Jack Well Complaint Phase II Investigations

Submitted To:

Alberta Energy Resources Conservation Board
Suite 1000, 250 – 5th Street SW
Calgary, AB
T2P 0R4

Submitted By:

Alberta Innovates – Technology Futures
3608 – 33 Street N.W.
Calgary, AB
T2L 2A6

Contributors:

S.J. Birks, A. Marandi, J.J. Gibson,

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Alberta Innovates Technology Futures

Executive Summary

In July of 2008 the Alberta Research Council (ARC) produced a report for Alberta Environment concluding that the gas present in Mr. Jack's water well included a small component of deeper, thermogenic gas. To further investigate the source of this gas and the possible connection between energy wells in the vicinity of the Jack well, additional data was collected from the nearby energy wells, and a series of additional tests were conducted including: a soil gas migration study, a cement integrity investigation, a lineament study and shut-in test. Alberta Innovates - Technology Futures (AITF, formerly ARC) was contracted by the ERCB to collect or oversee collection of this additional data. In addition to the original recommendations made in the 2008 report, an isotopic mudlog from a new nearby energy well, and a series of pumping tests on the Jack water well prior-to and after remedial cementing of the energy well in question, were also conducted to provide more information about the isotopic labeling of thermogenic gases in the area and the possible effects of remedial work on the energy well on the Jack water well.

The new information collected and reviewed as part of this report supports the original conclusion that gas in the Jack water well has a mixture of biogenic and thermogenic sources. The $\delta^{13}C$ composition of methane indicates a primarily biogenic source for methane, but the presence of ethane and propane, and their isotopic signatures indicate a contribution of thermogenic gases to the well. A review of the completion details and gas isotope composition of energy wells located near the Jack well identified two energy wells with surface casing vent flows and uncemented zones 100/06-12-078-08 W6M and 100/11-12-078-08 W6M. The results of the soil gas migration study confirmed that gas was leaking from these energy wells. The isotopic signatures of ethane sampled from the surface casing vents of these two energy wells is similar to the isotopic signature of ethane gas in the Jack water well. The 24 hour pressure build-up test conducted on 100/06-12-078-08 W6M showed no evidence of a direct connection between the energy well and the Jack water well over the test duration. The isotopic mudlog from a nearby energy well provided information on the isotopic signatures of the potential source formations. The $\delta^{13}C$ of ethane sampled from the Jack well is similar to ethane sampled from the Cadotte Formation. The lineament study identified a lineament in the area that aligns with the expected fracture orientation and trends towards energy well 100/06-12-078-08W6M. Water levels compiled from manual measurements made in 2001, 2006, 2008, 2009 and 2010 show a general trend of decreasing levels between 2001 and late 2008 (decrease of 12.6 m over time period), followed by an increasing trend that seems to have started in late 2008 or early 2009 (increase of 2.3 m over that time period). The spontaneous eruptions of the Jack water well stopped at about the same time that water levels in the well began rebounding (late 2008 to early 2009). The new neutron density logs indicate that after the remedial cementing of 100/06-12-078-08W6M, the top of the cement was 490 mKb, leaving an uncemented interval from 298 to 490 mKb. Two bubble tests conducted on the well after remedial work show that there are no longer surface casing vent flow from this well. Pumping tests conducted on the Jack water well before and after the remedial cementing was completed at 100/06-12-078-08W6M indicate some changes in the amount of gas discharging from the well, but these changes could also be related to the

increasing trend in water levels that occurred during this period. The $\delta^{13}C$ signature of methane gas sampled from the Jack well after the remedial cementing occurred at 100/06-12-078-08W6M was more negative, but still within the range of laboratory variability prior to the remedial cementing. The $\delta^{13}C$ of ethane remained within the pre-remedial cementing range, but concentrations of ethane and propane increased slightly. Despite the cessation of spontaneous eruptions at the Jack water well, the May 2010 sampling indicates that thermogenic gas is still present in the well water and repeat sampling is recommended to evaluate whether these concentrations are decreasing. The ethane isotope composition of the gas in the Jack water well indicates the Cadotte Formation as a possible source. While the results of this study helped to provide a better understanding of the isotopic labeling of gasses in the area and potential sources of gases to the Jack well, the results were not conclusive in identifying the source, pathway or method of introduction of thermogenic gas to the Jack well.

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1 INTRODUCTION

In July of 2008, the Alberta Research Council (ARC) produced a report examining all the data in the Alberta Environment and Energy Resources Conservation Board (ERCB) files regarding the Bruce Jack water well complaint (see ARC, 2008). This report concluded that a small component of a thermogenic gas was present in the Jack water well. Several recommendations were made for additional information to be gathered and evaluated to determine the source of this gas. Alberta Innovates - Technology Futures (AITF formerly ARC) was contracted by the ERCB to collect or oversee collection of this additional data. This report details and evaluates the new information collected.

2 METHODOLOGY

The results summarized in this report include work that was performed by consulting firms hired directly by the ERCB, data collected by logging companies hired by individual energy well operators as requested by the ERCB, as well as field and laboratory services provided by AITF. The results of the logging have already been reviewed by the ERCB. Methodologies for the gas migration studies (Baseline Water Resources, 2009; Lionhead Engineering, 2009, a, b, c) and the lineament study (Mollard and Associates, 2009) were provided by the consultants who did the work; and are only briefly described below.

2.1 Water and Energy Well Gas Sampling

Previous work in the area (ARC, 2008) included sampling of gas composition and carbon isotope data from energy wells within about a 1.5 km radius of the Jack water well (Figure 1). On March 19, 2009 AITF collected samples for composition and carbon isotopes from the following locations:

- Water injection well 100/06-12-078-08 W6M
    - Surface casing vent (SCV).
    - A gas sample was not taken from the production casing because no gas accumulated there.

- Water source well 100/11-18-078-07 W6M
    - Production tubing.
    - Production casing.
    - Exsolved gas sample was separated from the produced water.

The water source well 100/11-18-078-07 W6M was targeted because it was identified as being completed in the Cadotte Formation and is the source of water injected in to 100/06-12-078-08 W6M. In addition to the energy wells, AITF also collected another gas sample from the Jack water well on May 23, 2010.

Samples were collected in FlexFoil® gas bags and shipped to AITF in Vegreville for compositional analysis. Gas samples were analyzed for atmospheric gases and hydrocarbon fractions (methane, CH_4, C1; ethane, C_2H_6, C2; propane, C_3H_8, C3; and butane, C_4H_{10}, C4). A second sample was sent to the University of Alberta for carbon isotope ratio analysis of C1 through C4 hydrocarbons and CO_2.

2.2 Energy Well Soil Gas Migration Sampling

Gas migration studies around several energy wells were performed to determine whether gas was leaking outside the surface casing. On May 31, 2009 Lionhead Engineering (hired directly by Penn West Energy) conducted soil gas sampling at locations on three energy well leases (100/14-01-078-08 W6M, 100/16-12-078-08 W6M and 100/02-14-078-08 W6M). Samples were sent to Maxxam Analytics Inc. for hydrocarbon and atmospheric gas analysis. Samples were sent to the University of Alberta for stable carbon isotope analysis of hydrocarbon gases and CO_2. A letter report was issued by Lionhead Engineering (June 23, 2009). The ERCB deemed these samples were taken at an inappropriate time (soil moisture conditions were too high) and re-sampling was requested.

On July 16 and 17, 2009 Lionhead Engineering (hired directly by Penn West Energy) conducted soil gas sampling at locations on eight energy well leases (100/14-01-078-08 W6M, 100/08-11-078-08 W6M, 100/02-12-078-08 W6M, 100/06-12-078-08 W6M, 100/11-12-078-08 W6M, 102/11-12-078-08 W6M, 100/16-12-078-08 W6M and 100/02-14-078-08 W6M). Field soil vapour readings were taken with a hand-held RKI Eagle meter. Soil moisture conditions were acceptable at the time of sampling. Sampling was observed by ERCB personnel from the Grande Prairie Field Centre. Samples were sent to Maxxam Analytics Inc. for hydrocarbon and atmospheric gas analysis. Samples were sent to the University of Alberta for stable carbon isotope analysis of hydrocarbon gases and CO_2. Two letter reports were issued by Lionhead Engineering (July 23, 2009 and August 11, 2009).

On September 15 and 16, 2009, gas migration sampling was performed around two energy wells to confirm results provided by Lionhead Engineering and Penn West Energy. The investigation was performed by Baseline Water Resources Inc. of Calgary under contract to the ERCB. Two energy wells were investigated: 100/06-12-078-08 W6M and 100/11-12-078-08 W6M. Both energy wells had sample points starting as close to the casing as possible and then radiating in a "+" pattern away from the energy well in four directions except where surface obstacles were present. Boreholes were hand augured to a depth of approximately 80 cm and a soil vapour probe was installed. The probe was sand packed from the base of the screen to just above the screen and then sealed with bentonite powder which was saturated with fresh water. The probes were hooked to a pump and the ambient air removed. They were allowed to equilibrate with soil vapour overnight. Field soil vapour readings were taken with a hand-held GasTech® meter and the samples with the three highest readings and a background sample were transferred directly into Tedlar® bags. Samples were shipped to AITF in Vegreville for compositional analysis. Gas samples were analyzed for atmospheric gases and C1 through C4. Samples were sent to the University of Alberta for carbon isotope analysis of C1 through C4 and CO_2. A letter report of the field activities for these soil vapour investigations has been provided by Baseline (November 25, 2009).

2.3 New Energy Well Gas Mudlog

A new energy well was drilled by Exshaw Oil Corporation at 100/02-04-078-07 W6M on October 30, 2009. During drilling of this energy well a Pason gas detector was used to identify the presence of gas in the mud returns. At the request of the ERCB, gas samples were collected at several selected intervals including the Smoky Group, Doe Creek, Shaftsbury, the Base of Fish Scales, Paddy, Cadotte Formations and the Spirit River Group. A stratigraphic section for the Northwestern Plains and Deep Basin of Alberta is shown in Figure 2. Gas samples were analyzed in the field for composition by Continental Labs using a total hydrocarbon gas meter. Samples were then sent to the University of Alberta for carbon isotope analysis of C1 through C4 and CO_2.

2.4 Cement Integrity Investigations

The integrity of cement from all energy wells within a 1.5 km radius was investigated in a November 2006 report prepared for Penn West by Lionhead Engineering and Consulting Limited and summarized in the July 8, 2008 report by ARC (ARC, 2008). This information was used to identify energy wells that could potentially be the source of the thermogenic gases to the Jack well (Table 5). The wells included in Table 5 were selected based on having uncemented zones, surface casing vent flows and gas isotope signatures within the range expected for thermogenic gas. Four of the energy wells tested positive for gas migration. Three of these energy wells are located fairly close (less than 800 m) to the Jack water well:

- 100/14-01-078-08 W6M,
- 100/11-12-078-08 W6M,
- 100/06-12-078-08 W6M.

Energy well 100/06-12-078-08 W6M is the closest energy well to the Jack water well (429 m away). This water injection well had an uncemented section between 298 and about 1000m. The ERCB requested that new Radial Cement Bond and neutron density logging be performed on this well to determine the top of the cement in the borehole, the quality/integrity of the cement in isolating hydrocarbon-bearing zones and to identify zones where hydrocarbon gases may have entered the energy well bore. The logging of energy well 100/06-12-078-08 W6M was performed on January 19, 2010 by Hotwell Canada Limited (hired directly by Penn West).

2.5 Lineament Study

A lineament study of the Spirit River area was performed by J.D. Mollard and Associates Limited under contract to the ERCB. The study area extended from Township 73 to 82 and Range 2 to 13 W6M. Digital photography from 1961/'62 and 2008, digital elevation data, satellite imagery and regional surface hydrology data was used to identify lineaments in the Spirit River area that could possibly be related to the regional stress field and deeper bedrock structures (folds and faults). A description of the methodologies is provided in the Mollard and Associates Limited (2009) report.

2.6 Pressure Build-up Test

In order to evaluate whether a direct connection existed between energy well 100/06-12-078-08 W6M and Mr. Jack's water well, the surface casing vent was closed on the energy well and pressure was allowed to build up. The pressure build-up test was performed by Nelgar Oilfield Services Limited (hired directly by Penn West). The surface casing vent was shut in at 9:23 a.m. on March 19, 2009 and pressures were monitored for 24 hours. After the build-up the surface casing vent was opened and allowed to depressurize. During the pressure build-up, water levels and gas release from Mr. Jack's water well was monitored by AITF using a pressure transducer and a Calscan Hawk 9500 gas flow meter.

2.7 Pre and Post 100/06-12-078-08 W6M Remedial Cementing Testing of the Jack Water Well

Penn West decided to abandon the injector well located at 100/06-12-078-08 W6M and the down-hole portion of the well was prepared for abandonment between January 15 and 25, 2010. A pumping test was performed on Mr. Jack's water well prior to the remedial cementing of the energy well, and approximately one week, four weeks and 4 months after cementing, to see if there were any changes in the behavior of the water well. Details of the start and duration of the pumping and recovery phases of the tests are summarized in Table 1.

Table 1: Summary of pumping test timing.

	Pumping test #1 Pre-cementing	Pumping test #2 1st Post-cementing	Pumping test #3 2nd Post-cementing	Pumping test #4 3rd Post-cementing
Pump started	11:15 a.m., Sept. 26, 2009	9:10 a.m., Jan. 30, 2010	7:22 a.m., Feb. 28, 2010	3:20 p.m., May 22, 2010
Recovery (pump stopped)	4:47 p.m., Sept. 27, 2009	9:00 a.m., Jan. 31, 2010	7:36 a.m., Mar. 1, 2010	4:12 p.m., May 23, 2010
End of recovery monitoring	6:00 a.m., Sept. 28, 2009	1:05 p.m., Jan. 31, 2009	12:35 p.m., Mar. 1, 2010	9:00 p.m., May 23, 2010

For each of the tests a transducer was placed in the Jack water well before the start of the test to record the initial pre-pumping water levels. A Calscan Hawk 9500 gas and water flow meter was hooked into the Jack water well to measure gas flow from the casing and water flow from the discharge line. The existing pump in the Jack water well was used to conduct the test. After about 24 hours of pumping the pump was shut off and the recovery portion of the test included monitoring of water levels in the Jack water well. A third post-remedial cementing pumping test was initially started at 9:45 am on May 21, 2010, but was interrupted by a power failure and resumed at 3:20 pm the next day. For this pumping test, the discharge line was run through the gas separator in the AITF trailer so that free gas could be measured and a gas sample could be taken.

The Jack water well has a gas vent attached to the top of the casing (TOC). Water level logger data was measured as depths to water from the top of the vent, but are converted to depths from the TOC in the text of this report. The top of the vent is 0.61 m above the TOC.

The water level data from the pressure build up test and the pumping tests presented in Figures 14-18 are the original measurements from the top of the vent.

3 RESULTS

3.1 Water and Energy Well Gas Sampling

The results of new and previous Jack water well and energy well gas sampling are presented in Table 2, Figure 3 and copies of the new analytical reports are provided in Appendix A.

New samples collected from the Jack water well and energy wells have carbon isotope signatures similar to the ranges identified in previous investigations (ARC, 2008). In general, gas sampled from the Jack water well is characterized by high concentrations of methane and much lower concentrations of ethane or higher order hydrocarbons. The isotopic composition of the methane sampled between 2006 and 2008 stayed fairly consistent at -65.6 ‰ (n=8, stdev=0.3) with the exception of a sample taken on October 19, 2006 and analyzed at Zymax laboratory ($\delta^{13}C$ = -69.3 ‰). The sample analyzed by Zymax was a duplicate sample that was also analyzed by Maxxam. The $\delta^{13}C$ value reported by Maxxam was -65.80 ‰ which is similar to previous measurements. The difference between these duplicate samples taken using the same sampling protocol but analyzed at two different laboratories, highlights the magnitude of potential analytical uncertainty. As laboratory standards for methane isotope analyses are not readily available or universally applied there may be significant inter-laboratory variability. The post-remedial cementing sample collected from the Jack well in 2010 had an isotope signature that was slightly more negative than previous results. While this shift is consistent with a reduced thermogenic gas contribution to the well, the observed differences are not sufficient to rule out the possibility that the observed shift may be related to analytical uncertainty from the AITF laboratory. Comparisons of the results of known $\delta^{13}C$ methane standards submitted to isotope laboratories at University of Alberta, University of Calgary and the University of Victoria, suggest that their $\delta^{13}C_{methane}$ analyses are comparable (ARC, 2009). The AITF isotope laboratory was not yet open when this comparison was done, so we recommend that the isotope analyses on any future gas samples from the Jack well be submitted to both AITF Victoria and the University of Alberta, with known standards. Note that the sample submitted to Zymax was only analyzed for isotope content and concentrations are not available. As a result the Zymax sample is not included on any of the plots using gas concentrations.

Another consideration in comparing the data collected between 2006 and 2010 is the different sampling methods used. Free gas samples were sampled from the casing vent when gas flow rates were sufficiently high and from a gas separator when gas flow rates were lower. On the February 20, 2008 sampling visit gas samples were taken directly from the casing vent as well as using a gas separator and submitted for compositional and isotopic analyses. These two samples gave very similar hydrocarbon concentrations and isotopic signatures suggesting that the two different sample types give comparable results.

The Jack water well has methane isotope signatures that fall within the range indicative of primarily biogenic gas (Figure 3). The samples from energy well 100/11-18-078-07 W6M and 100/06-12-078-08 W6M have more positive methane $\delta^{13}C$ values and a larger percentage of higher order carbon gases (C2+) (Figure 3). The relative proportion of methane to ethane and propane can change as gases migrate, due to the preferential adsorption of higher order hydrocarbons in organic units.

Biogenic gases typically form in low-rank coal (peat to sub-bitumous). They are generated in shallow (<3 km) low-temperature (<100°C) rocks by anaerobic bacteria and are often characterized by low concentrations of C2+ hydrocarbons and isotopically light methane ($\delta^{13}C < -60$ ‰) (Jenden, 1993). Thermogenic gases are typically generated from the thermal degradation of kerogen at greater depths and temperatures. The geochemistry of thermogenic gases will depend on the source rock character and maturity, but they typically have a larger proportion of C2+ hydrocarbons and more positive $\delta^{13}C$ composition of methane (Jenden, 1993).

Based on knowledge of the regional stratigraphy of the area, potential sources of hydrocarbon gases to shallow groundwater would include the following: (i) Charlie Lake Formation, (ii) shale or coal units (e.g. Paddy, Cadotte, or Falher Formations), or (iii) shallow biogenic methane produced in the soil zone.

The concentrations of methane and ethane for the energy and water wells seem to indicate three mixing end-members (Figure 4). These end-members include a) a methane-ethane poor end-member associated with natural recharge and/or injected water, b) a methane-rich, ethane-free end-member consistent with shallow biogenic gas, and c) a mixed methane-ethane end-member attributed to the Charlie Lake Formation. Some of the water injection wells have very low concentrations of both methane and ethane, which is consistent with the practice of storing water for injection open to the atmosphere. These waters would degas resulting in low concentrations of both gases. Shallow groundwater is characterized by higher methane concentrations than ethane. Note also that the Cadotte Formation and Jack well samples cluster near the biogenic gas end-member but are distinguished in most cases by a measurable ethane content. Samples from energy well production casings display systematic variation in methane and ethane concentrations. Two energy wells fall on the mixing line between Charlie Lake Formation and the gas-free end-member possibly indicating gas dilution by water injection. Energy well surface casing vent samples (SCV) tend to plot along mixing lines between the Charlie Lake Formation and shallow biogenic gas end-members, along a mixing line with the gas-free end-member. This is attributed to dilution of gas concentrations by recharge water. While it is known that methane:ethane ratios can be sensitive to migration Fig. 4 provides a first look at the ratios in the different end-member waters available for mixing.

The Jack water well is characterized by very high concentrations of methane and fairly negative $\delta^{13}C$ compositions (Figure 5). Some of the energy wells have similar concentrations of methane, but their $\delta^{13}C$ is far more positive, plotting in the range expected for thermogenic gases (see also Figure 3). The isotopic composition of methane in the Jack water well (Figure

3 and 5) indicates a primarily biogenic source. The Jack well is located in an area where low-permeability lacustrine clays overly low permeability Smoky Group deposits (Hackbarth, 1977). The expected water yield for these deposits is quite low and there are few water wells in the area available to obtain information about local background water quality (Hackbarth, 1977) or gas concentrations. A recent survey of shallow groundwater and water from the major coal bed methane producing formations in central Alberta can provide some context for comparison (Cheung et al., 2010). We have included average values for shallow groundwater, the Horseshoe Canyon/ Belly River Group (HSC/BRG) and Manville Formations from the Cheung et al. (2010) dataset for central Alberta, plotted with one standard deviation denoted by the error bars in this study (Figures 5, 6, and 7). The Jack well is located just north of the region included the Cheung et al. (2010) study, so these ranges may not be entirely comparable because of differences in geology. However, in the absence of any local data on the composition of gases in shallow groundwater, these data provide a general idea of the range of gas concentrations and compositions sampled in shallow groundwater in the Central Plains region of southern Alberta.

The multiple sources of mixing for methane (multiple methane producing units at depth, soil zone biogenic methane, etc.) make it difficult to use methane alone to identify the origin of gases. The isotopic composition of higher order hydrocarbons like ethane and propane are generally preferred for identifying potential gas sources (Rowe and Muehlenbachs, 1999). The isotopic composition of ethane sampled from the Jack well is far more positive than the range typically found in shallow groundwater samples from central Alberta and more closely resembles ethane isotope compositions from production casing and SCV gases (Figure 6). This similarity suggests that the ethane in the Jack well has the same source as the ethane sampled in the production casing and SCV.

The $\delta^{13}C$ values measured for methane and ethane in the Jack water well and surrounding energy wells seem to suggest a mixture of biogenic and thermogenic gases in the well (Figure 7). The methane isotopic composition is within the range of what one would expect for biogenic methane, whereas the ethane composition is similar to some of the samples from water injection wells, and energy well SCV. Average values and one standard deviation for the data collected by Cheung et al. (2010) for central Alberta are included again for comparison. The same $\delta^{13}C_{methane}$-$\delta^{13}C_{ethane}$ plot using the data from the soil gas migration study (Figure 7, bottom panel) is illustrative of the large variability one can encounter in methane even within small areas. The bottom panel of Figure 7 includes the production casing and SCV samples for the energy wells located at 100/06-12-078-08 W6M and 100/11-12-078-08 W6M plotted with the soil gas samples obtained from the immediate vicinity of those wellheads (0.3m to 2m away from well head). Both of these wells had uncemented sections and SCV flows. High gas concentrations were consistent with leakage from the wells; however even in the immediate vicinity of the wellhead the isotopic composition of soil gases were often quite different from the production casing. The isotopic composition of soil gas samples more closely resembled the composition of SCV flows.

Time series of the isotopic composition of gases from the Jack water well and 100/06-12-078-08 W6M can be used to evaluate the variability of the isotopic labeling of these different sources and to identify trends in their composition. (Figure 8) There appears to be a trend of isotopic enrichment of about 2‰ over a 4 year period for all the hydrocarbon gases in the 100/06-12-078-08 W6M energy well (Figure 8). This may be a natural fractionation process in the reservoir/well whereby the isotopically lighter isotopes hydrocarbons have less mass and can move more quickly. The time-series of ethane $\delta^{13}C$ composition shows the similarity between the isotopic labeling of ethane sampled from the energy well and ethane sampled from the Jack water well.

After the remedial cementing was completed at energy well at 100/06-12-078-08 W6M the $\delta^{13}C$ value measured for methane from the Jack water well became slightly more negative (Figures 3, 5, 7 and 8) consistent with the post-cementing sample having a lower percentage of thermogenic methane. However, the post-remedial cementing sample was analyzed at a new laboratory (AITF Victoria) and an inter laboratory comparison with results from the University of Alberta should be performed to determine if the shift to more negative values is real, or simply a result of differences in laboratories.

The carbon isotope value of hydrocarbons from the Jack water well were compared to energy wells in the same section (100/06-12-078-08 W6M and 100/11-12-078-08 W6M) that have surface casing vent flows and have been shown to have gas migration issues (Figure 9). Shaded horizontal zones have been drawn from the range in $\delta^{13}C$ signatures in the Jack water well across energy well fields to facilitate comparison. The carbon isotope ratio of methane in the Jack water well (average -66‰ PDB) is more negative than any of the energy wells sampled and is within the range typical for biogenic methane. The carbon isotope ratio of ethane in the Jack water well is similar to that found in the surface casing vent of 100/06-12-078-08 W6M and 100/11-12-078-08 W6M.

The energy well located at 100/11-18-078-07 W6M was included in the 2009 sampling because it is the water source well that supplies water for the 100/06-12-078-08 W6M injector well. The carbon isotope ratio of ethane from this water supply well is > 2‰ more positive than the range of $\delta^{13}C$ values measured for ethane in the Jack well. The production casing sample for this well was the only well with a similar propane carbon isotope composition as the Jack well (Figure 9). Concentrations of propane in the Jack water well were generally low (2 to 138 ppm) which makes accurate determination of the carbon isotope ratio more difficult.

The hydrocarbon gas composition and isotopic values from the 2008 sampling of the Jack water well were used to calculate hypothetical mixing scenarios (using equations in Jenden et al. 1993) that could explain both the composition and isotopic signature of gases in the well (ARC, 2008). The model assumed mixing of biogenic and thermogenic end-members with the following characteristics:

- biogenic end-member
  - composition: methane = 999,999 ppm, ethane = 1 ppm
  - isotopic composition $\delta^{13}C_{methane}$ = -65.5 ‰, $\delta^{13}C_{ethane}$= -30.8 ‰

- thermogenic end-member
    - composition: methane = 838,000 ppm, ethane = 105,300 ppm
    - isotopic composition: $\delta^{13}C_{methane}$ = -50.7 ‰, $\delta^{13}C_{ethane}$= -31.1 ‰

Using the original end-members the gas concentrations and isotopic composition of gas sampled from the Jack water well in 2008 could be explained by mixture of 2% thermogenic gas with 98% biogenic gas. This calculation was useful for demonstrating that a gas can still plot in what has traditionally been thought of as the biogenic field on a plot of C1/C2+ vs. $\delta^{13}C$ methane (upper left section of Figure 3) even if it has a small component of thermogenic gas present. There are however, a number of assumptions that go into this calculation including:

- the gas is a mixture of only two sources,
- the concentrations and isotopic compositions of the two end-members are known and values are constant with time.

The range in concentrations (Figure 4) and isotopic signatures (Figures 3 and 5, 6 and 7) measured in SCV gases, production casing, water injection wells and soil gases suggest that it is unlikely that the gases available for mixing can be characterized by just two end-members. There is also some uncertainty about the value used to characterize the $\delta^{13}C_{methane}$ signature of the biogenic end-member. It was set at -65.5 ‰ in the original mixing calculation so that the mixing curve would pass through the data from the Jack water well (ARC, 2008). The shift to a more negative $\delta^{13}C_{methane}$ signature in gas from the Jack water well in the 2010 data indicates that the biogenic end-member signature should be more negative. The current investigation has also revealed that other formations, like the Cadotte, should be considered as potential sources of gas for mixing. The characteristics of the Cadotte Formation (using average values from 100/11-18-078-07 W6M, n=3):

- Composition: methane = 862,333 ppm, ethane = 3983 ppm
- Isotopic composition: $\delta^{13}C_{methane}$ = -43.7 ‰, $\delta^{13}C_{ethane}$= -26.5 ‰,

are quite different than the biogenic and thermogenic end-members used in the original mixing model calculations.

The increases in the concentrations of ethane and propane measured in the 2010 sample from the Jack water well suggest a small increase in the calculated percentage of thermogenic gas present in the Jack well, but the shift to a more negative $\delta^{13}C_{methane}$ signatures in the 2010 could indicate a smaller percentage of thermogenic gas. While the thermogenic contribution is likely small, it is our opinion on consideration of all evidence that the source of thermogenic gas is not well defined, and it is therefore unwise to quantitatively apply a simple mixing model as previously described. Repeat sampling and isotopic analyses of gases from the Jack water well is recommended to confirm the negative shift in $\delta^{13}C_{methane}$ and the increases in C2+. Sampling of the other gas-bearing geological formations is also recommended prior to application of any mixing model.

Table 2: Summary of gas analysis for Jack water well and energy wells, new data collected for this repor t are highlighted in yellow.

Designation	WELL ID	LSD	Pool or Zone	Depth interval (m)	Status	Sample Location	Lab comp/isotope	Consultant	Owner	Sampling Date (d-m-y)	Nitrogen (%)	arbon Dioxide pm)	Methane (ppm)	Ethane (ppm)	Propane (ppm)	I-Butane (ppm)	N-Butane (ppm)	I-C5 (ppm)	N-C5 (ppm)	C6 (ppm)	C7+ (ppm)	δ^{13}C CO_2 (‰)	δ^{13}C Methane (‰)	δ^{13}C Ethane (‰)	δ^{13}C Propane (‰)	δ^{13}C I-Butane (‰)	δ^{13}C N-Butane (‰)
Jack Well	1820001	SW-12-078-08 W6M	Smoky Group	47.2 - 54.9	Water well, active		AGAT	Matrix	Bruce Jack	7/2/2005	2.31	800	973300	1200	<100	<100	<100	<100	<100	100	300						
"	"	"	"	"	"	Headspace	GCHEM	GCHEM	"	16/5/2006			843548	782.5	2.2	0.11	0.01	0.34	0.07								
"	"	"	"	"	"	Headspace	GCHEM	GCHEM	"	19/5/2006			790343	773.3	2.5	0.18	0.34	2.81	0.47								
"	"	"	"	"	"	Headspace	GCHEM	GCHEM	"	19/5/2006			933130	929.5	3.6	0.33	0.58	0.55	0.34								
"	"	"	"	"	"	Well, after purge	Maxxam/UofA	Matrix	"	19/10/2006	6.23	200	933200	<100	7	<100	<100	<100	<100	<100	<100	-34.47	-65.90	-30.74			
"	"	"	"	"	"	Duplicate	Maxxam/UofA	Matrix	"	19/10/2006	7.08	100	922300	<100	<100	<100	<100	<100	<100	<100	<100	-33.87	-64.97	-30.53			
"	"	"	"	"	"	Well, pump on	Maxxam/UofA	Matrix	"	19/10/2006	7.72	60	915200	<100	<100	<100	<100	<100	<100	<100	<100	-25.10	-65.80	-30.36			
"	"	"	"	"	"	Well, pump on	Zymax	Matrix	"	19/10/2006												-0.30	-69.3	-32.2			
"	"	"	"	"	"	Duplicate	Maxxam/UofA	Matrix	"	19/10/2006	6.97	730	925100	<100	<100	<100	<100	<100	<100	<100	<100	-34.66	-65.57	-30.24			
"	"	"	"	"	"	Well	ARC, Veg/UofA	ARC/AENV	"	20/2/2008	2.85	410	848000.0	1910.0	14.1	0.0	0.0					-37.59	-65.48	-29.76	-23.05		
"	"	"	"	"	"	Duplicate	UofVictoria	ARC/AENV	"	20/2/2008													-65.8	-30.0	-24.6		
"	"	"	"	"	"	Casing vent gas	ARC, Veg/UofA	ARC/AENV	"	20/2/2008	4.84	1160	818000.0	1830.0	18.0	0.478	0.045	0.015	0.001	0.000	0.172		-65.44	-29.35	-22.79		
"	"	"	"	"	"	Duplicate	UofVictoria	ARC/AENV	"	20/2/2008													-65.7	-29.6	-24.2		
"	"	"	"	"	"	Free gas	AITFVeg/AITFVic	AITF	"	23/05/2010	7.53	1120	860000.0	4790.0	138.0	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-26.50	-68.4	-30.1			
Energy Well	100/06-05-078-07 W6M	06-05-078-07 W6M	Charlie Lake Fm	1580.0-1581.5	Pumping oil	SCV	AGAT	Matrix	Petrofund Energy Trust	23/09/2005	0.55	3500	894300	52300	24800	4100	5500	1500	1100	800	1300						
Energy Well	100/12-05-078-07 W6M	12-05-078-07 W6M	Charlie Lake Fm	1547.0-1556.0	Flowing gas	SCV	AGAT	Matrix	Petrofund Energy Trust	23/09/2005	10.54	6300	874600	8900	1600	700	400	200	200	400	900						
Energy Well	100/06-06-078-07 W4M	06-06-078-07 W4M	Charlie Lake Fm	1618.0-1635.0	Pumping oil	SCV	AGAT	Matrix	Petrofund Energy Trust	23/09/2005	0.45	6200	873200	67700	31300	5000	6700	1800	1300	800	900						
Energy Well	100/08-06-078-07 W6M	08-06-078-07 W6M	Charlie Lake Fm	1592.0-1600.0	Pumping oil	SCV	AGAT	Matrix	Petrofund Energy Trust	23/09/2005	4.80	1200	841500	62800	27500	4900	6600	1900	1300	1100	2400						
Energy Well	100/14-06-078-07 W6M	14-06-078-07 W6M	Charlie Lake Fm	1555.0-1558.0	Pumping oil	SCV	AGAT	Matrix	Petrofund Energy Trust	23/09/2005	0.22	1400	893600	63000	23700	4200	5900	1800	1400	1000	1100						
Energy Well	100/04-07-078-07 W6M	04-07-078-07 W6M	Charlie Lake Fm	1553.5 - 1556.5	Pumping oil	Production Casing	Maxxam/UofA	Lionhead	Trico	20/09/2006	3.64	3400	791600	94700	39600	6200	11400	2600	2400	1600	1500		-45.51	-35.26	-32.48		-32.98
	"	"	"	"	"	Production Casing	Maxxam/UofA	Maxxam	Trico	17/10/2006	2.25	4200	822400	86600	36000	5200	9500	2200	2300	2100	3500		-45.55	-35.09	-32.34	-33.00	-31.65
Energy Well	100/06-07-078-07 W6M	06-07-078-07 W6M	Charlie Lake Fm	1543.0-1545.0	Water Injection	SCV	AGAT	Matrix	Petrofund Energy Trust	23/09/2005	0.22	1800	858800	73500	39500	6900	9700	2800	2100	1400	1000						
Energy Well	100/08-07-078-07 W6M	08-07-078-08 W6M	Charlie Lake Fm	1534.0 - 1537.0	Pumping oil	SCV	AGAT	Matrix	Petrofund Energy Trust	23/09/2005	1.30	4800	853300	71100	36600	6600	8700	2300	1600	1000	800						
Energy Well	100/14-07-078-07 W6M	14-07-078-08 W6M	Gething Fm	1332.0-1335.0	Flowing Gas	SCV	AGAT	Matrix	Petrofund Energy Trust	23/09/2005	6.02	2300	832200	50200	28900	6500	9300	2900	2200	1700	1500						
Energy Well	100/11-18-078-07 W6M	11-18-078-07 W6M	CadotteFm	830.0 - 855.0	Water Source	Production Casing	ARC, Veg/UofA	ARC	PennWest	19/03/2009	16.80	4740	745000	3730	154	35.1	39.7					8.60	-43.60	-26.84	-24.44	-29.61	-22.93
Energy Well	100/11-18-078-07 W6M	11-18-078-07 W6M	CadotteFm	"	Water Source	Production Tubing	ARC, Veg/UofA	ARC	PennWest	19/03/2009	0.13	0	945000	4480	176	55.7	93.9					5.30	-43.49	-26.27	-26.33	-27.08	-27.75
Energy Well	100/11-18-078-07 W6M	11-18-078-07 W6M	CadotteFm	"	Water Source	Exsolved gas	ARC, Veg/UofA	ARC	PennWest	19/03/2009	3.00	555	897000	3740	133	30.4	31.8						-44.01	-26.40	-26.61	-25.76	-28.62
Energy Well	100/14-01-078-08 W6M	14-01-078-08 W6M	Charlie Lake Fm	1592.0 - 1594.5	Pumping oil	SCV	AGAT	Matrix	Pertofund Energy Trust	23/09/2005	3.00	5500	834700	67400	37000	6100	9700	2800	1900	1200	800						
"	"	"	"	"	"	SCV	Maxxam/UofA	Lionhead	Petrofund Energy Trust	22/09/2006	2.88	730	837700	69800	34200	5900	9400	2500	1800	1100	740		-51.31	-31.05	-27.92	-28.09	
"	"	"	"	"	"	SCV	Maxxam/UofA	Maxxam	Northstar	17/10/2006	4.59	700	819300	67500	35000	5900	9200	2400	1600	1100	600		-49.96	-30.94	-27.65	-28.71	-27.87
"	"	"	"	"	"	Production Casing	Maxxam/UofA	Lionhead	Northstar	22/09/2006	3.64	470	773400	89700	48000	9900	17600	5800	6300	3900	1500		-45.05	-35.40	-32.94	-33.02	-32.50
"	"	"	"	"	"	Production Casing	Maxxam/UofA	Maxxam	Northstar	17/10/2006	2.99	400	839000	80900	32400	4600	6900	1200	1100	400	<100		-45.62	-35.33	-31.99	-32.89	-31.51
Energy Well	100/16-01-078-08 W6M	16-01-078-08 W6M	Charlie Lake Fm	1563.2 - 1566.5	Pumping oil	Production Casing	Maxxam/UofA	Lionhead	Northstar	20/09/2006	2.73	370	713100	131000	76200	11700	19500	4000	3500	2700	3800		-44.76	-35.19	-33.03	-32.25	-32.15
"	"	"	"	"	"	Production Casing	Maxxam/UofA	Maxxam	Northstar	18/10/2006	2.13	400	716700	132700	79100	12500	21400	4400	3900	2400	2200		-45.06	-35.39	-32.93	-33.51	-32.05
Energy Well	102/16-01-078-08 W6M	16-01-078-08 W6M	Charlie Lake Fm	1507.8 - 1510.8	Flowing oil	Production Casing	Maxxam/UofA	Lionhead	Trico	22/09/2006	3.27	50	956300	2500	8	30	6	<100	<100	<100	<100	-18.13	-46.79	-28.72	-23.11	-30.05	-36.71
"	"	"	"	"	"	Production Casing	Maxxam/UofA	Maxxam	Trico	18/10/2006	0.86	22900	841900	78500	30000	2700	7800	1300	2200	1300	600	-17.68	-46.10	-35.02	-31.72	-31.09	-29.77
Energy Well	100/08-11-078-08 W6M	08-11-078-08 W6M	Charlie Lake Fm	1569.0 - 1575.0	Pumping oil	Production Casing	Maxxam/UofA	Lionhead	Northstar	22/09/2006	4.80	640	828100	68700	27100	5300	9400	1800	1400	440	200		-44.84	-34.63	-32.61	-31.95	-30.01
"	"	"	"	"	"	Production Casing	Maxxam/UofA	Maxxam	Northstar	17/10/2006	2.76	600	858700	68800	25200	4600	8000	1500	1200	300	<100		-44.91	-34.53	-31.73	-33.05	-31.89
Energy Well	100/15-11-078-08 W6M	15-11-078-08 W6M	Charlie Lake Fm	1563.5 - 1565.5	Pumping oil	Production Casing	Maxxam/UofA	Lionhead	UEI	11/10/2006	3.94	680	699400	113100	61000	12700	23100	7400	8700	80	13300		-45.54	-35.32	-32.11	-32.33	-31.04
"	"	"	"	"	"	Production Casing	Maxxam/UofA	Maxxam	UEI	17/10/2006	2.20	500	740500	118700	62400	12000	20700	5600	6200	4700	2900		-45.40	-35.23	-32.06	-32.74	-31.24
Energy Well	100/16-11-078-08 W6M	16-11-078-08 W6M	Charlie Lake Fm	1557.0 - 1562.5	Water Injection	SCV	AGAT	Matrix	Petrofund Energy Trust	23/09/2005	3.21	3800	843600	62600	35500	5700	8800	3000	2000	1200	900						
"	"	"	"	"	"	SCV	Maxxam/UofA	Lionhead	Northstar	22/09/2006	4.27	540	823600	63700	33200	5400	8100	2700	1900	1600	5300		-50.15	31.16	-27.56	-28.91	-27.79
"	"	"	"	"	"	SCV	Maxxam/UofA	Maxxam	Northstar	17/10/2006	1.90	600	855400	65600	34400	5600	8600	2900	2100	1500	1100		-50.34	31.21	-27.70	-29.42	-28.33
"	"	"	"	"	"	Production Casing	Maxxam/UofA	Maxxam	Northstar	17/10/2006	33.72	700	220000	68400	79400	17800	32100	12400	9900	9400	19500		-46.79	-35.00	-34.71	-31.64	-30.31
Energy Well	100/02-12-078-08 W6M	02-12-078-08 W6M	Charlie Lake Fm	1564.8 - 1566.2	Pumping oil	Production Casing	Maxxam/UofA	Lionhead	UEI	20/09/2006	2.95	440	815100	84800	37900	5800	9900	2500	2700	1000	4100		-45.52	-34.89	-34.16	-34.77	-32.72
"	"	"	"	"	"	Production Casing	Maxxam/UofA	Maxxam	UEI	18/10/2006	2.75	500	820900	87100	38400	5500	8800	2100	2200	1900	2200		-45.46	-35.27	-32.15	-32.92	-31.53
"	"	"	"	"	"	Production Casing	Zymax	Matrix	UEI	18/10/2006												-9.90	-45.40	-35.60	-31.80	-32.50	
"	"	"	"	"	"	SCV	GCHEM	GCHEM	Petrofund Energy Trust	11/05/2006			81318	1070	296.8	48.07	71.18	27.71	13.18								
Energy Well	100/06-12-078-08 W6M	06-12-078-08 W6M	Charlie Lake Fm	1570.0 - 1572.0	Water Injection	SCV	AGAT	Matrix	Petrofund Energy Trust	23/09/2005	0.18	2400	863300	71400	38200	6300	9500	2900	2000	1200	700						
"	"	"	"	"	"	SCV	Maxxam/UofA	Lionhead	Northstar	22/09/2005	5.05	670	808900	69200	35600	5900	9300	2900	2000	1100	540		-52.63	-33.01	-29.28	-30.07	-29.71
"	"	"	"	"	"	SCV	Maxxam/UofA	Maxxam	Northstar	17/10/2006	1.53	800	852000	70900	36400	5900	9200	3000	2100	1400	800		-49.95	31.36	-28.04	-28.95	-28.33
"	"	"	"	"	"	SCV	Zymax	Matrix	Northstar	17/10/2006												-24.00	-51.50	31.00	-27.00	-28.50	
"	"	"	"	"	"	Production Casing	Maxxam/UofA	Maxxam	Northstar	17/10/2006	35.93	100	229100	56300	85100	19100	36800	15500	13100	11700	14700		-65.30	-36.09	-32.91	-31.69	-28.79
"	"	"	"	"	"	SCV	GCHEM	GCHEM	Pertofund Energy Trust	12/05/2006			812821	72138	34673	5767	9048	2980	1349								
"	"	"	"	"	"	SCV	ARC, Veg/UofA	ARC	PennWest	19/03/2009	3.20	744	793000	70500	36300	7640	10700						-47.86	-30.98	-27.32	-28.21	-28.35
Energy Well	100/08-12-078-08 W6M	08-12-078-08 W6M	Charlie Lake Fm	1556.0 - 1557.5	Pumping oil	Production Casing	Maxxam/UofA	Lionhead	Northstar	22/09/2005	2.32	430	665100	131700	84100	16900	33000	10300	10500	90	480		-44.94	-35.42	-33.33	-33.67	-32.40
"	"	"	"	"	"	Production Casing	Maxxam/UofA	Maxxam	Northstar	19/10/2006	2.07	400	723200	140700	78300	11000	18300	2200	1500	500	100		-45.05	-35.55	-32.88	-33.28	-31.37
Energy Well	100/11-12-078-08 W6M	11-12-078-08 W6M	Charlie Lake Fm	1557.5 - 1601.5	Flowing Gas	SCV	AGAT	Matrix	Petrofund Energy Trust	23/09/2005	1.21	27200	859400	55200	29100	4700	7000	2200	1400	700	400						
"	"	"	"	"	"	SCV	Maxxam/UofA	Lionhead	Northstar	20/09/2006	0.09	60	873700	70900	35800	3300	8800	2700	1800	1000	920		-50.04	-30.86	-28.13	-28.00	
"	"	"	"	"	"	SCV	Maxxam/UofA	Maxxam	Northstar	17/10/2006	1.57	<100	853700	69300	36100	5900	9000	2900	2000	1400	1600		-50.15	-31.21	-27.67	-28.94	-28.34
"	"	"	"	"	"	Production Casing	Maxxam/UofA	Lionhead	Northstar	20/09/2006	36.35	90	336200	87200	83600	19900	40600	11700	11100	90	4200		-46.87	-35.53	-32.69	-33.56	-31.60
"	"	"	"	"	"	Production Casing	Maxxam/UofA	Maxxam	Northstar	17/10/2006	34.74	<100	349100	89200	91100	19800	39900	11100	10400	5600	3500		-47.21	-36.06	-32.93	-28.63	-33.22
Energy Well	PTF 11C-12-078-08W6	"	"	"	"	SCV	GCHEM	GCHEM	Petrofund Energy Trust	11/05/2006			662312	48344	22196	3476	5038	1432	553.1								
Energy Well	102/11-12-078-08 W6M	11-12-078-08 W6M	Charlie Lake Fm	1586.4 - 1588.4	Pumping oil	SCV	AGAT	Matrix	Petrofund Energy Trust	23/09/2005	0.09	400	876300	67000	34700	5800	8400	2600	1800	1000	900						
"	"	"	"	"	"	SCV	Maxxam/UofA	Lionhead	UEI	20/09/2006	17.01	140	687600	53400	26600	4200	6400	1900	1300	780	930		-49.68	-30.78	-28.40	-28.87	-28.50
"	"	"	"	"	"	SCV	Maxxam/UofA	Maxxam	UEI	17/10/2006	20.81	<100	646800	49400	24600	4000	6300	1900	1400	800	300		-51.21	-31.60	-27.47	-28.57	-27.61
"	"	"	"	"	"	SCV Duplicate	Maxxam/UofA	Maxxam	UEI	17/10/2006													-51.16	-31.42	-28.12	-29.31	-28.47
"	"	"	"	"	"	Production Casing	Maxxam/UofA	Lionhead	UEI	20/09/2006	3.12	170	561900	179700	121100	21400	38800	9300	9100	90	7300		-45.55	-35.04	-32.75	-32.57	-32.18
"	"	"	"	"	"	Production Casing	Maxxam/UofA	Maxxam	UEI	17/10/2006	1.69	<100	582800	192900	121300	19200	32900	8900	8100	7900	5600		-45.89	-35.09	-33.09	-33.32	-31.98
Energy Well	PTF 11D-12-078-08W6	"	"	"	"	SCV	GCHEM	GCHEM	Petrofund Energy Trust	11/05/2006			837484	72010	34694	5776	8826	2919	1280								
Energy Well	100/16-12-078-08 W6M	16-12-078-08 W6M	Charlie Lake Fm	1538.0 - 1540.3	Water Injection	SCV	AGAT	Matrix	Petrofund Energy Trust	23/09/2005	0.14	700	877500	62300	35500	6200	9400	2800	1900	1200	800						
"	"	"	"	"	"	SCV	Maxxam/UofA	Lionhead	Northstar	20/09/2006	2.65	100	847900	64100	34300	5800	8900	2500	1600	1000	500		-51.26	-31.08	-27.61	-27.99	-27.92
"	"	"	"	"	"	SCV	Maxxam/UofA	Maxxam	Northstar	17/10/2006	1.72	<100	876600	55400	29000	5100	8300	2700	1900	1100	600		-52.01	-31.31	-27.72	-28.98	-27.76
"	"	"	"	"	"	Production Casing	Maxxam/UofA	Lionhead	Northstar	20/09/2006	26.83	270	93500	3500	2500	1400	2200	1100	830	940	1200		-45.38	-33.06	-31.65	-30.06	-31.83
"	"	"	"	"	"	Production Casing	Maxxam/UofA	Maxxam	Northstar	17/10/2006	13.53	<100	72600	3000	2000	1700	3300	1900	1500	1500	1200		-44.74	-32.37	-32.18	-29.27	-29.68
"	"	"	"	"	"	Prod Casing Duplicate	Maxxam/UofA	Maxxam	Northstar	17/10/2006												-15.19	-43.24	-32.49	-31.23	-28.44	-27.92
Energy Well	100/02-13-078-08 W6M	02-13-078-08 W6M	Charlie Lake Fm	1536.0 - 1542.0	Pumping oil	SCV	AGAT	Matrix	Petrofund Energy Trust	18/01/2005	0.57	700	878200	66600	34400	5100	6400	1400	800	300	200						
"	"	"	"	"	"	SCV	AGAT	Matrix	Petrofund Energy Trust	23/09/2005	8.44	2600	786000	61800	35800	6500	9600	2700	1800	1000	400						
"	"	"	"	"	"	SCV	Maxxam/UofA	Lionhead	Trico	22/09/2005	12.35	190	742800	53700	28800	5200	7700	2000	1400	850	340		-51.85	-31.12	-27.99	-29.84	-28.51
"	"	"	"	"	"	Production Casing	Maxxam/UofA	Lionhead	Trico	22/09/2005	3.29	420	759000	103600	51400	9300	18000	5300	5300	40	4100		-45.07	-35.06	-32.47	-32.79	-31.35
"	"	"	"	"	"	Production Casing	Maxxam/UofA	Maxxam	Trico	17/10/2006	2.98	300	815800	92500	38600	5400	9100	2000	1700	800	800		-45.34	-35.68	-32.70	-33.10	-31.59
Energy Well	100/03-13-078-08 W6M	03-13-078-08 W6M	Charlie Lake Fm	1543.0 - 1546.0	Pumping oil	Production Casing	Maxxam/UofA	Lionhead	Northstar	22/09/2005	6.86	390	752500	91900	42200	7000	12600	3100	3000	30	5200		-45.28	-35.62	-33.14	-32.57	-31.86
"	"	"	"	"	"	Production Casing	Maxxam/UofA	Maxxam	Northstar	17/10/2006	3.28	400	765100	99500	49100	8600	16100	6500	12000	2600	1800		-45.24	-35.29	-32.23	-33.80	-31.93
Energy Well	100/04-13-078-08 W6M	04-13-078-08 W6M	Charlie Lake Fm	1544.7 - 1547.0	Flowing oil	Production Casing	Maxxam/UofA	Lionhead	UEI	22/09/2005	2.45	80	788800	109400	47500	7100	11700	2200	1800	680	500		-45.41	-35.68	-32.63	-32.67	-30.90
Energy Well	100/02-14-078-08 W6M	02-14-078-08 W6M	Charlie Lake Fm	directional	Pumping oil	Production Casing	Maxxam/UofA	Lionhead	Northstar	22/09/2005	4.46	510	745700	106800	51300	9600	16400	4300	4400	40	3100		-45.44	-35.02	-32.39	-32.80	-31.57
"	"	"	"	"	"	Production Casing	Maxxam/UofA	Maxxam	Northstar	17/10/2006	1.82	500	756300	113600	59800	10600	17500	5100	6100	5100	4500		-45.43	-35.51	-32.63	-31.61	-31.81
"	"	"	"	"	"	SCV	GCHEM	GCHEM	Petrofund Energy Trust	12/05/2006			10.37	0.583	3.1	0.06	0.16	0.15	0.07								
Energy Well	100/16-14-078-08 W4M	16-14-078-08 W4M	Charlie Lake Fm	1541.0-1544.0	Flowing oil	SCV	AGAT	Matrix	Petrofund Energy Trust	23/09/2005	1.25	800	902800	50500	19300	3000	5200	2000	1600	1000	800						
Energy Well	100/08-23-078-08 W6M	08-23-078-08 W6M	Gething Fm	1293.0-1297.5	Flowing gas	SCV	AGAT	Matrix	Petrofund Energy Trust	23/09/2005	2.17	7500	907700	37800	12700	2200	3900	1700	1400	1000	2300						

