ERNST WATER WELL COMPLAINT REVIEW

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EXECUTIVE SUMMARY

In early 2006 Alberta Environment (AENV) staff contacted Ms. Ernst to investigate a water well complaint and made arrangements to undertake sampling. The Alberta Research Council (ARC) was contracted by AENV to critically review the scientific and technical data contained in the AENV and Alberta Energy and Utilities (AEUB) Ernst water well complaint file. In addition, ARC was asked to do an independent review of all relevant data, including new data that has become available through Directive 35 (Standard Baseline Water-Well Testing for CBM/NGC Operations).

The ARC independent review and evaluation involved the examination of all the data contained in the AENV file and the following additional lines of evidence:

- Review of the local and regional geology and hydrostratigraphy.
- Calculation of hydraulic gradients between the aquifer in the Upper Horseshoe Canyon Formation and the CBM wells.
- A theoretical review of the potential of methane migration along a fracture (potentially induced by well stimulation) between the Horseshoe Canyon aquifer and the CBM well using the observed pressure gradients.
- An estimation of the change in dissolved methane concentrations in the Ernst well related to the measured decrease in well water levels from 2003 to 2007.
- A graphical and statistical approach to the evaluation of the major ion, bacteria, gas and isotope chemistry of the Ernst well, 145 surrounding water wells from the AENV database and CBM wells in the area.

The Alberta Research Council's overall conclusion of the evidence from the review of the AENV and AEUB files, along with a new review and evaluation of additional data and concepts, is that energy development projects in the area most likely have not adversely affected Ms. Ernst's private water supply well.

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1 INTRODUCTION

The Alberta Research Council (ARC) was contracted by Alberta Environment (AENV) to conduct a review of the technical and scientific data on the subject of a complaint placed by landowner Ms. Jessica Ernst, located SE-13-027-22 W4M, near Rosebud, Alberta. The complaint was about Coal Bed Methane (CBM) activities undertaken by EnCana Corporation and her concerns about the presence of methane gas in her water well and an associated or simultaneous decrease in water quality. Historically, methane has been observed in water wells in the Rosebud area. This is an expected occurrence because most water wells in the area are completed in coal. The complainant suggests that CBM activities in the area have increased the amount of methane in her well. ARC undertook this review to assess whether the evidence suggests that energy resource extraction operations have impacted the water quality on the landowner's property through the migration of methane from the CBM well to the water wells. ARC agreed to work under contract to Alberta Environment (AENV) to independently assess the situation and provide conclusions identifying whether or not the AENV investigation suggests groundwater has been impacted by CBM or conventional oil/gas extraction activities in the area.

This report summarizes ARC's independent conclusions based on scientific and technical data surrounding the investigation of the complaint. The review is based primarily on the collected information in AENV's water well complaint file. Available scientific and technical data include groundwater quality data, water well construction characteristics, oil and gas extraction and production activities, and local groundwater gas characteristics. In addition, ARC endeavoured to compile, review and assess supplementary information not included within the complaint file. This supplementary information includes results of an evaluation of CBM Baseline water well testing data in the general area (provided by AENV and Komex), digital elevation maps and a geological cross section of the area constructed by ARC.

2 REGIONAL GEOLOGIC AND HYDROGEOLOGIC SETTING

2.1 Stratigraphy

The study area is found within the Alberta Basin. A complete review of the geology of the basin is provided in Mossop and Shetsen (1994). A brief overview is given below. The Alberta basin originated in the late Proterozoic by rifting of the North American craton Early sedimentary deposition was dominated by carbonates, evaporates and shale. Uplift of the Rocky Mountains in the early Cretaceous deposited fluvial sandstone and shale into the developing foreland basin. Sea level rises and falls during the middle to late Cretaceous resulted in deposition of marine shale and coal-bearing fluvial sandstone. Peat accumulation provided the source material for the major coal-bearing strata including the Manville, Belly River and Edmonton (including the Horseshoe Canyon Formation) groups. The latter two formations are where the EnCana CBM wells are completed. A period of compression and uplift in the Tertiary led to the deposition of fluvial sandstone, siltstone and shale. Peat accumulation provided the source material for the coals in the Cretaceous/Tertiary Scollard Formation and the Tertiary Paskapoo

Formation. Glaciation during the Quaternary eroded the bedrock and deposited unconsolidated sediments on the bedrock. A description of the geology encountered in the area of investigation is as follows:

Belly River Group
The deepest formation penetrated by the EnCana CBM wells is the Belly River Group. The upper part (Oldman Formation) of the Belly River Group consists of sandstones, siltstones and coal (Lethbridge) deposited in a floodplain and lacustrian environment (Beaton et al. 2002).

Bearpaw Formation
A marine transgression deposited fine-grained marine sediments of the Bearpaw Formation directly onto the Belly River Group. These sediments are predominantly shale and siltstone, with some sandstone beds and claystone (Macdonald et al. 1987).

Edmonton Group
The Edmonton group is comprised of four formations, from oldest to youngest: the Horseshoe Canyon Formation, the Whitemud Formation, The Battle Formation and the Scollard Formation. Onlt the Horsehoe Canyon is present in the study area. The Horseshow Canyon formation consists of shale, siltstone and coal (Basal, Rockyford, Drumheller, and Weaver), deposited in deltaic and fluvial environments (Beaton et al 2002). In the area, the Horseshoe Canyon Formation is covered by Late Tertiary–Quaternary unconsolidated sediments or till.

2.2 Regional Stress Regime

The stress regime of upper Cretaceous – Tertiary coal-bearing strata in Alberta has a strong correlation to permeability and fracture directions in coal (face cleats). This in turn has a strong control on the direction that "fluids" (both gas and water) tend to migrate in these strata. Rock mechanics theory and field measurements shows that fractures trend in a direction normal to the least compressive stress. Horizontal stress orientations in Alberta have been measured using well breakout analyses (i.e. damage to boreholes caused by stresses acting on the rock) (Bachu and Michael 2002). Based on breakout analysis the most likely azimuth (orientation) of fractures and face cleats in the coal would be about 55°. No energy wells within a 2 km radius line up on a 055° azimuth to the Ernst well. This suggests that based on the likely fracture orientation, there is a low potential for any fluid (water or gas) leaking from an energy well to migrate towards the Ernst well. One well (00/14-12-027-22 W4M) is located approximately 800 m on a 70° azimuth. This well however is conventional gas. This well, and others, were investigated in section 3 of this report.

2.3 Hydrostratigraphy and Groundwater Flow and Gradients

Regional flow systems across the Alberta Basin are controlled in part by major recharge areas along the Rocky Mountain front in western Alberta. Flow within the basin is directed northeast along lithological boundaries towards the basin edge (Hitcheon 1969a,b). Bachu (1999) recognised that flow in the northern part of the basin was driven by topography northeastward, however, flow in Upper Cretaceous rocks in the southwestern part of the basin (including the study area) was directed southwestward, driven by erosional rebound due to stripping of up to 3800m of sediments (Parks, and Tóth 1995; Bachu 1999). Regionally, the Horseshoe Canyon Formation acts as an aquifer above the Bearpaw Formation aquitard. Below this the upper Belly River Formation acts as an aquifer.

In the Rosebud shallow groundwater system, flow within the overburden is directed towards the Rosebud River to the south and southeast. Regional groundwater flow in the Upper Horseshoe Canyon aquifer (Carbon Thompson and Weaver coals where most domestic wells including the Ernst well are completed) is directed to the northeast (Bachu and Michael 2002). Hydraulic conductivities of the rock are expected to be low to intermediate and yields from wells in this area are expected to be 1 to 5 imperial gallons per minute (Borneuf 1972). The Ernst well was tested at 2.7 imperial gallons per minute and had an estimated hydraulic conductivity of 10^{-6} m/s as estimated by ARC from the available pumping test data.

In the deeper (below 200 m) Horseshoe Canyon Formation groundwater flow is also directed to the northeast. Permeability data for the coal zones are not well reported in the literature. However, it is expected that permeability of the coal decreases with depth of burial. Unpublished data referred to by Bachu and Michael (2002) indicates permeabilities for deep coals on the order of a few mD which indicates very low primary permeability. Completion data from the EnCana wells in the area suggest that the coals (with the exception of the upper Carbon Thompson and Weaver members of the Horseshoe Canyon) are not water saturated based on CBM well completion data in the area.

Regionally groundwater flow in the Belly River aquifer is directed to the southwest due to erosional uplift (Parks and Tóth 1995; Bachu 1999). Coal permeability is expected to be on the order of a few mD, similar to that in the overlying Horseshoe Canyon coals. Completion data from the EnCana wells in the area show that the coals are not water saturated. The implication of this is that hydrocarbon gases are not expected to be transported from the deep (gas saturated) coals to the shallow (water saturated) coals in a dissolved state.

Large downward vertical gradients between the upper Horseshoe Canyon aquifer (where the Ernst well is completed) and the deeper Horseshoe Canyon coals (Drumheller and below) are expected and were calculated (Section 4.4.2). The Horseshoe Canyon and Belly River coal zones are underpressured (or lower) with respect to predicted hydraulic gradients based on elevation differences. These lower pressures have been interpreted to be due to erosional rebound caused by stripping of up to 3800m of sediments (Parks. and Tóth, 1995; Bachu 1999).

3 ENERGY WELL INFORMATION

A map of the energy wells in the vicinity of the Ernst well is shown on Figure 1. A list of gas well information (including the drilling date, loss of circulation, surface casing depth, total depth, cement returns and perforations) was supplied to AENV by EnCana (Appendix A). All wells in the vicinity had no reported loss of circulation during the drilling and all had adequate cement returns to the surface during cementing of the surface and/or production casing. The closest CBM well to the Ernst well was 00/07-13-27-22W4M. This well was completed in the Basal Belly River Formation with perforations from 648 to 654 mKb (metres from the Kelly bushing (usually 3 to 4 metres above ground surface)). AEUB records from the Petroleum Registry show that since November 2006 this well produces up to 2.3 m^3 of water per month. This is a relatively small amount of water that is likely coming from the Basal coal member of the Belly River formation and water from condensation.

A review of the tour reports by Brenda Austin of the AEUB (Table 1) indicated no unusual conditions were encountered during the drilling and completion of the energy wells adjacent to the Ernst well. All depths on the table are in mKb. No wellbore issues that would indicate gas migration to aquifers are evident. Compositional and/or isotopic data was available for some of the wells in the vicinity of the Ernst well. This data will be discussed in section 4 of this report.

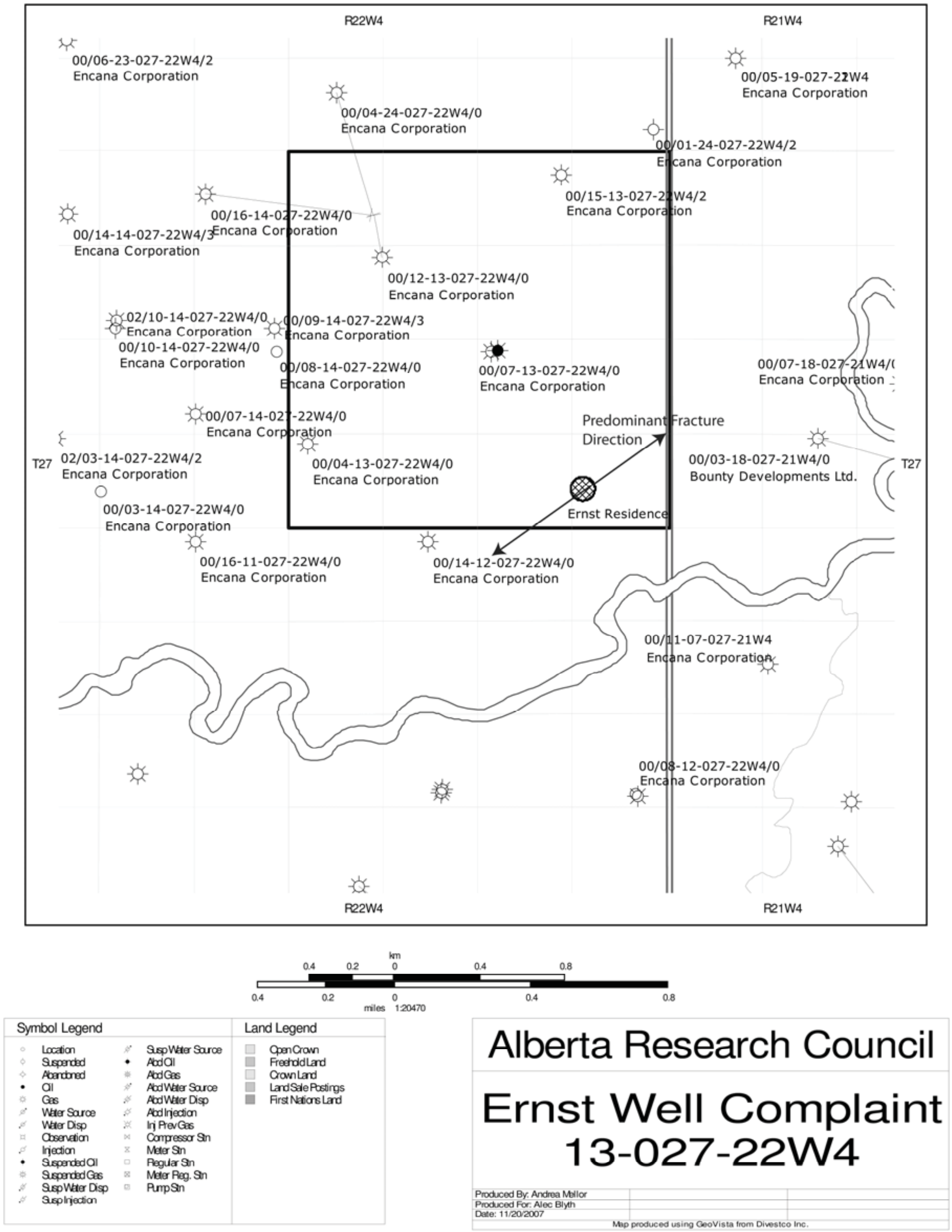

Figure 1 Energy well in the vicinity of the Ernst water well.

Table 1 AEUB review of wells near the Ernst residence.

Well Location	Spud date/FDD/On Prod	Surface Casing. (mKb)	Total Depth (mKb)	Perforation Depths (mKb) and Dates	Fracture Depths (mKb) and Dates	Comments
00/07-13-027-22W4	26 Jul 98 27 Jul 98 26 Jun 2000	38.0	746.0	648.0 – 654.0 5 Sep 98	648.0 – 654.0 9 Sep 98	No lost circulation reported Cement returns on surface and production casing. No wellbore issues evident.
02/07-13-027-22W4	18 May 02 23 May 02 7 Jun 02	198.0	1482.0	1438.0 – 1442.5 5 Jun 02 1206.0 – 1208.0 14 Oct 02	No frac on lower zone 1206.0 – 1208.0 26 Oct 02	Lower zone abandoned w/ Bridge plug capped w/ cement @ 1423 – 1433 on 14 Oct 02. No lost circulation reported Cement returns on surface and production casing. No wellbore issues evident.
00/14-12-027-22W4	27 Jun 03 28 Jun 03 28 Jan 07	159.0	1456.0	1426.5 – 1428.0 1 Aug 03 1426.0 – 1428.5 21 Sep 03 1205.5 – 1207.0 12 Nov 03	1426.0 – 1428.5 6 Oct 03 1205.5 – 1207.0 7 Dec 03	No lost circulation reported. Good cement returns on prod. csg. Trace returns on surface casing and evidence of top down cementing. Follow up with EnCana occurring. No wellbore issues that would gas migration to aquifers evident.

4 ERNST WATER WELL INFORMATION

4.1 Initiation of Well Complaint

The water well complaint by Ms. Ernst was originally made in public, to the media and to Members of the Alberta Legislative Assembly via written documents. In early 2006 AENV staff contacted Ms. Ernst to investigate the complaint and undertake sampling.

4.2 Well Design, Construction and Maintenance

The water well drilling report for the Ernst Water Well, available through the AENV Groundwater Information Centre (GIC) (Well ID # 0123548), is included in Appendix B. The well was constructed (date unknown) for the landowner at the time (F.L. Feckley). There is no lithology, well construction details or pumping test data. The only drilling information available is the location and the total depth of the well. There is also a 1986 chemistry report. This is a drilled well with the most likely construction technique being a hole drilled to competent bedrock with a steel casing inserted and seated into the bedrock. It is unknown what sealed the annulus between the borehole and the casing but it may only be drill cuttings and/or bentonite that were placed down the annulus. This method of sealing is not preferred, as there is no way to ensure a proper seal the entire length of the annulus. As well, the water saturated, fine grained material likely encountered in the borehole could have lead to bentonite bridging (sticking caused by water swelling the bentonite) at that point. If the well has indeed been constructed in this manner, this does present concerns about the adequacy of the seal to protect against contamination of water from ground surface entering the well. A water analyses (June 20, 2003) did indicate coliform bacteria were present and this could indicate a poor seal in the upper part of the well. After reaching competent bedrock, the hole would then be drilled further to the total depth of the well which is approximately 58 m. It is unknown if a liner was installed in the well to prevent loose material from the borehole wall entering the well. Although there is no reporting of any screened interval, based on the reported depth of the Ernst well and using lithology from nearby wells, it is likely that this is a multi-aquifer well completion.

Notes in the AENV complaint file indicate that the well did not have regular shock chlorination. Bacterial analysis (June 2007) indicate that iron related bacteria (IRB) and sulphur reducing bacteria (SRB) are present in the well water, suggesting that this is the case. Coliform bacteria have been detected in the well (June 20, 2003) which, as indicated above, may be a result of a poor seal.

4.3 Stratigraphy

No lithology records exist for the Ernst well. A good quality drilling report is available for a well drilled in the same quarter section (SE-13-027-22 W4M) for the County of Wheatland (Well ID # 0123549) (included in Appendix B). Two new AENV groundwater observation well network (GOWN) wells (installed in March 2007) are approximately 1.5 km to the east and provide detailed lithology information.

A geologic cross section through the Ernst well was constructed using lithology information from the Wheatland County well, a GOWN well and geophysical logs from the EnCana CBM well 00/07-13-027-22 W4M (Figure 2). The contour interval on this map is 2 m and the colour shading visually denotes elevation.

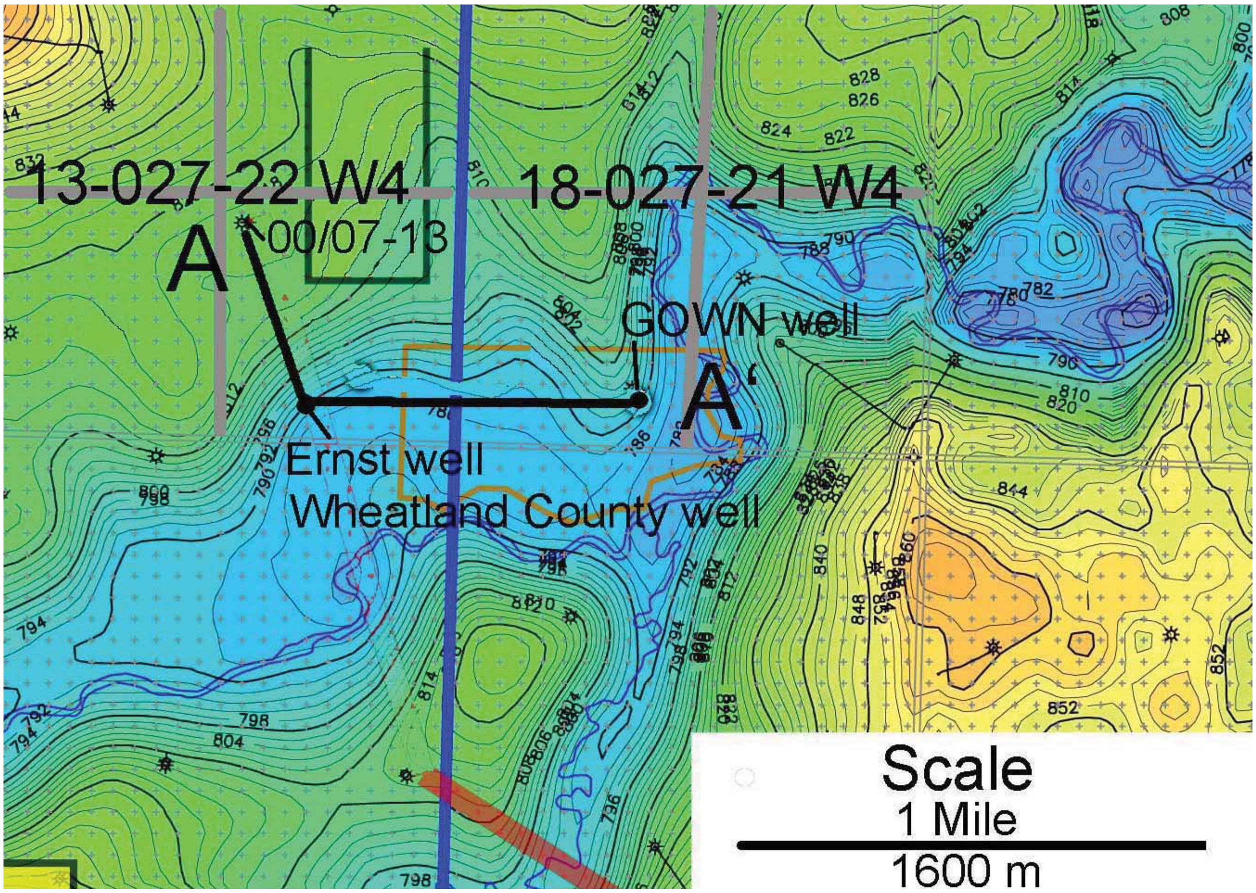

Figure 2 Map showing location of cross-section. DEM image supplied by EnCana.

The cross-section (Figure 3) illustrates that the Ernst well is completed in coal zones of the Upper Horseshoe Canyon Formation. Groundwater bearing zones are likely the two coal zones at a depth of about 30 m (760 MASL) and 55m (735 MASL). The EnCana 07-13-027-22W4M CBM well, located 650 m to the north of the Ernst well, has production casing perforations starting at 169.5 MASL which indicates a large vertical separation (563 m) from the Ernst well. A saturated sand and gravely sand layer was encountered in the Wheatland County well and in the GOWN well at a depth of about 2 to 5 m. This gravely sand layer is a potential impediment of any bentonite materials poured into a well annulus to achieve an adequate upper seal.

