PVT Water and Scale Analysis Report
Well BRI-GT-02
Aardwarmte Vierpolders
October 22, 2015

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PVT Water and Scale Analysis Samples from WELL BRI-GT-02

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1 PVT Analysis of Water Samples

1.1 Preamble

Vierpolders requested gas analysis as follows:

Measure the gas at different pressures to see if CO_2 and Methane come out of solution at different pressures. Suggested was to take 2 steps and therefore 3 gas samples, 18 bar, 9 bar and atmospheric pressure.

1.2 Surface Sampling

Two pressurized water samples were collected at the well BRI-GT-02. The water samples were collected using the displacement procedure into piston cylinders. Two “dead” (no gas dissolved) water samples were collected from the same sampling point into jerry cans.

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 Samples Restoration

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

1.4 Gas Analysis

1.4.1 Gas Separation

The samples were stabilized at 18 bar, with the free gas collected in a gas meter. The volume of gas collected from one sample was not enough so it was mixed with the gas from the other sample (released at 18 bar) and analyzed in the gas chromatograph. The composition of gas was subsequently measured using the procedure described below.

There was only enough gas for one more stage, which was carried out as above, only at atmospheric pressure.

1.4.2 Gas Composition

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

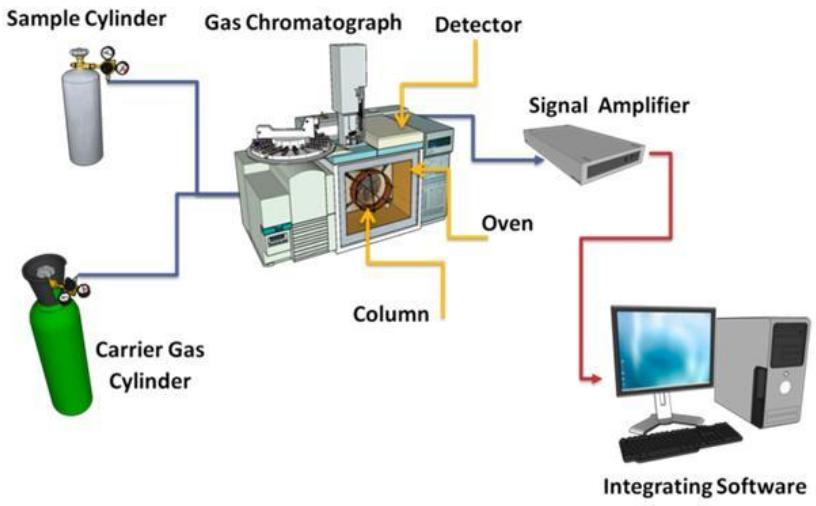

Figure 1 - General Chromatographic Procedure Layout

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+}).

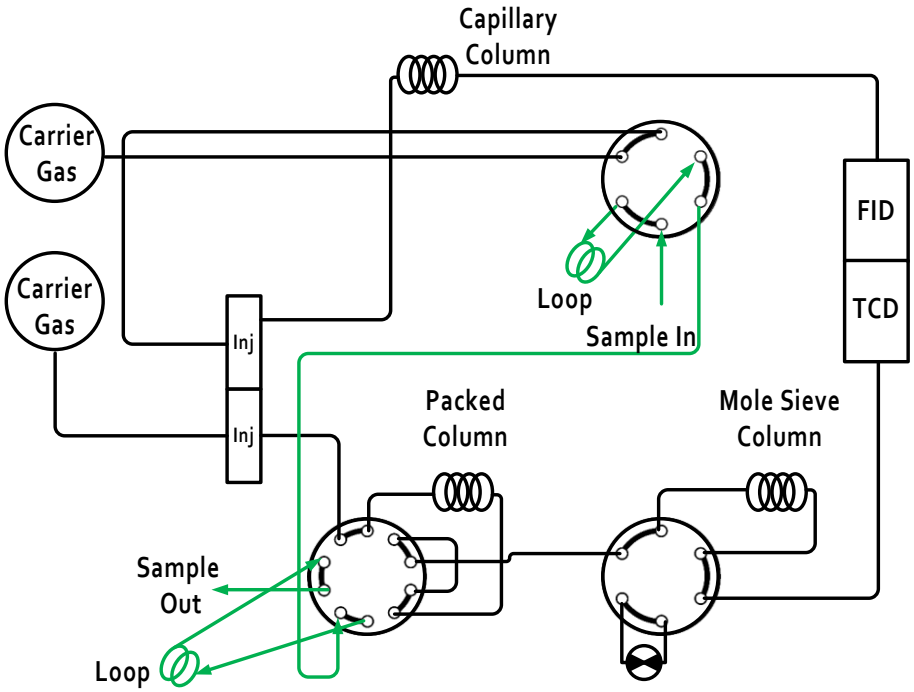

Figure 2 - Gas Chromatograph Layout

1.5 Water Physical Properties Measurement

1.5.1 Water Density Measurement

The density of the 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 3 - 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.

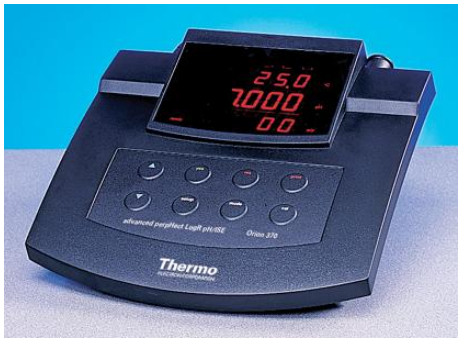

Figure 4 - Orion 370 pH meter

Table 1 - Composition of Flashed Gas at 0 bar (combined from both samples)