3.2 Energy Well Soil Gas Migration Sampling

The gas migration data are presented in Table 3, Figures 3 (bottom panel), 7 (bottom panel), 10 and 11 and relevant analytical reports are provided in Appendix B along with sample location maps. The original May 31, 2009 gas migration sampling by Lionhead Engineering was deemed invalid by the ERCB due to excessively moist soil conditions. This data is included in Table 3 for completeness but the values are shown in grey to indicate that they have been excluded from this analysis. Most of the energy wells had evidence of thermogenic gas migration near the wellhead. Gas concentrations decreased dramatically within about 4 m from the wellhead. The spatial and temporal variability in gas concentrations are likely related to sampling variability between companies, seasonal differences, soil moisture differences, and laboratory error.

The carbon isotope ratio of methane soil gas around the energy wells has a more enriched (more positive) isotope signature than the methane gas found in the Jack water well (-65.6‰ PDB) (Figures 3 and 7). The gas composition and isotopic signatures of soil gas sampled in the vicinity of 100/11-12-078-08 W6M have a thermogenic signature (Figure 3). Soil gas sampled in the vicinity of 100/06-12-078-08 W6M appears to reflect a mixture of thermogenic ethane with biogenic methane. The carbon isotope value of ethane from the gas migration study sampling conducted around 100/06-12-078-08 W6M is close (1 to 2 ‰ difference) to that found in the Jack water well (Figure 7 bottom panel).

Soil vapour samples in the vicinity of 100/06-12-078-08 W6M were also taken after the remedial cementing of the energy well on May 13, 2010, and September 22, 2010 (Figures 7 and 11 and Table 3). The May and September 2010 post-cementing samples revealed decreases in gas concentrations for most sampling points. Gas concentrations and isotope compositions for two post-cementing sampling visits are presented on Figure 11. Gas composition (but no isotope) data for an additional sampling point from the September 22, 2010 visit is included in Appendix B. Samples taken 0.3 m from the wellhead had methane concentrations that ranged from 64,900 ppm to 326,000 ppm pre-remedial cementing. Post-cementing gas samples taken 0.3 m from the well head ranged from 54,500 ppm on May 13, between 89,000 ppm and 117,400 ppm on September 22, 2010 and then decreased to 0% LEL on the November 11, 2010 visit. Some of the post-cementing $\delta^{13}C$ values for methane and ethane in soil gas showed a shift towards more negative values, consistent with a reduced presence of thermogenic gas. The gas migration tests performed on November 11, 2010 measured 0% LEL at the wellhead and all other measurement points in the field screening indicating that there is no longer any gas migration (Lionhead, 2010).

3.3 New Energy Well Gas Mudlog

A new energy well (located 5.6 km SE of the Jack water well) was drilled and completed at 100/02-04-078-07 W6M on October 30, 2009. Gas samples were collected to a depth of approximately 925 m (Spirit River Group). A summary of the gas composition and isotope data is presented in Table 4 and in Figure 12 (also included on Figure 7 and 9). Raw compositional and isotopic data is presented in Appendix C.

These new data provide better characterization of the isotopic signatures of the Cadotte Formation and show that the $\delta^{13}C$ of ethane in this unit ($\delta^{13}C$ = -29.3‰) is similar to the ethane gas found in the Jack water well (mean value $\delta^{13}C$ = -30.1 ‰) and the surface casing vents of several energy wells (Figure 7). These data are also consistent with a mud log from an energy well located approximately 65 km to the south (Muehlenbachs et. al. 2000). The method of identifying the source zone of a migrating gas using the gas compositions from mudlogs typically uses a match for ethane, propane and butane (see Rowe and Muehlenbachs, 1999). In the case of the Jack well, there was only a match for ethane. The only time propane was present in sufficient concentrations for isotope analyses was on the February 20, 2008 sampling visit. The $\delta^{13}C$ signatures for the four gas samples from the Jack water well taken during this visit (average $\delta^{13}C$= -23.66 ‰) were more positive (~7 ‰) than that in the Cadotte Formation $\delta^{13}C$ estimate obtained from the mudlog (average $\delta^{13}C$= -30.89 ‰). Butane was never present at high enough concentrations in the Jack well for isotopic analyses. The poor agreement between the propane isotope compositions could be due to analytical difficulties at low concentrations (propane was never greater than 100 ppm in gases from the Jack well). A match with multiple hydrocarbon isotopic signatures (e.g. ethane, and propane) between the gases measured in the Jack well and a geological unit would provide more certainty for the identification of a source depth.

3.4 Cement Integrity Investigations

The original neutron density log for energy well 100/6-12-078-08 W6M indicated gas was potentially entering from the Paddy (~850 mKb), the Shaftsbury (595 mKb), the Dunvegan (~500 mKb) and some thin gas bearing zones up hole. Following the request of the ERCB, new radial bond and neutron density logging was performed on January 19, 2010. Penn West decided to perform remedial cementing on the injector well at the same time. The remedial work consisted of cementing the perforations in the injection zone (Charlie Lake) and perforating and attempting a cement circulation to surface. The new radial bond logs collected for 100/06-12-078-08 W6M indicated that as of January 2010 the cement top is at 490 mKb. Previously the cement top for this well was at about 1000 m. There is still an uncemented interval between 298mKb to 490 mKb.

Surface casing vent flow tests performed by Hotwell Canada Ltd on May 13, 2010 and September 22, 2010 have found that there was no longer any vent flow measurable after the remedial cementing of the well. Gas migration tests performed on November 11, 2010 found 0% LEL in all of their soil measurements, indicating that gas migration is no longer occurring at this energy well (Lionhead, 2010).

3.5 Relationship Between Energy Well Activities and Gas in the Jack Water Well

The timing of major events (e.g. drilling, stimulation, acid treatments, remedial cement squeezes and water injection) in energy wells near the Jack water well was examined to see if they coincided with the changes to the Jack water well (appearance of sediment or gas). Figure 13 includes a Gantt chart summarizing these events, presented with manual water levels measured in the Jack well and total annual precipitation measured at the Spirit River meteorological station operated by Environment Canada (station # 3076069). The distance between the Jack water well and the energy well is noted in brackets on Figure 13.

The chronology of problems reported for the Jack water well was compiled using information from the ERCB database, AENV water well database and information supplied by Mr. Jack through his attorney (Mr. Ron Kruhlak) and presented in the report prepared by ARC in 2008. In the fall of 2005, Petrofund Energy Trust (now Penn West Energy Trust) initiated an investigation into a water well complaint by Mr. Jack regarding methane gas in his well. Mr. Jack indicated that the first change in his water well occurred on March 1, 2003 when sediment first appeared in his water. After pumping the well for about four weeks Mr. Jack observed gas started discharging from the well.

There are no energy well events that are coincident with the reported appearance of sediment and subsequent presence of gas in the Jack water well with the exception of an acid treatment of energy well 100/02-14-078-08 W6M. This energy well is located approximately 1370 m away, has no uncemented intervals and has no surface casing vent flow. There does not appear to be any relationship between water injection and the appearance of sediment and gas in the Jack water well (Figure 13). Water injection in the closest energy well (100/06-12-078-08 W6M) started about 10 months after gas was reported in the Jack water well. A hiatus in water injection in this well from September 2006 to May 2008 did not affect gas presence in the Jack water well.

Sometime in early 2009, before the site visit conducted by AITF on March 18, 2009, the behaviour of the Jack water well changed again in that the spontaneous gas eruptions stopped (personal communication with Mr. Jack). The disappearance of the eruptions occurred approximately 5 months after the tubing and packer on the injection tubing was replaced on energy well 100/06-12-078-08 W6M (August 8, 2008). This work should not have affected anything outside the production casing unless there was a hole in the production casing. Pressure testing conducted on this well on August 7, 2008 indicated that the production casing was not leaking at that time. There were water injections at a few nearby energy wells that started four to six months before the eruptions stopped (100/06-12-078-08 W6M, 100/16-11-078-08W6M, 100/16-12-078-08W6M, 100/06-07-078-07W6M).

Remedial cementing of energy well 100/06-12-078-08 W6M occurred in January, 2010 and there were a few changes in the Jack water well that occurred shortly after. After the cementing of the energy well the gas discharging to the water well decreased so that it was no longer measurable under both pumping and non-pumping conditions (rows labeled "Gas flow rate" in Table 6). The changes in behaviour observed during the pumping tests conducted before and after the remedial cementing are discussed in more detail in section 3.8.6. Linking changes in the amount of gas present in the water well with energy well activities during the period immediately before and after remedial cementing of 100/06-12-078-08 W6M is difficult because changes in static water levels that occurred during this interval would have also affected the solubility of gases in groundwater (Figure 13).

The water level history available for the Jack well (middle panel of Figure 13) was assembled using measurements reported in the original drillers report, a water level reported in the Matrix 2006 report, and measurements made by AITF during site visits made between 2008 and 2010. The water level time-series includes two prominent trends. The first is the decrease in water levels that occurred between 2001 and 2009. Between Nov. 2001 and March 2009 water levels in the well decreased by about 12.6 m. Interestingly, this decrease occurred even though regular usage of the well stopped in 2005, and was not used at all between February 2008 and March 2009 (Mr. Jack, personal communication). Between March 2009 and May 2010 water levels increased by 2.8 m. The decrease in water levels that occurred even when the well was not being pumped indicates a regional lowering of the water table, possibly due to changes in recharge or withdrawal by other users. Total annual precipitation amounts at the Spirit River meteorological station (Figure 13, bottom panel) show fairly consistent precipitation amounts, with the exception of the drought in 2005.

3.6 Lineament Study

The lineament study, covering Townships 73 to 88 and Range 2 to 13 W6M, was performed by J.D. Mollard and Associates Limited (2009). The main conclusions of the report were:

- The study area overlies a major geological structure referred to as the Peace River Arch. The Arch is a major structure in which the Precambrian granitic rocks are uplifted about 1000m and major faults cut the overlying sedimentary rocks.
- The Ft. St. Johns Grabben underlies the study area. Grabben faults extend to the base of the Triassic sedimentary rocks (deeper than all the energy wells), but late movement on the faults may have caused fracturing into the overlying sedimentary rock units.
- Bedrock in the Jack water well study area is characterized by fractures with dominant NW-SE and NE-SW orientations. A NW-SE lineament was identified through the Jack property.
- Correlation of dominant lineament and joint orientations with principal crustal stress directions suggest that bedrock fracture and/or fault systems may provide enhanced permeability pathways for the movement of fluids in the subsurface.

Table 3: Summary of gas migration data, new data are highlighted in yellow.

WELL ID	Pool or Zone	Depth Interval (m)	Status	Sample Location	Lab comp/isotope	Consultant	Sampling Date (d-m-y)	Nitrogen (%)	Carbon Dioxide (ppm)	Methane (ppm)	Ethane (ppm)	Propane (ppm)	I-Butane (ppm)	N-Butane (ppm)	I-C5 (ppm)	N-C5 (ppm)	C6 (ppm)	C7+ (ppm)	δ^{13}C CO_2 (‰)	δ^{13}C Methane (‰)	δ^{13}C Ethane (‰)	δ^{13}C Propane (‰)	δ^{13}C I-Butane (‰)	δ^{13}C N-Butane (‰)	Comment
100/14-01-078-08 W6M	Charlie Lake Fm	1592.0 - 1594.5	Pumping oil	Soil gas, 8 m	Maxxam/UofA	Lionhead	31/05/2009																		Wet soil conditions
				Soil gas, <1 m	Maxxam/UofA	Lionhead	16/07/2009	56.53	400	279300	1200	200	100	100	<100	<100	<100	<100	-27.62	-57.86	-35.52	-29.29	-29.44	-28.20	
100/02-12-078-08 W6M	Charlie Lake Fm	1564.8 - 1566.2	Pumping oil	Soil gas, <1 m, 1.1 m depth	GCHEM	GCHEM	11/05/2006			4218	134.3	131.2	71.37	145.1	115.9	61.55									
				"	GCHEM	GCHEM	19/05/2006			3162	152.3	137	61.56	117.8	125.5	111.6									
				Soil Gas, <1 m, 2.5 m depth	GCHEM	GCHEM	11/05/2006			40090	361.4	86.13	32.57	27.99	17.65	4.92									
				Soil Gas, background 30 m	GCHEM	GCHEM	11/05/2006			43.97	3.38	1.47	0.43	0.69	1.91	0.31									
				"	GCHEM	GCHEM	19/05/2006			9.95	0.52	0.59	0.31	0.79	1.15	1.11									
100/06-12-078-08 W6M	Charlie Lake Fm	1570.0 - 1572.0	Water Injection	Soil gas, <1 m, 1.1 m depth	GCHEM	GCHEM	12/05/2006			902585	7901	1175	135.7	81.38	32.19	7.44									
				"	GCHEM	GCHEM	19/05/2006			881436	7380	1215	135.4	81.96	30.19	10.8									
				Soil Gas, <1 m, 2.5 m depth	GCHEM	GCHEM	12/05/2006			575403	5131	803.1	103.8	64.01	0.08	7.25									
				Soil gas, background 100 m	GCHEM	GCHEM	12/05/2006			18.92	1.98	0.62	3.03	0.02	1.11	0.08									
				Soil gas, <1 m	Maxxam/UofA	Lionhead	16/07/2009	72.51	1400	73300	400	<100	<100	<100	<100	<100	<100	<100	-35.22	-54.90	-36.70	-30.78	-24.85	-25.68	
				Soil gas, 0.3 m (SVW-1)	ARC, Veg/UofA	Baseline	16/09/2009	55.20	8000	326000	2700	358	55.4	19.5					-44.87	-49.03	-32.51	-31.51	-31.30	-29.26	
				Soil gas, 0.3 m (SVW-2)	ARC, Veg/UofA	Baseline	16/09/2009	71.90	4000	64900	290	29.8	6.2	2.5					-25.75	-53.14	-31.90	-31.17			
				Soil gas, 2 m (SVW-6)	ARC, Veg/UofA	Baseline	16/09/2009	38.70	21000	580000	5750	9.2	11.4	0					-33.82	-49.04	-33.82				
				Soil gas, 20.5 m (SVW-15)	ARC, Veg/UofA	Baseline	16/09/2009	77.60	5000	2.1	0	0	0	0					-19.28						
				Soil gas, 0.3 m	Maxxam/UofA	Hotwell	13/05/2010	74.53	6200	54500	120	30	10	0	0	0	0	0	-47.35	-57.76					
				Soil gas, 2.0 m	Maxxam/UofA	Hotwell	13/05/2010	77.05	7200	23700	0	0	0	0	0	0	0	60	-49.73	-58.13	-36.62				
				Soil gas, 0.3 m NE of wellhead	Maxxam/UofA	Pennwest	22/09/2010	71.99	1600	89400	350	110	10	10	trace										
				Soil gas, 1.8 m NE of wellhead	Maxxam/UofA	Pennwest	22/09/2010	53.89	4000	317900	2500	110	30	10	10	trace			-36.14	-54.94	-36.07	-30.21	-28.64	-24.52	
				Soil gas, 0.3 m SE of wellhead	Maxxam/UofA	Pennwest	22/09/2010	70.31	3600	117400	450	120	10	10	trace				-40.49	-53.39	-37.93	-33.93	-31.33		
100/11-12-078-08 W6M	Charlie Lake Fm	1557.5 - 1601.5	Flowing Gas	Soil gas, <1 m	Maxxam/UofA	Lionhead	16/07/2009	74.04	28100	31300	1200	1300	400	800	600	700	1300	1900	-31.08	-52.48	-30.93	-30.35	-28.21	-28.15	
				Soil gas, 0.3 m (SVW-1)	ARC, Veg/UofA	Baseline	16/09/2009	78.2	9000	717	26.6	52.3	20.9	19.5					-28.73	-37.43	-25.26				
				Soil gas, 0.3 m (SVW-8)	ARC, Veg/UofA	Baseline	16/09/2009	79.6	27000	2540	1800	122	40.6	41.7					-31.84	-40.62	-27.35	-26.14	-27.03	-27.02	
				Soil gas, 0.3 m (SVW-8 dup)	ARC, Veg/UofA	Baseline	16/09/2009	77.4	22000	12700	982	552	114	115					-27.81	-40.62	-27.91	-25.9	-26.85	-26.61	
				Soil gas, 2 m (SVW-9)	ARC, Veg/UofA	Baseline	16/09/2009	78.5	2000	3.2	6	0.4	0.3	0.5					-16.98		-26.38				
				Soil gas, 21 m (SVW-15)	ARC, Veg/UofA	Baseline	16/09/2009	78.5	2000	5.6	0	0	0	0					-19.09						
PTF 11C-12-078-08W6	Charlie Lake Fm	1557.5 - 1601.5	Flowing Gas	Soil gas, <1 m, 1.1 m depth	GCHEM	GCHEM	11/05/2006			13840	967.4	540.2	98.88	150.6	73.22	29.9									
				Soil gas, <1 m, 2.5 m depth	GCHEM	GCHEM	11/05/2006			13912	417.9	169.5	23.17	34.92	27.63	9.73									
				Soil gas, background 100 m	GCHEM	GCHEM	11/05/2006			84.73	6.74	7.17	1.89	3.45	3.37	1.38									
PTF 11D-12-078-08W6	Charlie Lake Fm	1586.4 - 1588.4	Pumping oil	Soil gas, <1 m, 1.1 m depth	GCHEM	GCHEM	11/05/2006			6342	508.2	280.35	39.05	50.11	33.5	23.65									
				"	GCHEM	GCHEM	19/05/2006			16377	662.2	371.17	45.07	51.75	35.07	12.59									
				Soil Gas, <1 m, 2.5 m depth	GCHEM	GCHEM	11/05/2006			4127	282.5	151.65	21.9	33.12	17.07	11.95									
				"	GCHEM	GCHEM	19/05/2006			79314	237.2	889.15	67.69	99.24	37.89	18.72									
				Soil gas, background	GCHEM	GCHEM	11/05/2006			95.85	10.18	7.82	1.95	3.18	3.42	1.34									
				"	GCHEM	GCHEM	19/05/2006			84.73	6.74	7.17	1.89	3.45	3.37	1.38									
				Soil Gas, background 80 m	GCHEM	GCHEM	11/05/2006			2.4	0.07	0.13	0.04	0.01	0.53	1.55									
100/16-12-078-08 W6M	Charlie Lake Fm	1538.0 - 1540.3	Water Injection	Soil gas, 6 m	Maxxam/UofA	Lionhead	31/05/2009																		Wet soil conditions
				Soil gas, <1 m	Maxxam/UofA	Lionhead	16/07/2009	74.29	7400	44700	1100	600	100	200	100	100	<100	<100	-34.97	-56.14	-34.54	-27.66	-29.90	-29.39	
100/02-14-078-08 W6M	Charlie Lake Fm	directional	Pumping oil	Soil gas, < 1 m, 1.1 m depth	GCHEM	GCHEM	12/05/2006			238302	1952	270.4	29.48	17.45	6.88	1.66									
				"	GCHEM	GCHEM	19/05/2006			104217	778.2	106	21.04	7.91	5.12	1.59									
				Soil gas, <1 m	Maxxam/UofA	Lionhead	31/05/2009																		Wet soil conditions

Table 4: Summary of 100/02-04-078-07 W6M mud log data.

Sample Depth	Date sampled	CO_2 (ppm)	Total Gas (unit)	$\delta^{13}C\ C_1$	$\delta^{13}C\ C_2$	$\delta^{13}C\ C_3$	$\delta^{13}C$ i-C_4	$\delta^{13}C$ n-C_4	$\delta^{13}C\ CO_2$
340	28-Oct-09	131	1324	-56.78	-36.29	-32.02	-30.49	-33.44	-21.95
407	28-Oct-09	116	752	--	--	--	--	--	--
657	29-Oct-09	179	735	-55.18	-40.72	-38.40	-35.16	--	-18.40
734	29-Oct-09	98	444	-51.45	-35.00	-36.32	-28.88	-36.64	-12.20
844	29-Oct-09	115	705	-44.65	-28.11	-29.04	-30.49	--	-15.07
844 lab duplicate	29-Oct-09	115	705	-44.77	-28.22	-28.90	-29.23	-31.49	-15.57
871	29-Oct-09	111	607	-45.76	-29.37	-30.89	-29.31	-33.60	-29.13
920	29-Oct-09	--	442	-42.64	-29.01	-28.57	-27.99	-30.05	-11.74
925	29-Oct-09	--	846	-42.60	-28.91	-28.22	-28.05	-29.92	--

Table 5: Summary of uncemented intervals, surface casing vent flow and gas migration for energy wells within 1.5 km of the Jack water well.

WELL ID	Pool or Zone	Status	Uncemented Zones		SCVF	Possible source of SCVF	Gas Migration Outside Casing	Distance from Jack Well (m)
			Top (mKb)	Bottom (mKb)				
100/04-07-078-07 W6M	Charlie Lake Fm	Pumping oil	--	--	No	--	Not Tested	1712
100/14-01-078-08 W6M	Charlie Lake Fm	Pumping oil	290.0	543.0	**Yes**	Cadotte	**Yes**	720
100/16-01-078-08 W6M	Charlie Lake Fm	Pumping oil	283.9	400.0	No	--	Not Tested	1390
102/16-01-078-08 W6M	Charlie Lake Fm	Flowing oil	--	--	No	--	Not Tested	1408
100/16-02-078-08 W6M	Charlie Lake Fm	Abandoned	304.0	429.0	No	--	Not Tested	870
100/08-11-078-08 W6M	Charlie Lake Fm	Pumping oil	222.0	240.0	No	--	No	501
100/15-11-078-08 W6M	Charlie Lake Fm	Pumping oil	--	--	No	--	Not Tested	1246
100/16-11-078-08 W6M	Charlie Lake Fm	Water Injection	223.0	335.0	**Yes**	Cadotte	Not Tested	972
100/02-12-078-08 W6M	Charlie Lake Fm	Pumping oil	--	--	No	--	No	825
100/06-12-078-08 W6M	Charlie Lake Fm	Water Injection	298.0	[1]1000.0	**Yes**	Cadotte	**Yes**	429
100/08-12-078-08 W6M	Charlie Lake Fm	Pumping oil	--	--	No	--	Not Tested	1132
100/11-12-078-08 W6M	Charlie Lake Fm	Flowing Gas	252.0	745.0	**Yes**	Cadotte	**Yes**	795
102/11-12-078-08 W6M	Charlie Lake Fm	Pumping oil	--	--	**Yes**	Cadotte	No	774
100/16-12-078-08 W6M	Charlie Lake Fm	Water Injection	224.6	840.0	**Yes**	Cadotte	**Yes**	1438
100/02-13-078-08 W6M	Charlie Lake Fm	Pumping oil	--	--	**Yes**	Cadotte	Not Tested	1593
100/03-13-078-08 W6M	Charlie Lake Fm	Pumping oil	--	--	No	--	Not Tested	1417
100/02-14-078-08 W6M	Charlie Lake Fm	Pumping oil	--	--	No	--	Yes	1370

[1] Note: In January 2010, 100/06-12-078-08 W6M underwent remedial cementing work which brought the top of cement to 490 mkB.

3.7 Pressure Build-up Test

A pressure build-up test was performed to evaluate whether a direct connection existed between energy well 100/06-12-078-08 W6M and Mr. Jack's water well. The surface casing vent was closed on the energy well and pressure was allowed to build up. Water levels and gas flow from the casing of the Jack water well were monitored during the test. Figure 14 presents the surface casing vent pressure data along with the water level in the Jack water well prior and during the same time period.

Water levels in the Jack water well remained fairly constant during the buildup test in 100/06-12-078-08 W6M. It is important to note that fluctuations of up to about 1 cm may arise from instrumental drift and any minor effect of gas bubbling in the water column during non-pumping conditions. Note also that variations in water level of up to 5 cm are attributed to shifts in barometric pressure of the atmosphere. The Jack water well did not explosively erupt from the casing during the duration of the test and gas flow rates were too low to measure with the configuration of the gas flow meter. There does not appear to be a direct relationship between pressure build-up in the surface casing vent of 100/06-12-078-08 W6M and water levels in the Jack water well over the 24 hour test and pressures reached.

3.8 Jack Water Well Testing Pre- and Post- Remedial Cementing of 100/06-12-078-

3.8.1 Pre-Remedial Cementing of 100/06-12-078-08 W6M *(September 26, 2009)*

The pumping test data for the September 26, 2009 test is presented in Figure 15. For the pre-remedial cementing test, the Jack water well was pumped at a rate of 8.75 to 9 Igpm. The pumping rate declined slightly (by about 0.25 Igpm) over the test as a result of declining water levels in the water well and a greater head of water the pump was required to lift. After about 3 hours and 35 minutes of pumping, when the water level in the water well had been drawn down by approximately 2.66 m (30.54 m below Top of Casing; TOC) the water well started to erupt with gas (observed at the water well). The pressure head measured with the transducer became variable (by about 1 m) after this time, due to eruption of the gas from the casing and changes in the density of water above the transducer. Gas flow rates (red symbols on Figure 15) were not available until after the sensor on the gas flow meter was repaired on September 27, 2009. Instantaneous gas flow rates (recorded every 10 seconds) from the casing show a fairly regular pattern of gas eruption (at a rate of up to 7.5 cfm) for 80 to 90 seconds, followed by 30 or 40 seconds of rest. Near the end of the pumping portion of the test, the water had drawn down about 6.0 m (similar to the February 18, 2008 pumping test performed by ARC) and the well eruptions lasted for up to almost 4 minutes. The amount of gas exsolving from the pumped water was estimated to be 800 ml of gas per minute of pumping.

When the pump stopped, the water well immediately stopped degassing, and gas flow rates dropped below the detection limit of the instrument (about 0.035 cfm or 1 L/min). Recovery of the water well was monitored until 6:00 a.m. on September 28, 2009. The transducer was left in the Jack water well to record water levels every 15 minutes.

3.8.2 First Post- Remedial Cementing of 100/06-12-078-08 W6M (January 29, 2010)

The pumping test data for the January 29, 2010 test is presented in Figure 16. For the first post-remedial cementing test the Jack water well was pumped at a rate of 7.3 to 5.8 Igpm. Even though the same pump was used, the initial pumping rate was lower than in the pre-remedial cementing test because (at the request of Mr. Jack) about 100 m of discharge pipe was used to divert the water away from farming operations. This extra discharge pipe added friction and reduced the pumping rate. The pumping rate dropped by about 1.5 Igpm over the duration of the test. This was due to loss of pump efficiency when gas started exsolving from the water. After about 6 hours and 30 minutes of pumping, the pressure head measurements started to become variable due to gas exsolving from the water due to pressure head drop. The variability is about 20 cm, much less than the previous September 26, 2009 test. The water level in the water well was drawn down approximately 2.3 m at this time to a depth of about 29.63 m below TOC. There was no casing gas flow detected by the gas flow meter. The amount of gas exsolving from the pumped water was estimated to be 100 ml of gas per minute of pumping.

When the pump stopped, the gas flow rate remained below the detection limit of the instrument. Recovery of the water well was monitored until 1:05 p.m. on January 31, 2010. A transducer was left in the Jack water well to record water levels every 15 minutes.

3.8.3 Second Post- Remedial Cementing of 100/06-12-078-08 W6M (February 27, 2010)

The pumping test data for the February 27, 2010 test is presented in Figure 17. For the second post-remedial cementing test the Jack water well was pumped at a rate of 6.6 to 5.1 Igpm. Even though the same pump and discharge line was used, the initial pumping rate was lower than in the first post-remedial cementing test. The installed pump seems to be getting weaker with each additional test. The pumping rate dropped by about 1.5 Igpm over the duration of the test. This was due to loss of pump efficiency when gas started exsolving from the water. After about 6 hours and 30 minutes of pumping, the pressure head measurements started to become variable due to gas exsolving from the water due to pressure head drop and from pump cavitation. The variability is about 95 cm, which is similar to September 26, 2009 test. The water level in the water well was drawn down approximately 2.5 m at this time, to a depth of about 29.62 m below TOC. There was no casing gas flow detected by the gas flow meter or using a plastic bag over the gas vent on the well. Bubbling could be heard but with little to no gas produced. The amount of gas exsolving from the pumped water was estimated to be 100 ml of gas per minute of pumping in the first 7 hours of pumping. After 24 hours the exsolved gas was estimated to be about 50 ml per minute using the inverted bottle technique. The inverted bottle technique is a simple method for sampling free gas in groundwater that can also be used to estimate gas volumes. Using this technique groundwater is directed into an inverted bottle submersed in a water-filled pail. The gas displaces water in the inverted bottle, accumulating in the headspace.

When the pump stopped, the gas flow rate remained below the detection limit of the instrument. Recovery of the water well was monitored until 12:35 p.m. on March 1, 2010. A transducer was left in the Jack water well to record water levels every 15 minutes.

3.8.4 Third Post-Remedial Cementing of 100/06-12-078-08 W6M (May 22, 2010)

The pumping test data for the May 22, 2010 test is presented in Figure 18. For the third post-remedial cementing test the Jack water well was pumped at a rate of 7.75 to 6.7 Igpm. Even though the same pump and discharge line was used, the initial pumping rate was higher than in the first post-remedial cementing test. The pumping rate dropped by about 1.05 Igpm over the duration of the test. This was due to an increase in head and maybe some loss of pump efficiency when gas started exsolving from the water. After about 8 hours and 30 minutes of pumping, the pressure head measurements started to become variable due to gas exsolving from the water due to pressure head drop and from pump cavitation. The variability is about 3 cm, which is about 3% of the variation of the September 26, 2009 test. The water level in the water well was drawn down approximately 3.6 m at this time, to a depth of about 30.18 m below TOC. There was no casing gas flow detected by the gas flow meter or by using a plastic bag over the gas vent on the well. Bubbling could be heard but with little to no gas produced. The amount of gas exsolving from the pumped water in the first few minutes of pumping was estimated to be 140 ml of gas per minute using the inverted bottle technique, (300 ml per minute with the gas separator). After 6 hours of pumping the inverted bottle technique measured 460 ml of gas (800 ml of gas were measure in the gas separator over the same time period). After 24 hours the exsolved gas was estimated to be about 120 ml per minute using the inverted bottle technique while the gas separator still measured about 800 ml per minute of free gas production.

When the pump stopped, the gas flow rate remained below the detection limit of the flow meter. Recovery of the water well was monitored until 9:00 pm on May 23, 2010.

The aquifer test data was analyzed 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 raw data and graphical solutions are included in Appendix D.

The Theis (1935) confined aquifer solution was used to solve both the pumping test and the recovery test for the pumping tests performed on September 26, 2009, January 29, 2010 and February 27, 2010 (Table 7). A pumping recovery test was performed on the Jack well when it was drilled in November 19, 2001. The 2001 recovery data was used to solve the recovery portion of the pumping test (information on pumping rate was not available) giving a transmissivity in the range of 1.05 $\times 10^{-3}$ m^2/min to 9.79 $\times 10^{-3}$ m^2/min (ARC, 2008). A pumping test performed on February 18, 2008 gave apparent transmissivity estimates ranging between 1.65×10^{-3} m^2/min to 3.28×10^{-3} m^2/min (2.4 to 4.7 m^2/day) (ARC, 2008).