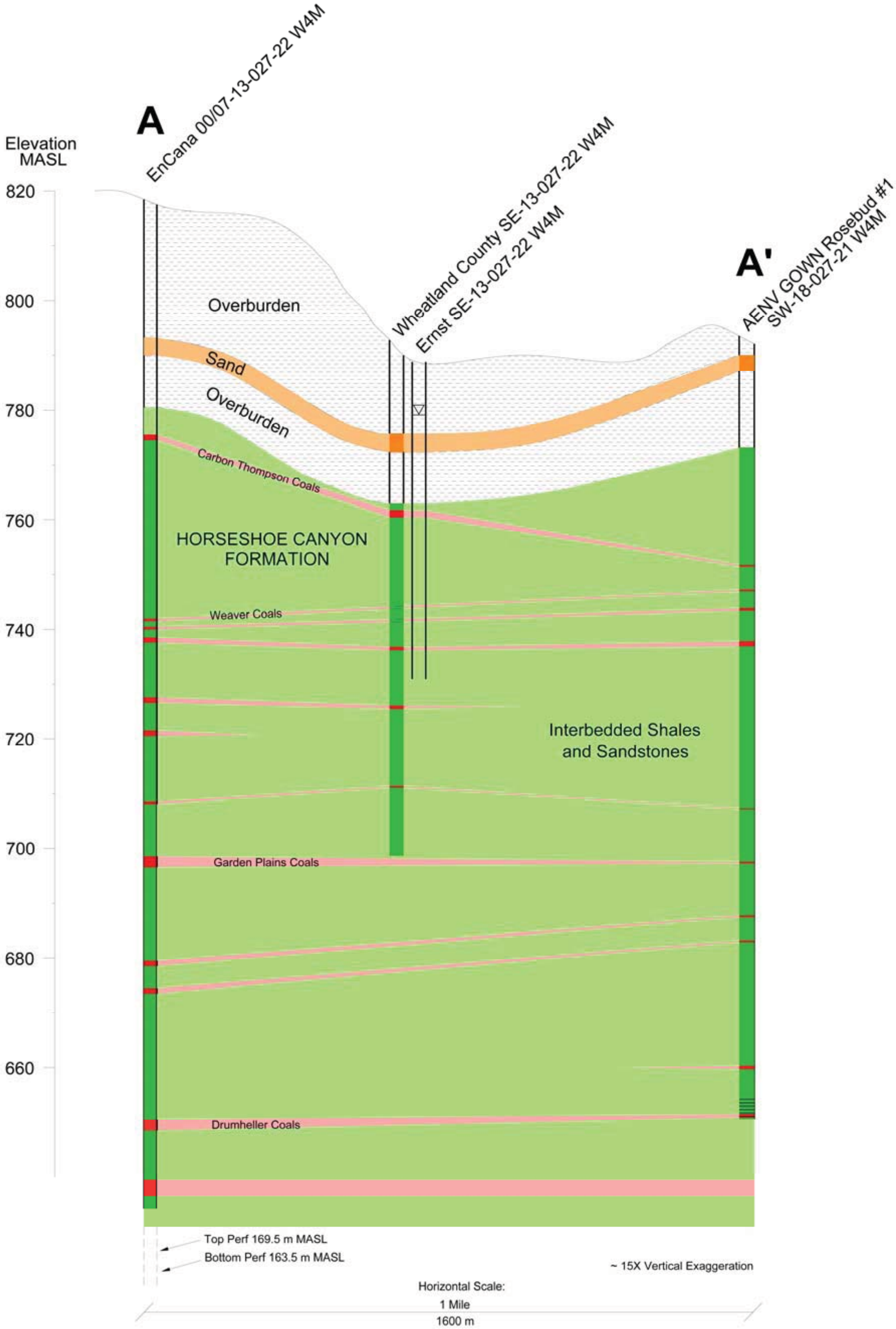

Figure 3 Geologic cross-section.

4.4 Hydrogeology

4.4.1 General Groundwater flow directions

Local and very shallow groundwater flow may be controlled by the unconfined sand and sandy gravel layer encountered at a depth of 2 to 5 m in several nearby water wells. More regionally, the shallow flow is likely controlled by topography and flow directions are likely from the Ernst well site to the Rosebud river to the south (Borneuf 1972). In the Ernst well, the deeper confined groundwater flow within the upper Horseshoe Canyon bedrock is part of the regional groundwater flow system flow directed to the northeast (Bachu and Michael 2002).

4.4.2 Vertical Hydraulic Gradient

An estimation was made of the vertical hydraulic gradient between the coal zones of the Ernst well and that of nearest EnCana CBM wells with pressure data using the following:

Depth of coal zone in Ernst well = 738 MASL.
Depth of upper coal zone in EnCana CBM well 00/06-24-027-22W4M = 655 MASL.
The head of water in the Ernst well = 780 MASL.
A shut-in pressure of 436.3 KPa was measured in the EnCana CBM well 00/06-24-027-22W4M (equivalent to 44.57 m of water). Therefore the equivalent head of water in the CBM well =699.6 MASL assuming density of 1000 kg/m^3 (fresh water).

The vertical gradient is estimated from = $\Delta h/\Delta l$ = (780-699.6)/(738-655) = 1.0. This suggests a large downward vertical gradient. If these coal zones become connected, groundwater would flow down into the CBM well. The rate of flow however, is going to be controlled by the hydraulic conductivity of the flow path. For example, if a fracture connects a CBM well to an overlying aquifer, the amount of groundwater produced could be significant, as determined by the fracture aperture.

4.4.3 Hydraulic Conductivity

One 114 minute pumping test was performed by AENV on the Ernst well on June 6, 2007. No analysis of this data was found in the AENV file. The aquifer test data was analysed by ARC for this report using AQTESOLV, Version 3.50 Professional, Aquifer Test Design and Analysis Computer Software (1996-2003 HydroSOLVE Inc.). This software provides analytical solutions for evaluating parameters in confined, unconfined, leaky, or fractured aquifer systems, and allows evaluation of the aquifer test data by visual curve matching to select the most appropriate interpretation to represent aquifer conditions at the site.

The Theis (1935) and the Cooper-Jacob (1946) confined aquifer solutions were used to solve the drawdown portion of the pumping test. An average apparent transmissivity of 3.8E-4 m^2/min (0.55 m^2/day) was calculated. This value suggests that the aquifer has low to moderate transmissivity. Graphical solutions are included in Appendix C. No storativity value can be determined because it is not possible to calculate from water level measurements taken in a well that is being pumped. To calculate a storativity, water level measurements must be made in a non-pumping well in a well located a short distance from the pumping well. A storativity value of 0.005 can be estimated for this bedrock aquifer based on values reported in the literature (Freeze and Cherry 1979).

4.4.4 Water levels and methane saturation

From water level records of the Ernst water well, there is a 1.24 m drop in the static water level in the Ernst well from June 20, 2003 (M&M Drilling Co, Ltd.) to June 6, 2007 (AENV), which corresponds to a drop in pressure of about 0.12 Atm (1.8 PSI) in the aquifer. This drop in pressure is expected to have effectively decreased the solubility of methane in the water and caused an increase in the amount of methane coming out of the water. This is similar to the case where pressure is decreased in a carbonated drink (by opening the top) and CO_2 bubbles out of solution. An estimation of the concentration of methane in water (in the Ernst Well) at saturation can be done using the head (height) of water above the coal zone and the Henry's Law equilibrium equation:

Head of water above coal zone on June 20, 2003 = 43.34 m or 4.19 Atm

Head of water above coal zone on June 6, 2007 = 42.09 m or 4.07 Atm

Henry's constant for methane = 1.4×10^{-3} Moles/Atm (at 298.15 °K)

A temperature correction needs to be done to the Henry's constant to account for the observed temperature of 281.55 °K (8.4 °C) in the Ernst well:

Henry's constant for methane in water at 8.4 °C = 1.02×10^{-3} Moles/Atm

Therefore, based on this equation, the concentration of methane in water is calculated to be 4.27×10^{-3} Moles/kg of water at saturation in July 2003 and 4.15×10^{-3} Moles/kg of water at saturation in July 2007.

This could explain an increase in the amount of methane coming out of the water. However, it does not explain the source of the methane.

4.4.5 Potential for Methane Gas Migration

In order to estimate methane gas migration potential from an active CBM site to an overlying water supply aquifer, an assessment of the forces controlling the methane gas bubble migration is helpful. If an aquifer overlying a CBM zone was connected to the CBM zone through and induced fracture (from well stimulation) methane bubbles would tend to rise in the fracture due to buoyancy forces. Groundwater flow downward in the fracture would tend to counteract the buoyancy force and prevent the bubble from rising. Appendix D provides a discussion on how those forces are determined and presents simplified calculations (personal communication with Dr. J, Jones, PhD., University of Waterloo) that determine what kinds of flow conditions prevent methane gas bubble migration into an overlying water supply.

An example of the application of this approach for the case of an induced fracture connecting a CMB zone with an overlying aquifer (e.g. either in the geological medium or in a casing annulus) provides some estimates of groundwater flow in the fractures (under the observed gradients at the site) were compared to the terminal velocity (maximum velocity the bubble can reach given the density and viscosity of the fluids involved) of methane bubbles. For a 100 μm fracture, the flow velocity in the aperture would stop a methane bubble of 245 μm or less from rising into an overlying aquifer. In coal fracturing operation the intended fracture apertures are in the order of 1000 μm (1 mm) (personal communication with Paul Smolarchuk, Canadian Spirit Energy). The groundwater flow velocity in a 1 mm fracture would stop a bubble of 2.5 mm or less from rising. This kind of assessment suggests that if an induced connection existed between the CBM well and the Ernst water well, methane bubbles would not tend to rise in a fracture because of the downward groundwater flow based on the hydraulic gradient estimated for the local area.

4.5 Water and Gas Chemistry

In this section ARC compiles, reviews and assesses water and gas chemistry data from the AENV and AEUB files (Ernst well complaint file and energy well data) and additional data from D35 water well testing in the area (collected under AEUB Directive 35). Data from D35 testing was provided by AENV and from EnCana's consultant (Komex). The chemistry from one hundred and forty five (145) water well tests from a radius of approximately 10 km from the Ernst well have become available from the new AENV database and are compared here with the Ernst water well and the CBM wells. Of these new well results, 41 have free gas analyses and/or isotope geochemistry. An analysis of this new chemistry data is organized into major ion chemistry, gas chemistry and isotope geochemistry.

4.5.1 Historical Major Ion and Bacteria Chemistry Prior to Complaint

Two historical water quality analyses are available for the Ernst water well prior to the initiation of the complaint (Table 2). Copies of the analyses are included in Appendix E. The May 2, 1986 and June 20, 2003 samples (analyzed by ARC Vegreville and WSH Labs, respectively) have routine potability analyses with ion balances within 3%. This is an acceptable lab QA/QC. It is not possible for ARC to comment on the field QA/QC as this type of information was not available. Both analyses show the Ernst well exceeds the aesthetic objectives (set by the Summary Guidelines for Canadian Drinking Water Quality set by Health Canada 2007) for total dissolved solids (TDS) and sodium. Sodium levels in the well (about 450 mg/L) exceed the 200 mg/L guideline and may be a concern for people on sodium reduced diets. In addition, the aesthetic objectives for iron and manganese are exceeded in the June 20, 2003 analysis. The maximum acceptable concentration for fluoride is exceeded in both analyses. The maximum acceptable concentration of total coliforms was exceeded in the June 20, 2003 analysis, with concentrations too numerous to count (TNTC). More recent sampling of this well (June 2007) showed no coliform bacteria.

4.5.2 Major Ions, Metals and Bacterial Chemistry

In addition to the historic water analysis from the Ernst well, several new water analyses were performed (Table 2). These routine potability analyses have a ion balances of 3% which is an acceptable value. The analyses show the Ernst well exceeds the aesthetic objectives for total dissolved solids (TDS), sodium and chloride. No parameters with health criteria (i.e. with maximum acceptable concentrations) have been exceeded. Copies of the analyses are included in Appendix E.

The major ion chemistry of the D35 water wells, the Ernst well and the GOWN wells is presented on Figure 4. There is a strong positive correlation of specific water types in the area, namely sodium-bicarbonate ($Na\text{-}HCO_3$) and sodium-bicarbonate-chloride ($Na\text{-}HCO_3\text{-}Cl$) type waters, with the presence of methane in the water (shown in Figure 4). The Ernst water well falls into this group. It is reported that in the reducing conditions, found where methane occurs in coalbed zones, it is expected that biochemical reduction of dissolved sulphate occurs, causing precipitation of sulphides, resulting in depleted dissolved sulphate content. Bicarbonate, on the other hand, tends to be enriched as a result of carbonate dissolution by oxygenated recharge water and by sulphate reduction methane production (fermentation). Calcium and magnesium tend to be depleted by inorganic precipitation of calcite due to reduced solubility in the presence of elevated bicarbonate (Van Voast 2003).

The major ion chemistry is presented on Schoeller plots (Figure 5 and 6). Most of the wells with methane have depleted calcium, magnesium and sulphate. Again, these wells show the water wells with methane tends to have sodium-bicarbonate (Na-HCO3) or sodium-bicarbonate-chloride (Na-HCO3-Cl) type waters. The Ernst water well falls into this group.

Table 2 Chemical Analyses for the Ernst Water Well

Parameter	Units	Ernst Well	Ernst Well	Ernst Well	Ernst Well	Ernst Well	Ernst Well	Ernst Well	Ernst Well	GCDWQ Recommended Limit	
Date	dd/mm/yyyy (hh:mm)	02/05/1986	20/06/2003	03/03/2006 10:00	03/03/2006 11:00	03/03/2006 12:30	06/06/2007	06/06/2007	06/06/2007	AO	MAC
Laboratory		ARC Veg	WSH Labs	ASL	ASL	ASL	ASL	ARC Veg	U of C		
pH	(units)	8.3	8.4	8.2	8.3	8.2	8.6	---	---	6.5 - 8.5	---
EC	(µS/cm)	1880	1480	1920	2050	1940	1860	---	---	---	---
TDS-calculated	(mg/L)	**1102**	**1044**	**1020**	**1150**	**1100**	**1080**	---	---	500	---
Total Alk. as CaCO3	(mg/L)	692	664	644	652	682	691	---	---	---	---
Sodium	(mg/L)	**465**	**439**	**423**	**479**	**450**	**443**	---	---	200	---
Potassium	(mg/L)	1	<0.5	1	1.1	1	0.1	---	---	---	---
Calcium	(mg/L)	4	4.9	4.1	4.9	4.6	1.1	---	---	---	---
Magnesium	(mg/L)	2	0.3	0.4	0.52	0.46	0.1	---	---	---	---
Iron	(mg/L)	0.05	**1.18**	---	---	---	0.075	---	---	0.3	---
Iron (total)	(mg/L)	---	---	0.42	0.505	0.349	0.369	---	---	---	---
Manganese	(mg/L)	---	**0.066**	---	---	---	0.004	---	---	0.05	---
Manganese (total)	(mg/L)	---	---	0.008	0.008	0.007	0.008	---	---	---	---
Chloride	(mg/L)	210	200	199	**300**	**252**	220	---	---	250	---
Fluoride	(mg/L)	**1.57**	**1.7**	0.9	0.8	0.9	---	---	---	---	1.5
Sulphate	(mg/L)	<5	<0.6	<0.5	<0.5	<0.5	<0.5	---	---	500	---
Carbonate	(mg/L)	---	6	<5	<5	<5	16	---	---	---	---
Bicarbonate	(mg/L)	843	795	786	796	832	810	---	---	---	---
NO3 as N	(mg/L)	---	<0.2	0.2	0.28	<0.05	0.08	---	---	---	10
NO2 as N	(mg/L)	<0.05	<0.3	0.2	<0.05	<0.05	<0.05	---	---	---	1
NO2+NO3 as N	(mg/L)	<0.05	<0.2	0.39	0.28	<0.05	0.08	---	---	---	10
Ion Balance %	(%)	103	102	103	93.1	92.1	96.6	---	---	---	---
Bacteria											
Total Coliforms	(cfu/100mL)	---	**TNTC**	---	---	---	---	---	---	---	0
Total Coliforms	(mpn/100mL)	---	---	---	---	---	<1	---	---	---	0
Escherichia Coli	(cfu/100mL)	---	0	---	---	---	---	---	---	---	0
Escherichia Coli	(mpn/100mL)	---	---	---	---	---	<1	---	---	---	0
S Reducing Bacteria	(cfu/100mL)	---	---	present	present	present	200	---	---	---	---
Iron Related Bacteria	(cfu/mL)	---	---	present	present	present	9000	---	---	---	---
Dissolved Hydrocarbons											
Benzene	(mg/L)	---	---	<0.0005	<0.0005	<0.0005	---	<0.0001	---	---	0.005
Toluene	(mg/L)	---	---	<0.0005	<0.0005	<0.0005	---	<0.0001	---	0.024	---
EthylBenzene	(mg/L)	---	---	<0.0005	<0.0005	<0.0005	---	<0.0001	---	0.0024	---
Xylenes	(mg/L)	---	---	<0.0005	<0.0005	<0.0005	---	<0.0001	---	0.3	---
F1(C6-C10)	(mg/L)	---	---	<0.1	<0.1	<0.1	---	<0.01	---	---	---
F2 (C10-C16)	(mg/L)	---	---	<0.05	<0.05	0.12	---	<0.005	---	---	---
F3(C16-C34)	(mg/L)	---	---	---	---	---	---	<0.02	---		
F4(C34-C50)	(mg/L)	---	---	---	---	---	---	<0.02	---		
Dissolved Gas Analysis											
Nitrogen	mg/L, MDL=6	---	---	---	---	---	---	12.30	---	---	---
Carbon Dioxide	mg/L, MDL=1	---	---	---	---	---	---	434.00	---	---	---
Oxygen	mg/L, MDL=6	---	---	---	---	---	---	3.38	---	---	---
Methane	µg/L, MDL=0.01	---	---	14200	11200	12800	---	24300.00	---	---	---
Ethane	µg/L, MDL=0.01	---	---	---	---	---	---	2.21	---	---	---
Propane	µg/L, MDL=0.01	---	---	---	---	---	---	<0.01	---	---	---
n-Butane	µg/L, MDL=0.01	---	---	---	---	---	---	<0.01	---	---	---
i-Butane	µg/L, MDL=0.01	---	---	---	---	---	---	<0.01	---	---	---
δ13C Methane	‰ PDB	---	---	---	---	---	---	---	-66.3		
Free Gas Analysis											
Nitrogen	(ppm), MDL=1000	---	---	---	---	---	---	137000	---	---	---
Carbon Dioxide	(ppm), MDL=300	---	---	---	---	---	---	1240	---	---	---
Oxygen	(ppm), MDL=1000	---	---	---	---	---	---	4330	---	---	---
Methane	(ppm), MDL=0.05	---	---	---	---	---	---	881000.00	---	---	---
Ethane	(ppm), MDL=0.05	---	---	---	---	---	---	26.70	---	---	---
Propane	(ppm), MDL=0.05	---	---	---	---	---	---	<0.05	---	---	---
n-Butane	(ppm), MDL=0.05	---	---	---	---	---	---	<0.05	---	---	---
i-Butane	(ppm), MDL=0.05	---	---	---	---	---	---	<0.05	---	---	---
δ13C CO2	‰ PDB	---	---	---	---	---	---	---	-2.80	---	---
δ13C Methane	‰ PDB	---	---	---	---	---	---	---	-67.40	---	---
δ13C Ethane	‰ PDB	---	---	---	---	---	---	---	nd	---	---
δ13C Propane	‰ PDB	---	---	---	---	---	---	---	nd	---	---
δ13C n-Butane	‰ PDB	---	---	---	---	---	---	---	nd	---	---
δ13C i-Butane	‰ PDB	---	---	---	---	---	---	---	nd	---	---

GCDWQ - Health Canada Guidelines for Canadian Drinking Water Quality (2007)
AO - Aesthetic objective
MAC - Maximum acceptable concentration
TNTC - Too numerous to count
nd - not detected by gas chromatography so not run for isotopes
--- not analyzed
Bold font denotes exceedence of GCDWQ limit

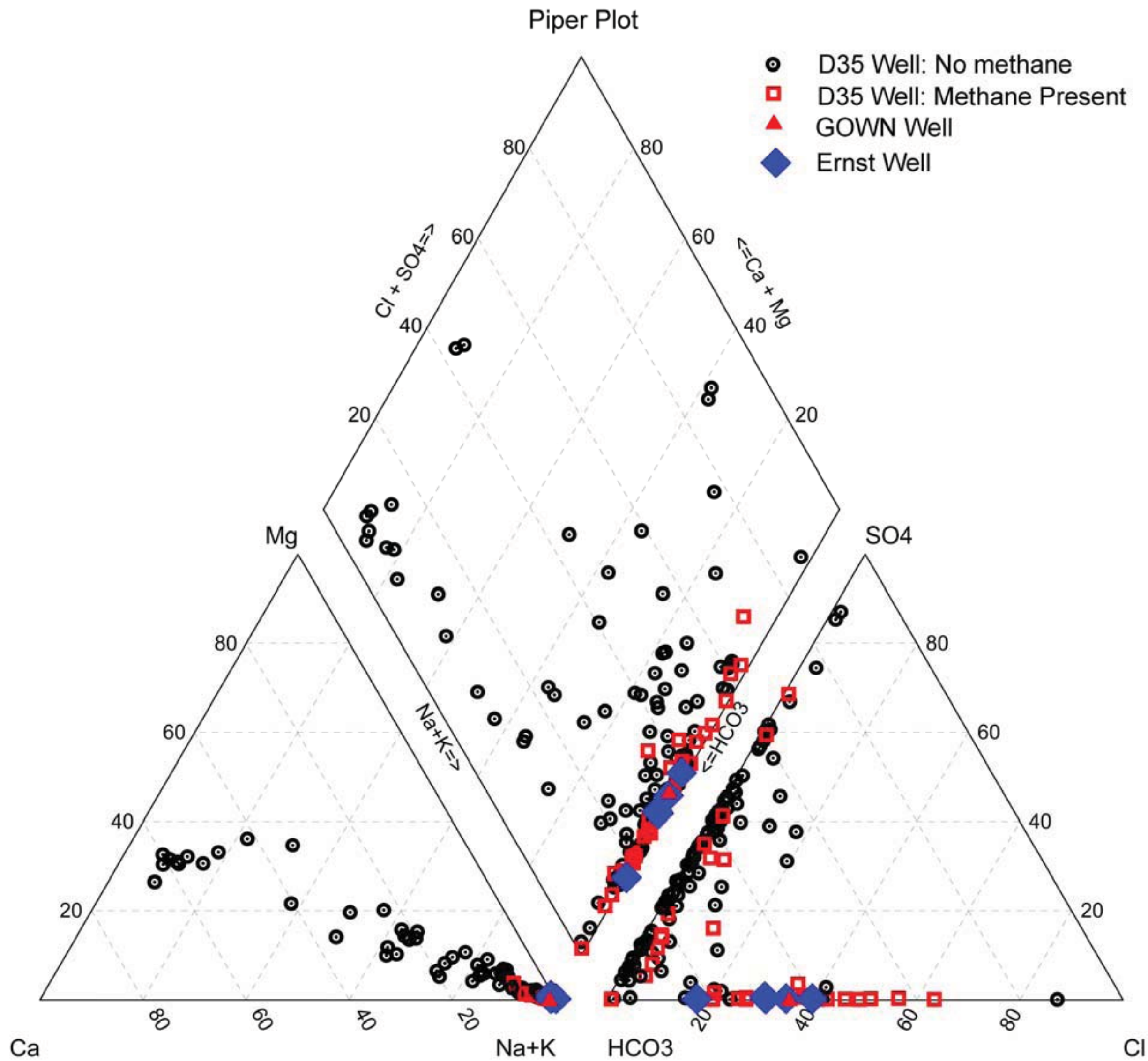

Figure 4. Piper plot of water chemistry from the Ernst well, Surrounding D35 water wells and the GOWN wells.

