Arbeitsbericht NAB 08-15

Oftringen Borehole - Hydraulic Packer Testing

Appendices

October 2008

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B. Yeatman (Solexperts AG)
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**Nationale Genossenschaft
für die Lagerung
radioaktiver Abfälle**

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KEYWORDS
EP-05, EWS, Oftringen, NOK, USM, Effingen-Member, Hydraulic Testing, Transmissivity, Conductivity, Head

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Keywords:

Oftringen, Hydraulic testing, Hydrotesting, Effinger Member, EWS

Appendices

Appendix A

Quick Look Report
Interval Oftr-i1

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QUICK LOOK REPORT OFTRINGEN - TEST OFTR-i1

TEST START (Date/Time)	:	20.10.2007 / 00:01	**TEST END (Date/Time)**	:	21.10.2007 / 04:20

DOUBLE PACKER TEST

Test Interval Information	:		top test interval	:	650.00 m bgl
borehole depth [1), 4)]	:	719.0 m	bottom of test interval	:	700.04 m bgl
borehole radius	:	0.073 m	total interval length	:	50.04 m
tubing radius	:	20.0 mm	midpoint of interval	:	675.02 m bgl
			P2-depth (z_2)	:	646.86 m bgl
interval volume, nominal [5)]	:	0.838 m^3	theoretical Cs-value	:	1.68E-09 m^3/Pa
slim tubing radius		4.75 mm	theoretical C-value (slim tube)	:	7.23E-09 m^3/Pa
WL prior to packer inflation [2)]	:	20.30 m bgl	P2 signal prior to packer inflation	:	6226.74 kPa
WL in annulus at test end [2)]	:	18.60 m bgl	P2 offset assuming ρ_{avg} = 997 kg/m3		98.63 kPa

1) all depths are not corrected for borehole deviation from vertical

2) WL = water level

3) assumes a total borehole system compressibility of 2E-09 Pa^{-1}

4) all depth measurements refer to ground level

5) cylindrical volume of isolated borehole section

Note all pressures cited in this report are absolute

Preliminariy information			
longitude of borehole	:	240887	
latitude of borehole	:	638346	
elevation of ground level (GL)	:	433.0 m asl	(reference point for all measurements)
assumed fresh water head	:	433.0 m asl	(assumed hydrostatic)
end of drilling	:	17.10.07 09:55	(Geotec)
porosity	:	3%	(assumed)
mud density [6)]	:	1032 kg/m^3	(Geotec end of drilling, 17.10.07)
borehole water density	:	997 kg/m^3	(Geotec after circulation of fresh water, 17.10.07; estimated using P2)
formation water density [7)]		1001.2 kg/m^3	(PVT correlation calculated by Saphir)
specific storativity [8)]	:	2.19E-06 m^{-1}	
formation water viscosity [7)]	:	6.74E-04 Pa s	(PVT correlation calculated by Saphir)
fluid compressibility [7)]	:	4.32E-10 1/Pa	(PVT correlation calculated by Saphir)
total compressibility [8)]	:	7.43E-09 1/Pa	(calculated assuming cf= 7.00E-09 1/Pa)

6) Taken from daily report No. 53

7) Assumed, using salinity 10'000 ppm, T = 45 °C, P = 6750 kPa

8) Calculated based on assumed porosity and compressibility values

Responible Test Engineers	
Onsite:	Fisch, H.R.; Reinhardt, S.
Test analysis and reporting:	Fisch, H.R., Senger, R.

Test Summary		
Test objectives	:	transmissivity, static formation pressure, flow model
borehole history	:	drilling through midpoint of interval: 15.10.2007 18:30:00, 101.525 h duration until start of test
geology	:	limestone - marl interbedded strata, and oolitic limestones
geophysics	:	Caliper log, salinity log, temperature log, sonic log
test phases	:	COM, PSR, PW, SW, SWS, PI, HI, HIS

QLR results	**Test zone 650.00 - 700.04 mbgl**	**T [m2/s]**	**K [m/s]**	**Formation Flow model**	**Freshwater Head [m asl]**
Analytical interpretation		6.0E-10	1.2E-11	radial flow	-
Numerical simulation		2.8E-10	5.5E-12	homogeneous	467

Note:
A complete list of results is provided in the summary tables

Mönchaltorf, 01.03.08 / 01.08.08, Revision 1a prepared by: SOLEXPERTS INTERA

Summary of Test Data

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Test Phase		INF	COM	PSR 2)	PW 1)
duration	[h]	1.70	0.42	3.08	3.89
T2 (i/f)	[°C]	45.05 / 45.15	45.15 / 45.12	45.12 / 45.20	45.20 / 45.27
P1 (i/f)	[kPa]	6240 / 6420	6420 / 6391	6393 / 6329	6329 / 6319
P2 (i/f)	[kPa]	6226.1/ 6229.9	6229.9 / 6232.2	6233.8 / 6318.4	5932.9 / 6316.1
P3 (i/f)	[kPa]	6229 / 6232	6232 / 6232	6232 / 6232	6232 / 6235
P4 (i/f)	[kPa]				
Measured C	[m^3/Pa]				2.3E-09
q	[l/min]				
Q	[l]				
inner boundaries		no analysis	no analysis	wellb. storage	wellb. storage
flow geometry				hom.	hom.
outer boundaries				inf.lat.ext.	inf.lat.ext.
T	[m^2/s]			1.86E-10 A)	3.00E-10 D)
K	[m/s]			3.71E-12 A)	6.00E-12 D)
k	[m^2]			2.55E-19	4.12E-19
S_S	[1/m]			1.00E-04 A)	
S	[-]			5.00E-03 A)	
Pi, P_f if matched	[kPa]			6893 A)	6318.4 B)
Head	[m asl]			478.7 C)	420.2 C)
Derived flow rate	[l/min]				
s (skin factor)	[-]				
S_{SS} (skin zone)	[1/m]				
t_S (skin zone)	[m]				
K_S (skin zone)	[m/s]				
figures				1,12	1,4
temperature effects				no	no
borehole history				yes	no
anomalies				no	no
bypass PA2				no	no
bypass PA1				no	no

comments

1) analytical with no superposition
2) numerical simulation with detailed borehole history effects

notes:
- i = initial, f = final
- T, K values in bold most representative of the undisturbed formation

A) matched parameter
B) input parameter
C) calculation assumes: freshwater density 1000 kg/m^3, g = 9.81 m^2/s, P_{atm} and z_2 as stated on front page
D) early-middle time fit
E) extrapolated head

Summary of Test Data

Test Phase		PW 2)		SW 1)		SW 2)		SWS 2)	
duration	[h]	3.89		2.33		2.33		7.79	
T2 (i/f)	[°C]	45.20 / 45.27		45.27 / 45.28		45.27 / 45.28		45.28 / 45.40	
P1 (i/f)	[kPa]	6329 / 6319		6319 / 6319		6319 / 6319		6319 / 6322	
P2 (i/f)	[kPa]	5932.9 / 6316.1		5700.6 / 6001.1		5700.6 / 6001.1		6002.4 / 6269.8	
P3 (i/f)	[kPa]	6232 / 6235		6235 / 6235		6235 / 6235		6235 / 6241	
P4 (i/f)	[kPa]								
Measured C	[m^3/Pa]	2.30E-09							
q	[l/min]								
Q	[l]								
inner boundaries		wellb. storage		wellb. storage		wellb. storage		wellb. storage	
flow geometry		hom.		hom.		hom.		hom.	
outer boundaries		inf.lat.ext.		inf.lat.ext.		inf.lat.ext.		inf.lat.ext.	
T	[m^2/s]	3.20E-10	A)	4.10E-10	D)	3.92E-10	A)	1.84E-10	A)
K	[m/s]	6.40E-12	A)	8.10E-12	D)	7.83E-12	A)	3.68E-12	A)
k	[m^2]	4.39E-19				5.37E-19		2.53E-19	
S_S	[1/m]	1.00E-04	A)			1.00E-04	A)	1.00E-04	A)
S	[-]	5.00E-03	A)			5.00E-03	A)	5.00E-03	A)
Pi, P_f if matched	[kPa]	6997	A)	6316	B)	6998	A)	6761	A)
Head	[m asl]	489.3	C)	419.9	C)	489.4	C)	465.3	C)
Derived flow rate	[l/min]								
s (skin factor)	[-]								
S_{SS} (skin zone)	[1/m]								
t_S (skin zone)	[m]								
K_S (skin zone)	[m/s]								
figures		1,13		1,6		1,14		1,15,16	
temperature effects		no		no		no		no	
borehole history		yes		no		yes		yes	
anomalies		no		no		no		no	
bypass PA2		no		no		no		no	
bypass PA1		no		no		no		no	

comments

notes:
- i = initial, f = final
- T, K values in bold most representable of the undisturbed formation

1) analytical with no superposition
2) numerical simulation with detailed borehole history effects

A) matched parameter
B) input parameter
C) calculation assumes: freshwater density 1000 kg/m^3, g = 9.81 m^2/s, P_{atm} and z_2 as stated on front page
D) early-middle time fit
E) extrapolated head

Summary of Test Data

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Test Phase		PI 1)		PI 2)		HI 1)		HI 2)	
duration	[h]	3.31		3.31		1.78		1.78	
T2 (i/f)	[°C]	45.5 45.44		45.5 45.44		45.44 / 45.42		45.44 / 45.42	
P1 (i/f)	[kPa]	6322 / 6322		6322 / 6322		6336 / 6325		6336 / 6325	
P2 (i/f)	[kPa]	6572.5 / 6382.1		6572.5 /6382.1		6382.1 / 6874.9		6382.1 / 6874.9	
P3 (i/f)	[kPa]	6241 / 6244		6241 / 6244		6244 / 6242		6244 / 6242	
P4 (i/f)	[kPa]								
Measured C	[m^3/Pa]	2.74E-09		2.74E-09					
q	[l/min]					4.7 / 0.013		4.7 / 0.013	
Q	[l]					5.469		5.469	
inner boundaries		wellb. storage		wellb. storage		wellb. storage		wellb. storage	
flow geometry		hom.		hom.		hom.		hom.	
outer boundaries		inf.lat.ext.		inf.lat.ext.		inf.lat.ext.		inf.lat.ext.	
T	[m^2/s]	1.90E-09		1.16E-09	A)	6.00E-10		2.60E-09	A)
K	[m/s]	3.80E-11		2.31E-11	A)	1.20E-11		5.20E-11	A)
k	[m^2]	2.61E-18		1.59E-18		8.23E-19		3.57E-18	
S_S	[1/m]			4.87E-05	A)			5.67E-05	A)
S	[-]			2.44E-03	A)			2.84E-03	A)
Pi, P_f if matched	[kPa]	6002	B)	6676	A)	6382.1	B)	7000	A)
Head	[m asl]	387.9	C)	456.6	C)	426.7	C)	489.6	C)
Derived flow rate	[l/min]								
s (skin factor)	[-]								
S_{SS} (skin zone)	[1/m]								
t_S (skin zone)	[m]								
K_S (skin zone)	[m/s]								
figures		1,7		1,17		1,8,9		1,8,18	
temperature effects		no		no		no		no	
borehole history		no		yes		no		yes	
anomalies		no		no		no		no	
bypass PA2		no		no		no		no	
bypass PA1		no		no		no		no	

comments

notes:
- i = initial, f = final
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1) analytical with no superposition
2) numerical simulation with detailed borehole history effects

A) matched parameter
B) input parameter
C) calculation assumes: freshwater density 1000 kg/m^3, g = 9.81 m^2/s, P_{atm} and z_2 as stated on front page
D) early-middle time fit
E) extrapolated head

Summary of Test Data

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Test Phase		HIS 1)		HIS 2)		HIS 2)	
duration	[h]	3.39		3.39		3.39	
T2 (i/f)	[°C]	45.42 / 45.48		45.42 / 45.48		45.42 / 45.48	
P1 (i/f)	[kPa]	6325 / 6325		6325 / 6325		6325 / 6325	
P2 (i/f)	[kPa]	6874.9 6739.2		6874.9 6739.2		6874.9 6739.2	
P3 (i/f)	[kPa]	6242 / 6245		6242 / 6245		6242 / 6245	
P4 (i/f)	[kPa]						
Measured C	[m^3/Pa]						
q	[l/min]						
Q	[l]						
inner boundaries		wellb. storage		wellb. storage		wellb. storage & skin	
flow geometry		hom.		hom.		hom.	
outer boundaries		inf.lat.ext.		inf.lat.ext.		inf.lat.ext.	
T	[m^2/s]	2.20E-09		4.78E-10	A)	3.46E-11	A)
K	[m/s]	4.40E-11		9.56E-12	A)	6.91E-13	A)
k	[m^2]	3.02E-18		6.56E-19		4.74E-20	
S_S	[1/m]			7.43E-06	A)	3.75E-06	A)
S	[-]			3.72E-04	A)	1.88E-04	A)
Pi, P_f if matched	[kPa]	6647	E)	7000	A)	6436	A)
Head	[m asl]	453.7	C)	489.6	C)	432.2	C)
Derived flow rate	[l/min]						
s (skin factor)	[-]					-1.11	
S_{SS} (skin zone)	[1/m]					3.06E-06	A)
t_S (skin zone)	[m]					0.159	A)
K_S (skin zone)	[m/s]					1.84E-11	A)
figures		1,8,10,11		1,8,19,20		1,8,23	
temperature effects		no		no		no	
borehole history		no		yes		yes	
anomalies		no		no		no	
bypass PA2		no		no		no	
bypass PA1		no		no		no	

comments

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1) analytical with no superposition
2) numerical simulation with detailed borehole history effects

A) matched parameter
B) input parameter
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D) early-middle time fit
E) extrapolated head

Summary of Test Data

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Test Phase		Simulation entire Seq. 2)		Simulation entire Seq. 2)	
duration	[h]	27.71		27.71	
T2 (i/f)	[°C]	45.1 / 45.48		45.1 / 45.48	
P1 (i/f)	[kPa]				
P2 (i/f)	[kPa]				
P3 (i/f)	[kPa]				
P4 (i/f)	[kPa]				
Measured C	[m^3/Pa]				
q	[l/min]				
Q	[l]				
inner boundaries		wellb. storage		wellb. storage & skin	
flow geometry		hom.		hom.	
outer boundaries		inf.lat.ext.		inf.lat.ext.	
T	[m^2/s]	**2.77E-10**	A)	1.98E-10	A)
K	[m/s]	**5.53E-12**	A)	3.95E-12	A)
k	[m^2]	3.79E-19		2.71E-19	
S_S	[1/m]	1.00E-04	A)	3.37E-06	A)
S	[-]	5.00E-03		1.69E-04	A)
Pi, P_f if matched	[kPa]	**6783**	A)	7000	A)
Head	[m asl]	**467.5**	C)	489.6	C)
Derived flow rate	[l/min]				
s (skin factor)	[-]			-1.48	
S_{SS} (skin zone)	[1/m]			1.66E-06	A)
t_S (skin zone)	[m]			0.256	A)
K_S (skin zone)	[m/s]			2.46E-10	A)
figures		1,21		1,24	
temperature effects		no		no	
borehole history		yes		yes	
anomalies		no		no	
bypass PA2		no		no	
bypass PA1		no		no	

comments

notes:
- i = initial, f = final
- T, K values in bold most representative of the undisturbed formation

1) analytical with no superposition
2) numerical simulation with detailed borehole history effects

A) matched parameter
B) input parameter
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D) early-middle time fit
E) extrapolated head

Test overview

Test Oftr-i1 (650.0 -700.0 m bgl) was performed on 19.-21.10.2007 in the Oftringen NOK EWS-Borehole. The test interval consists of a sequence of carbonates and marls (Eisenoolith, Kalksteine, Mergel) from the jurassic Dogger formation, mainly the so-called Hauptrogenstein formation. The test objectives were to obtain reliable estimates of interval transmissivity, formation storativity, and fresh-water hydraulic head using an appropriate flow model. The test was performed with a straddle-packer configuration with an interval length of 50.04 m. Pressures and temperatures were measures in the test interval (P2, T2) and in the interval below the lower packer (P1, T1) and in the annulus above the upper packer (P3, T3). In addition, pressure was measured in the tubing above the upper packer (P4).

The pressure response of the entire test sequence in Oftr-i1 is shown in **Figure 1**. The pressure history derived from water table measurements (source: Colenco, Solexperts) and fluid density measurements (SJ Geotec) is presented in **Figure 2**.

Following packer inflation (INF) the test sequence started with a COM and PSR phase to dissipate temperature and borehole history effects. Temperature effects are considered negligible, because downhole temperatures (T1, T2, T3) indicated only a relatively small gradual trend of less than 0.5 degree over the entire test duration, with noise of the same magnitude. The pulse withdrawal test (PW) was performed to measure the wellbore compressibility early in the test and obtain an initial estimate of the formation properties. A slug withdrawal (SW) followed by a shut-in phase (SWS) was performed to get a more distinct formation response combined with a larger radius of investigation for the determination of the formation properties. After the SWS sequence a pulse injection test (PI) was performed to determine wellbore compressibility for comparison with that from the earlier PW phase. This was followed by a constant-head injection sequence (HI) and shut-in sequence (HIS).

Due to the influence of the adjacent high voltage current transformer facility (NOK), the pressure and temperature signals of the downhole triple probe were noisy during the hole testing sequence.

Analysis

For the QLR analysis, the analytical and numerical methods were used for a standard analysis, which will be the basis for a possible detailed analysis depending on the test objectives and test results.

Analytical Analysis

Type curve and straight-line fitting methods are applied. Effects of the borehole pressure history are not taken into account.

Pulse withdrawal test (PW)

The PW test was initiated at unsteady pressure conditions during PSR while P2 was showing an upward trend of 5.7E-3 kPa/s. At start of the pulse test the interval pressure was exposed to a differential pressure of -390 kPa. The shut-in valve was kept open during 19 seconds. After shut-in, a water level increase equal to 0.71 m was measured in the 1.9” test string (P4 measurement), indicating a released volume of 0.89 liters due to de-compression of the test zone. The wellbore storage constant C (ΔV / ΔP) equals to 2.3E-09 m^3/Pa.

The pulse response was analyzed using CBP type-curves. Three analysis versions are presented. The analysis presented in **Figure 4** is based on uncorrected data. The early-middle time fit using α-type-curve of value 1.0 provides a transmissivity estimate of 3.0E-10 m^2/s.

For the analysis shown in **Figure 5**, the P2 data were corrected assuming a pressure trend of +0.004 kPa/s. As the shape of the data curve and the model curve diverge, the results of both early and late time matches are provided. T-values of 3.3E-10 m^2/s (early time) and 1.4E-10 m^2/s were obtained based on a type-curve of value 10. Note that the CBP type-curve matching method is not sensitive for high α-values as α type-curves greater 1 are difficult to distinguish with respect to the slope steepness. High α values are associated with high aquifer storativity values (S). As storativity estimates from pulse test analyses are commonly known as unreliable, the S and S_S results are not presented.

Slug test withdrawal test (SW)

Prior to start of the SW test, the water table in the 1.9” tubing was lowered to 75.9 m bgl (change of tubing water level does not affect the interval pressure while the shut-in tool is closed). A slim tubing was installed in the 1.9” NU API rods before start of SW. The slim tubing system consists of a stiff high pressure hose of ID = 9.5 mm and a packer at its bottom (OD =28 mm). The packer is inflated using pressurized nitrogen, sealing the annulus between the 1.9” tubing and the slim tubing. The slim tubing was installed to a depth of 88 m bgl, covering the span of expected water table change of the slug test. A pressure transducer attached just above the packer and with connection to the tube inside enables recording of water level changes, redundantly to the P2 sensor. The small diameter of the slim tubing allows for faster slug recovery.

Prior to start of SW, the P2 pressure curve showed a rising trend with roughly 5E-04 kPa/s. The SW test was started 3.9 hours after start of PW. Compared to the type-curve (**Figure 6**), the recovery of the slug appears to be accelerated at early time (for $\Delta t < 100$ s) but delayed in the later course. The pressure data shown in **Figure 6** are not corrected for the general pressure trend. Removal of trend would result in a more accentuated flattening of the H/H_o curve at late time. The analytical SW analysis provides an indicative transmissivity value of 4.1E-10 m^2/s.

Shut-in phase SWS

The slug test was shut-in after 2.3 hours and further pressure recovery (SWS) was recorded for 7.8 hours. No analytical analysis was conducted on the SWS data. The precedent SW phase recovered by approximately 65 percent. Therefore, the SWS phase cannot be treated simply as pressure recovery from a constant head test. The SWS phase is only analyzed using the numerical borehole simulator nSights (see below).

Pulse Injection Test (PI)

A pulse injection test (PI) was performed in order to confirm the C-value obtained during PW. During preparation of PW, the water in the 1.9" test rods was filled up to a level 6 cm below top of tubing. The "injection head" was screwed on top of tubing and connected to a bottle of pressurized nitrogen with the pressure reduction valve set to 4 bars. In the 0.5 hrs prior start of PI, the P2 pressure curve showed a rising slope of 0.0044 kPa/s. When starting the PI, the pressure at the nitrogen source decreased to less than 2 bars resulting differential interval pressure ΔP of 320 kPa. A water level decrease Δh equal to 0.70 m was measured in the 1.9" test string (P4 measurement), indicating a volume change of 0.88 liters due to compression of the test zone. The wellbore storage constant C (ΔV / ΔP) equals to 2.7E-09 m^3/Pa, a value comparable to the result obtained from PW (C=2.3 E-09 m^3/Pa).

After shut-in (open valve period = 10 s), the PI test recovered 66 % during a period of 1.7 hrs and then slowly turned into a reversed trend. The fit is accordingly poor (**Figure 7**) and provides a T estimate of 1.9E-09 m^2/s. After correcting for the pressure trend observed at end of SWS, a pulse pressure recovery of 80% is obtained. A late time fit performed on the late time section of the corrected data suggests a T value of 5.7E-10 m^2/s.

Constant Head Injection Test (HI)

The HI test was started using a hydrant as fresh water source, maintaining a fairly constant interval pressure between 6860 kPa and 6878 kPa during the whole duration (**Figure 8**). The applied pressure corresponds to a differential pressure between 478 and 496 kPa. The measured flow rate dropped continuously from 5400 ml/min at early time to 13.4 ml/min at late time. The semilog-plot $\Delta P/q$ versus $\log(\Delta t)$ suggests that transitional conditions prevailed until end of HI. The measured $\Delta P/q$ data were analyzed in a semilog plot using the straight-line method after Jacob-Lohman (**Figure 9**). Note that the test times within the fit range correspond to dimensionless time values 1 - 2 orders of magnitudes less than the critical time necessary for the methods approximation to be considered valid. The results T= 6.0E-10 m^2/s and K = 1.2E-11 m/s therefore represent indicative values.

HIS shut-in phase

The pressure recovery subsequent to the constant head injection test was recorded during 3.4 hrs. The log-log plot (**Figure 10**) using Agarwal equivalent time shows wellbore storage in early and middle time data. The log-log plot suggests that an additional log-cycle of test duration would have been required to enable flow model interpretation. A transmissivity of 2.2E-9 m^2/s was derived from the Agarwal semilog-plot, assuming that the slope of the transitional data corresponds to the radial flow stabilization period. A static formation pressure of 6647 kPa, an equivalent freshwater head of 20.6 m agl, was extrapolated on the Agarwal plot.

Numeric Analysis using nSights

In a first step, the diagnostic plots or Ramey graphs for the individual sequences were analyzed and fitted individually accounting for borehole history and taking into account of transient effects associated with the preceding test sequences. In a second step, the entire test sequence was simulated and fitted based on the Cartesian pressures and flow rates (for HI).

The so-called history periods BH, INF1, INF2, COM were not fitted but incorporated as test events with defined pressure in the simulation process. Please note that the fits of the Ramey plots for the PI and SW sequences are the result of the inverse parameter estimation using nSights and represent a solution of a numeric process that includes the effects of potential transient effects of the preceding test phases and the borehole history.

For the Cartesian fit, the PSR, PW, SW, SWS, PI, HI, and HIS phases were chosen and no weighting for individual events was applied. Both pressure and flow rate were matched using the "composite fit" option. The so-called history periods BH, INF1, INF2, COM, PW_a and PI_a were not fitted but incorporated as test events with defined pressure in the simulation process. The transitional phases PW_a, PI_a denote very short events of less than 0.006 hrs duration and represent the transitional phases during initiation of the pulse tests (open shut-in valve phase at start of pulse tests). In addition, the first 53 seconds (0.0146 hrs) of the HI test was incorporated as history sequence with defined pressure.

The diagnostic plots of the individual test sequences did not indicate characteristic responses of a composite flow model, or any other more complex flow models. Consequently, a homogeneous model was assumed in this first evaluation for estimating formation parameters (i.e., K, S_s, and P_f). The analyses used the wellbore compressibility of 2.3E-9 m^3/Pa determined from PW for the early sequences, and 2.74E-9 m^3/Pa determined from PW for the later sequences. During the parameter optimization, the specific storativity was allowed to vary within a plausible range from Ss = 1E-7 Pa^{-1} to 1E-4 Pa^{-1}.

The log-log diagnostic plot of the PSR indicates dominantly well-bore storage effects (**Figure 12**) providing only preliminary estimates of formation parameters (K = 3.71E-12 m/s, S_s= 1.E-4 m^{-1}, P_f = 6893 kPa), which produced a good fit of the observed data (**Figure 12**). The diagnostic plot of the PW sequence in terms of the normalized pressures produced a relatively poor fit (**Figure 13**) which yielded similar parameters as those from the PSR, characterized by specific storage values at the upper range of acceptable values (K = 6.40E-12 m/s, S_s= 1.E-4 m^{-1}, P_f = 6997 kPa). Similar results were obtained for the SW sequence (K = 7.83E-12 m/s, S_s= 1.E-4 m^{-1}, P_f = 6998 kPa) (**Figure 14**). The SWS log-log diagnostic plot (**Figure 15**) indicates the transition from the wellbore storage dominated period to the infinite-acting-radial flow (IARF) period, which produced a good fit (K = 3.68E-12 m/s, S_s= 1.E-4 m^{-1}, P_f = 6761 kPa). The Horner plot of the SWS phase (**Figure 15**) shows a good match of measured data and simulated data from early to late time.

The PI sequence indicates a pressure increase at late time reversing the earlier recovery trend (**Figure 1**), which indicates transient effects associated with the pressure decline in the formation induced by the SW-SWS sequence. The fit of the normalized PI curve is relatively poor at early time (**Figure 17**), but does reproduce well the late-time response, yielding relatively high values for K = 2.3E-11 m/s, and lower values for S_s of 4.87E-5 m^{-1} and P_f of 6676 kPa, compared to the results of the preceding sequences.

For the HI sequence the simulated flow rates tend to be higher than the measured flow rates (**Figure 18**), whereby the fitted parameters indicated relatively high values for K of 5.20E-11 m/s and formation pressures at the upper range of acceptable value (P_f = 7000 kPa). The subsequent HIS sequence produced a very good fit of the log-log diagnostic response (**Figure 19**), but the estimated formation pressure is at the upper range value (P_f = 7000 kPa). The corresponding Horner plot would indicate an extrapolated formation pressure of about 6650 kPa (**Figure 20**).

The simulation of the entire test sequence produced reasonably good fits for the earlier sequences (PSR, PW, SW, SWS), but the fit becomes poor for PI and especially for HIS (**Figure 21**). The sensitivity coefficients of the formation parameters during the different sequences (**Figure 22**) indicate that the SW-SWS test has the greatest sensitivities to all three parameters. The analyses used the wellbore compressibility of 2.51E-09 m^3/Pa (average of 2.3E-9 m^3/Pa and 2.74E-9 m^3/Pa, determined from PW and PI, respectively).

The fitted parameters from the Cartesian plot (K = 5.53E-12 m/s, S_s= 1.0E-4 m^{-1}, P_f = 6783 kPa) are significantly lower than those from HIS, but are comparable to those from SWS. The simulated HIS response, showing a more rapid decline compared to the measured pressures, suggests that the simulated pressure responds to the transients associated with the lower pressures during SW-SWS. This transient response is indicated in the PI data, but apparently not in the HIS data. This suggests a possible change in the flow model from homogeneous to composite. A fit of the HIS diagnostic response using a composite model produces a very good fit (**Figure 23**), but yields much lower estimates for K_f = 6.91E-13 m/s, S_s = 3.75E-6 m^{-1}, P_f=6436 kPa. The fitted parameters for the skin (i.e., inner zone) are K_s =1.81E-11 m/s, S_{ss}=3.06E-6 m^{-1}, and t_s=0.16 m (radial thickness of skin radius).

The simulation of the entire sequence assuming a composite model is shown in **Figure 24**. The overall fit of the pressure response is generally better for the composite model compared to the homogeneous model. The best-fit parameters indicates a formation conductivity (K=3.95E-12 m/s) which is similar to that from the homogeneous model, but the estimated formation pressure is at the upper bound (P_f = 7000 kPa). Similar to the homogeneous model, the SW-SWS sequence indicates the highest parameter sensitivity (**Figure 25**). Although the overall fit is better for the composite model, this model is not supported in the diagnostic plots of the PW (**Figure 26**) and SW (not shown) phases.

Results and Discussion

The estimated formation parameters for the different sequences vary significantly, indicating a range between 3.7E-12 m/s (T=1.8E-10 m^2/s) and 5.2 E-11 m/s (T=2.6E-9 m^2/s), based on a homogeneous flow model. Similarly, the matched static formation pressures range between 6667 and 7000 kPa, whereas the latter value corresponds to the upper limit of the plausibility range. The large range in properties is probably due to the relatively poor fit of some of the sequences and the apparent different response character of the late sequences (i.e., HI-HIS) and the earlier sequences (i.e., SW-SWS). The SW-SWS sequence shows a good fit with greatest sensitivity coefficients for K, S_s and P_f. However, the estimates for S_s are at the upper range of expected values (i.e., S_s=1.E-4). Although the quality of the Cartesian fit is better for the composite model, resulting diagnostic plots for PW and SW indicate distinct features in the simulated response which are not observed in the data. Therefore, the homogeneous model is preferred over the composite (skin) model.

FIGURES

ABBREVIATIONS

NOMENCLATURE

DEFINITIONS

FIELD DOCUMENTATION

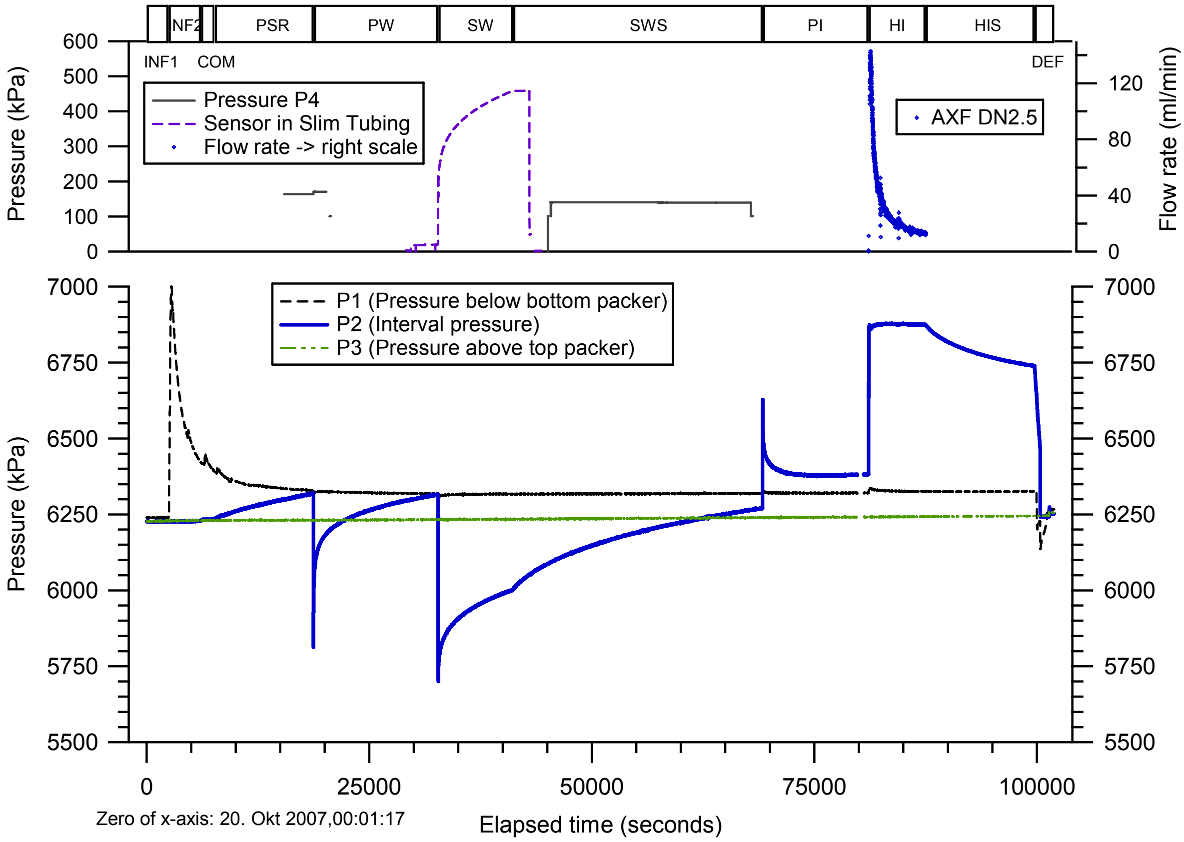


Figure 1: Oftr-i1: Overview plot

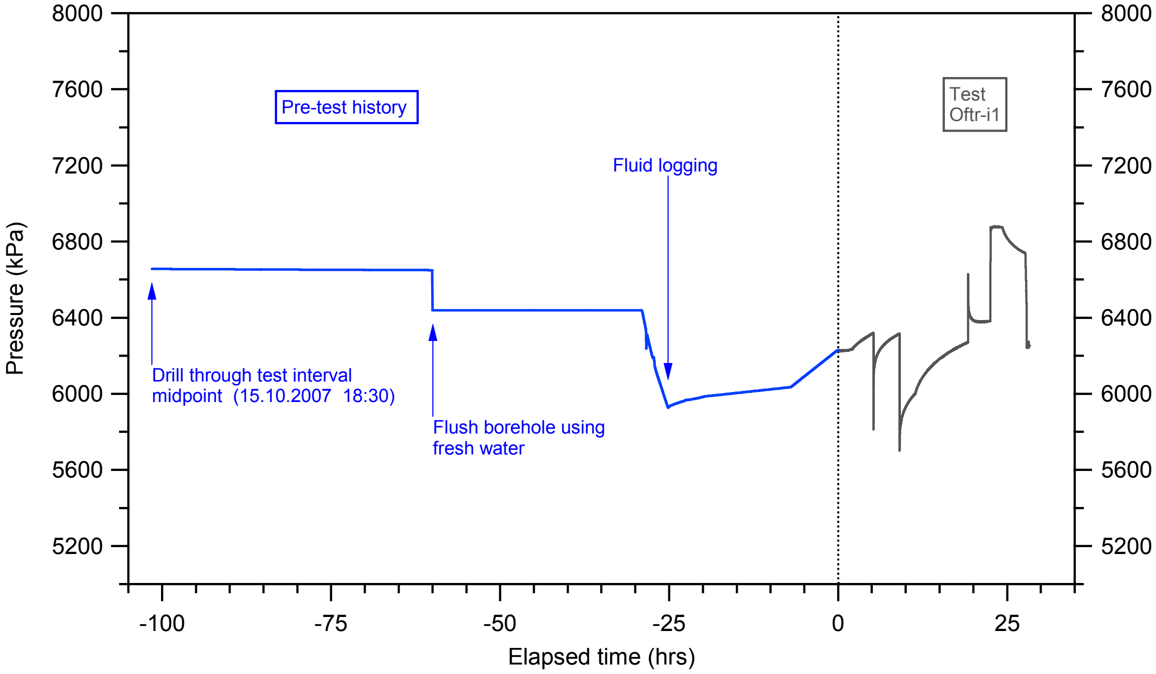


Figure 2: Oftr-i1: Borehole pressure history

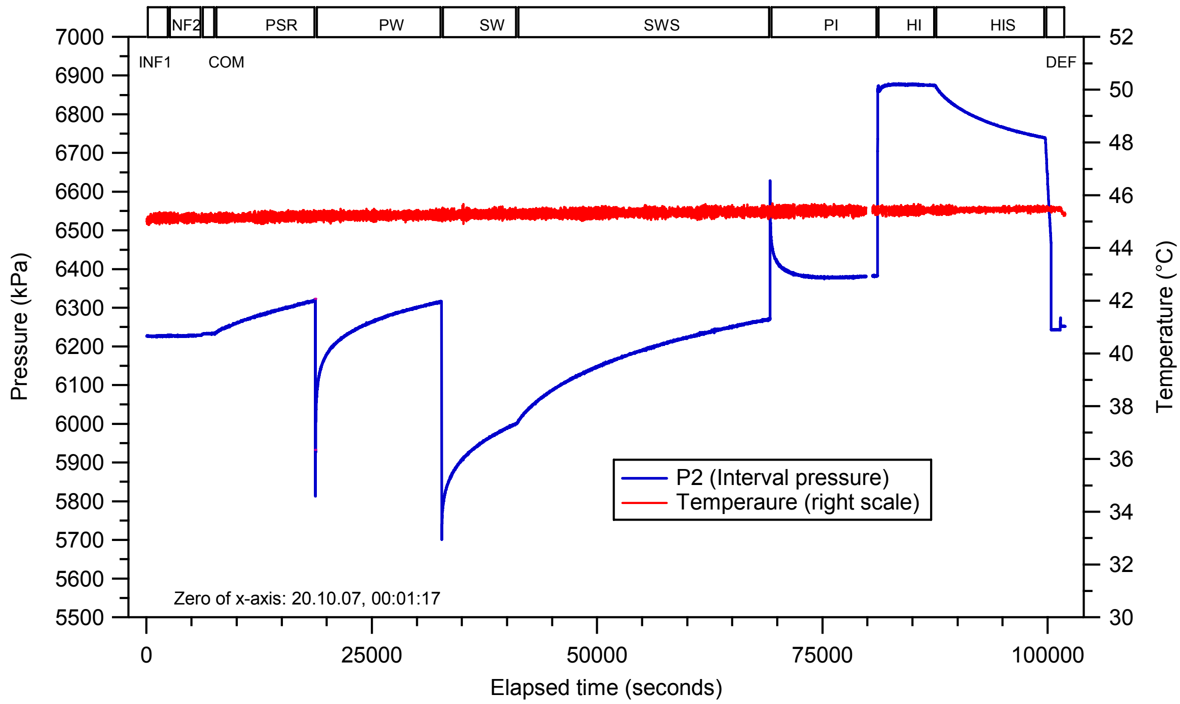


Figure 3: Oftr-i1: Measured downhole temperature (T2)

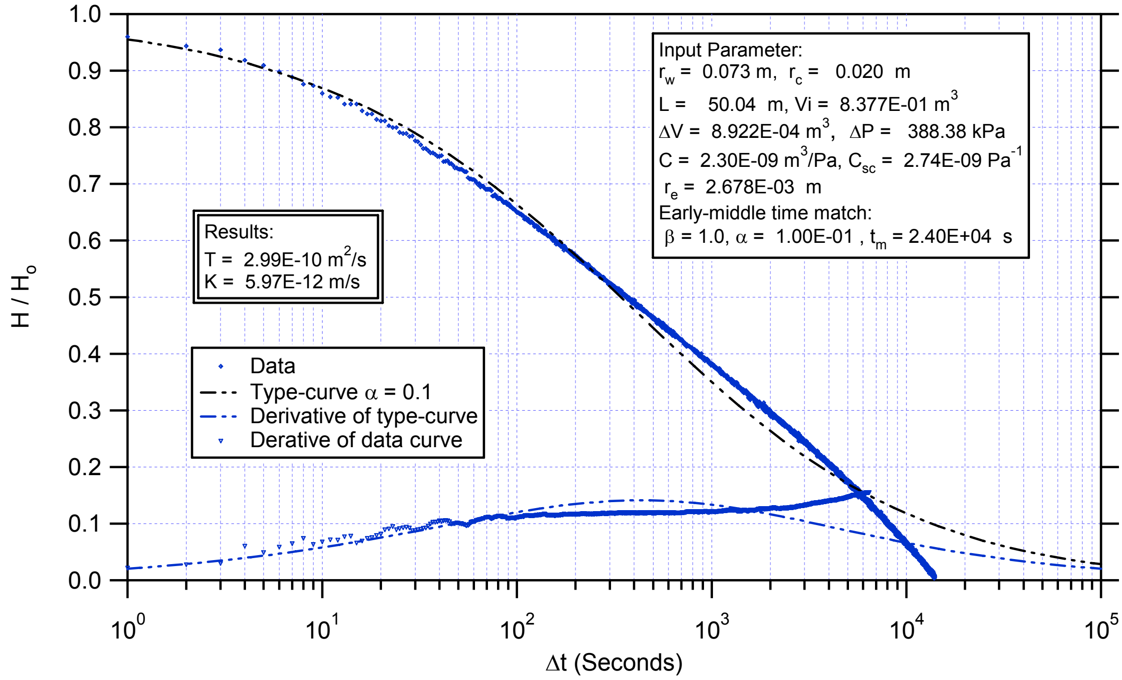


Figure 4: Oftr-i1: PW test analysis using CBP type-curves

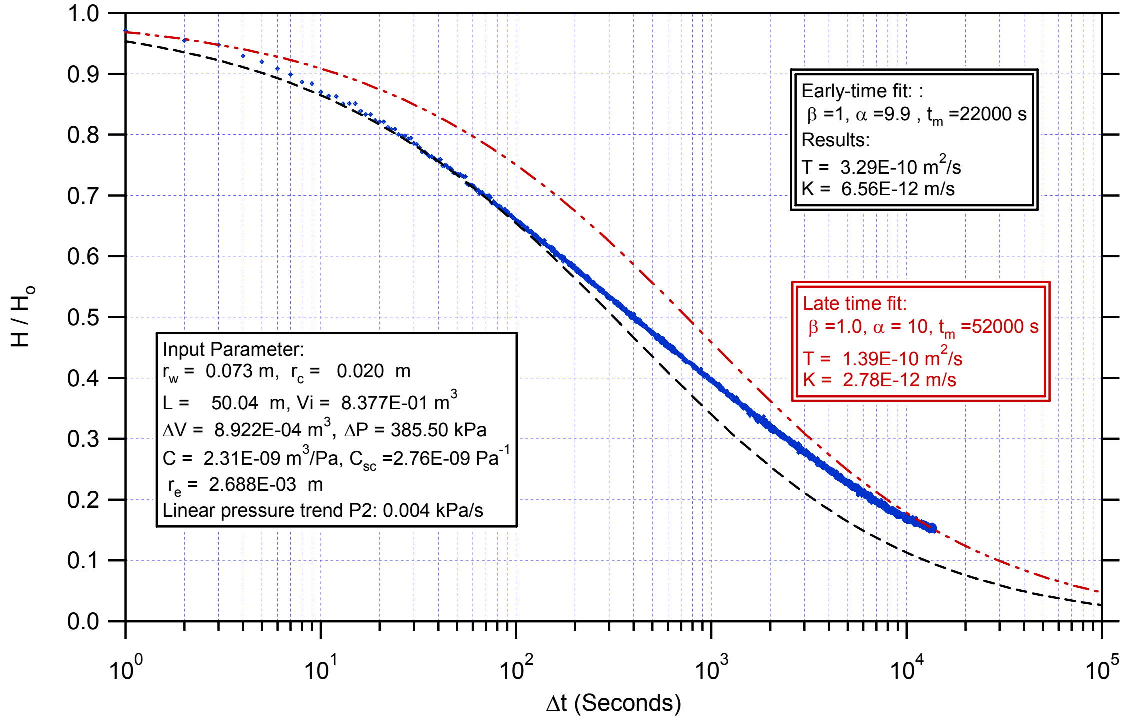


Figure 5: Oftr-i1: PW CBP analysis based on trend corrected data.

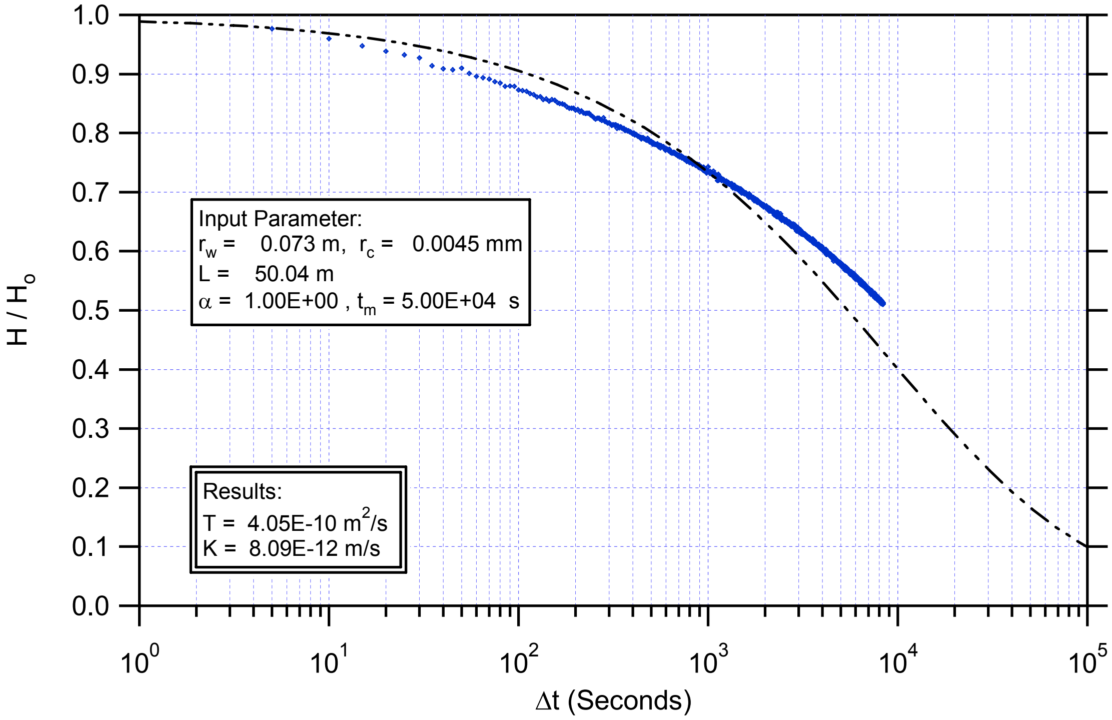


Figure 6: Oftr-i1: SW analysis using CBP type-curves

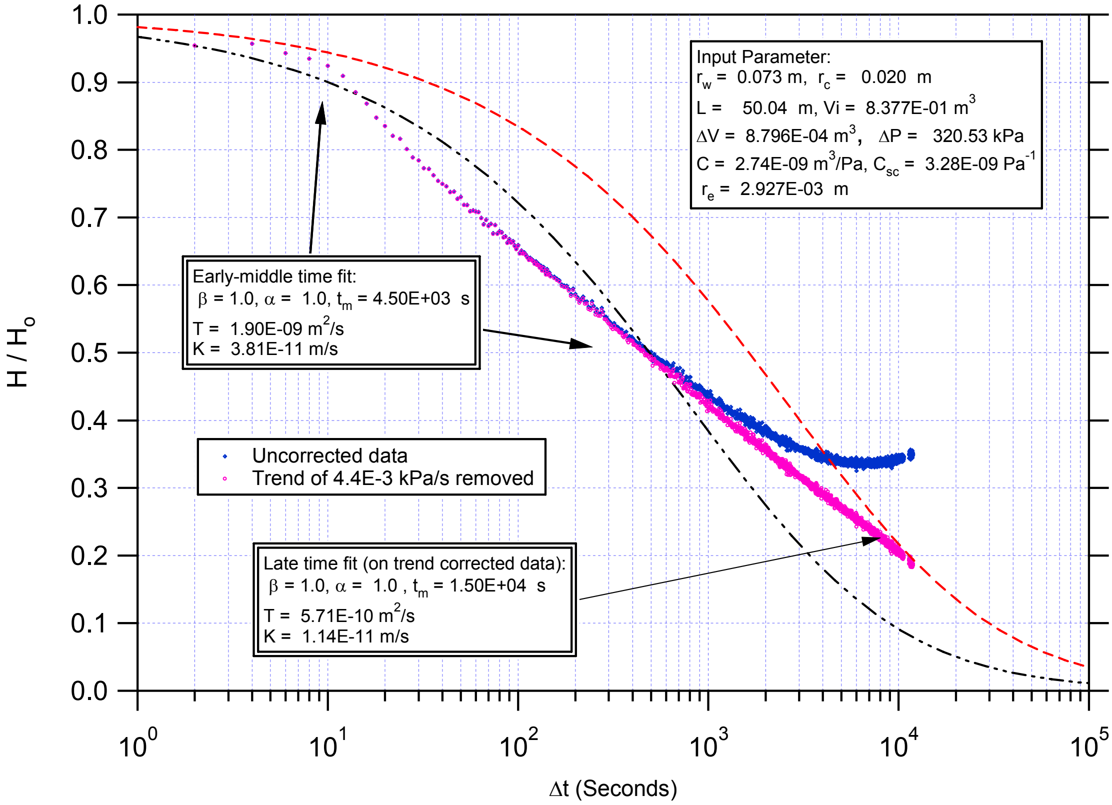


Figure 7: Oftr-i1: PI CBP analysis based on trend corrected data

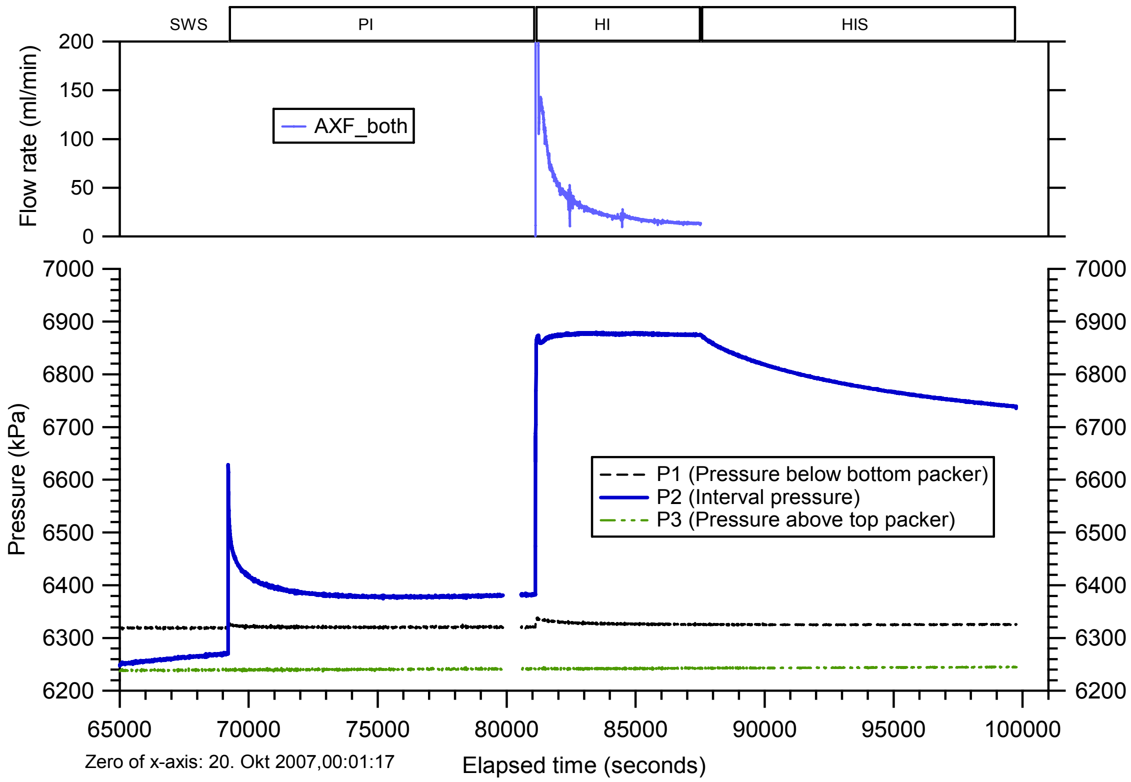


Figure 8: Oftr-i1: Detail of HI-HIS sequence

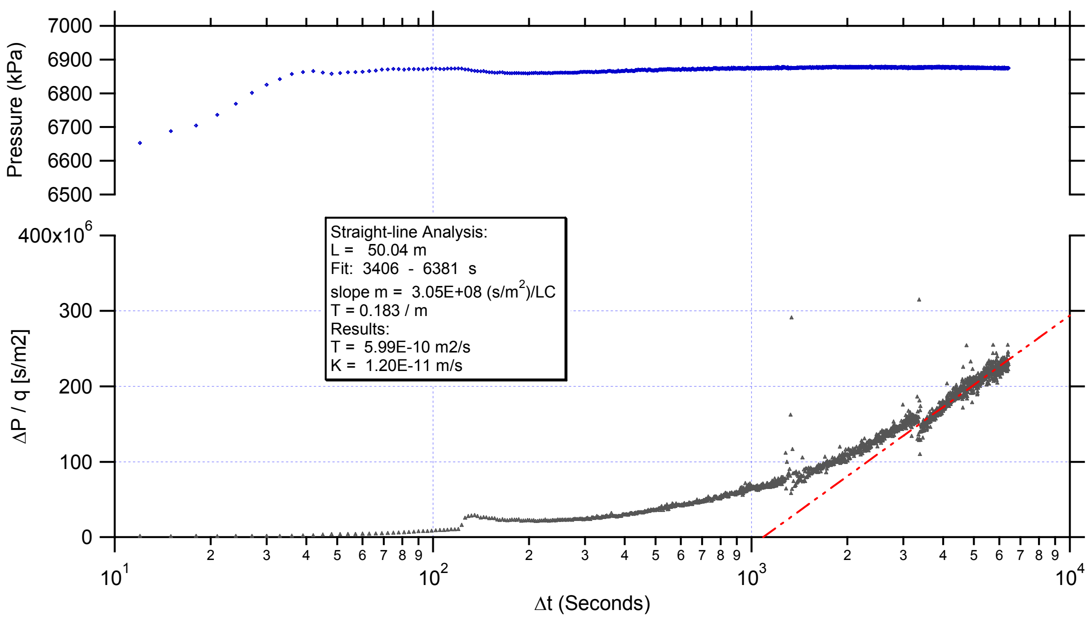


Figure 9: Oftr-i1: HI straight-line analysis

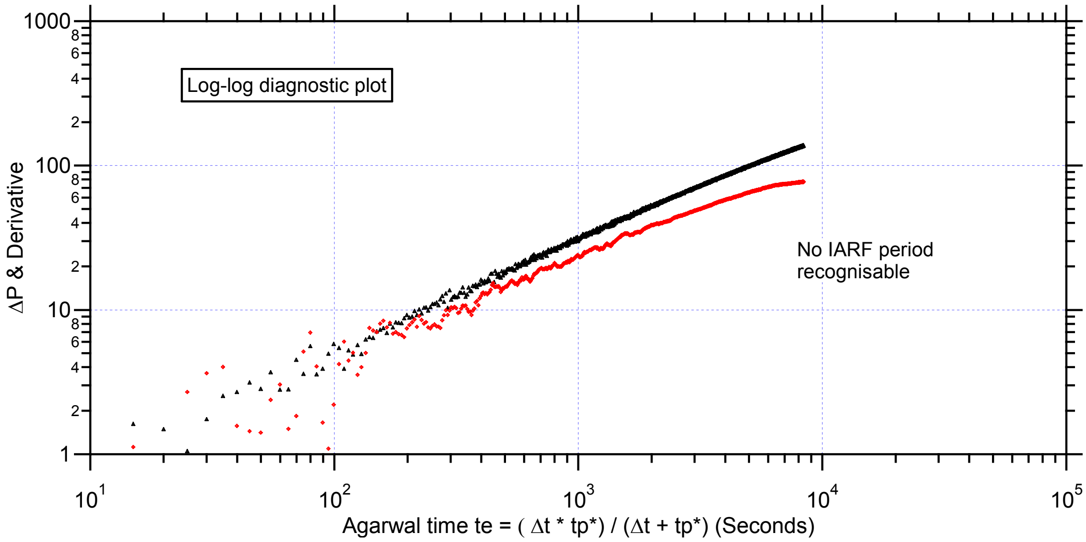


Figure 10: Oftr-i1: HIS diagnostic plot

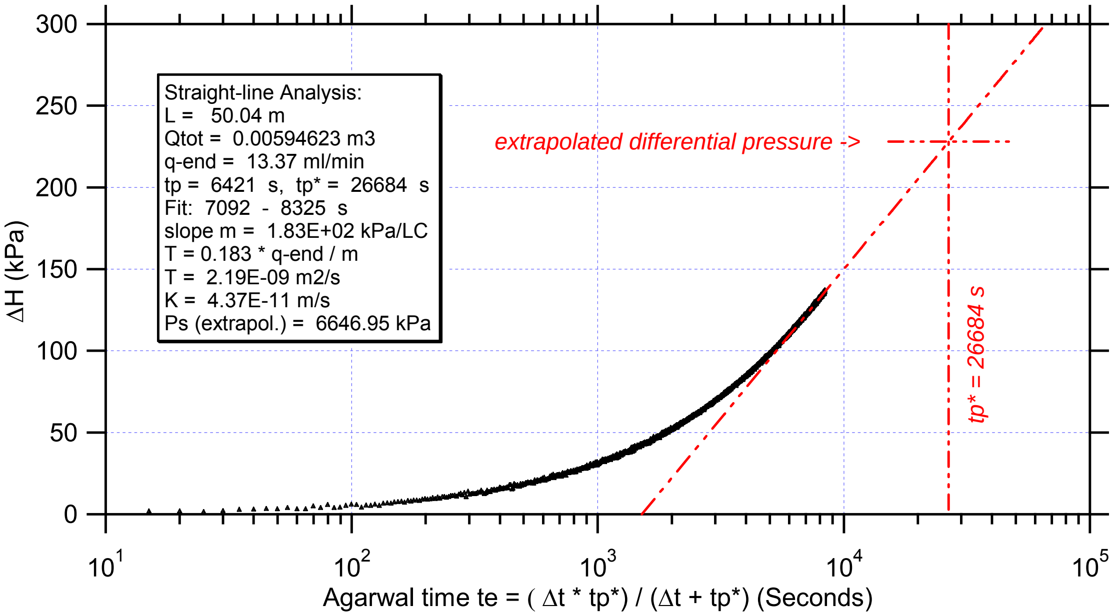
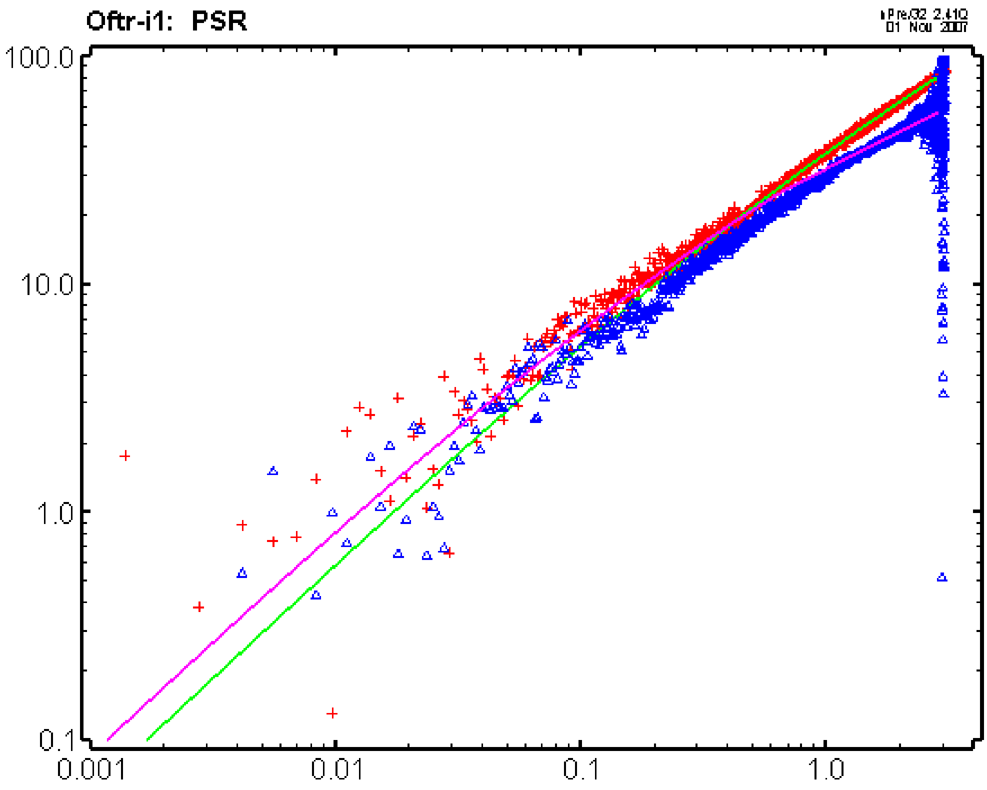


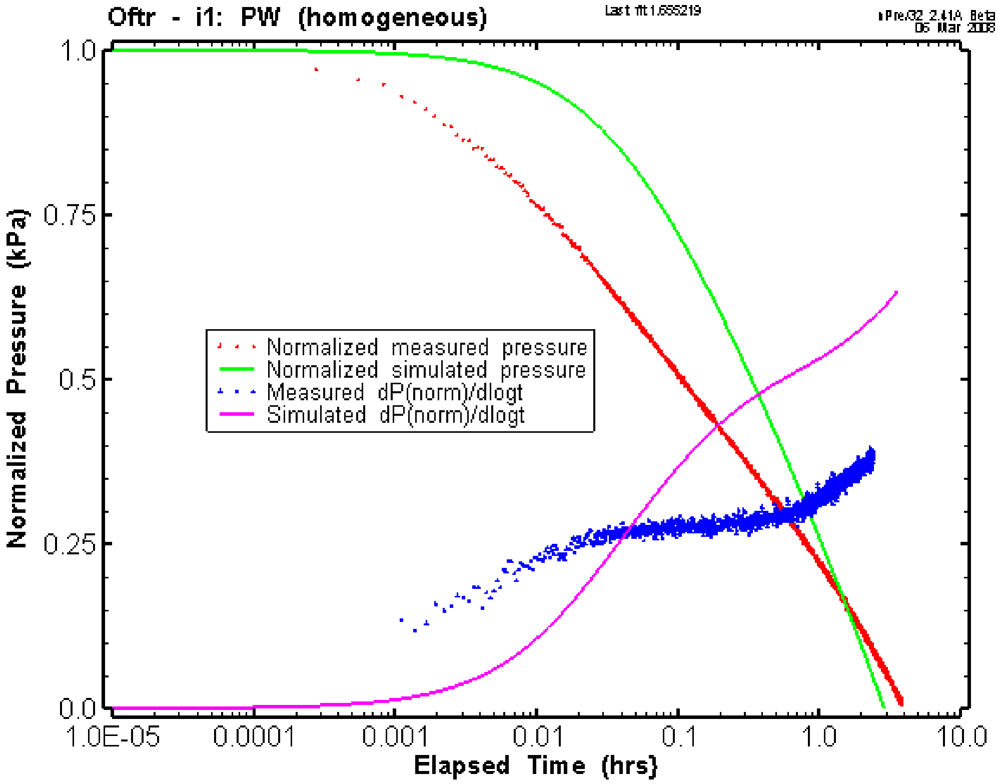
Figure 11: Oftr-i1: HIS Agarwal plot



Fit Statistics:

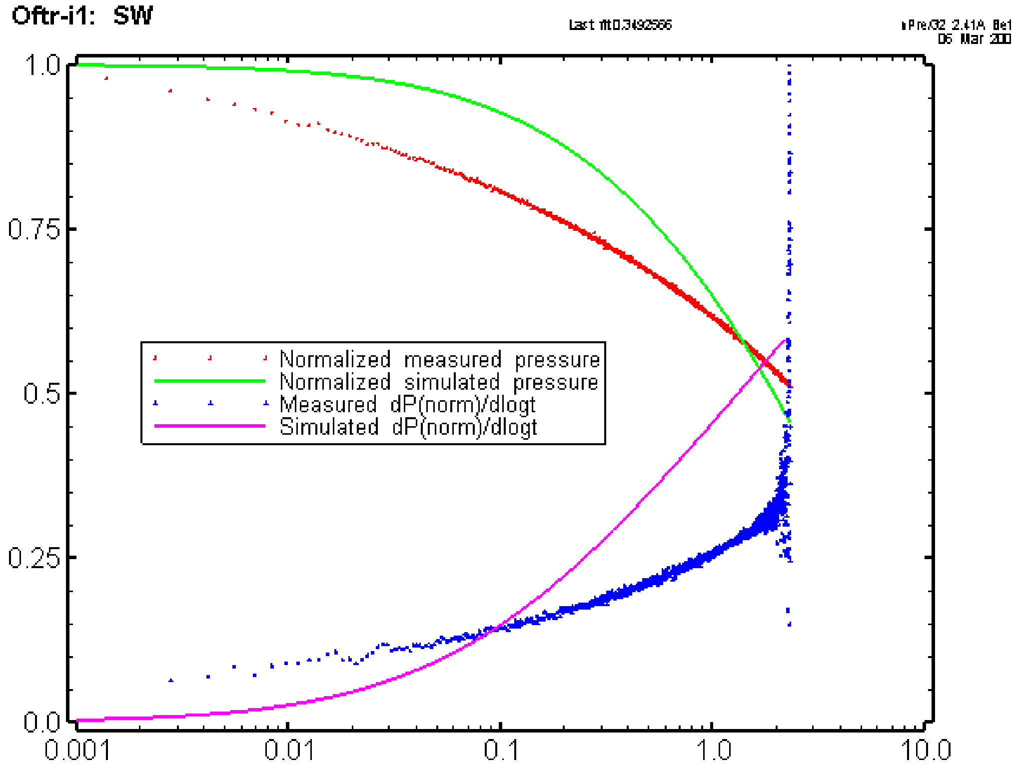
95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_f	[m/sec]	3.71E-12	2.45E-12	5.61E-12
P_f	[kPa]	6892.94	6766.01	7019.87
Ss_f	[1/m]	1.00E-04	4.60E-05	2.17E-04

Figure 12: Oftr-i1: PSR log-log diagnostic plot



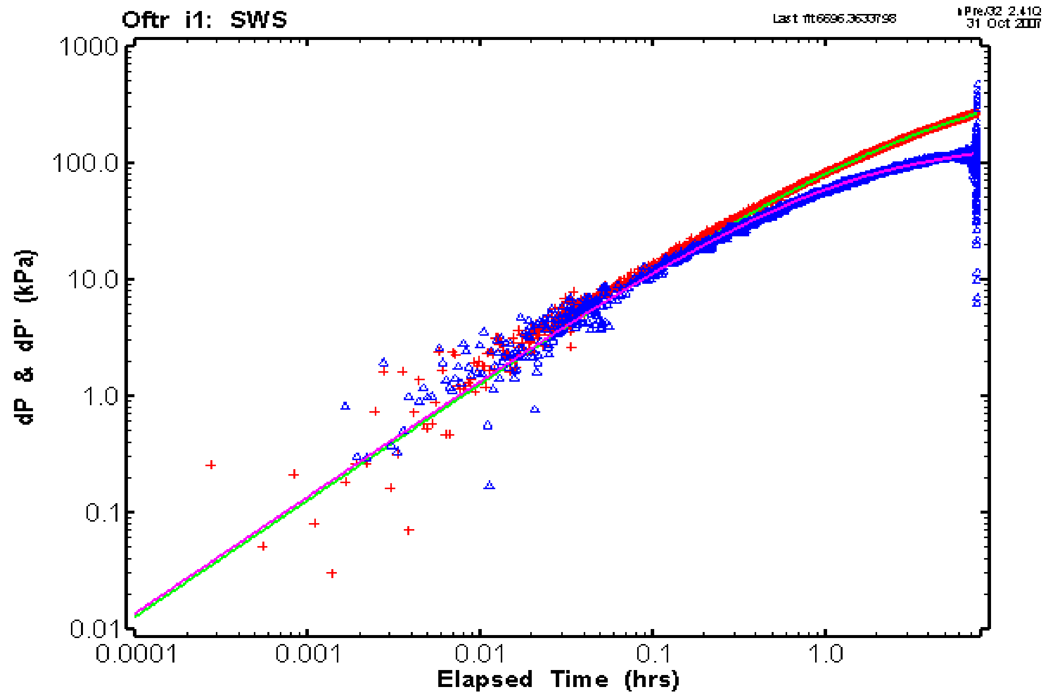
95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_f	[m/sec]	6.40E-12	5.01E-12	8.18E-12
P_f	[kPa]	6996.6	6901.6	7091.6
Ss_f	[1/m]	1.00E-04	8.21E-05	1.22E-04

Figure 13: Oftr-i1: PW normalized pressure (Ramey A)



95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_f	[m/sec]	7.83E-12	6.53E-14	9.37E-10
P_f	[kPa]	6997.56	???	???
Ss_f	[1/m]	1.00E-04	2.55E-05	3.92E-04

Figure 14: Oftr-i1: SW normalized pressure (Ramey A)



95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_f	[m/sec]	3.68E-12	3.51E-12	3.86E-12
P_f	[kPa]	6760.6	6746.5	6774.7
Ss_f	[1/m]	1.00E-04	9.12E-05	1.10E-04

Figure 15: Oftr-i1: SWS log-log diagnostic plot

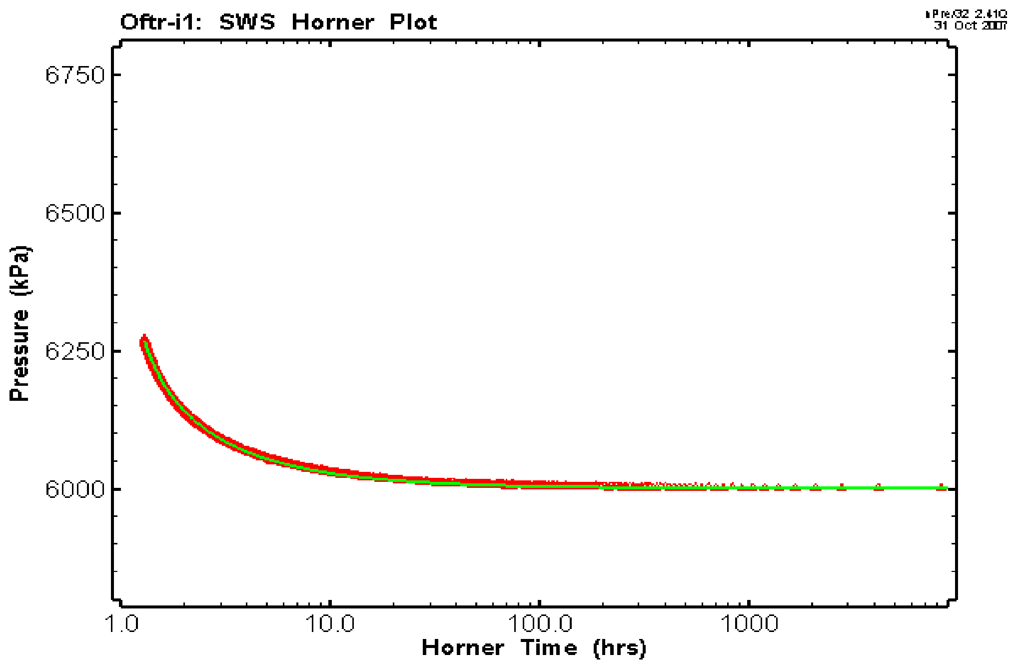
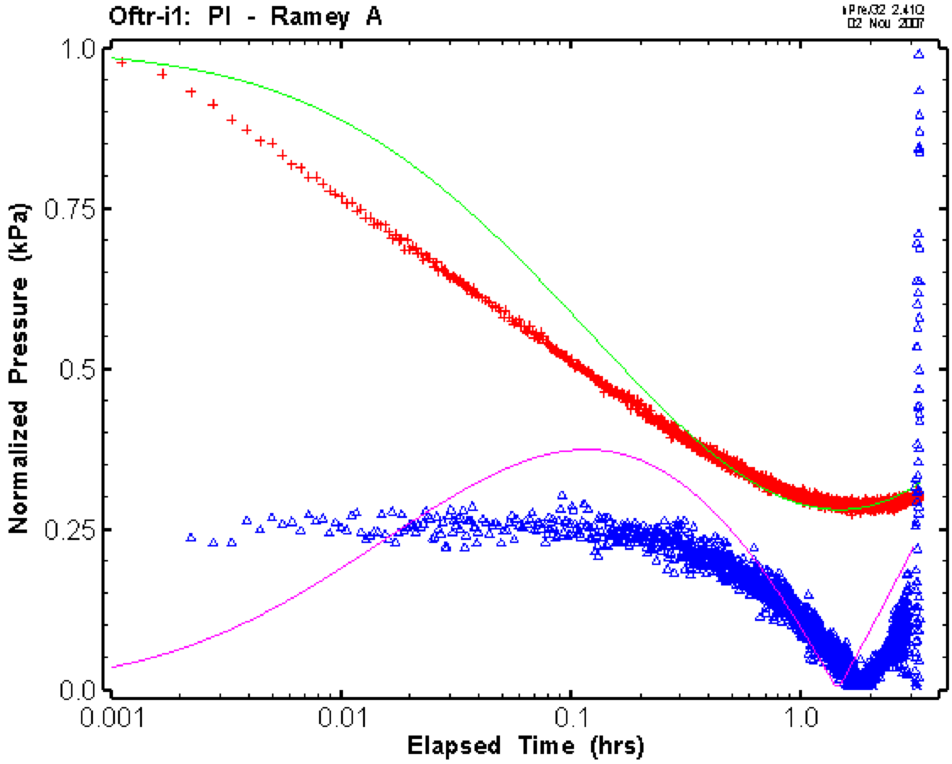
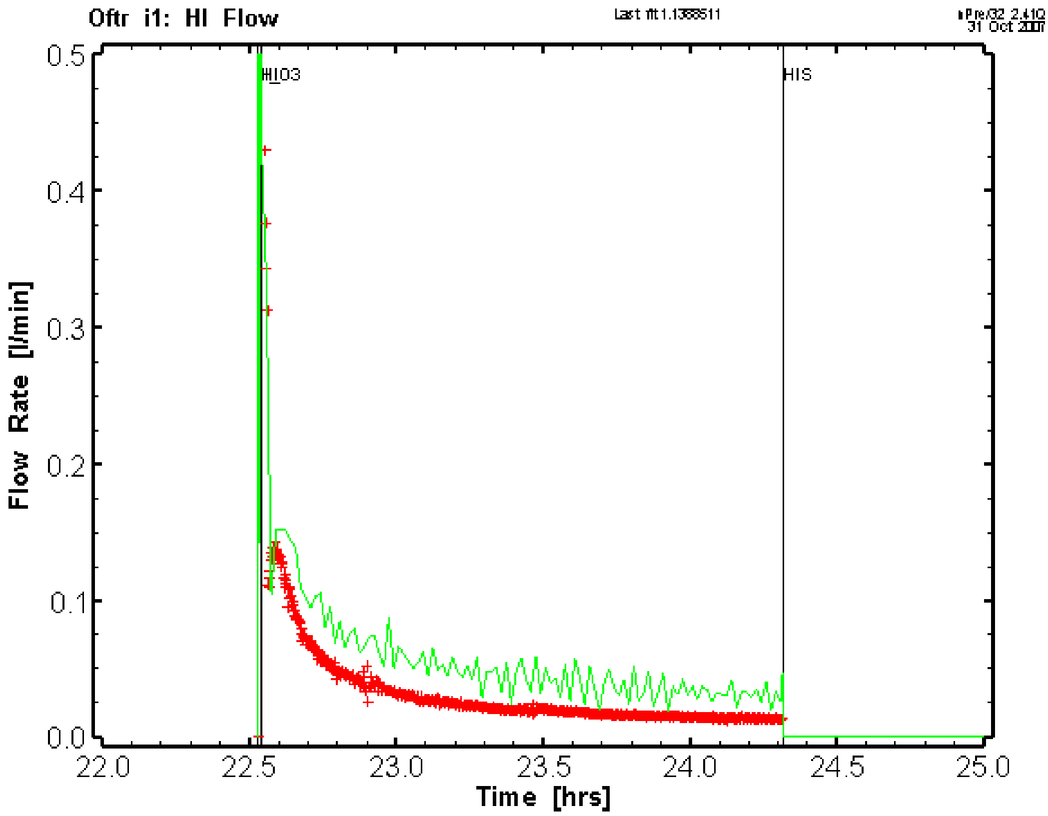


Figure 16: Oftr-i1: SWS Horner plot



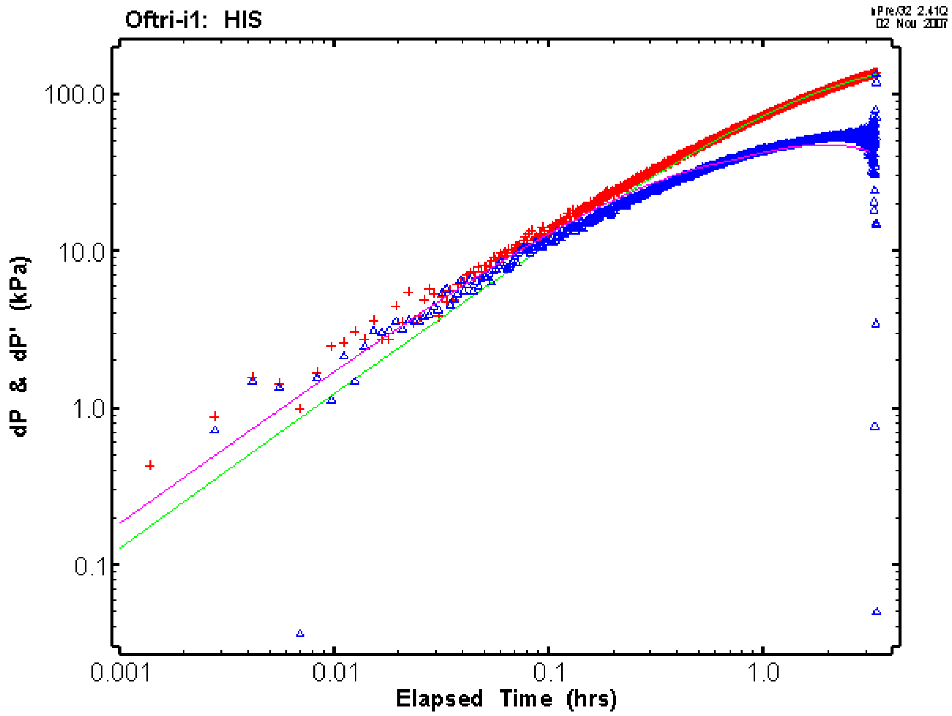
95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_f	[m/sec]	2.31E-11	8.90E-12	5.98E-11
P_f	[kPa]	6676.03	6517.37	6834.7
Ss_f	[1/m]	4.87E-05	1.29E-05	1.84E-04

Figure 17: Oftr-i1: PI normalized pressure (Ramey A)



95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_f	[m/sec]	5.20E-11	2.90E-12	9.32E-10
P_f	[kPa]	6999.99	6722.9	7277.1
Ss_f	[1/m]	5.67E-05	1.98E-06	1.62E-03

Figure 18: Oftr-i1: HI flow rate



95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_f	[m/sec]	9.56E-12	8.34E-12	1.09E-11
P_f	[kPa]	7000	6982.42	7017.57
Ss_f	[1/m]	7.43E-06	5.61E-06	9.82E-06

Figure 19: Oftr-i1: HIS log-log diagnostic plot

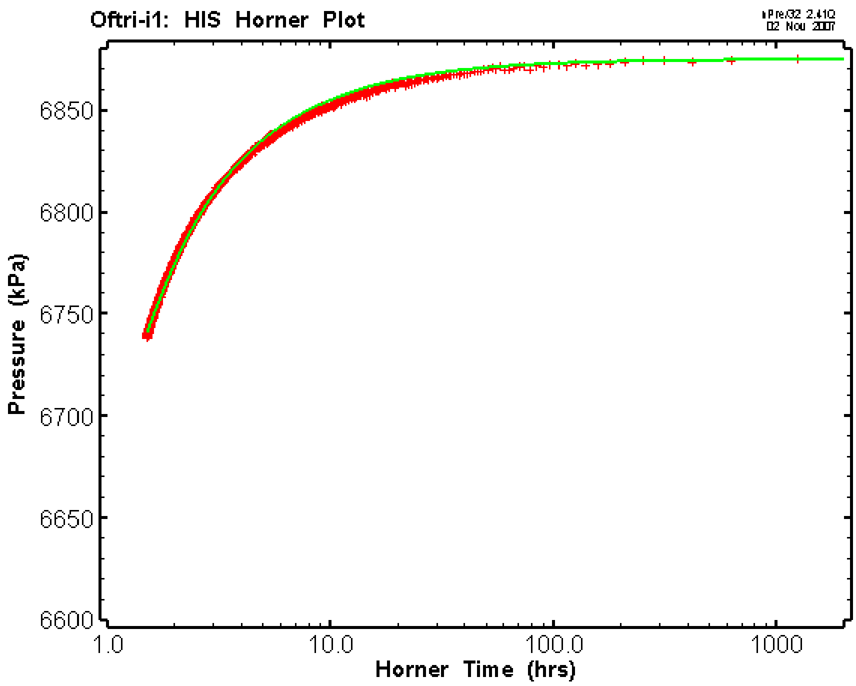
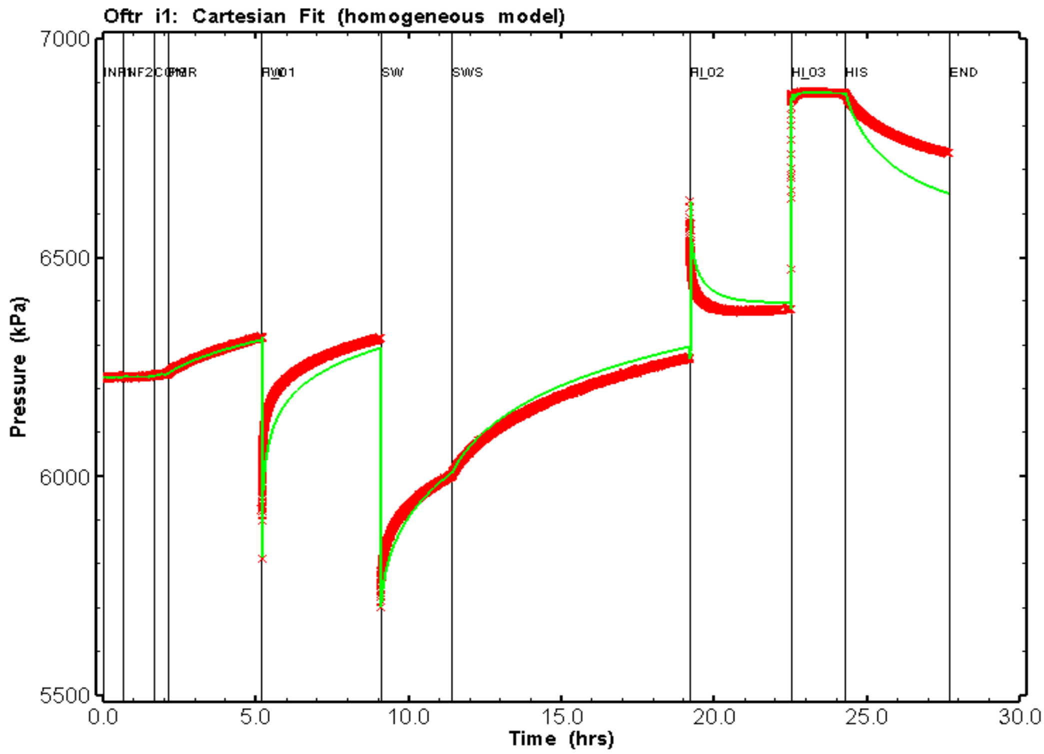
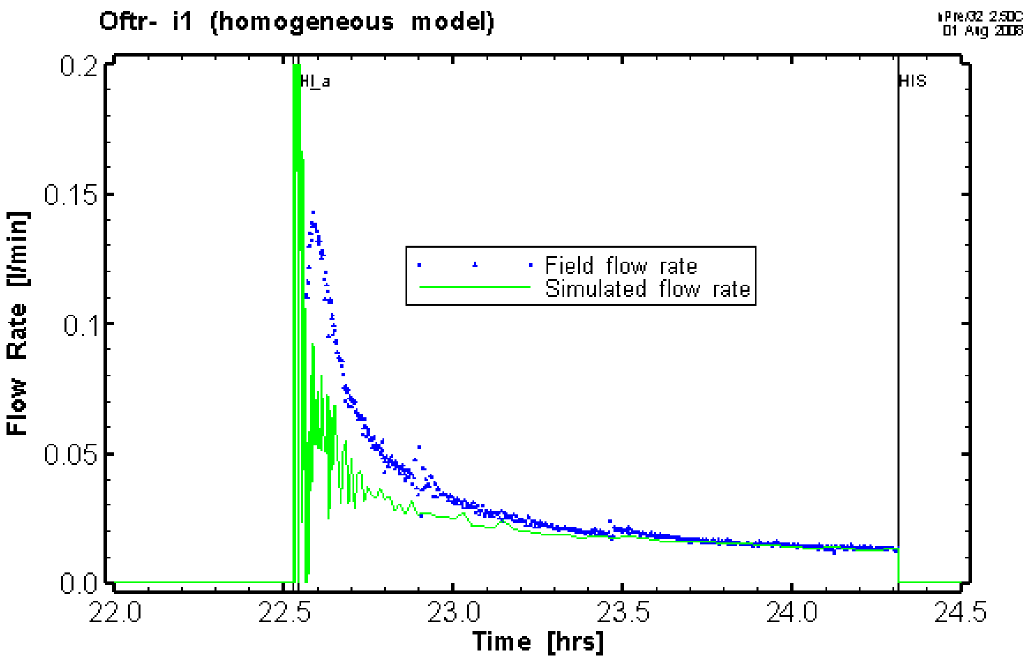


Figure 20: Oftr-i1: HIS Horner plot





95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_fm	[m/sec]	5.53E-12	5.13E-12	5.97E-12
P_fm	[kPa]	6782.7	6762.1	6803.4
ss_fm	[1/m]	1.00E-04	8.75E-05	1.14E-04

Figure 21: Oftr-i1: Cartesian fit of the entire test for homogeneous model

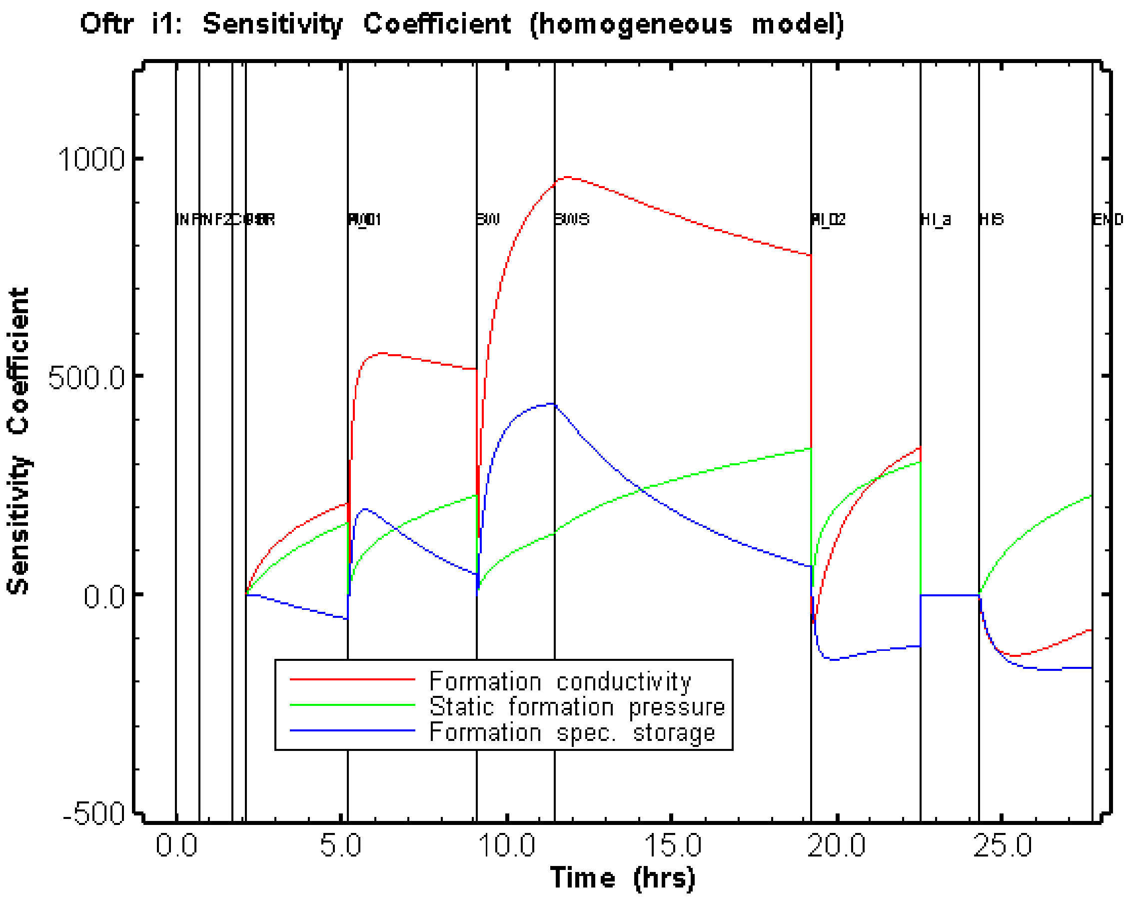
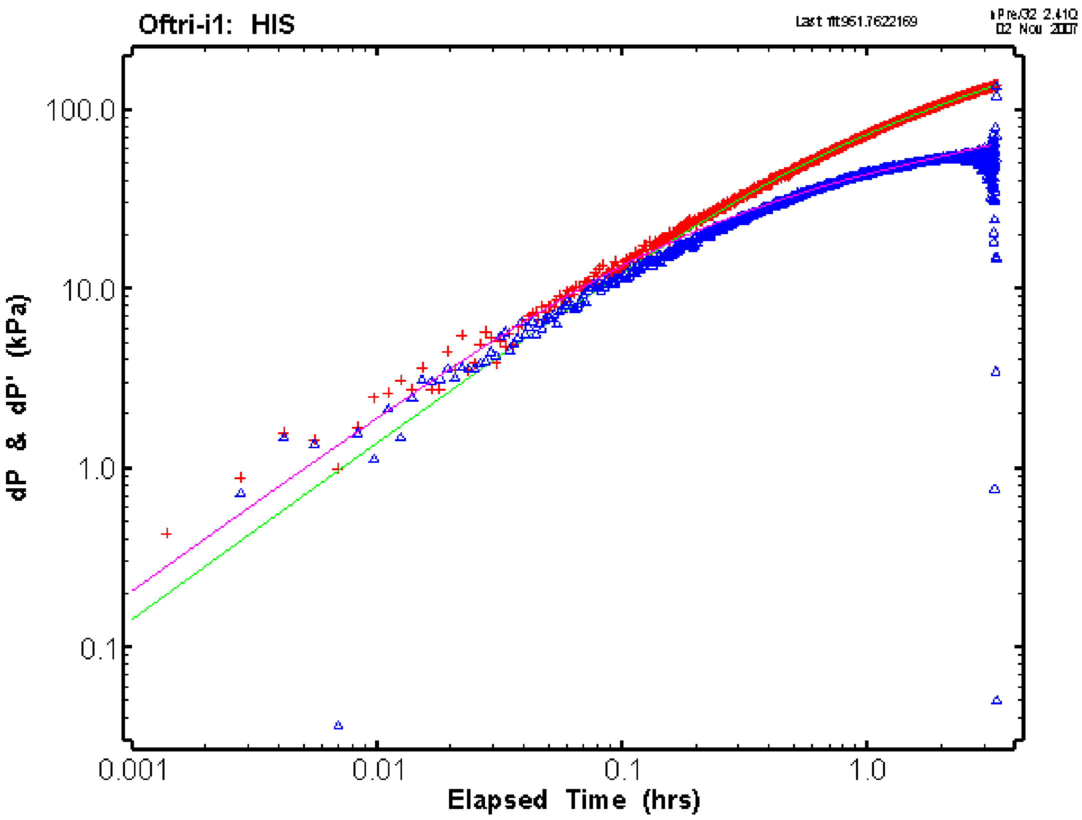
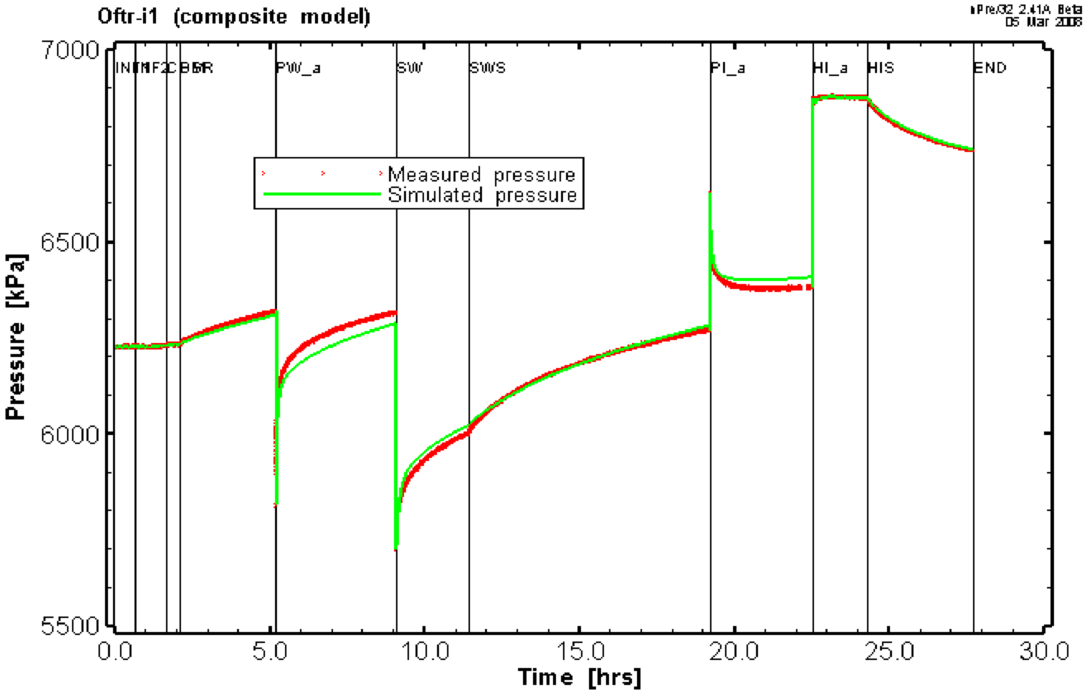


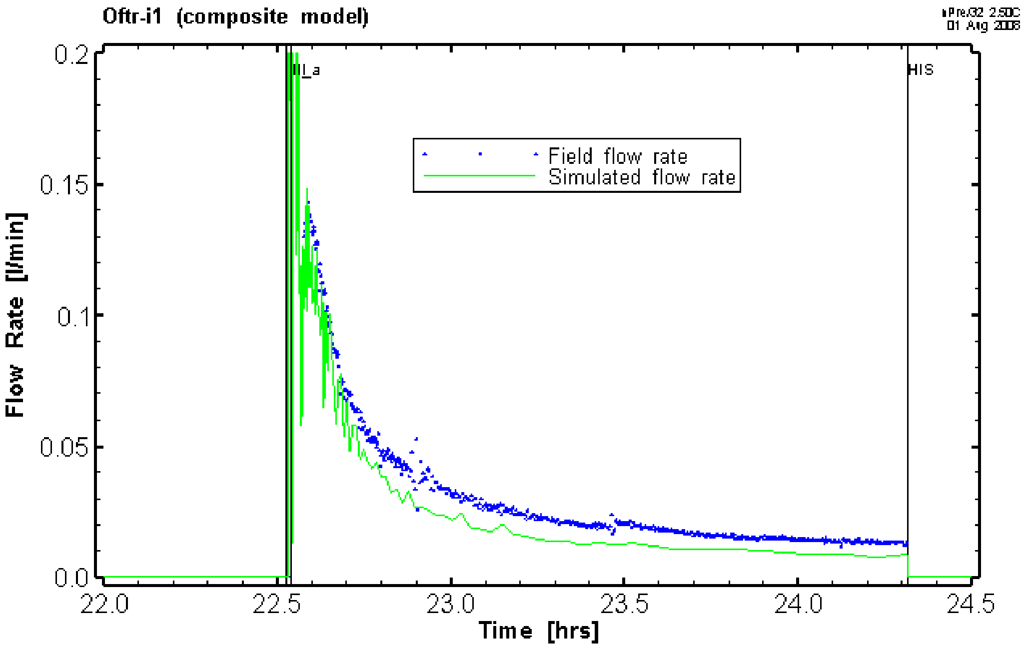
Figure 22: Oftr-i1: Sensitivity coefficients for the different formation parameters during the different sequences



95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_f	[m/sec]	6.91E-13	???	???
K_s	[m/sec]	1.84E-11	4.35E-12	7.74E-11
P_f	[kPa]	6436.4	4734.1	8138.7
Ss_f	[1/m]	3.75E-06	???	???
Ss_s	[1/m]	3.06E-06	2.21E-07	4.23E-05
t_s	[m]	0.159037	-0.17355	0.491621

Figure 23: Oftr-i1: HIS log-log diagnostic plot (composite model)





95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_fm	[m/sec]	3.95E-12	3.29E-12	4.75E-12
K_s	[m/sec]	2.46E-10	2.12E-10	2.86E-10
P_fm	[kPa]	7000.0	6945.0	7054.9
ss_fm	[1/m]	3.37E-06	2.21E-06	5.13E-06
ss_s	[1/m]	1.66E-06	1.15E-06	2.39E-06
t_s	[m]	0.26	0.20	0.31

Figure 24: Oftr-i1: Cartesian fit of the entire test for composite model

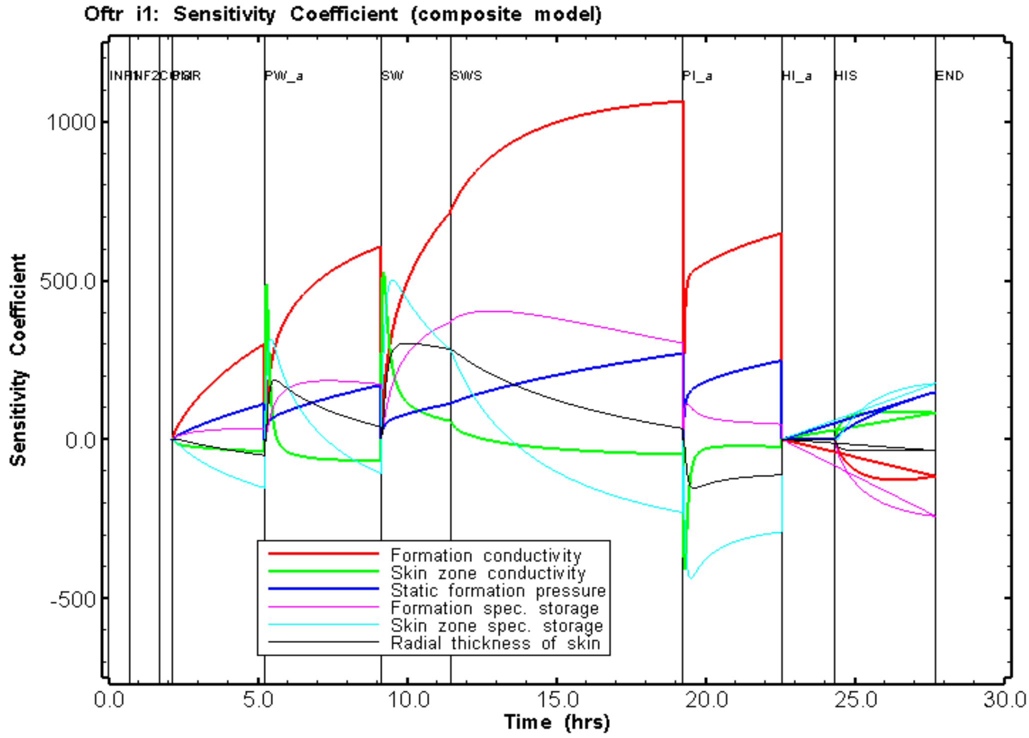


Figure 25: Oftr-i1, Composite model: Sensitivity coefficients for the different formation parameters during the different sequences (composite model)

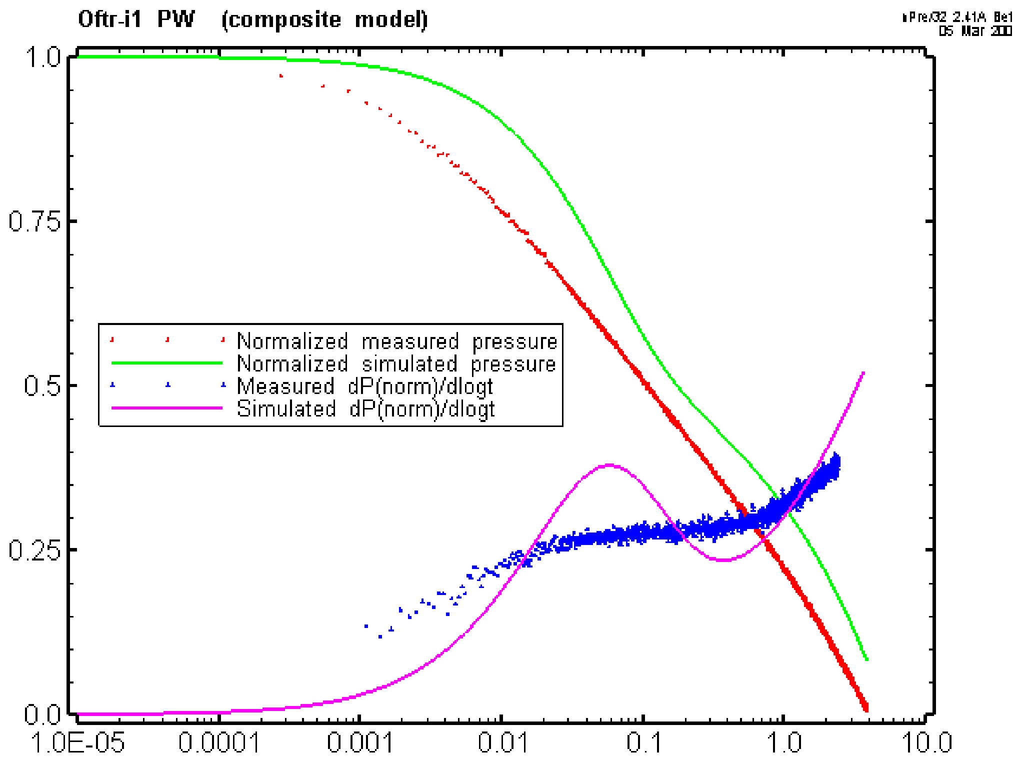


Figure 26: Oftr-i1, Composite model: Individual sequence plot for PW using the Cartesian fit parameters for the entire test

Abbreviations

	Test phases
COM	Compliance
INF	Packer inflation
INF1	Inflation of lower packer (INF2 = Inflation of upper packer)
DEF	Packer deflation
DEF1	Deflation of lower packer (DEF2 = Deflation of upper packer)
PSR	Static pressure recovery (shut-in valve closed)
SI	Slug injection test
SIS	Pressure recovery after slug injection test (shut-in)
SW	Slug withdrawal test
SWS	Pressure recovery after slug withdrawal test (shut-in)
PI	Pulse injection test
PW	Pulse withdrawal test
HI	Constant head injection test (constant pressure difference)
HIS	Pressure recovery after constant head injection test (shut-in)
HW	Withdrawal test applying constant differential head
HWS	Pressure recovery after constant head withdrawal test (shut-in)
MR	Multi-rate test: Test with variable flow rate
MRS	Pressure recovery after test with variable flow rate
RW	Pump test with constant flow rate
RWS	Pressure recovery after pump test with constant flow rate (shut-in)
RI	Constant flow injection test
RIS	Pressure recovery after constant flow injection test (shut-in)
VC	Shut-in valve is closed
VO	Shut-in valve is open
	General
CBP	Cooper, Bredehoeft, Papadopulos (type-curve matching method)
DAS	Data acquisition system
FS	Full scale
IARF	Infinite acting radial flow
LC	Log cycle
m agl	Meters above ground level
m bgl	Meters below ground level
m asl	Meters above sea level
OD	Outer diameter
PVT	Pressure volume temperature correlation
Sdev	Standard deviation
SLA	Straight-line analysis
TOC	Top of casing
WL	Water level (or WT = water table)

Nomenclature

	Description	SI-Unit		Description	SI-Unit
b	Y-intercept of linear regression		S_S	Specific storativity	m^{-1}
C	Wellbore storage constant	$m^3 Pa^{-1}$	S_{SS}	Specific storativity of skin zone	m^{-1}
C_S	Wellbore storage constant, shut-in	$m^3 Pa^{-1}$	s	Skin factor	-
C_D	Dimensionless wellbore constant	-	t, Δt	Time, elapsed time	s
c_f	Pore volume based compressibility	Pa^{-1}	t_C	Critical time	s
c_r	Rock compressibility	Pa^{-1}	t_D	Dimensionless time	-
c_{SC}	System compressibility (= test zone compressibility c_{tz})	Pa^{-1}	Δt_e	Equivalent time (after Agarwal)	s
c_w	Water compressibility	Pa^{-1}	Δt_H	Horner time	-
Δh	Differential head	m	t_p	Production time	s
g	Acceleration of gravity (9.81)	$m\ s^{-2}$	t_p*	Corrected production time	s
h_S	Static head	m	t_m	Match time	s
k	Intrinsic permeability	m^2	t_0	X-intercept of linear regression	s
K, K_f	Hydraulic conductivity of formation () special case	m/s	t_s	Thickness of skin zone	m
K_s	Hydraulic conductivity of skin zone () special case	m/s	T	Transmissivity	m^2/s
L	Interval length	m	T_W	Water temperature	°C
m	slope (regression)		z_1	P1 sensor depth	m
P	Pressure	Pa, kPa	z_2	P2 sensor depth	m
P_0	Minimal or maximal pressure	Pa, kPa	z_3	P3 sensor depth	m
P_{atm}	Probe signal at atmospheric pressure	Pa, kPa			
ΔP	Differential pressure, pressure change	Pa, kPa	α ,β	Type-curve match parameter	-
P_D	Dimensionless pressure	-	α	aquifer compressibility	Pa^{-1}
P_f	Static formation pressure	Pa, kPa	μ	Dynamic viscosity	Pa·s
P_i	Initial pressure	Pa, kPa	θ	Porosity	-
$P_{min/max}$	Minimal/maximal pressure	Pa, kPa	ρ_w	Density of fresh water	kg/m^3
P_{S1}	Static pressure in P1-Interval (below bottom packer)	Pa, kPa			
P_{S2}, P_f	Static pressure in test interval	Pa, kPa			
P_{S3}	Static pressure in annulus (above upper packer)	Pa, kPa			
q	Flow rate	$m^3 s^{-1}$			
q_{end}, q_e	Last flow rate	$m^3 s^{-1}$			
Q, Q_{tot}	Cumulative flow	m^3			
r_e	Effective radius (Slug, Pulse test)	m			
R_i	Radius of influence	m			
R^2	Correlation coefficient	-			
r_c	Tubing radius	m			
r_w	Wellbore radius	m			
R_1	Radius, composite model	m			
R_D	Dimensionless radius	-			
S	Storativity	-			
S_C	Sensitivity coefficient				

Definitions

$C_D = \frac{\rho g C}{2\pi S r_{w^2}}$	Wellbore constant, dimensionless
$H_D = \frac{P - P_i}{P_0 - P_i}$	Dimensionless pressure (slug und pulse tests)
$K = \frac{k \rho g}{\mu}$	Hydraulic conductivity
$P_D = \frac{2\pi T \Delta h}{q}$	Dimensionless pressure
$\Delta P = \rho \ g \Delta h$	Differential pressure
$q_D = \frac{q}{2\pi T \Delta h}$	Dimensionless flow
$t_D = \frac{t T}{r_w^2 S}$	Dimensionless time
$S = S_S L$	Storativity
$s = \left(\frac{K_f}{K_s} - 1\right) \ln\left(\frac{r_w + t_s}{r_w}\right)$	Skin factor
$S_S = \rho g (\alpha + \theta c_w)$	Specific storativity
$S_C = \frac{\partial P}{\partial r}$	Sensitivity coefficient.

where ∂P is the partial derivative of the calculated system response (i.e., pressure) with respect to a parameter varied by the derivative span ∂r .
For comparison of sensitivity coefficients for different parameters, the sensitivity coefficients are typically scaled by inverses of the respective standard deviations as follows:

$$S_{sc} = S \frac{\sigma_r}{\sigma_P} = \frac{\partial P}{\partial r} \cdot \frac{\sigma_r}{\sigma_P}$$

where S_{sc} is the scaled sensitivity coefficient, σ_r is the a priori standard deviation of the measurement error, and σ_P is the estimated standard deviation of the parameter.
If not otherwise stated, default values σ_r = 1 and σ_P = 1 were used.