Table 6: Changes in Jack water well behaviour over time

		Pumping tests Conducted Pre-Remedial Cementing of 6-12				Pumping tests Conducted Post-Remedial Cementing of 6-12		
		November 19, 2001	February 20, 2008	March 18, 2009	September 24, 2009	January 29, 2010	February 27, 2010	May 22, 2010
Non-Pumping Behaviour	Depth to static water level	16.27 m (from TOC)	26.75 m (from TOC)	29.38 m (from TOC)	27.88 m (from TOC)	27.33 m (from TOC)	27.12 m (from TOC)	26.58 m (from TOC)
	Gas flow rate	NA	Constant flow of ~60 L/min Mr. Jack measured 100 cf/min during eruption	Constant flow of ~5 L/min	Constant flow of ~5 L/min	None detected	None detected	None detected
	Gas eruption frequency	NA	Every 5-10 min	None since Jan. 19, 2009	None	None	None	None
	Gas location	NA	Casing (top slot in liner), small amount exsolved from water	NA	Casing (top slot in liner)	No gas	No gas	No gas
Pumping Behaviour	Relation to pumping	NA	Immediate eruptive degassing, that stopped when pumping stopped	NA	Pumped for 3 hours before eruptive degassing started, stopped when pumping stopped	No eruptive degassing even after pumping, exsolution of gas after 6.5 h of pumping	No eruptive degassing after pumping, exsolution of gas after 6.5 h of pumping	No eruptive degassing after pumping, exsolution of gas after 11 h of pumping
	Relation to water level	NA		NA	2.66 m drawdown before eruptive degassing	No eruptive degassing, exsolution after 2.3 m drawdown	No eruptive degassing, exsolution after 2.5 m drawdown	No eruptive degassing, exsolution after 3.6 m drawdown
	Water depth when eruptive degassing began				30.54 m TOC	No degassing, water level drawn down to 29.63 m TOC	No degassing, water level drawn down to 29.62 m TOC	No degassing, water level drawn down to 30.18 TOC
	Gas flow rate	NA	Mr. Jack measured 100cf/min during eruption	NA	~5 L/min	Below detection of flow meter	Below detection of flow meter	Below detection of flow meter
	Gas eruption frequency	NA	Constant	NA	Gas pulse every 50 sec	None	None	None
	Gas location	NA	Majority from casing (top slot in liner), small amount exsolved from water	NA	Majority from casing (~800 mL/min exsolved from water)	None from casing, <100 mL/min exsolved from water	None from casing, <100 mL/min exsolved from water	None from casing, <100 mL/min exsolved from water

Table 7: Summary of pumping test results

Date		Transmissivity (m^2/min)
Pre-remedial cementing of 100/06-12-078-08 W6M	November 19, 2001	1.05 x 10^{-3} to 9.79 x 10^{-3}
	February 18, 2009	1.65 x 10^{-3} to 3.28 x 10^{-3}
	September 26, 2009	1.46 x 10^{-3} to 2.73 x 10^{-3}
Post-remedial cementing of 100/06-12-078-08 W6M	January 29, 2010	2.91 x 10^{-3} to 3.32 x 10^{-3}
	February 27, 2010	4.21 x 10^{-3} to 4.70 x 10^{-3}

The post-remedial cementing transmissivity estimates are within the range estimated from the original recovery test performed in 2001. As was noted in previous report (ARC, 2008) the transmissivity estimates are generally higher than is normally found in shale and sandstone, possibly due to the presence of fractures in the aquifer. There is a slight increasing trend in the estimates of transmissivity, but this could be due to a decrease in gas surging during the pumping tests, allowing for a more representative estimate to be made.

3.8.5 Changes in Behavior of the Jack Well Pre- and Post-Remedial Cementing

The idea behind conducting pumping tests before and after remedial cementing of the energy well at 100/06-12-078-08 W6M was to see if there were any changes in behaviour of the water well after remedial cementing of the energy well. The tests were conducted over a 9 month period, a period when the water level in the Jack well was rising (1.3 m between the September 24, 2009 pumping test and the May 22, 2010 pumping tests). The rise in water levels combined with decreased pump efficiency due to increased discharge pipe length meant that the pumping tests performed after remedial cementing were not drawn down to the same water level as the pre-remedial cementing pumping test (pre-remedial cementing pumping test water levels were drawn down to 30.58 m below TOC, post-remedial cementing pumping test water levels did not go below 30.18 m below TOC). The lack of eruptive degassing during pumping for the post-remedial cementing pumping tests may be the result of not having attained the same degree of drawdown in those tests.

There were changes in the non-pumping gas flow rate before and after remedial cementing of 100/06-12-078-08 W6M. There are three measurements of gas flow rates available for the Jack water well prior to the remedial cementing. On February 20, 2008 Mr. Jack reported a constant gas flow of about 60 L/min, and on March 18, 2009 and September 24, 2009 AITF personal measured a constant gas flow of about 5 L/min prior to pumping. After the remedial cementing of the energy well gas flow rates were measured before each of the three pumping tests, but gas flow could not be detected by the gas flow meter. The 5 L/min of gas discharge were measured when the static water level in the Jack well was lower (27.88 m below TOC) than after the remedial cementing (27.33 m below TOC).

Without more frequent records of water levels, gas discharge and usage for the Jack water well, it is hard to evaluate the causes of the changes in the behaviour of the well, and to separate changes that may have been due to energy well activity versus those due to water level changes. Our best estimates of when gas eruptions first appeared (2003) and disappeared (2009) are based on anecdotal sources, and there are only a couple of water level measurements made during this period and no information on water usage.

Based on the limited gas flow and manual water level measurements available it appears that there was still constant gas discharge and spontaneous degassing during periods when the water levels were higher than present, indicating that the changes in the form and amount of gas present in the well cannot be entirely due to changes in water level. For example during the pumping test conducted in Feb. 2008 the pre-pumping water level was 26.75 m below TOC yet there was still a large volume of gas discharging before pumping and the well was spontaneously erupting. During the pumping test conducted on September 24, 2009 there was a constant flow of gas measurable at about 5 L/min when the static water level was 27.88m below TOC. The post remedial cementing pumping test conducted on January 29, 2010 even when the water levels were drawn down to 29.63 m below TOC there was no measurable gas flow (Table 6). Changes in the amount of gases present in the groundwater combined with changes in the solubility of those gases due to pressure changes could result in the variable relationship between water levels and gas discharge volumes observed for the Jack water well.

4 CONCLUSIONS

Alberta Innovates - Technology Futures' review of new investigations regarding the Jack water well complaint provides the following conclusions:

- The composition and $\delta^{13}C$ values of the hydrocarbon gases sampled in the Jack well are consistent with a mixture of biogenic and thermogenic sources.
    - The $\delta^{13}C$ of methane is within the range expected for predominantly biogenic methane. The concentrations and isotopic compositions of ethane and propane in gases sampled from the Jack water well are consistent with a component of thermogenic gas.
    - The isotopic signature of ethane in the Jack well is similar to that found in the Cadotte Formation and in SCV from 100/06-12-078-08 W6M and 100/11-12-078-08 W6M.
    - The $\delta^{13}C$ value measured for propane in the Jack well is similar to the propane $\delta^{13}C$ measured in the production casing from 100/11-18-078-07 W6M, a water source well completed across the Cadotte formation.
    - The more negative $\delta^{13}C$ composition of methane sampled in the Jack water well after remedial cementing of energy well 100/06-12-078-08 W6M could indicate a decrease in the thermogenic component of methane to this well. This single post-remedial cementing sample is within the range of $\delta^{13}C$ variability measured in water samples prior to the remedial cementing and it was analyzed at a different laboratory, so repeat sampling and submission of a duplicate and standard are included in the recommendations.

- New carbon isotope sampling of the surface casing vent of 100/06-12-078-08 W6M found an isotopic enrichment trend over a four year period that may be a natural fractionation process in the energy well.
- Gas migration studies confirm that gas migration to surface was occurring near the energy well bores at 100/11-12-078-08 W6M and 100/06-12-078-08 W6M. The gas and isotopic compositions of soil gas sampled in the vicinity of 100/11-12-078-08 W6M has a thermogenic signature. Soil gas sampled in the vicinity of 100/06-12-078-08 W6M appears to be a mixture of thermogenic and biogenic sources of hydrocarbon gases. After remedial cementing was conducted at 100/06-12-078-08 W6M repeated gas migration tests showed decreasing concentration of methane and ethane in soil gas, eventually reaching 0% LEL by the November 11, 2010 test. The $\delta^{13}C$ of methane in soil gas samples from the vicinity of this well became more negative, consistent with less of a contribution of thermogenic methane. It appears that leakage in the form of gas migration has ceased.
- A gas isotope mudlog from a new energy well drilled at 100/02-04-078-07 W6M (located 5.6 km SE of the Jack water well) provides an improved dataset to characterize the isotopic signature of gases from different formations in the area. The $\delta^{13}C$ composition of ethane gas sampled in the Jack well and surface casing vent from energy wells in the area is within 1 ‰ of the mud sampled from the Cadotte Formation suggesting that this formation could be the source of gas. The propane $\delta^{13}C$ of the Cadotte Formation did not match the limited propane dataset available for the Jack well.
- The results of the lineament study did not find any evidence of a direct connection between the Jack water well and any of the adjacent energy wells. However, the study did indicate that the study area is part of the Peace River Arch, an area that contains numerous faults and that fractures or fault systems may be pathways for the movement of fluids and gases.
- However, better knowledge of background gas concentrations in shallow groundwater and isotopic compositions and the regional gas characteristics from the Cadotte Formation and other geological formations would improve our ability to identify the source of the gases reaching the Jack well. Even if the gases present in the Jack water well can be linked to specific geological units, the presence of fractures and fault networks in the area will make it difficult to determine the pathways for gases to shallow aquifers. Better characterization of background shallow groundwater gas concentrations and isotopic compositions would help determine if there is a component of thermogenic gases naturally present in shallow groundwater in this region due to the fractured nature of the underlying geological units.
- Water levels compiled from manual measurements made in 2001, 2006, 2008, 2009 and 2010 show a general trend of decreasing levels between 2001 and late 2008 (decrease of 12.6 m over time period), followed by an increasing trend that seems to have started in late 2008 or early 2009 (increase of 2.3 m over that time period). The causes for the observed changes in water level are not clear.

- A lot of the activities summarized in this report were directed towards identifying whether the energy well located at 100/06-12-078-08 W6M could be the source of gases to the Jack well. The $\delta^{13}C$ signature of ethane sampled in the Jack well is similar to the $\delta^{13}C$ of ethane sampled from SCV at 100/06-12-078-08 W6M and soil gases sampled as part of the gas migration study, but other than the similarity in isotopic signature, there was no evidence of a direct connection between the two wells.
    - Water injection at 100/06-12-078-08 W6M started 10 months after gas first appeared in the Jack well, indicating that injection was not likely the cause of gas in the water well.
    - The pressure build-up test of the surface casing vent of 100/06-12-078-08 W6M indicates there is no direct connection between the surface casing vent in 100/06-12-078-08 W6M and the Jack water well over the pressures and time period tested.
    - The new cement bond and neutron density log of energy well 100/06-12-078-08 W6M indicate that as of January 2010 the cement top is at 490 mKb, so the uncemented portion of this well is from 298 to 490 mKb. The remedial cementing work conducted in January 2010 appears to have stopped the SCVF as indicated by bubble tests performed in May 2010 and September 2010 and gas migration tests performed in November 2010.
    - The isotopic results for 100/06-12-078-08 W6M seem to indicate a common source for the ethane in the SCV and soil gas from this energy well and the Jack well, but not necessarily a direct connection.
- There have been changes in the occurrence and frequency of eruptive degassing, the volume of gas discharging from the well and the form of the gas present in the well (free gas vs. dissolved gas).
    - Spontaneous degassing apparently stopped shortly before March 2009, more than 9 months before the remedial cementing of 100/06-12-078-08 W6M.
    - After remedial cementing of 100/06-12-078-08 W6M the amount of free gas discharging from the water well decreased, but the amount of dissolved methane in the well water increased. The increase in dissolved gases could be in part due to increasing water levels, with higher pressure heads resulting in higher concentrations of dissolved methane.
    - Prior to remedial cementing of the energy well at 100/06-12-078-08 W6M there was a measurable discharge of gas under non-pumping conditions, whereas on the three visits to the well post-remedial cementing no flow was detected. Over this time period static water levels in the Jack well increased from 27.88 m below the top of casing (TOC) on September, 24, 2009 to 26.58 m below TOC on May 22, 2010. This change in the amount of gas discharging under non-pumping conditions may have been influenced by the increases in water levels.
- These changes in the amount and form (free or dissolved) of gas in the Jack well may be due to differences in the solubility of methane in groundwater due to increases in pressure head as water levels rise. However, these changes would not significantly

affect the isotopic signature of the gas. Because the series of pumping test occurred over a period when there appears to have been a general increase in water levels it is not possible to separate changes related to remedial cementing of the energy well from changes related to the increase in water level with the data currently available.

- Pumping tests conducted on the Jack well before and after the remedial cementing of energy well 100/06-12-078-08 W6M have found no significant changes in aquifer transmissivity estimates. Transmissivity estimates have remained within an order of magnitude of the original estimates.

5 RECOMMENDATIONS

Alberta Innovates - Technology Futures' review of new investigations regarding the Jack water well complaint provides the following recommendations:

- If the Jack water well is to be used, the water well should be equipped in a manner such that there is no explosion potential.
- The Jack water well had a heavy bacterial presence (slime, sulfur reducing, heterotrophic and iron reducing bacteria) measured on February 20, 2008 (ARC 2008). This water well should be maintained with regular shock chlorination and may need cleaning by a water well professional.
- The Jack water well should not be over-pumped. Its yield is fairly unique in the immediate area and the water well likely could not easily be replaced. The water well has been used in the past to fill a dugout on the property. The volume of the small dugout on the Jack property is about 1250 m^3. The Jack's currently have permission to divert a total of 2386 m3/yr. (1136 m^3/yr., license for stock watering purposes; 1250 m3/yr., household purposes). A safe pumping rate for this water well was calculated to be about 3 imperial gallons per minute (ARC, 2008). Filling the dugout over a short period of time or multiple times a year would likely over-pump the water well and aquifer.
- The pump-tests conducted post-remedial cementing did not reach the same level of drawn down as the pre-remedial cementing test and the results relating to the amount of gas present in the well are therefore not directly comparable. We recommend that a pumping test be conducted with a stronger pump and a long enough duration to reach at least the same levels of drawdown (30.8 m below TOC) to see if gases are still discharging. Gas and water samples taken during the pumping test, combined with detailed monitoring of gas flow volumes and water levels will give better insight into the sources of gas as the well is drawn down.

- Resampling of the Jack water well to obtain gas and water samples for geochemical and isotopic analyses is recommended. The gas samples will be submitted to the AITF laboratory in Victoria, and the isotope laboratories at the University of Calgary and the University of Alberta. A methane standard gas sample will also be submitted to all laboratories. This repeat sampling will confirm whether the isotopic shift in the methane $\delta^{13}C$ composition measured is real and will allow us to see if the methane $\delta^{13}C$ values measured by the two laboratories are directly comparable.

Further recommendations will be developed once the new pump test and sampling results have been evaluated.

6 CLOSURE

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

Respectfully submitted,

S Jean B

Jean Birks, Ph.D.

PROFESSIONAL GEOLOGIST ALBERTA
JOHN GIBSON
15 Feb 2011

Dr. John J. Gibson, Ph.D., P.Geo., P.Geol.
Program Leader
Oil Sands and Mining Water Management Program

February 15, 2011
Alberta Innovates - Technology Futures

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Figure 1: Site map and energy well locations

Figure 2: Stratigraphic column for the Northwestern Plains and Deep Basin

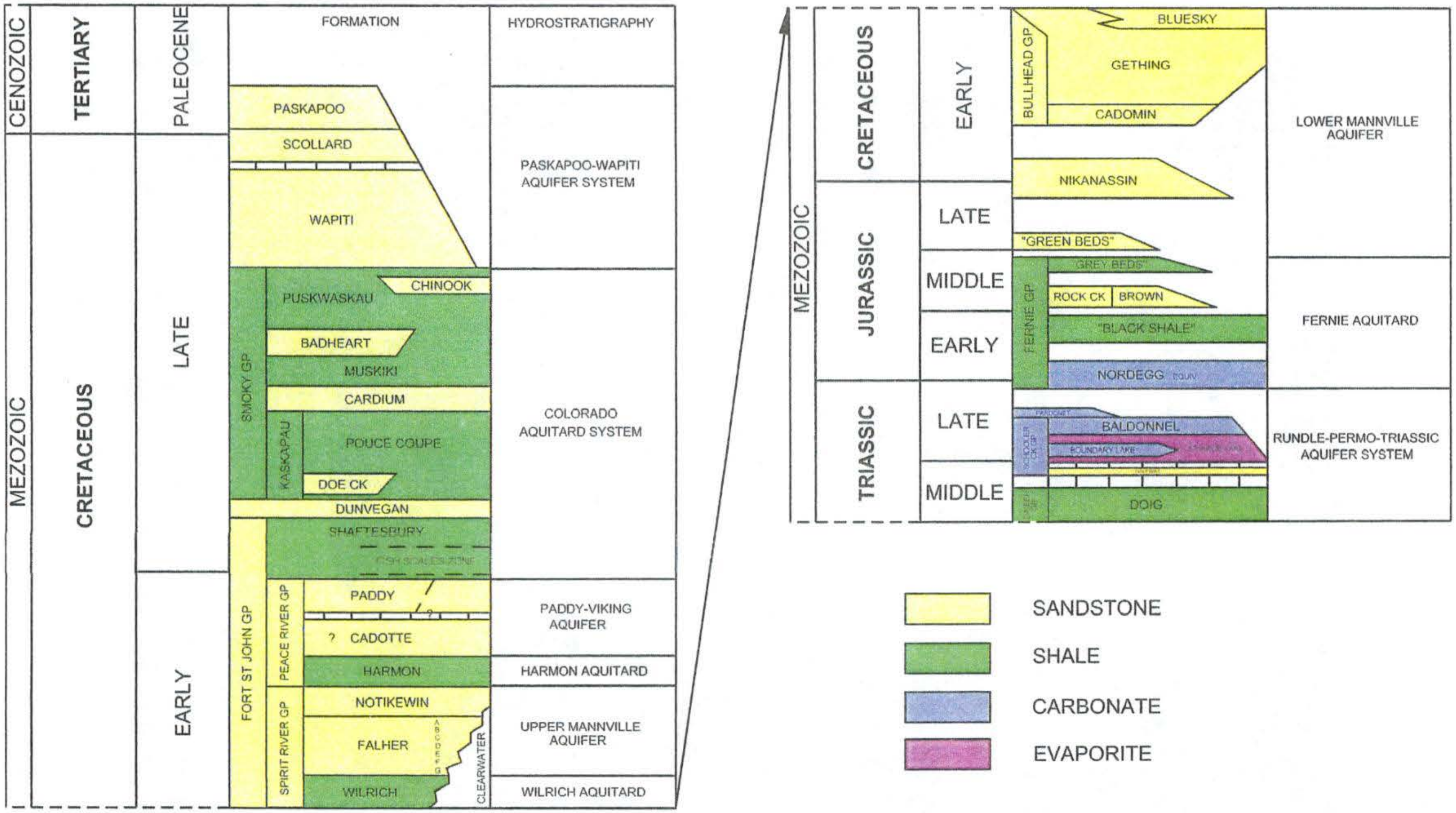


Figure 3: Summary of isotope data from ARC, 2008 (solid symbols) and new data (open symbols) top panel showing water and energy wells, bottom panel showing soil gas samples.

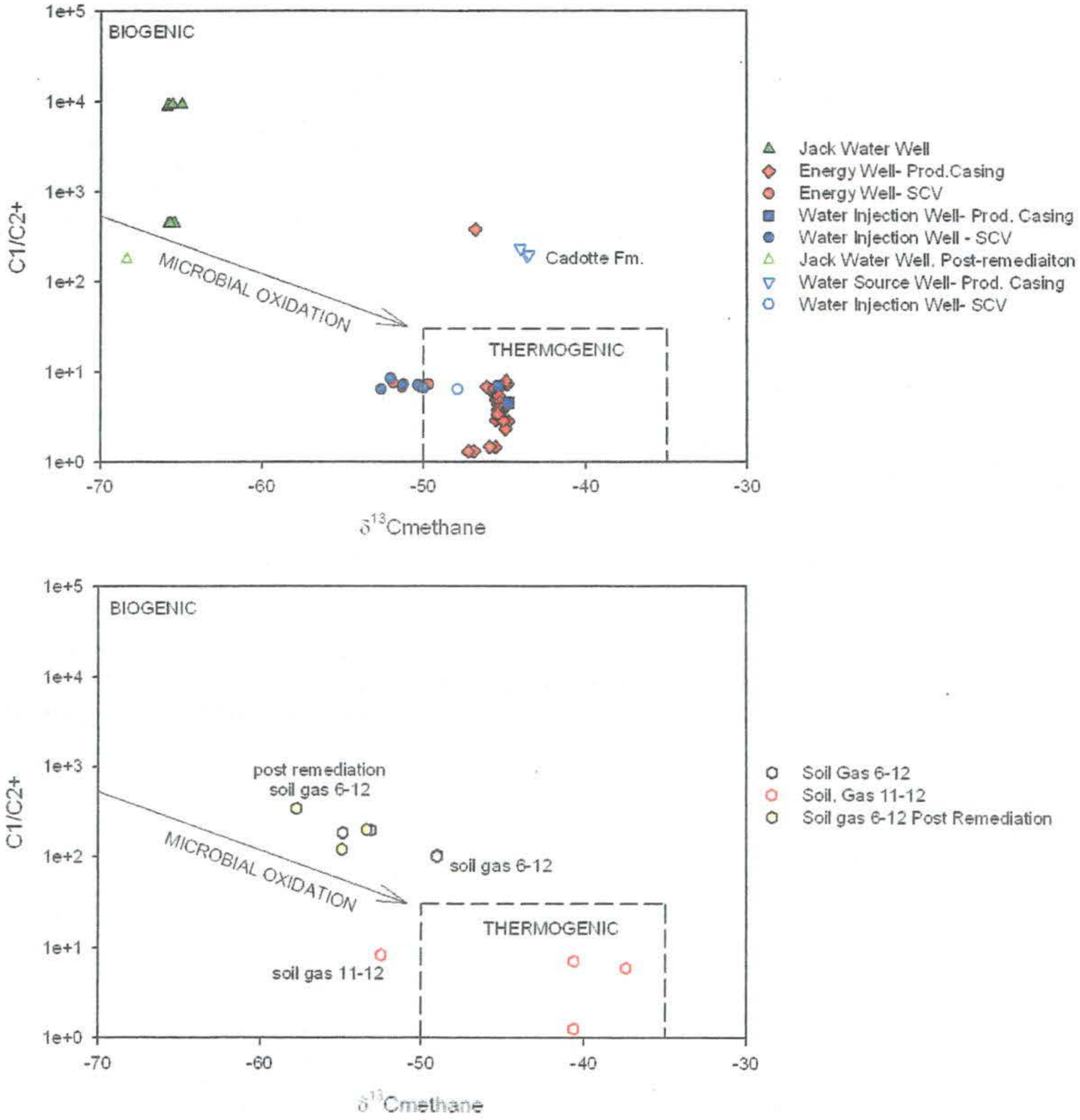


Figure 4: Methane and ethane concentrations measured in water and energy wells.

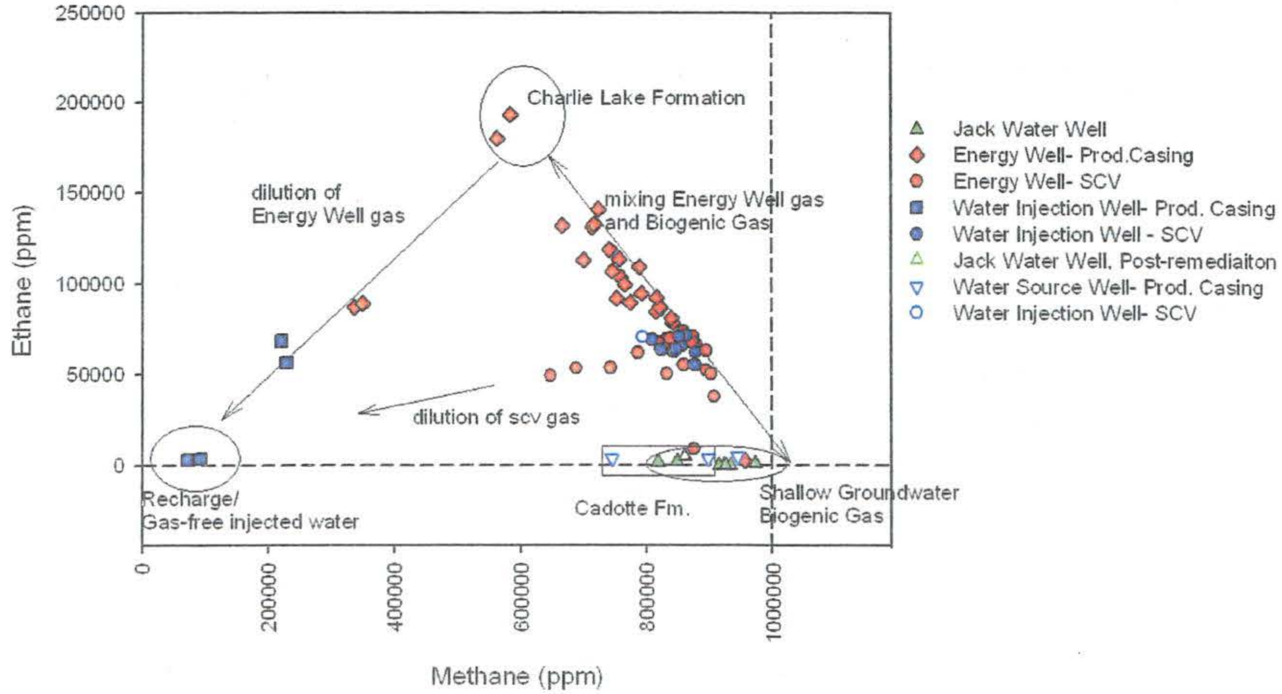


Figure 5: Summary of isotope data from ARC, 2008 (solid symbols) and new data (open symbols). Average values for the composition of shallow groundwater in Central Alberta, the Horseshoe Canyon/Belly River Group and Manville Formations from Cheung et al. (2010) are included.

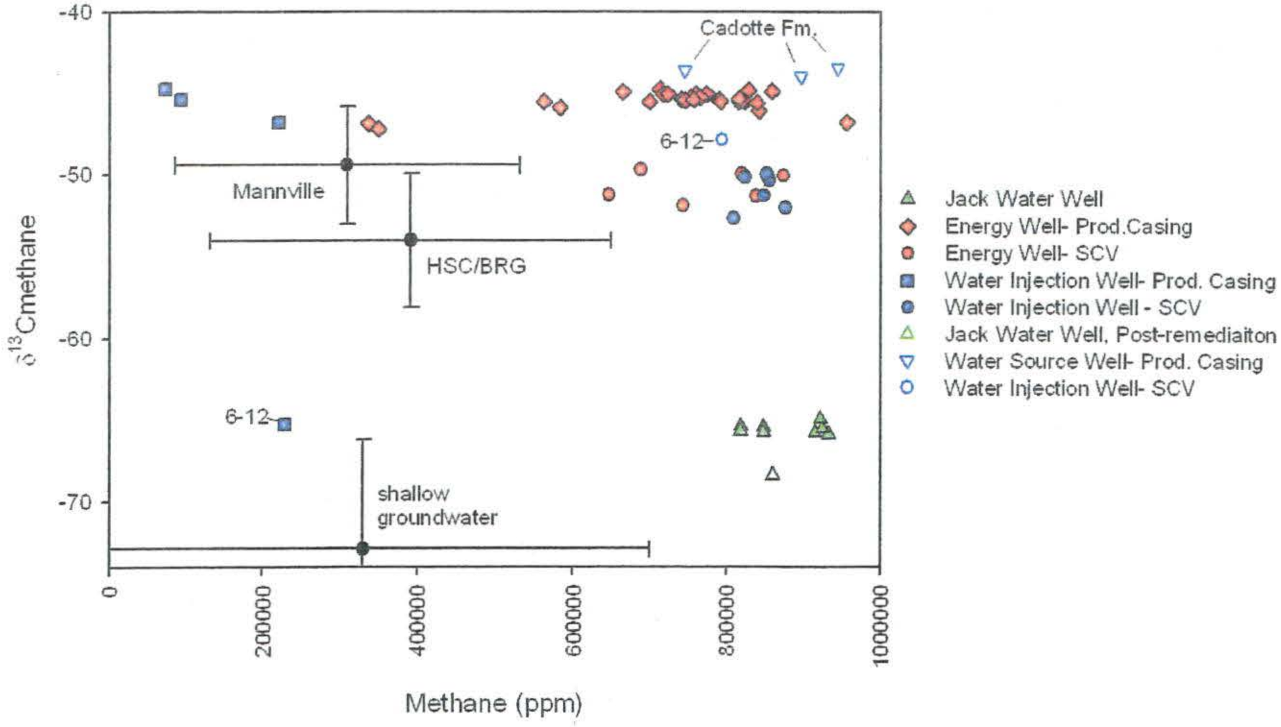


Figure 6: Summary of isotope data from ARC, 2008 (solid symbols) and new data (open symbols. Average values for the composition of shallow groundwater in Central Alberta, the Horseshoe Canyon/Belly River Group and Manville Formations from Cheung et al. (2010) are included.

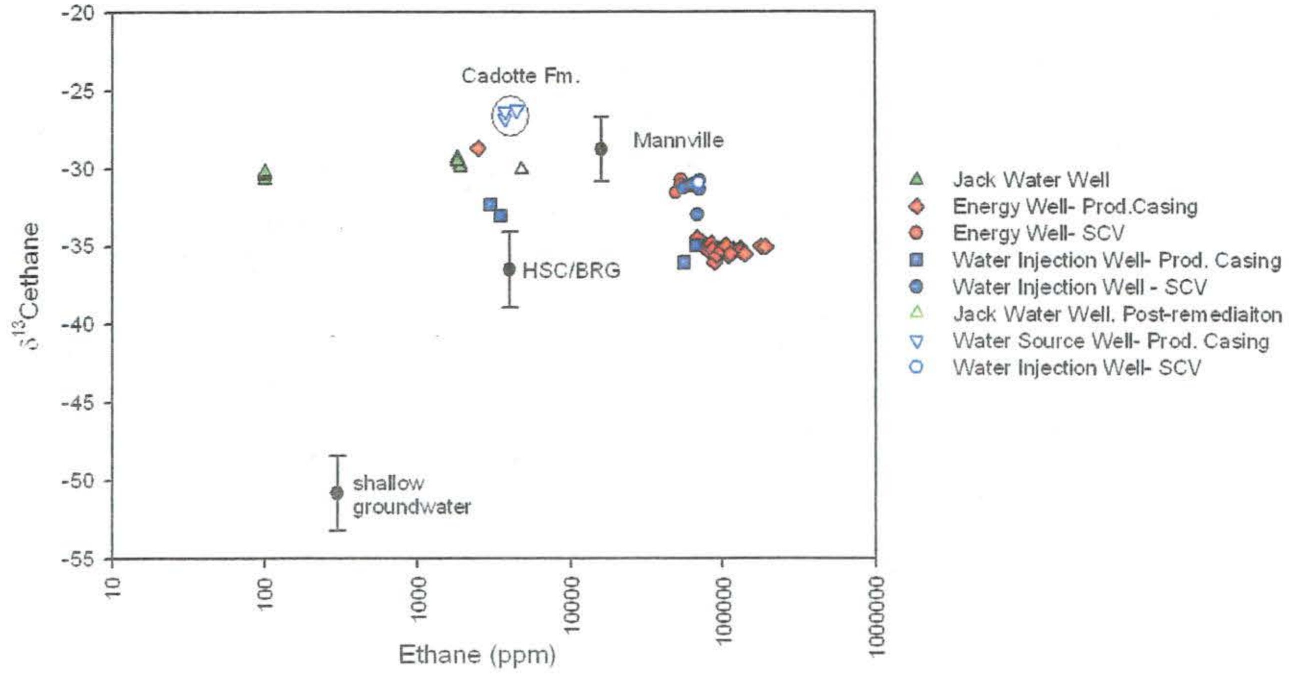


Figure 7: Methane and ethane carbon isotope compositions of the Jack water well, energy well gases and the mudlog (top panel) and samples from the soil gas migration study (bottom panel). Average values for the composition of shallow groundwater in Central Alberta, the Horseshoe Canyon/Belly River Group and Manville Formations from Cheung et al. (2010) are included.

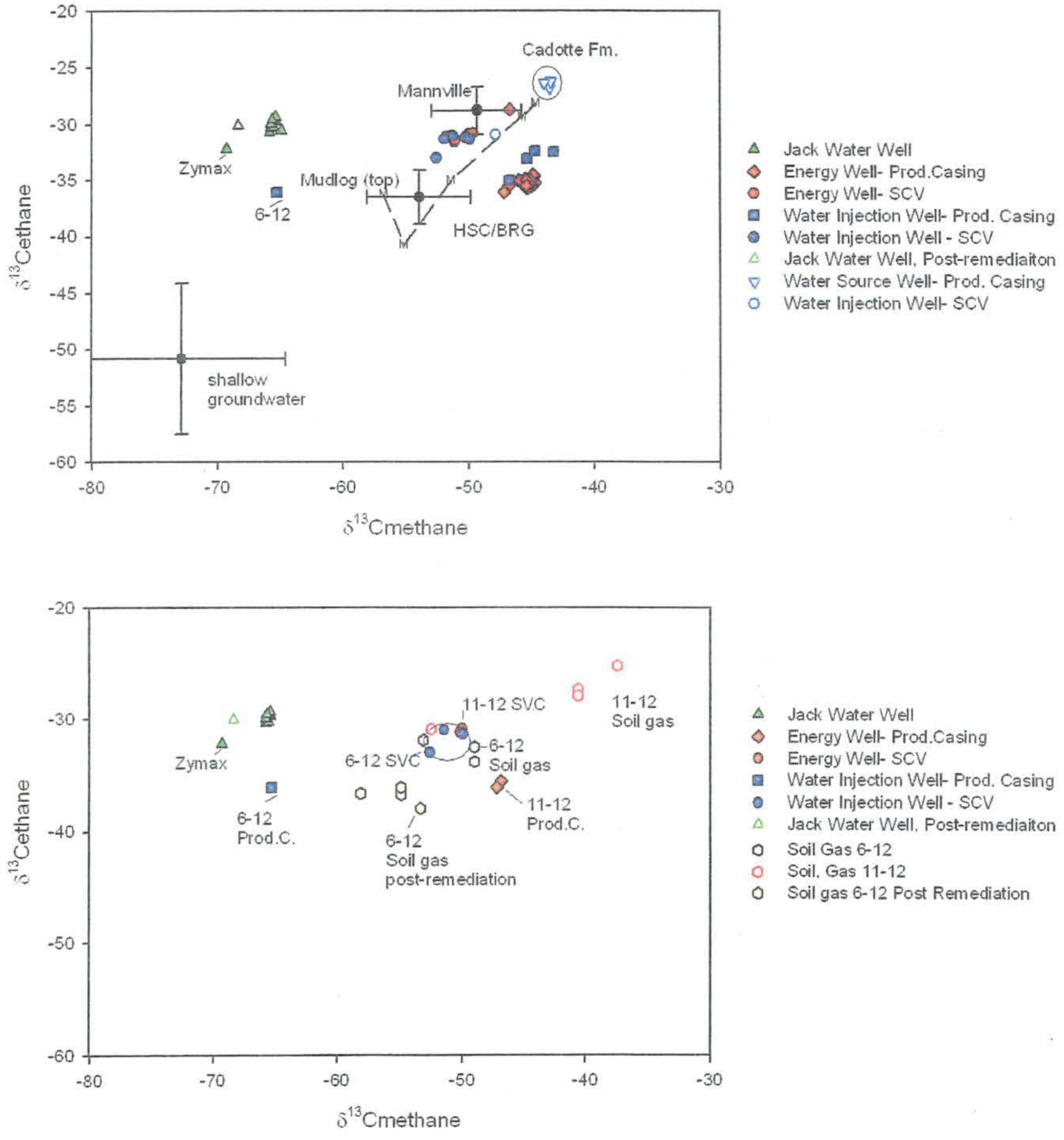


Figure 8: Carbon isotope values of hydrocarbon gases with time for Jack Water well and 100/06-12-078-08 W6M surface casing vent.

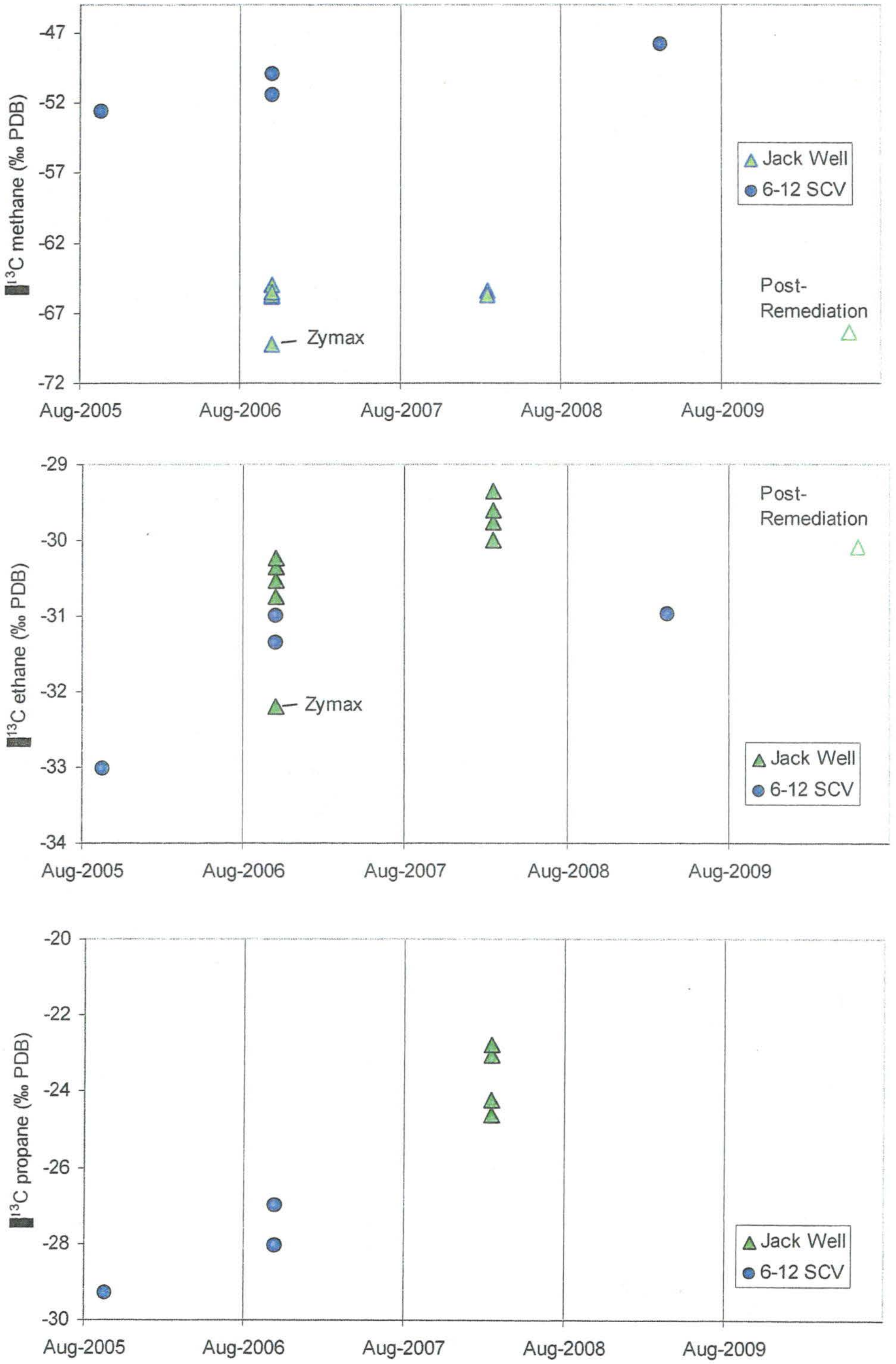


Figure 9: Carbon isotope values of hydrocarbon gases in the Jack Water well and surrounding energy wells.