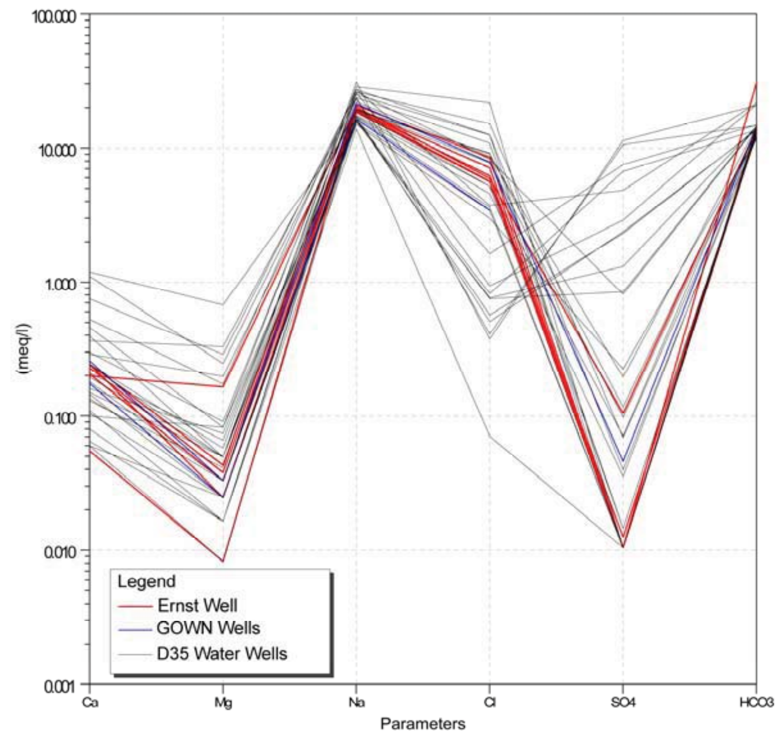

Figure 5 Schoeller plot of water wells with methane present.

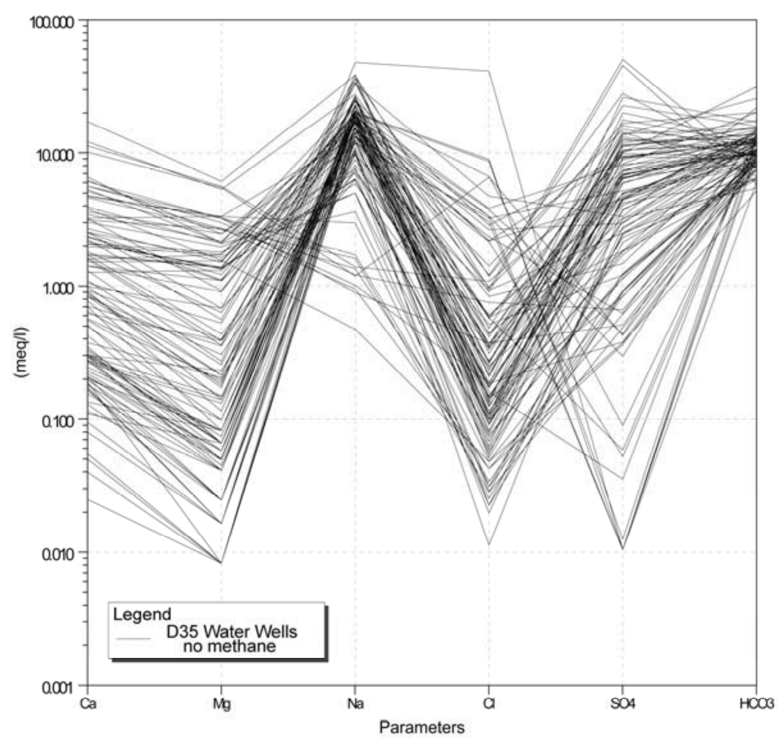

Figure 6 Schoeller plot of water wells with no methane.

4.5.3 Dissolved Organic Chemistry

An analysis for EPA volatile priority pollutants and extractable priority pollutants and CCME hydrocarbons (F1234) are available for the Ernst well (Appendix E). All volatile and extractable organic compounds were below the analytical detection limit with the exception of two compounds not expected to be related to CBM activities. These compounds are 2-Methyl-2-Propanol (2 µg/l), an alcohol used as is used as a solvent, and Bis (2-ethylhexyl) phthalate (3.6 µg/l), a plasticizer used in PVC plastic (Grant Prill, ARC, personal communication). A likely source for latter compound is new plastic tubing used during sampling. All BTEX and F1234 analyses were below detection limit with the exception of F2 (0.12 µg/l) from the March 3, 2006 sample taken at 12:30 pm. No Canadian Drinking Water Guideline limits have been exceeded for EPA priority pollutants or CCME hydrocarbons. One reliable dissolved gas analysis with a high precision (method detection limit = 0.01µg/L) was performed on the Ernst well (Table 2) with methane and a small amount of ethane detected.

4.5.4 Atmospheric Elements and Hydrocarbon Gas Chemistry

One reliable free gas analysis with a high precision (method detection limit = 0.01µg/L) is available for the Ernst well (Table 2). The sample appears to be free from atmospheric contamination (based on low oxygen and nitrogen values). The gas sample contains 881,000 ppm methane and 26.7 ppm ethane. C3 and higher gases were below the detection limit of 0.05 ppm. In addition to the Ernst well, 36 nearby water wells from the D35 database and 3 GOWN wells have gas chemistry. Methane and ethane concentration are similar to those measured in the Ernst well. A more rigorous, statistical approach to gas concentrations and isotopes is presented at the end of this section.

4.5.5 Stable Carbon Isotope Chemistry on Hydrocarbon Gas

Stable carbon isotopes sometimes can be used to help in the identification of the origin of gas in water wells. One carbon isotope analyses on hydrocarbon gas was available for the Ernst well (Table 2). In addition to the Ernst well, 27 nearby water wells from the D35 database and 3 GOWN wells have carbon isotope analyses on hydrocarbon gases and carbon dioxide. Carbon isotope analyses were available for the EnCana CBM wells located in 08-12-027-22 W4M, 03-14-027-22 W4M, 07-13-027-22 W4M, 06-24-027-22 W4M and 14-12-027-22 W4M. Carbon isotope analyses were also available for the EnCana conventional gas wells located in 08-12-027-22 W4M and 14-12-027-22 W4M.

Isotopic results from the Ernst well and the GOWN wells in Rosebud and Redland were performed by the Applied Geochemistry group at the University of Calgary using a gas chromatograph coupled to a Finnigan MAT delta plus XL mass spectrometer (3 kV). This analytical setup requires at least 500 ppm methane, 300 ppm ethane and 200 ppm propane in the injected gas to stay in the linear range of the mass spectrometer (Dr. Bernhard Mayer, personal communication). The reported $\delta^{13}C$ values have a precision of +-0.5 per mil for both free and dissolved gases (He headspace equilibration technique). The analytical techniques for gas isotope results reported for the D35 water wells are not known.

Several of the energy wells tested have questionable quality data. The qualitative QA/QC assessment of the EnCana well data is presented in Table 3. The GC analysis for 02/08-12-027-22 W4M and 00/08-12-027-22 W4M appears to be representative of CBM and conventional gas respectively, but the isotope values of the methane are not. It appears that the samples may have got mixed up and the CBM gas sample was labelled as the conventional gas sample and vice versa. The sample from 00/03-14-027-22 W4M is air contaminated, based on the composition being predominantly nitrogen and oxygen, with hydrocarbons below the detection limit. These analyses were not used in the ARC evaluation.

The new deep GOWN well in Rosebud, completed in the Drumheller coals, is representative of shallow (140 m) CBM in the area. Several of the CBM wells are representative of CBM gas compositions. However, deeper CBM well gas carbon isotopes are not well represented in the area due to the problems noted above. Data from CBM wells from Township 45, Ranges 20 and 21 used to compare the Ernst well carbon isotopes to typical deeper CBM well carbon isotopes.

Table 3 Energy well QA/QC data quality.

Well Name	Type	GC	Isotopes	Data Quality
02/08-12-027-22W4M	CBM	Yes	Yes	Isotope results may be from 00/08-12 (lab error?)
00/03-14-027-22W4M	CBM	Yes	Yes	Air contaminated sample
00/07-13-027-22W4M	CBM	Yes	No	Acceptable
00/06-24-027-22W4M	CBM	Yes	No	Acceptable
00/08-12-027-22W4M	Conv.	Yes	Yes	Isotope results may be from 00/08-12 (lab error?)
00/14-12-027-22W4M	Conv.	Yes	Yes	Acceptable

A histogram of the carbon isotope values of methane from the Ernst water well, the surrounding D35 water wells, CBM wells and conventional gas is presented in Figure 7. The methane values for the Ernst well fall within the general peak for methane values. A statistical analysis of the mean isotopic compositions is presented at the end of this section. From a visual observation of the plot, it is observed that the CBM wells have a less depleted methane isotope signature, while the one conventional gas signature is even less depleted. The D35 wells and Ernst well have methane isotope signatures that fall within the range of -60 to -80, typical of biogenic methane (Schoell 1980; Whiticar et al. 1986; Rice 1993).

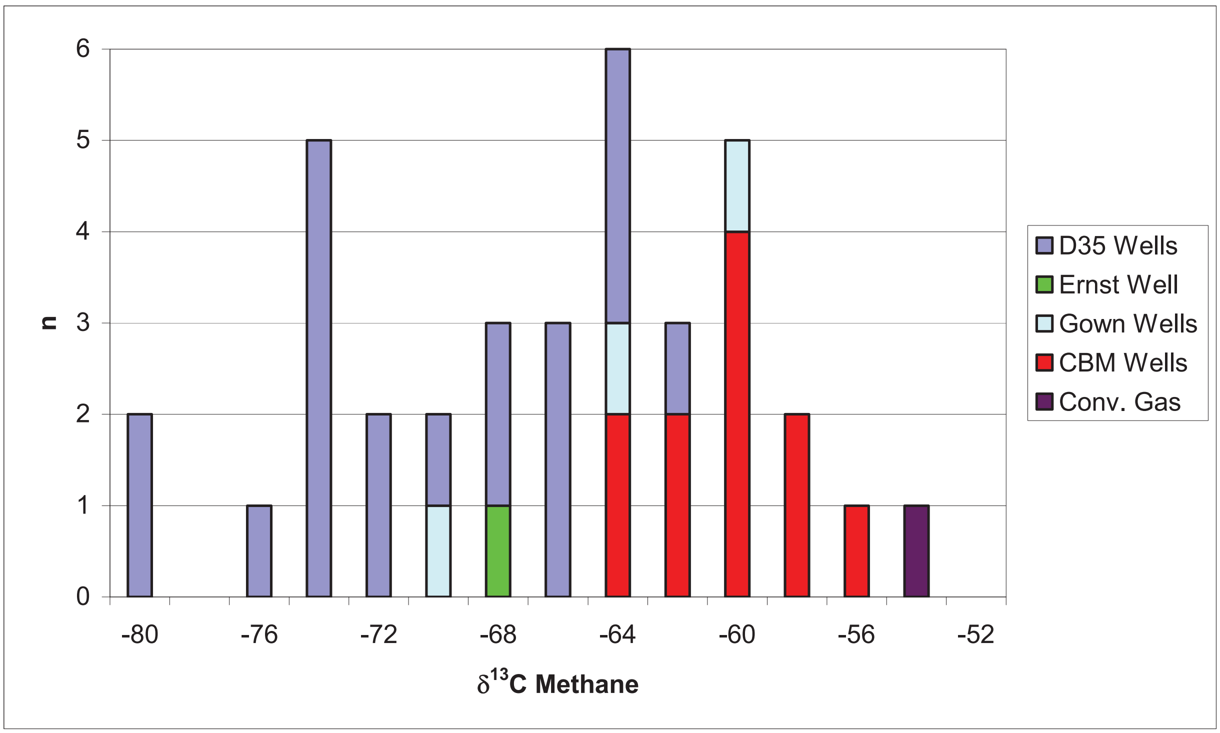

Figure 7 Histogram of the carbon isotope values of methane in all water wells and CBM wells.

A histogram of the carbon isotope values of ethane from the D35 water wells, the GOWN well, CBM wells and conventional gas is presented in Figure 8. The Ernst well and two of the GOWN wells do not contain enough ethane to get a meaningful ethane carbon isotope signature (i.e. below the method detection limit) therefore they do not appear on the diagram. The CBM wells have ethane isotope signatures that fall within the general range for the surrounding D35 water wells. The conventional gas well (Viking Formation) has a much less depleted ethane isotope signature.

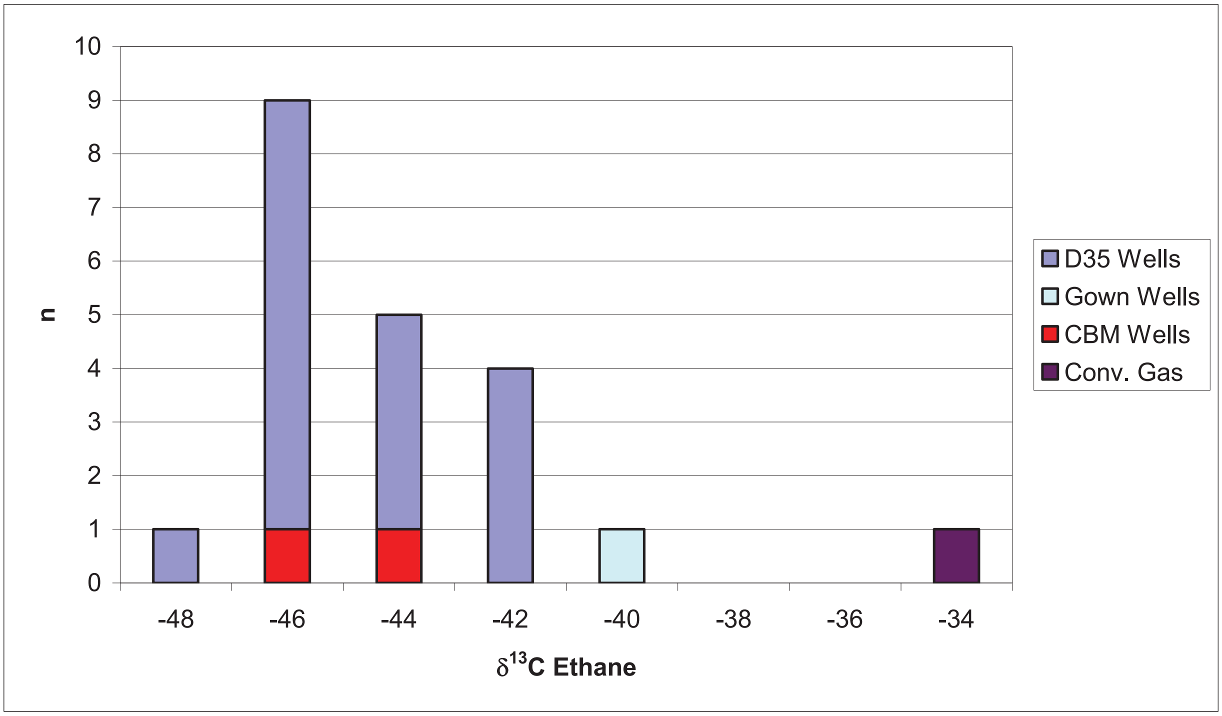

Figure 8. Histogram of the carbon isotope values of ethane in all water wells and CBM wells.

A plot of the methane concentration versus the methane carbon isotope signature ($\delta^{13}C_{Methane}$) is presented on Figure 9. Below the line at -60 ‰ typically represents a biogenic (bacterial) origin for methane (Schoell 1980 and 1983; Whiticar et al 1986; Rice 1993). The CBM well has a $\delta^{13}C_{Methane}$ value that is less enriched than the typical range of -60 to -80 ‰, typical of biogenic methane. This value represents a mixed thermogenic and biogenic origin. The water well data, including the Ernst well, all have $\delta^{13}C_{Methane}$ values that are clearly biogenic.

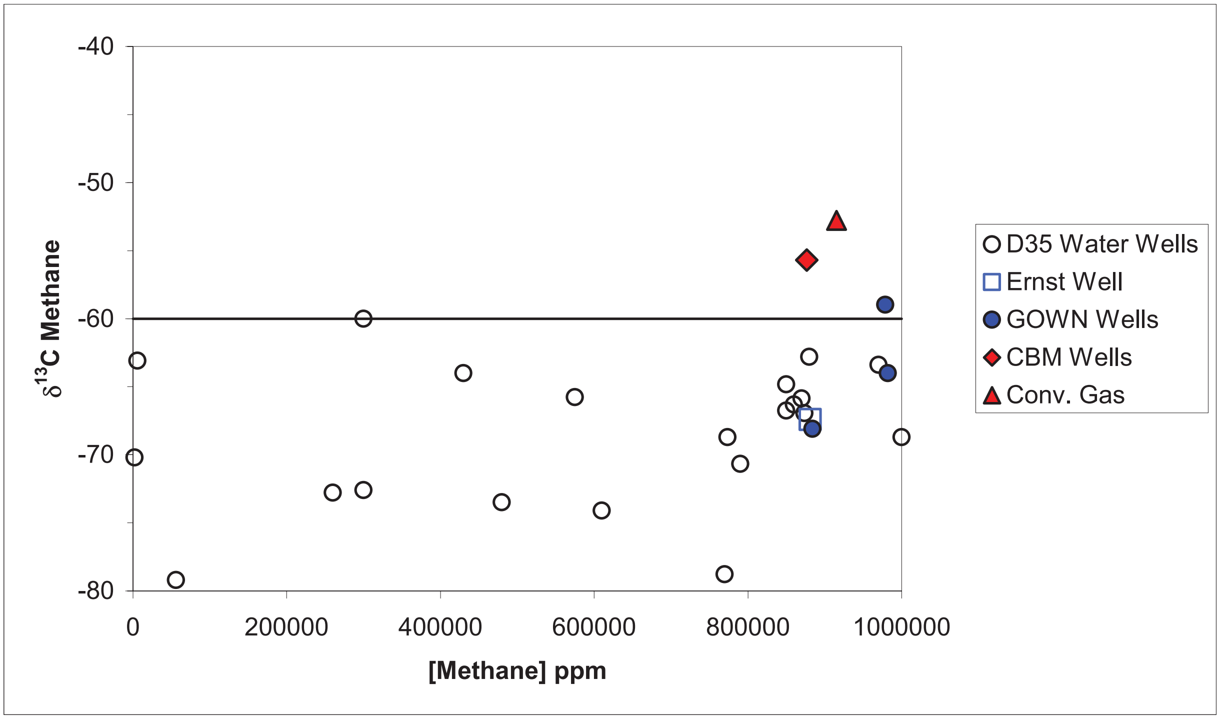

Figure 9. Methane concentration versus $\delta^{13}C$ of methane.

A plot of the ethane concentration versus the ethane carbon isotope signature ($\delta^{13}C_{Ethane}$) is presented on Figure 10. Most of the water wells have ethane concentrations below the lab detection limit (as high as 100 ppm for some analyses). The Ernst well has 26.6 ppm ethane, below the method detection limit to run carbon isotopic analysis of ethane and therefore does not appear on the plot. Of the D35 wells with detectable ethane, concentrations are several times less than that observed in the CBM wells or the deep GOWN well in Rosebud. The $\delta^{13}C_{Ethane}$ values of the water wells are within the range of $\delta^{13}C_{Ethane}$ values observed in the CBM well and the GOWN well. The ethane concentration and isotopic signature of ethane from the conventional gas well is markedly different from the water wells and the CBM wells. A more rigorous statistical approach to mean isotope values is presented at the end of this section.

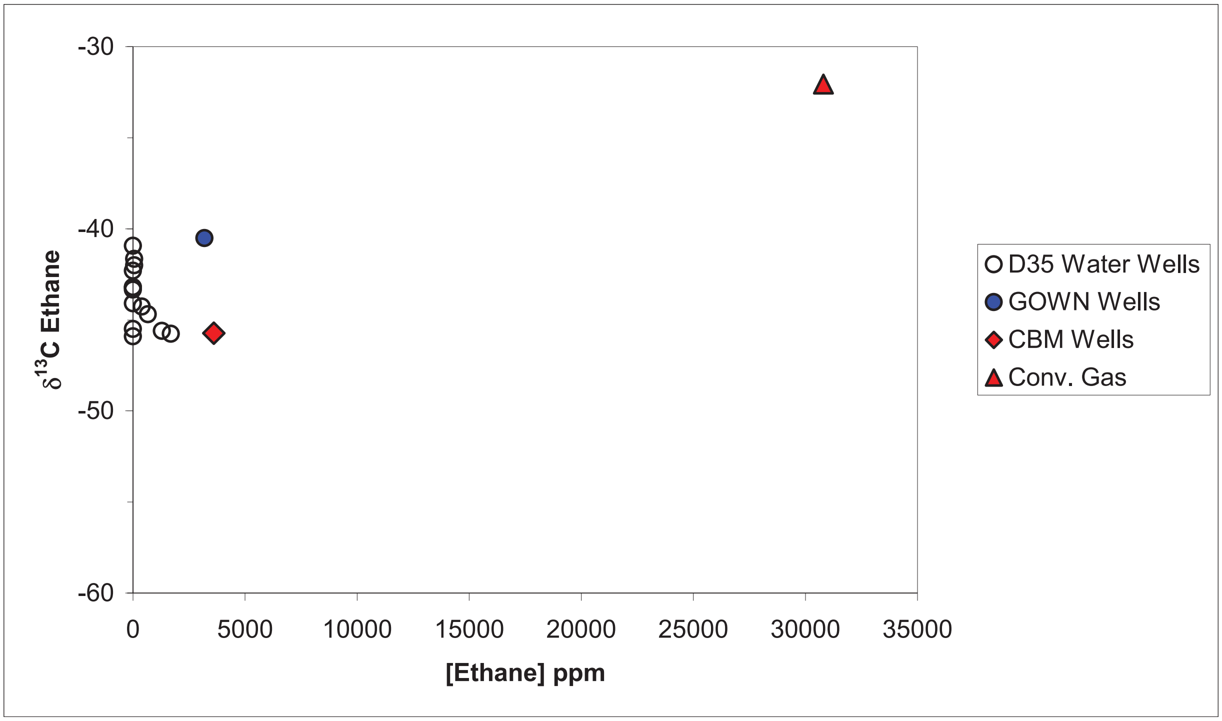

Figure 10. Ethane concentration versus $\delta^{13}C$ of ethane.

A plot of the methane carbon isotope signature ($\delta^{13}C_{Methane}$) versus the ethane carbon isotope signature ($\delta^{13}C_{Ethane}$) is presented on Figure 11. The Ernst well does not appear on this plot because ethane isotopes were below the method detection limit. The $\delta^{13}C_{Methane}$ values of the CBM wells, the deep GOWN well and the conventional gas well are less depleted than the water wells. The $\delta^{13}C_{Ethane}$ values of the CBM wells and the GOWN well are similar to the D35 water wells.