Definitions (continued)

T = K L	Transmissivity
$\frac{t_D}{C_D} = \frac{2\pi T t}{\rho \ g C}$	Dimensionless time axis
$t_e = \frac{t_p \cdot \Delta t}{t_p + \Delta t}$	Dimensionless Agarwal time (Agarwal, 1980)
$t_e^* = \frac{t_P^* \cdot \Delta t}{t_P^* + \Delta t}$	Modified Agarwal time (using corrected production time)
$t_P^* = \frac{Q}{q_{end}}$	Modified production time (Ehlid-Economides and Ramey, 1980)

Form

DAILY LOG REPORT

SOLEXPERTS

Oftringen Hydraulic Testing: Interval 1: 650 – 700 m

Date	***Time***	***Activity***	***Who***
19.10.07	*10:30*	*Arrival on site (Oftringen, NOK)*	*Fi, FP, Sti*
		On site meeting with H.P. Weber. *Caliper logs und results of fluid-logging are presented and discussed.* *First interval to be tested: 650.0 – 700.0 m (L = 50 m +/- 1 m)* *Formation: mainly consisting of Hauptrogenstein (Dogger)* *Use of grease "Bio Schmierfett L2"* *Trailer is grounded to earth (Ringleitung)* *Saturation of P1 pressure line*	
	15:00	*Start installation of double packer straddle*	*FP, Sti*
	17:10	*Water table in borehole is 41.95 m below top of claws of drill machine (=> 41.95 – 2.0 m = 39.95 m below ground level mbgl)*	
	17:35	*Check triple probe S1* *File: Oftr_2007_10_19_atm0.dat* *P1 = 107.8 kPa* *P2 = 92.4 kPa* *P3 = 102.0 kPa* *T1 = 12.9 °C*	
	18:15	*Coefficients changed to previous set-up* *P1 = 111.7 kPa* *P2 = 92.2 kPa* *P3 = 102.3 kPa* *T1 = 11.4 °C* *T2 = 11.0 °C* *T3 = 10.63 °C*	
	18:20	*Stop file*	
	18:30'	*Start installing 1.9" test rods*	
	19:00	*Arrival SR and PH*	*SR, PH*
	20:00	*Fi, FP, Sti leave site*	
	20:17	*Check triple probe S1 (last tubing installed: TU44)* *File: Oftr_2007_10_19_chk1.dat* *44 rods are in hole.* *P1 = 2623.2 kPa* *P2 = 2615.5 kPa* *P3 = 2614.0 kPa* *T1 = 24.8 °C* *T2 = 24.7 °C* *T3 = 24.7 °C* *Probe is working, pressures measurements reasonable*	
	21:05	*Continuation of installation* *Check triple probe S1 (last tubing installed: TU72)* *File: Oftr_2007_10_19_chk2.dat* *72 rods are in hole.* *P1 = 4392.3 kPa* *P2 = 4385.0 kPa* *P3 = 4382.7 kPa* *T1 = 32.0 °C* *T2 = 32.0 °C* *T3 = 32.9 °C* *Probe is working, pressures measurements reasonable*	
	22:20	*Continuation of installation*	
	23:38	*System on position. UPLS on 650 m bgl* *Preparation of pressure tanks for packers and downhole valve*	

Form

DAILY LOG REPORT

Date	Time	Activity	Who
20.10.07	00:01	**Interval 1: 650.00 – 750.04 m** Start file: Oftr_2007_10_19_oftr_i1.dat P1 = 6237.86 kPa P2 = 6227.15 kPa P3 = 6222.21 kPa T1 = 45.10 °C T2 = 45.14 °C T3 = 45.23 °C Water table: 20.30 m bgl	SR, PH
		Probe signal scatter range is larger than normal (scatter should be in less than 0.1 kPa)	
	00:12	INF PA1 (20 bar)	
	00:17	Change scan rate to 5 s	
	00:43	Packer seal at borehole wall	
	00:59	Packer pressure is stable	
	01:00	Refill tank	
	01:12	INF PA2 (22 bar)	
	01:18	Connect PA1 to pressure vessel to re-establish packer pressure	
	01:21	PA1 valve closed	
	01:30	Change scan rate to 10 s	
	01:43	PA2 packer seals at borehole wall = interval is isolated Start COM	
	01:47	Change scan rate to 5 s	
	01:49	Connect PA1 to pressure vessel to re-establish packer pressure	
	01:51	PA1 valve closed => pressure constant at 24 bar	
	02:08	VC, start PSR	
	02:10	Open PA1 valve. PA1 and PA2 are connected to the pressure vessel in order to maintain a constant inflation pressure	
	02:15	Preparation of swabbing tool	
	02:38	Change scan rate to 10 s	
	02:53	Swabbing to 45 m bgl	
	03:03	Water table (tubing): 51.77 m bgl	
	04:10	Lower P4-Sensor in 1.9" test tubing. Vertical position at about 20 m below water table (P4 ID 591 001 027)	
	04:20	Water table in 1.9" tubing: 51:26 m bgl P4 sensor signal = 164.02 kPa => Sensor at 67.98 m bgl	
	05:08	Sensor P4: 164.10 KPa ID 591001.027, SN2660	
	05:09	Scan rate 1 s	
	05:13	Start PW	
	05:15	P4: 171.09 kPa => ΔP = 6.99 kPa => dh = 0.71 m	
	05:16	Water table: 50.23 m bgl	
	05:25	Scan rate 5 s	
	05:38	Pull P4-Sensor out of borehole	
	05:44	P4 at atmosphere: 101.00 kPa	
	06:00	Arrival on site	Fi
	07:00	Swabbing to approximately 75 m bgl	
	07:15	Arrival on site	FP, Sti
	07:20	SR, PH leave site	SR, PH
	07:30	Water table in tubing = 92.3 – (2.83 + 0.58 m) = 88.89 m bgl	
	08:08	Slim-tubing 10 bar sensor shows 3.5 kPa at atmospheric pressure	

Form

DAILY LOG REPORT

SOLEXPERTS

Date	Time	Activity	Who
20.10.07	08:20	Slim tubing packer on position, at about 90.5 m below top of tubing.	Fi, FP, Sti
	08:40	Expand Slim tubing packer	
	08:50	Send provisional data analysis to Fbe (email), and phone call to discuss further testing procedure (SW – SWS using slim tubing). Fill borehole annulus before starting test of next interval	
	09:07:20	Start SW (open shut-in valve). Pressure is recovering more quickly than expected	
	09:30 - 10:45	Visit of H.P. Weber on site. Discussion on next intervals to be tested	
	11:26	Start SWS, recovery is much slower than expected	
	11:57	Deflate Slim tubing packer	
	12:00	Slim tubing sensor (CH4) switched off (in GMII-DAS). Pull slim tubing out of hole	
	12:07	In GMII DAS: switch CH4 on: Slim-tubing 10 bar sensor shows 2.7 kPa at atmospheric pressure	
	12:11	Fill 1.9" NU tubing with water up to top of test rods	
	12:25	Tubing is completely filled with fresh water.	
	12:32	P4 sensor shows 101.5 kPa at atmosphere. No change in water level in tubing -> no leaks	
	12:35	Installation of P4 sensor (6 bar) 4 m below top of tubing	
		Fill level adapted (below thread) P4 = 140.25 kPa	
	14:47	Change scan rate to 10 seconds	
	17:10	Check water level in test tubing: water level is at top of casing (unchanged)	
	18:50	Start preparation for pulse injection test (PI)	
	18:30	P4 removed (on atmospheric pressure, then switched off)	
		Water table in test rod is at 6 cm below top of tubing. Screw injection head on top of tubing. Connect injection head with nitrogen bottle using 6/4mm polyamide line.	
	19:08	P2 = 6269.7 kPa	
	19:08	Apply N2-head of 4 bar	
	19:12	Change scan rate to 2 sec	
	19:14	Start PI. During open valve phase of pulse, gas pressure drops to 1.7 bar	
	19:17	Change scan rate to 5 s	
	19:23	Water table in test rod is at 0.76 m => Δs = 0.70 m	
	19:30	PH/SR arrive on site	SR,PH
	19:50	FP/Sti leave site	FP, Sti
	20:55	Fi leaves site	Fi
	20:56	Scan rate 10 s	
	21:00	Preparing material for injection - test	SR,PH
		Public water supply provides 5 bar pressure (constant)	
	21:10	Pressure test flowboard 5 bar => o.k.	
	21:35	Pressure test flow lines 5 bar => o.k.	
	21:42	Stop scanning to change the scale reference of AXF002 (zero point adjustment) : Reference = -12.07 ml (GMII)	
	22:12	Stop scanning for loading Igor waves (AXF002, AXF015)	
	22:23	Start scanning	
	22:30	Scan rate = 3 s	
	22:33	Start HI-Test	

Form

DAILY LOG REPORT

Date	Time	Activity	Who
20.10.2007	22:54	Scan rate 5 s	SR, PH
	22:55	Inlet pressure (hydrant) is varying within 0.2 bar	
	23:00	Check flow lines: no leakage!	
21.10.2007	00:05	Check flow lines: no leakage!	
	00:18	Check flow lines: no leakage!	
	00:20	Shut in, Start HIS	
	01:07	Scan rate 10 s	
	03:12	Water table in annulus: 18.60 m bgl	
	03:43	Start deflation of upper packer (PA2)	
	03:47	Start deflation of lower packer (PA2)	
	04:10	Water table in annulus: 18.50 m bgl	
	04:11	Open valve	
	04:16	Water table tubing: 20.32 m bgl P1 = 6267.07 kPa P2 = 6253.00 kPa P3 = 6255.49 kPa T1 = 45.19 °C T2 = 45.23 °C T3 = 45.41 °C	
	04:20	Stop file	
	04:25	Fill up annulus with water	
	04:45	Packers are not fully apart yet from borehole wall	
	05:19	Start moving system on position Oftr-i2	

Fi *Hansruedi Fisch (Solexperts)*
FP *Fredi Portmann (Solexperts)*
SR *Sacha Reinhardt (Solexperts)*
Sti *Daniel Stillhard (Solexperts)*
PH *Peter Haller (Solexperts)*

Fbe *Dr. Bernd Frieg (Nagra)*

Form

INSTALLATION RECORD HDDP

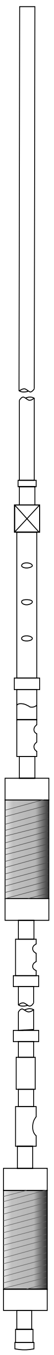
SOLEXPERTS

Seite 1 / 1

Oftringen NOK EWS Borehole: Hydraulic Testing

Borehole	NOK EWS 2007	**Direction**	vertical	**Reference point**	433.0	**Date**	19.10.2007	**Project Leader**	Fi/SR
Borehole Depth	719.0 m	**Casing depth**	376.5 m bgl	**Interval lenght**	50.04 m	**JOB Nr**	1763	**Location**	Oftringen
Borehole diameter	146 mm	**Stickup**	-2.83 m	**Water depth**	39.95 m bgl	**Test Name**	oftr_i1	**System**	HDDP 110
						Test depth (UPLS)	650.00 m bgl	**Probe ID**	TSSP S1

Note: All dephts shown are not correct for borehole deviation

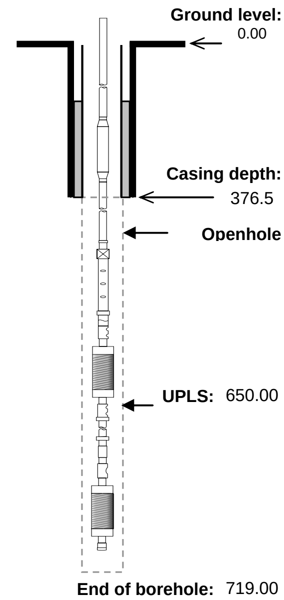


Component		Qty -	L unit m	L total m	Depth m	OD mm	ID mm	Wgt kg	Str t
Stickup	-2.83 m bgl								
Ground level					0.00				
Tubing 1.9" NU			645.56	645.56		56.1	40.3	#####	12.0
Pop joint			1.02		642.73	56.1	40.3	4.2	12
SIT Non Displacement Valve			0.84			79.0	24.0	20.6	15
Probe Shell Carrier mit Triple Sub	TSSP P3		1.97		646.56	70.0	10.9	48.0	25
	TSSP P2		0.30		646.86				
	TSSP P1		0.30		647.16				
			0.04						
X-Over	2"3/8 EU Pinx1.9" NU Box		0.51	7.27		66.0	40.0	2.1	16
Safety joint 3"1/16						78.0	50.5	5.5	24
Above Side Entry Sub (ASES)			0.52			66.0	32.0		24
Packer Stick Up			0.26			--	25.0		
Up. Packer Seal: Upper Packer	UPUS		0.26		648.75				
			1.25			108.0	32.0	82.4	17
	UPLS		0.24		650.00				
Straddle Length: Packer Stick Down			0.31			--	25.0		
Below Side Entry Sub (BSES)			0.52			66.0	32.0		24
X-Over	1.9" NU Pinx2"3/8 EU Box		0.26			--		3.0	16
Tubbing 1.9" NU			45.5			56.1	40.3	186.6	12
X-Over	2"3/8 EU Pinx1.9" NU Box		0.45	50.04		--		3.0	16
			0.3						
Filter	Screen		1.45			72.0	50.0	19.0	19
			0.3						
P1-Seal Sub			0.3			78.0	--		24
Packer Stick Up			0.16			--	32.0		
Lower Packer Seal: Lower Packer	LPUS		0.25		700.04				
			1.25	1.92		110.0	32.0	70.2	17
	LPLS		0.24		701.29				
Packer Stick Down			0.43			--	32.0		
End Cap					701.96	78.0	--		
End of Borehole					719.00				

Comments:

Water table in borehole prior to packer inflation: 20.3 m bgl.
P4: submersible pressure transducer on cable
P_{SL}: submersible pressure transducer at bottom of slim tubing
1) Bench test 19.10.07, except for P4 & P_{SL}. P4, P_{SL} measurement at atmospheric pressure on 20.10.07

Borehole configuration:



Probe	523 006.1	
values at atmosphere 1)	P1	111.7
	P2	92.1
	P3	102.3
	P4,P_{SL}	101.0,3.5
	T1	11.4
	T2	11.0
	T3	10.6
Total Weight (kg)	3111.9	

Form

TALLY LIST

SOLEXPERTS

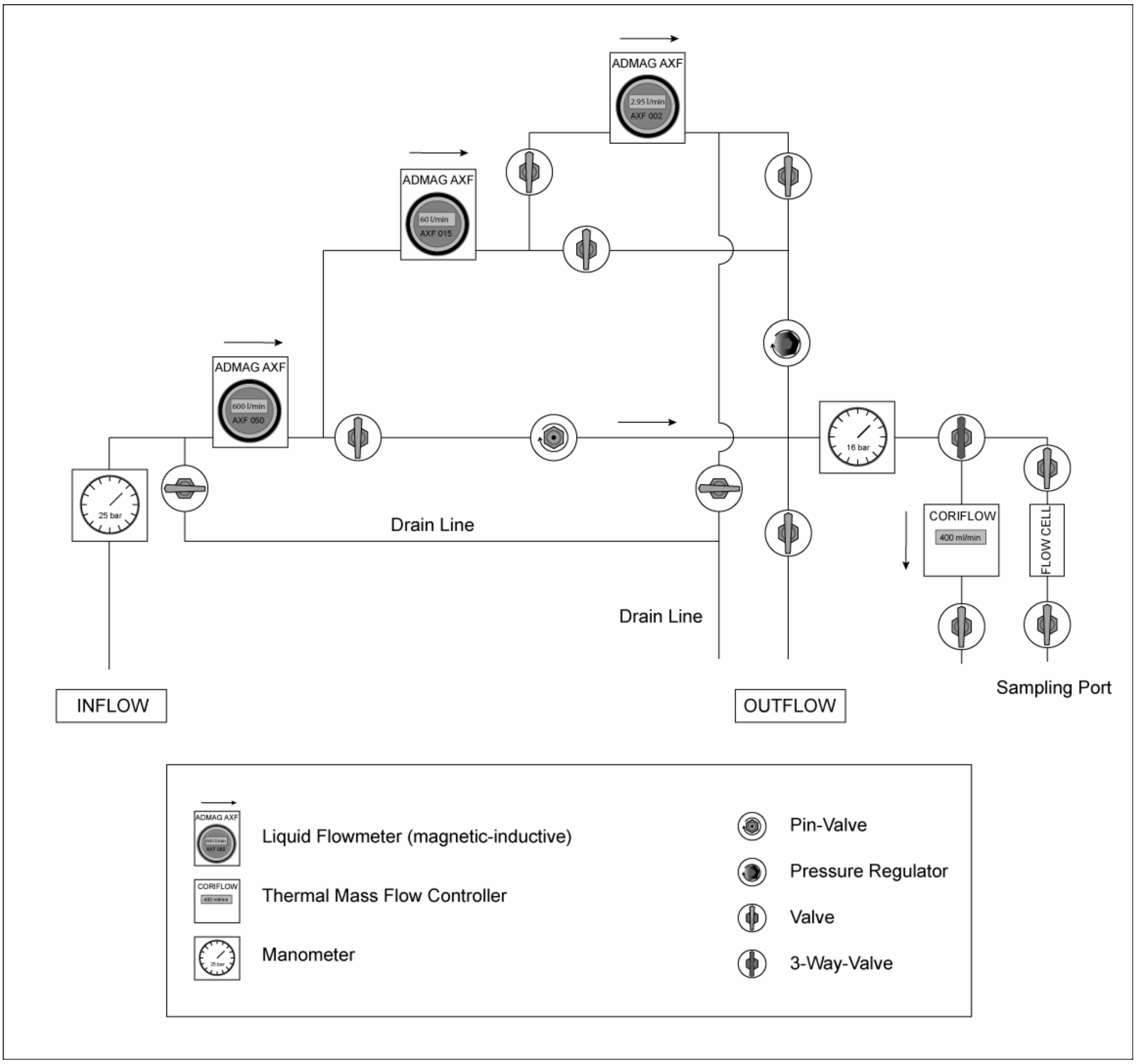
Borehole	NOK EWS 2007	Interval name	Test Oftr_i1
Depth	719.0 m	Interval depth	650 - 700 m
Date	19.10.2007	Location	Oftringen

TU	1	6.51	TU	51	6.50	TU	101	1.85	
TU	2	6.51	TU	52	6.51				
TU	3	6.51	TU	53	6.51				
TU	4	6.51	TU	54	6.51				
TU	5	6.51	TU	55	6.51				
TU	6	6.51	TU	56	6.51				
TU	7	6.51	TU	57	6.50				
TU	8	6.51	TU	58	6.51				
TU	9	6.51	TU	59	6.51				
TU	10	6.50	TU	60	6.51				
TU	11	6.50	TU	61	6.50				
TU	12	6.51	TU	62	6.50				
TU	13	6.50	TU	63	6.50				
TU	14	6.51	TU	64	6.50				
TU	15	6.51	TU	65	6.51				
TU	16	6.51	TU	66	6.50				
TU	17	6.51	TU	67	6.50				
TU	18	6.51	TU	68	6.51				
TU	19	6.50	TU	69	6.50				
TU	20	6.51	TU	70	6.50				
TU	21	6.51	TU	71	6.47				
TU	22	6.50	TU	72	6.50				
TU	23	6.51	TU	73	6.48				
TU	24	6.50	TU	74	6.50				
TU	25	6.50	TU	75	6.50				
TU	26	6.50	TU	76	6.50				
TU	27	6.50	TU	77	6.50				
TU	28	6.50	TU	78	6.50				
TU	29	6.50	TU	79	6.51				
TU	30	6.50	TU	80	6.51				
TU	31	6.50	TU	81	6.51				
TU	32	6.50	TU	82	6.50				
TU	33	6.51	TU	83	6.51				
TU	34	6.51	TU	84	6.50				
TU	35	6.50	TU	85	6.48				
TU	36	6.51	TU	86	6.50				
TU	37	6.50	TU	87	6.51				
TU	38	6.50	TU	88	6.50				
TU	39	6.51	TU	89	5.94				
TU	40	6.50	TU	90	5.94				
TU	41	6.51	TU	91	5.93				
TU	42	6.51	TU	92	5.94				
TU	43	6.50	TU	93	5.95				
TU	44	6.50	TU	94	5.95				
TU	45	6.50	TU	95	5.95				
TU	46	6.50	TU	96	5.95				
TU	47	6.51	TU	97	5.95				
TU	48	6.51	TU	98	5.95				
TU	49	6.51	TU	99	5.95				
TU	50	6.51	TU	100	5.95				
		325.28			318.43			1.85	0.00

Total string length: 645.56

Form

SURFACE EQUIPMENT LAYOUT



Flow meter	Lower limit of measuring range	(% of FS)	Upper limit of measuring range (l/min)	Accuracy between 3% and 100% of FS (% of rate)	Accuracy between 1% and 3% of FS (% of rate)	Equipment used
AXF DN2	0.030 l/min	1 %	2.95 l/min	0.35	0.5	yes
AXF DN15	0.6 l/min	1 %	60 l/min	0.35	0.5	yes
AXF DN50	11.78 l/min	1 %	1178.10 l/min	0.35	0.5	no
Coriflow	0.50 kg/h	2 %	25.00 kg/h	1	1	no

Form

BENCH TEST

SOLEXPERTS

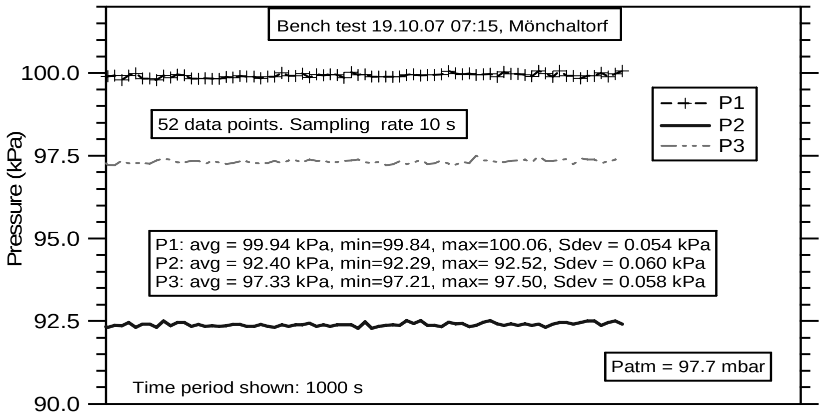
Project	**Location**	**Date**
Oftringen NOK EWS Borehole	Oftringen	07.10.2007
Well name	**Test name**	**Engineer**
NOK EWS 2007	Oftri-i1	Fi/SR

Transducer describtion	**Output units**
P1, P2, P3: 0-206.84 bar (3000 Psi), P4: 0-6 bar, P_{ST} = 0-10 bar	kPa, °C

P1#	**P2#**	**P3#**	**P4#**
43224	50370	43231	591.001.027

Offsite pretest bench test (Date: 19.10.07)

Measurement conditions (P, T and position)	**Sampling rate**
97.7 kPa 5.6 °C	10 s
( ) direct (x) vertical ( ) horizontal	

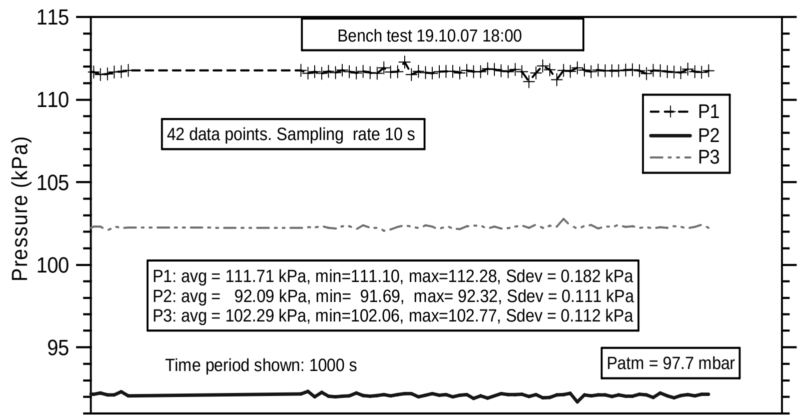


P1 average:	99.84	kPa
P2 average:	92.29	kPa
P3 average:	97.33	kPa
P4 average:	n.m.	kPa
P_{SL} average:	n.m.	kPa
P1 Sdev	0.054	kPa
P2 Sdev	0.060	kPa
P3 Sdev	0.058	kPa

File: TestData24.DAT

Onsite pretest bench test (Date: 19.10.07)

Measurement conditions (P, T and position)	**Sampling rate**
97.7 kPa 11.0 °C	10 s
( ) direct (x) vertical ( ) horizontal	



P1 average:	111.71	kPa
P2 average:	92.09	kPa
P3 average:	102.29	kPa
P4 average:	101.06	kPa [1)]
P_{SL} average:	3.56	kPa [1)]
P1 Sdev	0.182	kPa
P2 Sdev	0.111	kPa
P3 Sdev	0.112	kPa
P4 Sdev	0.056	kPa [1)]
P_{SL} Sdev	0.019	kPa [1)]

[1)] Data not shown, 20.10.07, 05:45-08:15, File Oftr_2007_10_19_oftr_i1.dat, Patm=97.8 kPa

File: Oftr_2007_10_19_atm0.DAT

Form

BENCH TEST

SOLEXPERTS

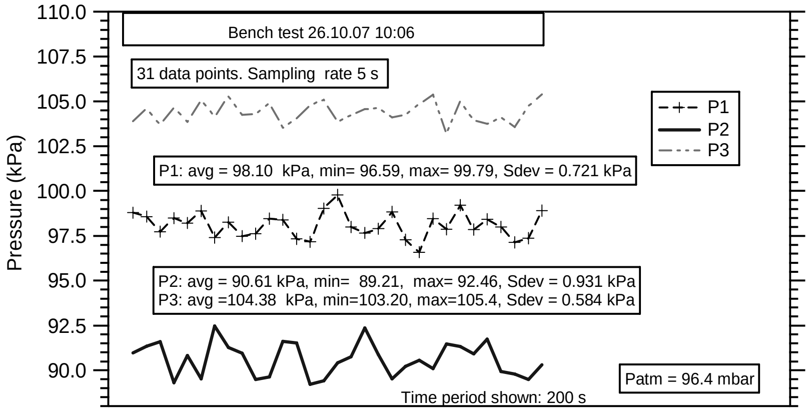
Project	**Location**	**Date**
Oftringen NOK EWS Borehole	Oftringen	07.12.2007
Well name	**Test name**	**Engineer**
NOK EWS 2007	Oftri-i1	Fi/SR

Transducer describtion	**Output units**
P1, P2, P3: 0-206.84 bar (3000 Psi), P4: 0-6 bar, P_{ST} = 0-10 bar	kPa, °C

P1#	**P2#**	**P3#**	**P4#**
43224	50370	43231	591.001.027

Onsite after test bench test (Date: 26.10.07)

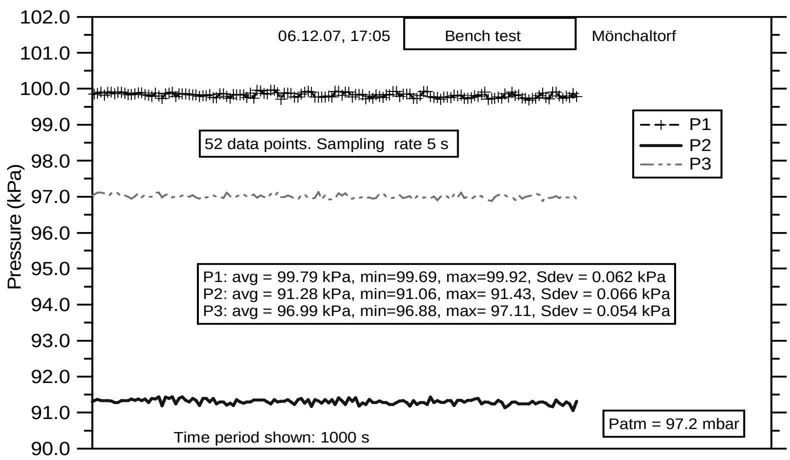
Measurement conditions (P, T and position)	**Sampling rate**
96.4 kPa 7.3 °C	5 s
( ) direct (x) vertical ( ) horizontal	



P1 average:	98.10 kPa
P2 average:	90.61 kPa
P3 average:	104.40 kPa
P4 average:	n.m. kPa
P_{SL} average:	n.m. kPa
P1 Sdev	0.721 kPa
P2 Sdev	0.931 kPa
P3 Sdev	0.584 kPa
File:	Oftr_2007_10_26_atm1.DAT

Offsite after test bench test (Date: 06.12.07)

Measurement conditions (P, T and position)	**Sampling rate**
97.7 kPa 9.6 °C	5 s
( ) direct (x) vertical ( ) horizontal	



P1 average:	99.69 kPa
P2 average:	91.28 kPa
P3 average:	96.99 kPa
P4 average: 1)	101.44 kPa
P_{SL} average:	n.m. kPa
P1 Sdev	0.062 kPa
P1 Sdev	0.062 kPa
P2 Sdev	0.066 kPa
P3 Sdev	0.054 kPa
P4 Sdev	0.007 kPa

1) not shown on graph

File: test8.dat

Form

BENCH TEST

SOLEXPERTS

Project	**Location**	**Date**
Oftringen NOK EWS Borehole	Oftringen	10.12.2007
Well name	**Test name**	**Engineer**
NOK EWS 2007	Oftri-i1	SR

Sensor describtion		**Output units**	
AXF002 Magnetic-inductive flow-meter Coriflow coriolis liquid flow controller		ml/min	
AXF002# 611086	**Coriflow#** 611091		

Onsite after test bench test (Date: 23.10.07)

Measurement conditions		**Sampling rate**
Inlet pressure (vessel)	5 bar	varying
( ) direct ( ) vertical (x) horizontal		

a) Check using measuring cylinder

Coriflow		Measuring cylinder			Difference	
setpoint	ml/min	volume [ml/min]	time [minutes]	measured flow [ml/min]	[ml/min]	[% of rate]
50%	208.33	825.0	4.0	206.3	-2.03	-0.99%

b) Comparison of instruments connected in series

Coriflow		AXF display	Remarks	Difference	
setpoint	ml/min	ml/min		[ml/min]	
5%	20.83	18.0	AXF: signal below lower limit of measuring range	-2.83	-13.60%
10%	41.67	39.5		-2.17	-5.20%
20%	83.33	81.5	varying from 77 to 86	-1.83	-2.20%
50%	208.33	206.5		-1.83	-0.88%
80%	333.33	333.5		0.17	0.05%
100%	416.67	416.5		-0.17	-0.04%

Remarks:
See daily log report Oftr-i3, 23.10.07, 02:45
Inconsistency in flow measurements may be due to high voltage current transformer facility (NOK)

Appendix B

Quick Look Report
Interval Oftr-i2

nagra.

QUICK LOOK REPORT OFTRINGEN - TEST OFTR-i2

TEST START (Date/Time)	:	21.10.2007 / 05:55	**TEST END (Date/Time)**	:	22.10.2007 / 13:37

DOUBLE PACKER TEST

Test Interval Information	:		top test interval	:	590.00	m bgl
borehole depth [1), 4)]	:	719.0 m	bottom of test interval	:	640.04	m bgl
borehole radius	:	0.073 m	total interval length	:	50.04	m
tubing radius	:	20.0 mm	midpoint of interval	:	615.02	m bgl
			P2-depth (z_2)	:	586.86	m bgl
interval volume, nominal [5)]	:	0.838 m^3	theoretical Cs-value [3)]	:	1.68E-09	m^3/Pa
slim tubing radius		4.75 mm	theoretical C-value (slim tube)	:	7.23E-09	m^3/Pa
WL prior to packer inflation [2)]	:	2.23 m bgl	P2 signal prior to packer inflation	:	5815.83	kPa
WL in annulus at test end [2) 6)]	:	1.24 m bgl	P2 offset assuming ρ_{avg} = 997 kg/m3		97.8	kPa

1) all depths are not corrected for borehole deviation from vertical
2) WL = water level
3) assumes a total borehole system compressibility of 2E-09 Pa^{-1}
Note all pressures cited in this report are absolute
4) all depth measurements refer to ground level
5) cylindrical volume of isolated borehole section
6) WL in annulus was unintentionally increased by 3 m during testing; the general trend of P3 was falling

Preliminariy information				
longitude of borehole	:	240887		
latitude of borehole	:	638346		
elevation of ground level (GL)	:	433.0	m asl	(reference point for all measurements)
assumed fresh water head	:	433.0	m asl	(assumed hydrostatic)
end of drilling	:	17.10.2007 09:55		(Geotec)
porosity	:	3%		(assumed)
mud density [7)]	:	1032	kg/m^3	(Geotec end of drilling, 17.10.07)
borehole water density	:	997	kg/m^3	(Geotec after circulation of fresh water, 17.10.07; estimated using P2)
formation water density [8)]		1002.1	kg/m^3	(PVT correlation calculated by Saphir)
specific storativity [9)]	:	2.19E-06	m^{-1}	
formation water viscosity [8)]	:	7.13E-04	Pa s	(PVT correlation calculated by Saphir)
fluid compressibility [8)]	:	4.33E-10	1/Pa	(PVT correlation calculated by Saphir)
total compressibility	:	7.43E-09	1/Pa	(calculated assuming c_f= 7.00E-09 1/Pa)

7) Taken from daily report No. 53
8) Assumed, using salinity 10'000 ppm, T = 42 °C, P = 6100 kPa
9) Calculated based on assumed porosity and compressibility values

Responible Test Engineers	
Onsite:	Fisch, H.R.; Reinhardt, S.
Test analysis and reporting:	Fisch, H.R., Dale, T.

Test Summary		
Test objectives	:	transmissivity, static formation pressure, flow model
borehole history	:	drilling through midpoint of interval on 12.10.2007 08:00; 213.9 h duration until start of test
geology	:	limestone - marl interbedded strata
geophysics	:	Caliper log, salinity log, temperature log, sonic log
test phases	:	COM, PSR, PI, SW, SWS, PI2

QLR results	**Test zone 590.00 - 640.04 mbgl**	**T [m2/s]**	**K [m/s]**	**Formation Flow model**	**Freshwater Head [m asl]**
Analytical interpretation		1.0E-11	2.0E-13	radial flow	-
Numerical simulation		1.79E-11	3.58E-13	homogeneous	454.5

Note:
A complete list of results is provided in the summary tables

Mönchaltorf, 08. March 2008, Revision 1 prepared by: SOLEXPERTS INTERA

Summary of Test Data Page 1/3

Test Phase		INF	COM	PSR 2)	PI_a 3)
duration	[h]	1.072	0.825	3.563	0.024
T2 (i/f)	[°C]	41.89 / 41.54	41.54 / 41.65	41.65 / 41.54	41.54 / 41.32
P1 (i/f)	[kPa]	5832 / 5868	5868 / 5879	5879 / 5904	5904 / 5904
P2 (i/f)	[kPa]	5815 / 5813	5813 / 5816	5816 / 5852	5852 / 6797
P3 (i/f)	[kPa]	5819 / 5819	5819 / 5814	5814 / 5812	5812 / 5810
P4 (i/f)	[kPa]				
Measured C	[m^3/Pa]				9.4E-10
q	[l/min]				
Q	[l]				
inner boundaries		no analysis	no analysis	wellb. storage	no analysis
flow geometry				hom.	
outer boundaries				inf.lat.ext.	
T	[m^2/s]			1.38E-09 A)	
K	[m/s]			2.76E-11 A)	
k	[m^2]				
Ss	[1/m]			2.63E-05 A)	
S	[-]			1.32E-03 A)	
Pi, P_f if matched	[kPa]			6045.05 A)	
Head	[m asl]			452.4 C)	
Derived flow rate	[l/min]				
s (skin factor)	[-]				
S_{SS} (skin zone)	[1/m]				
t_S (skin zone)	[m]				
K_S (skin zone)	[m/s]				
figures		1	1	1,10,11	5
temperature effects				no	
borehole history				yes	
anomalies				no	
bypass PA2				no	
bypass PA1				no	

comments

notes:
- i = initial, f = final
- T, K values in bold most representable of the undisturbed formation

1) analytical with no superposition
2) numerical simulation with detailed borehole history effects
3) The Pulse Injection phase was divided into two phases.
The first, PI_a, includes mulitple pressure increases.
The second, PI_b, is the post-shutin (recovery) sequence.
4) The SW phase was impacted by water leaking across slim-line packer.
5) Opitimized fit on PSR, PI_b, and SWS

A) matched parameter
B) input parameter
C) calculation assumes: freshwater density 1000 kg/m^3, g = 9.81 m^2/s, Patm and sensor depth as stated on front page
D) early-middle time fit
E) extrapolated head

Summary of Test Data Page 2/3

Test Phase		PI_b[1)]		PI_b[2) 3)]		SW[4)]	SWS[2)]	
duration	[h]	4.994		4.994		3.865	15.817	
T2 (i/f)	[°C]	41.32 / 41.42		41.32 / 41.42		41.42 / 41.42	41.42 / 41.56	
P1 (i/f)	[kPa]	5904 / 5925		5904 / 5925		5925 / 5935	5935 / 5967	
P2 (i/f)	[kPa]	6797 / 6326		6797 / 6326		4971 / 5101	5101 / 5559	
P3 (i/f)	[kPa]	5810 / 5834		5810 / 5834		5834 / 5831	5831 / 5826	
P4 (i/f)	[kPa]							
Measured C	[m^3/Pa]							
q	[l/min]							
Q	[l]							
inner boundaries		wellb. storage		wellb. storage		no analysis	wellb. stor.	
flow geometry		hom.		hom.			hom.	
outer boundaries		inf.lat.ext.		inf.lat.ext.			inf. lat. ext.	
T	[m^2/s]	9.76E-12	A)	3.14E-11	A)		1.20E-11	A)
K	[m/s]	1.95E-13	A)	6.27E-13	A)		2.40E-13	A)
k	[m^2]							
Ss	[1/m]			9.74E-06	A)		3.02E-05	A)
S	[-]			4.87E-04	A)		1.51E-03	A)
Pi, P_f if matched	[kPa]	5851.48	B)	6300	A)		6078.5	A)
Head	[m asl]	432.7	C)	478.37	C)		455.79	C)
Derived flow rate	[l/min]					~2E-3 [6)]		
s (skin factor)	[-]							
S_{SS} (skin zone)	[1/m]							
t_S (skin zone)	[m]							
K_S (skin zone)	[m/s]							
figures		1,5,6		1,12		1,8	1,13,14	
temperature effects		no		no			no	
borehole history		yes		yes			yes	
anomalies		no		no			no	
bypass PA2		no		no			no	
bypass PA1		no		no			no	

comments

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3) The Pulse Injection phase was divided into two phases.
The first, PI_a, includes mulitple pressure increases.
The second, PI_b, is the post-shutin (recovery) sequence.
4) The SW phase was impacted by water leaking around the slim-line packer
5) Opitimized fit on PSR, PI_b, and SWS
6) Calculated based on meas. C and SWS unit-slope (rough estimate)
A) matched parameter
B) input parameter
C) calculation assumes: freshwater density 1000 kg/m^3, g = 9.81 m^2/s, Patm and sensor depth as stated on front page
D) early-middle time fit
E) extrapolated head

Summary of Test Data

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Test Phase		PI2 [1]		Simulation entire Seq.[5]		Simulation entire Seq.[5]		
duration	[h]	0.439		30.16		30.16		
T2 (i/f)	[°C]	41.6 / 41.6		41.89 / 41.56		41.89 / 41.56		
P1 (i/f)	[kPa]	5966 / 5966		5832 / 5967		5832 / 5967		
P2 (i/f)	[kPa]	5869 / 5782		5815 / 5558		5815 / 5558		
P3 (i/f)	[kPa]	5828 / 5828		5819 / 5826		5819 / 5826		
P4 (i/f)	[kPa]							
Measured C	[m^3/Pa]	8.5E-10						
q	[l/min]							
Q	[l]							
inner boundaries		wellb. storage		wellb. stor.		wellb. stor. & skin		
flow geometry		hom.		hom.		hom.		
outer boundaries		inf.lat.ext.		inf. lat. ext.		inf. lat. ext.		
T	[m^2/s]	5.45E-12	A)	**1.79E-11**	A)	1.92E-11	A)	
K	[m/s]	1.09E-13	A)	**3.58E-13**	A)	3.83E-13	A)	
k	[m^2]							
Ss	[1/m]			1.55E-05	A)	3.62E-05	A)	
S	[-]			7.76E-04	A)	1.81E-03	A)	
Pi, P_f if matched	[kPa]	5559.1	B)	6065.6	A)	6574.7	A)	
Head	[m asl]	402.85	C)	**454.48**	C)	506.37	C)	
Derived flow rate	[l/min]							
s (skin factor)	[-]					-0.127		
S_{SS} (skin zone)	[1/m]					4.18E-05	A)	
t_S (skin zone)	[m]					0.01	A)	
K_S (skin zone)	[m/s]					4.17E-11	A)	
figures		9		15,16		17,18		
temperature effects		no		no		no		
borehole history		no		yes		yes		
anomalies		no		no		no		
bypass PA2		no		no		no		
bypass PA1		no		no		no		

comments

notes:
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E) extrapolated head

Test overview

Test Oftr-i2 (590.0 - 640.04 m bgl) was performed on 21.-22.10.2007 in the Oftringen NOK EWS-Borehole. The test interval consisted of a sequence of marls with interbedded limestone layer (623.8-628.0 m bgl). The test objectives were to obtain reliable estimates of interval transmissivity, and fresh-water hydraulic head using an appropriate flow model. The test was performed with a straddle-packer configuration with an interval length of 50.04 m. Pressures and temperatures were measured in the test interval (P2, T2) and in the interval below the lower packer (P1, T1) and in the annulus above the upper packer (P3, T3). In addition, pressure was measured in the tubing above the upper packer (P4).

The pressure response of the entire test sequence in Oftr-i2 is shown in **Figure 1**. The pressure history derived from water table measurements (source: Colenco, Solexperts) and fluid density measurements (SJ Geotec) is presented in **Figure 2**.

Following packer inflation (INF) the test sequence started with a COM and PSR phase to dissipate temperature and borehole history effects.

Temperature effects are considered negligible, because downhole temperatures (T1, T2, T3) indicated only a relatively small gradual trend of approximately 0.2 degree over the entire test duration, with noise of the same magnitude.

The pulse injection test (PI) was performed to measure the wellbore compressibility early in the test and obtain an initial estimate of the formation properties. Issues with the pressure regulation equipment at the start of the PI resulted in a non-ideal pressure increase and thus the PI was separated into two sections for the analysis. The pressure increase phase was labeled as PI_a with the subsequent shut-in recovery phase labeled as PI_b.

The slug withdrawal (SW) test was terminated once it was determined that water was bypassing the slim-line packer and entering the annulus of the test tubing. The SW was terminated and followed by the shut-in phase (SWS). The SW/SWS test was performed to get a more distinct formation response combined with a larger radius of investigation for the determination of the formation properties.

After the SWS sequence a pulse injection test was performed to confirm system compressibility.

Due to the influence of the adjacent high voltage current transformer facility (NOK), the pressure and temperature signals of the downhole triple probe were noisy during the hole testing sequence.

Analysis

For the QLR analysis, the analytical and numerical methods were used for a standard analysis, which will be the basis for a possible detailed analysis depending on the test objectives and test results.

Analytical Analysis

Type curve and straight-line fitting methods are applied. Effects of the borehole pressure history are not taken into account.

Pulse injection test (PI)

The PI test was initiated at unsteady pressure conditions during PSR while P2 was showing an upward trend of 2.1E-3 kPa/s. Prior to starting the pulse test, the "injection head" was screwed on top of the tubing and connected to a bottle of pressurized nitrogen with pressure reduction valve. The pressure regulation valve was adjusted after opening the shut-in valve. The adjustment resulted in a step-wise increase of interval pressure **Figure 5**. The pulse injection phase with open shut-in valve (PI_a) lasted 88 s and a differential pressure of 945 kPa was attained before shut-in.

After shut-in, a water level change equal to 0.705 m was measured in the 1.9" test string (dip meter measurement), indicating an added volume of 0.886 liters due to compression of the test zone. The wellbore storage constant C ($\Delta V/\Delta P$) equals to 9.4E-10 m^3/Pa. For the PI analysis, the history effect of the precedent relatively long PI_a period was not taken into account.

The pulse response was analyzed using CBP type-curves. Three analysis versions are presented. The analysis shown in **Figure 6** is based on uncorrected data. The early-middle time fit using an α-type-curve of value 10 provides a transmissivity estimate of 9.8E-12 m^2/s.

For the analysis shown in **Figure 7**, the P2 data were corrected assuming a linear pressure trend of +0.002 kPa/s. As the shape of the data curve and the model curve diverge, the results of both early and late time matches are provided. T-values of 1.1E-11 m^2/s (early time) and 3.5E-12 m^2/s were obtained based on a type-curve value α = 10. Note that the CBP type-curve matching method is not sensitive for high α-values as α type-curves greater 1 are difficult to distinguish with respect to the slope steepness. High α values are associated with high aquifer storativity values (S). As storativity estimates from pulse test analyses are commonly known as unreliable, the S and S_S results are not presented.

Slug test withdrawal test (SW)

The SW test was only analyzed using nSights (see below). Prior to start of the SW test, the water table in the 1.9" tubing was lowered to 95 m bgl (change of tubing water level does not affect the interval pressure while the shut-in tool is closed). A slim tubing was installed in the 1.9" NU API rods before start of SW. The slim tubing system consists of a stiff high pressure hose of ID = 9.5 mm and a packer at its bottom (OD =28 mm). The packer is inflated using pressurized nitrogen, sealing the annulus between the 1.9” tubing and the slim tubing. The slim tubing was installed to a depth of approximately 90 m bgl, covering the span of expected water table change of the slug test. A pressure transducer attached just above the packer and with connection to the tube inside enables recording of water level changes, redundantly to the P2 sensor. The small diameter of the slim tubing allows for faster slug recovery.

Prior to start of SW, the P2 pressure curve showed a decreasing trend of -0.0043 kPa/s. The SW test was started 5.0 hours after start of PI. Leaking around the slim tubing packer was noticed during the SW test. The analysis of SW is not possible because the water level rise in the annulus between slim tubing and 1.9” tubing was not measured, hence an equivalent radius is not deducible. A rough estimate of the production flow rate at end of SW was obtained from the analysis of the subsequent shut-in phase (SWS, see below).

Recovery phase of slug test (SWS)

The slug test was shut-in after 3.9 hours and further pressure recovery (SWS) was recorded for 15.8 hours. The early-time data of SWS were analyzed in a log-log plot to derive the last production rate of the precedent SW phase. The estimate is based on measured C-values (PI, PI2) and the ‘unit slope’ identifying the early-time pressure recovery phase with one log cycle pressure change per one log cycle of time (**Figure 8**). The result of 2.0 ml/min has to be considered as an indicative value. No further analytical analysis was conducted on the SWS data in view of the apparent history effects due to the precedent test events PSR, PI, SW.

Second pulse injection test (PI2)

A pulse injection test (PI2) was performed in order to confirm the C-value obtained during PI_a. During preparation of PI2, the water in the 1.9” test rods was filled up to a level 6 cm below top of tubing. In the 0.5 hrs prior start of PI, the P2 pressure curve showed a rising slope of 0.003 kPa/s. PI2 was initiated by open the shut-in valve exposing the test zone to a differential pressure of 310 kPa. A water level decrease Δh equal to 0.21 m was measured in the 1.9” test string, indicating a volume change of 0.264 liters due to compression of the test zone. The wellbore storage constant C (ΔV / ΔP) equals to 8.5E-10 m^3/Pa, a value comparable to the result obtained from PI_a (C=9.4E-10 m^3/Pa).

The PI2 test was recorded during a period of 0.44 hrs. A pressure recovery of 30% is obtained after correcting a linear trend of 0.003 kPa/s (**Figure 9**). The CBP match on the corrected data suggests a T-value of 5.4E-12 m^2/s.

nSights Analysis

In a first step, the diagnostic plots or Ramey graphs for the individual sequences were analyzed and fitted individually accounting for borehole history and taking into account of transient effects associated with the preceding test sequences. In a second step, the entire test sequence was simulated and fitted based on the Cartesian pressure plots. For the Cartesian fit, all test phases except the PI2 phase and except the history periods were chosen. 250 data points on a log scale were fitted for each of the test sequences PSR and SWS. A static spacing of 2.78E-03 hrs was chosen for the fit points of PI in order to obtain a better fit to the late time data of PI. The so-called history periods BH, INF1, INF2, COM and PI_a were not fitted but incorporated as test events with defined pressure in the simulation process. PI_a denotes a short event of 0.0244 hrs duration and represents the transitional phase during initiation of the pulse test (open shut-in valve phase at start of pulse tests). PI2 was not included in nSights analysis for this QLR but will be analyzed during the standard or detailed interpretation.

The diagnostic plots of the individual test sequences did not indicate characteristic responses of a composite flow model, or any other more complex flow models. Consequently, a homogeneous model was assumed in this first evaluation for estimating formation parameters (i.e., K, S_s, and P_f). The analyses used the wellbore compressibility of 1E-9 m^3/Pa which is very similar to 9.4E-10 m^3/Pa determined from PI.

The log-log diagnostic plot of the PSR indicates dominantly well-bore storage effects (**Figure 10**) providing only preliminary estimates of formation parameters (K = 2.76E-11 m/s, S_s= 2.6E-5 m^{-1}, P_f = 6044.2 kPa), which produced a good fit of the observed data (**Figure 10**) and for the Horner plot (**Figure 11**).

The initial pressure increase phase (PI_a, **Figure 5**) was incorporated as a pressure history sequence. The diagnostic plot of the PI_b sequence in terms of the normalized pressures produced a relatively poor fit (**Figure 12**) and yielded parameters different from the PSR (K = 6.27E-13 m/s, S_s= 9.74E-6 m^{-1}, P_f = 6300 kPa). Please note that the fit of the Ramey plots for the PI sequence is the result of the inverse parameter estimation using nSights and represents a solution of a numeric process that includes the effects of potential transient effects of the preceding test phases and the borehole history.

The SW sequence was incorporated as a pressure history sequence for the SWS analysis. The SWS log-log diagnostic plot (**Figure 13**) indicates the transition from the wellbore storage dominated period to the infinite-acting-radial flow (IARF) period. The analysis produced a good fit (K = 2.40E-13 m/s, S_s= 3.02E-5 m^{-1}, P_f = 6078.5 kPa) to the log-log diagnostic (**Figure 13**) and the Horner (**Figure 14**) plots. The K and S_s values are similar to the PI_b analysis but the P_f estimate is lower and more similar to the value for the PSR.

The simulation of the entire test sequence on a Cartesian plot (**Figure 15**) produced the fitted parameters (K = 3.58E-13 m/s, S_s= 1.58E-5 m^{-1}, P_f = 6065.6 kPa) that were most similar to the individual SWS fit (**Figure 13**). This is seen in (**Figure 15**) with poor fits to the earlier sequences (PSR and PI_b) but a good fit to the SWS sequence. The sensitivity coefficients of the formation parameters during the different sequences are presented in (**Figure 16**). This plot indicates that the PI_b test has the greatest sensitivity to the K and S_s parameters even though a good fit to this sequence was not obtained. The SWS sequence is shown to have the greater sensitivity to P_f which would be expected given the longer duration and greater pressure recovery of the sequence.

Because of the difficulty in obtaining a good fit to both the early and late time pressure curve for the PI_b sequence, a composite flow model was assumed and a fit to the Cartesian pressure curve of the entire testing sequence was conducted (nSights uses a composite model approach to simulate skin effects). The visual fit to the entire sequence (**Figure 17**) is better than for the homogeneous model with similar formation parameters except for a significantly higher P_f (K = 3.84E-13 m/s, S_s= 3.62E-5 m^{-1}, P_f = 6574.6 kPa). The fitted parameters for the skin (i.e., inner zone) are K_s =4.17E-11 m/s, S_{ss}=4.18E-5 m^{-1}, and t_s=0.01 m (radial thickness of the skin zone). However, even though the visual fit is better, the uncertainty range in the parameter estimates is significantly greater. The range between the upper and lower values for the 95% confidence intervals for the composite model (**Figure 17**) are significantly greater for most of the parameters than that of the homogeneous model (**Figure 15**). The resulting fit to the PI_b normalized pressure plot resulting from the composite model fit to the entire testing sequence is shown in **Figure 18**. The simulated curves (solid lines) show multiple slope changes at early time which are not observed in the field data. Therefore, there is insignificant data to indicate that the use of a composite model is appropriate.

Results and Discussion

The estimated formation parameters for the different sequences vary significantly based on a homogeneous flow model. The range in K varies between 2.4E-13 m/s (T=1.2E-11 m^2/s) and 2.8 E-11 m/s (T=1.4E-09 m^2/s). The range in S_s varies between 9.7E-6 m^{-1} to 3.0E-5 m^{-1}. The range in P_f is between 6044 kPa to 6300 kPa. This range in properties is due to the relatively poor fit of the early time sequences (PSR and PI_b) which may be influenced by the transient effects of the preceding borehole pressure history. The SWS sequence shows consistent parameter values between the sequence only fit and the entire testing sequence fit and thus these are considered the more representative parameter values.

FIGURES

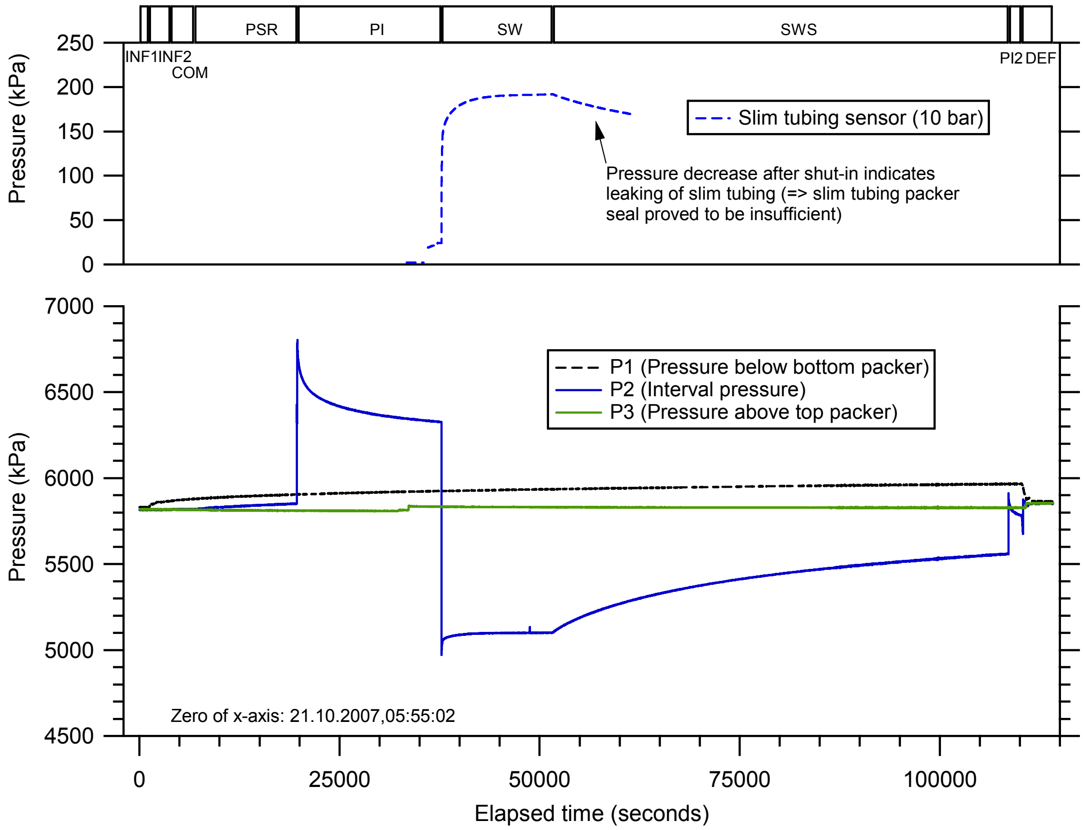


Figure 1: Oftr-i2: Overview plot

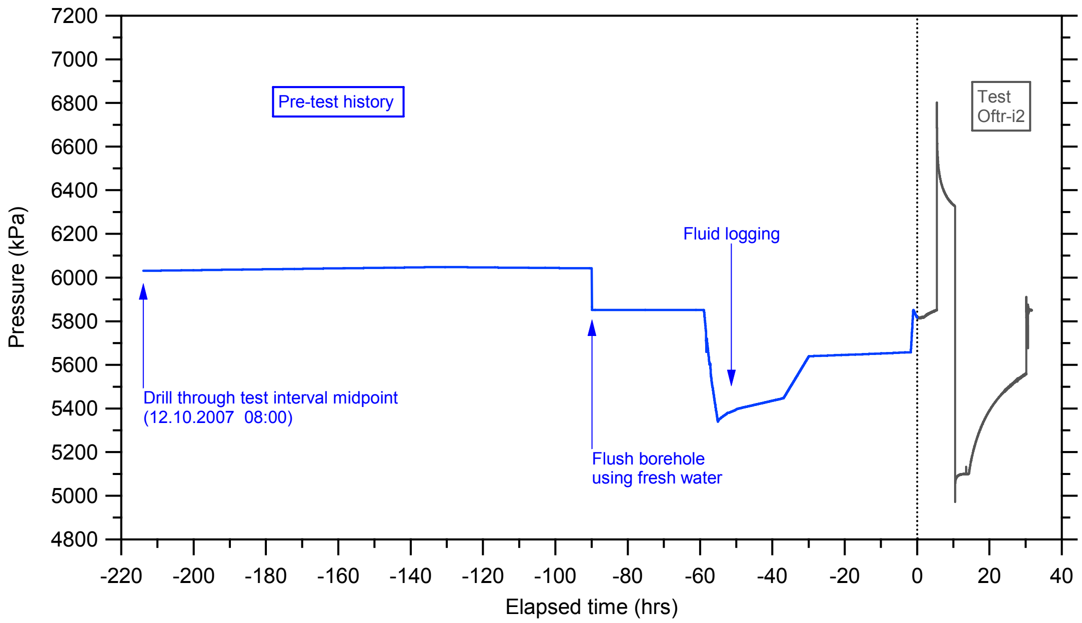


Figure 2: Oftr-i2: Borehole pressure history

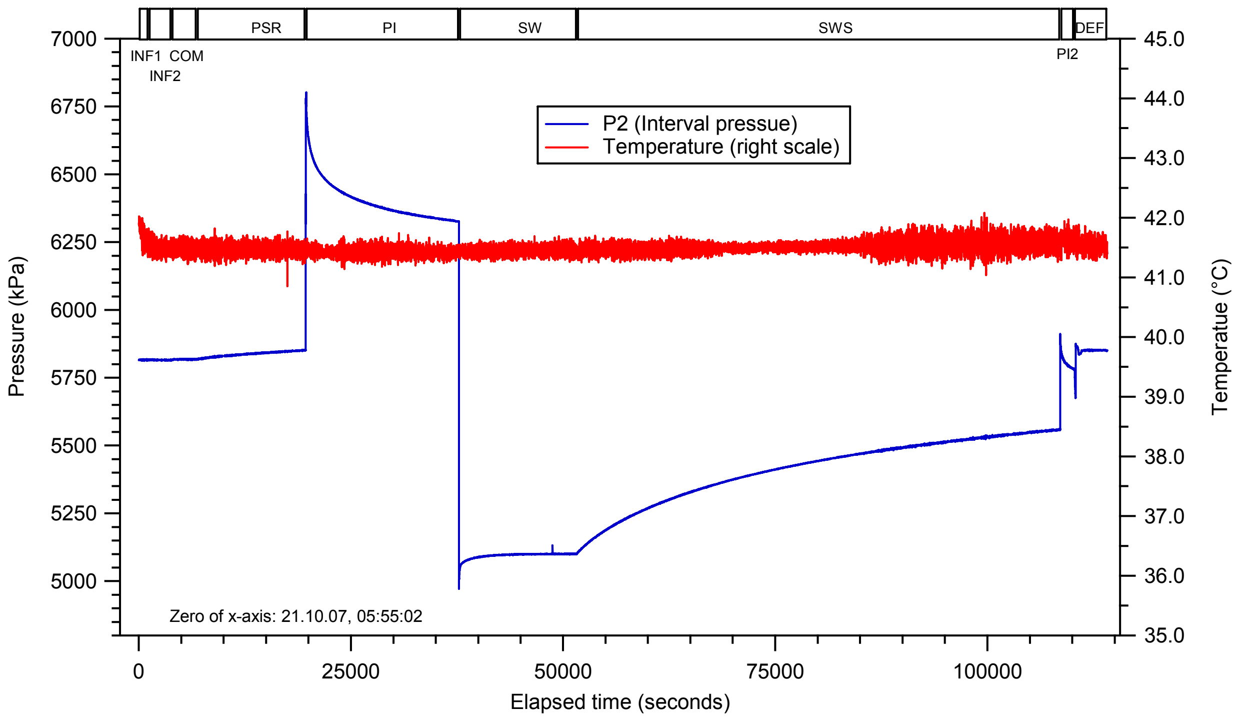


Figure 3: Oftr-i2: Measured downhole temperature (right scale)

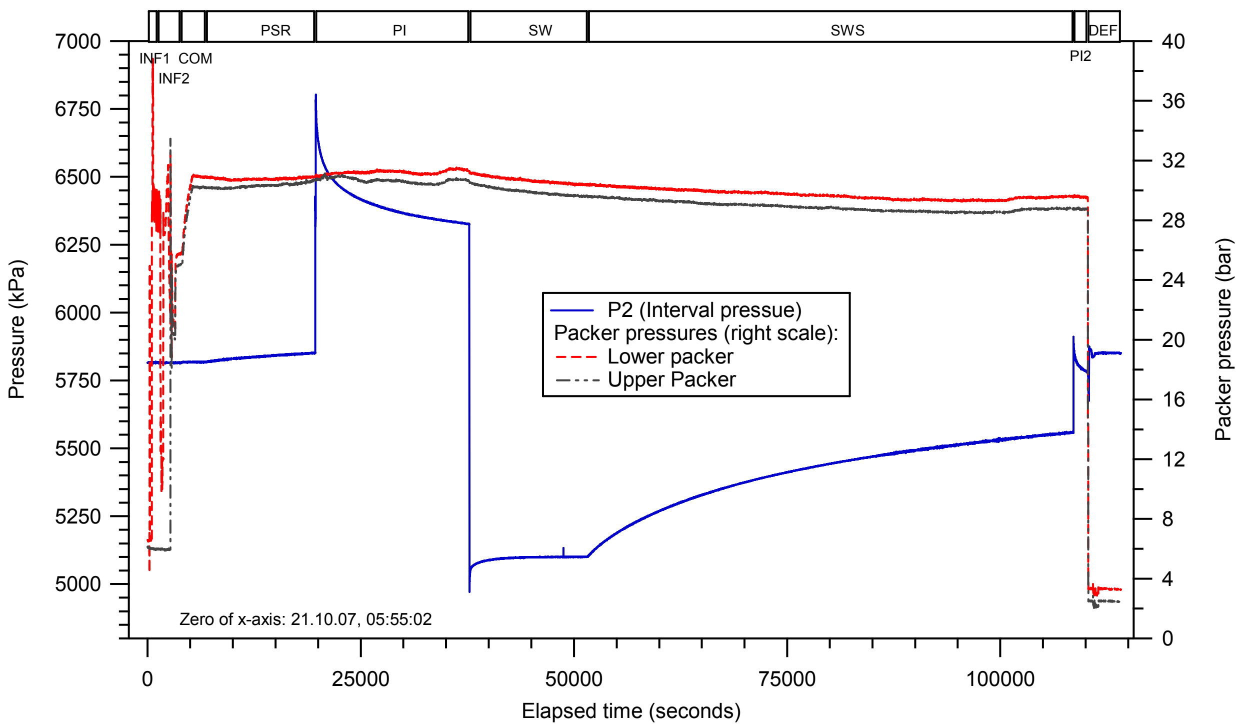


Figure 4: Oftr-i2: Measured packer pressure (right scale)

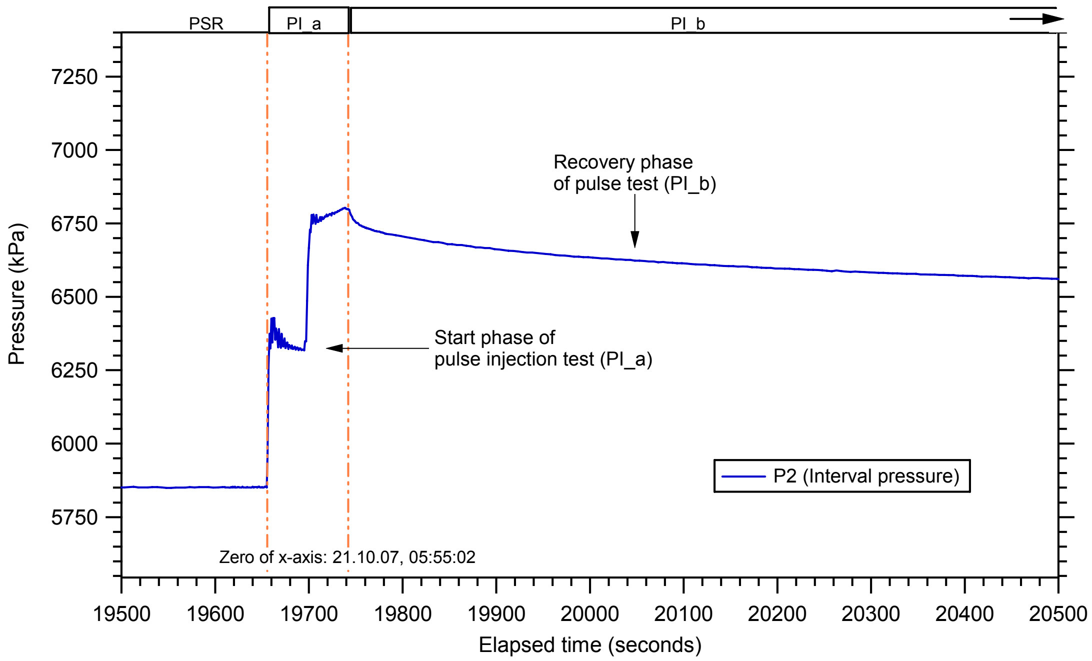


Figure 5: Oftr-i2: Detail of pulse injection test

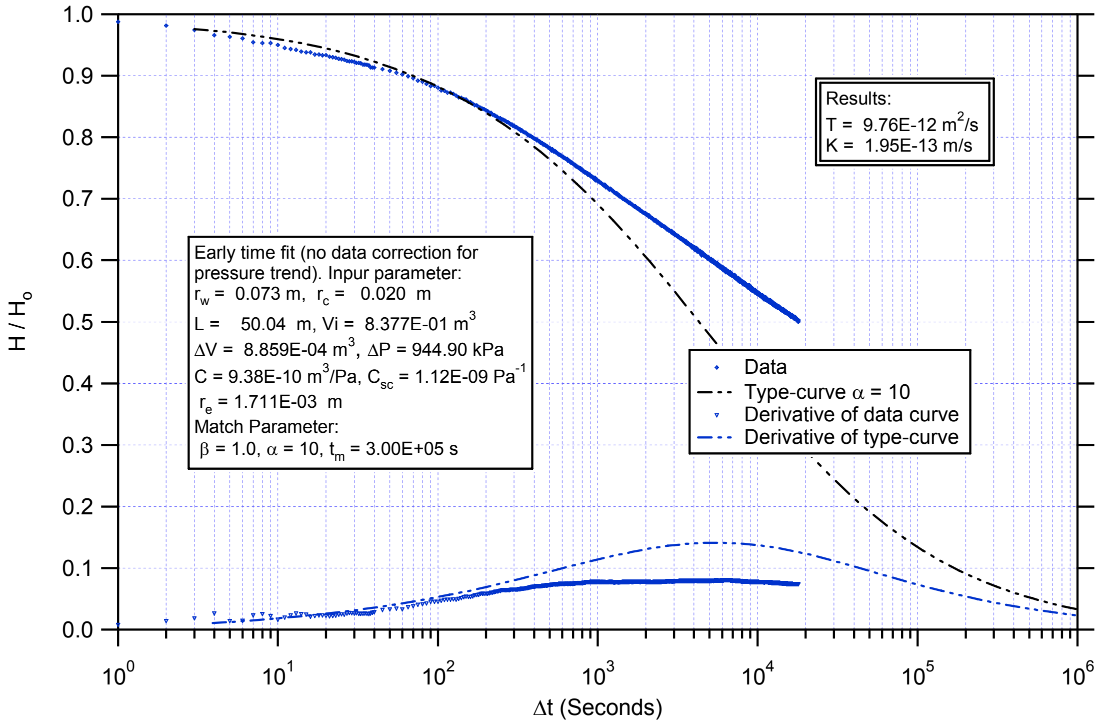


Figure 6: Oftr-i2: PI_b test analysis using CBP type-curves

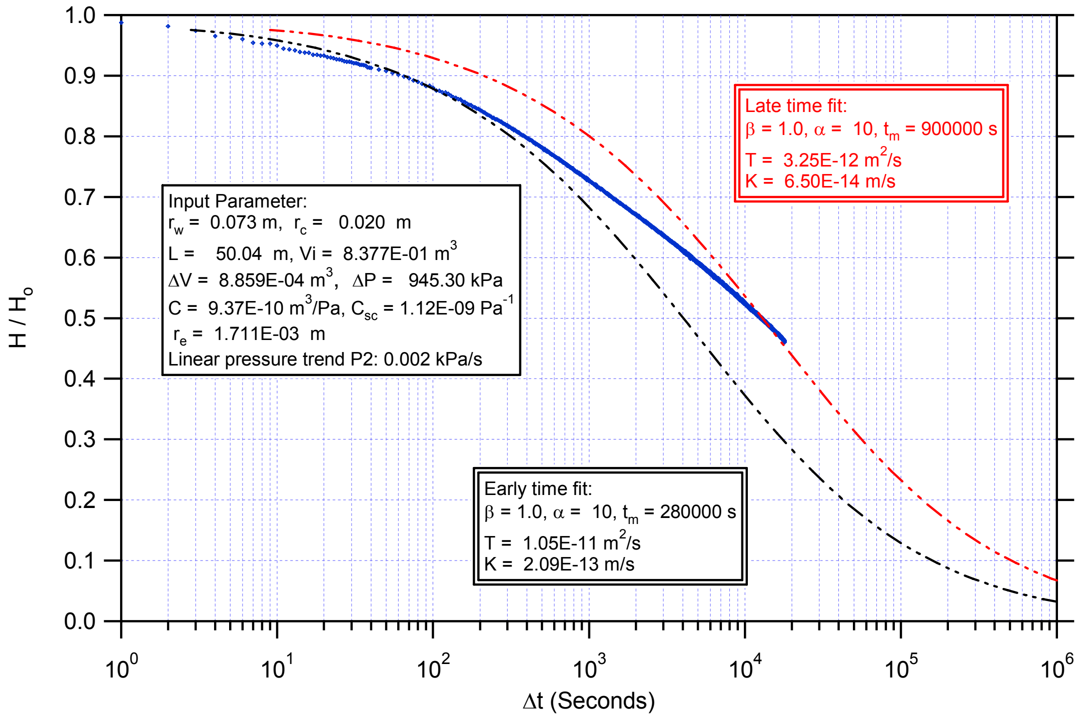


Figure 7: Oftr-i2: PI_b test analysis (CBP) based on trend corrected data.

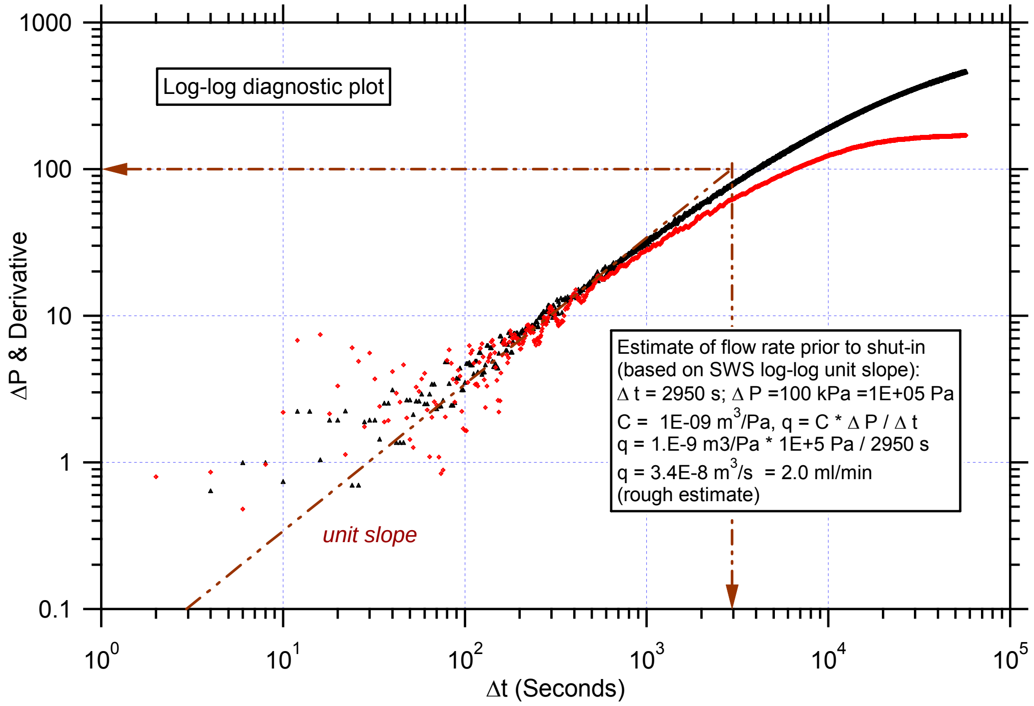


Figure 8: Oftr-i2: Estimate of q_e of SW based on log-log unit slope of SWS

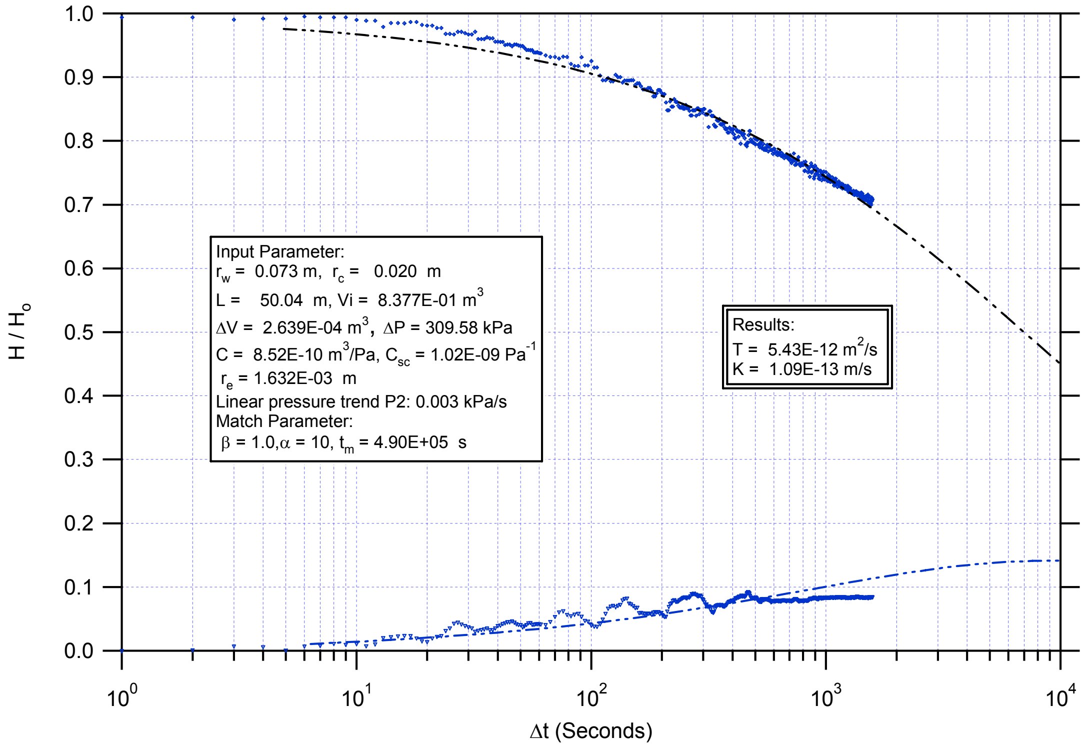


Figure 9: Oftr-i2: PI2 test analysis (CBP) based on trend corrected data

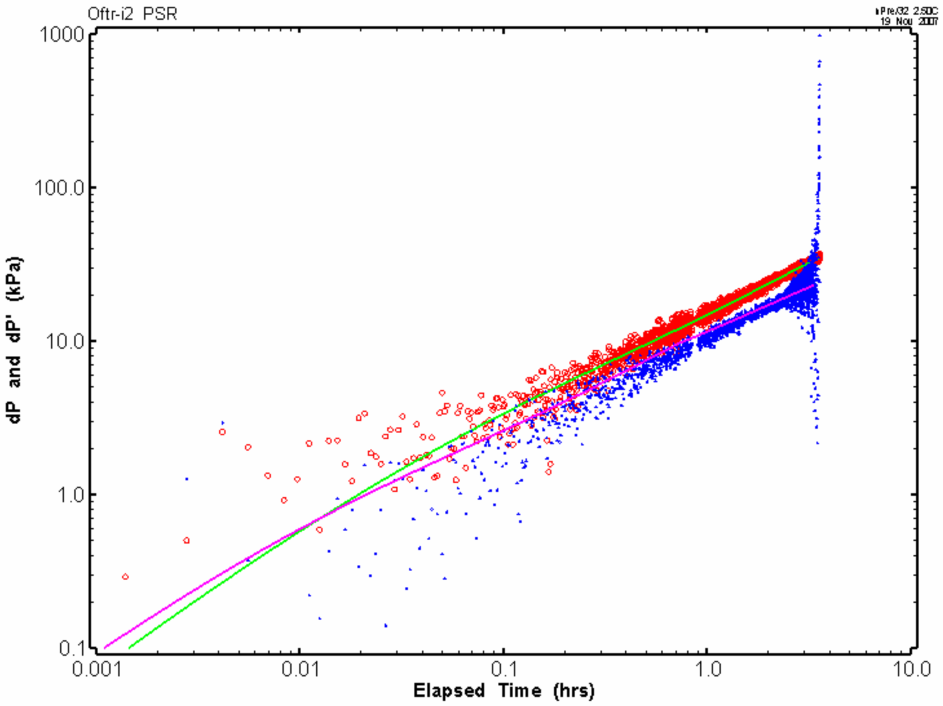


Figure 10: Oftr-i2: PSR log-log diagnostic plot

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_fm	[m/sec]	2.79E-11	2.65E-11	2.94E-11
P_fm	[kPa]	6045.1	6040.9	6049.2
ss_fm	[1/m]	2.68E-05	2.37E-05	3.01E-05

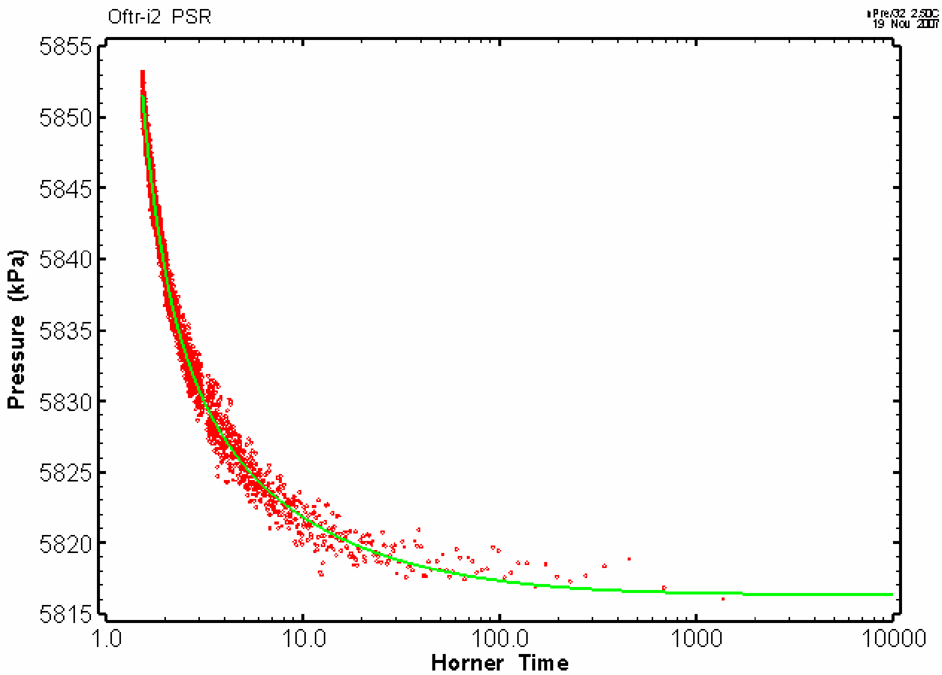
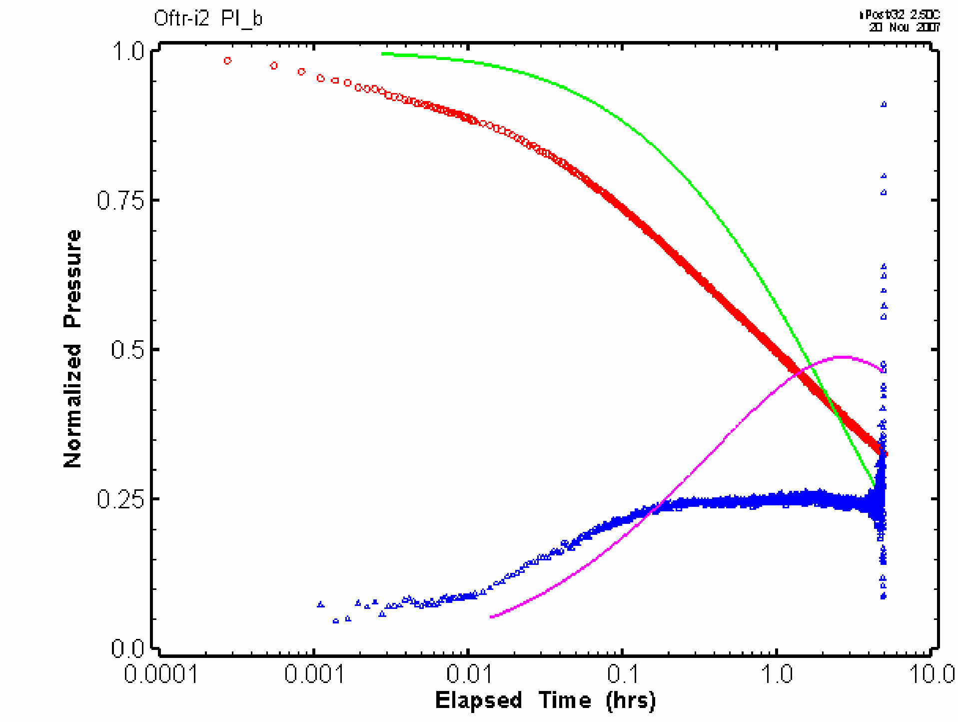


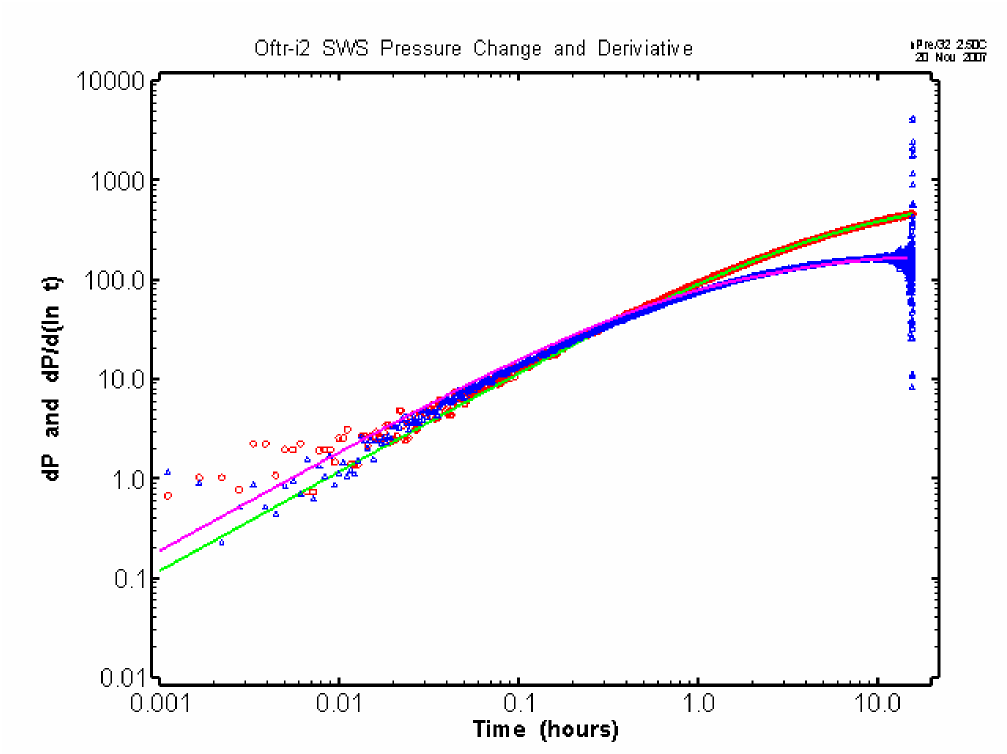
Figure 11: Oftr-i2: PSR Horner plot



Fit Statistics:

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_fm	[m/sec]	6.27E-13	1.68E-13	2.35E-12
P_fm	[kPa]	6300.0	6220.1	6379.9
ss_fm	[1/m]	9.74E-06	1.81E-06	5.24E-05

Figure 12: Oftr-i2: PI_b normalized pressure (Ramey A) plot.



95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_fm	[m/sec]	2.40E-13	2.23E-13	2.58E-13
P_fm	[kPa]	6078.5	6062.6	6094.5
ss_fm	[1/m]	2.96E-05	2.70E-05	3.26E-05

Figure 13: Oftr-i2: SWS log-log diagnostic plot

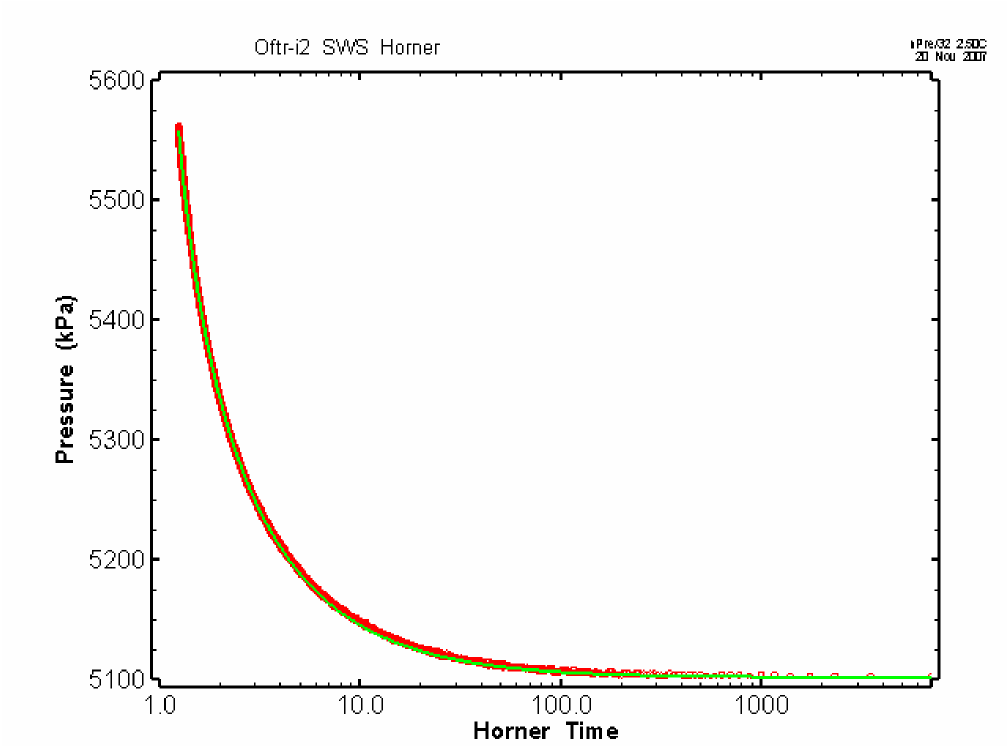
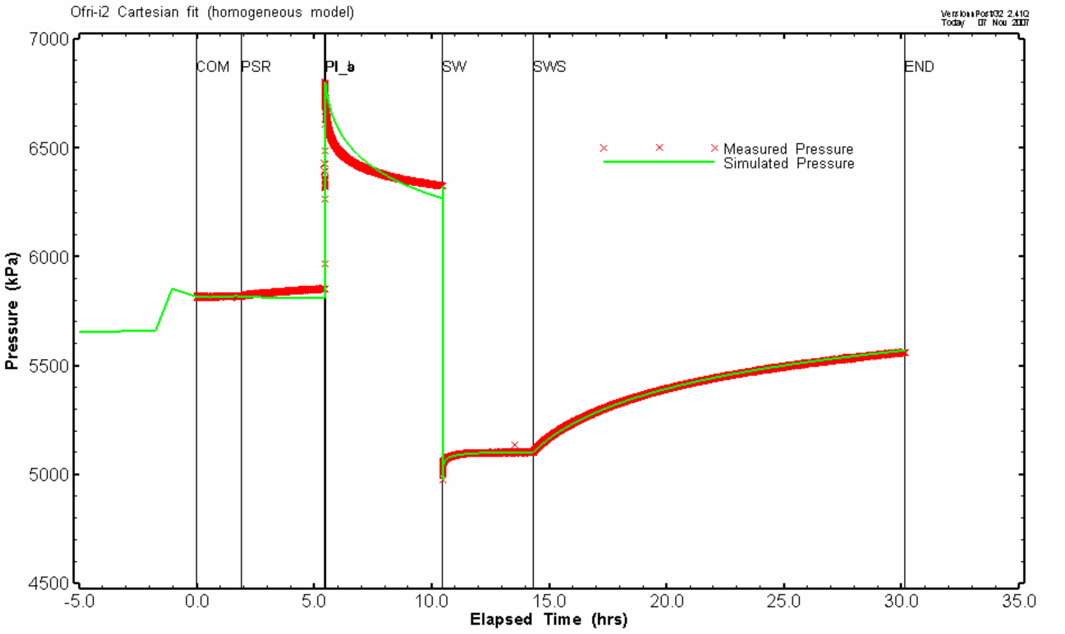


Figure 14: Oftr-i2: SWS Horner plot



Fit Statistics:

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_fm	[m/sec]	3.58E-13	3.18E-13	4.03E-13
P_fm	[kPa]	6065.6	6039.9	6091.4
ss_fm	[1/m]	1.55E-05	1.29E-05	1.86E-05

Figure 15: Oftr-i2: Cartesian fit of the entire test for homogeneous model

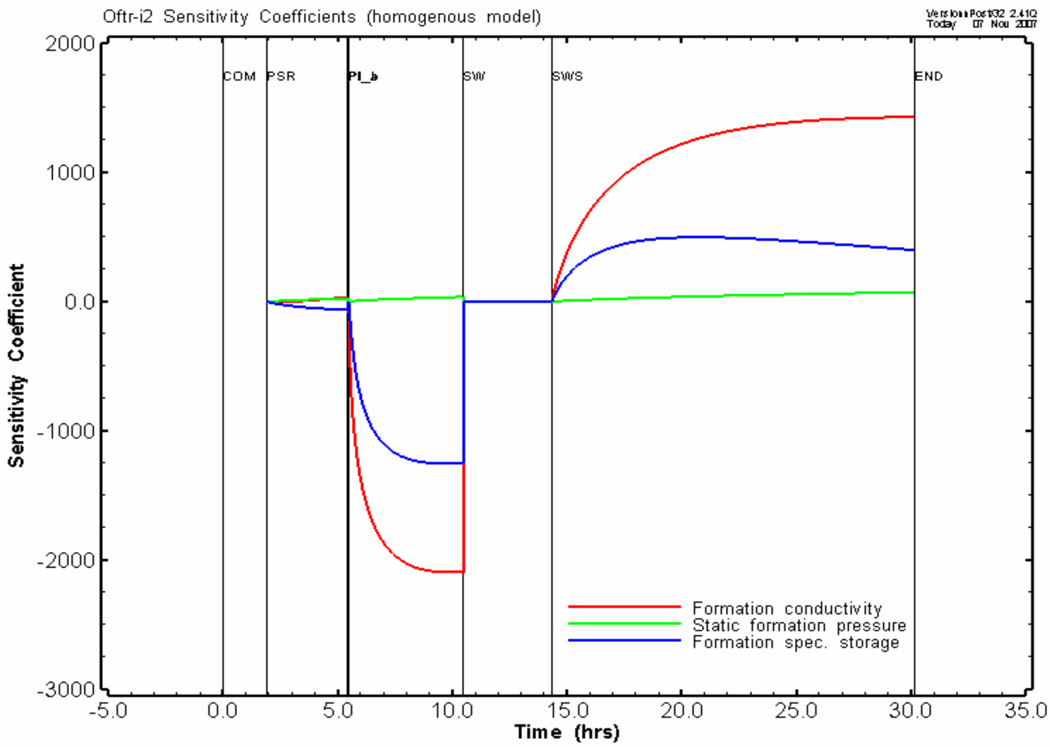
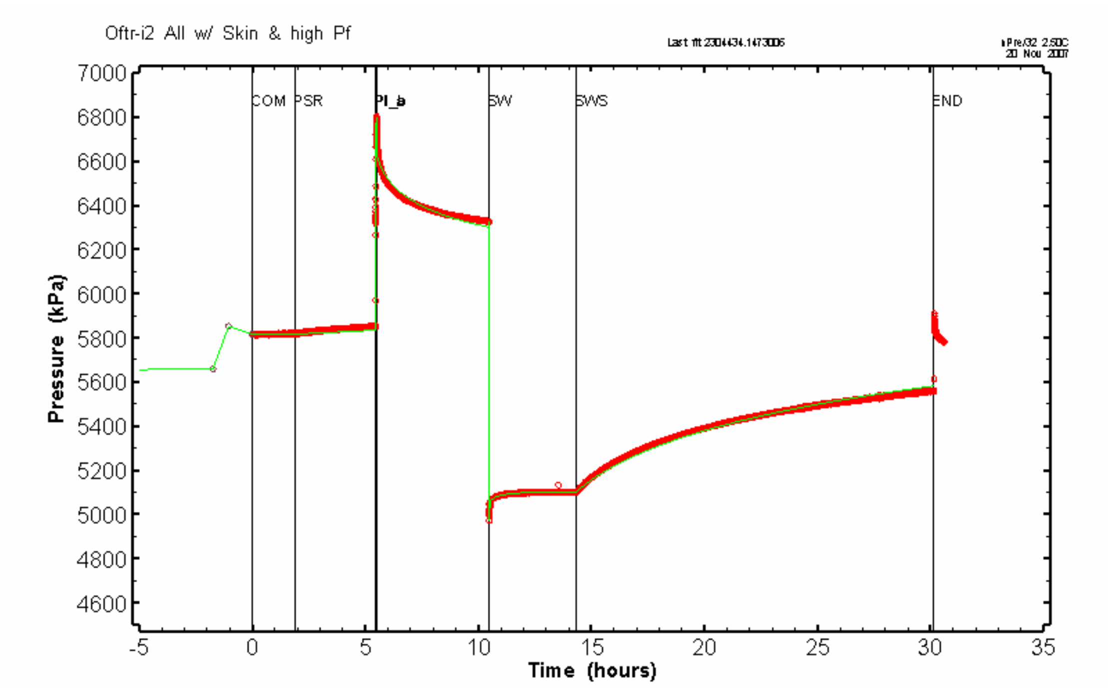


Figure 16: Oftr-i2: Sensitivity coefficients for the different formation parameters during the different sequences (homogenous model)



Fit Statistics:

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_fm	[m/sec]	3.84E-13	2.74E-13	5.36E-13
K_s	[m/sec]	4.17E-11	5.54E-16	3.14E-06
P_fm	[kPa]	6574.7	6525.0	6624.3
ss_fm	[1/m]	3.62E-05	2.02E-06	6.49E-04
ss_s	[1/m]	4.18E-05	1.05E-10	1.66E+01
t_s	[m]	0.01	-0.11	0.13

Figure 17: Oftr-i2: Cartesian fit of the entire test for composite model

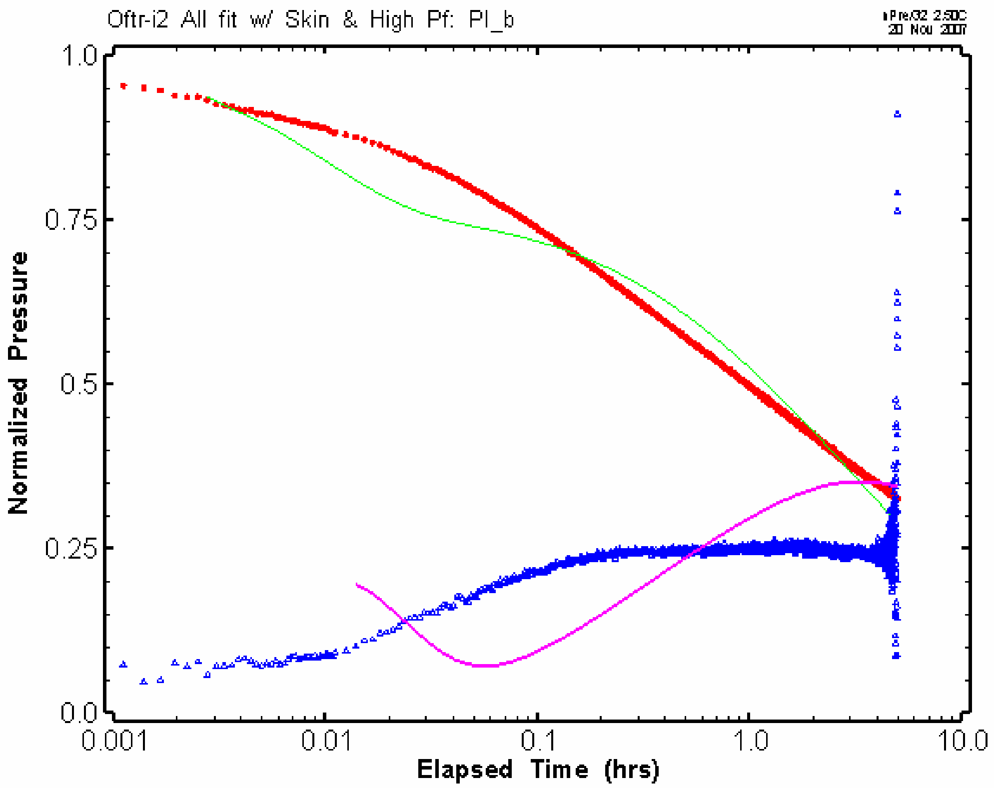


Figure 18: Oftr-i2: PI_b normalized pressure (Ramey A) plot
(using the Cartesian fit parameters to the entire composite model)

Abbreviations

	Test phases
COM	Compliance
INF	Packer inflation
INF1	Inflation of lower packer (INF2 = Inflation of upper packer)
DEF	Packer deflation
DEF1	Deflation of lower packer (DEF2 = Deflation of upper packer)
PSR	Static pressure recovery (shut-in valve closed)
SI	Slug injection test
SIS	Pressure recovery after slug injection test (shut-in)
SW	Slug withdrawal test
SWS	Pressure recovery after slug withdrawal test (shut-in)
PI	Pulse injection test
PW	Pulse withdrawal test
HI	Constant head injection test (constant pressure difference)
HIS	Pressure recovery after constant head injection test (shut-in)
HW	Withdrawal test applying constant differential head
HWS	Pressure recovery after constant head withdrawal test (shut-in)
MR	Multi-rate test: Test with variable flow rate
MRS	Pressure recovery after test with variable flow rate
RW	Pump test with constant flow rate
RWS	Pressure recovery after pump test with constant flow rate (shut-in)
RI	Constant flow injection test
RIS	Pressure recovery after constant flow injection test (shut-in)
VC	Shut-in valve is closed
VO	Shut-in valve is open
	General
CBP	Cooper, Bredehoeft, Papadopulos (type-curve matching method)
DAS	Data acquisition system
FS	Full scale
IARF	Infinite Acting Radial Flow
LC	Log cycle
m agl	Meters above ground level
m bgl	Meters below ground level
m asl	Meters above sea level
OD	Outer diameter
PVT	Pressure volume temperature correlation
SLA	Straight-line analysis
TOC	Top of casing
WL	Water level (or WT = Water table)

Nomenclature

	Description	SI-Unit		Description	SI-Unit
b	Y-intercept of linear regression		S_S	Specific storativity	m^{-1}
C	Wellbore storage constant	$m^3\ Pa^{-1}$	S_{SS}	Specific storativity of skin zone	m^{-1}
C_S	Wellbore storage constant, shut-in	$m^3\ Pa^{-1}$	s	Skin factor	-
C_D	Dimensionless wellbore constant	-	t, Δt	Time, elapsed time	s
c_f	Pore volume based compressibility	Pa^{-1}	t_C	Critical time	s
c_r	Rock compressibility	Pa^{-1}	t_D	Dimensionless time	-
c_{SC}	System compressibility (= test zone compressibility c_{tz})	Pa^{-1}	Δt_e	Equivalent time (after Agarwal)	s
c_w	Water compressibility	Pa^{-1}	Δt_H	Horner time	-
Δh	Differential head	m	t_p	Production time	s
g	Acceleration of gravity (9.81)	$m\ s^{-2}$	t_p*	Corrected production time	s
h_S	Static head	m	t_m	Match time	s
k	Intrinsic permeability	m^2	t_0	X-intercept of linear regression	s
K, K_f	Hydraulic conductivity of formation () special case	m/s	t_s	Thickness of skin zone	m
K_s	Hydraulic conductivity of skin zone () special case	m/s	T	Transmissivity	m^2/s
L	Interval length	m	T_W	Water temperature	°C
m	slope (regression)		z_1	P1 sensor depth	m
P	Pressure	Pa, kPa	z_2	P2 sensor depth	m
P_0	Minimal or maximal pressure	Pa, kPa	z_3	P3 sensor depth	m
P_{atm}	Probe signal at atmospheric pressure	Pa, kPa			
ΔP	Differential pressure, pressure change	Pa, kPa	α ,β	Type-curve match parameter	-
P_D	Dimensionless pressure	-	α	aquifer compressibility	Pa^{-1}
P_f	Static formation pressure	Pa, kPa	μ	Dynamic viscosity	Pa·s
P_i	Initial pressure	Pa, kPa	θ	Porosity	-
$P_{min/max}$	Minimal/maximal pressure	Pa, kPa	ρ_w	Density of fresh water	kg/m^3
P_{S1}	Static pressure in P1-Interval (below bottom packer)	Pa, kPa			
P_{S2}, P_f	Static pressure in test interval	Pa, kPa			
P_{S3}	Static pressure in annulus (above upper packer)	Pa, kPa			
q	Flow rate	$m^3\ s^{-1}$			
q_{end}, q_e	Last flow rate	$m^3\ s^{-1}$			
Q, Q_{tot}	Cumulative flow	m^3			
r_e	Effective radius (Slug, Pulse test)	m			
R_i	Radius of influence	m			
R^2	Correlation coefficient	-			
r_c	Tubing radius	m			
r_w	Wellbore radius	m			
R_1	Radius, composite model	m			
R_D	Dimensionless radius	-			
S	Storativity	-			
S_C	Sensitivity coefficient				
S_{SC}	Scaled sensitivity coefficient				

Definitions

$C_D = \dfrac{\rho\, g\, C}{2\pi\, S\, r_{w^2}}$	Wellbore constant, dimensionless
$H_D = \dfrac{P - P_i}{P_0 - P_i}$	Dimensionless pressure (slug und pulse tests)
$K = \dfrac{k\, \rho\, g}{\mu}$	Hydraulic conductivity
$P_D = \dfrac{2\pi\, T\, \Delta h}{q}$	Dimensionless pressure
$\Delta P = \rho\, g\, \Delta h$	Differential pressure
$q_D = \dfrac{q}{2\pi\, T\, \Delta h}$	Dimensionless flow
$t_D = \dfrac{t\, T}{r_w^2 S}$	Dimensionless time
$S = S_S\, L$	Storativity
$s = \left(\dfrac{K_f}{K_s} - 1\right) \ln\left(\dfrac{r_w + t_s}{r_w}\right)$	Skin factor
$S_S = \rho\, g\, (\alpha + \theta\, c_w)$	Specific storativity
$S_C = \dfrac{\partial P}{\partial r}$	Sensitivity coefficient.

where ∂P is the partial derivative of the calculated system response (i.e., pressure) with respect to a parameter varied by the derivative span ∂r .
For comparison of sensitivity coefficients for different parameters, the sensitivity coefficients are typically scaled by inverses of the respective standard deviations as follows:

$$S_{sc} = S \frac{\sigma_r}{\sigma_P} = \frac{\partial P}{\partial r} \cdot \frac{\sigma_r}{\sigma_P}$$

where S_{sc} is the scaled sensitivity coefficient, σ_r is the a priori standard deviation of the measurement error, and σ_P is the estimated standard deviation of the parameter.
If not otherwise stated, default values σ_r = 1 and σ_P = 1 were used.

Definitions (continued)

T = K L	Transmissivity
$\frac{t_D}{C_D} = \frac{2\pi T t}{\rho\ g C}$	Dimensionless time axis
$t_e = \frac{t_p \cdot \Delta t}{t_p + \Delta t}$	Dimensionless Agarwal time (Agarwal, 1980)
$t_e^* = \frac{t_P^* \cdot \Delta t}{t_P^* + \Delta t}$	Modified Agarwal time (using corrected production time)
$t_P^* = \frac{Q}{q_{end}}$	Modified production time (Ehlid-Economides and Ramey, 1980)

Oftringen Hydraulic Testing: Interval 2: 590 – 640 m

Date	***Time***	***Activity***	***Who***
21.10.07	*05:19*	*Start moving system to position Oftr-i2*	*SR, PH*
	05:51	*System on position*	
	05:55	***Interval 2: 590.00 – 640.04 m*** *Start file: Oftr_2007_10_19_oftr_i2.dat* *P1 = 5831.74 kPa* *P2 = 5816.12 kPa* *P3 = 5818.67 kPa* *T1 = 41.91 °C* *T2 = 42.01 °C* *T3 = 41.95 °C* *Water table: 2.23 m bgl*	
	06:02	*Change scan rate to 5 s*	
	06:02	*INF PA1 (20 bar)*	
	06:14	*Packer seal at borehole wall*	
	06:19	*Booster fails*	
	06:26	*Continuation inflation PA1 with pressure tank*	
	06:39	*INF PA2 (22 bar)*	
	06:58	*Packer seal at borehole wall, start COM*	
	07:00	*Fi arrives on site*	*Fi*
	07:15	*FP, Sti arrive on site*	*FP Sti*
	07:30	*SR, PH leave site*	*SR, PH*
	07:48	*Shut-in, start PSR*	
	10:45	*Connect ground cable between winch and trailer*	
	10:00	*Phone conservation with Fbe. Start pulse withdrawal or pulse injection.*	
	11:05	*Start preparation for Pulse injection test (PI)* *Fill tubing with fresh water up to the top.*	
		Water table in test rod is 6 cm below top of tubing. *Install injection head on top of tubing rods with 6/4mm pressure line connect to nitrogen bottle.* *P2 = 5852 kPa*	
	11:21:50	*Scan rate set to 1 second*	
	11:23	*Start PI* *Pressure increased first by about 500 kPa, then pressure increased again up to a differential pressure of 930 kPa (regulation of high range pressure reduction valve on nitrogen bottle does not allow fine adjusting => other valve is required!). Pressure duration between open valve and close valve is 88 seconds.*	
	11:24:45	*Scan rate set to 5 second*	
	11:40	*Scan rate set to 10 second*	
		Water table Water table in test rod is 0.765 m below top of rod => Δs = 0.705 m	
	12:00 – 14:00	*Additional ground cables connected aiming to reduce data noise*	
	15:05	*Start swabbing to approximately 95 m below top of tubing*	
	15:11	*Slim-Tubing pressure transducer connected to DAS, measuring atmospheric pressure: P = 2.3 kPa*	
	15:15:	*Swabbing causes increase in P3 pressure (some of the produced water entered the annulus)*	
		Scan rate set to 5s prior start of SW. *P2 pressure at end of PI = 6324.12 kPa*	

Date	***Time***	***Activity***	***Who***
21.10.07	*16:23:50*	*Start SW (P2 = 4996.55 kPa)*	*Fi, FP, Sti*
	18:00	*SR, PH arrive on site*	*SR, PH*
	18:05	*Fi leaves site*	*Fi*
	19:00	*FP, Sti leave site*	*FP, Sti*
	20:00	*Pressure recovery: 1.7 mm per minute (0.0167 kPa/min)*	
	20:14	*Scan rate 2 s*	
	20:15	*Shut in, start SWS*	
	20:21	*Scan rate 5 s*	
	22:30	*Slim tubing packer pressure is 12 bar (constant)*	
	22:45	*Slim-tubing move out of borehole*	
	23:40	*Fill up tubing with fresh water (leak test) up to the top*	
22.10.2007	*00:46*	*Scan rate 10 s*	*SR, PH*
	02:15	*Water level in tubing remains stable=> no leakage*	
		Leak rate in slim tubing at start of SWS (approx end of SW) was about 1.4 ml/min. From WBS-unit-slope (SWS): 2 ml/min assuming C = 1E-9 m3/Pa	
	06.45	*Arrival on site*	*Fi, FP*
		Discussion about observed leak of slim tubing packer, phone call to Fbe	
	08:15	*SR und PH leave site*	*SR, PH*
	08:40	*Slim tubing packer tested in 1.9“ API rod. Packer inflation = 12 bar. Injection pressure ~2 bar. Packer bypass can be observed. Conclusion: Slim tubing packer requires higher inflation pressure for reliable seal*	
		nSights-Analysis of whole test sequence	
	11:50	*Decision taken with Fbe: Add pulse injection, PI-duration 20 minutes and then DEF and move to next interval position*	
		Water table in test rod is 6 cm below top of tubing.	
	12:04:39	*Start PI2 (without using pressurized gas).* *Water table in 1.9 NU tubing is oscillating after opening of the valve*	
	12:10	*Water table after shut-in: 27.0 cm below top of casing.* Δs *= 21.0 cm,* ΔP *= 311 kPa* *C =* $\Delta V / \Delta P$ *= 0.21 m ** Π ** 0.02^2 / 311’000 Pa = 8.49E-10 m3/Pa* *C-sc = C /* $V_{interval}$ *= 8.49E-10 m3/Pa / 0.838 m3 = 1.0E-09 1/Pa*	
	12:38	*Deflate packers, open shut-in valve*	
	12:53	*Refill annulus, water table is maintained at top of casing.* *Outflow level is 2.0 – 0.58 m = 1.42 m above ground* *P1 = 5865.32 kPa (avg).* *P2 = 5851.58 kPa (avg)* *P2 (calc) = 586.86 + 1.42 = 588.28 m*9.81 = 5771.03 kPa* *P3 = 5853.37.kPa (avg)* *Offset P2 = 80.55 kPa (assuming* ρ *= 1000 kg/m*^{3}*)*	
	13:35	*Packer system is not free although P1,P2,P3 measure same water level*	
	13:37	*Stop file*	
	14:10	*Start moving system to position Oftr-i3*	
	14:48	*System on position*	

Fi *Hansruedi Fisch (Solexperts)*
FP *Fredi Portmann (Solexperts)*
SR *Sacha Reinhardt (Solexperts)*
Sti *Daniel Stillhard (Solexperts)*
PH *Peter Haller (Solexperts)*

Fbe *Dr. Bernd Frieg (Nagra)*

Form

INSTALLATION RECORD HDDP

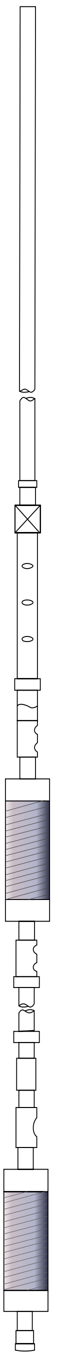
SOLEXPERTS

Seite 1 / 1

Oftringen NOK EWS Borehole: Hydraulic Testing

Date	21.10.2007	**Project Leader**	Fi/SR						
Borehole	NOK EWS 2007	**Direction**	vertical	**Reference point**	433.0	**JOB Nr**	1763	**Location**	Oftringen
Borehole Depth	719.0 m	**Casing depth**	376.5 m bgl	**Interval lenght**	50.04 m	**Test Name**	oftr_i2	**System**	HDDP 110
Borehole diameter	146 mm	**Stickup**	-3.36 m bgl	**Water depth**	2.23 m bgl	**Test depth (UPLS)**	590.00 m bgl	**Probe ID**	TSSP S1

Note: All dephts shown are not correct for borehole deviation



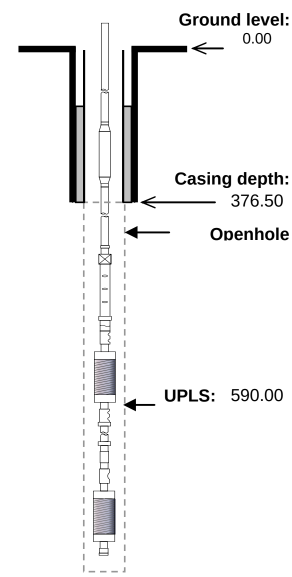
Component		Qty -	L unit m	L total m	Depth m	OD mm	ID mm	Wgt kg	Str t
Stickup	-3.36 m bgl								
Ground level					0.00				
Tubing 1.9" NU			586.09	586.09		56.1	40.3	2403	12.0
Pop joint			1.02		582.73	56.1	40.3	4.2	12
SIT Non Displacement Valve			0.84			79.0	24.0	20.6	15
Probe Shell Carrier mit Triple Sub	TSSP P3		1.97		586.56	70.0	10.9	48.0	25
	TSSP P2		0.30		586.86				
	TSSP P1		0.30		587.16				
			0.04						
X-Over	2"3/8 EU Pinx1.9" NU Box		0.51	7.27		66.0	40.0	2.1	16
Safety joint 3"1/16						78.0	50.5	5.5	24
Above Side Entry Sub (ASES)			0.52			66.0	32.0		24
Packer Stick Up			0.26			--	25.0		
Up. Packer Seal — **Upper Packer**	UPUS		0.26		588.75				
			1.25			108.0	32.0	82.4	17
	UPLS		0.24		590.00				
Straddle Length — **Packer Stick Down**			0.31			--	25.0		
Below Side Entry Sub (BSES)			0.52			66.0	32.0		24
X-Over	1.9" NU Pinx2"3/8 EU Box		0.26			--		3.0	16
Tubing 1.9" NU			45.5			56.1	40.3	186.6	12
X-Over	2"3/8 EU Pinx1.9" NU Box		0.45	50.04		--		3.0	16
			0.3						
Filter	Screen		1.45			72.0	50.0	19.0	19
			0.3						
P1-Seal Sub			0.3			78.0	--		24
Packer Stick Up			0.16			--	32.0		
Lower Packer Seal — **Lower Packer**	LPUS		0.25		640.04				
			1.25	1.92		110.0	32.0	70.2	17
	LPLS		0.24		641.29				
Packer Stick Down			0.43			--	32.0		
End Cap					641.96	78.0	--		
End of Borehole					719.00				

Comments:

Water table in borehole prior to packer inflation: 2.23 m bgl

1) Sensor signals at atmosphere: measurements date from 19.10.07

Borehole configuration:



Probe	523 006.1	
values at atmosphere [1]	P1	107.8
	P2	92.2
	P3	102.3
	P4	101.0
	T1	11.4
	T2	11.0
	T3	10.6
Total Weight (kg)	2868.1	

Form

TALLY LIST

SOLEXPERTS

Borehole	NOK EWS 2007	Interval name	Test Oftr_i2	Date	21.10.2007
Depth	719.0 m	Interval depth	590 - 640 m	Location	Oftringen

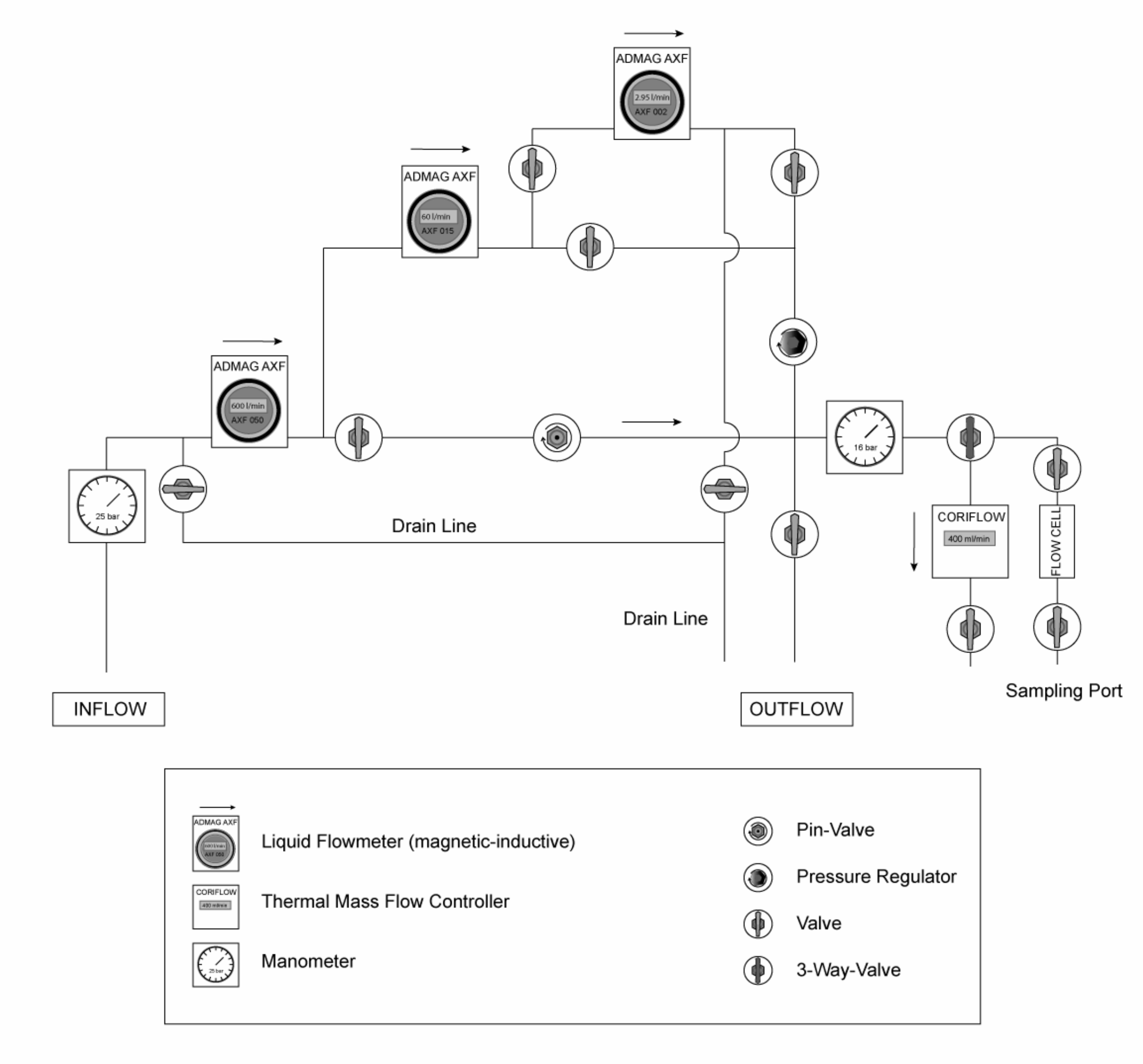
TU	1	6.51	TU	51	6.50					
TU	2	6.51	TU	52	6.51					
TU	3	6.51	TU	53	6.51					
TU	4	6.51	TU	54	6.51					
TU	5	6.51	TU	55	6.51					
TU	6	6.51	TU	56	6.51					
TU	7	6.51	TU	57	6.50					
TU	8	6.51	TU	58	6.51					
TU	9	6.51	TU	59	6.51					
TU	10	6.50	TU	60	6.51					
TU	11	6.50	TU	61	6.50					
TU	12	6.51	TU	62	6.50					
TU	13	6.50	TU	63	6.50					
TU	14	6.51	TU	64	6.50					
TU	15	6.51	TU	65	6.51					
TU	16	6.51	TU	66	6.50					
TU	17	6.51	TU	67	6.50					
TU	18	6.51	TU	68	6.51					
TU	19	6.50	TU	69	6.50					
TU	20	6.51	TU	70	6.50					
TU	21	6.51	TU	71	6.47					
TU	22	6.50	TU	72	6.50					
TU	23	6.51	TU	73	6.48					
TU	24	6.50	TU	74	6.50					
TU	25	6.50	TU	75	6.50					
TU	26	6.50	TU	76	6.50					
TU	27	6.50	TU	77	6.50					
TU	28	6.50	TU	78	6.50					
TU	29	6.50	TU	79	6.51					
TU	30	6.50	TU	80	6.51					
TU	31	6.50	TU	81	6.51					
TU	32	6.50	TU	82	6.50					
TU	33	6.51	TU	83	6.51					
TU	34	6.51	TU	84	6.50					
TU	35	6.50	TU	85	6.48					
TU	36	6.51	TU	86	6.50					
TU	37	6.50	TU	87	6.51					
TU	38	6.50	TU	88	6.50					
TU	39	6.51	TU	89	5.94					
TU	40	6.50	TU	90	5.94					
TU	41	6.51	TU	91	1.85					
TU	42	6.51	TU							
TU	43	6.50	TU							
TU	44	6.50	TU							
TU	45	6.50	TU							
TU	46	6.50	TU							
TU	47	6.51	TU							
TU	48	6.51	TU							
TU	49	6.51	TU							
TU	50	6.51	TU							
		325.28			260.81		0.00		0.00	

Total string length:	586.09

Form

SURFACE EQUIPMENT LAYOUT

Page 1/1



Flow meter	Lower limit of measuring range	(% of FS)	Upper limit of measuring range (l/min)	Accuracy between 3% and 100% of FS (% of rate)	Accuracy between 1% and 3% of FS (% of rate)	Equipment used
AXF DN2	0.030 l/min	1 %	2.95 l/min	0.35	0.5	no
AXF DN15	0.6 l/min	1 %	60 l/min	0.35	0.5	no
AXF DN50	11.78 l/min	1 %	1178.10 l/min	0.35	0.5	no
Coriflow	0.50 kg/h	2 %	25.00 kg/h	1	1	no

Form

BENCH TEST

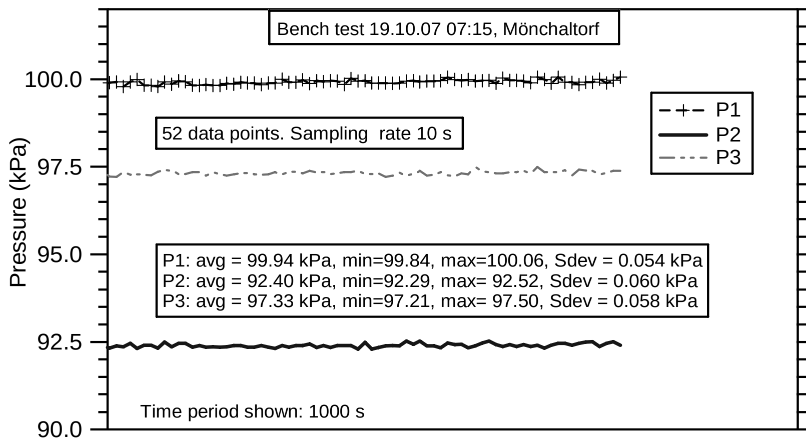
Project	Location	Date
Oftringen NOK EWS Borehole	Oftringen	18.12.2007
Well name	**Test name**	**Engineer**
NOK EWS 2007	Oftri-i1	Fi/SR

Transducer describtion	Output units
P1, P2, P3: 0-206.84 bar (3000 Psi), P4: 0-6 bar, P_{ST} = 0-10 bar	kPa, °C

P1#	P2#	P3#	P4#
43224	50370	43231	591.001.027

Offsite pretest bench test (Date: 19.10.07)

Measurement conditions (P, T and position)	Sampling rate
97.7 kPa 5.6 °C	10 s
( ) direct (x) vertical ( ) horizontal	

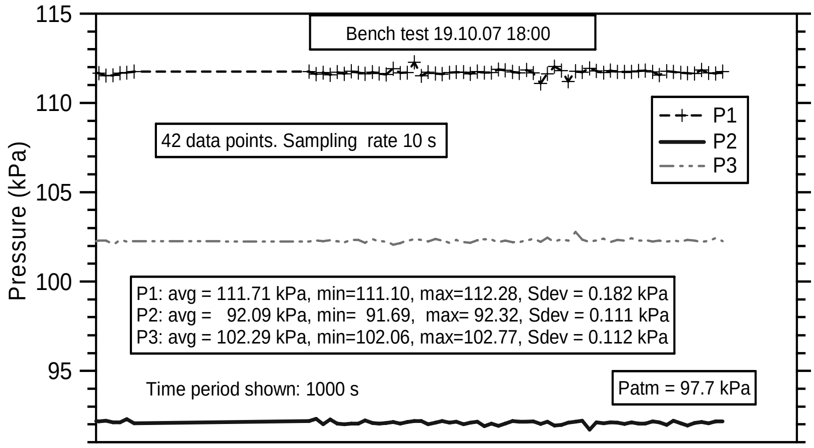


P1 average:	99.84	kPa
P2 average:	92.29	kPa
P3 average:	97.33	kPa
P4 average:	n.m.	kPa
P_{SL} average:	n.m.	kPa
P1 Sdev	0.054	kPa
P2 Sdev	0.060	kPa
P3 Sdev	0.058	kPa

File: TestData24.DAT

Onsite pretest bench test (Date: 19.10.07)

Measurement conditions (P, T and position)	Sampling rate
97.7 kPa 11.0 °C	10 s
( ) direct (x) vertical ( ) horizontal	



P1 average:	111.71	kPa
P2 average:	92.09	kPa
P3 average:	102.29	kPa
P4 average:	101.06	kPa [1)]
P_{SL} average:	3.56	kPa [1)]
P1 Sdev	0.182	kPa
P2 Sdev	0.111	kPa
P3 Sdev	0.112	kPa
P4 Sdev	0.056	kPa [1)]
P_{SL} Sdev	0.019	kPa [1)]

[1)] Data not shown, 20.10.07, 05:45-08:15, File Oftr_2007_10_19_oftr_i1.dat, Patm=97.8 kPa

File: Oftr_2007_10_19_atm0.DAT

Form

BENCH TEST

SOLEXPERTS

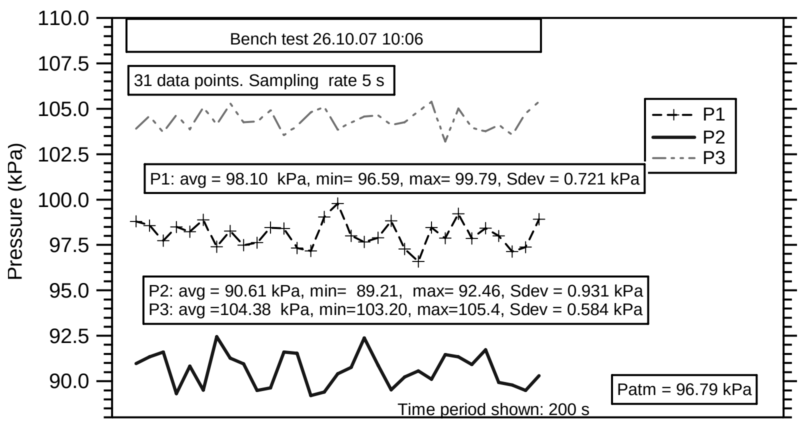
Project	Location	Date
Oftringen NOK EWS Borehole	Oftringen	18.12.2007
Well name	**Test name**	**Engineer**
NOK EWS 2007	Oftri-i1	Fi/SR

Transducer describtion	Output units
P1, P2, P3: 0-206.84 bar (3000 Psi), P4: 0-6 bar, P_{ST} = 0-10 bar	kPa, °C

P1#	P2#	P3#	P4#
43224	50370	43231	591.001.027

Onsite after test bench test (Date: 26.10.07)

Measurement conditions (P, T and position)	Sampling rate
96.4 kPa 7.3 °C	5 s
( ) direct (x) vertical ( ) horizontal	

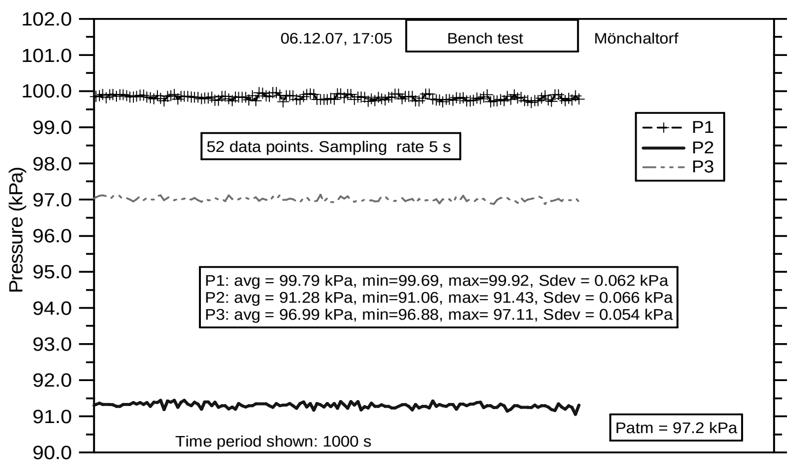


P1 average:	98.10 kPa
P2 average:	90.61 kPa
P3 average:	104.40 kPa
P4 average:	n.m. kPa
P_{SL} average:	n.m. kPa
P1 Sdev	0.721 kPa
P2 Sdev	0.931 kPa
P3 Sdev	0.584 kPa

File: Oftr_2007_10_26_atm2.DAT

Offsite after test bench test (Date: 06.12.07)

Measurement conditions (P, T and position)	Sampling rate
96.6 kPa 9.6 °C	5 s
( ) direct (x) vertical ( ) horizontal	



P1 average:	99.69 kPa
P2 average:	91.28 kPa
P3 average:	96.99 kPa
P4 average: [1]	101.44 kPa
P_{SL} average:	n.m. kPa
P1 Sdev	0.062 kPa
P1 Sdev	0.062 kPa
P2 Sdev	0.066 kPa
P3 Sdev	0.054 kPa
P4 Sdev	0.007 kPa

[1] not shown on graph

File: test8.dat

Appendix C

Quick Look Report
Interval Oftr-i3

nagra.