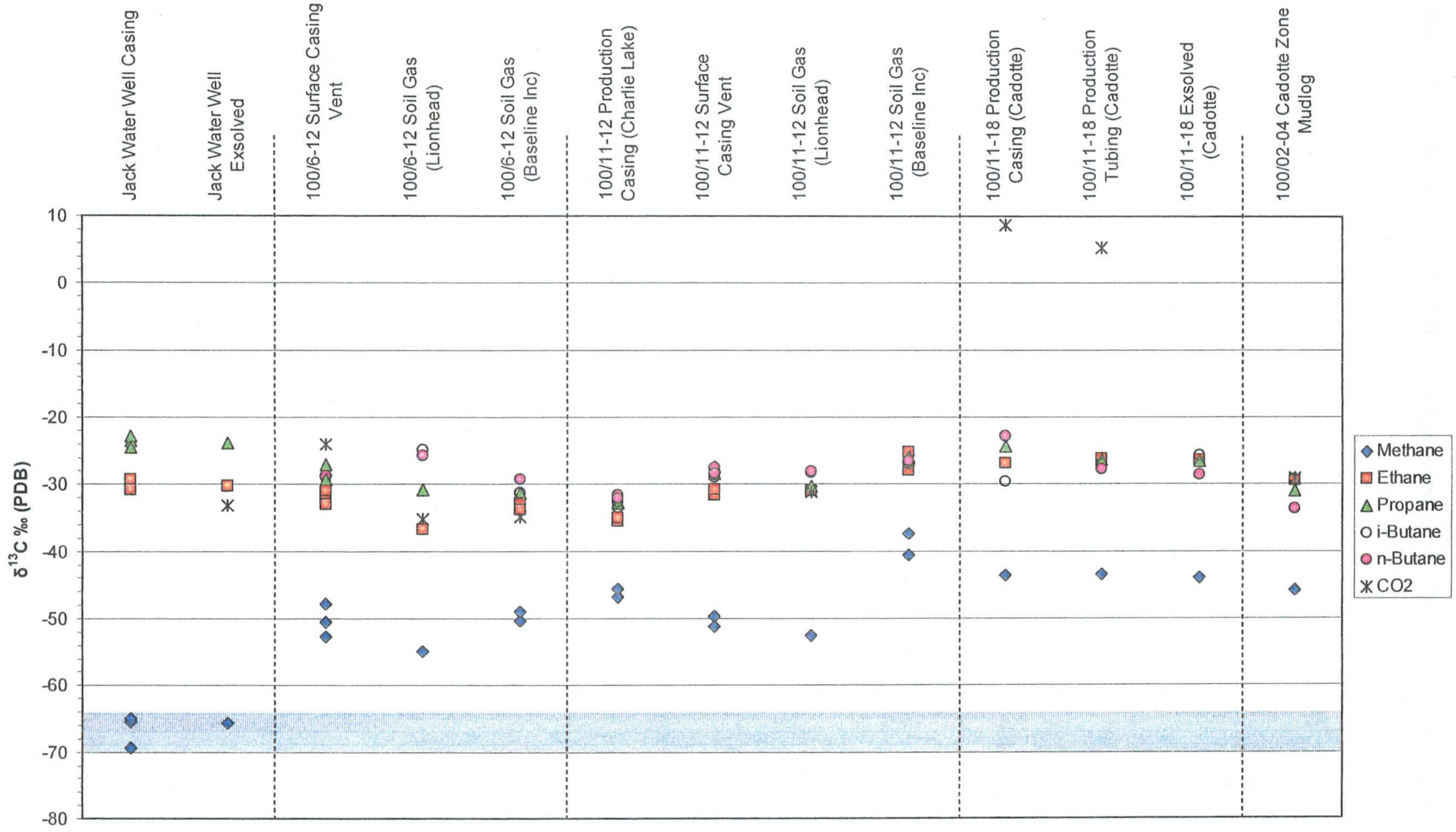
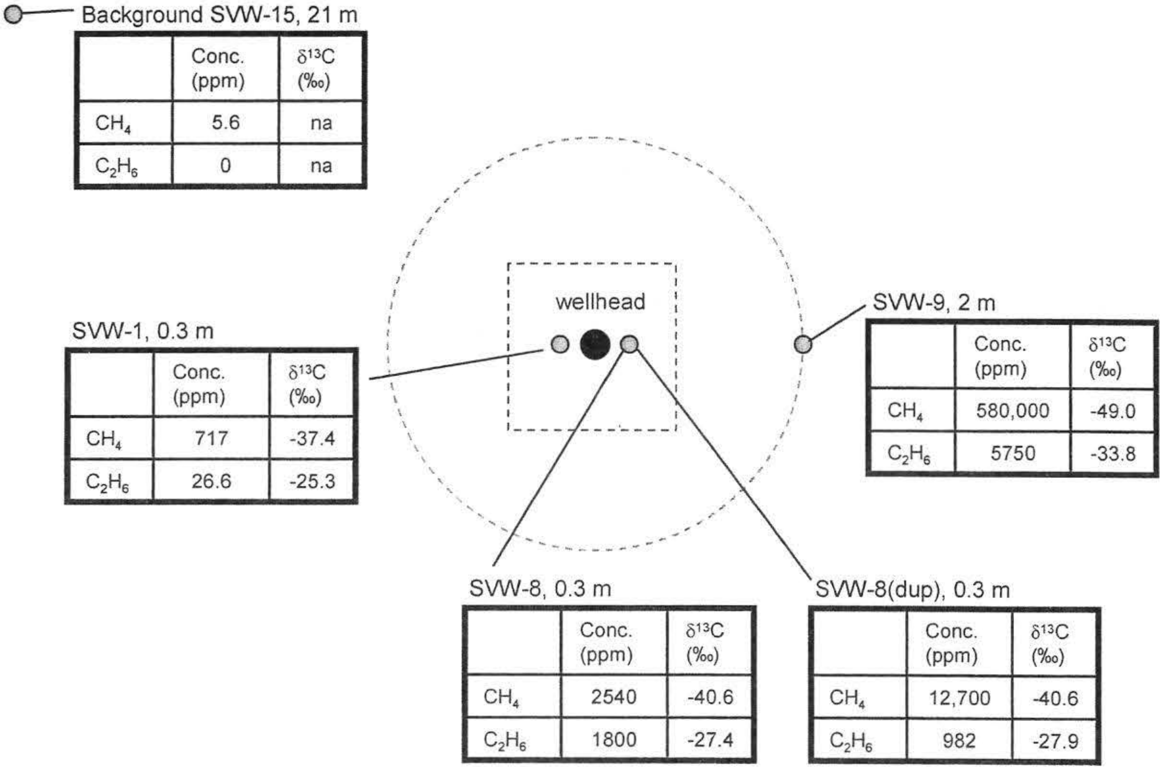


Figure 10: Soil migration study results for 100/11-12-078-08.

100/11-12-078-08 (Sept. 16, 2009)



Background SVW-15, 21 m

	Conc. (ppm)	δ13C (‰)
CH_4	5.6	na
C_2H_6	0	na

SVW-1, 0.3 m

	Conc. (ppm)	δ13C (‰)
CH_4	717	-37.4
C_2H_6	26.6	-25.3

SVW-9, 2 m

	Conc. (ppm)	δ13C (‰)
CH_4	580,000	-49.0
C_2H_6	5750	-33.8

SVW-8, 0.3 m

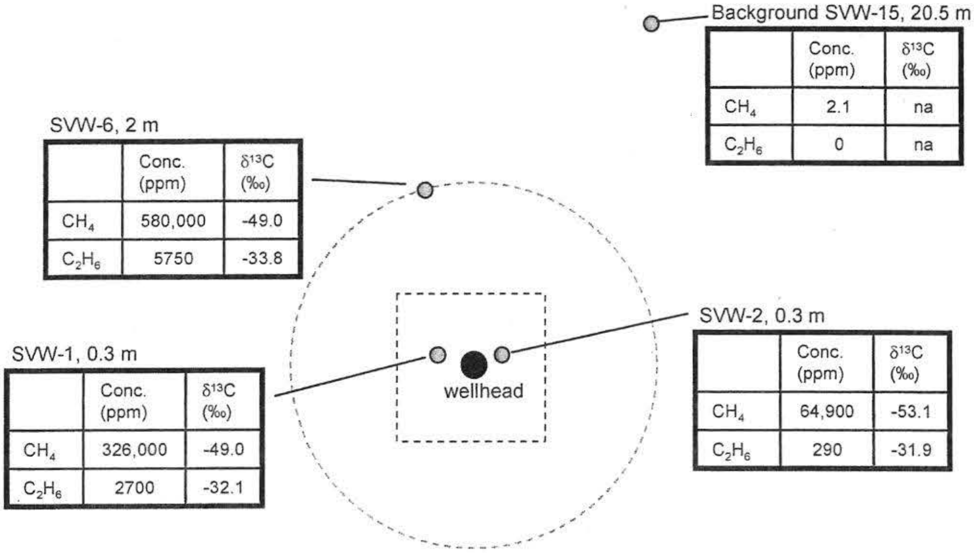
	Conc. (ppm)	δ13C (‰)
CH_4	2540	-40.6
C_2H_6	1800	-27.4

SVW-8(dup), 0.3 m

	Conc. (ppm)	δ13C (‰)
CH_4	12,700	-40.6
C_2H_6	982	-27.9

Figure 11: Soil migration study results for 100/06-12-078-08.

100/06-12-078-08 Pre-Remediation (Sept. 16, 2009)



Background SVW-15, 20.5 m

	Conc. (ppm)	δ¹³C (‰)
CH_4	2.1	na
C_2H_6	0	na

SVW-6, 2 m

	Conc. (ppm)	δ¹³C (‰)
CH_4	580,000	-49.0
C_2H_6	5750	-33.8

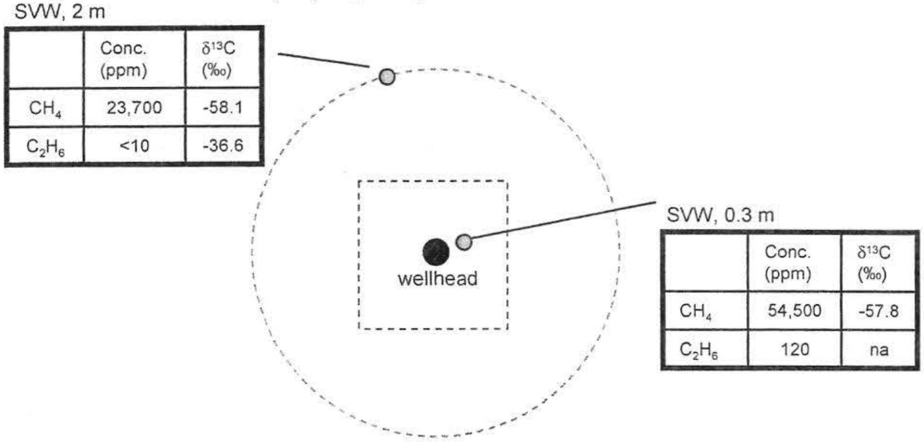
SVW-2, 0.3 m

	Conc. (ppm)	δ¹³C (‰)
CH_4	64,900	-53.1
C_2H_6	290	-31.9

SVW-1, 0.3 m

	Conc. (ppm)	δ¹³C (‰)
CH_4	326,000	-49.0
C_2H_6	2700	-32.1

100/06-12-078-08 Post-Remediation (May 13, 2010)



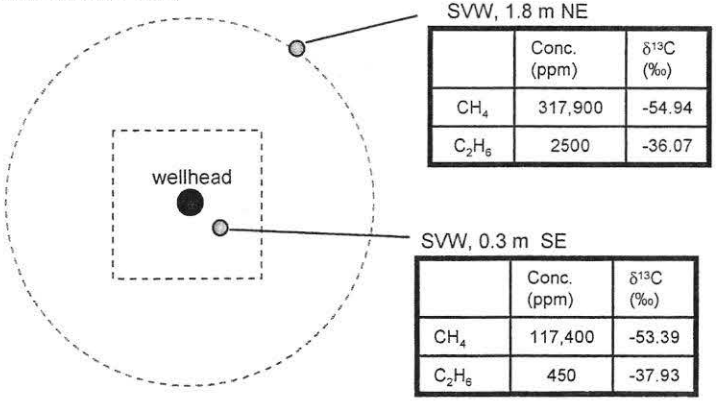
SVW, 2 m

	Conc. (ppm)	δ¹³C (‰)
CH_4	23,700	-58.1
C_2H_6	<10	-36.6

SVW, 0.3 m

	Conc. (ppm)	δ¹³C (‰)
CH_4	54,500	-57.8
C_2H_6	120	na

100/06-12-078-08 Post-Remediation (Sept.22, 2010)



SVW, 1.8 m NE

	Conc. (ppm)	δ¹³C (‰)
CH_4	317,900	-54.94
C_2H_6	2500	-36.07

SVW, 0.3 m SE

	Conc. (ppm)	δ¹³C (‰)
CH_4	117,400	-53.39
C_2H_6	450	-37.93

Figure 12: Carbon isotope mudlog of 100/02-04-078-07 W6M.

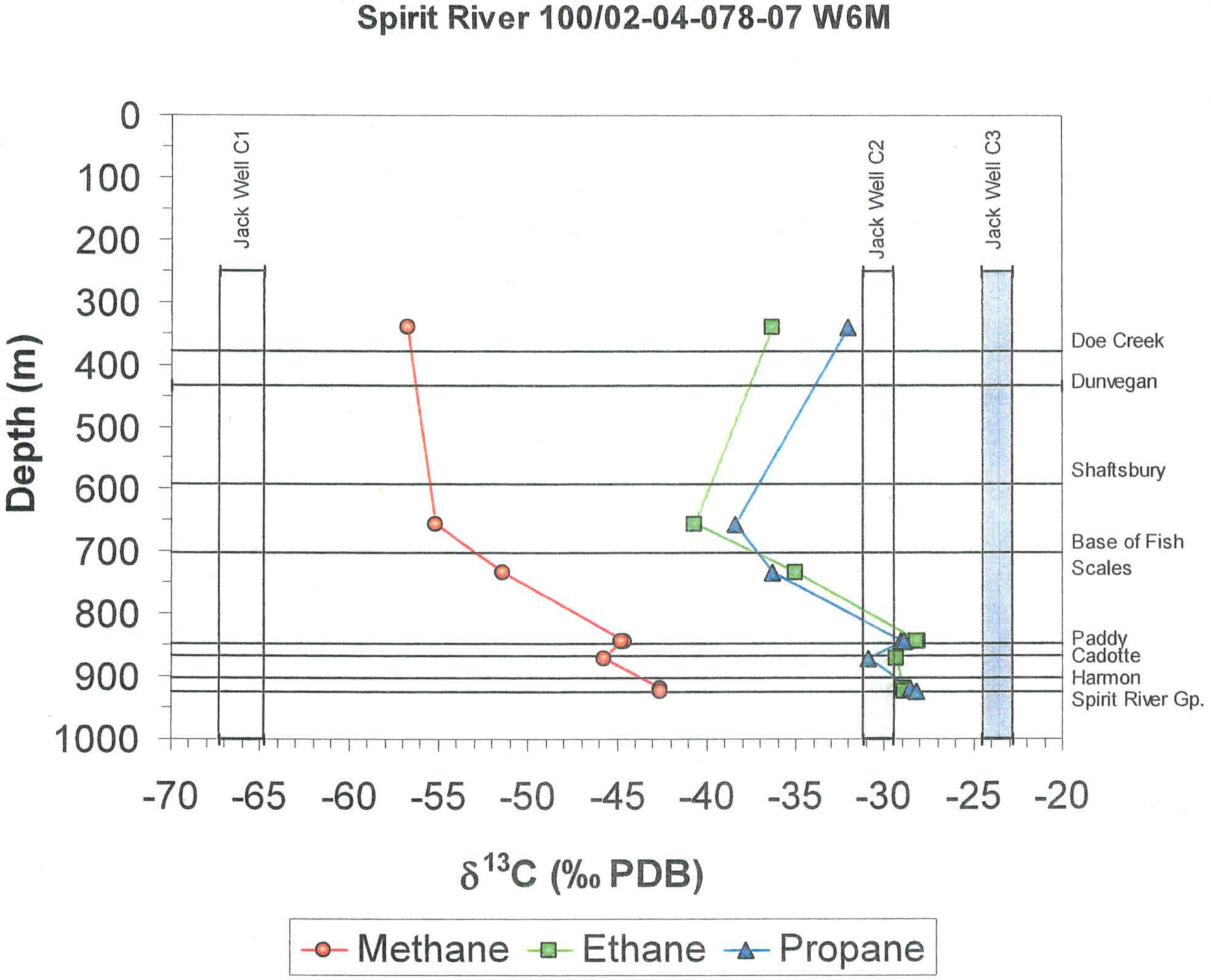


Figure 13: Gantt chart showing timing of events surrounding gas occurrence in the Jack water well.

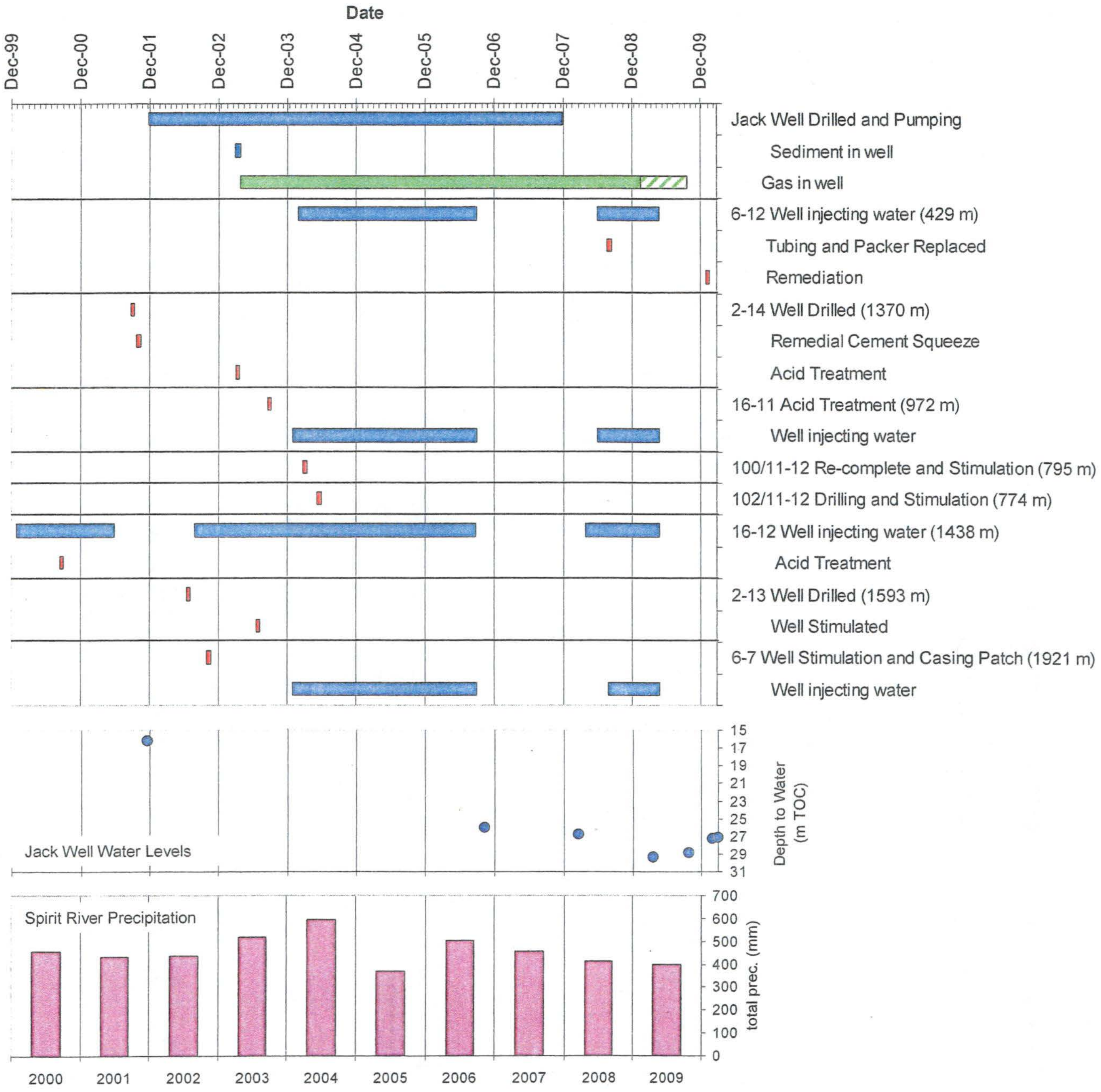
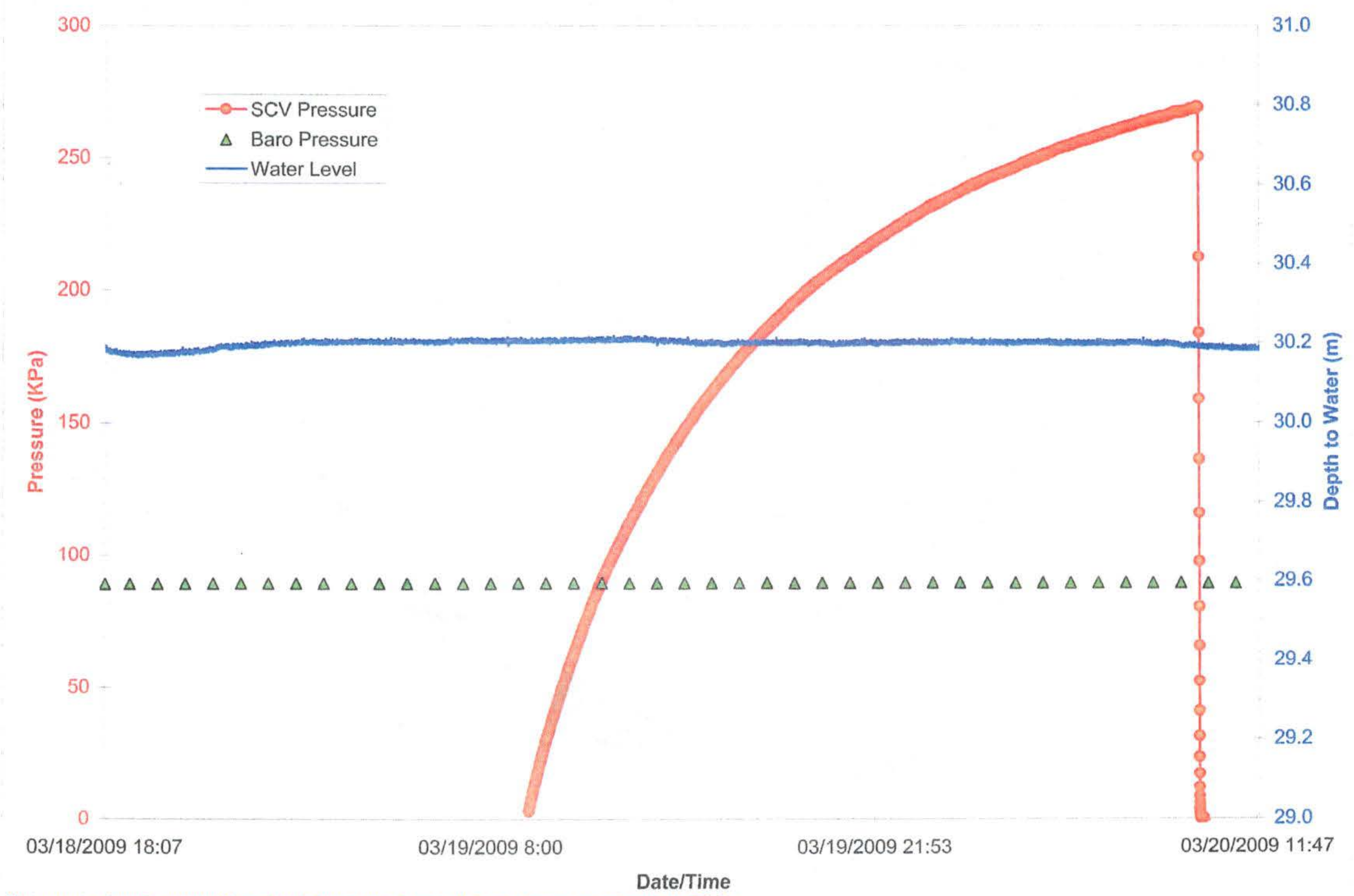


Figure 14: 100/06-12-078-08 W6M Surface casing vent build-up test and water levels in the Jack water well.



Note: water levels reported as depth from top of vent, 0.61 m above top of casing (TOC).

Figure 15: September 26, 2009 pumping test of the Jack water well.

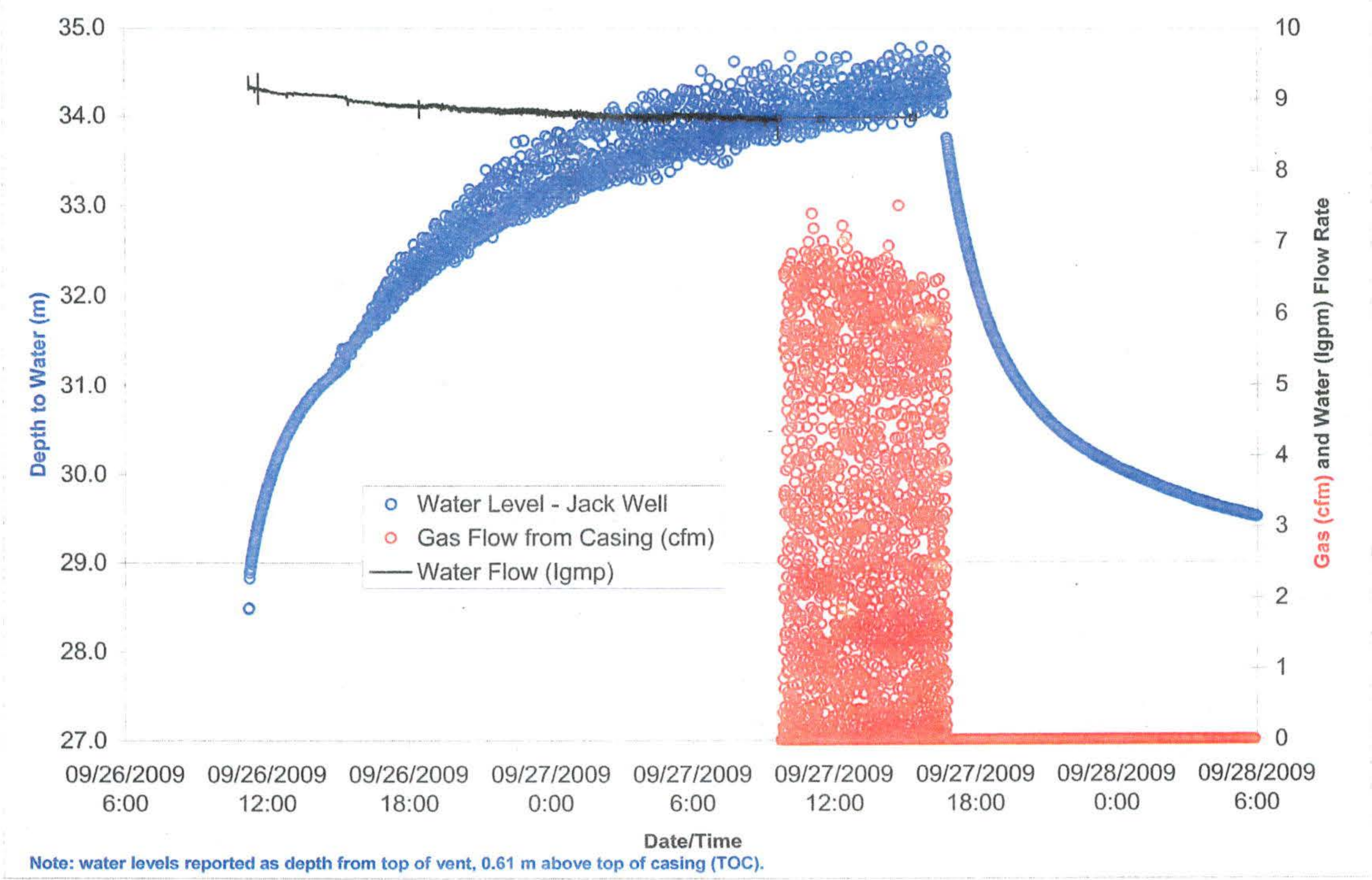
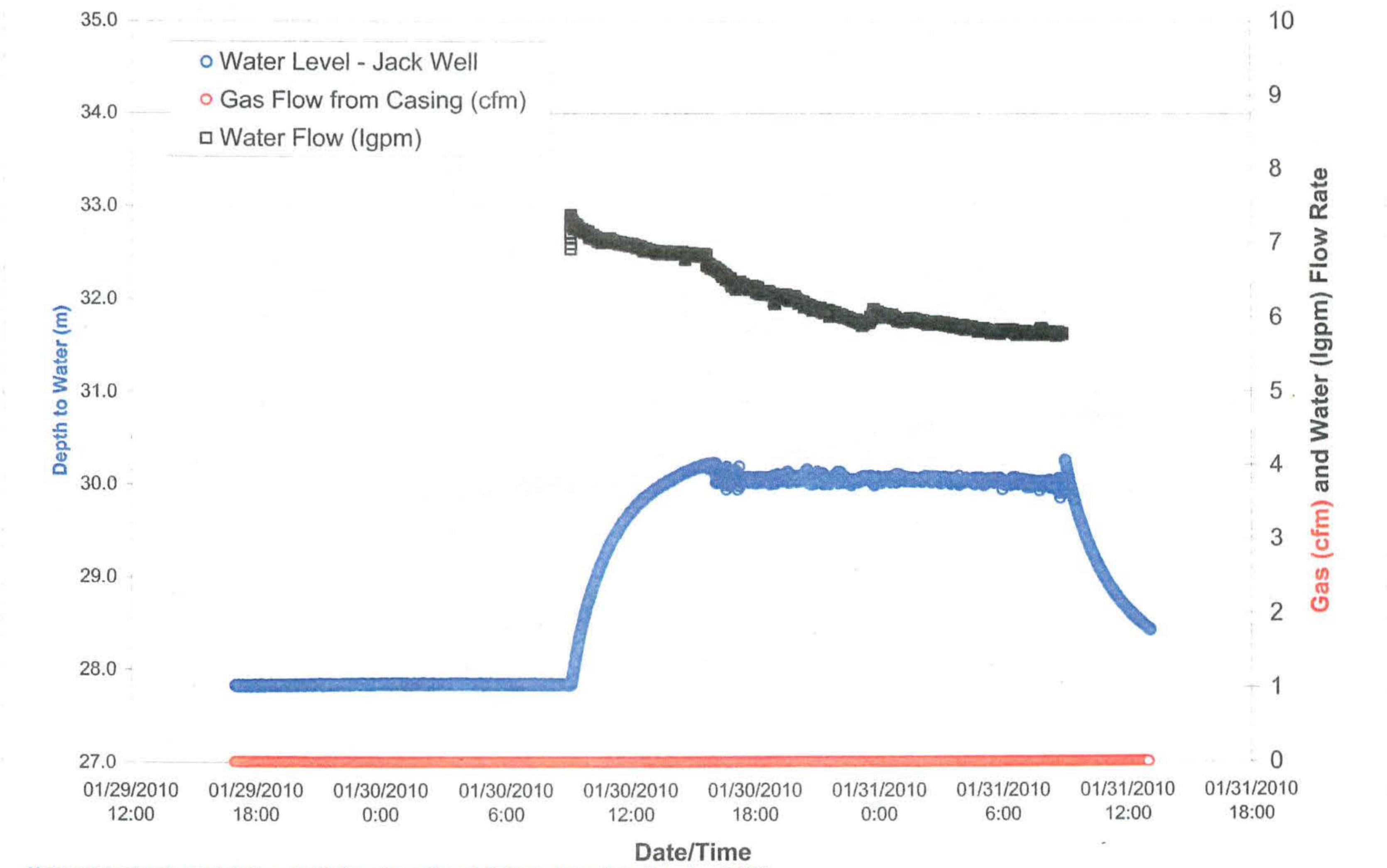
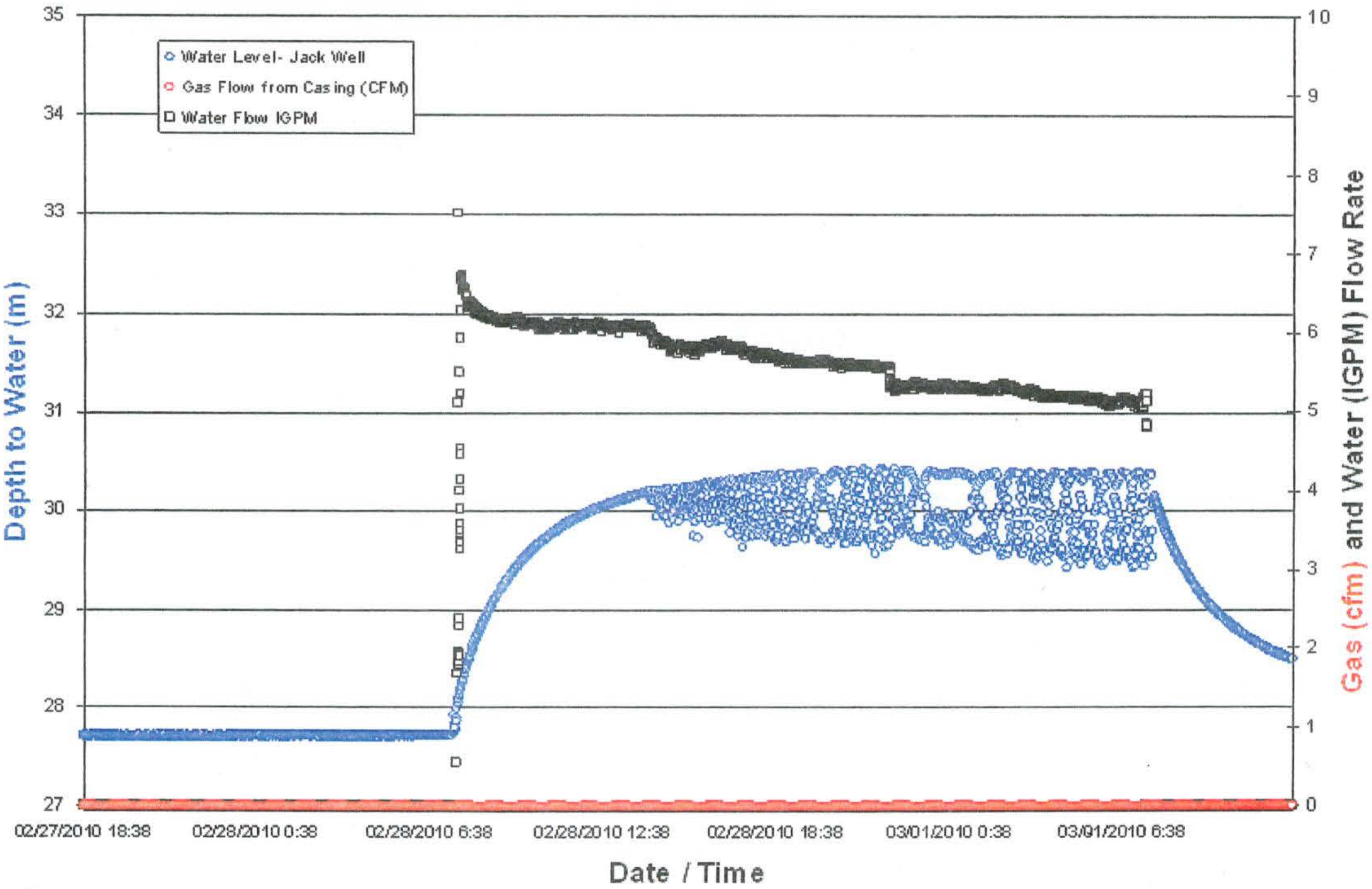


Figure 16: January 29, 2010 pumping test of the Jack water well.



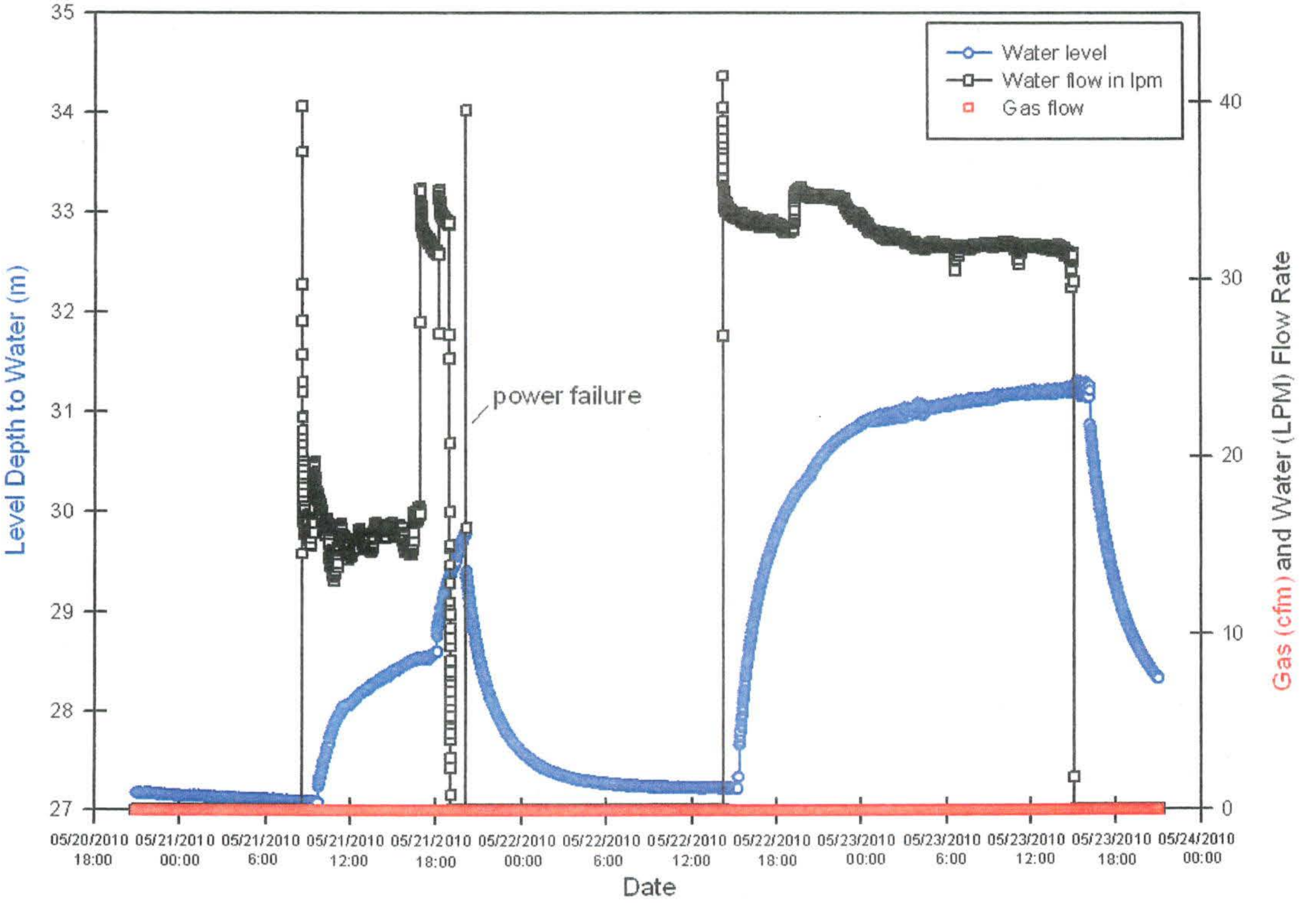
Note: water levels reported as depth from top of vent, 0.61 m above top of casing (TOC).

Figure 17: February 27, 2010 pumping test of the Jack water well.



Note: water levels reported as depth from top of vent. 0.61 m above top of casing (TOC).

Figure 18: May 22, 2010 pumping test of the Jack water well.



Note: water levels reported as depth from top of vent, 0.61 m above top of casing (TOC).