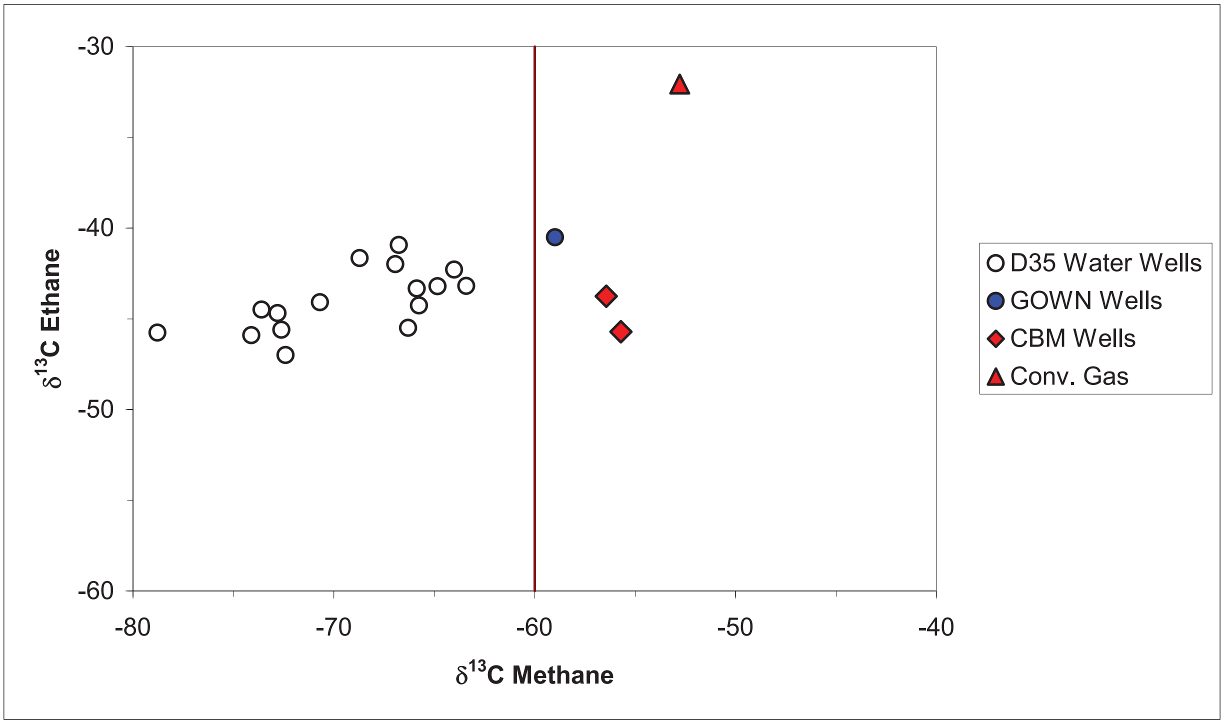

Figure 11. δ^{13}C Methane versus δ^{13}C Ethane.

A plot of the carbon isotopes of coexisting methane and CO_2 from water wells are presented on Figure 12. Lines of equal carbon isotope fractionation (α) between methane and CO2 are shown. These lines do not necessarily represent isotopic equilibrium, rather, they indicate the magnitude of isotopic separation between these coexisting pairs of carbon species (methane and carbon dioxide). Data above the α=1.055 line can be indicative of methane origination from the CO_2 reduction pathway while data below this line can be indicative of methane origination from the fermentation pathway (Whiticar et al. 1986). The data indicates that methane from the Ernst well and the majority of D35 well originates from the microbial reduction of CO_2 (i.e. biogenic origin).

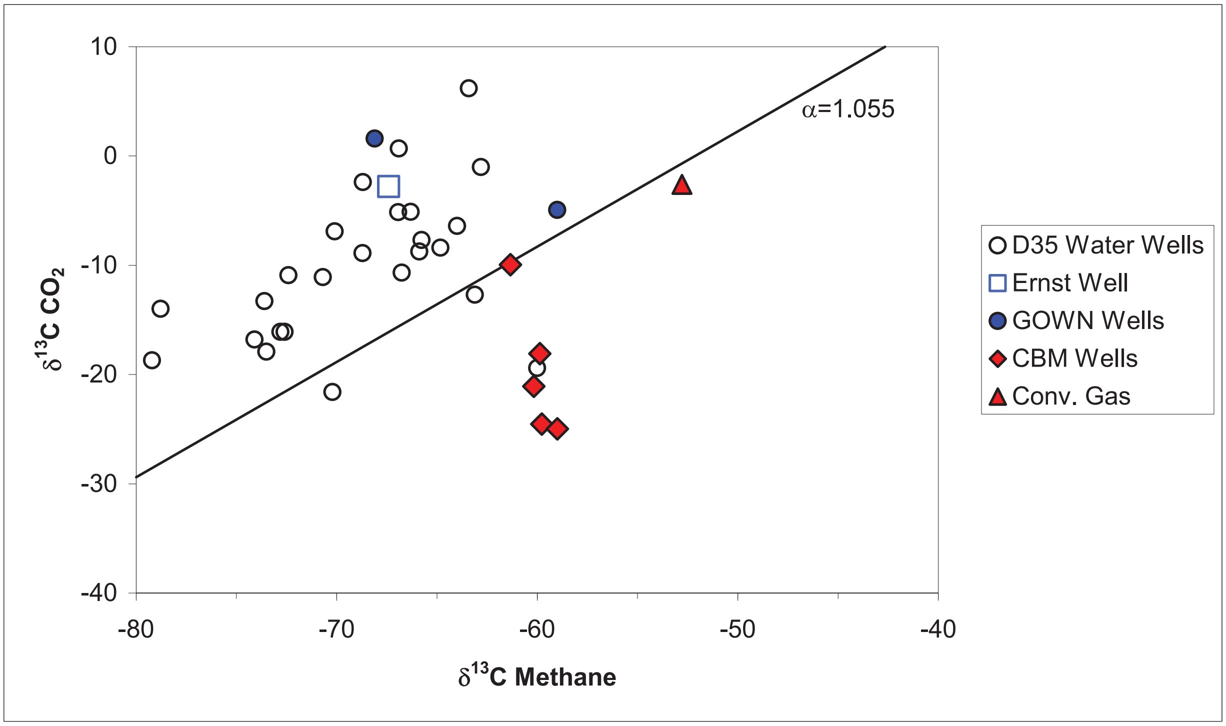

Figure 12. δ13C Methane versus δ13C CO_2. The α value is a line of equal fractionation between methane and CO_2.

Both the hydrocarbon gas composition and the isotopic signatures can be modified by mixing between different sources of gases (such as biogenic methane with thermogenic methane). These hypothetical mixing curves can be calculated using the equations of Jenden et al. (1993) shown on Figure 13. The y-axis of this plot is the ratio of methane to all other hydrocarbon gases.

For this investigation three different end member gases were considered to be the most likely sources and to be mixed in varying ratios: the statistical average biogenic gas in the area, a gas with an isotopic signature similar to the Ernst well, and typical CBM gas.

The first mixing scenario was the average biogenic gas found in the D35 water well ([Methane=437104 ppm], $\delta^{13}C_{methane}$=-68.7 ‰) mixed with a typical CBM gas ([Methane=876700 ppm], $\delta^{13}C_{methane}$=-55.7 ‰). The second scenario was this same average methane concentration gas with a methane isotopic signature ($\delta^{13}C_{methane}$=-68 ‰) chosen so the Ernst well would fall on the curve, mixed with the CBM gas. The tick marks on the curves represent mixtures of CBM gas with the gas from water wells, ranging from 0% to 100%

The Ernst well mixing curve 2 shows a possible 4% mix of the CBM member with a biogenic end-member (chosen to fall though the well). While this is possible, the gas composition and $\delta^{13}C_{methane}$ value of the Ernst well is not statistically any different from the average D35 water well (discussed below). A similar plot can be constructed for ethane. This plot is not shown as the Ernst well had ethane concentrations below the method detection limit for isotopic analysis.

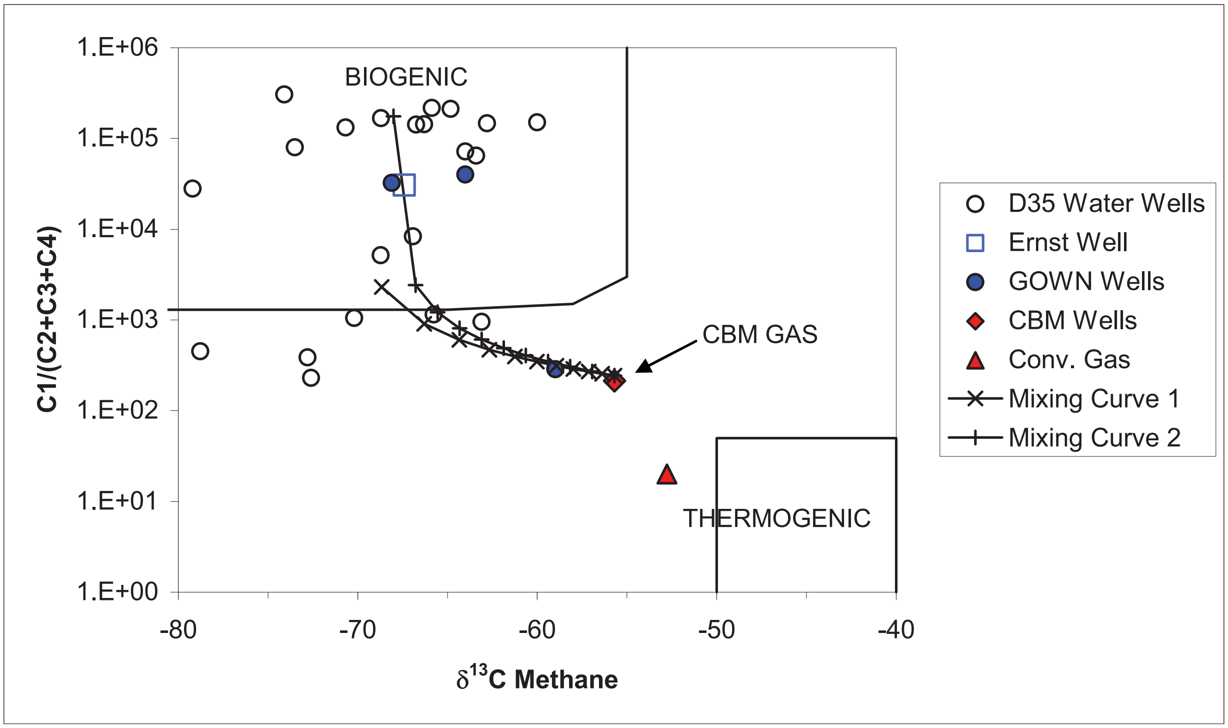

Figure 13. Mixing plot of $\delta^{13}C$ of methane versus the methane/C2+ ratio. Data for the bacterial and thermogenic fields are from Faber and Stahl 1984.

A statistical analysis was performed on gas concentration and gas carbon isotope data. The concentration of methane, ethane and propane along with the carbon isotope values of methane and ethane from water wells containing methane were compared to the Ernst water well and the CBM wells (Table 4). Hydrocarbon gases were detected in 36 of 145 (25%) of the wells in the Rosebud and Redland area.

Student T-Tests were used to compare methane concentrations in the Ernst well with the surrounding D35 water wells. T-Tests are based on a t-distribution, which is similar to a normal distribution, but is dependent upon the number of samples measured. There is no significant difference between the mean methane concentrations in the Ernst well with that of the D35 water well (5% level of significance). This statistically validates the contention that the methane concentrations in the Ernst well is the same as that of surrounding D35 water wells

Ethane was only detected by gas chromatography in 10 of 145 (7%) wells tested. Ethane concentrations ranged from 2 to 1700 ppm. Ethane carbon isotopes were measured in 16 wells by mass spectrometry, a more sensitive technique. Of these ten wells the average concentration was 619 ppm as compared to 3798 ppm in the CBM wells. Propane and butane were not detected by gas chromatography in any of the water wells as compared to 559 ppm and 351 respectively in the CBM wells. The propane and butane carbon isotopes were measured in two water wells but gas concentrations were below the method detection limit and the isotopes results may not be accurate.

Student T-Tests were used to compare mean methane carbon isotope value in the Ernst well with the surrounding D35 water wells and the CBM wells. There is no significant difference between the mean methane carbon isotope values in the Ernst well with that of the D35 water well (5% level of significance). This statistically validates the observation that the carbon isotope value of the methane in the Ernst water well is the same as the methane isotope signature of the surrounding D35 water wells.

There is a statistically significant difference between the mean methane carbon isotope values in the D35 wells with that of the CBM wells (5% level of significance). This statistically validates the observation that the carbon isotope values of the methane in the CBM wells is less depleted than the methane isotope signature of the surrounding water wells.

There is a statistically significant difference between the mean methane carbon isotope values in the Ernst well with that of the CBM wells (5% level of significance). This statistically validates the observation that the carbon isotope values of the methane in the CBM wells is less depleted than the methane isotope signature of the Ernst well.

Student T-Tests were used to compare mean ethane carbon isotope value in the D35 water wells and the CBM wells. There is no statistically significant difference between the mean ethane carbon isotope values in the D35 wells with that of the CBM wells (5% level of significance). This statistically validates the observation that the carbon isotope values of the ethane in the CBM wells are the same as the ethane isotope signatures of the surrounding water wells. This does not indicate the D35 water wells have been impacted by ethane from CBM wells. The similarity between ethane isotope signatures is expected as both the CBM wells and the D35 water wells are completed in the same formation (but different coal members) in the area. No statistical comparisons can be made with the Ernst well because the ethane concentration was below the method detection limit for carbon isotopes.

Table 4. Statistical values and T-Tests of the gas and isotope data.

D35 Water Wells			
	[Methane] (ppm)	$\delta^{13}C_{Methane}$ (‰)	$\delta^{13}C_{Ethane}$ (‰)
n	36	27	16
Min	5	-79.20	-47.00
Max	1000000	-60.00	-40.94
Mean	437104	-68.67	-44.00
Std.	378751	4.82	1.73

Ernst Water Wells			
	[Methane] (ppm)	$\delta^{13}C_{Methane}$ (‰)	$\delta^{13}C_{Ethane}$ (‰)
n	1	1	0
Min	881000	-67.40	
Max	881000	-67.40	
Mean	881000	-67.40	
Std.			

CBM Wells			
	[Methane] (ppm)	$\delta^{13}C_{Methane}$ (‰)	$\delta^{13}C_{Ethane}$ (‰)
n	3	11	3
Min	876700	-63.96	-45.72
Max	979000	-56.44	-40.51
Mean	930750	-60.09	-43.33
Std.	46660	2.04	2.63

T-Test	T-Test	Degees of Freedom	5% level of significance
Mean [Methane] D 35 and Ernst	-1.156	35	no significant difference
Mean $\delta^{13}C_{Methane}$ D 35 and Ernst	-0.259	26	no significant difference
Mean $\delta^{13}C_{Ethane}$ D 35 and Ernst			
Mean [Methane] D 35 and CBM Wells	-2.229	37	**significant difference**
Mean $\delta^{13}C_{Methane}$ D 35 and CBM Wells	-5.667	36	**significant difference**
Mean $\delta^{13}C_{Ethane}$ D 35 and CBM Wells	-0.573	17	no significant difference
Mean [Methane] Ernst and CBM Wells	-0.923	2	no significant difference
Mean $\delta^{13}C_{Methane}$ Ernst and CBM Wells	-3.426	10	**significant difference**
Mean $\delta^{13}C_{Ethane}$ Ernst and CBM Wells			

5 CONCLUSIONS

The Alberta Research Council review of the AENV Ernst complaint file and AEUB data, and their independent review of additional data and aspects of the complaint, provides the following conclusions:

- The Ernst water well is completed in the Upper Horseshoe Canyon Formation as are some of the upper perforations of the CBM wells. Local water wells appear to be predominantly producing water from the Carbon Thompson and Weaver coals of the Horseshoe Canyon Formation.
- In the Rosebud area, the deep GOWN well and CBM drilling and completions records indicate that the coals are not water saturated below the Weaver coal. Under natural conditions, flow between these coal zones is expected to be very limited.
- A local stress analysis indicates the most likely azimuth (orientation) of fractures and face cleats in the coal would be about 055° (Bachu and Michael 2002). Any fluid (water or gas) potentially leaking from a nearby energy well would not be directed towards the Ernst well.
- An estimate of downward vertical gradient between the Ernst well and the Horseshoe Canyon CBM zones is 1.0. This represents a very large downward vertical gradient. If these two zones become connected, water would very strongly want to drain down into the CBM well.
- A theoretical evaluation of the potential migration of methane as bubbles from the CBM well to the Ernst well (through an induced fracture) suggests that the downward flow of groundwater in the fracture would stop the upward migration of methane bubbles.
- A 1.24 m drop in static water level was observed in the Ernst well from June 2003 to June 2007. The cause of this decrease is unknown but possible causes include groundwater resource extraction by the Ernst well or nearby users or from drought. This drop in water level, and corresponding drop in pressure on the coal zone, can be shown to contribute to the amount of methane dissolved in the groundwater at saturation.
- For all the D35 wells in the area sodium-bicarbonate ($Na\text{-}HCO_3$) and sodium-bicarbonate-chloride ($Na\text{-}HCO_3\text{-}Cl$) type waters are strongly associated with the presence of methane in the water. The Ernst water well chemistry is not unique. It, along with many other wells in the area, has $Na\text{-}HCO_3\text{-}Cl$ type water.
- The methane carbon isotope values for the Ernst well fall within the general histogram peak for methane values for all D35 wells in the area. The CBM wells have a less depleted methane isotope signature.
- The ethane carbon isotope values for the CBM wells fall within the general histogram peak for ethane values for all D35 wells in the area.
- The CBM wells have $\delta^{13}C$ methane values that are less enriched than the typical range (-60 to -80 ‰) for biogenic methane. This value represents a mixed thermogenic and biogenic origin.
- The water well data, including the Ernst well, all have $\delta^{13}C$ methane values that are clearly biogenic. This means the methane likely formed at a shallow depth.

- The $\delta^{13}C$ ethane values of all the water wells are similar to the values of the CBM wells, but concentrations are lower (indicating a different origin or potential mixing).
- The hydrocarbon gas composition and isotopic values are modified by mixing between different sources of gases. Hypothetical mixing of 4% CBM gas with a biogenic end-member can produce results similar to the Ernst well. While gas mixing is possible, the gas composition and $\delta^{13}C_{methane}$ value of the Ernst well is not statistically any different from the average D35 water well in the area.
- Student T-Tests statistically validate the observation that the carbon isotope value of the methane in the Ernst water well is the same as the methane isotope signature of the surrounding D35 water wells.
- Student T-Tests statistically validate the observation that the carbon isotope values of the methane in the CBM wells is different than the methane isotope signature of the surrounding water wells.
- Student T-Tests statistically validate the observation that the carbon isotope value of the ethane in the CBM wells is the same as the ethane isotope signature of the surrounding D35 water wells.

Overall Conclusion

- The Alberta Research Council's overall conclusion of the evidence from the review of the AENV and AEUB files, along with a new review and evaluation of addition data and concepts, is that energy development projects in the area most likely have not adversely affected Ms. Ernst's private water supply well.

6 CLOSURE

This report details a thorough review of the AENV well complaint file for Ms. Ernst regarding Coal Bed Methane (CBM) and conventional gas activities undertaken by EnCana and the subsequent perceived decrease in water quality of the Ernst well.

This work was carried out in accordance with accepted hydrogeological practices.

Respectfully submitted,
Alberta Research Council
Permit to Practice P03619

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Research Hydrogeologist

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APPENDIX A

SUMMARY OF ENERGY WELL DRILLING AND COMPLETION DETAILS

Well info for Alberta Research Council request

20-Apr-2006

all wells within 1600m of Lauridsen and Ernst water wells

Well Head (/00 event sequence)	Spud Date	Rig Release	Lost circulation (Y/N)	Surface Casing Depth (m)	TD (m)	Cement returns (surface casing) (m3)	Cement returns (prod casing) (m3)	Perf Count	Perf date	Perf top (mKb)	Perf bottom (mKb)	Frac Count	Frac Date	Frac Top (mKb)	Frac Bottom (mKb)	Frac fluid
100/07-11-027-22W4/00	07-Dec-02	09-Dec-02	N	144	1287	1.00	7	11	13-Apr-05	342.8	343.8	2	24-May-04	636.0	639.0	NITRIFIED FOAM
									13-Apr-05	299.4	300.4		02-May-05	175.9	343.8	N2
									13-Apr-05	337.0	338.0					
									20-Apr-04	636.0	639.0					
									13-Apr-05	272.7	273.7					
									13-Apr-05	296.4	297.4					
									17-Jan-03	1188.5	1191.5					
									13-Apr-05	211.9	214.9					
									13-Apr-05	175.9	177.9					
									08-Jun-04	604.0	607.0					
									13-Apr-05	188.0	189.0					
100/04-11-027-22W4/00	29-Oct-97	30-Oct-97	N	20	771	0.7	1	2	17-Nov-97	669.0	672.0	1	24-Nov-97	669.0	672.0	N2
									27-Nov-97	616.5	619.5					
102/04-11-027-22W4/00	21-Jan-04	21-Jan-04	N	43	504	0.2	1.1	10	22-Apr-04	302.5	303.5	1	03-Jun-04	190.5	373.5	N2
									22-Apr-04	334.9	335.9					
									22-Apr-04	190.5	191.5					
									22-Apr-04	372.5	373.5					
									22-Apr-04	308.4	309.4					
									22-Apr-04	332.3	333.3					
									22-Apr-04	212.1	214.1					
									22-Apr-04	208.7	209.7					
									22-Apr-04	192.1	193.1					
									22-Apr-04	248.1	251.1					
100/14-02-027-22W4/00	28-Feb-95	03-Mar-95	N	45	756	0.02	2	2		615.0	618.0					
									29-Jul-95	664.0	668.0					
102/14-02-027-22W4/00	07-Oct-03	07-Oct-03	N	43	472	0.2	1.5	13	11-Feb-04	331.1	332.1	1	27-Feb-04	162.9	372.7	N2
									11-Feb-04	306.6	307.6					
									11-Feb-04	302.1	303.1					
									11-Feb-04	214.3	217.3					
									11-Feb-04	211.4	212.4					
									11-Feb-04	333.3	334.3					
									11-Feb-04	200.4	201.4					
									11-Feb-04	193.6	196.6					
									11-Feb-04	254.2	255.2					
									11-Feb-04	371.7	372.7					
									11-Feb-04	162.9	163.9					
									11-Feb-04	190.8	191.8					
									11-Feb-04	247.6	250.6					
103/14-02-027-22W4/00	17-Aug-04	19-Aug-04	N	144	1326	0.8	6	9	17-Feb-05	615.0	618.0					
									17-Feb-05	613.5	614.5					
									26-Feb-05	543.0	544.0					
									25-Oct-04	1226.0	1229.0					
									09-Jan-05	671.5	676.0					
									03-Mar-05	501.0	502.0					
									16-Jan-05	646.0	650.0					
									17-Feb-05	620.0	624.5					
									25-Oct-04	1223.0	1226.0					
100/10-03-027-22W4/00	18-Jun-95	20-Jun-95	N	44	764	0.7	1	2	29-Jul-95	680.0	683.0					
									29-Jul-95	673.0	678.0					
102/10-03-027-22W4/00	19-May-02	20-May-02	N	64	462	0.3	3	13	28-Jun-02	196.2	199.2					
									28-Jun-02	382.3	383.3					
									28-Jun-02	261.7	262.7					
									28-Jun-02	218.8	221.8					
									28-Jun-02	343.1	344.1					
									28-Jun-02	311.4	312.4					
									28-Jun-02	256.2	258.2					
									28-Jun-02	228.3	229.3					
									28-Jun-02	341.0	342.0					
									28-Jun-02	214.2	215.2					
									28-Jun-02	203.1	204.1					
									28-Jun-02	254.2	256.2					
									28-Jun-02	316.8	317.8					
100/16-02-027-22W4/00	14-Aug-04	16-Aug-04	N	143	1326	0	5	15	28-Mar-05	246.3	249.3	1	02-May-05	191.4	377.3	N2
									28-Mar-05	210.1	211.1					
									22-Jan-05	584.5	586.0					
									28-Mar-05	233.0	234.0					
									15-Sep-04	1223.5	1225.5					
									28-Mar-05	308.3	309.3					
									28-Mar-05	376.3	377.3					
									28-Mar-05	334.1	335.1					
									28-Mar-05	372.9	373.9					
									28-Mar-05	191.4	192.4					
									15-Sep-04	1225.5	1228.0					
									28-Mar-05	214.3	216.3					
									28-Mar-05	193.6	196.6					
									28-Mar-05	300.6	301.6					
									28-Mar-05	205.8	206.8					
102/16-02-027-22W4/00			N	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A							
100/06-02-027-22W4/00	18-Aug-89	24-Aug-89	N	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A							
102/06-02-027-22W4/00	27-Oct-03	07-Nov-03	N	150	1331		5	7	26-Apr-04	600.0	601.0					
									26-Feb-04	646.0	650.0					
									26-Feb-04	637.0	638.5					
									19-Feb-04	670.0	671.5					
									13-Jan-04	1221.5	1223.0					
									26-Feb-04	640.0	643.0					
									13-Jan-04	1225.0	1229.0					
103/06-02-027-22W4/00	14-May-05	25-May-05	N	69	754	1	2	16	30-Aug-05	311.1	312.1	1	22-Sep-05	191.5	654.9	N2
									30-Aug-05	213.9	214.4					
									30-Aug-05	377.5	378.0					
									30-Aug-05	217.0	219.0					
									30-Aug-05	654.4	654.9					
									04-Jul-05	498.5	499.5					
									30-Aug-05	389.4	389.9					
									16-Jul-05	235.0	239.0					
									30-Aug-05	248.8	251.8					
									04-Jul-05	500.5	503.5					
									30-Aug-05	306.5	307.0					
									10-Jul-05	256.5	264.0					
									30-Aug-05	196.0	197.0					
									30-Aug-05	197.5	198.5					
									30-Aug-05	191.5	192.0					
									30-Aug-05	227.4	227.9					

