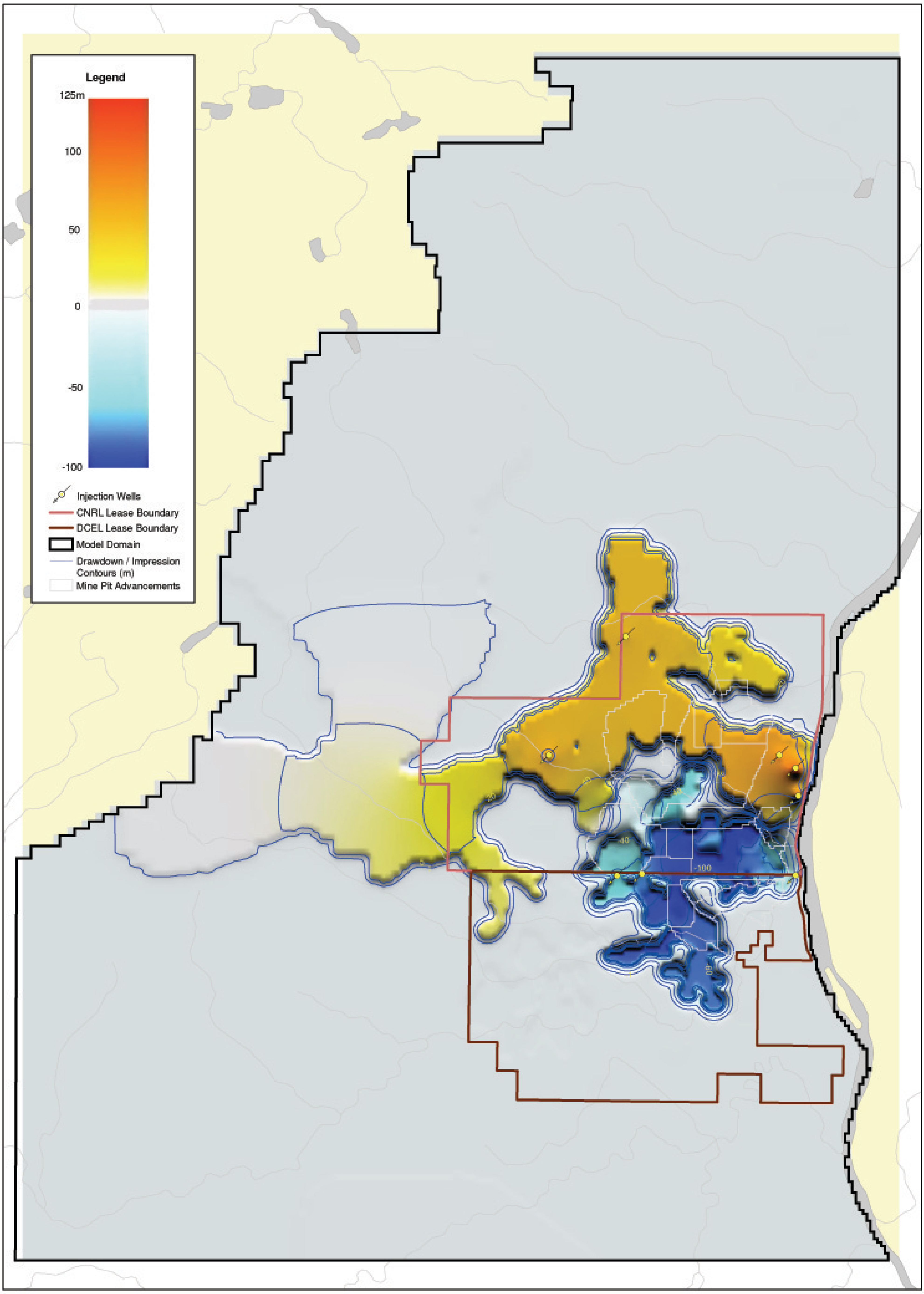
DEER CREEK Energy Limited	PROJECT Joslyn North Mine Project		BY	DATE	PROJECTION: UTM Zone 12 NAD83
		DRAWN	PS	13Oct05	DRAWING NAME Fig 8 Injection Well Scenario
		CHECKED	SB	13Oct05	
Millennium EMS Solutions Ltd.	TITLE Figure 4.8. Simulated Injection Well Scenario	SCALE	1:150,000		FIGURE 4.8



Deer Creek Energy Limited	PROJECT Joslyn North Mine Project	DRAWN BY PS 18Oct05 CHECKED BY SB 18Oct05		PROJECTION UTM Zone 12 NAD83 FILE REF. Fig 9 Basal Drawdown 2010
Millennium EMS Solutions Ltd.	TITLE Figure 4.9. Simulated Water Level Changes from Baseline Conditions in the Basal Water Sands - 2010 (DCEL and CNRL Inclusive)	SCALE 1:200,000		FIGURE NO. 4.9



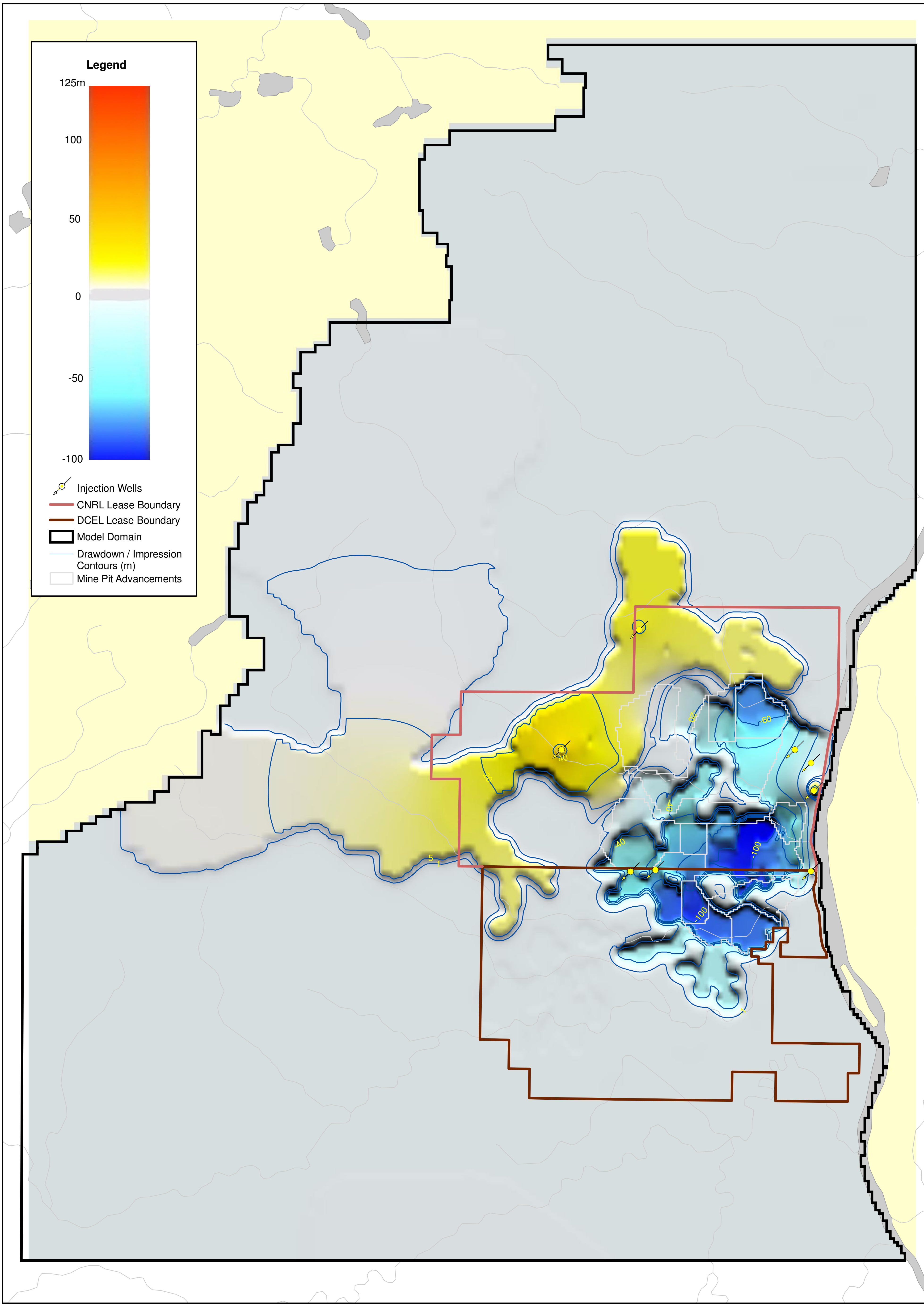
DEER CREEK Energy Limited	PROJECT: **Joslyn North Mine Project**	DRAWN BY: PS, 18Oct05	CHECKED BY: SB, 18Oct05	PROJECTION: UTM Zone 12 NAD83
Millennium EMS Solutions Ltd.	TITLE: **Figure 4.10. Simulated Water Level Changes from Baseline Conditions in the Basal Water Sands - 2015 (DCEL and CNRL Inclusive)**	SCALE: 1:200,000	FILE REF.: Fig 10 Basal Drawdown 2015	FIGURE NO.: 4.10



Deer Creek Energy Limited

Millennium EMS Solutions Ltd.

PROJECT: Joslyn North Mine Project	DRAWN BY	PS	19Oct05	PROJECTION: UTM Zone 12 NAD83
	CHECKED BY	SB	19Oct05	FILE REF.: Fig 11 Basal Drawdown 2020
TITLE: Figure 4.11. Simulated Water Level Changes from Baseline Conditions in the Basal Water Sands - 2020 (DCEL and CNRL Inclusive)	SCALE: 1:200,000			FIGURE NO.: 4.11



Deer Creek Energy Limited

Millennium EMS Solutions Ltd.

PROJECT

Joslyn North Mine Project

TITLE

Figure 4.12. Simulated Water Level Changes from Baseline Conditions in the Basal Water Sands - 2025 (DCEL and CNRL Inclusive)