Appendix A

Energy Well Analytical Reports

ALBERTA RESEARCH COUNCIL ORGANICS ANALYSIS DATA SHEET ARC SAMPLE NUMBER: T09-0876

Client: Jones, Don
Sample No: Group Sample No: Site Descrip/Comment: 11-18 Exsolved
Station No: Project No: Canister:
Agency: ARC Samp Type: SampMatrix: Collection: Samp Date: 19-Mar-09 Time: 1018 Samplers ID:

SubGroups	FILE	VMV	NAME	ConcRpt	MDL	ConcRptUnit	InjDate
DG_C1C4							
	w0876	106770	Butane	24.30	.01	ug/L	25-Mar-09
	w0876	106771	Ethane	905.00	.01	ug/L	25-Mar-09
	w0876	106772	Ethylene	0.00	.01	ug/L	25-Mar-09
	w0876	106773	Isobutane	14.50	.01	ug/L	25-Mar-09
	w0876	106774	Methane	24300.00	.01	ug/L	25-Mar-09
	w0876	106775	Propane	168.00	.01	ug/L	25-Mar-09
DG_TCD							
	L0876	106776	Carbon dioxide	11.40	1.00	mg/L	26-Mar-09
	L0876	106777	Nitrogen	9.21	6.00	mg/L	26-Mar-09
	L0876	107106	Oxygen	6.12	6.00	mg/L	26-Mar-09
G_C1C4							
	c0876	106778	Butane	31.80	.05	ppmv	25-Mar-09
	c0876	106779	Ethane	3740.00	.05	ppmv	25-Mar-09
	c0876	106780	Ethylene	0.00	.05	ppmv	25-Mar-09
	c0876	106781	Isobutane	30.40	.05	ppmv	25-Mar-09
	c0876	106782	Methane	897000.00	.05	ppmv	25-Mar-09
	c0876	106783	Propane	133.00	.05	ppmv	25-Mar-09
G_TCD							
	G0876	106784	Carbon dioxide	555.00	300.00	ppmv	26-Mar-09
	G0876	106785	Nitrogen	30000.00	1000.00	ppmv	26-Mar-09
	G0876	107107	Oxygen	9380.00	1000.00	ppmv	26-Mar-09

[ARC_Remarks]: Tedlar Bag

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: 30-Mar-09 Contact: Grant Prill 780 632-8455

Mail To: Jones, Don
Sustainable Ecosystems
Alberta Research Council

Calgary, Alberta
T2L 2A6

ALBERTA RESEARCH COUNCIL ORGANICS ANALYSIS DATA SHEET ARC SAMPLE NUMBER: T09-0877

Client: Jones, Don

Sample No: Group Sample No: Site Descrip/Comment: 11-18 Production Casing

Station No: Project No: Canister:

Agency: ARC Samp Type: SampMatrix: Collection: Samp Date: 19-Mar-09 Time: 1012 Samplers ID:

SubGroups	FILE	VMV	NAME	ConcRpt	MDL	ConcRptUnit	InjDate
G_C1C4							
	c0877	106778	Butane	39.70	.05	ppmv	25-Mar-09
	c0877	106779	Ethane	3730.00	.05	ppmv	25-Mar-09
	c0877	106780	Ethylene	0.00	.05	ppmv	25-Mar-09
	c0877	106781	Isobutane	35.10	.05	ppmv	25-Mar-09
	c0877	106782	Methane	745000.00	.05	ppmv	25-Mar-09
	c0877	106783	Propane	154.00	.05	ppmv	25-Mar-09
G_TCD							
	G0877	106784	Carbon dioxide	4740.00	300.00	ppmv	26-Mar-09
	G0877	106785	Nitrogen	168000.00	1000.00	ppmv	26-Mar-09
	G0877	107107	Oxygen	9470.00	1000.00	ppmv	26-Mar-09

[ARC_Remarks]: Tedlar Bag

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: 30-Mar-09 Contact: Grant Prill 780 632-8455

Mail To: Jones, Don
Sustainable Ecosystems
Alberta Research Council
Calgary, Alberta
T2L 2A6

ALBERTA RESEARCH COUNCIL ORGANICS ANALYSIS DATA SHEET ARC SAMPLE NUMBER: T09-0878

Client: Jones, Don

Sample No: Group Sample No: Site Descrip/Comment: 11-18 Production Tubing

Station No: Project No: Canister:

Agency: ARC Samp Type: SampMatrix: Collection: Samp Date: Time: Samplers ID:

SubGroups	FILE	VMV	NAME	ConcRpt	MDL	ConcRptUnit	InjDate
G_C1C4							
	c0878	106778	Butane	93.90	.05	ppmv	25-Mar-09
	c0878	106779	Ethane	4480.00	.05	ppmv	25-Mar-09
	c0878	106780	Ethylene	0.00	.05	ppmv	25-Mar-09
	c0878	106781	Isobutane	55.70	.05	ppmv	25-Mar-09
	c0878	106782	Methane	945000.00	.05	ppmv	25-Mar-09
	c0878	106783	Propane	176.00	.05	ppmv	25-Mar-09
G_TCD							
	G0878	106784	Carbon dioxide	0.00	300.00	ppmv	26-Mar-09
	G0878	106785	Nitrogen	1260.00	1000.00	ppmv	26-Mar-09
	G0878	107107	Oxygen	5020.00	1000.00	ppmv	26-Mar-09
	G0878Z	106784	Carbon dioxide	0.00	300.00	ppmv	26-Mar-09
	G0878Z	106785	Nitrogen	1340.00	1000.00	ppmv	26-Mar-09
	G0878Z	107107	Oxygen	5130.00	1000.00	ppmv	26-Mar-09

[ARC_Remarks]: Tedlar Bag

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: 30-Mar-09 Contact: Grant Prill 780 632-8455

Mail To: Jones, Don
Sustainable Ecosystems
Alberta Research Council

Calgary, Alberta
T2L 2A6

ALBERTA RESEARCH COUNCIL ORGANICS ANALYSIS DATA SHEET ARC SAMPLE NUMBER: T09-0879

Client: Jones, Don

Sample No: Group Sample No: Site Descrip/Comment: 6-12 Surface Casing

Station No: Project No: Canister:

Agency: ARC Samp Type: SampMatrix: Collection: Samp Date: 19-Mar-09 Time: 0905 Samplers ID:

SubGroups	FILE	VMV	NAME	ConcRpt	MDL	ConcRptUnit	InjDate
G_C1C4							
	c0879	106778	Butane	10700.00	.05	ppmv	25-Mar-09
	c0879	106779	Ethane	70500.00	.05	ppmv	25-Mar-09
	c0879	106780	Ethylene	0.00	.05	ppmv	25-Mar-09
	c0879	106781	Isobutane	7640.00	.05	ppmv	25-Mar-09
	c0879	106782	Methane	793000.00	.05	ppmv	25-Mar-09
	c0879	106783	Propane	36300.00	.05	ppmv	25-Mar-09
G_TCD							
	G0879	106784	Carbon dioxide	744.00	300.00	ppmv	26-Mar-09
	G0879	106785	Nitrogen	32700.00	1000.00	ppmv	26-Mar-09
	G0879	107107	Oxygen	0.00	1000.00	ppmv	26-Mar-09

[ARC_Remarks]: Tedlar Bag

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: 30-Mar-09 Contact: Grant Prill 780 632-8455

Mail To: Jones, Don
Sustainable Ecosystems
Alberta Research Council

Calgary, Alberta
T2L 2A6

Alberta Research Council
Environmental Monitoring
Vegreville, Alberta

Tabular Data Report

Sample No: T09-0874

Comments: 11-18 Exsolved
SmpDate: 19-Mar-09 Time: 1018 By: Matrix:
Canister #: User Sample No:

SubGroup: vpp

Analysis Date: 31-MAR-2009 05:40

FILE	RT	MQ	NAME	Concentration ug/L	MW	MolFormula	CAS
V0874A	0.00	T	Chloromethane	0.0	50	CH3Cl	74-87-3
V0874A	0.00	T	Vinyl chloride	0.0	63	C2H3Cl	75-01-4
V0874A	0.00	T	Bromomethane	0.0	95	CH3Br	74-83-9
V0874A	0.00	T	Chloroethane	0.0	65	C2H5Cl	75-00-3
V0874A	0.00	T	Trichlorofluoromethane	0.0			
V0874A	0.00	T	1,1-Dichloroethylene	0.0	96	C2H2Cl2	75-35-4
V0874A	0.00	T	Methylene chloride	.0	84	CH2Cl2	75-09-2
V0874A	0.00	T	trans-1,2-Dichloroethylene	0.0	97	C2H2Cl2	156-60-5
V0874A	0.00	T	MTBE	0.0	88	C5H12O	1634-04-4
V0874A	0.00	T	1,1-Dichloroethane	0.0	98	C2H4Cl2	75-34-3
V0874A	0.00	T	cis-1,2-Dichloroethylene	0.0	97	C2H2Cl2	156-59-4
V0874A	0.00	T	2,2-Dichloropropane	0.0			
V0874A	0.00	T	Chloroform	0.0	119	CHCl3	67-66-3
V0874A	0.00	T	1,1,1-Trichloroethane	0.0	132	C2H3Cl3	71-55-6
V0874A	0.00	T	1,2-Dichloroethane	0.0	98	C2H4Cl2	107-06-2
V0874A	0.00	T	1,1-Dichloropropylene	0.0			
V0874A	0.00	T	Carbon tetrachloride	0.0	154	CCl4	56-23-5
V0874A	0.00	T	1,2-Dichloropropane	0.0	113	C3H6Cl2	78-87-5
V0874A	0.00	T	Trichloroethylene	0.0	131	C2HCl3	79-01-6
V0874A	0.00	T	Dibromomethane	0.0			
V0874A	0.00	T	Bromodichloromethane	0.0	162	CHBrCl2	75-27-4
V0874A	0.00	T	2-Chloroethoxyethylene	0.0			
V0874A	0.00	T	cis-1,3-Dichloropropylene	0.0	111	C3H4Cl2	542-75-6
V0874A	0.00	T	trans-1,3-Dichloropropylene	0.0	111	C3H4Cl2	542-75-6
V0874A	0.00	T	1,1,2-Trichloroethane	0.0	132	C2H3Cl3	79-00-5
V0874A	0.00	T	1,3-Dichloropropane	0.0			
V0874A	0.00	T	Dibromochloromethane	0.0			
V0874A	0.00	T	1,2-Dibromoethane	0.0	188	C2H4Br2	106-93-4
V0874A	0.00	T	Tetrachloroethylene	0.0	166	C2Cl4	127-18-4
V0874A	0.00	T	Chlorobenzene	0.0	113	C6H5Cl	108-90-7
V0874A	0.00	T	1,1,1,2-Tetrachloroethane	0.0			
V0874A	0.00	T	Bromoform	0.0	250	CHBr3	75-25-2
V0874A	0.00	T	Styrene	0.0	104	C8H8	100-42-5
V0874A	0.00	T	1,1,2,2-Tetrachloroethane	0.0	166	C2H2Cl4	79-34-5
V0874A	0.00	T	1,2,3-Trichloropropane	0.0			
V0874A	0.00	T	Bromobenzene	0.0			
V0874A	0.00	T	2-Chlorotoluene	0.0			
V0874A	0.00	T	4-Chlorotoluene	0.0			
V0874A	0.00	T	tert-Butylbenzene	0.0	134	C10H14	98-06-6
V0874A	0.00	T	1,3-Dichlorobenzene	0.0	147	C6H4Cl2	541-73-1
V0874A	0.00	T	sec-Butylbenzene	0.0	134	C10H14	135-98-8
V0874A	0.00	T	1,4-Dichlorobenzene	0.0	147	C6H4Cl2	106-46-7

```
                                                                                          page   2

Sample No: T09-0874         Comments: 11-18 Exsolved
____________________         SmpDate: 19-Mar-09  Time: 1018  By:          Matrix:
                           Canister #:           User Sample No:

              SubGroup: vpp                                               Concentration
FILE      RT      MQ  NAME                                                    ug/L          MW   MolFormula  CAS
------    -----   --  -----------------------------------------  -----------------      ---  ----------  --------------------
       Analysis Date: 31-MAR-2009 05:40
V0874A     0.00   T   p-Isopropyltoluene                                        0.0      134  C10H14      99-87-6
V0874A     0.00   T   1,2-Dichlorobenzene                                       0.0      146  C6H4Cl2     95-50-1
V0874A     0.00   T   n-Butylbenzene                                            0.0      134  C10H14      104-51-8
V0874A     0.00   T   1,2-Dibromo-3-chloropropane                               0.0
V0874A     0.00   T   1,2,4-Trichlorobenzene                                    0.0      180  C6H3Cl3     120-82-1
V0874A     0.00   T   1,2,3-Trichlorobenzene                                    0.0
V0874A     4.70   32  Butane, 2-nitro-                                          1.7      103  C4H9NO2     600-24-8
V0874A     5.40   40  Pentane                                                   1.1       72  C5H12       109-66-0
V0874A     6.84   25  Acetic acid, methyl ester                                 1.1       74  C3H6O2      79-20-9
V0874A     7.92   72  Cyclopentane                                              2.4       70  C5H10       287-92-3
V0874A    11.68   43  1-Pentene, 2-methyl-                                      2.1       84  C6H12       763-29-1
V0874A    13.12   I   1,2-Dichloroethane-d4                                      .0
V0874A    14.05   I   Benzene-d6                                                 .0
V0874A    14.21   T   Benzene                                                  21.1       78  C6H6        71-43-2
V0874A    19.27   64  Cyclohexane, methyl-                                       .6       98  C7H14       108-87-2
V0874A    23.12   I   Toluene-d8                                                 .0      100  C7D8        2037-26-5
V0874A    23.49   T   Toluene                                                  35.5       92  C7H8        108-88-3
V0874A    32.55   T   Ethyl benzene                                             3.0      106  C8H10       100-41-4
V0874A    33.30   T   m,p-Xylene                                                9.4      106  C8H10       108-38-3 / 106-42-3
V0874A    35.51   T   o-Xylene                                                  3.4      106  C8H10       95-47-6
V0874A    38.40   I   4-Bromofluorobenzene                                       .0
V0874A    38.53   T   Isopropylbenzene                                           .4      120  C9H12       98-82-8
V0874A    40.52   T   n-Propylbenzene                                            .2      120  C9H12       103-65-1
V0874A    40.93   93  Benzene, 1-ethyl-4-methyl-                                1.2      120  C9H12       622-96-8
V0874A    40.98   70  Benzene, 1-ethyl-3-methyl-                                 .4      120  C9H12       620-14-4
V0874A    41.23   T   1,3,5-Trimethylbenzene                                     .3      120  C9H12       108-67-8
V0874A    41.72   76  Benzene, (1-methylethyl)-                                  .8      120  C9H12       98-82-8
V0874A    42.26   T   1,2,4-Trimethylbenzene                                    1.9      120  C9H12       95-63-6
V0874A    43.25   94  Benzene, 1,2,3-trimethyl-                                 2.0      120  C9H12       526-73-8
V0874A    43.66   55  Benzene, 1-propenyl-                                       .5      118  C9H10       637-50-3
V0874A    44.02   55  Benzene, 1,2-diethyl-                                      .3      134  C10H14      135-01-3
V0874A    44.06   62  Benzene, 1-methyl-3-propyl-                                .5      134  C10H14      1074-43-7
V0874A    44.21   59  5,6-DIMETHYLIDENE-2-NORBORNANONE                           .6      134  C9H10O      62289-63-8
V0874A    44.25   90  Benzene, 4-ethyl-1,2-dimethyl-                             .7      134  C10H14      934-80-5
V0874A    44.50   86  Benzene, 1-methyl-2-propyl-                                .5      134  C10H14      1074-17-5
V0874A    44.74   94  Benzene, 1-methyl-3-(1-methylethyl)- (CA                   .9      134  C10H14      535-77-3
V0874A    44.78   94  Benzene, 1-ethyl-2,3-dimethyl-                             .6      134  C10H14      933-98-2
V0874A    44.93   95  Benzene, 2-ethyl-1,3-dimethyl-                            1.3      134  C10H14      2870-04-4
V0874A    45.00   72  Benzene, (2-methyl-1-propenyl)-                            .5      132  C10H12      768-49-0
V0874A    45.09   90  .alpha.-Methylstyrene                                     1.0      118  C9H10       98-83-9
V0874A    45.14   64  Undecane                                                   .8      156  C11H24      1120-21-4
V0874A    45.32   23  Oxetane, 2-propyl-                                         .7      100  C6H12O      4468-64-8
V0874A    45.42   83  Benzene, 1-methyl-4-(1-methylethyl)- (CA                   .5      134  C10H14      99-87-6
V0874A    45.62   95  Benzene, 1-ethyl-2,3-dimethyl-                             .8      134  C10H14      933-98-2
V0874A    45.71   94  Benzene, 1,2,3,4-tetramethyl-                             1.7      134  C10H14      488-23-3
V0874A    46.12   64  Benzene, 2-ethenyl-1,4-dimethyl-                           .6      132  C10H12      2039-89-6
V0874A    46.20   47  METHYL N-DIMETHYLTHIOCARBAMATE                             .3      119  C4H9NOS     0-00-0
V0874A    46.36   74  Benzene, 1-methyl-2-(2-propenyl)-                         1.9      132  C10H12      1587-04-8
V0874A    46.58   55  Naphthalene, 1,2,3,4-tetrahydro-                           .6      132  C10H12      119-64-2
V0874A    46.96   70  Dodecane                                                   .9      170  C12H26      112-40-3
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Sample No: T09-0874        Comments: 11-18 Exsolved
____________________         SmpDate: 19-Mar-09  Time: 1018  By:          Matrix:
                           Canister #:          User Sample No:

            SubGroup: vpp                                         Concentration
FILE      RT      MQ  NAME                                           ug/L          MW   MolFormula  CAS
------    -----   --  -----------------------------------------  -----------------  ---  ----------  --------------------
       Analysis Date: 31-MAR-2009 05:40
V0874A    47.01   T   Naphthalene                                            1.1   128  C10H8       91-20-3
V0874A    47.19   30  trans-2-Phenyl-2-pentene                                .4   146  C11H14      0-00-0
V0874A    47.49   T   Hexachlorobutadiene                                     .6   261  C4C16       87-68-3
V0874A    47.65   35  2,4-Dimethylamphetamine                                 .4   163  C11H17N     75659-61-9
                                                    sum:             107
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                                                                                            page   4

Sample No: T09-0875          Comments: 11-18 Exsolved
__________________            SmpDate: 19-Mar-09  Time: 1018  By:            Matrix:
                             Canister #:           User Sample No:

           SubGroup: epp                                      Concentration
FILE      RT     MQ  NAME                                           ug/L          MW   MolFormula  CAS
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       Analysis Date: 26-MAR-2009 17:45
E0875     0.00   T   2-Chlorophenol                                        0.0   128  C6H5ClO     95-57-8
E0875     0.00   T   Bis(2-chloroisopropyl)ether                           0.0   170  C6H12Cl2O   39638-32-9
E0875     0.00   T   Hexachloroethane                                      0.0   234  C2Cl6       67-72-1
E0875     0.00   T   N-Nitroso-di-n-propylamine                            0.0   130  C6H14N2O    621-64-7
E0875     0.00   T   Nitrobenzene                                          0.0   123  C6H5NO2     98-95-3
E0875     0.00   T   Isophorone                                            0.0   138  C9H14O      78-59-1
E0875     0.00   T   2-Nitrophenol                                         0.0   139  C6H5NO3     88-75-5
E0875     0.00   T   2,4-Dimethylphenol                                    0.0   122  C8H10O      105-67-9
E0875     0.00   T   Bis(2-chloroethoxy)methane                            0.0   172  C5H10Cl2O2  111-91-1
E0875     0.00   T   2,4-Dichlorophenol                                    0.0   162  C6H4Cl2O    120-83-2
E0875     0.00   T   1,2,4-Trichlorobenzene                                0.0   180  C6H3Cl3     120-82-1
E0875     0.00   T   Hexachlorobutadiene                                   0.0   261  C4Cl6       87-68-3
E0875     0.00   T   4-Chloro-3-methylphenol                               0.0   142  C7H7ClO     59-50-7
E0875     0.00   T   Hexachlorocyclopentadiene                             0.0   270  C5Cl6       77-47-4
E0875     0.00   T   2,4,6-Trichlorophenol                                 0.0   196  C6H3Cl3O    88-06-2
E0875     0.00   T   2-Chloronaphthalene                                   0.0   162  C10H7Cl     91-58-7
E0875     0.00   T   Acenaphthylene                                        0.0   152  C12H8       208-96-8
E0875     0.00   T   Dimethyl phthalate                                    0.0   194  C10H10O4    131-11-3
E0875     0.00   T   2,6-Dinitrotoluene                                    0.0   182  C7H6N2O4    606-20-2
E0875     0.00   T   2,4-Dinitrophenol                                     0.0   184  C6H4N2O5    51-28-5
E0875     0.00   T   4-Nitrophenol                                         0.0   139  C6H5NO3     100-02-7
E0875     0.00   T   2,3,4,6-Tetrachlorophenol                             0.0   230  C6H2Cl4O    58-90-2
E0875     0.00   T   2,4-Dinitrotoluene                                    0.0   182  C7H6N2O4    121-14-2
E0875     0.00   T   4-Chlorophenyl phenyl ether                           0.0   204  C12H9ClO    7005-72-3
E0875     0.00   T   Diethyl phthalate                                     0.0   222  C12H14O4    84-66-2
E0875     0.00   T   2-Methyl-4,6-dinitrophenol                            0.0   198  C7H6N2O5    534-52-1
E0875     0.00   T   1,2-Diphenylhydrazine                                 0.0   184  C12H12N2    122-66-7
E0875     0.00   T   4-Bromophenyl phenyl ether                            0.0   248  C12H9BrO    101-55-3
E0875     0.00   T   Hexachlorobenzene                                     0.0   282  C6Cl6       118-74-1
E0875     0.00   T   Pentachlorophenol                                     0.0   264  C6HCl5O     87-86-5
E0875     0.00   T   Anthracene                                            0.0   178  C14H10      120-12-7
E0875     0.00   T   Fluoranthene                                          0.0   202  C16H10      206-44-0
E0875     0.00   T   Pyrene                                                0.0   202  C16H10      129-00-0
E0875     0.00   T   Benzidine                                             0.0   184  C12H12N2    92-87-5
E0875     0.00   T   Di-n-octyl phthalate                                  0.0   376  C23H36O4    117-84-0
E0875     0.00   T   Benzo(b)fluoranthene                                  0.0   252  C20H12      205-99-2
E0875     0.00   T   Benzo(k)fluoranthene                                  0.0   252  C20H12      207-08-9
E0875     0.00   T   Benzo(a)pyrene                                        0.0   252  C20H12      50-32-8
E0875     0.00   T   Indeno(1,2,3-cd)pyrene                                0.0   276  C22H12      193-39-5
E0875     0.00   T   Dibenzo(ah)anthracene                                 0.0   278  C22H14      53-70-3
E0875     0.00   T   Benzo(ghi)perylene                                    0.0   276  C22H12      191-24-2
E0875     4.25   90  Pentanoic acid                                       10.0   102  C5H10O2     109-52-4
E0875     7.19   T   Phenol                                                 .8    94  C6H6O       108-95-2
E0875     7.40   T   Bis(2-chloroethyl)ether                                .3   142  C4H8Cl2O    111-44-4
E0875     8.63   97  Pyridine, 5-ethyl-2-methyl-                           2.1   121  C8H11N      104-90-5
E0875     9.64   94  Ethanone, 1-phenyl-                                   9.9   120  C8H8O       98-86-2
E0875     9.91   96  Phenol, 4-methyl-                                    62.1   108  C7H8O       106-44-5
E0875    10.30   91  Benzenemethanol, .alpha.,.a                          61.6   136  C9H12O      617-94-7
E0875    11.20   86  Hexanoic acid, 2-ethyl- (CA                           2.1   144  C8H16O2     149-57-5
E0875    12.92   I   Naphthalene-d8                                         .0   136  C10D8       1146-65-2
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Sample No: T09-0875

Comments: 11-18 Exsolved

SmpDate: 19-Mar-09 Time: 1018 By: Matrix:

Canister #: User Sample No:

SubGroup: epp

Analysis Date: 26-MAR-2009 17:45

FILE	RT	MQ	NAME	Concentration ug/L	MW	MolFormula	CAS
E0875	13.00	T	Naphthalene	.3	128	C10H8	91-20-3
E0875	15.66	94	Benzeneacetic acid	93.9	136	C8H8O2	103-82-2
E0875	16.05	97	1H-Indole	11.4	117	C8H7N	120-72-9
E0875	20.94	T	Acenaphthene	.0	154	C12H10	83-32-9
E0875	21.24	97	pentadecane	1.5	212	C15H32	629-62-9
E0875	22.69	72	2,2-Di-(2'-chloroethoxy)-et	1.2	186	C6H12Cl2O2	0-00-0
E0875	23.27	T	Fluorene	.0	166	C13H10	86-73-7
E0875	23.59	98	Hexadecane	1.2	226	C16H34	544-76-3
E0875	24.16	T	N-Nitrosodiphenylamine	.1	198	C12H10N2O	86-30-6
E0875	25.83	98	Heptadecane	1.2	240	C17H36	629-78-7
E0875	27.25	43	4-Hexen-1-ol, 2-ethenyl-2,5	2.8	154	C10H18O	50598-21-5
E0875	27.53	I	Phenanthrene-d10	.0	188	C14D10	1517-22-2
E0875	27.63	T	Phenanthrene	.0	178	C14H10	85-01-8
E0875	27.95	98	Octadecane	1.1	254	C18H38	593-45-3
E0875	29.98	98	Nonadecane	1.2	268	C19H40	629-92-5
E0875	31.27	T	Di-n-butylphthalate	.2	278	C16H22O4	84-74-2
E0875	32.29	95	Phenol, 2,2'-methylenebis-	3.6	200	C13H12O2	2467-02-9
E0875	35.54	99	Docosane	1.1	310	C22H46	629-97-0
E0875	37.52	49	Neopentylidenecyclohexane	2.4	152	C11H20	39546-80-0
E0875	38.17	T	Butylbenzylphthalate	.8	312	C19H20O4	85-68-7
E0875	38.45	91	Squalene	1.3	410	C30H50	7683-64-9
E0875	39.71	T	Benzo(a)anthracene	.0	228	C18H12	56-55-3
E0875	39.73	I	Benzo(a)anthracene-d12	.0	240	C18D12	1719-03-5
E0875	39.98	T	Chrysene	.0	228	C18H12	218-01-9
E0875	41.28	T	Bis(2-ethylhexyl)phthalate	18.4	390	C24H38O4	117-81-7
E0875	46.90	98	Docosane	2.9	310	C22H46	629-97-0
E0875	49.33	97	Eicosane	2.4	282	C20H42	112-95-8
			sum:	298			

FILE: datafile RT: retention time MQ: T=target compound or ##=PBM library match quality

Flg: nd=not detected U=non-target compound or Unknown

MDL: method detection limit MW: molecular weight CAS: chemical abstracts service

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

By:

Date:

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

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Alberta Research Council                               Tabular Data Report
Environmental Monitoring                               ...................
Vegreville, Alberta

                                                                   page  1

Sample No: T09-0881        Comments: 11-18 Production Casing
___________________         SmpDate: 19-Mar-09  Time: 1012  By: DFJ       Matrix: TEDLAR
                         Canister #:            User Sample No:

             SubGroup: voc                                  Concentration
FILE      RT     MQ  NAME                                        ppbv           MW   MolFormula  CAS
------   -----   --  ----------------------------------------  ----------------  ---  ----------  --------------------
     Analysis Date: 26-MAR-2009 11:01
V0881     0.00   T   1-Butene                                           0.0     56  C4H8        106-98-9
V0881     0.00   T   trans-2-Butene                                     0.0     56  C4H8        624-64-6
V0881     0.00   T   cis-2-Butene                                       0.0     56  C4H8        590-18-1
V0881     0.00   T   3-Methyl-1-butene                                  0.0     70  C5H10       563-45-1
V0881     0.00   T   1-Pentene                                          0.0     70  C5H10       109-67-1
V0881     0.00   T   Isoprene                                           0.0     68  C5H8        78-79-5
V0881     0.00   T   trans-2-Pentene                                    0.0     70  C5H10       646-04-8
V0881     0.00   T   cis-2-Pentene                                      0.0     70  C5H10       627-20-3
V0881     0.00   T   2-Methyl-2-butene                                  0.0     70  C5H10       563-46-2
V0881     0.00   T   Cyclopentene                                       0.0     68  C5H8        142-29-0
V0881     0.00   T   4-Methyl-1-pentene                                 0.0     84  C6H12       691-37-2
V0881     0.00   T   2-Methyl-1-pentene                                 0.0     84  C6H12       763-29-1
V0881     0.00   T   cis-2-Hexene                                       0.0     84  C6H12       7688-21-3
V0881     0.00   T   trans-2-Hexene                                     0.0     84  C6H12       4050-45-7
V0881     0.00   T   2,4-Dimethylpentane                                0.0    100  C7H16       108-08-7
V0881     0.00   T   2,3,4-Trimethylpentane                             0.0    114  C8H18       565-75-3
V0881     0.00   T   Ethyl benzene                                      0.0    106  C8H10       100-41-4
V0881     0.00   T   Nonane                                             0.0    128  C9H20       111-84-2
V0881     0.00   T   Styrene                                            0.0    104  C8H8        100-42-5
V0881     0.00   T   o-Xylene                                           0.0    106  C8H10       95-47-6
V0881     0.00   T   Isopropylbenzene                                   0.0    120  C9H12       98-82-8
V0881     0.00   T   alpha Pinene                                       0.0    136  C10H16      80-56-8
V0881     0.00   T   n-Propylbenzene                                    0.0    120  C9H12       103-65-1
V0881     0.00   T   1,3,5-Trimethylbenzene                             0.0    120  C9H12       108-67-8
V0881     0.00   T   beta Pinene                                        0.0    136  C10H16      18172-67-3
V0881     0.00   T   1,2,4-Trimethylbenzene                             0.0    120  C9H12       95-63-6
V0881     2.79   T   Isobutane                                     65,500.0     58  C4H10       75-28-5
V0881     3.00   T   Butane                                        73,400.0     58  C4H10       106-97-8
V0881     3.11   72  Propane, 2,2-dimethyl-                         1,700.0     72  C5H12       463-82-1
V0881     3.16   0   Unknown                                        1,420.0      0
V0881     3.68   T   Isopentane                                    25,400.0     72  C5H12       78-78-4
V0881     4.00   T   Pentane                                       20,600.0     72  C5H12       109-66-0
V0881     4.25   50  Acetone                                          459.0     58  C3H6O       67-64-1
V0881     4.49   T   2,2-Dimethylbutane                                 806.0     86  C6H14       75-83-2
V0881     4.95   T   2,3-Dimethylbutane                                 869.0     86  C6H14       79-29-8
V0881     4.97   T   Cyclopentane                                       856.0     70  C5H10       287-92-3
V0881     5.01   T   2-Methylpentane                                6,000.0     86  C6H14       107-83-5
V0881     5.24   T   3-Methylpentane                                3,270.0     86  C6H14       96-14-0
V0881     5.52   T   Hexane                                         6,580.0     86  C6H14       110-54-3
V0881     5.67   80  2-Butanone                                     1,260.0     72  C4H8O       78-93-3
V0881     6.02   T   Methylcyclopentane                             1,510.0     84  C6H12       96-37-7
V0881     6.60   T   Cyclohexane                                    1,300.0     84  C6H12       110-82-7
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Sample No: T09-0881      Comments: 11-18 Production Casing
____________________       SmpDate: 19-Mar-09  Time: 1012  By: DFJ       Matrix: TEDLAR
                         Canister #:            User Sample No:

            SubGroup: voc                                         Concentration
FILE      RT     MQ  NAME                                           ppbv            MW   MolFormula  CAS
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       Analysis Date: 26-MAR-2009 11:01
V0881     6.62   T   Benzene                                              572.0     78  C6H6        71-43-2
V0881     6.64   T   2-Methylhexane                                     1,160.0    100  C7H16       591-76-4
V0881     6.69   T   2,3-Dimethylpentane                                  305.0    100  C7H16       565-59-3
V0881     6.79   T   3-Methylhexane                                     1,440.0    100  C7H16       589-34-4
V0881     7.00   T   2,2,4-Trimethylpentane                               216.0    114  C8H18       540-84-1
V0881     7.05   81  Isopropylcyclobutane                                 565.0     98  C7H14       872-56-0
V0881     7.19   T   Heptane                                            1,910.0    100  C7H16       142-82-5
V0881     7.26   78  Propanal, 2,2-dimethyl-                              229.0     86  C5H10O      630-19-3
V0881     7.63   T   Methylcyclohexane                                  1,590.0     98  C7H14       108-87-2
V0881     7.73   0   Unknown                                               90.5      0
V0881     7.80   0   Unknown                                               99.7      0
V0881     8.01   0   Unknown                                              134.0      0
V0881     8.25   T   2-Methylheptane                                      261.0    114  C8H18       592-27-8
V0881     8.35   T   Toluene                                              923.0     92  C7H8        108-88-3
V0881     8.38   T   3-Methylheptane                                      234.0    114  C8H18       589-81-1
V0881     8.79   T   Octane                                               417.0    114  C8H18       111-65-9
V0881     9.59   I   Chlorobenzene-d5                                        .0    112  C6D5Cl      3114-55-4
V0881     9.94   T   m,p-Xylene                                            97.4    106  C8H10       108-38-3 / 106-42-3
                                                      sum:         221,174
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                                                                                                          page   3

Sample No: T09-0882          Comments: 11-18 Production Tubing
___________________            SmpDate:              Time:        By:            Matrix: TEDLAR
                             Canister #:             User Sample No:

             SubGroup: voc                                                Concentration
FILE        RT       MQ  NAME                                                  ppbv            MW   MolFormula  CAS
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       Analysis Date: 26-MAR-2009 11:35
V0882     0.00     T   1-Butene                                                 0.0     56  C4H8        106-98-9
V0882     0.00     T   trans-2-Butene                                           0.0     56  C4H8        624-64-6
V0882     0.00     T   cis-2-Butene                                             0.0     56  C4H8        590-18-1
V0882     0.00     T   3-Methyl-1-butene                                        0.0     70  C5H10       563-45-1
V0882     0.00     T   1-Pentene                                                0.0     70  C5H10       109-67-1
V0882     0.00     T   Isoprene                                                 0.0     68  C5H8        78-79-5
V0882     0.00     T   trans-2-Pentene                                          0.0     70  C5H10       646-04-8
V0882     0.00     T   cis-2-Pentene                                            0.0     70  C5H10       627-20-3
V0882     0.00     T   2-Methyl-2-butene                                        0.0     70  C5H10       563-46-2
V0882     0.00     T   Cyclopentene                                             0.0     68  C5H8        142-29-0
V0882     0.00     T   4-Methyl-1-pentene                                       0.0     84  C6H12       691-37-2
V0882     0.00     T   2-Methyl-1-pentene                                       0.0     84  C6H12       763-29-1
V0882     0.00     T   cis-2-Hexene                                             0.0     84  C6H12       7688-21-3
V0882     0.00     T   trans-2-Hexene                                           0.0     84  C6H12       4050-45-7
V0882     0.00     T   2,4-Dimethylpentane                                      0.0    100  C7H16       108-08-7
V0882     0.00     T   2,2,4-Trimethylpentane                                   0.0    114  C8H18       540-84-1
V0882     0.00     T   2,3,4-Trimethylpentane                                   0.0    114  C8H18       565-75-3
V0882     0.00     T   Styrene                                                  0.0    104  C8H8        100-42-5
V0882     0.00     T   o-Xylene                                                 0.0    106  C8H10       95-47-6
V0882     0.00     T   Isopropylbenzene                                         0.0    120  C9H12       98-82-8
V0882     0.00     T   alpha Pinene                                             0.0    136  C10H16      80-56-8
V0882     0.00     T   n-Propylbenzene                                          0.0    120  C9H12       103-65-1
V0882     0.00     T   1,3,5-Trimethylbenzene                                   0.0    120  C9H12       108-67-8
V0882     0.00     T   beta Pinene                                              0.0    136  C10H16      18172-67-3
V0882     0.00     T   1,2,4-Trimethylbenzene                                   0.0    120  C9H12       95-63-6
V0882     2.78     T   Isobutane                                           43,500.0     58  C4H10       75-28-5
V0882     3.00     T   Butane                                              73,200.0     58  C4H10       106-97-8
V0882     3.10     64  Propane, 2,2-dimethyl-                               1,130.0     72  C5H12       463-82-1
V0882     3.20     4   Methanol                                            80,700.0     32  CH4O        67-56-1
V0882     3.69     T   Isopentane                                         103,000.0     72  C5H12       78-78-4
V0882     4.02     T   Pentane                                            136,000.0     72  C5H12       109-66-0
V0882     4.50     T   2,2-Dimethylbutane                                   3,400.0     86  C6H14       75-83-2
V0882     4.96     T   2,3-Dimethylbutane                                   5,390.0     86  C6H14       79-29-8
V0882     4.99     T   Cyclopentane                                         8,180.0     70  C5H10       287-92-3
V0882     5.02     T   2-Methylpentane                                     46,400.0     86  C6H14       107-83-5
V0882     5.26     T   3-Methylpentane                                     29,000.0     86  C6H14       96-14-0
V0882     5.54     T   Hexane                                              62,600.0     86  C6H14       110-54-3
V0882     5.92     47  Hexane, 2,4-dimethyl-                                1,250.0    114  C8H18       589-43-5
V0882     6.03     T   Methylcyclopentane                                  12,700.0     84  C6H12       96-37-7
V0882     6.12     40  1-Hexene, 4-methyl-                                    121.0     98  C7H14       3769-23-1
V0882     6.45     72  Pentane, 3,3-dimethyl-                                 281.0    100  C7H16       562-49-2
V0882     6.61     T   Cyclohexane                                         12,600.0     84  C6H12       110-82-7
V0882     6.62     T   Benzene                                              2,310.0     78  C6H6        71-43-2
V0882     6.64     T   2-Methylhexane                                       6,880.0    100  C7H16       591-76-4
V0882     6.69     T   2,3-Dimethylpentane                                  1,450.0    100  C7H16       565-59-3
V0882     6.79     T   3-Methylhexane                                       7,030.0    100  C7H16       589-34-4
V0882     6.96     94  Cyclopentane, 1,3-dimethyl-                          2,280.0     98  C7H14       2453-00-1
V0882     7.01     90  Cyclopentane, 1,3-dimethyl-, cis-                    1,720.0     98  C7H14       2532-58-3
V0882     7.05     94  Cyclopentane, 1,2-dimethyl-, cis-                    2,810.0     98  C7H14       1192-18-3
V0882     7.19     T   Heptane                                             11,200.0    100  C7H16       142-82-5
```

```
Sample No: T09-0882          Comments: 11-18 Production Tubing
___________________            SmpDate:            Time:      By:           Matrix: TEDLAR
                             Canister #:           User Sample No:

            SubGroup: voc                                            Concentration
FILE      RT      MQ  NAME                                               ppbv            MW   MolFormula  CAS
------   -----    --  ------------------------------------------   -----------------   ---  ----------  --------------------

       Analysis Date: 26-MAR-2009 11:35
V0882     7.54    33  Butane, 1-chloro-2-methyl-                             83.6        106  C5H11Cl     616-13-7
V0882     7.63    T   Methylcyclohexane                                   6,870.0         98  C7H14       108-87-2
V0882     7.70    80  Hexane, 2,5-dimethyl-                                 382.0        114  C8H18       592-13-2
V0882     7.74    90  Hexane, 2,4-dimethyl-                                 371.0        114  C8H18       589-43-5
V0882     7.80    91  Cyclopentane, ethyl-                                  387.0         98  C7H14       1640-89-7
V0882     7.89    87  Cyclopentane, 1,2,4-trimethyl-                        531.0        112  C8H16       2815-58-9
V0882     8.01    94  Cyclopentane, 1,2,3-trimethyl-, (1.alpha              471.0        112  C8H16       15890-40-1
V0882     8.18    64  Pyrrolidine                                           169.0         71  C4H9N       123-75-1
V0882     8.25    T   2-Methylheptane                                     1,470.0        114  C8H18       592-27-8
V0882     8.35    T   Toluene                                             1,600.0         92  C7H8        108-88-3
V0882     8.38    T   3-Methylheptane                                       629.0        114  C8H18       589-81-1
V0882     8.52    93  Cyclohexane, 1,3-dimethyl-, cis-                      897.0        112  C8H16       638-04-0
V0882     8.67    35  Cyclohexane, 1-ethyl-2-methyl-, trans- (              162.0        126  C9H18       4923-78-8
V0882     8.73    93  Cyclopentane, 1-ethyl-2-methyl-, cis-                 185.0        112  C8H16       930-89-2
V0882     8.79    T   Octane                                              1,270.0        114  C8H18       111-65-9
V0882     8.84    86  Cyclohexane, 1,2-dimethyl- (cis/trans)                307.0        112  C8H16       583-57-3
V0882     9.13    59  Heptane, 2,4-dimethyl-                                117.0        128  C9H20       2213-23-2
V0882     9.23    80  Heptane, 2,6-dimethyl-                                285.0        128  C9H20       1072-05-5
V0882     9.35    50  Nonanal                                               162.0        142  C9H18O      124-19-6
V0882     9.41    87  Cyclohexane, ethyl-                                   149.0        112  C8H16       1678-91-7
V0882     9.46    72  Cyclohexane, 1,1,3-trimethyl-                         201.0        126  C9H18       3073-66-3
V0882     9.59    I   Chlorobenzene-d5                                         .0        112  C6D5Cl      3114-55-4
V0882     9.67    37  1-Trifluoroacetoxydecane                              105.0        254  C12H21F3O2  0-00-0
V0882     9.76    53  Hexane, 3,3-dimethyl-                                 190.0        114  C8H18       563-16-6
V0882     9.82    T   Ethyl benzene                                          79.1        106  C8H10       100-41-4
V0882     9.87    50  Heptane, 3-ethyl-                                     165.0        128  C9H20       15869-80-4
V0882     9.94    T   m,p-Xylene                                            136.0        106  C8H10       108-38-3 / 106-42-3
V0882    10.27    T   Nonane                                                140.0        128  C9H20       111-84-2
                                                   sum:          672,646
```

```
Sample No: T09-0883        Comments: 6-12 Surface Casing
___________________          SmpDate: 19-Mar-09  Time: 0905  By:          Matrix: TEDLAR
                           Canister #:          User Sample No:

           SubGroup: voc                                    Concentration
FILE      RT     MQ  NAME                                        ppbv          MW   MolFormula  CAS
------   -----   --  ----------------------------------------  ----------------  ---  ----------  --------------------
       Analysis Date: 26-MAR-2009 12:09
V0883     0.00   T   1-Butene                                           0.0   56  C4H8        106-98-9
V0883     0.00   T   trans-2-Butene                                     0.0   56  C4H8        624-64-6
V0883     0.00   T   3-Methyl-1-butene                                  0.0   70  C5H10       563-45-1
V0883     0.00   T   1-Pentene                                          0.0   70  C5H10       109-67-1
V0883     0.00   T   Isoprene                                           0.0   68  C5H8        78-79-5
V0883     0.00   T   trans-2-Pentene                                    0.0   70  C5H10       646-04-8
V0883     0.00   T   cis-2-Pentene                                      0.0   70  C5H10       627-20-3
V0883     0.00   T   2-Methyl-2-butene                                  0.0   70  C5H10       563-46-2
V0883     0.00   T   Cyclopentene                                       0.0   68  C5H8        142-29-0
V0883     0.00   T   4-Methyl-1-pentene                                 0.0   84  C6H12       691-37-2
V0883     0.00   T   2-Methyl-1-pentene                                 0.0   84  C6H12       763-29-1
V0883     0.00   T   cis-2-Hexene                                       0.0   84  C6H12       7688-21-3
V0883     0.00   T   trans-2-Hexene                                     0.0   84  C6H12       4050-45-7
V0883     0.00   T   2,4-Dimethylpentane                                0.0  100  C7H16       108-08-7
V0883     0.00   T   2,2,4-Trimethylpentane                             0.0  114  C8H18       540-84-1
V0883     0.00   T   2,3,4-Trimethylpentane                             0.0  114  C8H18       565-75-3
V0883     0.00   T   Toluene                                            0.0   92  C7H8        108-88-3
V0883     0.00   T   3-Methylheptane                                    0.0  114  C8H18       589-81-1
V0883     0.00   T   Ethyl benzene                                      0.0  106  C8H10       100-41-4
V0883     0.00   T   m,p-Xylene                                         0.0  106  C8H10       108-38-3 / 106-42-3
V0883     0.00   T   Nonane                                             0.0  128  C9H20       111-84-2
V0883     0.00   T   Styrene                                            0.0  104  C8H8        100-42-5
V0883     0.00   T   o-Xylene                                           0.0  106  C8H10       95-47-6
V0883     0.00   T   Isopropylbenzene                                   0.0  120  C9H12       98-82-8
V0883     0.00   T   alpha Pinene                                       0.0  136  C10H16      80-56-8
V0883     0.00   T   n-Propylbenzene                                    0.0  120  C9H12       103-65-1
V0883     0.00   T   1,3,5-Trimethylbenzene                             0.0  120  C9H12       108-67-8
V0883     0.00   T   beta Pinene                                        0.0  136  C10H16      18172-67-3
V0883     0.00   T   1,2,4-Trimethylbenzene                             0.0  120  C9H12       95-63-6
V0883     2.80   T   Isobutane                                  4,180,000.0   58  C4H10       75-28-5
V0883     3.02   T   Butane                                     5,670,000.0   58  C4H10       106-97-8
V0883     3.25   T   cis-2-Butene                                  17,000.0   56  C4H8        590-18-1
V0883     3.69   T   Isopentane                                 2,170,000.0   72  C5H12       78-78-4
V0883     4.02   T   Pentane                                    1,650,000.0   72  C5H12       109-66-0
V0883     4.18   27  Cyclopropane                                   1,120.0   42  C3H6        75-19-4
V0883     4.50   T   2,2-Dimethylbutane                            28,900.0   86  C6H14       75-83-2
V0883     4.95   T   2,3-Dimethylbutane                            48,400.0   86  C6H14       79-29-8
V0883     4.99   T   Cyclopentane                                  33,300.0   70  C5H10       287-92-3
V0883     5.02   T   2-Methylpentane                              303,000.0   86  C6H14       107-83-5
V0883     5.25   T   3-Methylpentane                              171,000.0   86  C6H14       96-14-0
V0883     5.53   T   Hexane                                       282,000.0   86  C6H14       110-54-3
V0883     6.02   T   Methylcyclopentane                            55,400.0   84  C6H12       96-37-7
V0883     6.45   23  Pentane, 3,3-dimethyl-                         1,030.0  100  C7H16       562-49-2
V0883     6.61   T   Cyclohexane                                   25,300.0   84  C6H12       110-82-7
V0883     6.61   T   Benzene                                        2,190.0   78  C6H6        71-43-2
V0883     6.64   T   2-Methylhexane                                23,000.0  100  C7H16       591-76-4
V0883     6.69   T   2,3-Dimethylpentane                            6,680.0  100  C7H16       565-59-3
V0883     6.80   T   3-Methylhexane                                24,200.0  100  C7H16       589-34-4
V0883     6.95   76  Cyclopentane, 1,3-dimethyl-                   13,500.0   98  C7H14       2453-00-1
V0883     7.00   59  Cyclopentane, 1,3-dimethyl-, trans-            8,330.0   98  C7H14       1759-58-6
```

