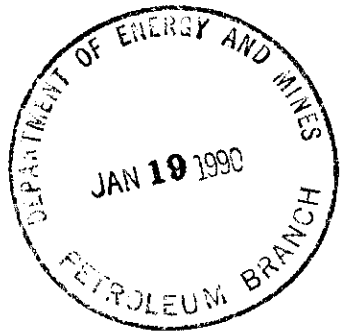
ENRON
Oil Canada Ltd.

(403) 298-2600

16 January 1990



Manitoba Energy & Mines
Petroleum Department
#555, 330 Graham Avenue
Winnipeg, Manitoba
R3C 4E3

Attention: Mr. John N. Fox,
Chief Petroleum Engineer

Dear Sir:

Re: Waskada Lower Amaranth Waterflood
Sensitivity Study - January 1990

Enclosed please find one copy of a recent detailed water compatibility study and a waterflood sensitivity study conducted on Lower Amaranth core samples using produced saline Lower Amaranth/Mississippian water and relatively fresh Swan River (Blairmore) source water.

A detailed water compatibility study between produced and source waters indicated that the waters are completely compatible in all proportions at ambient and reservoir temperatures. Therefore, no precipitation problems should result when produced and source waters are mixed in any proportion for injection. The measured saturation and stability indices indicate that the calcium carbonate ($CaCo_3$) scaling tendency is much less for the Swan River (Blairmore) source water and that calcium sulphate scaling ($CaSo_4$) exists only for the produced water. The corrosion tendency of the Swan River source water is significantly less than for the produced water. From a pure operational point of view, Swan River source water is far superior for injection purposes.

When produced water was flowed through the lower permeability core samples, a drastic air to liquid permeability reduction occurred, which was not entirely due to applied overburden pressure or the Klinkenberg slippage affect. It is hypothesized that the prevalent illite clay which bridges specific pore throats will allow the passage of gas molecules but impedes the flow of the larger water molecules. Therefore the effective permeability to water flow is much less than the total measured air permeability. The numerous pressure fall-off tests conducted in Waskada Unit No. 16 confirm this evident air/water permeability reduction. A fifty/fifty mixture of produced and source water resulted in a negligible reduction in the permeability to water flow in all three core samples when compared to 100% produced water injection. The injection of Swan River (Blairmore) source water

Manitoba Energy & Mines
Attention: Mr. John N. Fox
16 January 1990

resulted in an overall reduction in the permeability to water flow from 15% to 42% for the three core samples when compared to 100% produced water injection.This reduction in permeability is attributed to minor clay swelling. These results are considered positive, as complete blockage did not occur in any of the three core samples after injection of over twenty pore volumes of the relatively fresh Swan River source water through each of the cores.

After consideration of the total results of the above laboratory testing, Enron will recommend to partners that the 5-9-2-25 W1M well be re-completed as a Swan River (Blairmore) source well and the necessary flowlines and additional battery facilities be installed for a mixed produced/source water injection system for Waskada Unit No. 16.

If you wish to discuss any of the above information, please feel free to call the undersigned (403-298-2656) at your convenience.

Yours very truly,

ENRON OIL CANADA LTD.

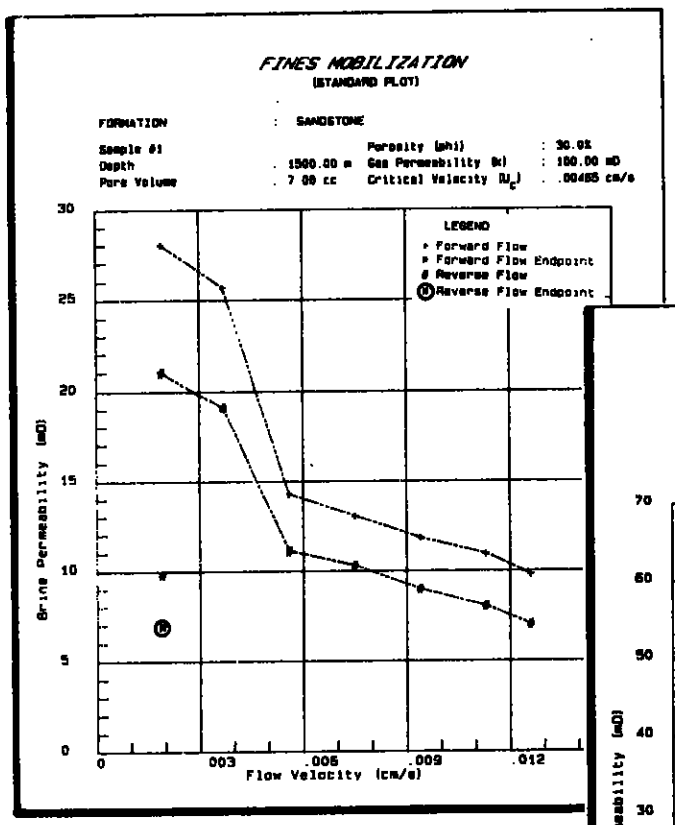
H. Dale Logie, P.Eng.
Chief Reservoir Engineer

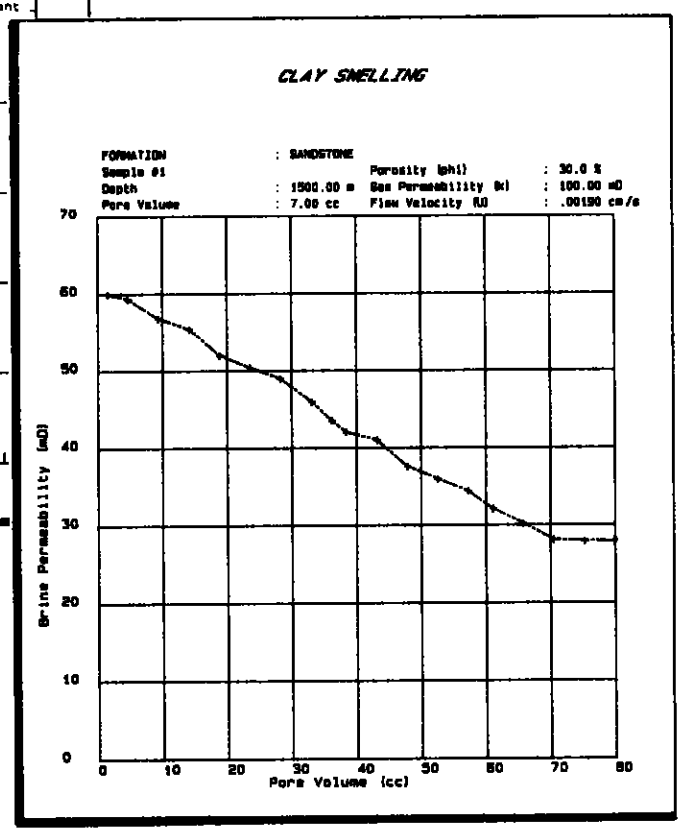
HDL:pdc
attach

xc: Waskada Unit No. 16 Working Interest Owners

WATERFLOOD SENSITIVITY STUDY

ENRON et al WASKADA
5-9-2-25W1
15A-10-2-25W1





Prepared for

ENRON OIL CANADA LTD.

Prepared by

Ben Nikakhtar, M.Sc., P.Eng.

FILE NO: 89-GC-391-1

January 10, 1990

GEOTECH PetroScience

PRODUCTION ENGINEERING RESEARCH & DEVELOPMENT

tti GEOTECHnical resources ltd.

4500 - 5th STREET N.E., CALGARY, ALBERTA T2E 7C3 (403) 230-4128

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EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

Three (3) waterflood sensitivity tests were conducted on two (2) samples from the Waskada 5-9-2-25W1 and one (1) sample from the Waskada 15A-10-2-25W1. Each sample was injected with the following sequence of waters:

1. Water from the Lower Amaranth 6-10-2-25W1 (produced).
2. 50/50 mixture of Lower Amaranth 6-10-2-25W1 and Swan River 10-7-1-25W1.
3. Water from Swan River 10-7-1-25W1 (injection).

The results showed that the 50/50 water mixture reduced permeability by 13% in the worst case and the Swan River water reduced permeability by 15% in the best case and 42% in the worst. The reduction in permeability is attributed to a minor clay swelling due to the very fresh nature of the water.

The liquid permeabilities measured on the low gas permeability samples (in the order of <3 md) were unusually low with respect to their gas permeabilities. This, however, was not the case with the high permeability sample (gas permeability = 46.44 md). The reduction for low permeability samples may be due to a fines migrations problem taking place at unusually low flowrates. A fines migration test is recommended to confirm this phenomenon.

A klinkenberg slippage test and several gas permeability measurements were conducted at net overburden pressure to explain the reason for the low liquid permeabilities. The klinkenberg test showed that the limiting (1.5 md) was within the normal range of gas permeability (2.41 md).

EXPERIMENTAL PROCEDURE

EXPERIMENTAL PROCEDURE

A total of eight (8) plug samples were cut for this study. Of the 8 samples, 4 (Samples #A, B, C and D) were cut from well Enron et al Waskada 5-9-2-25W1, and 4 (Samples #A, B, C and D) from well Enron et al Waskada 15A-10-2-25W1. Two samples (Samples #A and C) from well 5-9 and one sample (Sample #D) from well 15A-10 were selected for waterflood sensitivity tests.

Water samples from the Lower Amaranth 6-10-2-25W1 (produced water) and Swan River 10-7-1-25W1 (injection water) were received for use in the waterflood sensitivity tests. The produced water, when received, was in an emulsion form and was spun at reservoir temperature in an ultracentrifuge to separate water and oil. In total, 6 litres of the produced water were separated.

The objective of the experiment was to determine the sensitivity of the rock to three waters: produced water, 50/50 mixture of the produced and injection water, and injection water. Each plug sample was injected with the above waters in a continuous manner without stoppage.

Prior to injecting waters into the core samples, two detailed water compatability studies were conducted at room temperature (21°C) and at reservoir temperature of 43°C, using the above mentioned waters. This was done at the request of Enron to ensure waters are compatible in all proportions (see appendix for procedure and results).

The plug samples used in this study were nominally 1.5 inches (3.81 cm) in diameter and approximately 1 7/8 inches (4.76 cm) long. The samples were drilled and cut from the core using a solution of 5% KCl to avoid any ionic shocks to the clays.

The samples were then cleaned using toluene and methanol. Typically, in conjunction with toluene and methanol, acetone is used to remove water from sample. However, due to the abundant present of clays in this core, acetone was not used since dehydration may alter clay minerals. The samples were then placed in a humidity controlled oven at 45%

relative humidity and 80°C. To ensure that samples are dried and at the desired humidity, the weight of each sample was checked on a routine basis. Once the weight of the samples seem to stabilize, each was taken out and the petrophysical properties were measured.

Each of the samples used for waterflood sensitivity test was 100% saturated with the produced water (see water analysis in the appendix). The sample was then mounted in the coreholder and the reservoir pressure and temperature was applied. The conditions were as follows:

Pore Pressure: 8.0 MPa
Overburden Pressure: 19.0 MPa
Temperature: 43°C
Flowrate: 4 ml/hr

The produced water was injected at a constant flowrate of 4 ml/hr. The differential pressure and the cumulative produced volume of water was recorded as a function of time. Once the differential pressure across the sample stabilized, the next water (mixture of 50/50 produced and injection water) was injected at the same flowrate. Differential pressure and cumulative produced volume of water were recorded as a function of time. Once the differential pressure across the sample stabilized, the next water (injection water) was injected. Similarly, during this injection, the differential pressures and the cumulative volume of water throughput were recorded as function of time.

In addition to the waterflood sensitivity tests, gas permeabilities at net overburden pressure were also measured on 7 of the 8 samples. Klinkenberg slippage correction test was also conducted on Sample #D from well 5-9. The above tests were conducted to explain the reason for the low liquid permeability values obtained with the produced water.

DISCUSSION OF RESULTS

VIA RODEO OVERNIGHT MAIL

12 September 1989

ALL WORKING INTEREST OWNERS
WASKADA UNIT NO. 16
OPERATING COMMITTEE
(Addressee List Attached)

Gentlemen:

Re: Mail Ballot No. 3-89
Proposed Lab Work
Water Compatibility and Waterflood
Sensitivity Testing

Enron Oil Canada Ltd. herewith encloses Mail Ballot No. 3-89 requesting Working Interest Owners' approval to commence lab work to investigate the compatibility between Lower Amaranth produced and Swan River source water, as well as determine whether source water injection could result in formation plugging problems. The enclosed testing program submitted by Geotech will futher clarify the required work. The fines migration test of this program will be deleted but additional detailed water compatibility testing at ambient temperature will be included bringing the total cost to $9,500.

The water presently purchased for Unit waterflood injection operations fluctuates in quality and delivery pressure. Enron is evaluating the conversation of a shut-in former producing well to Swan River source water service. The proposed lab work will assist in assessing the optimum long term water injection requirements.

If you have any further questions, please contact Dale Logie at 298-2656.

Yours very truly,

ENRON OIL CANADA LTD.

L.E. Fenwick,
Chairman, Operating Committee
Waskada Unit No. 16

LEF:pdc
attach

September 7, 1989

GEOTECH

Mr. Dale Logie
ENRON OIL CANADA LTD.
1300, 700 - 9th Avenue S.W.
CALGARY, Alberta
T2P 3V4

Dear Dale:

Following our meeting a week ago on August 31, 1989, I am submitting the following testing program and the associated costs for the Special Core Analysis testing regarding the waterflood project in Waskada of the Spearfish Formation.

