# PVT Water Analysis Draft Report
# Well BRI-GT-01
# Aardwarmte Vierpolders
# September 1st, 2015

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# PVT Water Analysis
# Samples from WELL BRI-GT-01

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# 1 PVT Analysis of Water Samples

## 1.1 Surface Sampling

Two water samples and 1 gas sample were collected by PanTerra before the choke of the well BRI-GT-01 and respectively at the gas flare on August 12, 2015. The water samples were collected using the displacement procedure into piston cylinders. One “dead” (no gas dissolved) water sample was collected from the same sampling point into a jerry can.

## 1.2 Bottomhole Sampling

Two bottomhole samples were collected at ~ 2650 meters deep at the well BRI-GT-01 on August 15, 2015. The samples were collected using the displacement procedure into sampling cylinders. The samples were transferred at the wellsite from samplers into piston cylinders and shipped to PanTerra for analysis.

**Table 1 - Sampling Summary**

| Sample no./type | Sampling Point Temperature | Sampling Point Pressure | Date taken |
|---|---|---|---|
| | $^{0}$Celsius | bar | |
| Sample1 bottomhole | 83 | 205.5 | 15-8-2015 |
| Sample 2 bottomhole | 83 | 205.5 | 15-8-2015 |
| Sample 1 surface water | 72 | 17 | 12-8-2015 |
| Sample 2 surface water | 72 | 3.5 | 12-8-2015 |
| Sample 3 Surface Gas | 72 | 3 | 12-8-2015 |

## 1.3 Samples Quality Control

### 1.3.1 Visual Inspection upon Receiving the Samples

Upon receipt, the samples were visually inspected for any obvious faults, i.e. leaks, bent valves or any other mechanical problems. The sample cylinders were found to be in good condition.

### 1.3.2 Opening Pressure Measurement

The pressurized cylinders at room temperature were connected at the pressurizing water end to a high pressure pump, the opening pressure was read at the pump display.

### 1.3.3 Sample Volume Measurement

The pressurizing fluid (water) was drained from the sample water end. The samples were shaken until stable at working pressure and the amount of pressurizing water was recorded. The sample volumes were the difference between the total volume of the cylinders and the pressurizing fluid.

### 1.3.4 Samples Restoration

While connected to a positive displacement pump, the samples were homogenized by shaking for 24 hours prior to any removal of sample.

**Table 2 - Samples Quality Check Results**

| Sample no. | Type | Opening Pressure | Opening Temp | Sample Volume | $H_2S$ (y/n) | Valve Checked (y/n) | |
|---|---|---|---|---|---|---|---|
| | | bar | $^0$Celsius | (cc) | | top | bot |
| Sample1 | bottomhole | 161.99 | 24 | 650 | n | y | y |
| Sample 2 | bottomhole | 175.06 | 24 | 624 | n | y | y |
| Sample 1 | Surface Water | 15.06 | 26 | 272 | n | y | y |
| Sample 2 | Surface Water | 4.11 | 26 | 600 | n | y | y |
| Sample 3 | Surface Gas | 3.42 | 28 | 20 liters | n | y | y |

## 1.4 Flash Separation

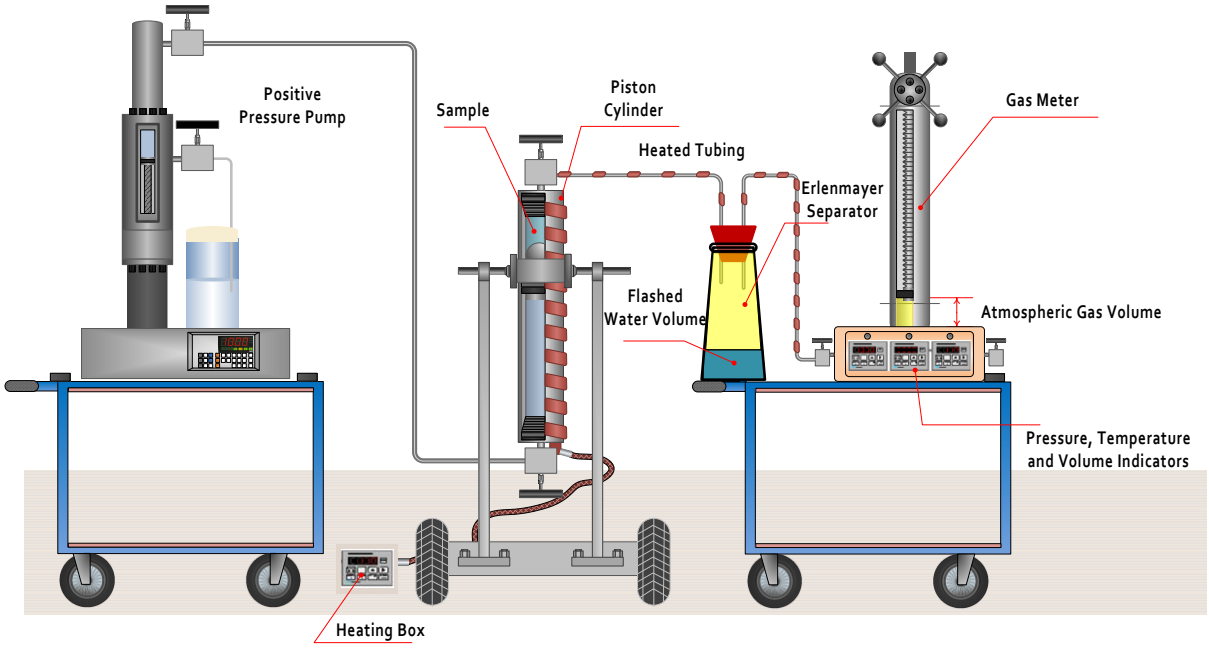


**Figure 1 - Flash Separation Layout**

A volume of single-phase water was pumped from the sample cylinder into a trap connected to a gas meter at atmospheric conditions of pressure and temperature. The flashed water and gas volumes, separation temperatures and atmospheric pressures were accurately recorded. The composition of gas was subsequently measured using the procedure described below. The flash GWR (gas water ratio) was calculated as the ratio between the flashed water and the collected gas.