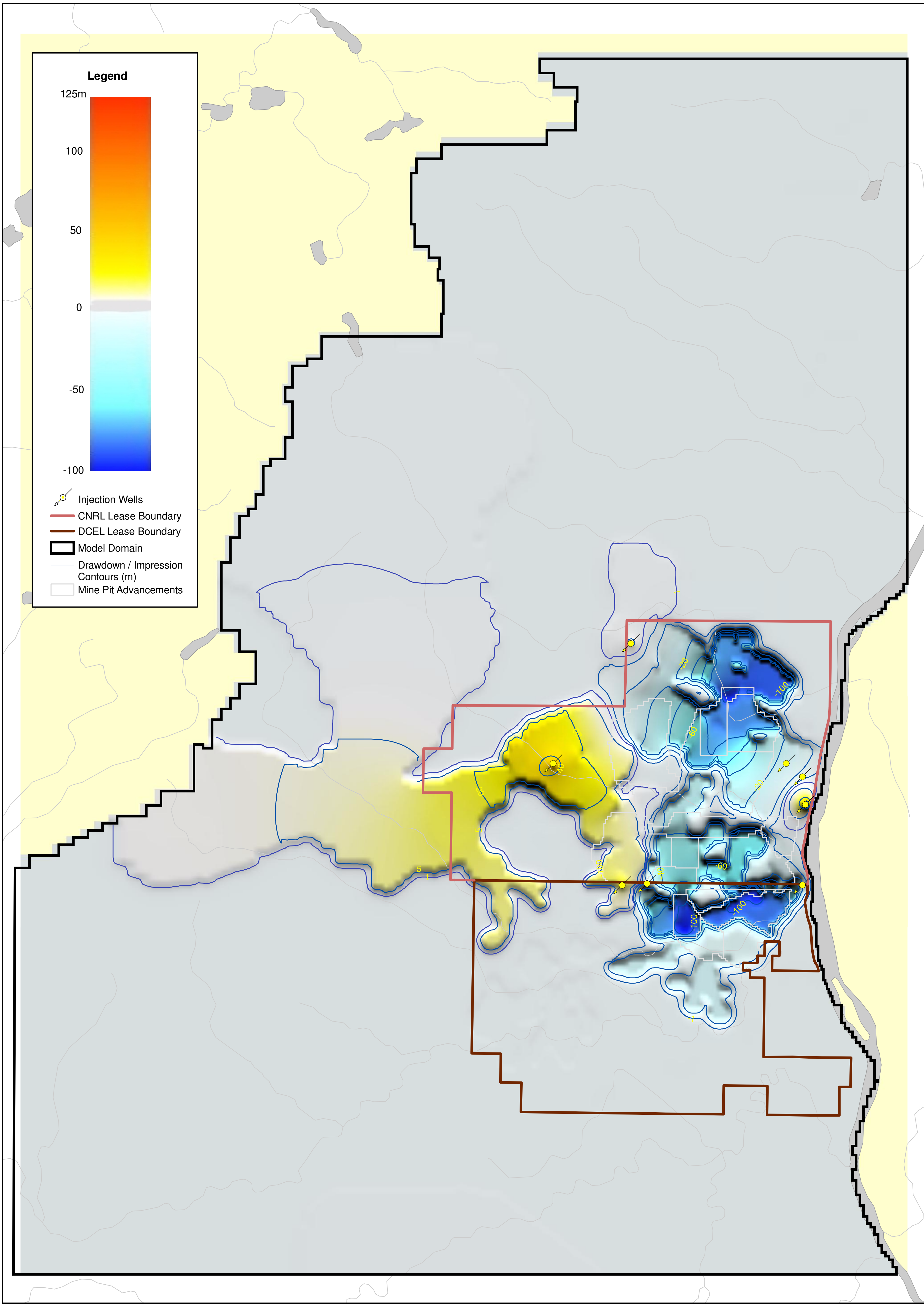
DRAWN BY	PS	19Oct05
CHECKED BY	SB	19Oct05

SCALE 1:200,000

PROJECTION UTM Zone 12 NAD83

FILE REF. Fig 12 Basal Drawdown 2025

FIGURE NO. 4.12



DEER CREEK Energy Limited

Millennium EMS Solutions Ltd.

PROJECT
Joslyn North Mine Project

TITLE
Figure 4.13. Simulated Water Level Changes from Baseline Conditions in the Basal Water Sands - 2030 (DCEL and CNRL Inclusive)

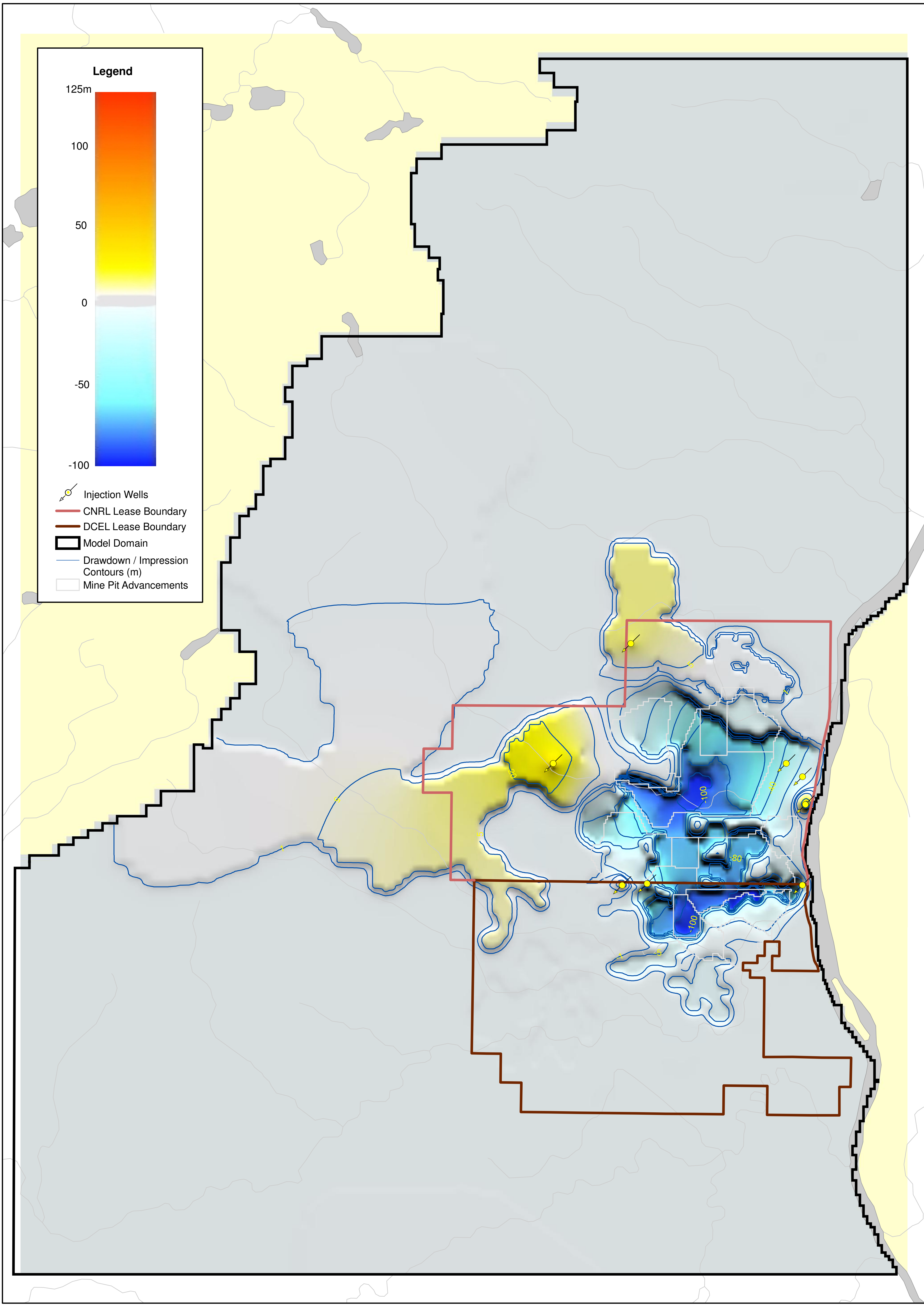
DRAWN BY	PS	19Oct05
CHECKED BY	SB	19Oct05

SCALE 1:200,000

PROJECTION UTM Zone 12 NAD83

FILE REF. Fig 13 Basal Drawdown 2030

FIGURE NO. 4.13



Deer Creek Energy Limited

Millennium EMS Solutions Ltd.

PROJECT	Joslyn North Mine Project	PROJECTION	UTM Zone 12 NAD83
DRAWN BY	PS	19Oct05	
CHECKED BY	SB	19Oct05	
FILE REF.	Fig 14 Basal Drawdown 2037		
TITLE	Figure 4.14. Simulated Water Level Changes from Baseline Conditions in the Basal Water Sands - 2037 (DCEL and CNRL Inclusive)		
SCALE	1:200,000	FIGURE NO.	4.14

APPENDIX B DATA

Appendix B-1. Hydraulic Heads

Location W4	9-36-94-12		4-5-95-11		4-7-95-11				9-16-95-11				11-17-95-11			
Well ID>>>	9-36-94-12-Q		4-5-95-11-Q		4-7-95-11 Q		4-7-95-11 BWS		9-16-95-11 Q		9-16-95-11 BWS		11-17-95-11-Q		11-17-95-11-BWS	
Easting	6339822		6340657		6342334		6342334		6344683		6344683		6344692		6344692	
Northing	453028		453733		452402		452402		456608		456608		454472		454472	
Installation Date	2004		2004		2005		2005		2005		2005		2004		Feb-04	
Ground Elevation (m)	320.74		318.7		320.18		320.18		300.2		300.2		306.58			
Stick-up TOC (m)					0.78				0.9							
TOC Elevation* (m)	321.701		319.302		320.96		321		301.1		301		306.72		pre-feb 2005 306.681 post-feb 2005 306.504	
Screen/Perf Interval (m)	7.9-11		9.14-12.19		1.5-4.55		81.0-83.0		2.90-5.95		53.0-56.0		1.7-3.05		69.0-71.0	
Hydraulic Conductivity (m/sec)																
Lithology	sand		sand		clay till				clay till				sand		basal water sand	
Date	**DWBD**	**GWSE**	**DWBD**	**GWSE**	**DWBD**	**GWSE**	**DWBD**	**GWSE**	**DWBD**	**GWSE**	**DWBD**	**GWSE**	**DWBD**	**GWSE**	**DWBD**	**GWSE**
pre-2003																
23-Jan-03																
25-Jan-03																
27-Jan-03																
3-Feb-03																
4-Feb-03																
5-Feb-03																
6-Feb-03																
6-Feb-03																
7-Feb-03																
8-Feb-03																
21-Mar-03																
21-Mar-03																
22-Mar-03																
8-May-03																
5-Sep-03																
11-Feb-04																
March 8-11, 2004	5.2	316.501	2.86	316.442									dry		33.07	273.611
13/14 April 2004																
11-13 May 2004													dry		28.02	278.661
18-Jun-04																
20-Jul-04																
23-Aug-04																
15-Dec-04																
(9-12)-Feb-05	5.09	316.61	2.77	316.53	1.69	319.27			1.68	299.42			2.19	304.53		
7,8-Mar-05															22.85	283.654
30-Mar-05							26.16				18.63					
6-Jul-05																
Q= Quaternary																
CW= Clearwater Formation																
OS= oil sands																
BWS= basal water sands																
BHL= Beaverhill Lake Formation																
WSW= water source well																
Italics= suspect measurement																

Location W4	16-19-95-11				4-29-95-11		3-2-95-12		14-4-95-12		15-13-95-12		4-16-95-12					
Well ID>>>	16-19-95-11 Q		16-19-95-11-BWS		4-29-95-11-BWS		3-2-95-12-BWS		14-4-95-12-BWS		15-13-95-12 Q		4-16-95-12-Q		4-16-95-12-Kcw		4-16-95-12-BWS	
Easting	6347051		6347051		6347268		6340908		6342089		6345153		6343986		6343986		6343986	
Northing	453704		453704		44307		449341		446069		451611		445744		445744		445744	
Installation Date	2005		Feb-04		Feb. 23, 2003		2004		Feb 20 2002		2005		Jan. 26, 2003		14-Dec-04		10-Mar-04	
Ground Elevation (m)					302.33				338.2		316.8		340.07		340.43			
Stick-up TOC (m)					0.9				1.5				0.66		0.911			
TOC Elevation* (m)	304.772		304.533		303.23		329.489		339.7		317.42		340.73		341.34		340.727	
Screen/Perf Interval (m)	2-5.3		65-66		54.9-57.9		85-86		95-98		1.8-3		3.69 - 6.74		12.19-15.24		107-108	
Hydraulic Conductivity (m/sec)																		
Lithology	sand		basal water sand		basal water sand		basal water sand		basal water sand		sand		clay till		clay till		basal water sand	
Date	**DWBD**	**GWSE**	**DWBD**	**GWSE**	**DWBD**	**GWSE**	**DWBD**	**GWSE**	**DWBD**	**GWSE**	**DWBD**	**GWSE**	**DWBD**	**GWSE**	**DWBD**	**GWSE**	**DWBD**	**GWSE**
pre-2003									32.40	307.30								
23-Jan-03																		
25-Jan-03																		
27-Jan-03																		
3-Feb-03													dry					
4-Feb-03																		
5-Feb-03																		
6-Feb-03																		
6-Feb-03																		
7-Feb-03																		
8-Feb-03																		
21-Mar-03																		
21-Mar-03													dry					
22-Mar-03																		
8-May-03																		
5-Sep-03																		
11-Feb-04													dry					
March 8-11, 2004			24.55	279.983	21.8	281.43	28.2	301.289	26.33	313.37							*12.65*	*328.077*
13/14 April 2004			23.45	281.083														
11-13 May 2004			23.14	281.393	22.08	281.15	28.43	301.059	26.08	313.62			dry				24	316.727
18-Jun-04																		
20-Jul-04			23.97	280.563														
23-Aug-04																		
15-Dec-04													2.93	337.8	9.99	331.35	21.76	318.967
(9-12)-Feb-05	1.04	303.732	26.88	277.653	21.16	282.07	28.35	301.14	25.13	314.57	dry		3.21	337.52	9.96	331.38	22.13	318.597
7,8-Mar-05																		
30-Mar-05																		
6-Jul-05													1.75	338.98	9.79	331.55	22.21	318.517
Q= Quaternary																		
CW= Clearwater Formation																		
OS= oil sands																		
BWS= basal water sands																		
BHL= Beaverhill Lake Formation																		
WSW= water source well																		
Italics= suspect measurement																		