1. Detailed water compatibility testing between the produced water (Blairmore) and the injection water (Miss, Spearfish and Blairmore) at reservoir temperature of 43°C.

   1 @ $540.00 $540.00

2. Plug sample selection, cutting, cleaning, basic petrophysical properties determination and geological description.

   Recommend 10 samples @ $65 each $650.00

3. Rebate for 4 samples used in waterflood sensitivity testing in items (4) and (5) below.

   4 @ $50 each ($200.00)

4. Waterflood sensitivity testing comprised of injecting produced water, followed by 50/50 mixture of produced and injection waters, followed by injection water. The flow rate will be kept constant at 4 ml/hr, and sufficient quantity of each water will be injected through the sample to maintain stabilized differential pressure across the sample. For each type of water, a plot of pore volume throughput versus permeability will be generated for presentation. The test will be conducted at reservoir pressure and temperature.

   1st water injection: $900.00
   2nd water injection: $600.00
   3rd water injection: $600.00

   Total : $2100.00

   3 samples @ 2100.00 each $6300.00

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4500 - 5th STREET N.E., CALGARY, ALBERTA T2E 7C3 (403) 230-4128
TELEX 03-821172 ENVOY 100: TELEX. GEO FAX: (403) 230-4370

GEOTECH

5. Fines migration test to determine the critical velocity, if any. Generally the Spearfish Formation does not have kaolinite clays which are the primary cause of plugging and permeability impairment in fines migration problems. However, previous experience with this core has shown silts and other clay fragments do get mobilized and plug pore throats. Critical velocity has sometimes been observed with this formation. The test is performed at reservoir pressure and temperature.

   1 @ $2000.00 $2000.00

6. Data analysis and report preparation. $1800.00

Should you wish to proceed with the recommended tests the total estimated cost for the above project is $11,090. Testing and data analysis should take approximately one month from the time all samples and fluids are received.

If you have any questions, please do not hesitate to call me.

Sincerely,

Ben Nikakhtar, M.Sc., P.Eng.
Production Engineering
Research & Development

Proposal #1268

BN/lm

DISCUSSION OF RESULTS

The experimental results are presented in a series of tables and figures collected at the back of this report. These results consist of the following:

1. A table summarizing the geological description of all samples (Table 1).
2. A summary of the petrophysical parameters of all samples (Table 2).
3. A tabular and graphical presentation of the waterflood sensitivity test for Sample #A and 5-9 well (Table 3 and Figure 1).
4. A tabular and graphical presentation of the waterflood sensitivity test for Sample #C of 5-9 well (Table 4 and Figure 2).
5. A tabular and graphical presentation of the waterflood sensitivity test for Sample #D of 15A-10 well (Table 5 and Figure 3).
6. A tabular and graphical presentation of the klinkenberg slippage test for Sample #D of 5-9 well (Table 6 and Figure 4).

Three (3) plug samples were selected in consultation with Enron Oil Canada for waterflood sensitivity tests for the Waskada Spearfish Formation. The objective of the study was to test the chemical compatability of the Swan River water 10-7-1-25W1 and its mixture (50/50) with the reservoir rock.

Due to the freshness of the river (injection) water which contains only 5423 g/m^3 of total dissolved solids, produced water from the lower Amaranth 6-10-2-25W1 was used to establish initial permeability.

The detailed water compatability tests conducted on the above two waters, showed that the waters are completely compatible in all proportions at the two test temperatures of 22 and 43 degrees centrigrade. However, it must be noted that scaling calculations indicate that both test waters and the water mixtures have a tendency for calcium carbonate scaling. In addition, the produced water has a tendency for calcium sulphate scaling. The detailed results of the water compatability test are contained in the appendix.

Flow through tests were conducted at low constant flowrate of 4 ml/hr to avoid imposing any mechanical interaction such as fines migration by the argillaceous and silty materials.

The gas permeabilities measured at net overburden pressure for Samples #A, #C, #D used in the waterflood sensitivity test were 1.82 md, 2.75 md and 46.44 md, respectively; and the porosities were 17.7%, 20.6% and 19.8%, respectively.

Figure 1 shows the result of liquid permeability versus pore volume throughput for Sample #A. As shown, Sample #A with a gas permeability of 1.82 md at NOB, resulted in a liquid permeability of 0.53 md after 10.45 pv of produced water throughput. Also, a slight permeability reduction was observed with pore volume throughput. The liquid permeability of 0.53 md is considered to be low with respect to the gas permeability of 1.82 md at NOB. Because of the high salinity of the produced water, it is unlikely that the permeability reduction is caused by a chemical incompatibility with the water. However, and with the understanding that very low flowrate was used, a mechanical interaction cannot be overruled. It is therefore recommended that a fines migration test be conducted using flowrates starting from 0.5 cc/hr to verify such a possibility. The result of the 50/50 water injection on this sample showed that liquid permeability decreased from 0.53 md to 0.48 md (a 9% drop) after 10.58 pv throughput. The decrease here shows that the 50/50 water is chemically compatible with the core.

The result of the injection water showed liquid permeability decreased from 0.48 md at the end of 50/50 water injection to 0.31 md (a 35% drop). If compared to the initial permeability with the produced water (0.53 md), the drop is approximately 42%.

Figure 2 shows the result of the waterflood sensitivity test for Sample #C of 5-9 well. The liquid permeability with the produced water after stabilization was 0.98 md compared to a gas permeability measured at NOB of 2.75 md. The decrease in permeability from liquid to gas permeability for Sample #C is very similar to Sample #A. For the purpose of avoiding repetition, the argument above is valid for the possible cause

of this reduction. The permeability with the 50/50 water after 10.1 pv injection dropped from 0.98 md (with produced water) to 0.85 md (a 13% drop). The decrease with the use of the injection water was slightly more dramatic, as it decreased from 0.85 md to 0.64 md (a 25% drop). The overall drop in permeability using the fresh water with respect to the produced water was 35%.

Figure 3 shows the result of the waterflood sensitivity test for Sample #D. The liquid permeability with the produced water was 35.46 md and its gas permeability measured at NOB was 46.44 md. The liquid permeability in this case is well within the normal range of its gas permeability. The results here indicate that the high permeability samples are not affected (based on the result of one sample) by the factors which caused the low permeability samples (#A and #C) to have unusual low liquid permeabilities. The injection of the 50/50 water did not alter permeability as it changed from 36.11 md to 35.77 md (the difference is within the experimental error). Using the injection water, permeability decreased from 35.77 md at the end of 50/50 mixture to 30.30 md (a 15% drop) after 25.21 pv injection. The overall drop with the fresh water with respect to the produced water was 15%.

As a result of the unusual low values of the liquid permeabilities for Samples #A and #C, a klinkenberg slippage test was conducted on Sample #D of well 5-9. The result, as shown in Figure 4, shows the limiting (liquid) permeability to be 1.50 md with a gas permeability of 2.41 md measured at NOB. This is considered to be within the normal range.

In conclusion, the results showed the following:

1. Liquid permeabilities when compared with their respective gas permeabilities were considered to be unusually low for low permeability samples, but normal for high permeability samples. The liquid permeability resulting from a klinkenberg slippage test showed the limiting permeability extrapolated to be within the normal range.

2. The reason for the low liquid permeabilities may be a mechanical

interaction in the form of migration of clays or silts. A fines migration test is recommended to confirm this theory.

3. The injection of the 50/50 mixture of the injection and produced waters was considered to be safe as it resulted in a 13% drop in permeability in the worst case.

4. The injection of the fresh water from the Swan River formation resulted in a 42% drop in permeability in the worst case, and a 15% drop in the best.

TABLES AND FIGURES

January 2, 1990

ENRON OIL CANADA

ENRON et al WASKADA
5-9-2-25W1

Formation: Spearfish

GEOLOGICAL DESCRIPTION

Sample	Depth	Description
A	882.55 m	**Silty Sandstone** - mottled light brown, hard - very fine lower grained to silt sized, subrounded, moderatey sorted - quartz and rare dark lithic grains - light green grey interstitial argillaceous material - minor dolomite cement - rare quartz overgrowths - mottled texture - good intergranular porosity - very dull oil stain with very dull orange brown fluorescence - good yellow chlorothene cut - framework #7
B	885.27 m	**Silty Sandstone** - mottled light brown, rusty brown patches, hard - very fine upper grained to silt sized, subangular to subrounded, moderately sorted - quartz, scattered dark lithic and rare white clay grains - brown to light green grey clay matrix - minor dolomite cement - minor quartz overgrowths - trace mica - mottled texture - very good intergranular porosity - mottled dull brown oil stain with very dull orange brown fluorescence - good yellow chlorothene cut - framework #7-8

January 2, 1990

ENRON OIL CANADA

ENRON et al WASKADA
5-9-2-25W1

Formation: Spearfish

GEOLOGICAL DESCRIPTION

Sample	Depth	Description
C	887.65 m	**Sandstone** - light brown, hard - very fine lower to fine lower grained, subangular to subrounded, well sorted - quartz, scattered dark lithic grains, and rare red hematitic grains - partings of light green grey argillaceous material - rare floating rusty red anhydrite blebs - horizontal partings - very good intergranular porosity - even light brown oil stain with dull orange brown fluorescence - framework #8-9
D	888.10 m	**Sandstone** - light brown, hard - very fine lower to medium upper grained, bimodal texture, subrounded to rounded, moderately sorted - clear to rusty orange quartz, scattered dark lithic and rare white clay or pink feldspar grains - patches of anhydrite cement - minor dolomite cement - grain-rimming clays - massive - good intergranular porosity - brown oil stain with very dull orange brown fluorescence - good yellow chlorothene cut - framework #9

Table 1 (con't)

January 2, 1990

ENRON OIL CANADA

ENRON et al WASKADA
15A-10-2-25W1

Formation: Spearfish

GEOLOGICAL DESCRIPTION

Sample	Depth	Description
A	877.20 m	**Sandstone** - light brown, hard - very fine lower to very fine upper grained, subrounded, well sorted - quartz, rare dark lithic grains scattered white clay and rare hematitic grains - light brown (oil stain) interstitial argillaceous material - trace dolomite cement - minor quartz overgrowths - slightly inclined laminations - broken vertical fracture (bitumen coated) - very good intergranular porosity - even dull brown oil stain with dull orange brown fluorescence - framework #9
B	877.29 m	**Sandstone** - light brown, hard - very fine lower to very fine upper grained, subrounded, well sorted - quartz, rare dark lithic grains, scattered white clay and rare hematitic grains - light brown (oil stain) interstitial argillaceous material - trace dolomite cement - minor quartz overgrowths - slightly inclined laminations - very good intergranular porosity - even dull brown oil stain with dull orange brown fluorescence - framework #9

Table 1 (con't)

ENRON OIL CANADA

ENRON et al WASKADA
15A-10-2-25W1

GEOTECH

Formation: Spearfish

GEOLOGICAL DESCRIPTION

Sample	Depth	Description
C	878.93 m	**Sandstone** - light brown, green with rusty red bands, hard - very fine lower to very fine upper grained, subrounded, well sorted - quartz, rare dark lithic and rare white clay grains - light brown to white clay matrix - minor dolomite cement - thin green and rusty red shale beds or laminae (2.5 mm thick) - slightly inclined bedding - good intergranular porosity - even brown oil stain (except shale) with dull orange brown fluorescence - good yellow chlorothene cut - framework #8
D	878.97 m	**Sandstone** - light brown, hard - very fine lower to fine lower grained, subangular to subrounded, well to moderately sorted - quartz, rare dark lithic grains, plus rare hematitic grains - patches of anhydrite cement - minor to trace dolomite cement - brown grain-rimming clays - rare green shale partings - poorly defined horizontal bedding - good intergranular porosity - mottled brown oil stain with dull orange brown fluorescence - framework #8

Table 1 (con't)

January 4, 1989

ENRON OIL CANADA LTD.

ENRON et al WASKADA
5-9-2-25W1
15A-10-2-25W1

Formation: Spearfish

SUMMARY OF PETROPHYSICAL RESULTS

Sample Number	Depth (m)	Porosity (%)	Gas[1] Permeability (md)	Gas[2] Permeability (md)	Grain Density (kg/m3)
			5-9-2-25W1		
A[T]	882.55	17.7	4.35	1.82	2705
B	885.27	18.9	1.97	NM	2701
C[T]	887.65	20.6	9.14	2.75*	2693
D**	888.10	15.7	3.94	2.41	2720
			15A-10-2-25W1		
A	877.20	13.9	9.97	9.39	2735
B	877.29	10.5	4.36	3.89	2735
C	878.93	18.8	9.13	6.74	2702
D[T]	878.97	19.8	62.80	46.44	2706

1 Gas permeability measured at 350 psig confining pressure.
2 Gas permeability measured at NOB = 1600 psig.
* Gas permeability at NOB was measured after waterflood sensitivity test.
NM Not measured.
** Performed klinkenberg test at NOB = 1600 psig.
T Waterflood sensitivity test was performed on this sample.

January 4, 1989

ENRON OIL CANADA LTD.