QUICK LOOK REPORT OFTRINGEN - TEST OFTR-i3

TEST START (Date/Time)	:	22.10.2007 / 14:51	**TEST END (Date/Time)**	:	23.10.2007 / 16:00

DOUBLE PACKER TEST

Test Interval Information	:		top test interval	:	550.00 m bgl
borehole depth [1), 4)]	:	719.0 m	bottom of test interval	:	600.04 m bgl
borehole radius	:	0.073 m	total interval length	:	50.04 m
tubing radius	:	20.0 mm	midpoint of interval	:	575.02 m bgl
			P2-depth (z_2)	:	546.86 m bgl
interval volume, nominal [5)]	:	0.838 m^3	theoretical Cs-value	:	1.68E-09 m^3/Pa
slim tubing radius		4.75 mm	theoretical C-value (slim tube)	:	7.23E-09 m^3/Pa
WL prior to packer inflation [2)]	:	-1.42 m bgl	P2 signal prior to packer inflation	:	5460.70 kPa
WL in annulus at test end [2) 6)]	:	-1.42 m bgl	P2 offset assuming ρ_{avg} = 997 kg/m3		98.2 kPa

1) all depths are not corrected for borehole deviation from vertical
4) all depth measurements refer to ground level
2) WL = water level
5) cylindrical volume of isolated borehole section
3) assumes a total borehole system compressibility of 2E-09 1/Pa
Note all pressures cited in this report are absolute

Preliminariy information			
longitude of borehole	:	240887	
latitude of borehole	:	638346	
elevation of ground level (GL)	:	433.0 m asl	(reference point for all measurements)
assumed fresh water head	:	433.0 m asl	(assumed hydrostatic)
end of drilling	:	17.10.07 09:55	(Geotec)
porosity	:	3%	(assumed)
mud density [6)]	:	1032 kg/m^3	(Geotec end of drilling, 17.10.07)
borehole water density	:	997 kg/m^3	(Geotec after circulation of fresh water, 17.10.07; estimated using P2)
formation water density [7)]		1003.3 kg/m^3	(PVT correlation calculated by Saphir)
specific storativity [8)]	:	2.19E-06 m^{-1}	
formation water viscosity [7)]	:	7.59E-04 Pa s	(PVT correlation calculated by Saphir)
fluid compressibility [7)]	:	4.35E-10 1/Pa	(PVT correlation calculated by Saphir)
total compressibility	:	7.44E-09 1/Pa	(calculated assuming c_f= 7.00E-09 1/Pa)

6) Taken from daily report No. 53
7) Assumed, using salinity 10'000 ppm, T = 38.7 °C, P = 5750 kPa
8) Calculated based on assumed porosity and compressibility values

Responible Test Engineers

Onsite: Fisch, H.R.; Reinhardt, S.

Test analysis and reporting: Rösli U.; Fisch H.R.; Trick Th.

Test Summary

test objectives	:	transmissivity, static formation pressure, flow model
borehole history	:	drilling through midpoint of interval: 10.10.2007, 21:30; 281.346 h duration until start of test
geology	:	mainly marl with interbedded limestone strata
geophysics	:	caliper log, salinity log, temperature log, sonic log
test phases	:	COM, PSR, PI, SW, SWS, PI2

QLR results	**Test zone 550.00 - 600.04 mbgl**	**T [m2/s]**	**K [m/s]**	**Formation Flow model**	**Freshwater Head [m asl]**
Analytical interpretation		2.9E-10	5.8E-12	radial flow	-
Numerical simulation		6.91E-11	1.38E-12	homogeneous	425.5

Note:
A complete list of results is provided in the summary tables

Mönchaltorf, 08.02.08 / 01.08.08, Revision 1 prepared by: SOLEXPERTS INTERA

Summary of Test Data

Test Phase		INF 1+2	COM	PSR 2)	PI 1)	
duration	[h]	0.675	0.364	0.721	4.025	
T2 (i/f)	[°C]	38.83 / 38.80	38.77 / 38.81	38.71 / 38.78	38.71 / 38.75	
P1 (i/f)	[kPa]	5473 / 5501	5502 / 5504	5504 / 5509	5508 / 5527	
P2 (i/f)	[kPa]	5460 / 5462	5461 / 5462	5461 / 5477	6067.8 / 5761	
P3 (i/f)	[kPa]	5462 / 5463	5462 / 5463	5463 / 5462	5460 / 5462	
P4 (i/f)	[kPa]					
Measured C	[m^3/Pa]				1.5E-09	
c_{SC}	[1/Pa]				1.8E-09	
q	[l/min]					
Q	[l]					
inner boundaries		no analysis	no analysis	no analysis	wellb. storage	
flow geometry					hom.	
outer boundaries					inf.lat.ext.	
T	[m^2/s]				3.19E-10	D)
K	[m/s]				6.37E-12	D)
k	[m^2]				4.91E-19	
S_S	[1/m]					
S	[-]					
Pi, P_f if matched	[kPa]				5477	B)
Head	[m asl]				434.44	C)
Derived flow rate	[l/min]					
s (skin factor)	[-]					
S_{SS} (skin zone)	[1/m]					
t_S (skin zone)	[m]					
K_S (skin zone)	[m/s]					
figures					1, 4	
temperature effects					no	
borehole history					no	
anomalies					no	
bypass PA2					no	
bypass PA1					no	

comments

1) analytical with no superposition
2) numerical simulation with detailed borehole history effects

notes:
- i = initial, f = final

- T value in bold most representative of the undisturbed formation

A) matched parameter
B) input parameter
C) calculation assumes: freshwater density 1000 kg/m^3, g = 9.81 m^2/s, P_{atm} and z_2 as stated on front page
D) mid time fit
E) late time fit
F) only early-middle time fit possible

Summary of Test Data		Page 2/3							
Test Phase		PI 1)		PI 2)		SW 1)		SW 2)	
duration	[h]	4.025		4.025		4.043		4.043	
T2 (i/f)	[°C]	38.71 / 38.75		38.71 / 38.75		38.89 / 38.81		38.89 / 38.81	
P1 (i/f)	[kPa]	5508 / 5527		5508 / 5527		5527 / 5539		5527 / 5539	
P2 (i/f)	[kPa]	6067.8 / 5761		6067.8 / 5761		4712/ 4856		4712/ 4856	
P3 (i/f)	[kPa]	5460 / 5462		5460 / 5462		5461 / 5462		5461 / 5462	
P4 (i/f)	[kPa]								
Measured C	[m^3/Pa]	1.5E-09							
c_{SC}	[1/Pa]	1.8E-09							
q	[l/min]								
Q	[l]								
inner boundaries		wellb. storage		wellb. storage		wellb. storage		wellb. storage	
flow geometry		hom.		hom.		hom.		hom.	
outer boundaries		inf.lat.ext.		inf.lat.ext.		inf.lat.ext.		inf.lat.ext.	
T	[m^2/s]	5.78E-12	E)	1.13E-10	A)	1.50E-11	F)	2.88E-10	A)
K	[m/s]	1.15E-13	E)	2.26E-12	A)	3.01E-13	F)	5.76E-12	A)
k	[m^2]	8.91E-21		1.74E-19		4.91E-19		4.44E-19	
S_S	[1/m]			1.00E-05	A)			2.61E-06	A)
S	[-]			5.00E-04	C)			1.31E-04	C)
Pi, P_f if matched	[kPa]	5477	B)	6027.4	A)			4604.6	A)
Head	[m asl]	434.44	C)	490.54	C)			345.51	C)
Derived flow rate	[l/min]								
s (skin factor)	[-]								
S_{SS} (skin zone)	[1/m]								
t_S (skin zone)	[m]								
K_S (skin zone)	[m/s]								
figures		1, 4		1, 8		1, 5		1, 9	
temperature effects		no		no		no		no	
borehole history		no		yes		no		yes	
anomalies		no		no		no		no	
bypass PA2		no		no		no		no	
bypass PA1		no		no		no		no	

comments

notes:
- i = initial, f = final

- T value in bold most representable of the undisturbed formation

1) analytical with no superposition
2) numerical simulation with detailed borehole history effects

A) matched parameter
B) input parameter
C) calculation assumes: freshwater density 1000 kg/m^3, g = 9.81 m^2/s, P_{atm} and z_2 as stated on front page
D) mid time fit
E) late time fit
F) only early-middle time fit possible

Summary of Test Data		Page 3/3			
Test Phase		SWS 2)	PI2 1)	PI2 2)	Simulation entire Seq. 2)
duration	[h]	14.414	0.487	0.487	25.07
T2 (i/f)	[°C]	38.81 / 38.74	38.64 / 39.07	38.64 / 39.07	38.83 / 39.07
P1 (i/f)	[kPa]	5539 / 5564	5565 / 5565	5565 / 5565	5473 / 5565
P2 (i/f)	[kPa]	4856/ 5188	6086 / 5868	6086 / 5868	5460 / 5868
P3 (i/f)	[kPa]	5462 / 5462	5462 / 5463	5462 / 5463	5462 / 5463
P4 (i/f)	[kPa]				
Measured C	$[m^3/Pa]$		1.4E-09		
c_{SC}	[1/Pa]		1.7E-09		
q	[l/min]				
Q	[l]				
inner boundaries		wellb. stor.	wellb. storage	wellb. storage	wellb. stor.
flow geometry		hom.	hom.	hom.	hom.
outer boundaries		inf. lat. ext.	inf.lat.ext.	inf.lat.ext.	inf. lat. ext.
T	$[m^2/s]$	9.46E-11 A)	2.62E-10 A)	1.56E-10 A)	**6.91E-11** A)
K	[m/s]	1.89E-12 A)	5.24E-12 F)	3.11E-12 F)	1.38E-12 A)
k	$[m^2]$	1.46E-19	4.04E-19	2.40E-19	1.06E-19
S_S	[1/m]	1.00E-05 A)		8.05E-06 A)	1.00E-05 A)
S	[-]	5.00E-04 C)		4.03E-04 C)	5.00E-04 C)
Pi, P_f if matched	[kPa]	5375 A)		6471.4 A)	**5389.7** A)
Head	[m asl]	424.04 C)		535.80 C)	425.54 C)
Derived flow rate	[l/min]				
s (skin factor)	[-]				
S_{SS} (skin zone)	[1/m]				
t_S (skin zone)	[m]				
K_S (skin zone)	[m/s]				
figures		1, 6, 10, 11	1, 7	1, 12	1, 13, 14, 15, 16
temperature effects		no	no	no	no
borehole history		yes	no	yes	yes
anomalies		no	no	no	no
bypass PA2		no	no	no	no
bypass PA1		no	no	no	no

comments

notes:
- i = initial, f = final

- T value in bold most representative of the undisturbed formation

1) analytical with no superposition
2) numerical simulation with detailed borehole history effects

A) matched parameter
B) input parameter
C) calculation assumes: freshwater density 1000 kg/m^3, g = 9.81 m^2/s, P_{atm} and z_2 as stated on front page
D) mid time fit
E) late time fit
F) only early-middle time fit possible

Test overview

Test Oftr-i3 (550.0 - 600.0 m bgl) was performed on 22.-23.10.2007 in the Oftringen NOK EWS-Borehole. The test interval consists of marls (so-called Effinger Mergel) with interbedded carbonates from 585.0 - 587.1 m bgl. The tested section belongs to the Effinger-Member of the jurassic Malm (Oxfordian) formation. The test objectives were to obtain reliable estimates of interval transmissivity and fresh-water hydraulic head using an appropriate flow model. The test was performed with a straddle-packer configuration with an interval length of 50.04 m. Pressures and temperatures were measures in the test interval (P2, T2) and in the interval below the lower packer (P1, T1) and in the annulus above the upper packer (P3, T3). In addition, pressure was measured in the tubing above the upper packer (P4).

The pressure response of the entire test sequence in Oftr-i3 is shown in **Figure 1**. The pressure history derived from water table measurements (source: Colenco, Solexperts) and fluid density measurements (SJ Geotec) is presented in **Figure 2**.

Following packer inflation (INF) the test sequence started with a COM and PSR phase to dissipate temperature and borehole history effects. Temperature effects are considered negligible, because downhole temperatures (T1, T2, T3) oscillate around a stable mean value of 38.8 °C with a noise band which reaches a maximum of about +/- 0.7 °C at the end SWS flow period (**Figure 3**). The pulse injection test (PI) was performed to measure the wellbore compressibility early in the test and obtain an initial estimate of the formation properties. A slug withdrawal (SW) followed by a shut-in phase (SWS) was performed to get a more distinct formation response combined with a larger radius of investigation for the determination of the formation properties. After the SWS sequence a second pulse injection test (PI2) was performed to determine wellbore compressibility for comparison with that from the earlier pulse injection test (PI).

Due to the influence of the adjacent high voltage current transformer facility (NOK), the pressure and temperature signals of the downhole triple probe were noisy during the hole testing sequence.

Analysis

For the QLR analysis, the analytical and numerical methods were used for a standard analysis, which will be the basis for a possible detailed analysis depending on the test objectives and test results.

Analytical Analysis

Type curve and straight-line fitting methods are applied. Effects of the borehole pressure history are not taken into account.

Pulse injection test (PI)

The PI test was initiated after a PSR phase which ended with a slightly decreasing pressure trend of about 1.7E-3 kPa/s (P2). The PSR flow period was too short to be analyzed. During preparation of PI, the water in the 1.9" test rods was filled up to a level 6 cm below top of tubing. The "injection head" was screwed on top of tubing and connected to a bottle of pressurized nitrogen. At start of the pulse test the interval pressure was exposed to a differential pressure of 589.8 kPa. The shut-in valve was kept open during 59 seconds. After shut-in, a water level decrease equal to 0.695 m was measured in the 1.9" test string, indicating a volume change of 0.873 liters due to compression of the test zone. The wellbore storage constant C ($\Delta V/\Delta P$) equals to 1.5E-09 m^3/Pa.

The pulse response was analyzed using CBP type-curves. The analysis is presented in **Figure 4**. The mid time data fit to α-type-curve of value 0.08 which provides a transmissivity estimate of 3.2E-10 m^2/s. However, the late time data diverge strongly from this type curve α = 0.08. Therefore, a late time fit is presented in the same plot using a α-type-curve of 0.1. The late time fit yields a considerably lower transmissivity of 5.78E-12 m^2/s.

Slug test withdrawal test (SW)

Prior to start of the SW test, the water table in the 1.9" tubing was lowered to 92.9 m bgl (change of tubing water level does not affect the interval pressure while the shut-in tool is closed). A slim tubing was installed in the 1.9" NU API rods before start of SW. The slim tubing system consists of a stiff high pressure hose of ID = 9.5 mm and a packer at its bottom (OD =28 mm). The packer is inflated using pressurized nitrogen, sealing the annulus between the 1.9" tubing and the slim tubing. The slim tubing was installed to a depth of 96 m bgl, covering the span of expected water table change of the slug test. A pressure transducer (P_{SL}) attached just above the packer and with connection to the tube inside enables recording of water level changes, redundantly to the P2 sensor. The small diameter of the slim tubing allows for faster slug recovery.

Prior to start of SW, the P2 pressure curve showed a decreasing trend with roughly 4E-03 kPa/s. The SW test was started 4.03 hours after start of PI. The pressure data shown in **Figure 5** are not corrected for the general pressure trend because of the short SW flow period. Removal of trend would mostly affect the H/H_o curve at late time. The analytical SW analysis provides an indicative transmissivity value of 1.5E-11 m^2/s.

Shut-in phase SWS

The slug test was shut-in after 4.0 hours and further pressure recovery (SWS) was recorded for 14.4 hours. The log pressure data of the SWS recovery flow phase in an Agarwal log time plot for the corrected production time (**Figure 6**) was too short and therefore an IARF phase is not recognizable.

Second pulse injection test (PI2)

A second pulse injection test (PI2) was performed in order to confirm the C-value obtained during PI. During preparation of PI2, the slim tubing was pulled out of the test string and the water in the 1.9” test rods was filled up to a level 6 cm below top of tubing. The “injection head” was screwed on top of the tubing and connected to a bottle of pressurized nitrogen applying a backpressure of 6 bars. In the 0.5 hrs prior start of PI2, the P2 pressure curve showed a rising slope of 2.0E-3 kPa/s. At start of the pulse test the interval pressure was exposed to a differential pressure of 897.1 kPa. A water level decrease Δh equal to 0.99 m was measured in the 1.9” test string, indicating a volume change of 1.24 liters due to compression of the test zone. The wellbore storage constant C ($\Delta V/\Delta P$) equals to 1.4E-09 m^3/Pa, a value comparable to the result obtained from PI (C=1.5 E-09 m^3/Pa).

After shut-in (open valve period = 33 s), the PI2 test recovered 24.4 % during a period of 0.49 hrs. The same α-type-curve as used for fitting PI mid time data was applied (**Figure 7**) and provided a T estimate of 2.6E-10 m^2/s.

Numerical Analysis using nSights

In a first step, the diagnostic plots for the individual sequences were analyzed and fitted individually, accounting for borehole history and taking into account transient effects associated with the preceding test sequences. In a second step, the entire test sequence was simulated and fitted based on the Cartesian pressure plot and accounting for borehole history. For the Cartesian fit, all test phases except history periods were chosen and no weighting for individual events was applied. The so-called history periods BH, INF1, INF2, COM, PI_a and PI2_a were not fitted but incorporated as test events with defined pressure in the simulation process. PI_a, PI2_a denote very short events of less than 0.02 hrs duration and represent transitional phases during initiation of the pulse injection tests (open shut-in valve phase at start of PI_a and PI2_a).

Please note that the fits of the Ramey plots for the PI and SW sequences are the result of the inverse parameter estimation using nSights and represent a solution of a numeric process that includes the effects of potential transient effects of the preceding test phases and the borehole history.

The analyses used the wellbore compressibility of 1.45E-9 m^3/Pa (C_{SC} = 1.7E-9 1/Pa) which corresponds to the mean value measured during the PI and PI2. The difference between the two C measurements is very small (comparable to the precision of the measurement) and therefore the same wellbore compressibility was used over the entire test sequences.

The diagnostic plots of the individual test sequences did not indicate characteristic responses of a composite flow model, or any other more complex flow models. Consequently, a homogeneous model was assumed in this first evaluation for estimating formation parameters (i.e., K, S_s, and P_f). During the parameter optimization, the specific storativity was allowed to vary within a plausible range from Ss = 1E-7 Pa^{-1} to1E-5 Pa^{-1}.

No fit was performed on the PSR flow period because of the very short data sequence. The entire PSR flow phase was dominated by wellbore storage effects. The diagnostic plot of the PI sequence in terms of the normalized pressures (Ramey A) produced a good fit (**Figure 8**) which yielded estimates of the parameters K = 2.3E-12 m/s and S_s = 1.0E-5 m^{-1}. The S_s estimate is at the upper bound of the plausible range. The calculated static formation pressure is very high with 6027.4 kPa.

The data fit of the SW sequences (**Figure 9**) is good and provides a K value which is about 2 times higher compared to the PI flow period (K = 5.8E-12 m/s, S_s= 2.6E-6 m^{-1}, P_f = 4604 kPa).

The SWS log-log diagnostic plot (**Figure 10**) indicates the transition from the wellbore storage dominated period to a possible infinite-acting-radial flow period (IARF). A good fit was obtained (**Figure 11**, K = 1.9E-12 m/s, P_f = 5375 kPa) but the simulated storativity (S_s=1.0E-5 m^{-1}) is at the upper end of the reasonable value range.

The simulated data fit of the PI2 flow period provides a good fit similar to the fit of the PI-phase (K= 3.1E-12 m/s, S_s= 8.1E-6 m^{-1}, P_f = 6471 kPa, **Figure 12**).

The simulation of the entire test sequence produces a good fit on a Cartesian plot (**Figure 13**) with calculated data similar to the SWS flow phase and a specific storativity at the upper bound of the plausible range (K = 1.4E-12 m/s, S_s =1.0E-05 m^{-1}, P_f = 5390 kPa). The diagnostic plot of the SWS phase (**Figure 16**) for the matching results of the entire test sequence confirms the good quality of the model. The Ramey plot of the PI phase using the same parameters (**Figure 15**) shows a match of comparatively inferior quality.

The sensitivity coefficients of the formation parameters during the different sequences indicate that the PI test has the greatest sensitivity to the K and S_s parameters whereas the SW-SWS test has a similar sensitivity to K and S_s but a higher sensitivity to P_f (**Figure 14**). The definition of the sensitivity coefficient is given in the Chapter “Definitions”.

Results and Discussion

The estimated formation conductivity for the different sequences varies over a range between 1.4E-12 m/s and 5.8E-12 m/s based on a homogeneous radial flow model without skin. The matched storativities vary over a range between 2.6E-06 and 1.0E-05 m^{-1}. The Ss value obtained from the SW optimization is in fair agreement with the initial Ss estimate (Ss value as expected based on assumed formation compressibility, porosity, and water compressibility).

The Ss values of the individually fitted PI1, SWS and PI2 sequences are high compared to the initial Ss estimate.

The range for the matched static formation pressures is very high between about 4600 and 6500 kPa. The analyses of the entire test sequence and of the SWS phase give static formation pressures of about 5400 kPa. The SWS sequence shows consistent parameter values between the sequence only fit and the entire testing sequence fit and thus these are considered the more representative parameter values. However, uncertainties remain regarding the static formation pressure, which does affect the parameter estimates for the formation conductivities.

FIGURES

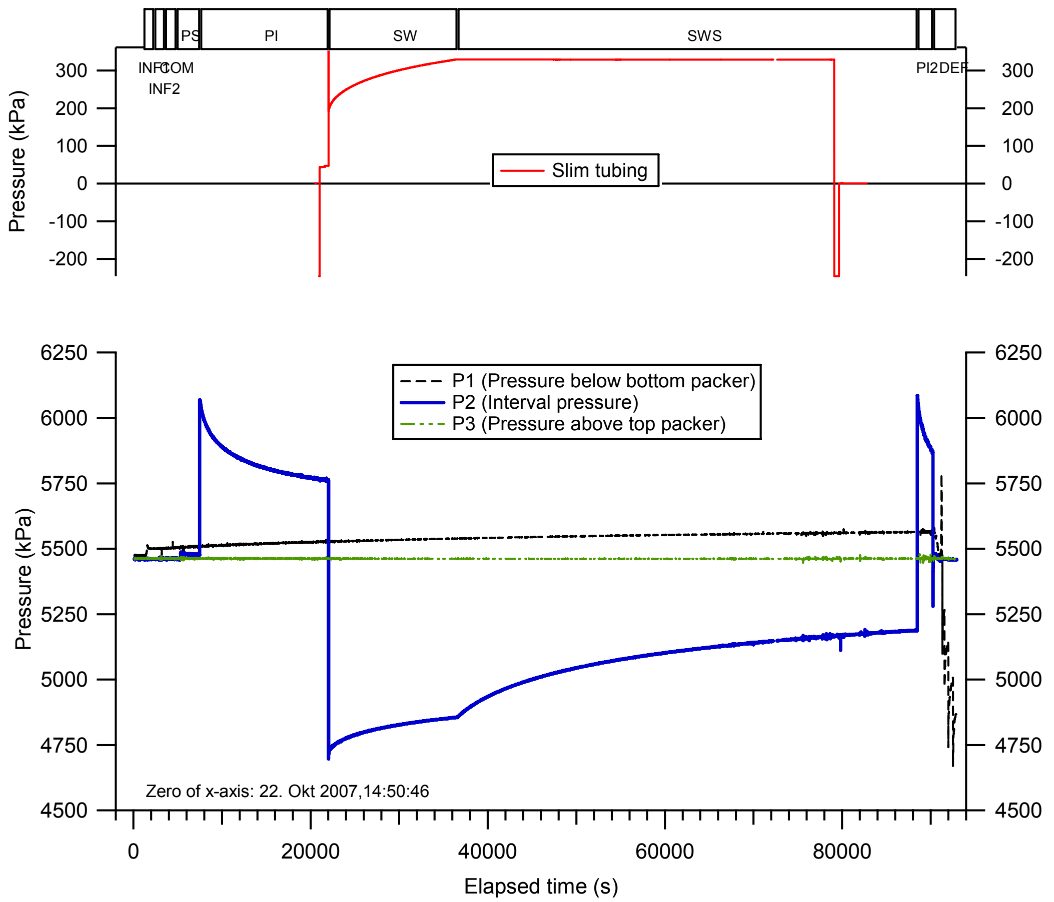


Figure 1: Oftr-i3: Overview plot

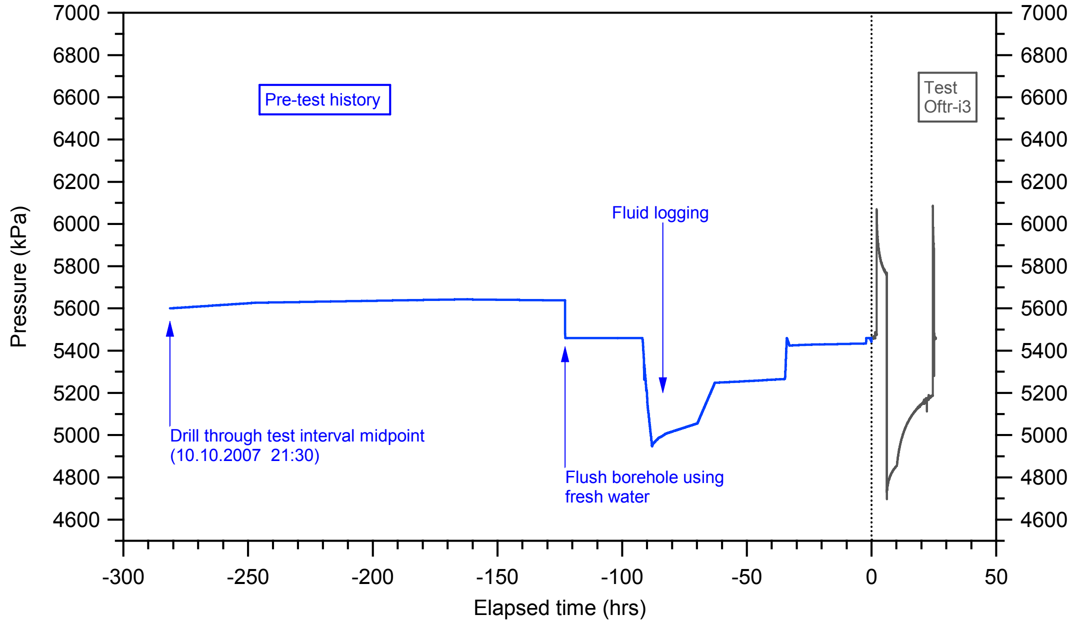


Figure 2: Oftr-i3: Borehole pressure history

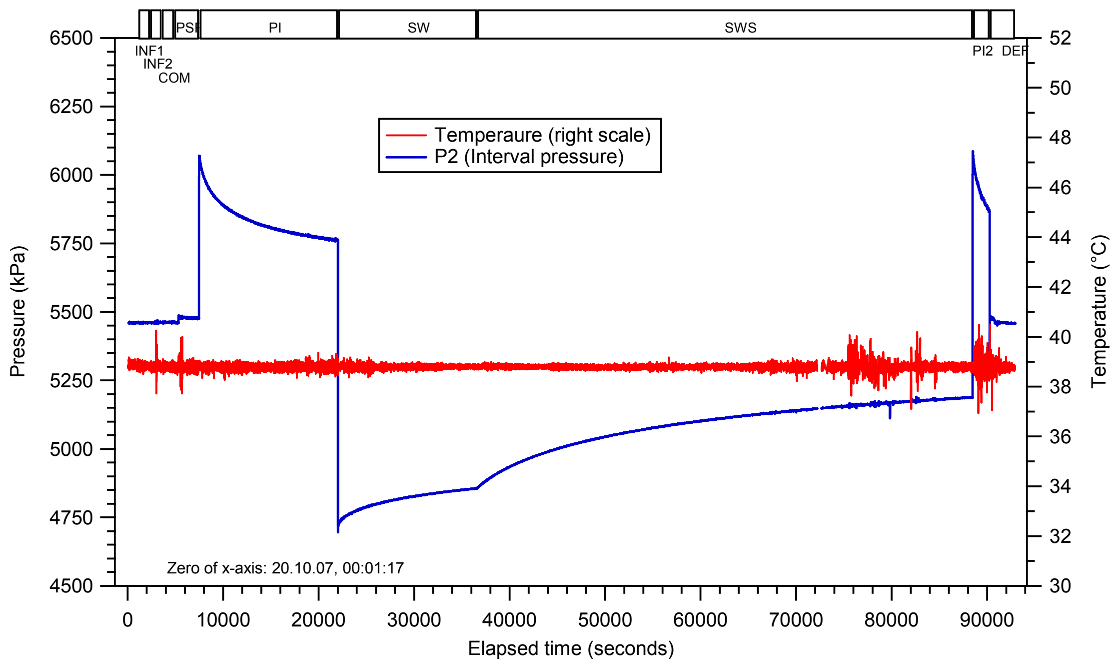


Figure 3: Oftr-i3: Measured downhole temperature (T2)

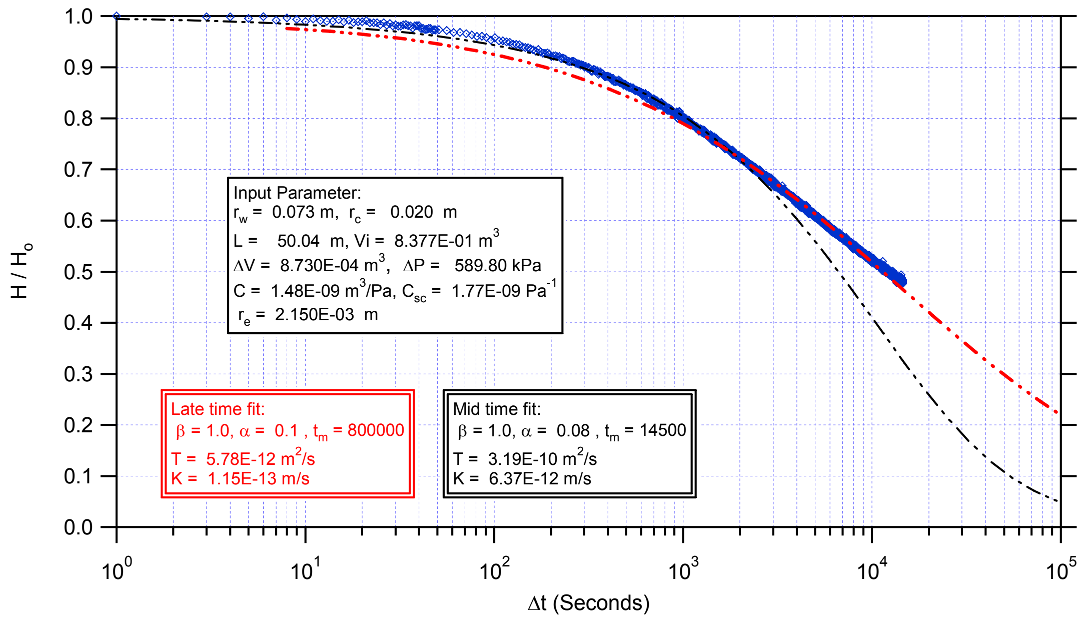


Figure 4: Oftr-i3: PI analysis using CBP type-curves

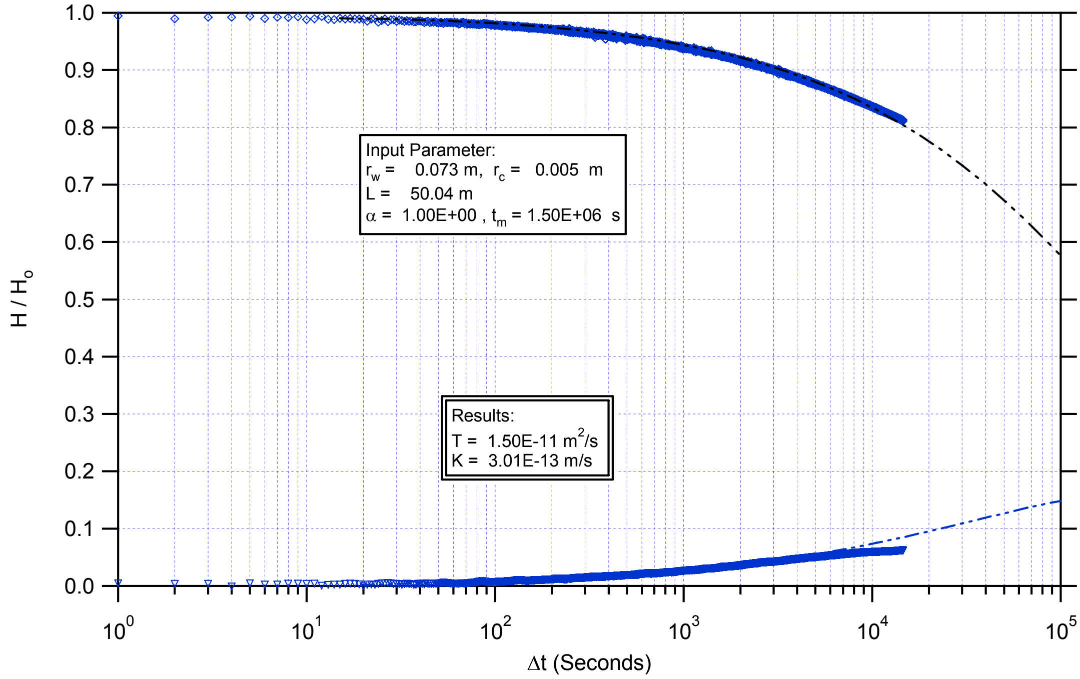


Figure 5: Oftr-i3: SW analysis using CBP type-curves

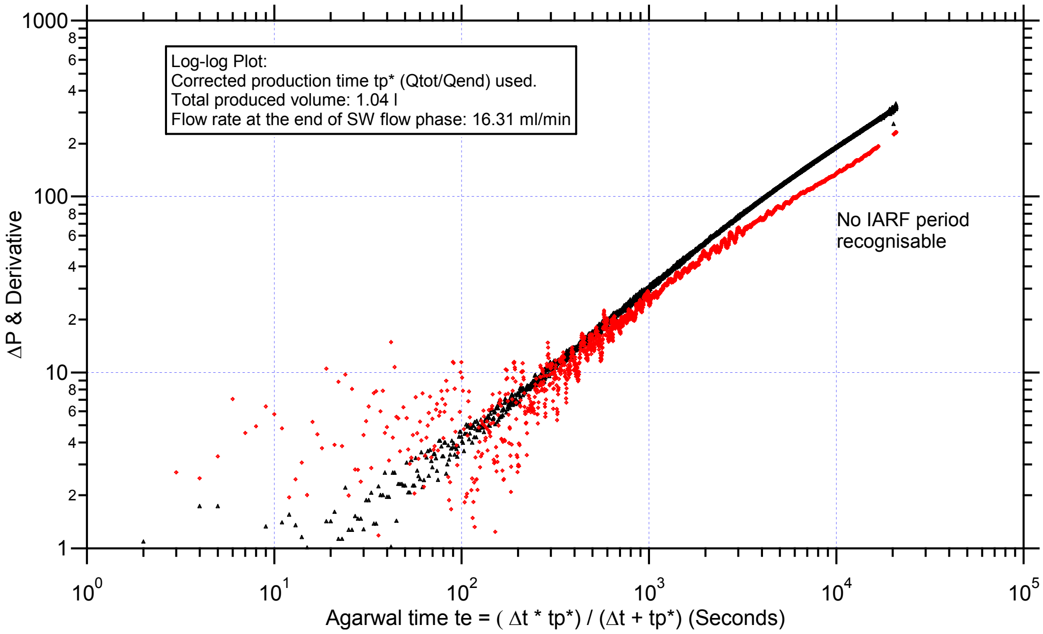


Figure 6: Oftr-i3: SWS log-log diagnostic plot (analytical analysis) using Agarwal time and corrected production time tp*

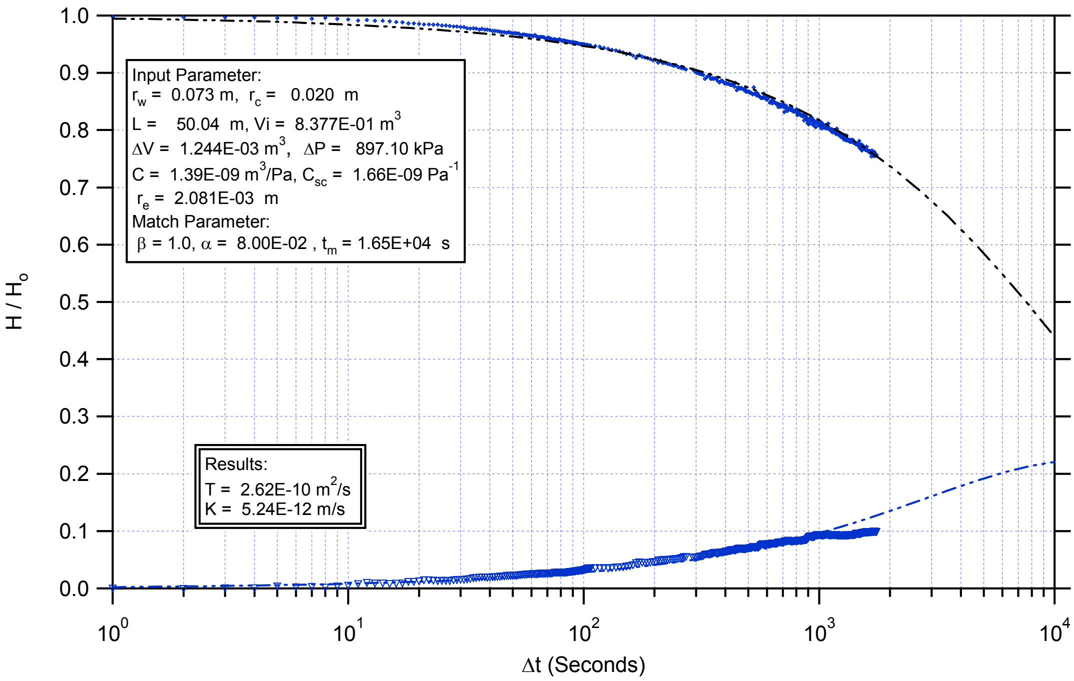
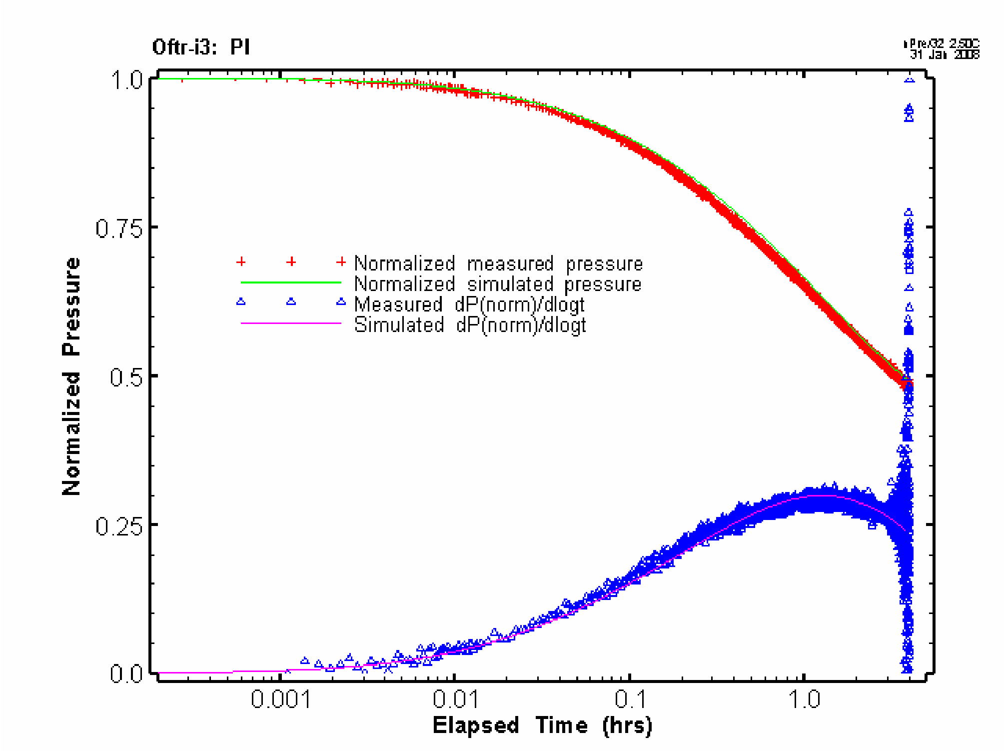


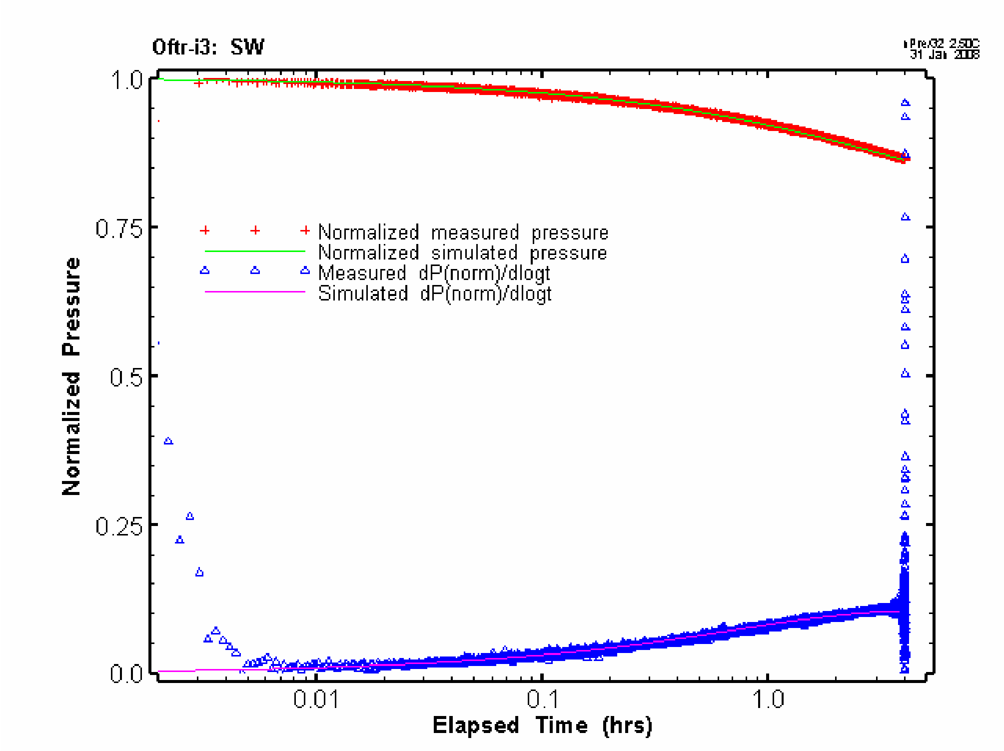
Figure 7: Oftr-i3: PI2 analysis using CBP type-curves



Fit Statistics:

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_f	[m/sec]	2.26E-12	1.78E-12	2.88E-12
P_f	[kPa]	6027.4	6004.7	6050.1
Ss_f	[1/m]	1.00E-05	7.26E-06	1.38E-05

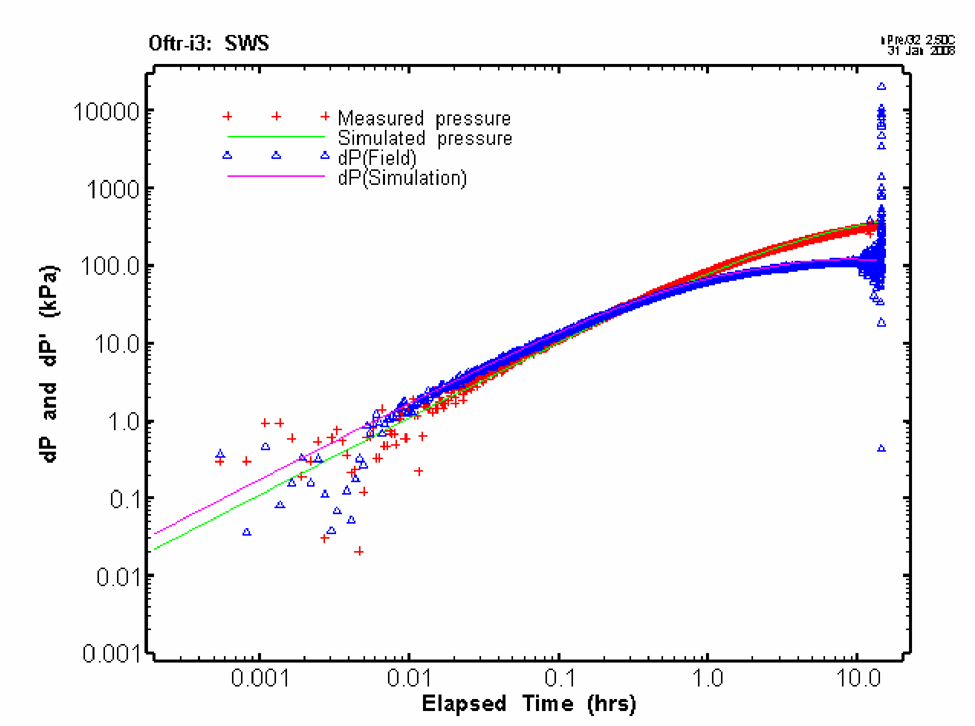
Figure 8: Oftr-i3: PI normalized pressure plot (Ramey A)



Fit Statistics:

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_f	[m/sec]	5.76E-12	4.12E-12	8.06E-12
P_f	[kPa]	4604.6	4503.0	4623.0
Ss_f	[1/m]	2.61E-06	1.67E-05	4.06E-05

Figure 9: Oftr-i3: SW normalized pressure plot (Ramey A)



Fit Statistics:

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_f	[m/sec]	1.89E-12	1.58E-12	2.25E-12
P_f	[kPa]	5375.0	5340.0	5410.0
Ss_f	[1/m]	1.00E-05	7.37E-06	1.36E-05

Figure 10: Oftr-i3: SWS log-log diagnostic plot

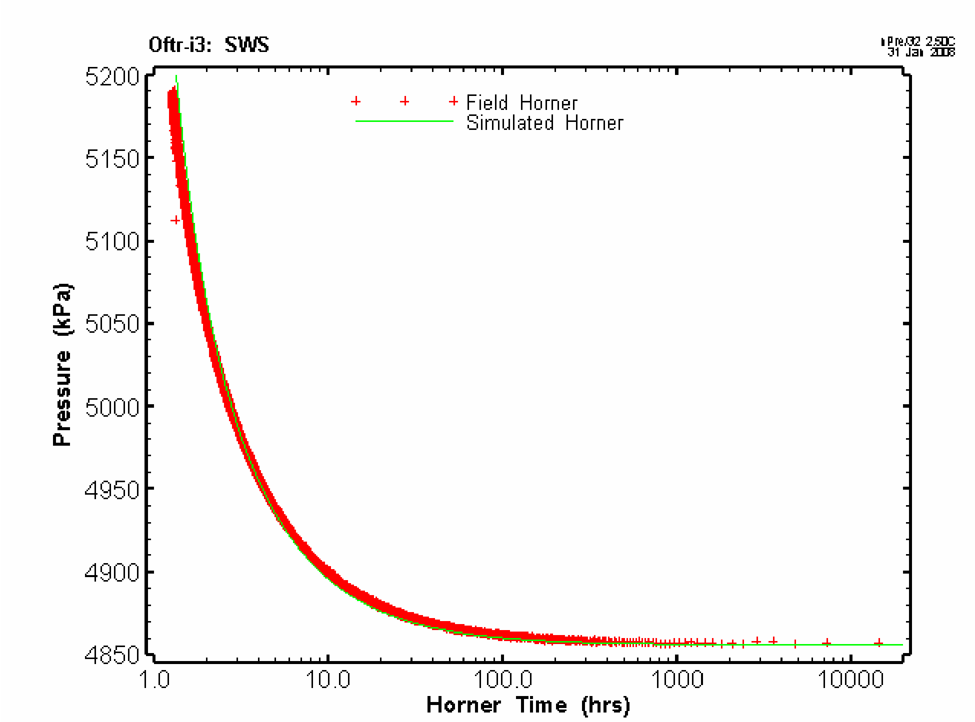
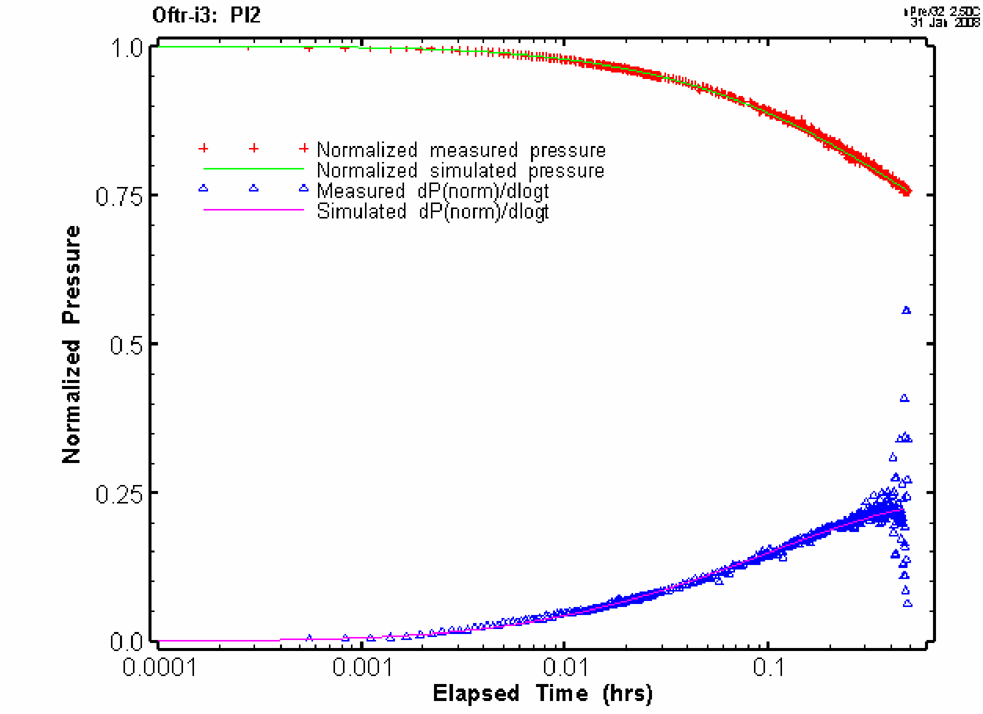


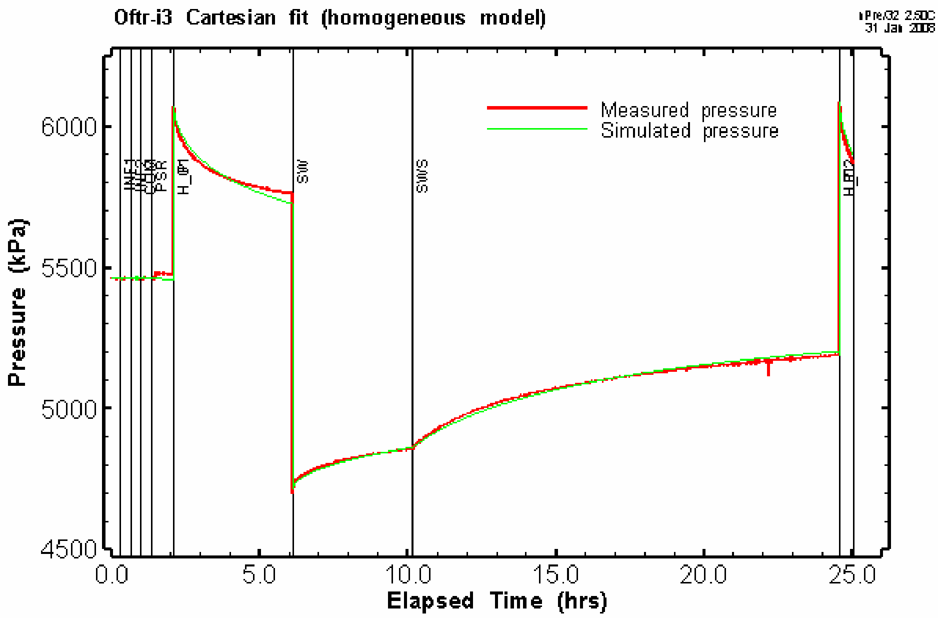
Figure 11: Oftr-i3: SWS Horner plot



Fit Statistics:

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_f	[m/sec]	3.11E-12	2.17E-12	4.44E-12
P_f	[kPa]	6471.4	6339.2	6603.6
Ss_f	[1/m]	8.05E-06	5.21E-06	1.24E-05

Figure 12: Oftr-i3: PI2 normalized pressure plot (Ramey A)



Fit Statistics:

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_f	[m/sec]	1.38E-12	1.33E-12	1.43E-12
P_f	[kPa]	5389.7	5384.0	5395.4
Ss_f	[1/m]	1.00E-05	9.43E-06	1.06E-05

Figure 13: Oftr-i3: Cartesian fit of the entire test for homogeneous model

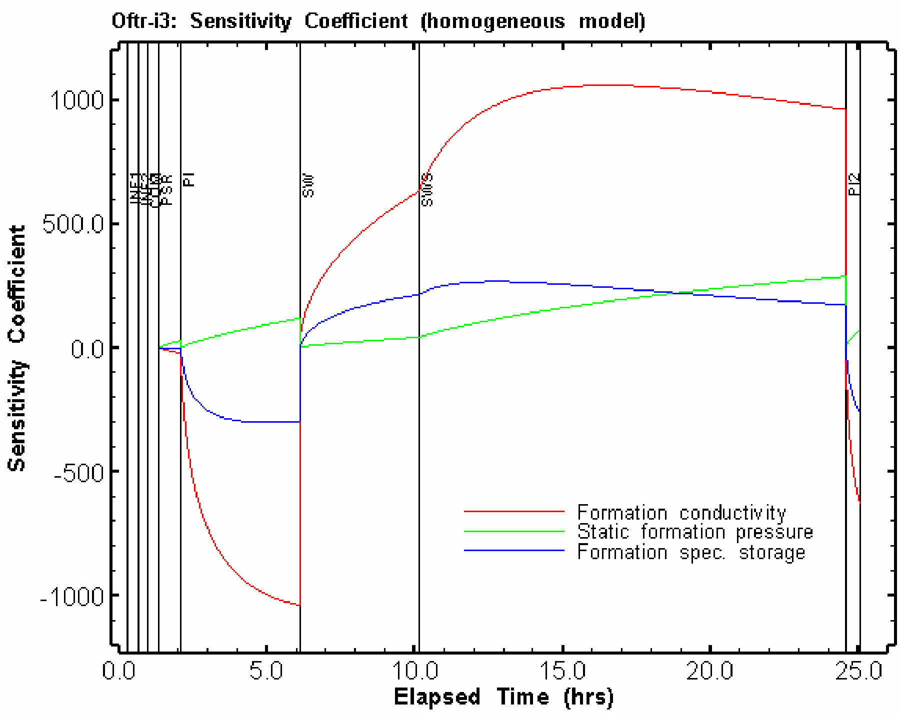


Figure 14: Oftr-i3: Sensitivity coefficients for the different formation parameters during the different sequences

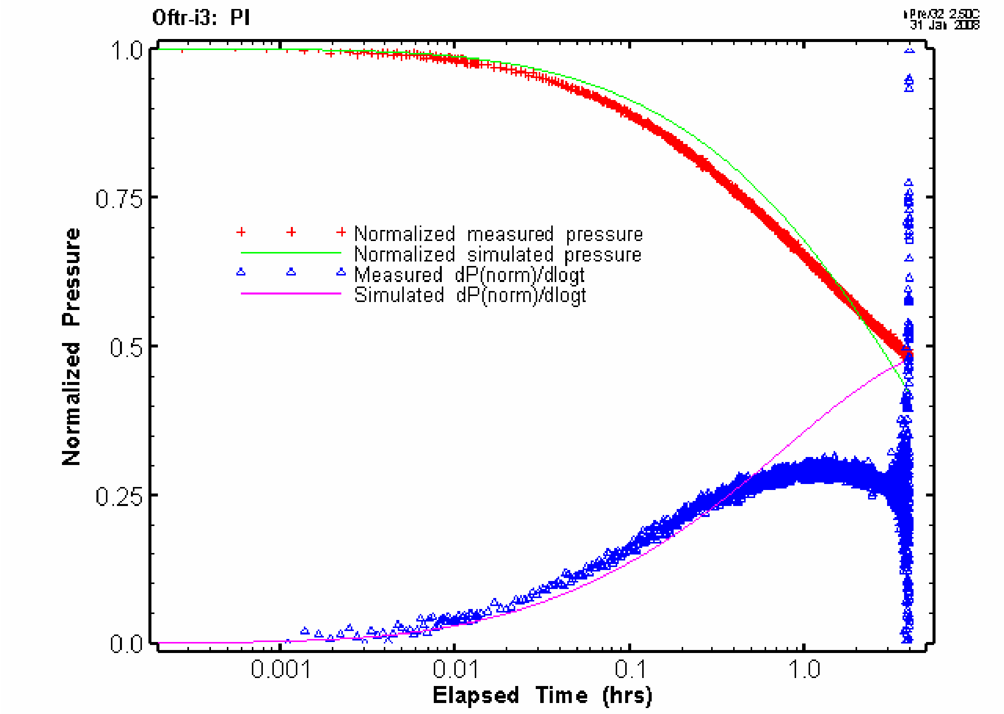


Figure 15: Oftr-i3: PI normalized pressure (Ramey A) plot for the entire test fit

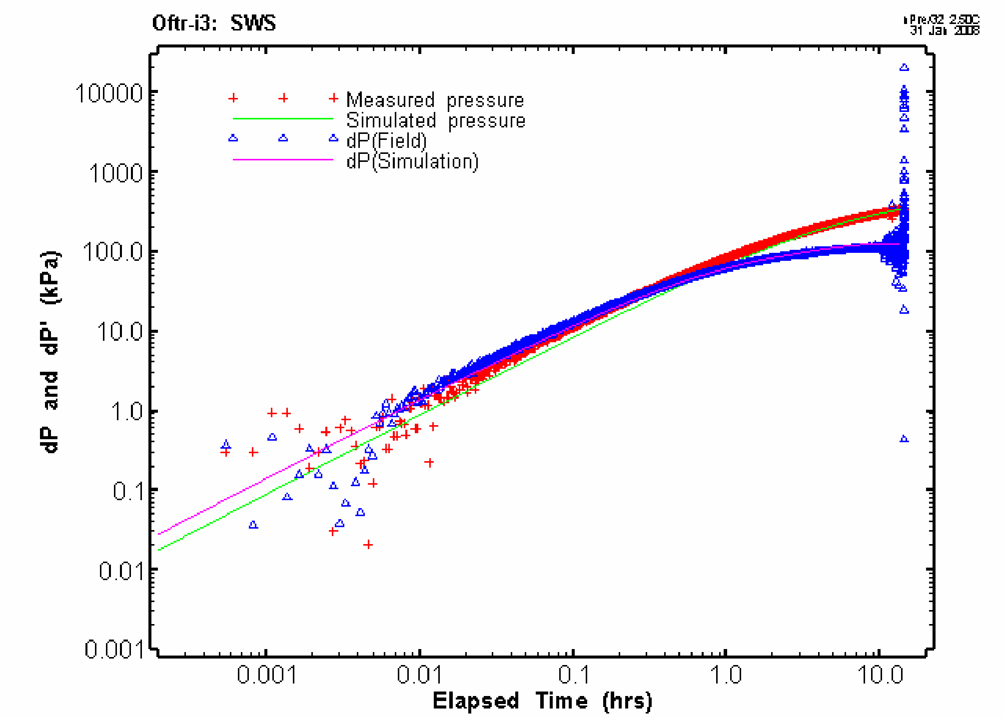


Figure 16: Oftr-i3: SWS log-log diagnostic plot for the entire test fit

Abbreviations

	Test phases
COM	Compliance
INF	Packer inflation
INF1	Inflation of lower packer (INF2 = Inflation of upper packer)
DEF	Packer deflation
DEF1	Deflation of lower packer (DEF2 = Deflation of upper packer)
PSR	Static pressure recovery (shut-in valve closed)
SI	Slug injection test
SIS	Pressure recovery after slug injection test (shut-in)
SW	Slug withdrawal test
SWS	Pressure recovery after slug withdrawal test (shut-in)
PI	Pulse injection test
PW	Pulse withdrawal test
HI	Constant head injection test (constant pressure difference)
HIS	Pressure recovery after constant head injection test (shut-in)
HW	Withdrawal test applying constant differential head
HWS	Pressure recovery after constant head withdrawal test (shut-in)
MR	Multi-rate test: Test with variable flow rate
MRS	Pressure recovery after test with variable flow rate
RW	Pump test with constant flow rate
RWS	Pressure recovery after pump test with constant flow rate (shut-in)
RI	Constant flow injection test
RIS	Pressure recovery after constant flow injection test (shut-in)
VC	Shut-in valve is closed
VO	Shut-in valve is open
	General
CBP	Cooper, Bredehoeft, Papadopulos (type-curve matching method)
DAS	Data acquisition system
FS	Full scale
IARF	Infinite acting radial flow
LC	Log cycle
m agl	Meters above ground level
m bgl	Meters below ground level
m asl	Meters above sea level
OD	Outer diameter
PVT	Pressure volume temperature correlation
Sdev	Standard deviation
SLA	Straight-line analysis
TOC	Top of casing
WL	Water level (or WT = water table)

Nomenclature

	Description	SI-Unit		Description	SI-Unit
b	Y-intercept of linear regression		S_S	Specific storativity	m^{-1}
C	Wellbore storage constant	$m^3\ Pa^{-1}$	S_{SS}	Specific storativity of skin zone	m^{-1}
C_S	Wellbore storage constant, shut-in	$m^3\ Pa^{-1}$	s	Skin factor	-
C_D	Dimensionless wellbore constant	-	t, Δt	Time, elapsed time	s
c_f	Pore volume based compressibility	Pa^{-1}	t_C	Critical time	s
c_r	Rock compressibility	Pa^{-1}	t_D	Dimensionless time	-
c_{SC}	System compressibility (= test zone compressibility c_{tz})	Pa^{-1}	Δt_e	Equivalent time (after Agarwal)	s
c_w	Water compressibility	Pa^{-1}	Δt_H	Horner time	-
Δh	Differential head	m	t_p	Production time	s
g	Acceleration of gravity (9.81)	$m\ s^{-2}$	t_p*	Corrected production time	s
h_S	Static head	m	t_m	Match time	s
k	Intrinsic permeability	m^2	t_0	X-intercept of linear regression	s
K, K_f	Hydraulic conductivity of formation () special case	m/s	t_s	Thickness of skin zone	m
K_s	Hydraulic conductivity of skin zone () special case	m/s	T	Transmissivity	m^2/s
L	Interval length	m	T_W	Water temperature	°C
m	slope (regression)		z_1	P1 sensor depth	m
P	Pressure	Pa, kPa	z_2	P2 sensor depth	m
P_0	Minimal or maximal pressure	Pa, kPa	z_3	P3 sensor depth	m
P_{atm}	Probe signal at atmospheric pressure	Pa, kPa			
ΔP	Differential pressure, pressure change	Pa, kPa	α ,β	Type-curve match parameter	-
P_D	Dimensionless pressure	-	α	aquifer compressibility	Pa^{-1}
P_f	Static formation pressure	Pa, kPa	μ	Dynamic viscosity	Pa·s
P_i	Initial pressure	Pa, kPa	θ	Porosity	-
$P_{min/max}$	Minimal/maximal pressure	Pa, kPa	ρ_w	Density of fresh water	kg/m^3
P_{S1}	Static pressure in P1-Interval (below bottom packer)	Pa, kPa			
P_{S2}, P_f	Static pressure in test interval	Pa, kPa			
P_{S3}	Static pressure in annulus (above upper packer)	Pa, kPa			
q	Flow rate	$m^3\ s^{-1}$			
q_{end}, q_e	Last flow rate	$m^3\ s^{-1}$			
Q, Q_{tot}	Cumulative flow	m^3			
r_e	Effective radius (Slug, Pulse test)	m			
R_i	Radius of influence	m			
R^2	Correlation coefficient	-			
r_c	Tubing radius	m			
r_w	Wellbore radius	m			
R_1	Radius, composite model	m			
R_D	Dimensionless radius	-			
S	Storativity	-			
S_C	Sensitivity coefficient				
S_{SC}	Scaled sensitivity coefficient				

Definitions

$C_D = \frac{\rho\, g\, C}{2\pi\, S\, r_{w^2}}$	Wellbore constant, dimensionless
$H_D = \frac{P - P_i}{P_0 - P_i}$	Dimensionless pressure (slug und pulse tests)
$K = \frac{k\, \rho\, g}{\mu}$	Hydraulic conductivity
$P_D = \frac{2\pi\, T\, \Delta h}{q}$	Dimensionless pressure
$\Delta P = \rho\ g\, \Delta h$	Differential pressure
$q_D = \frac{q}{2\pi\, T\, \Delta h}$	Dimensionless flow
$t_D = \frac{t\, T}{r_w^2 S}$	Dimensionless time
$S = S_S\, L$	Storativity
$s = \left(\frac{K_f}{K_s} - 1\right) \ln\left(\frac{r_w + t_s}{r_w}\right)$	Skin factor
$S_S = \rho\, g\, (\alpha + \theta\, c_w)$	Specific storativity
$S_C = \frac{\partial P}{\partial r}$	Sensitivity coefficient.

where ∂P is the partial derivative of the calculated system response (i.e., pressure) with respect to a parameter varied by the derivative span ∂r .
For comparison of sensitivity coefficients for different parameters, the sensitivity coefficients are typically scaled by inverses of the respective standard deviations as follows:

$$S_{sc} = S \frac{\sigma_r}{\sigma_P} = \frac{\partial P}{\partial r} \cdot \frac{\sigma_r}{\sigma_P}$$

where S_{sc} is the scaled sensitivity coefficient, σ_r is the a priori standard deviation of the measurement error, and σ_P is the estimated standard deviation of the parameter.
If not otherwise stated, default values σ_r = 1 and σ_P = 1 were used.

Definitions (continued)

T = K L	Transmissivity
$\frac{t_D}{C_D} = \frac{2\pi T t}{\rho g C}$	Dimensionless time axis
$t_e = \frac{t_p \cdot \Delta t}{t_p + \Delta t}$	Dimensionless Agarwal time (Agarwal, 1980)
$t_e^* = \frac{t_P^* \cdot \Delta t}{t_P^* + \Delta t}$	Modified Agarwal time (using corrected production time)
$t_P^* = \frac{Q}{q_{end}}$	Modified production time (Ehlid-Economides and Ramey, 1980)

Form

DAILY LOG REPORT

SOLEXPERTS

Date	Time	Activity	Who
22.10.07	14:48	System on position	Fi, FP, Sti
		Interval 3: 550.00 – 600.04 m	
	14:51	Start file Oftr-i3	
		Water table is on top of 7" casing	
		Start file: Oftr_2007_10_19_oftr_i2.dat P1 = 5473 kPa P2 = 5463 kPa P3 =5460 kPa T2 = 38.7 °C Water table: 1.42 m above ground level (=top of casing)	
	15:00	Visit of Stratis Vomvoris with colleagues on site	
	15:10	Start inflation of packer 1 (INF1)	
	15:30	Start inflation of packer 2 (INF2)	
	15:50	Both packers inflated to 20 bar	
	16:12	Shut-in (valve closed)	
	16:20	Fill water in 1.9" NU tubing. P2 shows pressure increase by 22 kPa: => valve is not completely closed	
	16:21	Close valve again, start PSR	
		Start preparation for Pulse injection test (PI) Water table in test rod is 6 cm below top of tubing.	
		Install injection head on top of tubing rods with 6/4mm pressure line connect to nitrogen bottle. P2 = 5460 kPa	
	16:55	Start PI-test	
		Water table in test rod is 0.755 m below top of rod => Δs = 0.695 m	
	17:50	Preparation of SW-test. Water level in test string is lowered using swabbing tool.	
	18:00	Cable of Daldrup winch is in disorder. Swabbing tool cannot be recovered before repair of winch.	
	19:00	Arrival of night shift crew	SR, PH
	19:30	Fi, FP, Sti leave site	Fi, FP, Sti
	19:50	Winch fixed, pull out swabbing tool	
	20:09	Water table at 69.29 m bgl	
	20:13	Phone call with Bernd Frieg: Principally same test sequence as in test zone i2. Slug test recovery of about 20 to 30 %, shut-in and recovery until morning	
	20:26	Swabbing, target water level depth = 90.0 m bgl	
	20:30	Water table at 92.86 m bgl	
	20:34	Slim tubing pressure sensor at atmosphere: 1.15 kPa	
	20:35	Slim tubing installation	
	20:39	Start recording of slim tubing sensor (P_{SL} = 43.74 KPa)	
	20:50	Inflation of Slim tubing packer (P = 28 bar)	
	20:52	P_{SL} (slim tubing) = 47.22 kPa)	
	20:56	Scan rate set to 1 s	
	20:57	Start SW-test	
	21:10	Scan rate set to 5 s	
23.10.07	00:58	Scan rate set to 1 s	SR, PH
	00:59	Packer pressure slim tubing = 28 bar	
	01:00	Shut-in, start SWS	
	01:30	Scan rate set to 5 s	

Form **DAILY LOG REPORT**	SOLEXPERTS

Date	Time	Activity	Who
23.10.07	02:45	Installation and field check of liquid flow controller Coriflow: 1.) Upstream pressure from hydrant (P = 5 bar +/- 0.2 bar, not constant): => 50% of maximum Flow = 208.335 ml/min, measured Volume in 4 min = 825 ml => measured flow = 206.35 ml/min Comparison to AXF002: Coriflow (%) AXF002 (ml/min) 50% (208.34 ml/min)) 206 – 210 100% (416.67 l/min) 409 – 425 Upstream pressure change of about 0.2 bar 2.) Upstream pressure from pressure tank (P = 5 bar): Coriflow (%) AXF002 (ml/min) 10% (41.67 ml/min) 39 – 40 5% (20.83 ml/min) 18 20% (83.33 ml/min)) 77 – 86 50% (208.34 ml/min)) 206 – 207 80% (333.34 ml/min)) 333 – 334 100% (416.67 l/min) 416 – 417	SR, PH
	04:16	Scan rate set to 10 s	
	07:00	Fi, FP and Sti arrive on site	Fi, FP, Sti
	08:00	SR, PH leave site	SR, PH
	10:55	Stop file for data backup	
	11:01	Restart file	
		Remark: Slim tubing packer has to be inflated to 30 bar	
		Calculation of corrected production time: Slope at end of SW: = 1.75 ml/min. Total flow volume during SW = 1109 ml tp* = Q-tot / q-end = 38'000 s	
	12:50	Pull slim tubing out of test string	FP, Sti
	13:15	Start preparation for pulse injection test (PI) Water table in test rod is 6 cm below top of tubing.	
	13:45	Slim tubing sensor 0-10 bar shows 0.8 kPa at atmospheric pressure	
		Install injection head on top of tubing rods with 6/4mm pressure line connected to nitrogen bottle.	
	14:50	Slim tubing sensor switched off (in GMII DAS)	
	14:00	Visit of Mr. Gurtner (contracted by Nagra). Check of grounding problem (triple probe signal noise)	
		Ground is a mesh system aiming personnel protection, not optimized for grounding of electronic instruments	
		P2 before start of PI2: 5187 kPa	
	15:25:25	Start PI2 (pressurised gas used; outlet pressure = 6 bar)	
		Water table Water table in test rod is 1.05 m below top of rod => Δs = 0.99 m. C_{SC} = 1.7E-09 1/Pa	
	15:55	Open shut-in valve	
	15:57	Start deflate packers	
	16.15	Water level in annulus is filled up to top of 7" casing (1.42 m above ground level)	
	16:39	Stop file	Fi
	17:00	Water table in annulus is still on top of casing (~1.40 m above ground level)	

Form

DAILY LOG REPORT

Date	***Time***	***Activity***	***Who***
23.10.07	*17:20*	*Disconnect PA2-sensor on Fast Logger and connect Coriflow on channel 8*	*Fi, FP, Sti*
	17:30	*Packers are still not fully deflated*	
	17:35	*Packers are free*	
	17:40	*Move System on position i4*	
		8 rods removed, pop joint added	
	18:00	*System on position, fill annulus up to the top (1.42 m above top of ground level)*	

Fi *Hansruedi Fisch (Solexperts)*
FP *Fredi Portmann (Solexperts)*
SR *Sacha Reinhardt (Solexperts)*
Sti *Daniel Stillhard (Solexperts)*
PH *Peter Haller (Solexperts)*

Fbe *Dr. Bernd Frieg (Nagra)*

Form

INSTALLATION RECORD HDDP

SOLEXPERTS

Seite 1 / 1

Oftringen NOK EWS Borehole: Hydraulic Testing

Date	22.10.2007	**Project Leader**	Fi/SR						
Borehole	NOK EWS 2007	**Direction**	vertical	**Reference point**	433.0	**JOB Nr**	1763	**Location**	Oftringen
Borehole Depth	719.0 m	**Casing depth**	376.5 m bgl	**Interval lenght**	50.04 m	**Test Name**	oftr_i3	**System**	HDDP 110
Borehole diameter	146 mm	**Stickup**	-3.64 m	**Water depth**	-1.42 m bgl	**Test depth (UPLS)**	550.00 m bgl	**Probe ID**	TSSP S1

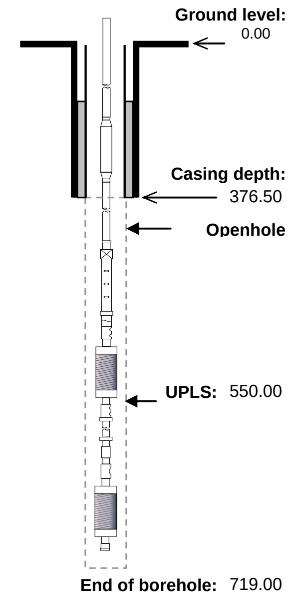
Note: All depths shown are not correct for borehole deviation

Component		Qty -	L unit m	L total m	Depth m	OD mm	ID mm	Wgt kg	Str t
Stickup	-3.64 m bgl								
Ground level					0.00				
Tubing 1.9" NU			546.37	546.37		56.1	40.3	2240.1	12.0
Pop joint			1.02	7.27	542.73	56.1	40.3	4.2	12
SIT Non Displacement Valve			0.84			79.0	24.0	20.6	15
Probe Shell Carrier mit Triple Sub	TSSP P3		1.97		546.56	70.0	10.9	48.0	25
	TSSP P2		0.30		546.86				
	TSSP P1		0.30		547.16				
			0.04						
X-Over	2"3/8 EU Pinx1.9" NU Box		0.51			66.0	40.0	2.1	16
Safety joint 3"1/16						78.0	50.5	5.5	24
Above Side Entry Sub (ASES)			0.52			66.0	32.0		24
Packer Stick Up			0.26			--	25.0		
Up. Packer Seal: Upper Packer	UPUS		0.26		548.75				
			1.25			108.0	32.0	82.4	17
	UPLS		0.24	50.04	550.00				
Straddle Length: Packer Stick Down			0.31			--	25.0		
Below Side Entry Sub (BSES)			0.52			66.0	32.0		24
X-Over	1.9" NU Pinx2"3/8 EU Box		0.26			--		3.0	16
Tubing 1.9" NU			45.5			56.1	40.3	186.6	12
X-Over	2"3/8 EU Pinx1.9" NU Box		0.45			--		3.0	16
			0.3						
Filter	Screen		1.45			72.0	50.0	19.0	19
			0.3						
P1-Seal Sub			0.3			78.0	--		24
Packer Stick Up			0.16			--	32.0		
Lower Packer Seal: Lower Packer	LPUS		0.25		600.04				
			1.25	1.92		110.0	32.0	70.2	17
	LPLS		0.24		601.29				
Packer Stick Down			0.43			--	32.0		
End Cap					601.96	78.0	--		
End of Borehole					719.00				

Comments:

[1] slim tubing sensor (0-10 bar)

Borehole configuration:



Probe		523 006.1
values at atmosphere	P1	111.7
	P2	92.1
	P3	102.3
	P_{SL} [1]	1.15
	T1	11.4
	T2	11.0
	T3	10.6
Total Weight (kg)		2705.3

Form

TALLY LIST

SOLEXPERTS

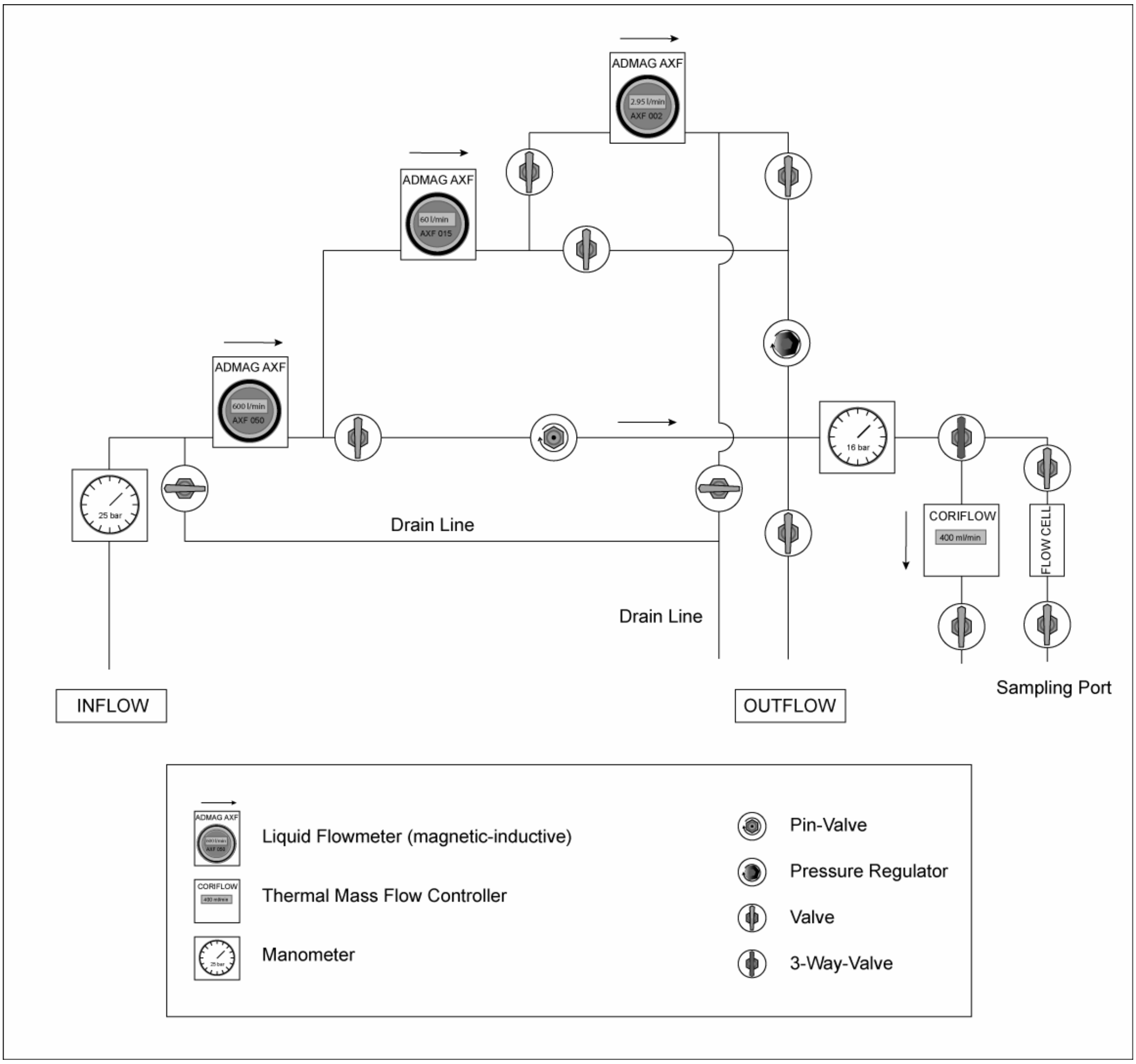
Borehole	NOK EWS 2007	Interval name	Test Oftr_i3	Date	22.10.2007
Depth	719.0 m	Interval depth	550 - 600 m	Location	Oftringen

TU	1	6.51	TU	51	6.50				
TU	2	6.51	TU	52	6.51				
TU	3	6.51	TU	53	6.51				
TU	4	6.51	TU	54	6.51				
TU	5	6.51	TU	55	6.51				
TU	6	6.51	TU	56	6.51				
TU	7	6.51	TU	57	6.50				
TU	8	6.51	TU	58	6.51				
TU	9	6.51	TU	59	6.51				
TU	10	6.50	TU	60	6.51				
TU	11	6.50	TU	61	6.50				
TU	12	6.51	TU	62	6.50				
TU	13	6.50	TU	63	6.50				
TU	14	6.51	TU	64	6.50				
TU	15	6.51	TU	65	6.51				
TU	16	6.51	TU	66	6.50				
TU	17	6.51	TU	67	6.50				
TU	18	6.51	TU	68	6.51				
TU	19	6.50	TU	69	6.50				
TU	20	6.51	TU	70	6.50				
TU	21	6.51	TU	71	6.47				
TU	22	6.50	TU	72	6.50				
TU	23	6.51	TU	73	6.48				
TU	24	6.50	TU	74	6.50				
TU	25	6.50	TU	75	6.50				
TU	26	6.50	TU	76	6.50				
TU	27	6.50	TU	77	6.50				
TU	28	6.50	TU	78	6.50				
TU	29	6.50	TU	79	6.51				
TU	30	6.50	TU	80	6.51				
TU	31	6.50	TU	81	6.51				
TU	32	6.50	TU	82	6.50				
TU	33	6.51	TU	83	6.51				
TU	34	6.51	TU	84	6.50				
TU	35	6.50	TU						
TU	36	6.51	TU						
TU	37	6.50	TU						
TU	38	6.50	TU						
TU	39	6.51	TU						
TU	40	6.50	TU						
TU	41	6.51	TU						
TU	42	6.51	TU						
TU	43	6.50	TU						
TU	44	6.50	TU						
TU	45	6.50	TU						
TU	46	6.50	TU						
TU	47	6.51	TU						
TU	48	6.51	TU						
TU	49	6.51	TU						
TU	50	6.51	TU						
		325.28			221.09		0.00		0.00

Total string length:	546.37

Form

SURFACE EQUIPMENT LAYOUT



Flow meter	Lower limit of measuring range	(% of FS)	Upper limit of measuring range (l/min)	Accuracy between 3% and 100% of FS (% of rate)	Accuracy between 1% and 3% of FS (% of rate)	Equipment used
AXF DN2	0.030 l/min	1 %	2.95 l/min	0.35	0.5	no
AXF DN15	0.6 l/min	1 %	60 l/min	0.35	0.5	no
AXF DN50	11.78 l/min	1 %	1178.10 l/min	0.35	0.5	no
Coriflow	0.50 kg/h	2 %	25.00 kg/h	1	1	no

Form

BENCH TEST

SOLEXPERTS

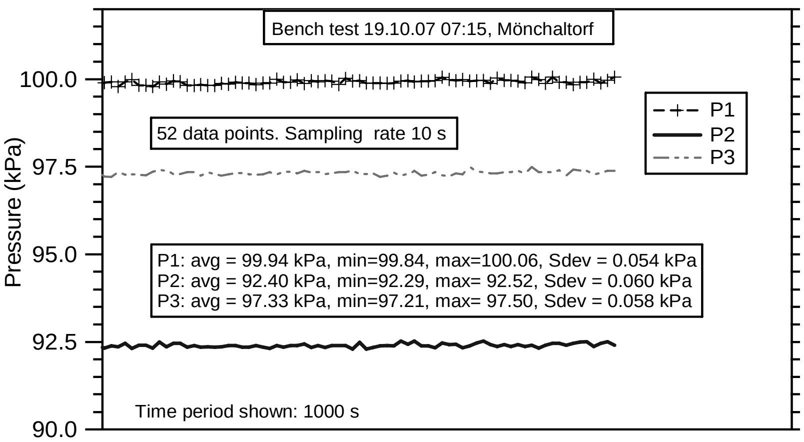
Project	**Location**	**Date**
Oftringen NOK EWS Borehole	Oftringen	18.12.2007
Well name	**Test name**	**Engineer**
NOK EWS 2007	Oftri-i3	Fi/SR

Transducer describtion	**Output units**
P1, P2, P3: 0-206.84 bar (3000 Psi), P4: 0-6 bar, P_{ST} = 0-10 bar	kPa, °C

P1#	**P2#**	**P3#**	**P4#**
43224	50370	43231	591.001.027

Offsite pretest bench test (Date: 19.10.07)

Measurement conditions (P, T and position)	**Sampling rate**
97.7 kPa 5.6 °C	10 s
( ) direct (x) vertical ( ) horizontal	

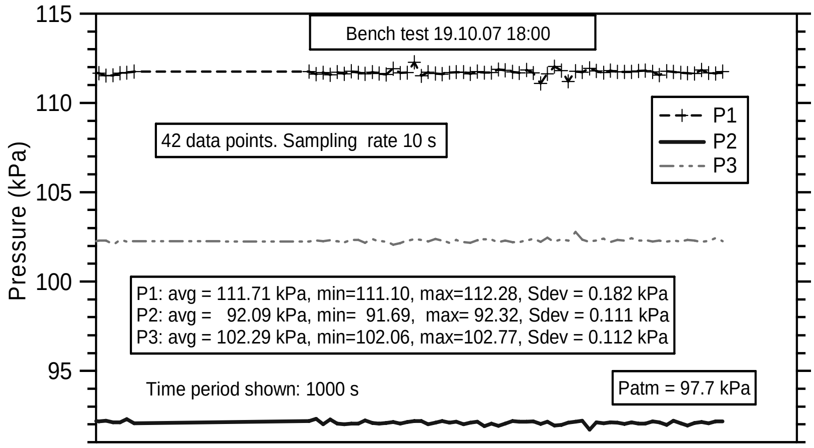


P1 average:	99.84	kPa
P2 average:	92.29	kPa
P3 average:	97.33	kPa
P4 average:	n.m.	kPa
P_{SL} average:	n.m.	kPa
P1 Sdev	0.054	kPa
P2 Sdev	0.060	kPa
P3 Sdev	0.058	kPa

File: TestData24.DAT

Onsite pretest bench test (Date: 19.10.07)

Measurement conditions (P, T and position)	**Sampling rate**
97.7 kPa 11.0 °C	10 s
( ) direct (x) vertical ( ) horizontal	



P1 average:	111.71	kPa
P2 average:	92.09	kPa
P3 average:	102.29	kPa
P4 average:	101.06	kPa [1]
P_{SL} average:	3.56	kPa [1]
P1 Sdev	0.182	kPa
P2 Sdev	0.111	kPa
P3 Sdev	0.112	kPa
P4 Sdev	0.056	kPa [1]
P_{SL} Sdev	0.019	kPa [1]

[1] Data not shown, 20.10.07, 05:45-08:15, File Oftr_2007_10_19_oftr_i1.dat, Patm=97.8 kPa

File: Oftr_2007_10_19_atm0.DAT

Form

BENCH TEST

SOLEXPERTS

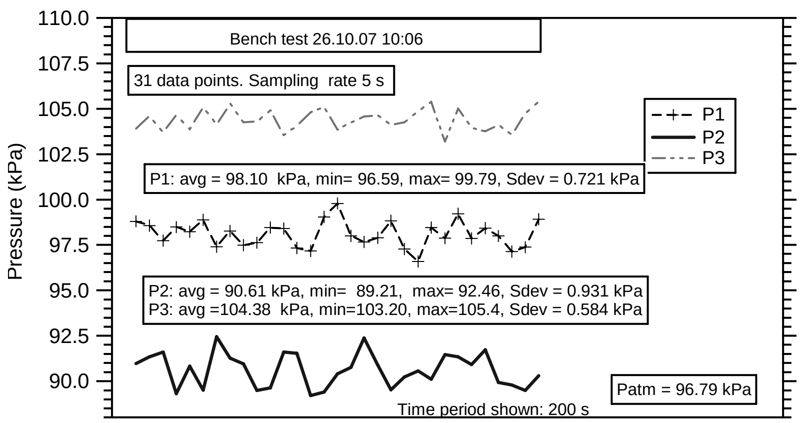
Project	Location	Date
Oftringen NOK EWS Borehole	Oftringen	18.12.2007
Well name	**Test name**	**Engineer**
NOK EWS 2007	Oftri-i3	Fi/SR

Transducer describtion	Output units
P1, P2, P3: 0-206.84 bar (3000 Psi), P4: 0-6 bar, P_{ST} = 0-10 bar	kPa, °C

P1#	P2#	P3#	P4#
43224	50370	43231	591.001.027

Onsite after test bench test (Date: 26.10.07)

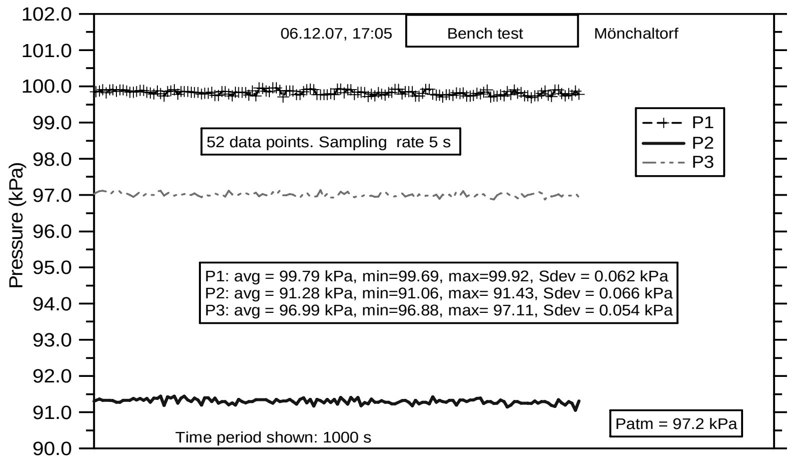
Measurement conditions (P, T and position)	Sampling rate
96.4 kPa 7.3 °C	5 s
( ) direct (x) vertical ( ) horizontal	



P1 average:	98.10 kPa
P2 average:	90.61 kPa
P3 average:	104.40 kPa
P4 average:	n.m. kPa
P_{SL} average:	n.m. kPa
P1 Sdev	0.721 kPa
P2 Sdev	0.931 kPa
P3 Sdev	0.584 kPa
File:	Oftr_2007_10_26_atm2.DAT

Offsite after test bench test (Date: 06.12.07)

Measurement conditions (P, T and position)	Sampling rate
96.6 kPa 9.6 °C	5 s
( ) direct (x) vertical ( ) horizontal	



P1 average:	99.69 kPa
P2 average:	91.28 kPa
P3 average:	96.99 kPa
P4 average: [1)]	101.44 kPa
P_{SL} average:	n.m. kPa
P1 Sdev	0.062 kPa
P1 Sdev	0.062 kPa
P2 Sdev	0.066 kPa
P3 Sdev	0.054 kPa
P4 Sdev	0.007 kPa

[1)] not shown on graph

File: test8.dat

Appendix D

Quick Look Report
Interval Oftr-i4

nagra

QUICK LOOK REPORT OFTRINGEN - TEST OFTR-i4

TEST START (Date/Time)	:	23.10.2007 / 18:03	**TEST END (Date/Time)**	:	24.10.2007 / 13:49

DOUBLE PACKER TEST

Test Interval Information	:			top test interval	:	500.00	m
borehole depth [1), 4)]	:	719.0	m	bottom of test interval	:	550.04	m
borehole radius	:	0.073	m	total interval length	:	50.04	m
tubing radius	:	20.0	mm	midpoint of interval	:	525.02	m
				P2-depth	:	496.86	m
interval volume, nominal [5)]	:	0.838	m^3	theoretical Cs-value[3)]	:	1.68E-09	m^3/Pa
slim tubing radius		4.75	mm	theoretical Cf-value (slim tube)	:	7.23E-09	m^3/Pa
WL prior to packer inflation [2)]	:	-1.42	m bgl	P2 signal prior to packer inflation	:	4971.0	kPa
WL in annulus at test end [2)]	:	-1.38	m bgl	P2 offset assuming ρ_{avg} = 997 kg/m3		97.6	kPa

1) all depths are not corrected for borehole deviation from vertical

2) WL = water level

3) assumes a total borehole system compressibility of 2E-09 Pa^{-1}

4) all depth measurements refer to ground level

5) cylindrical volume of isolated borehole section

Note all pressures cited in this report are absolute

Preliminariy information				
longitude of borehole	:	240887		
latitude of borehole	:	638346		
elevation of ground level (GL)	:	433.0	m asl	(reference point for all measurements)
assumed fresh water head	:	433.0	m asl	(assumed hydrostatic)
end of drilling	:	17.10.07 09:55		(Geotec)
porosity	:	3%		(assumed)
mud density [7)]	:	1032	kg/m^3	(Geotec end of drilling, 17.10.07)
borehole water density	:	997	kg/m^3	(Geotec after circulation of fresh water, 17.10.07; estimated using P2)
formation water density [8)]		1004.1	kg/m^3	(PVT correlation calculated by Saphir)
specific storativity [9)]	:	2.19E-06	m^{-1}	
formation water viscosity [8)]	:	8.05E-04	Pa s	(PVT correlation calculated by Saphir)
fluid compressibility [8)]	:	4.38E-10	1/Pa	(PVT correlation calculated by Saphir)
total compressibility	:	7.44E-09	1/Pa	(calculated assuming c_f= 7.00E-09 1/Pa)

7) Taken from daily report No. 53

8) Assumed, using salinity 10'000 ppm, T = 35.7 °C, P = 5200 kPa

9) Calculated based on assumed porosity and compressibility values

Responible Test Engineers	
Onsite:	Fisch, H.R.; Reinhardt, S.
Test analysis and reporting:	Rösli, U., Fisch, H.R.

Test Summary		
Test objectives	:	transmissivity, static formation pressure, flow model
borehole history	:	drilling through midpoint of interval: 04.10.2007, 17:30; 456.56 h duration until start of test
geology	:	marl - limestone interbedded strata
geophysics	:	Caliper log, salinity log, temperature log, sonic log
test phases	:	COM, PSR, PI, SW, SWS, PI2

QLR results	**Test zone 500.00 - 550.04 mbgl**	**T [m2/s]**	**K [m/s]**	**Formation Flow model**	**Freshwater Head [m asl]**
Analytical interpretation		2.25E-12	4.50E-14	radial flow	-
Numerical simulation		9.61E-13	1.92E-14	homogeneous	373.1

Note:
A complete list of results is provided in the summary tables

Mönchaltorf, 31.01.08 (Rev. 1); 01.08.08 (Rev. 2) prepared by: SOLEXPERTS INTERA

Summary of Test Data		Page 1/3			
Test Phase		INF	COM	PSR 2)	PI_a 1) 3)
duration	[h]	0.486	0.476	2.194	0.040
T2 (i/f)	[°C]	35.81 / 35.62	35.62 / 35.59	35.59 / 35.63	35.63 / 35.71
P1 (i/f)	[kPa]	4985 / 4982	4982 / 4972	4972 / 4969	4969 / 4970
P2 (i/f)	[kPa]	4971 / 4972	4972 / 4973	4973 / 4990	4990 / 5291
P3 (i/f)	[kPa]	4974 / 4974	4974 / 4974	4974 / 4974	4974 / 4974
P4 (i/f)	[kPa]				
Measured C	[m3/Pa]				3.6E-10
c_{SC}	[1/Pa]				4.3E-10
q	[l/min]				
Q	[l]				
inner boundaries		no analysis	no analysis	wellb. storage	no analysis
flow geometry				hom.	
outer boundaries				inf.lat.ext.	
T	[m^2/s]			(3.70E-11) A)	
K	[m/s]			(7.39E-13) A)	
k	[m^2]			(6.04E-20)	
S_S	[1/m]			(1.08E-06) A)	
S	[-]			(5.40E-05) C)	
Pi, P_f if matched	[kPa]			(5.19E+03) A)	
Head	[m asl]			(4.55E+02) C)	
Derived flow rate	[l/min]				
s (skin factor)	[-]				
S_{SS} (skin zone)	[1/m]				
t_S (skin zone)	[m]				
K_S (skin zone)	[m/s]				
figures				1,9,10	1,4
temperature effects				no	
borehole history				yes	
anomalies				no	
bypass PA2				no	
bypass PA1				no	

comments

notes:
- i = initial, f = final
- T value in bold most representable of the undisturbed formation

1) analytical with no superposition
2) numerical simulation with detailed borehole history effects
3) The Pulse Injection phase was divided into two phases.
The first, PI_a, includes the pressure increase during the flow phase.
The second, PI_b, is the post shut-in (recovery) sequence.

5) Opitimized fit on PSR, PI_b, and SWS
A) matched parameter
B) input parameter
C) calculation assumes: freshwater density 1000 kg/m^3, g = 9.81 m^2/s, P_{atm} and z_2 as stated on front page
D) early-middle time fit
E) extrapolated head

Summary of Test Data		Page 2/3							
Test Phase		PI_b[1)]		PI_b[2) 3)]		SW[2)]		SWS[2)]	
duration	[h]	1.546		1.546		2.076		12.218	
T2 (i/f)	[°C]	35.71 / 35.60		35.71 / 35.60		35.6 / 35.5		35.5 / 35.5	
P1 (i/f)	[kPa]	4970 / 4974		4970 / 4974		4974 / 4982		4982 / 5015	
P2 (i/f)	[kPa]	5291 / 5274		5291 / 5274		4160 / 4160		4160 / 4257	
P3 (i/f)	[kPa]	4974 / 4974		4974 / 4974		4975 / 4974		4974 / 4975	
P4 (i/f)	[kPa]								
Measured C	[m3/Pa]								
c_{SC}	[1/Pa]								
q	[l/min]								
Q	[l]								
inner boundaries		wellb. storage		wellb. storage		wellb. storage		wellb. storage	
flow geometry		hom.		hom.		hom.		hom.	
outer boundaries		inf.lat.ext.		inf.lat.ext.		inf. lat. ext.		inf. lat. ext.	
T	[m^2/s]	2.25E-12	A)	7.81E-12	A)	(8.81E-12)	A)	6.51E-13	A)
K	[m/s]	4.50E-14	A)	1.56E-13	A)	(1.76E-13)	A)	1.30E-14	A)
k	[m^2]	3.68E-21		1.27E-20		(1.44E-20)		1.06E-21	
S_S	[1/m]		A)	3.71E-07	A)	(2.62E-07)	A)	3.22E-06	A)
S	[-]		C)	1.86E-05	C)	(1.31E-05)	C)	1.61E-04	C)
Pi, P_f if matched	[kPa]	4989.85	B)	5932.5	B)	(3.13E+03)	B)	3575.6	B)
Head	[m asl]	434.8	C)	530.9	C)	(2.45E+02)	C)	290.68	C)
Derived flow rate	[l/min]					~1.3E-4 [6)]			
s (skin factor)	[-]								
S_{SS} (skin zone)	[1/m]								
t_S (skin zone)	[m]								
K_S (skin zone)	[m/s]								
figures		1,4,5		1,11		1,6,12		1,6,13,14	
temperature effects		no		no		no		no	
borehole history		no		yes		yes		yes	
anomalies		no		no		no		no	
bypass PA2		no		no		no		no	
bypass PA1		no		no		no		no	

comments

notes:
- i = initial, f = final
- T value in bold most representable of the undisturbed formation

1) analytical with no superposition
2) numerical simulation with detailed borehole history effects
3) The Pulse Injection phase was divided into two phases.
   The first, PI_a, includes the pressure increase during the flow phase.
   The second, PI_b, is the post shut-in (recovery) sequence.
5) Opitimized fit on PSR, PI_b, and SWS
6) Calculated based on meas. C and SWS unit-slope (rough estimate)
A) matched parameter
B) input parameter
C) calculation assumes: freshwater density 1000 kg/m^3, g = 9.81 m^2/s, P_{atm} and z_2 as stated on front page
D) early-middle time fit
E) extrapolated head

Summary of Test Data		Page 3/3			
Test Phase		PI2_a 3)	PI2_b 1)	PI2_b 2)3)	Simulation entire Seq. 5)
duration	[h]	0.034	0.471	0.471	19.76
T2 (i/f)	[°C]	35.5 / 35.7	35.7 / 35.6	35.7 / 35.6	41.89 / 41.56
P1 (i/f)	[kPa]	5015 / 5014	5014 / 5015	5014 / 5015	4972 /5015
P2 (i/f)	[kPa]	4257 / 4988	4988 / 4968	4988 / 4968	4973 / 4968
P3 (i/f)	[kPa]	4975 / 4974	4974 / 4974	4974 / 4974	4974 / 4974
P4 (i/f)	[kPa]				
Measured C	[m3/Pa]		4.2E-10		
c_{SC}	[1/Pa]		5.0E-10		
q	[l/min]				
Q	[l]				
inner boundaries		no analysis	wellb. storage	wellb. storage	wellb. stor.
flow geometry			hom.	hom.	hom.
outer boundaries			inf.lat.ext.	inf.lat.ext.	inf. lat. ext.
T	[m^2/s]		8.78E-12 A)	8.76E-12 A)	**9.61E-13** A)
K	[m/s]		1.76E-13 A)	1.75E-13 A)	**1.92E-14** A)
k	[m^2]			1.43E-20	1.57E-21
S_S	[1/m]			2.10E-07 A)	1.79E-06 A)
S	[-]			1.05E-05 C)	8.96E-05 C)
Pi, P_f if matched	[kPa]		4256.7 B)	5828.3 B)	**4384** B)
Head	[m asl]		360.11 C)	520.31 C)	373.08 C)
Derived flow rate	[l/min]				
s (skin factor)	[-]				
S_{SS} (skin zone)	[1/m]				
t_S (skin zone)	[m]				
K_S (skin zone)	[m/s]				
figures		1,7	1,7,8	15	16,17,18,19
temperature effects			no	no	no
borehole history			no	yes	yes
anomalies			no	no	no
bypass PA2			no	no	no
bypass PA1			no	no	no

comments

notes:
- i = initial, f = final
- T value in bold most representable of the undisturbed formation

1) analytical with no superposition
2) numerical simulation with detailed borehole history effects
3) The Pulse Injection phase was divided into two phases.
The first, PI2_a, includes pressure oscillations during the flow phase.
The second, PI_b, is the post shut-in (recovery) sequence.

5) Opitimized fit on PSR, PI_b, SWS and PI2_b
A) matched parameter
B) input parameter
C) calculation assumes: freshwater density 1000 kg/m^3, g = 9.81 m^2/s, P_{atm} and z_2 as stated on front page
D) early-middle time fit
E) extrapolated head

Test overview

Test Oftr-i4 (500.0 - 550.04 m bgl) was performed on 23.-24.10.2007 in the Oftringen NOK EWS-Borehole. The test interval consisted of a sequence of marls (so-called Effinger Mergel) with interbedded limestone layers from 513.3 to 521.7 m and from 538.9 to 545.5 m bgl. The lower interbedded limestone section is called “Gerstenhübel-Schichten”. The whole tested section belongs to the Effinger-Member of the jurassic Malm (Oxfordian) formation.

The test objectives were to obtain reliable estimates of interval transmissivity and fresh-water hydraulic head using an appropriate flow model. The test was performed with a straddle-packer configuration with an interval length of 50.04 m. Pressures and temperatures were measured in the test interval (P2, T2) and in the interval below the lower packer (P1, T1) and in the annulus above the upper packer (P3, T3). In addition, pressure was measured in the tubing above the upper packer (P4).

The pressure response of the entire test sequence in Oftr-i4 is shown in **Figure 1**. The pressure history derived from water table measurements (source: Colenco, Solexperts) and fluid density measurements (SJ Geotec) is presented in **Figure 2**.

Following packer inflation (INF) the test sequence started with a COM and PSR phase to dissipate temperature and borehole history effects. Temperature effects are considered negligible, because downhole temperatures (T1, T2, T3) indicated no trend over the entire test duration, with noise of about 0.2 °C.

The pulse injection test (PI) was performed to measure the wellbore compressibility early in the test and obtain an initial estimate of the formation properties. As the valve was open for about 145 s, the PI was separated into two sections for the analysis. The pressure increase phase was labeled as PI_a with the subsequent shut-in recovery phase labeled as PI_b. During the slug withdrawal (SW) test a small pressure change occurred due to a small change in packer pressure, which didn’t affect the main pressure trend. Shortly afterwards, the SW was terminated and followed by the shut-in phase (SWS). The SW/SWS test was performed to get a more distinct formation response combined with a larger radius of investigation for the determination of the formation properties. After the SWS sequence a second pulse injection test was performed to determine wellbore compressibility for comparison with that from the earlier PI phase.

Due to the influence of the adjacent high voltage current transformer facility (NOK), the pressure and temperature signals of the downhole triple probe were noisy during the hole testing sequence.

Analysis

For the QLR analysis, the analytical and numerical methods were used for a standard analysis, which will be the basis for a possible detailed analysis depending on the test objectives and test results.

Analytical Analysis

Type curve and straight-line fitting methods are applied. Effects of the borehole pressure history are not taken into account.

Pulse injection test (PI)

The PI test was initiated at unsteady pressure conditions during PSR while P2 was showing an upward trend of 1.35E-3 kPa/s, probably caused by compliance effects which may not have fully dissipated prior to start of PSR. The PSR flow period was too short to be analyzed. At start of the pulse test the interval pressure was exposed to a differential pressure of 303 kPa. The shut-in valve was kept open during 145 seconds. After shut-in, a water level decrease equal to 0.079 m was measured in the 1.9" test string (dip meter measurement), indicating a volume change of 0.11 liters due to compression of the test zone. The wellbore storage constant C (ΔV / ΔP) equals to 3.6E-10 m^3/Pa. For the PI analysis, the history effect of the precedent relatively long PI_a period was not taken into account (**Figure 4**).

The pulse response was analyzed using CBP type-curves. For the analysis shown in **Figure 5**, the P2 data were corrected assuming a linear pressure trend of +0.00135 kPa/s. A T-value of 2.25E-12 m^2/s was obtained based on a type-curve value $\alpha = 0.1$. Note that the CBP type-curve matching method is not sensitive for high α-values as α type-curves greater 1 are difficult to distinguish with respect to the slope steepness. High α values are associated with high aquifer storativity values (S). As storativity estimates from pulse test analyses are commonly known as unreliable, the S and S_S results are not presented.

Slug test withdrawal test (SW)

Prior to start of the SW test, the water table in the 1.9" tubing was lowered to 90.16 m bgl (change of tubing water level does not affect the interval pressure while the shut-in tool is closed). A slim tubing was installed in the 1.9" NU API rods before start of SW. The slim tubing system consists of a stiff high pressure hose of ID = 9.5 mm and a packer at its bottom (OD =28 mm). The packer is inflated using pressurized nitrogen, sealing the annulus between the 1.9" tubing and the slim tubing. The slim tubing was installed to a depth of approximately 95 m bgl, covering the span of expected water table change of the slug test. A pressure transducer attached just above the packer and with connection to the tube inside enables recording of water level changes, redundantly to the P2 sensor. The small diameter of the slim tubing allows for faster slug recovery.

Prior to start of SW, the P2 pressure curve showed a decreasing trend of -0.001 kPa/s. The SW test was started about 1.6 hours after start of PI. During the SW-phase a small pressure change occurred due to a small change in packer pressure, which didn't affect the main pressure trend. During SW, the shut-in valve was open for 2.08 hrs and approximately 36 ml of formation water were produced (calculation based on P4 pressure change) corresponding to an average flow of 0.29 ml/min. As only 5 kPa pressure recovery (0.45 %) was achieved during the SW-test, no analytical CBP analysis was conducted on the data.