Location W4	7-18-95-12		14-20-95-12						7-25-95-12		3-26-95-12				10-28-95-12	
Well ID>>>	7-18-95-12-BWS		14-20-95-12-Q		14-20-95-12-CW		14-20-95-12-BWS		7-25-95-12-BWS		3-26-95-12 Q		3-26-95-12-BWS		10-28-95-12-BWS	
Easting	6344715		6346828		6346828		6346828		6347533		6347185		6347185		6348234	
Northing	443139		444666		444666		444666		451673		449600		449600		446584	
Installation Date	2004		Jan. 26, 2003		Feb. 4, 2003		10-Mar-04		Feb-04		Feb-04		Feb-04		Feb-04	
Ground Elevation (m)			345.86		347.49						325					
Stick-up TOC (m)			0.75		0.61						0.79					
TOC Elevation* (m)	352.81		346.61		348.1		347.37		317.501		325.8		326.142		338.634	
Screen/Perf Interval (m)	132-135		5.35 - 8.40		21.03-24.08		132.5-133.5		82-83		7.62-10.67		103-104		123-124	
Hydraulic Conductivity (m/sec)																
Lithology	basal water sand		clay till		clay till		basal water sand		basal water sand		clay till		basal water sand		basal water sand	
Date	DWBD	GWSE	DWBD	GWSE	DWBD	GWSE	DWBD	GWSE	DWBD	GWSE	DWBD	GWSE	DWBD	GWSE	DWBD	GWSE
pre-2003																
23-Jan-03																
25-Jan-03																
27-Jan-03			dry													
3-Feb-03																
4-Feb-03																
5-Feb-03																
6-Feb-03																
6-Feb-03																
7-Feb-03																
8-Feb-03																
21-Mar-03																
21-Mar-03			5.39	341.22	8.17	339.93										
22-Mar-03																
8-May-03																
5-Sep-03																
11-Feb-04			3.69	342.92	8.05	340.05										
March 8-11, 2004	38.61	314.2					*15.36*	*332.01*	dry				37.96	288.182	47.17	291.464
13/14 April 2004													38.53	287.612	49.57	289.064
11-13 May 2004	38.98	313.83	4.11	342.5	8.12	339.98	32.64	314.73	84.64	232.861			38.06	288.082	48.4	290.234
18-Jun-04																
20-Jul-04															48.06	290.57
23-Aug-04																
15-Dec-04			3.29	343.32	7.98	340.12	31.65	315.72								
(9-12)-Feb-05	38.52	314.29	3.09	343.52	7.92	340.18	32.43	314.94			1.65	324.15	38.00	288.14	47.69	290.94
7,8-Mar-05									31.99	285.51						
30-Mar-05																
6-Jul-05			2.27	344.34	4.12	343.98	32.87	314.5								
Q= Quaternary																
CW= Clearwater Formation																
OS= oil sands																
BWS= basal water sands																
BHL= Beaverhill Lake Formation																
WSW= water source well																
Italics= suspect measurement																

Location W4	5-29-95-12		14-36-95-12										15-36-95-12			
Well ID>>>	5-29-95-12-BWS		14-36-95-12-Q		14-36-95-12-CW		14-36-95-12-BHL-BP-2W		14-36-95-12-BHL-BP-2Wb		14-36-95-12-BHL-BP-2WA		15-36-95-12 OS(A)		15-36-95-12 OS(B)	
Easting	6347960		6350115		6350115		6350115		6350115		6350115		6349997		6349997	
Northing	444037		451283		451283		451283		451283		451283		451694		451694	
Installation Date	Feb-04		Jan. 25, 2003		Feb. 4, 2003		Feb-75		Feb-75		Feb-75		Feb-05		Feb-05	
Ground Elevation (m)			314.34		314.49		314.8		314.8??		314.8		314.1		314.1	
Stick-up TOC (m)			0.77		0.61		1.2				1.2		na		na	
TOC Elevation* (m)	353.571		315.11		315.1		316		316??		316		na		na	
Screen/Perf Interval (m)	125-126		2.36 - 5.41		15.93-18.98		147.6-153.7 (open hole)		112.8-126.5?		112.8-126.5		81		102	
Hydraulic Conductivity (m/sec)											5.3 x 10-4		virbrating wire		virbrating wire	
Lithology	basal water sand		silty clay		clay shale/siltstone		limestone		basal water sand		basal water sand		oilsand		oilsand	
Date	**DWBD**	**GWSE**	**DWBD**	**GWSE**	**DWBD**	**GWSE**	**DWBD**	**GWSE**	**DWBD**	**GWSE**	**DWBD**	**GWSE**	**DWBD**	**GWSE**	**DWBD**	**GWSE**
pre-2003												281.70				
23-Jan-03																
25-Jan-03											33.89	282.11				
27-Jan-03			2.81	312.30			> 30									
3-Feb-03																
4-Feb-03							34.36	281.64	>38							
5-Feb-03																
6-Feb-03																
6-Feb-03																
7-Feb-03																
8-Feb-03																
21-Mar-03												291 inj				
21-Mar-03																
22-Mar-03			3.19	311.92	7.64	307.46										
8-May-03																
5-Sep-03																
11-Feb-04			3.05	312.06	8.97	306.13					33.39	282.61				
March 8-11, 2004	43.18	310.391														
13/14 April 2004			3.15	311.96	11.01	304.09	34.37	281.63			33.81	282.19				
11-13 May 2004	46.26	307.311	1.91	313.2	10.14	304.96	34.29	281.71			33.8	282.2				
18-Jun-04																
20-Jul-04											33.63	282.37				
23-Aug-04																
15-Dec-04			1.81	313.3	9.46	305.64					31.65	284.35				
(9-12)-Feb-05	47.02	306.55	2.28	312.83	11.51	303.59			33.39	282.61	33.37	282.63				
7,8-Mar-05																
30-Mar-05											32.05	283.95	6487.6	282.39	5749.3	290.33
6-Jul-05											30.05	285.95				
Q= Quaternary																
CW= Clearwater Formation																
OS= oil sands																
BWS= basal water sands																
BHL= Beaverhill Lake Formation																
WSW= water source well																
Italics= suspect measurement																

Location W4	15-12-95-13						7-3-96-11		15-3-96-11		5-4-96-11				6-4-96-11	
Well ID>>>	15-12-95-13-Q		15-12-95-13 Kcw		15-12-95-13-BWS		7-3-96-11-Q		15-3-96-11-BHL-BP-1W		5-4-96-11-Kcw		5-4-96-11-BWS		6-4-96-11-Q	
Easting	6343875		6343875		6343875		6350982		not available		6350782		6350782		6350759	
Northing	441665		441665		441665		458073		not available		455446		455446		455927	
Installation Date	Jan. 26, 2003		14-Dec-04		Mar. 10, 2004		Jan. 23, 2003		1975		Feb. 4, 2003		10-Mar-04		Jan. 21, 2003	
Ground Elevation (m)	360.81		360.89				277.07		270		299.95				296.47	
Stick-up TOC (m)	0.78		0.58				0.9		0.2		0.61				0.86	
TOC Elevation* (m)	361.59		361.47		361.538		277.97		272.8		300.56		300.21		297.33	
Screen/Perf Interval (m)	5.34 - 8.39		19.2-22.25		134.5-135.5		0.6-3.95		123.1-129.2 open hole		13-Oct		94-95		2.54-8.64	
Hydraulic Conductivity (m/sec)																
Lithology	clay till/sand		clay till		basal water sand				limestone		siltstone/till		basal water sand		sand	
Date	**DWBD**	**GWSE**	**DWBD**	**GWSE**	**DWBD**	**GWSE**	**DWBD**	**GWSE**	**DWBD**	**GWSE**	**DWBD**	**GWSE**	**DWBD**	**GWSE**	**DWBD**	**GWSE**
pre-2003									40	232						
23-Jan-03															5.50	291.83
25-Jan-03															5.50	291.83
27-Jan-03							dry									
3-Feb-03	dry														5.56	291.77
4-Feb-03															5.57	291.76
5-Feb-03											6.99	293.57			5.60	291.73
6-Feb-03															5.54	291.79
6-Feb-03																
7-Feb-03																
8-Feb-03																
21-Mar-03																
21-Mar-03	dry															
22-Mar-03											7.00	293.56				
8-May-03											7.02	293.54			5.40	291.93
5-Sep-03																
11-Feb-04	dry										7.02	293.54				
March 8-11, 2004					*21.91*	*339.628*							*14.21*	*286.001*		
13/14 April 2004													26.885	273.326		
11-13 May 2004	dry				46.32	315.218					7.09	293.47	26.59	273.621		
18-Jun-04																
20-Jul-04													25.44	274.77		
23-Aug-04													25.48	274.73		
15-Dec-04	dry		12.57	348.9	45.96	315.578							23.45	276.76		
(9-12)-Feb-05	dry		11.13	350.34	47.88	313.658					7.59	292.97	24.25	275.96		
7,8-Mar-05																
30-Mar-05																
6-Jul-05	dry		4.74	356.73	46.85	314.688							24.48	275.73		
Q= Quaternary																
CW= Clearwater Formation																
OS= oil sands																
BWS= basal water sands																
BHL= Beaverhill Lake Formation																
WSW= water source well																
Italics= suspect measurement																