Well info for Alberta Research Council request

20-Apr-2006

all wells within 1600m of Lauridsen and Ernst water wells

Well Head (/00 event sequence)	Spud Date	Rig Release	Lost circulation (Y/N)	Surface Casing Depth (m)	TD (m)	Cement returns (surface casing) (m3)	Cement returns (prod casing) (m3)	Perf Count	Perf date	Perf top (mKb)	Perf bottom (mKb)	Frac Count	Frac Date	Frac Top (mKb)	Frac Bottom (mKb)	Frac fluid
100/13-11-027-22W4/00	16-Jun-03	18-Jun-03	N	140	1342	2	1	2	11-Aug-03	682.5	684.0					
									17-Jul-03	1234.0	1236.0					
100/16-11-027-22W4/00	20-May-00	06-Jun-00	N	200	1463	0.5		2	29-Jul-00	1211.0	1214.0					
									15-Jul-00	1431.5	1433.0					
100/15-10-027-22W4/00	04-Jun-03	07-Jun-03	N	135	1548	2	4	3	04-Dec-03	718.0	720.0					
									23-Oct-03	1414.0	1417.0					
									13-Aug-03	1498.0	1500.0					
100/04-12-027-22W4/00	26-Jul-04	30-Jul-04	N	142	1439	0	6	5	17-Feb-05	602.0	603.0					
									29-Oct-04	1314.6	1320.5					
									11-Feb-05	666.0	670.0					
									11-Feb-05	671.0	673.5					
									17-Feb-05	604.0	605.0					
100/06-12-027-22W4/00	20-Jul-98	21-Jul-98	N	#N/A	751	#N/A	4	21	31-Jul-03	186.0	187.0	2	07-Sep-98	565.0	568.0	N2
									15-Sep-98	565.0	568.0		29-Sep-98	565.0	568.0	N2
									31-Jul-03	231.5	234.5					
									31-Jul-03	366.0	368.0					
									31-Jul-03	287.0	288.0					
									31-Jul-03	199.0	202.0					
									31-Jul-03	376.0	377.0					
									31-Jul-03	217.0	218.0					
									31-Jul-03	363.0	364.0					
									31-Jul-03	355.0	356.0					
									31-Jul-03	208.5	209.5					
									31-Jul-03	293.0	295.0					
									31-Jul-03	368.0	370.0					
									31-Jul-03	360.5	361.5					
									31-Jul-03	372.0	373.0					
									30-Aug-98	653.0	657.0					
									31-Jul-03	238.0	239.0					
									31-Jul-03	190.0	192.0					
									31-Jul-03	196.0	197.0					
									31-Jul-03	214.0	215.0					
									31-Jul-03	318.5	321.5					
102/06-12-027-22W4/00	31-Jan-02	04-Feb-02	N	202	1464	1	0.5	3	23-Feb-02	1208.0	1209.0					
									23-Feb-02	1210.0	1211.0					
									12-Feb-02	1398.0	1401.0					
100/08-12-027-22W4/00	07-Dec-02	09-Dec-02	N	132	1294	0.5	8	4	29-May-04	605.0	612.0					
									01-Feb-03	1192.5	1195.0					
									17-Jan-03	1207.5	1209.0					
									03-May-04	617.5	622.5					
102/08-12-027-22W4/00	22-Jan-04	22-Jan-04	N	43	503	0.2	1	14	27-Apr-04	280.2	282.2	1	24-Jun-04	163.0	399.3	N2
									27-Apr-04	204.3	205.3					
									27-Apr-04	163.0	167.0					
									27-Apr-04	186.0	188.0					
									27-Apr-04	194.6	195.6					
									27-Apr-04	305.4	306.4					
									27-Apr-04	344.5	345.5					
									27-Apr-04	350.2	351.2					
									27-Apr-04	307.2	308.2					
									27-Apr-04	181.1	182.1					
									27-Apr-04	169.5	170.5					
									27-Apr-04	398.3	399.3					
									27-Apr-04	217.2	220.2					
									27-Apr-04	176.8	177.8					
100/14-12-027-22W4/00	26-Jun-03	29-Jun-03	N	159	1456	1	3	3	20-Sep-03	1426.0	1428.5					
									11-Nov-03	1205.5	1207.0					
									31-Jul-03	1426.5	1428.0					
100/04-13-027-22W4/00	05-Feb-05	08-Feb-05	N	162	1467	2	6	1	17-Feb-05	1209.0	1212.0					
100/07-13-027-22W4/00	26-Jul-98	27-Jul-98	N	#N/A	744	#N/A	1	1	05-Sep-98	648.0	654.0	1	09-Sep-98	0.0	0.0	N2
102/07-13-027-22W4/00	22-May-02	24-May-02	N	194	1482	0.5	3	2	15-Oct-02	1206.0	1208.0					
									06-Jun-02	1438.0	1442.5					
100/12-13-027-22W4/00	17-Jul-03	20-Jul-03	N	140	1367		4	1	18-Oct-03	1263.0	1265.0					
100/15-13-027-22W4/00	18-Jun-03	21-Jun-03	N	162	1481	2	3	4	20-Sep-03	1216.0	1219.0					
									31-Jul-03	1459.5	1461.0					
									29-Aug-03	1399.5	1402.0					
									29-Aug-03	1404.5	1406.0					
100/03-14-027-22W4/00	06-Jul-05	06-Jul-05	N	66	746	0.5	2	20	27-Feb-06	378.0	379.0	2	14-Aug-05	621.5	645.0	N2
									27-Feb-06	238.8	239.8		02-Mar-06	201.4	657.6	N2
									27-Feb-06	201.4	202.0					
									27-Feb-06	508.7	509.7					
									24-Jul-05	644.0	645.0					
									27-Feb-06	373.1	374.1					
									09-Sep-05	248.5	251.0					
									27-Feb-06	324.3	325.3					
									27-Feb-06	301.9	302.9					
									27-Feb-06	237.6	238.6					
									24-Jul-05	621.5	623.5					
									27-Feb-06	367.9	368.9					
									27-Feb-06	656.6	657.6					
									27-Feb-06	204.5	205.5					
									25-Sep-05	223.0	225.0					
									27-Feb-06	212.6	213.6					
									27-Feb-06	207.5	208.5					
									27-Feb-06	205.7	206.7					
									27-Feb-06	649.9	650.9					
									04-Sep-05	416.0	418.0					
102/03-14-027-22W4/00			N	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A							
100/08-14-027-22W4/00	10-Jun-98	26-Jul-98	N	#N/A	759	#N/A	1	1	05-Sep-98	569.0	572.0					
100/01-24-027-22W4/00	27-Jul-98	28-Jul-98	N	#N/A	762	#N/A	1	1	21-Nov-98	430.0	433.0	1	26-Nov-98	430.0	433.0	N2
100/11-07-027-21W4/00	04-Jun-94	14-Jun-94	N	308	1501	#N/A	#N/A	5	27-Jun-94	1387.5	1389	3	05-Jul-94	1210.0	1212.0	
									15-Jul-94	654	659		10-Jul-94	1210.0	1212.0	
									27-Jun-1994	1388.5	1389		17-Jul-94	654.0	659.0	
									14-Jul-1994	654	659					
									28-Jun-94	1210	1212					
100/07-18-027-21W4/00	16-Aug-1974	25-Aug-1974	N	151	632	#N/A	#N/A	2	18-Jun-97	591.9	594.4					
									05-Sep-1974	591.9	594.4					
3-18-27-21	Bounty Resources Well															
2-18-27-21	Bounty Resources Well															

APPENDIX B

WATER WELL DRILLING REPORTS

Water Well Drilling Report

Alberta Environment

The data contained in this report is supplied by the Driller. The province disclaims responsibility for its accuracy.

Well I.D.:	0123548
Map Verified:	Map
Date Report Received:	1986/05/14
Measurements:	Imperial

1. Contractor & Well Owner Information

Company Name: UNKNOWN DRILLER		Drilling Company Approval No.: 99999
Mailing Address: UNKNOWN	City or Town: UNKNOWN AB CA	Postal Code:
WellOwner's Name: FECKLEY, F.L.	Well Location Identifier:	
P.O. Box Number: 723	Mailing Address: ROSEBUD	Postal Code: T0J 2T0
City:	Province:	Country:

2. Well Location

1/4 or LSD	Sec	Twp	Rge	Westof M
SE	13	027	22	4

Location in Quarter
0 FT from Boundary
0 FT from Boundary

Lot Block Plan

Well Elev: FT
How Obtain: Not Obtain

3. Drilling Information

Type of Work: Chemistry
Reclaimed Well
Date Reclaimed: Materials Used:
Method of Drilling: Drilled
Flowing Well: Rate: Gallons
Gas Present: No Oil Present: No

Proposed well use: Domestic
Anticipated Water Requirements/day
0 Gallons

6. Well Yield

Test Date (yyyy/mm/dd): Start Time:
Test Method:
Non pumping static level: FT
Rate of water removal: Gallons/Min
Depth of pump intake: FT
Water level at end of pumping: FT
Distance from top of casing to ground level: Inches

Drawdown	Depth To water level (feet) Elapsed Time Minutes:Sec	Recovery

Total Drawdown: FT
If water removal was less than 2 hr duration, reason why:

Recommended pumping rate: Gallons/Min
Recommended pump intake: FT
Type pump installed
Pump type:
Pump model:
H.P.:
Any further pumptest information?

4. Formation Log

Depth from ground level (feet)	Lithology Description

5. Well Completion

Date Started(yyyy/mm/dd): Date Completed(yyyy/mm/dd):
Well Depth: 190 FT Borehole Diameter: 0 Inches

Casing Type:	Liner Type:
Size OD: 0 Inches	Size OD: 0 Inches
Wall Thickness: 0 Inches	Wall Thickness: 0 Inches
Bottom at: 0 FT	Top: 0 FT Bottom: 0 FT

Perforations	Perforations Size:
from: 0 FT to: 0 FT	0 Inches x 0 Inches
from: 0 FT to: 0 FT	0 Inches x 0 Inches
from: 0 FT to: 0 FT	0 Inches x 0 Inches

Perforated by:

Seal:
from: 0 FT to: 0 FT
Seal:
from: 0 FT to: 0 FT
Seal:
from: 0 FT to: 0 FT

Screen Type: Screen ID: 0 Inches
from: 0 FT to: 0 FT Slot Size: 0 Inches
Screen Type: Screen ID: 0 Inches
from: 0 FT to: 0 FT Slot Size: 0 Inches
Screen Installation Method:

Fittings
Top: Bottom:
Pack:
Grain Size: Amount:
Geophysical Log Taken:
Retained on Files:
Additional Test and/or Pump Data
Chemistries taken By Driller: No
Held: 1 Documents Held: 1
Pitless Adapter Type:
Drop Pipe Type:
Length: Diameter:
Comments:

7. Contractor Certification

Driller's Name: UNKNOWN DRILLER
Certification No.:
This well was constructed in accordance with the Water Well regulation of the Alberta Environmental Protection & Enhancement Act. All information in this report is true.
Signature Yr Mo Day

Report 1

Water Well Drilling Report

Alberta Environment

The data contained in this report is supplied by the Driller. The province disclaims responsibility for its accuracy.

Well I.D.:	0123549
Map Verified:	Map
Date Report Received:	1987/10/27
Measurements:	Imperial

1. Contractor & Well Owner Information

Company Name: M&M DRILLING CO. LTD.		Drilling Company Approval No.: 118890
Mailing Address: BOX 1, SITE 22, RR 2	City or Town: STRATHMORE AB CA	Postal Code: T1P 1K5
WellOwner's Name: WHEATLAND, COUNTY OF	Well Location Identifier:	
P.O. Box Number: 90	Mailing Address: STRATHMORE	Postal Code: T0J 3H0
City:	Province:	Country:

2. Well Location

1/4 or LSD	Sec	Twp	Rge	Westof M
SE	13	027	22	4

Location in Quarter
0 FT from Boundary
0 FT from Boundary

Lot Block Plan

Well Elev: FT
How Obtain: Not Obtain

3. Drilling Information

Type of Work: New Well-Abandoned Reclaimed Well
Date Reclaimed: 1987/09/29
Materials Used: Unknown
Method of Drilling: Rotary
Flowing Well: No
Rate: Gallons
Gas Present: No
Oil Present: No

Proposed well use: Municipal
Anticipated Water Requirements/day
0 Gallons

6. Well Yield

Test Date (yyyy/mm/dd):
Start Time:
Test Method:
Non pumping static level: FT
Rate of water removal: Gallons/Min
Depth of pump intake: FT
Water level at end of pumping: FT
Distance from top of casing to ground level: Inches

Depth To water level (feet)

Drawdown	Elapsed Time Minutes:Sec	Recovery

Total Drawdown: FT
If water removal was less than 2 hr duration, reason why:

Recommended pumping rate: Gallons/Min
Recommended pump intake: FT
Type pump installed
Pump type:
Pump model:
H.P.:
Any further pumptest information?

4. Formation Log

Depth from ground level (feet)	Lithology Description
25	Brown Clay
32	Gray Clay
47	Gray Sandy Clay
58	Sand
89	Sandy Clay
93	Shale
95	Water Bearing Sandstone
97	Coal
105	Sandy Shale
107	Sandstone
115	Shale
127	Sandstone
137	Shale
165	Shale & Sandstone Ledges
175	Shale
177	Water Bearing Coal
185	Sandstone
200	Shale
207	Sandy Shale
210	Shale
212	Coal
232	Shale
235	Sandy Shale
251	Brown Shale
254	Sandstone
258	Shale
259	Water Bearing Coal
267	Shale
272	Sandy Shale & Sandstone Ledges
300	Shale

5. Well Completion

Date Started(yyyy/mm/dd): 1987/09/28	Date Completed(yyyy/mm/dd): 1987/09/29
Well Depth: 300 FT	Borehole Diameter: 0 Inches
Casing Type:	Liner Type:
Size OD: 0 Inches	Size OD: 0 Inches
Wall Thickness: 0 Inches	Wall Thickness: 0 Inches
Bottom at: 0 FT	Top: 0 FT Bottom: 0 FT
Perforations	Perforations Size:
from: 0 FT to: 0 FT	0 Inches x 0 Inches
from: 0 FT to: 0 FT	0 Inches x 0 Inches
from: 0 FT to: 0 FT	0 Inches x 0 Inches

Perforated by:

Seal:
from: 0 FT to: 0 FT
Seal:
from: 0 FT to: 0 FT
Seal:
from: 0 FT to: 0 FT

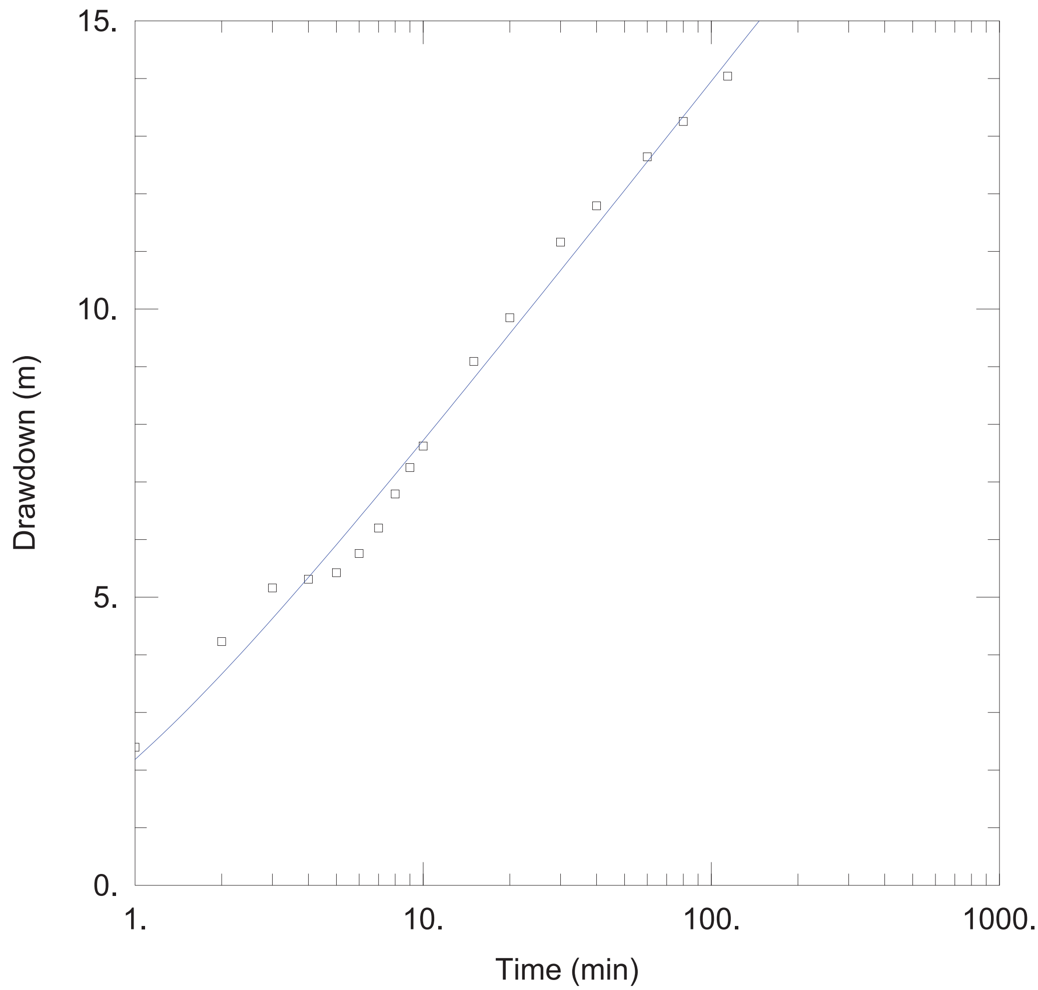
Screen Type: Screen ID: 0 Inches
from: 0 FT to: 0 FT Slot Size: 0 Inches
Screen Type: Screen ID: 0 Inches
from: 0 FT to: 0 FT Slot Size: 0 Inches
Screen Installation Method:

Fittings
Top: Bottom:
Pack:
Grain Size: Amount:
Geophysical Log Taken:
Retained on Files:
Additional Test and/or Pump Data
Chemistries taken By Driller: No
Held: 0 Documents Held: 2
Pitless Adapter Type:
Drop Pipe Type:
Length: Diameter:
Comments:
DRILLER REPORTS NOT ENOUGH WATER

7. Contractor Certification

Driller's Name: UNKNOWN DRILLER
Certification No.: VA5444
This well was constructed in accordance with the Water Well regulation of the Alberta Environmental Protection & Enhancement Act. All information in this report is true.
Signature Yr Mo Day

APPENDIX C
PUMPING TEST GRAPHICAL SOLUTION



ERNST WELL

Data Set:
Date: 11/19/07 Time: 12:17:13

PROJECT INFORMATION

Company: Alberta Research Council
Client: Alberta Environment
Project: 87890015
Location: SE-23-027-22 W4M
Test Well: Ernst Well
Test Date: June 6, 2007

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Ernst Well	0	0

Observation Wells

Well Name	X (m)	Y (m)
□ Ernst Well	0	0

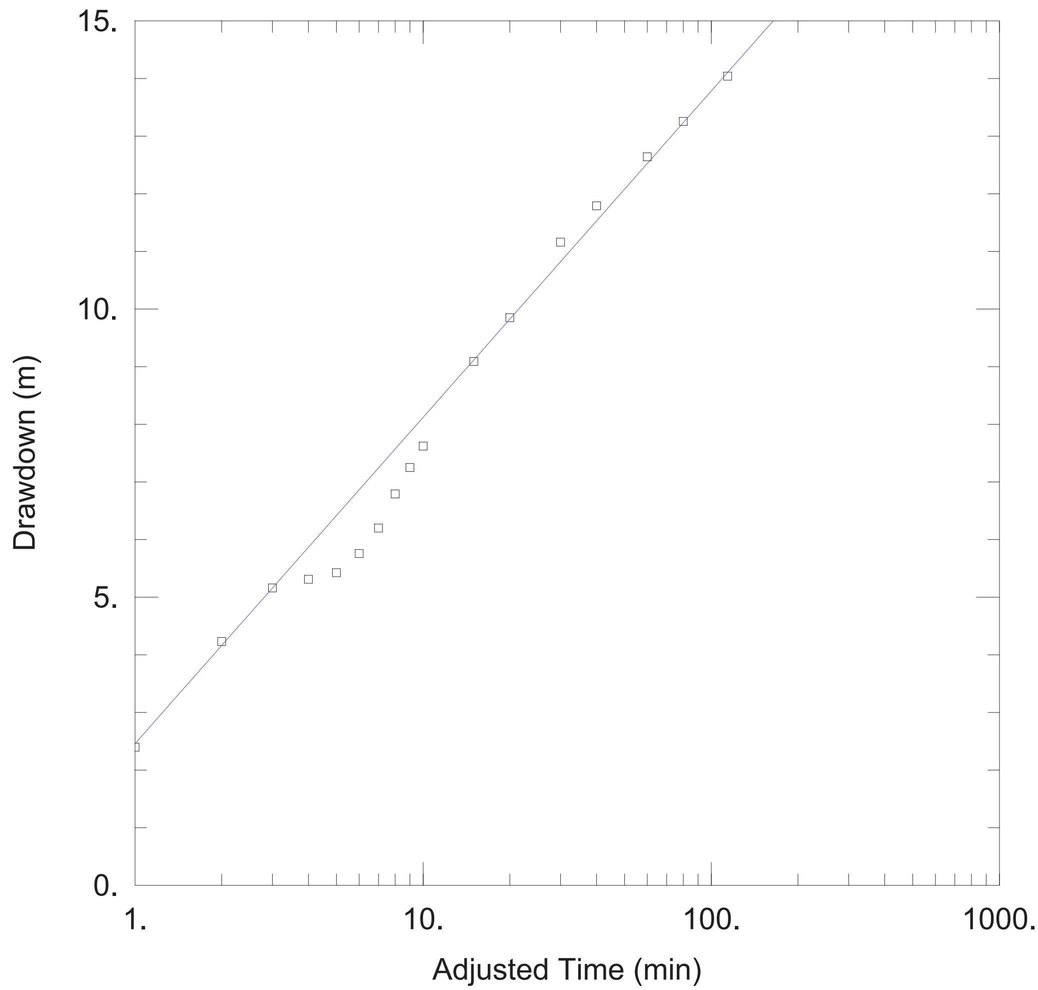
SOLUTION

Aquifer Model: Confined

Solution Method: Theis

T = 0.0003624 m^2/min
Kz/Kr = 1.