Sample No: T09-0883 Comments: 6-12 Surface Casing

SmpDate: 19-Mar-09 Time: 0905 By: Matrix: TEDLAR

Canister #: User Sample No:

SubGroup: voc

Analysis Date: 26-MAR-2009 12:09

FILE	RT	MQ	NAME	Concentration ppbv	MW	MolFormula	CAS
V0883	7.05	93	CYCLOBUTANE, ISOPROPYL-	11,000.0	98	C7H14	0-00-0
V0883	7.19	T	Heptane	21,700.0	100	C7H16	142-82-5
V0883	7.63	T	Methylcyclohexane	20,100.0	98	C7H14	108-87-2
V0883	7.89	45	2-(1-Methylethyl)-1,3-propanediol	1,180.0	118	C6H14O2	0-00-0
V0883	8.26	T	2-Methylheptane	1,820.0	114	C8H18	592-27-8
V0883	8.38	45	Octane, 3,4-dimethyl-	1,580.0	142	C10H22	15869-92-8
V0883	8.52	43	Cyclohexane, 1,2-dimethyl-, cis-	1,620.0	112	C8H16	2207-01-4
V0883	8.79	T	Octane	2,000.0	114	C8H18	111-65-9
V0883	9.59	I	Chlorobenzene-d5	.0	112	C6D5Cl	3114-55-4

sum: 14,775,350

FILE: datafile RT: retention time MQ: T=target compound or ##=PBM library match quality

Flg: nd=not detected U=non-target compound or Unknown

MDL: method detection limit MW: molecular weight CAS: chemical abstracts service

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

By:

Date:

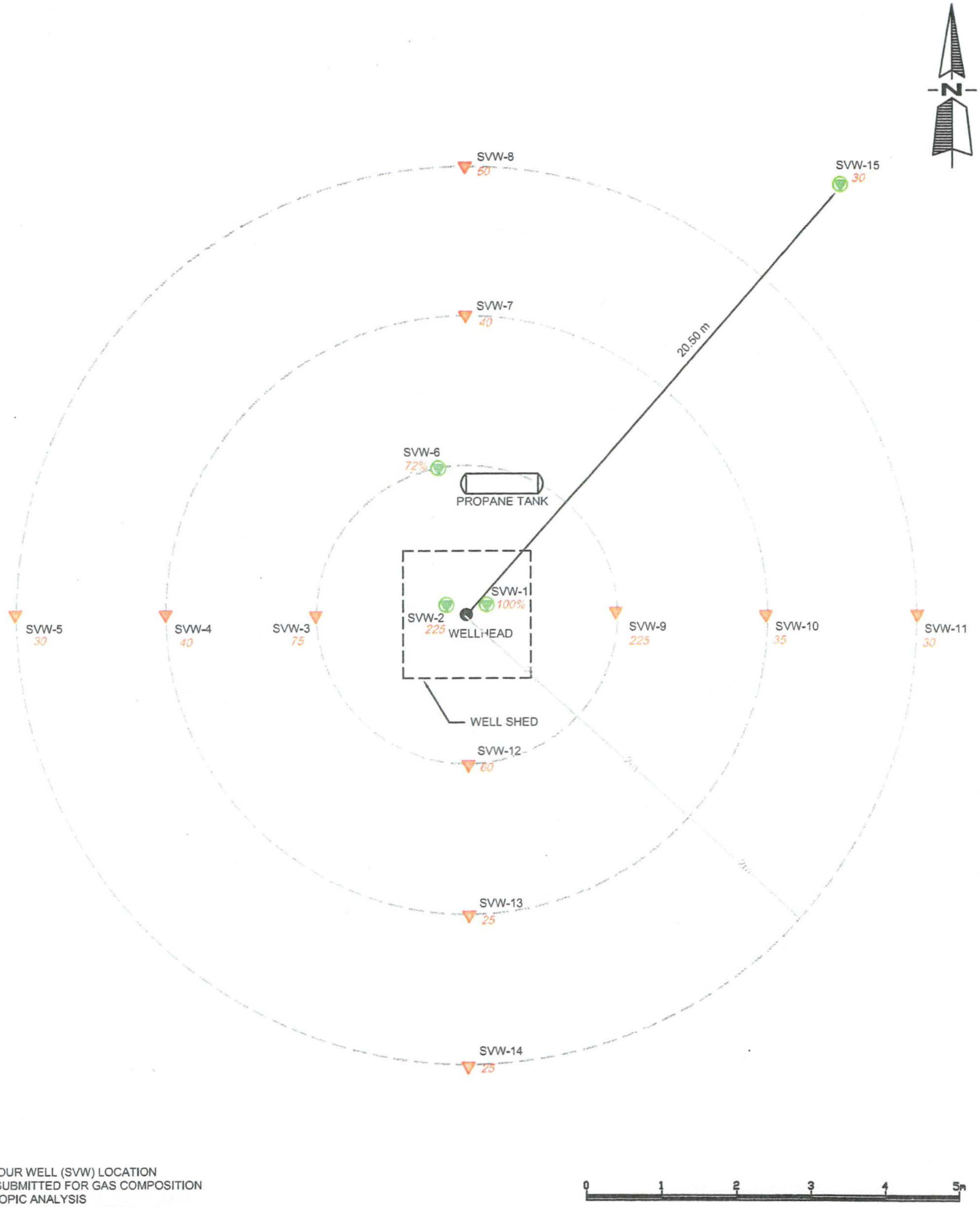
Contact Person: Grant Prill
Environmental Monitoring
Alberta Research Council
Vegreville, Alberta T9C 1T4
T9C 1T4
(780) 632-8455

University of Alberta - Isotope Lab

Sample ID	date sampled	Well Location	Sample Type	$\delta^{13}C\ C_1$	$\delta^{13}C\ C_2$	$\delta^{13}C\ C_3$	$\delta^{13}C$ i-C_4	$\delta^{13}C$ n-C_4	$\delta^{13}C\ CO_2$
	19-Mar-09	11-18-?	PRODUCTION CASING	-43.6	-26.84	-24.44	-29.61	-22.93	8.6
	19-Mar-09	11-18-?	EXSOLVED GAS	-43.49	-26.27	-26.33	-27.08	-27.75	5.3
	19-Mar-09	11-18-?	PRODUCTION TUBING	-44.01	-26.4	-26.61	-25.76	-28.62	
	19-Mar-09	6-12-?	SCV	-47.86	-30.98	-27.32	-28.21	-28.35	

Appendix B

Gas Migration Analytical Reports, Location Maps and Field LEL Data



LEGEND:

▽ SOIL VAPOUR WELL (SVW) LOCATION
● SAMPLE SUBMITTED FOR GAS COMPOSITION AND ISOTOPIC ANALYSIS
50 SOIL VAPOUR CONCENTRATION (ppm)
% LEL

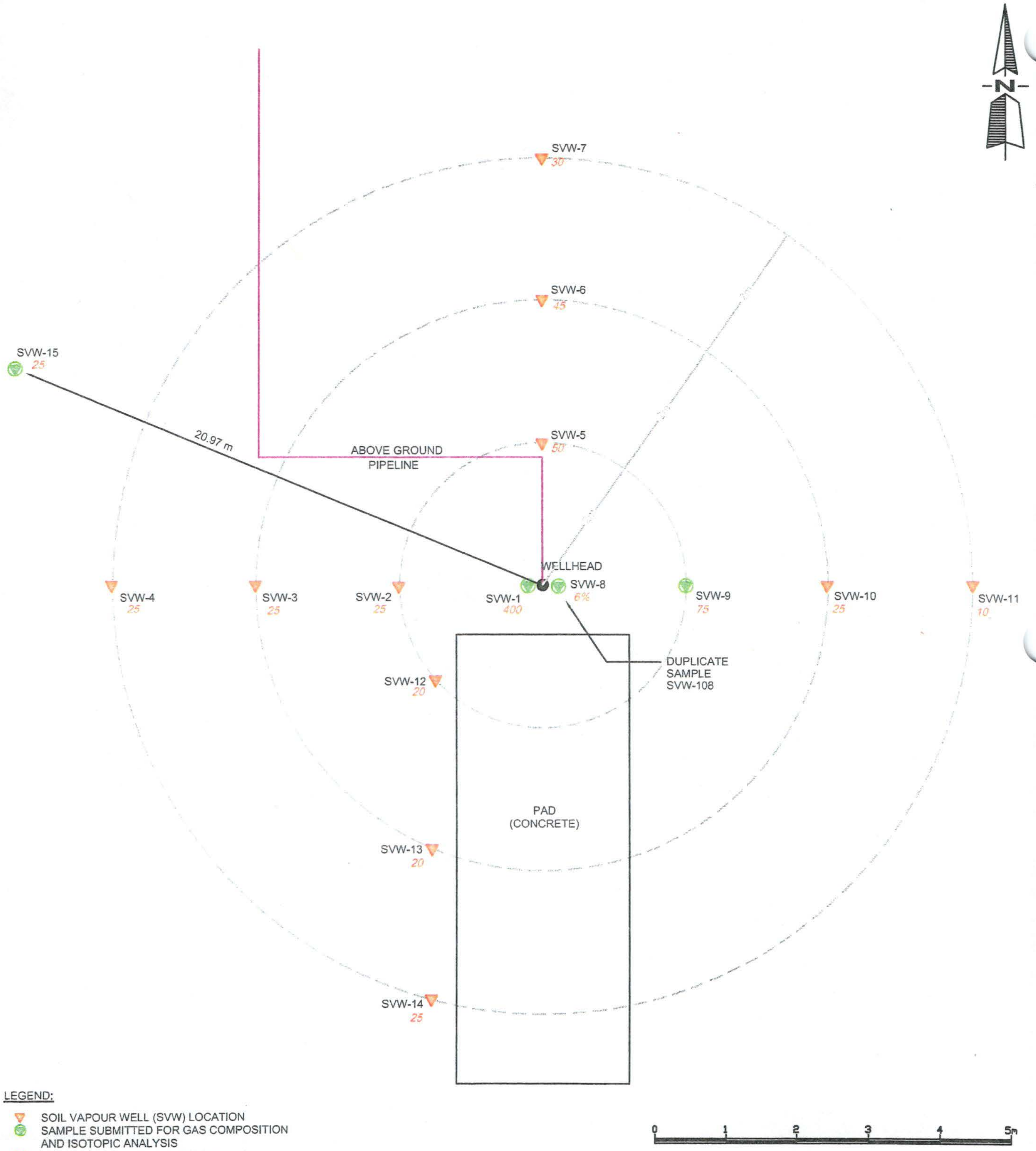
SAMPLE DATE: SEPTEMBER 16, 2009

Baseline
Water Resource Inc.

ERCB - SPIRIT RIVER
GAS MIGRATION PROJECT

Project	ERCB	By	CG	SOIL VAPOUR WELL LOCATIONS	Figure
File	09-7003	Chkd	BB		
Date	2009-10-20	Scale	1:75	PENNWEST 06-12-078-08 W6M	2
Rev Date		Drwn	TN		

THE STATED SCALE MAY NOT AGREE WITH SCALEBAR WHEN THIS DOCUMENT IS VIEWED IN PDF FORMAT OR IS PRINTED FROM A PDF FORMAT



LEGEND:

- ▼ SOIL VAPOUR WELL (SVW) LOCATION
- ● SAMPLE SUBMITTED FOR GAS COMPOSITION AND ISOTOPIC ANALYSIS
- 50 SOIL VAPOUR CONCENTRATION (ppm)
- % LEL

SAMPLE DATE: SEPTEMBER 16, 2009

Baseline
Water Resource Inc.

ERCB - SPIRIT RIVER
GAS MIGRATION PROJECT

Project	ERCB	By	CG
File	09-7003	Chkd	BB
Date	2009-10-20	Scale	1:75
Rev Date		Drwn	TN

SOIL VAPOUR WELL LOCATIONS
PENNWEST 00/11-12-078-08 W6M

Figure
3

THE STATED SCALE MAY NOT AGREE WITH SCALEBAR WHEN THIS DOCUMENT IS VIEWED IN PDF FORMAT OR IS PRINTED FROM A PDF FORMAT

Alberta Research Council
Environmental Monitoring
Vegreville, Alberta

Tabular Data Report

Sample No: T09-2954

Comments: Baseline- ERCB-PennWest 6-12-078-08 W6M
SmpDate: 16-Sep-09 Time: 0910 By: CRG Matrix: SILCO
Canister #: 2443 User Sample No: SVW-15

SubGroup: TCD

Analysis Date:

FILE	RT	MQ	NAME	Concentration percent	MW	MolFormula	CAS
G2954	0.00	T	Carbon monoxide	0.0	28	CO	630-08-0
G2954	1.52	T	Carbon dioxide	.5	44	CO2	124-38-9
G2954	3.33	T	Oxygen	20.9	32	O2	7782-44-7
G2954	6.07	T	Nitrogen	77.6	28	N2	7727-37-9
			sum:	99			

SubGroup: c1c4

Analysis Date: 22-SEP-2009 00:00

FILE	RT	MQ	NAME	Concentration ppmv	MW	MolFormula	CAS
c2954	0.00	T	Ethane	0.0	30	C2H6	74-84-0
c2954	0.00	T	Propane	0.0	44	C3H8	74-98-6
c2954	0.00	T	Propylene	0.0	42	C3H6	115-07-1
c2954	0.00	T	Isobutane	0.0	58	C4H10	75-28-5
c2954	0.00	T	Acetylene	0.0	26	C2H2	74-86-2
c2954	0.00	T	Butane	0.0	58	C4H10	106-97-8
c2954	0.00	T	trans-2-Butene	0.0	56	C4H8	624-64-6
c2954	0.00	T	1-Butene	0.0	56	C4H8	106-98-9
c2954	0.00	T	Isobutylene	0.0	56	C4H8	115-11-7
c2954	0.00	T	cis-2-Butene	0.0	56	C4H8	590-18-1
c2954	0.00	T	Propyne	0.0	40	C3H4	74-99-7
c2954	0.00	T	1,3-Butadiene	0.0	54	C4H6	106-99-0
c2954	0.00	T	Ethylacetylene	0.0	54	C4H6	107-00-6
c2954	1.74	T	Methane	2.1	16	CH4	74-82-8
c2954	2.87	T	Ethylene	0.0	28	C2H4	74-85-1
			sum:	2			

```
Sample No: T09-2955        Comments: Baseline- ERCB-PennWest 6-12-078-08 W6M
____________________        SmpDate: 16-Sep-09  Time: 0925  By: CRG      Matrix: SILCO
                         Canister #: 2518       User Sample No: SVW-6

            SubGroup: TCD                                    Concentration
FILE      RT      MQ  NAME                                         percent        MW   MolFormula  CAS
------   -----    --  -----------------------------------------  ----------------  ---  ----------  --------------------
       Analysis Date:
G2955     0.00    T   Carbon monoxide                                      0.0    28  CO          630-08-0
G2955     1.51    T   Carbon dioxide                                       2.1    44  CO2         124-38-9
G2955     3.34    T   Oxygen                                               5.3    32  O2          7782-44-7
G2955     6.12    T   Nitrogen                                            38.7    28  N2          7727-37-9
                                                      sum:          46

            SubGroup: c1c4                                   Concentration
FILE      RT      MQ  NAME                                          ppmv           MW   MolFormula  CAS
------   -----    --  -----------------------------------------  ----------------  ---  ----------  --------------------
       Analysis Date: 22-SEP-2009 00:00
c2955     0.00    T   Ethylene                                             0.0    28  C2H4        74-85-1
c2955     0.00    T   Propylene                                            0.0    42  C3H6        115-07-1
c2955     0.00    T   Acetylene                                            0.0    26  C2H2        74-86-2
c2955     0.00    T   Butane                                               0.0    58  C4H10       106-97-8
c2955     0.00    T   trans-2-Butene                                       0.0    56  C4H8        624-64-6
c2955     0.00    T   1-Butene                                             0.0    56  C4H8        106-98-9
c2955     0.00    T   Isobutylene                                          0.0    56  C4H8        115-11-7
c2955     0.00    T   cis-2-Butene                                         0.0    56  C4H8        590-18-1
c2955     0.00    T   Propyne                                              0.0    40  C3H4        74-99-7
c2955     0.00    T   1,3-Butadiene                                        0.0    54  C4H6        106-99-0
c2955     0.00    T   Ethylacetylene                                       0.0    54  C4H6        107-00-6
c2955     1.73    T   Methane                                        580,000.0    16  CH4         74-82-8
c2955     2.20    T   Ethane                                           5,750.0    30  C2H6        74-84-0
c2955     4.23    T   Propane                                              9.2    44  C3H8        74-98-6
c2955     7.81    T   Isobutane                                           11.4    58  C4H10       75-28-5
                                                      sum:     585,771
```

```
Sample No: T09-2956        Comments: Baseline- ERCB-PennWest 6-12-078-08 W6M
____________________         SmpDate: 16-Sep-09  Time: 0940  By: CRG       Matrix: SILCO
                          Canister #: 2654       User Sample No: SVW-2

            SubGroup: TCD                                          Concentration
FILE      RT      MQ  NAME                                               percent        MW   MolFormula  CAS
------    -----   --  ------------------------------------------  -----------------   ---  ----------  --------------------
       Analysis Date:
G2956     0.00    T   Carbon monoxide                                          0.0      28  CO          630-08-0
G2956     1.52    T   Carbon dioxide                                            .4      44  CO2         124-38-9
G2956     3.33    T   Oxygen                                                  19.6      32  O2          7782-44-7
G2956     6.07    T   Nitrogen                                                71.9      28  N2          7727-37-9
                                                            sum:           92

            SubGroup: c1c4                                         Concentration
FILE      RT      MQ  NAME                                               ppmv           MW   MolFormula  CAS
------    -----   --  ------------------------------------------  -----------------   ---  ----------  --------------------
       Analysis Date: 22-SEP-2009 00:00
c2956     0.00    T   Ethylene                                                 0.0      28  C2H4        74-85-1
c2956     0.00    T   Propylene                                                0.0      42  C3H6        115-07-1
c2956     0.00    T   Acetylene                                                0.0      26  C2H2        74-86-2
c2956     0.00    T   trans-2-Butene                                           0.0      56  C4H8        624-64-6
c2956     0.00    T   1-Butene                                                 0.0      56  C4H8        106-98-9
c2956     0.00    T   Isobutylene                                              0.0      56  C4H8        115-11-7
c2956     0.00    T   cis-2-Butene                                             0.0      56  C4H8        590-18-1
c2956     0.00    T   Propyne                                                  0.0      40  C3H4        74-99-7
c2956     0.00    T   1,3-Butadiene                                            0.0      54  C4H6        106-99-0
c2956     0.00    T   Ethylacetylene                                           0.0      54  C4H6        107-00-6
c2956     1.73    T   Methane                                             64,900.0      16  CH4         74-82-8
c2956     2.20    T   Ethane                                                 290.0      30  C2H6        74-84-0
c2956     4.22    T   Propane                                                 29.8      44  C3H8        74-98-6
c2956     7.79    T   Isobutane                                                6.2      58  C4H10       75-28-5
c2956     8.22    T   Butane                                                   2.5      58  C4H10       106-97-8
                                                            sum:        65,229
```

```
Sample No: T09-2957         Comments: Baseline- ERCB-PennWest 6-12-078-08 W6M
____________________         SmpDate: 16-Sep-09  Time: 0950  By: CRG       Matrix: SILCO
                           Canister #: 2447       User Sample No: SVW-1

            SubGroup: TCD                                      Concentration
FILE       RT      MQ  NAME                                          percent       MW   MolFormula  CAS
------    -----    --  -----------------------------------------  ----------------  ---  ----------  --------------------
       Analysis Date:
G2957      0.00    T   Carbon monoxide                                      0.0     28  CO          630-08-0
G2957      1.51    T   Carbon dioxide                                        .8     44  CO2         124-38-9
G2957      3.32    T   Oxygen                                              12.2     32  O2          7782-44-7
G2957      6.09    T   Nitrogen                                            55.2     28  N2          7727-37-9
                                                      sum:             68

            SubGroup: c1c4                                     Concentration
FILE       RT      MQ  NAME                                          ppmv          MW   MolFormula  CAS
------    -----    --  -----------------------------------------  ----------------  ---  ----------  --------------------
       Analysis Date: 22-SEP-2009 00:00
c2957      0.00    T   Ethylene                                             0.0     28  C2H4        74-85-1
c2957      0.00    T   Propylene                                            0.0     42  C3H6        115-07-1
c2957      0.00    T   Acetylene                                            0.0     26  C2H2        74-86-2
c2957      0.00    T   trans-2-Butene                                       0.0     56  C4H8        624-64-6
c2957      0.00    T   1-Butene                                             0.0     56  C4H8        106-98-9
c2957      0.00    T   Isobutylene                                          0.0     56  C4H8        115-11-7
c2957      0.00    T   cis-2-Butene                                         0.0     56  C4H8        590-18-1
c2957      0.00    T   Propyne                                              0.0     40  C3H4        74-99-7
c2957      0.00    T   1,3-Butadiene                                        0.0     54  C4H6        106-99-0
c2957      0.00    T   Ethylacetylene                                       0.0     54  C4H6        107-00-6
c2957      1.73    T   Methane                                        326,000.0     16  CH4         74-82-8
c2957      2.20    T   Ethane                                           2,700.0     30  C2H6        74-84-0
c2957      4.23    T   Propane                                            358.0     44  C3H8        74-98-6
c2957      7.81    T   Isobutane                                           55.4     58  C4H10       75-28-5
c2957      8.24    T   Butane                                              19.5     58  C4H10       106-97-8
                                                      sum:         329,133
```

```
Sample No: T09-3038          Comments: Baseline- ERCB-PennWest 11-12-078-08 W6M
______________________          SmpDate: 16-Sep-09  Time: 1055  By: CRG        Matrix: SILCO
                           Canister #: 1964       User Sample No: SVW-15

              SubGroup: TCD                                   Concentration
FILE       RT       MQ  NAME                                          percent        MW   MolFormula  CAS
------    -----     --  ----------------------------------------  ----------------   ---  ----------  --------------------
       Analysis  Date:
G3038      0.00     T   Carbon monoxide                                       0.0    28  CO          630-08-0
G3038      1.53     T   Carbon dioxide                                         .2    44  CO2         124-38-9
G3038      3.32     T   Oxygen                                               20.6    32  O2          7782-44-7
G3038      6.05     T   Nitrogen                                             78.5    28  N2          7727-37-9
                                                     sum:             99

              SubGroup: c1c4                                  Concentration
FILE       RT       MQ  NAME                                          ppmv           MW   MolFormula  CAS
------    -----     --  ----------------------------------------  ----------------   ---  ----------  --------------------
       Analysis Date: 24-SEP-2009 00:00
c3038      0.00     T   Ethane                                                0.0    30  C2H6        74-84-0
c3038      0.00     T   Ethylene                                              0.0    28  C2H4        74-85-1
c3038      0.00     T   Propane                                               0.0    44  C3H8        74-98-6
c3038      0.00     T   Propylene                                             0.0    42  C3H6        115-07-1
c3038      0.00     T   Isobutane                                             0.0    58  C4H10       75-28-5
c3038      0.00     T   Acetylene                                             0.0    26  C2H2        74-86-2
c3038      0.00     T   Butane                                                0.0    58  C4H10       106-97-8
c3038      0.00     T   trans-2-Butene                                        0.0    56  C4H8        624-64-6
c3038      0.00     T   1-Butene                                              0.0    56  C4H8        106-98-9
c3038      0.00     T   Isobutylene                                           0.0    56  C4H8        115-11-7
c3038      0.00     T   cis-2-Butene                                          0.0    56  C4H8        590-18-1
c3038      0.00     T   Propyne                                               0.0    40  C3H4        74-99-7
c3038      0.00     T   1,3-Butadiene                                         0.0    54  C4H6        106-99-0
c3038      0.00     T   Ethylacetylene                                        0.0    54  C4H6        107-00-6
c3038      1.75     T   Methane                                               5.6    16  CH4         74-82-8
                                                     sum:              6
```

```
Sample No: T09-3039        Comments: Baseline- ERCB-PennWest 11-12-078-08 W6M
____________________        SmpDate: 16-Sep-09  Time: 1110  By: CRG       Matrix: SILCO
                         Canister #: 1680       User Sample No: SVW-9

            SubGroup: TCD                                       Concentration
FILE      RT      MQ  NAME                                            percent         MW   MolFormula  CAS
------   -----    --  -----------------------------------------  -----------------   ---  ----------  --------------------
       Analysis Date:
G3039     0.00    T   Carbon monoxide                                       0.0       28  CO         630-08-0
G3039     1.53    T   Carbon dioxide                                         .2       44  CO2        124-38-9
G3039     3.33    T   Oxygen                                               21.1       32  O2         7782-44-7
G3039     6.06    T   Nitrogen                                             78.5       28  N2         7727-37-9
                                                         sum:         100

            SubGroup: c1c4                                      Concentration
FILE      RT      MQ  NAME                                            ppmv            MW   MolFormula  CAS
------   -----    --  -----------------------------------------  -----------------   ---  ----------  --------------------
       Analysis Date: 24-SEP-2009 00:00
c3039     0.00    T   Propylene                                             0.0       42  C3H6       115-07-1
c3039     0.00    T   Acetylene                                             0.0       26  C2H2       74-86-2
c3039     0.00    T   trans-2-Butene                                        0.0       56  C4H8       624-64-6
c3039     0.00    T   1-Butene                                              0.0       56  C4H8       106-98-9
c3039     0.00    T   Isobutylene                                           0.0       56  C4H8       115-11-7
c3039     0.00    T   cis-2-Butene                                          0.0       56  C4H8       590-18-1
c3039     0.00    T   Propyne                                               0.0       40  C3H4       74-99-7
c3039     0.00    T   1,3-Butadiene                                         0.0       54  C4H6       106-99-0
c3039     0.00    T   Ethylacetylene                                        0.0       54  C4H6       107-00-6
c3039     1.74    T   Methane                                               3.2       16  CH4        74-82-8
c3039     2.20    T   Ethane                                                6.0       30  C2H6       74-84-0
c3039     2.89    T   Ethylene                                               .9       28  C2H4       74-85-1
c3039     4.23    T   Propane                                                .4       44  C3H8       74-98-6
c3039     7.80    T   Isobutane                                              .3       58  C4H10      75-28-5
c3039     8.24    T   Butane                                                 .5       58  C4H10      106-97-8
                                                         sum:          11
```

```
Sample No: T09-3040          Comments: Baseline- ERCB-PennWest 11-12-078-08 W6M
____________________           SmpDate: 16-Sep-09  Time: 1120  By: CRG       Matrix: SILCO
                            Canister #: 1843       User Sample No: SVW-1

            SubGroup: TCD                                          Concentration
FILE       RT      MQ  NAME                                              percent          MW   MolFormula  CAS
------    -----    --  ----------------------------------------   -----------------    ---  ----------  --------------------
       Analysis Date:
G3040      0.00    T   Carbon monoxide                                           0.0      28  CO          630-08-0
G3040      1.52    T   Carbon dioxide                                             .9      44  CO2         124-38-9
G3040      3.33    T   Oxygen                                                   20.9      32  O2          7782-44-7
G3040      6.07    T   Nitrogen                                                 78.2      28  N2          7727-37-9
                                                      sum:            100

            SubGroup: c1c4                                         Concentration
FILE       RT      MQ  NAME                                              ppmv             MW   MolFormula  CAS
------    -----    --  ----------------------------------------   -----------------    ---  ----------  --------------------
       Analysis Date: 24-SEP-2009 00:00
c3040      0.00    T   Ethylene                                                  0.0      28  C2H4        74-85-1
c3040      0.00    T   Propylene                                                 0.0      42  C3H6        115-07-1
c3040      0.00    T   Acetylene                                                 0.0      26  C2H2        74-86-2
c3040      0.00    T   trans-2-Butene                                            0.0      56  C4H8        624-64-6
c3040      0.00    T   1-Butene                                                  0.0      56  C4H8        106-98-9
c3040      0.00    T   Isobutylene                                               0.0      56  C4H8        115-11-7
c3040      0.00    T   cis-2-Butene                                              0.0      56  C4H8        590-18-1
c3040      0.00    T   Propyne                                                   0.0      40  C3H4        74-99-7
c3040      0.00    T   1,3-Butadiene                                             0.0      54  C4H6        106-99-0
c3040      0.00    T   Ethylacetylene                                            0.0      54  C4H6        107-00-6
c3040      1.74    T   Methane                                                 717.0      16  CH4         74-82-8
c3040      2.21    T   Ethane                                                   26.6      30  C2H6        74-84-0
c3040      4.23    T   Propane                                                  52.3      44  C3H8        74-98-6
c3040      7.81    T   Isobutane                                                20.9      58  C4H10       75-28-5
c3040      8.24    T   Butane                                                   19.5      58  C4H10       106-97-8
                                                      sum:            836
```

```
Sample No: T09-3049        Comments: Baseline- ERCB- PennWest 11-12-078-08 W6M
____________________        SmpDate: 16-Sep-09  Time: 1130  By: CRG       Matrix: SILCO
                         Canister #: 1152       User Sample No: SVW-8


            SubGroup: TCD                                       Concentration
FILE      RT      MQ  NAME                                          percent         MW   MolFormula  CAS
------    -----   --  ------------------------------------------  -----------------  ---  ----------  --------------------
       Analysis Date:
G3049     0.00    T   Carbon monoxide                                         0.0    28  CO          630-08-0
G3049     1.51    T   Carbon dioxide                                          2.7    44  CO2         124-38-9
G3049     3.33    T   Oxygen                                                 18.0    32  O2          7782-44-7
G3049     6.06    T   Nitrogen                                               79.6    28  N2          7727-37-9
                                                       sum:             100


            SubGroup: c1c4                                      Concentration
FILE      RT      MQ  NAME                                          ppmv            MW   MolFormula  CAS
------    -----   --  ------------------------------------------  -----------------  ---  ----------  --------------------
       Analysis Date: 29-SE9-2009 00:00
c3049     0.00    T   Acetylene                                               0.0    26  C2H2        74-86-2
c3049     0.00    T   Isobutylene                                             0.0    56  C4H8        115-11-7
c3049     0.00    T   cis-2-Butene                                            0.0    56  C4H8        590-18-1
c3049     0.00    T   1,3-Butadiene                                           0.0    54  C4H6        106-99-0
c3049     0.00    T   Ethylacetylene                                          0.0    54  C4H6        107-00-6
c3049     1.73    T   Methane                                             2,540.0    16  CH4         74-82-8
c3049     2.19    T   Ethane                                              1,800.0    30  C2H6        74-84-0
c3049     2.87    T   Ethylene                                               48.2    28  C2H4        74-85-1
c3049     4.22    T   Propane                                               122.0    44  C3H8        74-98-6
c3049     6.57    T   Propylene                                               2.9    42  C3H6        115-07-1
c3049     7.80    T   Isobutane                                              40.6    58  C4H10       75-28-5
c3049     8.23    T   Butane                                                 41.7    58  C4H10       106-97-8
c3049    10.35    T   trans-2-Butene                                           .8    56  C4H8        624-64-6
c3049    10.47    T   1-Butene                                                 .6    56  C4H8        106-98-9
c3049    12.41    T   Propyne                                                21.5    40  C3H4        74-99-7
                                                       sum:           4,618
```

Sample No: T09-3050 Comments: Baseline- ERCB- PennWest 11-12-078-08 W6M
SmpDate: 16-Sep-09 Time: 1130 By: CRG Matrix: SILCO
Canister #: H2799 User Sample No: SVW-108

SubGroup: TCD

FILE	RT	MQ	NAME	Concentration percent	MW	MolFormula	CAS
Analysis Date:							
G3050	0.00	T	Carbon monoxide	0.0	28	CO	630-08-0
G3050	1.52	T	Carbon dioxide	2.0	44	CO2	124-38-9
G3050	3.33	T	Oxygen	18.5	32	O2	7782-44-7
G3050	6.06	T	Nitrogen	76.8	28	N2	7727-37-9
			sum:	97			
Analysis Date:							
G3050Z	0.00	T	Carbon monoxide	0.0	28	CO	630-08-0
G3050Z	1.52	T	Carbon dioxide	2.2	44	CO2	124-38-9
G3050Z	3.33	T	Oxygen	18.8	32	O2	7782-44-7
G3050Z	6.06	T	Nitrogen	77.4	28	N2	7727-37-9
			sum:	98			

SubGroup: c1c4

FILE	RT	MQ	NAME	Concentration ppmv	MW	MolFormula	CAS
Analysis Date: 29-SE9-2009 00:00							
c3050	0.00	T	Ethylene	0.0	28	C2H4	74-85-1
c3050	0.00	T	Acetylene	0.0	26	C2H2	74-86-2
c3050	0.00	T	trans-2-Butene	0.0	56	C4H8	624-64-6
c3050	0.00	T	1-Butene	0.0	56	C4H8	106-98-9
c3050	0.00	T	Isobutylene	0.0	56	C4H8	115-11-7
c3050	0.00	T	cis-2-Butene	0.0	56	C4H8	590-18-1
c3050	0.00	T	1,3-Butadiene	0.0	54	C4H6	106-99-0
c3050	1.72	T	Methane	12,700.0	16	CH4	74-82-8
c3050	2.18	T	Ethane	982.0	30	C2H6	74-84-0
c3050	4.20	T	Propane	552.0	44	C3H8	74-98-6
c3050	6.55	T	Propylene	.8	42	C3H6	115-07-1
c3050	7.78	T	Isobutane	114.0	58	C4H10	75-28-5
c3050	8.21	T	Butane	115.0	58	C4H10	106-97-8
c3050	12.38	T	Propyne	31.8	40	C3H4	74-99-7
c3050	15.58	T	Ethylacetylene	17.1	54	C4H6	107-00-6
			sum:	14,513			

FILE: datafile RT: retention time MQ: T=target compound or ##=PBM library match quality
Flg: nd=not detected U=non-target compound or Unknown
MDL: method detection limit MW: molecular weight CAS: chemical abstracts service

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

By: ____________________

Date:

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

University of Alberta - Isotope laboratory

16-Oct-09	LSD	SEC	T	R	M	Company	Sample ID	13C1	13C2	13C3	13iC4
SVW-15	6	12	78	8	6	ARC	T09=2954				
svw-6	6	12	78	8	6	ARC	T09=2955	-49.04	-33.82		
svw-2	6	12	78	8	6	ARC	T09=2956	-53.14	-31.9	-31.17	
svw-1	6	12	78	8	6	ARC	T09=2957	-49.03	-32.51	-31.51	-31.3
svw-15	11	12	78	8	6	ARC	T09-3038				
svw-9	11	12	78	8	6	ARC	T09-3038		-26.38		
svw-1	11	12	78	8	6	ARC	T09-3040	-37.43	-25.26		
svw-8	11	12	78	8	6	ARC	T09-3049	-40.62	-27.35	-26.14	-27.03
svw-108	11	12	78	8	6	ARC	T09-3050	-40.62	-27.91	-25.9	-26.85

Maxxam Analytics

Site: PENNWEST LIBRARY

Attention: HAROLD SLATER
PENN WEST PETROLEUM LTD.
CALGARY ENVIRONMENTAL
200, 207-9th Avenue SW
CALGARY, AB
CANADA T2P 1K3

Report Date: 2010/10/12

Job/Sample	Analysis Type	Well Name/Sample ID	Sample Point
B091320/ X19661	Carbon Isotope PPM	PENN WEST LIBRARY	SOIL GAS (0.3M NE OF WELLHEAD)
B091320/ X19662	Carbon Isotope Gas	PENN WEST LIBRARY	SOIL GAS (1.8M NE OF WELLHEAD)
B091320/ X19663	Carbon Isotope Gas	PENN WEST LIBRARY	SOIL GAS (0.3M SE OF WELLHEAD)

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

DARLYCE SIMPSON,
Email: dsimpson@maxxamanalytics.com
Phone# (780) 378-8500

==

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Report Distribution

eports(B091320)HAROLD SLATER	PENN WEST PETROLEUM LTD.	200, 207-9th Avenue SW	CALGARY, CANADA

Date of Issue 2010/10/12

All analyses are performed according to internal procedures that are based on current published reference methods.

Maxxam Analytics

GAS ANALYSIS PPM

MaxxID	
Client ID	
Meter Number	
Laboratory Number	B091320:X19661
Operator Name	PENN WEST PETROLEUM LTD.
LSD	
Well ID	
Well Name	PENN WEST LIBRARY
Initials of Sampler	PK/DS
Sampling Company	MAXXAM ANALYTICS
Field or Area	
Pool or Zone	
Sample Point	SOIL GAS (0.3M NE OF WELLHEAD)
Container Identity	TEDLAR BAG
Percent Full	
Test Recovery	
Test Type	
No.	
Multiple Recovery	
Interval From:	
Interval To:	
Elevations (m) KB	
Elevations (m) GRD	
Sample Gathering Point	
Solution Gas	
GPS	N 0.000000
GPS	W 0.000000
Production Rates Water m3/d	
Production Rates Oil m3/d	
Production Rates Gas 1000m3/d	
Gauge Pressures kPa Source	
Gauge Pressures kPa As Received	
Temperature °C Source	
Temperature °C As Received	21
Well Fluid Type	
Licence No.	
Date Sampled Start	2010/09/22 11:50
Date Sampled End	
Date Received	2010/09/24
Date Reported	2010/10/08
Date Reissued	2010/10/12
Analyst	MW

COMPOSITION

Component	Mole Fraction As Rec'd	ppm (v/v)
H2	Trace	
He	Trace	
O2	0.1886	
N2	0.7199	
CO2	0.0016	
H2S	0.0000	
C1	0.0894	
C2	0.0004	350
C3	0.0001	110
IC4	Trace	10
NC4	Trace	10
IC5	Trace	Trace
NC5	0.0000	
C6	0.0000	
C7+	0.0000	
TOTAL	1.0000	

PROPERTIES

Calculated Molar Mass Moisture Free as Sampled	Calculated Gross Heating Value (MJ/m3) @ 101.325 kPa & 15°C	Calculated Relative Densities Relative to Ari @15°C
18.5 Total	30.99 GPA 2172	0.640 Moisture Free as Sampled

Hydrogen Sulphide

On Site Gastec (ppm v/v)	On Site Tutweiler (mole%)	In Lab Gastec (ppm v/v)	In Lab Tutweiler (mole%)	In Lab H2S from GC (mole%)
		<1		

Onsite analysis is required for accurate source H2S content.