Location W4	7-4-96-11		16-5-96-11				13-6-96-11				7-1-96-12			
Well ID>>>	7-4-96-11-Q		16-5-96-11-OS		16-5-96-11-BWS		13-6-96-11-OS		13-6-96-11-BWS		7-1-96-12 OS(B)		7-1-96-12 OS(A)	
Easting	6350753		6351579		6351579		6351748		6351748		6351125		6351125	
Northing	456483		455063		455063		452373		452373		451667		451667	
Installation Date	Jan. 21, 2003		Feb-04		Feb-04		Feb-04		Feb-04		Feb-05		Feb-05	
Ground Elevation (m)	295.45		297.28		297.98		308.51		308.51		311.7		311.7	
Stick-up TOC (m)	0.86		na		na		na		na		na		na	
TOC Elevation* (m)	296.31		na		na		na		na		na		na	
Screen/Perf Interval (m)	3.79-6.84		85 m bgs		93.5 m bgs		97.3 mbgr		105.6 mbgr		78.6 m bgs		94 m bgs	
Hydraulic Conductivity (m/sec)			Vibrating wire		Vibrating wire		Vibrating wire		Vibrating wire		Vibrating wire		Vibrating wire	
Lithology	sand		oil sand		basal water sand		oil sand		basal water sand		oil sand		oil sand	
Date	**DWBD**	**GWSE**	**DWBD**	**GWSE**	**DWBD**	**GWSE**	**DWBD**	**GWSE**	**DWBD**	**GWSE**	**DWBD**	**GWSE**	**DWBD**	**GWSE**
pre-2003														
23-Jan-03	4.80	291.51												
25-Jan-03	4.80	291.51												
27-Jan-03														
3-Feb-03	4.80	291.51												
4-Feb-03														
5-Feb-03	4.87	291.44												
6-Feb-03	4.82	291.49												
6-Feb-03														
7-Feb-03														
8-Feb-03														
21-Mar-03														
21-Mar-03														
22-Mar-03														
8-May-03	4.62	291.69												
5-Sep-03														
11-Feb-04														
March 8-11, 2004														
13/14 April 2004			6021.5	265.20	5652	288.38								
11-13 May 2004			6022.4	265.15	5653.3	288.31	6403.2	278.78	6209.9	278.43				
			P=	90.614201	P=	103.152957	P=	96.081182	P=	107.308104				
				63.80203416		72.63065186		67.65137019		75.55631724				
			WL =	276.08	WL =	277.11	WL =	278.86	WL =	278.47				
			Poly, P=	90.57842663										
18-Jun-04				63.77684521										
20-Jul-04			Poly, WL=	276.06										
23-Aug-04														
15-Dec-04														
(9-12)-Feb-05			6026.5	264.94	5658.9	288.00	6408.8	278.47	6215.3	278.14				
7,8-Mar-05														
30-Mar-05											6123.4	282.27	6040.8	282.31
6-Jul-05														
Q= Quaternary														
CW= Clearwater Formation														
OS= oil sands														
BWS= basal water sands														
BHL= Beaverhill Lake Formation														
WSW= water source well														
Italics= suspect measurement														

Location W4	5-2-96-12						16-1-96-13			
Well ID>>>	5-2-96-12 Q		5-2-96-12-OS		5-2-96-12-BWS		16-1-96-13 Q		16-1-96-13-BWS	
Easting	6350808		6350808		6350808		6350808		6350808	
Northing	4492040		449240		449240		449240		449240	
Installation Date	Feb-05		Feb-04		2004		Feb-05		2004	
Ground Elevation (m)	325.3		325.3				375.4		375.4	
Stick-up TOC (m)	0.71		na				0.85			
TOC Elevation* (m)	326		na		326.496		376.25		377.045	
Screen/Perf Interval (m)	10.6-12.1		112.7 m bgs		122-123		3-6.2		117-118	
Hydraulic Conductivity (m/sec)			Vibrating wire							
Lithology	clay till		oil sand		basal water sand		clay till		perfed in OS - abandon	
Date	**DWBD**	**GWSE**	**DWBD**	**GWSE**	**DWBD**	**GWSE**	**DWBD**	**GWSE**	**DWBD**	**GWSE**
pre-2003										
23-Jan-03										
25-Jan-03										
27-Jan-03										
3-Feb-03										
4-Feb-03										
5-Feb-03										
6-Feb-03										
6-Feb-03										
7-Feb-03										
8-Feb-03										
21-Mar-03										
21-Mar-03										
22-Mar-03										
8-May-03										
5-Sep-03										
11-Feb-04										
March 8-11, 2004					55.32	271.176			dry	
13/14 April 2004			5610.9	282.32	49.775	276.721				
11-13 May 2004			5612.6	282.22	45.88	280.616			dry	
			P=	99.087052						
				69.76782234						
			WL =	282.37						
18-Jun-04										
20-Jul-04					39.74	286.756				
23-Aug-04										
15-Dec-04										
(9-12)-Feb-05			5619.5	281.84	45.38	281.12				
7,8-Mar-05	12.53	313.47					dry		filled wilth oil	
30-Mar-05										
6-Jul-05										
Q= Quaternary										
CW= Clearwater Formation										
OS= oil sands										
BWS= basal water sands										
BHL= Beaverhill Lake Formation										
WSW= water source well										
Italics= suspect measurement										

Water Level Measurements in Observation Wells in Sand Aquifer

	Aquifer Observation Wells															
Monitoring/Observation Well	16-19-95-11-Q		15-29-95-11-Q		5-32-95-11-Q		7-32-95-11-Q		7-31-95-11-Q		11-4-96-11-Q		16-5-96-11-Q		13-6-96-12-Q	
Installation Date	9-Feb-04		Jan. 25, 2003		Feb-04		Jan. 25, 2003		Jan. 22, 2003		20-Feb-02		Feb-04		Feb-04	
Ground Elevation (m)			301.33		301.45		300.69		304.59		298.2		297.28		308.59	
Stick-up TOC (m)			0.90				0.71		0.90		1		0.76			
TOC Elevation* (m)	304.772		302.23		302.471		301.4		305.49		299.2		298.04		309.479	
Depth of Well (m)	9.14		7.16		12.19		8.24		5.34		9.9		15.24		7.62	
Screen/Perf Interval (m)	6-9.14		4.11-7.16		3-6.1		5.24-8.24		2.34-5.34		7.6-9.1		2.1-6.86		3.05-6.1	
Hydraulic Conductivity (m/sec)																
Lithology	sand		sand		sand		sand		sand		sand		sand		sand	
Date	**DWBD**	**GWSE**	**DWBD**	**GWSE**	**DWBD**	**GWSE**	**DWBD**	**GWSE**	**DWBD**	**GWSE**	**DWBD**	**GWSE**	**DWBD**	**GWSE**	**DWBD**	**GWSE**
pre-2003																
23-Jan-03																
25-Jan-03			5.86	296.37					dry		6.94	292.26				
3-Feb-03			5.86	296.37			4.87	296.53	2.29	303.20	6.94	292.26				
5-Feb-03																
6-Feb-03																
6-Feb-03																
7-Feb-03																
8-Feb-03																
8-May-03																
5-Sep-03																
March 8-11, 2004	2.26	302.51	5.9	296.33	2.6	299.87	4.75	296.65	2.51	302.98		299.20	2.81	295.23	5.89	303.59
13/14 April 2004	1.96	302.81														
11-13 May 2004	1.88	302.89	5.92	296.31	2.55	299.92	4.78	296.62	2.33	303.16	6.96	292.24	2.8	295.24	4.05	305.43
18-Jun-04																
20-Jul-04			5.8	296.43	2.34	300.13	4.65	296.75	1.42	304.07	6.95	292.25	2.68	295.36	1.56	307.92
23-Aug-04																
28-Sep-04																
26-Oct-04																
30-Nov-04																
27-Dec-04																
15-Dec							4.70	296.70			6.99	292.21	2.77	295.27		
(9-12) Feb-05	1.04	303.73	5.87	296.36	2.49	299.98	4.75	296.65	2.41	303.08	7.01	292.19	2.81	295.23	2.26	307.22
10-Mar-05											5.56	293.64	2.93	295.11		
22-Sep-05											6.6	292.60	2.31	295.73		
15-Oct-05											6.685	292.52	2.33	295.71		

Appendix B-2. Groundwater Chemistry

Location>>>	9-36-94-12		4-5-95-11	4-7-95-11		9-16-95-11		11-17-95-11	
Well ID>>>	9-36-94-12-Q		4-5-95-11-Q	4-7-95-11 Q	4-7-95-11 BWS	9-16-95-11 Q	9-16-95-11 BWS	11-17-95-11-BWS	
Date Sampled>>>	9-Mar-04	11-Feb-05	9-Mar-04	11-Feb-05	30-Mar-05	11-Feb-05	30-Mar-05	11-Mar-04	7-Mar-05
Parameters									
Calcium (Ca)	87.6	103.0	120	394	27.1	156	14.0	48.7	24.1
Magnesium (Mg)	22.5	27.7	32.3	85.6	67.1	34.0	47.7	113.0	104.0
Sodium (Na)	7	12	28	280	4,740	20	3,340	5280	5400
Potassium (K)	2.2	1.2	3.1	7.0	31.3	4.1	28.6	66.4	68.3
Carbonate (CO_3)	<5	<5	<5	<5	39	<5	66	103	167
Bicarbonate (HCO_3)	381	449	530	717	3,350	690	5,000	3500	4190
Sulphate (SO4)	9.9	6.9	46.5	1220	6.9	5.0	5.9	46.8	22.5
Chloride (Cl)	3	2	3	34	6,110	3	2,660	6030	6550
Total Dissolved Solids	320	374	494	2,380	12,700	562	8,620	13,400	14,400
Conductivity	560	659	832	3,000	19,300	988	12,700	20,700	21,900
pH	8.10	7.80	8.00	7.70	8.3	7.70	8.40	8.5	8.4
Hydroxide (OH)	<5	<5	<5	<5	<5	<5	<5	<5	<5
Hardness ($CaCO_3$)	311	371	433	1,340	344	530	231	587	488
Alkalinity (PP as $CaCO_3$)	-	-	-	-	-	-	-		-
Alkalinity (Total as $CaCO_3$)	312	368	434	588	2,810	566	4,210	3040	3720
Ion Balance	101	105	402	102	93.5	100	95	105	95
Nitrate (N)	0.2	<0.1	0.1	0.5	<0.1	0.1	<0.1	<0.1	0.1
Nitrate plus Nitrite (N)	0.2	<0.1	0.1	0.5	<0.1	0.1	<0.1	<0.1	0.1
Nitrite (N)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Fluoride (F)	-	-	-	-	-	-	-		-
Phenols	-	-	-	-	-	-	-		-
Dissolved trace elements									
Aluminum (Al)	0.01	0.02	0.02	<0.01	0.03	<0.01	<0.01	0.04	0.02
Antimony (Sb)		0.002		0.0009	0.0011	0.0006	0.0083		0.0017
Arsenic (As)		0.0016		0.0006	0.0010	<0.0004	0.0025		<0.0004
Barium (Ba)	0.07	0.569	0.097	0.131	1.96	0.383	1.06	0.116	0.227
Beryllium (Be)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron (B)	0.07	0.11	0.1	0.43	4.26	0.17	6.83	4.03	4.91
Cadmium (Cd)	<0.001	0.0002	<0.001	0.0002	0.0001	0.0001	0.0005	<0.001	<0.0001
Chromium (Cr)	<0.005	<0.005	<0.005	0.005	<0.005	<0.005	<0.005	<0.005	0.006
Cobalt (Co)	<0.002	<0.002	<0.002	0.002	<0.002	0.002	<0.002	<0.002	<0.002
Copper (Cu)	<0.001	<0.001	0.001	0.003	0.044	0.001	0.032	0.159	0.004
Iron (Fe)	0.432	16	4.2	0.019	0.712	1.38	0.457	0.669	0.991
Lead (Pb)	<0.005	0.0007	<0.005	0.0005	0.0167	0.0005	0.0014	0.011	0.0011
Lithium (Li)		0.016		0.11	0.782	0.034	0.675		0.936
Manganese (Mn)	0.533	1.27	0.259	0.455	0.038	0.351	0.06	0.31	0.416
Mercury (Hg)		0.0001		<0.0001	0.0008	<0.0001	0.0004		0.0001
Molybdenum (Mo)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.037	0.078	0.025
Nickel (Ni)	<0.002	<0.002	<0.002	0.012	0.008	0.004	0.018	0.069	0.025
Phosphorus (P)		-		-	-	-	-		-
Selenium (Se)		<0.0004		0.0027	0.201	<0.0004	0.0888		<0.0004
Silicon (Si)		-		-	-	-	-		-
Silver (Ag)	<0.005	<0.0001	<0.005	<0.0001	0.0001	<0.0001	<0.0001	<0.005	<0.0001
Strontium (Sr)	0.221	-	0.325	-	6.03	-	3.85	4.26	-
Sulphur (S)		-		-	-	-	-		-
Thallium (Tl)	<0.05	0.0001	<0.05	<0.0001	<0.0001	<0.0001	<0.0001	<0.05	<0.0001
Tin (Sn)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Titanium (Ti)	0.003	0.003	0.002	0.002	0.007	0.004	0.009	0.007	0.006
Uranium (U)		0.0008		0.0156	<0.0001	0.0009	0.0001		0.0009
Vanadium (V)	0.012	0.002	0.01	0.001	0.053	0.002	0.039	<0.001	0.024
Zinc (Zn)	0.055	0.006	0.141	0.009	0.179	0.016	0.067	0.354	0.058
Zirconium (Zr)		-		-	-	-	-		-
Hydrocarbons									
Benzene		-		-	-	-			
Toluene		-		-	-	-			
Ethylbenzene		-		-	-	-			
Xylene (Total)		-		-	-	-			
F1(C6-C10)-BTEX		-		-	-	-			
F2 (C10-C16 Hydrocarbons)		-		-	-	-			