Shut-in phase SWS

The slug test was shut-in after 2.08 hours and further pressure recovery (SWS) was recorded for 12.22 hours. The early-time data of SWS were analyzed in a log-log plot to derive the last production rate of the precedent SW phase. The estimate is based on the measured C-value (PI) and the 'unit slope' identifying the early-time pressure recovery phase with one log cycle pressure change per one log cycle of time (**Figure 6**). The result of 0.13 ml/min has to be considered as an indicative value. No further analytical analysis was conducted on the SWS data in view of the apparent history effects due to the precedent test events PSR, PI, SW.

Second pulse injection test (PI2)

A pulse injection test (PI2) was performed in order to confirm the C-value obtained during PI_a. During preparation of PI2, the water in the 1.9" test rods was filled up to a level 6 cm below top of tubing. In the 0.5 hrs prior start of PI, the P2 pressure curve showed a rising slope of 0.00121 kPa/s. PI2 was initiated by open the shut-in valve and exposing the test zone to a differential pressure of 732 kPa (**Figure 7**). A water level decrease Δh equal to 0.245 m was measured in the 1.9" test string, indicating a volume change of 0.308 liters due to compression of the test zone. The wellbore storage constant C (ΔV / ΔP) equals to 4.2E-10 m^3/Pa, a value comparable to the result obtained from PI_a (C=3.6E-10 m^3/Pa).

The PI2 test was recorded during a period of 0.47 hrs. A pressure recovery of 3% is obtained after correcting a linear trend of 0.0012 kPa/s (**Figure 8**). The CBP match on the corrected data suggests a T-value of 7.7E-12 m^2/s.

Numeric Analysis using nSights

In a first step, the diagnostic plots for the individual sequences were analyzed and fitted individually, accounting for borehole history and taking into account transient effects associated with the preceding test sequences. In a second step, the entire test sequence was simulated and fitted based on the Cartesian pressure plot and accounting for borehole history. For the Cartesian fit, all test phases except history periods were chosen and no weighting for individual events was applied. The so-called history periods BH, INF1, INF2, COM, PI_a, H05 and PI2_a were not fitted but incorporated as test events with defined pressure in the simulation process. PI_a, PI2_a and H05 denote very short events of less than 0.04 hrs duration and represent transitional phases such as the measured pressure increase during initiation of a pulse injection test (open shut-in valve phase at start of PI_a and PI2_a) or the pressure drop at initiation of the slug withdrawal test (SW).

Please note that the fits of the Ramey plots for the PI and SW sequences are the result of the inverse parameter estimation using nSights and represent a solution of a numeric process that includes the effects of potential transient effects of the preceding test phases and the borehole history.

The diagnostic plots of the individual test sequences did not indicate characteristic responses of a composite flow model, or any other more complex flow models. Consequently, a homogeneous model was assumed in this first evaluation for estimating formation parameters (i.e., K, S_s, and P_f). The analyses used the wellbore compressibility of 4.2E-10 m^3/Pa (C_{SC} = 5.03E-10 1/Pa) which was determined from PI2_b.

The log-log diagnostic plot of the PSR indicates dominantly wellbore storage effects (**Figure 9**) providing only preliminary estimates of formation parameters (K = 7.39E-13 m/s, S_s= 1.08E-6 m^{-1}, P_f = 5189.3 kPa). Additionally this phase may be influenced by compliance effects which may not have fully dissipated prior to start of PSR. The fit to the observed data (**Figure 9**) and to the Horner plot is quite good (**Figure 10**).

The initial pressure increase phase (PI_a, **Figure 4**) was incorporated as a pressure history sequence. The Ramey plot of the PI_b sequence in terms of the normalized pressures produced a relatively good fit (**Figure 11**), but yielded parameters different from the PSR, characterized by specific storage values at the lower range of acceptable values and a high static formation pressure (K = 1.56E-13 m/s, S_s= 3.71E-7 m^{-1}, P_f = 5932.5kPa).

The SW phase indicates a pressure change of only 5 kPa, which amounts to a recovery of 0.45% of the imposed pressure change of 1114 kPa at the start of SW. The diagnostic plot of the SW sequence in terms of the normalized pressures produced a relatively good fit (**Figure 12**) yielding parameters similar to the PI_b phase but with a very low static formation pressure (K = 1.76E-13 m/s, S_s= 2.62E-7 m^{-1}, P_f = 3129.5 kPa), Even though optimization produced a good fit (Figure 12), the extremely low recovery indicates that the parameters estimates are considered unreliable due to near zero sensitivity (Figure 17).

Despite the long duration of the SWS phase of 12.22 hours, the SWS log-log diagnostic plot (**Figure 13**) indicates dominantly wellbore storage effects at early time followed by a transition period without reaching an infinite acting radial flow (IARF) regime. The optimization was performed on the middle and late-time time data as the early time data were affected by the pressure change which occurred together with a change in packer pressure at the end of the SW. The analysis produced a relatively good fit with a low static formation pressure (K = 1.30E-14 m/s, S_s= 3.22E-6 m^{-1}, P_f = 3575.6 kPa) to the log-log diagnostic and the Horner (**Figure 14**) plots.

The second PI phase was analyzed similar to the first PI phase. The initial pressure increase phase with a duration of 107 s (PI2_a, **Figure 8**) was incorporated as a pressure history sequence. The diagnostic plot of the PI2_b sequence in terms of the normalized pressures produced a relatively good fit (**Figure 15**) and yielded parameters similar to the PI_b phase (K = 1.75E-13 m/s, S_s= 2.10E-7 m^{-1}, P_f = 5828.3 kPa). However, the range between the upper and lower values for the 95% confidence intervals could not be determined, indicating a rather poor quality of the model.

The simulation of the entire test sequence on a Cartesian plot (**Figure 16**) produced the fitted parameters K = 1.91E-14 m/s and S_s= 1.8E-6 m^{-1} with a static formation pressure P_f of 4384 kPa. The results were similar to those received from the individual SWS fit (**Figure 13**), but with a higher static formation pressure. **Figure 16** shows a good fit to all sequences except for the PSR phase which is more likely affected by compliance effects. The diagnostic plots of the PI_b and SWS phases (**Figure 18** and **Figure 19**) for the matching results of the entire test sequence confirm the good quality of the model. The sensitivity coefficients of the formation parameters during the different sequences are presented in **Figure 17**. The SWS phase indicates the greatest parameter sensitivity. The definition of the sensitivity coefficient is given in the Chapter “Definitions”.

Results and Discussion

The shut-in wellbore storage constant values (C) obtained from the pulse injection tests PI_b and PI2_b are very low and correspond to system compressibility values (c_{SC}) of 4.3E-10 Pa^{-1} (for PI_b) and 5.0E-10 Pa^{-1} (for PI2_b). These values are very similar to the expected compressibility of water at depth and temperature conditions of the test zone (expected c_w.= 4.4E-10 Pa^{-1}). The measured low c_{SC} values can be explained by the relatively large water volume in the 50 m long interval section diminishing the effect of the elastic behavior of the packer on this parameter (c_{SC} = C / $V_{interval}$). The measured system compressibilities are considered approximate values because of the limited accuracy inherent to this type of field measurement.

The Ss values of the individually fitted PI_b, and PI2_b sequences are low compared to the initial Ss estimate (Ss values as expected based on assumed formation compressibility, porosity, and water compressibility). Only little percental recovery was observed during these test events indicating that the estimated Ss parameter is not well constrained and may have limited reliability.

The estimated formation parameters for the different sequences vary significantly based on a homogeneous flow model. The range in K varies between 1.3E-14 m/s (T=6.5E-13 m^2/s) and 1.75 E-13 m/s (T=8.8E-12 m^2/s). Whereas the higher estimates are from short tests indicating low parameter sensitivity, the low estimate is from the fit of the SWS diagnostic and is similar to that from the from the Cartesian fit. The range in S_s varies between 2.1E-7 m^{-1} and 3.2E-6

m^{-1}. The Ss value obtained from the Cartesian fit agrees with the initial Ss estimate derived from assumed formation properties. The static formation pressure P_f shows a very wide range between 3576 kPa and 5933 kPa, based on the SWS and PI responses, respectively. Because of low permeability of the formation and the relatively short duration of the test phases, only early time data were available for extrapolation of formation pressures, which is subject to large uncertainty.

The lowest static formation pressure (P_f) of 3576 kPa was obtained from the diagnostic fit of the SWS phase, which is lower than the initial pressure at the start of SW. Without potential transient effects from preceding test sequences and from borehole history, the formation pressure can be extrapolated from the Horner diagnostic plot (Figure 14); an optimization on the Horner diagnostic plot (without preceding transient effects) gives an estimate for P_f of 4384 kPa. The simulated estimate of P_f = 3576 kPa implies that the observed pressure recovery during SWS responds to a pressure buildup in the formation from the relatively high prescribed pressure in the borehole during drilling (Figure 2). Alternatively, the formation should not “see” a pressure buildup during borehole history, which would imply a formation pressure between 4300 kPa (from the SWS Horner extrapolation) and 5250 kPa (from the PI recovery). An optimization on the Horner diagnostic plot (without preceding transient events) gives an estimate for P_f = 4384 kPa, K_f = 9.6E-14 m/s, S_s = 4.9E-6 m^{-1}. The Horner P_f estimate corresponds to the P_f estimate from the entire sequence fit.

The simulation results of the entire sequence fit, accounting for both PI and SWS, are considered the most representative parameter estimates. However, uncertainties remain regarding the static formation pressure, which does affect the parameter estimates for the formation conductivities. A preliminary assessment indicates a potential range for K_f between 1.E-13 and 1.E-14 m/s.

FIGURES

ABBREVIATIONS
NOMENCLATURE
DEFINITIONS
FIELD DOCUMENTATION

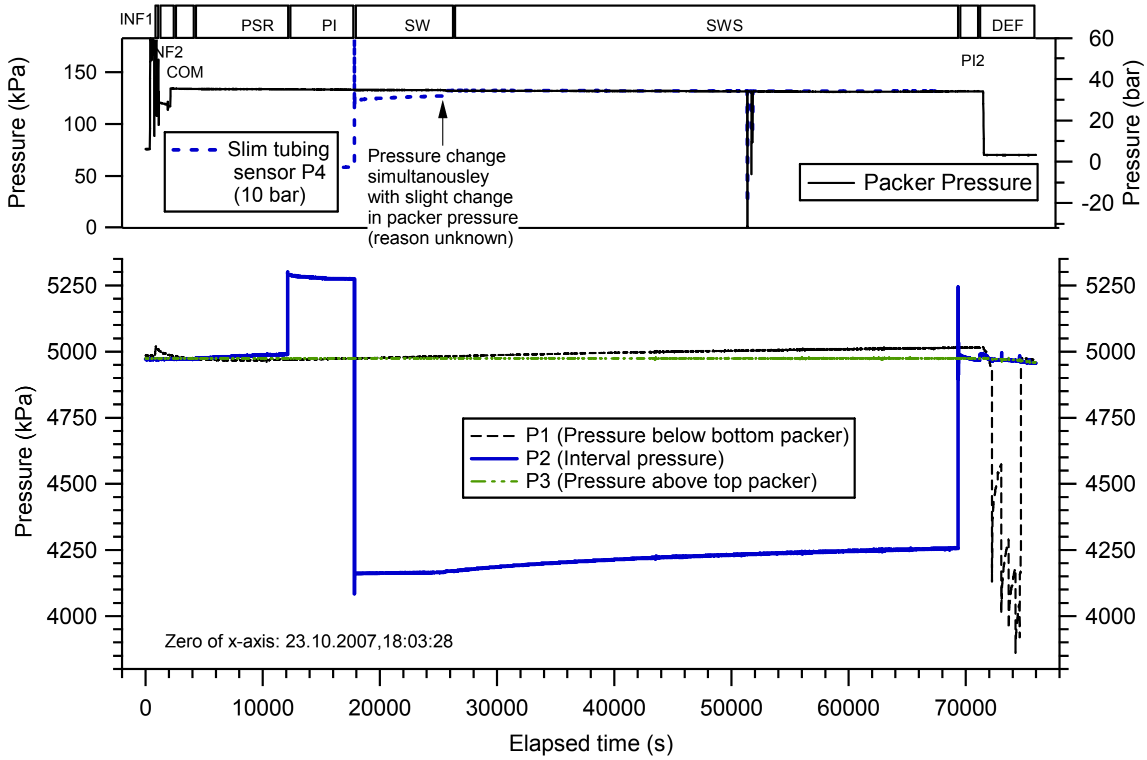


Figure 1: Ofrt-i4: Overview plot

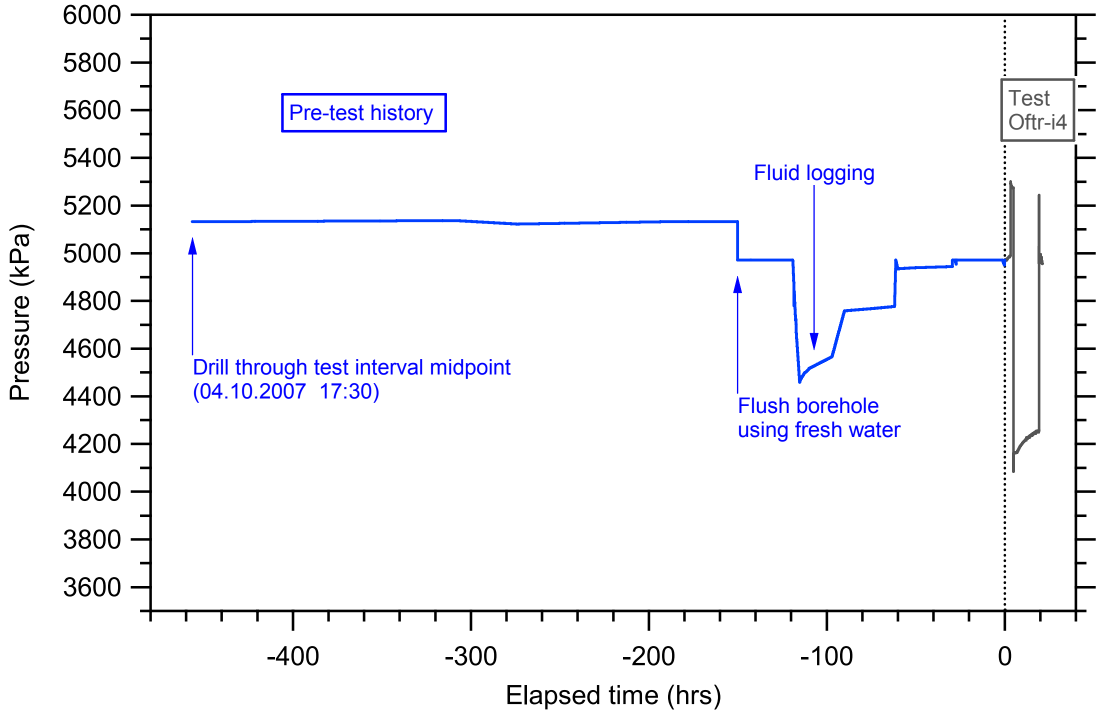


Figure 2: Ofrt-i4: Borehole pressure history

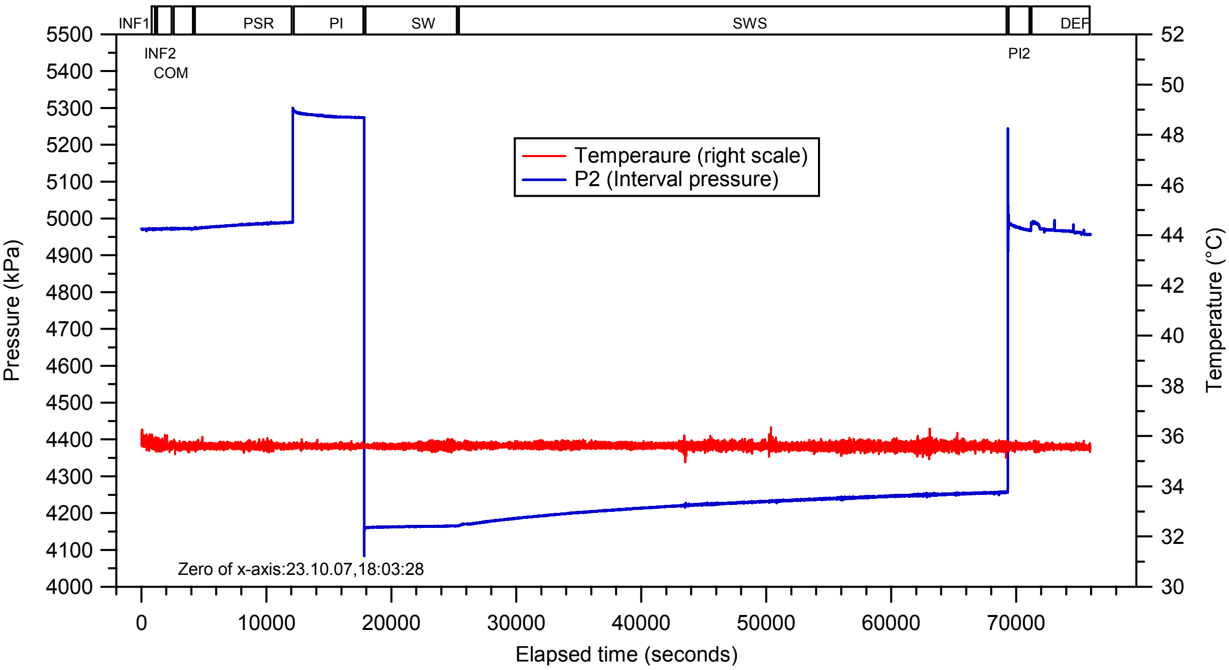


Figure 3: Oftr-i4: Measured downhole temperature (T2)

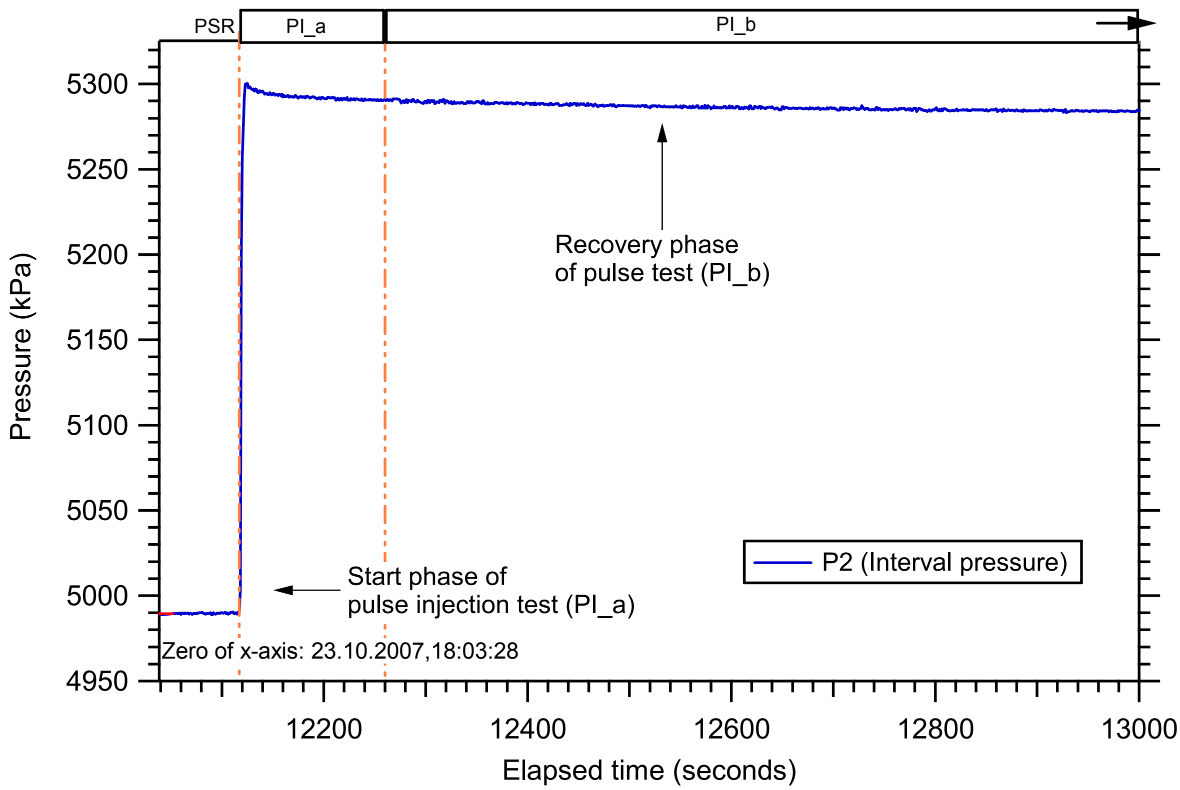


Figure 4: Oftr-i4: Detail of pulse injection test PI

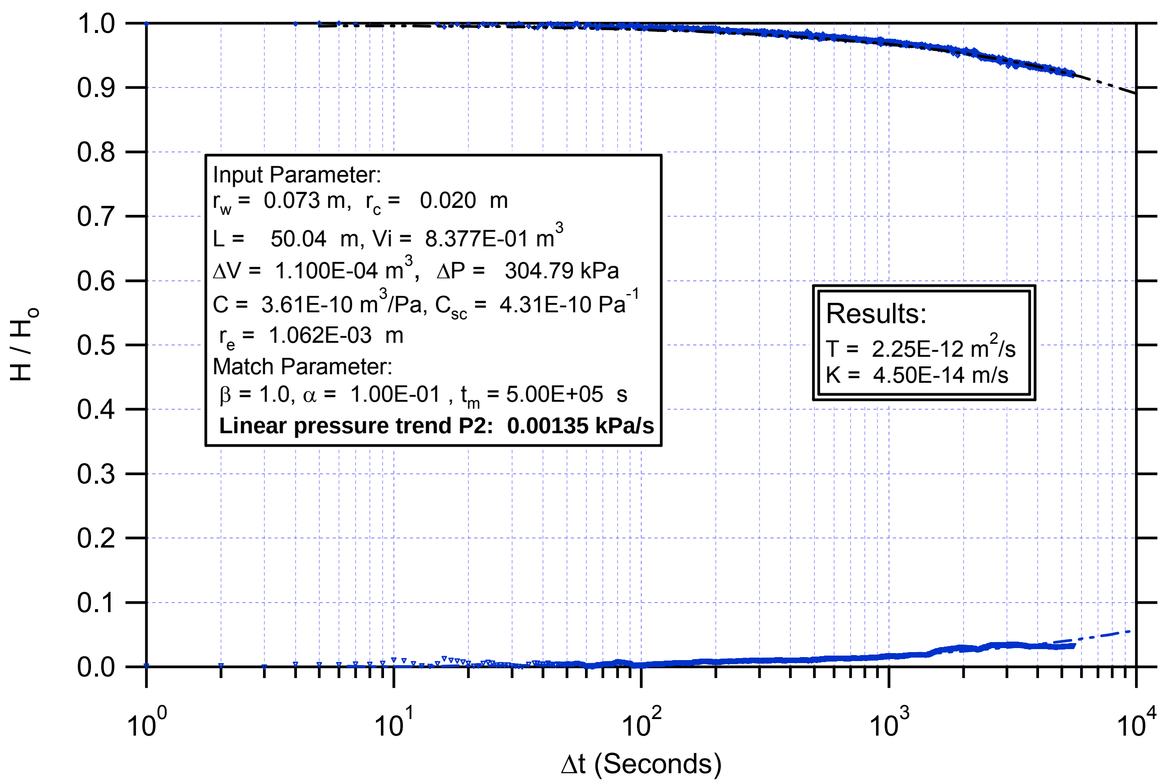


Figure 5: Oftr-i4: PI_b test analysis using CBP type-curves, based on trend corrected data.

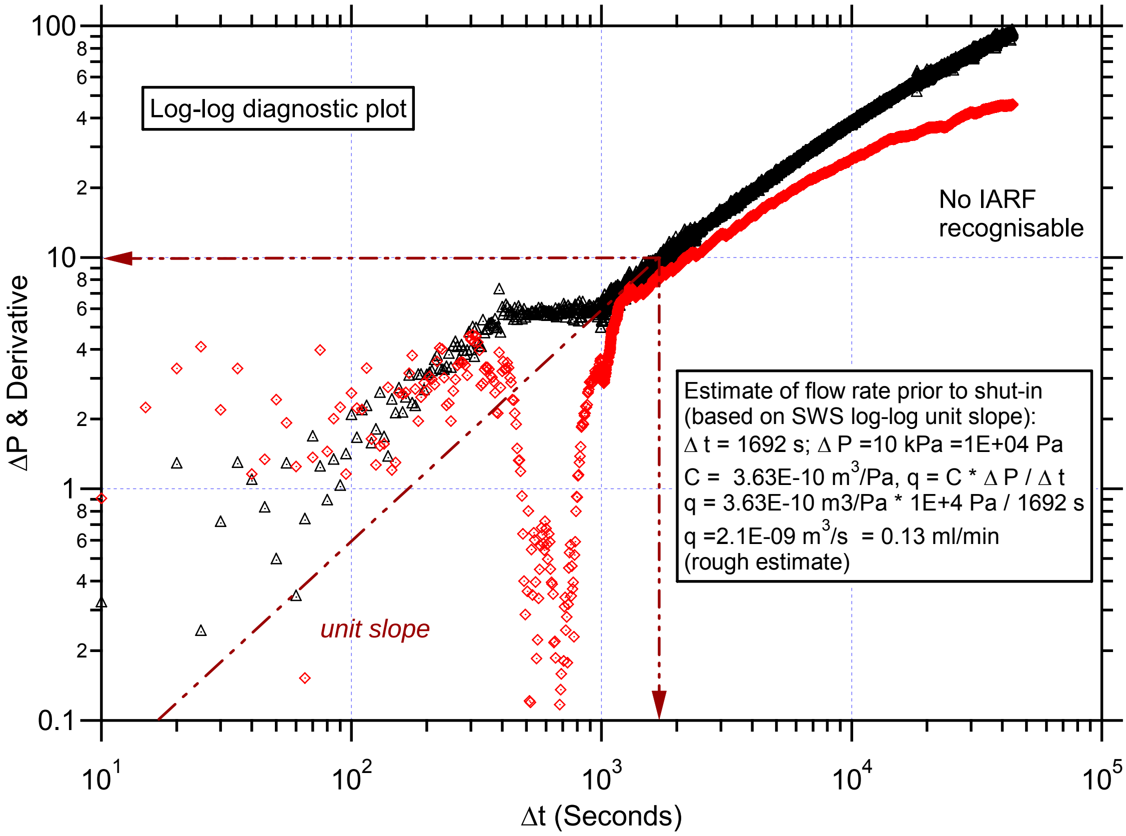


Figure 6: Oftr-i4: Estimate of q_e of SW based on log-log unit slope of SWS

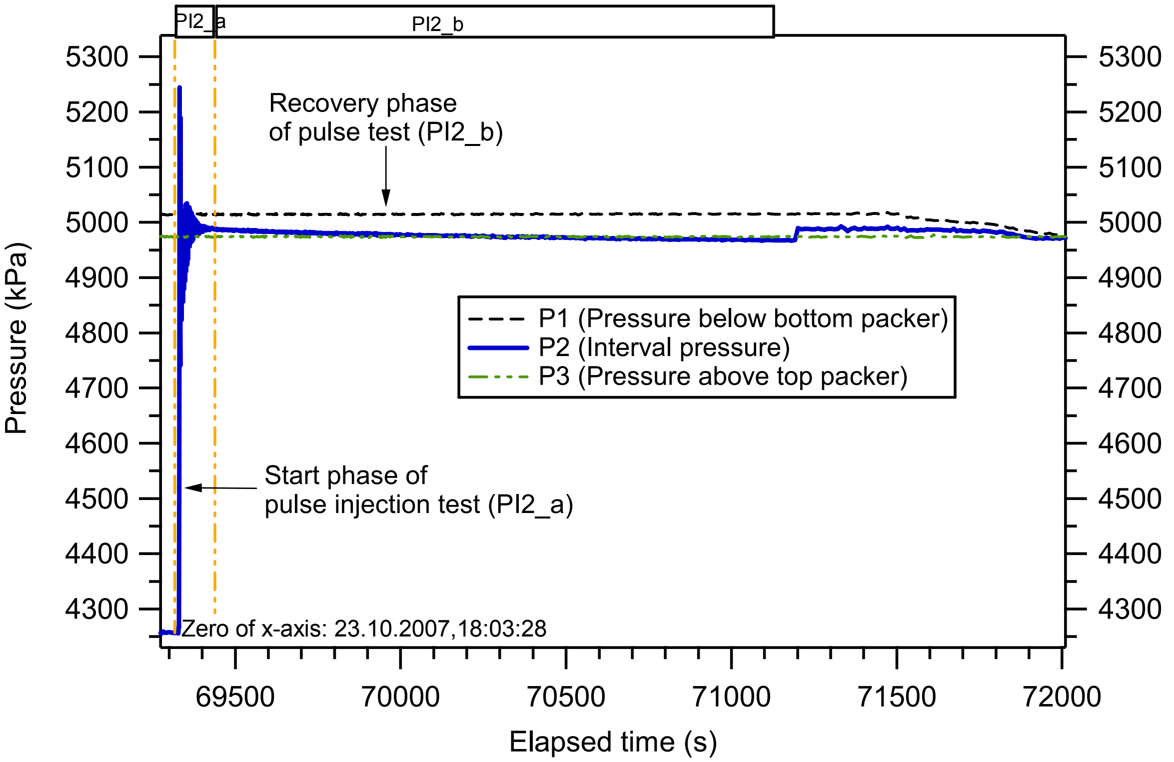


Figure 7: Oftr-i4: Detail of pulse injection test PI2

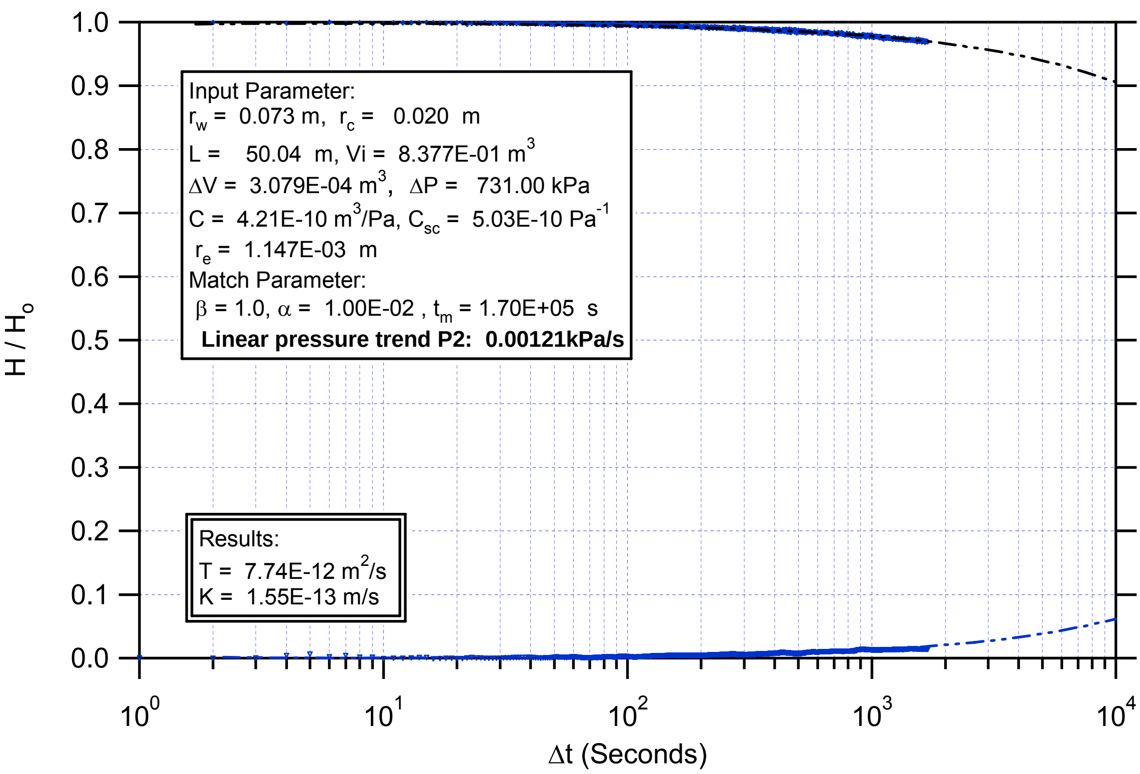


Figure 8: Oftr-i4: PI2_b test analysis (CBP) based on trend corrected data

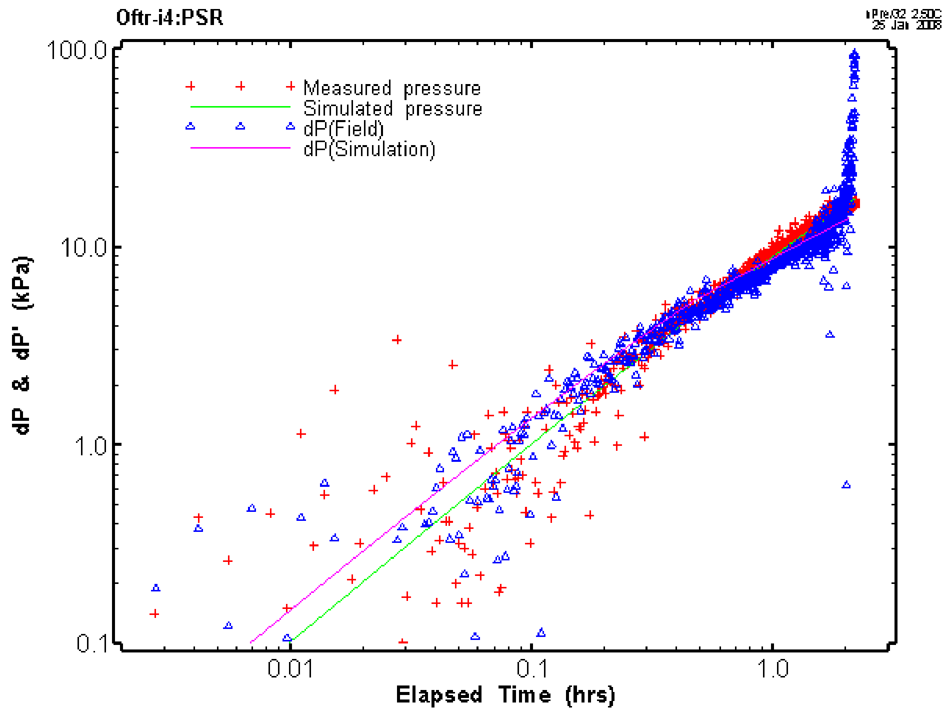


Figure 9: Oftr-i4: PSR log-log diagnostic plot

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_fm	[m/sec]	7.39E-13	2.77E-16	1.97E-09
P_fm	[kPa]	5189.3	???	???
ss_fm	[1/m]	1.08E-06	1.42E-13	8.19E00

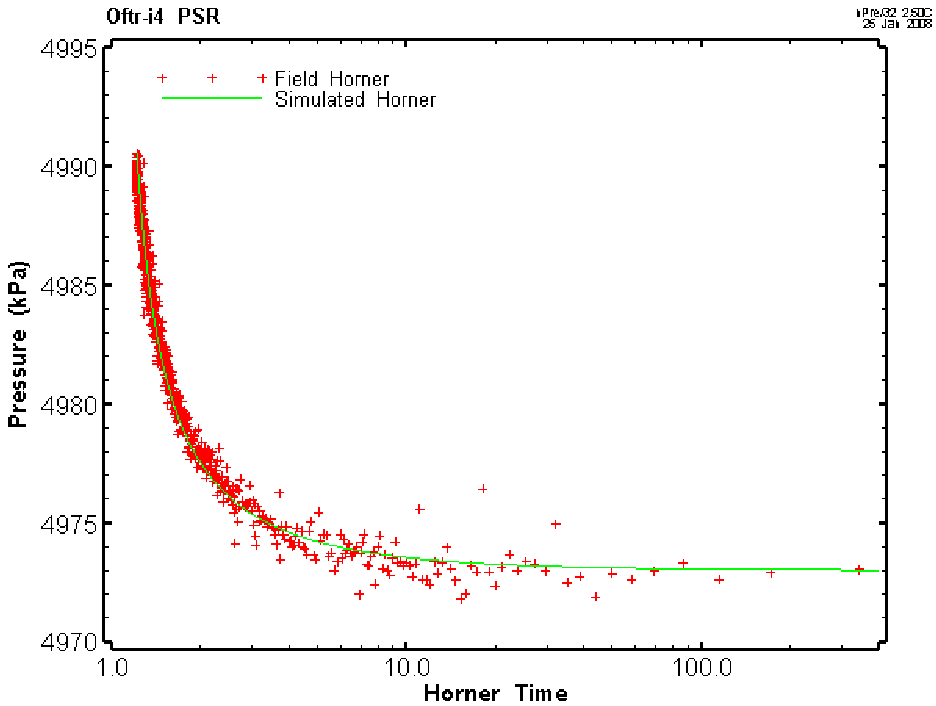


Figure 10: Oftr-i4: PSR Horner plot

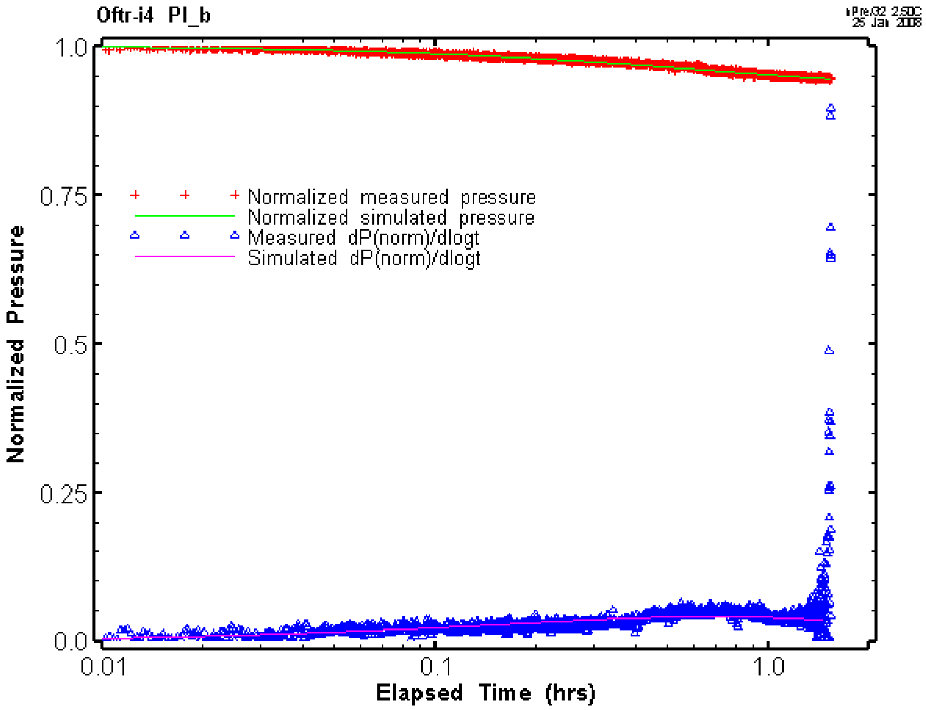


Figure 11: Oftr-i4: PI_b normalized pressure (Ramey A) plot.

Fit Statistics:

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_fm	[m/sec]	1.56E-13	1.09E-14	2.23E-12
P_fm	[kPa]	5932.5	5085.2	6779.7
ss_fm	[1/m]	3.71E-07	2.00E-08	6.91E-06

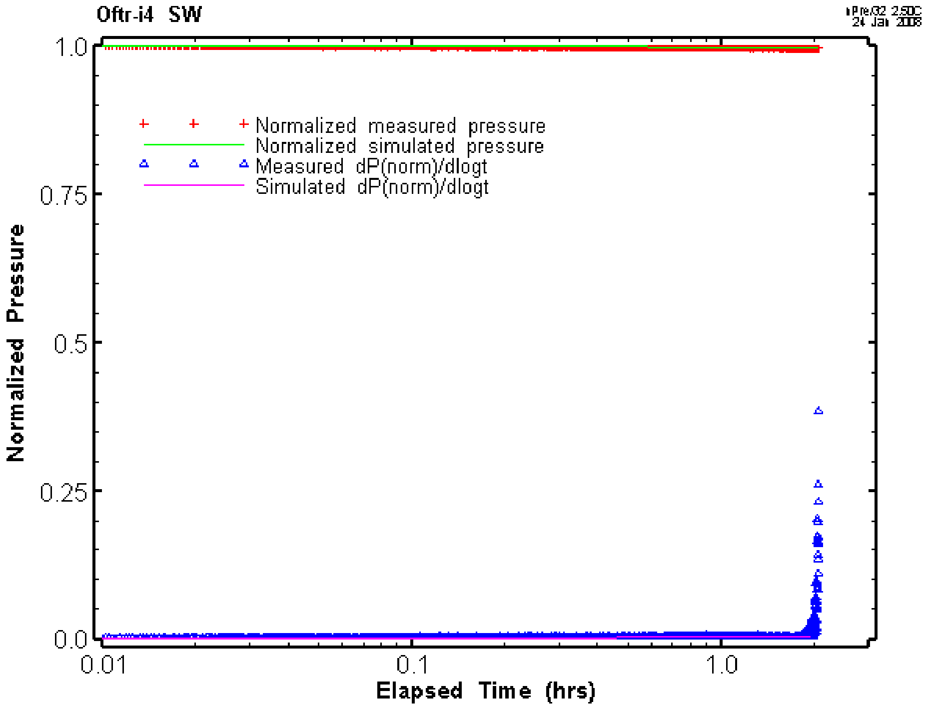


Figure 12: Oftr-i4: SW normalized pressure (Ramey A) plot

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_fm	[m/sec]	1.76E-13	1.32E-15	2.37E-11
P_fm	[kPa]	3129.5	1349.2	4909.7
ss_fm	[1/m]	2.62E-07	1.15E-09	5.94E-05

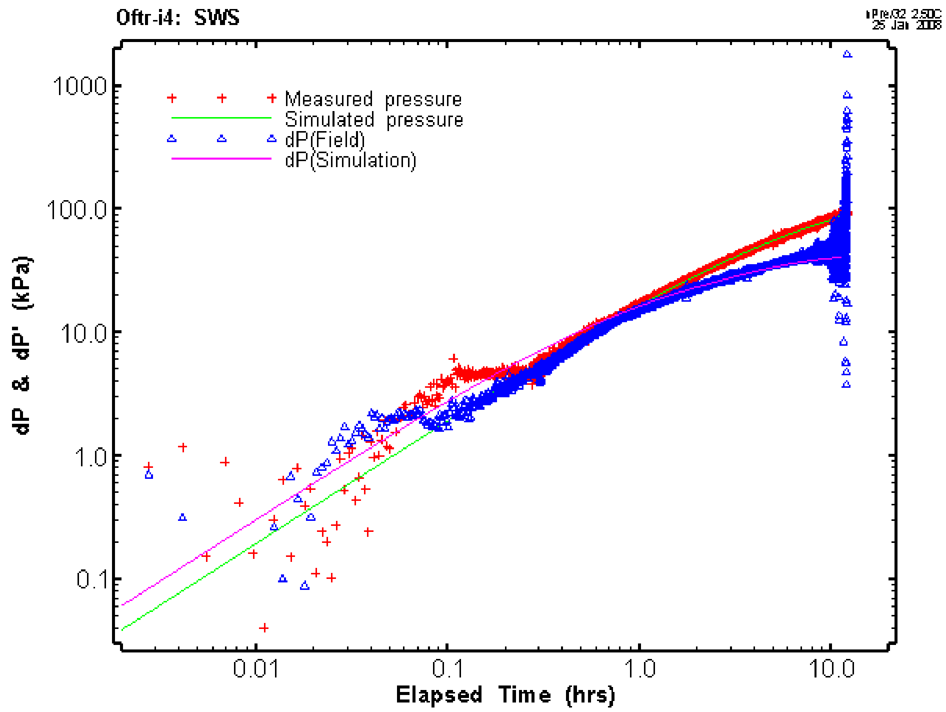


Figure 13: Oftr-i4: SWS log-log diagnostic plot

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_fm	[m/sec]	1.30E-14	1.19E-14	1.41E-14
P_fm	[kPa]	3575.6	3532.7	3618.4
ss_fm	[1/m]	3.22E-06	2.88E-06	3.61E-06

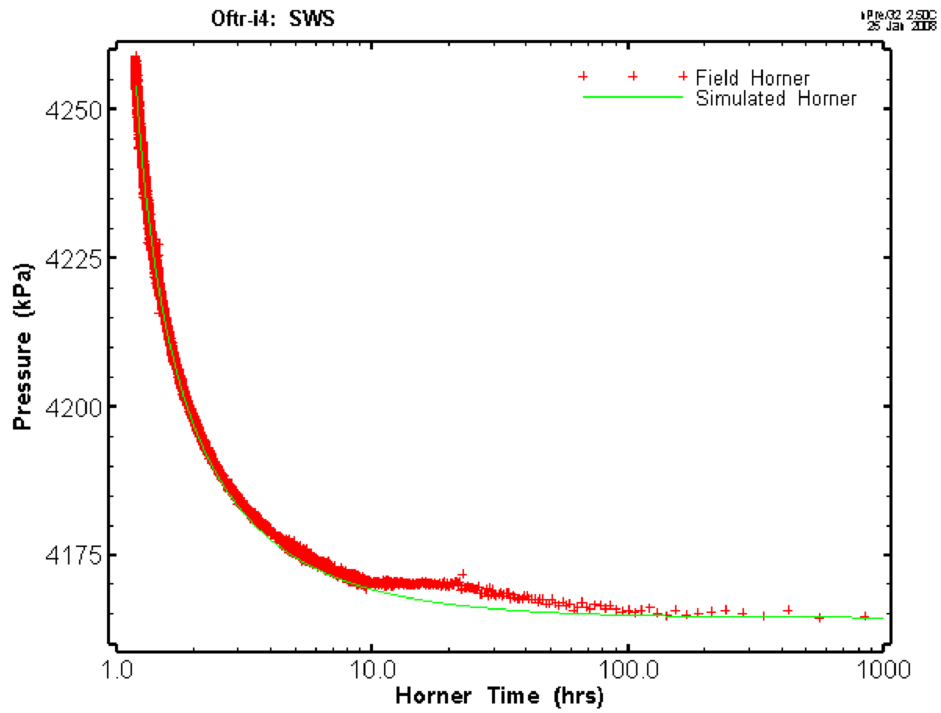


Figure 14: Oftr-i4: SWS Horner plot

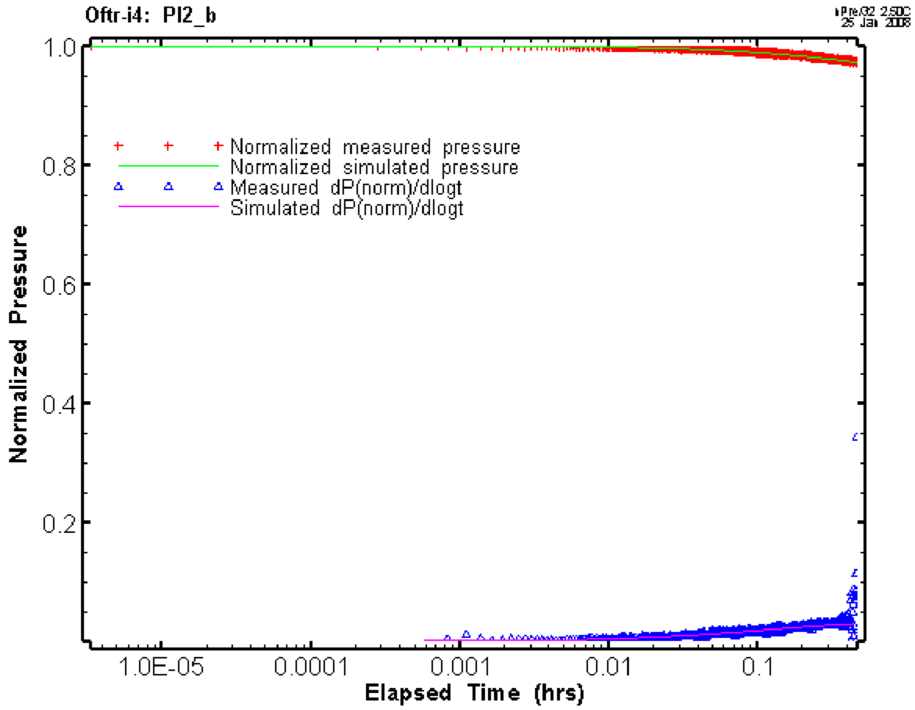


Figure 15: Oftr-i4: PI2_b normalized pressure (Ramey A) plot

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_fm	[m/sec]	1.75E-13	??	??
P_fm	[kPa]	5828.3	??	??
ss_fm	[1/m]	2.10E-07	??	??

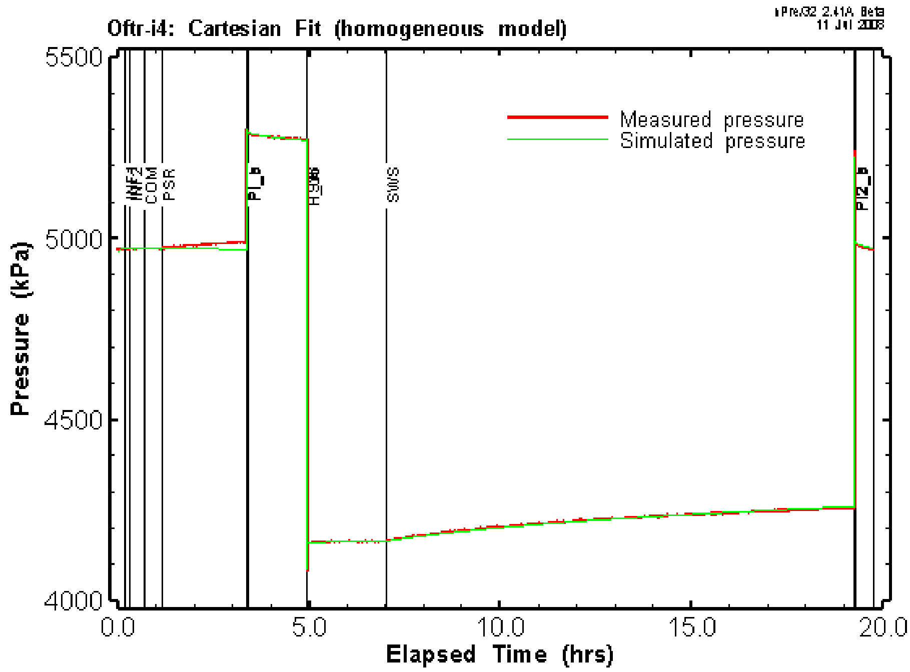


Figure 16: Oftr-i4: Cartesian fit of the entire test for homogeneous model

Fit Statistics:

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_fm	[m/sec]	1.92E-14	1.81E-14	2.04E-14
P_fm	[kPa]	4384	4357	4411
ss_fm	[1/m]	1.79E-06	1.64E-06	1.95E-06

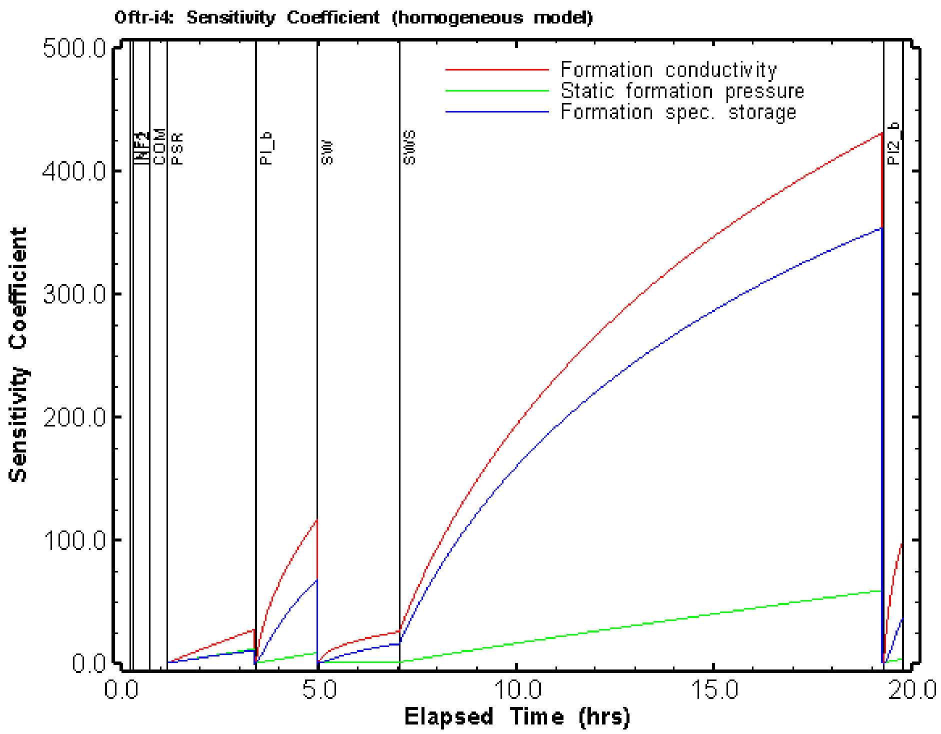


Figure 17: Oftr-i4: Sensitivity coefficients for the different formation parameters during the different sequences (homogenous model)

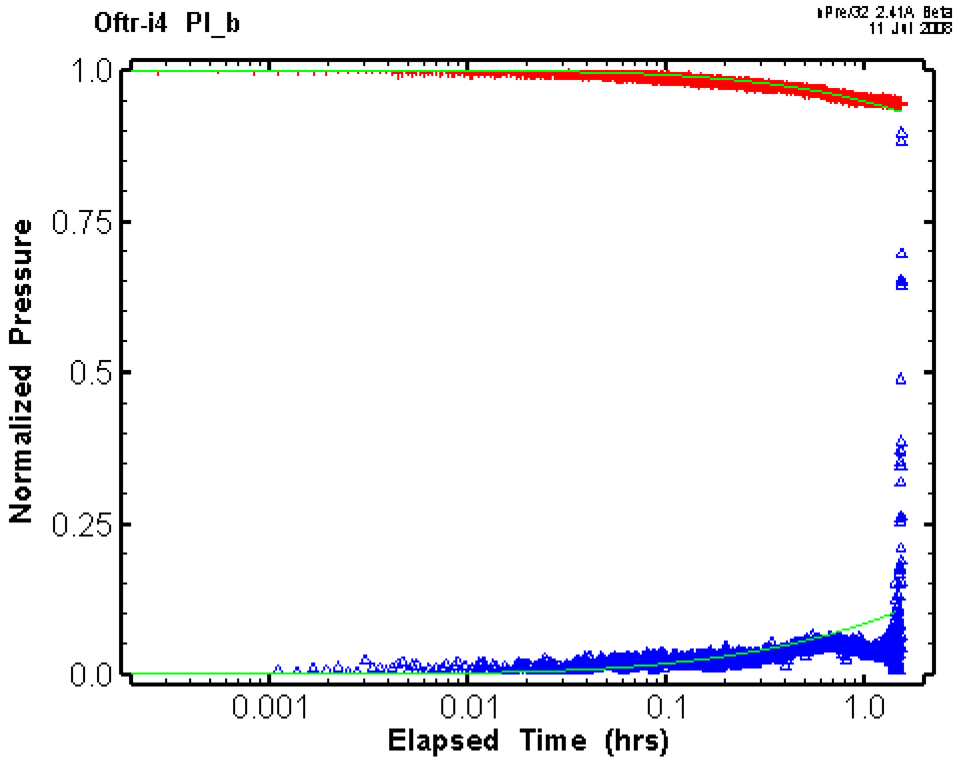


Figure 18: Oftr-i4: PI_b normalized pressure (Ramey A) plot for the entire test fit

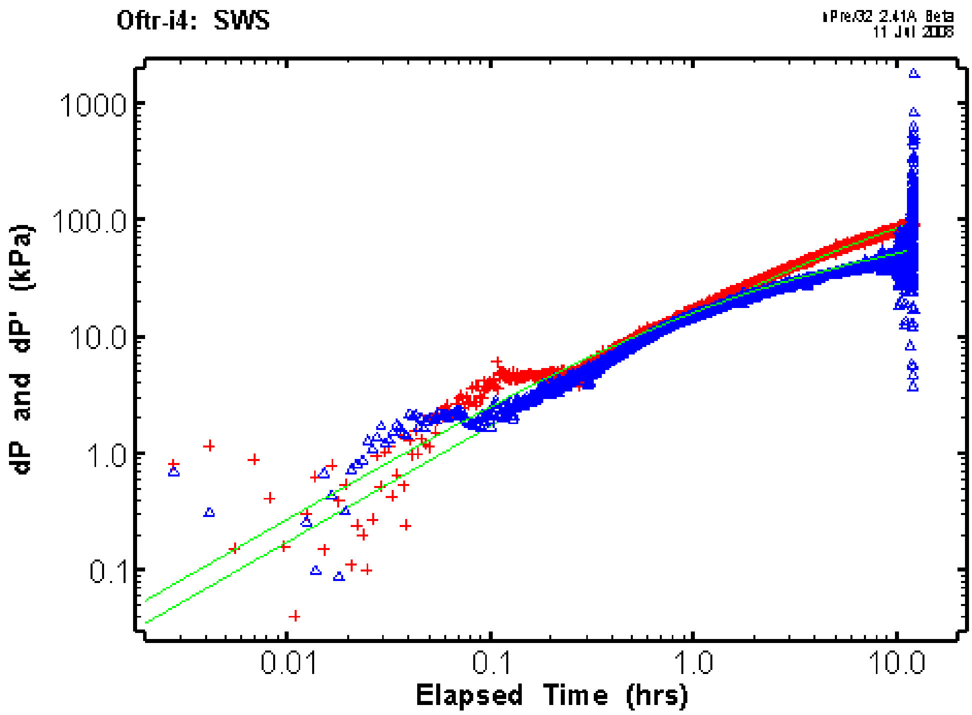


Figure 19: Oftr-i4: SWS log-log diagnostic plot for the entire test fit

Abbreviations

	Test phases
COM	Compliance
INF	Packer inflation
INF1	Inflation of lower packer (INF2 = Inflation of upper packer)
DEF	Packer deflation
DEF1	Deflation of lower packer (DEF2 = Deflation of upper packer)
PSR	Static pressure recovery (shut-in valve closed)
SI	Slug injection test
SIS	Pressure recovery after slug injection test (shut-in)
SW	Slug withdrawal test
SWS	Pressure recovery after slug withdrawal test (shut-in)
PI	Pulse injection test
PW	Pulse withdrawal test
HI	Constant head injection test (constant pressure difference)
HIS	Pressure recovery after constant head injection test (shut-in)
HW	Withdrawal test applying constant differential head
HWS	Pressure recovery after constant head withdrawal test (shut-in)
MR	Multi-rate test: Test with variable flow rate
MRS	Pressure recovery after test with variable flow rate
RW	Pump test with constant flow rate
RWS	Pressure recovery after pump test with constant flow rate (shut-in)
RI	Constant flow injection test
RIS	Pressure recovery after constant flow injection test (shut-in)
VC	Shut-in valve is closed
VO	Shut-in valve is open
	General
CBP	Cooper, Bredehoeft, Papadopulos (type-curve matching method)
DAS	Data acquisition system
FS	Full scale
IARF	Infinite acting radial flow
LC	Log cycle
m agl	Meters above ground level
m bgl	Meters below ground level
m asl	Meters above sea level
OD	Outer diameter
PVT	Pressure volume temperature correlation
Sdev	Standard deviation
SLA	Straight-line analysis
TOC	Top of casing
WL	Water level (or WT = water table)

Nomenclature

	Description	SI-Unit		Description	SI-Unit
b	Y-intercept of linear regression		S_S	Specific storativity	m^{-1}
C	Wellbore storage constant	$m^3\ Pa^{-1}$	S_{SS}	Specific storativity of skin zone	m^{-1}
C_S	Wellbore storage constant, shut-in	$m^3\ Pa^{-1}$	s	Skin factor	-
C_D	Dimensionless wellbore constant	-	t, Δt	Time, elapsed time	s
c_f	Pore volume based compressibility	Pa^{-1}	S_{SS}	Specific storativity of skin zone	m^{-1}
c_r	Rock compressibility	Pa^{-1}	s	Skin factor	-
c_{SC}	System compressibility (= test zone compressibility)	Pa^{-1}	t_C	Critical time	s
c_w	Water compressibility	Pa^{-1}	t_D	Dimensionless time	-
Δh	Differential head	m	Δt_e	Equivalent time (after Agarwal)	s
g	Acceleration of gravity (9.81)	$m\ s^{-2}$	Δt_H	Horner time	-
h_S	Static head	m	t_p	Production time	s
k	Intrinsic permeability	m^2	t_p^*	Corrected production time	s
K, K_f, (K_2)	Hydraulic conductivity of formation () special case	m/s	t_m	Match time	s
K_s, (K_1)	Hydraulic conductivity of skin zone () special case	m/s	t_0	X-intercept of linear regression	s
L	Interval length	m	t_s	Thickness of skin zone	m
m	slope (regression)		T	Transmissivity	m^2/s
P	Pressure	Pa, kPa	T_W	Water temperature	°C
P_0	Minimal or maximal pressure	Pa, kPa	z_1	P1 sensor depth	m
P_{atm}	Probe signal at atmospheric pressure	Pa, kPa	z_2	P2 sensor depth	m
ΔP	Differential pressure, pressure change	Pa, kPa	z_3	P3 sensor depth	m
P_D	Dimensionless pressure	-			
P_f	Static formation pressure	Pa, kPa	α, β	Type-curve match parameter	-
P_i	Initial pressure	Pa, kPa	α	aquifer compressibility	Pa^{-1}
$P_{min/max}$	Minimal/maximal pressure	Pa, kPa	μ	Dynamic viscosity	Pa·s
P_{S1}	Static pressure in P1-Interval (below bottom packer)	Pa, kPa	θ	Porosity	-
P_{S2}, P_f	Static pressure in test interval	Pa, kPa	ρ_w	Density of fresh water	kg/m^3
P_{S3}	Static pressure in annulus (above upper packer)	Pa, kPa			
q	Flow rate	$m^3\ s^{-1}$			
q_{end}, q_e	Last flow rate	$m^3\ s^{-1}$			
Q, Q_{tot}	Cumulative flow	m^3			
r_e	Effective radius (Slug, Pulse test)	m			
R_i	Radius of influence	m			
R^2	Correlation coefficient	-			
r_c	Tubing radius	m			
r_w	Wellbore radius	m			
R_1	Radius, composite model	m			
R_D	Dimensionless radius	-			
S	Storativity	-			
S_C	Sensitivity coefficient				
S_{SC}	Scaled sensitivity coefficient				

Definitions

$C_D = \dfrac{\rho\, g\, C}{2\pi\, S\, r_{w^2}}$	Wellbore constant, dimensionless
$H_D = \dfrac{P - P_i}{P_0 - P_i}$	Dimensionless pressure (slug und pulse tests)
$K = \dfrac{k\, \rho\, g}{\mu}$	Hydraulic conductivity
$P_D = \dfrac{2\pi\, T\, \Delta h}{q}$	Dimensionless pressure
$\Delta P = \rho\ g \Delta h$	Differential pressure
$q_D = \dfrac{q}{2\pi\, T\, \Delta h}$	Dimensionless flow
$t_D = \dfrac{t\, T}{r_w^2 S}$	Dimensionless time
$S = S_S\, L$	Storativity
$s = \left(\dfrac{K_2}{K_1} - 1\right) \ln\left(\dfrac{r_w + t_s}{r_w}\right)$	Skin factor
$S_S = \rho\, g\, (\alpha + \theta\, c_w)$	Specific storativity
$S_C = \dfrac{\partial P}{\partial r}$	Sensitivity coefficient.

where ∂P is the partial derivative of the calculated system response (i.e., pressure) with respect to a parameter varied by the derivative span ∂r .
For comparison of sensitivity coefficients for different parameters, the sensitivity coefficients are typically scaled by inverses of the respective standard deviations as follows:

$$S_{sc} = S \frac{\sigma_r}{\sigma_P} = \frac{\partial P}{\partial r} \cdot \frac{\sigma_r}{\sigma_P}$$

where S_{sc} is the scaled sensitivity coefficient, σ_r is the a priori standard deviation of the measurement error, and σ_P is the estimated standard deviation of the parameter.
If not otherwise stated, default values σ_r = 1 and σ_P = 1 were used.

Definitions (continued)

T = K L	Transmissivity
$\frac{t_D}{C_D} = \frac{2\pi T t}{\rho \; g C}$	Dimensionless time axis
$t_e = \frac{t_p \cdot \Delta t}{t_p + \Delta t}$	Dimensionless Agarwal time (Agarwal, 1980)
$t_e^* = \frac{t_P^* \cdot \Delta t}{t_P^* + \Delta t}$	Modified Agarwal time (using corrected production time)
$t_P^* = \frac{Q}{q_{end}}$	Modified production time (Ehlid-Economides and Ramey, 1980)

Form

DAILY LOG REPORT

SOLEXPERTS

Oftringen Hydraulic Testing: Interval 4: 500 – 550 m

Date	Time	Activity	Who
23.10.2007	18:00	System on position, fill annulus up to the top (1.42 m above top of ground level)	Fi, FP, Sti
		Interval 4: 500.00 – 550.04 m	
	18:03	Start file Oftr-i4	
	18:05	Start file: Oftr_2007_10_19_oftr_i4.dat P1 = 4983 kPa P2 = 4971 kPa P3 =4974 kPa T2 = 35.8 °C Water table: 1.42 m above ground level (=top of casing)	
	18:09	Start inflation of packer 1	
	18:23	Start inflation of packer 2	
	18:40	Increase packer pressures by 10 bar, PA1 and PA2 packer pressures are hydraulically connected and measured by sensor PA2 only	
	18:45	All packers are inflated to 35 bar	
	19:13	Shut-in, Start PSR	
	19:00	FP and Sti leave site	
	19:15	Night shift crew arrives on site	SR, PH
	19:30	Phone call with Fbe for discussion of test procedure	
	20:15	Preparing equipment for pulse injection test	
	20:50	Fill up tubing up to the top	
	21:00	Water level in tubing: 0.016 m below top	
	21:24	Scan rate set to 1 s	
	21:25:25	Start PI-test, valve open during 145 s, no difference in pressure gradient observed after shut-in	
	21:30	Test if valve has closed: Release pressure on water column => i.O., valve is closed	
	21:31	Water level in tubing: 0.095 m below top => Δs = 79 mm, ΔV = 100.8 ml	
	21:45	Measuring Volume change with gauge: ΔV = 110 ml $C = \Delta V / \Delta P$ = 0.00011 / 303'250 Pa = 3.63E-10 m^3/Pa $C_{SC} = C / V_{interval}$ = 3.63E-10 m3/Pa / 0.838 m^3 = 4.33E-10 1/Pa	
	21:48	Scan rate set to 5 s	
	22:00	Start swabbing at 95 m bgl	
	22:13	Water level in test rods at 93.61 m below top of tubing (90.16 m bgl)	
	22:18	Installation of slim tubing, packer slim tubing at about 95 m bgl	
	22:23	Start slim tubing sensor: P4 = 56.30 kPa	
	22:52	Inflation of slim tubing packer (28 bar)	
	22:29	Scan rate set to 1 s	
	23:00	Start SW-test	
	23:13	Scan rate 5 s	
	23:30	SR leaves site for food	
	23:50	SR arrives on site	
24.10.2007	01:21	Scan rate set to 1 s	SR, PH
	01:06:40	Slight pressure change due to little change in packer pressure without any noticeable influence	
	01:22	Shut in, Start SWS	
	01:45	Scan rate 5 s	
	06:00	Scatter of triple probe increases significantly	
	07:00	Fi, FP and Sti arrive on site	Fi, FP, Sti

Form

DAILY LOG REPORT

Date	***Time***	***Activity***	***Who***
24.10.2007	*09:00*	*Saturate flow board; re-connect Coriflow in order to compare flow rates of flow meters using DAS. Reference Coriflow set to -5.6 ml/min (device displays 0.8% at zero flow)*	
	10:00	*Coriflow Setpoint = 10%*	
	10:30	*Visit of Fbe and Web. Short discussion of further testing*	
	12:50	*Phone call with Fbe: stop SWS, then PI2*	
	12:55	*Slim tubing pressure sensor switched off*	
		Remove slim tubing, prepare for PI2	
	13:02	*Slim tubing pressure sensor shows 0.64 kPa at atmosphere*	
		Fill 1.9" NU tubing up to the top (0.06 m below top of rods)	
		P2 before start of PI2 = 4257 kPa	
	13:18:57	*Start PI2* *Oscillating water table, shut-in after stabilisation at 13:20:44 (valve was open for 107 seconds)*	
	13:20	*Water table Water table in test rod is 30.5 cm below top of rod => Δs = 0.245 m. ΔP = 583 kPa.* *C-SC = 7.4E-10 1/Pa*	
	13:49	*Open shut-in valve*	
	13:55	*Start to deflate packers. Water level in annulus is filled up to top of 7" casing (1.42 m above ground level)*	
	15:05	*Packers are free* *Water level in 7"casing is 10 cm below top (=1.32 above ground level)*	
	15:09	*Stop file*	

Fi *Hansruedi Fisch*
FP *Fredi Portmann*
SR *Sacha Reinhardt*
Sti *Daniel Stillhard*
PH *Peter Haller*

Fbe *Dr. Bernd Frieg (Nagra)*
Web *Hanspeter Weber (Nagra)*

Form

INSTALLATION RECORD HDDP

SOLEXPERTS

Seite 1 / 1

Oftringen NOK EWS Borehole: Hydraulic Testing

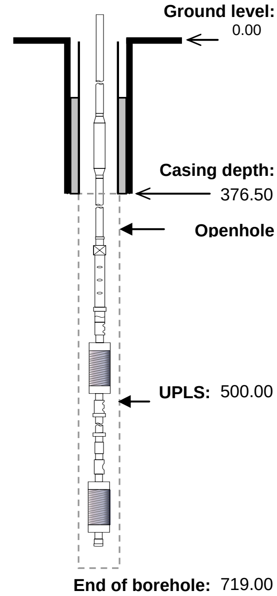
						Date	23.10.2007	**Project Leader**	Fi/SR
Borehole	NOK EWS 2007	**Direction**	vertical	**Reference point**	433.0	**JOB Nr**	1763	**Location**	Oftringen
Borehole Depth	719.0 m	**Casing depth**	376.5 m bgl	**Interval lenght**	50.04 m	**Test Name**	oftr_i4	**System**	HDDP 110
Borehole diameter	146 mm	**Stickup**	-3.45 m	**Water depth**	-1.42 m bgl	**Test depth (UPLS)**	500.00 m bgl	**Probe ID**	TSSP S1

Note: All dephts shown are not correct for borehole deviation

		Qty -	L unit m	L total m	Depth m	OD mm	ID mm	Wgt kg	Str t
Stickup	-3.45 m bgl								
Ground level					0.00				
Tubing 1.9" NU			496.18	496.18		56.1	40.3	#####	12.0
Pop joint			1.02		492.73	56.1	40.3	4.2	12
SIT Non Displacement Valve			0.84			79.0	24.0	20.6	15
Probe Shell Carrier mit Triple Sub	TSSP P3		1.97		496.56	70.0	10.9	48.0	25
	TSSP P2		0.30		496.86				
	TSSP P1		0.30		497.16				
			0.04						
X-Over	2"3/8 EU Pinx1.9" NU Box		0.51	7.27		66.0	40.0	2.1	16
Safety joint 3"1/16						78.0	50.5	5.5	24
Above Side Entry Sub (ASES)			0.52			66.0	32.0		24
Packer Stick Up			0.26			--	25.0		
Up. Packer Seal	UPUS		0.26		498.75				
Upper Packer			1.25			108.0	32.0	82.4	17
	UPLS		0.24		500.00				
Straddle Length: Packer Stick Down			0.31			--	25.0		
Below Side Entry Sub (BSES)			0.52			66.0	32.0		24
X-Over	1.9" NU Pinx2"3/8 EU Box		0.26			--		3.0	16
Tubbing 1.9" NU			45.5			56.1	40.3	186.6	12
X-Over	2"3/8 EU Pinx1.9" NU Box		0.45	50.04		--		3.0	16
			0.3						
Filter	Screen		1.45			72.0	50.0	19.0	19
			0.3						
P1-Seal Sub			0.3			78.0	--		24
Packer Stick Up			0.16			--	32.0		
Lower Packer Seal	LPUS		0.25		550.04				
Lower Packer			1.25	1.92		110.0	32.0	70.2	17
	LPLS		0.24		551.29				
Packer Stick Down			0.43			--	32.0		
End Cap					551.96	78.0	--		
End of Borehole					719.00				

Comments:

Borehole configuration:



Probe	523 006.1	
values at atmosphere	P1	111.7
	P2	92.1
	P3	102.3
	P_{SL}	1.15
	T1	11.4
	T2	11.0
	T3	10.6
Total Weight (kg)	2499.5	

Form

TALLY LIST

SOLEXPERTS

Borehole	NOK EWS 2007	Interval name	Test Oftr_i4	Date	23.10.2007
Depth	719.0 m	Interval depth	500 - 550 m	Location	Oftringen

TU 1	6.51	TU 51	6.50				
TU 2	6.51	TU 52	6.51				
TU 3	6.51	TU 53	6.51				
TU 4	6.51	TU 54	6.51				
TU 5	6.51	TU 55	6.51				
TU 6	6.51	TU 56	6.51				
TU 7	6.51	TU 57	6.50				
TU 8	6.51	TU 58	6.51				
TU 9	6.51	TU 59	6.51				
TU 10	6.50	TU 60	6.51				
TU 11	6.50	TU 61	6.50				
TU 12	6.51	TU 62	6.50				
TU 13	6.50	TU 63	6.50				
TU 14	6.51	TU 64	6.50				
TU 15	6.51	TU 65	6.51				
TU 16	6.51	TU 66	6.50				
TU 17	6.51	TU 67	6.50				
TU 18	6.51	TU 68	6.51				
TU 19	6.50	TU 69	6.50				
TU 20	6.51	TU 70	6.50				
TU 21	6.51	TU 71	6.47				
TU 22	6.50	TU 72	6.50				
TU 23	6.51	TU 73	6.48				
TU 24	6.50	TU 74	6.50				
TU 25	6.50	TU 75	6.50				
TU 26	6.50	TU 76	6.50				
TU 27	6.50	TU Pop J.	1.85				
TU 28	6.50						
TU 29	6.50						
TU 30	6.50						
TU 31	6.50						
TU 32	6.50						
TU 33	6.51						
TU 34	6.51						
TU 35	6.50						
TU 36	6.51						
TU 37	6.50						
TU 38	6.50						
TU 39	6.51						
TU 40	6.50						
TU 41	6.51						
TU 42	6.51						
TU 43	6.50						
TU 44	6.50						
TU 45	6.50						
TU 46	6.50						
TU 47	6.51						
TU 48	6.51						
TU 49	6.51						
TU 50	6.51						
	325.28		170.90		0.00		0.00

Total string length:	496.18

Form *SURFACE EQUIPMENT LAYOUT*	SOLEXPERTS

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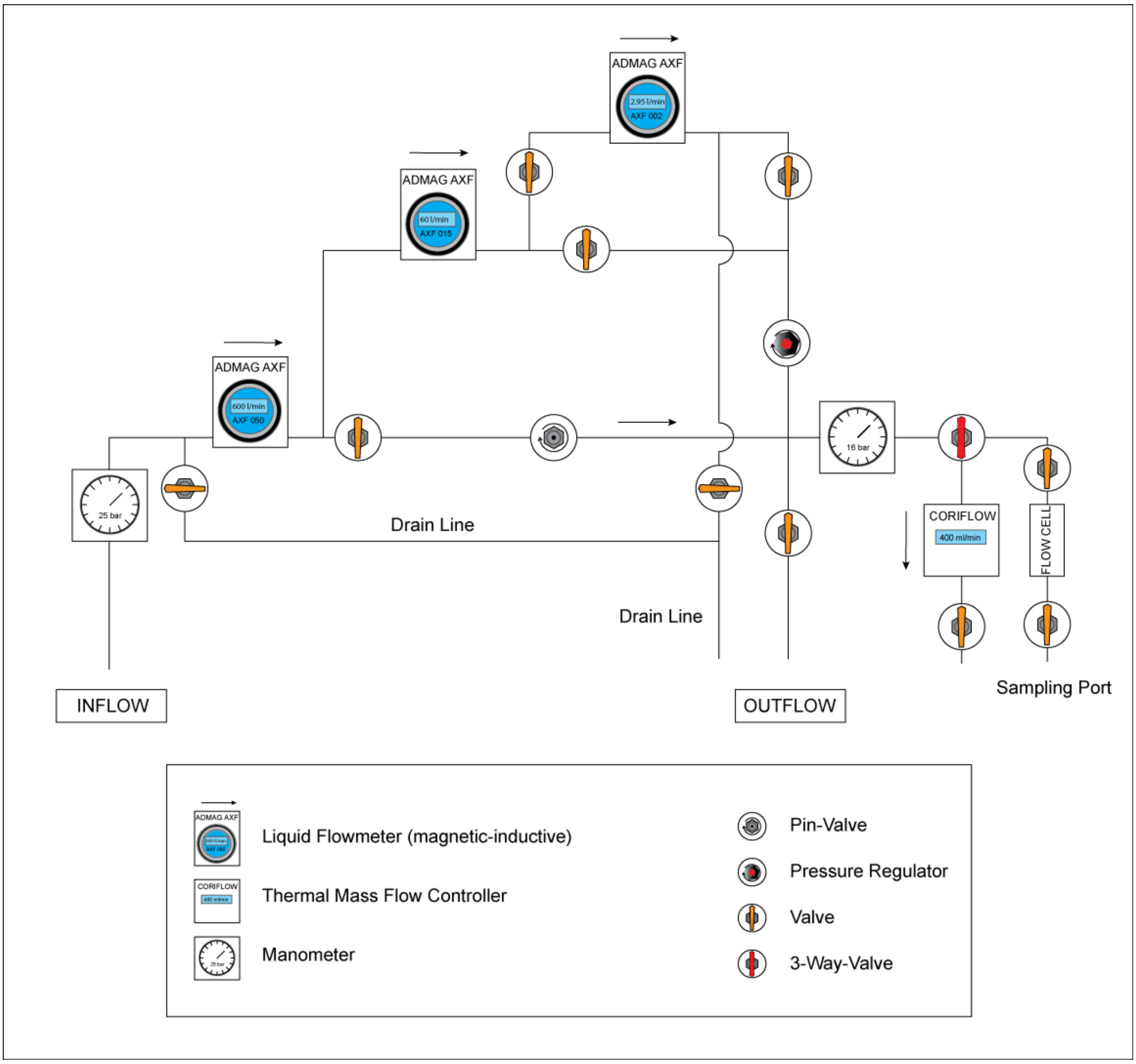


Flow meter	Lower limit of measuring range	(% of FS)	Upper limit of measuring range (l/min)	Accuracy between 3% and 100% of FS (% of rate)	Accuracy between 1% and 3% of FS (% of rate)	Equipment used
AXF DN2	0.030 l/min	1 %	2.95 l/min	0.35	0.5	yes
AXF DN15	0.6 l/min	1 %	60 l/min	0.35	0.5	yes
AXF DN50	11.78 l/min	1 %	1178.10 l/min	0.35	0.5	no
Coriflow	0.50 kg/h	2 %	25.00 kg/h	1	1	no

Form

BENCH TEST

SOLEXPERTS

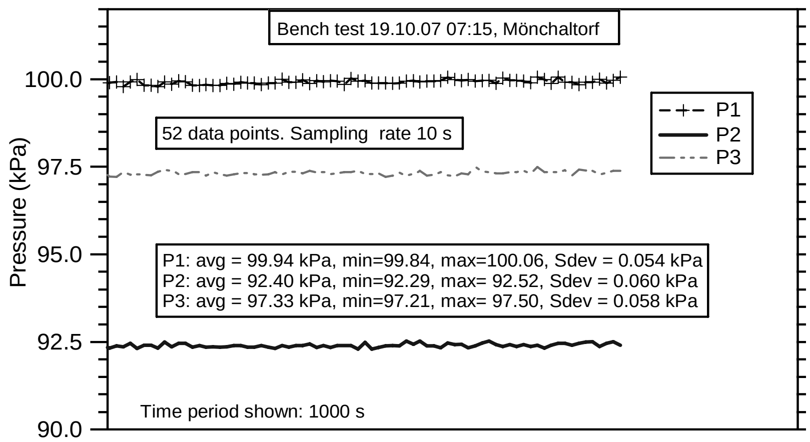
Project	Location	Date
Oftringen NOK EWS Borehole	Oftringen	18.12.2007
Well name	**Test name**	**Engineer**
NOK EWS 2007	Oftri-i4	Fi/SR

Transducer describtion	Output units
P1, P2, P3: 0-206.84 bar (3000 Psi), P4: 0-6 bar, P_{ST} = 0-10 bar	kPa, °C

P1#	P2#	P3#	P4#
43224	50370	43231	591.001.027

Offsite pretest bench test (Date: 19.10.07)

Measurement conditions (P, T and position)	Sampling rate
97.7 kPa 5.6 °C	10 s
( ) direct (x) vertical ( ) horizontal	

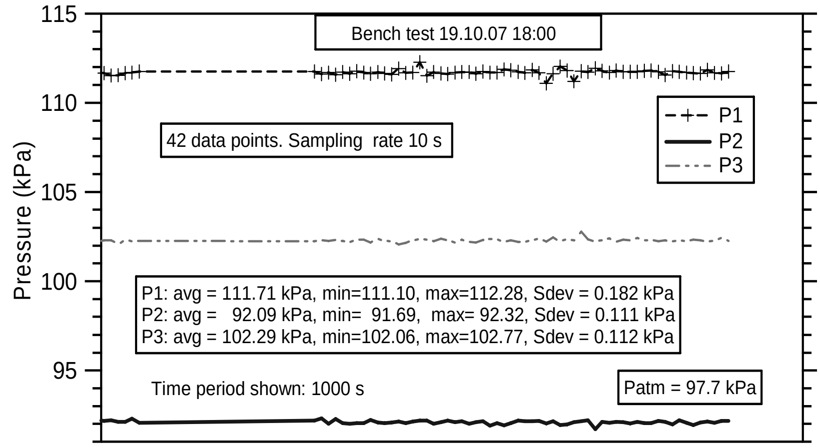


P1 average:	99.84	kPa
P2 average:	92.29	kPa
P3 average:	97.33	kPa
P4 average:	n.m.	kPa
P_{SL} average:	n.m.	kPa
P1 Sdev	0.054	kPa
P2 Sdev	0.060	kPa
P3 Sdev	0.058	kPa

File: TestData24.DAT

Onsite pretest bench test (Date: 19.10.07)

Measurement conditions (P, T and position)	Sampling rate
97.7 kPa 11.0 °C	10 s
( ) direct (x) vertical ( ) horizontal	



P1 average:	111.71	kPa
P2 average:	92.09	kPa
P3 average:	102.29	kPa
P4 average:	101.06	kPa [1)]
P_{SL} average:	3.56	kPa [1)]
P1 Sdev	0.182	kPa
P2 Sdev	0.111	kPa
P3 Sdev	0.112	kPa
P4 Sdev	0.056	kPa [1)]
P_{SL} Sdev	0.019	kPa [1)]

[1)] Data not shown, 20.10.07, 05:45-08:15,
File Oftr_2007_10_19_oftr_i1.dat, Patm=97.8 kPa

File: Oftr_2007_10_19_atm0.DAT

Form

BENCH TEST

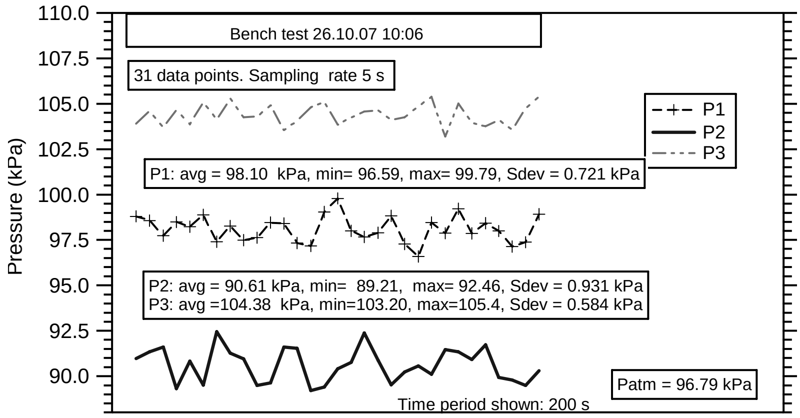
Project	Location	Date
Oftringen NOK EWS Borehole	Oftringen	18.12.2007
Well name	**Test name**	**Engineer**
NOK EWS 2007	Oftri-i4	Fi/SR

Transducer describtion	Output units
P1, P2, P3: 0-206.84 bar (3000 Psi), P4: 0-6 bar, P_{ST} = 0-10 bar	kPa, °C

P1#	P2#	P3#	P4#
43224	50370	43231	591.001.027

Onsite after test bench test (Date: 26.10.07)

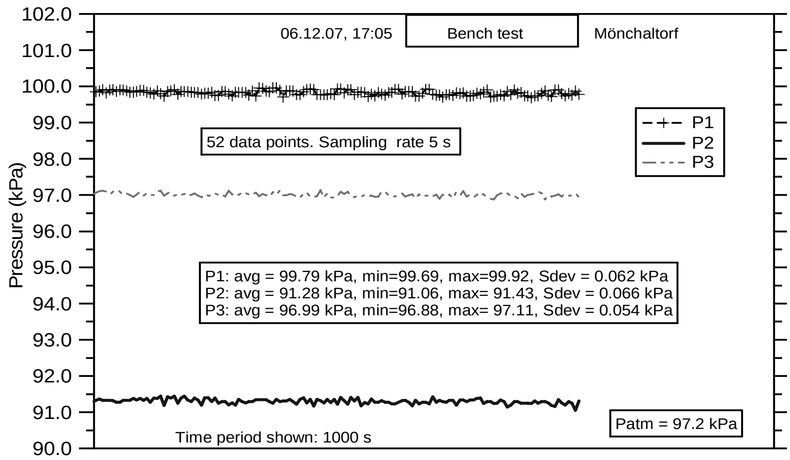
Measurement conditions (P, T and position)	Sampling rate
96.4 kPa 7.3 °C	5 s
( ) direct (x) vertical ( ) horizontal	



P1 average:	98.10 kPa
P2 average:	90.61 kPa
P3 average:	104.40 kPa
P4 average:	n.m. kPa
P_{SL} average:	n.m. kPa
P1 Sdev	0.721 kPa
P2 Sdev	0.931 kPa
P3 Sdev	0.584 kPa
File:	Oftr_2007_10_26_atm2.DAT

Offsite after test bench test (Date: 06.12.07)

Measurement conditions (P, T and position)	Sampling rate
96.6 kPa 9.6 °C	5 s
( ) direct (x) vertical ( ) horizontal	



P1 average:	99.69 kPa
P2 average:	91.28 kPa
P3 average:	96.99 kPa
P4 average: [1)]	101.44 kPa
P_{SL} average:	n.m. kPa
P1 Sdev	0.062 kPa
P1 Sdev	0.062 kPa
P2 Sdev	0.066 kPa
P3 Sdev	0.054 kPa
P4 Sdev	0.007 kPa

[1)] not shown on graph

File: test8.dat

Appendix E

Quick Look Report
Interval Oftr-i5

nagra.

QUICK LOOK REPORT OFTRINGEN - TEST OFTR-i5

TEST START (Date/Time)	:	24.10.2007 / 16:06	**TEST END (Date/Time)**	:	25.10.2007 / 20:39

DOUBLE PACKER TEST

Test Interval Information	:			top test interval	:	449.85	m
borehole depth [1), 4)]	:	719.0	m	bottom of test interval	:	499.89	m
borehole radius	:	0.073	m	total interval length	:	50.04	m
tubing radius	:	20.0	mm	midpoint of interval	:	474.87	m
				P2-depth	:	446.71	m
interval volume, nominal [5)]	:	0.838	m^3	theoretical Cs-value[3)]	:	1.68E-09	m^3/Pa
slim tubing radius		4.75	mm	theoretical C-value (slim tube)	:	7.23E-09	m^3/Pa
WL prior to packer inflation [2)]	:	-1.42	m bgl	P2 signal prior to packer inflation	:	4480.28	kPa
WL in annulus at test end [2)]	:	-1.42	m bgl	P2 offset assuming ρ_{avg} = 997 kg/m3		97.3	kPa

1) all depths are not corrected for borehole deviation from vertical
2) WL = water level
3) assumes a total borehole system compressibility of 2E-09 Pa^{-1}
4) all depth measurements refer to ground level
5) cylindrical volume of isolated borehole section
Note all pressures cited in this report are absolute

Preliminariy information				
longitude of borehole	:	240887		
latitude of borehole	:	638346		
elevation of ground level (GL)	:	433.0	m asl	(reference point for all measurements)
assumed fresh water head	:	433.0	m asl	(assumed hydrostatic)
end of drilling	:	17.10.07 09:55		(Geotec)
porosity	:	3%		(assumed)
mud density [7)]	:	1032	kg/m^3	(Geotec end of drilling, 17.10.07)
borehole water density	:	997	kg/m^3	(Geotec after circulation of fresh water, 17.10.07; estimated using P2)
formation water density [8)]		1005.0	kg/m^3	(PVT correlation calculated by Saphir)
specific storativity [9)]	:	2.19E-06	m^{-1}	
formation water viscosity [8)]	:	8.57E-04	Pa s	(PVT correlation calculated by Saphir)
fluid compressibility [8)]	:	4.42E-10	1/Pa	(PVT correlation calculated by Saphir)
total compressibility	:	7.44E-09	1/Pa	(calculated assuming c_f= 7.00E-09 1/Pa)

7) Taken from daily report No. 53
8) Assumed, using salinity 10'000 ppm, T = 32.6 °C, P = 4750 kPa
9) Calculated based on assumed porosity and compressibility values

Responible Test Engineers	
Onsite:	Fisch, H.R.; Hayer, J.
Test analysis and reporting:	Rösli, U., Fisch, H.R.

Test Summary		
test objectives	:	transmissivity, static formation pressure, flow model
borehole history	:	drilling through midpoint of interval: 02.10.2007, 05:30; 538.6 h duration until start of test
geology	:	light-grey dark-grey striped argillaceous limestone; 475 - 490m dark-grey to black marls and argillaceous marls; 493 - 499 m fractured
geophysics	:	Caliper log, salinity log, temperature log, sonic log
test phases	:	COM, PSR, PW1, PW2, SW

QLR results	**Test zone 449.85 - 499.89 mbgl**	**T [m2/s]**	**K [m/s]**	**Formation Flow model**	**Freshwater Head [m asl]**
Analytical interpretation		(1.27E-13)	(2.54E-15)	radial flow	-
Numerical simulation		1.15E-12	2.29E-14	homogeneous	293.3

Note:
A complete list of results is provided in the summary tables

Mönchaltorf, 08.02.08 / 01.08.08, Revision 1 prepared by: SOLEXPERTS INTERA

Summary of Test Data

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Test Phase		INF	COM	PSR 2)		PW1 1)	
duration	[h]	0.876	0.525	1.392		12.127	
T2 (i/f)	[°C]	32.68 / 32.66	32.66 / 32.7	32.70 / 32.59		32.55 / 32.52	
P1 (i/f)	[kPa]	4493 / 4494	4494 / 4488	4488 / 4486		4486 / 4512	
P2 (i/f)	[kPa]	4480 / 4485	4485 / 4485	4485 / 4482		4178 / 4185	
P3 (i/f)	[kPa]	4483 / 4483	4483 / 4484	4484 / 4484		4484 / 4484	
P4 (i/f)	[kPa]						
Measured C	[m3/Pa]					6.1E-10	
c_{SC}	[1/Pa]					7.3E-10	
q	[l/min]						
Q	[l]						
inner boundaries		no analysis	no analysis	wellb. storage		wellb. storage	
flow geometry				hom.		hom.	
outer boundaries				inf.lat.ext.		inf.lat.ext.	
T	[m^2/s]			(1.14E-13)	A)	(1.27E-13)	D)
K	[m/s]			(2.27E-15)	A)	(2.54E-15)	D)
k	[m^2]			(1.97E-22)		(2.21E-22)	
S_S	[1/m]			(6.48E-05)	A)		
S	[-]			(3.24E-03)			
Pi, P_f if matched	[kPa]			(3201.9)	A)	4481.86	B)
Head	[m asl]			(302.8)	C)	(433.2)	C)
Derived flow rate	[l/min]						
s (skin factor)	[-]						
S_{SS} (skin zone)	[1/m]						
t_S (skin zone)	[m]						
K_S (skin zone)	[m/s]						
figures				1,8,7		1,5	
temperature effects				no		no	
borehole history				yes		no	
anomalies				no		no	
bypass PA2				no		no	
bypass PA1				no		no	

comments

notes:
- i = initial, f = final
- T value in bold most representable of the undisturbed formation

1) analytical with no superposition
2) numerical simulation with detailed borehole history effects

5) Opitimized fit on PW1, PW2
A) matched parameter
B) input parameter
C) calculation assumes: freshwater density 1000 kg/m ^{3}, g = 9.81 m^2/s, P_{atm} and z_2 as stated on front page
D) early-middle time fit
E) extrapolated head

Summary of Test Data		Page 2/3				
Test Phase		PW1 2)		PW2 1)		PW2 2)	
duration	[h]	12.127		12.763		12.763	
T2 (i/f)	[°C]	32.55 / 32.52		32.59 / 32.54		32.59 / 32.54	
P1 (i/f)	[kPa]	4486 / 4512		4510 / 4529		4510 / 4529	
P2 (i/f)	[kPa]	4178 / 4185		3601 / 3670		3601 / 3670	
P3 (i/f)	[kPa]	4484 / 4484		4484 / 4484		4484 / 4484	
P4 (i/f)	[kPa]						
Measured C	[m3/Pa]			5.2E-10			
c_{SC}	[1/Pa]			6.2E-10			
q	[l/min]						
Q	[l]						
inner boundaries		wellb. storage		wellb. storage		wellb. storage	
flow geometry		hom.		hom.		hom.	
outer boundaries		inf.lat.ext.		inf.lat.ext.		inf.lat.ext.	
T	[m^2/s]	4.37E-12	A)	(1.61E-13)	D)	4.10E-12	A)
K	[m/s]	8.73E-14	A)	(3.22E-15)	D)	8.19E-14	A)
k	[m^2]	7.59E-21		(2.80E-22)		7.12E-21	
S_S	[1/m]	5.83E-07	A)			4.89E-07	A)
S	[-]	2.92E-05				2.45E-05	
Pi, P_f if matched	[kPa]	3499.4	A)	4185	B)	2880.1	A)
Head	[m asl]	333.1	C)	(403.0)	C)	270.0	C)
Derived flow rate	[l/min]						
s (skin factor)	[-]						
S_{SS} (skin zone)	[1/m]						
t_S (skin zone)	[m]						
K_S (skin zone)	[m/s]						
figures		1,9		1,6		1,10	
temperature effects		no		no		no	
borehole history		yes		no		yes	
anomalies		no		no		no	
bypass PA2		no		no		no	
bypass PA1		no		no		no	

comments

notes:
- i = initial, f = final
- T value in bold most representable of the undisturbed formation

1) analytical with no superposition
2) numerical simulation with detailed borehole history effects

5) Opitimized fit on PW1, PW2
A) matched parameter
B) input parameter
C) calculation assumes: freshwater density 1000 kg/m ^{3}, g = 9.81 m^2/s, P_{atm} and z_2 as stated on front page
D) early-middle time fit
E) extrapolated head

Summary of Test Data		Page3/3		
Test Phase		SW	Simulation entire Seq.[5)]	
duration	[h]	0.823	28.55	
T2 (i/f)	[°C]	32.54 / 32.49	32.68 / 32.49	
P1 (i/f)	[kPa]	4529 / 4531	4493 / 4531	
P2 (i/f)	[kPa]	3578 / 3579	4480 / 3579	
P3 (i/f)	[kPa]	4483 / 4483	4483 / 4483	
P4 (i/f)	[kPa]			
Measured C	[m3/Pa]			
c_{SC}	[1/Pa]			
q	[l/min]			
Q	[l]			
inner boundaries		no analysis	wellb. stor.	
flow geometry			hom.	
outer boundaries			inf. lat. ext.	
T	[m^2/s]		**1.15E-12** A)	
K	[m/s]		2.29E-14 A)	
k	[m^2]		1.99E-21	
S_S	[1/m]		1.30E-06 A)	
S	[-]		6.51E-05	
Pi, P_f if matched	[kPa]		**3109.4** A)	
Head	[m asl]		293.3 C)	
Derived flow rate	[l/min]			
s (skin factor)	[-]			
S_{SS} (skin zone)	[1/m]			
t_S (skin zone)	[m]			
K_S (skin zone)	[m/s]			
figures		1	11,12	
temperature effects		no	no	
borehole history		no	yes	
anomalies		no	no	
bypass PA2		no	no	
bypass PA1		no	no	

comments

notes:
- i = initial, f = final
- T value in bold most representative of the undisturbed formation

1) analytical with no superposition
2) numerical simulation with detailed borehole history effects

5) Opitimized fit on PW1, PW2
A) matched parameter
B) input parameter
C) calculation assumes: freshwater density 1000 kg/m ^{3}, g = 9.81 m^2/s, P_{atm} and z_2 as stated on front page
D) early-middle time fit
E) extrapolated head

Test overview

Test Oftr-i5 (449.85 - 499.89 m bgl) was performed on 24.-25.10.2007 in the Oftringen NOK EWS-Borehole. The test interval consisted of a sequence of marls and argillaceous marls (so-called Effinger Mergel) with interbedded limestone layers. The test objectives were to obtain reliable estimates of interval transmissivity and fresh-water hydraulic head using an appropriate flow model. The test was performed with a straddle-packer configuration with an interval length of 50.04 m. Pressures and temperatures were measured in the test interval (P2, T2) and in the interval below the lower packer (P1, T1) and in the annulus above the upper packer (P3, T3). In addition, pressure was measured in the tubing above the upper packer (P4).

The pressure response of the entire test sequence in Oftr-i5 is shown in **Figure 1**. The pressure history derived from water table measurements (source: Colenco, Solexperts) and fluid density measurements (SJ Geotec) is presented in **Figure 2**.

Following packer inflation (INF) the test sequence started with a COM and PSR phase to dissipate temperature and borehole history effects. Temperature effects are considered negligible, because downhole temperatures (T1, T2, T3) indicated only a relatively small gradual trend of less than -0.3° C over the entire test duration, with noise of up to 0.5 °C (**Figure 3**). The PSR phase is influenced by compliance effects due to not fully stabilized packer pressures (**Figure 4**). The pulse withdrawal test (PW) was performed to measure the wellbore compressibility early in the test and obtain an initial estimate of the formation properties. Three hours after begin of the PW1 test, the interval pressure showed a reversed trend (decreasing absolute pressure). After PW, a second pulse test with increased differential drawdown was initiated (PW2). The aim of PW2 was to record a greater percentage of pressure recovery and to confirm wellbore compressibility. A short duration slug withdrawal (SW) was performed to confirm the PW/PW2 results. It was stopped after a flowing period of 0.82 hours due to time restriction.

Due to the influence of the adjacent high voltage current transformer facility (NOK), the pressure and temperature signals of the downhole triple probe were noisy during the hole testing sequence.

Analysis

For the QLR analysis, the analytical and numerical methods were used for a standard analysis, which will be the basis for a possible detailed analysis depending on the test objectives and test results.

Analytical Analysis

Type curve and straight-line fitting methods are applied. Effects of the borehole pressure history are not taken into account.

First pulse withdrawal test (PW1)

The PW1 test was initiated after a PSR phase which ended with a slightly decreasing pressure trend of about 8.5E-4 kPa/s (P2). The PSR flow period was too short to be analyzed. At start of the pulse test the interval pressure was exposed to a differential pressure of -304 kPa. The shut-in valve was kept open during 55 seconds. After shut-in, a water level increase equal to 0.15 m was measured in the 1.9” test string (P4 measurement), indicating a released volume of 0.19 liters due to de-compression of the test zone. The wellbore storage constant C ($\Delta V/\Delta P$) equals to 6.1E-10 m^3/Pa.

The PW test recovered 5 % during a period of 3.3 hours and then slowly turned into a reversed trend. The pulse response was analyzed using CBP type-curves. The analysis of the recovery phase is presented in **Figure 5**. The fit using α-type-curve of value 1.0 provides a transmissivity estimate of 1.3E-13 m^2/s. Note that the CBP type-curve matching method is not sensitive for high α-values as α type-curves greater 1 are difficult to distinguish with respect to the slope steepness. High α values are associated with high aquifer storativity values (S). As storativity estimates from pulse test analyses are commonly known as unreliable, the S and S_S results are not presented.

Second pulse withdrawal test (PW2)

A second pulse withdrawal test PW2 was initiated after the PW1 phase. At start of the pulse test the interval pressure was exposed to a differential pressure of -584.1 kPa. The shut-in valve was kept open during 25 seconds. After shut-in, a water level increase equal to 0.24 m was measured in the 1.9” test string (P4 measurement), indicating a released volume of 0.30 liters due to de-compression of the test zone. The wellbore storage constant C ($\Delta V/\Delta P$) equals to 5.2E-10 m^3/Pa.

The PW2 test recovered 13 % during a period of 12.8 hours. The pulse response was analyzed using CBP type-curves. The analysis is presented in **Figure 6**. The normalized pressure in the CBP plot shows a flattening of the data at late time in comparison to the type-curve. The fit using α-type-curve of value 1.0 provides a transmissivity estimate of 1.6E-13 m^2/s.

The two pulse withdrawal tests give similar results with respect to wellbore storage and transmissivity. In view of the potential transient effects from the preceding borehole pressure history, as observed during PW2, the transmissivity and hydraulic conductivity values from the analytical analysis are considered unreliable and shown between brackets in the summary table.

Slug test withdrawal test (SW)

Prior to start of the SW test, the water table in the 1.9” tubing was lowered to approximately 90 m bgl (change of tubing water level does not affect the interval pressure while the shut-in tool is closed). A slim tubing was installed in the 1.9” NU API rods before start of SW. The slim tubing system consists of a stiff high pressure hose of ID = 9.5 mm and a packer at its bottom (OD =28 mm). The packer is inflated using pressurized nitrogen, sealing the annulus between the 1.9” tubing and the slim tubing. The slim tubing was installed to a depth of 95 m bgl, covering the span of expected water table change of the slug test. A pressure transducer attached just above the packer and with connection to the tube inside enables recording of water level changes, redundantly to the P2 sensor. The small diameter of the slim tubing allows for faster slug recovery.

Prior to start of SW, the P2 pressure curve showed a rising trend with roughly 3E-04 kPa/s. The SW test was started 12.8 hours after start of PW2. As only 0.76 kPa pressure recovery (0.83 %) was achieved during the SW-test, no analytical CBP analysis was conducted on the data.

Numeric Analysis using nSights

In a first step, the diagnostic plots for the individual sequences were analyzed and fitted individually accounting for borehole history and taking into account of transient effects associated with the preceding test sequences. In a second step, the entire test sequence was simulated and fitted based on the Cartesian pressures and flow rates (for HI).

For the Cartesian fit, only the PW1 and PW2 phases were chosen and no weighting for individual events was applied. The so-called history periods BH, INF1, INF2, COM, PSR, PW1_a and PW2_a were not fitted but incorporated as test events with defined pressure in the simulation process. The transitional phases PW1_a and PW2_a denote very short events of less than 0.025 hrs duration and represent transitional phases during initiation of the pulse withdrawal tests (open shut-in valve phase at start of pulse tests).

Please note that the fits of the Ramey plots for the PW1 and PW2 sequences are the result of the inverse parameter estimation using nSights and represent a solution of a numeric process that includes the effects of potential transient effects of the preceding test phases and the borehole history.

The diagnostic plots of the individual test sequences did not indicate characteristic responses of a composite flow model, or any other more complex flow models. Consequently, a homogeneous model was assumed in this first evaluation for estimating formation parameters (i.e., K, S_s, and P_f). The analyses used the wellbore compressibility of 6.1-10 m^3/Pa (c_{SC} = 7.3E-10 1/Pa) determined from PW1.

The log-log diagnostic plot of the PSR phase indicates dominantly wellbore storage effects (**Figure 7**) providing a good fit in the Horner plot (**Figure 8**) but providing only preliminary estimates of formation parameters (K = 2.27E-15 m/s, S_s= 6.5E-5 m^{-1}, P_f = 3202 kPa). The results are considered unreliable given the PSR being affected by compliance effects (due to non-stabilized packer pressures, see **Figure 4**).

The diagnostic plot of the PW1 sequence in terms of the normalized pressures produced a good fit on the whole phase including the late time which is dominated by a pressure decrease reversing the earlier recovery trend, probably induced by borehole pressure history effects (**Figure 9**). The PW1 fit gives a conductivity value about 1.6 orders of magnitude higher than the corresponding result from the PSR phase (K = 8.73E-14 m/s, S_s= 5.83E-7 m^{-1}, P_f. = 3499.4 kPa).

The PW2 sequence fit of the normalized PW2 curve is relatively good (**Figure 10**) and yielded values for the conductivity and for the specific storativity (K =8.19E-14 m/s, S_s = 4.89E-7 m^{-1}) similar to PW1 but a lower value for the static formation pressure (P_f = 2880 kPa).

During SW, only 0.83% of pressure recovery was recorded. The simulation result of this phase was considered unreliable and is therefore not presented.

The simulation of the entire test sequence produced a good fit for all sequences (**Figure 11**) with a calculated conductivity slightly lower than obtained from the PW phases but with a reliable specific storativity and an intermediate static formation pressure (K = 2.29E-14 m/s, S_s= 1.30E-6 m^{-1}, P_f. = 3109.4 kPa). The PSR phase was incorporated as a pressure history period because of the above mentioned compliance effects.

The sensitivity coefficients of the formation parameters during the PW phases (**Figure 12**) indicate a high sensitivity of the analysis to the conductivity but a very low sensitivity to the static formation pressure. Therefore, the estimates of the static formation pressure should be used with prudence.

Results and Discussion

The shut-in wellbore storage constant values (C) obtained from the pulse withdrawal tests PW1 and PW2 are very low and correspond to system compressibility values (c_{SC}) of 7.3E-10 Pa^{-1} (for PW1) and 6.2E-10 Pa^{-1} (for PW2). These values are very similar to the expected compressibility of water at depth and temperature conditions of the test zone (expected c_w = 4.4E-10 Pa^{-1}). The measured low c_{SC} values can be explained by the relatively large water volume in the 50 m long interval section diminishing the effect of the elastic behavior of the packer on this parameter ($c_{SC} = C / V_{interval}$). The measured system compressibilities are considered approximate values because of the limited accuracy inherent to this type of field measurement. The low T and K values obtained from the analytical analyses of the PW phases are considered unreliable in view of the potential transient effects from the preceding borehole pressure history.

The Ss values of the individually fitted PW1 and PW2 sequences using nSights are low compared to the initial Ss estimate (Ss values as expected based on assumed formation compressibility, porosity, and water compressibility). Only little percental recovery was observed during these test events indicating that the estimated Ss parameter is not well constrained and may have limited reliability.

The estimated formation parameters for the different sequences vary between 2.3E-14 m/s (T=1.2E-12 m^2/s) and 8.7E-14 m/s (T = 4.4E-12 m^2/s), based on a homogeneous flow model. The range in S_s varies between 4.9E-7 m^{-1} and 1.3E-6 m^{-1}. The highest Ss value obtained from the Cartesian fit agrees quite well with the initial Ss estimate derived from assumed formation properties. The matched static formation pressures range between 2880 and 3500 kPa. Because of the low permeability of the formation and the relatively short duration of the test phases, only early time data were available for the extrapolation of formation pressures which is subject to large uncertainty. The uncertainty is also indicated by the low sensitivity of the analysis to the static formation pressure. The analysis of the entire test sequence provides an intermediate static formation pressure P_f. = 3109 kPa, a hydraulic conductivity value of K = 2.29E-14 m/s and a plausible specific storativity of 1.3E-06 m^{-1}. Therefore, the parameters obtained from the entire testing sequence fit are considered the most representative parameter values.