## 1.5 Water and Gas Physical Properties Measurement

### 1.5.1 Water Density Measurement

The density of the flashed water was measured using a digital u-tube handheld densitometer, model Anton Paar DMA 35. A sample causes a change in the oscillation frequency of a vibrating glass U tube. The change is directly proportional to the density of the sample. The embedded software allows for temperature correction when the ambient temperature is different than standard.


Figure 2 - DMA 35 Densitometer

### 1.5.2 Water pH Measurement

The pH meter used is an Orion 370 pH meter. Before any measurement, a 3-point calibration measurement is run for the standard buffers that will correspond with the selected calibration pH mode (pH 4/7/10). After calibration, the pH electrodes are rinsed with deionized (D.I.) $H_2O$ and blot dry. For the actual measurement, the bottom part of the electrode is immersed in the sample, and when the "ready" light comes up a stable pH value is obtained and frozen and the display can be read. For each new sample, the step above is repeated and the electrode is rinsed every time in deionized water.

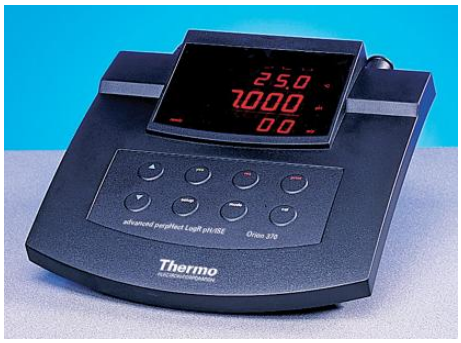


Figure 3 - Orion 370 pH meter

### 1.5.3 Gas Composition

The resulted gas fraction from the flash or directly from the gas sampling bottle was analyzed using the gas chromatography procedure.

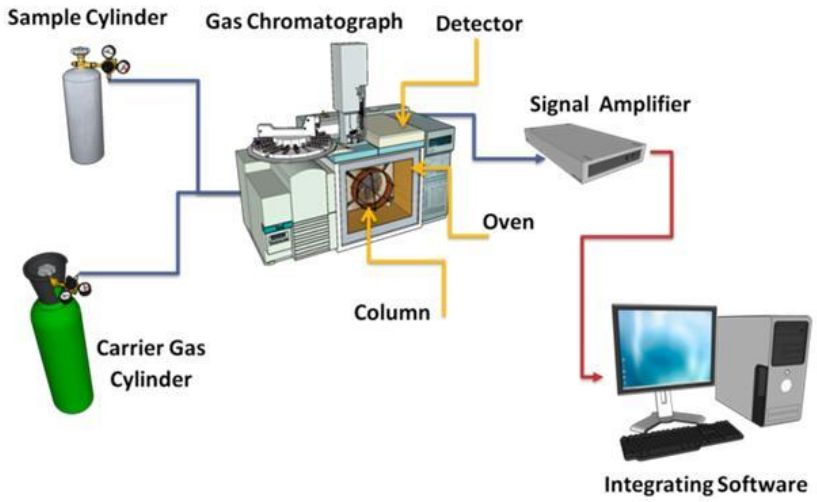


Figure 4 - General Chromatographic Procedure Layout

Compositions up to $C_{11+}$were measured. Components: porous polymer and mole sieve columns, TCD detector (for $C_1$-$C_3$, permanent gases), capillary column and FID detector (for $C_4$ to $C_{11+}$).