H2S degrades variably in all sample containers and is also matrix dependant.

QC Check Std # 5878/8167 Date 2010/09/27 QC Passed Yes

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

Results relate only to items tested

Remarks:

2010/10/12 13:38

Maxxam Analytics

GAS MIGRATION ANALYSIS

MaxxID:	Client ID:	Meter Number:	Laboratory Number: B091320:X19662
Operator Name: NN WEST PETROLEUM LTD.		LSD:	Well ID:
Well Name: PENN WEST LIBRARY		Initials of Sampler: PK/DS	Sampling Company: MAXXAM ANALYTICS
Field or Area:	Pool or Zone:	Sample Point: SOIL GAS (1.8M NE OF WELLHEAD)	Container Identity: TEDLAR BAG
Percent Full:			
Test Recovery:		Sample Gathering Point:	Solution Gas:
Test Type:	No.:	Multiple Recovery:	

Interval
From:
To:

Elevations (m)
KB:
GRD:

N 0.000000
GPS

W 0.000000
GPS

Production Rates
Water m3/d:
Oil m3/d:
Gas 1000m3/d:

Gauge Pressures kPa
Source:
As Received:

Temperature °C
Source:
As Received: 21

Well Fluid Type:

Licence No.:

Date Sampled Start	Date Sampled End	Date Received	Date Reported	Date Reissued	Analyst
2010/09/22 12:50		2010/09/24	2010/10/08	2010/10/12	MW ,DT1

COMPOSITION

Component	Mole Fraction As Rec'd	ppm (v/v)	$\delta^{13}C$ ‰
H2	Trace		
He	Trace		
O2	0.1366		
N2	0.5389		
CO2	0.0040		-36.14
H2S	0.0000		
1	0.3179		-54.94
C2	0.0025		-36.07
C3	0.0001	110	-30.21
IC4	Trace	30	-28.68
NC4	Trace	10	-24.52
IC5	Trace	10	
NC5	Trace	Trace	
C6	0.0000		
C7+	0.0000		
TOTAL	1.0000		

PROPERTIES

Calculated Molar Mass Moisture Free as Sampled	Calculated Gross Heating Value (MJ/m3) @ 101.325 kPa & 15°C	Calculated Relative Densities Relative to Ari @15°C
17.5 Total	34.38 GPA 2172	0.604 Moisture Free as Sampled

Hydrogen Sulphide

On Site		In Lab		
Gastec (ppm v/v)	Tutweiler (mole%)	Gastec (ppm v/v)	Tutweiler (mole%)	H2S from GC (mole%)
		<1		

Onsite analysis is required for accurate source H2S content.
H2S degrades variably in all sample containers and is also matrix dependant.

$$\delta^{13}C‰ = [(^{13}C/^{12}C_{sample} - ^{13}C/^{12}C_{standard}) / (^{13}C/^{12}C_{standard})] * 1000$$

INTERPRETATION

QC Check Std # 5878/8167 Date 2010/09/27 QC Passed Yes

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

Results relate only to items tested

Remarks:

CALGARY 2021-41 Avenue N.E., Calgary, Canada T2E 6P2 Tel: (403) 291-3077 Fax (403) 291-[illegible] GRANDE PRAIRIE #101, 7002 - 98 Street, Clairmont, Canada T0H 0W0 Tel: (780) 532-0227 Fax (780) 532-0288
EDMONTON 6744-50 Street, Edmonton, Canada T6B 3M9 Tel: (780) 378-8500 Fax (780) 378-[illegible] RED DEER Bay #3, 4845 79 Street, Red Deer, Canada T4P 2T4 Tel: (403) 341-8811 Fax (403) 341-8815

To view or Download your data on-line via MaxxLINK, please call 1-800-386-7247

2010/10/12 13:38

Maxxam Analytics

GAS MIGRATION ANALYSIS

			B091320:X19663
MaxxID	Client ID	Meter Number	Laboratory Number
PENN WEST PETROLEUM LTD.			
Operator Name		LSD	Well ID
PENN WEST LIBRARY		PK/DS	MAXXAM ANALYTICS
Well Name		Initials of Sampler	Sampling Company
		SOIL GAS (0.3M SE OF WELLHEAD)	TEDLAR BAG
Field or Area	Pool or Zone	Sample Point	Container Identity

Percent Full:

Test Recovery:

Test Type: No.: Multiple Recovery:

Interval — From: To:

Elevations (m) — KB: GRD:

Sample Gathering Point:

Solution Gas:

N 0.000000 (GPS)

W 0.000000 (GPS)

Production Rates — Water m3/d: Oil m3/d: Gas 1000m3/d:

Gauge Pressures kPa — Source: As Received:

Temperature °C — Source: As Received: 21

Well Fluid Type:

Licence No.:

Date Sampled Start	Date Sampled End	Date Received	Date Reported	Date Reissued	Analyst
2010/09/22 11:40		2010/09/24	2010/10/08	2010/10/12	MW ,DT1

COMPOSITION

Component	Mole Fraction As Rec'd	ppm (v/v)	$\delta^{13}C$ ‰
H2	Trace		
He	Trace		
O2	0.1754		
N2	0.7031		
CO2	0.0036		-40.49
H2S	0.0000		
C1	0.1174		-53.39
C2	0.0004	450	-37.93
C3	0.0001	120	-33.93
IC4	Trace	10	-31.33
NC4	Trace	10	
IC5	Trace	Trace	
NC5	0.0000		
C6	0.0000		
C7+	Trace	20	
TOTAL	1.0000		

PROPERTIES

Calculated Molar Mass Moisture Free as Sampled	Calculated Gross Heating Value (MJ/m3) @ 101.325 kPa & 15°C	Calculated Relative Densities Relative to Ari @15°C
20.3 Total	25.72 GPA 2172	0.701 Moisture Free as Sampled

Hydrogen Sulphide

On Site		In Lab		
		<1		
Gastec (ppm v/v)	Tutweiler (mole%)	Gastec (ppm v/v)	Tutweiler (mole%)	H2S from GC (mole%)

Onsite analysis is required for accurate source H2S content.

H2S degrades variably in all sample containers and is also matrix dependant.

$$\delta^{13}C ‰ = [(^{13}C/^{12}C_{sample} - {}^{13}C/^{12}C_{standard}) / ({}^{13}C/^{12}C_{standard})] * 1000$$

INTERPRETATION

QC Check Std # 5878/8167 Date 2010/09/27 QC Passed Yes

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

Results relate only to items tested

Remarks:

Dr. Karlis Muehlenbachs' Carbon Isotope Abundance

28-Sep-10	LSD	Company	Sample ID	13C1	13C2	13C3	13iC4	13nC4	CO2
Soil Gas (1.8m NE of WH)	Penn West Library	Penn West	B091320-X19662	-54.94	-36.07	-30.21	-28.68	-24.52	-36.14
Soil Gas (0.3m SW of WH)	Penn West Library	Penn West	B091320-X19663	-53.39	-37.93	-33.93	-31.33		-40.49

Carbon Isotope Abundance done by Dr. Karlis Muehlenbachs at the University of Alberta
Email: karlis.muehlenbachs@ualberta.ca

Maxxam Analytics
Driven by Service and Science

Soil Gas Summary

Maxxam File #: B091320 – X19662, X19663
Sampling Date: 2010/09/22

Location: Penn West Library

Interpretation:

	Maxxam
SCV Gas Possible Depth:	**400 – 600 m**
SCV Gas Geologic Formation:	**From or near Dunvegan**

Maxxam's Remarks:

- These gases have similar signatures to the soil gas samples taken previously from this area.
- Based on the gas and carbon isotopic data, a possible source for these soil gases is from the Dunvegan formation, at a depth of 400 to 600 m.

- Maxxam's interpretation and remarks were done by Darlyce Simpson
- Email: darlyce.simpson@maxxamanalytics.com

Maxxam Analytics

Gas Migration Data Sheet

Company Name: Penn West
Contact Name: Harold Slater
Phone: 403-777-2500
Email: harold.slater@pennwest.com

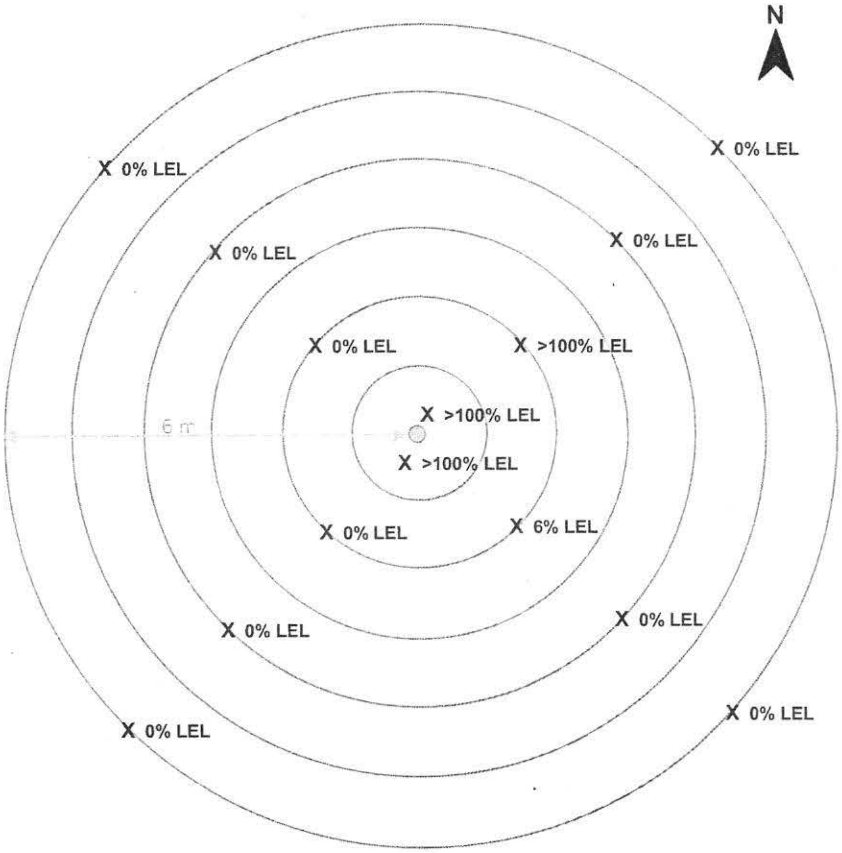
Field Contact: Larry Gordey
Phone: 780-818-2330

Maxxam Job Number: B091320

UWI: Penn West Library
Pad/Surface: N/A
License: N/A
Well Name: N/A
Date: 2010/09/22
Initials: PK/DS

SOIL GAS SURVEY DATA

Note: Please record observed "zero" readings for soil gas Lower Explosive Limit (LEL). Do not leave blanks. The centre dot in the diagram represents the wellbore/casing.



On the diagram, indicate the location of sample points and record percentage LEL readings, including observed "zero" readings.
Briefly describe test results and the condition of the area around the wellbore and on lease,
e.g., vegetation growth, bare spots, contaminated soil, etc.
Note: Postion and number of test points are subject to the proximity of buried facilities.

Gravel pad, clay underneath

Surrounded by pasture, no apparent vegetation stress

0.3m NE of wellhead - clay has oily smell

Following ERCB ID 99-3, Appendix 3

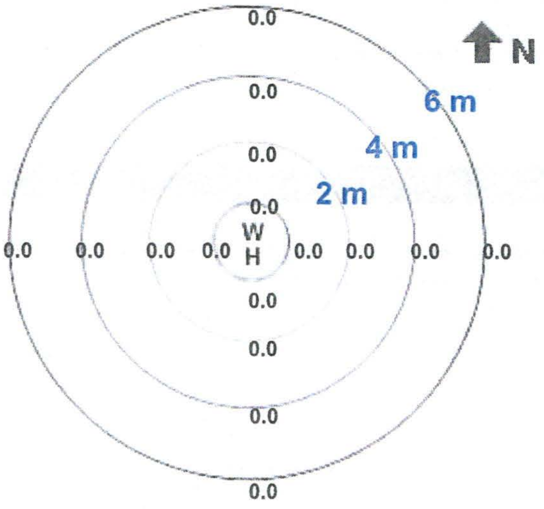
LIONHEAD ENGINEERING
A CCS Company

GAS MIGRATION TEST REPORT

WELL NAME:	NORTHSTAR ET AL SPIRITR 6-12-78-8	**UNIQUE WELL IDENTIFIER :**	00/06-12-078-08W6/

GAS MIGRATION TEST % LEL MEASUREMENTS

DISTANCE	NORTH	EAST	SOUTH	WEST
At Wellhead	0.0 %	0.0 %	0.0 %	0.0 %
At 2m from Wellhead	0.0 %	0.0 %	0.0 %	0.0 %
At 4m from Wellhead	0.0 %	0.0 %	0.0 %	0.0 %
At 6m from Wellhead	0.0 %	0.0 %	0.0 %	0.0 %



Is Gas Migration a fire, public safety, or off lease environmental hazard? NO

Maximum LEL Reading: 0.0 %

EUB Classification: NO GM

COMMENTS:

The RKI eagle has an accuracy level of +/- 5% LEL.
There is suspected Hydrocarbon contamination visible around wellhead to depths of 1m and greater.
The test points were also checked with methane elimination procedure to find that the readings were still zero % LEL.
There is no gas migration found along NESW axis points at 1.5-2m's below surface.

PICTURE(S):

First hole is drilled ~75cm
from well center
on a ~15 degree angle
down towards well bore.
Test bore hole was
drilled ~60cm deep.

TESTED BY:	MARK HUNT	**TEST DATE:**	11-Nov-10

Penn West

Gas Migration Testing - November 11, 2010

NORTHSTAR ET AL SPIRITR 6-12-78-8

6-12-78-8W6 Penn West 11-Nov-10 Hydro vac nearby pipeline

First hole is drilled ~75cm from well center on a ~15 degree angle down towards well bore. Test bore hole was drilled ~60cm deep.

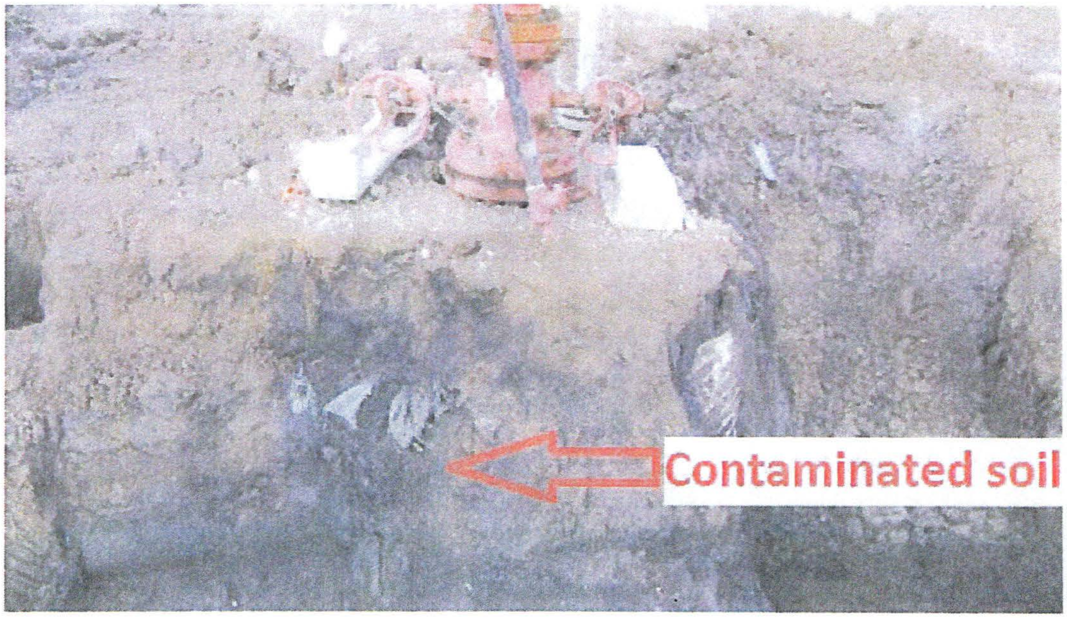
175cm – 200cm Deep North Of Well

<u>Prepared by</u>: Lionhead Engineering

Penn West

Gas Migration Testing - November 11, 2010

NORTHSTAR ET AL SPIRITR 6-12-78-8



6-12-78-8W6 Penn west 11-Nov-10 Soil

175cm – 200cm Deep East Of Well

Prepared by: ***Lionhead Engineering***

Penn West

Gas Migration Testing - November 11, 2010

NORTHSTAR ET AL SPIRITR 6-12-78-8

6-12-78-8W6 Penn west 11-Nov-10 Excavated furrows south 175cm-200cm

***Prepared by:* Lionhead Engineering**

Penn West

Gas Migration Testing - November 11, 2010

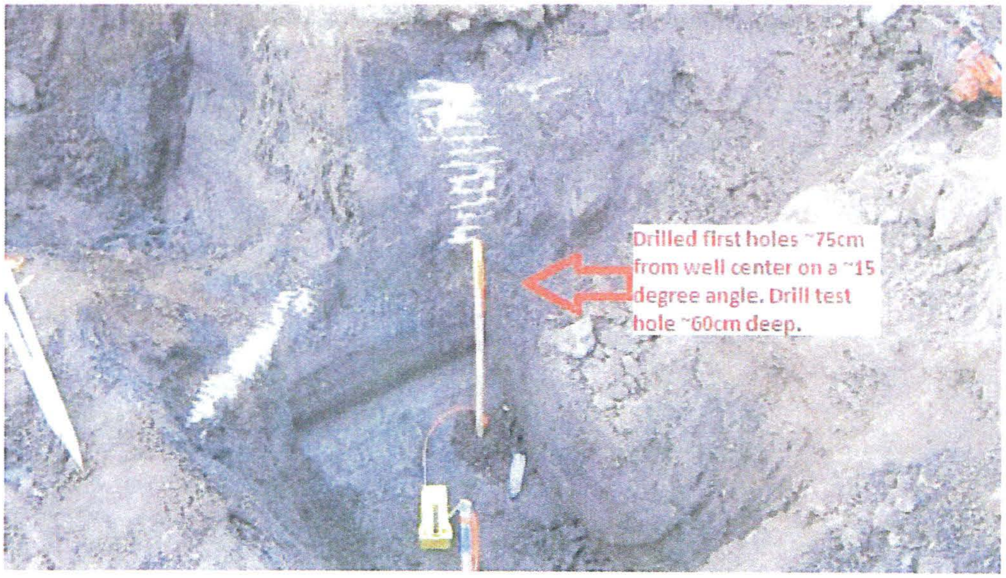
NORTHSTAR ET AL SPIRITR 6-12-78-8

6-12-78-8W6 Penn west 11-Nov-10 Excavated furrows west 175cm-200cm

Penn West
Gas Migration Testing – November 11, 2010

NORTHSTAR ET AL SPIRITR 6-12-78-8

6-12-78-8W6 Penn West 11-Nov-10 Found cason drainage culvert while digging south furrow



6-12-78-8W6 Penn West 11-Nov-10 Excavated furrows near well south 175cm-200cm

Penn West

Gas Migration Testing - November 11, 2010

NORTHSTAR ET AL SPIRITR 6-12-78-8

Drilled first holes ~75cm from well center on a ~15 degree angle. Drill test hole ~60cm deep.

6-12-78-8W6 Penn West 11-Nov-10 Excavated furrows near well west 175cm-200cm

Baseline
Water Resource Inc.

P.O. Box 75003, RPO Cambrian
Calgary, AB T2K 6J8
Phone: (403) 282-3999
Fax: (403) 282-0815

November 25, 2009

Energy Resources Conservation Board
640 – 5th Avenue SW
Calgary, AB
T2P 3G4

Attention: Michael Bevan, M.Sc., P.Geol.

RE: PENN WEST 06/11-12-078-08 W6M Gas Migration Assessments

Baseline Water Resource Inc. (BWRI) was retained by the Energy Resources Conservation Board (ERCB) to conduct gas migration assessments on September 15-16, 2009, at two well sites near Spirit River, Alberta (Figure 1). The purpose of the assessments were to determine if formation gas from the Penn West 06-12-078-08 W6M and Penn West 11-12-078-08 W6M energy wells was migrating to surface. These locations were selected by the ERCB because of their proximity to a water well known to contain thermogenic gases. The location of the two energy wells and the approximate location of the water well are presented in Figure 2.

The following report consists of details of the field investigation, however, discussion or interpretation of results is not included. Photographs of the gas migration assessments are provided in Appendix A.

SCOPE OF WORK

The Scope of Work included the following:

- Review and coordinate ground disturbance procedures with Penn West operations. Arrange for professional line locators to locate underground facilities.
- Install and purge Soil Vapour Wells (SVW) at each site.
- Collect Organic Vapour Measurements (OVM) from each SVW to determine lab sample submission requirements.

- Collect soil gas samples from the three SVW's with the greatest OVM readings and a background sample at each site for submission to the Alberta Research Council (ARC) in Vegreville, Alberta for gas composition and to the University of Alberta (UofA) in Edmonton, Alberta for isotopic analysis.
- Collect one field duplicate gas sample for submission to the ARC for gas composition and the UofA for isotopic analysis.
- Collect two soil samples (06-12-078-08 W6M (SVW-1) and 11-12-078-08 W6M SVW-1)) for submission to ARC for Petroleum Hydrocarbon Fractions (PHC) (F1-F4) and BTEX analysis.
- Decommission all SVW's and remove all flags, stakes and paint prior to leaving site.
- Prepare a report outlining the findings of the gas migration assessments.

FIELD METHODOLOGIES - STANDARD OPERATING PROCEDURES

SAFETY

Prior to commencing work, BWRI ensured that all client and BWRI Ground Disturbance procedures were followed. The most stringent protocols were used. BWRI Ground Disturbance procedures are outlined in the "Company Policy and Procedure Manual: Safe Work and Environmental Operations" (Sec. 7.2). In addition to the Alberta 1 Call (Ticket # 9248852), a professional line locating contractor, Red Alta, based out of Edmonton, Alberta was retained to complete a 30 m radius sweep at each subject site (wellhead). BWRI field personnel reviewed all available surveys and drawings with site operators to ensure all underground facilities had been identified. Ground disturbance activities were not conducted without prior approval from both the client and the owner of the underground facility. In addition, a Penn West consultant was onsite for the duration of all ground disturbance activities.

PROCEDURE

Gas migration testing was conducted in accordance with the standardized procedures provided in ERCB's Directive 020: Well Abandonment Guide (revised edition July 24, 2007).

Fifteen boreholes were hand augured to a minimum depth of 80 cm below ground surface (bgs). Two locations were bored within 30 cm of the wellhead. Twelve locations were bored at 2 m intervals every 90° to a maximum distance of 6 m. One sample location was selected to provide a background measurement. Excess fill (gravel) was removed prior to completing the borehole to ensure the slotted area of the SVW was completed in native subsoil. Whenever possible, the sample bearing (0°) was followed for SVW placement, however, site specific conditions (i.e. pipelines, above ground facilities, boulders) may have resulted in field personnel adjusting the location.

INSTALLATION

The SVW's are comprised of a 70 cm long by 10 cm diameter slotted PVC pipe equipped with a sampling port and valve. One SVW was inserted into each borehole. Frac sand (10/20 size) was placed around the slotted portion of the SVW and sealed at ground surface with hydrated bentonite powder and soil cuttings to ensure that no mixing of soil and atmospheric gases occurred. Each SVW was purged for a minimum of 10 minutes using an SKC transfer pump at a rate of 3 L/min. SVW's were then left to equilibrate overnight. The next day, OVM's were collected from each SVW using an RKI Eagle gas detector. Field calibration of the RKI Eagle was conducted prior to measurement collection.

SOIL GAS SAMPLING

The three SVW's with the greatest OVM readings and the background SVW were selected for soil gas sample collection at each site. One field duplicate sample was collected for QA/QC purposes. Samples submitted to ARC were collected using 6 L Silco Steel canisters provided by ARC. Samples submitted to the UofA were collected in 3 L high quality foil lined gas bags provided by BWRI.

SILCO STEEL CANISTERS

Nine gas samples were collected using 6 L Silco Steel canisters and submitted to ARC for gas composition analysis. A short piece of 1/8 inch Teflon tubing was attached to the canister and connected to the SVW sample port with a 1 inch piece of Tygon tubing provided by ARC. New Teflon and Tygon tubing was used at each sample location. Once connected, the canister was opened and allowed to fill for 5 minutes. Samples were placed in a cooler and shipped to ARC on September 17, 2009 via Purolator Courier based in Edmonton, Alberta.

FOIL GAS BAGS

Nine gas samples were collected using 3 L high quality foil gas bags and submitted to UofA for isotopic analysis. A lung sampler connected to an SKC pump was used to create negative pressure and draw the soil gas sample from the SVW sample port into the foil gas bag. New ¼ inch Teflon and Tygon tubing was attached to the sampling port and the lung sampler at each sample location. The SKC pump was set at a rate of 3 L/min and ran for 30 seconds to draw approximately 1500 mL of soil gas into each bag. Samples were delivered to the UofA in Edmonton, Alberta on September 17, 2009.

SOIL SAMPLING

A soil sample (06-12-078-08 W6M (SVW-1) and 11-12-078-08 W6M (SVW-1)) was collected from a depth of approximately 50 cm bgs at each site. Soil was placed into two 250 mL jars at each sample location and submitted to ARC for PHC F1-F4 and BTEX analysis. The samples were placed in a cooler with ice and shipped to ARC on September 17, 2009 via Purolator Courier based in Edmonton, Alberta.

COMPLETION

All SVW's were removed and backfilled with soil cuttings, fill and bentonite to previous grade. SVW's were cleaned of any soil and bentonite with a bleach solution. All stakes, flags and paint from utility locates were removed prior to leaving site.

RESULTS

PENN WEST 06-12-078-08 W6M

The Penn West 06-12-078-08 W6M wellsite consisted of a wellhead, well shed, propane bullet, and underground pipelines at the time of assessment (Figure 3).

On September 15, 2009 BWRI installed fifteen SVW's. A sample bearing of 0° was implemented on site. Subsurface soil conditions ranged from dry to moist throughout the site and were deemed suitable to complete the assessment. A previous precipitation event in the vicinity of the site was on September 7, 2009.

On September 16, 2009 OVM measurements were collected to determine sampling requirements. Measurements ranged from 25 parts per million (ppm) (SVW-13 and SVW-14) to 100% lower explosive limit (LEL) (SVW-1). The locations selected for soil gas sampling were SVW-1 (100% LEL), SVW-2 (225 ppmv), SVW-6 (72% LEL), and the background location (SVW-15) (30 ppm). The background location (SVW-15) was installed approximately 20.5 m northeast (45°) of the wellhead.

A soil sample was collected from the SVW-1 borehole and submitted to ARC for PHC F1-F4 and BTEX analysis. The soil sample was labeled SS-1 on the chain of custody.

Sample locations and OVM measurements are provided in Figure 3.

PENN WEST 11-12-078-08 W6M

The Penn West 11-12-078-08 W6M wellsite consisted of a wellhead, concrete pad, aboveground pipelines, and underground pipelines at the time of assessment (Figure 4).

On September 15, 2009 BWRI installed fifteen SVW's. A sample bearing of 0° was implemented on site. Subsurface soil conditions ranged from dry to moist throughout the site and were deemed suitable to complete the assessment. A previous precipitation event in the vicinity of the site was on September 7, 2009.

On September 16, 2009 OVM measurements were collected to determine sampling requirements. Measurements ranged from 10 ppm (SVW-11) to 6% LEL (SVW-8). The locations selected for soil gas sampling were SVW-1 (400 ppm), SVW-8 (6% LEL), SVW-9 (75 ppm), and the background location (SVW-15) (25 ppm). The background location (SVW-15) was installed approximately 20.97 m northwest (315°) of the wellhead. A field duplicate was collected from SVW-8 and labeled SVW-108 on the chain of custody.

A soil sample was collected from the SVW-1 borehole and submitted to ARC for PHC F1-F4 and BTEX analysis. The soil sample was labeled SS-1 on the chain of custody.

Sample locations and OVM measurements are provided in Figure 4.

REFERENCES

Alberta Energy and Utilities Board, 2007. "*EUB Directive 020: Well Abandonment Guide*" July, 2007. Appendix 2.

CONCLUSION

BWRI appreciates the opportunity to assist the ERCB with this project. If you have any comments or suggestions regarding the report, please do not hesitate to contact either of the undersigned at 403-282-3999.

Respectfully submitted,

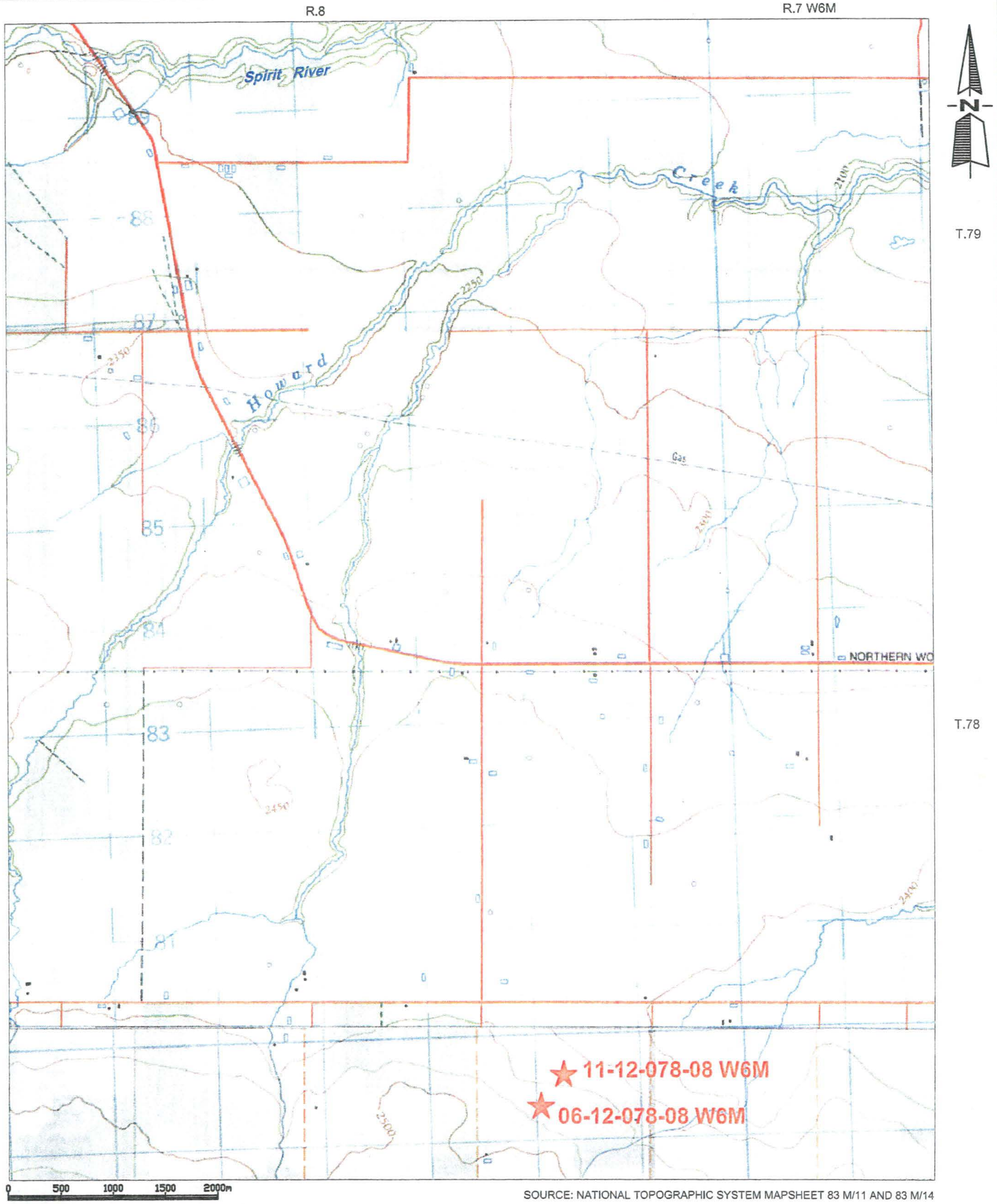
S. Brent Bowerman, P.Geol.
President

Clint R. Ganes, B.Sc.
Operations Manager

DISCLAIMER

Baseline Water Resource Inc. has used proficient skill and diligence conducting the gas migration assessment and preparation of this report. This report is a representation of the conditions and information present and available at the time of the assessment. Information received from all other sources is considered to be accurate but cannot be guaranteed. Baseline Water Resource Inc. is not responsible for any individual interpretation of this material nor any decisions based upon the findings in this report.

FIGURES



SOURCE: NATIONAL TOPOGRAPHIC SYSTEM MAPSHEET 83 M/11 AND 83 M/14

Baseline
Water Resource Inc.

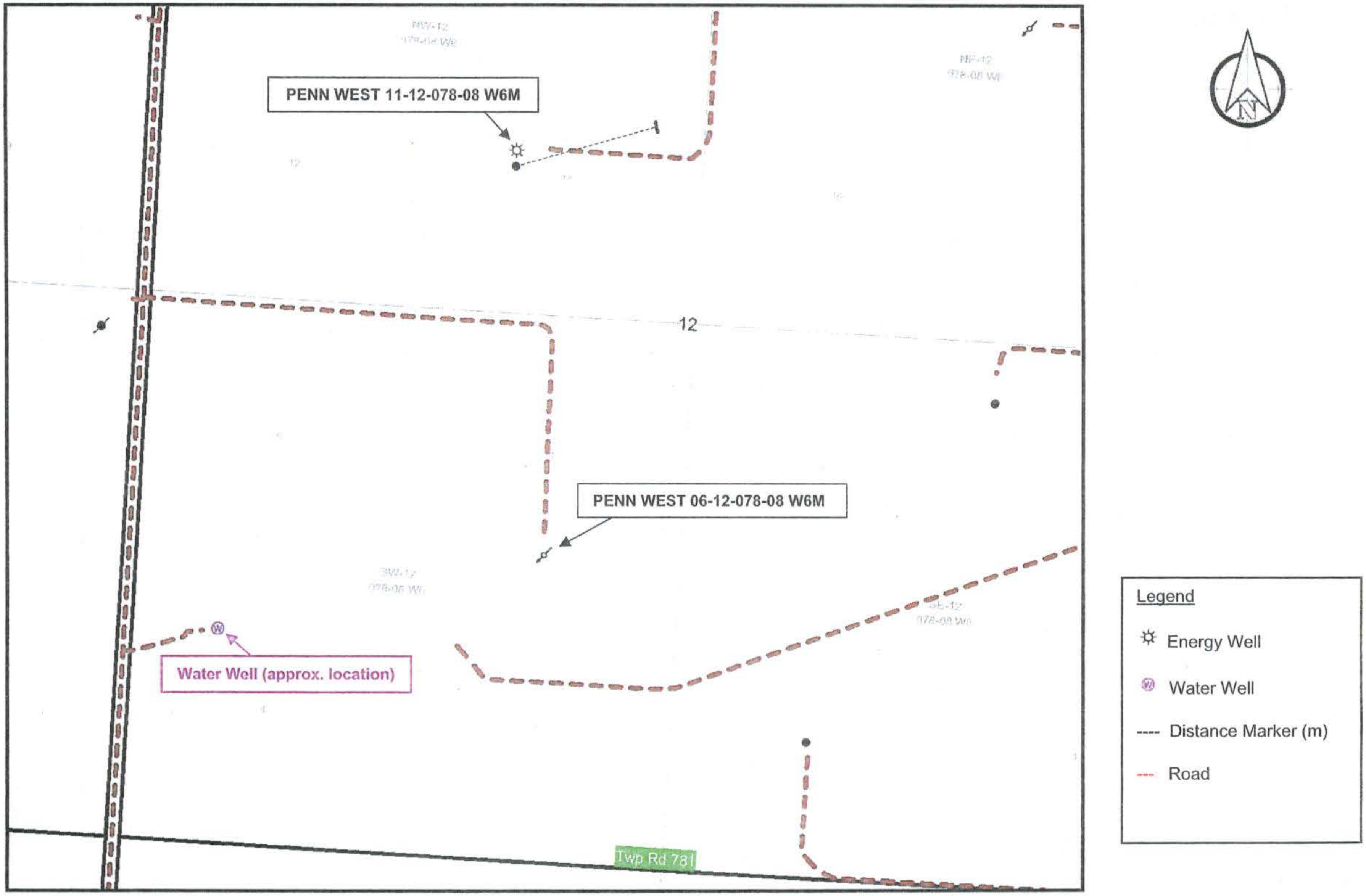
ERCB - SPIRIT RIVER
GAS MIGRATION PROJECT

Project	ERCB	By	CG
File	09-7003	Chkd	CG
Date	2009-10-20	Scale	1:50,000
Rev Date	-	Drwn	TN

SITE LOCATION MAP
PENNWEST 06-12 AND 11-12-078-08 W6M

Figure
1

THE STATED SCALE MAY NOT AGREE WITH SCALEBAR WHEN THIS DOCUMENT IS VIEWED IN PDF FORMAT OR IS PRINTED FROM A PDF FORMAT



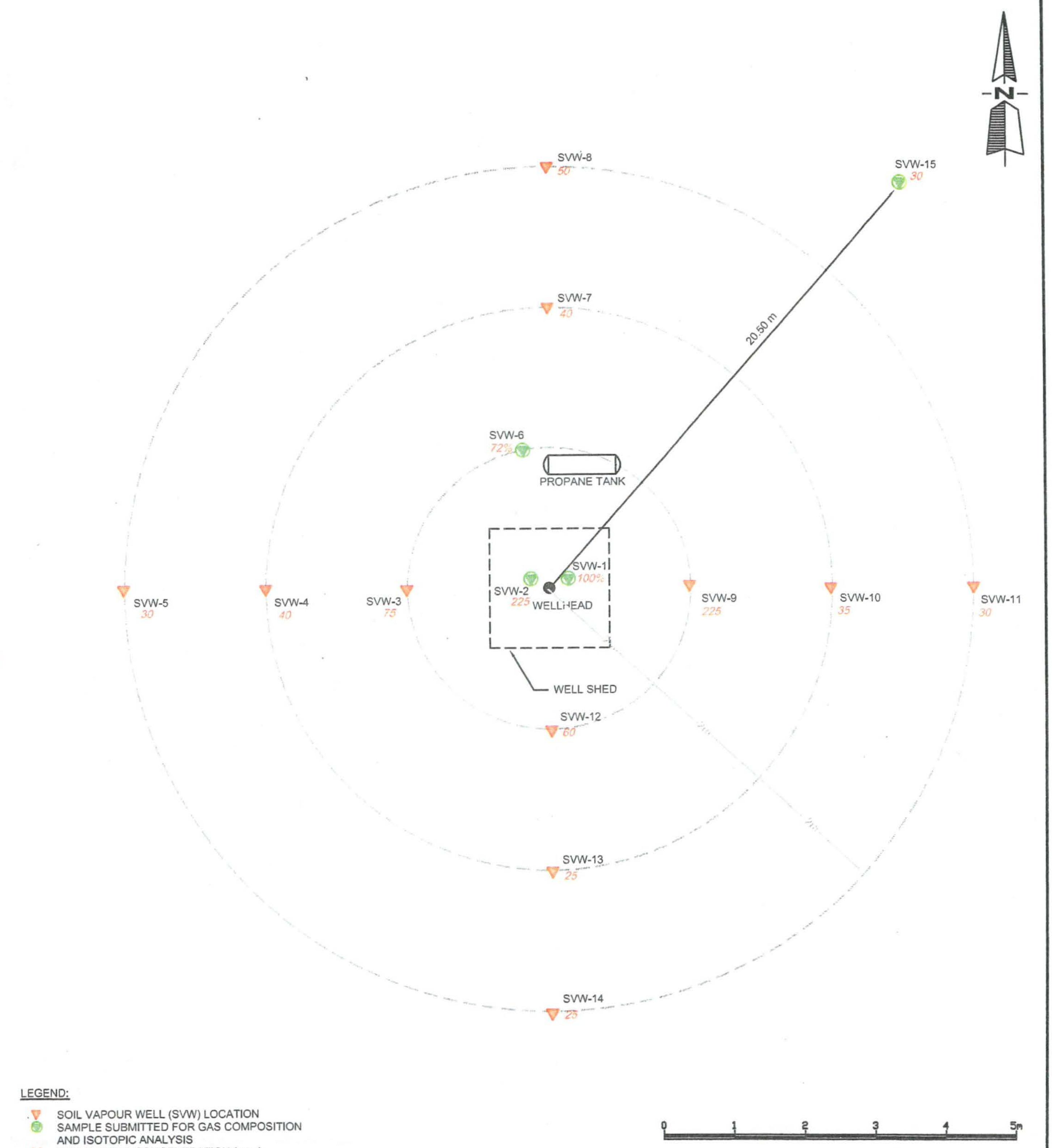
Baseline
Water Resource Inc.