Notes
1) N/A = Not Applicable
2) ( ) = Results < Reliable Detection Limit and is subject to reduce levels of confidence
3) - = Not Tested
(4) All units except ion balance, conductivity and pH are in mg/L

Location>>>	16-19-95-11				15-27-95-11	15-29-95-11	7-31-95-11	5-32-95-11		7-32-95-11
Well ID>>>	**16-19-95-11-Q**		**16-19-95-11-BWS**		**15-27-95-11 BWS**	**15-29-95-11-Q**	**7-31-95-11-Q**	**5-32-95-11-Q**		**7-32-95-11-Q**
Date Sampled>>>	**11-Mar-04**	**11-Feb-05**	**11-Mar-04**	**11-Feb-05**	**30-Mar-05**	**10-Mar-04**	**10-Mar-04**	**10-Mar-04**	**11-Feb-05**	**10-Mar-04**
Parameters										
Calcium (Ca)	35.1	Frozen	79.7	45.7	21.2	49.8	63.3	71.2	76.5	35.8
Magnesium (Mg)	13.0		118.0	118.0	156	9.5	14.9	12.4	12.3	7.2
Sodium (Na)	198		5560	5420	5510	14	82	20	16	4
Potassium (K)	4.8		41.3	37.9	71.3	2.6	3.6	2.8	2	1.5
Carbonate (CO_3)	<5		78	125	<5	<5	<5	<5	<5	<5
Bicarbonate (HCO_3)	702		3780	4110	3730	192	400	308	304	145
Sulphate (SO4)	10.8		20.9	7.2	10.0	11.9	47	6.1	3.1	7.7
Chloride (Cl)	<1		6470	6930	7600	1	2.0	2	2	<1
Total Dissolved Solids	607		14,200	14,700	15,200	183	409	266	261	132
Conductivity	982		20,900	23,400	22,500	298	663	455	457	230
pH	8.1		8.3	8.3	8.2	8.1	7.90	7.7	7.6	8.6
Hydroxide (OH)	<5		<5	<5	<5	<5	<5	<5	<5	<5
Hardness ($CaCO_3$)	141		685	600	695	163	219	229	242	119
Alkalinity (PP as $CaCO_3$)	-			-	-	-	-	-	-	-
Alkalinity (Total as $CaCO_3$)	575		3230	3580	3060	157	328	253	249	127
Ion Balance	98.5		104	93.1	92.6	115	106.00	105	109	102
Nitrate (N)	0.1		<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1
Nitrate plus Nitrite (N)	0.1		<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1
Nitrite (N)	<0.05		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Fluoride (F)	-			-	-	-	-	-	-	-
Phenols	-		0.013	-	-	-	-	-	-	-
Dissolved trace elements										
Aluminum (Al)	0.08		0.01		<0.01			0.07	0.08	
Antimony (Sb)	-				0.0011				0.0006	
Arsenic (As)	-				0.0036				<0.0004	
Barium (Ba)	0.741		1.26		1.1			0.153	0.112	
Beryllium (Be)	<0.001		<0.001		<0.001			<0.001	<0.001	
Boron (B)	0.80		4.44		3.91			<0.05	0.09	
Cadmium (Cd)	<0.001		<0.001		<0.0001			<0.001	<0.0001	
Chromium (Cr)	<0.005		<0.005		<0.005			<0.005	<0.005	
Cobalt (Co)	<0.002		<0.002		0.002			<0.002	<0.002	
Copper (Cu)	<0.001		0.064		0.029			<0.001	<0.001	
Iron (Fe)	0.059		0.633		1.15			16.2	10.9	
Lead (Pb)	<0.005		<0.005		0.0713			<0.005	0.0006	
Lithium (Li)	-				1.28				0.006	
Manganese (Mn)	0.059		0.125		0.296			0.408	0.202	
Mercury (Hg)	-				0.0002				<0.0001	
Molybdenum (Mo)	<0.005		<0.005		0.011			<0.005	<0.005	
Nickel (Ni)	0.003		0.012		0.047			<0.002	<0.002	
Phosphorus (P)	-				-				-	
Selenium (Se)	-				0.215				0.0006	
Silicon (Si)	-				-				-	
Silver (Ag)	<0.005		<0.005		0.0003			<0.005	<0.0001	
Strontium (Sr)	0.357		7.52		8.47			0.139	-	
Sulphur (S)	-				-				-	
Thallium (Tl)	<0.05		<0.05		<0.0001			<0.05	<0.0001	
Tin (Sn)	<0.05		<0.05		<0.05			<0.05	<0.05	
Titanium (Ti)	0.004		0.004		0.010			0.006	0.008	
Uranium (U)	-				<0.0001				0.0003	
Vanadium (V)	<0.001		0.015		0.057			0.005	0.008	
Zinc (Zn)	0.058		0.205		0.015			0.056	0.014	
Zirconium (Zr)	-				-				-	
Hydrocarbons										
Benzene	-		0.0014		-				-	
Toluene	-		<0.0005		-				-	
Ethylbenzene	-		<0.0005		-				-	
Xylene (Total)	-		<0.0005		-				-	
F1(C6-C10)-BTEX	-		<0.1		-				-	
F2 (C10-C16 Hydrocarbons)	-		0.43		-				-	

Notes
1) N/A = Not Applicable
2) ( ) = Results < Reliable Detec
3) - = Not Tested
(4) All units except ion balance,

Location>>>	3-2-95-12		14-4-95-12			4-16-95-12			
Well ID>>>	3-2-95-12-BWS		14-4-95-12-BWS			4-16-95-12-Q		4-16-95-12-KC	
Date Sampled>>>	11-Mar-04	11-Feb-05	5-Mar-02	5-Mar-02	11-Feb-05	16-Dec-04	11-Feb-05	16-Dec-04	11-Feb-05
Parameters									
Calcium (Ca)	73.6	48.2	87.6	92.1	37.4	508	515	29.3	242.0
Magnesium (Mg)	113.0	115.0	125.0	128.0	138.0	227.0	255.0	15.9	65.7
Sodium (Na)	5750	5740	7,050	7,390	5,930	496	480	769	335
Potassium (K)	35	36.1	47.7	51.7	35.7	18.6	19.4	11.7	6.6
Carbonate (CO_3)	97	146	<0.5	<0.5	58	<5	<5	13	<5
Bicarbonate (HCO_3)	3850	3940	4,010	4,010	3,890	594	602	1,090	739
Sulphate (SO4)	7.4	2.5	92.6	<0.1	7.4	2470	2550	717	901
Chloride (Cl)	7420	7380	9,020	8,440	7,720	2	2	48	16
Total Dissolved Solids	15,400	15,400	18,400	18,100	15,800	4,020	4,120	2,140	1,930
Conductivity	22,900	24,400	31,100	31,100	25,400	4,720	4,670	3,280	2,660
pH	8.4	8.3	7.65	7.59	8.20	7.6	7.7	8.30	8.10
Hydroxide (OH)	<5	<5	<0.5	<0.5	<5	<5	<5	<5	<5
Hardness ($CaCO_3$)	649	594	730	760	662	2,200	2,340	139	875
Alkalinity (PP as $CaCO_3$)		-	<0.5	<0.5	-		-		-
Alkalinity (Total as $CaCO_3$)	3320	3470	3,290	3,290	3,290	487	493	912	606
Ion Balance	95.7	94.5	1.00	1.11	95.90	108	108	106.00	103.00
Nitrate (N)	<0.1	<0.1	<0.003	<0.003	<0.1	0.3	<0.1	<0.1	<0.1
Nitrate plus Nitrite (N)	<0.1	<0.1	<0.003	<0.003	<0.1	0.1	<0.1	<0.1	<0.1
Nitrite (N)	<0.05	<0.05	<0.003	<0.003	<0.05	<0.05	<0.05	<0.05	<0.05
Fluoride (F)		-			-		-		-
Phenols		-			-		-		-

Dissolved trace elements									
Aluminum (Al)		<0.01	-	-					
Antimony (Sb)		0.0007	-	-					
Arsenic (As)		<0.0004	-	-					
Barium (Ba)		1.00	-	-					
Beryllium (Be)		<0.001	-	-					
Boron (B)		5.42	-	-					
Cadmium (Cd)		<0.0001	-	-					
Chromium (Cr)		<0.005	-	-					
Cobalt (Co)		<0.002	-	-					
Copper (Cu)		0.003	-	-					
Iron (Fe)		0.8	<0.01	<0.01					
Lead (Pb)		0.0006	-						
Lithium (Li)		1.2	-	-					
Manganese (Mn)		0.345	0.222	0.216					
Mercury (Hg)		0.0002	-	-					
Molybdenum (Mo)		<0.005	-	-					
Nickel (Ni)		0.014	-	-					
Phosphorus (P)		-	-	-					
Selenium (Se)		<0.0004	-	-					
Silicon (Si)		-	-	-					
Silver (Ag)		<0.0001	-	-					
Strontium (Sr)		-	-	-					
Sulphur (S)		-	-	-					
Thallium (Tl)		0.0003	-	-					
Tin (Sn)		<0.05	-	-					
Titanium (Ti)		0.011	-	-					
Uranium (U)		<0.0001	-	-					
Vanadium (V)		0.04	-	-					
Zinc (Zn)		0.032	-	-					
Zirconium (Zr)		-	-	-					
Hydrocarbons									
Benzene		-	-	-					
Toluene		-	-	-					
Ethylbenzene		-	-	-					
Xylene (Total)		-	-	-					
F1(C6-C10)-BTEX		-	-	-					
F2 (C10-C16 Hydrocarbons)		-	-	-					

Notes
1) N/A = Not Applicable
2) ( ) = Results < Reliable Detec
3) - = Not Tested
(4) All units except ion balance,