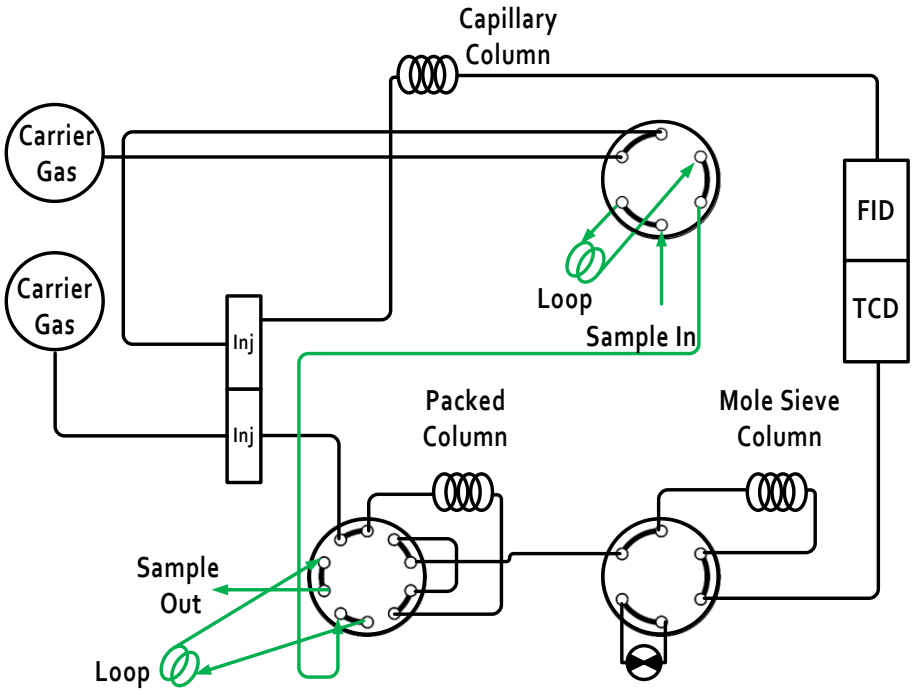


Figure 5 - Gas Chromatograph Layout

**Table 3 - Composition of Flashed Gas from Sample 1 Bottomhole**

| Component | | Mole% | Weight% |
|---|---|---|---|
| $H_2$ | Hydrogen | 0.000 | 0.000 |
| $H_2S$ | Hydrogen Sulphide | 0.000 | 0.000 |
| $CO_2$ | Carbon Dioxide | 3.213 | 7.779 |
| $N_2$ | Nitrogen | 4.268 | 6.576 |
| C1 | Methane | 89.682 | 79.144 |
| C2 | Ethane | 1.787 | 2.956 |
| C3 | Propane | 0.400 | 0.970 |
| C4 | i-Butane | 0.074 | 0.238 |
| C4 | n-Butane | 0.211 | 0.676 |
| C5 | i-Pentane | 0.076 | 0.301 |
| C5 | n-Pentane | 0.112 | 0.443 |
| C6 | Hexanes | 0.098 | 0.453 |
| | MC Pentane | 0.006 | 0.028 |
| | Benzene | 0.007 | 0.030 |
| | Cyclohexane | 0.005 | 0.022 |
| C7 | Heptanes | 0.025 | 0.130 |
| | MC Hexane | 0.004 | 0.021 |
| | Toluene | 0.000 | 0.002 |
| C8 | Octanes | 0.011 | 0.065 |
| | E-Benzene | 0.000 | 0.001 |
| | M/P Xylene | 0.001 | 0.005 |
| | O-Xylene | 0.000 | 0.000 |
| C9 | Nonanes | 0.003 | 0.020 |
| | 1,2,4 TMB | 0.000 | 0.003 |
| C10 | Decanes | 0.004 | 0.029 |
| C11+ | Undecanes + | 0.013 | 0.109 |
| | Total | 100.000 | 100.000 |

| Calculated Gas Properties | |
|---|---|
| Gas Density (kg $m^{-3}$ @ 15°C) | 0.812 |
| Gas Mole Weight (g $mol^{-1}$) | 18.179 |
| Real Relative (to air) Density of Gas | 0.628 |
| Mole weight of Heptanes Plus (g $mol^{-1}$) | 106.239 |
| Density of Heptanes plus (g $cm^{-3}$ at 60°F ) | 0.764 |
| Mole Weight of Undecanes plus (g $mol^{-1}$) | 147.000 |
| Density of Undecanes plus (g $cm^{-3}$ at 60°F) | 0.789 |
| Calorific Value (MJ $m^{-3}$ ) | 38.364 |

**Table 4 - Composition of Flashed Gas from Sample 2 Bottomhole**

| Component | | Mole% | Weight% |
|---|---|---|---|
| $H_2$ | Hydrogen | 0.000 | 0.000 |
| $H_2S$ | Hydrogen Sulphide | 0.000 | 0.000 |
| $CO_2$ | Carbon Dioxide | 3.412 | 8.381 |
| $N_2$ | Nitrogen | 4.322 | 6.758 |
| C1 | Methane | 90.538 | 81.076 |
| C2 | Ethane | 1.298 | 2.179 |
| C3 | Propane | 0.155 | 0.382 |
| C4 | i-Butane | 0.028 | 0.092 |
| C4 | n-Butane | 0.056 | 0.183 |
| C5 | i-Pentane | 0.024 | 0.096 |
| C5 | n-Pentane | 0.041 | 0.164 |
| C6 | Hexanes | 0.053 | 0.248 |
| | MC Pentane | 0.004 | 0.019 |
| | Benzene | 0.010 | 0.045 |
| | Cyclohexane | 0.004 | 0.017 |
| C7 | Heptanes | 0.019 | 0.102 |
| | MC Hexane | 0.004 | 0.024 |
| | Toluene | 0.003 | 0.016 |
| C8 | Octanes | 0.007 | 0.039 |
| | E-Benzene | 0.000 | 0.001 |
| | M/P Xylene | 0.000 | 0.002 |
| | O-Xylene | 0.000 | 0.001 |
| C9 | Nonanes | 0.001 | 0.008 |
| | 1,2,4 TMB | 0.000 | 0.003 |
| C10 | Decanes | 0.003 | 0.024 |
| C11+ | Undecanes + | 0.017 | 0.141 |
| | Total | 100.000 | 100.000 |

| Calculated Gas Properties | |
|---|---|
| Gas Density (kg $m^{-3}$ @ 15°C) | 0.800 |
| Gas Mole Weight (g $mol^{-1}$) | 17.915 |
| Real Relative (to air) Density of Gas | 0.619 |
| Mole weight of Heptanes Plus (g $mol^{-1}$) | 107.436 |
| Density of Heptanes plus (g $cm^{-3}$ at 60°F ) | 0.776 |
| Mole Weight of Undecanes plus (g $mol^{-1}$) | 147.000 |
| Density of Undecanes plus (g $cm^{-3}$ at 60°F) | 0.789 |
| Calorific Value (MJ $m^{-3}$ ) | 37.553 |