ENRON et al WASKADA
5-9-2-25W1

GEOTECH

Sample: A

Formation: Spearfish

Porosity (phi): 17.7%
Gas Permeability (routine): 4.35 md
Gas Permeability (@ 1600 psig NOB): 1.82 md

Pore Volume: 9.13 cc
Grain Density: 2705 kg/m3

RESULTS OF WATERFLOOD SENSITIVITY TEST

Data Number	Cumulative Pore Volume Throughput	Differential Pressure Across Sample (kPa)	Liquid Permeability (md)
		Produced Water	
1	0.90	62.40	0.59
2	1.88	64.30	0.60
3	2.85	63.80	0.58
4	4.60	63.20	0.60
5	5.95	68.90	0.57
6	6.97	67.80	0.59
7	7.75	68.60	0.57
8	8.79	70.00	0.56
9	9.72	71.80	0.55
10	10.45	73.80	0.53
		Mixture of 50% Produced and 50% Injection Water	
11	12.24	63.60	0.52
12	12.90	64.30	0.51
13	13.63	64.50	0.50
14	14.47	64.70	0.50
15	15.23	65.10	0.48
16	16.10	66.00	0.48
17	16.91	65.60	0.48
18	17.77	65.60	0.48
19	18.60	65.20	0.49
20	19.36	64.90	0.48
21	20.16	64.00	0.48
22	21.03	66.40	0.48
		Injection Water	
23	22.40	65.80	0.43
24	23.25	67.10	0.41

Table 3

RESULTS OF WATERFLOOD SENSITIVITY TEST

Data Number	Cumulative Pore Volume Throughput	Differential Pressure Across Sample (kPa)	Liquid Permeability (md)
25	24.14	67.10	0.42
26	25.01	69.70	0.39
27	25.81	71.00	0.37
28	26.65	72.00	0.38
29	27.50	73.80	0.36
30	28.35	73.60	0.36
31	29.14	73.80	0.36
32	30.02	74.10	0.36
33	30.81	74.20	0.36
34	31.67	75.70	0.35
35	32.55	76.80	0.34
36	33.32	76.60	0.35
37	34.15	77.00	0.34
38	35.09	77.80	0.34
39	35.81	78.60	0.33
40	36.80	79.00	0.33
41	37.46	79.70	0.34
42	38.29	79.60	0.32
43	39.22	80.80	0.32
44	40.79	83.80	0.31
45	41.65	86.20	0.31
46	42.36	85.70	0.31

Table 3 (con't)

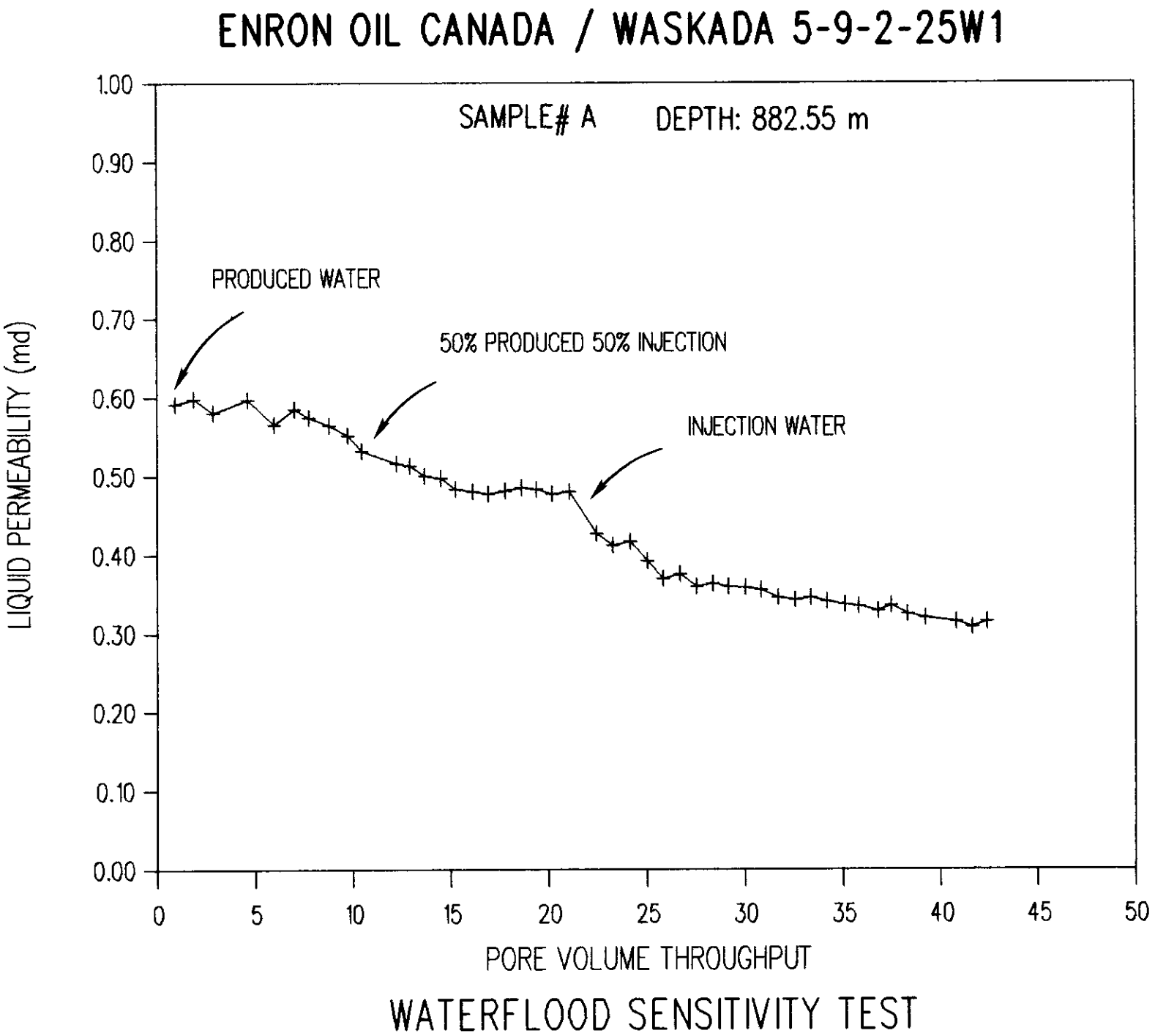

ENRON OIL CANADA / WASKADA 5-9-2-25W1
SAMPLE# A DEPTH: 882.55 m
PRODUCED WATER
50% PRODUCED 50% INJECTION
INJECTION WATER
LIQUID PERMEABILITY (md)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
5
10
15
20
25
30
35
40
45
50
PORE VOLUME THROUGHPUT
WATERFLOOD SENSITIVITY TEST

FIGURE 1

January 4, 1990

ENRON OIL CANADA LTD.

ENRON et al WASKADA
5-9-2-25W1

GEOTECH

Sample: C

Formation: Spearfish

Porosity (phi): 20.6%
Gas Permeability (routine): 9.14 md
Gas Permeability (@ 1600 psig NOB): 2.75 md

Pore Volume: 10.66 cc
Grain Density: 2693 kg/m3

RESULTS OF WATERFLOOD SENSITIVITY TEST

Data Number	Cumulative Pore Volume Throughput	Differential Pressure Across Sample (kPa)	Liquid Permeability (md)
		Produced Water	
1	0.53	52.60	0.99
2	1.01	47.60	1.01
3	1.79	45.60	1.03
4	2.74	45.00	1.03
5	4.31	44.00	1.02
6	8.16	45.40	0.97
7	8.38	45.90	0.98
8	9.09	45.90	0.98
		Mixture of 50% Produced and 50% Injection Water	
9	10.29	39.90	0.96
10	11.03	40.50	0.97
11	13.45	40.74	0.91
12	16.95	43.20	0.87
13	17.94	44.20	0.86
14	19.19	44.20	0.85
		Injection Water	
15	20.62	37.90	0.85
16	21.72	39.40	0.83
17	23.03	42.50	0.77
18	24.34	44.80	0.73
19	26.97	47.50	0.69
20	30.33	51.00	0.68
21	33.63	53.70	0.67
22	41.31	60.30	0.64

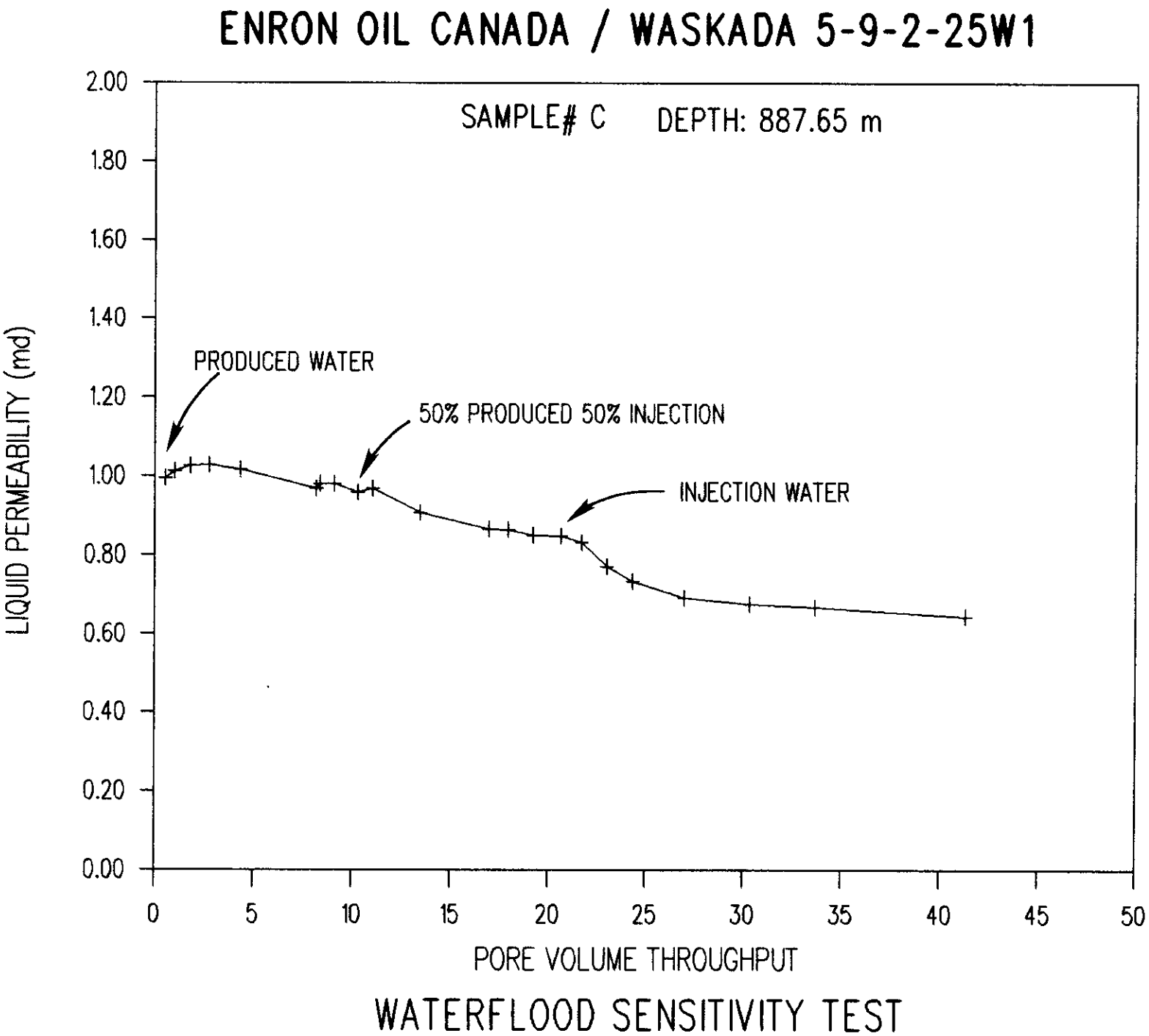

ENRON OIL CANADA / WASKADA 5-9-2-25W1
SAMPLE# C DEPTH: 887.65 m
LIQUID PERMEABILITY (md)
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
PRODUCED WATER
50% PRODUCED 50% INJECTION
INJECTION WATER
0
5
10
15
20
25
30
35
40
45
50
PORE VOLUME THROUGHPUT
WATERFLOOD SENSITIVITY TEST

FIGURE 2

January 4, 1990

ENRON OIL CANADA LTD.