Component		Mole%	Weight%
H_2	Hydrogen	0.000	0.000
H_2S	Hydrogen Sulphide	0.000	0.000
CO_2	Carbon Dioxide	3.971	9.338
N_2	Nitrogen	1.248	1.868
C1	Methane	90.148	77.284
C2	Ethane	2.926	4.702
C3	Propane	0.481	1.134
C4	i-Butane	0.131	0.407
C4	n-Butane	0.224	0.694
C5	i-Pentane	0.066	0.254
C5	n-Pentane	0.116	0.448
C6	Hexanes	0.109	0.490
	MC Pentane	0.007	0.032
	Benzene	0.097	0.406
	Cyclohexane	0.023	0.103
C7	Heptanes	0.065	0.336
	MC Hexane	0.039	0.206
	Toluene	0.041	0.203
C8	Octanes	0.065	0.371
	E-Benzene	0.004	0.022
	M/P Xylene	0.012	0.067
	O-Xylene	0.005	0.028
C9	Nonanes	0.052	0.334
	1,2,4 TMB	0.010	0.070
C10	Decanes	0.074	0.528
C11+	Undecanes +	0.086	0.675
	Total	100.000	100.000

Calculated Gas Properties	
Gas Density (kg m^{-3} @ 15°C)	0.831
Gas Mole Weight (g mol^{-1})	18.714
Real Relative (to air) Density of Gas	0.643
Mole weight of Heptanes Plus (g mol^{-1})	109.108
Density of Heptanes plus (g cm^{-3} at 60°F)	0.788
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})	40.465

Table 2 - Composition of Flashed Gas at 18 bar (combined from both samples)

Component		Mole%	Weight%
H_2	Hydrogen	0.000	0.000
H_2S	Hydrogen Sulphide	0.000	0.000
CO_2	Carbon Dioxide	0.950	2.419
N_2	Nitrogen	5.031	8.154
C1	Methane	91.939	85.344
C2	Ethane	1.703	2.962
C3	Propane	0.269	0.685
C4	i-Butane	0.042	0.141
C4	n-Butane	0.033	0.111
C5	i-Pentane	0.006	0.026
C5	n-Pentane	0.008	0.034
C6	Hexanes	0.007	0.036
	MC Pentane	0.001	0.003
	Benzene	0.001	0.002
	Cyclohexane	0.000	0.002
C7	Heptanes	0.002	0.011
	MC Hexane	0.000	0.003
	Toluene	0.001	0.003
C8	Octanes	0.001	0.006
	E-Benzene	0.000	0.000
	M/P Xylene	0.000	0.001
	O-Xylene	0.000	0.000
C9	Nonanes	0.001	0.006
	1,2,4 TMB	0.000	0.001
C10	Decanes	0.002	0.012
C11+	Undecanes +	0.004	0.036
	Total	100.000	100.000

Calculated Gas Properties	
Gas Density (kg m^{-3} @ 15°C)	0.773
Gas Mole Weight (g mol^{-1})	17.283
Real Relative (to air) Density of Gas	0.598
Mole weight of Heptanes Plus (g mol^{-1})	119.311
Density of Heptanes plus (g cm^{-3} at 60°F)	0.778
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})	38.228