**Table 5 - Gas Composition of Sample 3 Surface Gas**

| Component | | Mole% | Weight% |
|---|---|---|---|
| $H_2$ | Hydrogen | 0.000 | 0.000 |
| $H_2S$ | Hydrogen Sulphide | 0.000 | 0.000 |
| $CO_2$ | Carbon Dioxide | 2.100 | 5.245 |
| $N_2$ | Nitrogen | 2.155 | 3.427 |
| C1 | Methane | 92.926 | 84.605 |
| C2 | Ethane | 1.984 | 3.386 |
| C3 | Propane | 0.354 | 0.885 |
| C4 | i-Butane | 0.048 | 0.159 |
| C4 | n-Butane | 0.065 | 0.214 |
| C5 | i-Pentane | 0.020 | 0.084 |
| C5 | n-Pentane | 0.020 | 0.081 |
| C6 | Hexanes | 0.046 | 0.218 |
| | MC Pentane | 0.004 | 0.018 |
| | Benzene | 0.055 | 0.243 |
| | Cyclohexane | 0.013 | 0.063 |
| C7 | Heptanes | 0.037 | 0.201 |
| | MC Hexane | 0.020 | 0.114 |
| | Toluene | 0.021 | 0.108 |
| C8 | Octanes | 0.033 | 0.199 |
| | E-Benzene | 0.002 | 0.011 |
| | M/P Xylene | 0.006 | 0.035 |
| | O-Xylene | 0.002 | 0.015 |
| C9 | Nonanes | 0.021 | 0.147 |
| | 1,2,4 TMB | 0.004 | 0.027 |
| C10 | Decanes | 0.030 | 0.227 |
| C11+ | Undecanes + | 0.035 | 0.289 |
| | Total | 100.000 | 100.000 |

| Calculated Gas Properties | |
|---|---|
| Gas Density (kg $m^{-3}$ @ 15°C) | 0.786 |
| Gas Mole Weight (g $mol^{-1}$) | 17.621 |
| Real Relative (to air) Density of Gas | 0.608 |
| Mole weight of Heptanes Plus (g $mol^{-1}$) | 105.989 |
| Density of Heptanes plus (g $cm^{-3}$ at 60°F ) | 0.789 |
| Mole Weight of Undecanes plus (g $mol^{-1}$) | 147.000 |
| Density of Undecanes plus (g $cm^{-3}$ at 60°F) | 0.789 |
| Calorific Value (MJ $m^{-3}$ ) | 39.577 |