ENRON et al WASKADA
15A-10-2-25W1

GEOTECH

Sample: D

Formation: Spearfish

Porosity (phi): 19.3%
Gas Permeability (routine): 52.60 md
Gas Permeability (@ 1600 psig NOB): 46.44 md

Pore Volume: 9.68 cc
Grain Density: 2706 kg/m3

RESULTS OF WATERFLOOD SENSITIVITY TEST

Data Number	Cumulative Pore Volume Throughput	Differential Pressure Across Sample (kPa)	Liquid Permeability (md)
		Produced Water	
1	3.32	1.46	35.85
2	3.57	1.35	35.96
3	3.81	1.38	35.05
4	4.06	1.34	35.42
5	6.13	1.24	35.28
6	7.29	1.24	35.28
7	8.12	1.22	35.86
8	9.06	1.24	35.28
10	9.89	1.26	34.73
11	11.04	1.26	34.72
12	11.29	1.26	34.37
13	11.91	1.26	35.02
14	12.20	1.26	35.46
		Mixture of 50% Produced and 50% Injection Water	
15	13.19	1.08	36.01
16	14.17	1.06	36.10
17	15.24	1.02	35.85
18	21.68	1.06	35.23
19	22.80	1.07	35.58
20	23.29	1.06	35.77
		Injection Water	
21	25.28	0.91	33.13
22	26.27	0.90	33.13
23	26.42	0.91	33.65
24	27.23	0.91	33.43
25	28.10	0.93	32.08
26	28.74	0.95	31.96

RESULTS OF WATERFLOOD SENSITIVITY TEST

Data Number	Cumulative Pore Volume Throughput	Differential Pressure Across Sample (kPa)	Liquid Permeability (md)
27	30.29	0.99	31.71
28	31.20	0.99	32.33
29	32.49	1.11	29.54
30	33.57	1.14	29.62
31	34.35	1.10	31.07
32	35.40	1.14	30.28
33	37.61	1.20	30.17
34	39.39	1.30	29.94
35	40.81	1.37	30.92
36	42.09	1.39	30.27
37	43.42	1.49	29.35
38	44.75	1.42	30.53
39	46.13	1.52	30.20
40	47.66	1.62	30.76
41	48.50	1.62	30.30

Table 5 (con't)

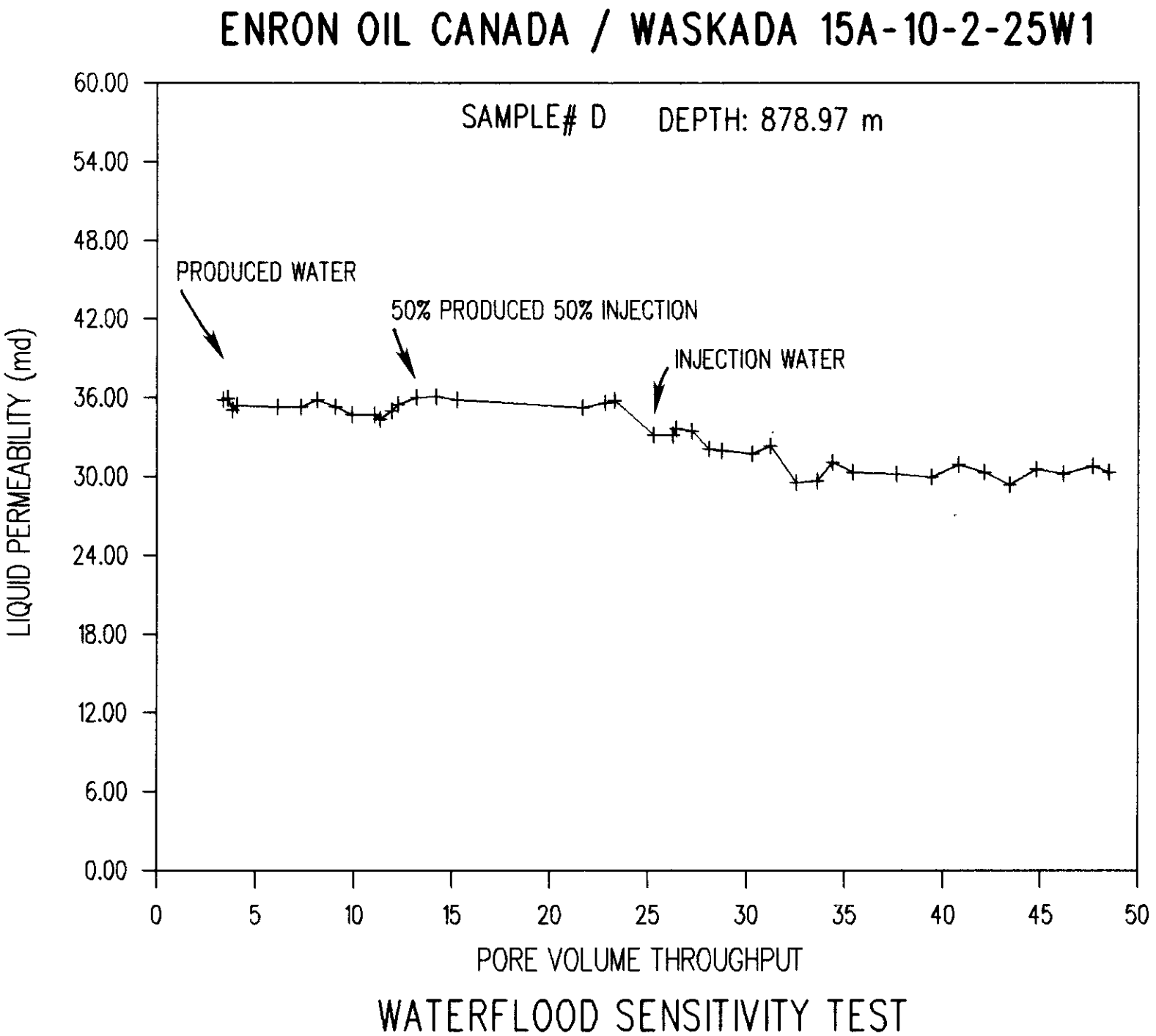

ENRON OIL CANADA / WASKADA 15A-10-2-25W1
SAMPLE# D DEPTH: 878.97 m
PRODUCED WATER
50% PRODUCED 50% INJECTION
INJECTION WATER
LIQUID PERMEABILITY (md)
60.00
54.00
48.00
42.00
36.00
30.00
24.00
18.00
12.00
6.00
0.00
0
5
10
15
20
25
30
35
40
45
50
PORE VOLUME THROUGHPUT
WATERFLOOD SENSITIVITY TEST

FIGURE 3

January 4, 1990

ENRON OIL CANADA LTD.

ENRON et al WASKADA
5-9-2-25W1

GEOTECH

Sample:D

Formation: Spearfish
Depth: 888.10 m

Gas Permeability (k): 3.94 md
Gas Permeability @ NOB (k): 2.41 md
Grain Density (rho): 2720 kg/m3

Porosity (phi): 15.7%
Limiting Perm (K_L): 1.50 md

KLINKENBERG SLIPPAGE DATA

Inverse Mean Pressure (1/psia)	Gas Permeability (md)
0.07481	2.50
0.07412	2.48
0.07317	2.39
0.07264	2.44
0.07009	2.41
0.06830	2.38
0.06604	2.34
0.06393	2.33
0.05512	2.20
0.04845	2.12
0.04321	2.06
0.03900	2.01
0.03264	1.91
0.02806	1.88

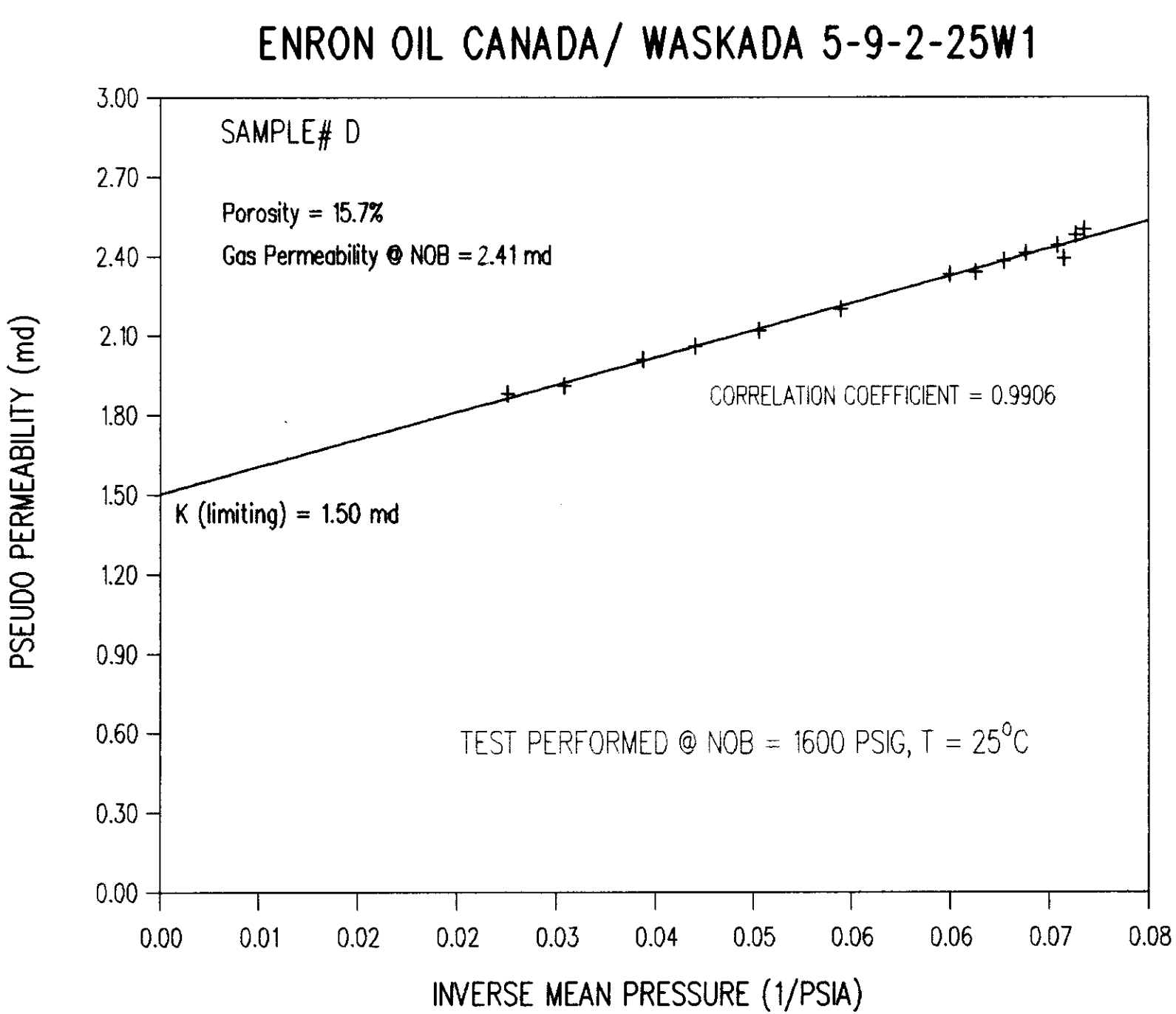

ENRON OIL CANADA/ WASKADA 5-9-2-25W1
SAMPLE# D
Porosity = 15.7%
Gas Permeability @ NOB = 2.41 md
CORRELATION COEFFICIENT = 0.9906
K (limiting) = 1.50 md
TEST PERFORMED @ NOB = 1600 PSIG, T = 25°C
PSEUDO PERMEABILITY (md)
3.00
2.70
2.40
2.10
1.80
1.50
1.20
0.90
0.60
0.30
0.00
0.00
0.01
0.02
0.02
0.03
0.04
0.05
0.06
0.06
0.07
0.08
INVERSE MEAN PRESSURE (1/PSIA)
KLINKENBERG SLIPPAGE CORRECTION PLOT

FIGURE 4

APPENDICES

APPENDIX

DETAILED WATER COMPATABILITY STUDY

ENRON et al WASKADA
LOWER AMARANTH 6-10-2-25W1

versus

SWAN RIVER 10-7-1-25W1

GEOTECH

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Results of the Detailed Water Compatibility study between ENRON ET AL WASKADA LOWER AMARANTH 6-10-2-25W1 and SWAN RIVER 10-7-1-25W1 indicate that the waters are completely compatible in all proportions at the two test temperatures, 22 and 43 degrees centigrade.

However it must be noted that scaling calculations indicate that both test waters and the water mixtures have a tendency for calcium carbonate scaling. In addition, the 6-10-2-25W1 water has a tendency for calcium sulphate scaling.

INTRODUCTION

One of the primary concerns in the implementation of an effective waterflood or water disposal program is the compatibility between the fluid which is being injected into the reservoir and formation water. Chemical reactions between two waters that can cause precipitate formation and negatively influence aquifer permeability and/or damage injection wells can be listed as:

1. Precipitation of alkaline earth metal such as calcium, barium, strontium and magnesium as relatively insoluble carbonates, sulfates, orthophosphates, fluorides and hydroxides.

2. Precipitation of metals such as iron, aluminum, manganese, chromium, and cadmium as insoluble carbonates, bicarbonates, hydroxides, orthophosphates and sulfides.

3. Precipitation of oxidation-reduction reaction products.

Although all these reactions are feasible during water injection operations, only a few of them would be anticipated under normal circumstances. Most often problems are limited to precipitates such as calcium and barium sulfates along with calcium carbonate and iron hydroxides. To avoid compatibility problems it may be necessary to treat the water prior to injection. The most radical treatment system would consist of such processes as ion exchange or chemical precipitation to remove scale forming ions; calcium, magnesium, sulphate and bicarbonate.

Though the compatibility between the injection and formation water is essential for any successful water injection operation, it is not the only criterion to be met. The other desired properties of the injection water for trouble free operation are as follows:

1. The water should not be corrosive to the water handling facilities.

2. It should not contain suspended matter in sufficient quantity to clog injection wells.

3. Content of calcium and magnesium salts should be over 10% of the total dissolved solids in the event that any swelling type clays are present in the formation to be flooded.