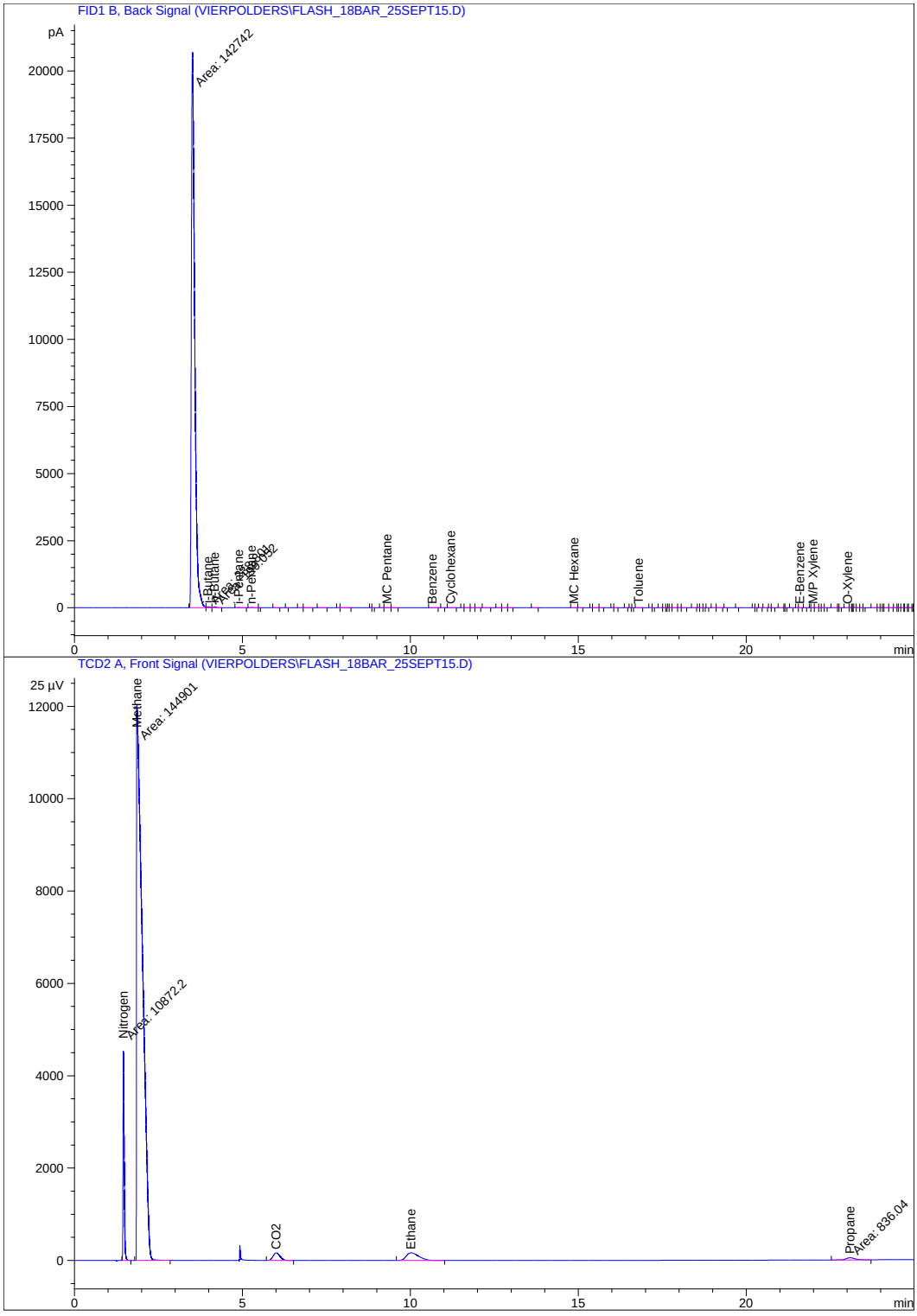

Figure 5 - Chromatogram Flashed Gas at 0 bar (combined from both samples)

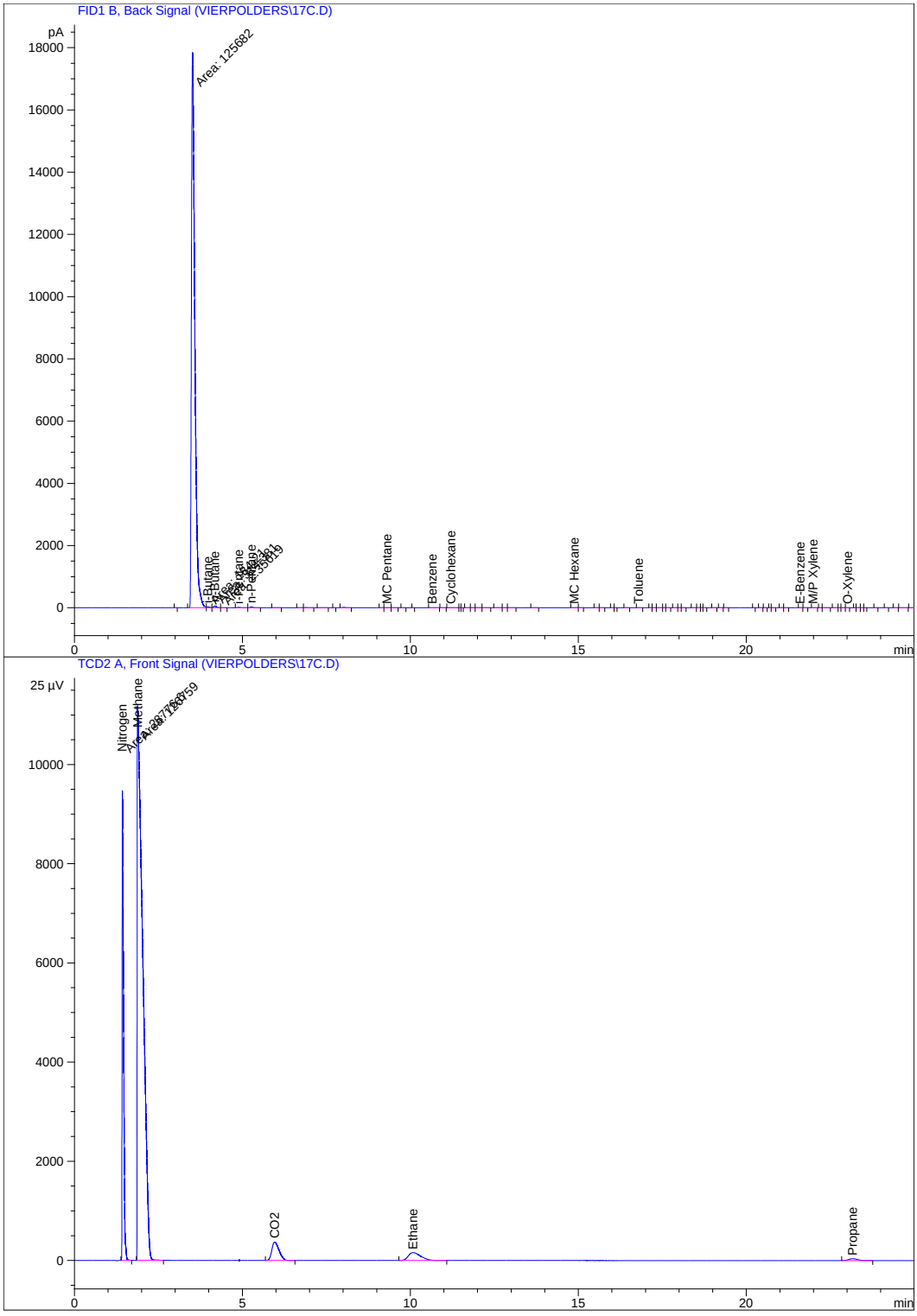

Figure 6 - Chromatogram Flashed Gas from Bottomhole Sample 2

Table 3 - Physical Properties of Surface Water Sample

Sample no.	Type	pH @ 25^0C	Density (g/cm^3) @ 15^0C
Sample 1	Surface Water	6.01	1.0824

1.5.3 Water Composition Analysis

REPORT

Request 15R0482/2 reference: c13043151001

Sampling by Client
Sample type Other sample types
Sample description **Sample 1**
Sampling date 29-09-2015 13:10