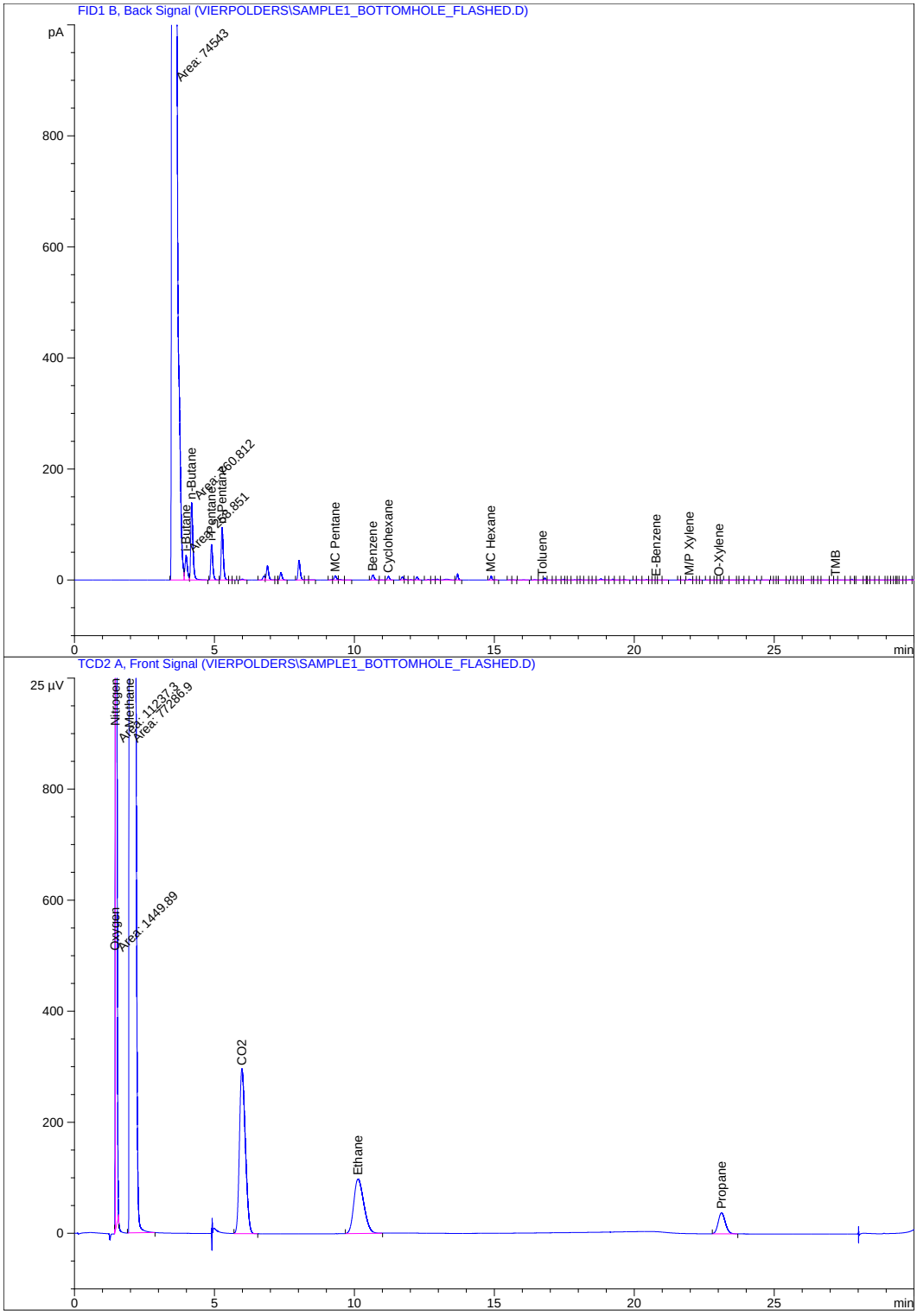


**Figure 6 - Chromatogram Flashed Gas from Bottomhole Sample 1**

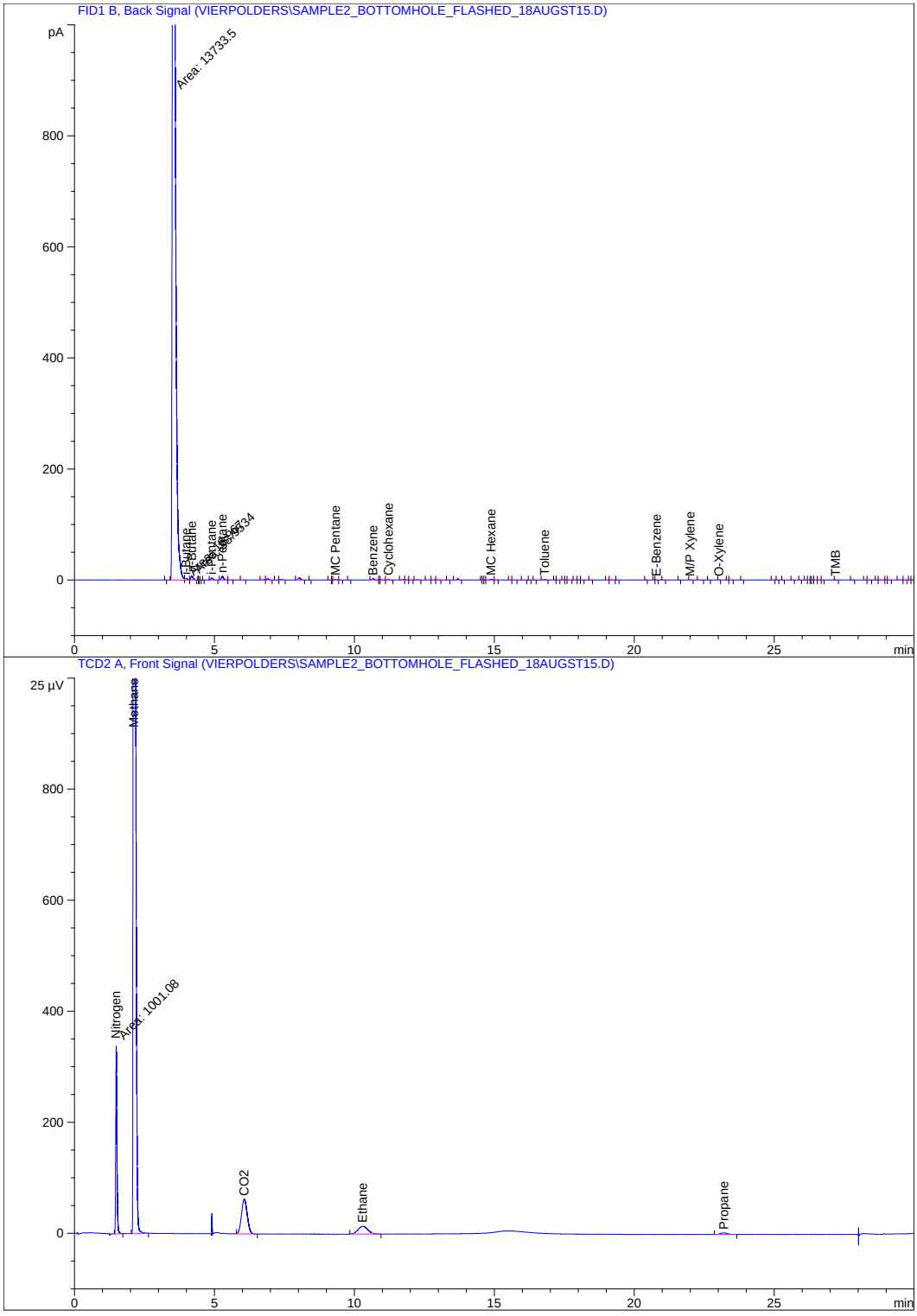


**Figure 7 - Chromatogram Flashed Gas from Bottomhole Sample 2**

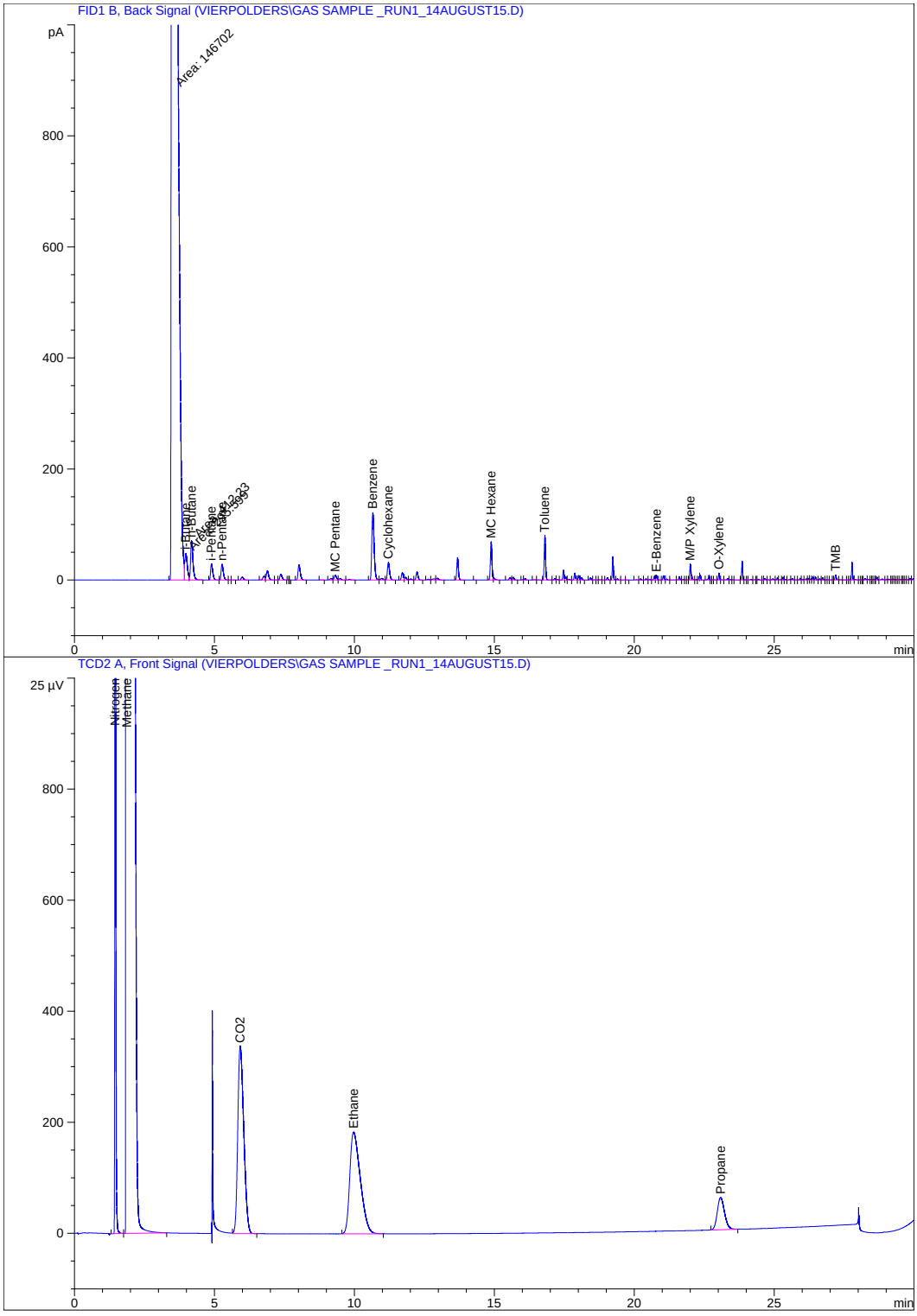


**Figure 8 - Chromatogram Gas from Sample 3 Surface Gas**

Table 6 - Physical Properties of Samples

| Sample no. | Type | pH @ 25$^0$C of flashed water | Density (g/cm$^3$) of flashed water @ 15$^0$C | GWR (ncm$^3$/cm$^3$) of live water | Bubble Point Pressure (bar) & 83$^0$C |
|---|---|---|---|---|---|
| Sample 1 | Bottomhole | 6.01 | 1.087 | 1.0677 | 700 |
| Sample 2 | Bottomhole | 6.05 | 1.082 | 1.0821 | 705 |
| Sample 1 | Surface Water | 6.34 | 1.087 | n/a | n/a |

### 1.5.4 Bubble Point Measurement

The water at reservoir conditions is in liquid phase and uncompressible. Below the saturation point (bubble point) the gas comes out and the two-phase sample is vastly more compressible. That is the bubble point. It can be determined from the PV graph. The experiment is carried out by reducing the pressure in a PVT bottle or cell and measuring the volumes at each step. Below the bubble point, the reduction in pressure will result in a much higher volume increase due to the gas expansion.