4. The water should be oxygen free.

5. Preferably, the concentration of biodegradable organic matter should be low in order to not nourish the growth of bacteria and algae.

EXPERIMENTAL

Details of the analytical procedure are presented in **APPENDIX B: EXPERIMENTAL PROCEDURE.**

Enron Oil Canada Ltd. requested that detailed water compatibility studies be undertaken, at temperatures of 22 C and 43 C, between water samples obtained from ENRON et al WASKADA Lower Amaranth 6-10-2-25W1 and Swan River 10-7-1-25W1. Results of the Detailed Water Compatibility study are reported herein.

CHEMICAL CHARACTERISTICS OF THE TEST WATERS

The inorganic compositions of the two test waters are presented in APPENDIX A as Water Analysis Reports 5986-W1 and W2.

A. Lower Amaranth 6-10-2-25W1 Wellhead Water (5986-W1)

Inspection of the water analysis data indicates that this is a very high brine with a salinity of 169,107 ppm and total dissolved solids of 170,669 mg/L. In addition, this water contains elevated levels of calcium, magnesium, strontium and sulphate, all of which have scale forming potential.

The elevated calcium level combined with the bicarbonate result in both the Saturation Index, 2.87, and Stability Index, 2.01, indicating a strong potential for calcium carbonate scaling in this water.

Results of calcium sulphate scaling calculations indicate that this water has a potential for calcium sulphate scaling to occur.

B. Swan River 10-7-1-25W1 Source Water (5986-W2)

Inspection of the water analysis data indicates that this water is quite fresh with a salinity of only 3,455 ppm and total dissolved solids of 5,423 mg/L. In addition, this water contains low levels of calcium, magnesium, strontium and only a slightly elevated sulphate level. Due to an abnormally high pH, 8.89, the carbonate and bicarbonate levels are elevated.

The low calcium level combined with the elevated bicarbonate, carbonate and pH result in both the Saturation Index, 1.77, and Stability Index, 5.33, indicating a significant potential for calcium carbonate scaling in this water.

Results of calcium sulphate scaling calculations indicate that this water has no tendency for calcium sulphate scaling.

RESULTS OF THE DETAILED WATER COMPATIBILITY STUDY

Results of the Visual Water Compatibility studies are presented in **APPENDIX B** as Tables 1 and 2.

A. 6-10-2-25W1 versus 10-7-1-25W1 at 22 Degrees Centrigrade

Results of the Visual Water Compatibility Study, presented in Table 2 of **APPENDIX B**, indicate that the solution transmittances remained well above the 93% cutoff for complete compatibility for all the water mixtures throughout the 72 hour test period. In addition, as noted in the comments, the test mixtures remained clear and colorless throughout test period.

Results of water analyses undertaken on the 70:30, 50:50 and 30:70 mixtures of the test waters are presented in APPENDIX A as water analysis reports 5986-W3, W4 and W5. Results of the calcium carbonate scaling calculations on these indicate a significant potential for calcium carbonate scale formation in these waters, as is expected. Results of calcium sulphate scaling calculations undertaken on the 50:50 test mixture indicate that this water mixture does not a tendency for calcium sulphate scaling.

On the basis of this compatibility study these two waters can be taken as being compatible in all proportions at a temperature of 22 degrees centigrade. However, it must be recognized that both test waters and the water mixtures have a tendency for calcium carbonate scaling and the 6-10 water has a tendency for calcium sulphate scaling.

B. 6-10-2-25W1 versus 10-7-1-25W1 at 43 Degrees Centigrade

Results of the Visual Water Compatibility Study, presented in Table 1 of **APPENDIX B**, indicate that, with the exception of the undiluted 6-10 water, the solution transmittances remained well above the 93% cutoff for complete compatibility for all the water mixtures throughout the 72 hour test period. In addition, as noted in the comments, the test mixtures remained clear and colorless throughout test period. In the case of the undiluted 6-10 water, the solution transmittances were slightly below 93%, however, the difference is so slight that there should not be a concern regarding this water.

Results of water analyses undertaken on the 70:30, 50:50 and 30:70 mixtures of the test waters are presented in APPENDIX A as water analysis reports 5986-W6, W7 and W8. Results of the calcium carbonate scaling calculations on these indicate a significant potential for calcium carbonate scale formation in these waters, as is expected. Results of calcium sulphate scaling calculations undertaken on the 50:50 test mixture indicate that this water mixture does not a tendency for calcium sulphate scaling.

On the basis of this compatibility study these two waters can be taken as being compatible in all proportions at a temperature of 43 degrees centigrade. However, it must be recognized that both the test waters and the water mixtures have a tendency for calcium carbonate scaling and the 6-10 water has a tendency for calcium sulphate scaling.

GEOTECH

APPENDIX A

WATER ANALYSIS REPORTS

GEOTECHnical resources ltd.

4500 - 5th STREET N.E. CALGARY, ALBERTA T2E 7C3
(403) 230-4128

WATER ANALYSIS

89AS5986

5986-W1

CONTAINER IDENTITY
5986F1

OPERATOR'S NAME
ENRON OIL CANADA LTD.

SAMPLE LOCATION | WELL NAME | ELEVATIONS KB | GRD
ENRON ET AL WASKADA 6-10-2-25W1

FIELD OR AREA | POOL OR ZONE | TYPE OF SAMPLER | COMPANY
LOWER AMARANTH

TEST TYPE NO | TEST RECOVERY

SAMPLING POINT | AMT AND TYPE OF CUSHION | MUD RESISTIVITY Ω/m
PRODUCED WATER

MULTIPLE RECOVERY
TEST INTERVAL
FROM

PUMPING | FLOWING | GAS LIFT | SWAB

TO

WATER m^3/d | OIL m^3/d | GAS $10^3m^3/d$

SEPARATOR | TREATER | RESERVOIR | SAMPLED | RECEIVED

PERFORATIONS
FROM

GAUGE PRESSURE K/Pa

TEMPERATURE (°C)

TO

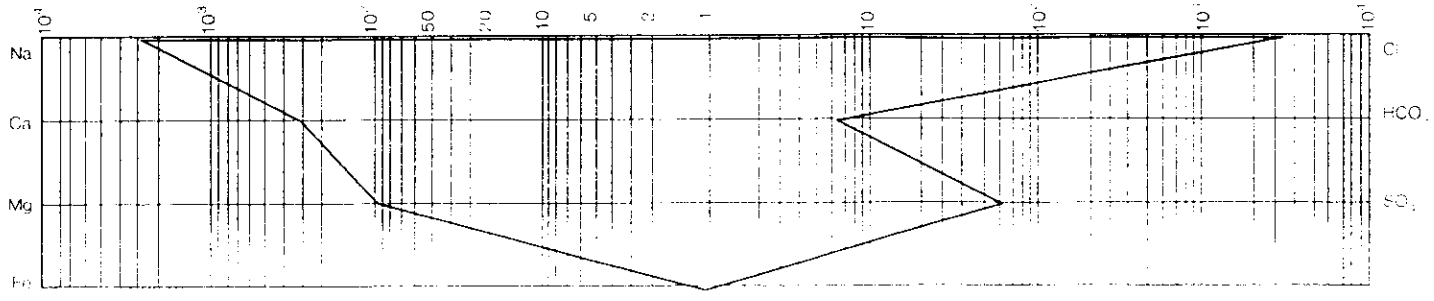
DATE SAMPLED Y M D	H:M	DATE RECEIVED Y M D	DATE ANALYZED Y M D	ANALYST
N/A		08-NOV-89	22-NOV-89	GB/VB

SUMMARY DATA

TOTAL HARDNESS AS CaCO	18659	g/m³
TOTAL ALKALINITY	315	g/m³
SALINITY AS NaCl	169107	ppm
SATURATION INDEX	2.87	CaCO3 SCALING TENDENCY
STABILITY INDEX	2.01	CaCO3 SCALING TENDENCY
CORROSION TENDENCY	472	

Scaling calculations done at 43 C

LOGARITHMIC PATTERN MEQ PER LITRE



REMARKS

GEOTECHnical resources ltd.
4500 - 5th STREET N.E., CALGARY, ALBERTA T2E 7C3
(403) 230-4126

WATER ANALYSIS
DETAILED REPORT

OPERATOR'S NAME	ENRON OIL CANADA LTD.	FILE NUMBER ▶	89AS5986
WELL NAME	ENRON ET AL WASKADA	LABORATORY NUMBER ▶	5986-W1
LOCATION	6-10-2-25W1		
SAMPLING POINT	PRODUCED WATER		

CATIONS

ION	g/m³	MASS FRACTION	MEQ/L
Na	57000	0.33	2480
K	600	0.00	15.3
Ca	5530	0.03	276
Mg	1140	0.01	93.8
Ba	0.181	0.00	0.003
Sr	137	0.00	3.1
Fe	0.18	0.00	0.01
Mn			
Al			
Si			
B	65.1		
U			
Th			

ANIONS

ION	g/m³	MASS FRACTION	MEQ/L
Cl	102800	0.61	2901
Br			
I	23	0.00	0.18
F			
HCO_3	384	0.00	6.3
CO_3	0.00	0.00	0.00
OH	0.00	0.00	0.00
SO_4	2990	0.02	62.3
H_2S			
PO_4			

TOTAL SOLIDS (g/m³)

EVAPORATED AT 110°C

EVAPORATED AT 180°C

AT IGNITION

CALCULATED 170669

SPECIFIC GRAVITY at 15°C

REFRACTIVE INDEX (R at 25°C 1.368

OBSERVED pH 7.77 at 25°C

RESISTIVITY (RW) Ω·m at 25°C 0.058

REDOX POTENTIAL (Eh)

DISSOLVED O_2 g/m³

TOTAL METALS

METAL	g/m³
Fe	
Mn	

Cations/Anions: 0.97

Interval: to

KB: GRD:

Perfs to

REMARKS

GEOTECHnical resources ltd.
4500 - 5th STREET N.E., CALGARY, ALBERTA T2E 7C3
(403) 230-4128

WATER ANALYSIS

FILE NUMBER ▶ 89AS5986

LABORATORY NUMBER ▶ 5986-W2

CONTAINER IDENTITY: 5986F2

OPERATOR'S NAME: ENRON OIL CANADA LTD.

SAMPLE LOCATION | WELL NAME: ENRON ET AL WASKADA 10-7-1-25W1 | ELEVATIONS KB / GRD

FIELD OR AREA | POOL OR ZONE: SWAN RIVER | NAME OF SAMPLER | COMPANY

TEST TYPE NO | TEST RECOVERY

SAMPLING POINT: INJECTION WATER | AMT. AND TYPE OF CUSHION | MUD RESISTIVITY Ω/m

MULTIPLE RECOVERY TEST INTERVAL FROM

TO

PUMPING | FLOWING | GAS LIFT | SWAB

WATER m^3/d | OIL m^3/d | GAS $10^3m^3/d$

SEPARATOR | TREATER | RESERVOIR | SAMPLED | RECEIVED

PERFORATIONS FROM

TO

GAUGE PRESSURE K/Pa

TEMPERATURE (C)

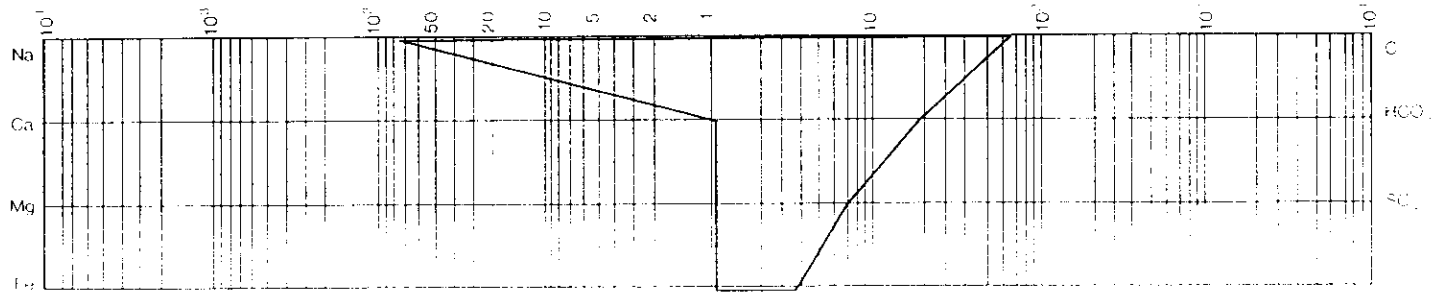
DATE SAMPLED Y M D	TIME	DATE RECEIVED Y M D	DATE ANALYZED Y M D	ANALYST
N/A		08-NOV-89	22-NOV-89	GB/VB

SUMMARY DATA

TOTAL HARDNESS AS $CaCO_3$	40	g/m³
TOTAL ALKALINITY	987	g/m³
SALINITY AS NaCl	3455	ppm
SATURATION INDEX	1.77	CaCO3 SCALING TENDENCY
STABILITY INDEX	5.33	CaCO3 SCALING TENDENCY
CORROSION TENDENCY	3.33	

Scaling calculations done at 43 C

LOGARITHMIC PATTERN MEQ PER LITRE



REMARKS

GEOTECHnical resources ltd.
4500 - 5th STREET N.E., CALGARY, ALBERTA T2E 7C3
(403) 230-4128