Analysis description	Method	Qual	Dupl.	Result	UoM	Rem.	Lab.
Destruction			1	y	y/n		ALWEST
Aluminium (after destruction)			1	80	µg/l		ALWEST
Arseen (after destruction)			1	< 10	µg/l		ALWEST
Barium (after destruction)			1	2800	µg/l		ALWEST
Cadmium (after destruction)			1	0.9	µg/l		ALWEST
Calcium (after destruction)			1	5700	mg/l		ALWEST
Chromium (after destruction)			1	2300	µg/l		ALWEST
Potassium (after destruction)			1	510	mg/l		ALWEST
Mercury (after destruction)			1	0.1	µg/l		ALWEST
Lead (after destruction)			1	< 5	µg/l		ALWEST
Magnesium (after destruction)			1	800	mg/l		ALWEST
Sodium (after destruction)			1	39000	mg/l		ALWEST
Nickel (after destruction)			1	2500	µg/l		ALWEST
Strontium			1	340	mg/l		ALWEST
Iron total (after destruction)			1	50	mg/l		ALWEST
Zinc (after destruction)			1	130	µg/l		ALWEST
Aromatic and aliphatic hydrocarbons	CO.W.15.1						
benzene			1	210	µg/l		
toluene			1	47	µg/l		
ethylbenzene			1	1.4	µg/l		
n-propylbenzene			1	< 1	µg/l		
iso-propylbenzene			1	< 1	µg/l		
n-butylbenzene			1	< 1	µg/l		
iso-butylbenzene			1	< 1	µg/l		
secundary-butylbenzene			1	< 1	µg/l		
tertiary-butylbenzene			1	< 1	µg/l		
n-pentylbenzene			1	< 1	µg/l		
o-xylene			1	2.6	µg/l		
m+p-xylene			1	4.5	µg/l		
4-isopropyltoluene			1	< 1	µg/l		
1,2,3-trimethylbenzene			1	< 1	µg/l		
1,2,4-trimethylbenzene			1	< 1	µg/l		
1,3,5-trimethylbenzene			1	< 1	µg/l		
1,2,3,4-tetramethylbenzene			1	< 1	µg/l		
1,2,3,5-tetramethylbenzene			1	< 1	µg/l		
1,2,4,5-tetramethylbenzene			1	< 1	µg/l		
2-ethyltoluene			1	< 1	µg/l		
3-ethyltoluene			1	< 1	µg/l		
4-ethyltoluene			1	< 1	µg/l		
1,2-diethylbenzene			1	< 1	µg/l		

Figure 7 – Water Analysis Composition Sample 1 – part 1

Analysis description	Method	Qual.	Dupl.	Result	UoM	Rem.	Lab.
Aromatic and aliphatic hydrocarbons	CO.W.15.1						
1,3-diethylbenzene			1	< 1	µg/l		
1,4-diethylbenzene			1	< 1	µg/l		
1,3-diisopropylbenzene			1	< 1	µg/l		
1,3,5-triisopropylbenzene			1	< 1	µg/l		
styrene			1	< 1	µg/l		
naphthalene			1	< 1	µg/l		
biphenyl			1	< 2.5	µg/l		
biphenylether			1	< 2.5	µg/l		
chlorobenzene			1	< 1	µg/l		
1,2-dichlorobenzene			1	< 1	µg/l		
1,3-dichlorobenzene			1	< 1	µg/l		
1,4-dichlorobenzene			1	< 1	µg/l		
1,2,3-trichlorobenzene			1	< 1	µg/l		
1,2,4-trichlorobenzene			1	< 1	µg/l		
1,3,5-trichlorobenzene			1	< 1	µg/l		
2-chlorotoluene			1	< 1	µg/l		
4-chlorotoluene			1	< 1	µg/l		
cyclohexane			1	< 5	µg/l		
methylcyclohexane			1	< 5	µg/l		
cyclohexene			1	< 1	µg/l		
1,2,3,4-tetrachlorobenzene			1	< 1	µg/l		
1,2,3,5+1,2,4,5-tetrachlorobenzene			1	< 1	µg/l		
bromobenzene			1	< 2.5	µg/l		
benzyl chloride			1	nd	µg/l		
alpha alpha dichlorotoluene			1	nd	µg/l		
Total Aromatic and aliphatic hydrocarbon			1	270	µg/l		
Sum BTEX			1	270	µg/l		

Figure 8 - Water Analysis Composition Sample 1 – part 2

REPORT

Request 15R0482/2 reference: c13043151001

Sampling by Client
Sample type Other sample types
Sample description **Sample 2**
Sampling date 29-09-2015 13:11

Analysis description	Method	Qual	Dupl.	Result	UoM	Rem.	Lab.
Destruction			1	y	y/n		ALWEST
Aluminium (after destruction)			1	70	µg/l		ALWEST
Arseen (after destruction)			1	< 10	µg/l		ALWEST
Barium (after destruction)			1	2800	µg/l		ALWEST
Cadmium (after destruction)			1	2.1	µg/l		ALWEST
Calcium (after destruction)			1	5900	mg/l		ALWEST
Chromium (after destruction)			1	420	µg/l		ALWEST
Potassium (after destruction)			1	490	mg/l		ALWEST
Mercury (after destruction)			1	0.1	µg/l		ALWEST
Lead (after destruction)			1	15	µg/l		ALWEST
Magnesium (after destruction)			1	800	mg/l		ALWEST
Sodium (after destruction)			1	40000	mg/l		ALWEST
Nickel (after destruction)			1	370	µg/l		ALWEST
Strontium			1	340	mg/l		ALWEST
Iron total (after destruction)			1	32	mg/l		ALWEST
Zinc (after destruction)			1	76	µg/l		ALWEST
Aromatic and aliphatic hydrocarbons	CO.W.15.1						
benzene			1	210	µg/l		
toluene			1	53	µg/l		
ethylbenzene			1	1.8	µg/l		
n-propylbenzene			1	< 1	µg/l		
iso-propylbenzene			1	< 1	µg/l		
n-butylbenzene			1	< 1	µg/l		
iso-butylbenzene			1	< 1	µg/l		
secundary-butylbenzene			1	< 1	µg/l		
tertiary-butylbenzene			1	< 1	µg/l		
n-pentylbenzene			1	< 1	µg/l		
o-xylene			1	4.0	µg/l		
m+p-xylene			1	6.3	µg/l		
4-isopropyltoluene			1	< 1	µg/l		
1,2,3-trimethylbenzene			1	< 1	µg/l		
1,2,4-trimethylbenzene			1	< 1	µg/l		
1,3,5-trimethylbenzene			1	< 1	µg/l		
1,2,3,4-tetramethylbenzene			1	< 1	µg/l		
1,2,3,5-tetramethylbenzene			1	< 1	µg/l		
1,2,4,5-tetramethylbenzene			1	< 1	µg/l		
2-ethyltoluene			1	< 1	µg/l		
3-ethyltoluene			1	< 1	µg/l		
4-ethyltoluene			1	< 1	µg/l		
1,2-diethylbenzene			1	< 1	µg/l		