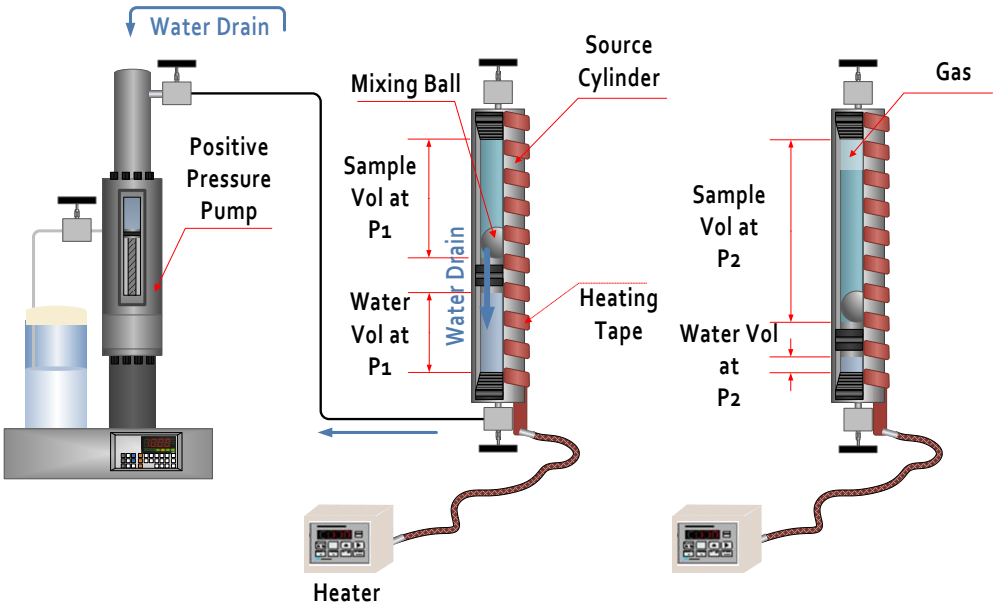


Figure 9 - Bubble Point Measurement Principle

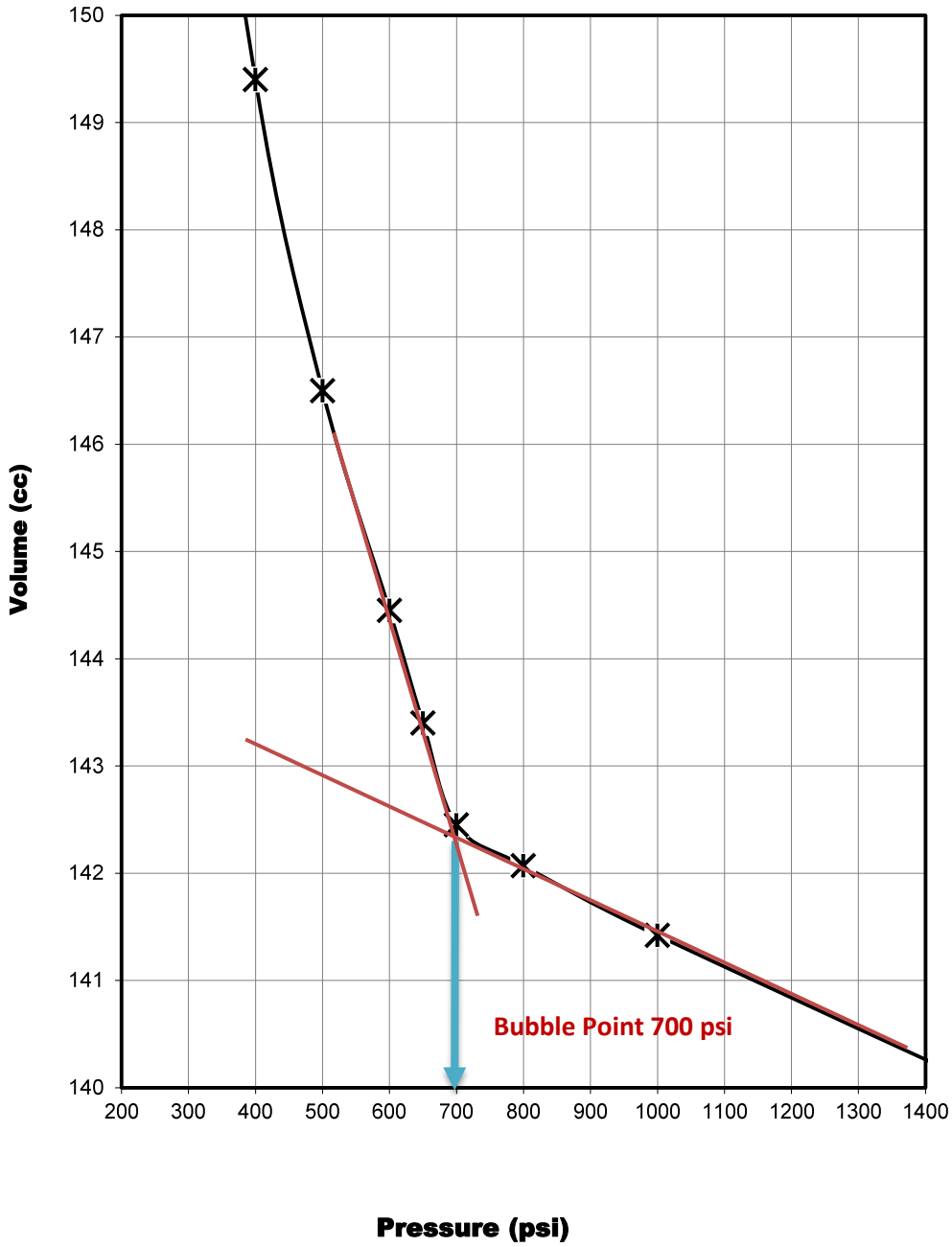


Figure 10 - Bubble Point Measurement Bottomhole Sample 1

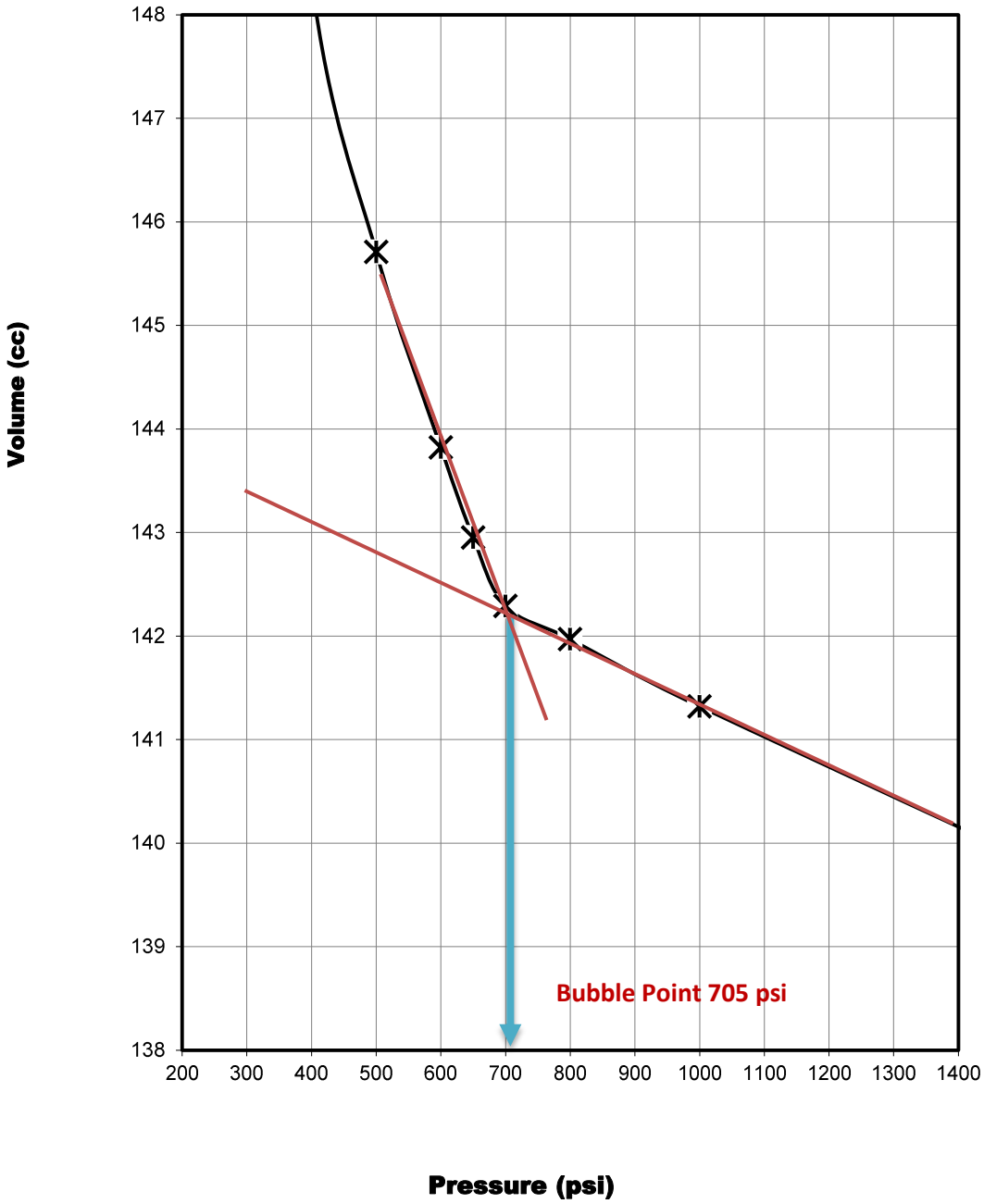


Figure 11 - Bubble Point Measurement Bottomhole Sample 2

### 1.5.5 Water Composition Analysis

Waterlaboratorium Noord

PRELIMINARY REPORT

Date 28-08-2015
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Sample 1533938

| | |
|---|---|
| Company | Panterra Geoconsultant B.V. |
| Attn. | de heer L. Pirlea |
| Address | Weversbaan 1-3 |
| Postal code | 2352 BZ LEIDERDORP |
| Project | water analysis |
| Sampling by | @Opdrachtgever |
| Sample type | Other sample types |
| Sample description | Sample 1 + 2: Bottomhole |
| Sampling date | 15-08-2015 13:30 |
| Your reference | water analysis |

| Parameter | Result | UoM |
|---|---|---|
| Suspended solids (f589/2 TSS) | 63 | mg/l |
| Residue after evaporation at 105oC (TDS) | 140000 | mg/l |
| Hydrogen carbonate | < 10 | mg/l |
| Hydrogen carbonate (in mmol) | 0.133 | mmol/l |
| Temporary hardness (in mmol) | < 0.1 | mmol/l |
| Carbonate | < 10 | mg/l |
| Chloride | 78000 | mg/l |
| Sulphate | 330 | mg/l |
| Aluminum | < 500 | ug/l |
| Barium | 4200 | ug/l |
| Calcium | 5900 | mg/l |
| Potassium | 630 | mg/l |
| Lithium | 7300 | ug/l |
| Magnesium | 900 | mg/l |
| Sodium | 43000 | mg/l |
| Strontium | 356000 | ug/l |
| Iron | 76 | mg/l |