WATER ANALYSIS
DETAILED REPORT

OPERATOR'S NAME	ENRON OIL CANADA LTD.
WELL NAME	ENRON ET AL WASKADA
LOCATION	10-7-1-25W1
SAMPLING POINT	INJECTION WATER

LSD NUMBER ▶ 89AS5986

LABORATORY NUMBER ▶ 5986-W2

CATIONS

ION	g/m³	MASS FRACTION	MEQ/L
Na	1900	0.35	82.6
K	6.25	0.00	0.16
Ca	10.6	0.00	0.53
Mg	2.38	0.00	0.2
Ba	0.183	0.00	0.003
Sr	1.54	0.00	0.04
Fe	0.2	0.00	0.011
Mn			
Al			
Si			
B	3.91		
U			
Th			

ANIONS

ION	g/m³	MASS FRACTION	MEQ/L
Cl	2100	0.39	59.3
Br			
I	< 1.0		
F			
HCO_3	1010	0.19	16.7
CO_3	90.8	0.02	3.03
OH	0.00	0.00	0.00
SO_4	297	0.05	6.2
H_2S			
PO_4			

TOTAL SOLIDS (g/m³)

EVAPORATED AT 110°C	EVAPORATED AT 180°C
AT IGNITION	CALCULATED
	5423

SPECIFIC GRAVITY at 15°C	REFRACTIVE INDEX (RI) at 25°C
	1.342

OBSERVED pH at 25°C	RESISTIVITY (RW) Ω·m at 25°C
8.89	1.283

REDOX POTENTIAL (Eh)	DISSOLVED O_2 g/m³

TOTAL METALS

METAL	g/m³
Fe	
Mn	

Cations/Anions: 0.98

Interval: to

KB: GRD:

Perfs to

REMARKS

GEOTECHnical resources ltd.
4500 - 5th STREET N.E., CALGARY, ALBERTA T2E 7C3
(403) 230-4128

WATER ANALYSIS

FILE NUMBER ▶ 89AS5986

LABORATORY NUMBER ▶ 5986-W3

CONTAINER IDENTITY

OPERATOR'S NAME
ENRON OIL CANADA LTD.

SAMPLE LOCATION | WELL NAME
ENRON ET AL WASKADA

ELEVATIONS KB GR

FIELD OR AREA | POOL OR ZONE | NAME OF SAMPLER | COMPANY

TEST TYPE NO | TEST RECOVERY

SAMPLING POINT | AMT. AND TYPE OF CUSHION | MUD RESISTIVITY Ω/m
70% 6-10/30% 10-7 @ 43C

MULTIPLE RECOVERY TEST INTERVAL
FROM | PUMPING | FLOWING | GAS LIFT | SWAB

TO | WATER m^3/d | OIL m^3/d | GAS $10^3m^3/d$

SEPARATOR | TREATER | RESERVOIR | SAMPLED | RECEIVED

PERFORATIONS
FROM | GAUGE PRESSURE kPa
TEMPERATURE (°C)

TO

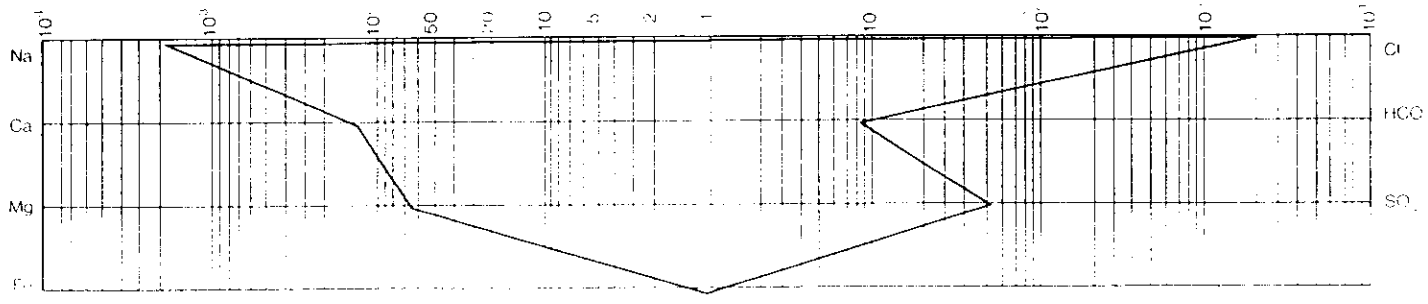
DATE SAMPLED Y M D	DATE RECEIVED Y M D	DATE ANALYZED Y M D	ANALYST
N/A	08-NOV-89	22-NOV-89	GB/VB

SUMMARY DATA

TOTAL HARDNESS AS CaCO3	9596	g/m^3
TOTAL ALKALINITY	428	g/m^3
SALINITY AS NaCl	115315	ppm
SATURATION INDEX	2.87	CaCO3 SCALING TENDENCY
STABILITY INDEX	2.21	CaCO3 SCALING TENDENCY
CORROSION TENDENCY	239	

Scaling calculations done at 43 C

LOGARITHMIC PATTERN MEQ PER LITRE



REMARKS

GEOTECHnical resources ltd.
4500 - 5th STREET N.E., CALGARY, ALBERTA T2E 7C3
(403) 230-4128

WATER ANALYSIS
DETAILED REPORT

OPERATOR'S NAME	ENRON OIL CANADA LTD.
WELL NAME	ENRON ET AL WASKADA
LOCATION	
SAMPLING POINT	70% 6-10/30% 10-7 @ 43C

FILE NUMBER ▶ 89AS5986

LABORATORY NUMBER ▶ 5986-W3

CATIONS

ION	g/m³	MASS FRACTION	MEQ/L
Na	41000	0.35	1784
K	484	0.00	12.4
Ca	2590	0.02	130
Mg	742	0.01	61
Ba	< 0.05		
Sr	64.4	0.00	1.47
Fe	< 0.05		
Mn			
Al			
Si			
B	46.4		
U			
Th			

ANIONS

ION	g/m³	MASS FRACTION	MEQ/L
Cl	70100	0.6	1980
Br			
I	11.2	0.00	0.09
F			
HCO_3	521	0.00	8.5
CO_3	0.00	0.00	0.00
OH	0.00	0.00	0.00
SO_4	2470	0.02	51.4
H_2S			
PO_4			

TOTAL SOLIDS (g/m³)

EVAPORATED AT 110°C

EVAPORATED AT 180°C

AT IGNITION

CALCULATED 118029

SPECIFIC GRAVITY at 15°C

REFRACTIVE INDEX (RI) at 25°C 1.360

OBSERVED pH at 25°C 7.96

RESISTIVITY (RW) Ω·m at 25°C 0.073

REDOX POTENTIAL (E_H)

DISSOLVED O_2 g/m³

TOTAL METALS

METAL	g/m³
Fe	
Mn	

Cations/Anions: 0.97

Interval: to

KB: GRD:

Perfs to

REMARKS

GEOTECHnical resources ltd.
4500 - 5th STREET N.E., CALGARY, ALBERTA T2E 7C3
(403) 230-4128

WATER ANALYSIS

FILE NUMBER ▶ 89AS5986

LABORATORY NUMBER ▶ 5986-W4

CONTAINER IDENTITY

OPERATOR'S NAME
ENRON OIL CANADA LTD.

SAMPLE LOCATION | WELL NAME
ENRON ET AL WASKADA

ELEVATION KB | GR

FIELD OR AREA | POOL OR ZONE | NAME OF SAMPLER | COMPANY

TEST TYPE NO | TEST RECOVERY

SAMPLING POINT
50% 6-10/50% 10-7 @ 43C

AMT. AND TYPE OF CUSHION | MUD RESISTIVITY Ω/m

MULTIPLE RECOVERY TEST INTERVAL
FROM

PUMPING | FLOWING | GAS LIFT | SWAB

TO

WATER m^3/d | OIL m^3/d | GAS $10^3m^3/d$

SEPARATOR | TREATER | RESERVOIR | SAMPLED | RECEIVED

PERFORATIONS
FROM

GAUGE PRESSURE K/Pa

TEMPERATURE (°C)

TO

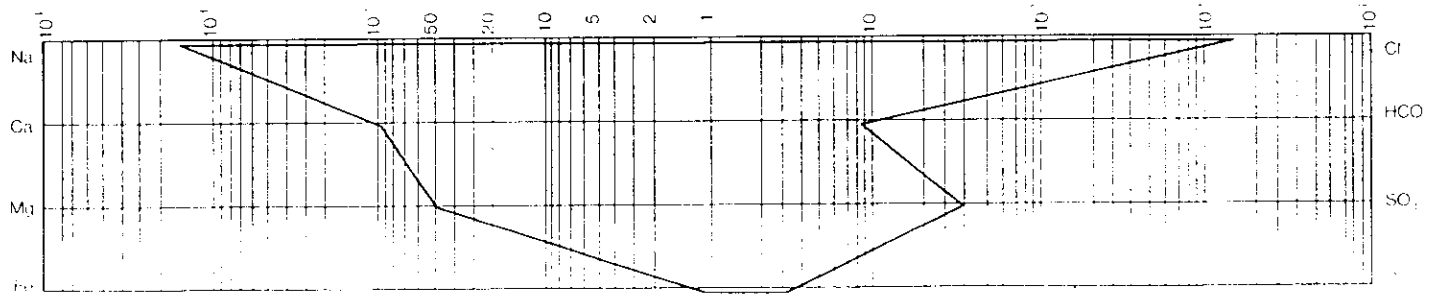
DATE SAMPLED Y M D	H:M	DATE RECEIVED Y M D	DATE ANALYZED Y M D	ANALYST
N/A		08-NOV-89	22-NOV-89	GB/VB

SUMMARY DATA

TOTAL HARDNESS AS $CaCO_3$	6693	g/m³
TOTAL ALKALINITY	598	g/m³
SALINITY AS NaCl	86199	ppm
SATURATION INDEX	3.13	CaCO3 SCALING TENDENCY
STABILITY INDEX	1.96	CaCO3 SCALING TENDENCY
CORROSION TENDENCY	127	

Scaling calculations done at 43 C

LOGARITHMIC PATTERN MEQ PER LITRE



REMARKS

GEOTECHnical resources ltd.
4500 - 5th STREET N.E., CALGARY, ALBERTA T2E 7C3
(403) 230-4128

WATER ANALYSIS
DETAILED REPORT

OPERATOR'S NAME	ENRON OIL CANADA LTD.	FILE NUMBER ▶	89AS5986
WELL NAME	ENRON ET AL WASKADA	LABORATORY NUMBER ▶	5986-W4
LOCATION			
SAMPLING POINT	50% 6-10/50% 10-7 @ 43C		

CATIONS

ION	g/m³	MASS FRACTION	MEQ/L
Na	33200	0.37	1445
K	332	0.00	8.5
Ca	1820	0.02	90.8
Mg	509	0.01	41.9
Ba	< 0.05		
Sr	46.3	0.00	1.06
Fe	< 0.05		
Mn			
Al			
Si			
B	33.9		
U			
Th			

ANIONS

ION	g/m³	MASS FRACTION	MEQ/L
Cl	52400	0.58	1480
Br			
I	7.5	0.00	0.06
F			
HCO_3	540	0.01	8.8
CO_3	93.1	0.00	3.1
OH	0.00	0.00	0.00
SO_4	1740	0.02	36.2
H_2S			
PO_4			

TOTAL SOLIDS (g/m³)

EVAPORATED AT 110°C	EVAPORATED AT 180°C
AT IGNITION	CALCULATED
	90722

SPECIFIC GRAVITY at 15°C	REFRACTIVE INDEX (R) at 25°C
	1.356

OBSERVED pH at 25°C	RESISTIVITY (RW) Ω·m at 25°C
8.23	0.091

REDOX POTENTIAL (E_H)	DISSOLVED O_2 g/m³

TOTAL METALS

METAL	g/m³
Fe	
Mn	

Cations/Anions: 1.04

Interval: to

KB: GRD:

Perfs to

REMARKS

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WATER ANALYSIS

FILE NUMBER ▶ 89AS5986

LAS ROAD NO. NUMBER ▶ 5986-W5

CONTAINER IDENTITY

OPERATOR'S NAME
ENRON OIL CANADA LTD.