FIGURES

ABBREVIATIONS
NOMENCLATURE
DEFINITIONS
FIELD DOCUMENTATION

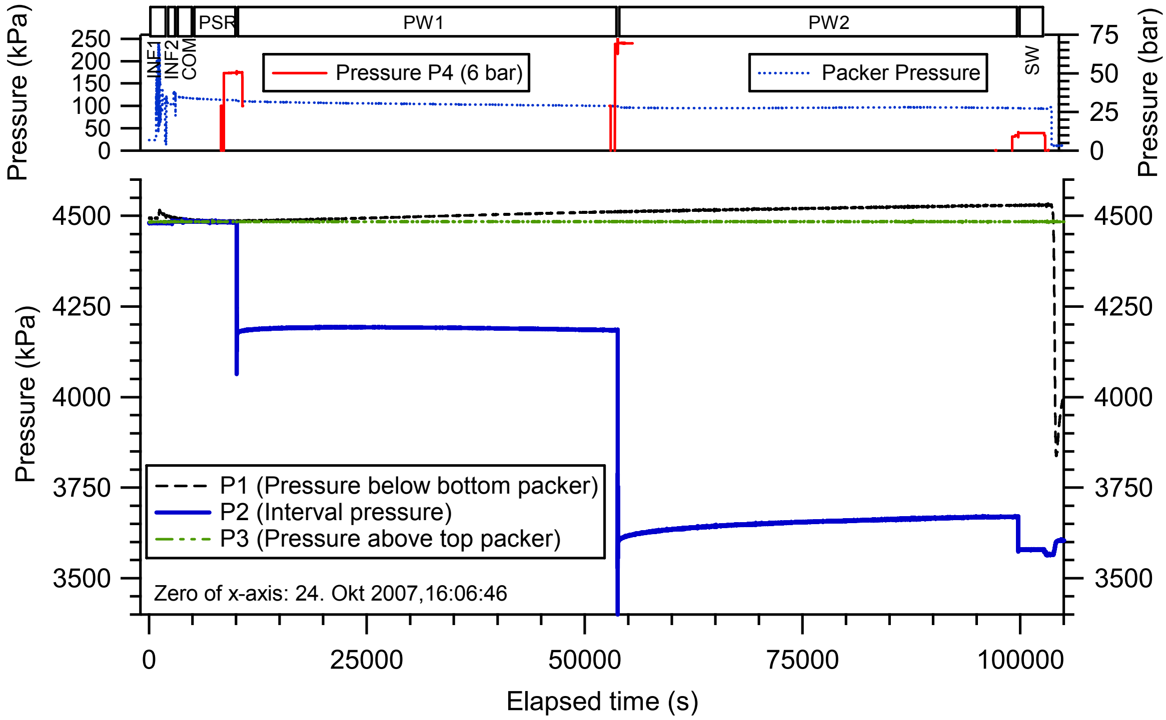


Figure 1: Ofrt-i5: Overview plot

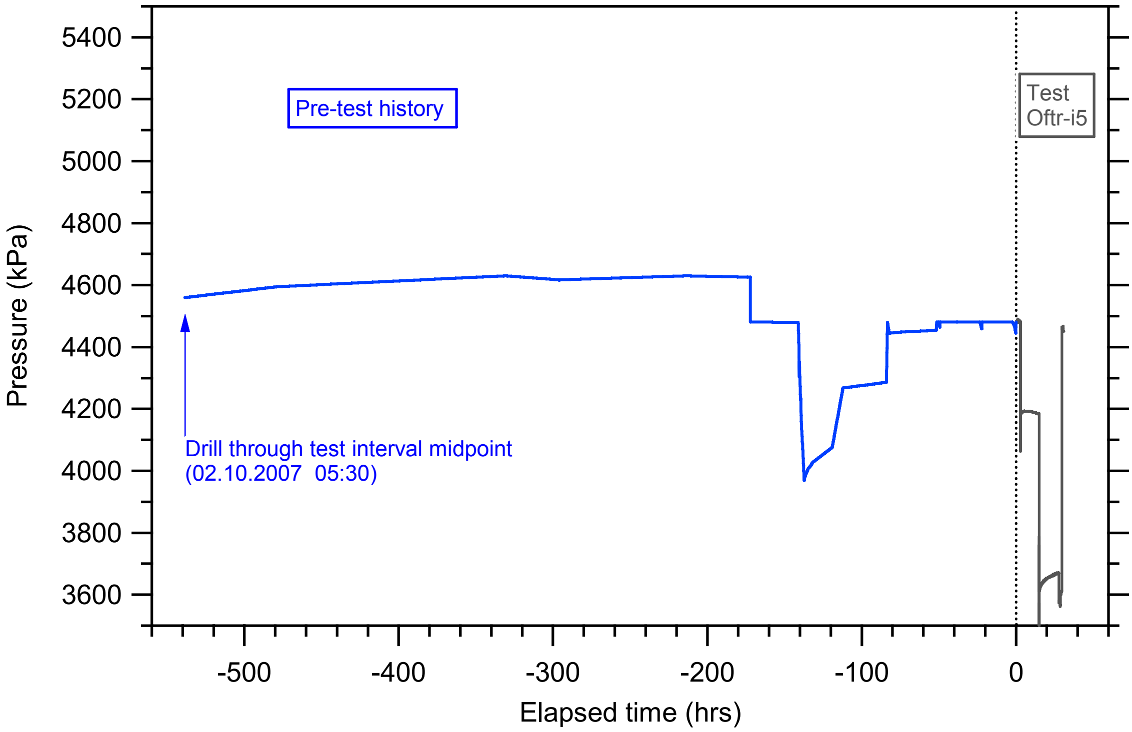


Figure 2: Ofrt-i5: Borehole pressure history

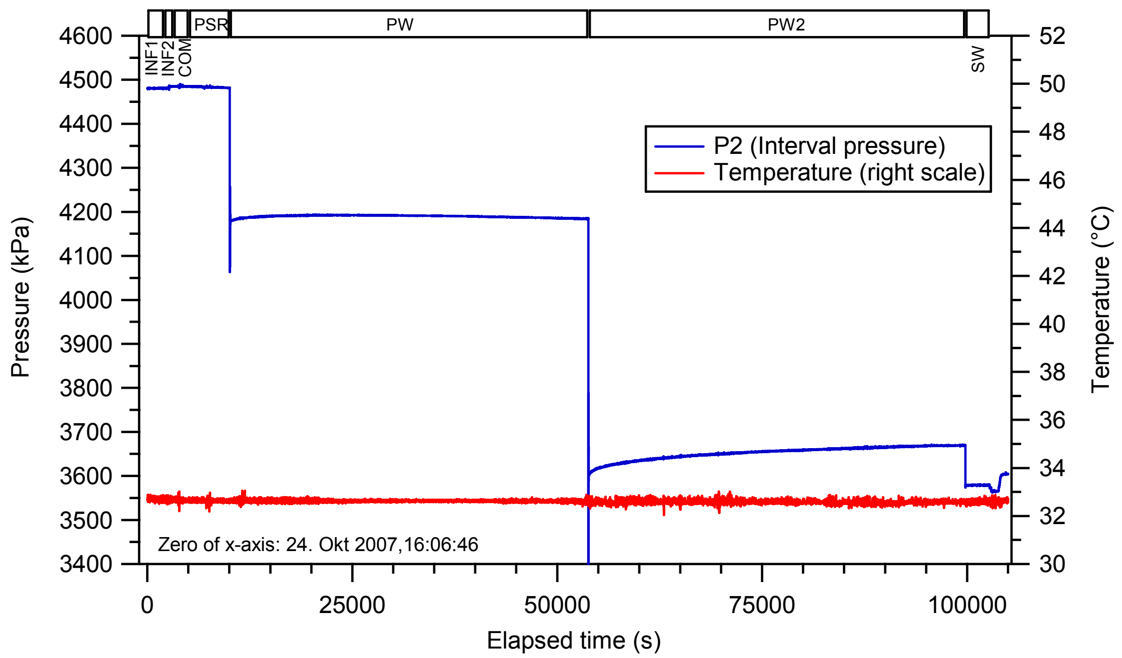


Figure 3: Oftr-i5: Measured downhole temperature (T2)

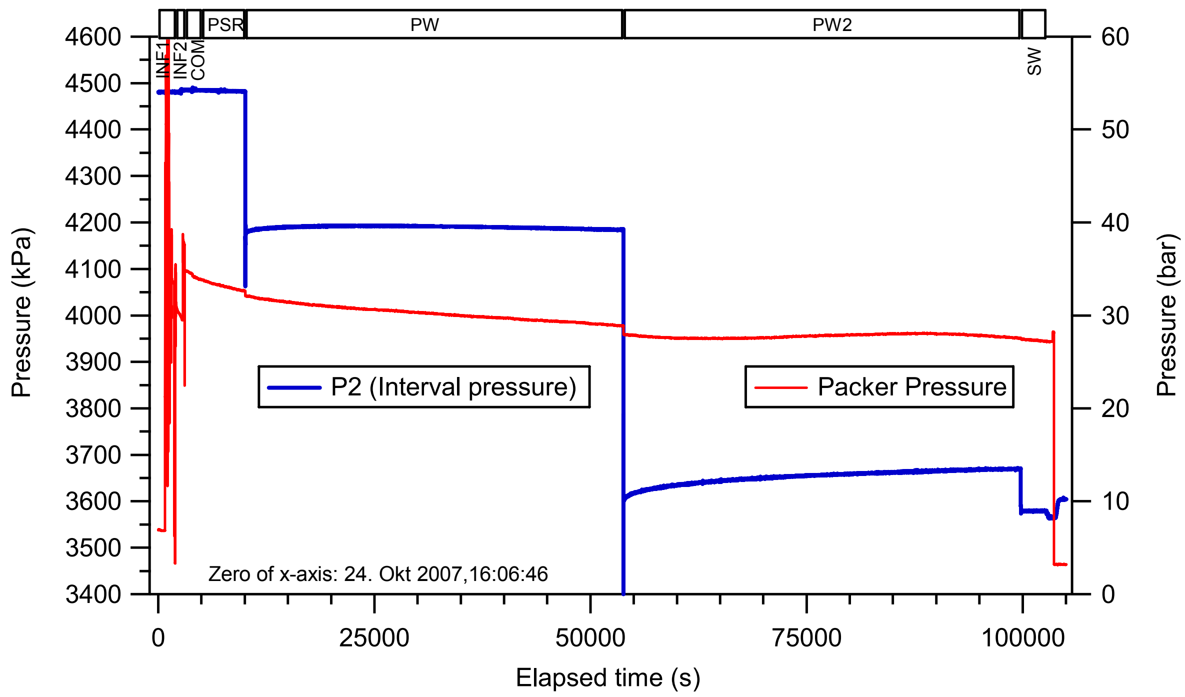


Figure 4: Oftr-i5: Measured packer pressure

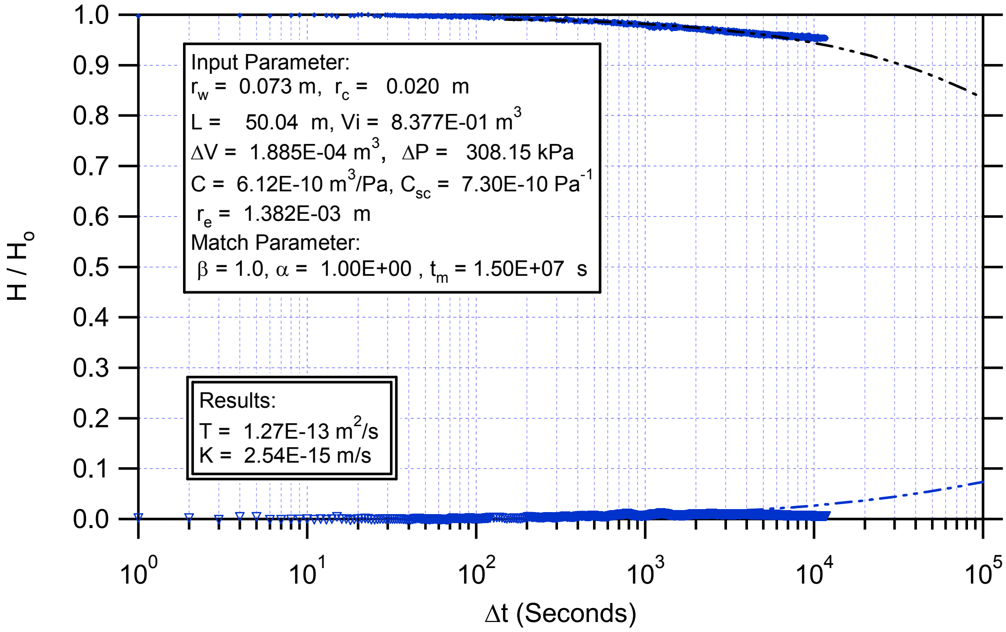


Figure 5: Oftr-i5: PW1 test analysis using CBP type-curves

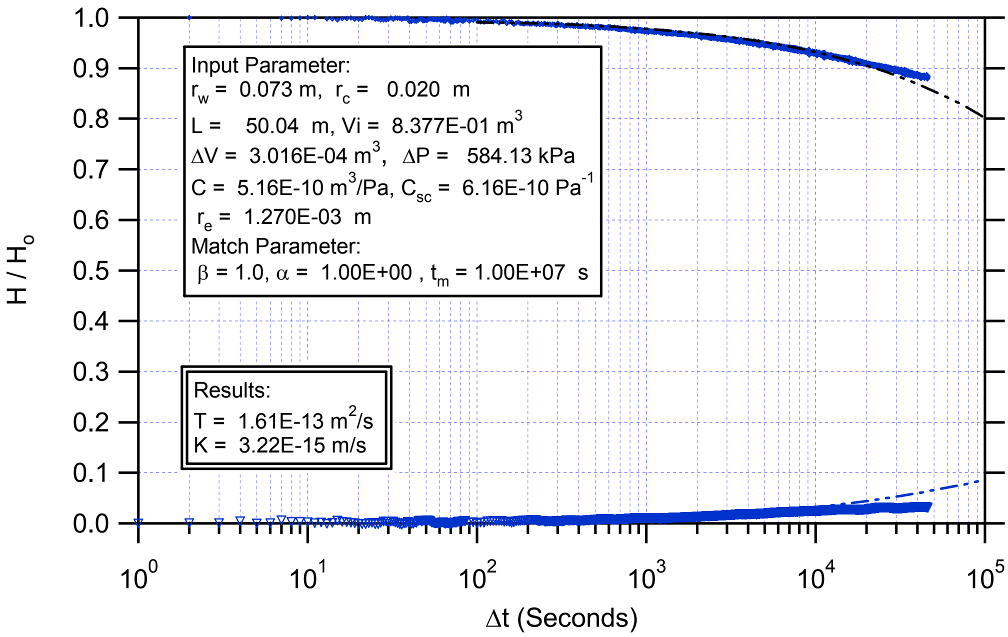


Figure 6: Oftr-i5: PW2 test analysis using CBP type-curves

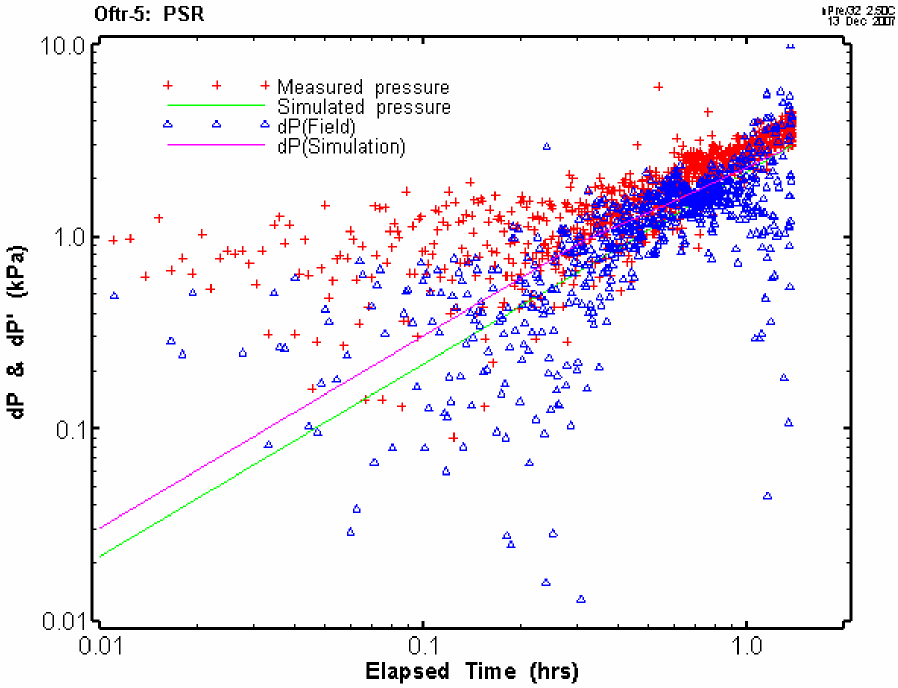


Figure 7: Oftr-i5: PSR log-log diagnostic plot

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_fm	[m/sec]	(2.27E-15)	???	???
P_fm	[kPa]	(3201.9)	???	???
ss_fm	[1/m]	(6.48E-05)	???	???

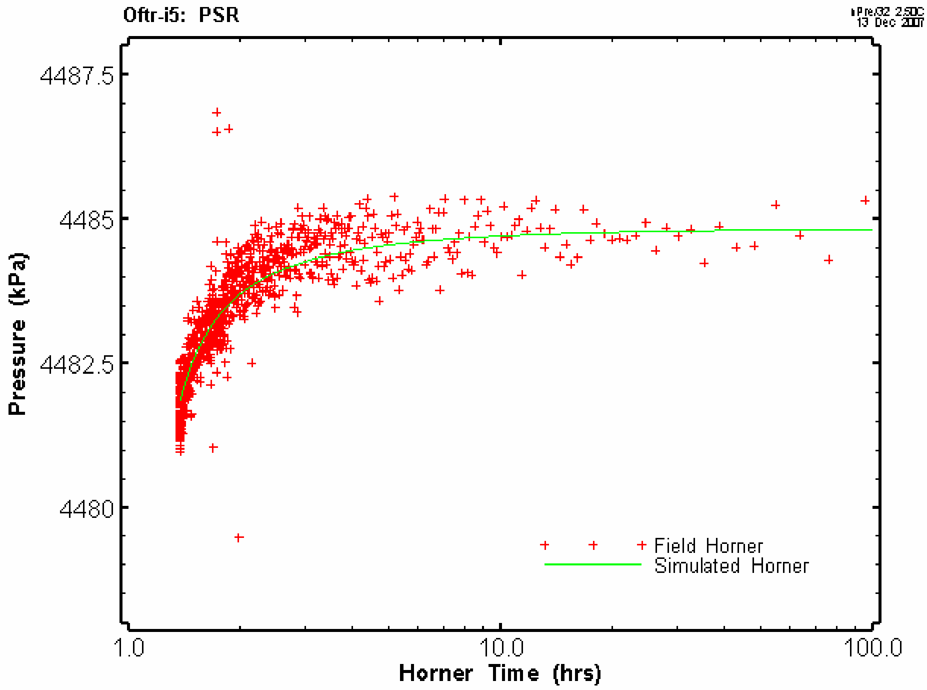


Figure 8: Oftr-i5: PSR Horner plot

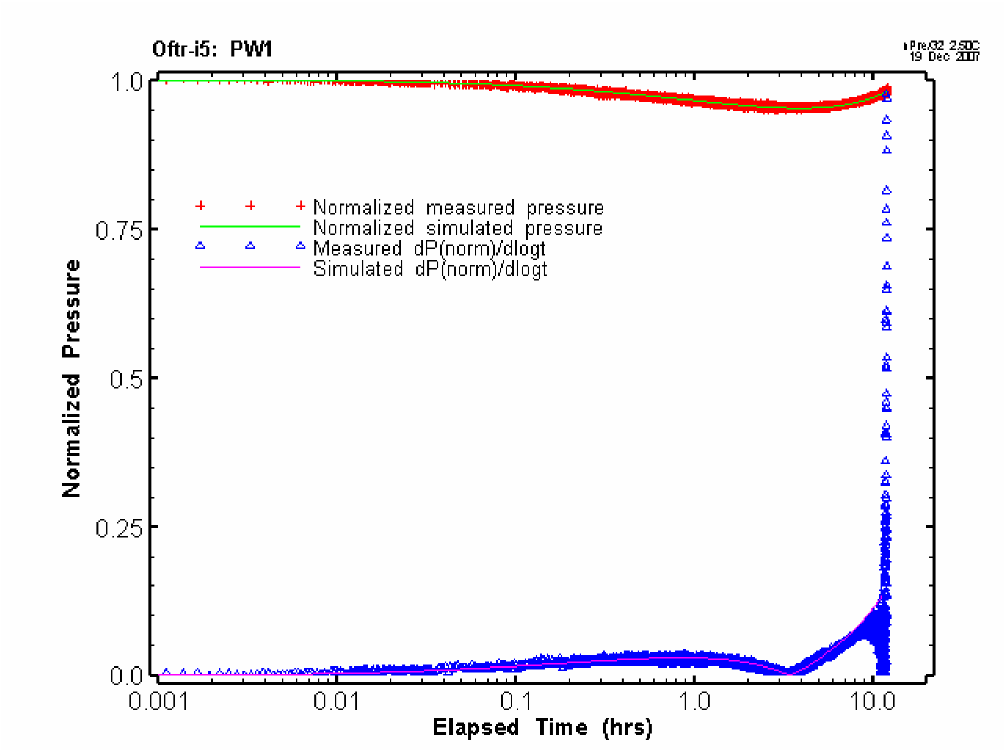


Figure 9: Oftr-i5: PW1 normalized pressure (Ramey A) plot.

Fit Statistics:

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_fm	[m/sec]	8.73E-14	4.90E-14	1.55E-13
P_fm	[kPa]	3499.4	3287.6	3711.2
ss_fm	[1/m]	5.83E-07	3.05E-07	1.11E-06

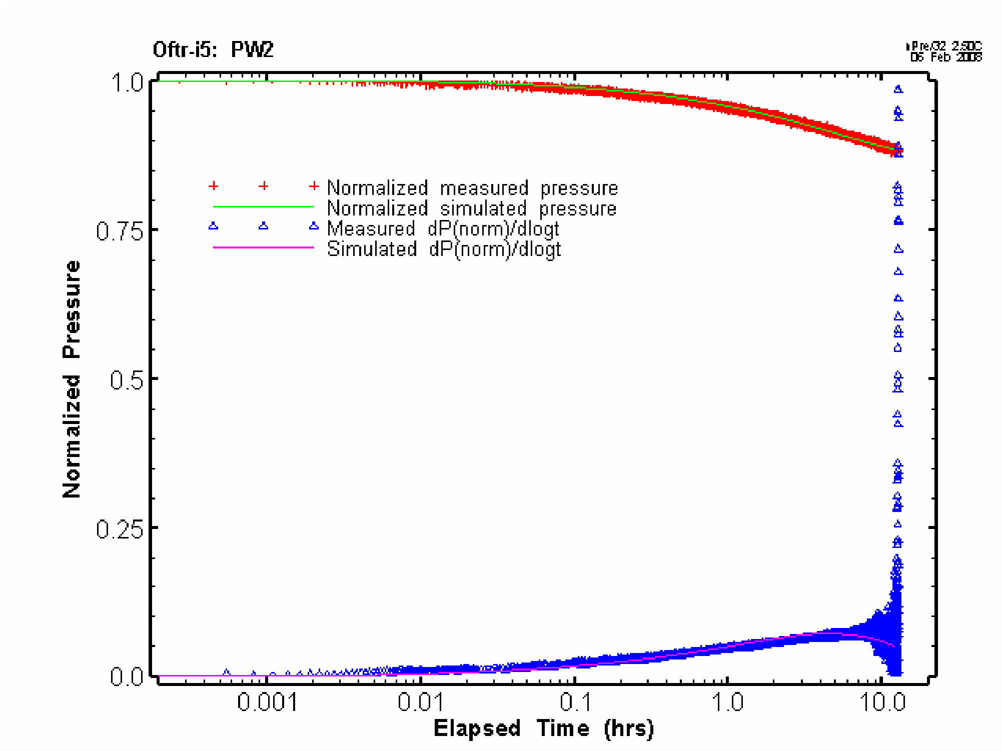


Figure 10: Oftr-i5: PW2 normalized pressure (Ramey A) plot

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_fm	[m/sec]	8.19E-14	6.04E-14	1.11E-13
P_fm	[kPa]	2880.1	2778.6	2981.7
ss_fm	[1/m]	4.89E-07	3.37E-08	7.07E-07

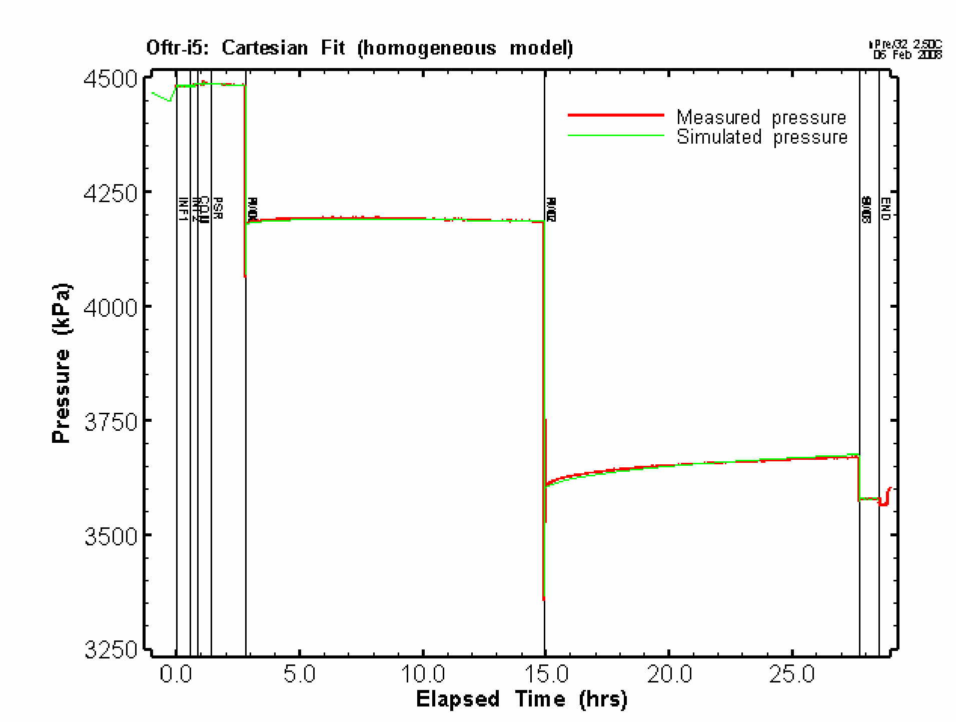


Figure 11: Oftr-i5: Cartesian fit of the entire test for homogeneous model

Fit Statistics:

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_fm	[m/sec]	2.29E-14	2.09E-14	2.50E-14
P_fm	[kPa]	3109.4	3051.7	3167.2
ss_fm	[1/m]	1.30E-06	1.13E-06	1.50E-06

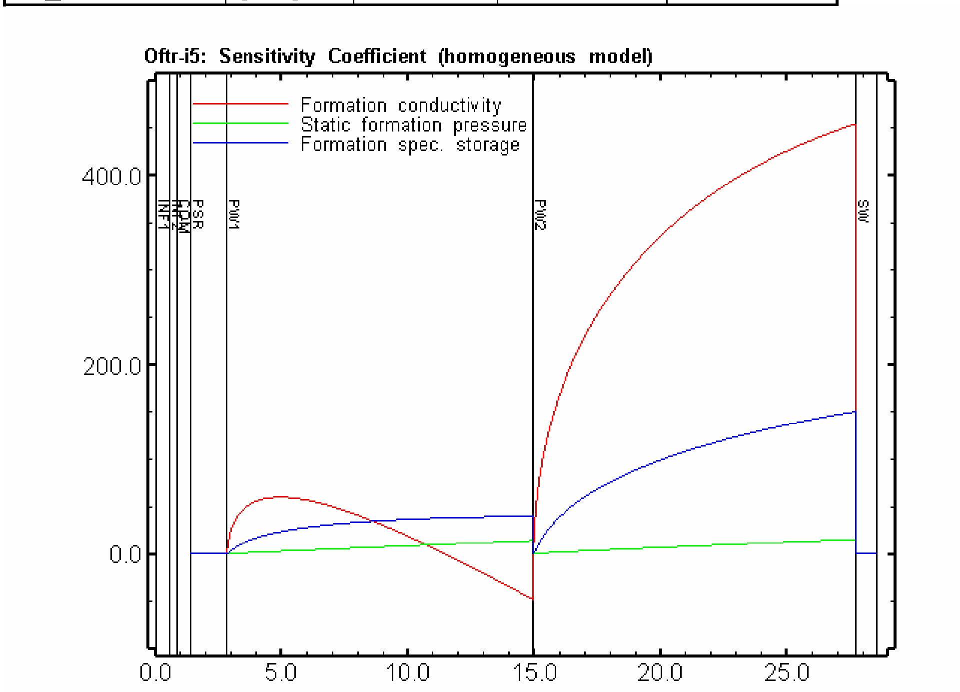


Figure 12: Oftr-i5: Sensitivity coefficients for the different formation parameters during the different sequences (homogenous model)

Abbreviations

	Test phases
COM	Compliance
INF	Packer inflation
INF1	Inflation of lower packer (INF2 = Inflation of upper packer)
DEF	Packer deflation
DEF1	Deflation of lower packer (DEF2 = Deflation of upper packer)
PSR	Static pressure recovery (shut-in valve closed)
SI	Slug injection test
SIS	Pressure recovery after slug injection test (shut-in)
SW	Slug withdrawal test
SWS	Pressure recovery after slug withdrawal test (shut-in)
PI	Pulse injection test
PW	Pulse withdrawal test
HI	Constant head injection test (constant pressure difference)
HIS	Pressure recovery after constant head injection test (shut-in)
HW	Withdrawal test applying constant differential head
HWS	Pressure recovery after constant head withdrawal test (shut-in)
MR	Multi-rate test: Test with variable flow rate
MRS	Pressure recovery after test with variable flow rate
RW	Pump test with constant flow rate
RWS	Pressure recovery after pump test with constant flow rate (shut-in)
RI	Constant flow injection test
RIS	Pressure recovery after constant flow injection test (shut-in)
VC	Shut-in valve is closed
VO	Shut-in valve is open
	General
CBP	Cooper, Bredehoeft, Papadopulos (type-curve matching method)
DAS	Data acquisition system
FS	Full scale
IARF	Infinite acting radial flow
LC	Log cycle
m agl	Meters above ground level
m bgl	Meters below ground level
m asl	Meters above sea level
OD	Outer diameter
PVT	Pressure volume temperature correlation
Sdev	Standard deviation
SLA	Straight-line analysis
TOC	Top of casing
WL	Water level (or WT = water table)

Nomenclature

	Description	SI-Unit		Description	SI-Unit
b	Y-intercept of linear regression		S_S	Specific storativity	m^{-1}
C	Wellbore storage constant	$m^3 Pa^{-1}$	S_{SS}	Specific storativity of skin zone	m^{-1}
C_S	Wellbore storage constant, shut-in	$m^3 Pa^{-1}$	s	Skin factor	-
C_D	Dimensionless wellbore constant	-	t, Δt	Time, elapsed time	s
c_f	Pore volume based compressibility	Pa^{-1}	t_C	Critical time	s
c_r	Rock compressibility	Pa^{-1}	t_D	Dimensionless time	-
c_{SC}	System compressibility (= test zone compressibility c_{tz})	Pa^{-1}	Δt_e	Equivalent time (after Agarwal)	s
c_w	Water compressibility	Pa^{-1}	Δt_H	Horner time	-
Δh	Differential head	m	t_p	Production time	s
g	Acceleration of gravity (9.81)	$m\ s^{-2}$	t_p*	Corrected production time	s
h_S	Static head	m	t_m	Match time	s
k	Intrinsic permeability	m^2	t_0	X-intercept of linear regression	s
K, K_f	Hydraulic conductivity of formation () special case	m/s	t_s	Thickness of skin zone	m
K_s	Hydraulic conductivity of skin zone () special case	m/s	T	Transmissivity	m^2/s
L	Interval length	m	T_W	Water temperature	°C
m	slope (regression)		z_1	P1 sensor depth	m
P	Pressure	Pa, kPa	z_2	P2 sensor depth	m
P_0	Minimal or maximal pressure	Pa, kPa	z_3	P3 sensor depth	m
P_{atm}	Probe signal at atmospheric pressure	Pa, kPa			
ΔP	Differential pressure, pressure change	Pa, kPa	α ,β	Type-curve match parameter	-
P_D	Dimensionless pressure	-	α	aquifer compressibility	Pa^{-1}
P_f	Static formation pressure	Pa, kPa	μ	Dynamic viscosity	Pa·s
P_i	Initial pressure	Pa, kPa	θ	Porosity	-
$P_{min/max}$	Minimal/maximal pressure	Pa, kPa	ρ_w	Density of fresh water	kg/m^3
P_{S1}	Static pressure in P1-Interval (below bottom packer)	Pa, kPa			
P_{S2}, P_f	Static pressure in test interval	Pa, kPa			
P_{S3}	Static pressure in annulus (above upper packer)	Pa, kPa			
q	Flow rate	$m^3 s^{-1}$			
q_{end}, q_e	Last flow rate	$m^3 s^{-1}$			
Q, Q_{tot}	Cumulative flow	m^3			
r_e	Effective radius (Slug, Pulse test)	m			
R_i	Radius of influence	m			
R^2	Correlation coefficient	-			
r_c	Tubing radius	m			
r_w	Wellbore radius	m			
R_1	Radius, composite model	m			
R_D	Dimensionless radius	-			
S	Storativity	-			
S_C	Sensitivity coefficient				
S_{SC}	Scaled sensitivity coefficient				

Definitions

$C_D = \dfrac{\rho \, g \, C}{2\pi \, S \, r_{w^2}}$	Wellbore constant, dimensionless
$H_D = \dfrac{P - P_i}{P_0 - P_i}$	Dimensionless pressure (slug und pulse tests)
$K = \dfrac{k \, \rho \, g}{\mu}$	Hydraulic conductivity
$P_D = \dfrac{2\pi \, T \, \Delta h}{q}$	Dimensionless pressure
$\Delta P = \rho \; g \, \Delta h$	Differential pressure
$q_D = \dfrac{q}{2\pi \, T \, \Delta h}$	Dimensionless flow
$t_D = \dfrac{t \, T}{r_w^2 S}$	Dimensionless time
$S = S_S \, L$	Storativity
$s = \left(\dfrac{K_f}{K_s} - 1 \right) \ln \left(\dfrac{r_w + t_s}{r_w} \right)$	Skin factor
$S_S = \rho \, g \, (\alpha + \theta \, c_w)$	Specific storativity

$$S_C = \frac{\partial P}{\partial r}$$

Sensitivity coefficient.

where ∂P is the partial derivative of the calculated system response (i.e., pressure) with respect to a parameter varied by the derivative span ∂r .
For comparison of sensitivity coefficients for different parameters, the sensitivity coefficients are typically scaled by inverses of the respective standard deviations as follows:

$$S_{sc} = S \frac{\sigma_r}{\sigma_P} = \frac{\partial P}{\partial r} \cdot \frac{\sigma_r}{\sigma_P}$$

where S_{sc} is the scaled sensitivity coefficient, σ_r is the a priori standard deviation of the measurement error, and σ_P is the estimated standard deviation of the parameter.
If not otherwise stated, default values σ_r = 1 and σ_P = 1 were used.

Definitions (continued)

T = K L	Transmissivity
$\frac{t_D}{C_D} = \frac{2\pi T t}{\rho\ g C}$	Dimensionless time axis
$t_e = \frac{t_p \cdot \Delta t}{t_p + \Delta t}$	Dimensionless Agarwal time (Agarwal, 1980)
$t_e^* = \frac{t_P^* \cdot \Delta t}{t_P^* + \Delta t}$	Modified Agarwal time (using corrected production time)
$t_P^* = \frac{Q}{q_{end}}$	Modified production time (Ehlid-Economides and Ramey, 1980)

Form

DAILY LOG REPORT

SOLEXPERTS

Date	**Time**	**Activity**	**Who**
24.10.2007	*16:00*	*System on position, fill annulus up to the top (1.42 m above top of ground level)*	*Fi, Sti*
		Interval 5: 449.85 – 499.89 m	
	16:07	*Start file Oftr-i5*	
		Start file: Oftr_2007_10_19_oftr_i5.dat *P1 = 4494 kPa* *P2 = 4481 kPa* *P3 = 4484 kPa* *T2 = 32.8 °C* *Water table: 1.42 m above ground level (=top of casing)*	
	16:20	*Start inflation of packer 1*	
	16:35	*Start inflation of packer 2 (packer pressure increase is not recorded). Slow increase of packer pressure*	
	17:00	*Both packer are pressurized by pressure vessel at 35 bar (PA1 and PA2 pressure lines are interconnected)* *Packers are pulling with extra 0.5 tons downwards (drillometer of Daldrup, measured by famous Meyk Hössel)*	
		Water table: 1.42 m above ground level (=top of casing)	
	17:13	*Daldrup lowers drill head in order to decrease the tension on test string*	
	17:31	*Shut-in (Start PSR)*	
	17:35	*Arrival of night-shift crew*	*JH, CAD*
	18:25	*Swabbing to 32.87 m below top of 1.9" tubing rods*	
	18:25	*Recording P4-sensor at atmospheric pressure P4 = 100 kPa*	
		Installation of P4 Sensor in 1.9"NU tubing (depth 40.33 m below top of rods).	
	18:40	*Water table in 1.9''NU: 32.47 m below top of rods, P4 Sensor 173.49 kPa*	
	18:54	*Scan rate 1 s*	
	18:55	*Start PW-test, valve open during 55 s, Water table in 1.9''NU: 32.32 m below top of rods, P4 Sensor 174.90 kPa*	
	19:07	*Remove P4,atmospheric pressure 99.72 kPa*	
	19:30	*Swabbing to 32.87 m below top of 1.9" tubing rods*	
	20:02	*Phone call with Fbe for discussion of test procedure*	
	22:15	*Phone call with Fbe for discussion of test procedure, PW measurement until following morning*	
25.10.2007	*06:48*	*Recording P4-sensor at atmospheric pressure P4 = 100.28 kPa*	*Fi, Sti*
	06:55	*Installation of P4 Sensor in 1.9"NU tubing (depth calculated 101.28 m below top of rods).*	
	07:00	*Water table in 1.9''NU: 87.32 m below top of rods, P4 Sensor 283.13 kPa*	
	07:01	*Scan rate 1 s* *P2 pressure before PW2 = 4184 kPa*	
	07:09	*Start PW2-test, valve open during 25 s, Water table in 1.9''NU: 87.08 m below top of rods, P4 Sensor 240.09 kPa* *=> Δs = 0.240 m. ΔP = 732 kPa.* *C-SC = 5.0E-10 1/Pa*	
	07:30	*Data backup on BD553* *Raw data saved on "1763 Oftringen raw data"*	
		Replacement of swab cups	*Sti*
	15:30	*Arrival of guests Iain Robertson and Alex Tiernan (Ritchies, Scotland) with ATH and TF (Solexperts)*	
	16:00	*Web arrives on site*	

Form

DAILY LOG REPORT

Date	**Time**	**Activity**	**Who**
25.10.07	17:30	Phone call with Bernd: 1. Swabbing to maximum depth compatible with slim tubing length 2. Slug withdrawal test during ½ hrs 3. Stop test if inflow during slug is small 4. No final PI required 5. Pull system out of hole 6. Change of straddle to a length between 4 and 5 meters, depending caliper log	Fi
	17:50	Water table in 1.9" NU test rod = 87.32 below top of casing	
		Decrease water level in 1.9" tubing using swabbing tool Water level is 111.5 m => add 22.5 litres	
	18:30	Arrival of day-shift crew	JH, CAD
	19:06	Slim tubing sensor at atmosphere shows 0.82 kPa	
	19:40	Installation of slim tubing, packer slim tubing at about 95 m bgl	
	19:42	Start slim tubing sensor: P = 34.46 kPa	
	19:45	Inflation of Slim tubing packer (30 bar)	
	19:47	Scan rate 1 s	
	19:49	Start SW-test	
	19:52	Scan rate 5 s	
	20:38	Deflate slim packer	
	20:40	Slim tubing pressure sensor switched off	
	20:45	Remove slim tubing	
	20:47	Slim tubing pressure sensor shows 1.06 kPa at atmosphere	
	21:00	Start to deflate packers. Water level in annulus is filled up to top of 7" casing (1.42 m above ground level	
	22:44	Packers are free Water level in 7"casing is 1.0 m below top (=0.42m above ground level)	
	22:50	Stop file	
	23:00	Start pull out test rods and packer system	
26.10.07	02:20	Test rods uninstalled	
	04:00	Packer system uninstalled	
	04:25	Redress of packers, installing new packer sleeves, both packer sleeves are damaged after the first test cycle.	
	06:30	Saturate packer, prepare system for installation	
	06:55	SR, PH arrive on site	SR, PH
	08:10	JH, Cad leave site	JH, CAD

Fi *Hansruedi Fisch*
SR *Sacha Reinhardt*
JH *Jörg Hayer*
Cad *Stefan Caduff*
PH *Peter Haller*
FP *Fredi Portmann*
Sti *Daniel Stillhard*

Nagra:
Web *Hanspeter Weber*
Fbe *Bernd Frieg*

Form

INSTALLATION RECORD HDDP

SOLEXPERTS

Seite 1 / 1

Oftringen NOK EWS Borehole: Hydraulic Testing

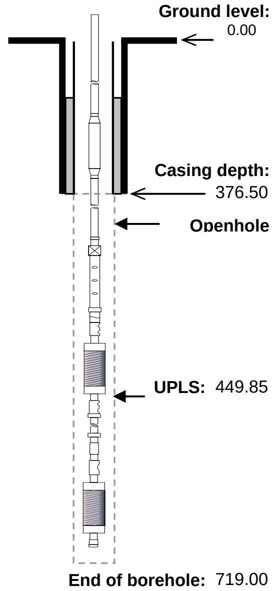
Date	24.10.2007	Project Leader	Fi/SR								
Borehole	NOK EWS 2007	Direction	vertical	Reference point	433.0	JOB Nr	1763	Location	Oftringen		
Borehole Depth	719.0 m	Casing depth	376.5 m bgl	Interval lenght	50.04 m	Test Name	oftr_i5	System	HDDP 110		
Borehole diameter	146 mm	Stickup	-2.90 m	Water depth	-1.42 m bgl	Test depth (UPLS)	449.85 m bgl	Probe ID	TSSP S1		

Note: All dephts shown are not correct for borehole deviation

Component			Qty -	L unit m	L total m	Depth m	OD mm	ID mm	Wgt kg	Str t
Stickup		-2.90 m bgl								
Ground level						0.00				
Tubing 1.9" NU				445.48	445.48		56.1	40.3	#####	12.0
Pop joint				1.02		442.58	56.1	40.3	4.2	12
SIT Non Displacement Valve				0.84			79.0	24.0	20.6	15
Probe Shell Carrier mit Triple Sub	TSSP P3			1.97		446.41	70.0	10.9	48.0	25
	TSSP P2			0.30		446.71				
	TSSP P1			0.30		447.01				
				0.04						
X-Over	2"3/8 EU Pinx1.9" NU Box			0.51	7.27		66.0	40.0	2.1	16
Safety joint 3"1/16							78.0	50.5	5.5	24
Above Side Entry Sub (ASES)				0.52			66.0	32.0		24
Packer Stick Up				0.26			--	25.0		
Up. Packer Seal	Upper Packer	UPUS		0.26		448.60	108.0	32.0	82.4	17
				1.25						
		UPLS		0.24		449.85				
Straddle Length	Packer Stick Down			0.31			--	25.0		
	Below Side Entry Sub (BSES)			0.52			66.0	32.0		24
	X-Over	1.9" NU Pinx2"3/8 EU Box		0.26			--		3.0	16
	Tubing 1.9" NU			45.5	50.04		56.1	40.3	186.6	12
	X-Over	2"3/8 EU Pinx1.9" NU Box		0.45			--		3.0	16
	Filter	Screen		0.3			72.0	50.0	19.0	19
				1.45						
				0.3						
	P1-Seal Sub			0.3			78.0	--		24
	Packer Stick Up			0.16			--	32.0		
Lower Packer Seal	Lower Packer	LPUS		0.25		499.89	110.0	32.0	70.2	17
				1.25	1.92					
		LPLS		0.24		501.14				
Packer Stick Down				0.43			--	32.0		
End Cap						501.81	78.0	--		
End of Borehole						719.00				

Comments:
P4: submersible pressure transducer on cable
P_{SL}: submersible pressure transducer at bottom of slim tubing

Borehole configuration:



Probe	523 006.1	
values at atmosphere	P1	111.7
	P2	92.1
	P3	102.3
	P4/P_{SL}	101.1/1.1
	T1	11.4
	T2	11.0
	T3	10.6
Total Weight (kg)	2291.6	

Form

TALLY LIST

SOLEXPERTS

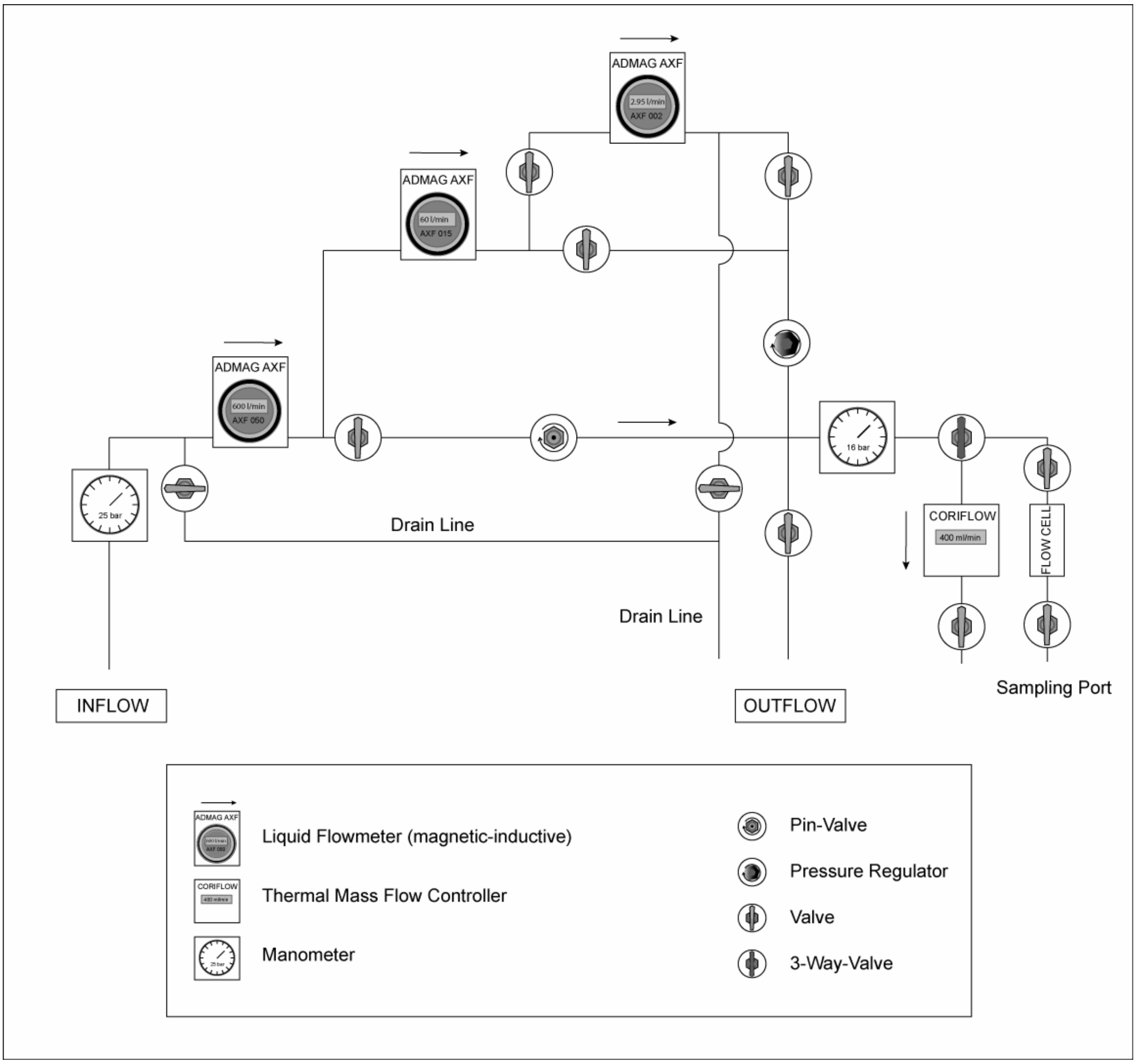
Borehole	NOK EWS 2007	Interval name	Test Oftr_i5	Date	24.10.2007
Depth	719.0 m	Interval depth	450 - 500 m	Location	Oftringen

TU	1	6.51	TU	51	6.50			
TU	2	6.51	TU	52	6.51			
TU	3	6.51	TU	53	6.51			
TU	4	6.51	TU	54	6.51			
TU	5	6.51	TU	55	6.51			
TU	6	6.51	TU	56	6.51			
TU	7	6.51	TU	57	6.50			
TU	8	6.51	TU	58	6.51			
TU	9	6.51	TU	59	6.51			
TU	10	6.50	TU	60	6.51			
TU	11	6.50	TU	61	6.50			
TU	12	6.51	TU	62	6.50			
TU	13	6.50	TU	63	6.50			
TU	14	6.51	TU	64	6.50			
TU	15	6.51	TU	65	6.51			
TU	16	6.51	TU	66	6.50			
TU	17	6.51	TU	67	6.50			
TU	18	6.51	TU	68	6.51			
TU	19	6.50	TU	Pop J.	2.05			
TU	20	6.51	TU	Pop J.	1.05			
TU	21	6.51						
TU	22	6.50						
TU	23	6.51						
TU	24	6.50						
TU	25	6.50						
TU	26	6.50						
TU	27	6.50						
TU	28	6.50						
TU	29	6.50						
TU	30	6.50						
TU	31	6.50						
TU	32	6.50						
TU	33	6.51						
TU	34	6.51						
TU	35	6.50						
TU	36	6.51						
TU	37	6.50						
TU	38	6.50						
TU	39	6.51						
TU	40	6.50						
TU	41	6.51						
TU	42	6.51						
TU	43	6.50						
TU	44	6.50						
TU	45	6.50						
TU	46	6.50						
TU	47	6.51						
TU	48	6.51						
TU	49	6.51						
TU	50	6.51						
		325.28			120.20	0.00		0.00

Total string length:	445.48

Form

SURFACE EQUIPMENT LAYOUT



Flow meter	Lower limit of measuring range	(% of FS)	Upper limit of measuring range (l/min)	Accuracy between 3% and 100% of FS (% of rate)	Accuracy between 1% and 3% of FS (% of rate)	Equipment used
AXF DN2	0.030 l/min	1 %	2.95 l/min	0.35	0.5	no
AXF DN15	0.6 l/min	1 %	60 l/min	0.35	0.5	no
AXF DN50	11.78 l/min	1 %	1178.10 l/min	0.35	0.5	no
Coriflow	0.50 kg/h	2 %	25.00 kg/h	1	1	no

Form

BENCH TEST

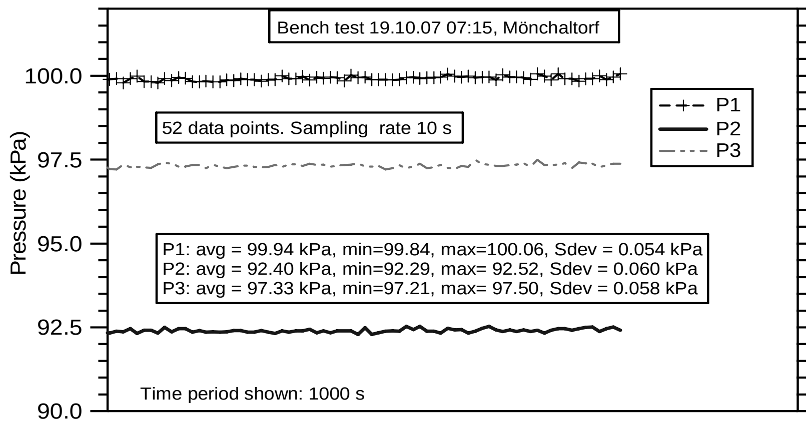
Project	Location	Date
Oftringen NOK EWS Borehole	Oftringen	20.12.2007
Well name	**Test name**	**Engineer**
NOK EWS 2007	Oftri-i5	Fi/SR

Transducer describtion	Output units
P1, P2, P3: 0-206.84 bar (3000 Psi), P4: 0-6 bar, P_{ST} = 0-10 bar	kPa, °C

P1#	P2#	P3#	P4#
43224	50370	43231	591.001.027

Offsite pretest bench test (Date: 19.10.07)

Measurement conditions (P, T and position)	Sampling rate
97.7 kPa 5.6 °C	10 s
( ) direct (x) vertical ( ) horizontal	

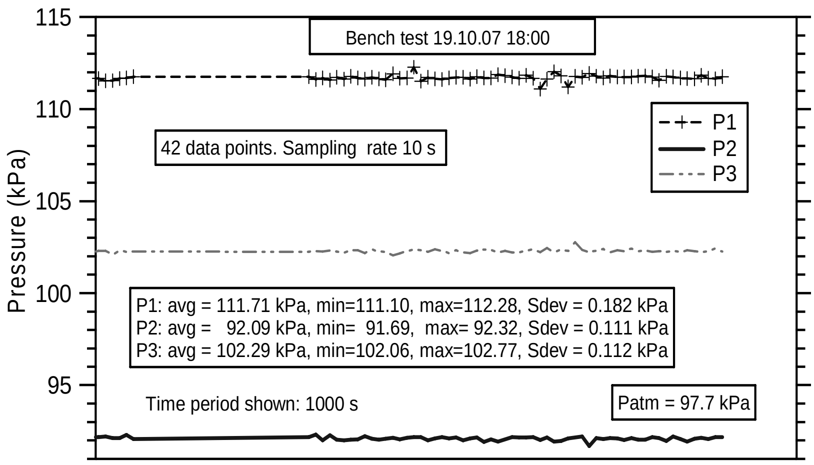


P1 average:	99.84	kPa
P2 average:	92.29	kPa
P3 average:	97.33	kPa
P4 average:	n.m.	kPa
P_{SL} average:	n.m.	kPa
P1 Sdev	0.054	kPa
P2 Sdev	0.060	kPa
P3 Sdev	0.058	kPa

File: TestData24.DAT

Onsite pretest bench test (Date: 19.10.07)

Measurement conditions (P, T and position)	Sampling rate
97.7 kPa 11.0 °C	10 s
( ) direct (x) vertical ( ) horizontal	



P1 average:	111.71	kPa	
P2 average:	92.09	kPa	
P3 average:	102.29	kPa	
P4 average:	101.06	kPa	1)
P_{SL} average:	3.56	kPa	1)
P1 Sdev	0.182	kPa	
P2 Sdev	0.111	kPa	
P3 Sdev	0.112	kPa	
P4 Sdev	0.056	kPa	1)
P_{SL} Sdev	0.019	kPa	1)

1) Data not shown, 20.10.07, 05:45-08:15, File Oftr_2007_10_19_oftr_i1.dat, Patm=97.8 kPa

File: Oftr_2007_10_19_atm0.DAT

Form

BENCH TEST

SOLEXPERTS

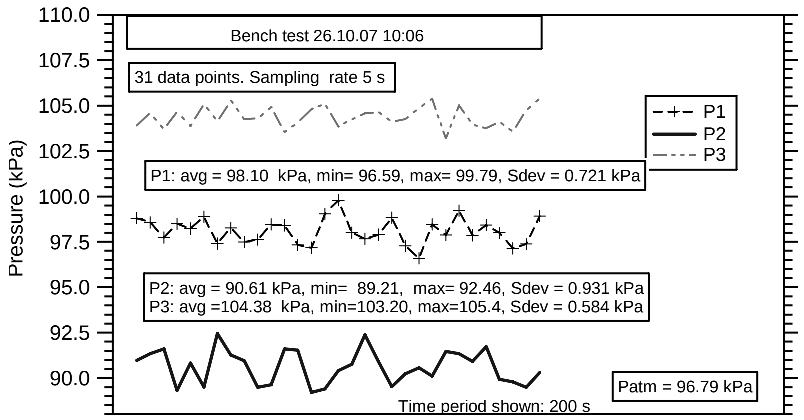
Project	Location	Date
Oftringen NOK EWS Borehole	Oftringen	20.12.2007
Well name	**Test name**	**Engineer**
NOK EWS 2007	Oftri-i5	Fi/SR

Transducer describtion	Output units
P1, P2, P3: 0-206.84 bar (3000 Psi), P4: 0-6 bar, P_{ST} = 0-10 bar	kPa, °C

P1#	P2#	P3#	P4#
43224	50370	43231	591.001.027

Onsite after test bench test (Date: 26.10.07)

Measurement conditions (P, T and position)	Sampling rate
96.4 kPa 7.3 °C	5 s
( ) direct (x) vertical ( ) horizontal	

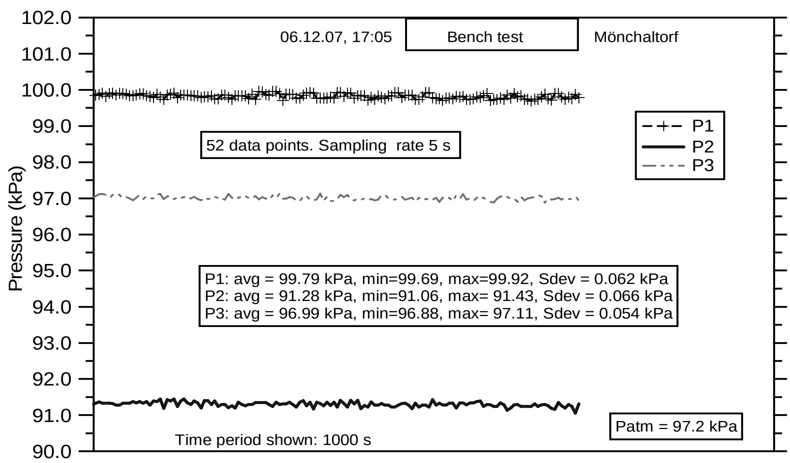


P1 average:	98.10 kPa
P2 average:	90.61 kPa
P3 average:	104.40 kPa
P4 average:	n.m. kPa
P_{SL} average:	n.m. kPa
P1 Sdev	0.721 kPa
P2 Sdev	0.931 kPa
P3 Sdev	0.584 kPa

File: Oftr_2007_10_26_atm2.DAT

Offsite after test bench test (Date: 06.12.07)

Measurement conditions (P, T and position)	Sampling rate
96.6 kPa 9.6 °C	5 s
( ) direct (x) vertical ( ) horizontal	



P1 average:	99.69 kPa
P2 average:	91.28 kPa
P3 average:	96.99 kPa
P4 average: [1]	101.44 kPa
P_{SL} average:	n.m. kPa
P1 Sdev	0.062 kPa
P1 Sdev	0.062 kPa
P2 Sdev	0.066 kPa
P3 Sdev	0.054 kPa
P4 Sdev	0.007 kPa

[1] not shown on graph

File: test8.dat

Appendix F

Quick Look Report
Interval Oftr-i6d

nagra.

QUICK LOOK REPORT OFTRINGEN - TEST OFTR-i6d

TEST START (Date/Time)	:	28.10.2007 / 08:07	**TEST END (Date/Time)**	:	29.10.2007 / 13:03

DOUBLE PACKER TEST

Test Interval Information	:		top test interval	:	408.50 m bgl
borehole depth [1), 4)]	:	719.0 m	bottom of test interval	:	417.59 m bgl
borehole radius	:	0.073 m	total interval length	:	9.09 m
tubing radius	:	20.0 mm	midpoint of interval	:	413.05 m bgl
			P2-depth (z_2)	:	405.36 m bgl
interval volume, nominal [5)]	:	0.152 m^3	theoretical Cs-value[3)]	:	3.04E-10 m^3/Pa
slim tubing radius		4.75 mm	theoretical C-value (slim tube)	:	7.23E-09 m^3/Pa
WL prior to packer inflation [2)]	:	-1.42 m bgl	P2 signal prior to packer inflation	:	4072.69 kPa
WL in annulus at test end [2)]	:	5.13 m bgl	P2 offset assuming ρ_{avg} = 997 kg/m3		94.15 kPa

1) all depths are not corrected for borehole deviation from vertical
2) WL = water level
3) assumes a total borehole system compressibility of 2E-09 Pa^{-1}
4) all depth measurements refer to ground level
5) cylindrical volume of isolated borehole section
Note all pressures cited in this report are absolute

Preliminariy information			
longitude of borehole	:	240887	
latitude of borehole	:	638346	
elevation of ground level (GL)	:	433.0 m asl	(reference point for all measurements)
assumed fresh water head	:	433.0 m asl	(assumed hydrostatic)
end of drilling	:	17.10.07 09:55	(Geotec)
porosity	:	3%	(assumed)
mud density [6)]	:	1032 kg/m^3	(Geotec end of drilling, 17.10.07)
borehole water density	:	997 kg/m^3	(Geotec after circulation of fresh water, 17.10.07; estimated using P2)
formation water density [7)]		1005.4 kg/m^3	(PVT correlation calculated by Saphir)
specific storativity [8)]	:	2.19E-06 m^{-1}	
formation water viscosity [7)]	:	8.92E-04 Pa s	(PVT correlation calculated by Saphir)
fluid compressibility [7)]	:	4.46E-10 1/Pa	(PVT correlation calculated by Saphir)
total compressibility [8)]	:	7.45E-09 1/Pa	(calculated assuming cf= 7.00E-09 1/Pa)

6) Taken from daily report No. 53
7) Assumed, using salinity 10'000 ppm, T = 30.9°C, P = 4130 kPa
8) Calculated based on assumed porosity and compressibility values

Responible Test Engineers	
Onsite:	Hayer, J.; Reinhardt, S.
Test analysis and reporting:	Rösli, U.; Fisch, H.R.

Test Summary		
Test objectives	:	water sample, transmissivity, static formation pressure, flow model
borehole history	:	drilling through midpoint of interval: 27.09.2007, 01:40; 750.45 h duration until start of test
geology	:	limestone (Geissberg Member)
geophysics	:	Caliper log, salinity log, temperature log, sonic log
test phases	:	COM, PSR, PW, HW, HWS, RW, PSR2, RW2, sampling

QLR results	**Test zone 408.50 - 417.59 mbgl**	**T [m2/s]**	**K [m/s]**	**Formation Flow model**	**Freshwater Head [m asl]**
Analytical interpretation		(6.86E-06)	(7.55E-07)	radial flow	-
Numerical simulation		3.59E-07	3.95E-08	homogeneous	**432.4**

Note:
A complete list of results is provided in the summary tables

Mönchaltorf, 13.03.08 / 01.08.08, Revision 1 prepared by: SOLEXPERTS INTERA

Summary of Test Data

Page 1 / 3

Test Phase		INF	COM	PSR	PSR 2)	PW 1)
duration	[h]	0.79	0.14	0.99		2.26
T2 (i/f)	[°C]	30.2 / 30.6	30.6 / 30.6	30.6 / 30.6		30.6 / 30.8
P1 (i/f)	[kPa]	4088 / 4091	4091 / 4091	4091/ 4081		4081 / 4073
P2 (i/f)	[kPa]	4073 / 4073	4073 / 4071	4071 / 4065		3938 / 4028
P3 (i/f)	[kPa]	4074 / 4075	4075 /4075	4075 / 4076		4075 / 4076
P4 (i/f)	[kPa]					
Measured C	[m^3/Pa]					2.66E-07
c_{SC}	[1/Pa]					1.75E-06
q	[l/min]					
Q	[l]					
inner boundaries		no analysis	no analysis		wellb. storage	wellb. storage
flow geometry					hom.	hom.
outer boundaries					inf.lat.ext.	inf.lat.ext.
T	[m^2/s]				2.94E-07 A)	(6.86E-06) A)
K	[m/s]				3.23E-08 A)	(7.55E-07) A)
k	[m^2]				2.92E-15	(6.83E-14)
S_S	[1/m]				5.76E-06	
S	[-]				5.24E-05	
Pi, P_f if matched	[kPa]				4075.6 A)	(4065.46) B)
Head	[m asl]			**432.4** 3)	433.5 C)	(432.5) C)
Derived flow rate	[l/min]					
s (skin factor)	[-]					
S_{SS} (skin zone)	[1/m]					
t_S (skin zone)	[m]					
K_S (skin zone)	[m/s]					
figures					1,3,4,6,9,10	1,3,6,7
temperature effects					no	no
borehole history					yes	no
anomalies					no	no
bypass PA2					no	no
bypass PA1					no	no

comments

notes:
- i = initial, f = final
- T, K values in bold most representable of the undisturbed formation

1) analytical with no superposition
2) numerical simulation with detailed borehole history effects
3) head best estimate corresponds to P2 pressure at end of PSR
A) matched parameter
B) input parameter
C) calculation assumes: freshwater density 1000 kg/m^3, g = 9.81 m^2/s, P_{atm} and z_2 as stated on front page
D) early-middle time fit
E) late time fit

Summary of Test Data

Test Phase		PW[2)]		HW	HWS	PSR2	
duration	[h]	2.26		1.57	0.52	0.56	
T2 (i/f)	[°C]	30.6 / 30.8		30.8 / 31.0	31.0 / 30.6	30.5 / 30.4	
P1 (i/f)	[kPa]	4081 / 4073		4073 / 4072	4072 / 4072	4071 / 4071	
P2 (i/f)	[kPa]	3938 / 4028		4028 / 3605	3605 / 3666	3986 / 3966	
P3 (i/f)	[kPa]	4075 / 4076		4076 / 4075	4075 / 4075	4010 / 4009	
P4 (i/f)	[kPa]						
Measured C	[m^3/Pa]	2.46E-07					
c_{SC}	[1/Pa]	1.62E-06					
q	[l/min]						
Q	[l]						
inner boundaries		wellb. storage		no analysis	no analysis	wellb. storage	
flow geometry		hom.				hom.	
outer boundaries		inf.lat.ext.				inf.lat.ext.	
T	[m^2/s]	1.80E-05	A)			5.66E-07	A)
K	[m/s]	1.98E-06	A)			6.23E-08	A)
k	[m^2]	1.79E-13				5.64E-15	
S_S	[1/m]	1.69E-07				1.01E-07	A)
S	[-]	1.54E-06				9.18E-07	
Pi, P_f if matched	[kPa]	4023.2	A)			3919.4	A)
Head	[m asl]	428.2	C)			417.6	C)
Derived flow rate	[l/min]						
s (skin factor)	[-]						
S_{SS} (skin zone)	[1/m]						
t_S (skin zone)	[m]						
K_S (skin zone)	[m/s]						
figures		1,3,6,11				1,3,12,13	
temperature effects		no				no	
borehole history		yes				yes	
anomalies		no				no	
bypass PA2		no				no	
bypass PA1		no				no	

comments

notes:
- i = initial, f = final
- T, K values in bold most representable of the undisturbed formation

1) analytical with no superposition
2) numerical simulation with detailed borehole history effects
3) head best estimate corresponds to P2 pressure at end of PSR
A) matched parameter
B) input parameter
C) calculation assumes: freshwater density 1000 kg/m^3, g = 9.81 m^2/s, P_{atm} and z_2 as stated on front page
D) early-middle time fit
E) late time fit

Summary of Test Data Page 3 / 3

Test Phase		RW2 2)		Simulation entire Seq. 2)		
duration	[h]	6.23		9.58		
T2 (i/f)	[°C]	30.4 / 30.9		30.6 / 30.7		
P1 (i/f)	[kPa]	4071 / 4073		4046 / 4010		more
P2 (i/f)	[kPa]	3966 / 3671		4050 / 3684		see
P3 (i/f)	[kPa]	4009 / 4010		4055 / 4056		separate
P4 (i/f)	[kPa]					table
Measured C	[m^3/Pa]					in
c_{SC}	[1/Pa]					report
q	[l/min]					
Q	[l]					
inner boundaries		wellb. storage		wellb. storage		
flow geometry		hom.		hom.		
outer boundaries		inf.lat.ext.		inf.lat.ext.		
T	[m^2/s]	2.17E-07	A)	**3.59E-07**	A)	
K	[m/s]	2.39E-08	A)	**3.95E-08**	A)	
k	[m^2]	2.16E-15		3.57E-15		
S_S	[1/m]	1.00E-06	B)	1.00E-06	B)	
S	[-]	9.09E-06		9.09E-06		
Pi, P_f if matched	[kPa]	4500	A)	4171.9	A)	
Head	[m asl]	476.8	C)	443.3	C)	
Derived flow rate	[l/min]					
s (skin factor)	[-]					
S_{SS} (skin zone)	[1/m]					
t_S (skin zone)	[m]					
K_S (skin zone)	[m/s]					
figures		1,3,8,14		1,3,15,16		
temperature effects		no		no		
borehole history		yes		yes		
anomalies		no		no		
bypass PA2		no		no		
bypass PA1		no		no		

comments

notes:
- i = initial, f = final
- T, K values in bold most representable of the undisturbed formation

1) analytical with no superposition
2) numerical simulation with detailed borehole history effects
3) head best estimate corresponds to P2 pressure at end of PSR
A) matched parameter
B) input parameter
C) calculation assumes: freshwater density 1000 kg/m^3, g = 9.81 m^2/s, P_{atm} and z_2 as stated on front page
D) early-middle time fit
E) late time fit

Test overview

Test Oftr-i6d (408.5 – 417.59 m bgl) was performed on 28.-29.10.2007 in the Oftringen NOK EWS-Borehole. The test interval consisted of limestones of the Geissberg Member. On 03.-04.11.2007, the same borehole section was tested using the same packer positions (see QLR Oftr-i10).

The test objectives were to obtain reliable estimates of interval transmissivity and fresh-water hydraulic head using an appropriate flow model. The test was performed with a straddle-packer configuration with an interval length of 9.09 m. Pressures and temperatures were measured in the test interval (P2, T2) and in the interval below the lower packer (P1, T1) and in the annulus above the upper packer (P3, T3). In addition, pressure was measured in the tubing above the upper packer (P4).

The pressure response of the entire test sequence in Oftr-i6d is shown in **Figure 1**. The start and end times and pressures (P2) for the various phases are given in **Table 1**. The pressure history derived from water table measurements (source: Colenco, Solexperts) and fluid density measurements (SJ Geotec) is presented in **Figure 2**.

Following packer inflation (INF) the test sequence started with a COM and PSR phase to dissipate temperature and borehole history effects. Temperature effects are considered negligible, because downhole temperatures (T1, T2, T3) indicated only relatively small variations of up to 0.7 °C, with noise of up to 0.7 °C (**Figure 4**).

The packer pressures are shown in (**Figure 5**). Although the packer pressures were not fully stabilized at start of the first shut-in phase (PSR), a possible effect on the interval pressure is very unlikely because of the relatively high transmissivity and compressibility (see below) of the test zone (**Figure 5**).

The pulse withdrawal test (PW) was performed to measure the wellbore compressibility early in the test and obtain an initial estimate of the formation properties. The test showed a fast pressure recovery and the pulse final pressure stabilized at a lower level compared to the pulse initial pressure (**Figure 6**). A constant head withdrawal test (HW) was then conducted using the 3-inch submersible pump. About 21 minutes after HW test start and at a drawdown of about 54 m, the flow rate decreased and the pump stopped, presumably because of the interference of produced gas. The test zone was then shut-in for 0.47 hrs. Then a constant rate withdrawal test (RW) was attempted. The pump failed, presumably because of persistence of gas in the test zone and in the test tubing. After another 0.52 hrs long shut-in phase it was decided to deflate the upper packer in order to free any gas being present in the interval. This measure caused a distinct P2 pressure rise (**Figure 1)**. The upper packer was then re-inflated and the shut-in valve closed to initiate a second PSR phase (PSR2, see **Table 1**). A constant rate pump test was started (RW2), maintaining a more or less constant flow rate of 1.05 l/min. Several water samples were taken during RW2 (see daily log report attached). After about 6 hours and a differential drawdown of 34 m, the pump rate was adjusted to about 0.6 l/min in order to limit the drawdown, and therefore limit the risk of degassing. Formation water production stopped about 0.36 hrs later due to entrance of gas into the pump housing and the test zone was shut-in. About 390 liters of water were produced during RW2. More formation water was produced during a series of short term pumping periods with interim pressure recovery phases. In **Table 1** and **Figure 1**, this production phase is named "Sampling".

Throughout the entire testing, the 3-inch pump worked properly except when gas interfered and the pump control unit displayed "Trockenlauf" (dry run). Evidence of gas production is also provided by the measured high test zone compressibility values, abundance of gas bubbles observed in the extraction line (equipped with flow cells, see attached form Surface Equipment Layout), pungent odor at the surface and gas samples taken by SJ Geotec (analyzed by Hydroisotop, Nagra AN 08-097) at the sampling port (see Surface Equipment Layout).

Due to the influence of the adjacent high voltage current transformer facility (NOK), the pressure and temperature signals of the downhole triple probe were noisy during the hole testing sequence.

Table 1: Oftr-i6: list of test phases

Event	Start	End	Duration		P-start	P-end
	[s]	[s]	[s]	[hrs]	[kPa]	[kPa]
INF1	2	1337	1335	0.37	4072.69	4072.29
INF2	1337	2857	1520	0.42	4072.29	4072.53
COM	2857	3377	520	0.14	4072.53	4071.32
PSR	3377	6938	3561	0.99	4071.32	4065.46
HI_05	6938	7013	75	0.02	4065.46	3937.58
PW	7013	15162	8149	2.26	3937.58	4027.67
HW	15162	17647	2485	0.69	4027.67	3604.74
HWS	17647	19337	1690	0.47	3604.74	3666.29
RW	19337	20837	1500	0.42	3666.29	3683.23
RWS	20837	22702	1865	0.52	3683.23	3700.16
VO	22702	22982	280	0.08	3700.16	3777.17
VC	22982	24082	1100	0.31	3777.17	3764.05
VO2	24082	27132	3050	0.85	3764.05	3812.94
DEF2	27132	28037	905	0.25	3812.94	4006.15
INF22	28037	28792	755	0.21	4006.15	3986.42
PSR2	28792	30807	2015	0.56	3986.42	3966.35
RW2	30807	53247	22440	6.23	3966.35	3671.37
VC2	53247	54807	1560	0.43	3671.37	3711.33
Sampling	54807	96797	41990	11.66	3711.33	3660.19
VC3	96797	99802	3005	0.83	3660.19	3665.04
DEF	99802	104162	4360	1.21	3665.04	3896.2

Analysis

For the QLR analysis, the analytical and numerical methods were used for a standard analysis, which will be the basis for a possible detailed analysis depending on the test objectives and test results. Only the first test phases until RW2 were investigated by the analytical analysis and by the nSights simulations (**Figure 3**).

Analytical Analysis

Type curve and straight-line fitting methods were applied. Effects of the borehole pressure history were not taken into account.

Pulse Withdrawal Test (PW)

The PW test was initiated after a PSR phase which ended with a slightly decreasing pressure trend of about 1.06E-3 kPa/s (P2). The PSR flow period was too short to be analyzed. At start of the pulse test the interval pressure was exposed to a differential pressure of -128 kPa. The shut-in valve was kept open during 75 seconds. After shut-in, a water level increase equal to 27.07 m was measured in the 1.9” test string, indicating a released volume of 34.02 liters due to de-compression of the test zone. The wellbore storage constant C ($\Delta V/\Delta P$) equals to 2.7E-07 m^3/Pa.

The PW test recovered 70.4 % during a period of about 1.5 hours and then stabilized at a pressure of about 4028 kPa (**Figure 6**). The pulse response was analyzed using CBP type-curves. The analysis of the recovery phase is presented in **Figure 7**. Only the very early-time data were fitted. The fit using α-type-curve of value 1.0 provides a transmissivity estimate of 6.9E-06 m^2/s. Note that the CBP type-curve matching method is not sensitive for high α-values as α type-curves greater 1 are difficult to distinguish with respect to the slope steepness. High α values are associated with high aquifer storativity values (S). As storativity estimates from pulse test analyses are commonly known as unreliable, the S and S_S results are not presented.

Withdrawal Tests (HW and RW)

The HW test was initiated at steady pressure conditions. Due to the occurrence of gas, the flow rate and the related pressure were not constant and after 1.6 hrs the pump was switched off. An RW test was started which was stopped also because of interference of gas. The HW test and the RW were not analyzed because of the apparent non-ideal test conditions.

Second Constant Rate Withdrawal Test (RW2)

The upper packer was deflated in order to allow any trapped gas to escape the test interval. After re-inflation of the upper packer and a second PSR phase, a second constant rate withdrawal test (RW2) with an average flow rate of about 1008 ml/min was started. During RW2, a continuous decrease of the interval pressure was noticed. The test was shut-in after about 6.2 hours because of interference of produced gas. The log-log diagnostic plot of RW2 flow phase (**Figure 8**) shows only wellbore storage effects. A possible IARF regime is not recognizable.

nSights Analysis

In a first step, the diagnostic plots for the individual sequences were analyzed and fitted individually accounting for borehole history and taking into account of transient effects associated with the preceding test sequences. In a second step, the entire test sequence was simulated and fitted based on the Cartesian pressure plots.

For the Cartesian fit, the PSR, PW, PSR2 and RW phases were chosen and no weighting for individual events was applied. The so-called history periods BH, INF1, INF2, COM, HW, HWS, RW, RWS, VO, VC, VO", DEF2 and INF22 were not fitted but incorporated as test events with defined pressure in the simulation process. The transitional phase PW_a denotes a very short event of less than 0.025 hrs duration and represent the transitional phase during initiation of the pulse withdrawal test (open shut-in valve phase at start of pulse test).

Please note that the fit of the Ramey plot for the PW sequence is the result of the inverse parameter estimation using nSights and represents a solution of a numeric process that includes the effects of potential transient effects of the preceding test phases and the borehole history.

A homogeneous model was assumed in this first evaluation for estimating formation parameters (i.e., K, S_s, and P_f). The analyses used the wellbore compressibility of 2.46E-07 m^3/Pa (c_{SC} = 1.6E-06 1/Pa) determined as gas compressibility at pressure conditions of the test zone. During the parameter optimization, the specific storativity was allowed to vary within a plausible range from Ss = 1E-7 Pa^{-1} to1E-5 Pa^{-1}

The log-log diagnostic plot of the PSR phase indicates dominantly wellbore storage effects (**Figure 9**) providing a good fit in the Horner plot (**Figure 10**). The obtained formation parameters (K = 3.3E-08 m/s, S_s= 5.8E-6 m^{-1}, P_f = 4076 kPa) are considered as rough estimates because of the large 95% confidence intervals, especially for the conductivity parameter.

The data fit of the PW sequence (**Figure 11**) is of relatively poor quality and provides a K value which is about 2 times higher than the estimate from the PSR phase together with a similar static formation pressure (K = 1.2E-06 m/s, S_s= 1.7E-07 m^{-1}, P_f = 4023 kPa).

The PSR2 log-log diagnostic plot (**Figure 12**) indicates the transition from the wellbore storage dominated period to the infinite-acting-radial flow (IARF) period. The numerical analysis produced a poor fit (**Figure 13**) with a value for the conductivity K which is two times higher than the PSR numerical result and a low specific storativity (K = 6.2E-08 m/s, S_s= 1.01E-7 m^{-1}, P_f = 3919.4 kPa). The limits for the 95% confidence intervals were only determinable for the static formation pressure P_f and represent a rater large range, indicating a poor quality of the fit.

The data fit of the RW2 sequences (**Figure 14**) is also of poor quality and provides a K value 2 times lower than the results obtained from PSR2, calculated for a constant specific storativity S_s= 1.0E-6 m^{-1} (K = 2.3E-08 m/s, P_f = 4500.0 kPa).

The simulation of the entire test sequence on a Cartesian plot (**Figure 15**) produced the fitted parameters K = 3.73E-08 m/s and P_f = 4184.6 kPa, whereas the specific storativity was held constant S_s= 1.0E-6 m^{-1}. The calculated conductivity is similar to the individual PSR, PSR2 and RW2 fits. The sensitivity coefficients of the formation parameters during the different sequences are presented in **Figure 16** which suggests quite a high sensitivity for K and P_f. The definition of the sensitivity coefficient is given in the Chapter “Definitions”.

Results and Discussion

The shut-in wellbore storage constant values (C) obtained from the pulse withdrawal tests PW is very high and correspond to system compressibility values (c_{SC}) of 1.8E-06 Pa^{-1}. This value is only slightly higher than the expected compressibility of gas at pressure conditions of the test zone (expected c_g = 1.6E-06 Pa^{-1}, see below) which reflects the upper limit to be expected. The measured system compressibility is considered a rough approximation because of the limited accuracy inherent to this type of field measurement. For the numerical simulation with nSights the calculated gas compressibility (see above) was applied. The low T and K values obtained from the analytical analyses of the PW phase are considered unreliable in view of the potential transient effects from the preceding borehole pressure history.

The shut-in wellbore storage constant value C=2.7E-07 m^3/Pa obtained from the first pulse withdrawal test PW corresponds to a system compressibility value (c_{SC}) of 1.75E-06 Pa^{-1}. This value is similar to the expected compressibility of gas at pressure conditions of the test zone.

The compressibility of gas at a depth of 4065 kPa equals to 2.46E-7 m^3/Pa. Dividing this value by the interval volume gives 1.6E-06 Pa^{-1} which marks the upper limit of the plausibility range for the c_{SC} parameter. The calculation of c_{SC} (c_{SC} = C / $V_{inteterval}$) assumes that all of the gas phase is restricted to the test zone and the no gas was present in the test string during the measurement of C which may be incorrect. If gas was present in the test tubing, the measured shut-in wellbore storage constant and the derived system compressibility would be overestimated.

For the numerical simulation with nSights the calculated gas compressibility of 1.6E-06 Pa^{-1} was used. The low T and K values obtained from the analytical analyses of the PW phase are considered unreliable in view of the poor match quality.

The estimated formation parameters for the different sequences vary slightly based on a homogeneous flow model. The range in K varies between 2.0E-06 m/s (T=1.8E-05 m^2/s) and 2.4E-08 m/s (T=2.2E-07 m^2/s), where the highest value of 2.0E-06 m/s is simulated from the PW test phase and the other values from the other test phases (PSR, PSR2, RW2, entire sequence) are quite similar (2.4E-08 m/s to 6.3E-08 m/s). The range in calculated S_s varies between 1.0E-7 m^{-1} and 5.8E-6 m^{-1}. The range in P_f is between 4500 kPa and 3919 kPa.

This range in properties and the overall poor quality of the fits is probably due to the presence of gas in the interval. Gas might have considerably changed the behavior between the individual test phases. A more accurate estimation of the formation properties would require an advanced model able to simulate variable gas and water saturations, and a test zone compressibility varying with test duration.

FIGURES

ABBREVIATIONS

NOMENCLATURE

DEFINITIONS

FIELD DOCUMENTATION

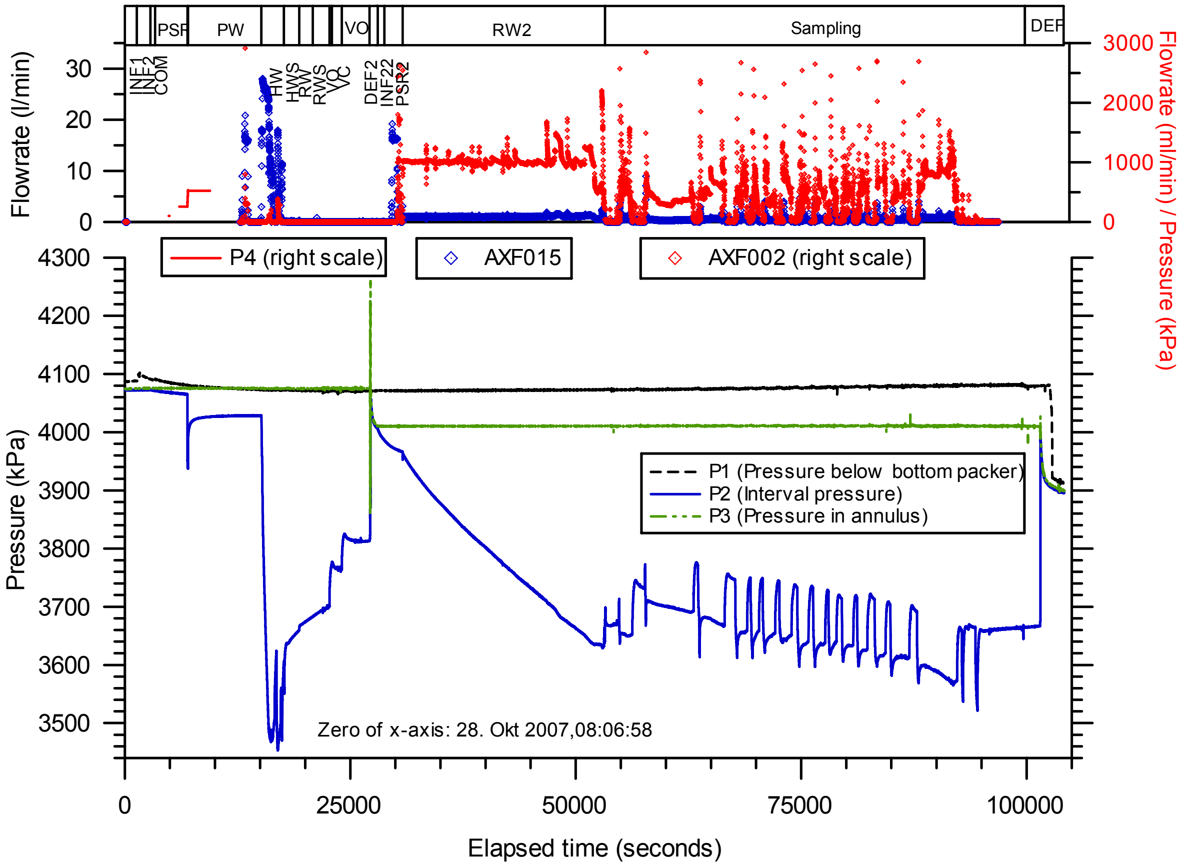


Figure 1: Oftr-i6d: Overview plot

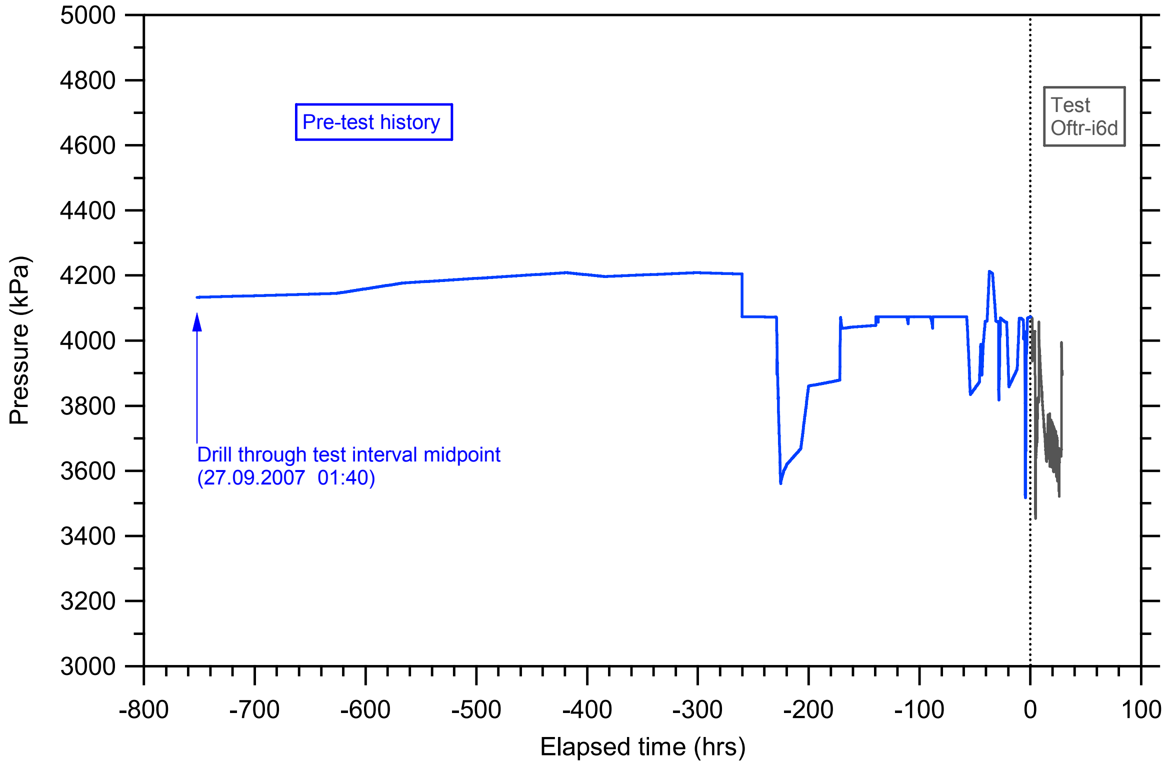


Figure 2: Oftr-i6d: Borehole pressure history

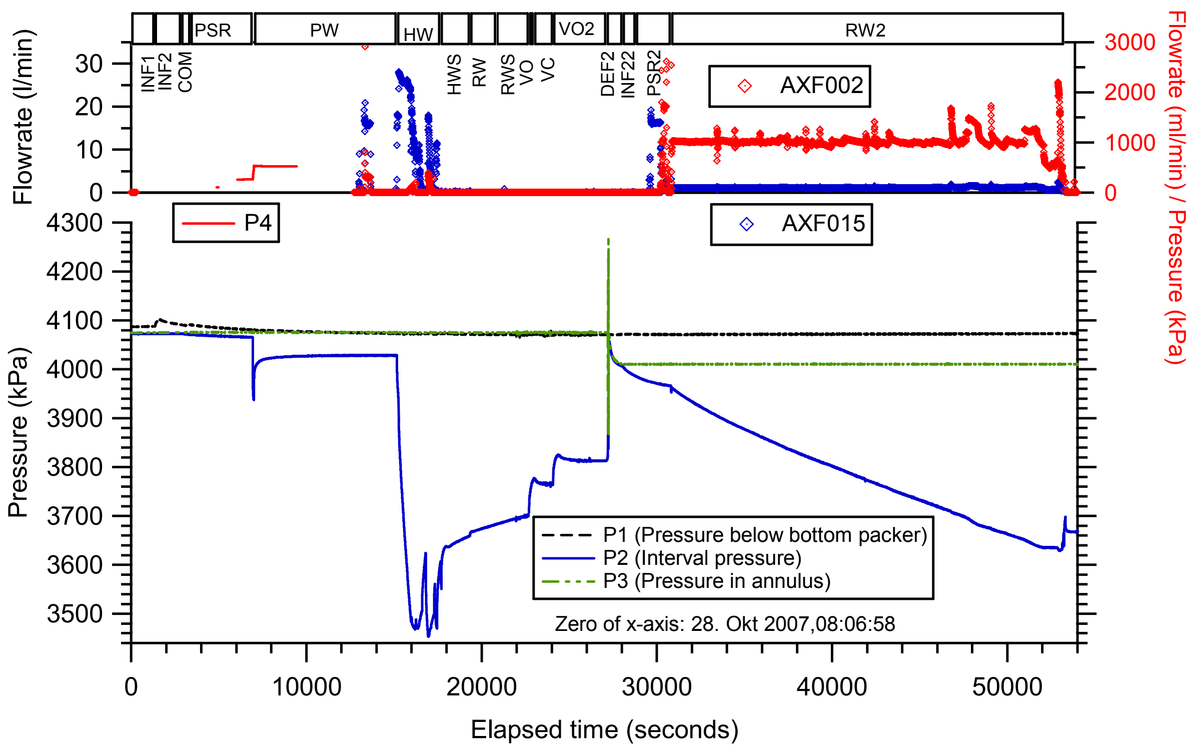


Figure 3: Oftr-i6d: Overview plot until RW

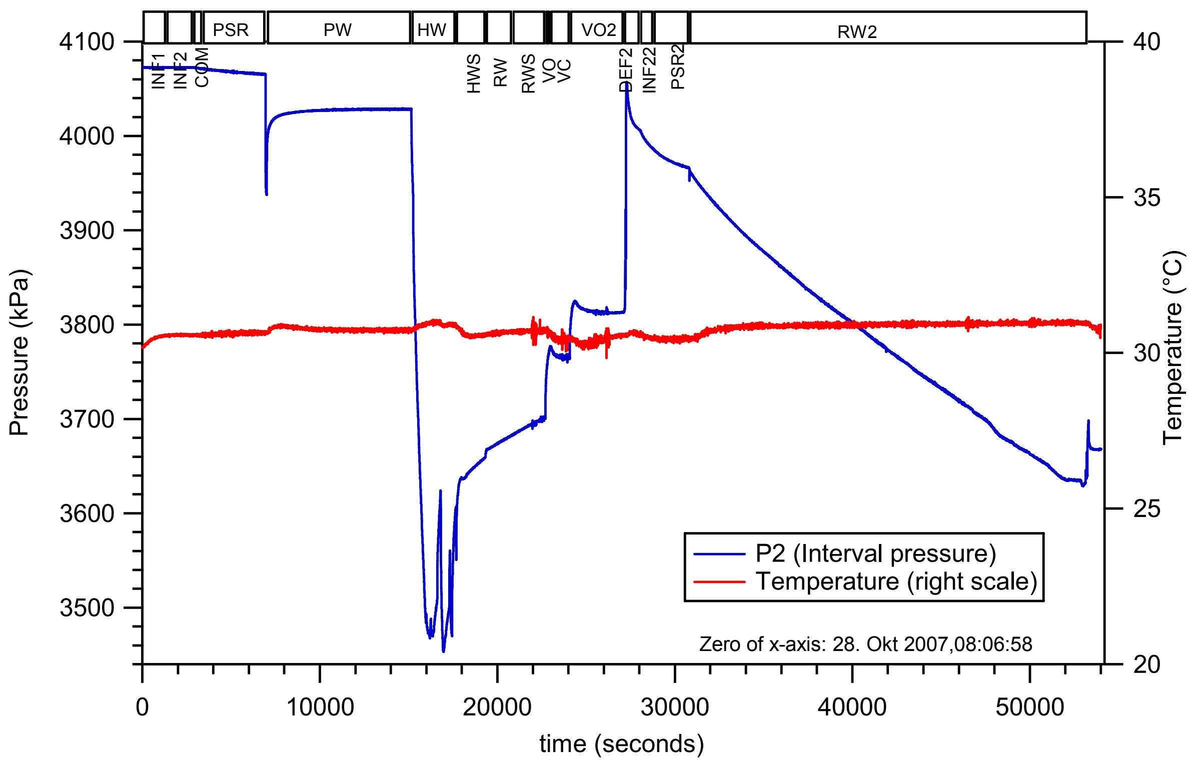


Figure 4: Oftr-i6d: Measured downhole temperature until RW

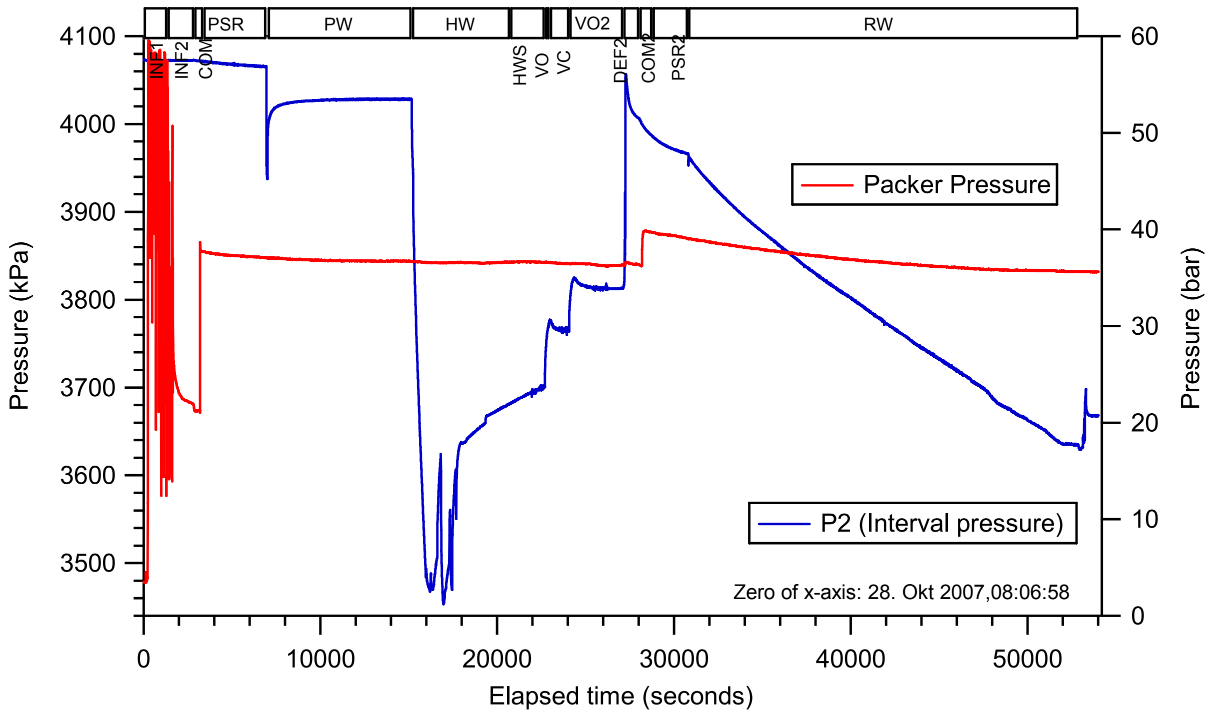


Figure 5: Oftr-i6d: Measured packer pressure

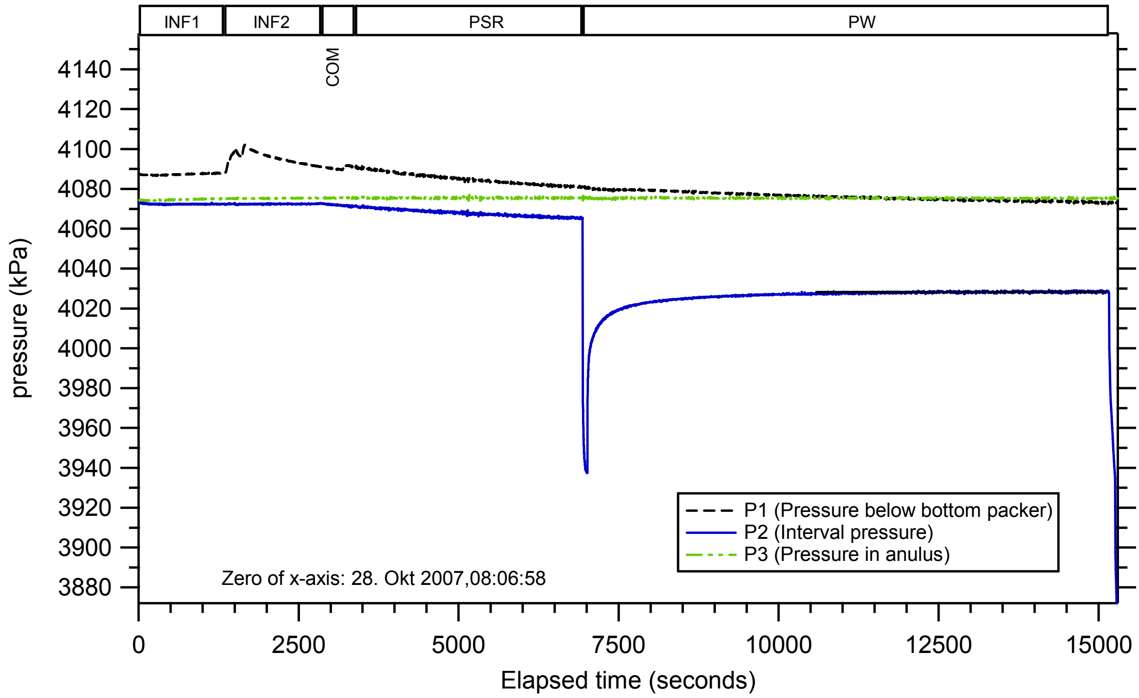


Figure 6: Oftr-i6d: Detail of PW

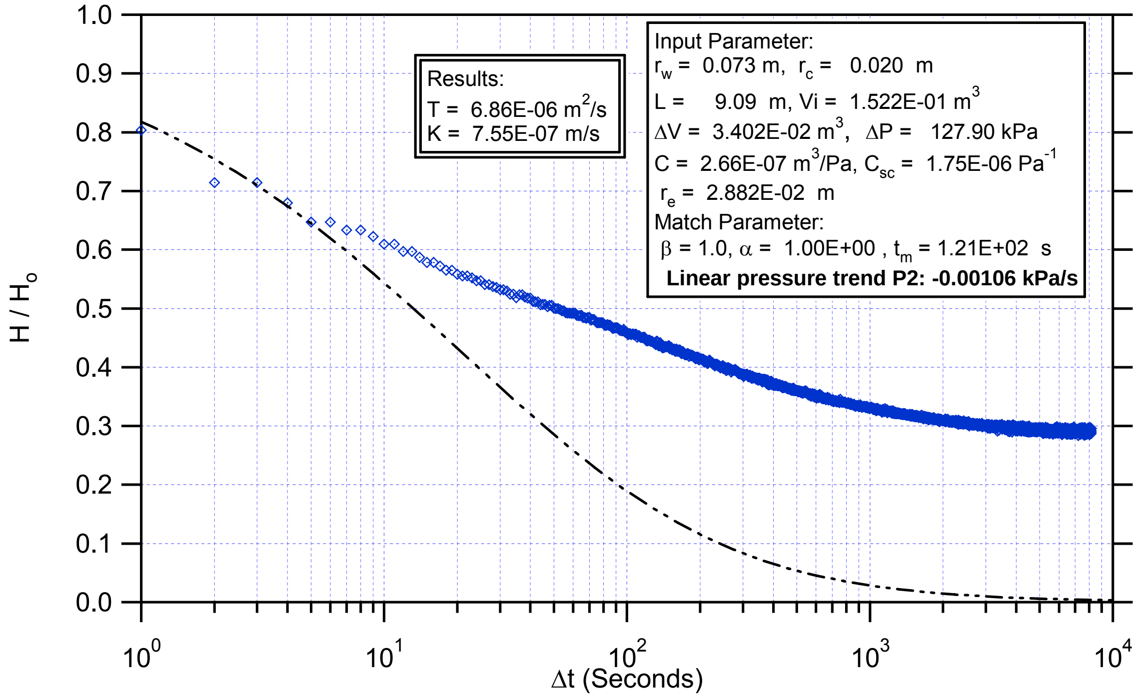


Figure 7: Oftr-i6d: PW test analysis using CBP type-curves

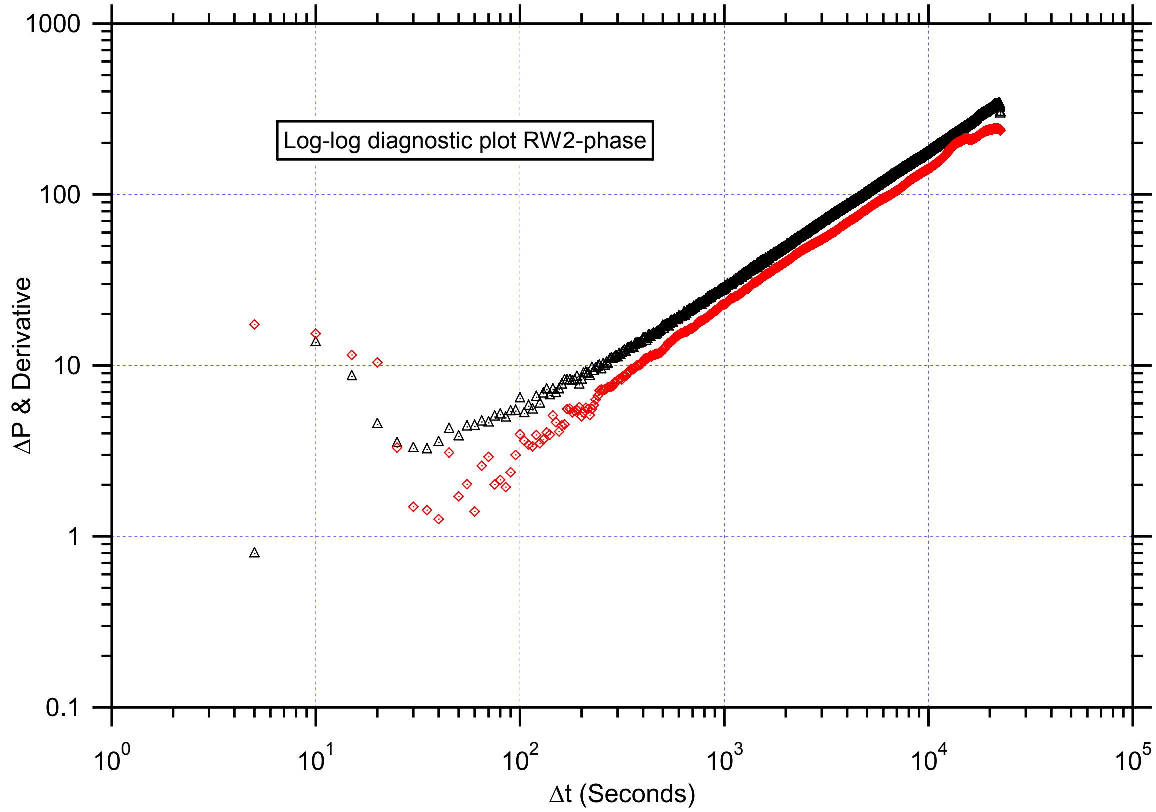


Figure 8: Ofrt-i6d: Log-log diagnostic plot of the RW2-phase

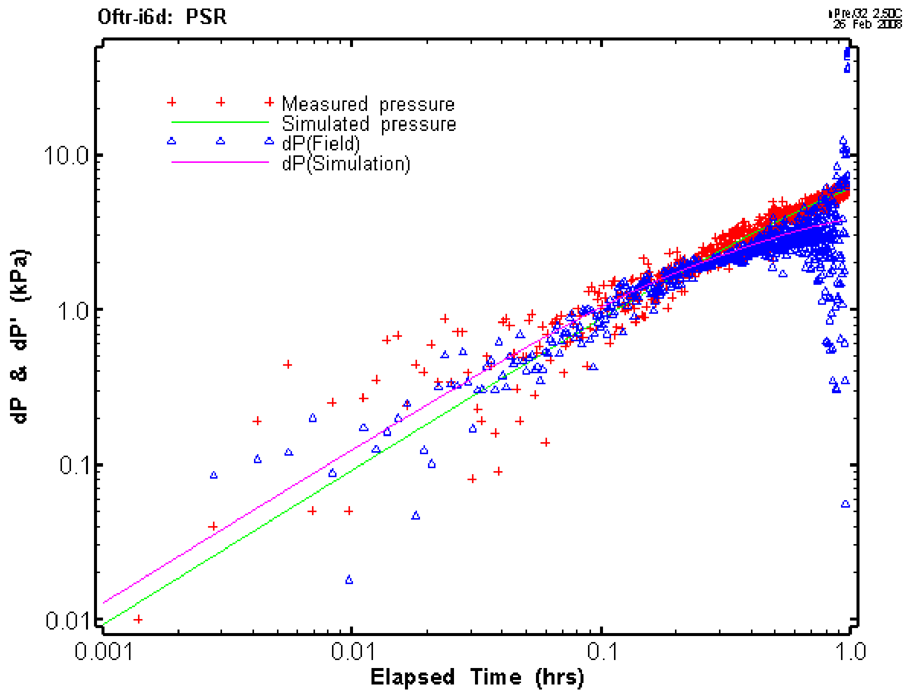


Figure 9: Oftr-i6d: PSR log-log diagnostic plot (for Horner fit)

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_fm	[m/sec]	3.23E-08	2.78E-11	3.84E-05
P_fm	[kPa]	4075.6	3991.8	4159.4
ss_fm	[1/m]	5.76E-06	???	???

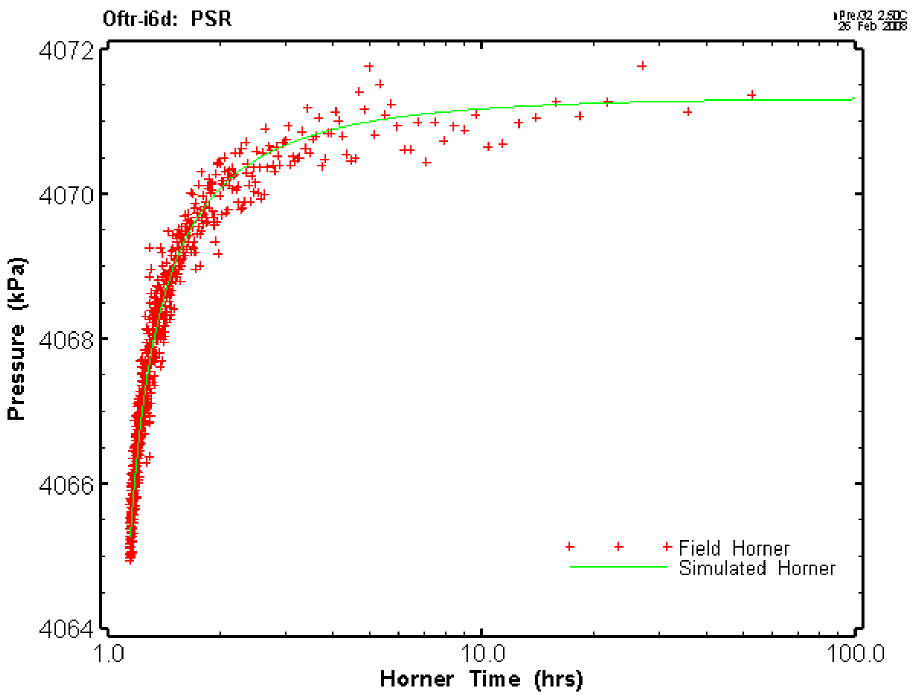


Figure 10: Oftr-i6d: PSR Horner plot (for Horner fit)

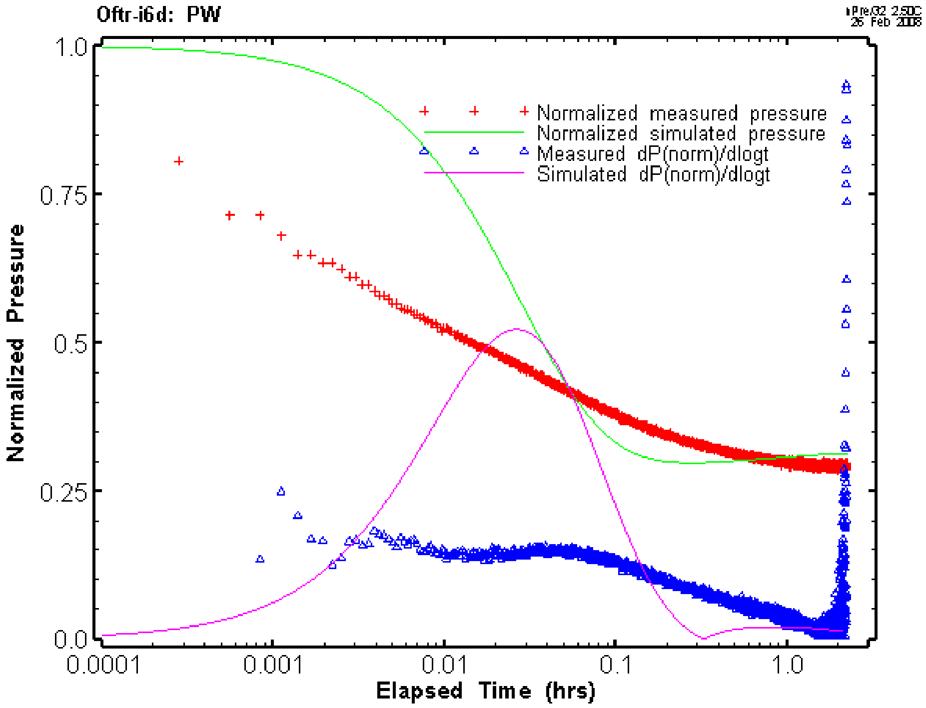


Figure 11: Oftr-i6d: PW normalized pressure (Ramey A) plot

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_fm	[m/sec]	2.68E-06	1.76E-06	4.07E-06
P_fm	[kPa]	4023.2	4003.2	4043.2
ss_fm	[1/m]	1.69E-07	7.02E-10	4.08E-05

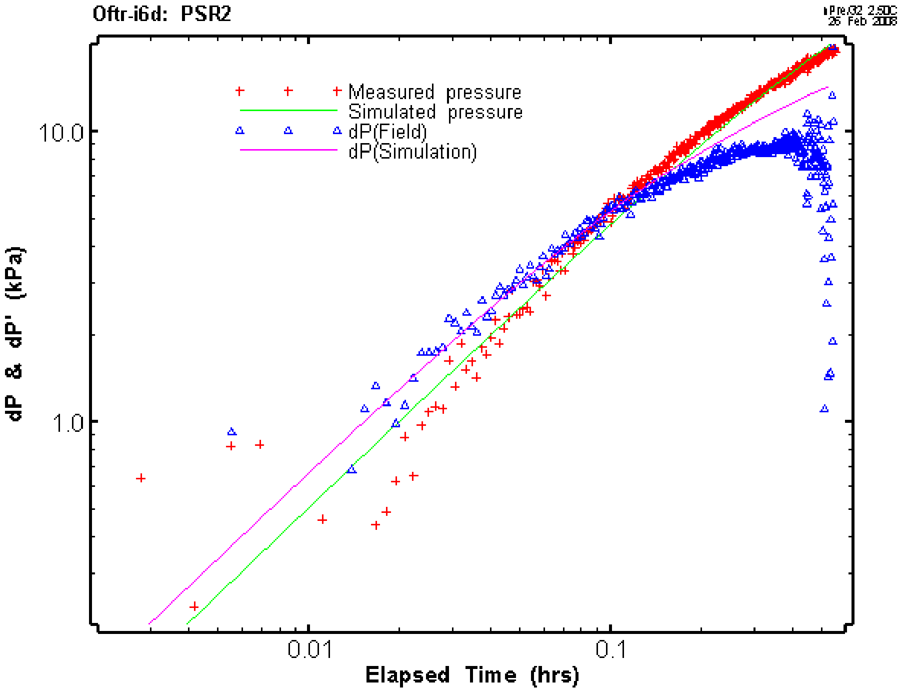


Figure 12: Oftr-i6d: PSR2 log-log diagnostic plot

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_fm	[m/sec]	6.23E-08	???	???
P_fm	[kPa]	3919.4	3459.5	4379.3
ss_fm	[1/m]	1.01E-07	???	???

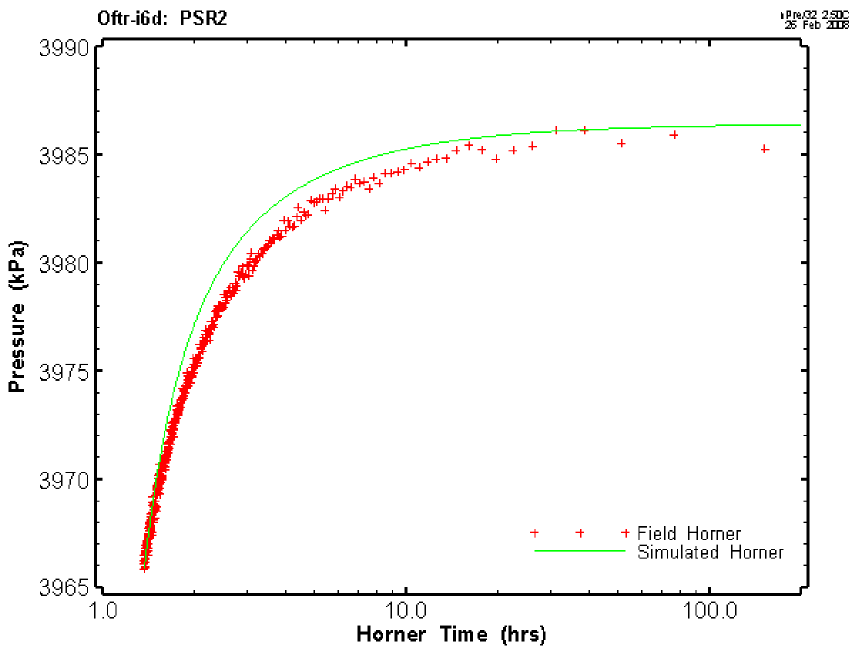


Figure 13: Oftr-i6d: PSR2 Horner plot

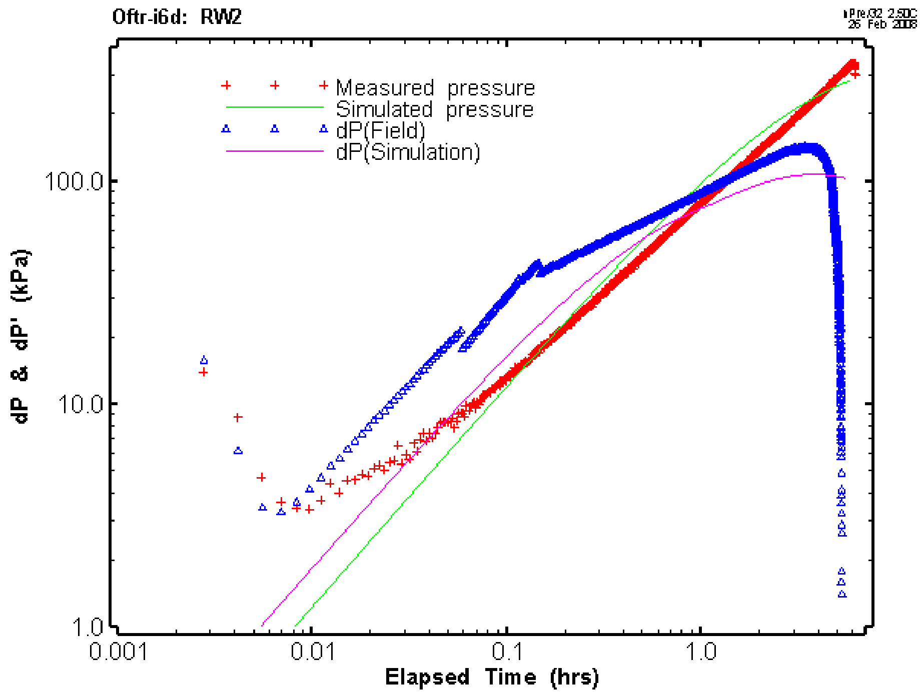


Figure 14: Oftr-i6d: RW2 log-log diagnostic plot

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_fm	[m/sec]	2.39E-08	2.35E-08	2.43E-08
P_fm	[kPa]	4500.0	4486.0	4514.0
ss_fm	[1/m]	1.00E-06	1.00E-06	1.00E-06

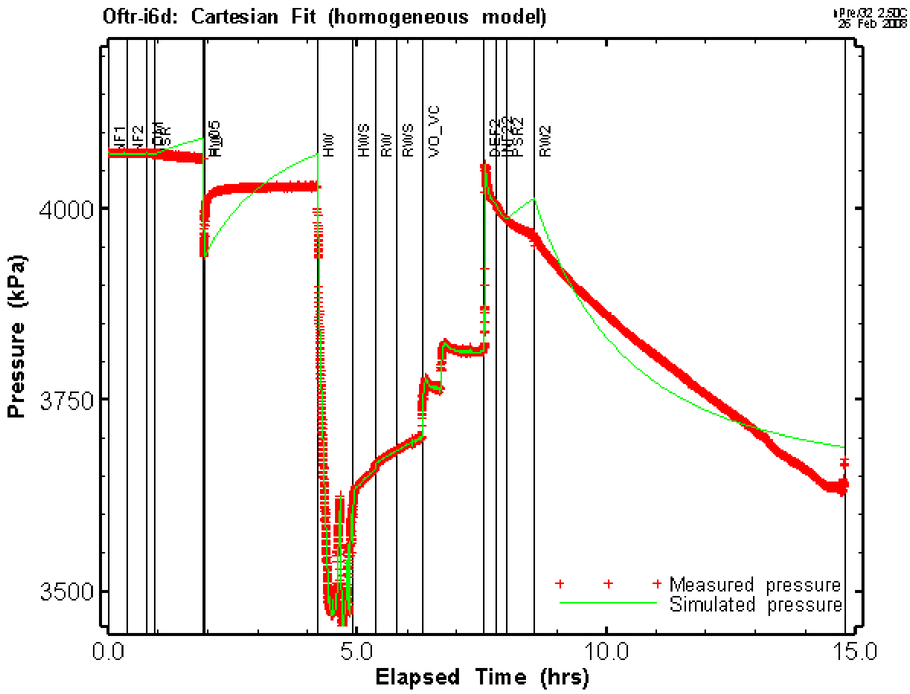


Figure 15: Oftr-i6d: Cartesian fit of the entire test for homogeneous model

Fit Statistics:

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_fm	[m/sec]	3.95E-08	3.91E-08	4.00E-08
P_fm	[kPa]	4171.9	4167.2	4176.7
ss_fm	[1/m]	1.00E-06	1.00E-06	1.00E-06

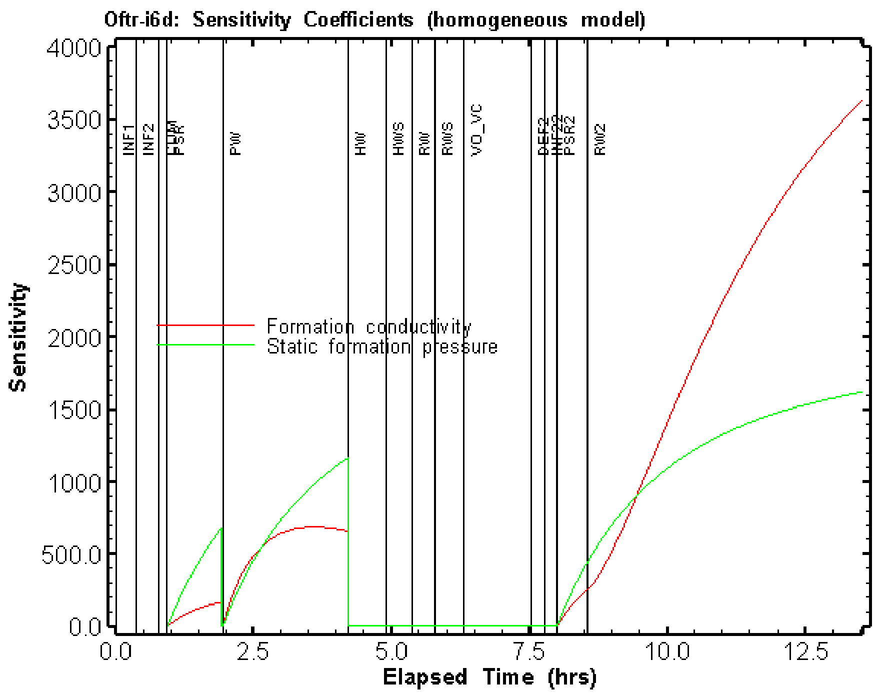


Figure 16: Oftr-i6d: Sensitivity coefficients for the different formation parameters during the different sequences (homogenous model)

Abbreviations

	Test phases
COM	Compliance
INF	Packer inflation
INF1	Inflation of lower packer (INF2 = Inflation of upper packer)
DEF	Packer deflation
DEF1	Deflation of lower packer (DEF2 = Deflation of upper packer)
PSR	Static pressure recovery (shut-in valve closed)
SI	Slug injection test
SIS	Pressure recovery after slug injection test (shut-in)
SW	Slug withdrawal test
SWS	Pressure recovery after slug withdrawal test (shut-in)
PI	Pulse injection test
PW	Pulse withdrawal test
HI	Constant head injection test (constant pressure difference)
HIS	Pressure recovery after constant head injection test (shut-in)
HW	Withdrawal test applying constant differential head
HWS	Pressure recovery after constant head withdrawal test (shut-in)
MR	Multi-rate test: Test with variable flow rate
MRS	Pressure recovery after test with variable flow rate
RW	Pump test with constant flow rate
RWS	Pressure recovery after pump test with constant flow rate (shut-in)
RI	Constant flow injection test
RIS	Pressure recovery after constant flow injection test (shut-in)
VC	Shut-in valve is closed
VO	Shut-in valve is open
	General
CBP	Cooper, Bredehoeft, Papadopulos (type-curve matching method)
DAS	Data acquisition system
FS	Full scale
IARF	Infinite Acting Radial Flow
LC	Log cycle
m agl	Meters above ground level
m bgl	Meters below ground level
m asl	Meters above sea level
OD	Outer diameter
PVT	Pressure volume temperature correlation
SLA	Straight-line analysis
TOC	Top of casing
WL	Water level (or WT = Water table)

Nomenclature

	Description	SI-Unit		Description	SI-Unit
b	Y-intercept of linear regression		S_S	Specific storativity	m^{-1}
C	Wellbore storage constant	$m^3\ Pa^{-1}$	S_{SS}	Specific storativity of skin zone	m^{-1}
C_S	Wellbore storage constant, shut-in	$m^3\ Pa^{-1}$	s	Skin factor	-
C_D	Dimensionless wellbore constant	-	t, Δt	Time, elapsed time	s
c_f	Pore volume based compressibility	Pa^{-1}	t_C	Critical time	s
c_r	Rock compressibility	Pa^{-1}	t_D	Dimensionless time	-
c_{SC}	System compressibility (= test zone compressibility c_{tz})	Pa^{-1}	Δt_e	Equivalent time (after Agarwal)	s
c_w	Water compressibility	Pa^{-1}	Δt_H	Horner time	-
Δh	Differential head	m	t_p	Production time	s
g	Acceleration of gravity (9.81)	$m\ s^{-2}$	t_p^*	Corrected production time	s
h_S	Static head	m	t_m	Match time	s
k	Intrinsic permeability	m^2	t_0	X-intercept of linear regression	s
K, K_f	Hydraulic conductivity of formation () special case	m/s	t_s	Thickness of skin zone	m
K_s	Hydraulic conductivity of skin zone () special case	m/s	T	Transmissivity	m^2/s
L	Interval length	m	T_W	Water temperature	°C
m	slope (regression)		z_1	P1 sensor depth	m
P	Pressure	Pa, kPa	z_2	P2 sensor depth	m
P_0	Minimal or maximal pressure	Pa, kPa	z_3	P3 sensor depth	m
P_{atm}	Probe signal at atmospheric pressure	Pa, kPa			
ΔP	Differential pressure, pressure change	Pa, kPa	α ,β	Type-curve match parameter	-
P_D	Dimensionless pressure	-	α	aquifer compressibility	Pa^{-1}
P_f	Static formation pressure	Pa, kPa	μ	Dynamic viscosity	Pa·s
P_i	Initial pressure	Pa, kPa	θ	Porosity	-
$P_{min/max}$	Minimal/maximal pressure	Pa, kPa	ρ_w	Density of fresh water	kg/m^3
P_{S1}	Static pressure in P1-Interval (below bottom packer)	Pa, kPa			
P_{S2}, P_f	Static pressure in test interval	Pa, kPa			
P_{S3}	Static pressure in annulus (above upper packer)	Pa, kPa			
q	Flow rate	$m^3\ s^{-1}$			
q_{end}, q_e	Last flow rate	$m^3\ s^{-1}$			
Q, Q_{tot}	Cumulative flow	m^3			
r_e	Effective radius (Slug, Pulse test)	m			
R_i	Radius of influence	m			
R^2	Correlation coefficient	-			
r_c	Tubing radius	m			
r_w	Wellbore radius	m			
R_1	Radius, composite model	m			
R_D	Dimensionless radius	-			
S	Storativity	-			
S_C	Sensitivity coefficient				
S_{SC}	Scaled sensitivity coefficient				

Definitions

$C_D = \dfrac{\rho\, g\, C}{2\pi\, S\, r_{w^2}}$	Wellbore constant, dimensionless
$H_D = \dfrac{P - P_i}{P_0 - P_i}$	Dimensionless pressure (slug und pulse tests)
$K = \dfrac{k\, \rho\, g}{\mu}$	Hydraulic conductivity
$P_D = \dfrac{2\pi\, T\, \Delta h}{q}$	Dimensionless pressure
$\Delta P = \rho\ g\, \Delta h$	Differential pressure
$q_D = \dfrac{q}{2\pi\, T\, \Delta h}$	Dimensionless flow
$t_D = \dfrac{t\, T}{r_w^2 S}$	Dimensionless time
$S = S_S\, L$	Storativity
$s = \left(\dfrac{K_f}{K_s} - 1\right) \ln\left(\dfrac{r_w + t_s}{r_w}\right)$	Skin factor
$S_S = \rho\, g\, (\alpha + \theta\, c_w)$	Specific storativity
$S_C = \dfrac{\partial P}{\partial r}$	Sensitivity coefficient.

where ∂P is the partial derivative of the calculated system response (i.e., pressure) with respect to a parameter varied by the derivative span ∂r.
For comparison of sensitivity coefficients for different parameters, the sensitivity coefficients are typically scaled by inverses of the respective standard deviations as follows:

$$S_{sc} = S\,\frac{\sigma_r}{\sigma_P} = \frac{\partial P}{\partial r} \cdot \frac{\sigma_r}{\sigma_P}$$

where S_{sc} is the scaled sensitivity coefficient, σ_r is the a priori standard deviation of the measurement error, and σ_P is the estimated standard deviation of the parameter.
If not otherwise stated, default values σ_r = 1 and σ_P = 1 were used.