| Total dissolved salts (calculated) | 127980 | mg/l |
| Total hardness calculated | 183.9 | mmol/l |

Figure 12 – Water Analysis Composition Combined Bottomhole Samples 1+2

Waterlaboratorium Noord

Date 28-08-2015
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Sample 1533917

PRELIMINARY REPORT

| | |
|---|---|
| Company | Panterra Geoconsultant B.V. |
| Attn. | de heer L. Pirlea |
| Address | Weversbaan 1-3 |
| Postal code | 2352 BZ LEIDERDORP |
| Project | water analysis |
| Sampling by | @Opdrachtgever |
| Sample type | Other sample types |
| Sample description | Sample 3 surface |
| Sampling date | 12-08-2015 14:00 |
| Your reference | water analysis |

| Parameter | Result | UoM |
|---|---|---|
| Suspended solids (f589/2 TSS) | 15 | mg/l |
| Residue after evaporation at 105oC (TDS) | 130000 | mg/l |
| Hydrogen carbonate | 21 | mg/l |
| Hydrogen carbonate (in mmol) | 0.338 | mmol/l |
| Temporary hardness (in mmol) | 0.169 | mmol/l |
| Carbonate | < 10 | mg/l |
| Chloride | 75000 | mg/l |
| Sulphate | 320 | mg/l |
| Aluminum | < 500 | ug/l |
| Barium | 4100 | ug/l |
| Calcium | 5800 | mg/l |
| Potassium | 670 | mg/l |
| Lithium | 6900 | ug/l |
| Magnesium | 880 | mg/l |
| Sodium | 42000 | mg/l |
| Strontium | 350000 | ug/l |
| Iron | 30 | mg/l |
| Total dissolved salts (calculated) | 124820 | mg/l |
| Total hardness calculated | 181.1 | mmol/l |

**Figure 13 - Water Analysis Composition Surface Samples**