Figure 9 - Water Analysis Composition Sample 2 – part 1

Analysis description	Method	Qual.	Dupl.	Result	UoM	Rem.	Lab.
Aromatic and aliphatic hydrocarbons	CO.W.15.1						
1,3-diethylbenzene			1	< 1	µg/l		
1,4-diethylbenzene			1	< 1	µg/l		
1,3-diisopropylbenzene			1	< 1	µg/l		
1,3,5-triisopropylbenzene			1	< 1	µg/l		
styrene			1	< 1	µg/l		
naphthalene			1	1.9	µg/l		
biphenyl			1	< 2.5	µg/l		
biphenylether			1	< 2.5	µg/l		
chlorobenzene			1	< 1	µg/l		
1,2-dichlorobenzene			1	< 1	µg/l		
1,3-dichlorobenzene			1	< 1	µg/l		
1,4-dichlorobenzene			1	< 1	µg/l		
1,2,3-trichlorobenzene			1	< 1	µg/l		
1,2,4-trichlorobenzene			1	< 1	µg/l		
1,3,5-trichlorobenzene			1	< 1	µg/l		
2-chlorotoluene			1	< 1	µg/l		
4-chlorotoluene			1	< 1	µg/l		
cyclohexane			1	< 5	µg/l		
methylcyclohexane			1	< 5	µg/l		
cyclohexene			1	< 1	µg/l		
1,2,3,4-tetrachlorobenzene			1	< 1	µg/l		
1,2,3,5+1,2,4,5-tetrachlorobenzene			1	< 1	µg/l		
bromobenzene			1	< 2.5	µg/l		
benzyl chloride			1	nd	µg/l		
alpha alpha dichlorotoluene			1	nd	µg/l		
Total Aromatic and aliphatic hydrocarbon			1	280	µg/l		
Sum BTEX			1	280	µg/l		

Figure 10 - Water Analysis Composition Sample 2 – part 2

2 Scale Analysis

Scaling or the formation of mineral deposits can occur on surfaces of metal, rock or other materials. Scale is caused by a precipitation process as a result of a change in pressure and temperature and the subsequent change in the composition of a solution. Typical scales consist of e.g. calcium carbonate, calcium sulfate, barium sulfate, strontium sulfate, iron sulfide, iron oxides or iron carbonate.

Occasionally salt deposits restrict or even shut-off the production conduit as the produced water composition is severely affected by the change in pressure and temperature. Not only produced formation water can cause problems, also water used in well operations can be potential sources of scale, including water used in water flood operations.

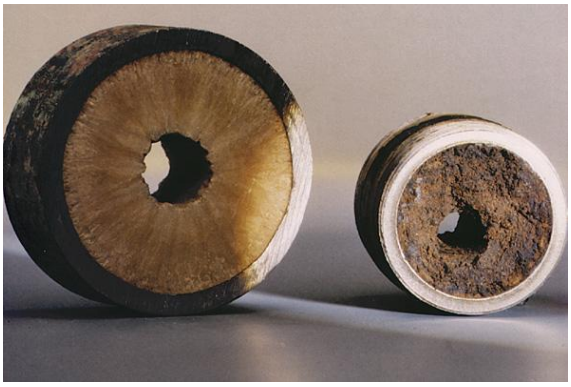

Figure 11 - Scaling example

2.1 Scope of Work

Aardwarmte Vierpolders requested PanTerra to investigate the composition of the solids from production and basin water samples taken from the well: **Well BRI-GT-02**. The results will be used to determine the source of the scale/solids and to evaluate the feasibility of water filtration or possibly other remedial treatments.

2.2 Samples Preparation

The submitted samples (Basin Water provided in a blue jerry can and production water in 3 white jerry cans) were treated according to LPSA procedures, i.e. settling down the solids for 2-3 hours from 1 Liter of representative water sample before using the deposit for the LPSA analysis. Ultrasound was needed for both samples in order to separate the fines from the aggregates. Deposits from the production water were also used for XRD analysis.

2.3 Procedures

2.3.1 X-Ray Diffraction Analysis

X-ray diffraction (XRD) is a non-destructive method and a useful tool for determining the mineral abundances in rocks and crystalline phases in unknown samples. PanTerra routinely analyze rock samples, clay samples and any other solid material. XRD analysis provides reliable information for reservoir characterization. Further PanTerra is able to monitor samples from the upstream industry like production fluids, water treatments filters, trapped suspended sediments in oil and many more. For bulk rock analysis the samples are ground to a fine powder and placed into sample holders. For clay analysis the clay fraction (< 2µm) is separated and dispersed on glass plates.