Definitions (continued)

T = K L	Transmissivity
$\frac{t_D}{C_D} = \frac{2\pi T t}{\rho\ g C}$	Dimensionless time axis
$t_e = \frac{t_p \cdot \Delta t}{t_p + \Delta t}$	Dimensionless Agarwal time (Agarwal, 1980)
$t_e^* = \frac{t_P^* \cdot \Delta t}{t_P^* + \Delta t}$	Modified Agarwal time (using corrected production time)
$t_P^* = \frac{Q}{q_{end}}$	Modified production time (Ehlid-Economides and Ramey, 1980)

Form **DAILY LOG REPORT**	SOLEXPERTS

Oftringen Hydraulic Testing: Interval 6: 408.5 – 417.59 m

Date	*Time*	*Activity*	*Who*
26.10.2007	*08:15*	*Waiting on Daldrup*	*SR, PH*
	09:00	*Drillers arrive on site*	
		Test TSSPS1 at atmospheric pressure, probe horizontal *Start file: Oftr_2007_10_26_atm1.dat* *P1 = 155.00 kPa* *P2 = 94.99 kPa* *P3 = 100.45 kPa* *T1 = 6.68 °C* *T2 = 6.48 °C* *T3 = 6.43 °C*	
	09:10	*Start installation of system: straddle length: 4.54 m*	
	10:06	*Test TSSPS1 at atmospheric pressure, probe vertical* *Start file: Oftr_2007_10_26_atm2.dat* *P1 = 98.26 kPa* *P2 = 89.83 kPa* *P3 = 103.54 kPa* *T1 = 7.43 °C* *T2 = 7.31 °C* *T3 = 7.16 °C*	
	10:15	*Start installation of test tubing*	
	10:30	*Installation of chemical measuring instruments (pH, Lf, O2)*	
	11:19	*Orbisphere calibration: Probe with testcap: 10.00 mg/l*	
	11:23	*Check triple probe S1 (last tubing installed: TU26)* *File: Oftr_2007_10_26_chk1.dat* *26 rods are in hole.* *P1 = 1738.69 kPa* *P2 = 1694.27 kPa* *P3 = 1694.15 kPa* *T1 = 18.74 °C* *T2 = 18.61 °C* *T3 = 18.47 °C* *Water table: 6.94 m bgl* *Stick up rods: 2.74 m*	
	11:29	*Solexperts technician not sure, if packer line couplings are tighten or not. Decision: move out system up to packer line couplings to check!*	
	12:20	*Test rods out of borehole, check packer line couplings, tighten packer line couplings*	
	12:22	*Restart installation of test tubing*	
	13:42	*Check triple probe S1 (last tubing installed: TU26)* *File: Oftr_2007_10_26_chk2.dat* *26 rods are in hole.* *P1 = 1712.86 kPa* *P2 = 1697.08 kPa* *P3 = 1695.03 kPa* *T1 = 18.45 °C* *T2 = 18.31 °C* *T3 = 18.11 °C* *Water table: 6.89 m bgl* *Stick up rods: 2.74 m*	
	13:45	*Continuation of installation*	
	14:20	*Installation of 3" pump housing with pump ("torpedo")*	

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SOLEXPERTS

Date	Time	Activity	Who
26.10.2007	14:41	Check triple probe S1 (last tubing installed: TU49 + Torpedo) File: Oftr_2007_10_26_chk3.dat 49 rods and pump housing are in hole. P1 = 3230.56 kPa P2 = 3217.61 kPa P3 = 3218.77 kPa T1 = 26.10 °C T2 = 26.06 °C T3 = 25.90 °C Probe works fine, values reasonable	SR, PH
	15:15	System on position, fill annulus up to the top	
		Interval 6: 407.64 – 412.27 m	
	15:20	Start file: Oftr_2007_10_26_oftr_i6.dat P1 = 4066.35 kPa P2 = 4055.03 kPa P3 = 4056.13 kPa T1 = 29.70 °C T2 = 29.81 °C T3 = 29.73 °C Water table: 0.02 m bgl	
	15:26	Start inflation of packer 1	
		Probe gives bad values	
	16:00	Change scan rate to 10 s	
	16:15	Phone call to electronic department Solexperts	
	16:17	Stop scanning	
		Check resistance of probe: changing values between 1.7 and 5.8 kΩ => short in downhole probe Comparison with probe S3: 4.2 kΩ (constant)	
	16:44	Restart scanning => still bad values	
	16:50	Stop scanning	
		Phone call to Fbe	
	17:05	Start move out system to find error (humidity)	
	19:00	JH, Cad arrive on site	
	19:05	Tubing out of borehole	
		Humidity in connector probe to flat pack cable, O-ring defect.	
	19:30	Test TSSP-S1 at atmospheric pressure, probe vertical Start file: Oftr_2007_10_26_atm3.dat P1 = 98.01 kPa P2 = 90.59 kPa P3 = 106.10 kPa T1 = 12.04 °C T2 = 11.92 °C T3 = 11.60 °C	
		Test chemical equipment => OK	SR, JH
	20:00	Drilling team leave site for dinner	
	20:45	Test TSSP-S1 at atmospheric pressure, probe vertical Start file: Oftr_2007_10_26_atm4.dat P1 = 98.35 kPa P2 = 90.08 kPa P3 = 106.85 Pa T1 = 10.04 °C T2 = 10.92 °C T3 = 10.60 °C Probe works fine	
	21:00	SR, PH leave site	SR, PH

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Date	*Time*	*Activity*	*Who*
26.10.2007	22:00	Start reinstallation of system: straddle length: 4.54 m	PH,Cad
	22:02	Test TSSPS1 at atmospheric pressure, probe vertical Start file: Oftr_2007_10_26_atm5.dat P1 = 100.50 kPa P2 = 89.95 kPa P3 = 106.57 kPa T1 = 8.65 °C T2 = 8.47 °C T3 = 8.62 °C	
	22:06	Start installation of test tubing	
	22:50	Check triple probe S1 (last tubing installed: TU20) File: Oftr_2007_10_26_chk4.dat 20 rods are in hole. P1 = 1327.06 kPa P2 = 1304.79 kPa P3 = 1303.80 kPa T1 = 16.89 °C T2 = 16.74 °C T3 = 16.64 °C Probe works fine, values reasonable	
	23:58	Check triple probe S1 (last tubing installed: TU47) File: Oftr_2007_10_26_chk5.dat 47 rods and pump housing are in hole. P1 = 3082.55 kPa P2 = 3073.27 kPa P3 = 33072.11 kPa T1 = 24.63 °C T2 = 24.57 °C T3 = 24.48 °C Probe works fine, values reasonable	
27.10.07		**Interval 6: 407.64 – 412.27 m (2nd test)**	
	01:03	Start file: Oftr_2007_10_27_oftr_i6.dat P1 = 4067.28 kPa P2 = 4056.56 kPa P3 = 4057.12 kPa T1 = 29.69 °C T2 = 29.73 °C T3 = 29.67 °C Water table:- 0.08 m bgl	
	01:15	Drill rig doesn't work, no compressed air for packer booster	
	01:35	Start inflation of packer 1	
	01:55	Start inflation of packer 2 (packer pressure increase is not recorded). Slow increase of packer pressure	
	02:10	Both packer are pressurized by pressure vessel at 35 bar (PA1 and PA2 pressure lines are interconnected)	
	02:45	Shut-in (Start PSR)	
	02:57	Fill up tubing with water	
	03:15	Open shut-in valve	
	03:19	Start pumping test, maximum drawdown 60 m P2 start 4052.32 kPa Q= ca. 13 l/min	
	03:29	Bypass at lower packer. Stop pumping test after phone call with Fbe.	
	03:32	Shut-in, start HWS	
	04:09	Stop HWS, open shut-in valve	
	04:20	Start deflate packers. Water level in annulus is filled up to top of 7" casing (1.42 m above ground level)	

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Date	***Time***	***Activity***	***Who***
27.10.2007		*Packers are free Water level in 7"casing is 0.32 m below top (=1.10 m above ground level)*	*JH, Cad*
	05:25	*Stop file*	
	07:00	*SR, PH arrive on site*	*SR, PH*
	07:05	*Try to call drillmaster to move system, not reachable, mobile switched off.*	
	07:10	*JH, Cad leave site*	*JH, Cad*
	7:17	*Phone conversation with Fbe: change system position to 408.73 m bgl (UPLS), before pump test a PW test down to 60 m bgl to check bypass has to be conducted. Afterwards fill up tubing to top.*	
	07:35	*Call again drillmaster, not reachable*	
	08:20	*SR, PH leave site to get drill master*	
	09:00	*SR, PH and Meyk Hössel on site (drillmaster)*	
	09:10	*Move system on position 408.73 m bgl*	
		Interval 6b: 408.64 – 413.27 m	
	09:32	*Start file: Oftr_2007_10_27_oftr_i6b.dat P1 = 4085.09 kPa P2 = 4065.10 kPa P3 = 4066.32 kPa T1 = 30.42 °C T2 = 30.82 °C T3 = 31.35 °C Water table: 0.24 m bgl*	
	09:40	*Bad values again on TSSP, check resistance of probe (winch, directly to TSSP): changing values between 1.7 and 5.6 kΩ => short-circuit in downhole probe (resistance should be 4.25 kΩ as it was checked at atmosphere). Values at power box: 24.2 V => o.k.*	
	10:15	*Information to Fbe, decision: - move out system and check cable connection on humidity; - optionally rebuild cable connector and cable line in probe head; - installation of autonomic logger in interval for security and backup; - photographical documentation of errors found; - change of straddle length to have placed the packers on other positions (wait on instructions from Fbe)*	
	10:50	*Start move out system*	
	12:42	*Tubing out of borehole*	
	12:54	*Test TSSP-S1 at atmospheric pressure, probe vertical Start file: Oftr_2007_10_27_atm1.dat Probe works fine!*	
	13:00	*Discussion with Fbe about straddle length: 9.0 m with UPLS at 407.50 and LPUS 416.50 m*	
	13:05	*Stop scanning, measuring resistance at winch: 5.8 kΩ (changing)*	
	13:40	*Water in cable connection, most possible leakage is on top at the entry of flat pack cable (blue particles of cable holder color found in connector).*	
	14:30	*FP arrives on site*	
	15:00	*Rebuild connector (cable side part)*	
	15:30	*Remove system to change straddle length (interval: 9.09 m)*	
	16:20	*Start reinstallation of system: straddle length: 9.09 m*	

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Date	Time	Activity	Who
27.10.2007	16:45	Check probe head: water in cable line, redress probe head	SR, PH, FP
	17:15	Check new TSSP power box with electromagnetic shield	
	18:30	JH, Sti arrive on site	JH, Sti
	19:28	Test new probe head with TSSP S1 (Probe horizontal): Start file: Oftr_2007_10_27_atm2.dat P1 = 102.69 kPa P2 = 96.48 kPa P3 = 103.91 kPa T1 = 12.97 °C T2 = 13.30 °C T3 = 13.52 °C Probe works fine	
	19:36	Installation of probe carrier, connect flat pack cable	
	20:06	Test TSSP-S1 at atmospheric pressure, probe vertical Start file: Oftr_2007_10_27_atm3.dat P1 = 116.99 kPa P2 = 91.55 kPa P3 = 97.75 kPa T1 = 10.45 °C T2 = 10.38 °C T3 = 10.76 °C (P1 in water)	
	20:10	SR leaves site	
	20:15	Start installation of test tubing	
	22:07	Check triple probe S1 (last tubing installed: TU46) File: Oftr_2007_10_27_chk6.dat 46 rods are in hole. P1 = 3044.68 kPa P2 = 3033.43 kPa P3 = 3032.46 kPa T1 = 24.63 °C T2 = 24.45 °C T3 = 24.41 °C Probe works fine, values reasonable	
	22:30	Continuation installation	
		Installation of 3" pump housing with pump (torpedo)	
		Interval 6c: 407.50 – 416.60 m	
	23:43	Start file: Oftr_2007_10_27_oftr_i6c.dat P1 = 4076.38 kPa P2 = 4063.27 kPa P3 = 4064.28 kPa T1 = 30.00 °C T2 = 29.98 °C T3 = 29.99 °C Water table: - 0.93 m bgl	
28.10.2007	00:02	Start inflation of packer 1	
	00:29	Start inflation of packer 2 (packer pressure increase is not recorded). Slow increase of packer pressure	
	01:00	Both packers are pressurized by pressure vessel at 35 bar (PA1 and PA2 pressure lines are interconnected)	
	01:01	Water table: 1.05 m above ground level (=top of casing)	
	01:06	Shut-in (Start PSR)	
	01:16	Swabbing to 60 m below top of 1.9" tubing rods	

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SOLEXPERTS

Date	Time	Activity	Who
28.10.2007	01:23	Recording P4-sensor at atmospheric pressure P4 = 101.05 kPa	JH, Sti
	01:52	Installation of P4 Sensor in 1.9"NU tubing (depth calculated 70.83 m below top of rods).	
	01:54	Water table in 1.9"NU: 60.45 m below top of rods, P4 Sensor 164.29 kPa	
	02:00	Scan rate 1 s	
	02:01	Start PW-test, valve open during 65 s, Water table in 1.9"NU: 37.80 m below top of rods, P4 Sensor: 424.70 kPa	
	02:16	Bypass at lower packer. Stop test after phone call with Fbe.	
	02:19	Phone conversation with Fbe: start pumping test to check again the bypass	
	02:49	Remove P4, atmospheric pressure 100.89 kPa	
	02:50	Fill up tubing with water	
	03:10	Open shut-in valve	
	03:11	Start pumping test, maximum drawdown 60 m P2 start 4029.10 kPa Q= ca. 13 l/min	
	03:54	Stop pumping test, bypass at lower packer	
	03:54	Phone conversation with Fbe: change system position to 408.50 m bgl (UPLS), before pump test a PW test without PSR down to 60 m bgl to check bypass has to be conducted	
	04:00	Start deflate packers. Water level in annulus is filled up to top of 7" casing (1.42 m above ground level)	
	04:43	Stop file	
	05:00	Sending SMS to drillmaster	
	06:30	Call drillmaster to move system	
	07:00	SR, FP arrive on site	SR, FP
	07:10	Drillmaster arrive on site	
	07:16	JH, Sti leave site	JH, Sti
	07:30	Move system on position 408.50 m bgl	
		Interval 6d: 408.50 – 417.59 m	
	08:07	Start file: Oftr_2007_10_28_oftr_i6d.dat P1 = 4087.28 kPa P2 = 4072.74 kPa P3 = 4074.32 kPa T1 = 30.22 °C T2 = 30.19 °C T3 = 30.17 °C Water table: - 1.42 m bgl	
	08:10	Start inflation of packer 1	
	08:35	Start inflation of packer 2 (packer pressure increase is not recorded).	
	09:00	Release tension on tubing, stick up: 3.57 m bgl	
	09:01	Connect packers on pressure vessel	
	09:03	Close valve, start PSR	
	09:15	Prepare swabbing equipment, swabbing on 60 m bgl	
	09:28	Start P4 sensor: Patm = 100.83 kPa	
	09:29	Stop P4 sensor for installation	
	09:40	Water table in 1.9"NU: 65.29 m below top of rods, P4 Sensor 257.22 kPa	
	10:01	Scan rate 1 s	
	10:02	Start PW-test, valve open during 75 s, Water table in 1.9"NU: P4-sensor: 522.84 kPa => ΔP = 265.62 kPa, Δh = 27.07 m	
	10:14	Change scan rate to 5 s	
	10:43	Stop P4-sensor and take out of borehole	

Form **DAILY LOG REPORT**	SOLEXPERTS

Date	Time	Activity	Who
28.10.2007	10:50	Calibrate O2-Sensor, test chemical data recording at GMII-data acquisition => OK	SR, FP
	11:05	Saturate tubing and flow lines, clean flow-board and lines	
	12:19	Start HW-test using 3"-downhole pump	
	12:40	Flow rate decreases, pump stops, gas in pump	
	12:55	Phone call to Fbe: reduce drawdown to 40 m bgl. (=3680 kPa)	
	13:00	Pump switched of	
	13:30	Open valve at well head	
	13:35	Phone call with Fbe: shut in, saturate tubing and flowboard, start constant rate test with 2 l/min flow rate	
	13:54	Shut in =>no change in pressure rate (still gas phase below shut in tool)	
	14:05	Fill up tubing up to top	
	14:25	Open valve, pressure raises about 70 kPa and starts recovering slowly.	
	14:30	Close valve	
	14:32	Fill up tubing up to top	
	14:48	Open valve, pressure raises about 70 kPa up and starts recovering slowly.	
	15:00	Information to Fbe: deflate upper packer to remove gas in interval	
	15:10	Call drill master for security reasons	FP
	15:30	Deflation of upper packer (PA2)	
	15:55	Start inflation of upper packer	
	16:07	Valve close	
	16:10	Fill up tubing, saturate flow lines and flowboard, flush chemical measuring cell, calibrate Orbisphere	
	16:40	Start RW	
	16:55	Check flow lines on leakages	
	17:00	Take water sample	
	17:35	Sampling	
	18:50	JH, Sti arrive on site	JH, Sti
	19:00	FP leaves site	FP
	19:00	Sampling	
	19:15	SR leaves site	SR
	21:00	Sampling	
	22:37	Phone conversation with Fbe: reduce Q 0.6 l/min	
	22:55	Gas extraction, pump gets no water	
	22:57	Shut-in	
	23:15	Phone conversation with Fbe: fill up tubing with water, Water table tubing before refill 8,95 m below top of rods	
	23.20	Open valve, start pump, Q = 0.6 l/min	
		Change sampling intervals, 11.2 l water filled in tubing => 19 min for exchange (Q = 0.6 l/ min)	
		Measurements taken during sampling see separate table below	
29.10.2007	03:00	Sampling	
	05:00	Sampling	
	07:00	SR arrives on site	SR
	07:20	Sampling	
	07:50	JH leave site	JH
	09:00	Sampling	
	09:45	K. Jäggi (Geotec AG) takes gas sample	
	10:00	FP arrives on site	FP

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Date	**Time**	**Activity**	**Who**
29.10.2007	10:30	Pressure stable, no recovery	SR, FP
	10:50	Phone call with Fbe: Shut-in, wait until pressure starts recovering, move out pump and tubing with valve closed, take out water samples using double valve pump as early as possible. Interval has to be built with screen directly below upper packer.	
		Total water volume produced: 542 l	
	11:00	Shut in	
	11:45	Water table in 1.9" tubing: 38.75 m bgl => water volume in test rods: 463 l	
	11:51	Start deflate upper packer	
	12:05	Preparation of 1.5" double valve pump	
	12:36	Deflate lower packer	
	12:57	Water table casing: 16.47 m bgl	
	13.02	Stop file	
	13:05	Packer free, start move out system	
	15:14	Top of shut-in tool at 141.44 m bgl	
	15:20	Start installation of double valve pump	
	16:05	Pump above valve. Volume of production line: 7.25 l (ID: 8 mm, length: 141.2 m)	
	16:25	Empty production line (7.5 l taken)	
	16:27	Taking first water sample (250 ml, Geotec)	
	16:28	Second to tenth water sample (1 l each)	
	16:48	Taking eleventh sample (250 ml)	
	16:50	Produce 25 l	
	17:18	2 x 10 l water sample, 1 x 250 ml water sample	
	17:50	Pull double valve pump out of borehole	
	19:00	Double valve pump out of borehole	
	19:01	Open downhole shut-in tool	
	19:05	Start move out test rods	
	19:50	JH, Sti arrive on site	JH, Sti
	20:20	Tubing out of borehole	

Remarks:
Equipment test (by FP): A test was carried out in order to check how much water would flow through the 3-inch submersible pump without extra pressure (pump switched off). This test was to find out if the pump would act as a flow resistor during a slug injection or slug withdrawal tests. The pump was fixed in vertical position. Water was poured into the pump from the top and an outflow rate of 2.4 l/min was measured at the bottom of the pump.

Fi Hansruedi Fisch
SR Sacha Reinhardt
JH Jörg Hayer
Cad Stefan Caduff
PH Peter Haller
FP Fredi Portmann
Sti Daniel Stillhard

Nagra:
Fbe Dr. Bernd Frieg

Form

DAILY LOG REPORT

Measurements taken during sampling (28./29.10.07)

Date / Time	*P2 [kPa]*	*Pump rate [l/min]*	*pH*	*Electric conductivity [ms/cm]*	*O_2 [mg/l]*	*T [°C]*
28.10.07						
17:00	*3935*	*1.004*	*6.35*	*0.746*	*9.59*	*4.1*
17:35	*3889*	*1.010*	*6.30*	*0.884*	*5.15*	*4.0*
18:20	*3847*	*1.015*	*5.49*	*1.274*	*-*	*-*
18:40	*3829*	*1.032*	*3.94*	*2.930*	*0.85*	*4.1*
19:00	*3808*	*0.960*	*5.39*	*15.850*	*0.24*	*4.1*
19:30	*3786*	*1.041*	*3.42*	*16.920*	*1.04*	*4.0*
20:00	*3765*	*0.992*	*2.21*	*15.340*	*1.34*	*4.1*
20:30	*3739*	*1.001*	*2.63*	*13.840*	*1.06*	*4.2*
21:00	*3715*	*0.971*	*3.16*	*12.800*	*1.01*	*4.1*
21:30	*3079*	*0.472*	*4.32*	*10.020*	*0.44*	*4.1*
22:00	*3656*	*0.461*	*4.24*	*0.941*	*1.06*	*4.0*
23:30	*3654*	*0.382*	*-*	*-*	*-*	*-*
29.10.07						
03:00	*3657*	*0.580*	*5.21*	*0.781*	*2.07*	*4.2*
04:00	*3644*	*0.310*	*5.05*	*0.942*	*2.06*	*4.1*
05:00	*3631*	*0.503*	*4.92*	*1.032*	*2.06*	*4.0*
06:00	*3632*	*0.527*	*4.99*	*1.072*	*2.04*	*4.1*
07:00	*3607*	*0.687*	*3.62*	*1.090*	*2.05*	*4.0*
08:00	*3611*	*0.410*	*4.46*	*11.320*	*3.03*	*3.9*
09:00	*3591*	*0.820*	*4.89*	*11.720*	*0.98*	*3.8*

Water parameters were measured using probes installed in flow cells. Please note that occasionally gas bubbles were observed in the flow cells (in these cases, pH was varying strongly or indicated "out of range"). The occurrence of gas may have affected the above measurements.

Form

INSTALLATION RECORD HDDP with Pump Housing

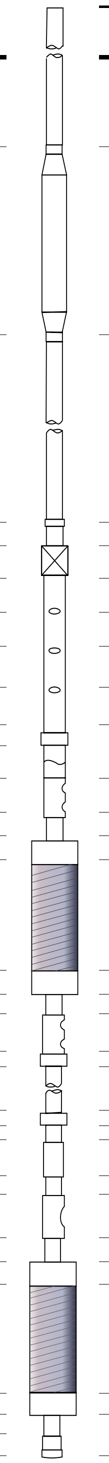
SOLEXPERTS

Seite 1 / 1

Packertests Oftringen

Date	27.12.2007	**Project Leader**	Fi/SR						
Borehole	NOK EWS 2007	**Direction**	vertical	**Reference point**	433.0	**JOB Nr**	1763	**Location**	Oftringen
Borehole Depth	719 m	**Casing depth**	376.5 m bgl	**Interval lenght**	9.09 m	**Test Name**	oftr_i6d	**System**	HDDP 110
Borehole diameter	146 mm	**Stickup**	-3.59 m	**Water depth**	13.77 m bgl	**Test depth (UPLS)**	408.50 m bgl	**Probe ID**	TSSP S1

Note: All depths shown are not correct for borehole deviation

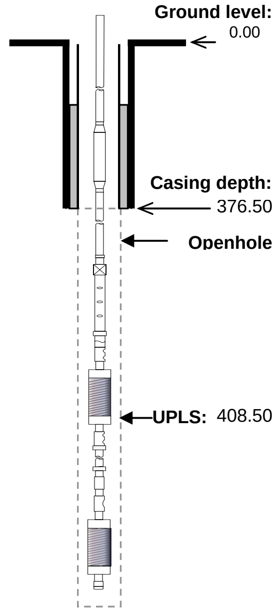


Component		Qty -	L unit m	L total m	Depth m	OD mm	ID mm	Wgt kg	Str t
Stickup	-3.59 m bgl								
Ground level					0.00				
Tubing 1.9" NU			104.10	404.82		56.1	40.3	426.8	12
Downhole Pump 3"			1.48			106.0	--	20.6	12
					101.99				
Tubing 1.9" NU			299.24			56.1	40.3	1226.9	12
					401.23				
Pop joint			1.02	7.27		56.1	40.3	4.2	12
SIT Non Displacement Valve			0.84			79.0	24.0	20.6	15
Probe Shell Carrier mit Triple Sub	TSSP P1		1.97			70.0	10.9	48.0	25
					405.06				
	TSSP P2		0.30		405.36				
	TSSP P3		0.30		405.66				
			0.04						
X-Over	2"3/8 EU Pinx1.9" NU Box		0.51			66.0	40.0	2.1	16
Safety joint 3"1/16						78.0	50.5	5.5	24
Above Side Entry Sub (ASES)			0.52			66.0	32.0		24
Packer Stick Up			0.26			--	25.0		
Up. Packer Seal	UPUS		0.26		407.25				
Upper Packer			1.25			108.0	32.0	82.4	17
	UPLS		0.24		408.50				
Straddle Length – **Packer Stick Down**			0.31	9.09		--	25.0		
Below Side Entry Sub (BSES)			0.52			66.0	32.0		24
X-Over	1.9" NU Pinx2"3/8 EU Box		0.26			--		3.0	16
Tubbing 1.9" NU			4.55			56.1	40.3	18.7	12
X-Over	2"3/8 EU Pinx1.9" NU Box		0.45			--		3.0	16
Filter			0.3						
	Screen		1.45			72.0	50.0	19.0	19
			0.3						
P1-Seal Sub			0.3			78.0	--		24
Packer Stick Up			0.16			--	32.0		
Lower Packer	LPUS		0.25		417.59				
Lower Packer			1.25	1.92		110.0	32.0	70.2	17
	LPLS		0.24		418.84				
Packer Stick Down			0.43			--	32.0		
End Cap					419.51	78.0	--		
End of Borehole					719.00				

Comments:

P4: submersible pressure transducer on cable; pressure at atmosphere measured on 28.10.07, 09:30

Borehole configuration:



Probe	523 006.1	
values at atmosphere	P1	116.99
	P2	91.55
	P3	97.75
	P4	100.83
	T1	10.45
	T2	10.43
	T3	10.38
Total Weight (kg)	**1950.9**	

Form

TALLY LIST

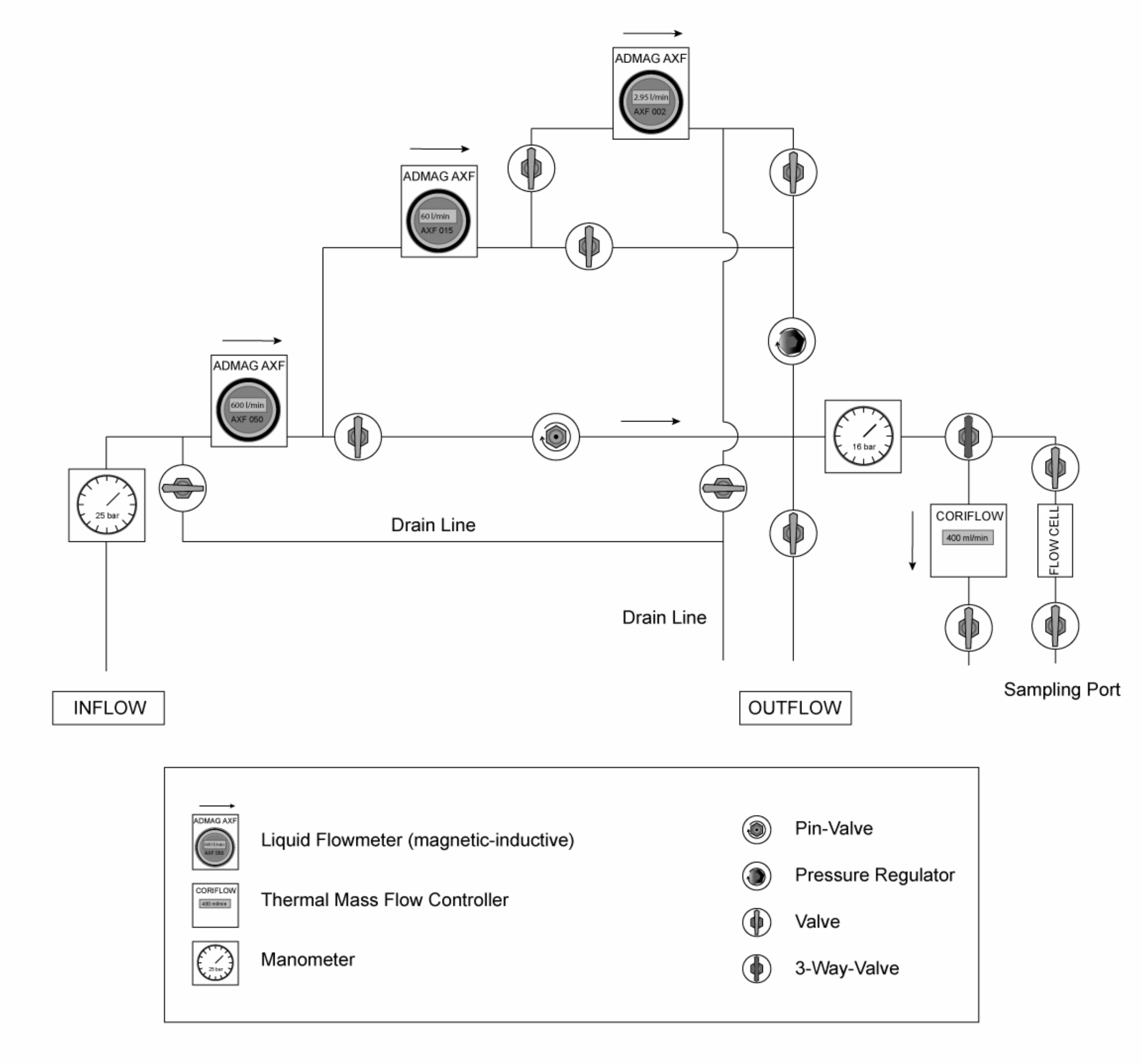
Borehole	NOK EWS 2007	Interval name	Test Oftr_i6d	Date	28.10.2007
Depth	719.0 m	Interval depth	408.5 - 417.6	Location	Oftringen

TU	1	6.51	TU	47	6.51					
TU	2	6.51	TU	48	6.51					
TU	3	6.51	TU	49	6.51					
TU	4	6.51	TU	50	6.51					
TU	5	6.51	TU	51	6.50					
TU	6	6.51	TU	52	6.51					
TU	7	6.51	TU	53	6.51					
TU	8	6.51	TU	54	6.51					
TU	9	6.51	TU	55	6.51					
TU	10	6.50	TU	56	6.51					
TU	11	6.50	TU	57	6.50					
TU	12	6.51	TU	58	6.51					
TU	13	6.50	TU	59	6.51					
TU	14	6.51	TU	60	6.51					
TU	15	6.51	TU	61	6.50					
TU	16	6.51	Pop Joint		1.86					
TU	17	6.51	Pop Joint		3.60					
TU	18	6.51	Pop Joint		1.02					
TU	19	6.50								
TU	20	6.51								
TU	21	6.51								
TU	22	6.50								
TU	23	6.51								
TU	24	6.50								
TU	25	6.50								
TU	26	6.50								
TU	27	6.50								
TU	28	6.50								
TU	29	6.50								
TU	30	6.50								
TU	31	6.50								
TU	32	6.50								
TU	33	6.51								
TU	34	6.51								
TU	35	6.50								
TU	36	6.51								
TU	37	6.50								
TU	38	6.50								
TU	39	6.51								
TU	40	6.50								
TU	41	6.51								
TU	42	6.51								
TU	43	6.50								
TU	44	6.50								
TU	45	6.50								
TU	46	6.50								
		299.24			104.10		0.00		0.00	

Total string length 1:	299.24	Total string length 2:	104.10

Form

SURFACE EQUIPMENT LAYOUT



Flow meter	Lower limit of measuring range	(% of FS)	Upper limit of measuring range (l/min)	Accuracy between 3% and 100% of FS (% of rate)	Accuracy between 1% and 3% of FS (% of rate)	Equipment used
AXF DN2	0.030 l/min	1 %	2.95 l/min	0.35	0.5	yes
AXF DN15	0.6 l/min	1 %	60 l/min	0.35	0.5	yes
AXF DN50	11.78 l/min	1 %	1178.10 l/min	0.35	0.5	no
Coriflow	0.50 kg/h	2 %	25.00 kg/h	1	1	no

Form

BENCH TEST

SOLEXPERTS

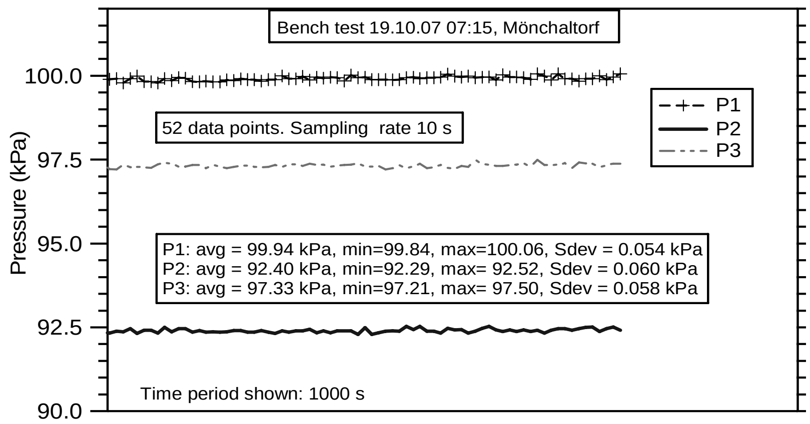
Project	Location	Date
Oftringen NOK EWS Borehole	Oftringen	20.12.2007
Well name	**Test name**	**Engineer**
NOK EWS 2007	Oftri-i6	Fi/SR

Transducer describtion	Output units
P1, P2, P3: 0-206.84 bar (3000 Psi), P4: 0-6 bar, P_{ST} = 0-10 bar	kPa, °C

P1#	P2#	P3#	P4#
43224	50370	43231	591.001.027

Offsite pretest bench test (Date: 19.10.07)

Measurement conditions (P, T and position)			Sampling rate
	97.7 kPa	5.6 °C	10 s
( ) direct	(x) vertical	( ) horizontal	

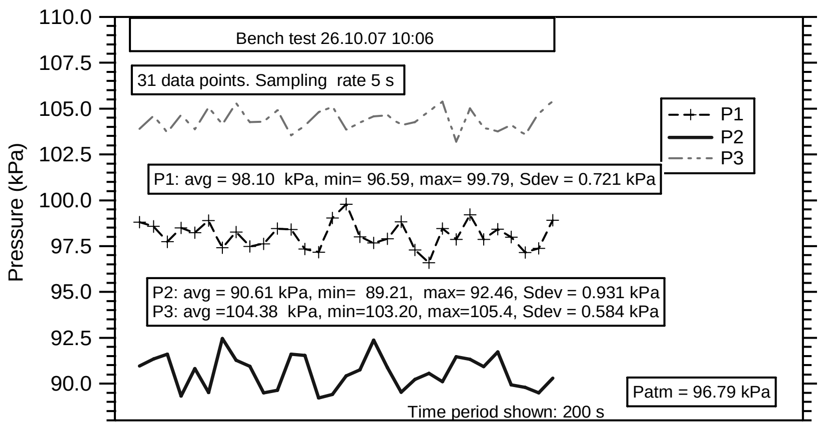


P1 average:	99.84	kPa
P2 average:	92.29	kPa
P3 average:	97.33	kPa
P4 average:	n.m.	kPa
P_{SL} average:	n.m.	kPa
P1 Sdev	0.054	kPa
P2 Sdev	0.060	kPa
P3 Sdev	0.058	kPa

File: TestData24.DAT

Onsite pretest bench test (Date: 26.10.07)

Measurement conditions (P, T and position)			Sampling rate
	96.4 kPa	7.3 °C	5 s
( ) direct	(x) vertical	( ) horizontal	



P1 average:	98.10	kPa
P2 average:	90.61	kPa
P3 average:	104.40	kPa
P4 average:	n.m.	kPa
P_{SL} average:	n.m.	kPa
P1 Sdev	0.721	kPa
P2 Sdev	0.931	kPa
P3 Sdev	0.584	kPa

File: Oftr_2007_10_26_atm2.DAT

Form

BENCH TEST

SOLEXPERTS

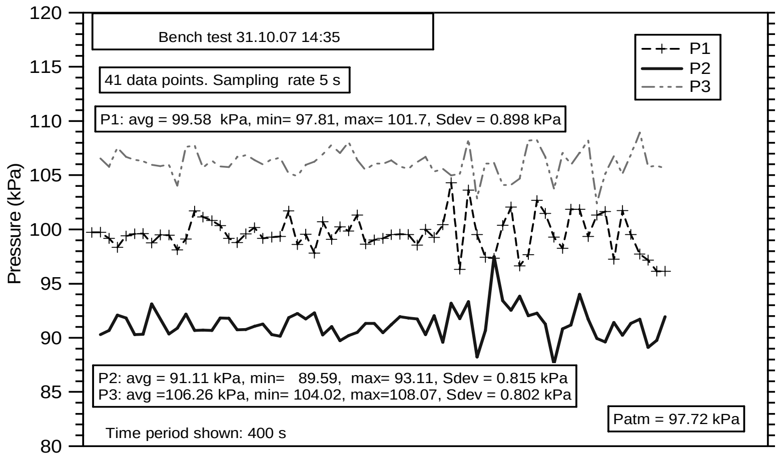
Project	**Location**	**Date**
Oftringen NOK EWS Borehole	Oftringen	20.12.2007
Well name	**Test name**	**Engineer**
NOK EWS 2007	Oftri-i6	Fi/SR

Transducer describtion	**Output units**
P1, P2, P3: 0-206.84 bar (3000 Psi), P4: 0-6 bar, P_{ST} = 0-10 bar	kPa, °C

P1#	**P2#**	**P3#**	**P4#**
43224	50370	43231	591.001.027

Onsite after test bench test (Date: 31.10.07)

Measurement conditions (P, T and position)	**Sampling rate**
( ) direct (x) vertical ( ) horizontal	



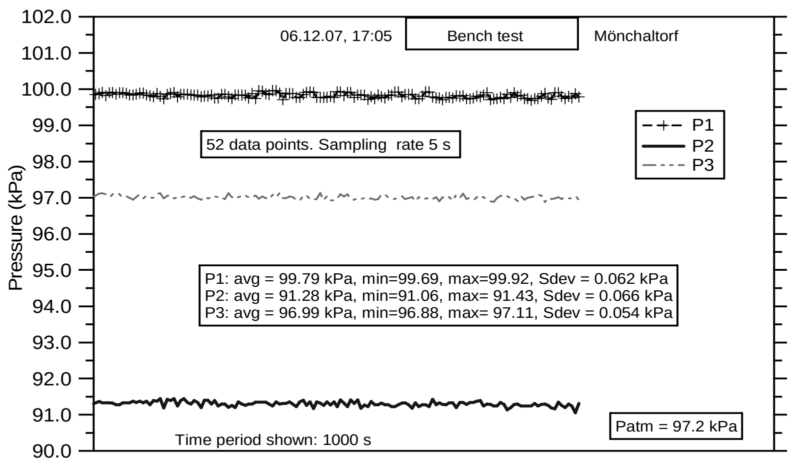
P1 average:	99.58	kPa
P2 average:	91.11	kPa
P3 average:	106.26	kPa
P4 average:	101.36	kPa [1)]
P_{SL} average:	n.m	kPa
P1 Sdev	0.898	kPa
P2 Sdev	0.815	kPa
P3 Sdev	0.815	kPa
P4 Sdev	0.0085	kPa [1)]
P_{SL} Sdev	n.m	kPa

[1)] Data not shown, 01.11.07, 20:50
Oftr_2007_11_01_oftr_i8.DAT, Patm=98.2 kPa

File: Oftr_2007_10_31_atm1.DAT

Offsite after test bench test (Date: 06.12.07)

Measurement conditions (P, T and position)	**Sampling rate**
96.6 kPa 9.6 °C	5 s
( ) direct (x) vertical ( ) horizontal	



P1 average:	99.69	kPa
P2 average:	91.28	kPa
P3 average:	96.99	kPa
P4 average: [1)]	101.44	kPa
P_{SL} average:	n.m.	kPa
P1 Sdev	0.062	kPa
P1 Sdev	0.062	kPa
P2 Sdev	0.066	kPa
P3 Sdev	0.054	kPa
P4 Sdev	0.007	kPa

[1)] not shown on graph

File: test8.dat

Appendix G

Quick Look Report
Interval Oftr-i7

nagra.

QUICK LOOK REPORT OFTRINGEN - TEST OFTR-i7

TEST START (Date/Time)	:	30.10.2007 / 01:26	**TEST END (Date/Time)**	:	30.10.2007 / 17:40

DOUBLE PACKER TEST

Test Interval Information	:		top test interval	:	632.50 m
borehole depth [1), 4)]	:	719.0 m	bottom of test interval	:	641.59 m
borehole radius	:	0.073 m	total interval length	:	9.09 m
tubing radius	:	20.0 mm	midpoint of interval	:	637.05 m
			P2-depth	:	629.36 m
interval volume, nominal [5)]	:	0.152 m^3	theoretical Cs-value [3)]	:	3.04E-10 m^3/Pa
slim tubing radius		4.75 mm	theoretical C-value (slim tube)	:	7.23E-09 m^3/Pa
WL prior to packer inflation [2)]	:	-1.42 m bgl	P2 signal prior to packer inflation	:	6269.43 kPa
WL in annulus at test end [2)]	:	-0.48 m bgl	P2 offset assuming ρ_{avg} = 997 kg/m3		100.0 kPa

1) all depths are not corrected for borehole deviation from vertical

2) WL = water level

3) assumes a total borehole system compressibility of 2E-09 Pa^{-1}

4) all depth measurements refer to ground level

5) cylindrical volume of isolated borehole section

Note all pressures cited in this report are absolute

Preliminariy information			
longitude of borehole	:	240887	
latitude of borehole	:	638346	
elevation of ground level (GL)	:	433.0 m asl	(reference point for all measurements)
assumed fresh water head	:	433.0 m asl	(assumed hydrostatic)
end of drilling	:	17.10.07 09:55	(Geotec)
porosity	:	3%	(assumed)
mud density [7)]	:	1032 kg/m^3	(Geotec end of drilling, 17.10.07)
borehole water density	:	997 kg/m^3	(Geotec after circulation of fresh water, 17.10.07; estimated using P2)
formation water density [8)]		1001.06 kg/m^3	(PVT correlation calculated by Saphir)
specific storativity [9)]	:	2.19E-06 m^{-1}	
formation water viscosity [8)]	:	6.74E-04 Pa s	(PVT correlation calculated by Saphir)
fluid compressibility [8)]	:	4.32E-10 1/Pa	(PVT correlation calculated by Saphir)
total compressibility [9)]	:	7.43E-09 1/Pa	(calculated assuming c_f= 7.00E-09 1/Pa)

7) Taken from daily report No. 53

8) Assumed, using salinity 10'000 ppm, T = 45 °C, P = 6370 kPa

9) Calculated based on assumed porosity and compressibility values

Responible Test Engineers	
Onsite:	Reinhardt, S.; Hayer, J.
Test analysis and reporting:	Fisch, H.R.; Trick, T.; Hayer, J., Rösli, U.

Test Summary		
test objectives	:	transmissivity, static formation pressure, flow model
borehole history	:	drilling through midpoint of interval: 12.10.2007, 23:46; 409.692 h duration until start of test
geology	:	clay-marls and carbonate-marls
geophysics	:	Caliper log, salinity log, temperature log, sonic log
test phases	:	COM, PSR, PW, PI

QLR results	**Test zone 632.50 - 641.59 mbgl**	**T [m2/s]**	**K [m/s]**	**Formation Flow model**	**Freshwater Head [m asl]**
Analytical interpretation		(1.5E-13)	(1.7E-14)	radial flow	-
Numerical simulation		6.9E-13	7.6E-14	homogeneous	282.2

Note:
A complete list of results is provided in the summary tables

Mönchaltorf, 27.02.08 / 01.08.08, Revision 1 prepared by: SOLEXPERTS INTERA

Summary of Test Data Page 1/2

Test Phase		INF 1+2	COM	PSR 2)	PW 1)
duration	[h]	1.022	0.525	1.519	11.885
T2 (i/f)	[°C]	43.74 / 44.96	44.96 / 44.96	44.96 / 45.07	45.07 / 44.95
P1 (i/f)	[kPa]	6281 / 6291	6291 / 6279	6279 / 6264	6264 / 6250
P2 (i/f)	[kPa]	6271 / 6270	6270 / 6270	6270 / 6255	5532 / 5650
P3 (i/f)	[kPa]	6270 / 6270	6270 / 6269	6269 / 6267	6267 / 6262
P4 (i/f)	[kPa]				
Measured C	[m3/Pa]				9.2E-11
c_{SC}	[1/Pa]				6.0E-10
q	[l/min]				
Q	[l]				
inner boundaries		no analysis	no analysis	wellb. storage	wellb. storage
flow geometry				hom.	hom.
outer boundaries				inf.lat.ext.	inf.lat.ext.
T	[m^2/s]			(2.88E-12) A)	(1.51E-13) A)
K	[m/s]			(3.17E-13) A)	(1.66E-14) A)
k	[m^2]			(2.18E-20)	(1.14E-21)
S_S	[1/m]			(5.13E-06) A)	
S	[-]			(4.67E-05)	
Pi, P_f if matched	[kPa]			(6230.2) A)	(6250.4) B)
Head	[m asl]			(428.5) C)	(430.59) C)
Derived flow rate	[l/min]				
s (skin factor)	[-]				
S_{SS} (skin zone)	[1/m]				
t_S (skin zone)	[m]				
K_S (skin zone)	[m/s]				
figures				1, 7	1, 5
temperature effects				no	no
borehole history				yes	no
anomalies				no	no
bypass PA2				no	no
bypass PA1				no	no

comments

(page 1 of 2)

notes:
- i = initial, f = final
- T value in bold most representable of the undisturbed formation

1) analytical with no superposition
2) numerical simulation with detailed borehole history effects

A) matched parameter
B) input parameter
C) calculation assumes: freshwater density 1000 kg/m^3, g = 9.81 m^2/s, P_{atm} and z_2 as stated on front page

Summary of Test Data

Page 2/2

Test Phase		PW [2)]		PI [1)]		PI [2)]		Simulation entire Seq. [2)]	
duration	[h]	11.885		1.414		1.414		16.39	
T2 (i/f)	[°C]	45.07 / 44.95		44.95 / 44.92		44.95 / 44.92		43.74 / 44.92	
P1 (i/f)	[kPa]	6264 / 6250		6250 / 6251		6250 / 6251		6281 / 6251	
P2 (i/f)	[kPa]	5532 / 5650		6289 / 6228		6289 / 6228		6271 / 6228	
P3 (i/f)	[kPa]	6267 / 6262		6262 / 6262		6262 / 6262		6270 / 6262	
P4 (i/f)	[kPa]								
Measured C	[m3/Pa]			8.6E-11					
c_{SC}	[1/Pa]			5.7E-10					
q	[l/min]								
Q	[l]								
inner boundaries		wellb. storage		wellb. storage		wellb. storage		wellb. stor.	
flow geometry		hom.		hom.		hom.		hom.	
outer boundaries		inf.lat.ext.		inf.lat.ext.		inf.lat.ext.		inf. lat. ext.	
T	[m^2/s]	1.25E-12	A)	(1.20E-13)	A)	1.33E-12	A)	**6.89E-13**	A)
K	[m/s]	1.37E-13	A)	(1.31E-14)	A)	1.46E-13	A)	**7.58E-14**	A)
k	[m^2]	9.40E-21		(8.99E-22)		1.00E-20		5.20E-21	
S_S	[1/m]	1.01E-06	A)			8.32E-07	A)	1.76E-06	A)
S	[-]	9.18E-06				7.56E-06		1.60E-05	
Pi, P_f if matched	[kPa]	4892.9	A)	(5650.4)	B)	6325.9	A)	**4795.0**	A)
Head	[m asl]	292.21	C)	(369.43)	C)	438.28	C)	282.23	C)
Derived flow rate	[l/min]								
s (skin factor)	[-]								
S_{SS} (skin zone)	[1/m]								
t_S (skin zone)	[m]								
K_S (skin zone)	[m/s]								
figures		1, 8		1, 6		1,9		1, 10, 11	
temperature effects		no		no		no		no	
borehole history		yes		no		yes		yes	
anomalies		no		no		no		no	
bypass PA2		no		no		no		no	
bypass PA1		no		no		no		no	

comments
(page 1 of 2)

notes:
- i = initial, f = final
- T value in bold most representable of the undisturbed formation

1) analytical with no superposition
2) numerical simulation with detailed borehole history effects

A) matched parameter
B) input parameter
C) calculation assumes: freshwater density 1000 kg/m^3, g = 9.81 m^2/s, P_{atm} and z_2 as stated on front page

Test overview

Test Oftr-i7 (632.50 - 641.59 m bgl) was performed on 30.10.2007 in the Oftringen NOK EWS-Borehole. The test interval consists of marls which vary between clay-marls and carbonate-marls (so-called Effinger Mergel). The tested section belongs to the Effinger-Member of the jurassic Malm (Oxfordian) formation. The test objectives were to obtain reliable estimates of interval transmissivity and fresh-water hydraulic head using an appropriate flow model. The test was performed with a straddle-packer configuration with an interval length of 9.09 m. Pressures and temperatures were measures in the test interval (P2, T2) and in the interval below the lower packer (P1, T1) and in the annulus above the upper packer (P3, T3). In addition, pressure was measured in the tubing above the upper packer (P4). Test interval Oftr-i7 covers a subsector of the earlier investigated interval Oftr-i2, 590 - 640.04 m bgl.

The pressure responses of the entire test sequence in Oftr-i7 are shown in **Figure 1**. The pressure history derived from water table measurements (source: Colenco, Solexperts) and fluid density measurements (SJ Geotec) is presented in **Figure 2**.

Following packer inflation (INF) the test sequence started with a COM and PSR phase to dissipate temperature and borehole history effects. Temperature effects are considered negligible, because downhole temperatures (T1, T2, T3) oscillate around a stable mean value of 44.95 °C with a stable noise band of about +/- 0.5 °C (**Figure 3**). The PSR phase is influenced by compliance effects due to not fully stabilized packer pressures (**Figure 4**).

The test sequence consists of a pulse withdrawal test (PW) which was performed to measure the wellbore compressibility early in the test and obtain an initial estimate of the formation properties. During the 11.9 hr long PW phase, the packer pressure (measured at surface) decreased from 30.8 to 26.3 bar (both packer inflation lines were connected together). Subsequently a pulse injection test (PI) was performed to determine wellbore compressibility for comparison with that from the earlier pulse withdrawal n test (PW).

Due to the influence of the adjacent high voltage current transformer facility (NOK), the pressure and temperature signals of the downhole triple probe were noisy during the hole testing sequence.

Analysis

For the QLR analysis, the analytical and numerical methods were used for a standard analysis, which will be the basis for a possible detailed analysis depending on the test objectives and test results.

Analytical Analysis

Type curve and straight-line fitting methods are applied. Effects of the borehole pressure history are not taken into account.

Pulse withdrawal test (PW)

The PW test was initiated after a short PSR phase which ended with a slightly decreasing pressure trend of about 2.0E-3 kPa/s (P2). During preparation of PW, the water level in the 1.9" test was lowered to 79 m bgl. During the pulse withdrawal test the shut-in valve was opened during about 65 seconds causing a water level increase in the 1.9" test rod of 5.3 cm (ΔP4 = 0.52 kPa), indicating a volume release of 0.0666 liters due to de-compression of the test zone. The calculated wellbore storage constant C (ΔV/ΔP) equals to 9.2E-11 m^3/Pa.

The pulse response was analyzed using CBP type-curves compensating the linear pressure trend measured at the end of the PSR phase. The analysis is presented in **Figure 5**. The trend correction allows fitting the entire data curve to a CBP type-curve with a α–value 1.0 which provides a transmissivity estimate of 1.5E-13 m^2/s and a hydraulic conductivity of 1.7E-14 m/s. After shut-in, the PI test recovered 28 % during a period of 11.77 hrs.

Pulse injection test (PI)

A pulse injection test (PI) was performed subsequently to the PW test in order to confirm the C-value obtained during the PW. The PW ended with a slightly increasing pressure trend of about 5.0E-4 kPa/s (P2). During preparation of PI, the water in the 1.9" test rods was filled up to the top of the rods. During the pulse test the shut-in valve was opened during about 56 seconds causing a manually measured water volume change of 0.055 liters due to compression of the test zone. The volume change measured by the P4 differential pressure (ΔP4 = 0.373 kPa, ΔV = 0.049 liters) could be affected by a slight change of the vertical position of the sensor and is therefore not considered. The calculated wellbore storage constant C (ΔV/ΔP) equals to 8.6E-11 m^3/Pa.

The pulse response was analyzed using CBP type-curves compensating the linear pressure trend at the end of the PW phase. The analysis is presented in **Figure 6**. The trend corrected data were fitted using a CBP α–type-curve of value 1.0 (same as used for PW analysis) which provided a transmissivity estimate of 1.2E-13 m^2/s and a hydraulic conductivity of 1.3E-14 m/s. After shut-in, the PI test recovered 10 % during a period of 1.4 hrs.

Numerical Analysis using nSights

In a first step, the diagnostic plots for the individual sequences were analyzed and fitted individually accounting for borehole history and taking into account of transient effects associated with the preceding test sequences. In a second step, the entire test sequence was simulated and fitted based on the Cartesian pressure plots.

For the Cartesian fit, the PSR, PW and PI phases were chosen and no weighting for individual events was applied. The so-called history periods BH, INF1, INF2, COM, PW_a and PI_a were not fitted but incorporated as test events with defined pressure in the simulation process. The transitional phases PW_a and PI_a denote very short events of less than 0.025 hrs duration and represent the transitional phases during initiation of the pulse tests (open shut-in valve phase at start of pulse tests).

Please note that the fits of the Ramey plots for the PW and PI sequences are the result of the inverse parameter estimation using nSights and represent a solution of a numeric process that includes the effects of potential transient effects of the preceding test phases and the borehole history.

A homogeneous model was assumed in this first evaluation for estimating formation parameters (i.e., K, S_s, and P_f). The analyses used the wellbore compressibility of 9.2E-11 m^3/Pa (c_{SC} = 6.0E-10 1/Pa) determined from field measurements during PW. The diagnostic plots of the individual test sequences did not indicate characteristic responses of a composite flow model, or any other more complex flow models. Consequently, a homogeneous model was assumed in this first evaluation for estimating formation parameters (i.e., K, S_s, and P_f).

The log-log diagnostic plot of the PSR indicates dominantly wellbore storage effects (**Figure 7**) providing only preliminary estimates of formation parameters (K = 3.2E-13 m/s, S_s = 5.1E-06 m^{-1}, P_f = 6230 kPa) which produced a good fit of the measured data. However, packer pressures were not fully stabilized at start of PSR and the simulation may have been affected by ongoing compliance effects. The results of the PSR analysis are given little confidence.

The diagnostic plot of the PW sequence in terms of the normalized pressures (Ramey A) produced a good quality fit (**Figure 8**) and provides similar K and Ss values compared to the PSR shut-in period but a considerably lower static formation pressure (K = 1.4E-13 m/s, S_s= 1.0 E-6 m^{-1}, P_f = 4893 kPa). It is assumed that the observed decrease in packer pressure of 4.5 bar during PW had little or no effect on the interval pressure. This is concluded from a packer system test conducted in the 7-inch casing on 31.10.07. During this test, a sudden pressure release of 10 bar (from 33 to 23 bar) resulted in a P2 decrease of 4.4 kPa/bar. A similar effect in the Oftr-i7 interval is expected but should be smaller due to the smaller borehole diameter of 5¾-inch.

The simulated data fit of the PI period provides a good fit (**Figure 9**). The obtained formation parameters are similar to the PSR phase and differ from the PW phase only by the high static formation pressure (K= 1.5E-13 m/s, S_s= 8.2E-7 m^{-1}, P_f = 6326 kPa).

The simulation of the entire test sequence produces a good fit (**Figure 10**) with matched parameters for the conductivity and the static formation pressure slightly lower than those from the PW phase (K = 7.6E-14 m/s, S_s =1.8E-6 m^{-1}, P_f = 4795 kPa). The sensitivity coefficients of the formation parameters during the different sequences (**Figure 11**) indicate that the PW test has the greatest sensitivity to K and S_s. The sensitivity to the static formation pressure P_f. is low what might explain the wide range of values for this parameter. The definition of the sensitivity coefficient is given in the Chapter "Definitions".

Results and Discussion

The shut-in wellbore storage constant values (C) obtained from the pulse tests PW and PI are very low and correspond to system compressibility values (c_{SC}) of 6.0E-10 Pa^{-1} (for PW) and 5.7E-10 Pa^{-1} (for PI). These values are very similar to the expected compressibility of water at depth and temperature conditions of the test zone (expected c_w = 4.3E-10 Pa^{-1}). The measured system compressibilities are considered approximate values because of the limited accuracy inherent to this type of field measurement. The low T and K values obtained from the analytical analyses of the PW and PI phases are considered unreliable in view of the potential transient effects from the preceding borehole pressure history.

The estimated formation conductivity for the different sequences varies over a range between 7.6E-14 m/s and 3.2E-13 m/s based on a homogeneous radial flow model. The matched specific storativities vary over a range between 7.6E-07 and 1.8E-06 m^{-1}. The estimated formation pressures vary within a range of 4795 for the entire sequence fit and 6326 kPa for the PI fit. The relative long PW sequence shows fairly consistent parameter values between the sequence only fit and the entire testing sequence fit and thus these are considered the more representative parameter values.

The specific storativity values (Ss) of the individually fitted PW and PI sequences using nSights are similar or slightly lower than the initial Ss estimate (Ss values as expected based on assumed formation compressibility, porosity, and water compressibility). Only little percental recovery was observed during these test events indicating that the estimated Ss parameter is not well constrained and may have limited reliability.

The calculated freshwater head from this simulation (h_s = 282 m asl) is very low compared to the result from the adjacent and overlapping Interval Oftr-i2. The static head estimate has to be used with care because testing duration was too short to obtain a reliable estimate.

FIGURES

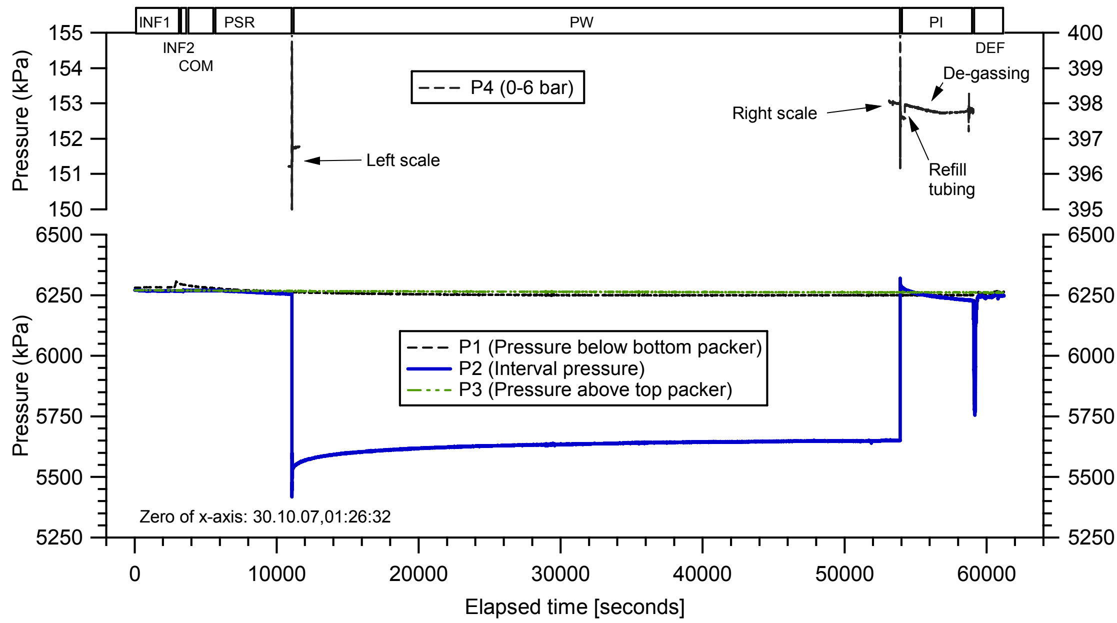


Figure 1: Oftr-i7: Overview plot

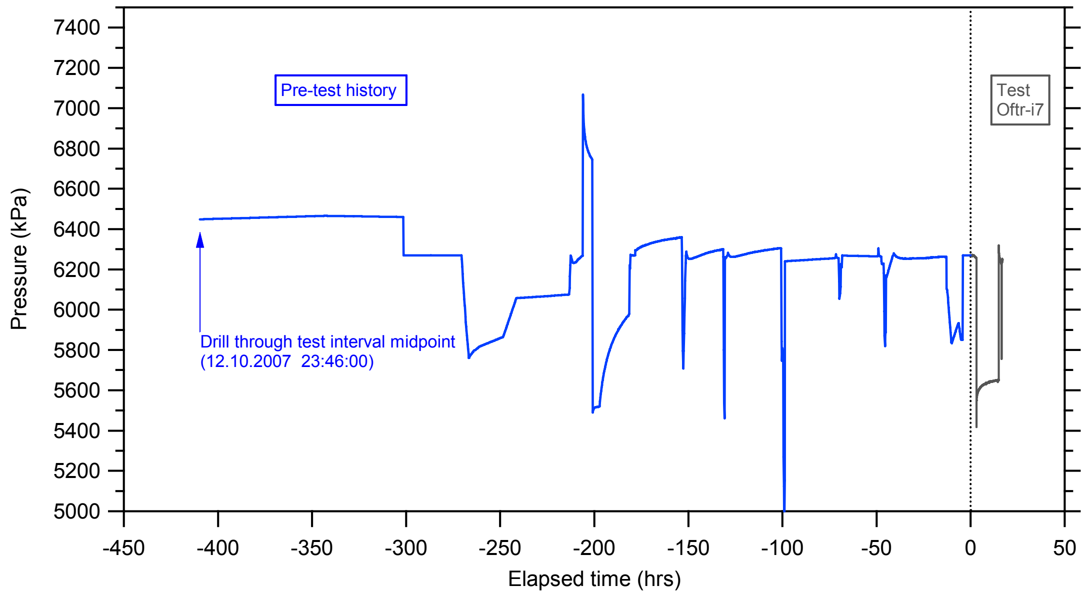


Figure 2: Oftr-i7: Borehole pressure history

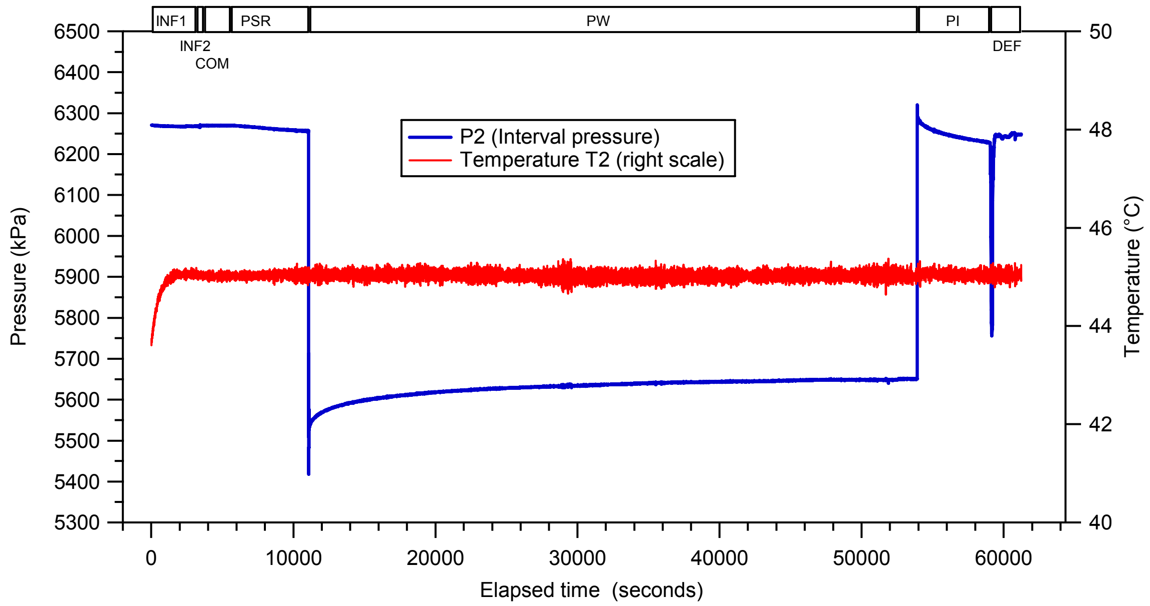


Figure 3: Oftr-i7: Measured downhole temperature (T2)

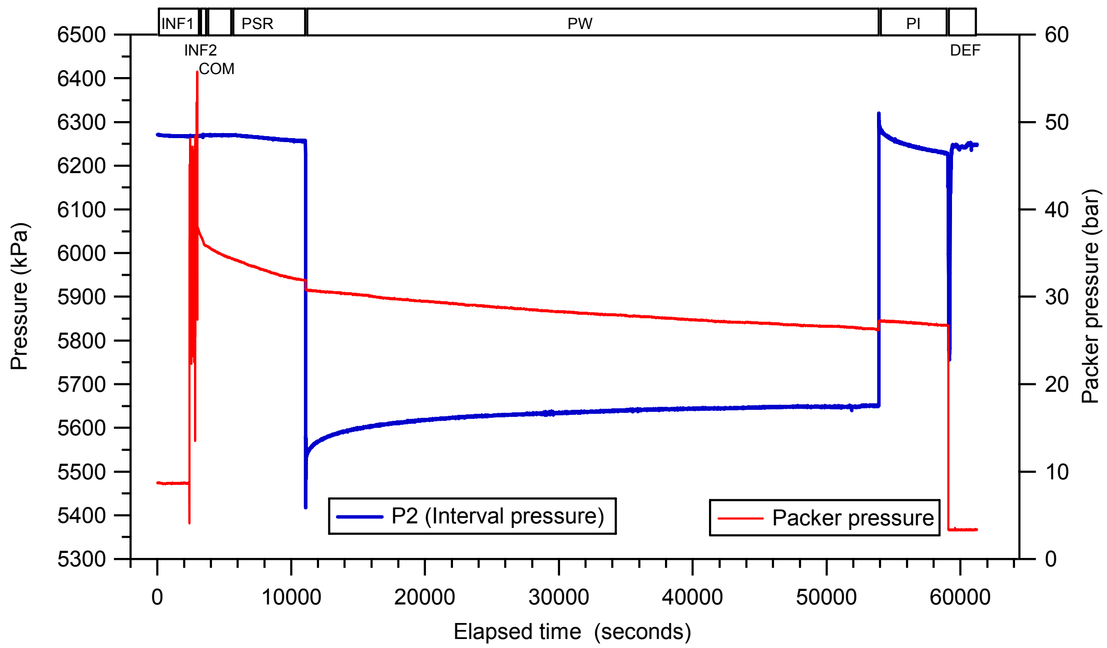


Figure 4: Oftr-i7: Measured packer pressure

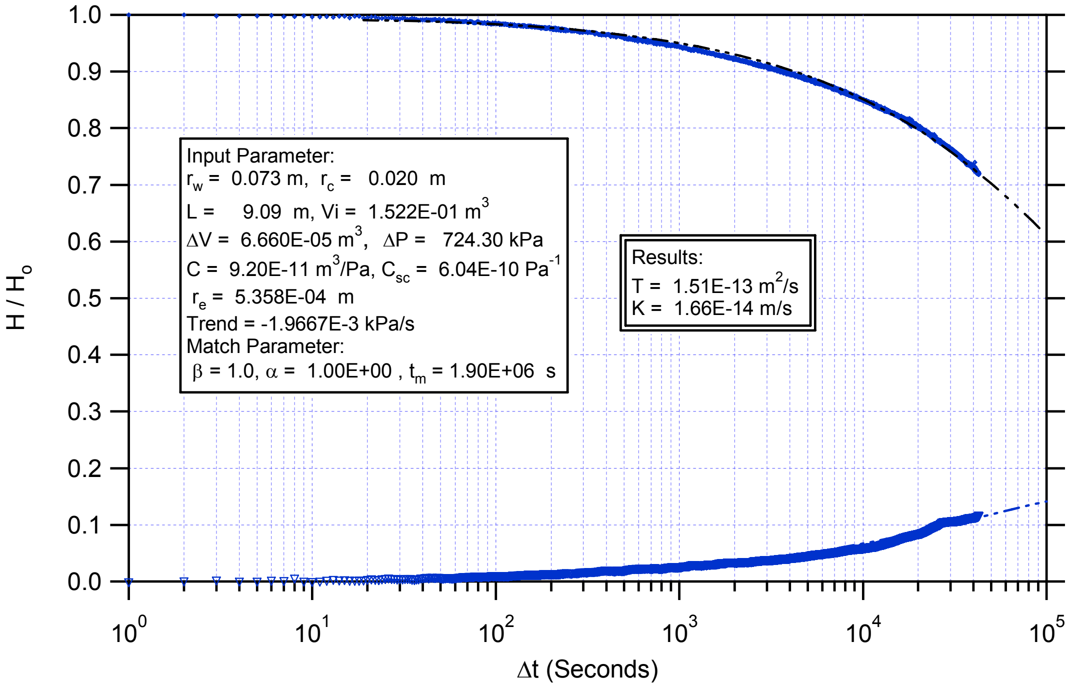


Figure 5: Oftr-i7: PW analysis using CBP type-curves and trend corrected data

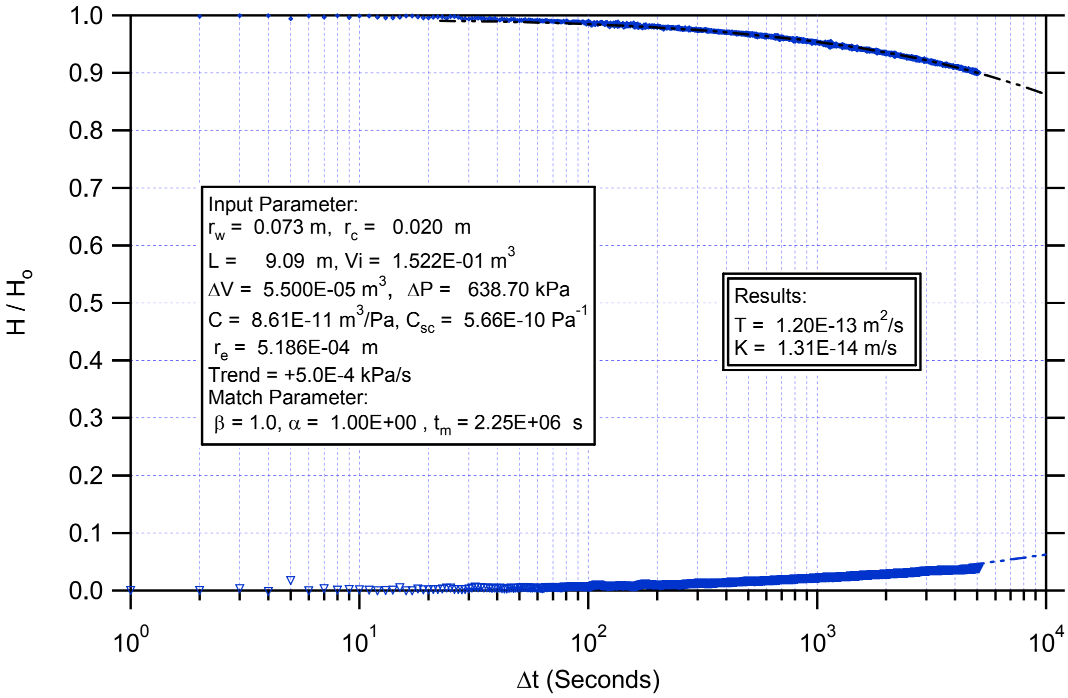
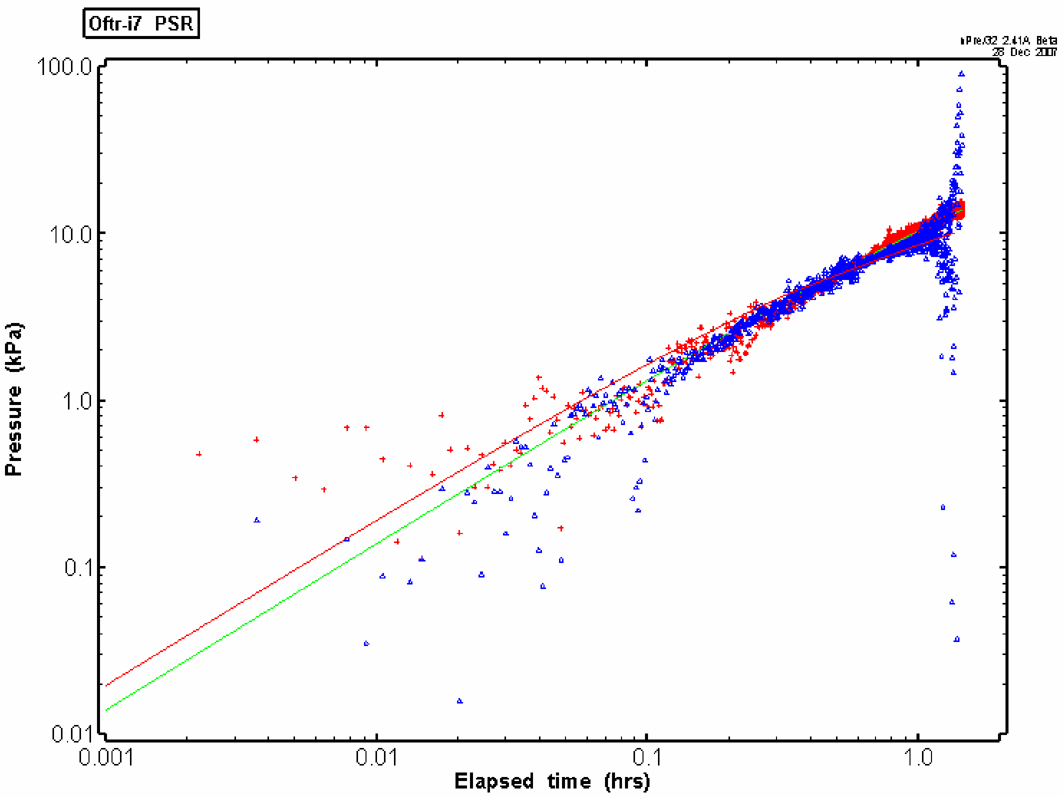


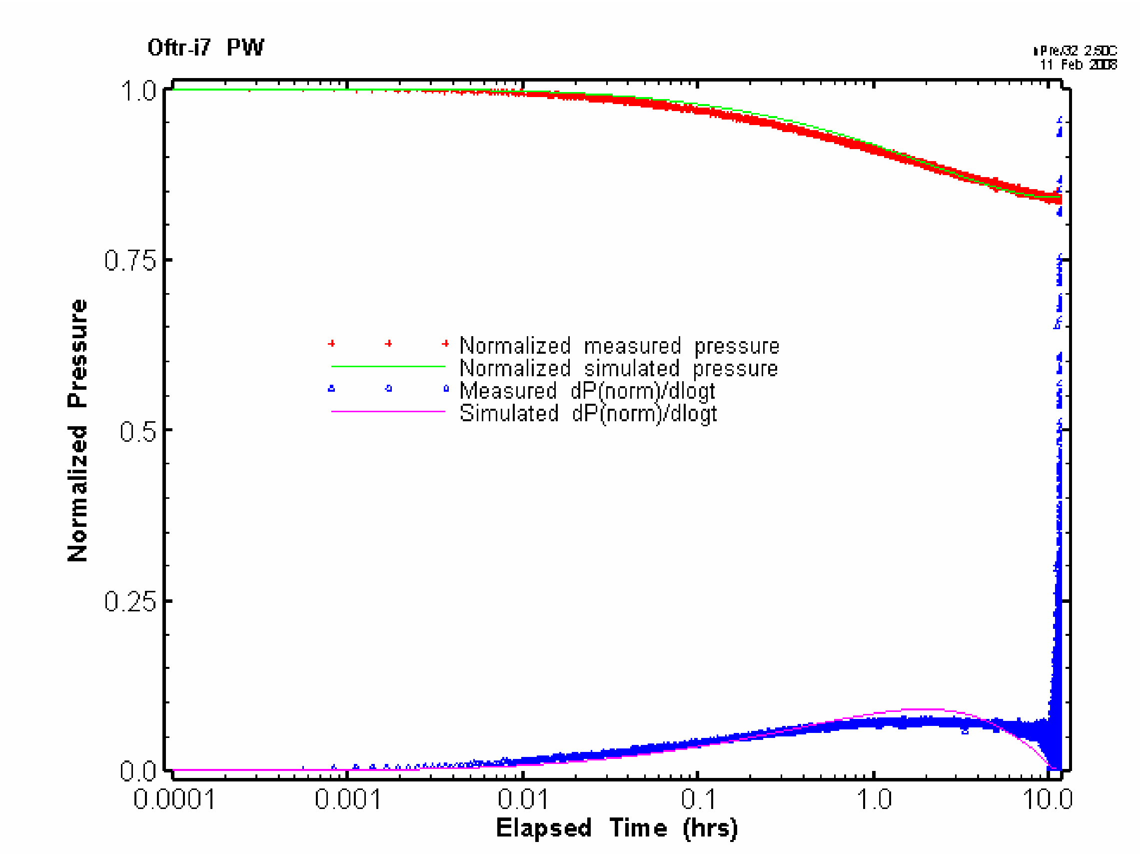
Figure 6: Oftr-i7: PI analysis using CBP type-curves and trend corrected data



Fit Statistics:

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_f	[m/sec]	3.17E-13	???	???
P_f	[kPa]	6230.2	5591.0	6869.4
Ss_f	[1/m]	5.13E-06	???	???

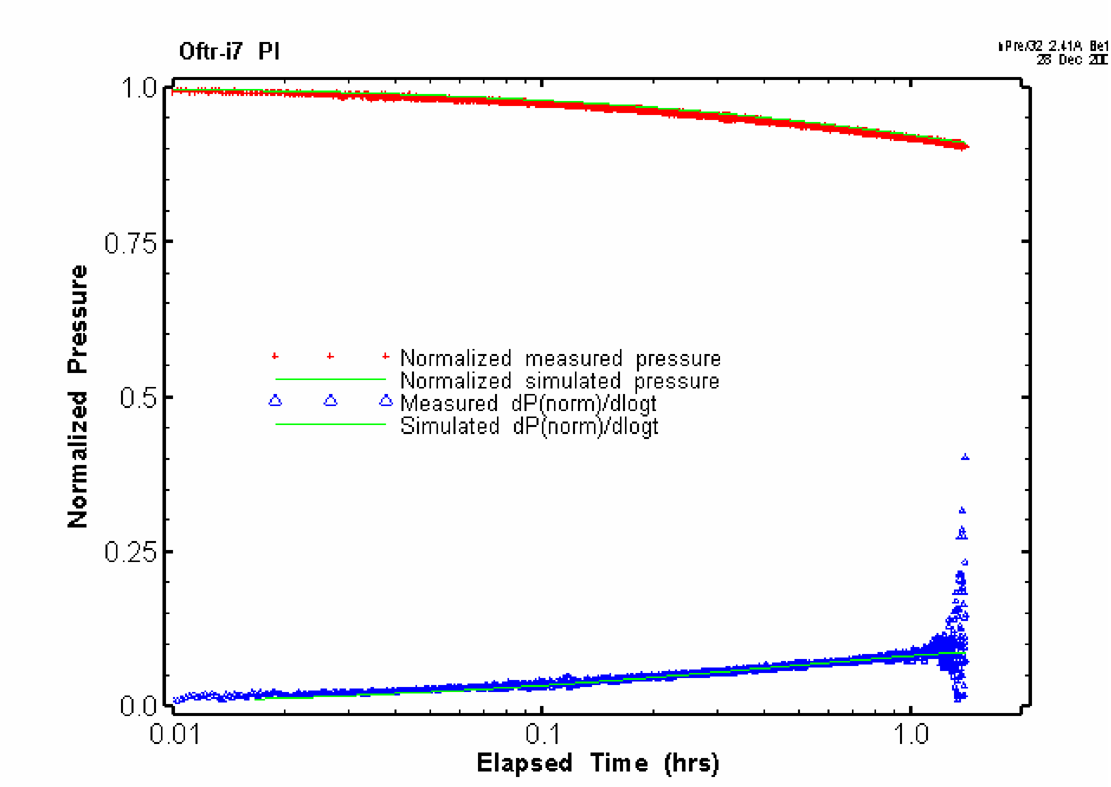
Figure 7: Oftr-i7: PSR log-log diagnostic plot



Fit Statistics:

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_f	[m/sec]	1.37E-13	9.82E-14	1.90E-13
P_f	[kPa]	4892.9	4776.8	5009.0
Ss_f	[1/m]	1.01E-06	6.81E-07	1.49E-06

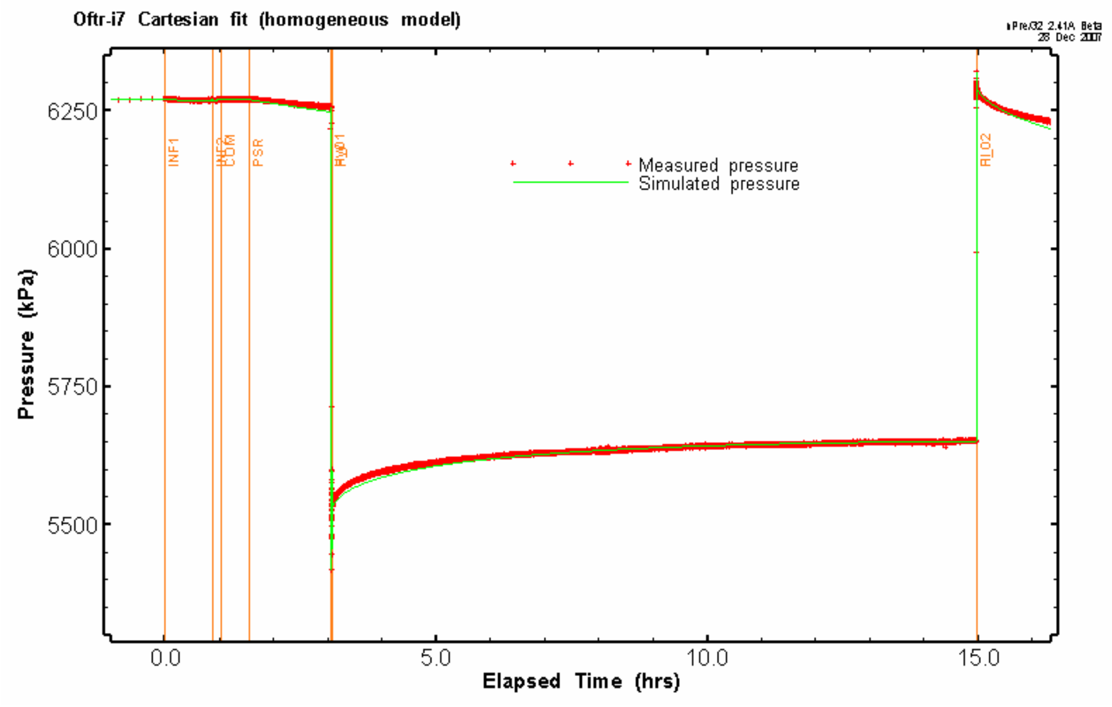
Figure 8: Oftr-i7: PW normalized pressure plot (Ramey A)



Fit Statistics:

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_f	[m/sec]	1.46E-13	1.80E-14	1.18E-12
P_f	[kPa]	6325.9	6304.0	6347.9
Ss_f	[1/m]	8.32E-07	8.43E-08	8.21E-06

Figure 9: Oftr-i7: PI normalized pressure plot (Ramey A)



Fit Statistics:

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_f	[m/sec]	7.58E-14	7.21E-14	7.97E-14
P_f	[kPa]	4795.0	4768.1	4821.8
Ss_f	[1/m]	1.76E-06	1.64E-06	1.88E-06

Figure 10: Oftr-i7: Cartesian fit of the entire test for homogeneous model

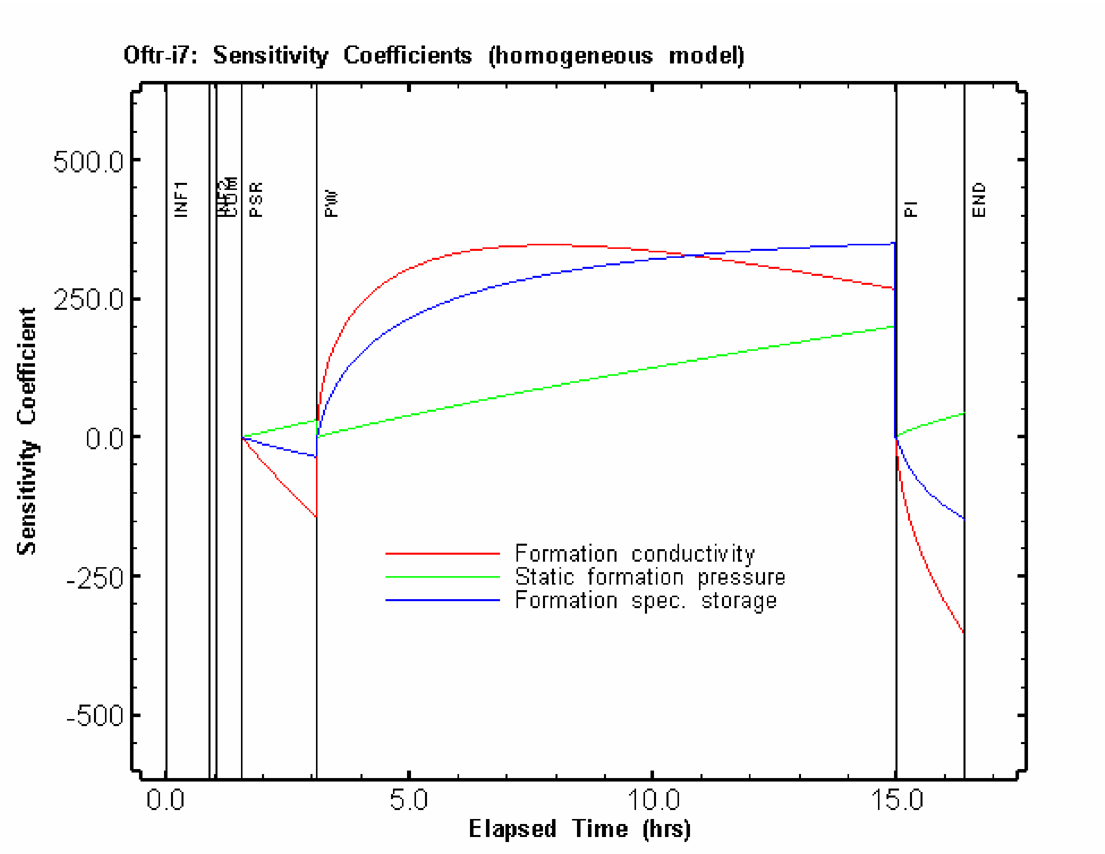


Figure 11: Oftr-i7: Sensitivity coefficients for the different formation parameters during the different sequences

Abbreviations

	Test phases
COM	Compliance
INF	Packer inflation
INF1	Inflation of lower packer (INF2 = Inflation of upper packer)
DEF	Packer deflation
DEF1	Deflation of lower packer (DEF2 = Deflation of upper packer)
PSR	Static pressure recovery (shut-in valve closed)
SI	Slug injection test
SIS	Pressure recovery after slug injection test (shut-in)
SW	Slug withdrawal test
SWS	Pressure recovery after slug withdrawal test (shut-in)
PI	Pulse injection test
PW	Pulse withdrawal test
HI	Constant head injection test (constant pressure difference)
HIS	Pressure recovery after constant head injection test (shut-in)
HW	Withdrawal test applying constant differential head
HWS	Pressure recovery after constant head withdrawal test (shut-in)
MR	Multi-rate test: Test with variable flow rate
MRS	Pressure recovery after test with variable flow rate
RW	Pump test with constant flow rate
RWS	Pressure recovery after pump test with constant flow rate (shut-in)
RI	Constant flow injection test
RIS	Pressure recovery after constant flow injection test (shut-in)
VC	Shut-in valve is closed
VO	Shut-in valve is open
	General
CBP	Cooper, Bredehoeft, Papadopulos (type-curve matching method)
DAS	Data acquisition system
FS	Full scale
IARF	Infinite acting radial flow
LC	Log cycle
m agl	Meters above ground level
m bgl	Meters below ground level
m asl	Meters above sea level
OD	Outer diameter
PVT	Pressure volume temperature correlation
Sdev	Standard deviation
SLA	Straight-line analysis
TOC	Top of casing
WL	Water level (or WT = water table)

Nomenclature

	Description	SI-Unit		Description	SI-Unit
b	Y-intercept of linear regression		S_S	Specific storativity	m^{-1}
C	Wellbore storage constant	$m^3\ Pa^{-1}$	S_{SS}	Specific storativity of skin zone	m^{-1}
C_S	Wellbore storage constant, shut-in	$m^3\ Pa^{-1}$	s	Skin factor	-
C_D	Dimensionless wellbore constant	-	t, Δt	Time, elapsed time	s
c_f	Pore volume based compressibility	Pa^{-1}	t_C	Critical time	s
c_r	Rock compressibility	Pa^{-1}	t_D	Dimensionless time	-
c_{SC}	System compressibility (= test zone compressibility c_{tz})	Pa^{-1}	Δt_e	Equivalent time (after Agarwal)	s
c_w	Water compressibility	Pa^{-1}	Δt_H	Horner time	-
Δh	Differential head	m	t_p	Production time	s
g	Acceleration of gravity (9.81)	$m\ s^{-2}$	t_p*	Corrected production time	s
h_S	Static head	m	t_m	Match time	s
k	Intrinsic permeability	m^2	t_0	X-intercept of linear regression	s
K, K_f	Hydraulic conductivity of formation () special case	m/s	t_s	Thickness of skin zone	m
K_s	Hydraulic conductivity of skin zone () special case	m/s	T	Transmissivity	m^2/s
L	Interval length	m	T_W	Water temperature	°C
m	slope (regression)		z_1	P1 sensor depth	m
P	Pressure	Pa, kPa	z_2	P2 sensor depth	m
P_0	Minimal or maximal pressure	Pa, kPa	z_3	P3 sensor depth	m
P_{atm}	Probe signal at atmospheric pressure	Pa, kPa			
ΔP	Differential pressure, pressure change	Pa, kPa	α ,β	Type-curve match parameter	-
P_D	Dimensionless pressure	-	α	aquifer compressibility	Pa^{-1}
P_f	Static formation pressure	Pa, kPa	μ	Dynamic viscosity	Pa·s
P_i	Initial pressure	Pa, kPa	θ	Porosity	-
$P_{min/max}$	Minimal/maximal pressure	Pa, kPa	ρ_w	Density of fresh water	kg/m^3
P_{S1}	Static pressure in P1-Interval (below bottom packer)	Pa, kPa			
P_{S2}, P_f	Static pressure in test interval	Pa, kPa			
P_{S3}	Static pressure in annulus (above upper packer)	Pa, kPa			
q	Flow rate	$m^3\ s^{-1}$			
q_{end}, q_e	Last flow rate	$m^3\ s^{-1}$			
Q, Q_{tot}	Cumulative flow	m^3			
r_e	Effective radius (Slug, Pulse test)	m			
R_i	Radius of influence	m			
R^2	Correlation coefficient	-			
r_c	Tubing radius	m			
r_w	Wellbore radius	m			
R_1	Radius, composite model	m			
R_D	Dimensionless radius	-			
S	Storativity	-			
S_C	Sensitivity coefficient				
S_{SC}	Scaled sensitivity coefficient				

Definitions

$C_D = \frac{\rho \, g \, C}{2\pi \, S \, r_{w^2}}$	Wellbore constant, dimensionless
$H_D = \frac{P - P_i}{P_0 - P_i}$	Dimensionless pressure (slug und pulse tests)
$K = \frac{k \, \rho \, g}{\mu}$	Hydraulic conductivity
$P_D = \frac{2\pi \, T \, \Delta h}{q}$	Dimensionless pressure
$\Delta P = \rho \, g \, \Delta h$	Differential pressure
$q_D = \frac{q}{2\pi \, T \, \Delta h}$	Dimensionless flow
$t_D = \frac{t \, T}{r_w^2 S}$	Dimensionless time
$S = S_S \, L$	Storativity
$s = \left(\frac{K_f}{K_s} - 1 \right) \ln \left(\frac{r_w + t_s}{r_w} \right)$	Skin factor
$S_S = \rho \, g \, (\alpha + \theta \, c_w)$	Specific storativity
$S_C = \frac{\partial P}{\partial r}$	Sensitivity coefficient.

where ∂P is the partial derivative of the calculated system response (i.e., pressure) with respect to a parameter varied by the derivative span ∂r .
For comparison of sensitivity coefficients for different parameters, the sensitivity coefficients are typically scaled by inverses of the respective standard deviations as follows:

$$S_{sc} = S \frac{\sigma_r}{\sigma_P} = \frac{\partial P}{\partial r} \cdot \frac{\sigma_r}{\sigma_P}$$

where S_{sc} is the scaled sensitivity coefficient, σ_r is the a priori standard deviation of the measurement error, and σ_P is the estimated standard deviation of the parameter.
If not otherwise stated, default values σ_r = 1 and σ_P = 1 were used.

Definitions (continued)

T = K L	Transmissivity
$\frac{t_D}{C_D} = \frac{2\pi T t}{\rho \; g C}$	Dimensionless time axis
$t_e = \frac{t_p \cdot \Delta t}{t_p + \Delta t}$	Dimensionless Agarwal time (Agarwal, 1980)
$t_e^* = \frac{t_P^* \cdot \Delta t}{t_P^* + \Delta t}$	Modified Agarwal time (using corrected production time)
$t_P^* = \frac{Q}{q_{end}}$	Modified production time (Ehlid-Economides and Ramey, 1980)

Form

DAILY LOG REPORT

Oftringen Hydraulic Testing: Interval 7: 632.50 – 641.59 m

Date	*Time*	*Activity*	*Who*
29.10.2007	20:20	Tubing out of borehole from interval i6	SR, FP
	20:39	Drill small holes in x-over 1.33 m and 1.47 m below UPLS to facilitate evasion of potential gas trapped in the test zone	JH, Sti
	21:10	Start installation of system: straddle length: 9.09 m	
	21:12	Test TSSP-S1 at atmospheric pressure, probe vertical Start file: Oftr_2007_10_29_atm1.dat P1 = 99.04 kPa P2 = 89.93 kPa P3 = 105.04 kPa T1 = 9.66 °C T2 = 10.05 °C T3 = 9.79 °C Water table: 41.40 m bgl, fill up casing with water	
	21:15	SR, FP leave site	SR, FP
	21:20	Start installation of test tubing	
	22:45	Check triple probe S1 (last tubing installed: TU32) File: Oftr_2007_10_29_chk1.dat 32 rods are in hole. P1 = 2174.12 kPa P2 = 2158.33 kPa P3 = 2157.59 kPa T1 = 20.03 °C T2 = 19.92 °C T3 = 19.80 °C Water table: -1.42 m bgl, top casing Stick up rods: 2.78 m	
	23:00	Continuation installation	
	23:50	Check triple probe S1 (last tubing installed: TU64) File: Oftr_2007_10_29_chk2.dat 64 rods and pump housing are in hole. P1 = 4206.85 kPa P2 = 4198.32 kPa P3 = 4195.87 kPa T1 = 29.52 °C T2 = 29.45 °C T3 = 29.45 °C Probe works fine, values reasonable	
30.10.2007	00:25	Continuation of installation	
	01:00	System sticks slightly in the borehole, TU 96 1.5 m installed	
	01:30	System free, pulling with 6 tons overload possible. Further installation without problems	
	01:25	System on position, fill annulus up to the top	
		Interval 7: 632.50 – 641.59 m	
	01:32	Start file: Oftr_2007_10_30_oftr_i7.dat P1 = 6281.66 kPa P2 = 6269.33 kPa P3 = 6270.50 kPa T1 = 44.41 °C T2 = 44.45 °C T3 = 44.46 °C Water table: -1.42 m bgl, at top of casing	
	02:00	Start inflation of packer 1	
	02:15	Start inflation of packer 2 (packer pressure increase is not recorded). Slow increase of packer pressure	

Form

DAILY LOG REPORT

SOLEXPERTS

Date	Time	Activity	Who
30.10.07	02:27	Both packers are pressurized by pressure vessel at 35 bar (PA1 and PA2 pressure lines are interconnected)	
	03:00 03:10	Shut-in (Start PSR) Swabbing to 80 m below top of 1.9" tubing rods	JH, Sti
	04:10	Recording P4-sensor at atmospheric pressure P4 = 99.85 kPa	
	04:15	Installation of P4 Sensor in 1.9"NU tubing (calculated depth = 82.57 m below top of rods).	
	04:30	Water table in 1.9''NU: 77.34 m below top of rods, P4 Sensor 151.23 kPa	
	04:31	Scan rate 1 s	
	04:35	Start PW-test, valve open during 65 s, Water table in 1.9''NU: 77.15 m below top of rods, P4 Sensor: 151.75 kPa => ΔP = 0.52 kPa, $\Delta s_{calculated}$ = 5.3 cm	
	04:48	Remove P4, signal at atmospheric pressure = 99.66 kPa	
	05:15	Sti leaves site	Sti
	07:00	SR arrives on site	SR
	07:15	JH leaves site	JH
	08:00	FP arrives on site	FP
	10:00	Flush flowboard and chemical flow cell	
	16:00	Fill up tubing to top of the test rods	
	16:07	Installation of P4-Sensor	
	16:11	Start P4-Sensor, P4 = 397.986 kPa	
	16:19	Change scan rate to 1 s	
	16:25	Start PI-test	
		P4 = 397.613 => ΔP = 0.373 kPa = 3.80 cm => ΔV = 0.049 l	
	16:30	Fill up tubing to top: ΔV = 0.055 l	
	17:14	Scan rate 5 s	
	17:40	Packer deflation	
	18:14	Water table: -0.48 m bgl	
	18:27	Stop file	
	18:45	System blocked, packer need more time to deflate	
	18:55	Attempt to move system, overload 3-4 tons	
	19:00	JH, Sti arrive on site	
	19:05	FP leaves site	
	19:15	Overload of 8-10 tons	
	19:45	Pump water in tubing and borehole to deflate packers	
	20:00	Move system stepwise with 11.5 tons overload	
	20:45	System free, take out 2 rods for next interval	

JH Jörg Hayer
FP Fredi Portmann
Sti Daniel Stillhard
SR Sacha Reinhardt

Fbe Dr. Bernd Frieg (Nagra)

Form

INSTALLATION RECORD HDDP

SOLEXPERTS

Seite 1 / 1

Oftringen NOK EWS Borehole: Hydraulic Testing						Date	29.10.2007	Project Leader	Fi/SR
Borehole	NOK EWS 2007	Direction	vertical	Reference point	433.0	JOB Nr	1763	Location	Oftringen
Borehole Depth	719.0 m	Casing depth	376.5 m bgl	Interval lenght	9.09 m	Test Name	oftr_i7	System	HDDP 110
Borehole diameter	146 mm	Stickup	-3.50 m	Water depth	-1.42 m bgl	Test depth (UPLS)	632.50 m bgl	Probe ID	TSSP S1

Note: All depths shown are not correct for borehole deviation

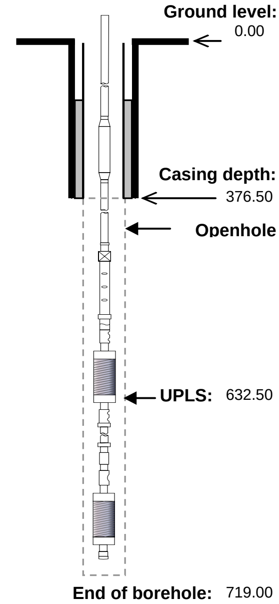
		Qty -	L unit m	L total m	Depth m	OD mm	ID mm	Wgt kg	Str t
Stickup	-3.50 m bgl								
Ground level					0.00				
Tubing 1.9" NU			628.73	628.73		56.1	40.3	2578	12.0
Pop joint			1.02		625.23	56.1	40.3	4.2	12
SIT Non Displacement Valve			0.84			79.0	24.0	20.6	15
Probe Shell Carrier mit Triple Sub	TSSP P3		1.97		629.06	70.0	10.9	48.0	25
	TSSP P2		0.30		629.36				
	TSSP P1		0.30		629.66				
			0.04						
X-Over	2"3/8 EU Pinx1.9" NU Box		0.51	7.27		66.0	40.0	2.1	16
Safety joint 3"1/16						78.0	50.5	5.5	24
Above Side Entry Sub (ASES)			0.52			66.0	32.0		24
Packer Stick Up			0.26			--	25.0		
Up. Packer Seal	UPUS		0.26		631.25				
Upper Packer			1.25			108.0	32.0	82.4	17
	UPLS		0.24		632.50				
Straddle Length: Packer Stick Down			0.31			--	25.0		
Below Side Entry Sub (BSES)			0.52			66.0	32.0		24
X-Over	1.9" NU Pinx2"3/8 EU Box		0.26			--		3.0	16
Tubbing 1.9" NU			4.55			56.1	40.3	18.7	12
X-Over	2"3/8 EU Pinx1.9" NU Box		0.45	9.09		--		3.0	16
			0.3						
Filter	Screen		1.45			72.0	50.0	19.0	19
			0.3						
P1-Seal Sub			0.3			78.0	--		24
Packer Stick Up			0.16			--	32.0		
Lower Packer Seal	LPUS		0.25		641.59				
Lower Packer			1.25	1.92		110.0	32.0	70.2	17
	LPLS		0.24		642.84				
Packer Stick Down			0.43			--	32.0		
End Cap					643.51	78.0	--		
End of Borehole					719.00				

Comments:

1) Bench test 26.10.07, except for P4

2) P4 measurement at atmospheric pressure on 30.10.07, 04:50

Borehole configuration:



Probe		523 006.1
values at atmosphere [1]	P1	98.1
	P2	90.6
	P3	104.4
	P4	99.66 [2]
	T1	7.5
	T2	7.3
	T3	7.1
Total Weight (kg)		2875.0

Form

TALLY LIST

SOLEXPERTS

Borehole	NOK EWS 2007	Interval name	Test Oftr_i7
Depth	719.0 m	Interval depth	632.5- 641.59 m
Date	29.10.2007	Location	Oftringen

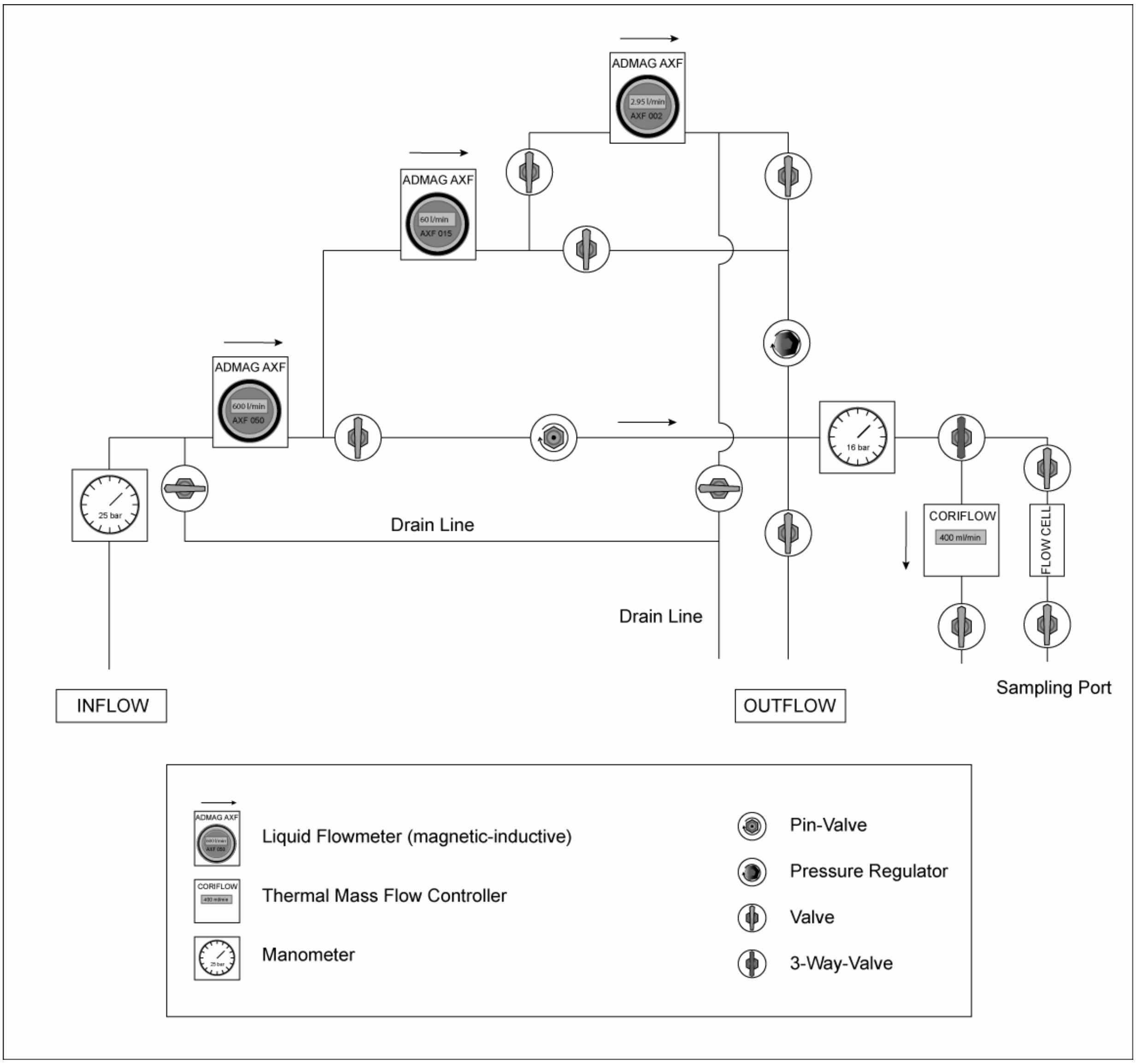
TU	1	6.51	TU	51	6.50				
TU	2	6.51	TU	52	6.51				
TU	3	6.51	TU	53	6.51				
TU	4	6.51	TU	54	6.51				
TU	5	6.51	TU	55	6.51				
TU	6	6.51	TU	56	6.51				
TU	7	6.51	TU	57	6.50				
TU	8	6.51	TU	58	6.51				
TU	9	6.51	TU	59	6.51				
TU	10	6.50	TU	60	6.51				
TU	11	6.50	TU	61	6.50				
TU	12	6.51	TU	62	6.50				
TU	13	6.50	TU	63	6.50				
TU	14	6.51	TU	64	6.50				
TU	15	6.51	TU	65	6.51				
TU	16	6.51	TU	66	6.50				
TU	17	6.51	TU	67	6.50				
TU	18	6.51	TU	68	6.51				
TU	19	6.50	TU	69	6.50				
TU	20	6.51	TU	70	6.50				
TU	21	6.51	TU	71	6.47				
TU	22	6.50	TU	72	6.50				
TU	23	6.51	TU	73	6.48				
TU	24	6.50	TU	74	6.50				
TU	25	6.50	TU	75	6.50				
TU	26	6.50	TU	76	6.50				
TU	27	6.50	TU	77	6.50				
TU	28	6.50	TU	78	6.50				
TU	29	6.50	TU	79	6.51				
TU	30	6.50	TU	80	6.51				
TU	31	6.50	TU	81	6.51				
TU	32	6.50	TU	82	6.50				
TU	33	6.51	TU	83	6.51				
TU	34	6.51	TU	84	6.50				
TU	35	6.50	TU	85	6.48				
TU	36	6.51	TU	86	6.50				
TU	37	6.50	TU	87	6.51				
TU	38	6.50	TU	88	6.50				
TU	39	6.51	TU	89	5.94				
TU	40	6.50	TU	90	5.94				
TU	41	6.51	TU	91	5.93				
TU	42	6.51	TU	92	5.94				
TU	43	6.50	TU	93	5.95				
TU	44	6.50	TU	94	5.95				
TU	45	6.50	TU	95	5.95				
TU	46	6.50	TU	96	5.95				
TU	47	6.51	TU	97	5.95				
TU	48	6.51	PopJoint		1.85				
TU	49	6.51	PopJoint		1.02				
TU	50	6.51							
		325.28			303.45		0.00		0.00

Total string length:	628.73

Form

SURFACE EQUIPMENT LAYOUT

SOLEXPERTS



Flow meter	Lower limit of measuring range	(% of FS)	Upper limit of measuring range (l/min)	Accuracy between 3% and 100% of FS (% of rate)	Accuracy between 1% and 3% of FS (% of rate)	Equipment used
AXF DN2	0.030 l/min	1 %	2.95 l/min	0.35	0.5	no
AXF DN15	0.6 l/min	1 %	60 l/min	0.35	0.5	no
AXF DN50	11.78 l/min	1 %	1178.10 l/min	0.35	0.5	no
Coriflow	0.50 kg/h	2 %	25.00 kg/h	1	1	no

Form

BENCH TEST

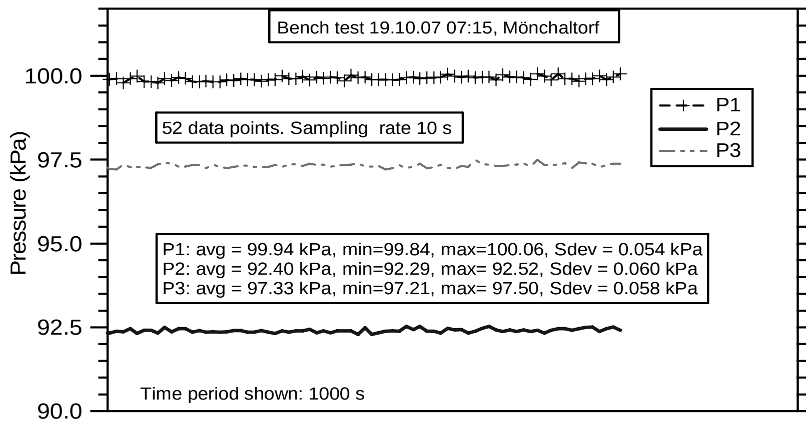
Project	**Location**	**Date**
Oftringen NOK EWS Borehole	Oftringen	20.12.2007
Well name	**Test name**	**Engineer**
NOK EWS 2007	Oftri-i7	Fi/SR

Transducer describtion	**Output units**
P1, P2, P3: 0-206.84 bar (3000 Psi), P4: 0-6 bar, P_{ST} = 0-10 bar	kPa, °C

P1#	**P2#**	**P3#**	**P4#**
43224	50370	43231	591.001.027

Offsite pretest bench test (Date: 19.10.07)

Measurement conditions (P, T and position)	**Sampling rate**
97.7 kPa 5.6 °C	10 s
( ) direct (x) vertical ( ) horizontal	

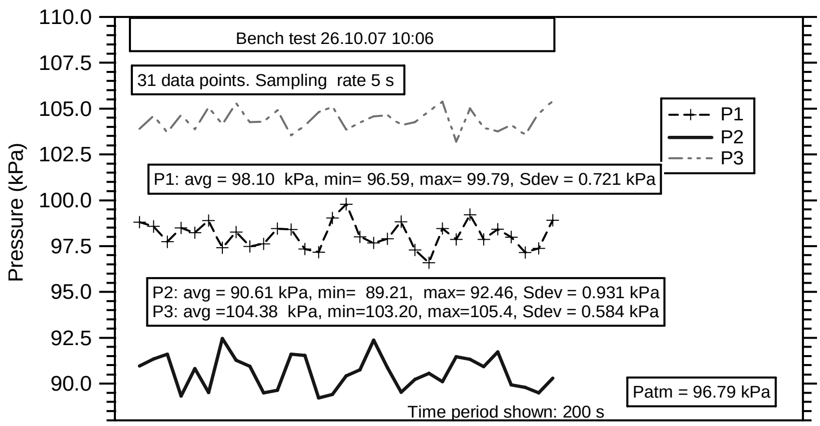


P1 average:	99.84	kPa
P2 average:	92.29	kPa
P3 average:	97.33	kPa
P4 average:	n.m.	kPa
P_{SL} average:	n.m.	kPa
P1 Sdev	0.054	kPa
P2 Sdev	0.060	kPa
P3 Sdev	0.058	kPa

File: TestData24.DAT

Onsite pretest bench test (Date: 26.10.07)

Measurement conditions (P, T and position)	**Sampling rate**
96.4 kPa 7.3 °C	5 s
( ) direct (x) vertical ( ) horizontal	



P1 average:	98.10	kPa
P2 average:	90.61	kPa
P3 average:	104.40	kPa
P4 average:	n.m.	kPa
P_{SL} average:	n.m.	kPa
P1 Sdev	0.721	kPa
P2 Sdev	0.931	kPa
P3 Sdev	0.584	kPa

File: Oftr_2007_10_26_atm2.DAT

Form

BENCH TEST

SOLEXPERTS

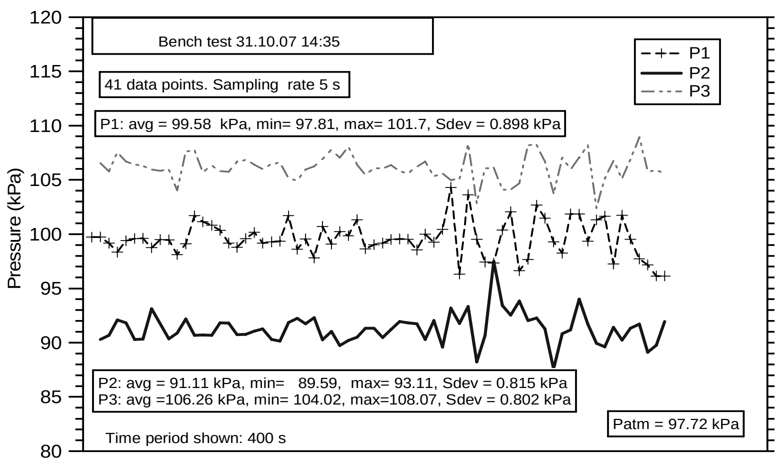
Project	Location	Date
Oftringen NOK EWS Borehole	Oftringen	20.12.2007
Well name	**Test name**	**Engineer**
NOK EWS 2007	Oftri-i7	Fi/SR

Transducer describtion	Output units
P1, P2, P3: 0-206.84 bar (3000 Psi), P4: 0-6 bar, P_{ST} = 0-10 bar	kPa, °C

P1#	P2#	P3#	P4#
43224	50370	43231	591.001.027

Onsite after test bench test (Date: 31.10.07)

Measurement conditions (P, T and position)	Sampling rate
( ) direct (x) vertical ( ) horizontal	



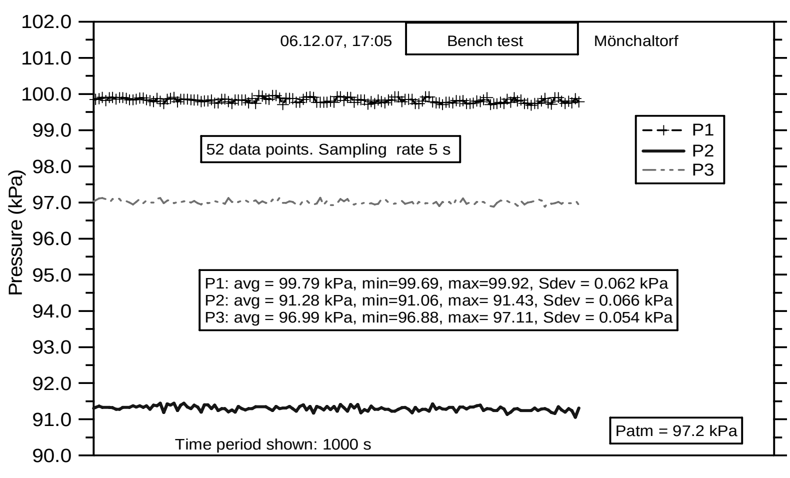
P1 average:	99.58 kPa
P2 average:	91.11 kPa
P3 average:	106.26 kPa
P4 average:	101.36 kPa [1)]
P_{SL} average:	n.m kPa
P1 Sdev	0.898 kPa
P2 Sdev	0.815 kPa
P3 Sdev	0.815 kPa
P4 Sdev	0.0085 kPa [1)]
P_{SL} Sdev	n.m kPa

[1)] Data not shown, 01.11.07, 20:50 Oftr_2007_11_01_oftr_i8.DAT, Patm=98.2 kPa

File: Oftr_2007_10_31_atm1.DAT

Offsite after test bench test (Date: 06.12.07)

Measurement conditions (P, T and position)	Sampling rate
96.6 kPa 9.6 °C	5 s
( ) direct (x) vertical ( ) horizontal	



P1 average:	99.69 kPa
P2 average:	91.28 kPa
P3 average:	96.99 kPa
P4 average: [1)]	101.44 kPa
P_{SL} average:	n.m. kPa
P1 Sdev	0.062 kPa
P1 Sdev	0.062 kPa
P2 Sdev	0.066 kPa
P3 Sdev	0.054 kPa
P4 Sdev	0.007 kPa

[1)] not shown on graph

File: test8.dat

Appendix H

Quick Look Report
Interval Oftr-i8c

nagra.