Client / Project:
ERCB
Spirit River Gas Migration Assessment

Figure No. / Title:
Figure 2. Well Locations

BWRI Project No.:
09-7003

Date:
November 25, 2009



LEGEND:

- 🔻 SOIL VAPOUR WELL (SVW) LOCATION
- 🟢 SAMPLE SUBMITTED FOR GAS COMPOSITION AND ISOTOPIC ANALYSIS
- *50* SOIL VAPOUR CONCENTRATION (ppm)
- *%* LEL

SAMPLE DATE: SEPTEMBER 16, 2009

Baseline
Water Resource Inc.

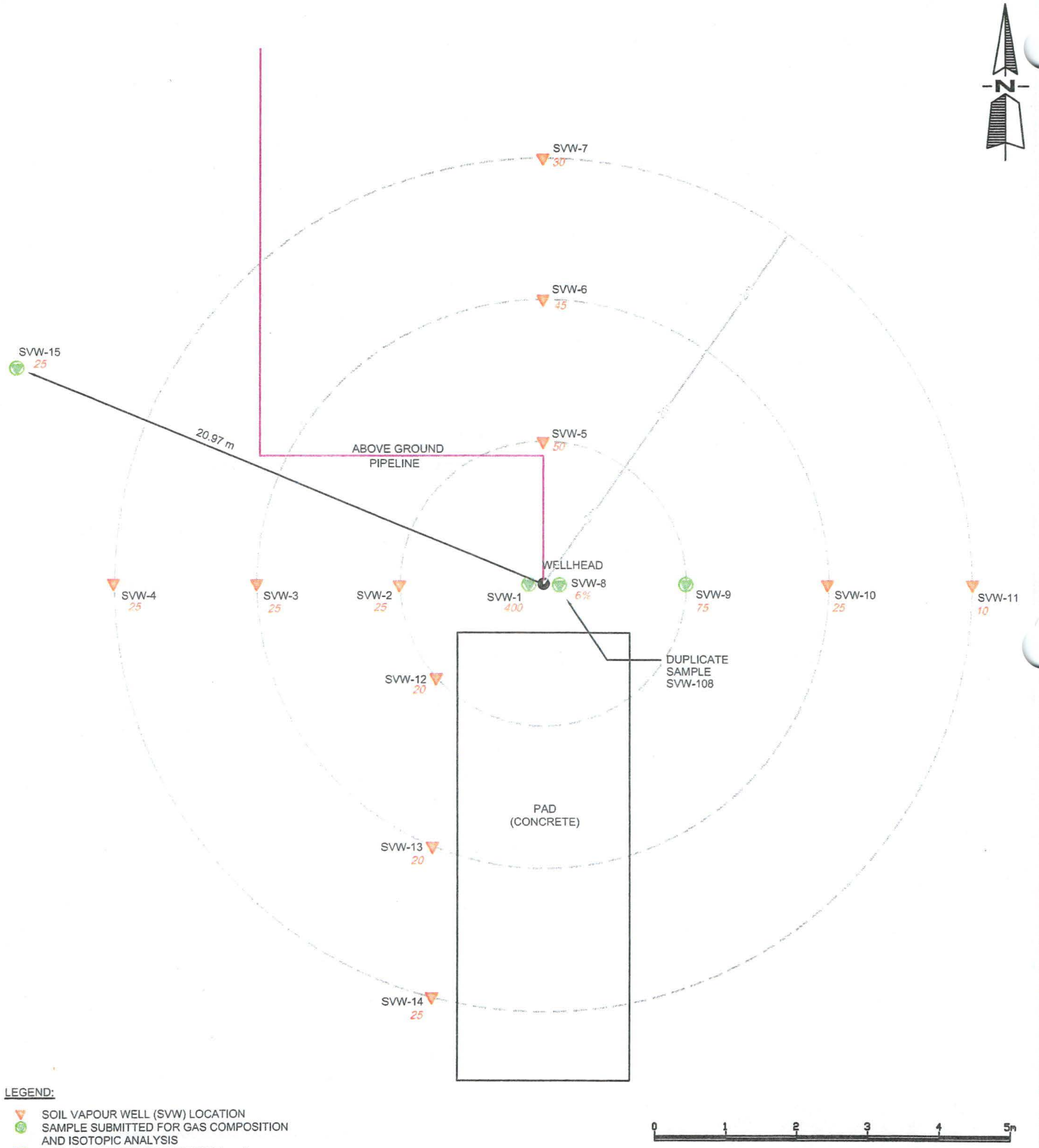
ERCB - SPIRIT RIVER
GAS MIGRATION PROJECT

Project	ERCB	By	CG
File	09-7003	Chkd	BB
Date	2009-10-20	Scale	1:75
Rev Date		Drwn	TN

SOIL VAPOUR WELL LOCATIONS
PENNWEST 06-12-078-08 W6M

Figure
3

THE STATED SCALE MAY NOT AGREE WITH SCALEBAR WHEN THIS DOCUMENT IS VIEWED IN PDF FORMAT OR IS PRINTED FROM A PDF FORMAT



SAMPLE DATE: SEPTEMBER 16, 2009

Baseline Water Resource Inc.

ERCB - SPIRIT RIVER
GAS MIGRATION PROJECT

Project	ERCB	By	CG
File	09-7003	Chkd	BB
Date	2009-10-20	Scale	1:75
Rev Date		Drwn	TN

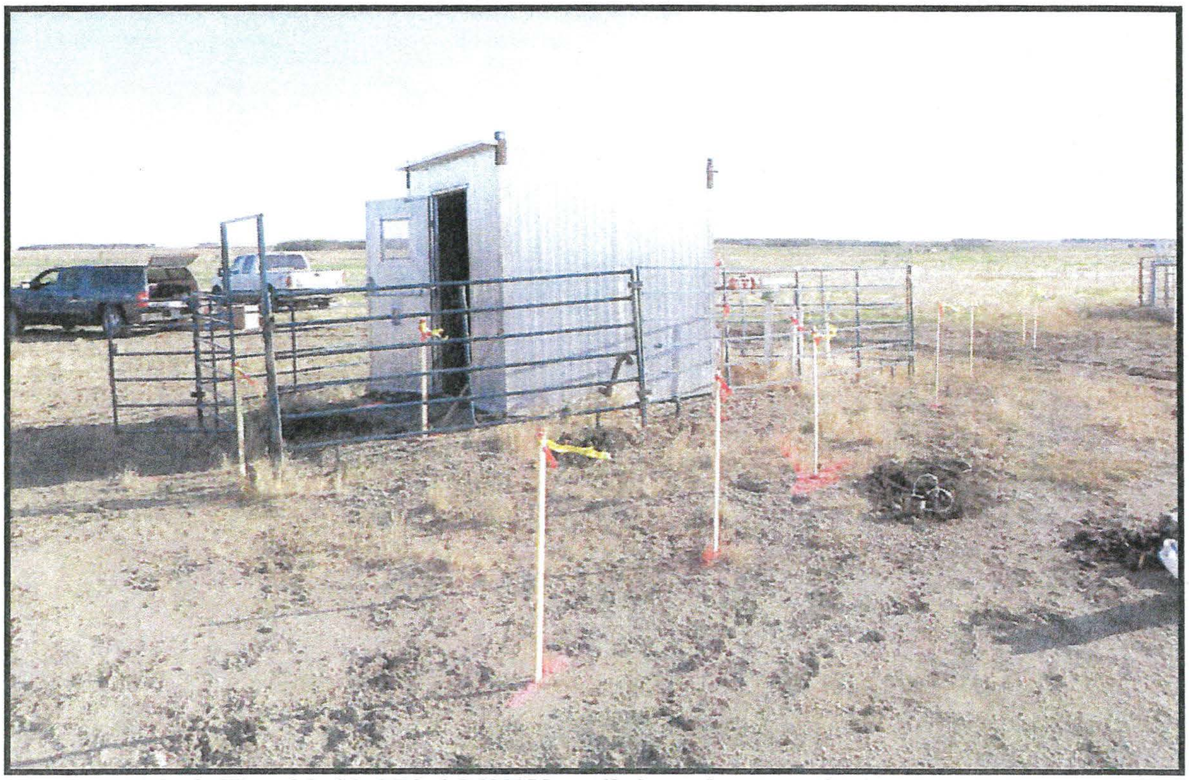
SOIL VAPOUR WELL LOCATIONS
PENNWEST 00/11-12-078-08 W6M

Figure
4

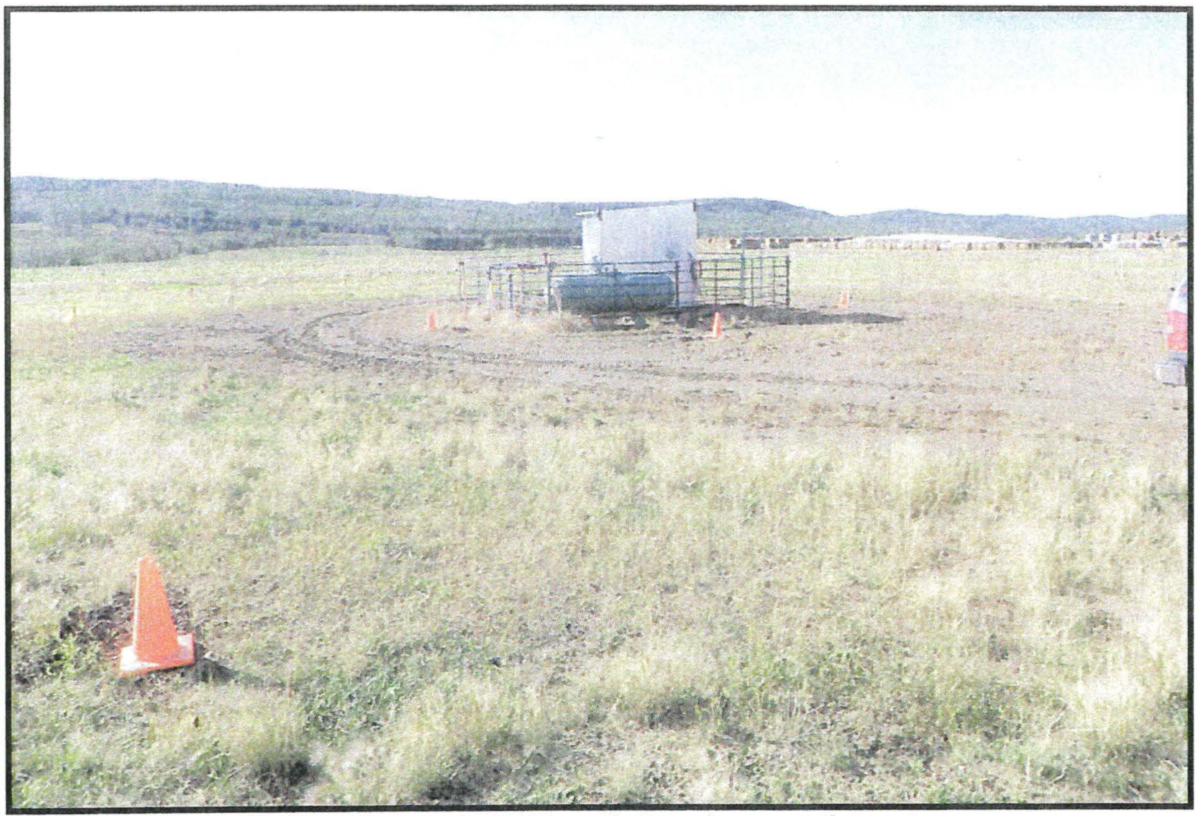
THE STATED SCALE MAY NOT AGREE WITH SCALEBAR WHEN THIS DOCUMENT IS VIEWED IN PDF FORMAT OR IS PRINTED FROM A PDF FORMAT

APPENDIX A

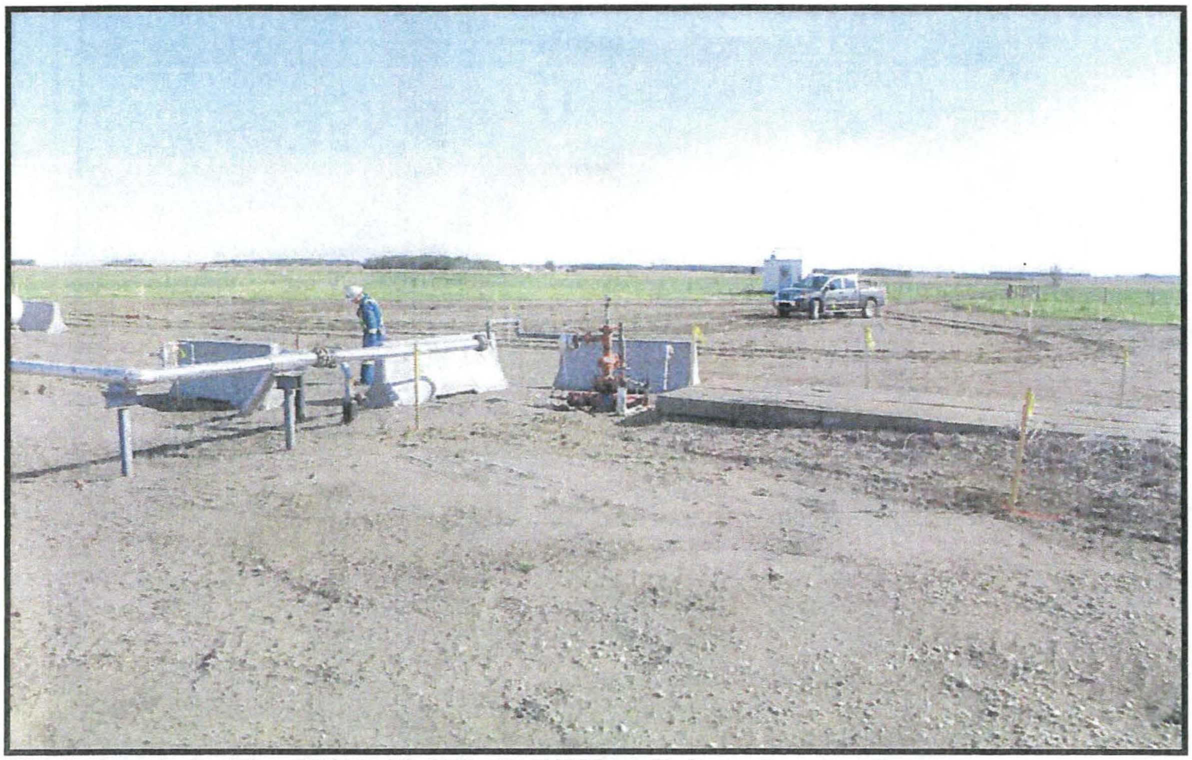
Site Photographs



Photograph 1. The 06-12-078-08 W6M wellsite, view northeast.



Photograph 2. The 06-12-078-08 W6M wellsite, view southwest.



Photograph 3. The 00/11-12-078-08 W6M wellsite, view northeast.

Photograph 4. The 00/11-12-078-08 W6M wellsite, view southwest.

Photograph 5. View of an open borehole with SVW.

Photograph 6. View of an installed SVW with 10/20 frac sand.

Photograph 7. View of SVW sealed with hydrated bentonite powder.

Photograph 8. View of SVW being purged after installation.

Photograph 9. Soil gas sampling with a Silco Steel canister.

Photograph 10. Soil gas sampling with a lung sampler and foil gas sampling bag.

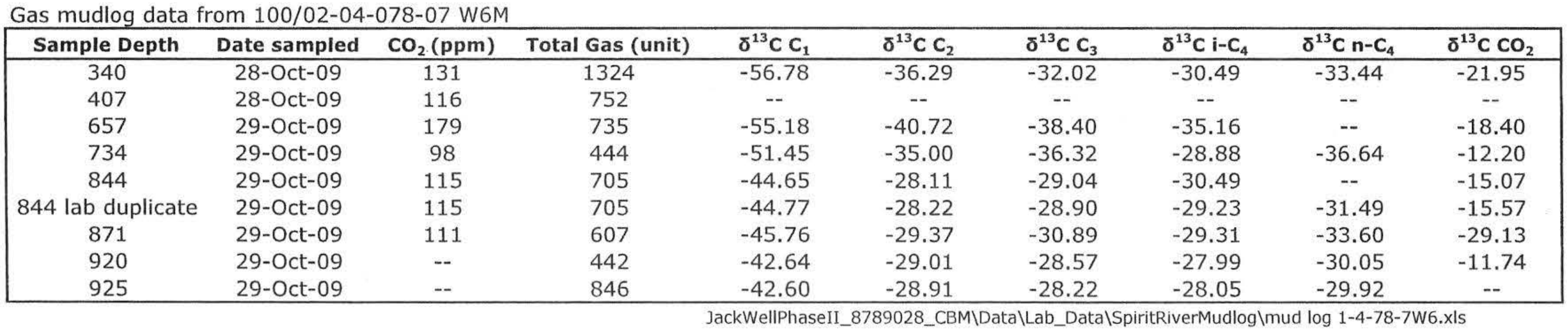
Appendix C

Isotopic Mudlog (100/02-04-078-07 W6M) Analytical Results

MORNING REPORT **OCT. 28, 29, 2009**

EXSHAW OIL SPIRIT 2-4-78-7 GAS SAMPLING

DEPTH(m)	SAMPLE #	DATE	TIME	CO2	GAS (unit)
340.0m	1	Oct. 28,2009	15:54hr	131ppm	1324
407.0m	2	Oct.28, 2009	17:28hr	116.0ppm	752
657.0m	3	Oct.29, 2009	01:56hr	179.0ppm	735
703.0m	Missed	Oct.29, 2009	05:08hr	93.0ppm	1097
734.0m	4	Oct.29, 2009	05:58hr	98.0ppm	444
844.0m	5	Oct.29,2009	08:40hr	115.0ppm	705
871.0m	6	Oct. 29, 2009	09:34hr	111ppm	607
920.0m	7	Oct.29,2009	11:16hr	ppm	442
925.0m	8	Oct.29, 2009	11:29hr	ppm	846
END					



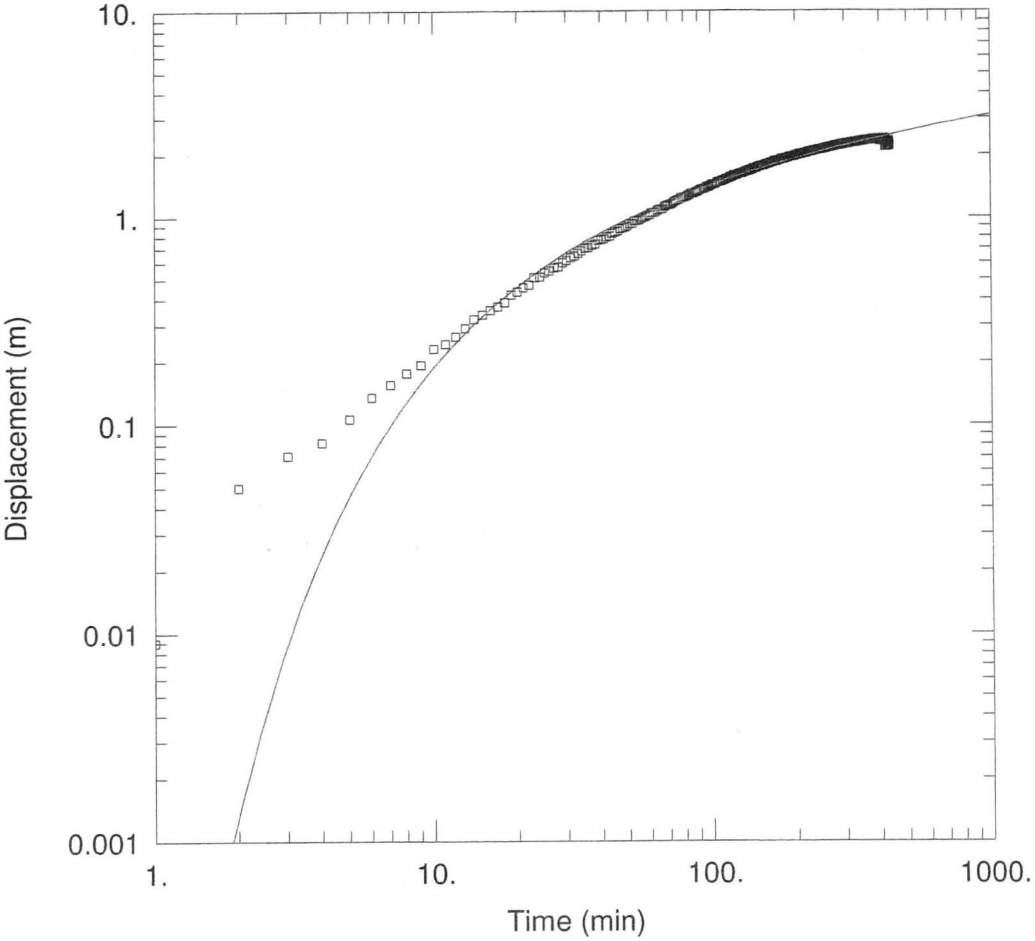
Gas mudlog data from 100/02-04-078-07 W6M

Sample Depth	Date sampled	CO_2 (ppm)	Total Gas (unit)	$\delta^{13}C$ C_1	$\delta^{13}C$ C_2	$\delta^{13}C$ C_3	$\delta^{13}C$ i-C_4	$\delta^{13}C$ n-C_4	$\delta^{13}C$ CO_2
340	28-Oct-09	131	1324	-56.78	-36.29	-32.02	-30.49	-33.44	-21.95
407	28-Oct-09	116	752	--	--	--	--	--	--
657	29-Oct-09	179	735	-55.18	-40.72	-38.40	-35.16	--	-18.40
734	29-Oct-09	98	444	-51.45	-35.00	-36.32	-28.88	-36.64	-12.20
844	29-Oct-09	115	705	-44.65	-28.11	-29.04	-30.49	--	-15.07
844 lab duplicate	29-Oct-09	115	705	-44.77	-28.22	-28.90	-29.23	-31.49	-15.57
871	29-Oct-09	111	607	-45.76	-29.37	-30.89	-29.31	-33.60	-29.13
920	29-Oct-09	--	442	-42.64	-29.01	-28.57	-27.99	-30.05	-11.74
925	29-Oct-09	--	846	-42.60	-28.91	-28.22	-28.05	-29.92	--

JackWellPhaseII_8789028_CBM\Data\Lab_Data\SpiritRiverMudlog\mud log 1-4-78-7W6.xls

Appendix D

Pumping Test Results



WELL TEST ANALYSIS

Data Set: C:\...\jack well Jan 29 2010 pumptest._pumping(2).aqt
Date: 08/08/10 Time: 09:51:31

PROJECT INFORMATION

Company: AITF
Client: AENV
Location: Jack Well
Test Well: Jack Well
Test Date: Jan. 29, 2010

WELL DATA

Pumping Wells

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

Observation Wells

Well Name	X (m)	Y (m)
□ Jack Well	0	0

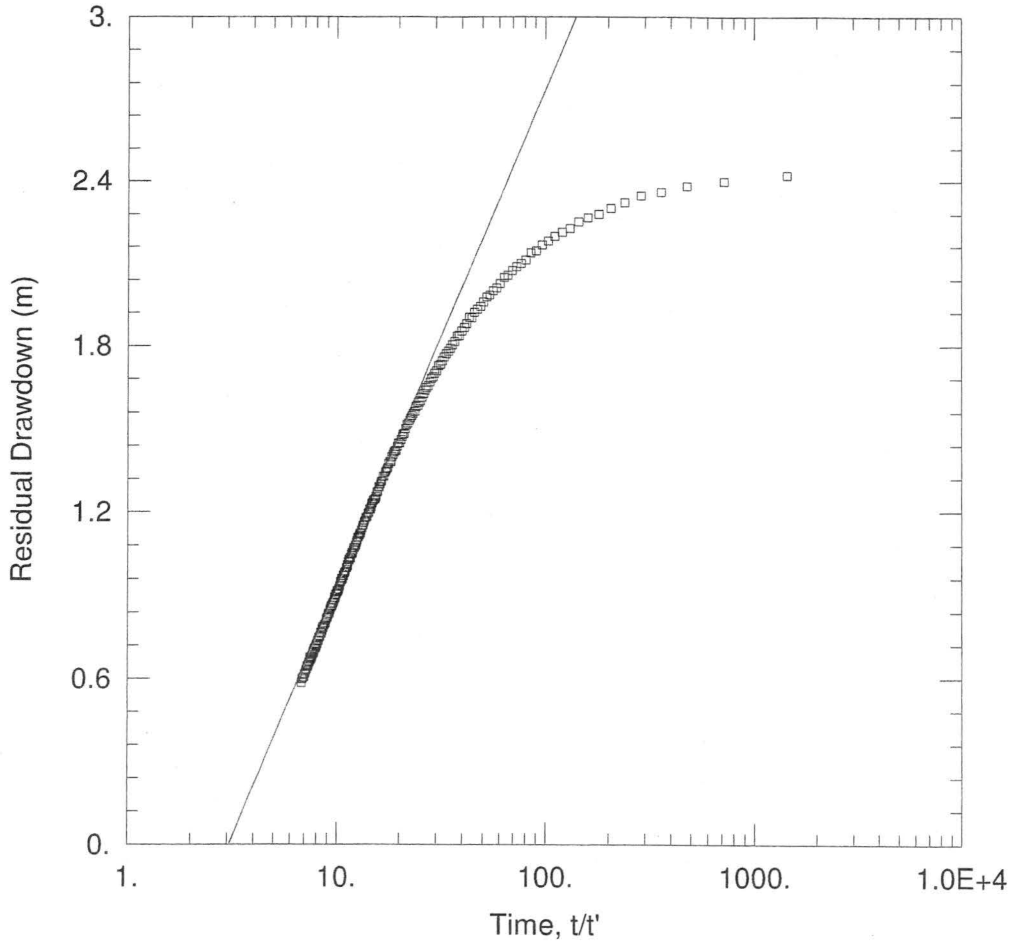
SOLUTION

Aquifer Model: Confined

Solution Method: Theis

T = 0.003316 m^2/min
Kz/Kr = 1.

S = 37.81
b = 5.18 m



WELL TEST ANALYSIS

Data Set: C:\...\jack well Jan 29 2010 pumptest._recovery.aqt
Date: 08/08/10 Time: 09:52:01

PROJECT INFORMATION

Company: AITF
Client: AENV
Location: Jack Well
Test Well: Jack Well
Test Date: Jan. 29, 2010

AQUIFER DATA

Saturated Thickness: 5.18 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

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

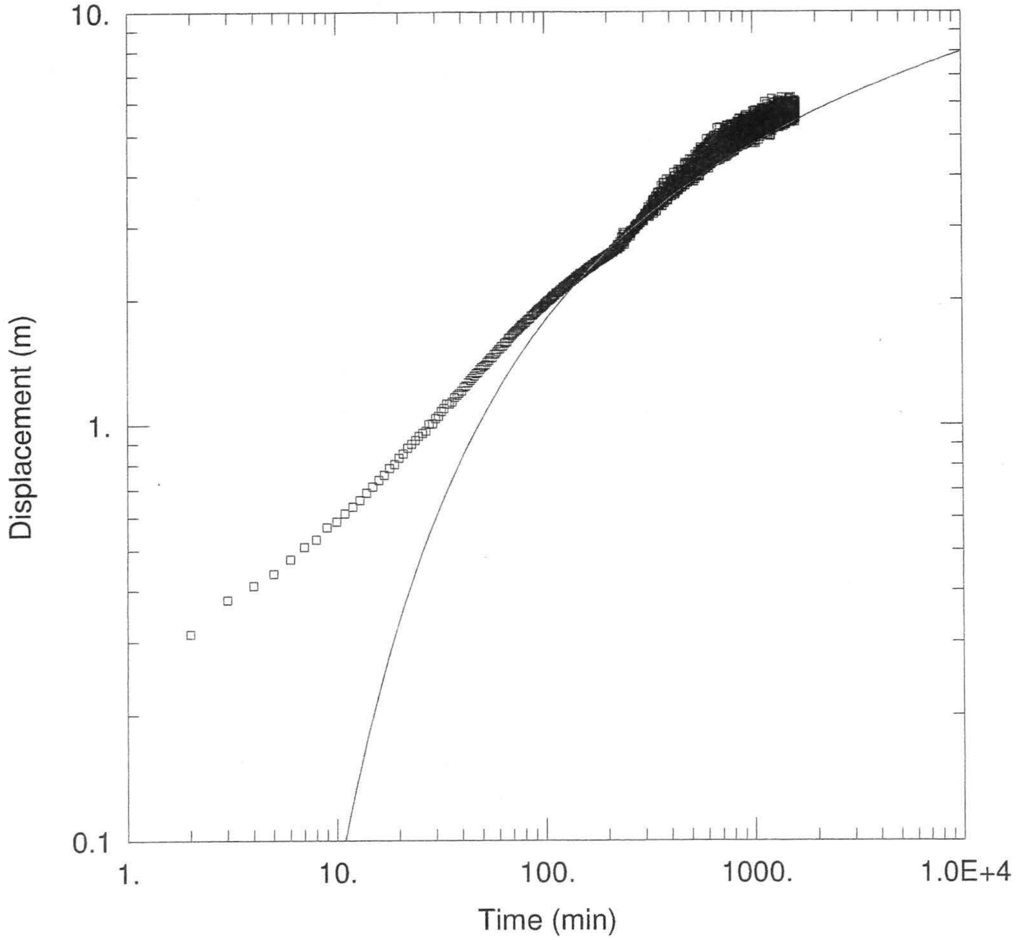
Observation Wells

Well Name	X (m)	Y (m)
□ Jack Well	0	0

SOLUTION

Aquifer Model: Confined
Solution Method: Theis (Recovery)

T = 0.002908 m^2/min
S/S' = 3.073



WELL TEST ANALYSIS

Data Set: C:\...\jack well Sept 26 2009 pumptest._no recov.aqt
Date: 08/08/10 Time: 09:53:17

PROJECT INFORMATION

Company: AITF
Client: AENV
Location: Jack Well
Test Well: Jack Well
Test Date: Sept. 26, 2009

WELL DATA

Pumping Wells

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

Observation Wells

Well Name	X (m)	Y (m)
□ Jack Well	0	0

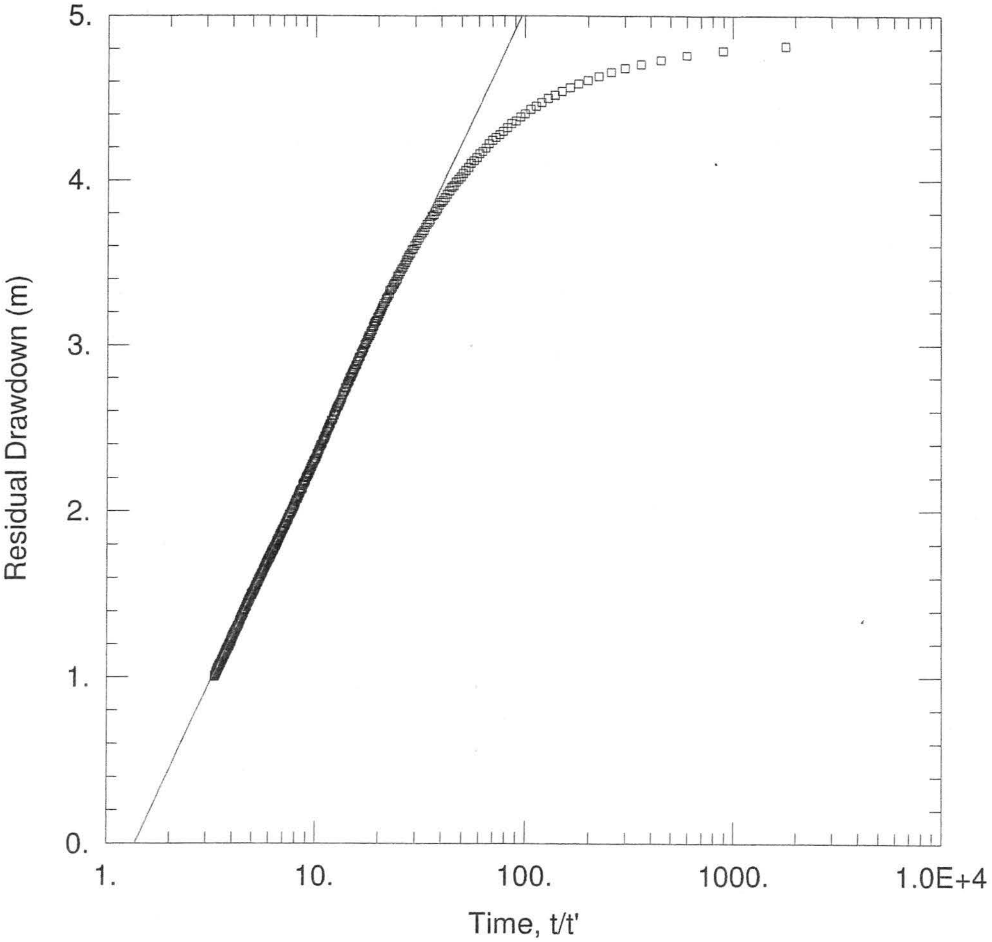
SOLUTION

Aquifer Model: Confined

Solution Method: Theis

T = 0.001458 m^2/min
Kz/Kr = 1.

S = 34.19
b = 5.18 m



WELL TEST ANALYSIS

Data Set: C:\...\jack well Sept 26 2009 pumptest._recovery.aqt
Date: 08/08/10 Time: 09:55:32

PROJECT INFORMATION

Company: AITF
Client: AENV
Location: Jack Well
Test Well: Jack Well
Test Date: Sept. 26, 2009

AQUIFER DATA

Saturated Thickness: 5.18 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

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

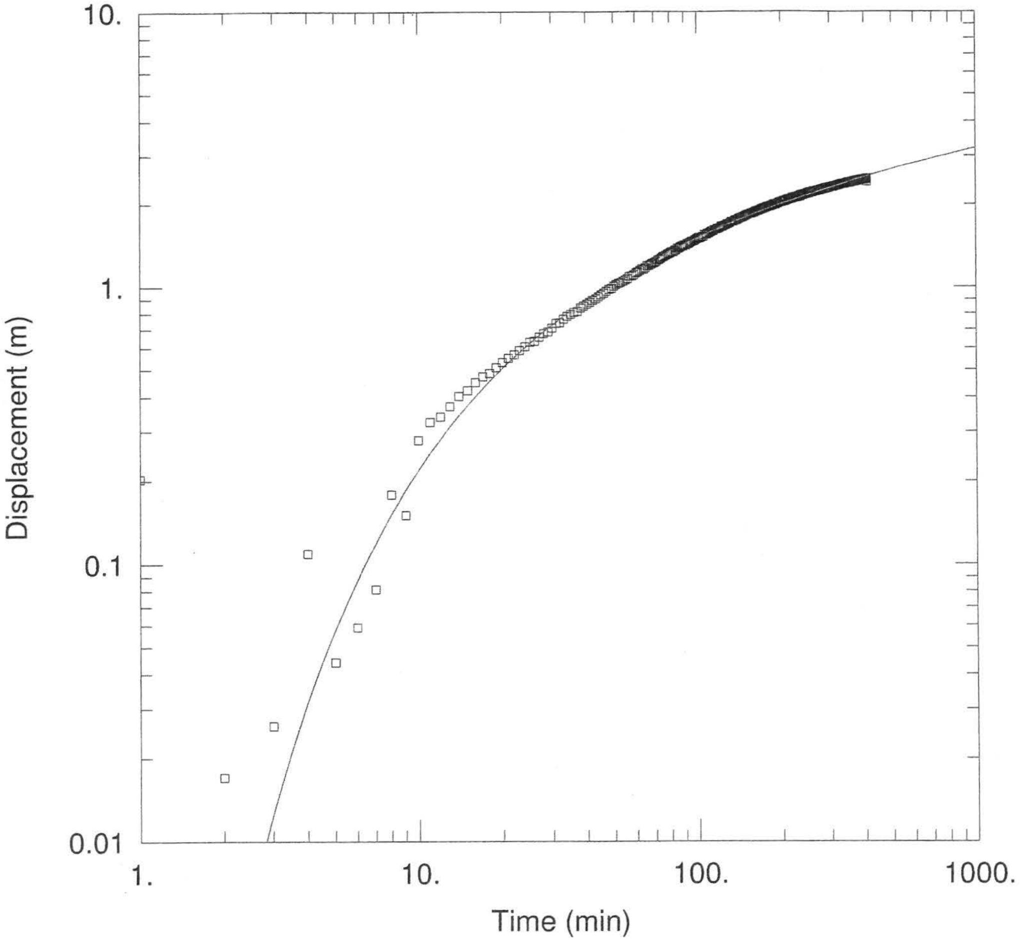
Observation Wells

Well Name	X (m)	Y (m)
□ Jack Well	0	0

SOLUTION

Aquifer Model: Confined
Solution Method: Theis (Recovery)

$T = 0.002725\ m^2/min$
S/S' = 1.378



WELL TEST ANALYSIS

Data Set: C:\...\jack well Feb 28 2010 pumptest._no recov.aqt
Date: 08/08/10 Time: 09:51:05

PROJECT INFORMATION

Company: AITF
Client: AENV
Location: Jack Well
Test Well: Jack Well
Test Date: Feb. 28, 2010

WELL DATA

Pumping Wells

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

Observation Wells

Well Name	X (m)	Y (m)
□ Jack Well	0	0

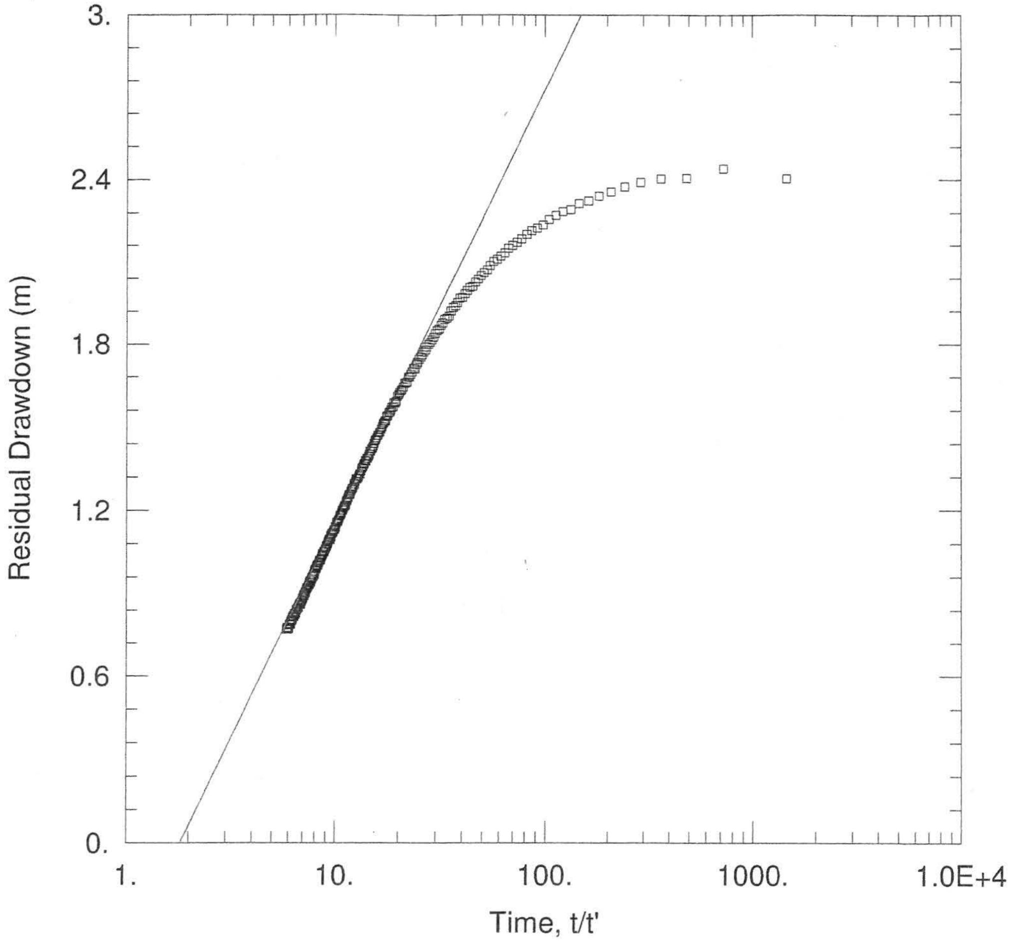
SOLUTION

Aquifer Model: Confined

T = 0.004211 m^2/min
Kz/Kr = 1.

Solution Method: Theis

S = 43.98
b = 5.18 m



WELL TEST ANALYSIS

Data Set: C:\...\jack well Feb 28 2010 pumptest._recovery.aqt
Date: 08/08/10 Time: 09:56:38

PROJECT INFORMATION

Company: AITF
Client: AENV
Location: Jack Well
Test Well: Jack Well
Test Date: Feb. 28, 2010

AQUIFER DATA

Saturated Thickness: 5.18 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

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

Observation Wells

Well Name	X (m)	Y (m)
□ Jack Well	0	0

SOLUTION

Aquifer Model: Confined
Solution Method: Theis (Recovery)

T = 0.004697 m^2/min
S/S' = 1.841

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