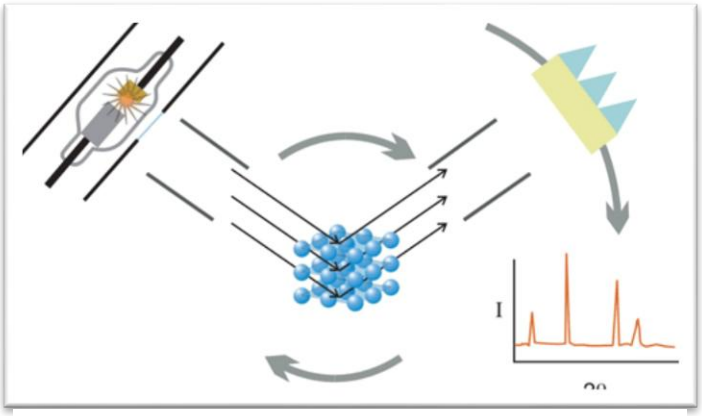

Figure 12 - XRD

X-ray diffraction (XRD) is commonly used for determining the mineral abundance in samples and crystalline phases in unknown solid samples. This information helps to better understand the quality of a reservoir. Quality information about the reservoir saves time and money and improves the recovery. Therefore, XRD analysis of rock samples combined with our in-house reservoir characterization tools allows us to evaluate specific questions of interest.

A pulverized sample is rotated while exposed to an X-ray beam. The X-ray beam is diffracted by the sample and the diffraction patterns recorded. The diffraction patterns are used to identify types and relative quantities of the minerals present.

2.3.2 Laser Particle Size Analysis (LPSA)

Particle size distribution analysis, based on laser diffraction, can be conducted on a large variety of sample types such as; powders, emulsions, suspensions and particles in liquids.

Advances in sophisticated data processing and automation have allowed this to become the dominant method used for determining the Particle Size Distribution (PSD). Corrections can be applied for the shape factors of specific sample types, which make it possible to correlate the particle size distribution directly with sieve analyses results. Analyses conducted with the Malvern MastersizerX can be measured in four size ranges: 0.1-80 µm, 0.5-180 µm, 1.2-600 µm and 4.0-2000 µm.

A total of 32 size bands are available throughout these ranges.

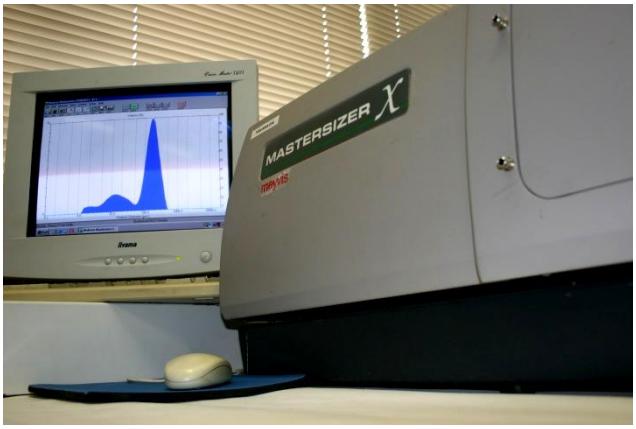

Figure 13 - LPSA equipment

2.4 Results

PANterra GEO CONSULTANTS BV
Version 1.1a

Tue, Sep 22, 2015 10:27AM

:Run Number 1

Sample File Name: PAN2015 , Record: 326
Measured on: Last saved on: Tue, Sep 22, 2015 10:26AM

Source: Input

Presentation: (2OHD) 1.330, 1.530 + i 0.10000
Polydisperse model

Volume Result

Residual = 0.000 %
d (0.5) = 1.59 µm
D [4, 3] = 2.39 µm
Sauter Mean (D[3,2]) = 1.25 µm
Specific Surface Area = 4.8065 sq. m. / gm

Concentration = 0.000 %
d (0.1) = 0.62 µm
Span = 2.84

Focus = 0 mm.
Obscuration = 0.00 %
d (0.9) = 5.13 µm
Mode = 0.72 µm
Density = 1.00 gm. / c.c.

Size (Lo) µm	Result In %	Size (Hi) µm	Result Below %
0.20	1.54	0.48	1.54
0.48	5.97	0.59	7.51
0.59	8.98	0.71	16.48
0.71	9.99	0.86	26.47
0.86	9.12	1.04	35.59
1.04	7.34	1.26	42.93
1.26	5.82	1.52	48.75
1.52	5.49	1.84	54.24
1.84	6.39	2.23	60.63
2.23	7.49	2.70	68.12
2.70	7.56	3.27	75.68
3.27	6.92	3.95	82.60
3.95	5.70	4.79	88.30
4.79	4.23	5.79	92.53
5.79	2.94	7.01	95.47
7.01	2.03	8.48	97.49

Size (Lo) µm	Result In %	Size (Hi) µm	Result Below %
8.48	1.33	10.27	98.83
10.27	0.72	12.43	99.55
12.43	0.32	15.05	99.87
15.05	0.13	18.21	100.00
18.21	0.00	22.04	100.00
22.04	0.00	26.68	100.00
26.68	0.00	32.29	100.00
32.29	0.00	39.08	100.00
39.08	0.00	47.30	100.00
47.30	0.00	57.25	100.00
57.25	0.00	69.30	100.00
69.30	0.00	83.87	100.00
83.87	0.00	101.52	100.00
101.52	0.00	122.87	100.00
122.87	0.00	148.72	100.00
148.72	0.00	180.00	100.00