QUICK LOOK REPORT OFTRINGEN - TEST OFTR-i8c

TEST START (Date/Time)	:	01.11.2007 / 20:48	**TEST END (Date/Time)**	:	02.11.2007 / 08:03

DOUBLE PACKER TEST

Test Interval Information	:		top test interval	:	621.50 m bgl
borehole depth [1), 4)]	:	719.0 m	bottom of test interval	:	630.59 m bgl
borehole radius	:	0.073 m	total interval length	:	9.09 m
tubing radius	:	20.0 mm	midpoint of interval	:	626.05 m bgl
			P2-depth (z_2)	:	618.36 m bgl
interval volume, nominal [5)]	:	0.152 m^3	theoretical Cs-value	:	3.04E-10 m^3/Pa
slim tubing radius		4.75 mm	theoretical C-value (slim tube)	:	7.23E-09 m^3/Pa
WL prior to packer inflation [2)]	:	-1.39 m bgl	P2 signal prior to packer inflation	:	6166.91 kPa
WL in annulus at test end [2)]	:	-1.43 m bgl	P2 offset assuming ρ_{avg} = 997 kg/m3		105.40 kPa

1) all depths are not corrected for borehole deviation from vertical
4) all depth measurements refer to ground level
2) WL = water level
5) cylindrical volume of isolated borehole section
3) assumes a total borehole system compressibility of 2E-09 Pa^{-1}
Note all pressures cited in this report are absolute

Preliminariy information			
longitude of borehole	:	240887	
latitude of borehole	:	638346	
elevation of ground level (GL)	:	433.0 m asl	(reference point for all measurements)
assumed fresh water head	:	433.0 m asl	(assumed hydrostatic)
end of drilling	:	17.10.07 09:55	(Geotec)
porosity	:	3%	(assumed)
mud density [6)]	:	1032 kg/m^3	(Geotec end of drilling, 17.10.07)
borehole water density	:	997 kg/m^3	(Geotec after circulation of fresh water, 17.10.07; estimated using P2)
formation water density [7)]		1001.37 kg/m^3	(PVT correlation calculated by Saphir)
specific storativity [9)]	:	2.19E-06 m^{-1}	
formation water viscosity [7)]	:	6.85E-04 Pa s	(PVT correlation calculated by Saphir)
fluid compressibility [7)]	:	4.33E-10 1/Pa	(PVT correlation calculated by Saphir)
total compressibility [8)]	:	7.43E-09 1/Pa	(calculated assuming cf= 7.00E-09 1/Pa)

6) Taken from daily report No. 53
7) Assumed, using salinity 10'000 ppm, T = 44.1°C, P = 6260 kPa
8) Calculated based on assumed porosity and compressibility values

Responible Test Engineers	
Onsite:	Hayer, J.; Reinhardt, S.
Test analysis and reporting:	Rösli, U.; Fisch, H.R.

Test Summary		
Test objectives	:	transmissivity, static formation pressure, flow model
borehole history	:	drilling through midpoint of interval: 12.10.2007, 17:00; 483.817 h duration until start of test
geology	:	limestone - marl interbedded strata
geophysics	:	Caliper log, salinity log, temperature log, sonic log
test phases	:	COM, PSR, PW, PI

QLR results	**Test zone 621.50 - 630.59 mbgl**	**T [m2/s]**	**K [m/s]**	**Formation Flow model**	**Freshwater Head [m asl]**
Analytical interpretation		(2.71E-12)	(2.98E-13)	radial flow	-
Numerical simulation		1.05E-12	1.16E-13	homogeneous	197.1

Note:
A complete list of results is provided in the summary tables

Mönchaltorf, 07.03.08 / 02.08.08, Revision 1 prepared by: SOLEXPERTS INTERA

Summary of Test Data

Page 1/2

Test Phase		INF	COM	PSR [2)]		PW [1)]	
duration	[h]	0.66	0.34	0.78		8.06	
T2 (i/f)	[°C]	42.55 / 44.14	44.14 / 44.16	44.16 / 44.19		44.09 / 44.17	
P1 (i/f)	[kPa]	6174 / 6200	6200/ 6196	6196 / 6193		6192 / 6184	
P2 (i/f)	[kPa]	6168 / 6166	6166 / 6166	6166 / 6172		5324 / 5446	
P3 (i/f)	[kPa]	6164 / 6165	6165 / 6166	6166 / 6167		6166 / 6168	
P4 (i/f)	[kPa]						
Measured C	[m^3/Pa]					1.22E-10	
c_{SC}	[1/Pa]					8.02E-10	
q	[l/min]						
Q	[l]						
inner boundaries		no analysis	no analysis	wellb. storage		wellb. storage	
flow geometry				hom.		hom.	
outer boundaries				inf.lat.ext.		inf.lat.ext.	
T	[m^2/s]			(1.15E-09)	A)	(2.71E-12)	D)
K	[m/s]			(1.27E-10)	A)	(2.98E-13)	D)
k	[m^2]			(8.86E-18)		(2.08E-20)	
S_S	[1/m]			(1.00E-07)	A)		
S	[-]			(9.09E-07)			
Pi, P_f if matched	[kPa]			(6190.0)	A)	(6172.25)	B)
Head	[m asl]			(434.9)	C)	(433.1)	C)
Derived flow rate	[l/min]						
s (skin factor)	[-]						
S_{SS} (skin zone)	[1/m]						
t_S (skin zone)	[m]						
K_S (skin zone)	[m/s]						
figures				1, 7, 8		1, 5	
temperature effects				no		no	
borehole history				yes		no	
anomalies				no		no	
bypass PA2				no		no	
bypass PA1				no		no	

comments

1) analytical with no superposition
2) numerical simulation with detailed borehole history effects

notes:
- i = initial, f = final
- T, K values in bold most representable of the undisturbed formation

A) matched parameter
B) input parameter
C) calculation assumes: freshwater density 1000 kg/m^3, g = 9.81 m^2/s, P_{atm} and z_2 as stated on front page
D) early-middle time fit
E) extrapolated head

Summary of Test Data Page 2/2

Test Phase		PW [2)]		PI [1)]		PI [2)]		Simulation entire Seq. [2)]	
duration	[h]	8.06		1.35		1.35		11.23	
T2 (i/f)	[°C]	44.09 / 44.17		44.06 / 44.29		44.06 / 44.29		42.55 / 44.29	
P1 (i/f)	[kPa]	6192 / 6184		6182 / 6181		6182 / 6181		6174 / 6181	
P2 (i/f)	[kPa]	5324 / 5446		6160 / 6097		6160 / 6097		6168 / 6097	
P3 (i/f)	[kPa]	6166 / 6168		6166 / 6164		6166 / 6164		6164 / 6164	
P4 (i/f)	[kPa]								
Measured C	[m^3/Pa]			6.64E-11					
c_{SC}	[1/Pa]			4.36E-10					
q	[l/min]								
Q	[l]								
inner boundaries		wellb. storage		wellb. storage		wellb. storage		wellb. storage	
flow geometry		hom.		hom.		hom.		hom.	
outer boundaries		inf.lat.ext.		inf.lat.ext.		inf.lat.ext.		inf.lat.ext.	
T	[m^2/s]	3.64E-12	A)	(8.29E-14)	A)	4.77E-12	A)	**1.05E-12**	A)
K	[m/s]	4.00E-13	A)	(9.12E-15)	A)	5.25E-13	A)	**1.16E-13**	A)
k	[m^2]	2.79E-20		(6.36E-22)		3.66E-20		8.09E-21	
S_S	[1/m]	1.37E-06	A)			6.39E-07	A)	2.73E-06	A)
S	[-]	1.25E-05				5.81E-06		2.48E-05	
Pi, P_f if matched	[kPa]	4076	A)	(5445.59)	B)	6692	A)	**3857**	A)
Head	[m asl]	219.4	C)	(359.0)	C)	486.1	C)	**197.1**	C)
Derived flow rate	[l/min]								
s (skin factor)	[-]								
S_{SS} (skin zone)	[1/m]								
t_S (skin zone)	[m]								
K_S (skin zone)	[m/s]								
figures		1, 9		1, 6		1, 10		11, 12	
temperature effects		no		no		no		no	
borehole history		yes		no		yes		yes	
anomalies		no		no		no		no	
bypass PA2		no		no		no		no	
bypass PA1		no		no		no		no	

comments

notes:
- i = initial, f = final
- T, K values in bold most representable of the undisturbed formation

1) analytical with no superposition
2) numerical simulation with detailed borehole history effects

A) matched parameter
B) input parameter
C) calculation assumes: freshwater density 1000 kg/m^3, g = 9.81 m^2/s, P_{atm} and z_2 as stated on front page
D) early-middle time fit
E) extrapolated head

Test overview

Test Oftr-i8c (621.5 – 630.59 m bgl) was performed on 01.-02.11.2007 in the Oftringen NOK EWS-Borehole. The test interval consisted of a sequence of marls with interbedded limestone layers. The test objectives were to obtain reliable estimates of interval transmissivity and fresh-water hydraulic head using an appropriate flow model. The test was performed with a straddle-packer configuration with an interval length of 9.09 m. Pressures and temperatures were measured in the test interval (P2, T2) and in the interval below the lower packer (P1, T1) and in the annulus above the upper packer (P3, T3). In addition, pressure was measured in the tubing above the upper packer (P4).

The pressure response of the entire test sequence in Oftr-i8c is shown in **Figure 1**. The pressure history derived from water table measurements (source: Colenco, Solexperts) and fluid density measurements (SJ Geotec) is presented in **Figure 2**.

Following packer inflation (INF) the test sequence started with a COM and PSR phase to dissipate temperature and borehole history effects.

Temperature effects are considered negligible, because downhole temperatures (T1, T2, T3) indicated only a relatively small gradual trend of approximately 0.2 degree over the entire test duration, with noise of the same magnitude (**Figure 3**). The PSR phase is possibly influenced by compliance effects due to a decreasing and not fully stabilized packer pressures (Fehler! Verweisquelle konnte nicht gefunden werden.).

The pulse withdrawal test (PW) was performed to measure the wellbore compressibility early in the test and obtain an initial estimate of the formation properties.

After the PW test a pulse injection test (PI) was performed to confirm system compressibility.

Due to the influence of the adjacent high voltage current transformer facility (NOK), the pressure and temperature signals of the downhole triple probe were noisy during the hole testing sequence.

Analysis

For the QLR analysis, the analytical and numerical methods were used for a standard analysis, which will be the basis for a possible detailed analysis depending on the test objectives and test results.

Analytical Analysis

Type curve and straight-line fitting methods are applied. Effects of the borehole pressure history are not taken into account.

Pulse injection test (PW)

The PW test was initiated after a short PSR phase which ended with a slightly increasing pressure trend of about 1.2E-3 kPa/s (P2) probably caused by compliance effects which may not have fully dissipated prior to start of PSR. The PSR flow period was too short to be analyzed. During preparation of PW, the water in the 1.9” test rods was swapped to a level of 80 m below top of tubing. During the pulse test the shut-in valve was opened during about 35 seconds causing a water level increase in the 1.9” test rod of 8.2 cm, indicating a volume release of 0.103 liters due to de-compression of the test zone. The wellbore storage constant C ($\Delta V/\Delta P$) equals to 1.2E-10 m^3/Pa.

The pulse response was analyzed using CBP type-curves. The analysis is presented in **Figure 5**. To avoid an impact from the observed pressure trend, the data were fitted at early time using an α-type-curve of value 0.1. This provides a transmissivity estimate of 2.7E-12 m^2/s and a hydraulic conductivity value of 3.0E-13 m/s. As storativity estimates from pulse test analyses are commonly known as unreliable, the S and S_S results are not presented.

Pulse injection test (PI)

A pulse injection test (PI) was performed subsequently to the PW test in order to confirm the C-value obtained during the PW. The PW ended with a stable pressure trend of 5446 kPa (P2). During preparation of PI, the water in the 1.9” test rods was filled up to the top of the tube. During the pulse test the shut-in valve was opened during about 20 seconds causing a water level decrease in the 1.9” test rod of 3.77 cm, indicating a volume change of 0.0474 liters due to compression of the test zone. The wellbore storage constant C ($\Delta V/\Delta P$) equals to 6.64E-11 m^3/Pa.

The pulse response was analyzed using CBP type-curves. The analysis is presented in **Figure 6**. The fit using an α-type-curve of value 1.0 provides a transmissivity estimate of 8.3E-14 m^2/s and a hydraulic conductivity value of 9.1E-15 m/s. Note that the CBP type-curve matching method is not sensitive for high α-values as α type-curves greater 1 are difficult to distinguish with respect to the slope steepness. High α values are associated with high aquifer storativity values (S). After shut-in, the PI test recovered 9 % during a period of 1.4 hrs.

nSights Analysis

In a first step, the diagnostic plots for the individual sequences were analyzed and fitted individually accounting for borehole history and taking into account of transient effects associated with the preceding test sequences. In a second step, the entire test sequence was simulated and fitted based on the Cartesian pressure plots. For the Cartesian fit, all test phases except history periods were chosen and no weighting for individual events was applied. The so-called history periods BH, INF1, INF2, COM, PW_a and PI_a were not fitted but incorporated as test events with defined pressure in the simulation process. PW_a and PI_a denote very short events of less than 0.01 hrs duration and represent transitional phases during initiation of the pulse tests (open shut-in valve phase at start of pulse tests).

Please note that the fits of the Ramey plots for the PW and PI sequences are the result of the inverse parameter estimation using nSights and represent a solution of a numeric process that includes the effects of potential transient effects of the preceding test phases and the borehole history.

The diagnostic plots of the individual test sequences did not indicate characteristic responses of a composite flow model, or any other more complex flow models. Consequently, a homogeneous model was assumed in this first evaluation for estimating formation parameters (i.e., K, S_s, and P_f). The analyses used the wellbore compressibility of 1.2E-10 m^3/Pa determined from PI. The difference to the wellbore compressibility determined for the PI test (6.6E-11 m^3/Pa) is not significant and therefore the wellbore compressibility was used over the entire test sequences. During the parameter optimization, the specific storativity was allowed to vary within a plausible range from Ss = 1E-7 Pa^{-1} to 1E-5 Pa^{-1}.

The data for the PSR phase with a slightly increasing trend scatter over a wide range in the log-log diagnostic plot indicating dominantly wellbore storage effects (**Figure 7**). Thus, only preliminary estimates of formation parameters are provided (K = 1.3E-10 m/s, S_s= 1.0E-7 m^{-1}, P_f = 6190 kPa), which produced a relatively poor fit of the observed data and for the Horner plot (**Figure 8**).

The diagnostic plot of the PW sequence in terms of the normalized pressures (Ramey A) produced a good fit (**Figure 9**) and provides quite different parameters from the PSR with a low conductivity K of 4.0E-13 m/s, a specific storativity S_s of 1.4E-6 m^{-1} and a very low static formation pressure P_f of 4076 kPa.

The simulated data fit of the PI flow period provides a good fit (**Figure 10**). The obtained K and specific storativity values are similar to the PW simulation results, whereas the static formation pressure is considerably higher (K= 5.3 E-13 m/s, S_s= 6.4 E-7 m^{-1}, P_f = 6692 kPa).

The simulation of the entire test sequence produces a good fit (**Figure 11**) with calculated data similar to the PW phase, but with an even lower static formation pressure (K = 1.2E-13 m/s, S_s =2.7E-6 m^{-1}, P_f = 3857 kPa). The sensitivity coefficients of the formation parameters during the different sequences (**Figure 12**) indicate that the PW test has the greatest sensitivity to conductivity and specific storativity, mainly because of the relatively long duration of 8.1 hours, however, the sensitivity to the static formation pressure P_f is generally very low what might explain the wide range of the determined values for $P_{f.}$ The definition of the sensitivity coefficient is given in the Chapter "Definitions".

Results and Discussion

The shut-in wellbore storage constant values (C) obtained from the pulse tests PW and PI are very low and correspond to system compressibility values (c_{SC}) of 8.0E-10 Pa^{-1} (for PW) and 4.4E-10 Pa^{-1} (for PI). These values are very similar to the expected compressibility of water at depth and temperature conditions of the test zone (expected c_w = 4.3E-10 Pa^{-1}). The measured system compressibilities are considered approximate values because of the limited accuracy inherent to this type of field measurement. The low T and K values obtained from the analytical analyses of the PW and PI phases are considered unreliable in view of the potential transient effects from the preceding borehole pressure history.

The estimated formation conductivity for the different sequences varies over a range from 1.2E-13 m/s to 5.3E-13 m/s based on a homogeneous radial flow model, with the exception of the conductivity determined for the PSR which is considerably higher with 1.3E-10 m/s and seems not to reflect true formation properties. The PSR was possibly influenced by compliance effects which were not fully dissipated. The matched specific storativities except for the PSR phase vary over a range between 6.4E-07 and 2.7E-06 m^{-1}. The range for the matched static formation pressures is very high between about 3857 and 6692 kPa. The analyses of the entire test sequence and of the PW phase give similar conductivities and static formation pressures. Thus, the parameters received from the entire testing sequence fit are considered the most representative parameter values.

The specific storativity values (Ss) of the individually fitted PW and PI sequences are slightly lower than the initial Ss estimate (Ss values as expected based on assumed formation compressibility, porosity, and water compressibility) but agree with storativity values derived from recent data of rock samples (available only for revision of this QLR). Only little percental recovery was observed during these test events indicating that the estimated Ss parameter is not well constrained and may have limited reliability.

The calculated freshwater head from entire testing sequence fit (h_s = 197 m asl) is very low compared to the result from the adjacent and overlapping Interval Oftr-i2 and is even lower than the result from the adjacent Interval Oftr-i7 (h_s = 282 m asl). The static head estimate has to be used with care because testing duration was too short to obtain a reliable estimate.

FIGURES

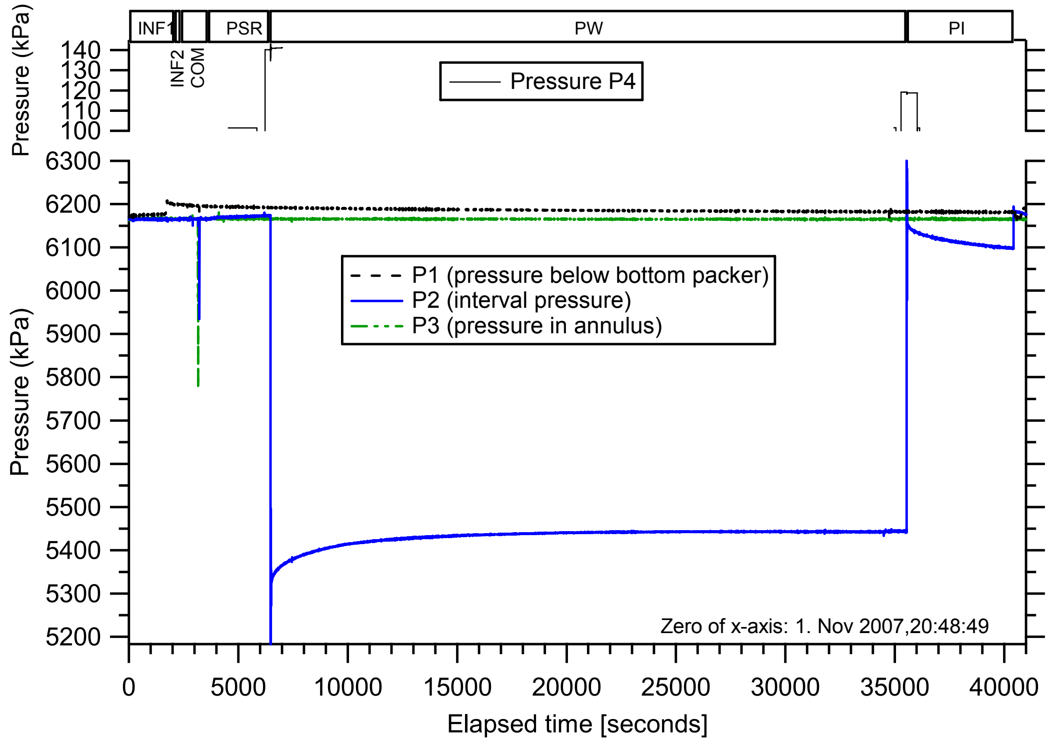


Figure 1: Ofrt-i8c: Overview plot

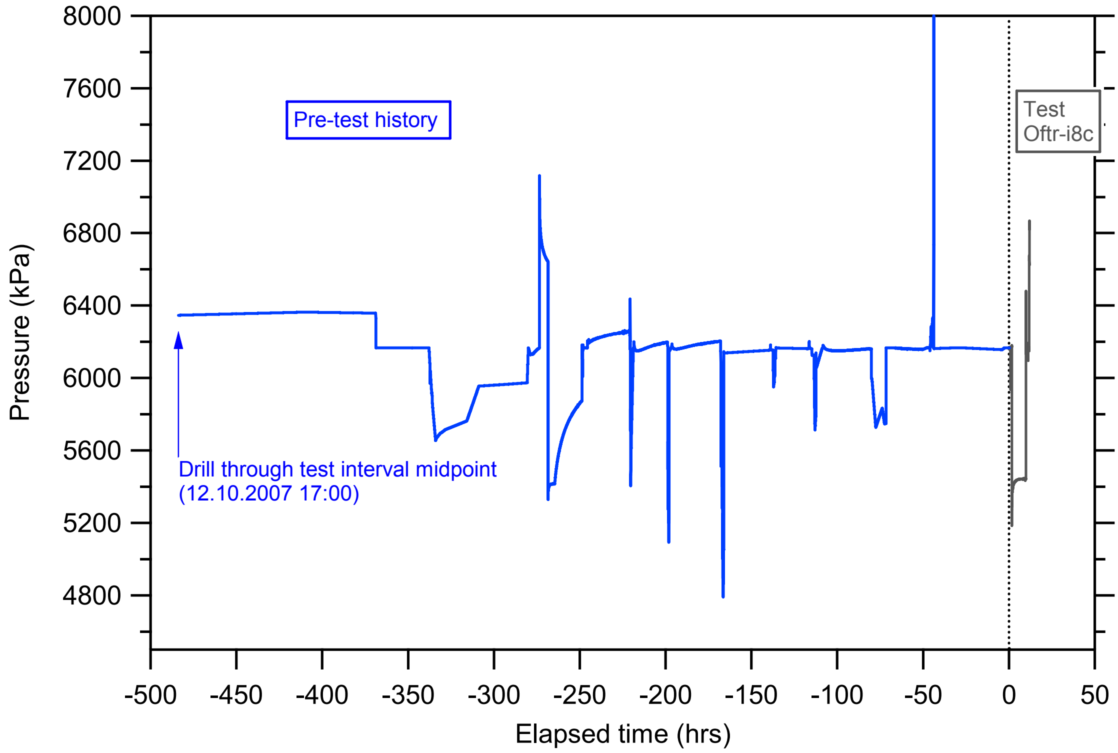


Figure 2: Ofrt-i8c: Borehole pressure history

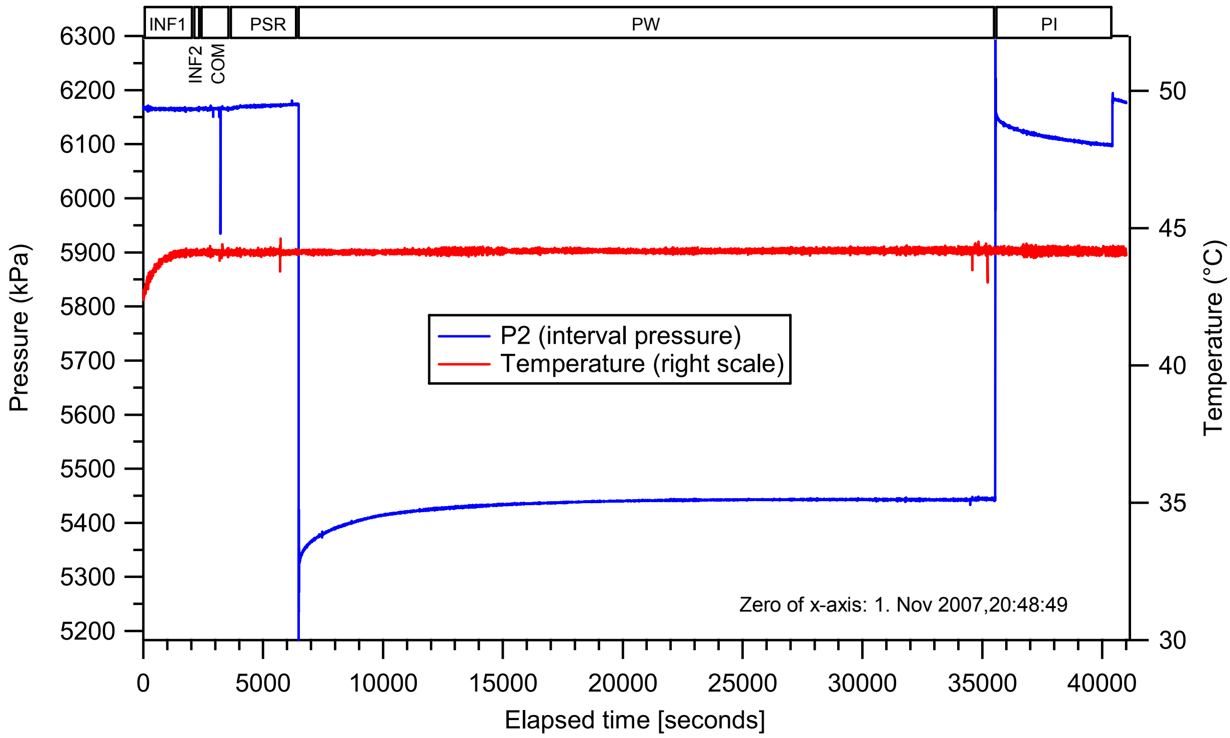


Figure 3: Ofrt-i8c: Measured downhole temperature (T2)

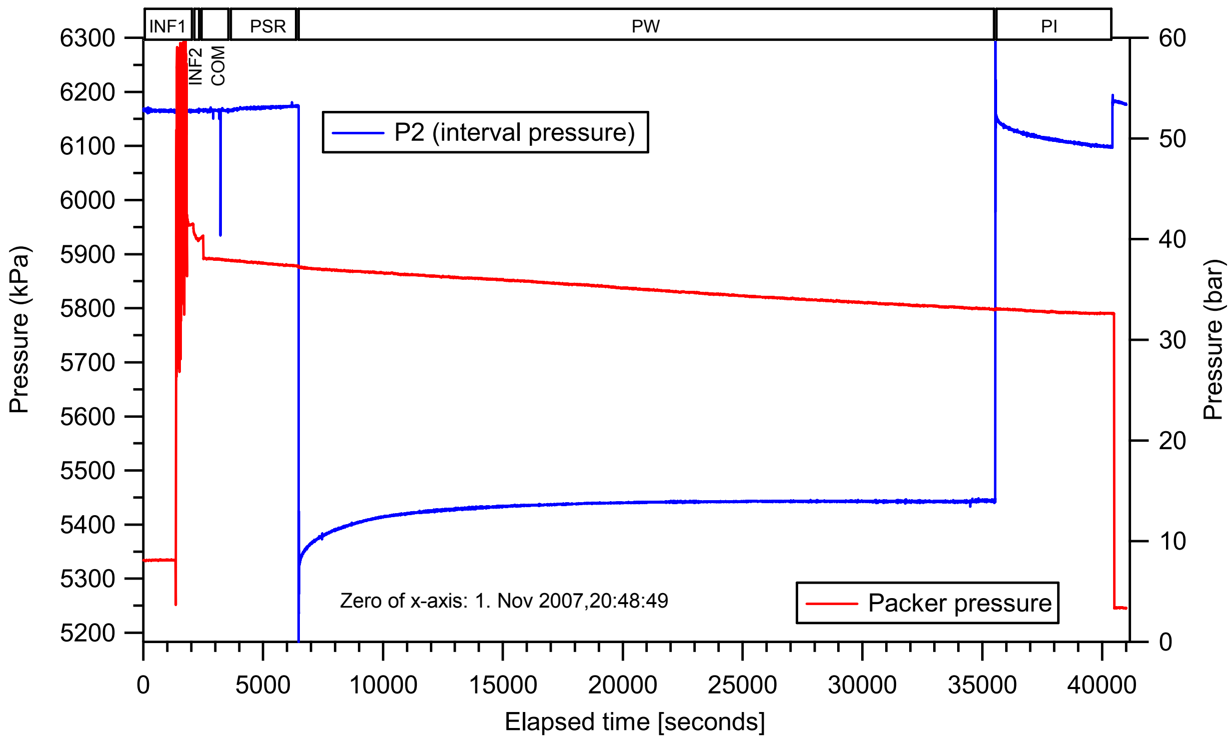


Figure 4: Ofrt-i8c: Measured packer pressure

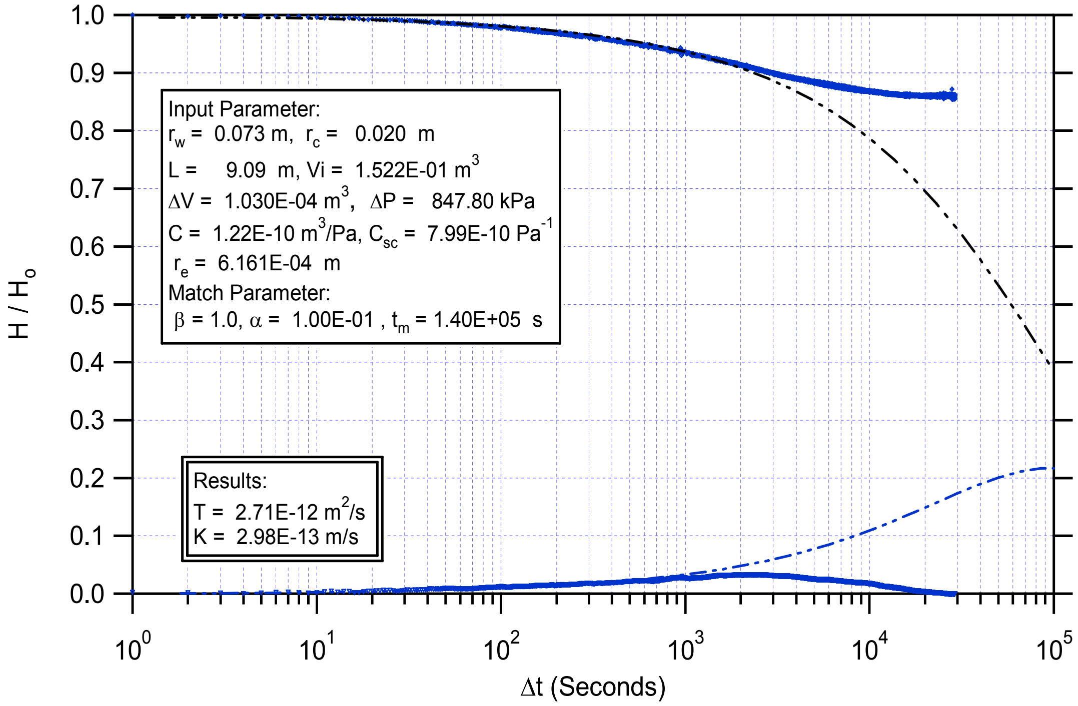


Figure 5: Oftr-i8c: PW test analysis using CBP type-curves

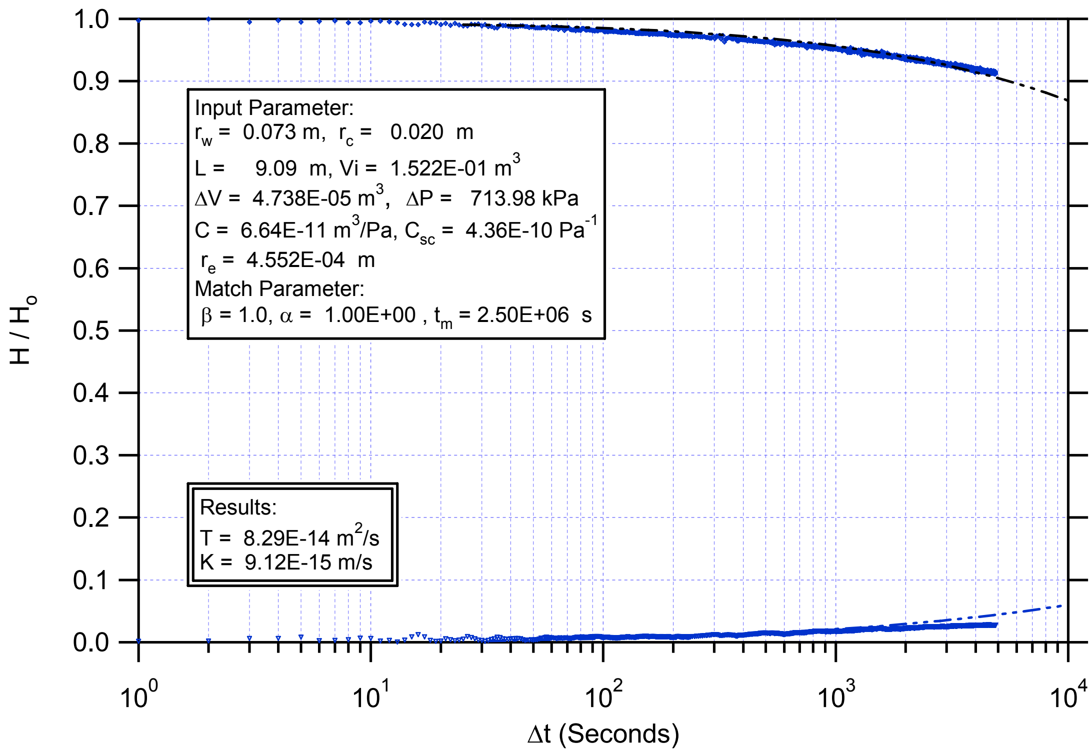


Figure 6: Oftr-i8c: PI test analysis (CBP).

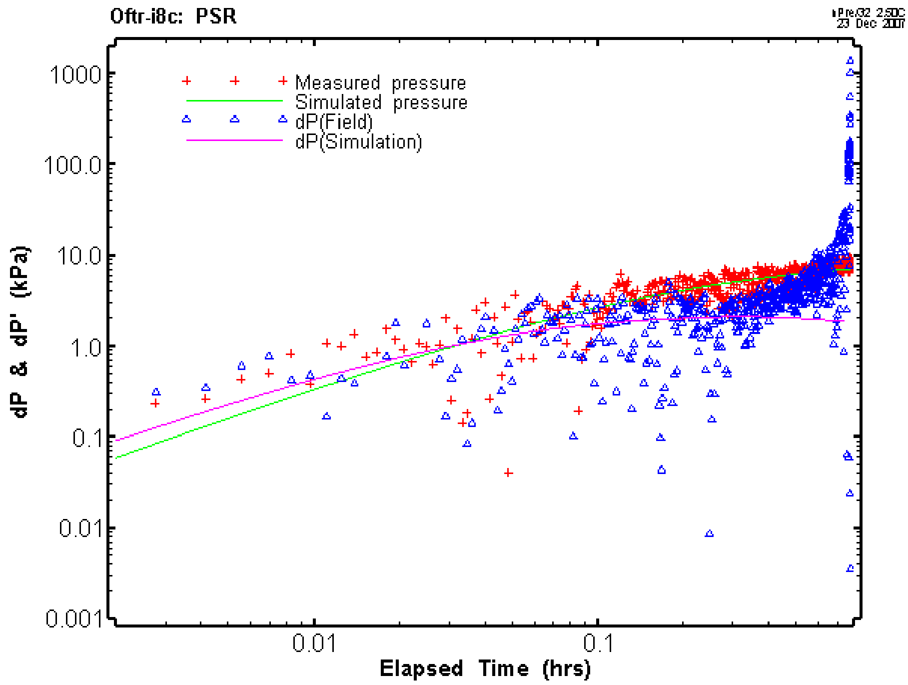


Figure 7: Oftr-i8c: PSR log-log diagnostic plot

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_fm	[m/sec]	1.27E-10	7.40E-11	2.17E-10
P_fm	[kPa]	6189.9	6175.7	6204.0
ss_fm	[1/m]	1.00E-07	9.04E-11	1.11E-04

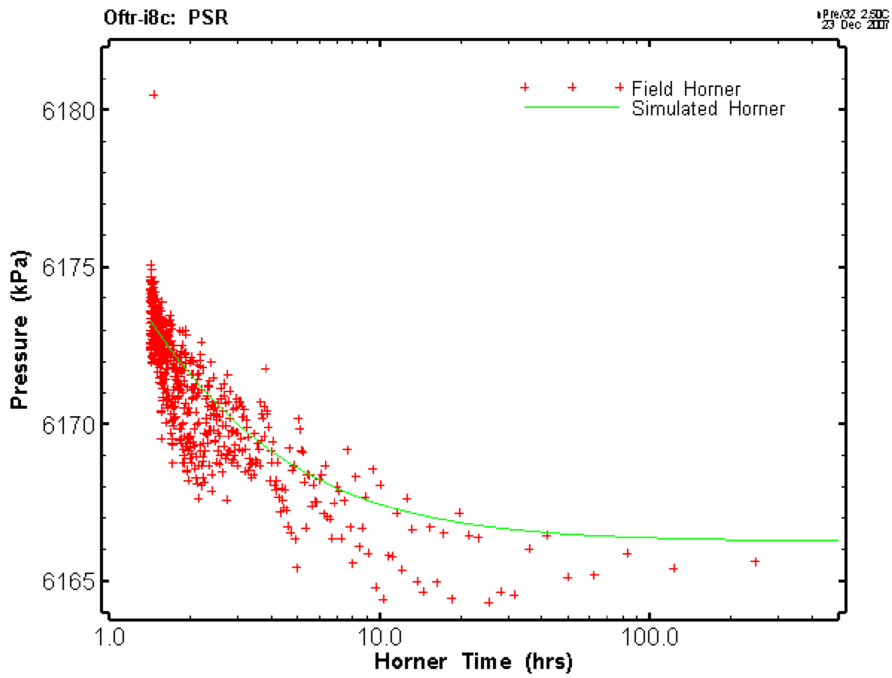
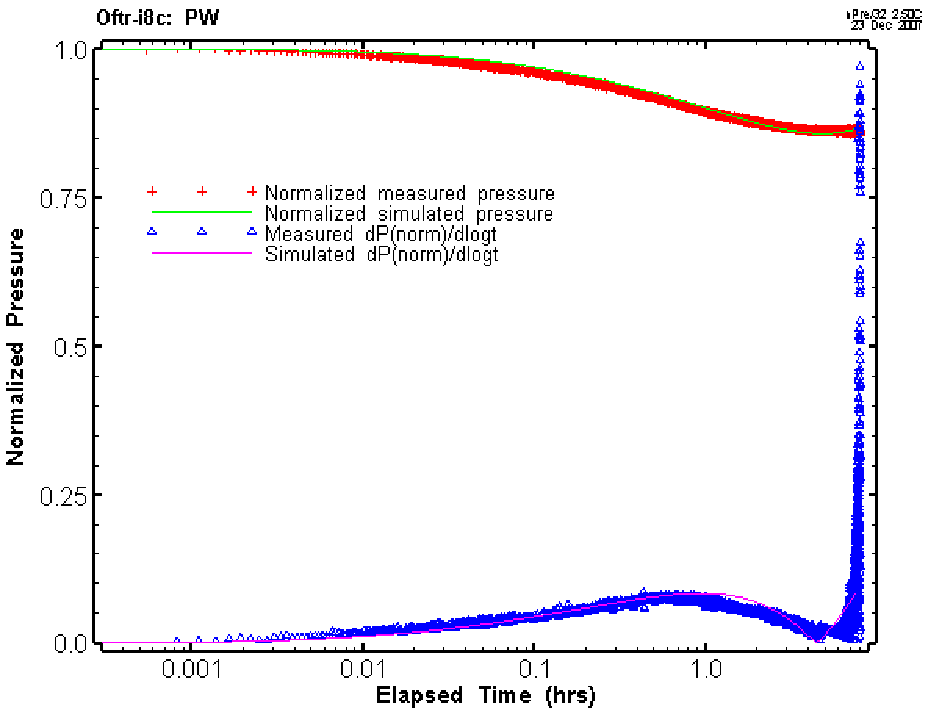


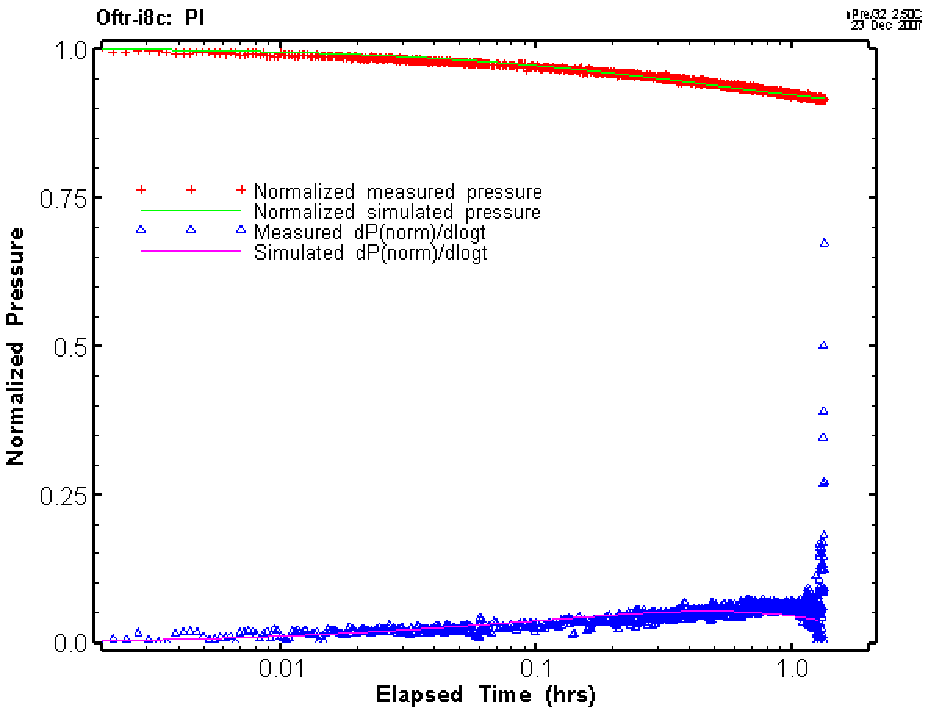
Figure 8: Oftr-i8c: PSR Horner plot



Fit Statistics:

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_fm	[m/sec]	4.00E-13	1.87E-13	5.12E-13
P_fm	[kPa]	4075.8	3720.2	4431.3
ss_fm	[1/m]	1.37E-06	7.56E-06	7.56E-07

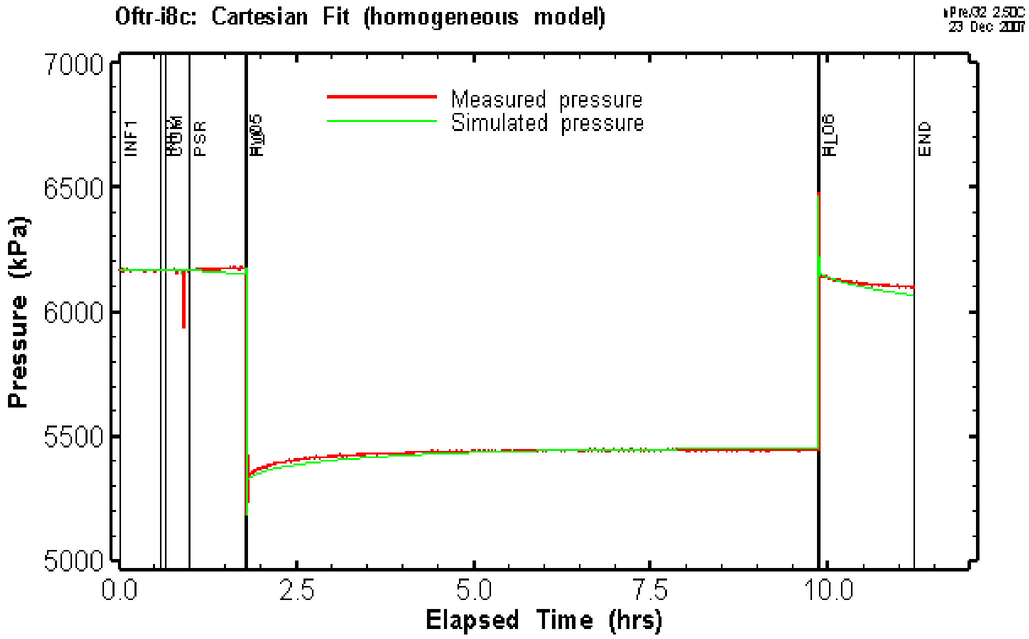
Figure 9: Oftr-i8c: PW normalized pressure (Ramey A) plot.



Fit Statistics:

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_fm	[m/sec]	5.25E-13	2.69E-14	1.03E-11
P_fm	[kPa]	6691.9	5709.4	7674.5
ss_fm	[1/m]	6.39E-07	2.25E-08	1.82E-05

Figure 10: Oftr-i8c: PI normalized pressure (Ramey A) plot.



Fit Statistics:

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_fm	[m/sec]	1.16E-13	1.00E-13	1.35E-13
P_fm	[kPa]	3857.1	3702.7	4011.6
ss_fm	[1/m]	2.73E-06	2.21E-06	3.37E-06

Figure 11: Oftr-i8c: Cartesian fit of the entire test for homogeneous model

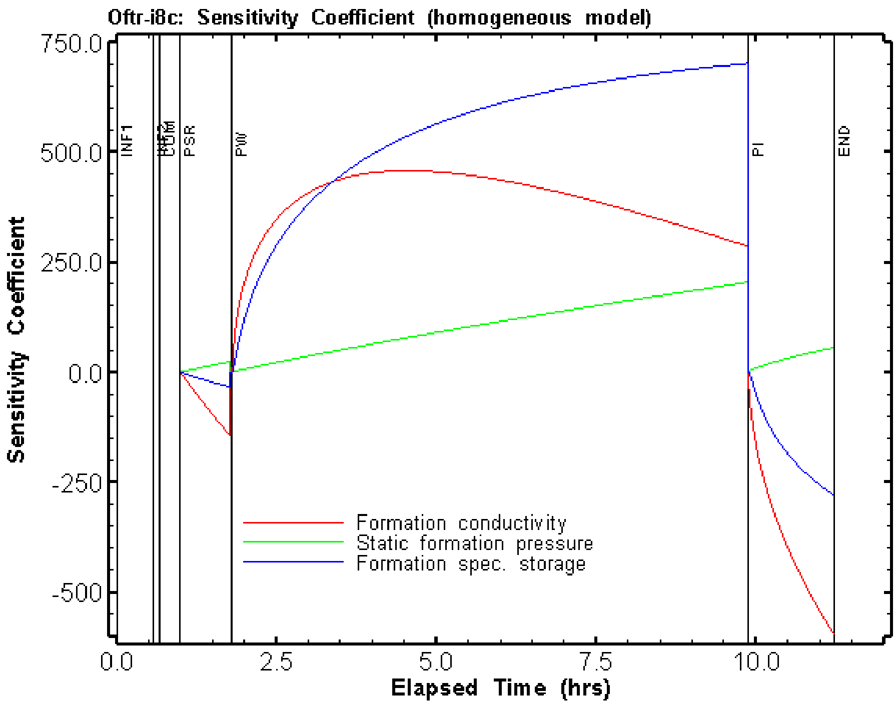


Figure 12: Oftr-i8c: Sensitivity coefficients for the different formation parameters during the different sequences (homogenous model)

Abbreviations

	Test phases
COM	Compliance
INF	Packer inflation
INF1	Inflation of lower packer (INF2 = Inflation of upper packer)
DEF	Packer deflation
DEF1	Deflation of lower packer (DEF2 = Deflation of upper packer)
PSR	Static pressure recovery (shut-in valve closed)
SI	Slug injection test
SIS	Pressure recovery after slug injection test (shut-in)
SW	Slug withdrawal test
SWS	Pressure recovery after slug withdrawal test (shut-in)
PI	Pulse injection test
PW	Pulse withdrawal test
HI	Constant head injection test (constant pressure difference)
HIS	Pressure recovery after constant head injection test (shut-in)
HW	Withdrawal test applying constant differential head
HWS	Pressure recovery after constant head withdrawal test (shut-in)
MR	Multi-rate test: Test with variable flow rate
MRS	Pressure recovery after test with variable flow rate
RW	Pump test with constant flow rate
RWS	Pressure recovery after pump test with constant flow rate (shut-in)
RI	Constant flow injection test
RIS	Pressure recovery after constant flow injection test (shut-in)
VC	Shut-in valve is closed
VO	Shut-in valve is open
	General
CBP	Cooper, Bredehoeft, Papadopulos (type-curve matching method)
DAS	Data acquisition system
FS	Full scale
IARF	Infinite Acting Radial Flow
LC	Log cycle
m agl	Meters above ground level
m bgl	Meters below ground level
m asl	Meters above sea level
OD	Outer diameter
PVT	Pressure volume temperature correlation
SLA	Straight-line analysis
TOC	Top of casing
WL	Water level (or WT = Water table)

Nomenclature

	Description	SI-Unit		Description	SI-Unit
b	Y-intercept of linear regression		S_S	Specific storativity	m^{-1}
C	Wellbore storage constant	$m^3\ Pa^{-1}$	S_{SS}	Specific storativity of skin zone	m^{-1}
C_S	Wellbore storage constant, shut-in	$m^3\ Pa^{-1}$	s	Skin factor	-
C_D	Dimensionless wellbore constant	-	t, Δt	Time, elapsed time	s
c_f	Pore volume based compressibility	Pa^{-1}	t_C	Critical time	s
c_r	Rock compressibility	Pa^{-1}	t_D	Dimensionless time	-
c_{SC}	System compressibility (= test zone compressibility c_{tz})	Pa^{-1}	Δt_e	Equivalent time (after Agarwal)	s
c_w	Water compressibility	Pa^{-1}	Δt_H	Horner time	-
Δh	Differential head	m	t_p	Production time	s
g	Acceleration of gravity (9.81)	$m\ s^{-2}$	t_p*	Corrected production time	s
h_S	Static head	m	t_m	Match time	s
k	Intrinsic permeability	m^2	t_0	X-intercept of linear regression	s
K, K_f	Hydraulic conductivity of formation () special case	m/s	t_s	Thickness of skin zone	m
K_s	Hydraulic conductivity of skin zone () special case	m/s	T	Transmissivity	m^2/s
L	Interval length	m	T_W	Water temperature	°C
m	slope (regression)		z_1	P1 sensor depth	m
P	Pressure	Pa, kPa	z_2	P2 sensor depth	m
P_0	Minimal or maximal pressure	Pa, kPa	z_3	P3 sensor depth	m
P_{atm}	Probe signal at atmospheric pressure	Pa, kPa			
ΔP	Differential pressure, pressure change	Pa, kPa	α ,β	Type-curve match parameter	-
P_D	Dimensionless pressure	-	α	aquifer compressibility	Pa^{-1}
P_f	Static formation pressure	Pa, kPa	μ	Dynamic viscosity	Pa·s
P_i	Initial pressure	Pa, kPa	θ	Porosity	-
$P_{min/max}$	Minimal/maximal pressure	Pa, kPa	ρ_w	Density of fresh water	kg/m^3
P_{S1}	Static pressure in P1-Interval (below bottom packer)	Pa, kPa			
P_{S2}, P_f	Static pressure in test interval	Pa, kPa			
P_{S3}	Static pressure in annulus (above upper packer)	Pa, kPa			
q	Flow rate	$m^3\ s^{-1}$			
q_{end}, q_e	Last flow rate	$m^3\ s^{-1}$			
Q, Q_{tot}	Cumulative flow	m^3			
r_e	Effective radius (Slug, Pulse test)	m			
R_i	Radius of influence	m			
R^2	Correlation coefficient	-			
r_c	Tubing radius	m			
r_w	Wellbore radius	m			
R_1	Radius, composite model	m			
R_D	Dimensionless radius	-			
S	Storativity	-			
S_C	Sensitivity coefficient				
S_{SC}	Scaled sensitivity coefficient				

Definitions

$C_D = \frac{\rho g C}{2\pi S r_{w^2}}$	Wellbore constant, dimensionless
$H_D = \frac{P - P_i}{P_0 - P_i}$	Dimensionless pressure (slug und pulse tests)
$K = \frac{k \rho g}{\mu}$	Hydraulic conductivity
$P_D = \frac{2\pi T \Delta h}{q}$	Dimensionless pressure
$\Delta P = \rho \; g \Delta h$	Differential pressure
$q_D = \frac{q}{2\pi T \Delta h}$	Dimensionless flow
$t_D = \frac{t T}{r_w^2 S}$	Dimensionless time
$S = S_S L$	Storativity
$s = \left(\frac{K_f}{K_s} - 1\right) \ln\left(\frac{r_w + t_s}{r_w}\right)$	Skin factor
$S_S = \rho g (\alpha + \theta c_w)$	Specific storativity
$S_C = \frac{\partial P}{\partial r}$	Sensitivity coefficient.

where ∂P is the partial derivative of the calculated system response (i.e., pressure) with respect to a parameter varied by the derivative span ∂r .
For comparison of sensitivity coefficients for different parameters, the sensitivity coefficients are typically scaled by inverses of the respective standard deviations as follows:

$$S_{sc} = S \frac{\sigma_r}{\sigma_P} = \frac{\partial P}{\partial r} \cdot \frac{\sigma_r}{\sigma_P}$$

where S_{sc} is the scaled sensitivity coefficient, σ_r is the a priori standard deviation of the measurement error, and σ_P is the estimated standard deviation of the parameter.
If not otherwise stated, default values σ_r = 1 and σ_P = 1 were used.

Definitions (continued)

T = K L	Transmissivity
$\frac{t_D}{C_D} = \frac{2\pi T t}{\rho \ g C}$	Dimensionless time axis
$t_e = \frac{t_p \cdot \Delta t}{t_p + \Delta t}$	Dimensionless Agarwal time (Agarwal, 1980)
$t_e^* = \frac{t_P^* \cdot \Delta t}{t_P^* + \Delta t}$	Modified Agarwal time (using corrected production time)
$t_P^* = \frac{Q}{q_{end}}$	Modified production time (Ehlid-Economides and Ramey, 1980)

Form

DAILY LOG REPORT

SOLEXPERTS

Date	**Time**	**Activity**	**Who**
30.10.2007	21:00	System on position, fill annulus up to the top	JH, Sti
		Interval 8: 621.50 – 630.59 m	
	21:09	Start file: Oftr_2007_10_30_oftr_i8.dat P1 = 6173.44 kPa P2 = 6161.57 kPa P3 = 6162.70 kPa T1 = 41.11 °C T2 = 41.30 °C T3 = 41.28 °C Water table: -1.42 m bgl, (= top of 7" casing)	
	21:40	Start inflation of packer 1 (INF1)	
	22:15	Start inflation of packer 2 (packer pressure increase is not recorded). Slow increase of packer pressure	
	22:41	Both packers are pressurized using pressure vessel at 35 bar (PA1 and PA2 pressure lines are interconnected)	
	22:50	Fix installation rods with clamp and tubing spider, slight movement of rods (few cm)	
	23:01	Shut-in (Start PSR), linear pressure increase in interval	
	23:31	Open shut-in valve, slight movement of the water table in tubing	
	23:33	Close valve, linear pressure increase in interval	
	23:48	Disconnect packer lines from pressure tank, interval pressure increase slows down	
	23:59	Connect pressure tank, interval pressure increases	
31.10.2007	00:10	Various phone calls with B. Frieg	
	00:30	Decrease packer pressure to 20 bars. This causes a decrease of interval pressure	
	00:45	Deflate packers. Deflation is accelerated by injecting water into the test zone	
	01:10	Stop file	
	01:30	Start pulling system out of borehole	
	05:00	Tubing is out of borehole	
	06:30	System is out of borehole	
	07:00	SR, FP arrive on site	
	07:30 07:35	JH, Sti leave site Evaluate reasons explaining possible leakages to the test zone: 1) Blow water out of packers for pressurising with nitrogen. Upper Packer in test-tubing (ID 146 mm), pressurise to 30 bars => no visible leakages on packer seal and sliding ends. Same procedure and results at lower packer 2) Packers out of test-tubing: check with nitrogen and leakage spray (8 bar pressure on packer which grows to a OD of 146 mm) => no visible leakages 3) Check mandrill threads 4) Check shut-in tool: pressure decreases from 120 bar (shut in tool closed to 95 bar (tool starts opening). Repeat three times with same observation. Possible bypass from control line shut in tool to interval. Unscrew shut-in tool from probe head to check any water passing packer control line through the valve: no bypass observable. Shut-in tool works fine. Previous observations not reproducible. Possible explanation: particles in o-rings have been removed while opening and closing valve.	JH, Sti SR, FP

Form

DAILY LOG REPORT

Date	Time	Activity	Who
31.10.07		5. Check packer lines in interval => no leakages Arrangements: – change shut-in tool – check system and shut-in tool functionality in 7 inch casing after installation in borehole at 20 m depth: pressurize packers, close shut-in tool, check interval pressure behaviour	SR, FP
	12:50	Check functionality of cable head connector	
	13:20	Start installation of system	
	14:31	Test TSSP-S1 at atmospheric pressure, probe vertical in borehole File: Oftr_2007_10_31_atm1.dat P1 = 99.17 kPa P2 = 90.31 kPa P3 = 105.84 kPa T1 = 14.20 °C T2 = 14.28 °C T3 = 14.27 °C	
	14:38	Fill up casing to the top	
	14:50	Check electric resistivity at cable head and cable winch	
	15:32	Start installation of tubing	
	15:52	Functionality test of packers in borehole Start File: Oftr_2007_10_31_oftr_8_test.dat P1 = 308.98 kPa P2 = 180.00 kPa P3 = 178.17 kPa T1 = 11.96 °C T2 = 11.85 °C T3 = 11.90 °C	
	15:53	Inflation of lower packer (INF1)	
	16:10	Inflation of upper packer (INF2)	
	16:50	Packer are inflated	
	16:52	Fill tubing up to the top	
	16:55	Close shut-in valve, pressure in interval increases	
	17:05	Disconnect PA1 from pressure vessel, slow pressure decrease	
	17:13	Stop file to connect PA2 sensor to power box	
	17:17	Start scanning	
	17:22	Disconnect PA2 from pressure vessel => slow pressure decrease	
	17:25	Open shut-in valve	
	17:27	Decrease PA1 – pressure to 23 bar	
	17:30	Close shut-in valve (110 bar)	
	17:33	Remove water from tubing to check if valve is closed (it is not)	
	17:36	Shut-in valve is closed (125 bar)	
	17:37	Fill up tubing to check if valve is closed (yes), pressure in interval increases	
	14:42	Decrease PA2 – pressure to 23 bar	
	17:50	Open shut-in tool	
	17:51	Close shut-in tool	
	17:55	AK arrives on site	AK
	18:00	Deflate packers, open shut-in tool	
	18:17	Packer deflated, stop file	
	18:18	Move system out of borehole	
	18:50	JH arrives on site	JH
	19:00	System is out of borehole	

Form

DAILY LOG REPORT

Date	***Time***	***Activity***	***Who***
31.10.2007	*19:30*	*Further planning:* *- FP, Sti: check upper packer (especially mandrill with possible hair cracks).* *- JH drives to Solexperts to get both the TAM 4"1/4 and the TAM 3"1/6 packer system including mandrills*	
	19:35	*JH, AK leave site*	*JH, AK*
	20:00	*SR leaves site*	*SR*
	20:05	*Start packer redress, rebuild packer lines and mount new packer sleeve*	
		Pressurize packer mandrill to 50 bars using nitrogen, keep pressure level	
	23:00	*FP, DS leave site*	*FP, DS*
01.11.2007	*00:25*	*JH, AK back on site*	*JH, AK*
	01:00	*Prepare water tank from Daldrup to check the complete packer system submerged in water, pump water into another tank*	
	01:45	*Preparation of installation form for 3"1/6 System*	
	02:45	*Fill up water tank with 10 m^3 of fresh water*	
	03:15	*JH, AK leave site*	*JH, AK*
	07:00	*SR, FP, JH, AK arrive on site*	*SR,FP, JH,AK*
		Preparation of "old" packer sleeve for testing in water tank: Sleeve pressurized at 15 bars = no leaking noticeable.	*JH, AK*
		Test packer sleeve at 46 bars (water), keep 15 minutes pressurized	*FP, SR*
	07:40	*Preparation system for installation*	
	08:40	*Start installation of system*	
	10:11	*Test TSSP-S1 at atmospheric pressure, probe vertical in borehole* *File: Oftr_2007_11_01_atm1.dat* *P1 = 136.04 kPa* *P2 = 91.69 kPa* *P3 = 106.73 kPa* *T1 = 5.98 °C* *T2 = 5.80 °C* *T3 = 5.57 °C* *P1: already below water table* *Water table= -0.34 m bgl*	
	10:35	*Resistivity at connector head to probe: 4.2 KOhm (o.k.)* *Resistivity at winch to probe: 4.04 to 4.25 (changing) => possible humidity somewhere between connector and winch.* *Phone call to Solexperts electronician, research at connector*	
	11:45	*Humidity in connector at flat pack*	
	11:50	*Redress of connector at flat pack*	
	13:05	*Check resistivity at connector and winch with backup probe (TSSP S3) connected: 4.28 kOhm => OK*	
	13:14	*Connect cable connector on probe head, if connector is plugged, the resistivity values are changing between 3.80 and 4.35, if connector is unplugged, the resisitivity between cable to backup probe (4.28 kOhm) and between probe head and downhole probe is good (4.24 kOhm). Possible creeping current on machine? Voltage between tubing and grounding: -0.5 – 20 mV (changing)!*	
	14:00	*Install system in casing for testing the upper packer*	

Form

DAILY LOG REPORT

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Date	Time	Activity	Who
01.11.07	14:27	Functionality test of packers in borehole Start File: Oftr_2007_11_01_oftr_8_test.dat P1 = 213.55 kPa P2 = 183.37kPa P3 = 182.65 kPa T1 = 11.17 °C T2 = 11.18 °C T3 = 10.76 °C	
	14:30	Inflation of lower and upper packer to 30 bars	
	15:40	Connect “old” upper packer to 65 bar (tubing), packer in water, no nitrogen bubbles visible	
	15:48	Packer inflated and stable	
	15:50	Fill tubing up to top	
	15:53	Close shut-in valve, pressure in interval increases up to 5 kPa	
	16:01	Disconnect pressure vessel	
	16:02	P2 stable, 5 kPa higher than before valve was closed	
	16:28	Connect pressure vessel, pressures: P2: + 9 kPa, PA2 +1 bar	
	16:30	Phone call to B.Frieg o.k. for installation	
	16:45	Open valve,	
	16:49	Deflate packers	
	16:50	Stop file	
	17:10	Sti arrives on site	Sti
	17:15	Start installation	
	17:20	FP leaves site	FP
	18:12	Check triple probe S1 (last tubing installed: TU30) File: Oftr_2007_11_01_chk1.dat P1 = 2039.00 kPa P2 = 2032.87 kPa P3 = 2031.81 kPa T1 = 19.37 °C T2 = 19.28 °C T3 = 19.10 °C Water table: -1.42 m bgl, top casing	
		Open packer lines to release packer pressure	
	18:20	Continuation of installation	
	18:58	Check triple probe S1 (last tubing installed: TU56) File: Oftr_2007_11_01_chk2.dat P1 = 3694.62 kPa P2 = 3692.49 kPa P3 = 3690.00 kPa T1 = 27.43 °C T2 = 27.27 °C T3 = 27.17 °C Water table: -1.42 m bgl, top casing	
	18:59	Open packer lines to release packer pressure	
	19:00	JH, AK arrives on site	
	19:10	SR leaves site	
	19::20	Continuation of installation, installation longsome, deflation of packer every other 10 rods	
	20:48	System on position, fill annulus up to the top	

Form

DAILY LOG REPORT

SOLEXPERTS

Date	Time	Activity	Who
		Interval 8: 621.50 – 630.59 m	
01.11.07	20:50	Start file: Oftr_2007_11_01_oftr_i8.dat P1 = 6171.59 kPa P2 = 6167.36 kPa P3 = 6166.95 kPa T1 = 42.87 °C T2 = 42.82 °C T3 = 42.88 °C Water table: -1.39 m bgl, analysis file oftr-i8c.pxp	
	21:13	Start inflation of packer 1	
	21:20	Start inflation of packer 2, slow increase of packer pressure	
	21:35	Both packers are pressurized by pressure vessel at 35 bar (PA1 and PA2 pressure lines are interconnected)	
	21:43	Solexperts technician is installing swabbing tool without instruction, heavy peaks in P2 and P3 on graph	
	21:50	Shut-in (Start PSR)	
	22.00	Swabbing to 80 m below top of 1.9” tubing rods	
	22:11	Recording P4-sensor at atmospheric pressure P4 = 101.35 kPa	
	22:27	Water table in 1.9’’NU: 88.13 m below top of rods	
	22:34	Installation of P4 Sensor in 1.9”NU tubing (depth calculated 92.08 m below top of rods). P4 Sensor 140.12 kPa	
	22:35	Scan rate set to 1 s	
	22:37	Start PW-test, valve open during 35 s. Water table in 1.9’’NU: 87.96 m below top of rods, P4 Sensor: 140.93 kPa => Δs = 8.2 cm	
	22:52	Remove P4, atmospheric pressure = 99.66 kPa	
	23:30	Sti leaves site	Sti
02.11.2007	06:19	Fill up tubing up to the top	
	06:32	Recording P4-sensor at atmospheric pressure P4 = 101.54 kPa	
	06:37	Water table in 1.9’’NU 0.05 m below top of rods	
	06:38	Installation of P4 Sensor in 1.9”NU tubing (depth calculated 1.79 m below top of rods). P4 Sensor 119.12 kPa	
	06:39	Scan rate set to 1 s	
	06:40	Start PI-test, valve open during 20 s, Water table in 1.9’’NU: 0.11 m below top of rods, P4 Sensor: 118.75 kPa => ds = 3.77 cm	
	06:51	Remove P4, signal at atmospheric pressure = 101.31 kPa	
	07:00	SR arrives on site	SR
	07:30	JH, AK leave site	JH, AK
	07:55	Order drill master on site	SR
	08:01	Open shut-in tool	
	08:03	Deflate PA1	
	08:10	FP arrives on site	FP
	08:15	Prepare CR5 pump to accelerate packer pressure release	
	08:35	Drill master arrives on site	
	08:43	Deflate PA2	
	08:43	Pump into interval to support packer release from borehole wall	
	08:44	Stop file	
	08:50	System is pulled 1 meter upwards, then it is blocked again. Overload 1 ton, continue pumping. Continue pulling system (2 tons overload) while injecting water, system moves upwards.	
	09:50	Drill-meter indicates increased overload, stop pumping, pull with overload 5 tons	
	10:00	System is blocked, little quantities of water are still outflowing from the packer lines	

Form

DAILY LOG REPORT

SOLEXPERTS

Date	Time	Activity	Who
02.11.07	10:27	Start file: Oftr_2007_11_02_oftr_i8_test.dat P1 = 5770 kPa P2 = 6158 kPa P3 = 6159 kPa T1 = 37.6 °C T2 = 37.5 °C T3 = 37.8 °C => lower packer is blocked, upper packer is free (P1 is lower than P2 ≅ P3)	SR, FP
	10:45	Information passed to Fbe and get instructions. Start to pull using more force (8 to 10 tons) and wait. Prudence with rotating tubing	
	10:46	Increase pulling force to 6 tons. System is moving upwards (15 cm), pull force decreases to 5 tons, pulling force increased to 6 tons, system is moving upwards by another 14 cm. P1 pressure is stepping down by approximately 2.5 bars at each step and then increases slowly	
	11:00	Packers are deflating with 70 ml/min (PA1 delivers 50 ml/min, PA2 20 ml/min)	
	11:05	Pulling force 4.5 tons	
	11:07	Increase pulling force to 6 tons. P1-pressure drops by 4 bars and then increases slowly, system moves by 16 cm upwards, pull force drops down to 5 tons.	
	11:10	P1 pressure decreases and stabilises	
	11:13	Flow rate PA1: 50 ml/min, close valve PA2	
	11:15	Pulling force on 6 tons, system moved upwards by 26 cm	
	11:19	Flow rate PA1: 50 ml/min	
	11:35	Flow rate PA1: 30 ml/min	
	11:40	Decease pulling force to system weight, increase pulling force to 5 tons while rotating tubing (quarter turn)	
	11:43	Increase pulling force to 6 tons, P1-pressure drops 4 bars and increases slowly, system moves by 30 cm upwards, pulling force drops down to 5 tons. Pulling force at 6 tons, system movement 15 cm, ongoing while keeping pulling force at 6 tons	
	11:47	Continue keeping pulling force at 6 tons, system is moving continuously	
	11:51	System is not moving anymore, pulling force at 6 tons, flow rate PA1: 25 ml/min	
	11:55	Connect water hose to well head	
	12:00	Start injecting water at 20 bars (maximum pump pressure)	
	12:02	Increase pulling force to 8 tons	
	12:04	Move system downwards (15 cm), pull with 8 tons, system movement 20 cm, flow rate PA1: 20 m/min	
	12:06	Release pulling force to 4 bars to let P1 pressure recover, increase pulling force to 8 tons, release it again to 4 bars, increase it, etc.	
	12:30	Distance of system movement since start of above procedure: 80 cm. Flow rate PA1: 15 ml/min	
	12:31	Wait for release of P1 pressure	
	12:49	Pull with 8 tons, movement of system: 24 cm	
	12:50	Disconnect water hose from wellhead	
	12:52	Release pulling force to 4 tons to support P1 pressure recovery, increase pulling force to 8 tons, release it again to 4 tons, increase it, etc.	

Form

DAILY LOG REPORT

Date	Time	Activity	Who
02.11.07	12:57	Packer is detached	SR, FP
	12:58	Stop file	
	13:00	Start moving system to position of Interval 9	

AK Andreas Kern
DS Dragan Stojanovic
JH Jörg Hayer
FP Fredi Portmann
Sti Daniel Stillhard
SR Sacha Reinhardt

Fbe Dr. Bernd Frieg (Nagra)

Form

INSTALLATION RECORD HDDP

SOLEXPERTS

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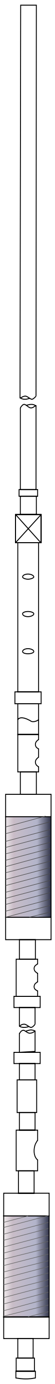
Oftringen NOK EWS Borehole: Hydraulic Testing

Date	30.10.2007	**Project Leader**	Fi/SR						
Borehole	NOK EWS 2007	**Direction**	vertical	**Reference point**	433.0	**JOB Nr**	1763	**Location**	Oftringen
Borehole Depth	719.0 m	**Casing depth**	376.5 m bgl	**Interval lenght**	9.09 m	**Test Name**	oftr_i8	**System**	**HDDP** 110
Borehole diameter	146 mm	**Stickup**	-3.60 m	**Water depth**	-1.39 m bgl	**Test depth (UPLS)**	621.50 m bgl	**Probe ID**	**TSSP** S1

Note: All depths shown are not correct for borehole deviation



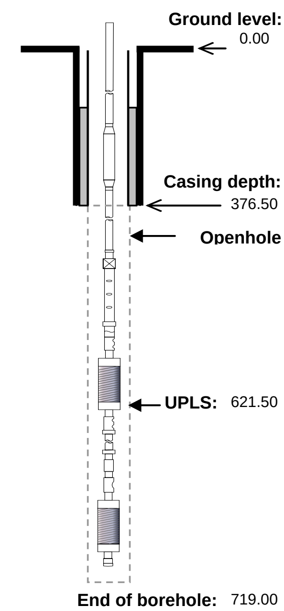
Component			Qty -	L unit m	L total m	Depth m	OD mm	ID mm	Wgt kg	Str t
Stickup		-3.60 m bgl								
Ground level						0.00				
Tubing 1.9" NU				617.83	617.83		56.1	40.3	2533	12.0
Pop joint				1.02		614.23	56.1	40.3	4.2	12
SIT Non Displacement Valve				0.84			79.0	24.0	20.6	15
Probe Shell Carrier mit Triple Sub	TSSP P3			1.97		618.06	70.0	10.9	48.0	25
	TSSP P2			0.30		618.36				
	TSSP P1			0.30		618.66				
				0.04						
X-Over	2"3/8 EU Pinx1.9" NU Box			0.51	7.27		66.0	40.0	2.1	16
Safety joint 3"1/16							78.0	50.5	5.5	24
Above Side Entry Sub (ASES)				0.52			66.0	32.0		24
Packer Stick Up				0.26			--	25.0		
Up. Packer Seal		UPUS		0.26		620.25				
	Upper Packer			1.25			108.0	32.0	82.4	17
		UPLS		0.24		621.50				
Straddle Length	Packer Stick Down			0.31			--	25.0		
	Below Side Entry Sub (BSES)			0.52			66.0	32.0		24
	X-Over	1.9" NU Pinx2"3/8 EU Box		0.26			--		3.0	16
	Tubing 1.9" NU			4.55			56.1	40.3	18.7	12
	X-Over	2"3/8 EU Pinx1.9" NU Box		0.45	9.09		--		3.0	16
				0.3						
	Filter	Screen		1.45			72.0	50.0	19.0	19
				0.3						
	P1-Seal Sub			0.3			78.0	--		24
	Packer Stick Up			0.16			--	32.0		
Lower Packer Seal		LPUS		0.25		630.59				
	Lower Packer			1.25	1.92		110.0	32.0	70.2	17
		LPLS		0.24		631.84				
Packer Stick Down				0.43			--	32.0		
End Cap						632.51	78.0	--		
End of Borehole						719.00				

Comments:

[1] Bench test 31.10.07, except for P4

[2] P4 measurement at atmospheric pressure on 01.11.07, 22:10

Borehole configuration:



Probe	523 006.1	
values at atmosphere	P1	99.6
	P2	91.1
	P3	106.3
	P4	101.4
	T1	14.3
	T2	14.2
	T3	14.1
Total Weight (kg)	**2830.4**	

Form

TALLY LIST

Borehole	NOK EWS 2007	Interval name	Test Oftr_i8	Date	30.10.2007
Depth	719.0 m	Interval depth	621.5- 630.6 m	Location	Oftringen

TU	1	6.51	TU	51	6.50			
TU	2	6.51	TU	52	6.51			
TU	3	6.51	TU	53	6.51			
TU	4	6.51	TU	54	6.51			
TU	5	6.51	TU	55	6.51			
TU	6	6.51	TU	56	6.51			
TU	7	6.51	TU	57	6.50			
TU	8	6.51	TU	58	6.51			
TU	9	6.51	TU	59	6.51			
TU	10	6.50	TU	60	6.51			
TU	11	6.50	TU	61	6.50			
TU	12	6.51	TU	62	6.50			
TU	13	6.50	TU	63	6.50			
TU	14	6.51	TU	64	6.50			
TU	15	6.51	TU	65	6.51			
TU	16	6.51	TU	66	6.50			
TU	17	6.51	TU	67	6.50			
TU	18	6.51	TU	68	6.51			
TU	19	6.50	TU	69	6.50			
TU	20	6.51	TU	70	6.50			
TU	21	6.51	TU	71	6.47			
TU	22	6.50	TU	72	6.50			
TU	23	6.51	TU	73	6.48			
TU	24	6.50	TU	74	6.50			
TU	25	6.50	TU	75	6.50			
TU	26	6.50	TU	76	6.50			
TU	27	6.50	TU	77	6.50			
TU	28	6.50	TU	78	6.50			
TU	29	6.50	TU	79	6.51			
TU	30	6.50	TU	80	6.51			
TU	31	6.50	TU	81	6.51			
TU	32	6.50	TU	82	6.50			
TU	33	6.51	TU	83	6.51			
TU	34	6.51	TU	84	6.50			
TU	35	6.50	TU	85	6.48			
TU	36	6.51	TU	86	6.50			
TU	37	6.50	TU	87	6.51			
TU	38	6.50	TU	88	6.50			
TU	39	6.51	TU	89	5.94			
TU	40	6.50	TU	90	5.94			
TU	41	6.51	TU	91	5.93			
TU	42	6.51	TU	92	5.94			
TU	43	6.50	TU	93	5.95			
TU	44	6.50	TU	94	5.95			
TU	45	6.50	TU	95	5.95			
TU	46	6.50	PopJoint		1.85			
TU	47	6.51	PopJoint		2.02			
TU	48	6.51						
TU	49	6.51						
TU	50	6.51						
		325.28			292.55		0.00	0.00

Total string length:	617.83

Form

SURFACE EQUIPMENT LAYOUT

SOLEXPERTS

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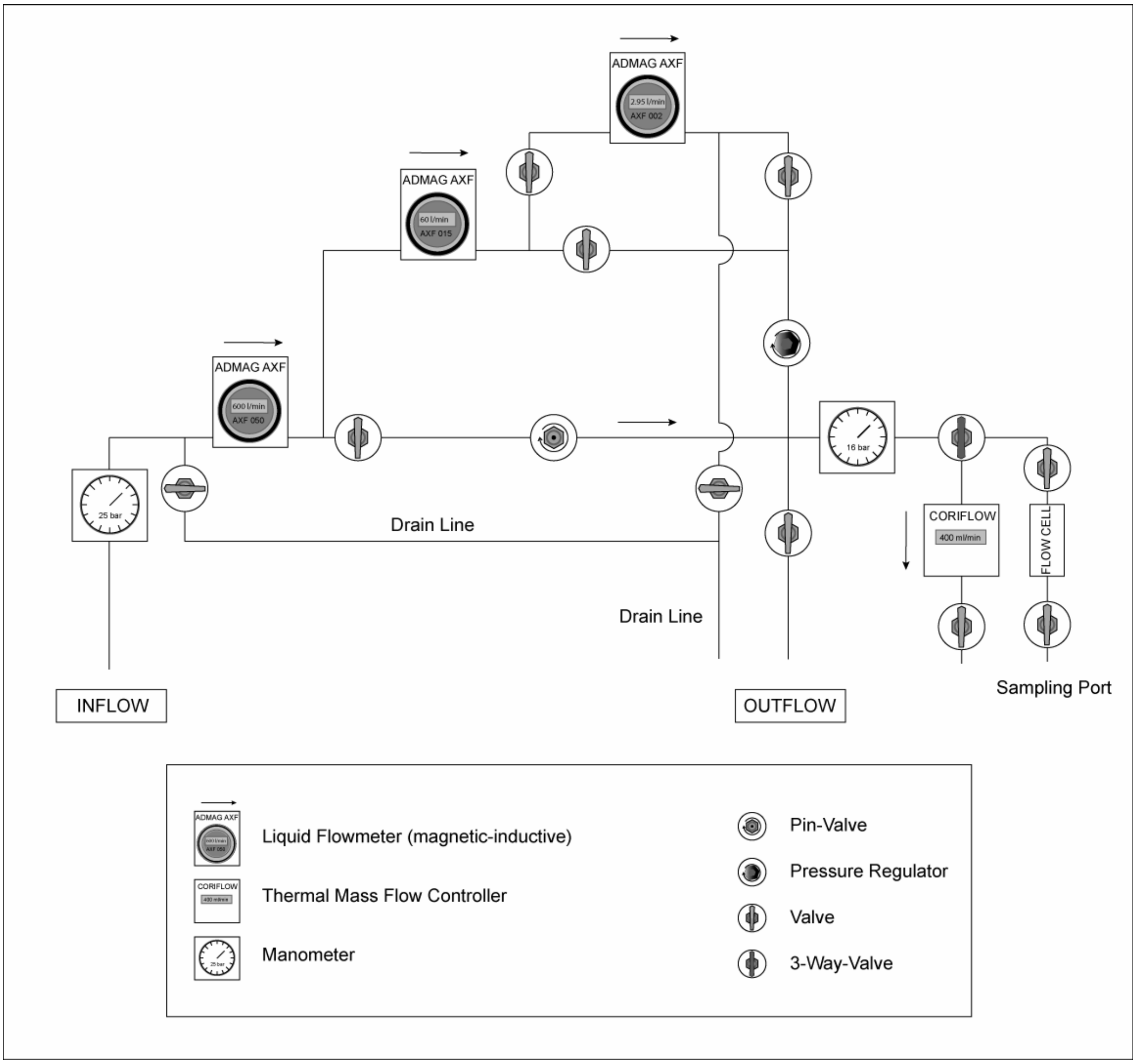


Flow meter	Lower limit of measuring range	(% of FS)	Upper limit of measuring range (l/min)	Accuracy between 3% and 100% of FS (% of rate)	Accuracy between 1% and 3% of FS (% of rate)	Equipment used
AXF DN2	0.030 l/min	1 %	2.95 l/min	0.35	0.5	no
AXF DN15	0.6 l/min	1 %	60 l/min	0.35	0.5	no
AXF DN50	11.78 l/min	1 %	1178.10 l/min	0.35	0.5	no
Coriflow	0.50 kg/h	2 %	25.00 kg/h	1	1	no

Form

BENCH TEST

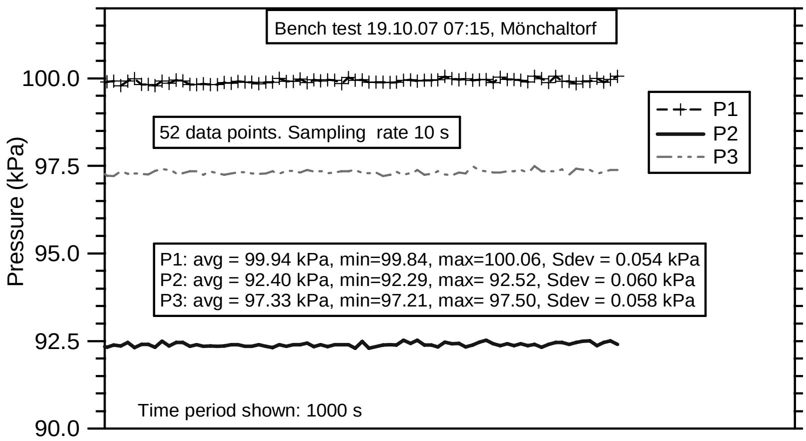
Project	Location	Date
Oftringen NOK EWS Borehole	Oftringen	20.12.2007
Well name	**Test name**	**Engineer**
NOK EWS 2007	Oftri-i8	Fi/SR

Transducer describtion	Output units
P1, P2, P3: 0-206.84 bar (3000 Psi), P4: 0-6 bar, P_{ST} = 0-10 bar	kPa, °C

P1#	P2#	P3#	P4#
43224	50370	43231	591.001.027

Offsite pretest bench test (Date: 19.10.07)

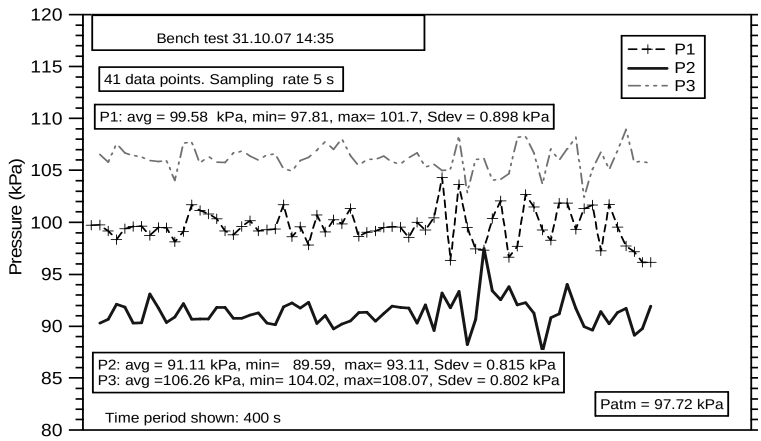
Measurement conditions (P, T and position)	Sampling rate
97.7 kPa 5.6 °C	10 s
( ) direct (x) vertical ( ) horizontal	



P1 average:	99.84	kPa
P2 average:	92.29	kPa
P3 average:	97.33	kPa
P4 average:	n.m.	kPa
P_{SL} average:	n.m.	kPa
P1 Sdev	0.054	kPa
P2 Sdev	0.060	kPa
P3 Sdev	0.058	kPa
File:	TestData24.DAT	

Onsite pretest bench test (Date: 31.10.07)

Measurement conditions (P, T and position)	Sampling rate
97.4 kPa 14.2 °C	5 s
( ) direct (x) vertical ( ) horizontal	



P1 average:	99.58	kPa	
P2 average:	91.11	kPa	
P3 average:	106.26	kPa	
P4 average:	101.36	kPa	1)
P_{SL} average:	n.m	kPa	
P1 Sdev	0.898	kPa	
P2 Sdev	0.815	kPa	
P3 Sdev	0.815	kPa	
P4 Sdev	0.0085	kPa	1)
P_{SL} Sdev	n.m	kPa	

1) Data not shown, 01.11.07, 20:50

Oftr_2007_11_01_oftr_i8.DAT, Patm=98.2 kPa

File: Oftr_2007_10_31_atm1.DAT

Form

BENCH TEST

Project	Location	Date
Oftringen NOK EWS Borehole	Oftringen	20.12.2007
Well name	**Test name**	**Engineer**
NOK EWS 2007	Oftri-i8	Fi/SR

Transducer describtion		Output units	
P1, P2, P3: 0-206.84 bar (3000 Psi), P4: 0-6 bar, P_{ST} = 0-10 bar		kPa, °C	
P1#	**P2#**	**P3#**	**P4#**
43224	50370	43231	591.001.027

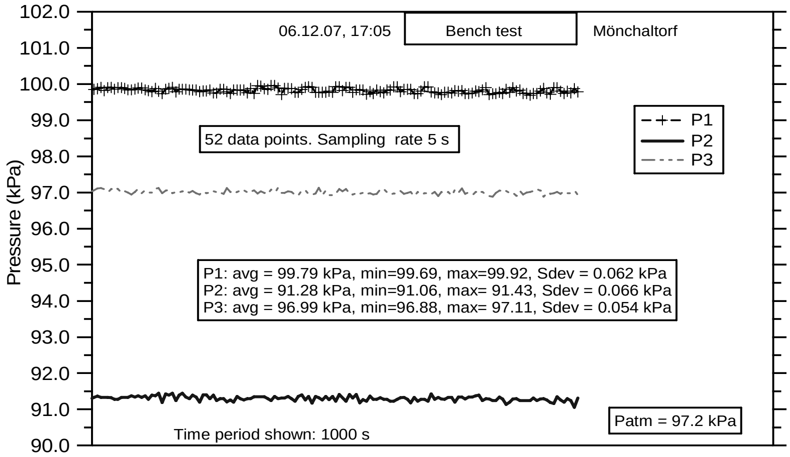
Onsite after test bench test (Date: -)

Measurement conditions (P, T and position)	Sampling rate
( ) direct ( ) vertical ( ) horizontal	

No onsite after test bench test was carried out

Offsite after test bench test (Date: 06.12.07)

Measurement conditions (P, T and position)	Sampling rate
96.6 kPa 9.6 °C	5 s
( ) direct (x) vertical ( ) horizontal	



P1 average:	99.69	kPa
P2 average:	91.28	kPa
P3 average:	96.99	kPa
P4 average: [1)]	101.44	kPa
P_{SL} average:	n.m.	kPa
P1 Sdev	0.062	kPa
P1 Sdev	0.062	kPa
P2 Sdev	0.066	kPa
P3 Sdev	0.054	kPa
P4 Sdev	0.007	kPa

[1)] not shown on graph

File: test8.dat

Appendix I

Quick Look Report
Interval Oftr-i9

nagra.

QUICK LOOK REPORT OFTRINGEN - TEST OFTR-i9

TEST START (Date/Time)	:	02.11.2007 / 13:21	**TEST END (Date/Time)**	:	03.11.2007 / 08:26

DOUBLE PACKER TEST

Test Interval Information	:		top test interval	:	583.00 m
borehole depth [1), 4)]	:	719.0 m	bottom of test interval	:	592.09 m
borehole radius	:	0.073 m	total interval length	:	9.09 m
tubing radius	:	20.0 mm	midpoint of interval	:	587.55 m
			P2-depth	:	579.86 m
interval volume, nominal [5)]	:	0.152 m^3	theoretical C_s-value[3)]	:	3.04E-10 m^3/Pa
slim tubing radius		4.75 mm	theoretical C-value (slim tube)	:	7.23E-09 m^3/Pa
WL prior to packer inflation [2)]	:	-0.90 m bgl	P2 signal prior to packer inflation	:	5783.46 kPa
WL in annulus at test end [2)]	:	-0.97 m bgl	P2 offset assuming ρ_{avg} = 997 kg/m3		103.3 kPa

1) all depths are not corrected for borehole deviation from vertical
4) all depth measurements refer to ground level
2) WL = water level
5) cylindrical volume of isolated borehole section
3) assumes a total borehole system compressibility of 2E-09 Pa^{-1}
Note all pressures cited in this report are absolute

Preliminariy information			
longitude of borehole	:	240887	
latitude of borehole	:	638346	
elevation of ground level (GL)	:	433.0 m asl	(reference point for all measurements)
assumed fresh water head	:	433.0 m asl	(assumed hydrostatic)
end of drilling	:	17.10.07 09:55	(Geotec)
porosity	:	3%	(assumed)
mud density [6)]	:	1032 kg/m^3	(Geotec end of drilling, 17.10.07)
borehole water density	:	997 kg/m^3	(Geotec after circulation of fresh water, 17.10.07; estimated using P2)
formation water density [7)]		1002.44 kg/m^3	(PVT correlation calculated by Saphir)
specific storativity [8)]	:	2.19E-06 m^{-1}	
formation water viscosity [7)]	:	7.27E-04 Pa s	(PVT correlation calculated by Saphir)
fluid compressibility [7)]	:	4.34E-10 1/Pa	(PVT correlation calculated by Saphir)
total compressibility	:	7.43E-09 1/Pa	(calculated assuming c_f= 7.00E-09 1/Pa)

6) Taken from daily report No. 53
7) Assumed, using salinity 10'000 ppm, T = 41°C, P = 5880 kPa
8) Calculated based on assumed porosity and compressibility values

Responible Test Engineers	
Onsite:	Hayer, J.; Reinhardt, S.; A. Kern
Test analysis and reporting:	Rösli, U.; Fisch, H.R.

Test Summary		
Test objectives	:	transmissivity, static formation pressure, flow model
borehole history	:	drilling through midpoint of interval: 11.10.2007, 07:45; 533.60 h duration until start of test
geology	:	limestone - marl interbedded strata, 584.97 - 587.17 m bgl dense light-grey marls, 586.55 - 587 m bgl inclined fracture with slickenside filled with calcite
geophysics	:	Caliper log, salinity log, temperature log, sonic log
test phases	:	COM, PSR, PW, SW, SWS, PI

QLR results	**Test zone 583.00 - 592.09 mbgl**	**T [m2/s]**	**K [m/s]**	**Formation Flow model**	**Freshwater Head [m asl]**
Analytical interpretation		1.19E-10	1.31E-11	radial flow	-
Numerical simulation		1.85E-10	2.03E-11	homogeneous	377.9
		1.55E-11	**1.70E-12**	**composite**	**405.6**

Note:
A complete list of results is provided in the summary tables

Mönchaltorf, 29.02.08 / 02.08.08, Revision 1 prepared by: SOLEXPERTS INTERA

Summary of Test Data

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Test Phase		INF	COM	PSR 2)	PW 1)
duration	[h]	0.803	0.063	0.732	1.274
T2 (i/f)	[°C]	37.12 / 38.16	38.16 / 38.07	38.07 / 38.84	38.83 / 39.43
P1 (i/f)	[kPa]	5794 / 5582	5582 / 5573	5573 / 5516	5515 / 5490
P2 (i/f)	[kPa]	5783 / 5784	5784 / 5785	5785 / 5810	4967 / 5477
P3 (i/f)	[kPa]	5786 / 5785	5785 / 5785	5785 / 5786	5785 / 5786
P4 (i/f)	[kPa]				
Measured C	[m3/Pa]				8.0E-10
c_{SC}	[1/Pa]				5.3E-09
q	[l/min]				
Q	[l]				
inner boundaries		no analysis	no analysis	wellb. storage	wellb. storage
flow geometry				hom.	hom.
outer boundaries				inf.lat.ext.	inf.lat.ext.
T	[m^2/s]			(1.89E-09) A)	(1.93E-09) D)
K	[m/s]			(2.08E-10) A)	(2.12E-10) D)
k	[m^2]			(1.54E-17)	(1.57E-17)
S_S	[1/m]			(6.95E-07) A)	
S	[-]			(6.32E-06)	
Pi, P_f if matched	[kPa]			(5875.9) B)	(5810.4) B)
Head	[m asl]			(441.6) C)	(434.9) C)
Derived flow rate	[l/min]				
s (skin factor)	[-]				
S_{SS} (skin zone)	[1/m]				
t_S (skin zone)	[m]				
K_S (skin zone)	[m/s]				
figures				1,11,12	1,5,6
temperature effects				no	no
borehole history				yes	no
anomalies				no	no
bypass PA2				no	no
bypass PA1				no	no

comments

1) analytical with no superposition
2) numerical simulation with detailed borehole history effects
5) Opitimized fit on PW, SW, SWS, PI
6) Calculated based on meas. C and SWS unit-slope (rough estimate)
A) matched parameter
B) input parameter
C) calculation assumes: freshwater density 1000 kg/m^3, g = 9.81 m^2/s, P_{atm} and z_2 as stated on front page
D) early to middle time fit
E) middle to late time fit

notes:
- i = initial, f = final
- T, Pf values in bold most representable of the undisturbed formation

Summary of Test Data

Page 2/4

Test Phase		PW[1]		PW [2]		SW [1]	
duration	[h]	1.274		1.274		4.312	
T2 (i/f)	[°C]	38.83 / 39.43		38.83 / 39.43		39.22 / 40.30	
P1 (i/f)	[kPa]	5515 / 5490		5515 / 5490		5491 / 5511	
P2 (i/f)	[kPa]	4967 / 5477		4967 / 5477		5030 / 5120	
P3 (i/f)	[kPa]	5785 / 5786		5785 / 5786		5785 / 5786	
P4 (i/f)	[kPa]						
Measured C	[m3/Pa]	8.0E-10					
c_{SC}	[1/Pa]	5.3E-09					
q	[l/min]						
Q	[l]						
inner boundaries		wellb. storage		wellb. storage		wellb. storage	
flow geometry		hom.		hom.		hom.	
outer boundaries		inf.lat.ext.		inf.lat.ext.		inf. lat. ext.	
T	[m^2/s]	1.19E-10	E)	7.24E-10	A)	1.41E-10	A)
K	[m/s]	1.31E-11	E)	7.97E-11	A)	1.55E-11	A)
k	[m^2]	9.68E-19		5.89E-18		1.15E-18	
S_S	[1/m]			1.00E-05	A)		
S	[-]			9.09E-05			
Pi, P_f if matched	[kPa]	5810.37	B)	5281.8	A)	5477.35	B)
Head	[m asl]	434.9	C)	381.0	C)	401.0	C)
Derived flow rate	[l/min]					~1.09E-3 [6]	
s (skin factor)	[-]						
S_{SS} (skin zone)	[1/m]						
t_S (skin zone)	[m]						
K_S (skin zone)	[m/s]						
figures		1,5,6		1,5,13		1,7,8	
temperature effects		no		no		no	
borehole history		no		yes		no	
anomalies		no		no		no	
bypass PA2		no		no		no	
bypass PA1		no		no		no	

comments

notes:
- i = initial, f = final
- T, Pf values in bold most representable of the undisturbed formation

1) analytical with no superposition
2) numerical simulation with detailed borehole history effects
5) Opitimized fit on PW, SW, SWS, PI
6) Calculated based on meas. C and SWS unit-slope (rough estimate)
A) matched parameter
B) input parameter
C) calculation assumes: freshwater density 1000 kg/m^3, g = 9.81 m^2/s, P_{atm} and z_2 as stated on front page
D) early to middle time fit
E) middle to late time fit

Summary of Test Data

Page 3/4

Test Phase		SW 2)		SWS 2)		PI 1)	
duration	[h]	4.312		11.078		0.821	
T2 (i/f)	[°C]	39.22 / 40.30		40.30 / 41.10		41.04 / 40.95	
P1 (i/f)	[kPa]	5491 / 5511		5491 / 5571		5571 / 5573	
P2 (i/f)	[kPa]	5030 / 5120		5120 / 5480		6066 / 5805	
P3 (i/f)	[kPa]	5785 / 5786		5786 / 5786		5785 / 5786	
P4 (i/f)	[kPa]						
Measured C	[m3/Pa]					9.6E-10	
c_{SC}	[1/Pa]					6.3E-09	
q	[l/min]						
Q	[l]						
inner boundaries		wellb. storage		wellb. storage		wellb. storage	
flow geometry		hom.		hom.		hom.	
outer boundaries		inf. lat. ext.		inf. lat. ext.		inf.lat.ext.	
T	[m^2/s]	3.08E-10	A)	1.85E-10	A)	(9.36E-10)	D)
K	[m/s]	3.39E-11	A)	2.03E-11	A)	(1.03E-10)	D)
k	[m^2]	2.51E-18		1.50E-18		(7.61E-18)	
S_S	[1/m]	9.87E-06	A)	1.00E-05	A)		
S	[-]	8.97E-05		9.09E-05			
Pi, P_f if matched	[kPa]	4828.2	A)	5251.0	A)	(4508.0)	B)
Head	[m asl]	334.8	C)	377.88	C)	(302.1)	C)
Derived flow rate	[l/min]						
s (skin factor)	[-]						
S_{SS} (skin zone)	[1/m]						
t_S (skin zone)	[m]						
K_S (skin zone)	[m/s]						
figures		1,14		1,9,15,16		1,10	
temperature effects		no		no		no	
borehole history		yes		yes		no	
anomalies		no		no		no	
bypass PA2		no		no		no	
bypass PA1		no		no		no	

comments

notes:
- i = initial, f = final
- T, Pf values in bold most representable of the undisturbed formation

1) analytical with no superposition
2) numerical simulation with detailed borehole history effects
5) Opitimized fit on PW, SW, SWS, PI
6) Calculated based on meas. C and SWS unit-slope (rough estimate)
A) matched parameter
B) input parameter
C) calculation assumes: freshwater density 1000 kg/m^3, g = 9.81 m^2/s, P_{atm} and z_2 as stated on front page
D) early to middle time fit
E) middle to late time fit

Summary of Test Data

Page 4/4

Test Phase		PI [1)]	PI [2)]	Simulation entire Seq.[5)]	Simulation entire Seq.[5)]
duration	[h]	0.821	0.821	19.08	19.08
T2 (i/f)	[°C]	41.04 / 40.95	41.04 / 40.95	38.07 / 40.95	38.07 / 40.95
P1 (i/f)	[kPa]	5571 / 5573	5571 / 5573	5573 / 5573	5573 / 5573
P2 (i/f)	[kPa]	6066 / 5805	6066 / 5805	5785 / 5805	5785 / 5805
P3 (i/f)	[kPa]	5785 / 5786	5785 / 5786	5785 / 5786	5785 / 5786
P4 (i/f)	[kPa]				
Measured C	[m3/Pa]	9.6E-10			
c_{SC}	[1/Pa]	6.3E-09			
q	[l/min]				
Q	[l]				
inner boundaries		wellb. storage	wellb. storage	wellb. stor.	wellb. stor. & skin
flow geometry		hom.	hom.	hom.	composite
outer boundaries		inf.lat.ext.	inf.lat.ext.	inf. lat. ext.	inf. lat. ext.
T	[m^2/s]	1.01E-10 E)	3.25E-10 A)	3.68E-10 A)	**1.55E-11** A)
K	[m/s]	1.11E-11 E)	3.57E-11 A)	4.05E-11 A)	1.70E-12 A)
k	[m^2]	8.21E-19	2.64E-18	2.99E-18	1.26E-19
S_S	[1/m]		1.00E-05 A)	1.00E-05 A)	1.00E-05 A)
S	[-]		9.09E-05	9.09E-05	9.09E-05
Pi, P_f if matched	[kPa]	4508.04 B)	5999.0 A)	5176.3 A)	**5523** A)
Head	[m asl]	302.15 C)	454.13 C)	370.27 C)	405.61 C)
Derived flow rate	[l/min]				
s (skin factor)	[-]				-1.49 [7)]
S_{SS} (skin zone)	[1/m]				1.32E-06 A)
t_S (skin zone)	[m]				0.23 A)
K_S (skin zone)	[m/s]				8.48E-11 A)
figures		1,10	1,17	18,19	20,21,22
temperature effects		no	no	no	no
borehole history		no	yes	yes	yes
anomalies		no	no	no	no
bypass PA2		no	no	no	no
bypass PA1		no	no	no	no

comments

notes:
- i = initial, f = final
- T, Pf values in bold most representable of the undisturbed formation

1) analytical with no superposition
2) numerical simulation with detailed borehole history effects
5) Opitimized fit on PW, SW, SWS, PI
6) Calculated based on meas. C and SWS unit-slope (rough estimate)
7) Calculated using equation given in Chapter "Definitions"

A) matched parameter
B) input parameter
C) calculation assumes: freshwater density 1000 kg/m^3, g = 9.81 m^2/s, P_{atm} and z_2 as stated on front page
D) early to middle time fit
E) middle to late time fit

Test overview

Test Oftr-i9 (583.0 - 592.09 m bgl) was performed on 02.-03.11.2007 in the Oftringen NOK EWS-Borehole. The test interval consisted of a sequence of marls with interbedded limestone layers containing a section of dense light-grey marls between 584.97 and 587.17 m bgl and a fracture filled with calcite at 586.55 - 587 m bgl. During the temperature and salinity logging undertaken by Colenco, a possible minor inflow zone at 588.7 m was identified. The test objectives were to obtain reliable estimates of interval transmissivity and fresh-water hydraulic head using an appropriate flow model. The hydraulic test was performed with a straddle-packer configuration with an interval length of 9.09 m. Pressures and temperatures were measured in the test interval (P2, T2) and in the interval below the lower packer (P1, T1) and in the annulus above the upper packer (P3, T3). In addition, pressure was measured in the tubing above the upper packer (P4). Test interval Oftr-i9 covers a subsector of the earlier investigated interval Oftr-i3, 550 - 600.04 m bgl.

The pressure response of the entire test sequence in Oftr-i2 is shown in **Figure 1**. The pressure history derived from water table measurements (source: Colenco, Solexperts) and fluid density measurements (SJ Geotec) is presented in **Figure 2**.

Following packer inflation (INF) the test sequence started with a COM and PSR phase to dissipate temperature and borehole history effects. The packers were inflated individually but the inflation lines were connected together once the packers were expanded. The packer pressures are shown in **Figure 4**.

The temperature (T1, T2, T3) shows an increasing trend especially at the beginning of the sequence with a flattening at late time and an overall temperature increase of 4.0° C (**Figure 3**). For the simulation, the final temperature of 41° C was used as interval temperature. The PSR phase might be influenced by compliance effects which may not have fully dissipated prior to start of PSR.

The pulse withdrawal test (PW) was performed to measure the wellbore compressibility early in the test and obtain an initial estimate of the formation properties. A slug withdrawal (SW) followed by a shut-in phase (SWS) was performed to get a more distinct formation response combined with a larger radius of investigation for the determination of the formation properties. After the SWS sequence a pulse injection test (PI) was performed to determine wellbore compressibility for comparison with that from the earlier pulse withdrawal test (PW).

Due to the influence of the adjacent high voltage current transformer facility (NOK), the pressure and temperature signals of the downhole triple probe were noisy during the hole testing sequence.

Analysis

For the QLR analysis, the analytical and numerical methods were used for a standard analysis, which will be the basis for a possible detailed analysis depending on the test objectives and test results.

Analytical Analysis

Type curve and straight-line fitting methods are applied. Effects of the borehole pressure history are not taken into account.

Pulse withdrawal test (PW)

The PW test was initiated at unsteady pressure conditions during PSR while P2 was showing an upward trend of 7.6E-3 kPa/s. The pulse withdrawal phase with open shut-in valve lasted 32 s and a differential pressure of -843 kPa was attained before shut-in.

After shut-in, a water level change equal to 0.5382 m was measured in the 1.9” test string (ΔP4 = 5.28 kPa), indicating a released volume of 0.676 liters due to de-compression of the test zone. The wellbore storage constant C ($\Delta V/\Delta P$) equals to 8.0E-10 Pa/m^3. For the analytical PW analysis, the history effect of the 33 s long open valve period (prior to shut-in) was not taken into account.

The pulse response was analyzed using CBP type-curves. Two analysis versions are presented in **Figure 6.** As the shape of the data curve and the model curve diverge, the results of both early and late time matches are provided. T-values of 1.9E-09 m^2/s (early time) and 1.2E-10 m^2/s were obtained based on a type-curve value α = 0.01 and α = 1, respectively. Note that the CBP type-curve matching method is not sensitive for high α-values as α type-curves greater 1 are difficult to distinguish with respect to the slope steepness. High α values are associated with high aquifer storativity values (S). As storativity estimates from pulse test analyses are commonly known as unreliable, the S and S_S results are not presented.

Slug test withdrawal test (SW)

Prior to start of the SW test, a slim tubing was installed in the 1.9” NU API rods. The slim tubing system consists of a stiff high pressure hose of ID = 9.5 mm and a packer at its bottom (OD =28 mm). The packer is inflated using pressurized nitrogen, sealing the annulus between the 1.9” tubing and the slim tubing. The slim tubing was installed to a depth of approximately 91 m bgl, covering the span of expected water table change of the slug test. A pressure transducer attached just above the packer and with connection to the tube inside enables recording of water level changes, redundantly to the P2 sensor. The small diameter of the slim tubing allows for faster slug recovery.

Prior to start of SW, the P2 pressure curve still showed an increasing trend due to the PW pressure recovery. The SW test was started 1.27 hours after start of PW. The analysis of SW was obtained based on a type-curve value α = 0.05 and provided a good fit with a transmissivity of 1.4E-10 m^2/s (**Figure 7**). Towards end of SW, P2 pressure rouse at a rate of 0.152 kPa/min which corresponds to production rate of 1.1 ml/min ($C_{slim\ tube}$ = 7.23E-09 m3/Pa). A similar production flow rate at end of SW was obtained from the analysis of the subsequent shut-in phase SWS (see below).

Recovery phase of slug test (SWS)

The slug test was shut-in after 4.3 hours and further pressure recovery (SWS) was recorded for 11.1 hours. The early-time data of SWS were analyzed in a log-log plot to confirm the last flow rate of the precedent SW phase. The estimate is based on measured C-values (PW) and the 'unit slope' identifying the early-time pressure recovery phase with one log cycle pressure change per one log cycle of time (**Figure 8**). The result of 1.7 ml/min has to be considered as an indicative value, less precise than the flow derived from late SW pressure data (see above). A log-log diagnostic plot using Agarwal time and corrected production time is shown in **Figure 9**. The shape of the derivative does not support the presence of IARF regime and therefore, no further analytical analysis was conducted on the SWS data. The SWS phase is likely to be affected by history effects of the precedent test events PSR, PW, SW.

Pulse injection test (PI)

A pulse injection test (PI) was performed in order to confirm the C-value obtained during the PW phase. During preparation of PI, the water in the 1.9" test rods was filled up to top of the tubing. During the 0.5 hrs prior to start of PI, the P2 pressure curve showed a rising trend of 0.003 kPa/s. The PI test was initiated by open the shut-in valve exposing the test zone to a differential pressure of 657 kPa. A water volume change of 0.264 liters was measured in the 1.9" test string due to compression of the test zone. The wellbore storage constant C ($\Delta V/\Delta P$) equals to 9.6E-10 m^3/Pa, a value comparable to the result obtained from PW (C = 8.0E-10 Pa/m^3).