SAMPLE LOCATION | WELL NAME
ENRON ET AL WASKADA

ELEVATIONS KB | GRD

FIELD OR AREA | POOL OR ZONE | NAME OF SAMPLER | COMPANY

TEST TYPE NO | TEST RECOVERY

SAMPLING POINT
30% 6-10/70% 10-7 @ 43C

AMT. AND TYPE OF CUSHION | MUD RESISTIVITY Ω/m

MULTIPLE RECOVERY TEST INTERVAL
FROM | TO

PUMPING | FLOWING | GAS LIFT | SWAB

WATER m^3/d | OIL m^3/d | GAS $10^3m^3/d$

SEPARATOR | TREATER | RESERVOIR | SAMPLED | RECEIVED

PERFORATIONS
FROM | TO

GAUGE PRESSURE K/Pa

TEMPERATURE (°C)

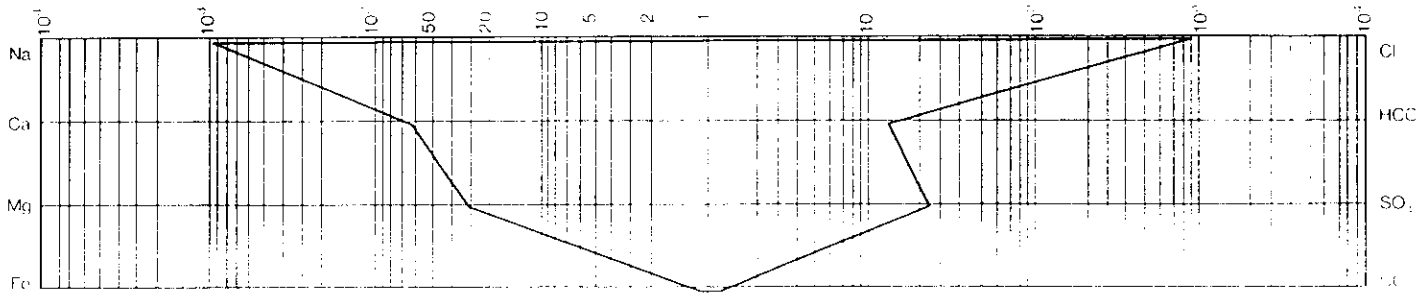
DATE SAMPLED Y M D	FM	DATE RECEIVED Y M D	DATE ANALYZED Y M D	ANALYST
N/A		08-NOV-89	22-NOV-89	GB/VB

SUMMARY DATA

TOTAL HARDNESS AS $CaCO_3$	4132	g/m³
TOTAL ALKALINITY	754	g/m³
SALINITY AS NaCl	52970	ppm
SATURATION INDEX	3.05	CaCO3 SCALING TENDENCY
STABILITY INDEX	2.14	CaCO3 SCALING TENDENCY
CORROSION TENDENCY	62	

Scaling calculations done at 43 C

LOGARITHMIC PATTERN MEQ PER LITRE



REMARKS

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WATER ANALYSIS
DETAILED REPORT

OPERATOR'S NAME	ENRON OIL CANADA LTD.	I.E.C. NUMBER ▶	89AS5986
WELL NAME	ENRON ET AL WASKADA	LABORATORY NUMBER ▶	5986-W5
LOCATION			
SAMPLING POINT	30% 6-10/70% 10-7 @ 43C		

CATIONS

ION	g/m³	MASS FRACTION	MEQ/L
Na	20000	0.36	870
K	204	0.00	5.2
Ca	1130	0.02	56.4
Mg	310	0.01	25.5
Ba	0.73	0.00	0.011
Sr	29.2	0.00	0.67
Fe	< 0.05		
Mn			
Al			
Si			
B	22.4		
U			
Th			

ANIONS

ION	g/m³	MASS FRACTION	MEQ/L
Cl	32200	0.58	909
Br			
I	4.4	0.00	0.03
F			
HCO_3	838	0.01	13.7
CO_3	39.6	0.00	1.32
OH	0.00	0.00	0.00
SO_4	1170	0.02	24.4
H_2S			
PO_4			

TOTAL SOLIDS (g/m³)

EVAPORATED AT 110°C	EVAPORATED AT 180°C
AT IGNITION	CALCULATED
	55949

SPECIFIC GRAVITY at 15°C	REFRACTIVE INDEX (R.I.) at 25°C
	1.351

OBSERVED pH at 25°C	RESISTIVITY (RW) Ω·m at 25°C
8.26	0.134

REDOX POTENTIAL (E_h) | DISSOLVED O_2 g/m³

TOTAL METALS

METAL	g/m³
Fe	
Mn	

Cations/Anions: 1.01

Interval: to

KB: GRD:

Perfs to

REMARKS

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WATER ANALYSIS

FILE NUMBER ▶ 89AS5986

LABORATORY NUMBER ▶ 5986-W6

CONTAINER IDENTITY

OPERATOR'S NAME
ENRON OIL CANADA LTD.

SAMPLE LOCATION | WELL NAME
ENRON ET AL WASKADA

ELEVATIONS KB | GRD

FIELD OR AREA | POOL OR ZONE | NAME OF SAMPLER | COMPANY

TEST TYPE NO | TEST RECOVERY

SAMPLING POINT | AMT. AND TYPE OF CUSHION | MUD RESISTIVITY Ω/m
70% 6-10/30% 10-7 @ 22C

MULTIPLE RECOVERY TEST INTERVAL
FROM | TO

PUMPING | FLOWING | GAS LIFT | SWAB

WATER m^3/d | OIL m^3/d | GAS $10^3m^3/d$

SEPARATOR | TREATER | RESERVOIR | SAMPLED | RECEIVED

PERFORATIONS
FROM | TO

GAUGE PRESSURE K/Pa

TEMPERATURE (°C)

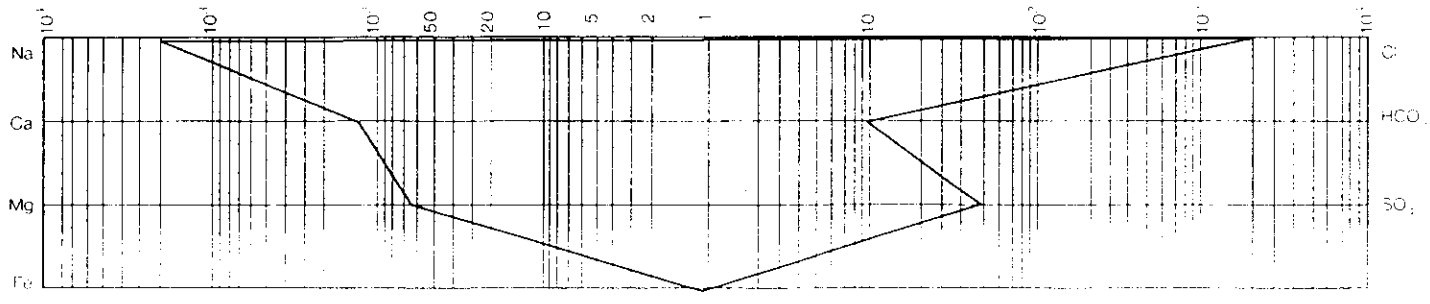
DATE SAMPLED Y M D	H:M	DATE RECEIVED Y M D	DATE ANALYZED Y M D	ANALYST
N/A		08-NOV-89	22-NOV-89	GB/VB

SUMMARY DATA

TOTAL HARDNESS AS CaCO	9182	g/m
TOTAL ALKALINITY	492	g/m³
SALINITY AS NaCl	115973	ppm
SATURATION INDEX	2.52	CaCO3 SCALING TENDENCY
STABILITY INDEX	2.95	CaCO3 SCALING TENDENCY
CORROSION TENDENCY	208	

Scaling calculations done at 22 C

LOGARITHMIC PATTERN MEQ PER LITRE



REMARKS

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WATER ANALYSIS
DETAILED REPORT

OPERATOR'S NAME	ENRON OIL CANADA LTD.	FILE NUMBER ▶	89AS5986
WELL NAME	ENRON ET AL WASKADA	LABORATORY NUMBER ▶	5986-W6
LOCATION			
SAMPLING POINT	70% 6-10/30% 10-7 @ 22C		

CATIONS

ION	g/m³	MASS FRACTION	MEQ/L
Na	43600	0.36	1897
K	477	0.00	12.2
Ca	2470	0.02	124
Mg	714	0.01	58.7
Ba	0.09	0.00	0.001
Sr	65.5	0.00	1.5
Fe	< 0.05		
Mn			
Al			
Si			
B	46.3		
U			
Th			

ANIONS

ION	g/m³	MASS FRACTION	MEQ/L
Cl	70500	0.59	1990
Br			
I	11.4	0.00	0.09
F			
HCO_3	599	0.00	9.8
CO_3	0.00	0.00	0.00
OH	0.00	0.00	0.00
SO_4	2320	0.02	48.3
H_2S			
PO_4			

TOTAL SOLIDS (g/m³)

EVAPORATED AT 110°C — EVAPORATED AT 180°C

AT IGNITION — CALCULATED

120804

SPECIFIC GRAVITY at 15°C — REFRACTIVE INDEX (R) at 25°C

1.360

OBSERVED pH at 25°C — RESISTIVITY (RW) Ω·m at 25°C

8.00 — 0.072

REDOX POTENTIAL (Eh) — DISSOLVED O_2 g/m³

TOTAL METALS

METAL	g/m³
Fe	
Mn	

Cations/Anions: 1.02

Interval: to

KB: GRD:

Perfs to

REMARKS

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(403) 230-4123

WATER ANALYSIS

FILE NUMBER ▶ 89AS5986

LABORATORY NUMBER ▶ 5986-W7

CONTAINER IDENTITY

OPERATOR'S NAME
ENRON OIL CANADA LTD.

SAMPLE LOCATION | WELL NAME
ENRON ET AL WASKADA

ELEVATIONS KB | GRD

FIELD OR AREA | POOL OR ZONE | NAME OF SAMPLER | COMPANY

TEST TYPE NO | TEST RECOVERY

SAMPLING POINT | AMT AND TYPE OF CUSHION | MUD RESISTIVITY Ω/m
50% 6-10/50% 10-7 @ 22C

MULTIPLE RECOVERY TEST INTERVAL
FROM | TO

PUMPING | FLOWING | GAS LIFT | SWAB

WATER m^3/d | OIL m^3/d | GAS $10^3m^3/d$

SEPARATOR | TREATER | RESERVOIR | SAMPLED | RECEIVED

PERFORATIONS
FROM | TO

GAUGE PRESSURE kPa

TEMPERATURE °C

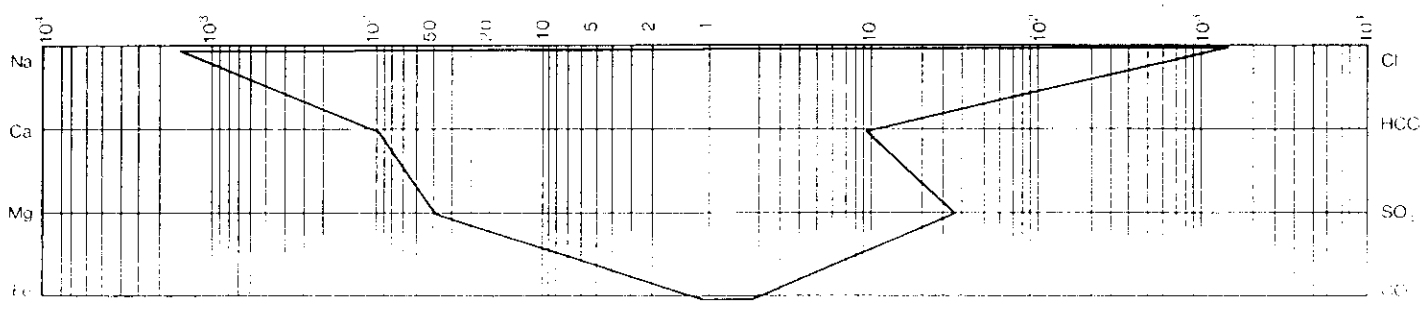
DATE SAMPLED Y M D	H M	DATE RECEIVED Y M D	DATE ANALYZED Y M D	ANALYST
N/A		08-NOV-89	22-NOV-89	GB/VB

SUMMARY DATA

TOTAL HARDNESS AS $CaCO_3$	6710	g/m³
TOTAL ALKALINITY	583	g/m³
SALINITY AS NaCl	84554	ppm
SATURATION INDEX	2.66	CaCO3 SCALING TENDENCY
STABILITY INDEX	2.86	CaCO3 SCALING TENDENCY
CORROSION TENDENCY	128	

Scaling calculations done at 22 C

LOGARITHMIC PATTERN MEQ PER LITRE



REMARKS

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WATER ANALYSIS
DETAILED REPORT

OPERATOR'S NAME	ENRON OIL CANADA LTD.
WELL NAME	ENRON ET AL WASKADA
LOCATION	
SAMPLING POINT	50% 6-10/50% 10-7 @ 22C

FILE NUMBER ▶	89AS5986
LABORATORY NUMBER ▶	5986-W7

CATIONS

ION	g/m³	MASS FRACTION	MEQ/L
Na	32500	0.37	1414
K	350	0.00	9
Ca	1840	0.02	91.8
Mg	501	0.01	41.2
Ba	< 0.05		
Sr	45.9	0.00	1.05
Fe	< 0.05		
Mn			
Al			
Si			
B	34.1		
U			
Th			

ANIONS

ION	g/m³	MASS FRACTION	MEQ/L
Cl	51400	0.58	1450
Br			
I	7.5	0.00	0.06
F			
HCO_3	588	0.01	9.6
CO_3	60.5	0.00	2.02
OH	0.00	0.00	0.00
SO_4	1610	0.02	33.5
H_2S			
PO_4			

TOTAL SOLIDS (g/m³)

EVAPORATED AT 110°C | EVAPORATED AT 180°C

AT IGNITION | CALCULATED

88937

SPECIFIC GRAVITY at 15°C | REFRACTIVE INDEX (RI) at 25°C

1.355

OBSERVED pH at 25°C

8.20

RESISTIVITY (RW) Ω·m at 23°C

0.093

REDOX POTENTIAL (Eh) | DISSOLVED O₂ g/m³

TOTAL METALS

METAL	g/m³
Fe	
Mn	

Cations/Anions: 1.04

Interval: to

KB: GRD:

Perfs to

REMARKS

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WATER ANALYSIS

LAB NUMBER ▶ 89AS5986

CONTAINER IDENTITY

LABORATORY NO. ▶ 5986-W8

OPERATOR'S NAME
ENRON OIL CANADA LTD.