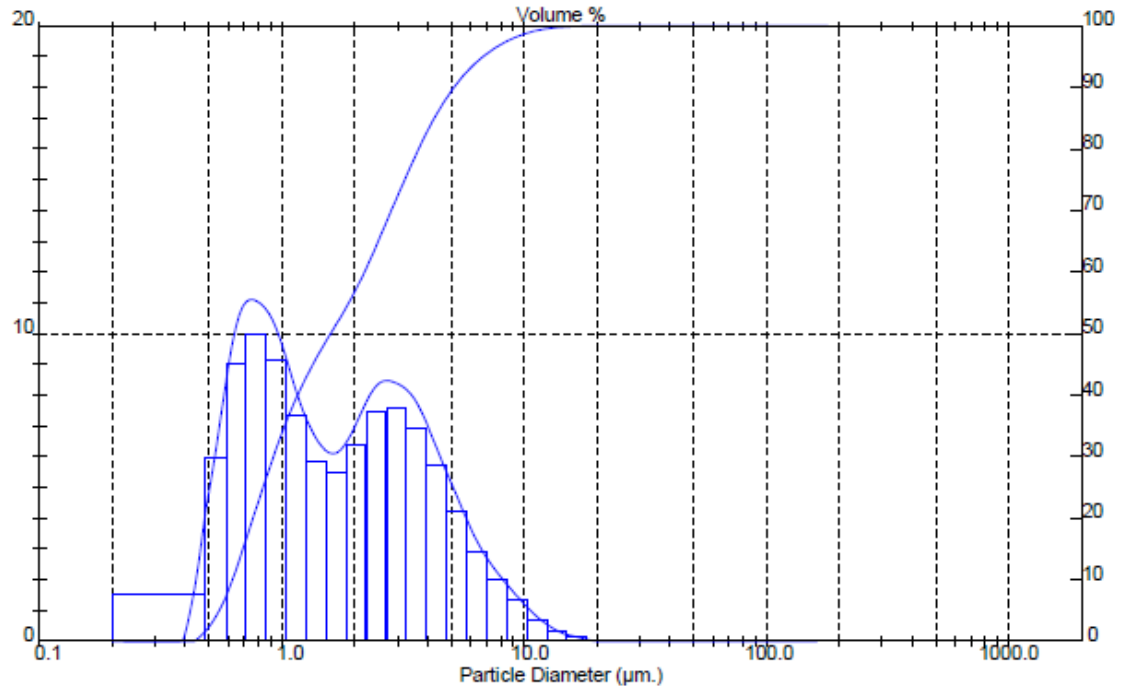

Figure 14 - Basin Water LPSA

PANterra GEO CONSULTANTS BV
Version 1.1a

Wed, Sep 23, 2015 1:40PM

13043#prod_water :Run Number 1

production water (white jerrycans)
c13043 Vierpolders
well: BRI-GT-02

Sample File Name: PAN2015 , Record: 349 Source: Analysed
Measured on: Wed, Sep 23, 2015 11:09AM Last saved on: Wed, Sep 23, 2015 11:09AM

Presentation: (2OHD) 1.330, 1.530 + i 0.10000
Polydisperse model

Volume Result

Focus = 100 mm.

Residual = 0.158 %
d (0 .5) = 4.06 µm
D [4, 3] = 4.93 µm
Sauter Mean (D[3,2]) = 2.34 µm
Specific Surface Area = 2.5641 sq. m. / gm

Concentration = 0.006 %
d (0.1) = 0.88 µm
Span = 2.18

Obscuration = 16.64 %
d (0.9) = 9.73 µm

Mode = 5.13 µm
Density = 1.00 gm. / c.c.

Size (Lo) µm	Result In %	Size (Hi) µm	Result Below %
0.20	0.65	0.48	0.65
0.48	2.25	0.59	2.90
0.59	3.26	0.71	6.16
0.71	3.49	0.86	9.65
0.86	3.07	1.04	12.72
1.04	2.49	1.26	15.21
1.26	2.32	1.52	17.52
1.52	2.99	1.84	20.51
1.84	4.59	2.23	25.10
2.23	6.57	2.70	31.68
2.70	7.96	3.27	39.64
3.27	9.06	3.95	48.69
3.95	9.74	4.79	58.43
4.79	9.79	5.79	68.22
5.79	9.18	7.01	77.40
7.01	7.93	8.48	85.33

Size (Lo) µm	Result In %	Size (Hi) µm	Result Below %
8.48	6.21	10.27	91.55
10.27	4.28	12.43	95.82
12.43	2.52	15.05	98.35
15.05	1.16	18.21	99.51
18.21	0.31	22.04	99.82
22.04	0.00	26.68	99.82
26.68	0.00	32.29	99.82
32.29	0.00	39.08	99.82
39.08	0.00	47.30	99.82
47.30	0.02	57.25	99.84
57.25	0.16	69.30	100.00
69.30	0.00	83.87	100.00
83.87	0.00	101.52	100.00
101.52	0.00	122.87	100.00
122.87	0.00	148.72	100.00
148.72	0.00	180.00	100.00