Location>>>				7-18-95-12	
Well ID>>>	*4-16-95-12-BWS*			7-18-95-12-BWS	
Date Sampled>>>	***11-Mar-04***	***14-Dec-04***	***11-Feb-05***	**11-Mar-04**	**11-Feb-05**
Parameters	*Affected by injection*				
Calcium (Ca)	*68.8*	*1.8*	*2.4*	115.0	55.6
Magnesium (Mg)	*81.8*	*2.8*	*1.4*	178.0	175.0
Sodium (Na)	*3,670*	*325*	*286*	6,940	6,960
Potassium (K)	*52.7*	*11.4*	*8.9*	57.7	53.5
Carbonate (CO_3)	*<5*	*69*	*12*	40	74
Bicarbonate (HCO_3)	*2,350*	*413*	*482*	3,680	3,830
Sulphate (SO4)	*62.1*	*66.1*	*75.9*	10.2	4.0
Chloride (Cl)	*4,690*	*157*	*75*	8,520	9,110
Total Dissolved Solids	*9,780*	*837*	*699*	17,700	18,300
Conductivity	*15,500*	*1,460*	*1,160*	27,400	30,000
pH	*8.30*	*9.3*	*8.6*	8.20	8.20
Hydroxide (OH)	*<5*	*<5*	*<5*	<5	<5
Hardness ($CaCO_3$)	*509*	*16*	*12*	1,020	859
Alkalinity (PP as $CaCO_3$)			-		-
Alkalinity (Total as $CaCO_3$)	*1,930*	*454*	*416*	3,080	3,260
Ion Balance	*99.40*	*99.10*	*108.00*	107.00	99.70
Nitrate (N)	*<0.1*	*0.100*	*<0.1*	<0.1	<0.1
Nitrate plus Nitrite (N)	*<0.1*	*0.200*	*<0.1*	<0.1	<0.1
Nitrite (N)	*<0.05*	*0.090*	*<0.05*	<0.05	<0.05
Fluoride (F)			-		-
Phenols	*0.022*		-		-

Dissolved trace elements					
Aluminum (Al)	*0.15*			0.02	
Antimony (Sb)					
Arsenic (As)					
Barium (Ba)	*0.514*			0.924	
Beryllium (Be)	*<0.001*			<0.001	
Boron (B)	*3.14*			4.55	
Cadmium (Cd)	*<0.001*			<0.001	
Chromium (Cr)				<0.005	
Cobalt (Co)	*0.003*			<0.002	
Copper (Cu)	*0.191*			0.02	
Iron (Fe)	*0.60*			0.75	
Lead (Pb)	*<0.005*			<0.005	
Lithium (Li)					
Manganese (Mn)	*0.57*			0.20	
Mercury (Hg)					
Molybdenum (Mo)	*0.018*			<0.005	
Nickel (Ni)	*0.015*			0.012	
Phosphorus (P)					
Selenium (Se)					
Silicon (Si)					
Silver (Ag)	*<0.005*			<0.005	
Strontium (Sr)	*3.97*			8.34	
Sulphur (S)					
Thallium (Tl)	*<0.05*			<0.05	
Tin (Sn)	*<0.05*			<0.05	
Titanium (Ti)	*0.013*			0.005	
Uranium (U)					
Vanadium (V)	*0.005*			0.023	
Zinc (Zn)	*0.098*			0.218	
Zirconium (Zr)					
Hydrocarbons					
Benzene	*0.0024*	*0.0038*			
Toluene	*0.0009*	*<0.0005*			
Ethylbenzene	*<0.0005*	*<0.0005*			
Xylene (Total)	*0.0006*	*<0.0005*			
F1(C6-C10)-BTEX	*<0.1*	*<0.1*			
F2 (C10-C16 Hydrocarbons)	*1.6*	*<0.05*			

Notes
1) N/A = Not Applicable
2) ( ) = Results < Reliable Detec
3) - = Not Tested
(4) All units except ion balance,

Location>>>	14-20-95-12										
Well ID>>>	14-20-95-12-BWS			14-20-95-12-KC				14-20-95-12-Q			
Date Sampled>>>	11-Mar-04	14-Dec-04	11-Feb-05	22-Mar-03	12-Feb-04	16-Dec-04	11-Feb-05	22-Mar-03	12-Feb-04	16-Dec-04	11-Feb-05
Parameters											
Calcium (Ca)	128.0	31.5	*24.0*	12.9	7.2	43.8	15.3	303.0	372.0	229	325
Magnesium (Mg)	188.0	48.6	*33.4*	6.3	5.6	21.9	8.4	142.0	168.0	121	147
Sodium (Na)	7,200	2,890	*2,090*	1,190	1,130	760	915	395	545	259	410
Potassium (K)	71.2	22.9	*15.1*	5.5	7.0	5.8	5.2	9.4	16.4	7.0	12.5
Carbonate (CO_3)	14	7	*7*	74.6	30	14	33	<0.5	<5	<5	<5
Bicarbonate (HCO_3)	3,330	1,310	*985*	1,740	1,820	1,230	1,520	649	632	852	727
Sulphate (SO4)	32	3.4	*1.4*	45.2	6.9	287.0	111.0	1,690	2,000	787	1,540
Chloride (Cl)	9,670	4,220	*3,010*	645	629	358	479	6.1	9.0	3.0	7.0
Total Dissolved Solids	18,900	7,870	*5,670*	2,840	2,710	2,090	2,310	2,870	3,420	1,820	2,800
Conductivity	27,600	13,100	*10,100*	4,470	4,520	3,420	3,860	4,310	3,940	2,590	3,510
pH	8.1	8.3	*8.3*	8.57	8.40	8.30	8.40	8.17	7.90	7.9	7.9
Hydroxide (OH)	<5	<5	*<5*	<0.5	<5	<5	<5	<0.5	<5	<5	<5
Hardness ($CaCO_3$)	1,090	279	*197*	58	41	200	73	1,300	1,620	1,070	1,420
Alkalinity (PP as $CaCO_3$)		-	-	62.2		-	-	<0.5		-	-
Alkalinity (Total as $CaCO_3$)	2,760	1,090	*819*	1,550	1,540	1,030	1,300	532	518	698	596
Ion Balance	103.00	93.6	*94.0*	1.06	103.00	101.00	98.90	0.96	108.00	108.00	105.00
Nitrate (N)	<0.1	<0.1	*<0.1*	0.018	<0.1	<0.1	<0.1	0.043	<0.1	<0.1	<0.1
Nitrate plus Nitrite (N)	<0.1	<0.1	*<0.1*	0.029	0.100	<0.1	<0.1	0.074	<0.1	<0.1	<0.1
Nitrite (N)	<0.05	<0.05	*0.130*	0.011	0.090	<0.05	0.080	0.031	<0.05	<0.05	<0.05
Fluoride (F)			-	1.24			-	0.72			-
Phenols	0.025		-	0.033			-	0.059			-
Dissolved trace elements											
Aluminum (Al)	0.12			0.015	1.33			0.004	0.08		
Antimony (Sb)				0.0021				0.0006			
Arsenic (As)				0.0020				0.0004			
Barium (Ba)	1.03			0.119	0.22			0.0396	0.02		
Beryllium (Be)	<0.001			<0.0002	<0.005			<0.0002	<0.001		
Boron (B)	4.25			3.22	3.08			0.64	0.87		
Cadmium (Cd)	<0.001			<0.0002	<0.001			<0.0002	<0.001		
Chromium (Cr)	<0.005			0.003	<0.005			<0.001	<0.005		
Cobalt (Co)	<0.002			0.0022	<0.002			0.0044	0.004		
Copper (Cu)	0.02			0.0030	0.003			0.0050	0.0070		
Iron (Fe)	0.54			(0.01)	0.9520			0.07	0.014		
Lead (Pb)	0.005			(0.0004)	<0.005			<0.0003	<0.005		
Lithium (Li)				0.202				0.337			
Manganese (Mn)	0.279			0.098	0.009			0.310	0.783		
Mercury (Hg)				<0.4				<0.2			
Molybdenum (Mo)	0.005			0.0156	<0.005			0.0035	0.006		
Nickel (Ni)	0.011			0.0097	0.005			0.0173	0.008		
Phosphorus (P)				0.2				<0.1			
Selenium (Se)				0.0005				(0.0002)			
Silicon (Si)				2.67				5.30			
Silver (Ag)	<0.005			<0.0001	<0.005			<0.0001	<0.005		
Strontium (Sr)	8.29			0.490	0.58			2.48	3.57		
Sulphur (S)				11.4				636			
Thallium (Tl)	<0.05			<0.0002	<0.05			<0.0002	<0.05		
Tin (Sn)	<0.05			<0.001	<0.05			<0.001	<0.05		
Titanium (Ti)	0.034			0.003	0.038			0.002	0.002		
Uranium (U)				0.0025				0.0356			
Vanadium (V)	0.039			0.003	0.007			<0.001	0.002		
Zinc (Zn)	0.071			0.0110	0.014			0.0145	0.014		
Zirconium (Zr)				0.0284				0.0071			
Hydrocarbons											
Benzene	0.0068			<0.0004				<0.0004			
Toluene	0.0006			<0.0004				<0.0004			
Ethylbenzene	<0.0005			<0.0004				<0.0004			
Xylene (Total)	<0.0005			<0.0008				<0.0008			
F1(C6-C10)-BTEX	<0.1			<0.1				<0.1			
F2 (C10-C16 Hydrocarbons)	0.21			<0.2				<0.1			

Notes
1) N/A = Not Applicable
2) ( ) = Results < Reliable Detec
3) - = Not Tested
(4) All units except ion balance,

Location>>>	3-26-95-12			10-28-95-12		5-29-95-12	
Well ID>>>	3-26-95-12 Q	3-26-95-12-BWS		10-28-95-12-BWS		5-29-95-12-BWS	
Date Sampled>>>	11-Feb-05	11-Mar-04	11-Feb-05	11-Mar-04	11-Feb-05	11-Mar-04	11-Feb-05
Parameters							
Calcium (Ca)	65	83.8	50.2	111.0	36.5	137.0	70.7
Magnesium (Mg)	29	135.0	142.0	172.0	166.0	233.0	232.0
Sodium (Na)	313	6,310	6,470	7,460	7,270	8,780	8,340
Potassium (K)	7.9	44.8	34.8	79.9	69.6	69.5	56.2
Carbonate (CO_3)	<5	55	57	50	91	25	29
Bicarbonate (HCO_3)	924	3,570	3,950	3,420	3,660	3,360	3,470
Sulphate (SO4)	6	11	2	25	12	11	3
Chloride (Cl)	198.0	8,110	8,800	9,360.0	10,700.0	11,900.0	12,900.0
Total Dissolved Solids	1,070	16,500	17,500	18,900	20,100	22,800	23,300
Conductivity	1,920	24,800	27,000	29,100	31,200	33,200	36,700
pH	8.0	8.30	8.20	8.20	8.20	8.20	8.10
Hydroxide (OH)	<5	<5	<5	<5	<5	<5	<5
Hardness ($CaCO_3$)	282	765	710	985	775	1,300	1,130
Alkalinity (PP as $CaCO_3$)	-		-		-		-
Alkalinity (Total as $CaCO_3$)	758	3,020	3,330	2,890	3,150	2,790	2,890
Ion Balance	93.30	101.0	94.2	107.00	91.30	105.00	91.70
Nitrate (N)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Nitrate plus Nitrite (N)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Nitrite (N)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Fluoride (F)	-		-		-		-
Phenols	-		-		-		-