S = 0.0005065
b = 0.92 m



ERNST WELL

Data Set:
Date: 11/19/07 Time: 12:14:56

PROJECT INFORMATION

Company: Alberta Research Council
Client: Alberta Environment
Project: 87890015
Location: SE-23-027-22 W4M
Test Well: Ernst Well
Test Date: June 6, 2007

AQUIFER DATA

Saturated Thickness: 0.92 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Ernst Well	0	0

Observation Wells

Well Name	X (m)	Y (m)
□ Ernst Well	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Cooper-Jacob

T = 0.0004045 m^2/min S = 0.0003347

APPENDIX D

ASSESSMENT OF METHANE GAS MIGRATION POTENTIAL

Assessment of the forces controlling the methane gas bubble migration (personal communication with Dr. Jon Jones, PhD., University of Waterloo).

Buoyancy Force:

Buoyancy is the upward force exerted on an object produced by the surrounding fluid in which it is fully or partially immersed due to the pressure difference of the fluid between the top and the bottom of the object. Buoyancy is the force that gives the wings on airplanes the lift required for them to fly.

The net upward buoyancy force is equal to the magnitude of the weight of the fluid displaced by the object.

In simpler terms: Suppose you put a rubber ball in a beaker of water. One of three things will happen:

1) If the weight of the rubber ball equals the weight of the volume of water it displaces: the ball will remain stationary

2) If the weight of the ball is less than the weight of the volume of water it displaces: the ball will begin to float upwards until it breaks through the water surface and will continue to rise until the weight of the volume of water displaced equals the weight of the rubber ball. This is why ice bergs float. A cubic meter of iceberg weighs less than a cubic meter of ocean water.

3) If the weight of the ball is greater than the weight of the volume of water it displaces: the rubber ball will sink to the bottom of the beaker.

Weight Force (In Terms of Methane Gas and Water):

One cubic metre of methane gas under 1 atmosphere of pressure at 15° C has a mass of ~ 0.68 kg. One cubic metre of water under the same conditions has a mass of ~ 1000 kg. So if we placed a bubble of methane gas in our beaker, it would always float upwards because the mass of the methane is much less than the mass of the water it displaces.

Comparison of Forces:

Looking at the forces acting on the bubble of methane gas:

The net force pulling the methane gas bubble upwards is: Fb - Wm

Where Fb = Buoyant force [MLT-2]

Wm = Weight of the bubble [MLT-2]

We have established that the weight of the methane gas bubble is much less than the buoyant force (which is equal to the weight of the water that the bubble displaces). Therefore, the gas bubble will migrate upwards at some velocity.

If the velocity at which the methane gas bubble is rising were to be counteracted by water flowing downwards at the same velocity, then the bubble would remain stationary. If the water velocity were increased, the bubble would be pushed downward. Conversely, if the water velocity were decreased, the bubble would again begin to move upward, albeit at a slower rate.

The velocity at which a gas bubble migrates upward in a column of water is a function of the size of the bubble, i.e. the larger the bubble, the larger the upward velocity due to the increase in the net upward buoyant force. Also note that, as the gas bubble migrates upwards, it will be hindered by friction exerted on the bubble due to the viscosity of the fluid it is rising through.

Calculation Results:
Given the velocity that a gas bubble migrates upward in a column of water, it is simply a matter of determining if there is sufficient downward water velocity to counteract the upward migration of the bubble.

Radius of gas bubble (m)	Terminal upward velocity (m/s)
1.0×10^{-6}	2.18×10^{-6}
1.0×10^{-5}	2.18×10^{-4}
1.0×10^{-4}	2.18×10^{-2}
1.0×10^{-3}	2.18×10^{0}

Note: The upward velocities values listed represent theoretical maximum values. There are a number of factors that can affect these values.

The three most likely scenarios for the migration of the gas bubbles in natural systems would be through fractures, porous media and through cylindrical conduits like boreholes. The formulae for calculating the water velocities in these openings can be found in any standard hydrogeology textbook. Naturally, the site-specific conditions (and corresponding hydrological parameters) will dictate which particular formula (or formulae) is used.

Partial List of Mitigating Factors Affecting Upward Gas Migration

1. Tortuosity: Except for the case of upward migration through a borehole, the bubble will have to take a circuitous path in its upward migration as it manoeuvres through interconnected pore throats or fracture networks. As a result, the upward migration of the gas will be hindered.

2. Relative Size of the Gas Bubble to Pore Throat, Borehole or Fracture Aperture it is Flowing Through: If the diameter of the bubble is of the same order as the opening it is flowing through, there will be additional frictional forces slowing down the upward migration of the gas. The velocity values listed above assume that these forces are negligible.

3. Gas Entry Pressure: For the case of gas migration through fracture apertures or pore throats that are smaller than the diameter of the gas bubble, sufficient upward buoyant force is required for the bubble to exceed the gas entry pressure. All other factors being constant, a single gas bubble whose initial buoyant force is insufficient to overcome the gas entry pressure will remain trapped. However, the usual case is a large number of gas bubbles migrating simultaneously.

As the gas consolidates at entrapment sites, the buoyancy force will increase and eventually upward migration will resume.

4. Bubble Volume as a Function of Pressure: As the gas bubble migrates upward, the column of fluid exerting pressure on the bubble decreases. As a result, the bubble increases in size, thereby generating greater upward velocity due to an increase in the buoyant force. A quantitative expression relating the dynamics between bubble expansion and while moving upward and the accompanying increase in velocity are very difficult to obtain. For the velocities listed above, it was assumed that the size of the bubble remains constant. Whereas the first three mitigating factors in this list would tend to decrease the rate of upward gas migration, this factor would increase it.

5. Any geochemical processes that would make the bubble lose mass during migration (and thereby reduce its volume and decrease its upward velocity). However, it is very likely that this factor would be negligible in most instances.

APPENDIX E

CHEMICAL ANALYSES

ALBERTA ENVIRONMENT
CHEMICAL ANALYSIS REPORT

WELL NAME: FECKLEY, F.L.
LOCATION: LSD SE SEC 13 TWP 027 RG 22 M 4
WELL DEPTH: 190
AQUIFER:
SAMPLING DATE: 5/2/1986 TIME: 0

WELL ID No:0123548
SAMPLE No: 6282
WATER LEVEL: -9
LABORATORY: VG
PRINT DATE: 11/28/2007

FIELD:	MG/L	FIELD:	MG/L
BICARBONATE	-9	CARBONATE	-9
CHLORIDE	-9	CONDUCTIVITY	-9
DISSOLVED OXYGEN	-9	EH	-9
IRON	-9	MANGANESE	-9
PH	-9	SULPHATE	-9
S2	-9	TEMPERATURE°C	-9
TOTAL ALKALINITY	-9	TOTAL HARDNESS	-9

LABORATORY: Analysis Date: 5/23/1986

COD	-9	CONDUCTIVITY	1880
DIC	-9	FLUORIDE	1.57
ION BALANCE	1.03	PH	8.3
SAR	-9	SIO2	9.1
TOTAL ALKALINITY	692	TC	-9
TDS	1102	TN	-9
DOC	-9		
AMMONIUM-N	-9	BICARBONATE	842.7211
CALCIUM	3.992	CARBONATE	-9
CHLORIDE	210.2949	MAGNESIUM	2.001536
NITRATE-N	-9	NITRITE-N	0.0504*
PHOSPHATE	-9	POTASSIUM	1.0112
SODIUM	465.0002	SULPHATE	4.9968*
$NO_2 + NO_3$	0.0144*	TOTAL HARDNESS	18
ALUMINUM	-9	ARSENIC	-9
BARIUM	-9	BERYLIUM	-9
CADMIUM	-9	CHROMIUM	-9
COBALT	-9	COPPER	-9
IRON	0.05	LEAD	-9
MANGANESE	-9	MERCURY	-9
MOLYBDENUM	-9	NICKEL	-9
SELENIUM	-9	STRONTIUM	-9
VANADIUM	-9	ZINC	-9
HYDROCARBONS	-9	PESTICIDES	-9
PHENOLICS	-9	OTHER 3	0

Remarks:
-9 indicates that no analysis was done for this parameter
*Indicates concentrations less than.
Temperature reported in Degree Centigrade. Conductivity reported in microsiemens/cm, pH in pH units. Alkalinity and Hardness expressed as Calcium Carbonate. FE, VA, PB, AL, AG expressed as extractable. FE in field measurements and all remaining metals expressed as total.

EH - Oxidation-Reduction Potential
DIC - Dissolved Inorganic Carbon
DOC - Dissolved Organic Carbon
TDS - Total Dissolved Solids

SAR - Sodium Adsorption Ratio
COD - Chemical Oxygen Demand
TN - Total Particulate Nitrogen
TC - Total Particulate Carbon

NOTE: This data may not be fully checked.
The Province disclaims all responsibility for its accuracy

M & M Drilling Co. Ltd.

Box 1, Site 22, RR 2, Strathmore, AB T1P 1K5
(403) 934-4271 • Fax (403) 934-4865

Name:	ERNST, JESSICA	*Test #:*	1061 - 2211
Address:	BOX 753	*Date:*	6/20/2003
Location:	ROSEBUD, ALBERTA	*Start Time:*	8:45 AM
Post. Code:	T0J 2T0 *Phone:* 677-2074	*Static Level:*	28' 5"
Tested For:	ENCANA CORP., G. PEKRUL	*Well Name:*	ECA/ECOG REDLANDS
Well Location/Description:	SE-13-27-22-W4 HOUSE WELL	*Land Location:*	14-12-27-22-W4
Pumping Rate:	STATIC & SAMPLES ONLY	*AFE Number:*	CD05391
GPS	N-51-18-02.2 W-112-57-41.1	*Readings By:*	DAVID SAWYER

☑ PRE-TEST ☐ POST TEST ☐ REALESTATE

Well Location On Site: IN OLD BARN NORTH OF HOUSE
Pit Type: WELL HEAD
Pit Condition: N/A
Pump Size and Type: 2 WIRE SUBMERSIBLE
Tank Size and Type: MARK IV CONSTANT PRESSURE
Casing Size and Type:
Liner Size and Type: N/A
Well Depth: N/A

Water: - *Appearance* ☑ Clear ☐ Colour
- *Odor* ☐ None ☑ Yes SLIGHT H2S
- *Suspended Solids:* ☐ None ☑ Yes FEW BLACK PARTICLES

Pumping Procedure: - *Open Discharge:* ☑ No ☐ Yes
- *Pressure Tank* ☐ No ☑ Yes
- *Pressure Reading* N/A
- *Special Fitting* ☐ None ☑ Yes 3/4" PUMP OUT HOSE

Samples Taken: ☐ Chemical23: ☐ *Other Sample*
☑ Chemical51:
☑ Coliform Bacteri
☐ Heavy Metals:
☑ TOC
☑ H2S:
☐ OilAndGrease:

Lab where samples were tested: ☑ WSH ☐ Other
Measurement Taken From: CASING TOP
Miscellaneous test information: SAMPLES TAKEN FROM PUMP OUT HOSE
WELL OFF FOR ONE HOUR BEFORE STATIC TAKEN

WSH Labs (1992) LTD.
3851B - 21 Street N.E.
Calgary, Alberta
Canada T2E6T5
Ph: (403) 250 9164
Fax: (403) 291-4597
Website: www.wshlabs.com

M & M Drilling Co. Ltd.	P.O # 2795	Client I.D	Jessica Ernest
Box 1, Site 22, RR# 2	Lab # 39189	Legal	SE-13-27-22-W4
Strathmore, AB T1P 1K5	Ph 934-4271	Date Sampled	
Attn Bill Murray	Fax 934-4865	Date Received	6/21/03
		Date Reported	6/26/03

WATER RESULTS

Cations	mg/L	Anions	mg/L	General Parameters	mg/L	
Saturation Index	0.4	Bicarbonates	795	E.C (US/CM)	1480	
Calcium	4.9	Bromides	<0.6	Coliform,Total	TNTC	CFU/100ml
Iron	1.18	Carbonates	6	Escherichia Co (*E.coli*)	0	CFU/100ml
Magnesium	0.3	Chlorides	200	H.P.C		(MPN/mL)
Manganese	0.066	Fluorides	1.7	Hardness ($CaCO_3$)	13	*SOFT*
Potassium	<0.5	Nitrates	<0.2	pH	8.40	
Silicon		Nitrites	<0.3	Sulfides (S)	0.007	
Sodium	439	NO_3+NO_2	<0.2	T. Alkalinity ($CaCO_3$)	664	
Ammonium	<0.1	Phosphates	N/A	TDS (Calculated)	1044	
		Sulfates	<0.6	Turbidity (N.T.U)	<0.3	
Sum of Cations	19.36			T.O.C.	7.1	
Sum of Anions	18.95			T.K.N.		
Ionic Balance	1.02			T.P.		
% Difference	1.05			Ammonia N		
T.D.S. / E.C. Ratio	0.71			Color (T.C.U)		
SAR	51.99 *(May limit plant growth)*					

Trace Metals Profile

	ug/L		ug/L		ug/L
Phosphorus	188	Cadmium	<0.8	Barium	86
Thallium	<5	Nickel	<2	Lithium	67
Arsenic	<2	Beryllium	<0.8	Tin	1
Selenium	6	Thorium	8	Molybdenum	<1
Chromium	<0.8	Vanadium	1	Antimony	<1
Zinc	6	Bismuth	<2	Titanium	<1
Lead	<2	Silver	<0.8	Zirconium	<1
Copper	5	Aluminum	91	Uranium	
Cobalt	2	Strontium	60	Mercury	

Silty samples may account for higher iron, manganese and silicon content.
*TDS : Total Dissolved Solids *SAR : Sodium Adsorption Ratio
*TNTC :Too Numerous To Count *< Denotes Less Than detection limit
The Results above are related only to the items analyzed.
Please See Reverse For Uncertainty of Measurement and Methods used for analyses.
Please See Attached For Canadian Drinking Water Quality Guidelines

Certified By

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L367943-1 3								
Sampled By: NOT PROVIDED on 03-MAR-06 @ 12:30								
Matrix: WATER								
BTEX, F1 (C6-C10) and F2 (>C10-C16)								
F2 (>C10-C16)	0.12		0.05	mg/L	04-MAR-06	04-MAR-06	DNH	R377278
BTEX and F1 (C6-C10)								
Benzene	<0.0005		0.0005	mg/L	03-MAR-06	04-MAR-06	NOS	R377831
Toluene	<0.0005		0.0005	mg/L	03-MAR-06	04-MAR-06	NOS	R377831
EthylBenzene	<0.0005		0.0005	mg/L	03-MAR-06	04-MAR-06	NOS	R377831
Xylenes	<0.0005		0.0005	mg/L	03-MAR-06	04-MAR-06	NOS	R377831
F1(C6-C10)	<0.1		0.1	mg/L	03-MAR-06	04-MAR-06	NOS	R377831
F1-BTEX	<0.1		0.1	mg/L	03-MAR-06	04-MAR-06	NOS	R377831
Extractable Metals								
Extractable Trace Metals								
Silver (Ag)	<0.005		0.005	mg/L		03-MAR-06	CLL	R377833
Aluminum (Al)	0.09		0.01	mg/L		03-MAR-06	CLL	R377833
Boron (B)	0.28		0.05	mg/L		03-MAR-06	CLL	R377833
Barium (Ba)	0.162		0.003	mg/L		03-MAR-06	CLL	R377833
Beryllium (Be)	<0.001		0.001	mg/L		03-MAR-06	CLL	R377833
Cadmium (Cd)	<0.001		0.001	mg/L		03-MAR-06	CLL	R377833
Cobalt (Co)	<0.002		0.002	mg/L		03-MAR-06	CLL	R377833
Chromium (Cr)	0.036		0.005	mg/L		03-MAR-06	CLL	R377833
Copper (Cu)	0.014		0.001	mg/L		03-MAR-06	CLL	R377833
Molybdenum (Mo)	<0.005		0.005	mg/L		03-MAR-06	CLL	R377833
Nickel (Ni)	<0.002		0.002	mg/L		03-MAR-06	CLL	R377833
Lead (Pb)	<0.005		0.005	mg/L		03-MAR-06	CLL	R377833
Tin (Sn)	<0.05		0.05	mg/L		03-MAR-06	CLL	R377833
Strontium (Sr)	0.119		0.005	mg/L		03-MAR-06	CLL	R377833
Titanium (Ti)	0.002		0.001	mg/L		03-MAR-06	CLL	R377833
Thallium (Tl)	<0.05		0.05	mg/L		03-MAR-06	CLL	R377833
Vanadium (V)	<0.001		0.001	mg/L		03-MAR-06	CLL	R377833
Zinc (Zn)	0.021		0.001	mg/L		03-MAR-06	CLL	R377833
Extractable Major Metals								
Calcium (Ca)	4.6		0.5	mg/L		03-MAR-06	CLL	R377833
Potassium (K)	1.0		0.1	mg/L		03-MAR-06	CLL	R377833
Magnesium (Mg)	0.46		0.01	mg/L		03-MAR-06	CLL	R377833
Sodium (Na)	450		0.5	mg/L		03-MAR-06	CLL	R377833
Iron (Fe)	0.349		0.005	mg/L		03-MAR-06	CLL	R377833
Manganese (Mn)	0.007		0.001	mg/L		03-MAR-06	CLL	R377833
Iron Bacteria	Present				04-MAR-06	10-MAR-06	ODY	R379600
Note: Approximate IRB population 100 CFU/mL								
Methane, dissolved	12.8		0.005	mg/L		04-MAR-06	NOS	R377855
Sulfur Reducing Bacteria	Present				04-MAR-06	10-MAR-06	ODY	R379601
Note: Approximate SRB population 1,000 CFU/mL								
Routine Potable Water								
Iron (Fe)-Extractable	0.29		0.06	mg/L		04-MAR-06	HSC	R377811
Manganese(Mn)-Extractable	<0.02		0.02	mg/L		04-MAR-06	HSC	R377811
Chloride (Cl)	252		0.1	mg/L		04-MAR-06	HSC	R377821
Fluoride (F)	0.9		0.1	mg/L	04-MAR-06	04-MAR-06	HSC	R377821
Nitrate+Nitrite-N	<0.05		0.05	mg/L	04-MAR-06	04-MAR-06	HSC	R377821
Nitrate-N	<0.05		0.05	mg/L	04-MAR-06	04-MAR-06	HSC	R377821
Nitrite-N	<0.05		0.05	mg/L	04-MAR-06	04-MAR-06	HSC	R377821

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L367943-1 3								
Sampled By: NOT PROVIDED on 03-MAR-06 @ 12:30								
Matrix: WATER								
Routine Potable Water								
Sulphate (SO4)	<0.5		0.5	mg/L	04-MAR-06	04-MAR-06	HSC	R377821
Turbidity	4.4		0.2	NTU		04-MAR-06	HSC	R377797
pH, Conductivity and Total Alkalinity								
pH	8.2		0.1	pH		04-MAR-06	HSC	R377815
Conductivity (EC)	1940		3	uS/cm		04-MAR-06	HSC	R377815
Bicarbonate (HCO3)	832		5	mg/L		04-MAR-06	HSC	R377815
Carbonate (CO3)	<5		5	mg/L		04-MAR-06	HSC	R377815
Hydroxide (OH)	<5		5	mg/L		04-MAR-06	HSC	R377815
Alkalinity, Total (as CaCO3)	682		5	mg/L		04-MAR-06	HSC	R377815
Ion Balance Calculation								
Ion Balance	92.1			%		04-MAR-06		
TDS (Calculated)	1100			mg/L		04-MAR-06		
Hardness (as CaCO3)	12			mg/L		04-MAR-06		
ICP metals for routine water								
Calcium (Ca)	4.0		0.5	mg/L		04-MAR-06	HSC	R377811
Potassium (K)	1.1		0.1	mg/L		04-MAR-06	HSC	R377811
Magnesium (Mg)	0.4		0.1	mg/L		04-MAR-06	HSC	R377811
Sodium (Na)	433		1	mg/L		04-MAR-06	HSC	R377811
.367943-2 2								
Sampled By: NOT PROVIDED on 03-MAR-06 @ 11:00								
Matrix: WATER								
BTEX, F1 (C6-C10) and F2 (>C10-C16)								
F2 (>C10-C16)	<0.05		0.05	mg/L	04-MAR-06	04-MAR-06	DNH	R377278
BTEX and F1 (C6-C10)								
Benzene	<0.0005		0.0005	mg/L	03-MAR-06	04-MAR-06	NOS	R377831
Toluene	<0.0005		0.0005	mg/L	03-MAR-06	04-MAR-06	NOS	R377831
EthylBenzene	<0.0005		0.0005	mg/L	03-MAR-06	04-MAR-06	NOS	R377831
Xylenes	<0.0005		0.0005	mg/L	03-MAR-06	04-MAR-06	NOS	R377831
F1(C6-C10)	<0.1		0.1	mg/L	03-MAR-06	04-MAR-06	NOS	R377831
F1-BTEX	<0.1		0.1	mg/L	03-MAR-06	04-MAR-06	NOS	R377831
Extractable Metals								
Extractable Trace Metals								
Silver (Ag)	<0.005		0.005	mg/L		03-MAR-06	CLL	R377833
Aluminum (Al)	0.08		0.01	mg/L		03-MAR-06	CLL	R377833
Boron (B)	0.28		0.05	mg/L		03-MAR-06	CLL	R377833
Barium (Ba)	0.178		0.003	mg/L		03-MAR-06	CLL	R377833
Beryllium (Be)	<0.001		0.001	mg/L		03-MAR-06	CLL	R377833
Cadmium (Cd)	<0.001		0.001	mg/L		03-MAR-06	CLL	R377833
Cobalt (Co)	<0.002		0.002	mg/L		03-MAR-06	CLL	R377833
Chromium (Cr)	0.037		0.005	mg/L		03-MAR-06	CLL	R377833
Copper (Cu)	0.016		0.001	mg/L		03-MAR-06	CLL	R377833
Molybdenum (Mo)	<0.005		0.005	mg/L		03-MAR-06	CLL	R377833
Nickel (Ni)	<0.002		0.002	mg/L		03-MAR-06	CLL	R377833
Lead (Pb)	<0.005		0.005	mg/L		03-MAR-06	CLL	R377833
Tin (Sn)	<0.05		0.05	mg/L		03-MAR-06	CLL	R377833
Strontium (Sr)	0.127		0.005	mg/L		03-MAR-06	CLL	R377833
Titanium (Ti)	0.003		0.001	mg/L		03-MAR-06	CLL	R377833
Thallium (Tl)	<0.05		0.05	mg/L		03-MAR-06	CLL	R377833
Vanadium (V)	<0.001		0.001	mg/L		03-MAR-06	CLL	R377833
Zinc (Zn)	0.067		0.001	mg/L		03-MAR-06	CLL	R377833