SAMPLE LOCATION | WELL NAME
ENRON ET AL WASKADA

ELEVATIONS KB GRD

FIELD OR AREA | POOL OR ZONE | NAME OF SAMPLER | COMPANY

TEST TYPE NO | TEST RECOVERY

SAMPLING POINT | AMT AND TYPE OF CUSHION | MUD RESISTIVITY Ω/m
30% 6-10/70% 10-7 @ 22C

MULTIPLE RECOVERY TEST INTERVAL FROM

PUMPING | FLOWING | GAS LIFT | SWAB

TO

WATER m^3/d | OIL m^3/d | GAS $10^3m^3/d$

SEPARATOR | TREATER | RESERVOIR | SAMPLED | RECEIVED

PERFORATIONS FROM

GAUGE PRESSURE K/Pa

TEMPERATURE (°C)

TO

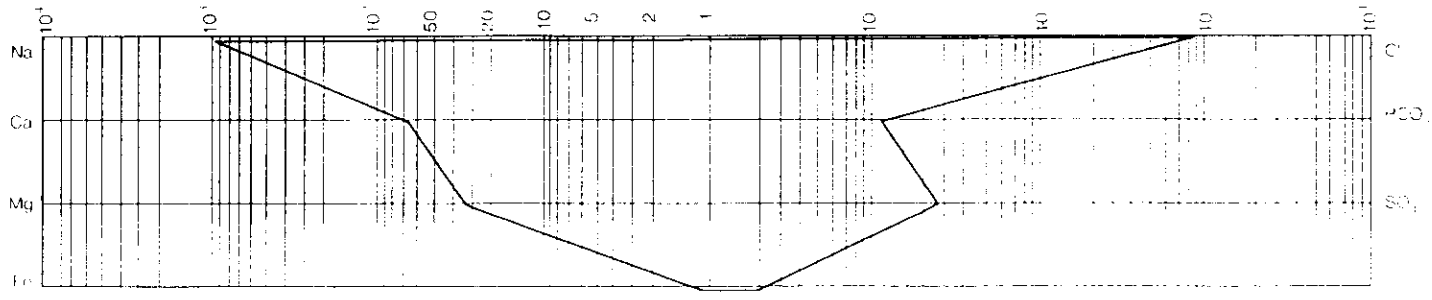
DATE SAMPLED Y M D	R.M	DATE RECEIVED Y M D	DATE ANALYZED Y M D	ANALYST
N/A		08-NOV-89	22-NOV-89	GB/VB

SUMMARY DATA

TOTAL HARDNESS AS $CaCO_3$	4420	g/m³
TOTAL ALKALINITY	707	g/m³
SALINITY AS NaCl	50996	ppm
SATURATION INDEX	2.49	CaCO3 SCALING TENDENCY
STABILITY INDEX	3.13	CaCO3 SCALING TENDENCY
CORROSION TENDENCY	63.8	

Scaling calculations done at 22 C

LOGARITHMIC PATTERN MEQ PER LITRE



REMARKS

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WATER ANALYSIS

FILE NUMBER ▶ 89AS5986

LABORATORY NUMBER ▶ 5986-W8

CONTAINER IDENTITY

OPERATOR'S NAME
ENRON OIL CANADA LTD.

SAMPLE LOCATION | WELL NAME
ENRON ET AL WASKADA

ELEVATIONS KB | GRD

FIELD OR AREA | POOL OR ZONE | NAME OF SAMPLER | COMPANY

TEST TYPE NO | TEST RECOVERY

SAMPLING POINT | AMT AND TYPE OF CUSHION | MUD RESISTIVITY Ω/m
30% 6-10/70% 10-7 @ 22C

MULTIPLE RECOVERY TEST INTERVAL
FROM | TO

PUMPING | FLOWING | GAS LIFT | SWAB

WATER m^3/d | OIL m^3/d | GAS $10^3m^3/d$

SEPARATOR | TREATER | RESERVOIR | SAMPLED | RECEIVED

PERFORATIONS
FROM | TO

GAUGE PRESSURE K/Pa

TEMPERATURE (°C)

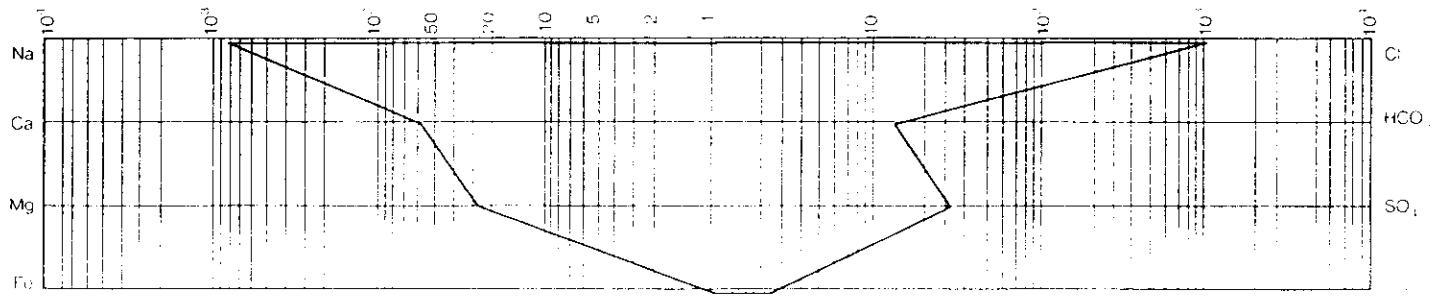
DATE SAMPLED Y M D	H M	DATE RECEIVED Y M D	DATE ANALYZED Y M D	ANALYST
N/A		08-NOV-89	22-NOV-89	GB/VB

SUMMARY DATA

TOTAL HARDNESS AS CaCO	4420	g/m
TOTAL ALKALINITY	707	g/m³
SALINITY AS NaCl	51654	ppm
SATURATION INDEX	2.49	CaCO3 SCALING TENDENCY
STABILITY INDEX	3.13	CaCO3 SCALING TENDENCY
CORROSION TENDENCY	64.6	

Scaling calculations done at 22 C

LOGARITHMIC PATTERN MEQ PER LITRE



REMARKS

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WATER ANALYSIS
DETAILED REPORT

OPERATOR'S NAME	ENRON OIL CANADA LTD.
WELL NAME	ENRON ET AL WASKADA
LOCATION	
SAMPLING POINT	30% 6-10/70% 10-7 @ 22C

FILE NUMBER ▶ 89AS5986

LABORATORY NUMBER ▶ 5986-W8

CATIONS

ION	g/m³	MASS FRACTION	MEQ/L
Na	20000	0.36	870
K	208	0.00	5.3
Ca	1210	0.02	60.4
Mg	331	0.01	27.2
Ba	0.3	0.00	0.004
Sr	30.5	0.00	0.7
Fe	< 0.05		
Mn			
Al			
Si			
B	23.8		
U			
Th			

ANIONS

ION	g/m³	MASS FRACTION	MEQ/L
Cl	31400	0.58	886
Br			
I	4.1	0.00	0.03
F			
HCO_3	730	0.01	11.9
CO_3	65.2	0.00	2.17
OH	0.00	0.00	0.00
SO_4	1250	0.02	26
H_2S			
PO_4			

TOTAL SOLIDS (g/m³)

EVAPORATED AT 110°C

EVAPORATED AT 180°C

AT IGNITION

CALCULATED 55252

SPECIFIC GRAVITY at 15°C

REFRACTIVE INDEX (R) 1.350 at 25°C

OBSERVED pH 8.13 at 25°C

RESISTIVITY (RW) Ω·m 0.133 at 25°C

REDOX POTENTIAL (E)

DISSOLVED O_2 g/m³

TOTAL METALS

METAL	g/m³
Fe	
Mn	

Cations/Anions: 1.04

Interval: to

KB: GRD:

Perfs to

REMARKS

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APPENDIX B

DATA FROM THE DETAILED WATER COMPATIBILITY STUDY

TABLE 1
DETAILED WATER COMPATIBILITY STUDY
ENRON OIL CANADA LTD.
ENRON ET AL WASKADA

Date: November 23, 1989 File No: 89AS5986

W1: WELLHEAD SAMPLE 6-10 Temperature: 43°C
W2: SOURCE 10-7 Wavelength: 420 nm

% TRANSMITTANCE AS A FUNCTION OF TIME

	%W1	%W2	0 hr	2 hr	4 hr	8 hr	24 hr	72 hr
1	100	0	91.0	92.8	90.9	93.0	91.8	91.0
2	90	10	92.0	96.8	95.0	97.0	96.0	97.0
3	80	20	91.0	97.9	99.9	99.1	95.0	95.9
4	70	30	94.0	94.0	96.0	94.1	95.0	97.0
5	60	40	96.0	93.4	93.9	96.5	95.6	98.0
6	50	50	95.0	96.1	96.0	98.2	94.6	97.0
7	40	60	93.4	98.0	96.5	96.5	97.0	98.2
8	30	70	96.0	98.0	95.9	98.0	94.9	94.5
9	20	80	96.5	93.0	95.0	95.0	95.9	97.2
10	10	90	97.0	100	100	97.2	96.0	95.2
11	0	100	95.0	100	98.0	97.0	95.6	98.2

COMMENTS : Blank is deionized water. W1 - clear,colorless W2 - clear,colorless

0 hr: All mixtures are clear and colorless.

2 hr: Mixtures show no visual change.

4 hr: Mixtures show no visual change.

8 hr: Mixtures show no visual change.

24 hr: Mixtures show no visual change.

48 hr: Mixtures show no visual change.

72 hr: Mixtures show no visual change.

TABLE 2
DETAILED WATER COMPATIBILITY STUDY
ENRON OIL CANADA LTD.
ENRON ET AL WASKADA

Date: November 23, 1989 File No: 89AS5986

W1: WELLHEAD SAMPLE 6-10
W2: SOURCE 10-7

Temperature: 22°C
Wavelength: 420 nm

% TRANSMITTANCE AS A FUNCTION OF TIME

	%W1	%W2	0 hr	2 hr	4 hr	8 hr	48 hr	72 hr
1	100	0	94.1	94.5	91.0	92.3	95.7	96.2
2	90	10	94.0	95.0	92.9	93.0	95.0	96.9
3	80	20	93.0	96.1	94.0	95.0	96.0	97.6
4	70	30	96.0	96.8	95.9	96.2	95.9	94.9
5	60	40	90.5	92.8	93.0	93.2	96.9	97.9
6	50	50	95.0	96.9	94.1	95.1	95.1	97.1
7	40	60	99.0	97.2	97.8	98.0	98.0	97.0
8	30	70	96.0	96.6	97.0	96.8	96.5	97.2
9	20	80	95.5	98.0	97.8	96.2	97.2	95.0
10	10	90	98.2	98.5	98.6	98.2	97.8	98.0
11	0	100	98.0	97.0	97.0	97.3	97.8	97.8

COMMENTS : Blank is deionized water. W1 - clear,colorless W2 - clear,colorless

0 hr: All mixtures are clear and colorless.

2 hr: Mixtures show no visual change.

4 hr: Mixtures show no visual change.

8 hr: Mixtures show no visual change.

24 hr: Mixtures show no visual change.

48 hr: Mixtures show no visual change.

72 hr: Mixtures show no visual change.

GEOTECH

APPENDIX C

EXPERIMENTAL PROCEDURE

The detailed water compatibility study consists of:

- chemical analysis of each water
- visual water compatibility study between each water
- chemical analysis of three water mixtures from each water compatibility study
- theoretical calculations and evaluation of each compatibility study

The visual water compatibility study consists of preparing mixtures of waters varying from 100% of one water to 100% of the other in steps of 10%. The stability of these water mixtures is monitored as a function of time by determining the transmittance of the sample. If a precipitate forms, the solution transmittance will decrease due to light scattering from the precipitate particles. With this procedure, a light precipitate, with small particles, will result in a greater decrease than a heavy precipitate with large particles. Thus, the transmittance data must be coupled with visual observations regarding the character of any precipitate which forms. The general interpretation is that if the transmittance remains above 93%, there is no visible precipitate formation and the solutions can be taken as being compatible, for transmittance between 89% and 93% the solution is slightly cloudy, for transmittance between 82% and 89% the solution is cloudy with some precipitate formation, for a transmittance between 76% and 82% the solution is turbid with distinct precipitate and for a transmittance less than 76% the solution is strongly turbid with settled precipitate. As the transmittance decreases from 93% the waters are becoming progressively more incompatible and below 82% the waters should be taken as being incompatible.

Using information obtained from the chemical analyses, the calcium carbonate Saturation Index and Stability Index along with the Corrosion Tendency are calculated. A value of the Saturation Index less than zero indicates potential corrosion while a value greater than zero indicates a scaling tendency. A value of the Stability Index less than 6.5 indicates a scaling tendency while a value greater than 6.5 indicates potential corrosion. A value of the Corrosion Tendency greater than 0.1 indicates potential corrosion if there is dissolved oxygen present in the water.

In addition, the calcium sulphate scaling tendency is calculated after the method of Skillman and Davis.