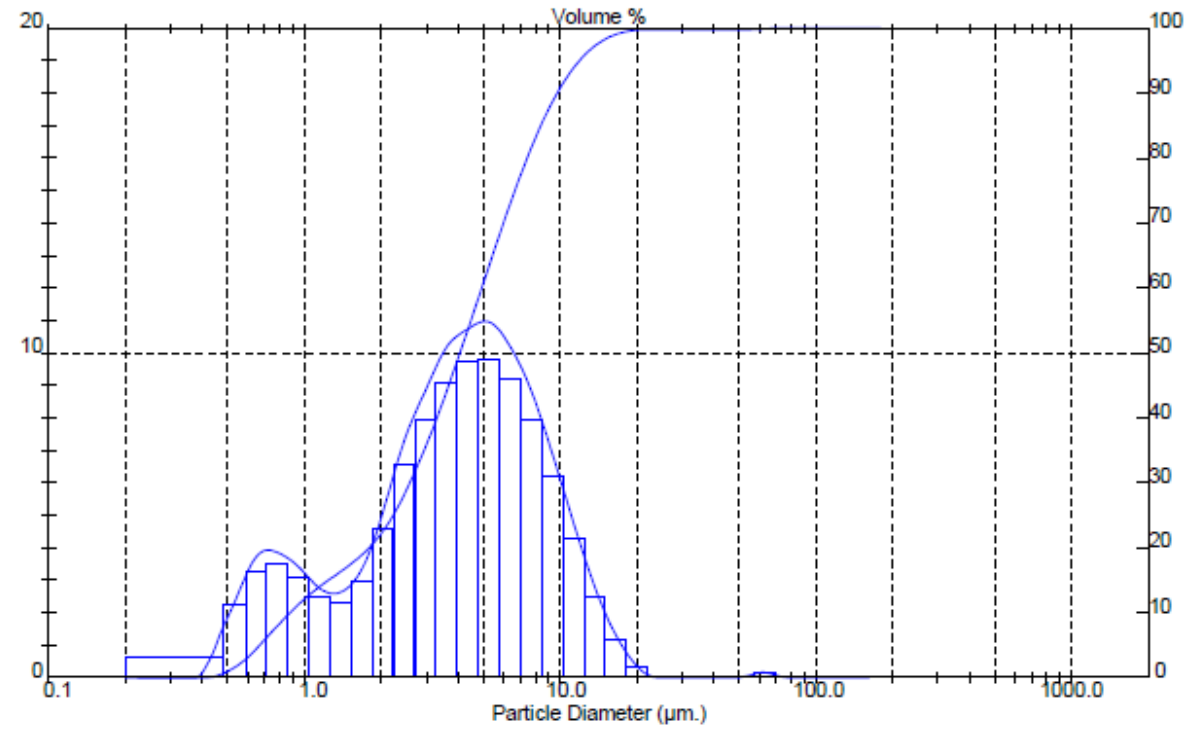

Figure 15 - Production Water LPSA

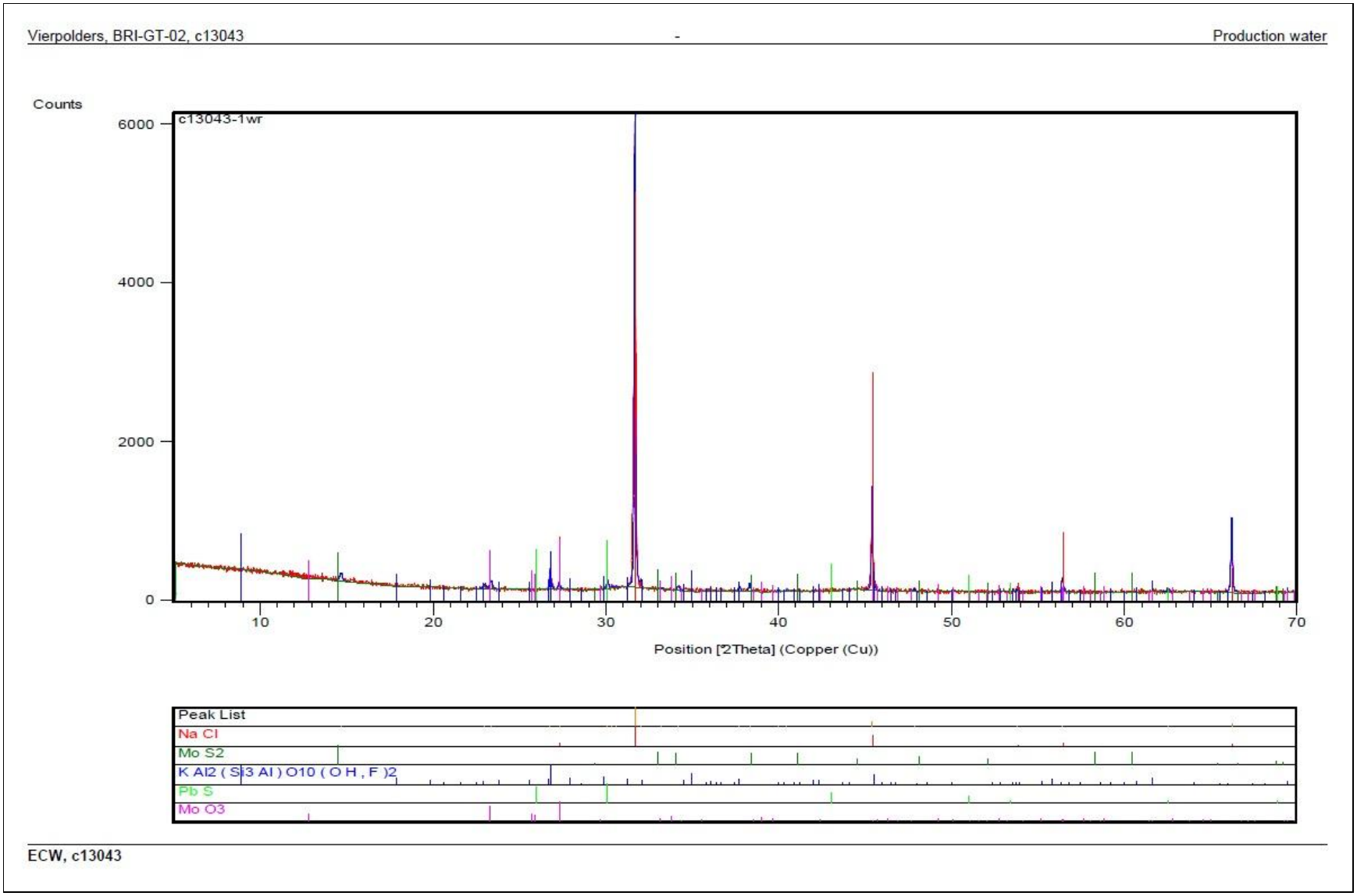

Figure 16 - XRD Results Production Water

Well	Sample	Plug depth (m)	Sample Type	Whole Rock Composition (%BW)					TOTAL % (Whole Rock)
				NaCl	MoS_2	MoO_3	$KAl_2(Si_3Al)O_{10}(OH,F)_2$	PbS	
BRI-GT-02	Prod water	-	Deposit (Production water)	94	3	2	tr	1	100

tr = trace (<0.5wt%)

Figure 17 - Semi-quantitative results of the whole rock XRD analysis on deposit from Well BRI-GT-02