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L367943-2 2								
Sampled By: NOT PROVIDED on 03-MAR-06 @ 11:00								
Matrix: WATER								
Extractable Metals								
Extractable Major Metals								
Calcium (Ca)	4.9		0.5	mg/L		03-MAR-06	CLL	R377833
Potassium (K)	1.1		0.1	mg/L		03-MAR-06	CLL	R377833
Magnesium (Mg)	0.52		0.01	mg/L		03-MAR-06	CLL	R377833
Sodium (Na)	479		0.5	mg/L		03-MAR-06	CLL	R377833
Iron (Fe)	0.505		0.005	mg/L		03-MAR-06	CLL	R377833
Manganese (Mn)	0.008		0.001	mg/L		03-MAR-06	CLL	R377833
Iron Bacteria	Present				04-MAR-06	10-MAR-06	ODY	R379600
Note: Approximate IRB population 100 CFU/mL								
Methane, dissolved	11.2		0.005	mg/L		04-MAR-06	NOS	R377855
Sulfur Reducing Bacteria	Present				04-MAR-06	10-MAR-06	ODY	R379601
Note: Approximate SRB population 1,000 CFU/mL								
Routine Potable Water								
Iron (Fe)-Extractable	0.22		0.06	mg/L		04-MAR-06	HSC	R377811
Manganese(Mn)-Extractable	<0.02		0.02	mg/L		04-MAR-06	HSC	R377811
Chloride (Cl)	300		0.1	mg/L		04-MAR-06	HSC	R377821
Fluoride (F)	0.8		0.1	mg/L	04-MAR-06	04-MAR-06	HSC	R377821
Nitrate+Nitrite-N	0.28		0.05	mg/L	04-MAR-06	04-MAR-06	HSC	R377821
Nitrate-N	0.28		0.05	mg/L	04-MAR-06	04-MAR-06	HSC	R377821
Nitrite-N	<0.05		0.05	mg/L	04-MAR-06	04-MAR-06	HSC	R377821
Sulphate (SO4)	<0.5		0.5	mg/L	04-MAR-06	04-MAR-06	HSC	R377821
Turbidity	5.5		0.2	NTU		04-MAR-06	HSC	R377797
pH, Conductivity and Total Alkalinity								
pH	8.3		0.1	pH		04-MAR-06	HSC	R377815
Conductivity (EC)	2050		3	uS/cm		04-MAR-06	HSC	R377815
Bicarbonate (HCO3)	796		5	mg/L		04-MAR-06	HSC	R377815
Carbonate (CO3)	<5		5	mg/L		04-MAR-06	HSC	R377815
Hydroxide (OH)	<5		5	mg/L		04-MAR-06	HSC	R377815
Alkalinity, Total (as CaCO3)	652		5	mg/L		04-MAR-06	HSC	R377815
Ion Balance Calculation								
Ion Balance	93.1			%		04-MAR-06		
TDS (Calculated)	1150			mg/L		04-MAR-06		
Hardness (as CaCO3)	14			mg/L		04-MAR-06		
ICP metals for routine water								
Calcium (Ca)	4.6		0.5	mg/L		04-MAR-06	HSC	R377811
Potassium (K)	1.3		0.1	mg/L		04-MAR-06	HSC	R377811
Magnesium (Mg)	0.5		0.1	mg/L		04-MAR-06	HSC	R377811
Sodium (Na)	454		1	mg/L		04-MAR-06	HSC	R377811
L367943-3 1								
Sampled By: NOT PROVIDED on 03-MAR-06 @ 10:00								
Matrix: WATER								
BTEX, F1 (C6-C10) and F2 (>C10-C16)								
F2 (>C10-C16)	<0.05		0.05	mg/L	04-MAR-06	04-MAR-06	DNH	R377278
BTEX and F1 (C6-C10)								
Benzene	<0.0005		0.0005	mg/L	03-MAR-06	04-MAR-06	NOS	R377831
Toluene	<0.0005		0.0005	mg/L	03-MAR-06	04-MAR-06	NOS	R377831
EthylBenzene	<0.0005		0.0005	mg/L	03-MAR-06	04-MAR-06	NOS	R377831
Xylenes	<0.0005		0.0005	mg/L	03-MAR-06	04-MAR-06	NOS	R377831

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L367943-3 1								
Sampled By: NOT PROVIDED on 03-MAR-06 @ 10:00								
Matrix: WATER								
BTEX, F1 (C6-C10) and F2 (>C10-C16)								
BTEX and F1 (C6-C10)								
F1(C6-C10)	<0.1		0.1	mg/L	03-MAR-06	04-MAR-06	NOS	R377831
F1-BTEX	<0.1		0.1	mg/L	03-MAR-06	04-MAR-06	NOS	R377831
Extractable Metals								
Extractable Trace Metals								
Silver (Ag)	<0.005		0.005	mg/L		03-MAR-06	CLL	R377833
Aluminum (Al)	0.10		0.01	mg/L		03-MAR-06	CLL	R377833
Boron (B)	0.27		0.05	mg/L		03-MAR-06	CLL	R377833
Barium (Ba)	0.143		0.003	mg/L		03-MAR-06	CLL	R377833
Beryllium (Be)	<0.001		0.001	mg/L		03-MAR-06	CLL	R377833
Cadmium (Cd)	<0.001		0.001	mg/L		03-MAR-06	CLL	R377833
Cobalt (Co)	<0.002		0.002	mg/L		03-MAR-06	CLL	R377833
Chromium (Cr)	0.037		0.005	mg/L		03-MAR-06	CLL	R377833
Copper (Cu)	0.013		0.001	mg/L		03-MAR-06	CLL	R377833
Molybdenum (Mo)	0.005		0.005	mg/L		03-MAR-06	CLL	R377833
Nickel (Ni)	<0.002		0.002	mg/L		03-MAR-06	CLL	R377833
Lead (Pb)	<0.005		0.005	mg/L		03-MAR-06	CLL	R377833
Tin (Sn)	<0.05		0.05	mg/L		03-MAR-06	CLL	R377833
Strontium (Sr)	0.105		0.005	mg/L		03-MAR-06	CLL	R377833
Titanium (Ti)	0.002		0.001	mg/L		03-MAR-06	CLL	R377833
Thallium (Tl)	<0.05		0.05	mg/L		03-MAR-06	CLL	R377833
Vanadium (V)	<0.001		0.001	mg/L		03-MAR-06	CLL	R377833
Zinc (Zn)	0.016		0.001	mg/L		03-MAR-06	CLL	R377833
Extractable Major Metals								
Calcium (Ca)	4.1		0.5	mg/L		03-MAR-06	CLL	R377833
Potassium (K)	1.0		0.1	mg/L		03-MAR-06	CLL	R377833
Magnesium (Mg)	0.43		0.01	mg/L		03-MAR-06	CLL	R377833
Sodium (Na)	423		0.5	mg/L		03-MAR-06	CLL	R377833
Iron (Fe)	0.420		0.005	mg/L		03-MAR-06	CLL	R377833
Manganese (Mn)	0.008		0.001	mg/L		03-MAR-06	CLL	R377833
Iron Bacteria	Present				04-MAR-06	10-MAR-06	ODY	R379600
Note: Approximate IRB population 100 CFU/mL								
Methane, dissolved	14.2		0.005	mg/L		04-MAR-06	NOS	R377855
Sulfur Reducing Bacteria	Present				04-MAR-06	10-MAR-06	ODY	R379601
Note: Approximate SRB population 1,000 CFU/mL								
Routine Potable Water								
Iron (Fe)-Extractable	0.28		0.06	mg/L		04-MAR-06	HSC	R377811
Manganese(Mn)-Extractable	0.05		0.02	mg/L		04-MAR-06	HSC	R377811
Chloride (Cl)	199		0.1	mg/L		04-MAR-06	HSC	R377821
Fluoride (F)	0.9		0.1	mg/L	04-MAR-06	04-MAR-06	HSC	R377821
Nitrate+Nitrite-N	0.39		0.05	mg/L	04-MAR-06	04-MAR-06	HSC	R377821
Nitrate-N	0.20		0.05	mg/L	04-MAR-06	04-MAR-06	HSC	R377821
Nitrite-N	0.20		0.05	mg/L	04-MAR-06	04-MAR-06	HSC	R377821
Sulphate (SO4)	<0.5		0.5	mg/L	04-MAR-06	04-MAR-06	HSC	R377821
Turbidity	4.1		0.2	NTU		04-MAR-06	HSC	R377797
pH, Conductivity and Total Alkalinity								
pH	8.2		0.1	pH		04-MAR-06	HSC	R377815
Conductivity (EC)	1920		3	uS/cm		04-MAR-06	HSC	R377815

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L367943-3 1								
Sampled By: NOT PROVIDED on 03-MAR-06 @ 10:00								
Matrix: WATER								
Routine Potable Water								
pH, Conductivity and Total Alkalinity								
Bicarbonate (HCO3)	786		5	mg/L		04-MAR-06	HSC	R377815
Carbonate (CO3)	<5		5	mg/L		04-MAR-06	HSC	R377815
Hydroxide (OH)	<5		5	mg/L		04-MAR-06	HSC	R377815
Alkalinity, Total (as CaCO3)	644		5	mg/L		04-MAR-06	HSC	R377815
Ion Balance Calculation								
Ion Balance	103			%		04-MAR-06		
TDS (Calculated)	1020			mg/L		04-MAR-06		
Hardness (as CaCO3)	13			mg/L		04-MAR-06		
ICP metals for routine water								
Calcium (Ca)	4.4		0.5	mg/L		04-MAR-06	HSC	R377811
Potassium (K)	1.1		0.1	mg/L		04-MAR-06	HSC	R377811
Magnesium (Mg)	0.4		0.1	mg/L		04-MAR-06	HSC	R377811
Sodium (Na)	431		1	mg/L		04-MAR-06	HSC	R377811

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L514885-1 ERNST RAW WATER								
Sampled By: NOT PROVIDED on 06-JUN-07 @ 13:20								
Matrix: WATER								
Total Metals								
Total Major Metals								
Calcium (Ca)	4.1		0.5	mg/L		08-JUN-07	HAS	R532997
Potassium (K)	1.0		0.1	mg/L		08-JUN-07	HAS	R532997
Magnesium (Mg)	0.4		0.1	mg/L		08-JUN-07	HAS	R532997
Sodium (Na)	429		1	mg/L		08-JUN-07	HAS	R532997
Iron (Fe)	0.369		0.005	mg/L		08-JUN-07	HAS	R532997
Manganese (Mn)	0.008		0.001	mg/L		08-JUN-07	HAS	R532997
Total Trace Metals								
Silver (Ag)	<0.005		0.005	mg/L		11-JUN-07	MX	R533892
Aluminum (Al)	0.20		0.01	mg/L		11-JUN-07	MX	R533892
Boron (B)	0.31		0.05	mg/L		11-JUN-07	MX	R533892
Barium (Ba)	0.145		0.003	mg/L		11-JUN-07	MX	R533892
Beryllium (Be)	<0.002		0.002	mg/L		11-JUN-07	MX	R533892
Cadmium (Cd)	<0.001		0.001	mg/L		11-JUN-07	MX	R533892
Cobalt (Co)	<0.002		0.002	mg/L		11-JUN-07	MX	R533892
Chromium (Cr)	0.007		0.005	mg/L		11-JUN-07	MX	R533892
Copper (Cu)	0.002		0.001	mg/L		11-JUN-07	MX	R533892
Molybdenum (Mo)	<0.005		0.005	mg/L		11-JUN-07	MX	R533892
Nickel (Ni)	<0.002		0.002	mg/L		11-JUN-07	MX	R533892
Lead (Pb)	<0.005		0.005	mg/L		11-JUN-07	MX	R533892
Tin (Sn)	<0.05		0.05	mg/L		11-JUN-07	MX	R533892
Strontium (Sr)	0.112		0.002	mg/L		11-JUN-07	MX	R533892
Titanium (Ti)	0.006		0.001	mg/L		11-JUN-07	MX	R533892
Thallium (Tl)	<0.05		0.05	mg/L		11-JUN-07	MX	R533892
Vanadium (V)	0.002		0.001	mg/L		11-JUN-07	MX	R533892
Zinc (Zn)	0.003		0.001	mg/L		11-JUN-07	MX	R533892
Iron Bacteria	9000		25	CFU/mL		18-JUN-07	DJK	R536466
Sulfur Reducing Bacteria	200		200	CFU/mL		17-JUN-07	DJK	R536367
TC and EC by MPN								
MPN - Total Coliforms	<1		1	MPN/100mL		08-JUN-07	RBD	R533072
MPN - E. coli	<1		1	MPN/100mL		08-JUN-07	RBD	R533072
Major Ions & Dissolved Metals								
Chloride (Cl)	220		0.1	mg/L		08-JUN-07	HSC	R533173
Dissolved Trace Metals								
Silver (Ag)	<0.005		0.005	mg/L		13-JUN-07	CVM	R534421
Aluminum (Al)	0.01		0.01	mg/L		13-JUN-07	CVM	R534421
Boron (B)	0.30		0.05	mg/L		13-JUN-07	CVM	R534421
Barium (Ba)	0.145		0.003	mg/L		13-JUN-07	CVM	R534421
Beryllium (Be)	0.008		0.001	mg/L		13-JUN-07	CVM	R534421
Cadmium (Cd)	<0.001		0.001	mg/L		13-JUN-07	CVM	R534421
Cobalt (Co)	<0.002		0.002	mg/L		13-JUN-07	CVM	R534421
Chromium (Cr)	0.007		0.005	mg/L		13-JUN-07	CVM	R534421
Copper (Cu)	<0.001		0.001	mg/L		13-JUN-07	CVM	R534421
Molybdenum (Mo)	<0.005		0.005	mg/L		13-JUN-07	CVM	R534421
Nickel (Ni)	<0.002		0.002	mg/L		13-JUN-07	CVM	R534421
Lead (Pb)	<0.005		0.005	mg/L		13-JUN-07	CVM	R534421
Tin (Sn)	<0.05		0.05	mg/L		13-JUN-07	CVM	R534421
Strontium (Sr)	0.095		0.005	mg/L		13-JUN-07	CVM	R534421
Titanium (Ti)	<0.001		0.001	mg/L		13-JUN-07	CVM	R534421
Thallium (Tl)	<0.05		0.05	mg/L		13-JUN-07	CVM	R534421

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L514885-1 ERNST RAW WATER								
Sampled By: NOT PROVIDED on 06-JUN-07 @ 13:20								
Matrix: WATER								
Major Ions & Dissolved Metals								
Dissolved Trace Metals								
Vanadium (V)	0.002		0.001	mg/L		13-JUN-07	CVM	R534421
Zinc (Zn)	0.006		0.001	mg/L		08-JUN-07	HAS	R532996
ICP metals for routine water								
Calcium (Ca)	1.1		0.5	mg/L		09-JUN-07	HSC	R533485
Potassium (K)	0.1		0.1	mg/L		09-JUN-07	HSC	R533485
Magnesium (Mg)	0.1		0.1	mg/L		09-JUN-07	HSC	R533485
Sodium (Na)	443		1	mg/L		09-JUN-07	HSC	R533485
Ion Balance Calculation								
Ion Balance	96.6			%		11-JUN-07		
TDS (Calculated)	1080			mg/L		11-JUN-07		
Hardness (as CaCO3)	3			mg/L		11-JUN-07		
Iron (Fe)-Dissolved	0.075		0.005	mg/L		08-JUN-07	HAS	R532996
Manganese (Mn)-Dissolved	0.004		0.001	mg/L		08-JUN-07	HAS	R532996
Nitrate and Nitrite as N	0.08		0.07	mg/L		11-JUN-07		
Nitrate-N	0.08		0.05	mg/L		08-JUN-07	HSC	R533173
Nitrite-N	<0.05		0.05	mg/L		08-JUN-07	HSC	R533173
Sulphate (SO4)	<0.5		0.5	mg/L		08-JUN-07	HSC	R533173
pH, Conductivity and Total Alkalinity								
pH	8.6		0.1	pH		08-JUN-07	MAT	R533178
Conductivity (EC)	1860		3	uS/cm		08-JUN-07	MAT	R533178
Bicarbonate (HCO3)	810		5	mg/L		08-JUN-07	MAT	R533178
Carbonate (CO3)	16		5	mg/L		08-JUN-07	MAT	R533178
Hydroxide (OH)	<5		5	mg/L		08-JUN-07	MAT	R533178
Alkalinity, Total (as CaCO3)	691		5	mg/L		08-JUN-07	MAT	R533178

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALBERTA RESEARCH COUNCIL ORGANICS ANALYSIS DATA SHEET ARC SAMPLE NUMBER: T07-1626

VOLATILE PRIORITY POLLUTANTS

Contact: Miller

SmpNo : 07MU081000 ProjNo : ABMOTH GrpSmpNo :

StaNo : StaType:

Comment: Rosebud

Matrix : 6

SmpDate: 6-Jun-07 @ 1310 Samplers..ID1 : 195635

EndDate: @ ..ID2 :

METHOD: A102.1 | TimeLines (days)

SCAN: VPP | from sample date

	Max	Actual
Date Received : 8-Jun-07 by: DRC\	-	2 --
Date Extracted: 12-Jun-07 by: SS	7	6 ok
Date Analyzed : 13-Jun-07 by: BJS	7	7 ok

Raw DataFile : V1626

VMV_CODE	COMPOUND NAME	ug/L	flag	MDL	+\-	VMV_CODE	COMPOUND NAME	ug/L	flag	MDL	+\-
100651	1,1,1,2-Tetrachloroethane	0.0		.1	.1	95227	1,1,1-Trichloroethane	0.0		.1	.1
95224	1,1,2,2-Tetrachloroethane	0.0		.1	.1	95228	1,1,2-Trichloroethane	0.0		.1	.1
95214	1,1-Dichloroethane	0.0		.1	.1	95216	1,1-Dichloroethylene	0.0		.1	.1
100645	1,1-Dichloropropylene	0.0		.1	.1	100652	1,2,3-Trichlorobenzene	0.0		.1	.1
100655	1,2,3-Trichloropropane	0.0		.1	.1	100653	1,2,4-Trichlorobenzene	0.0		.1	.1
100656	1,2,4-Trimethylbenzene	0.0		.1	.1	100640	1,2-Dibromo-3-chloropropane	0.0		.3	.1
100641	1,2-Dibromoethane	0.0		.1	.1	95211	1,2-Dichlorobenzene	0.0		.1	.1
95215	1,2-Dichloroethane	0.0		.1	.1	95218	1,2-Dichloropropane	0.0		.1	.1
100657	1,3,5-Trimethylbenzene	0.0		.1	.1	95212	1,3-Dichlorobenzene	0.0		.1	.1
100644	1,3-Dichloropropane	0.0		.1	.1	95213	1,4-Dichlorobenzene	0.0		.1	.1
100643	2,2-Dichloropropane	0.0		.1	.1	95207	2-Chloroethoxyethylene	0.0		.4	.1
100638	2-Chlorotoluene	0.0		.1	.1	100639	4-Chlorotoluene	0.0		.1	.1
95200	Benzene	0.0		.1	.1	100634	Bromobenzene	0.0		.1	.1
95201	Bromodichloromethane	0.0		.1	.1	95202	Bromoform	0.0		.5	.1
95203	Bromomethane	0.0		.1	.1	95204	Carbon tetrachloride	0.0		.1	.1
95205	Chlorobenzene	0.0		.1	.1	95206	Chloroethane	0.0		.1	.1
95208	Chloroform	0.0		.1	.1	106204	Chloromethane	0.0		.5	.1
95209	Dibromochloromethane	0.0		.1	.1	95210	Dibromomethane	0.0		.1	.1
95221	Ethyl benzene	0.0		.1	.1	100646	Hexachlorobutadiene	0.0		.3	.1
100647	Isopropylbenzene	0.0		.1	.1	102608	MTBE	0.0		.1	.1
95222	Methylene chloride	0.0		2.0	.1	100649	Naphthalene	0.0		.1	.1
95223	Styrene	0.0		.1	.1	100397	TRIHALOMETHANES	0.0		.1	.1
95225	Tetrachloroethylene	0.0		.3	.1	95226	Toluene	0.0		.1	.1
100654	Trichloroethylene	0.0		.1	.1	95229	Trichlorofluoromethane	0.0		.1	.1
95232	Vinyl chloride	0.0		.5	.1	100407	XYLENES	0.0		.1	.1
100642	cis-1,2-Dichloroethylene	0.0		.1	.1	95219	cis-1,3-Dichloropropylene	0.0		.3	.1
95234	m,p-Xylene	0.0		.1	.1	100637	n-Butylbenzene	0.0		.1	.1
100650	n-Propylbenzene	0.0		.1	.1	95233	o-Xylene	0.0		.1	.1
100648	p-Isopropyltoluene	0.0		.1	.1	100635	sec-Butylbenzene	0.0		.1	.1
100636	tert-Butylbenzene	0.0		.1	.1	95217	trans-1,2-Dichloroethylene	0.0		.1	.1
95220	trans-1,3-Dichloropropylene	0.0		.3	.1						

Zero (0) values indicate that the analyte is not DETECTED. MDL - Method Detection Limit

flags B - This analyte is found in the blank as well as the sample. The blank value has been subtracted.

X - Estimated value. The target compound meets the identification criteria, but is less than the MDL.

H - Compound Detected Q - Qualifying ions present but failed the ion ratio limits.

M - This value is calculated by an alternate Raw DataFile.

* - asterik following the value for Actual days taken indicates the prescribed time for that event was exceeded.

** - the Date Sampled is unknown, therefore timeline calculations can not be performed.

Certified For: Yogesh Kumar

Date: 15-Jun-07

Contact Person: Grant Prill

BUSINESS UNIT MANAGER
ANALYTICAL CHEMISTRY
ALBERTA RESEARCH COUNCIL
BAG 4000, VEGREVILLE, ALBERTA
T9C 1T4 (780) 632-8455

mail to: Miller Leslie
Alberta Environment
2nd Floor Deerfoot Square
2938-11st NE
Calgary, Alberta T2E 7L7

VOLATILE PRIORITY POLLUTANTS

Contact: Miller

SmpNo : 07MU081000 ProjNo : ABMOTH GrpSmpNo :

StaNo : StaType:

Comment: Rosebud

Matrix : 6

SmpDate: 6-Jun-07 @ 1310 Samplers..ID1 : 195635

EndDate: @ ..ID2 :

METHOD: A102.1

SCAN: VPP

		TimeLines (days) from sample date Max	Actual	
Date Received :	8-Jun-07 by: DRC\	-	2	--
Date Extracted:	12-Jun-07 by: SS	7	6	ok
Date Analyzed :	13-Jun-07 by: BJS	7	7	ok
Raw DataFile :	V1626			

TENTATIVELY IDENTIFIED COMPOUNDS // COMMENTS	ESTIMATED CONCENTRATION ug/L
2-Propanol, 2-Methyl	2.0

Laboratory's comments regarding this sample:

The following items regarding the sample were recorded. A Yes notation indicates a problem with the specified item.

- Inappropriate Sample Container - No
- Inappropriate Temperature - No
- Inappropriate Headspace - No
- Broken / Leaking Container - No

This sample was analyzed by GC/MS. An additional GC/FID scan may have been used for screening purposes and to assist with quantitative data analysis.

Estimated concentrations for tentively identified compounds are calculated assuming an equal response to internal standards.

* - asterik following the value for Actual days taken indicates the prescribed time for that event was exceeded.

** - the Date Sampled is unknown, therefore timeline calculations can not be performed.

Certified For: Yogesh Kumar BUSINESS UNIT MANAGER
ANALYTICAL CHEMISTRY
ALBERTA RESEARCH COUNCIL
BAG 4000, VEGREVILLE, ALBERTA
T9C 1T4 (780) 632-8455

____

Date: 15-Jun-07

Contact Person: Grant Prill

mail to: Miller Leslie
Alberta Environment
2nd Floor Deerfoot Square
2938-11st NE
Calgary, Alberta T2E 7L7

If there are any questions or concerns regarding this report, please contact the person indicated above.

Please check the mailing information and inform the lab if changes are required.