Dissolved trace elements							
Aluminum (Al)	0.02	0.01	0.01	0.03			
Antimony (Sb)	0.0008		0.0008				
Arsenic (As)	0.001		<0.0004				
Barium (Ba)	0.269	0.311	2.07	0.673			
Beryllium (Be)	<0.001	<0.001	<0.001	<0.001			
Boron (B)	1.11	4.31	5.73	4.4			
Cadmium (Cd)	0.0001	<0.001	<0.0001	<0.001			
Chromium (Cr)	<0.005	<0.005	<0.005	<0.005			
Cobalt (Co)	<0.002	0.005	<0.002	0.003			
Copper (Cu)	0.0010	0.0110	0.0040				
Iron (Fe)	0.019	0.387	0.625	0.68			
Lead (Pb)	0.0006	<0.005	0.0006	<0.005			
Lithium (Li)	0.206		1.39				
Manganese (Mn)	0.217	0.292	0.143	0.167			
Mercury (Hg)	0.0001		0.0002				
Molybdenum (Mo)	<0.005	0.018	0.006	0.007			
Nickel (Ni)	0.004	0.078	0.023	0.031			
Phosphorus (P)	-		-				
Selenium (Se)	0.005		<0.0004				
Silicon (Si)	-		-				
Silver (Ag)	<0.0001	<0.005	<0.0001	<0.005			
Strontium (Sr)	-	6.61	-	7.74			
Sulphur (S)	-		-				
Thallium (Tl)	0.0001		0.0003	<0.05			
Tin (Sn)	<0.05	<0.05	<0.05	<0.05			
Titanium (Ti)	0.004	0.005	0.019	0.006			
Uranium (U)	0.002		<0.0001				
Vanadium (V)	0.003	0.039	0.043	0.036			
Zinc (Zn)	0.01	0.114	0.054	0.207			
Zirconium (Zr)	-		-				
Hydrocarbons							
Benzene	-		-				
Toluene	-		-				
Ethylbenzene	-		-				
Xylene (Total)	-		-				
F1(C6-C10)-BTEX	-		-				
F2 (C10-C16 Hydrocarbons)	-		-				

Notes
1) N/A = Not Applicable
2) ( ) = Results < Reliable Detec
3) - = Not Tested
(4) All units except ion balance,

Location>>>												
Well ID>>>	14-36-95-12-BWS-BP-2Wb		14-36-95-12-BWS-2Wa		14-36-95-12-KC				14-36-95-12-Q			
Date Sampled>>>	17-Mar-75	15-Dec-04	*23-Mar-03*	11-Feb-05	23-Mar-03	12-Feb-04	16-Dec-04	11-Feb-05	23-Mar-03	12-Feb-04	16-Dec-04	11-Feb-05
Parameters			Affected by injection									
Calcium (Ca)	179.0	159.0	*133.0*	51.6	25.6	21.4	25.3	24.8	138	133	143	140
Magnesium (Mg)	218.0	197.0	*0.7*	181.0	8.4	15.5	20.1	23.2	52.8	51.9	54.4	54.2
Sodium (Na)	7,750	7,800	*212*	7,260	390	2130	2640	2740	210	282	228	234
Potassium (K)	90.0	58.3	*2.7*	51.4	4.5	13.4	17.0	14.4	6.1	6.2	6.7	5.4
Carbonate (CO_3)	0	<5	*<0.5*	31	14.2	13	<5	<5	<0.5	<5	<5	<5
Bicarbonate (HCO_3)	3,660	3,970	*825*	3,760	932	3,360	3,950	4,310	924	835	801	820
Sulphate (SO4)	210.0	3.2	*1.9*	2.1	90.8	59.5	28.4	25.9	149	174	141	159
Chloride (Cl)	10,420	10,300	*152*	10,200	63.5	1,210.0	1,960.0	1,990.0	171	126	197	162
Total Dissolved Solids	21,900	20,500	*908*	19,600	1,060	5,120	6,630	6,940	1,180	1,180	1,160	1,160
Conductivity	29,000	30,900	*1,790*	29,900	1,860	8,080	10,400	10,800	2,350	1,830	1,960	1,930
pH	7.10	7.90	*7.51*	8.10	8.40	8.10	8.10	8.10	8.05	7.90	7.80	7.90
Hydroxide (OH)		<5	*<0.5*	<5	<0.5	<5	<5	<5	<0.5	<5	<5	<5
Hardness ($CaCO_3$)		1,210	*330*	874	98	117	146	157	560	546	581	573
Alkalinity (PP as $CaCO_3$)		-	*<0.5*	-	11.8		-	-	<0.5		-	-
Alkalinity (Total as $CaCO_3$)		3,260	*676*	3,130	787	2,780	3,240	3,540	758	684	656	672
Ion Balance		103.00	*0.89*	95.50	0.98	105.00	98.0	96.4	0.89	112.00	100.00	102.00
Nitrate (N)		<0.1	*(0.005)*	<0.1	0.044	<0.1	<0.1	<0.1	0.171	<0.1	<0.1	<0.1
Nitrate plus Nitrite (N)		<0.1	*0.011*	<0.1	0.066	<0.1	<0.1	<0.1	0.179	<0.1	<0.1	<0.1
Nitrite (N)		<0.05	*0.006*	<0.05	0.022	<0.05	<0.05	<0.05	0.008	<0.05	<0.05	<0.05
Fluoride (F)			*<0.05*	-	0.88			-	0.52			-
Phenols			*0.011*	-	0.025			-	0.013			-
Dissolved trace elements												
Aluminum (Al)			*(0.001)*		0.075	1.04			0.002	<0.01		
Antimony (Sb)			*<0.0002*		0.0024				(0.0002)			
Arsenic (As)			*(0.0003)*		0.0017				0.0006			
Barium (Ba)			*0.0316*		0.0906	0.458			0.185	0.132		
Beryllium (Be)			*<0.0002*		<0.0002	<0.001			<0.0002	<0.001		
Boron (B)			*0.05*		0.89	3.53			0.56	0.56		
Cadmium (Cd)			*<0.0002*		<0.0002	<0.001			<0.0002	<0.001		
Chromium (Cr)			*(0.001)*		0.002	<0.005			(0.001)	<0.005		
Cobalt (Co)			*0.0040*		0.0015	0.003			0.0009	<0.002		
Copper (Cu)			*<0.0002*		0.0054	0.004			0.0024	0.002		
Iron (Fe)			*<0.01*		0.04	0.563			0.02	0.006		
Lead (Pb)			*<0.0003*		0.0009	<0.005			<0.0003	<0.005		
Lithium (Li)			*0.019*		0.051				0.155			
Manganese (Mn)			*0.291*		0.107	0.32			0.276	0.365		
Mercury (Hg)			*<0.2*		<0.2				<0.2			
Molybdenum (Mo)			*<0.0002*		0.0226	0.014			0.0024	<0.005		
Nickel (Ni)			*0.0123*		0.0064	0.008			0.0039	0.003		
Phosphorus (P)			*<0.1*		<0.1				<0.1			
Selenium (Se)			*0.0004*		<0.0002				(0.0002)			
Silicon (Si)			*0.27*		6.34				9.69			
Silver (Ag)			*<0.0001*		<0.0001	<0.005			<0.0001	<0.005		
Strontium (Sr)			*0.312*		0.353	1.58			1.03	0.95		
Sulphur (S)			*0.9*		27.5				50.5			
Thallium (Tl)			*<0.0002*		<0.0002	<0.05			<0.0002	<0.05		
Tin (Sn)			*<0.001*		0.003	<0.05			<0.001	<0.05		
Titanium (Ti)			*<0.001*		<0.001	0.035			<0.001	0.002		
Uranium (U)			*<0.0004*		0.0189				0.0306			
Vanadium (V)			*<0.001*		0.002	0.014			<0.001	0.005		
Zinc (Zn)			*0.0034*		0.0498	0.023			0.0086	0.012		
Zirconium (Zr)			*0.0009*		0.0111				0.0049			
Hydrocarbons												
Benzene			*<0.0009*		<0.0004				<0.0004			
Toluene			*<0.0009*		<0.0004				<0.0004			
Ethylbenzene			*<0.0009*		<0.0004				<0.0004			
Xylene (Total)			*<0.002*		<0.0008				<0.0008			
F1(C6-C10)-BTEX			*<0.2*		<0.1				<0.1			
F2 (C10-C16 Hydrocarbons)			*(0.1)*		-				<0.1			

Notes
1) N/A = Not Applicable
2) ( ) = Results < Reliable Detec
3) - = Not Tested
(4) All units except ion balance,

Location>>>	15-12-95-13					16-3-96-11
Well ID>>>	**15-12-95-13-KC**		***15-12-95-13-BWS***			**16-3-96-11 BWS**
Date Sampled>>>	**16-Dec-04**	**11-Feb-05**	***10-Mar-04***	***14-Dec-04***	***11-Feb-05***	**8-Mar-05**
Parameters			*Affected by injection*	*Affected by injection*	*Affected by injection*	
Calcium (Ca)	22.3	66.4	*105.0*	*53.0*	*55.4*	159
Magnesium (Mg)	10.5	35.2	*0.2*	*140.0*	*155*	216
Sodium (Na)	741	747	*13*	*6,570*	*6,440*	22,300
Potassium (K)	11.5	11.0	*31.2*	*43.4*	*42.3*	156.0
Carbonate (CO_3)	33	<5	*27*	*<5*	*69*	<5
Bicarbonate (HCO_3)	1,270	1,050	*<5*	*3,840*	*3,890*	3,290
Sulphate (SO4)	65	774	*95.3*	*4.6*	*2.9*	318.0
Chloride (Cl)	400	193	*50*	*9,020*	*8,990*	32,700
Total Dissolved Solids	1,910	2,350	*357*	*17,700*	*17,700*	57,500
Conductivity	3,190	3,530	*769*	*26,300*	*26,700*	75,400
pH	8.50	8.20	*11.10*	*8.20*	*8.20*	7.70
Hydroxide (OH)	<5	<5	*20*	*<5*	*<5*	<5
Hardness ($CaCO_3$)	99	311	*263*	*709*	*777*	1,290
Alkalinity (PP as $CaCO_3$)	-	-	-	-	-	-
Alkalinity (Total as $CaCO_3$)	1,100	862	*102*	*3,150*	*3,300*	2,700
Ion Balance	99.80	100.00	*121.00*	*94.80*	*92.80*	102.00
Nitrate (N)	0.3	0.2	*0.300*	*<0.1*	*0.3*	0.1
Nitrate plus Nitrite (N)	0.3	0.3	*0.300*	*<0.1*	*<0.1*	0.100
Nitrite (N)	<0.05	0.2	*<0..05*	*<0.05*	*<0.05*	<0.05
Fluoride (F)		-	-	-	-	-
Phenols		-	-	-	-	-

Dissolved trace elements						
Aluminum (Al)						<0.04
Antimony (Sb)						<0.002
Arsenic (As)						0.0011
Barium (Ba)						0.54
Beryllium (Be)						<0.004
Boron (B)						3.6
Cadmium (Cd)						<0.0004
Chromium (Cr)						<0.005
Cobalt (Co)						<0.008
Copper (Cu)						<0.004
Iron (Fe)						0.08
Lead (Pb)						<0.0004
Lithium (Li)						1.47
Manganese (Mn)						0.330
Mercury (Hg)						0.0024
Molybdenum (Mo)						<0.02
Nickel (Ni)						<0.008
Phosphorus (P)						-
Selenium (Se)						<0.0004
Silicon (Si)						-
Silver (Ag)						<0.0004
Strontium (Sr)						-
Sulphur (S)						-
Thallium (Tl)						<0.0004
Tin (Sn)						<0.2
Titanium (Ti)						0.006
Uranium (U)						<0.0004
Vanadium (V)						0.126
Zinc (Zn)						0.019
Zirconium (Zr)						-
Hydrocarbons						
Benzene						
Toluene						
Ethylbenzene						
Xylene (Total)						
F1(C6-C10)-BTEX						
F2 (C10-C16 Hydrocarbons)						

Notes
1) N/A = Not Applicable
2) ( ) = Results < Reliable Detec
3) - = Not Tested
(4) All units except ion balance,