ALBERTA RESEARCH COUNCIL   ORGANICS ANALYSIS DATA SHEET   ARC SAMPLE NUMBER: T07-1627

EXTRACTABLE PRIORITY POLLUTANTS

Contact: Miller
SmpNo : 07MU081000 ProjNo : ABMOTH GrpSmpNo :
StaNo : StaType:
Comment: Rosebud
Matrix : 6
SmpDate: 6-Jun-07 @ 1310 Samplers..ID1 : 195635
EndDate: @ ..ID2 :

METHOD: EC/3
SCAN: EPP

		TimeLines (days) from sample date Max	Actual
Date Received : 8-Jun-07	by: DRC\	-	2 --
Date Extracted: 11-Jun-07	by: drc	7	5 ok
Date Analyzed : 13-Jun-07	by: drc	21	7 ok

Raw DataFile : E1627

VMV_CODE	COMPOUND NAME	ug/L	flag	MDL	+\-
100730	1,2,4-Trichlorobenzene	0.0		.1	.1
103632	2,3,4,6-Tetrachlorophenol	0.0		.1	.2
100700	2,4-Dichlorophenol	0.0		.1	.2
100703	2,4-Dinitrophenol	0.0		.1	.2
100733	2,6-Dinitrotoluene	0.0		.1	.1
100699	2-Chlorophenol	0.0		.2	.2
100704	2-Nitrophenol	0.0		.1	.2
100698	4-Chloro-3-methylphenol	0.0		.1	.2
100705	4-Nitrophenol	0.0		.1	.2
100710	Acenaphthylene	0.0		.1	.1
100731	Benzidine	0.0		.2	.2
100716	Benzo(a)pyrene	0.0		.1	.2
100715	Benzo(ghi)perylene	0.0		.2	.1
100739	Bis(2-chloroethoxy)methane	0.0		.1	.1
100741	Bis(2-chloroisopropyl)ether	0.0		.1	.1
100743	Butylbenzylphthalate	0.0		.1	.1
100744	Di-n-butylphthalate	0.0		.1	.1
100718	Dibenzo(ah)anthracene	0.0		.5	.1
100746	Dimethyl phthalate	0.0		.1	.1
100720	Fluorene	0.0		.1	.1
100727	Hexachlorobutadiene	0.0		.5	.1
100729	Hexachloroethane	0.0		.5	.1
100749	Isophorone	0.0		.1	.1
100736	N-Nitrosodiphenylamine	0.0		.1	.1
100735	Nitrobenzene	0.0		.1	.1
100723	Phenanthrene	0.0		.1	.1
100724	Pyrene	0.0		.1	.1
100734	1,2-Diphenylhydrazine	0.0		.1	.1
100708	2,4,6-Trichlorophenol	0.0		.1	.2
100701	2,4-Dimethylphenol	0.0		.2	.2
100732	2,4-Dinitrotoluene	0.0		.1	.1
100725	2-Chloronaphthalene	0.0		.1	.1
100702	2-Methyl-4,6-dinitrophenol	0.0		.1	.2
100738	4-Bromophenyl phenyl ether	0.0		.1	.1
100742	4-Chlorophenyl phenyl ether	0.0		.1	.1
100709	Acenaphthene	0.0		.1	.1
100711	Anthracene	0.0		.1	.1
100712	Benzo(a)anthracene	0.0		.1	.1
100713	Benzo(b)fluoranthene	0.0		.1	.1
100714	Benzo(k)fluoranthene	0.0		.1	.1
100740	Bis(2-chloroethyl)ether	0.0		.1	.1
100748	Bis(2-ethylhexyl)phthalate	3.6	H	.1	.4
100717	Chrysene	0.0		.1	.1
100747	Di-n-octyl phthalate	0.0		.1	.1
100745	Diethyl phthalate	0.0		.1	.1
100719	Fluoranthene	0.0		.1	.1
100726	Hexachlorobenzene	0.0		.1	.1
100728	Hexachlorocyclopentadiene	0.0		.1	.1
100721	Indeno(1,2,3-cd)pyrene	0.0		.1	.1
100737	N-Nitroso-di-n-propylamine	0.0		.2	.1
100722	Naphthalene	0.0		.1	.1
100706	Pentachlorophenol	0.0		.1	.2
100707	Phenol	0.0		.1	.2

Zero (0) values indicate that the analyte is not DETECTED.   MDL - Method Detection Limit

flags B - This analyte is found in the blank as well as the sample. The blank value has been subtracted.
X - Estimated value. The target compound meets the identification criteria, but is less than the MDL.
H - Compound Detected   Q - Qualifying ions present but failed the ion ratio limits.
M - This value is calculated by an alternate Raw DataFile.

* - asterik following the value for Actual days taken indicates the prescribed time for that event was exceeded.

** - the Date Sampled is unknown, therefore timeline calculations can not be performed.

Certified For: Yogesh Kumar

Date: 13-Jun-07

Contact Person: Grant Prill

BUSINESS UNIT MANAGER
ANALYTICAL CHEMISTRY
ALBERTA RESEARCH COUNCIL
BAG 4000, VEGREVILLE, ALBERTA
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2nd Floor Deerfoot Square
2938-11st NE
Calgary, Alberta   T2E 7L7

If there are any questions or concerns regarding this report, please contact the person indicated above.

Please check the mailing information and inform the lab if changes are required.

EXTRACTABLE PRIORITY POLLUTANTS

Contact: Miller
SmpNo : 07MU081000 ProjNo : ABMOTH GrpSmpNo :
StaNo : StaType:
Comment: Rosebud
Matrix : 6
SmpDate: 6-Jun-07 @ 1310 Samplers..ID1 : 195635
EndDate: @ ..ID2 :

METHOD: EC/3
SCAN: EPP

		TimeLines (days) from sample date Max	Actual	
Date Received :	8-Jun-07 by: DRC\	-	2	--
Date Extracted:	11-Jun-07 by: drc	7	5	ok
Date Analyzed :	13-Jun-07 by: drc	21	7	ok

Raw DataFile : E1627

TENTATIVELY IDENTIFIED COMPOUNDS // COMMENTS	ESTIMATED CONCENTRATION
No additional compounds reported	

Laboratory's comments regarding this sample:

The following items regarding the sample were recorded. A Yes notation indicates a problem with the specified item.

Inappropriate Sample Container - No
Inappropriate Temperature - No
Inappropriate Headspace - No
Broken / Leaking Container - No

This sample was analyzed by GC/MS. An additional GC/FID scan may have been used for screening purposes and to assist with quantitative data analysis.
Estimated concentrations for tentively identified compounds are calculated assuming an equal response to internal standards.
* - asterik following the value for Actual days taken indicates the prescribed time for that event was exceeded.
** - the Date Sampled is unknown, therefore timeline calculations can not be performed.

Certified For: Yogesh Kumar

____

Date: 13-Jun-07
Contact Person: Grant Prill

BUSINESS UNIT MANAGER
ANALYTICAL CHEMISTRY
ALBERTA RESEARCH COUNCIL
BAG 4000, VEGREVILLE, ALBERTA
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Calgary, Alberta T2E 7L7

If there are any questions or concerns regarding this report, please contact the person indicated above.
Please check the mailing information and inform the lab if changes are required.

ALBERTA RESEARCH COUNCIL ORGANICS ANALYSIS DATA SHEET ARC SAMPLE NUMBER: T07-1628

CCME Hydrocarbons in Water

Contact: Miller
SmpNo : 07MU081000 ProjNo : ABMOTH GrpSmpNo :
StaNo : StaType:
Comment: Rosebud
Matrix : 6
SmpDate: 6-Jun-07 @ 1310 Samplers..ID1 : 195635
EndDate: @ ..ID2 :

METHOD: 3319
SCAN: F123W

		TimeLines (days) from sample date Max	Actual
Date Received : 8-Jun-07	by: DRC\	-	2
Date Extracted: 12-Jun-07	by: SS	10	6 ok
Date Analyzed : 13-Jun-07	by: BJS	14	7 ok

Raw DataFile : V1628

DataFile	Analyzed	VMV_CODE	COMPOUND NAME	ug/L	flag	MDL	+\-
V1628	13-Jun-07	106092	F1 Benzene	0.0		.1	
V1628	13-Jun-07	106094	F1 Ethylbenzene	0.0		.1	
V1628	13-Jun-07	106091	F1 Hydrocarbons(C6-C10)-BTEX	0.0		10.0	
V1628	13-Jun-07	106093	F1 Toluene	0.0		.1	
V1628	13-Jun-07	106095	F1 m,p-Xylene	0.0		.1	
V1628	13-Jun-07	106096	F1 o-Xylene	0.0		.1	
E1628	13-Jun-07	106097	F2 Hydrocarbons(C10-C16)	0.0		5.0	
E1628	13-Jun-07	106098	F3 Hydrocarbons(C16-C34)	0.0		20.0	
E1628	13-Jun-07		F4 Hydrocarbons(C34-C50)	0.0		20.0	

Zero (0) values indicate that the analyte is not DETECTED. MDL - Method Detection Limit

flags B - This analyte is found in the blank as well as the sample. The blank value has been subtracted.
X - Estimated value. The target compound meets the identification criteria, but is less than the MDL.
H - Compound Detected Q - Qualifying ions present but failed the ion ratio limits.
M - This value is calculated by an alternate Raw DataFile.

* - asterik following the value for Actual days taken indicates the prescribed time for that event was exceeded.
** - the Date Sampled is unknown, therefore timeline calculations can not be performed.

Certified For: Yogesh Kumar
BUSINESS UNIT MANAGER
ANALYTICAL CHEMISTRY
ALBERTA RESEARCH COUNCIL
BAG 4000, VEGREVILLE, ALBERTA
T9C 1T4 (780) 632-8455

Date: 15-Jun-07
Contact Person: Grant Prill

mail to: Miller Leslie
Alberta Environment
2nd Floor Deerfoot Square
2938-11st NE
Calgary, Alberta T2E 7L7

ALBERTA RESEARCH COUNCIL | ORGANICS ANALYSIS DATA SHEET | ARC SAMPLE NUMBER: T07-1629

Client: Miller

Sample No: 07MU081000 Group Sample No: Site Descrip/Comment: Rosebud

Station No: Project No: ABMOTH Canister:

Agency: 202 Samp Type: 1 SampMatrix: 6 Collection: 1 Samp Date: 6-Jun-07 Time: 1310 Samplers ID: 195635

SubGroups	FILE	VMV	NAME	ConcRpt	MDL	ConcRptUnit	InjDate
DG_C1C4							
	W1629	106770	Butane	0.00	.01	ug/L	11-Jun-07
	W1629	106771	Ethane	2.21	.01	ug/L	11-Jun-07
	W1629	106772	Ethylene	0.00	.01	ug/L	11-Jun-07
	W1629	106773	Isobutane	0.00	.01	ug/L	11-Jun-07
	W1629	106774	Methane	24300.00	.01	ug/L	11-Jun-07
	W1629	106775	Propane	0.00	.01	ug/L	11-Jun-07
DG_TCD							
	L1629	106776	Carbon dioxide	434.00	1.00	mg/L	12-Jun-07
	L1629	106777	Nitrogen	12.30	6.00	mg/L	12-Jun-07
	L1629		Oxygen	3.38	6.00	mg/L	12-Jun-07
G_C1C4							
	C1629	106778	Butane	0.00	.05	ppmv	11-Jun-07
	C1629	106779	Ethane	26.70	.05	ppmv	11-Jun-07
	C1629	106780	Ethylene	0.00	.05	ppmv	11-Jun-07
	C1629	106781	Isobutane	0.00	.05	ppmv	11-Jun-07
	C1629	106782	Methane	881000.00	.05	ppmv	11-Jun-07
	C1629	106783	Propane	0.00	.05	ppmv	11-Jun-07
G_TCD							
	G1629	106784	Carbon dioxide	1240.00	300.00	ppmv	11-Jun-07
	G1629	106785	Nitrogen	137000.00	1000.00	ppmv	11-Jun-07
	G1629		Oxygen	4330.00	1000.00	ppmv	11-Jun-07

[ARC_Remarks]:

SubGroups

DG_C1C4 and DG_TCD - Disolved Gas in water sample

G_C1C4 and G_TCD - Free Gas from canister

Certified For: Yogesh Kumar, Business Unit Manager
Environmental Monitoring
Alberta Research Council
Vegreville, Alberta
T9C 1T4

By:

Date: 14-Jun-07

Contact Person: Grant Prill
Environmental Monitoring
Alberta Research Council
Vegreville, Alberta T9C 1T4
T9C 1T4
(780) 632-8455

University of Calgary
Carbon Isotope Analyses

		Free Gas				Dissolved Gas		
Sample I.D.	**Field Site**	$\delta^{13}C_{CH4}$ (‰)	$\delta^{13}C_{C2}$ (‰)	$\delta^{13}C_{Co2}$ (‰)	δD_{CH4} (‰)	$\delta^{13}C_{CH4}$ (‰)	$\delta^{13}C_{C2}$ (‰)	$\delta^{13}C_{CO2}$ (‰)
KC62-1	Rosebud #1	-59.0	-40.5	-5.0	-285.0	n.r.	n.r.	n.r.
KC63-1	Jessica	-67.4	n.a.	-2.8	-298.3	-66.3	n.a.	n.a.
KC64-1	Lauridain	-63.3	n.a.	1.9	-291.2	-62.5	n.a.	n.a.
KC65-1	Signer	-66.9	n.a.	0.7	-297.2	-66.3	n.a.	n.a
KC66-1	Rosebud #2	-64.0	n.d	n.a	n.a.	-63.4	n.d.	n.a.
KC67-1	Rosebud #3	-68.1	n.d.	1.6	n.a.	-69.5	n.d.	n.a.

n.a. Not Analyzed
n.d. Not Detected
n.r. Not Received

Maxxam Analytics Inc

CARBON ISOTOPE ANALYSIS

Laboratory Number	A610309:A78171
Sample Point I.D.	
Client I.D.	
Meter Number	
Operator Name	ALBERTA ENVIRONMENT
LSD	0008-12-027-22-W4M
Well ID	102/08-12-027-22W4/0 **
Well Name	ENCANA 0008-12-027-22-W4M
Name of Sampler	DB/AS
Company	MAXXAM
Field or Area	REDLAND
Pool or Zone	
Sample Point	WELLHEAD
Container Identity	Tedlar Bag
Percent Full	
Test Recovery	
Interval 1 / Interval 2 / Interval 3 — From / To	
Elevations (m) — KB	820.4
Elevations (m) — GRD	818.0
Sample Gathering Point	
Solution Gas	
Test Type / No.	
Multiple Recovery	
Well Fluid Status	
Well Status Mode	
Production Rates — Water m3/d / Oil m3/d / Gas 1000m3/d	
Gauge Pressures kPa — Source / As Received	
Temperature °C — Source	
Temperature °C — As Received	18.8
Well Status Type	
Well Type	
Gas or Condensate Project	
Licence No	294935
Date Sampled Start	2006/03/14 11:38
Date Sampled End	
Date Received	2006/03/15
Date Reported	2006/03/30
Date Revision Reported	2006/03/30
Analyst	MW ,MS2

COMPOSITION

COMPONENT	MOLE FRACTION AS REC'D	MOLE FRACTION AIR FREE	CARBON ISOTOPE ABUNDANCE
H2	0.0012	0.0012	
He	Trace	Trace	
O2	0.0005		
N2	0.0336	0.0317	
CO2	Trace	Trace	-56.15
H2S	0.0000	0.0000	
C1	0.9611	0.9635	-40.81
C2	0.0033	0.0033	-31.12
C3	0.0003	0.0003	-30.48
IC4	0.0000	0.0000	-33.1
NC4	0.0000	0.0000	-13.23
IC5	0.0000	0.0000	
NC5	0.0000	0.0000	
C6	0.0000	0.0000	
C7+	0.0000	0.0000	
TOTAL	1.0000	1.0000	

SAMPLE CLASSIFICATION

Mud Depth (m):

NOTES

Carbon isotope abundance is measured in units of:

$$\text{*delta 13C (PDB) ppt} = \frac{(13C/12C)-(13C/12C)PDB}{(13C/12C)PDB} \times 1000$$

Where PDB is an international sample of Belemnite taken from the Pee Dee formation in South Carolina.

** Information not supplied by client -- data derived from LSD Information

Results relate only to items tested

Remarks:

Maxxam Analytics Inc

CARBON ISOTOPE ANALYSIS

Laboratory Number	A610309:A78172
Sample Point I.D.	
Client I.D.	
Meter Number	
Operator Name	ALBERTA ENVIRONMENT
LSD	0008-12-027-22-W4M
Well ID	100/08-12-027-22W4/0 **
Well Name	ENCANA 0008-12-027-22-W4M
Name of Sampler	DB/AS
Company	MAXXAM
Field or Area	HUSSAR
Pool or Zone	BELLY RIVER & VIK & MANN
Sample Point	WELLHEAD
Container Identity	Tedlar Bag
Percent Fill	
Test Recovery	
Test Type No.	
Multiple Recovery	
Interval 1	From: 1207.5 To: 1209.0
Interval 2	From: 1192.5 To: 1195.0
Interval 3	
Elevations (m)	KB 822.2, GRD 818.0
Sample Gathering Point	
Solution Gas	
Well Fluid Status	
Well Status Mode	
Production Rates	Water m3/d: , Oil m3/d: , Gas 1000m3/d:
Gauge Pressures kPa	Source 220, As Received
Temperature °C	Source 10, As Received 18.8
Well Status Type	
Well Type	
Licence No.	276864
Gas or Condensate Project	
Date Sampled Start	2006/03/14 11:43
Date Sampled End	
Date Received	2006/03/15
Date Reported	2006/03/30
Date Revision Reported	2006/03/30
Analyst	MW ,MS2

COMPOSITION

COMPONENT	MOLE FRACTION AS REC'D	MOLE FRACTION AIR FREE	CARBON ISOTOPE ABUNDANCE
H2	0.0000	0.0000	
He	0.0008	0.0008	
O2	0.0002		
N2	0.0230	0.0222	
CO2	0.0006	0.0006	-12.2
H2S	0.0000	0.0000	
C1	0.9532	0.9542	-59.5
C2	0.013100	0.0131	-34.71
C3	0.005500	0.0055	-29.92
IC4	0.0008	0.0008	-29.4
NC4	0.0015	0.0015	-29.04
IC5	0.0005	0.0005	
NC5	0.0004	0.0004	
C6	0.0002	0.0002	
C7+	0.0002	0.0002	
TOTAL	1.0000	1.0000	

SAMPLE CLASSIFICATION

Mud Depth (m):

NOTES

Carbon isotope abundance is measured in units of:

$$\text{*delta 13C (PDB) ppt} = \frac{(13C/12C)-(13C/12C)PDB}{(13C/12C)PDB} \times 1000$$

Where PDB is an international sample of Belemnite taken from the Pee Dee formation in South Carolina.

** Information not supplied by client -- data derived from LSD information

Results relate only to items tested

Remarks:

Maxxam Analytics Inc

CARBON ISOTOPE ANALYSIS

A610309:A78173
Laboratory Number

Sample Point I.D.	
Client I.D.	
Meter Number	
Operator Name	ALBERTA ENVIRONMENT
LSD	0014-12-027-22-W4M
Well ID	100/14-12-027-22W4/0 **
Well Name	ENCANA 0014-12-027-22-W4M
Name of Sampler	DB/AS
Company	MAXXAM
Field or Area	HUSSAR
Pool or Zone	VIKING
Sample Point	WELLHEAD
Container Identity	Tedlar Bag
Percent Full	
Test/Recovery	
Test Type No.	
Multiple Recovery	
Interval 1	From: 1426.5 To: 1428.0
Interval 2	From: 1205.5 To: 1207.0
Interval 3	
Elevations (m)	KB 823.4 GRD 819.5
Sample Gathering Point	
Solution Gas	
Well Fluid Status	
Well Status Mode	
Production Rates	Water m3/d: Oil m3/d: Gas 1000m3/d:
Gauge Pressures kPa	Source 150 As Received
Temperature °C	Source 10 As Received 18.8
Well Status Type	
Well Type	
Gas or Condensate Project	
Licence No.	287031
Date Sampled Start	2006/03/14 10:55
Date Sampled End	
Date Received	2006/03/15
Date Reported	2006/03/30
Date Revision Reported	2006/03/30
Analyst	MW ,MS2

COMPOSITION

COMPONENT	MOLE FRACTION AS REC'D	MOLE FRACTION AIR FREE	CARBON ISOTOPE ABUNDANCE
H2	Trace	Trace	
He	0.0008	0.0008	
O2	0.0003		
N2	0.0285	0.0273	
CO2		0.0013	-2.59
H2S	0.0000	0.0000	
C1	0.9153	0.9167	-52.78
C2	0.0308	0.0309	-32.06
C3	0.0128	0.0128	-29.53
IC4	0.0022	0.0022	-28.62
NC4	0.0032	0.0032	-28.24
IC5	0.0010	0.0010	
NC5	0.0009	0.0009	
C6	0.0010	0.0010	
C7+	0.0019	0.0019	
TOTAL	1.0000	1.0000	

SAMPLE CLASSIFICATION

Mud Depth (m):

NOTES

Carbon isotope abundance is measured in units of:

$$\text{*delta 13C (PDB) ppt} = \frac{(13C/12C)-(13C/12C)PDB}{(13C/12C)PDB} \times 1000$$

Where PDB is an international sample of Belemnite taken from the Pee Dee formation in South Carolina.

** Information not supplied by client -- data derived from LSD information

Results relate only to items tested

Remarks:

Maxxam Analytics Inc

CARBON ISOTOPE ANALYSIS

Laboratory Number	A610309:A78174
Sample Point I.D.	
Client I.D.	
Meter Number	
Operator Name	ALBERTA ENVIRONMENT
LSD	0003-14-027-22-W4M
Well ID	100/03-14-027-22W4/0 **
Well Name	ENCANA 0003-14-027-22-W4M
Name of Sampler	DB/AS
Company	MAXXAM
Field or Area	HUSSAR
Pool or Zone	
Sample Point	WELLHEAD
Container Identity	Tedlar Bag
Percent Full	
Test Recovery	
Test Type / No.	
Multiple Recovery	
Interval 1 / Interval 2 / Interval 3 (From / To)	
Elevations (m)	834.6
KB	
GRD	
Sample Gathering Point	
Solution Gas	
Well Fluid Status	
Well Status Mode	
Production Rates: Water m3/d / Oil m3/d / Gas 1000m3/d	
Gauge Pressures kPa: Source	10
Gauge Pressures kPa: As Received	
Temperature °C: Source	
Temperature °C: As Received	18.8
Well Status Type	
Well Type	
Gas or Condensate Project	
Licence No.	352872
Date Sampled Start	2006/03/14 11:58
Date Sampled End	
Date Received	2006/03/15
Date Reported	2006/03/30
Date Revision Reported	2006/03/30
Analyst	MW ,MS2

COMPOSITION

COMPONENT	MOLE FRACTION AS REC'D	MOLE FRACTION AIR FREE	CARBON ISOTOPE ABUNDANCE
H2	0.0000	0.0000	
He	Trace	Trace	
O2	0.2082		
N2	0.7434	0.0000	
CO2	0.0484	1.0000	-11.21
H2S	0.0000	0.0000	
C1	Trace	Trace	-60.3
C2	0.0000	0.0000	-43.33
C3	0.0000	0.0000	-31.17
IC4	0.0000	0.0000	-28.73
NC4	0.0000	0.0000	-29.31
IC5	0.0000	0.0000	
NC5	0.0000	0.0000	
C6	0.0000	0.0000	
C7+	0.0000	0.0000	
TOTAL	1.0000	1.0000	

SAMPLE CLASSIFICATION

Mud Depth (m):

NOTES

Carbon isotope abundance is measured in units of:

$$\text{*delta 13C (PDB) ppt} = \frac{(13C/12C)-(13C/12C)PDB}{(13C/12C)PDB} \times 1000$$

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Remarks.

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