Location>>>	5-4-96-11										
Well ID>>>	5-4-96-11-BWS			5-4-96-11-KC				5-4-96-11-Q			
Date Sampled>>>	11-Mar-04	15-Dec-04	11-Feb-05	23-Mar-03	12-Feb-04	16-Dec-04	11-Feb-05	23-Mar-03	12-Feb-04	16-Dec-04	11-Feb-05
Parameters	Affected by injection	Affected by injection	Affected by injection								
Calcium (Ca)	63.5	30.5	36.6	58.8	64.3	69.4	77.3	16.7	17.2	16.7	19.1
Magnesium (Mg)	84.3	21.2	24.7	11.9	12.4	14	15.1	3.9	3.8	3.9	4.4
Sodium (Na)	2,940	823	833	31.6	18	22	22	1.7	2	2	2
Potassium (K)	82.0	47.4	49.3	2.4	2.4	3.1	2.9	(0.4)	0.7	1	0.5
Carbonate (CO_3)	112	<5	<5	<0.5	<5	<5	<5	<0.5	<5	<5	<5
Bicarbonate (HCO_3)	1,500	498	492	371	279	337	342	95.8	60.0	67.0	69.0
Sulphate (SO4)	41.8	2.2	2.5	13.2	3.9	1.9	1.6	4.9	7.2	4.0	5.3
Chloride (Cl)	3,910.0	1,180.0	1,340	1.4	<1	2.0	3	(0.6)	2	2	3
Total Dissolved Solids	7,970	2,350	2,530	302	240	278	290	76	61	63	69
Conductivity	13,100	4,450	4,510	602	426	501	515	141	115	122	129
pH	8.70	8.20	8.1	8.20	8.00	7.90	7.90	7.37	7.50	7.50	7.60
Hydroxide (OH)	<5	<5	<5	<0.5	<5	<5	<5	<0.5	<5	<5	<5
Hardness ($CaCO_3$)	506	163	193	200	212	231	255	58	59	58	66
Alkalinity (PP as $CaCO_3$)		-	-	<0.5		-	-	<0.5		-	-
Alkalinity (Total as $CaCO_3$)	1410	408	403	304	229	276	280	78.5	49.0	55.0	57.0
Ion Balance	100.00	97.1	90.0	0.84	109.00	101.00	107.00	0.73	105.00	102.00	106.00
Nitrate (N)	<0.1	<0.1	<0.1	0.069	0.200	<0.1	<0.1	0.068	0.200	<0.1	<0.1
Nitrate plus Nitrite (N)	<0.1	<0.1	<0.1	0.091	0.300	<0.1	<0.1	0.068	0.300	<0.1	<0.1
Nitrite (N)	<0.05	<0.05	0.160	0.022	0.070	<0.05	0.130	<0.003	0.070	<0.05	0.120
Fluoride (F)			-	<0.05			-	<0.05			-
Phenols	0.065		-	0.014			-	0.014			-
Dissolved trace elements											
Aluminum (Al)	0.35			0.004	<0.01			0.004	0.1		
Antimony (Sb)				<0.0002				(0.0002)			
Arsenic (As)				<0.0002				<0.0002			
Barium (Ba)	1.68			0.217	0.338			0.0198	0.02		
Beryllium (Be)	<0.001			<0.0002	<0.001			<0.0002	<0.001		
Boron (B)	2.58			0.09	0.09			<0.01	<0.05		
Cadmium (Cd)	<0.001			<0.0002	<0.001			<0.0002	<0.001		
Chromium (Cr)	<0.005			<0.001	<0.005			<0.001	<0.005		
Cobalt (Co)	0.005			0.0031	<0.002			(0.0003)	<0.002		
Copper (Cu)	0.002			0.0014	0.001			(0.0003)	0.001		
Iron (Fe)	0.44			(0.01)	3			0.15	0.034		
Lead (Pb)	<0.005			<0.0003	<0.005			<0.0003	<0.005		
Lithium (Li)				(0.005)				<0.004			
Manganese (Mn)	0.849			0.284	0.262			0.057	0.261		
Mercury (Hg)				<0.2				<0.5			
Molybdenum (Mo)	<0.005			0.0032	<0.005			<0.0002	<0.005		
Nickel (Ni)	0.003			0.0031	<0.002			(0.0007)	<0.002		
Phosphorus (P)				<0.1				<0.1			
Selenium (Se)				<0.0002				<0.0002			
Silicon (Si)				11.8				4.30			
Silver (Ag)	<0.005			<0.0001	<0.005			<0.0001	<0.005		
Strontium (Sr)	3.98			0.284	0.214			<0.004	0.024		
Sulphur (S)				4.7				1.7			
Thallium (Tl)	<0.05			<0.0002	<0.05			<0.0002	<0.05		
Tin (Sn)	<0.05			<0.001	<0.05			<0.001	<0.05		
Titanium (Ti)	0.02			<0.001	0.002			<0.001	<0.001		
Uranium (U)				0.0013				<0.0004			
Vanadium (V)	<0.001			<0.001	0.002			<0.001	0.001		
Zinc (Zn)	0.044			0.0253	0.026			0.0024	0.005		
Zirconium (Zr)				0.0027				0.0006			
Hydrocarbons											
Benzene	0.0012			<0.0004				<0.0004			
Toluene	<0.0005			<0.0004				<0.0004			
Ethylbenzene	<0.0005			<0.0004				<0.0004			
Xylene (Total)	<0.0005			<0.0008				<0.0008			
F1(C6-C10)-BTEX	<0.1			<0.1				<0.1			
F2 (C10-C16 Hydrocarbons)	0.32			0.3				<0.1			

Notes
1) N/A = Not Applicable
2) ( ) = Results < Reliable Detec
3) - = Not Tested
(4) All units except ion balance,

Location>>>	3-4-96-11	11-4-96-11	2-5-96-11	9-5-96-11	16-5-96-11	13-6-96-11		15-36-96-11	5-2-96-12		
Well ID>>>	3-4-96-11-WSW	11-4-96-11-Q	2-5-96-11-WSW	9-5-96-11-WSW	16-5-96-11-Q	13-6-96-11-Q		15-36-96-11-BP 1W	5-2-96-12 Q	5-2-96-12-BWS	
Date Sampled>>>	9-Sep-03	10-Mar-02	9-Sep-03	9-Sep-03	10-Mar-04	11-Mar-04	11-Feb-05	1975	7-Mar-05	11-Mar-04	11-Feb-05
Parameters											
Calcium (Ca)	45.3	41.7	46.7	44.8	23.0	180.0	255.0	191.0	59.4	36.1	16.2
Magnesium (Mg)	8.8	6.1	7.4	7.0	2.0	75.1	124.0	344.0	15.5	228.0	137.0
Sodium (Na)	9	3	5	7	4	1 040	840	8,425	598	7,740	159
Potassium (K)	0.9	0.6	1.0	1.3	1.1	14.3	9.9	142.5	15.5	119.0	137.0
Carbonate (CO_3)	<5	<0.5	<5	<5	<5	<5	<5	0	<5	217	2530
Bicarbonate (HCO_3)	188.0	172	182	183	76	1 160	974	2,274	1,140	3,310	783
Sulphate (SO4)	3.9	2.1	2.5	2.5	5.7	1 700	1890.0	156.0	196.0	26.1	11.6
Chloride (Cl)	<1	1	<1	<1	3	194	139	14,300	304	9,860	10,100
Total Dissolved Solids	156	139	152	153	78	3 770	3,740	25,950	1,750	19,900	21,000
Conductivity	304	272	291	288	128	4 810	4,890	33,000	2,760	30,100	31,500
pH	8.00	7.61	7.90	7.90	7.80	7.90	7.90	7.20	7.90	8.60	10.20
Hydroxide (OH)					<5	<5	<5		<5	<5	<5
Hardness ($CaCO_3$)	149	130	147	141	66	759	1,150		212	1,030	695
Alkalinity (PP as $CaCO_3$)					-		-		-		-
Alkalinity (Total as $CaCO_3$)	154.0	141	149	150	63	951	799		933	3,080	4,850
Ion Balance	1.00	0.94	1.05	1.03	103.00	101.00	101.00		97.80	106.00	91.20
Nitrate (N)	<0.1		<0.1		0.400	<0.1	<0.1		<0.1	<0.1	<0.1
Nitrate plus Nitrite (N)	<0.1		<0.1		0.400	<0.1	<0.1		<0.1	<0.1	<0.1
Nitrite (N)	<0.05		<0.05		<0.05	<0.05	<0.05		<0.05	<0.05	<0.05
Fluoride (F)					-	-	-		-		-
Phenols					-		-		-		-
Dissolved trace elements											
Aluminum (Al)	<0.01		0.02	<0.01	0.04	0.05			0.16		0.04
Antimony (Sb)	0.0007		0.0007	0.0007					0.0032		0.003
Arsenic (As)	<0.0004		<0.0004	0.0017					0.0021		0.0037
Barium (Ba)	0.0633		0.0841	0.0789	0.016	0.095			0.11		0.268
Beryllium (Be)	<0.0005		<0.0005	<0.0005	<0.001	<0.001			<0.001		<0.001
Boron (B)	0.019		0.025	0.024	<0.05	1.59			1.11		5.26
Cadmium (Cd)	<0.0001		<0.0001	<0.0001	<0.001	<0.001			0.0002		0.0002
Chromium (Cr)	<0.0004		0.0004	<0.0004	<0.005	<0.005			0.007		<0.005
Cobalt (Co)	<0.0001		<0.0001	<0.0001	<0.002	0.008			0.003		<0.002
Copper (Cu)	<0.0006		0.0009	<0.0006	<0.001	0.016			0.005		0.02
Iron (Fe)	3.44	<0.01	3.44	10.6	0.367	0.04			1.27		0.153
Lead (Pb)	<0.0001		0.0023	<0.0001	<0.005	<0.005			0.0015		0.0416
Lithium (Li)									0.098		1.75
Manganese (Mn)	0.169	0.427	0.169	0.316	0.057	0.327			0.282		0.041
Mercury (Hg)									<0.0001		0.0002
Molybdenum (Mo)	0.0002		0.0002	0.0003	<0.005	0.019			0.029		0.05
Nickel (Ni)	<0.0001		<0.0001	<0.0001	<0.002	0.049			0.014		0.015
Phosphorus (P)									-		-
Selenium (Se)	<0.0004		<0.0004	<0.0004					0.0108		<0.0004
Silicon (Si)									-		-
Silver (Ag)	<0.0002		<0.0002	<0.0002	<0.005	<0.005			<0.0001		<0.0001
Strontium (Sr)	0.0886		0.121	0.109	0.025	1.26			-		-
Sulphur (S)									-		-
Thallium (Tl)	<0.00005		<0.00005	<0.00005	<0.05	<0.05			<0.0001		0.0003
Tin (Sn)	<0.0002		0.0002	<0.0002	<0.05	<0.05			<0.05		<0.05
Titanium (Ti)	0.0009		0.0022	0.0019	0.002	0.003			0.007		0.028
Uranium (U)	<0.0001		<0.0001	<0.0001					0.0142		<0.0001
Vanadium (V)	0.0003		0.0014	0.0013	0.014	0.017			0.004		0.05
Zinc (Zn)	0.009		0.016	0.011	0.054	0.066			0.022		0.13
Zirconium (Zr)									-		-
Hydrocarbons											
Benzene											-
Toluene											-
Ethylbenzene											-
Xylene (Total)											-
F1(C6-C10)-BTEX											-
F2 (C10-C16 Hydrocarbons)											-

Notes
1) N/A = Not Applicable
2) ( ) = Results < Reliable Detec
3) - = Not Tested
(4) All units except ion balance,