The decline in pressure during the PI test was recorded for 0.82 hrs. A pressure recovery of 40% was obtained (**Figure 10**). As the shape of the data curve and the model curve diverge, the results of both early and late time matches are provided. T-values of 9.36E-10 m^2/s (early time) and 1.01E-10 m^2/s were obtained based on a type-curve value α = 0.02 and α = 0.5, respectively.

nSights Analysis

In a first step, the diagnostic plots for the individual sequences were analyzed and fitted individually accounting for borehole history and taking into account of transient effects associated with the preceding test sequences. In a second step, the entire test sequence was simulated and fitted based on the Cartesian pressure plots.

The diagnostic plots of the individual test sequences did not indicate characteristic responses of a composite flow model, or any other more complex flow models. Consequently, a homogeneous model was assumed in this first evaluation for estimating formation parameters (i.e., K, S_s, and P_f). The analyses used the wellbore compressibility of 8E-10 m^3/Pa which is nearly identical to the 8.03E-10 m^3/Pa determined from PW. During the parameter optimization, the specific storativity was allowed to vary within a plausible range from Ss = 1E-7 Pa^{-1} to1E-5 Pa^{-1}.

The log-log diagnostic plot of the PSR indicates dominantly well-bore storage effects providing only preliminary estimates of formation parameters (K = 2.1E-10 m/s, P_f = 5876 kPa, S_s= 7.0E-7 m^{-1}), which produced an acceptable fit of the short observed data section. The 95% confidence interval given for the storativity varies over a wide range and indicates a rather poor quality of the estimated data (**Figure 11**). Additionally this phase may be influenced by compliance effects which may not have fully dissipated prior to start of PSR.

The initial pressure decrease phase (PW_a, **Figure 5**) was incorporated as a pressure history sequence. The diagnostic plot of the PW sequence in terms of the normalized pressures produced a good fit (**Figure 13**) and yielded K and P_f values lower than those derived from the PSR (K = 7.97E-11 m/s, P_f = 5281.8 kPa). Inverse parameter estimation runs which included the optimization of the storativity parameter suggested an Ss value higher than 1E-5 m^{-1}. The Ss was then fixed to 1.0E-05 m^{-1} which corresponds to the upper limit of the plausibility range.

The numerical analysis of the relatively short SW recovery period (4.31 hrs, 20% recovery, see **Figure 14**) provided a good fit, again with lower values for the K and P_f estimates (K = 3.39E-11 m/s, P_f = 4828.2 kPa, S_s= 9.9E-6 m^{-1}).

The simulation of the SWS shut-in period provides good fits of ΔP and Derivative in the log-log diagnostic plot (**Figure 15**) with parameter estimates of K = 2.0E-11 m/s and P_f = 5251 kPa. The storativity was fixed at the upper limit of the plausibility range (S_s= 1.0E-5 m^{-1}) after several simulations suggested higher Ss values. The same fit is shown in a Horner plot in **Figure 16**.

The second pulse test, carried out as an injection test (PI), produced similar results compared to the SW test with respect to hydraulic conductivity (**Figure 17**, K = 3.57E-11 m/s) but yielded a significantly higher static formation pressure of P_f = 5999 kPa using a constant storativity of S_s= 1.0E-5 m^{-1} (The storativity was fixed at the upper limit of the plausibility range after several simulations suggested higher Ss values).

The simulation of the entire test sequence on a Cartesian plot (**Figure 18**) produced the fitted parameters K = 4.05E-11 m/s, P_f = 5176 kPa. The fit quality is rather poor to all of the fitted test events. The storativity was fixed at the upper limit of the plausibility range after several simulations suggested higher Ss values. The Cartesian fit parameters are most similar to the individual SWS fit. The sensitivity coefficients of the formation parameters during the different sequences are presented in **Figure 19**. This plot indicates that the PW and PI tests have the greatest sensitivity to the K parameter. The SWS sequence is shown to have the greater sensitivity to P_f which would be expected given the longer duration and greater pressure recovery of the sequence. The definition of the sensitivity coefficient is given in the Chapter "Definitions".

Because of the poor quality of the Cartesian fit for the entire test, a composite flow model was assumed and a fit to the Cartesian pressure curve of the entire testing sequence was conducted (**Figure 20**). The visual fit to the entire sequence (**Figure 20**) is better than for the homogeneous model with similar storativity parameter but significantly lower K and higher P_f (K = 1.7E-12 m/s, S_s= 1.0-5 m^{-1}, P_f = 5523 kPa,). The fitted parameters for inner zone are K_s =8.5E-11 m/s, S_{ss}=1.3E-6 m^{-1}, and t_s=0.26 m (thickness of inner zone or thickness of skin). The range between the upper and lower values for the 95% confidence intervals for the composite model (Figure 20) is small for most of the parameters. The sensitivity coefficients of the formation parameters during the different sequences are presented in **Figure 21**.

Figure 22 shows individual sequence plots for PW, SW (both Ramey plots using normalized pressure) and SWS (log-log diagnostic plot and Horner plot) together with the simulated data of the Cartesian fit (composite model) produced for the entire test. The individual sequence plots in **Figure 22** show good agreement between the measured pressure and the simulated data, especially for SW and SWS. The match is poor for the PI test as shown in the Cartesian plot (**Figure 20)**.

The presented solution for the composite model is not unique. Limiting the upper limit of the storativity range to 2E-6 m/s results in a fit of comparable quality and gives similar K and P_f parameters, similar widths of confidence intervals but produces a greater radius of the inner zone (simulation results and graphs not shown).

Results and Discussion

The estimated formation parameters for the different sequences vary significantly based on a homogeneous flow model. The range in K varies between 2.0E-11 m/s (T=1.9E-10 m^2/s) and 8.0 E-11 m/s (T=7.2E-10 m^2/s). The optimized storativity parameter exceeded the upper limit of the plausibility range in most cases (SW, SWS, Cartesian fit) and was then fixed at Ss =1.0E-5 m^{-1}. The T and K values obtained from the analytical analyses of the PW and PI phases are considered unreliable in view of the potential transient effects from the preceding borehole pressure history.

The T and K estimates from the homogeneous model are considerably higher than those obtained from test in the 50 m interval Oftr-i3, assuming a homogeneous model. The P_f results vary significantly between 4828 kPa and 5999 kPa corresponding to a range in freshwater head estimates of 119 meters. Relatively low P_f values resulted from the simulations of withdrawal tests (PW, SW, SWS; P_f ranging from 4828 to 5259 kPa) whereas the highest P_f value of 5999 kPa was obtained from the injection test (PI). This large range in properties is also reflected by the poor fit to the entire test sequence. The SWS sequence shows consistent parameter values between the sequence-only fit and the Cartesian fit of the entire testing sequence fit. The fit quality for the Cartesian fit is poor indicating that the homogeneous model may be inappropriate or other effects may have influenced the test. For the homogeneous model, the results of SWS-fit are preferred because of the higher sensitivity to the formation parameters (**Figure 19**). However, the calculated freshwater head from the SWS simulation (h_s = 378 m asl) is very low compared to computed heads from adjacent intervals (Oftr-i1, -i2, -i3).

The use of a composite model for the Cartesian fit provides a significantly lower K value of 1.7E-12 m/s and a slightly higher static formation pressure of 5523 kPa. The composite (skin) model is preferred over the homogeneous model because of the superior quality of the Cartesian fit and the good agreement of the simulated pressure curve with measured data when displayed diagnostic plots of individual sequences (individual sequence fits for the composite model were not produced for this QLR).

These estimates compare reasonably well with those derived from the analysis of the test in Interval i-3 (K = 1.4E-12 m/s, Pf=5390 kPa) based on a homogeneous model. A composite model having higher-permeable inner zone is typically related to drilling-induced disturbance resulting in micro fractures in the formation in the immediate vicinity of the borehole. Evidence for an inclined fracture was given in the core description (Tagesrapport Nr. 47, Nagra,11.10.07), but no characteristic response (i.e., ¼ unit slope or ½ unit slope) could be identified in the diagnostic plots. The apparent fracture (or fractures) may have limited radial extent corresponding to the estimated thickness of the inferred skin.

FIGURES

ABBREVIATIONS
NOMENCLATURE
DEFINITIONS
FIELD DOCUMENTATION

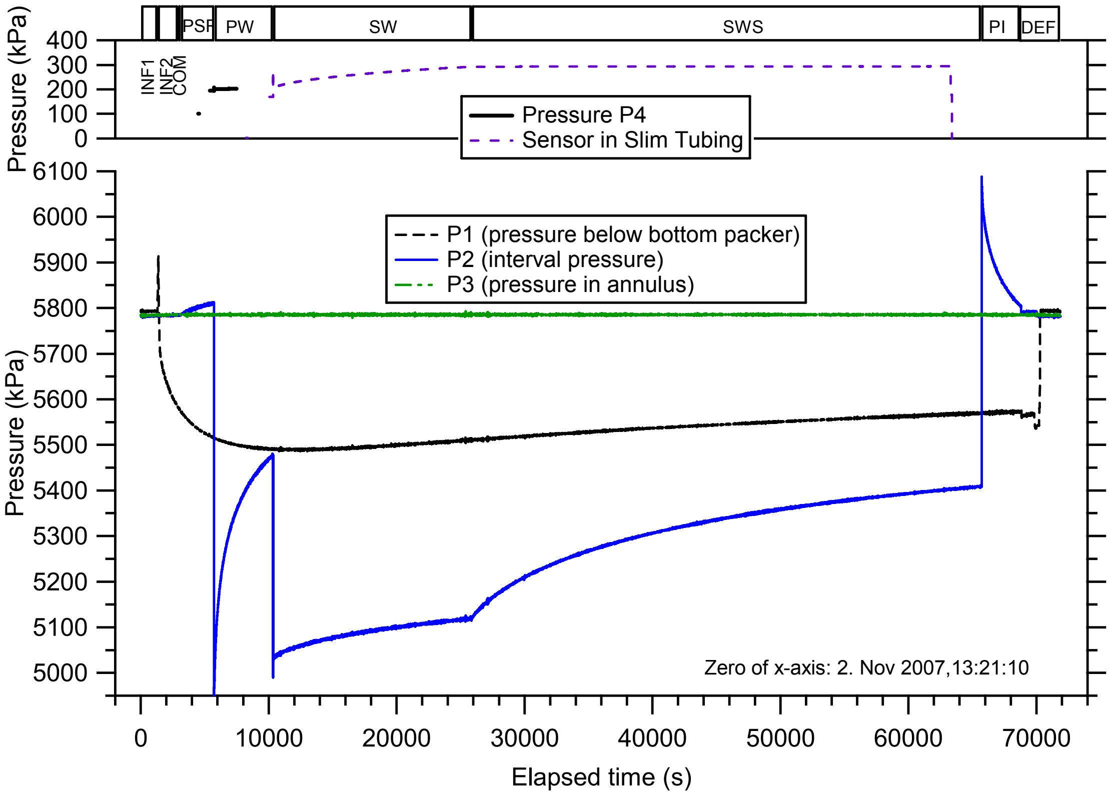


Figure 1: Ofrt-i9: Overview plot

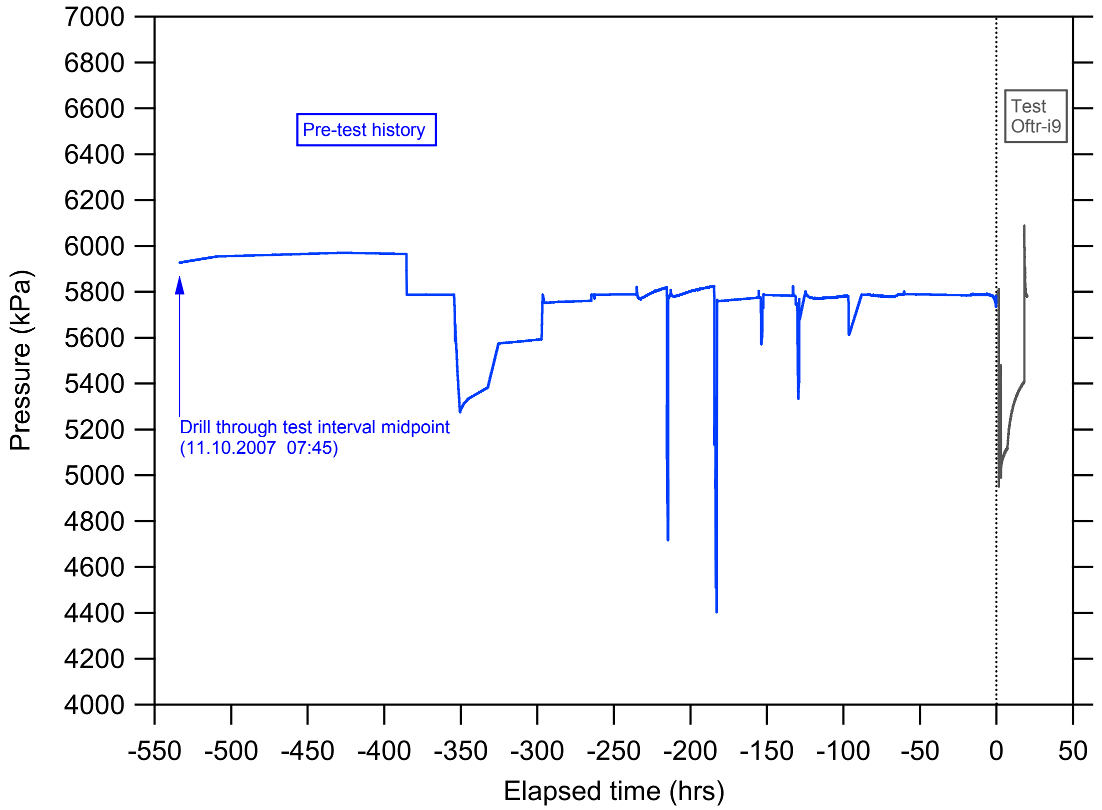


Figure 2: Ofrt-i9: Borehole pressure history

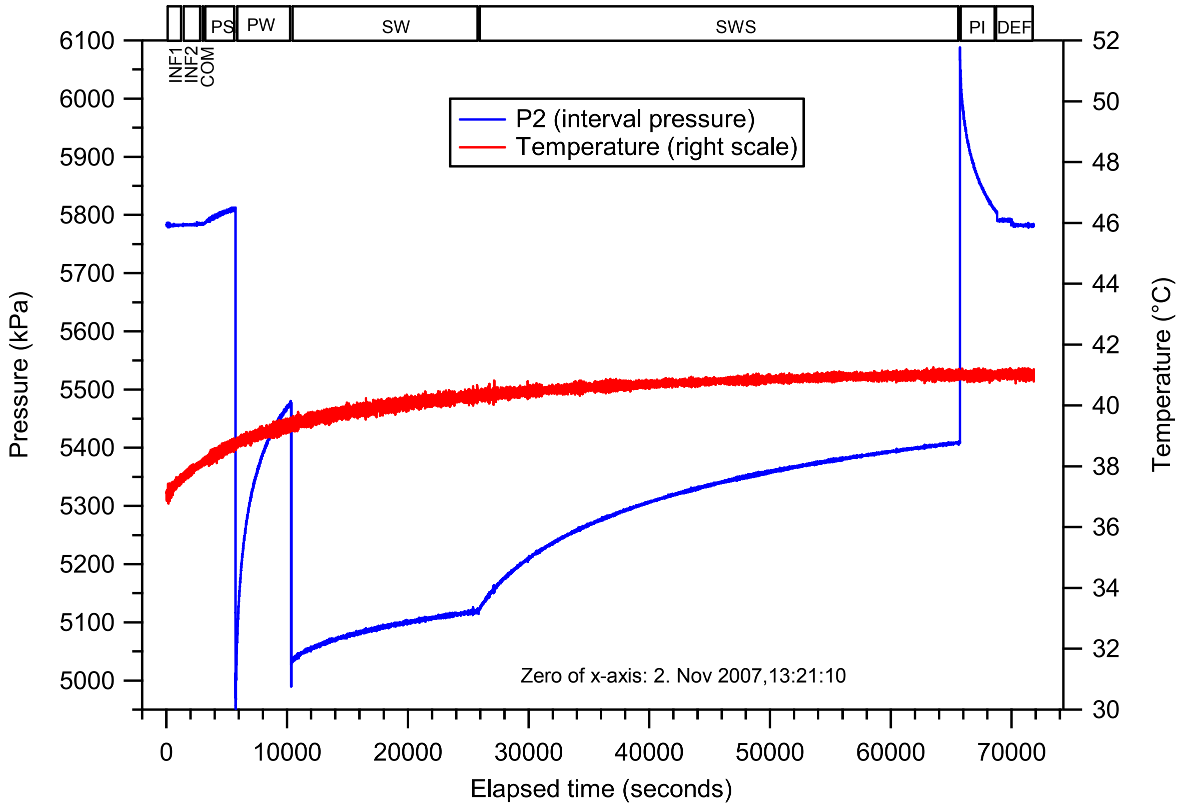


Figure 3: Ofrt-i9: Measured downhole temperature

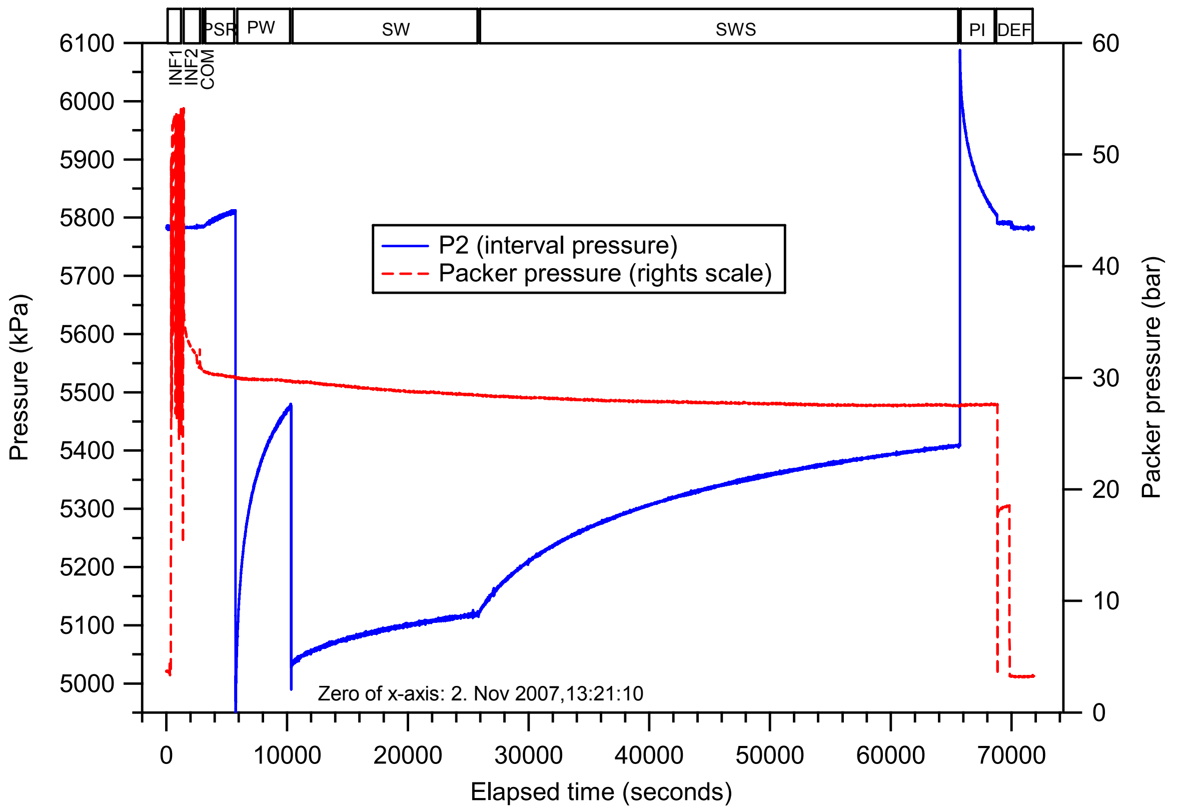


Figure 4: Ofrt-i9: Measured packer pressure

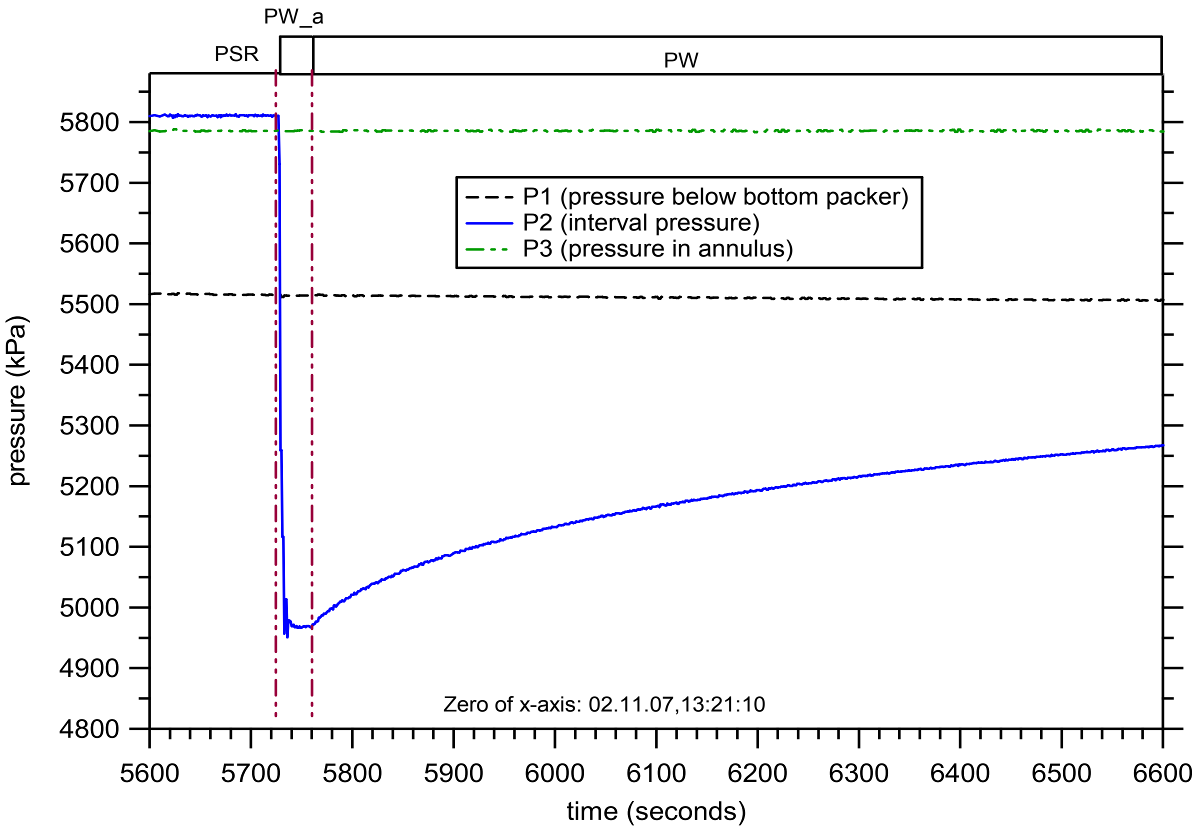


Figure 5: Oftr-i9: Detail of pulse withdrawal test

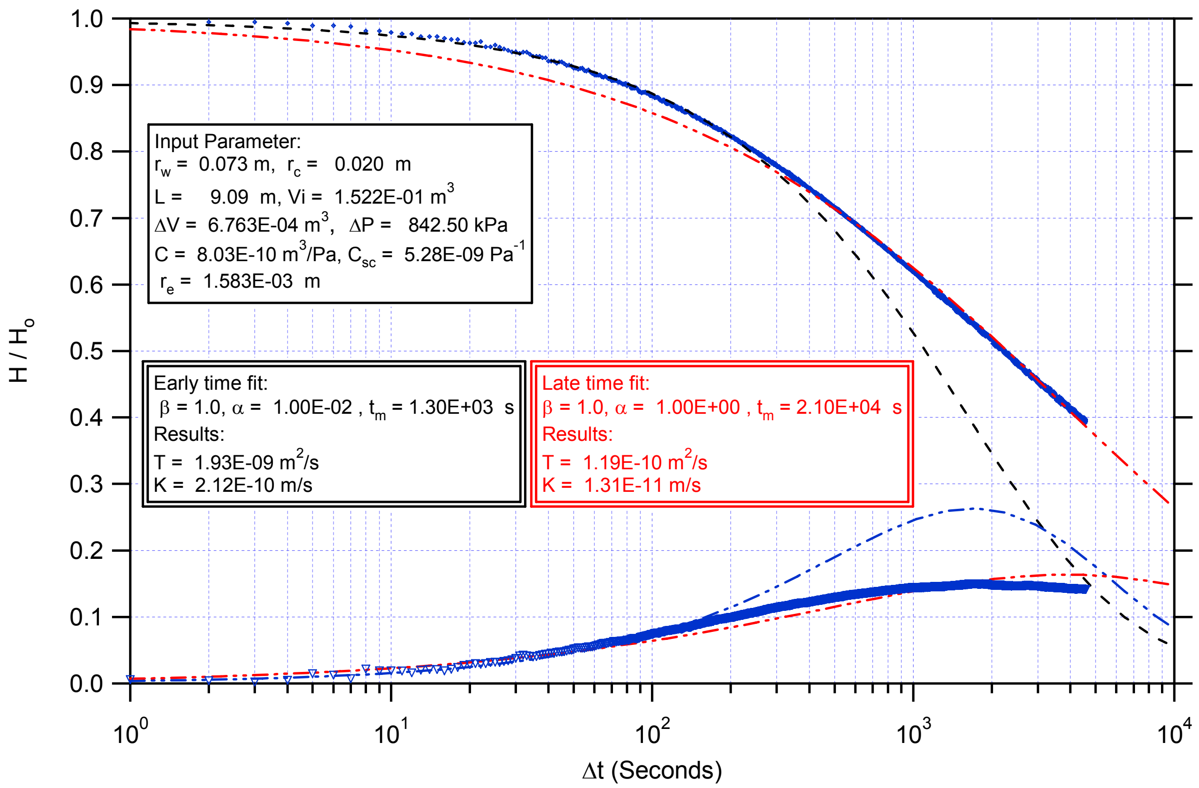


Figure 6: Oftr-i9: PW test analysis using CBP type-curves

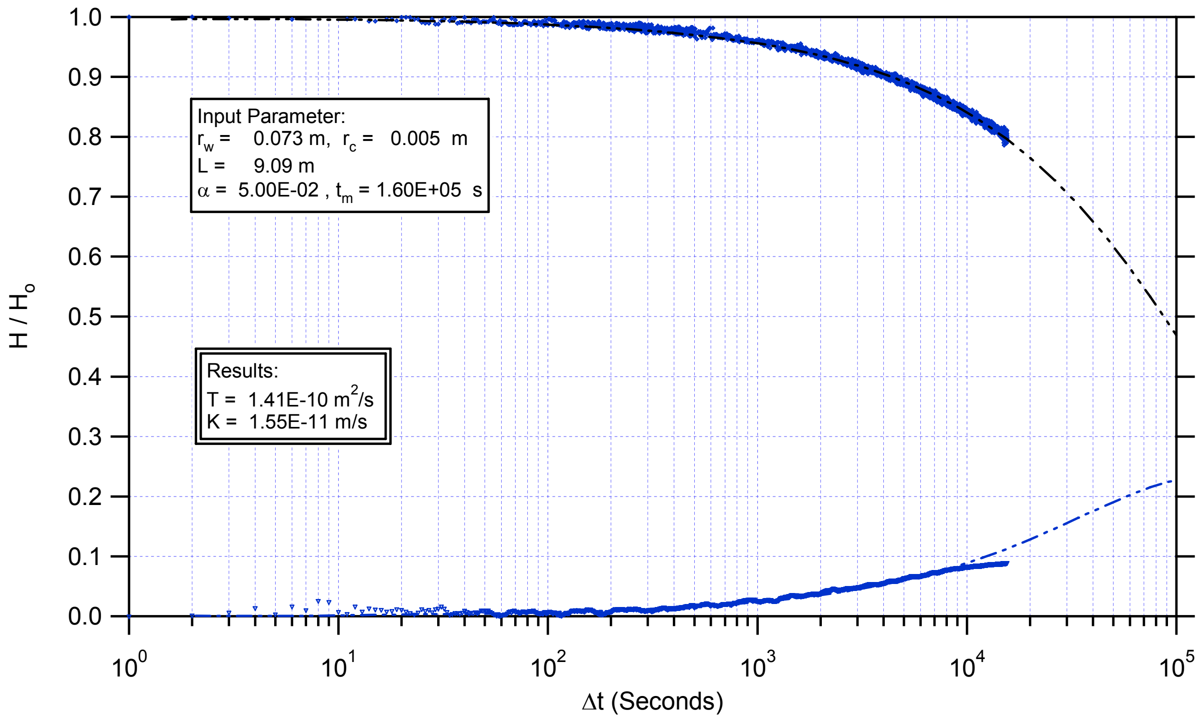


Figure 7: Oftr-i9: SW test analysis using CBP type-curves

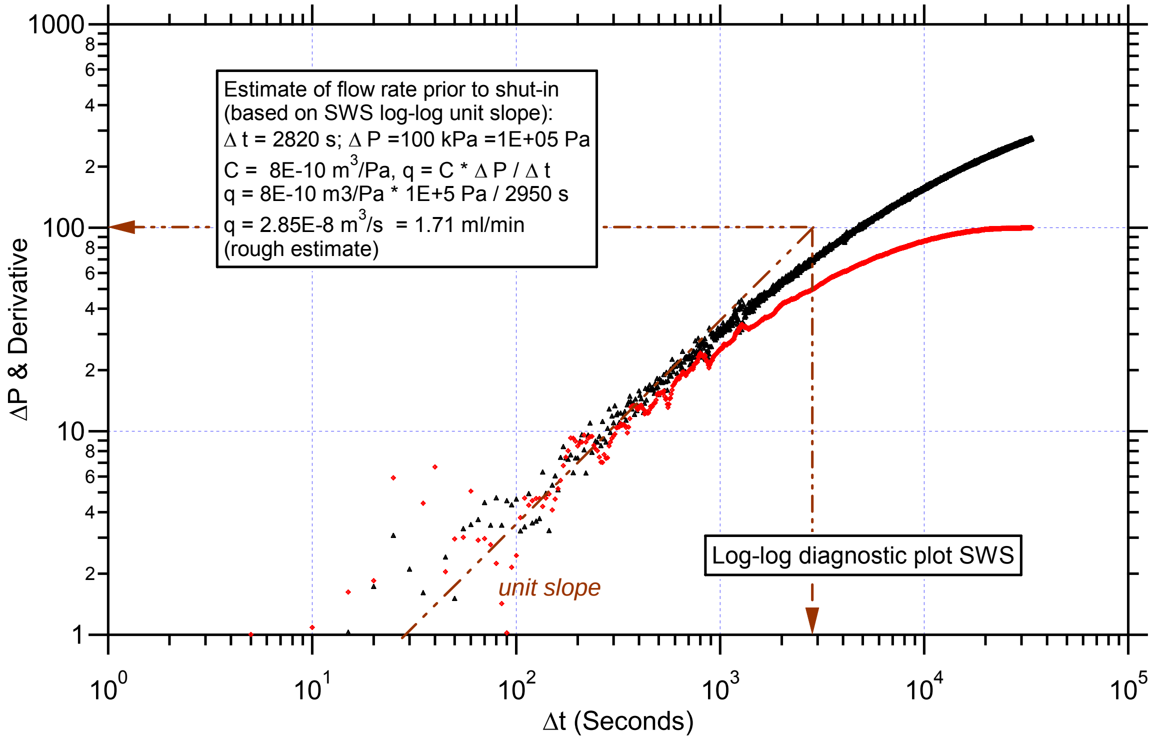


Figure 8: Oftr-i9: Estimated of q_e of SW based on log-log unit slope of SWS

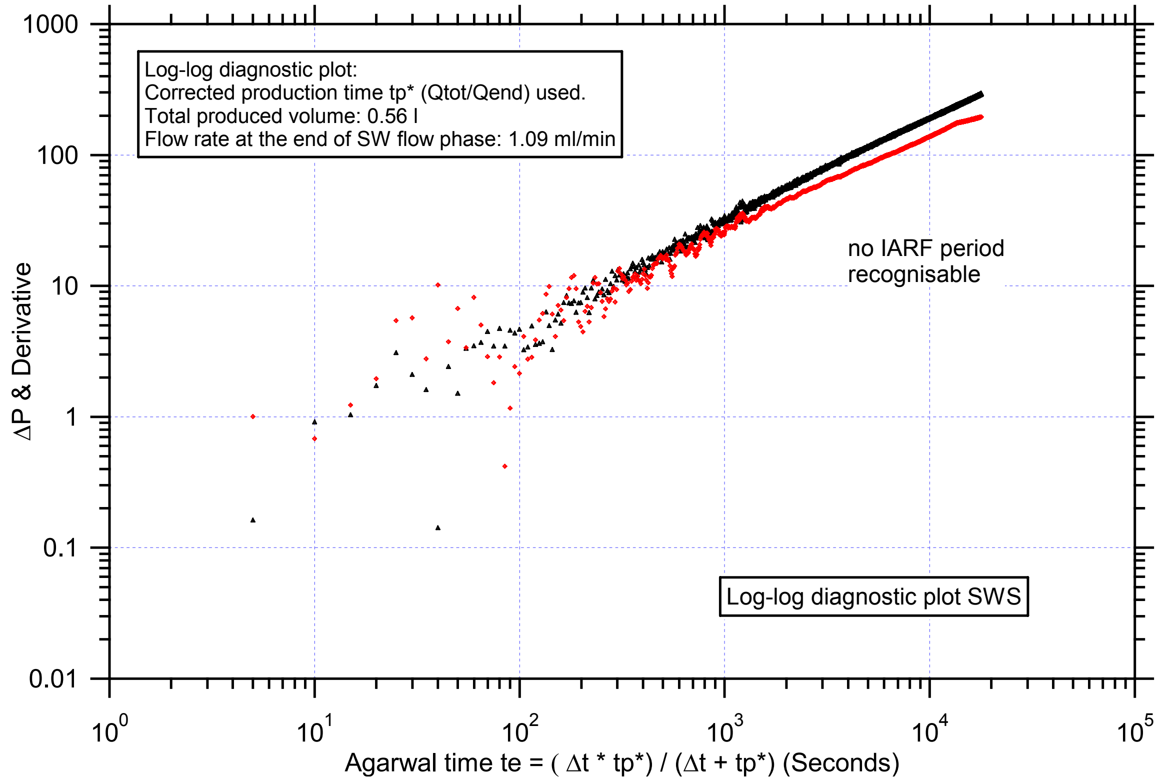


Figure 9: Oftr-i9: SWS log-log Agarwal time plot for corrected production time tp*

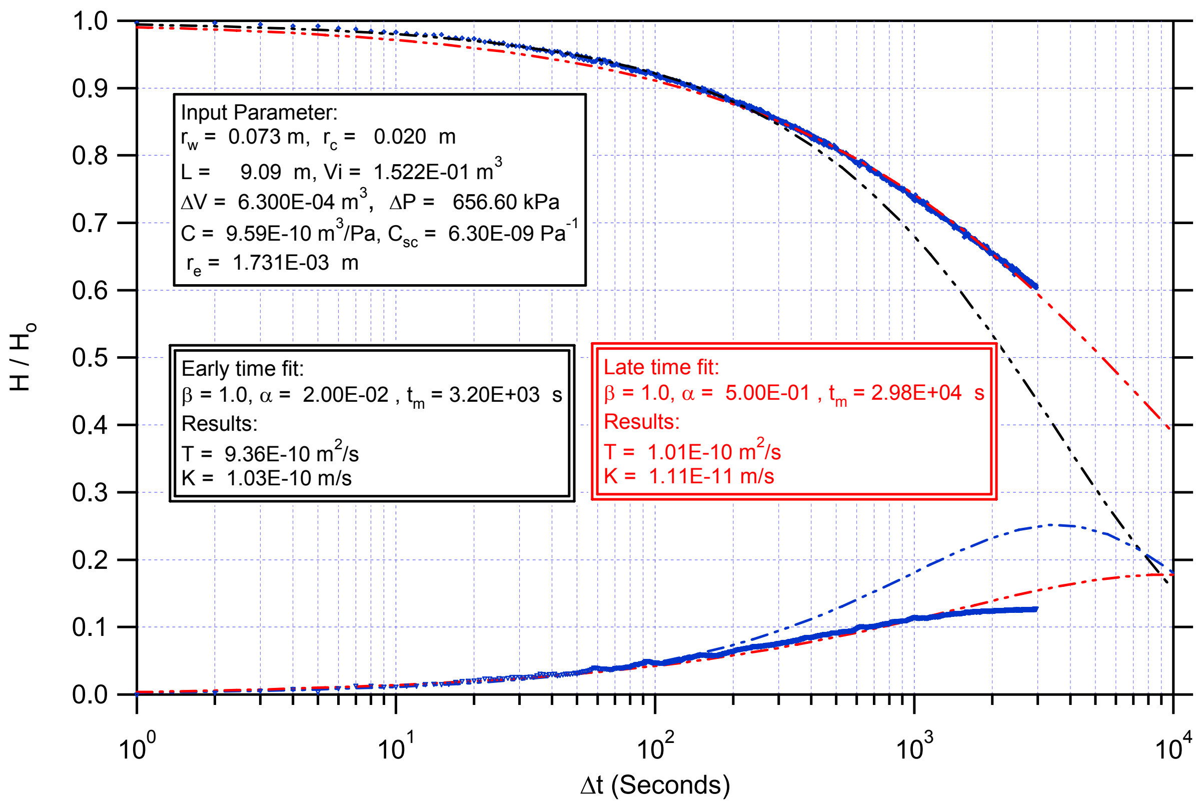


Figure 10: Oftr-i9: PI test analysis using CBP type-curves

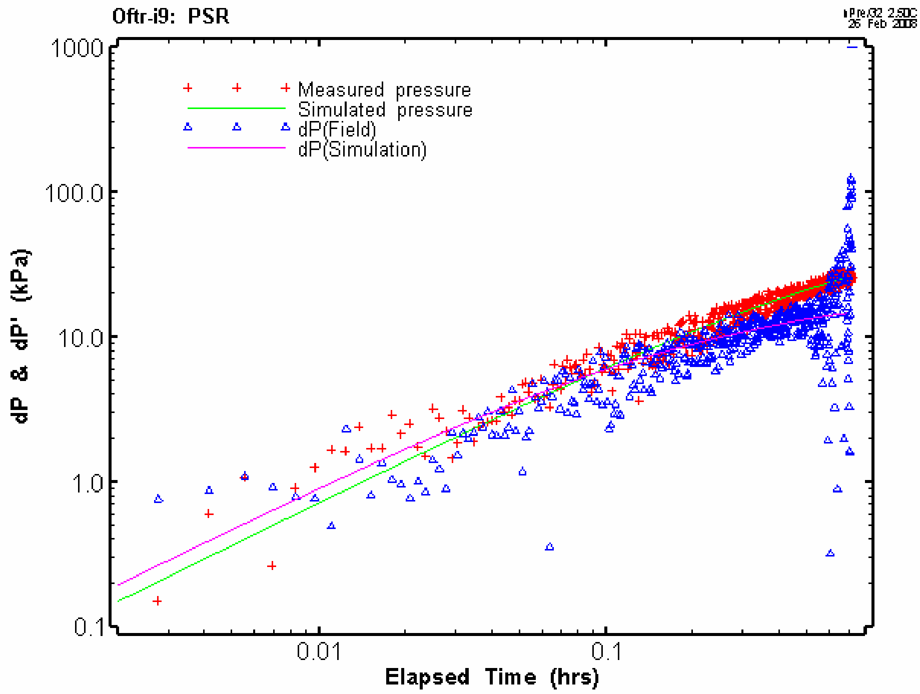


Figure 11: Oftr-i9: PSR log-log diagnostic plot (for Horner fit)

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_fm	[m/sec]	2.08E-10	8.21E-11	5.28E-10
P_fm	[kPa]	5875.9	5818.1	5933.6
ss_fm	[1/m]	6.95E-07	2.39E-09	2.03E-04

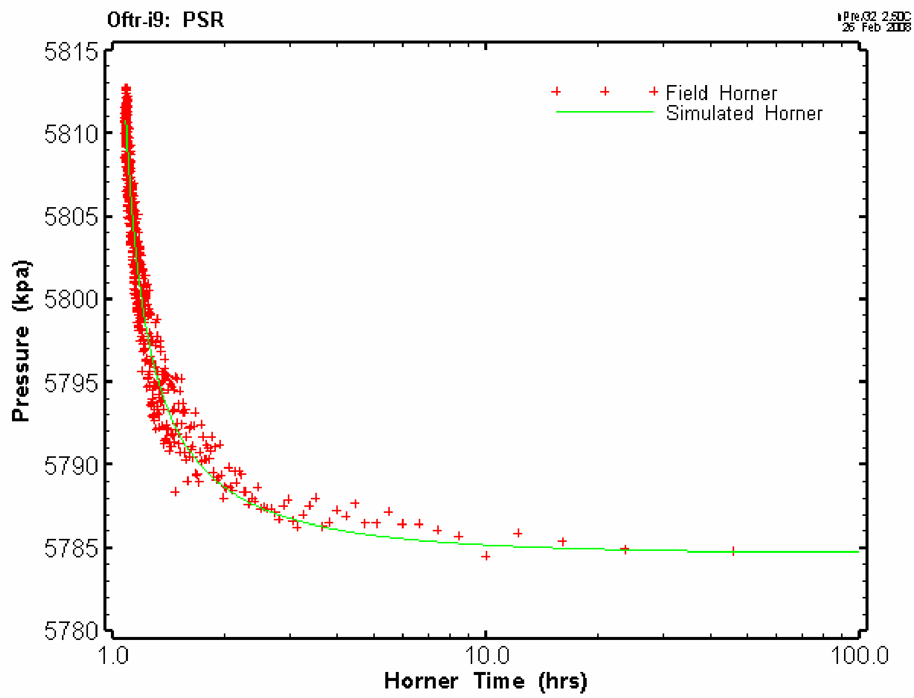


Figure 12: Oftr-i9: PSR Horner plot (for Horner fit)

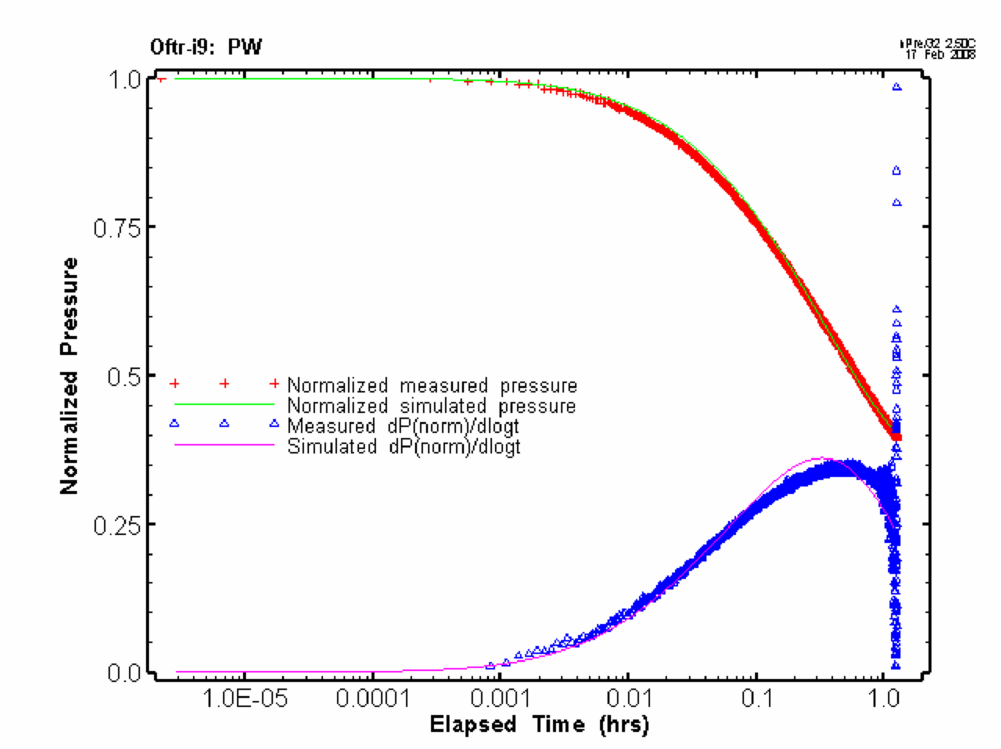


Figure 13: Oftr-i9: PW normalized pressure (Ramey A) plot.

Fit Statistics:

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_fm	[m/sec]	7.97E-11	7.93E-11	8.00E-11
P_fm	[kPa]	5281.8	5178.9	5284.8
ss_fm [1]	[1/m]	1E-05	held constant [1]	

[1] see text

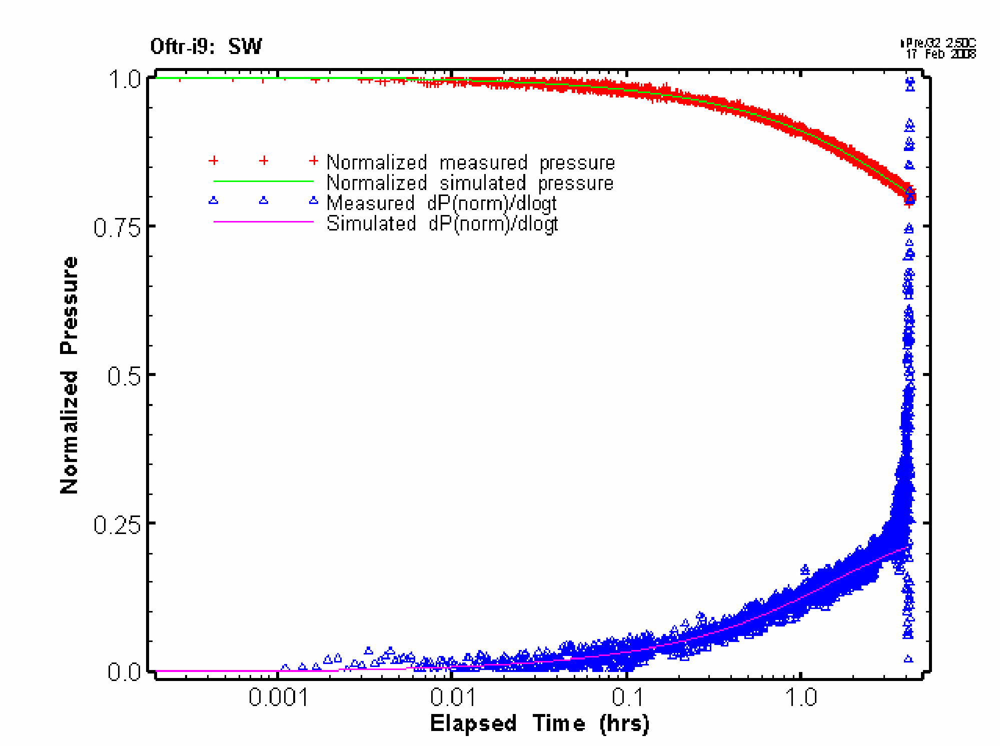


Figure 14: Oftr-i9: SW normalized pressure (Ramey A) plot

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_fm	[m/sec]	3.39E-11	2.96E-11	3.87E-11
P_fm	[kPa]	4828.2	4822.3	4834.1
ss_fm	[1/m]	9.87E-06	8.14E-06	1.20E-05

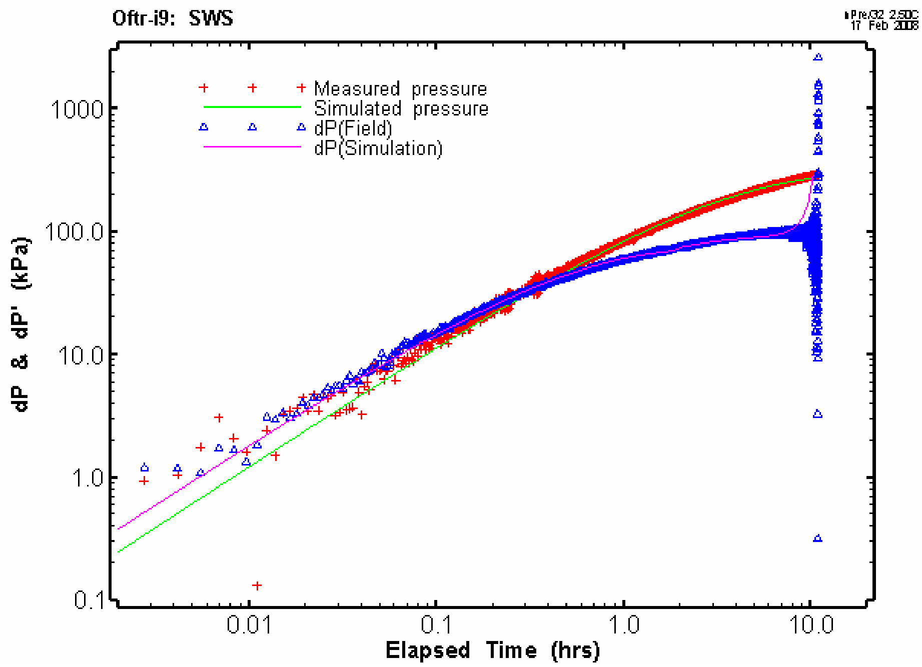


Figure 15: Oftr-i9: SWS log-log diagnostic plot

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_fm	[m/sec]	2.03E-11	2.01E-11	2.05E-11
P_fm	[kPa]	5251.0	5249.1	5253.0
ss_fm	[1/m]	1.00E-05	held constant [1)]	

1) see text

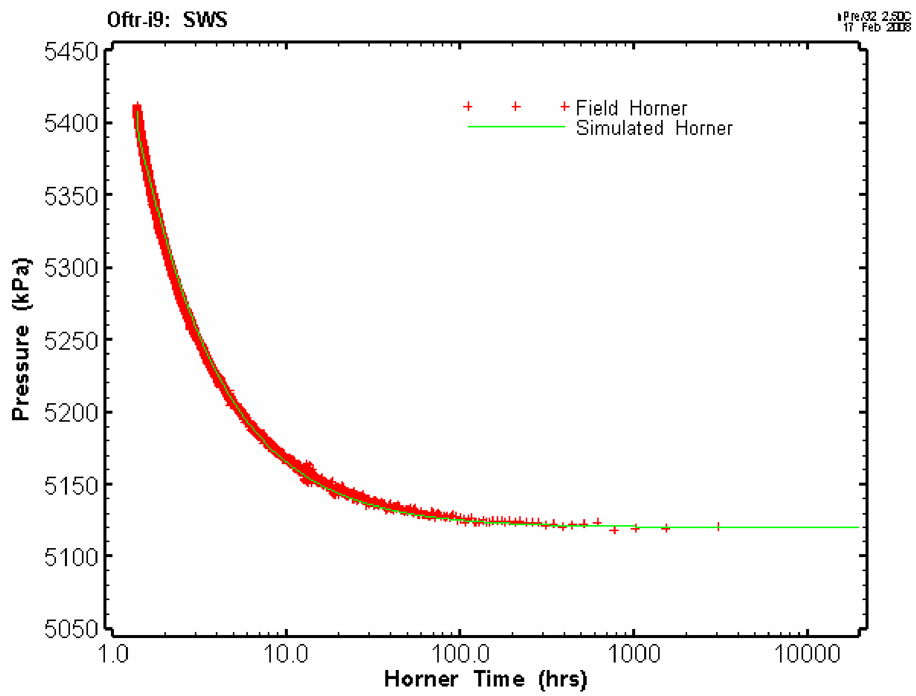


Figure 16: Oftr-i9: SWS Horner plot

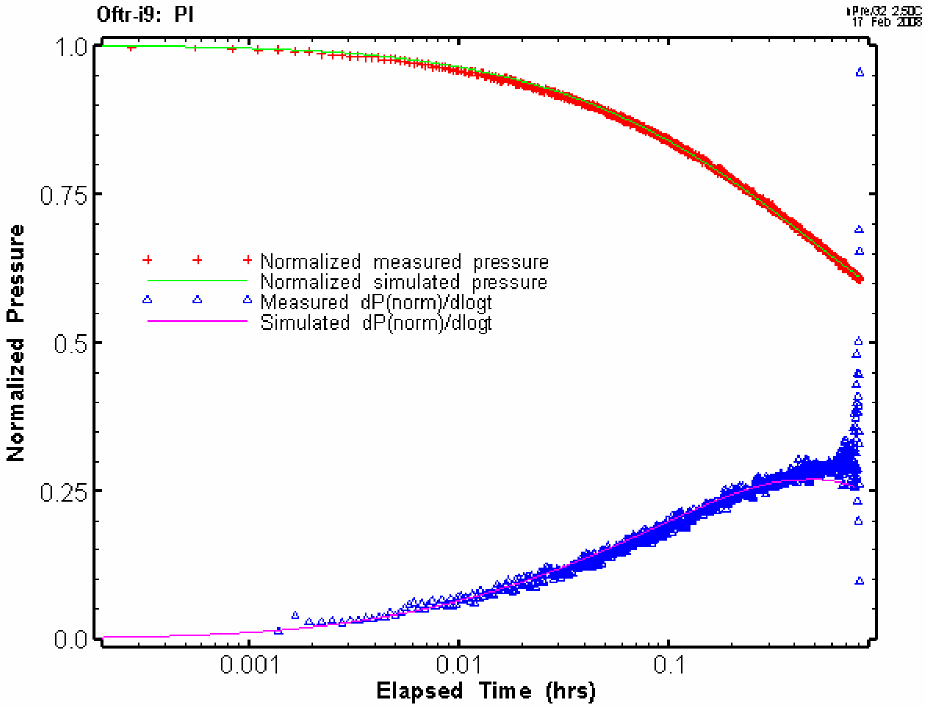


Figure 17: Oftr-i9: PI normalized pressure (Ramey A) plot

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_fm	[m/sec]	3.57E-11	3.55E-11	3.59E-11
P_fm	[kPa]	5999.0	5993.4	6004.7
ss_fm	[1/m]	1.00E-05	held constant 1)	

1) see text

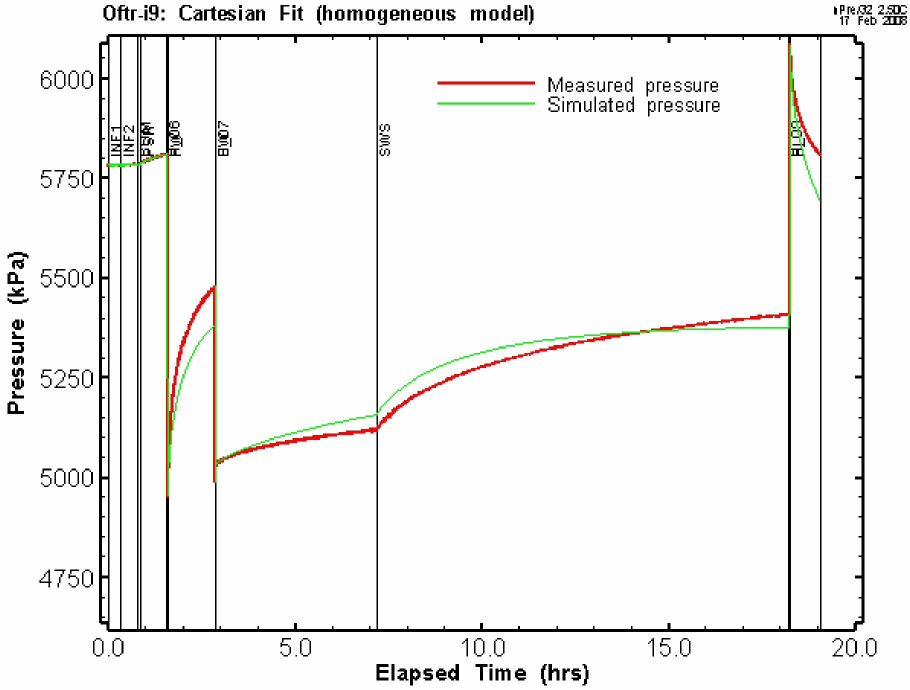


Figure 18: Oftr-i9: Cartesian fit of the entire test for homogeneous model

Fit Statistics:

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_fm	[m/sec]	4.05E-11	4.00E-11	4.10E-11
P_fm	[kPa]	5176.3	73.6	5179.0
ss_fm	[1/m]	1.00E-05	held constant [1]	

[1] see text

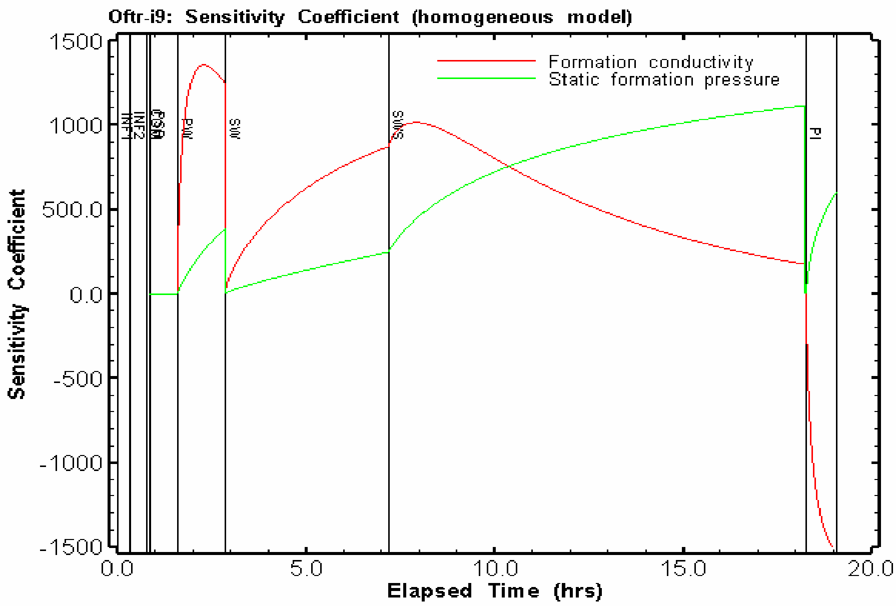


Figure 19: Oftr-i9: Sensitivity coefficients for the different formation parameters during the different sequences (homogenous model)

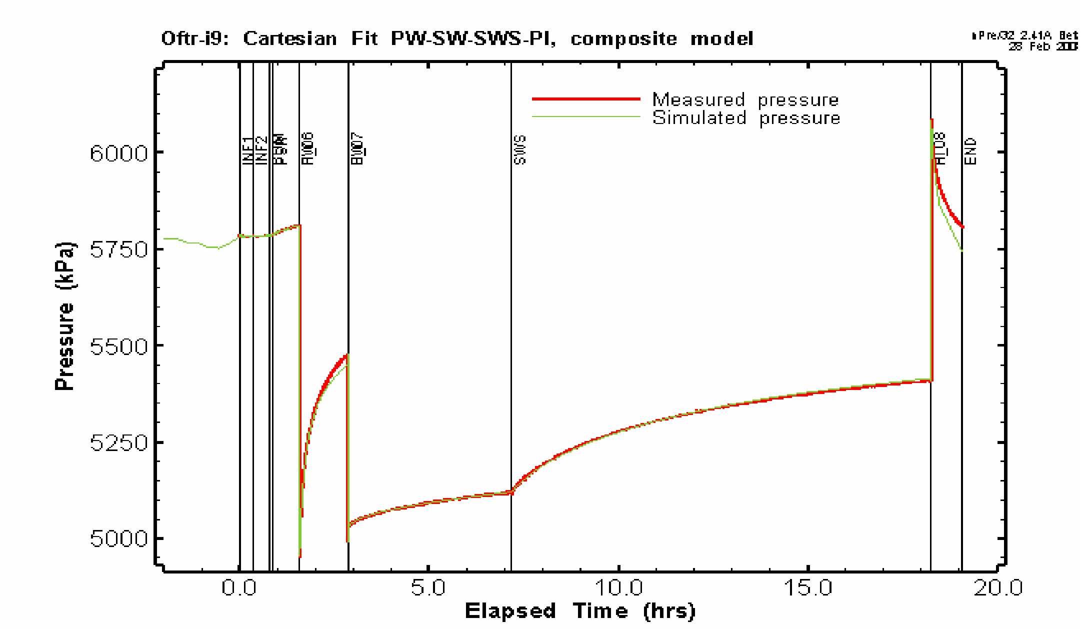


Figure 20: Oftr-i9: Cartesian fit of the entire test for the composite model

Fit Statistics:

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_fm	[m/sec]	1.70E-12	1.12E-12	2.60E-12
K_s	[m/sec]	8.48E-11	7.74E-11	9.29E-11
P_fm	[kPa]	5523.1	5494.7	5551.5
ss_fm	[1/m]	1.00E-05	5.76E-06	1.74E-05
ss_s	[1/m]	1.32E-06	1.04E-06	1.67E-06
t_s	[m]	0.26	0.23	0.29

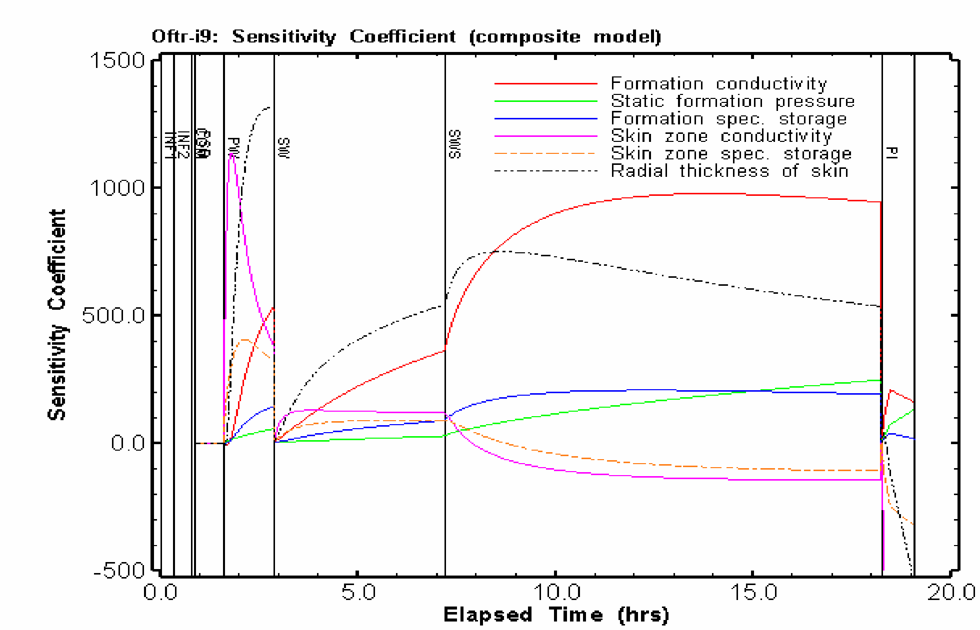


Figure 21: Oftr-i9: Sensitivity coefficients for the different formation parameters during the different sequences (composite model)

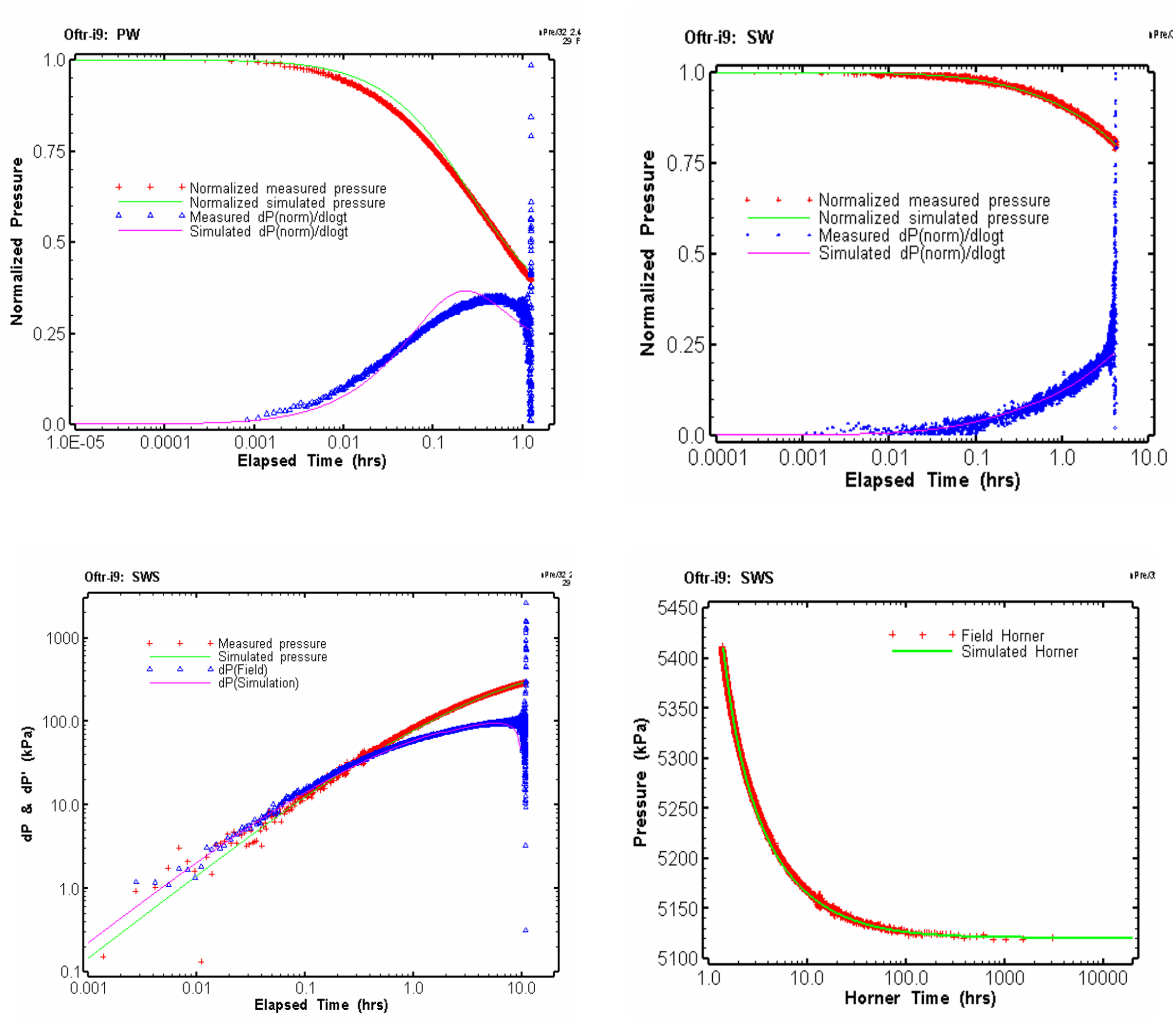


Figure 22: Oftr-i9: Composite model: individual sequence plots for PW, SW and SWS (diagnostic plot and Horner plot) using the Cartesian fit parameters for the entire test.

Abbreviations

	Test phases
INF	Packer inflation
INF1	Inflation of lower packer (INF2 = Inflation of upper packer)
DEF	Packer deflation
DEF1	Deflation of lower packer (DEF2 = Deflation of upper packer)
PSR	Static pressure recovery (shut-in valve closed)
SI	Slug injection test
SIS	Pressure recovery after slug injection test (shut-in)
SW	Slug withdrawal test
SWS	Pressure recovery after slug withdrawal test (shut-in)
PI	Pulse injection test
PW	Pulse withdrawal test
HI	Constant head injection test (constant pressure difference)
HIS	Pressure recovery after constant head injection test (shut-in)
HW	Withdrawal test applying constant differential head
HWS	Pressure recovery after constant head withdrawal test (shut-in)
MR	Multi-rate test: Test with variable flow rate
MRS	Pressure recovery after test with variable flow rate
RW	Pump test with constant flow rate
RWS	Pressure recovery after pump test with constant flow rate (shut-in)
RI	Constant flow injection test
RIS	Pressure recovery after constant flow injection test (shut-in)
VC	Shut-in valve is closed
VO	Shut-in valve is open
	General
CBP	Cooper, Bredehoeft, Papadopulos (type-curve matching method)
DAS	Data acquisition system
FS	Full scale
IARF	Infinite Acting Radial Flow
LC	Log cycle
m agl	Meters above ground level
m bgl	Meters below ground level
m asl	Meters above sea level
OD	Outer diameter
PVT	Pressure volume temperature correlation
SLA	Straight-line analysis
TOC	Top of casing
WL	Water level (or WT = Water table)

Nomenclature

	Description	SI-Unit		Description	SI-Unit
b	Y-intercept of linear regression		S_S	Specific storativity	m^{-1}
C	Wellbore storage constant	$m^3 Pa^{-1}$	S_{SS}	Specific storativity of skin zone	m^{-1}
C_S	Wellbore storage constant, shut-in	$m^3 Pa^{-1}$	s	Skin factor	-
C_D	Dimensionless wellbore constant	-	t, Δt	Time, elapsed time	s
c_f	Pore volume based compressibility	Pa^{-1}	t_C	Critical time	s
c_r	Rock compressibility	Pa^{-1}	t_D	Dimensionless time	-
c_{SC}	System compressibility (= test zone compressibility c_{tz})	Pa^{-1}	Δt_e	Equivalent time (after Agarwal)	s
c_w	Water compressibility	Pa^{-1}	Δt_H	Horner time	-
Δh	Differential head	m	t_p	Production time	s
g	Acceleration of gravity (9.81)	$m\ s^{-2}$	t_p^*	Corrected production time	s
h_S	Static head	m	t_m	Match time	s
k	Intrinsic permeability	m^2	t_0	X-intercept of linear regression	s
K, K_f	Hydraulic conductivity of formation () special case	m/s	t_s	Thickness of skin zone	m
K_s	Hydraulic conductivity of skin zone () special case	m/s	T	Transmissivity	m^2/s
L	Interval length	m	T_W	Water temperature	°C
m	slope (regression)		z_1	P1 sensor depth	m
P	Pressure	Pa, kPa	z_2	P2 sensor depth	m
P_0	Minimal or maximal pressure	Pa, kPa	z_3	P3 sensor depth	m
P_{atm}	Probe signal at atmospheric pressure	Pa, kPa			
ΔP	Differential pressure, pressure change	Pa, kPa	α ,β	Type-curve match parameter	-
P_D	Dimensionless pressure	-	α	aquifer compressibility	Pa^{-1}
P_f	Static formation pressure	Pa, kPa	μ	Dynamic viscosity	Pa·s
P_i	Initial pressure	Pa, kPa	θ	Porosity	-
$P_{min/max}$	Minimal/maximal pressure	Pa, kPa	ρ_w	Density of fresh water	kg/m^3
P_{S1}	Static pressure in P1-Interval (below bottom packer)	Pa, kPa			
P_{S2}, P_f	Static pressure in test interval	Pa, kPa			
P_{S3}	Static pressure in annulus (above upper packer)	Pa, kPa			
q	Flow rate	$m^3 s^{-1}$			
q_{end}, q_e	Last flow rate	$m^3 s^{-1}$			
Q, Q_{tot}	Cumulative flow	m^3			
r_e	Effective radius (Slug, Pulse test)	m			
R_i	Radius of influence	m			
R^2	Correlation coefficient	-			
r_c	Tubing radius	m			
r_w	Wellbore radius	m			
R_1	Radius, composite model	m			
R_D	Dimensionless radius	-			
S	Storativity	-			
S_C	Sensitivity coefficient				
S_{SC}	Scaled sensitivity coefficient				

Definitions

$C_D = \dfrac{\rho\, g\, C}{2\pi\, S\, r_{w^2}}$	Wellbore constant, dimensionless
$H_D = \dfrac{P - P_i}{P_0 - P_i}$	Dimensionless pressure (slug und pulse tests)
$K = \dfrac{k\, \rho\, g}{\mu}$	Hydraulic conductivity
$P_D = \dfrac{2\pi\, T\, \Delta h}{q}$	Dimensionless pressure
$\Delta P = \rho\ g\, \Delta h$	Differential pressure
$q_D = \dfrac{q}{2\pi\, T\, \Delta h}$	Dimensionless flow
$t_D = \dfrac{t\, T}{r_w^2 S}$	Dimensionless time
$S = S_S\, L$	Storativity
$s = \left(\dfrac{K_f}{K_s} - 1\right) \ln\left(\dfrac{r_w + t_s}{r_w}\right)$	Skin factor
$S_S = \rho\, g\, (\alpha + \theta\, c_w)$	Specific storativity
$S_C = \dfrac{\partial P}{\partial r}$	Sensitivity coefficient.

where ∂P is the partial derivative of the calculated system response (i.e., pressure) with respect to a parameter varied by the derivative span ∂r .
For comparison of sensitivity coefficients for different parameters, the sensitivity coefficients are typically scaled by inverses of the respective standard deviations as follows:

$$S_{sc} = S\,\frac{\sigma_r}{\sigma_P} = \frac{\partial P}{\partial r} \cdot \frac{\sigma_r}{\sigma_P}$$

where S_{sc} is the scaled sensitivity coefficient, σ_r is the a priori standard deviation of the measurement error, and σ_P is the estimated standard deviation of the parameter.
If not otherwise stated, default values σ_r = 1 and σ_P = 1 were used.

Definitions (continued)

$T = K\ L$	Transmissivity
$\frac{t_D}{C_D} = \frac{2\pi T t}{\rho\ g C}$	Dimensionless time axis
$t_e = \frac{t_p \cdot \Delta t}{t_p + \Delta t}$	Dimensionless Agarwal time (Agarwal, 1980)
$t_e^* = \frac{t_P^* \cdot \Delta t}{t_P^* + \Delta t}$	Modified Agarwal time (using corrected production time)
$t_P^* = \frac{Q}{q_{end}}$	Modified production time (Ehlid-Economides and Ramey, 1980)

Form

DAILY LOG REPORT

Date	Time	Activity	Who
		Interval Oftr-i9: 583.0 – 592.09 m	
02.11.07	*13:21*	*Start file: Oftr_2007_11_02_oftr_i9.dat* *P1 = 5792.54 kPa* *P2 = 5783.74 kPa* *P3 = 5784.44 kPa* *T1 = 37.04 °C* *T2 = 37.77 °C* *T3 = 37.93 °C* *Water table: -0.90 m bgl*	*SR, FP,*
	13:24	*Start inflation of packer 1*	
	13:46	*Start inflation of packer 2*	
	14:07	*Both packers are pressurized by pressure vessel at 35 bar (PA1 and PA2 pressure lines are interconnected)*	
	14:13	*Shut-in (Start PSR)*	
	14:20	*Fix installation rods with clamp and tubing spider, slight movement of the rods*	
	14:25	*Swabbing to 80 m below top of 1.9" tubing rods*	
	14:36	*Recording P4-sensor at atmospheric pressure P4 = 101.14 kPa*	
	14:45	*Water table in 1.9''NU: 85.05 m below top of rods,*	
	14:51	*Installation of P4 Sensor in 1.9"NU tubing, P4 Sensor 195.71 kPa*	
	14:55	*Scan rate 1 s*	
	14:56	*Start PW-test, P4 Sensor: 200.99 kPa => ds = 53.82 cm*	
	15:25	*Scan rate 5 s, Stop scanning P4 sensor*	
	15:32	*Water table in test rods:84.01m below top of rods*	
	15:37	*Recording slim-tubing-sensor at atmospheric pressure Pslim = 2.48 kPa*	
	15:40	*Install slim tubing*	
	15:53	*Inflate slim tubing packer to 25 bar*	
	16:00	*Change clamping jaws*	
	16:09	*Start slim-tubing-sensor*	
	16:12	*Scan rate 1 s*	
	16:13	*Start SW-test*	
	16:21	*Scan rate 5 s*	
	16:40	*Test of Packer pressure on "old" upper packer with*	
	18:10	*FP leaves site*	
	19:10	*JH, AK, Sti arrive on site*	*JH, AK*
	19:30	*SR leaves site*	*SR*
	20:30	*Shut-in, Start SWS*	
	21:00	*AK leaves site*	*AK*
03.11.07	*06:55*	*Deflate slim-packer*	
	07:05	*SR arrives on site*	*SR*
	07:10	*FP arrives on site*	*FP*
	07:17	*Pull out slim-tubing*	
	07:19	*Fill up Tubing with water up to top*	
	07:25	*Start preparation for Pulse Injection Test (PI)* *Water table in test rod is at top of tubing.*	
	07:30	*Install injection head on top of tubing rods with 6/4mm pressure line connected to nitrogen bottle, pressure 4 bars.* *P2 = 5408.20 kPa, set scan rate to 1 s*	
	07:38	*Start PI-test, valve open during 10 s*	
	07:40	*Water table Water table in test rod is 0.48 m below top of rod => Δs = 0.48 m = 612 ml, measured 630 ml*	
	07:45	*JH leaves site*	*JH*

Form **DAILY LOG REPORT**	SOLEXPERTS

Date	***Time***	***Activity***	***Who***
03.11.07	*08:22*	*Pressure curve decrease below end pressure of PSR-Phase (=> deflate packers)*	*SR, FP*
	08:25	*Open valve, deflate packers*	
	09:05	*Both packers away from borehole wall*	
	09:07	*Water table tubing: -0.71 m bgl, water table casing: -0.98 m bgl*	
	09:18	*Stop file*	
	09:23	*Fill up casing to the top*	
	09:30	*Start moving system upwards to position of Interval 10*	
	09:35	*System blocked (5 tons overload), open packer lines (TU-No. 89 is moved out)*	
	09:38	*Start file: Oftr_2007_11_03_oftr_i9_test.dat* *P1 = 5721 kPa* *P2 = 5709 kPa* *P3 = 5710 kPa* *T1 = 40.6 °C* *T2 = 40.8 °C* *T3 = 40.8 °C*	
	09:42	*Pulling force 4 tons, system free*	
	09:43	*Stop file*	
	09:50	*Continue to pull system upwards*	
	09:58	*System is blocked again (5 tons overload), open packer lines (TU-No. 86 moved out)*	
	10:10	*Continue to pull system upwards*	

Remark: After inflation of lower packer, the pressure below (P1) starts to decrease by about 300 kPa. Then the pressure increases slowly towards "normal static" pressure. This behaviour is probably related to a period of underpressure which occurred while pulling the blocked packer system after end of test Oftr-i8.

SR Sacha Reinhardt
JH Jörg Hayer
AK Andreas Kern
FP Fredi Portmann
Sti Daniel Stillhard

Form

INSTALLATION RECORD HDDP

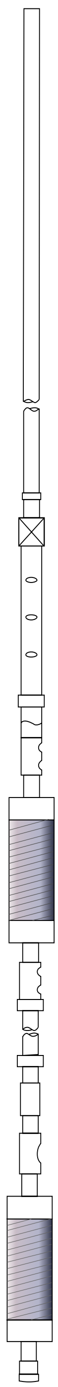
SOLEXPERTS

Seite 1 / 1

Oftringen NOK EWS Borehole: Hydraulic Testing

Date	02.11.2007	**Project Leader**	Fi/SR						
Borehole	**NOK EWS 2007**	**Direction**	vertical	**Reference point**	433.0	**JOB Nr**	1763	**Location**	Oftringen
Borehole Depth	719.0 m	**Casing depth**	376.5 m bgl	**Interval lenght**	9.09 m	**Test Name**	oftr_i9	**System**	**HDDP** 110
Borehole diameter	146 mm	**Stickup**	-2.57 m	**Water depth**	-0.90 m bgl	**Test depth (UPLS)**	583.00 m bgl	**Probe ID**	**TSSP** S1

Note: All depths shown are not correct for borehole deviation



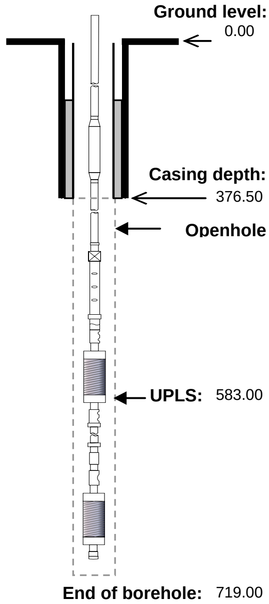
Component		Qty -	L unit m	L total m	Depth m	OD mm	ID mm	Wgt kg	Str t
Stickup	-2.57 m bgl								
Ground level					0.00				
Tubing 1.9" NU			578.30	578.30		56.1	40.3	2371	12.0
Pop joint			1.02	7.27	575.73	56.1	40.3	4.2	12
SIT Non Displacement Valve			0.84			79.0	24.0	20.6	15
Probe Shell Carrier mit Triple Sub	TSSP P3		1.97		579.56	70.0	10.9	48.0	25
	TSSP P2		0.30		579.86				
	TSSP P1		0.30		580.16				
			0.04						
X-Over	2"3/8 EU Pinx1.9" NU Box		0.51			66.0	40.0	2.1	16
Safety joint 3"1/16						78.0	50.5	5.5	24
Above Side Entry Sub (ASES)			0.52			66.0	32.0		24
Packer Stick Up			0.26			--	25.0		
Up. Packer Seal — **Upper Packer**	UPUS		0.26		581.75				
			1.25			108.0	32.0	82.4	17
	UPLS		0.24		583.00				
Straddle Length — **Packer Stick Down**			0.31	9.09		--	25.0		
Below Side Entry Sub (BSES)			0.52			66.0	32.0		24
X-Over	1.9" NU Pinx2"3/8 EU Box		0.26			--		3.0	16
Tubbing 1.9" NU			4.55			56.1	40.3	18.7	12
X-Over	2"3/8 EU Pinx1.9" NU Box		0.45			--		3.0	16
Filter			0.3			72.0	50.0	19.0	19
	Screen		1.45						
			0.3						
P1-Seal Sub			0.3			78.0	--		24
Packer Stick Up			0.16			--	32.0		
Lower Packer Seal — **Lower Packer**	LPUS		0.25	1.92	592.09				
			1.25			110.0	32.0	70.2	17
	LPLS		0.24		593.34				
Packer Stick Down			0.43			--	32.0		
End Cap					594.01	78.0	--		
End of Borehole					719.00				

Comments:

P4: submersible pressure transducer on cable

P_{SL}: submersible pressure transducer at bottom of slim tubing

Borehole configuration:



Probe	523 006.1	
values at atmosphere	P1	99.6
	P2	91.1
	P3	106.3
	P4/P_{SL}	101.4/2.5
	T1	14.3
	T2	14.2
	T3	14.0
Total Weight (kg)	**2668.3**	

Form
TALLY LIST

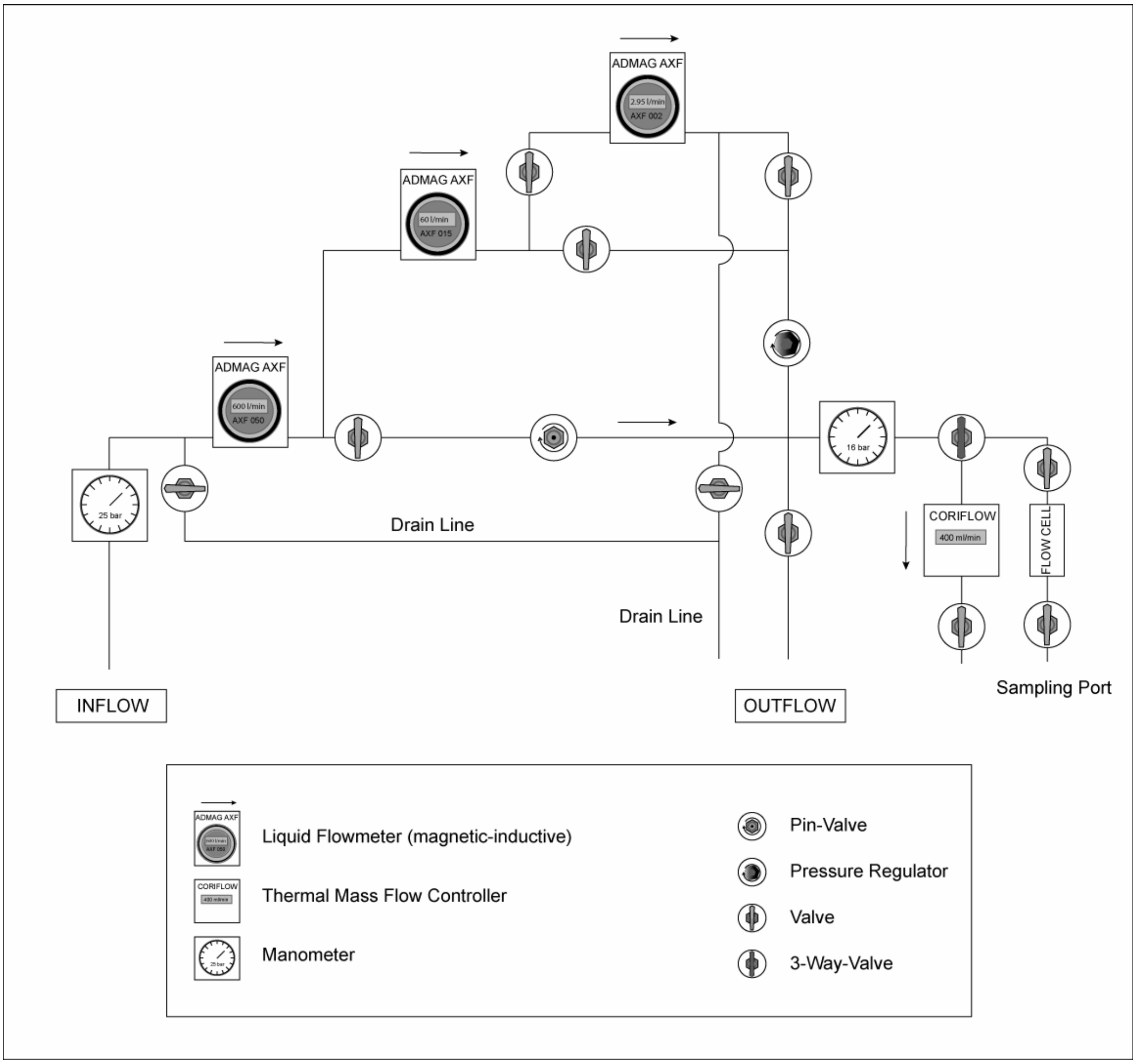
Borehole	NOK EWS 2007	Interval name	Test Oftr_i9	Date	02.11.2007
Depth	719.0 m	Interval depth	583.0 - 592.1 m	Location	Oftringen

TU	1	6.51	TU	51	6.50				
TU	2	6.51	TU	52	6.51				
TU	3	6.51	TU	53	6.51				
TU	4	6.51	TU	54	6.51				
TU	5	6.51	TU	55	6.51				
TU	6	6.51	TU	56	6.51				
TU	7	6.51	TU	57	6.50				
TU	8	6.51	TU	58	6.51				
TU	9	6.51	TU	59	6.51				
TU	10	6.50	TU	60	6.51				
TU	11	6.50	TU	61	6.50				
TU	12	6.51	TU	62	6.50				
TU	13	6.50	TU	63	6.50				
TU	14	6.51	TU	64	6.50				
TU	15	6.51	TU	65	6.51				
TU	16	6.51	TU	66	6.50				
TU	17	6.51	TU	67	6.50				
TU	18	6.51	TU	68	6.51				
TU	19	6.50	TU	69	6.50				
TU	20	6.51	TU	70	6.50				
TU	21	6.51	TU	71	6.47				
TU	22	6.50	TU	72	6.50				
TU	23	6.51	TU	73	6.48				
TU	24	6.50	TU	74	6.50				
TU	25	6.50	TU	75	6.50				
TU	26	6.50	TU	76	6.50				
TU	27	6.50	TU	77	6.50				
TU	28	6.50	TU	78	6.50				
TU	29	6.50	TU	79	6.51				
TU	30	6.50	TU	80	6.51				
TU	31	6.50	TU	81	6.51				
TU	32	6.50	TU	82	6.50				
TU	33	6.51	TU	83	6.51				
TU	34	6.51	TU	84	6.50				
TU	35	6.50	TU	85	6.48				
TU	36	6.51	TU	86	6.50				
TU	37	6.50	TU	87	6.51				
TU	38	6.50	TU	88	6.50				
TU	39	6.51	TU	89	5.94				
TU	40	6.50							
TU	41	6.51							
TU	42	6.51							
TU	43	6.50							
TU	44	6.50							
TU	45	6.50							
TU	46	6.50							
TU	47	6.51							
TU	48	6.51							
TU	49	6.51							
TU	50	6.51							
		325.28			253.02		0.00		0.00

Total string length: 578.30

Form

SURFACE EQUIPMENT LAYOUT



Flow meter	Lower limit of measuring range	(% of FS)	Upper limit of measuring range (l/min)	Accuracy between 3% and 100% of FS (% of rate)	Accuracy between 1% and 3% of FS (% of rate)	Equipment used
AXF DN2	0.030 l/min	1 %	2.95 l/min	0.35	0.5	no
AXF DN15	0.6 l/min	1 %	60 l/min	0.35	0.5	no
AXF DN50	11.78 l/min	1 %	1178.10 l/min	0.35	0.5	no
Coriflow	0.50 kg/h	2 %	25.00 kg/h	1	1	no

Form

BENCH TEST

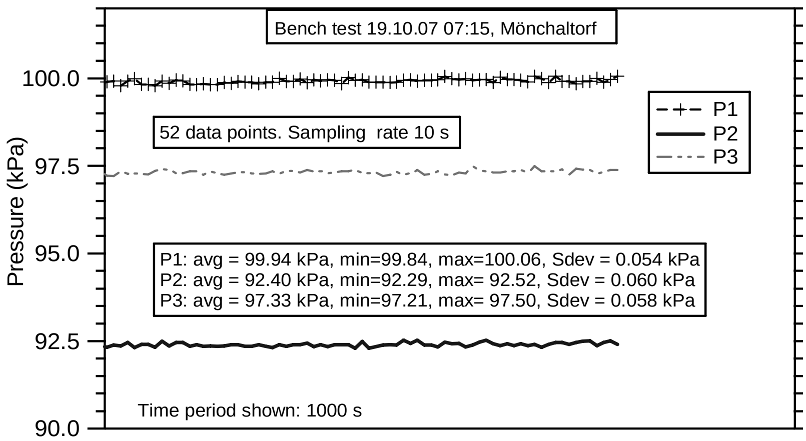
Project	Location	Date
Oftringen NOK EWS Borehole	Oftringen	20.12.2007
Well name	**Test name**	**Engineer**
NOK EWS 2007	Oftri-i9	Fi/SR

Transducer describtion	Output units
P1, P2, P3: 0-206.84 bar (3000 Psi), P4: 0-6 bar, P_{ST} = 0-10 bar	kPa, °C

P1#	P2#	P3#	P4#
43224	50370	43231	591.001.027

Offsite pretest bench test (Date: 19.10.07)

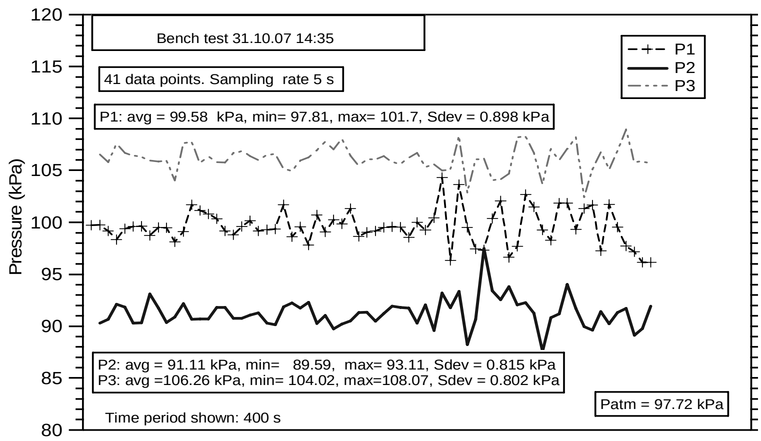
Measurement conditions (P, T and position)	Sampling rate
97.7 kPa 5.6 °C	10 s
( ) direct (x) vertical ( ) horizontal	



P1 average:	99.84 kPa
P2 average:	92.29 kPa
P3 average:	97.33 kPa
P4 average:	n.m. kPa
P_{SL} average:	n.m. kPa
P1 Sdev	0.054 kPa
P2 Sdev	0.060 kPa
P3 Sdev	0.058 kPa
File:	TestData24.DAT

Onsite pretest bench test (Date: 31.10.07)

Measurement conditions (P, T and position)	Sampling rate
97.4 kPa 14.2 °C	5 s
( ) direct (x) vertical ( ) horizontal	



P1 average:	99.58 kPa
P2 average:	91.11 kPa
P3 average:	106.26 kPa
P4 average:	101.36 kPa [1)]
P_{SL} average:	n.m kPa
P1 Sdev	0.898 kPa
P2 Sdev	0.815 kPa
P3 Sdev	0.815 kPa
P4 Sdev	0.0085 kPa [1)]
P_{SL} Sdev	n.m kPa

[1)] Data not shown, 01.11.07, 20:50
Oftr_2007_11_01_oftr_i8.DAT, Patm=98.2 kPa

File: Oftr_2007_10_31_atm1.DAT

Form

BENCH TEST

Project	Location	Date
Oftringen NOK EWS Borehole	Oftringen	21.12.2007
Well name	**Test name**	**Engineer**
NOK EWS 2007	Oftri-i9	Fi/SR

Transducer describtion	Output units
P1, P2, P3: 0-206.84 bar (3000 Psi), P4: 0-6 bar, P_{ST} = 0-10 bar	kPa, °C

P1#	P2#	P3#	P4#
43224	50370	43231	591.001.027

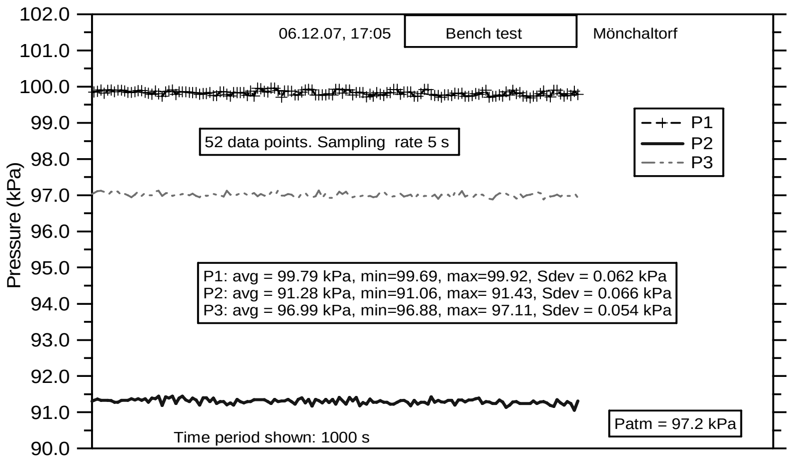
Onsite after test bench test (Date: -)

Measurement conditions (P, T and position)	Sampling rate
( ) direct ( ) vertical ( ) horizontal	

No onsite after test bench test was carried out

Offsite after test bench test (Date: 06.12.07)

Measurement conditions (P, T and position)	Sampling rate
96.6 kPa 9.6 °C	5 s
( ) direct (x) vertical ( ) horizontal	



P1 average:	99.69 kPa
P2 average:	91.28 kPa
P3 average:	96.99 kPa
P4 average: [1)]	101.44 kPa
P_{SL} average:	n.m. kPa
P1 Sdev	0.062 kPa
P1 Sdev	0.062 kPa
P2 Sdev	0.066 kPa
P3 Sdev	0.054 kPa
P4 Sdev	0.007 kPa

[1)] not shown on graph

File: test8.dat

Appendix J

Quick Look Report
Interval Oftr-i10

nagra.

QUICK LOOK REPORT OFTRINGEN - TEST OFTR-i10

TEST START (Date/Time)	:	03.11.2007 / 09:38	**TEST END (Date/Time)**	:	04.11.2007 / 17:23

DOUBLE PACKER TEST

Test Interval Information	:			top test interval	:	408.50	m bgl
borehole depth [1), 4)]	:	719.0	m	bottom of test interval	:	417.59	m bgl
borehole radius	:	0.073	m	total interval length	:	9.09	m
tubing radius	:	20.0	mm	midpoint of interval	:	413.05	m bgl
				P2-depth (z_2)	:	405.36	m bgl
interval volume, nominal [5)]	:	0.152	m^3	theoretical Cs-value[3)]	:	3.04E-10	m^3/Pa
slim tubing radius		4.75	mm	theoretical C-value (slim tube)	:	7.23E-09	m^3/Pa
WL prior to packer inflation [2)]	:	1.92	m bgl	P2 signal prior to packer inflation	:	4046.65	kPa
WL in annulus at test end [2)]	:	-1.40	m bgl	P2 offset assuming ρ_{avg} = 997 kg/m3		100.78	kPa

1) all depths are not corrected for borehole deviation from vertical

2) WL = water level

3) assumes a total borehole system compressibility of 2E-09 Pa^{-1}

4) all depth measurements refer to ground level

5) cylindrical volume of isolated borehole section

Note all pressures cited in this report are absolute

Preliminariy information				
longitude of borehole	:	240887		
latitude of borehole	:	638346		
elevation of ground level (GL)	:	433.0	m asl	(reference point for all measurements)
assumed fresh water head	:	433.0	m asl	(assumed hydrostatic)
end of drilling	:	17.10.07 09:55		(Geotec)
porosity	:	3%		(assumed)
mud density [6)]	:	1032	kg/m^3	(Geotec end of drilling, 17.10.07)
borehole water density	:	997	kg/m^3	(Geotec after circulation of fresh water, 17.10.07; estimated using P2)
formation water density [7)]		1005.3	kg/m^3	(PVT correlation calculated by Saphir)
specific storativity [8)]	:	2.19E-06	m^{-1}	
formation water viscosity [7)]	:	8.87E-04	Pa s	(PVT correlation calculated by Saphir)
fluid compressibility [7)]	:	4.46E-10	1/Pa	(PVT correlation calculated by Saphir)
total compressibility [8)]	:	7.45E-09	1/Pa	(calculated assuming cf= 7.00E-09 1/Pa)

6) Taken from daily report No. 53

7) Assumed, using salinity 10'000 ppm, T = 30.9°C, P = 4130 kPa

8) Calculated based on assumed porosity and compressibility values

Responible Test Engineers	
Onsite:	Hayer, J.; Reinhardt, S.
Test analysis and reporting:	Rösli, U.; Fisch, H.R.

Test Summary		
Test objectives	:	water sample, transmissivity, static formation pressure, flow model
borehole history	:	drilling through midpoint of interval: 27.09.2007, 01:40; 895.973 h duration until start of test
geology	:	limestone (Geissberg Member)
geophysics	:	Caliper log, salinity log, temperature log, sonic log
test phases	:	COM, PSR, SW, SWS, SW2, SWS2, PI, PI2, PI3, SW3, SWS3, SW4, SWS4, SW5, SWS5, SW6, SWS6, pumping, air-lifts, swabbing

QLR results	**Test zone 408.50 - 417.59 mbgl**	**T [m2/s]**	**K [m/s]**	**Formation Flow model**	**Freshwater Head [m asl]**
Analytical interpretation		1.91E-05	2.10E-06	radial flow	-
Numerical simulation		2.31E-05	2.54E-06	homogeneous	426.8

Note:
A complete list of results is provided in the summary tables

Mönchaltorf, 04. March 2008, Revision 1a prepared by: SOLEXPERTS INTERA

Summary of Test Data

Test Phase		INF	COM	PSR	SW
duration	[h]	0.53	0.17	1.30	0.01
T2 (i/f)	[°C]	31.2 / 30.7	30.7 / 30.6	30.6 / 30.7	30.7 / 30.6
P1 (i/f)	[kPa]	4063 / 4076.7	4077 / 4071	4071 / 4047	4046 / 4046
P2 (i/f)	[kPa]	4046 / 4052	4052 / 4052	4052 / 4055	4044 / 4050
P3 (i/f)	[kPa]	4051 / 4054	4054 /4055	4055 / 4055	4053 / 4055
P4 (i/f)	[kPa]				
Measured C	[m^3/Pa]				
c_{SC}	[1/Pa]				
q	[l/min]				
Q	[l]				
inner boundaries		no analysis	no analysis	no analysis	no analysis
flow geometry					
outer boundaries					
T	[m^2/s]				
K	[m/s]				
k	[m^2]				
S_S	[1/m]				
S	[-]				
Pi, P_f if matched	[kPa]				
Head	[m asl]				
Derived flow rate	[l/min]				
s (skin factor)	[-]				
S_{SS} (skin zone)	[1/m]				
t_S (skin zone)	[m]				
K_S (skin zone)	[m/s]				
figures					
temperature effects					
borehole history					
anomalies					
bypass PA2					
bypass PA1					

comments

notes:
- i = initial, f = final
- T, K values in bold most representable of the undisturbed formation

1) analytical with no superposition
2) numerical simulation with detailed borehole history effects
A) matched parameter
B) input parameter
C) calculation assumes: freshwater density 1000 kg/m^3, g = 9.81 m^2/s, P_{atm} and z_2 as stated on front page
D) early-middle time fit
E) late time fit
F) Estimate based on log-log unit slope of SWS5

Summary of Test Data		Page 2 / 5			
Test Phase		SW2 1)	SW2 2)	PI 1)	PI2 1)
duration	[h]	0.03	0.03	1.27	0.37
T2 (i/f)	[°C]	30.6 / 30.7	30.6 / 30.7	30.7 / 30.7	30.7/30.7
P1 (i/f)	[kPa]	4041 / 4039	4041 / 4039	4031 / 4024	4024 / 4023
P2 (i/f)	[kPa]	3857 / 3992	3857 / 3992	4089 / 4045	4158 / 4054
P3 (i/f)	[kPa]	4054 / 4056	4054 / 4056	4054 / 4055	4056 / 4056
P4 (i/f)	[kPa]				
Measured C	[m^3/Pa]			2.27E-07 A)	5.72E-08 A)
c_{SC}	[1/Pa]			1.49E-06 A)	3.76E-07 A)
q	[l/min]				
Q	[l]				
inner boundaries		wellb. storage	wellb. storage	wellb. storage	wellb. storage
flow geometry		hom.	hom.	hom.	hom.
outer boundaries		inf.lat.ext.	inf.lat.ext.	inf.lat.ext.	inf.lat.ext.
T	[m^2/s]	1.91E-05 A)	**2.31E-05** A)	6.94E-06 A)	4.46E-05 A)
K	[m/s]	2.10E-06 A)	**2.54E-06** A)	7.64E-07 A)	4.91E-06 A)
k	[m^2]	1.89E-13	2.28E-13	6.87E-14	4.41E-13
S_S	[1/m]		1.00E-07 A)		
S	[-]		9.09E-07		
Pi, P_f if matched	[kPa]	4052.81 B)	4016.2 A)	4024.9 B)	4044.86 B)
Head	[m asl]	430.5 C)	426.8 C)	427.7 C)	429.7 C)
Derived flow rate	[l/min]				
s (skin factor)	[-]				
S_{SS} (skin zone)	[1/m]				
t_S (skin zone)	[m]				
K_S (skin zone)	[m/s]				
figures		3, 6, 7	3, 6, 20	3, 8, 9	3, 8, 10
temperature effects		no	no	no	no
borehole history		no	yes	no	no
anomalies		no	no	no	no
bypass PA2		no	no	no	no
bypass PA1		no	no	no	no

comments

notes:
- i = initial, f = final
- T, K values in bold most representable of the undisturbed formation

1) analytical with no superposition
2) numerical simulation with detailed borehole history effects
A) matched parameter
B) input parameter
C) calculation assumes: freshwater density 1000 kg/m^3, g = 9.81 m^2/s, P_{atm} and z_2 as stated on front page
D) early-middle time fit
E) late time fit
F) Estimate based on log-log unit slope of SWS5

Summary of Test Data		Page 3 / 5							
Test Phase		PI3 1)		SW3 1)		SW3 1)		SW3 2)	
duration	[h]	0.75		0.40		0.40		0.40	
T2 (i/f)	[°C]	30.7 / 30.7		30.6 / 30.8		30.6 / 30.8		30.6 / 30.8	
P1 (i/f)	[kPa]	4024 / 4021		4019 / 4020		4019 / 4020		4019 / 4020	
P2 (i/f)	[kPa]	4141 / 4058		3210 / 3918		3210 / 3918		3210 / 3918	
P3 (i/f)	[kPa]	4056 / 4055		4053 / 4055		4053 / 4055		4053 / 4055	
P4 (i/f)	[kPa]								
Measured C	[m^3/Pa]	6.51E-08							
c_{SC}	[1/Pa]	4.28E-07							
q	[l/min]								
Q	[l]								
inner boundaries		wellb. storage		wellb. storage		wellb. storage		wellb. storage	
flow geometry		hom.		hom.		hom.		hom.	
outer boundaries		inf.lat.ext.		inf.lat.ext.		inf.lat.ext.		inf.lat.ext.	
T	[m^2/s]	1.69E-05	A)	7.14E-06	D)	1.00E-05	E)	6.70E-06	A)
K	[m/s]	1.86E-06	A)	7.86E-07	D)	1.10E-06	E)	7.37E-07	A)
k	[m^2]	1.67E-13		7.07E-14		9.89E-14		6.63E-14	
S_S	[1/m]							1.00E-07	A)
S	[-]							9.09E-07	
Pi, P_f if matched	[kPa]	4053.85	B)	4057.54	B)	4057.54	B)	4282.7	B)
Head	[m asl]	430.6	C)	431.0	C)	431.0	C)	453.9	C)
Derived flow rate	[l/min]								
s (skin factor)	[-]								
S_{SS} (skin zone)	[1/m]								
t_S (skin zone)	[m]								
K_S (skin zone)	[m/s]								
figures		3, 8, 11		3, 12, 13		3, 12, 13		3, 12, 21	
temperature effects		no		no		no		no	
borehole history		no		no		no		yes	
anomalies		no		no		no		no	
bypass PA2		no		no		no		no	
bypass PA1		no		no		no		no	

comments

notes:
- i = initial, f = final
- T, K values in bold most representable of the undisturbed formation

1) analytical with no superposition
2) numerical simulation with detailed borehole history effects
A) matched parameter
B) input parameter
C) calculation assumes: freshwater density 1000 kg/m^3, g = 9.81 m^2/s, P_{atm} and z_2 as stated on front page
D) early-middle time fit
E) late time fit
F) Estimate based on log-log unit slope of SWS5

Summary of Test Data		Page 4 / 5			
Test Phase		SWS3 2)	SW4	SW5	SWS5 1)
duration	[h]	0.40	0.01	0.05	1.07
T2 (i/f)	[°C]	30.7 / 30.6	30.7 / 30.7	30.7 / 30.8	30.8 / 30.8
P1 (i/f)	[kPa]	4020 / 4016	4014 / 4014	4014 / 4013	4013 / 4013
P2 (i/f)	[kPa]	3218 / 3950	2175 / 2379	3198 / 2956	2958 / 3809
P3 (i/f)	[kPa]	4055 / 4054	4052 / 4056	4059 / 4054	4054 / 4054
P4 (i/f)	[kPa]				
Measured C	[m^3/Pa]				(3.35E-09) F)
c_{SC}	[1/Pa]				(2.20E-08) F)
q	[l/min]				
Q	[l]				
inner boundaries		wellb. storage	no analysis	no analysis	wellb. storage
flow geometry		hom.			hom.
outer boundaries		inf.lat.ext.			inf.lat.ext.
T	[m^2/s]	(1.02E-07) A)			(1.66E-05) A)
K	[m/s]	(1.12E-08) A)			(1.83E-06) A)
k	[m^2]	(1.01E-15)			(1.65E-13)
S_S	[1/m]	(1.00E-05) B)			
S	[-]	(9.09E-05)			
Pi, P_f if matched	[kPa]	(3882.50) A)			(2957.84) B)
Head	[m asl]	(413.1) C)			(318.9)
Derived flow rate	[l/min]			~27.15	
s (skin factor)	[-]				
S_{SS} (skin zone)	[1/m]				
t_S (skin zone)	[m]				
K_S (skin zone)	[m/s]				
figures		12, 22, 23		14	3, 14, 15, 16, 17
temperature effects		no	no	no	no
borehole history		yes	no	no	no
anomalies		no	no	no	no
bypass PA2		no	no	no	no
bypass PA1		no	no	no	no

comments

notes:
- i = initial, f = final
- T, K values in bold most representable of the undisturbed formation

1) analytical with no superposition
2) numerical simulation with detailed borehole history effects
A) matched parameter
B) input parameter
C) calculation assumes: freshwater density 1000 kg/m^3, g = 9.81 m^2/s, P_{atm} and z_2 as stated on front page
D) early-middle time fit
E) late time fit
F) Estimate based on log-log unit slope of SWS5

Summary of Test Data		Page 5 / 5 more see separate table in report			
Test Phase		SW6 [1)]	SW6 [1)]	SWS6 [2)]	Simulation entire Seq. [2)]
duration	[h]	1.69	1.69	0.67	9.58
T2 (i/f)	[°C]	30.7 / 30.7	30.7 / 30.7	30.7 / 30.7	30.6 / 30.7
P1 (i/f)	[kPa]	4012 / 4010	4012 / 4010	4010 / 4010	4046 / 4010
P2 (i/f)	[kPa]	2504 / 3684	2504 / 3684	3684 / 3698	4050 / 3684
P3 (i/f)	[kPa]	4054 / 4056	4054 / 4056	4056 / 4056	4055 / 4056
P4 (i/f)	[kPa]				
Measured C	[m^3/Pa]				
c_{SC}	[1/Pa]				
q	[l/min]				
Q	[l]				
inner boundaries		wellb. storage	wellb. storage	wellb. storage	wellb. storage
flow geometry		hom.	hom.	hom.	hom.
outer boundaries		inf.lat.ext.	inf.lat.ext.	inf.lat.ext.	inf.lat.ext.
T	[m^2/s]	4.40E-06 D)	5.97E-06 E)	9.45E-07 A)	4.74E-06 A)
K	[m/s]	4.84E-07 D)	6.57E-07 E)	1.04E-07 A)	5.22E-07 A)
k	[m^2]	4.35E-14	5.91E-14	9.35E-15	4.69E-14
S_S	[1/m]			1.00E-05 B)	1.00E-05 A)
S	[-]			9.09E-05	9.09E-05
Pi, P_f if matched	[kPa]	3807.42 B)	3807.42 B)	3576.4 A)	3881 A)
Head	[m asl]	405.5 C)	405.5 C)	381.9 C)	413.0 C)
Derived flow rate	[l/min]				
s (skin factor)	[-]				
S_{SS} (skin zone)	[1/m]				
t_S (skin zone)	[m]				
K_S (skin zone)	[m/s]				
figures		3, 18, 19	3, 18, 19	18, 24, 25	26, 27
temperature effects		no	no	no	no
borehole history		no	no	yes	yes
anomalies		no	no	no	no
bypass PA2		no	no	no	no
bypass PA1		no	no	no	no

comments

notes:
- i = initial, f = final
- T, K values in bold most representable of the undisturbed formation

1) analytical with no superposition
2) numerical simulation with detailed borehole history effects
A) matched parameter
B) input parameter
C) calculation assumes: freshwater density 1000 kg/m^3, g = 9.81 m^2/s, P_{atm} and z_2 as stated on front page
D) early-middle time fit
E) late time fit
F) Estimate based on log-log unit slope of SWS5

Test overview

Test Oftr-i10 (408.5 – 417.59 m bgl) was performed on 03.-04.11.2007 in the Oftringen NOK EWS-Borehole with a double-packer and an interval length of 9.09 m.. The test interval consisted of limestones of the Geissberg Member. On 28.-29.10.2007, the same borehole section was tested using the same packer positions (see QLR Oftr-i6d). During the test Oftr-i6d, interference of gas impeded to maintain continuous pumping rates and the extraction of a representative formation sample failed. The test objectives of the second test in this borehole section, Test Oftr-i10, were to retry extraction of a representative formation sample and to obtain improved estimates of interval transmissivity and fresh-water hydraulic head using an appropriate flow model. Pressures and temperatures were measured in the test interval (P2, T2) and in the interval below the lower packer (P1, T1) and in the annulus above the upper packer (P3, T3). In addition, pressure was measured in the tubing above the upper packer (P4).

The pressure response of the entire test sequence in Oftr-i10 is shown in **Figure 1**. The pressure history derived from water table measurements (source: Colenco, Solexperts) and fluid density measurements (SJ Geotec) is presented in **Figure 2**.

Following packer inflation (INF) the test sequence started with a COM and PSR phase to dissipate temperature and borehole history effects.

Temperature effects are considered negligible, because downhole temperatures (T1, T2, T3) indicated only relatively small variations of approximately 0.3 °C during the SW test phases, which might have been caused by the inflow of warmer formation water into the borehole. The noise in temperature measurements is about 0.1 °C (**Figure 4**). The PSR phase is influenced by compliance effects due to not fully stabilized packer pressures (**Figure 5**).

The first slug withdrawal test (SW, SWS) was performed using the slim tubing. Opening the shut-in valve to initiate the SW test produced a pressure drop of only 10.5 kPa. The pressure recovered very quickly by about 6.5 kPa in 37s and the test was shut-in. After shut-in, less than 1 kPa pressure change was recorded during SWS. The applied differential pressure and the application of the slim tubing were considered inappropriate and therefore, the SW-SWS test phases were not analyzed. The second slug test (SW2) was carried out after removal of the slim tubing. During the slug test SW2, the water level varied within the 1.9" test tubing. The SWS2 pressure recovered at a level lower than the initial pressure (pressure prior start of SW2). A first pulse injection test (PI) was performed to measure the wellbore compressibility (and derive system compressibility) and to obtain another estimate of the formation properties. PI was followed by a second and a third pulse injection test (PI2, PI3). All three tests showed a fast pressure recovery and the pulse final pressures always stabilized at a higher level compared to the pulse initial pressures (**Figure 4**).

Further SW/SWS tests were performed to get more distinct formation responses for the determination of the formation properties (SW3 to SWS6). A final short SW test (SW7-SWS7) was followed by the installation of a downhole double-valve pump in the 1.9-inch test tubing and multiple pumping cycles, each causing small differential pressure of less than 10 kPa. The maximum (cumulated) drawdown during these pumping activities was about 65 kPa. The aim of the pumping was to produce true formation water containing less than 1% drilling fluid (marked with tracer). This goal was not met. No flow rates were measured since no test analysis was foreseen for the formation water sampling phase. As the use of the double-valve pump proofed to be inefficient, a series of air-lift cycles (SW8 to SWS19) and a series of swabbing cycles (SW20 to SWS25) were performed before the de-installation of the system. The start and end times and pressures (P2) for the various phases are given in **Table 1**.

Due to the influence of the adjacent high voltage current transformer facility (NOK), the pressure and temperature signals of the downhole triple probe were noisy during the hole testing sequence.

Table 1: The Oftr-i10 test phases with time and pressure (P2) values

Event	Group	Start	End	Duration		P-start	Pend
		[s]	[s]	[s]	[hrs]	[kPa]	[kPa]
INF1		4928	5808	880	0.24	4046.0	4049.1
INF2		5808	6858	1050	0.29	4049.1	4051.5
COM		6858	7458	600	0.17	4051.5	4052.0
PSR		7458	12132	4674	1.30	4052.0	4055.0
SW		12138	12175	37	0.01	4043.7	4050.1
SWS		12175	14281	2106	0.59	4050.1	4052.8
SW2		14286	14382	96	0.03	3856.5	3991.9
SWS2		14382	18650	4268	1.19	3991.9	4024.9
PI		18697	23268	4571	1.27	4089.2	4044.9
PI2		23278	24614	1336	0.37	4158.2	4053.8
PI3		24624	27337	2713	0.75	4140.7	4057.5
SW3		27348	28798	1450	0.40	3210.2	3917.8
SWS3		28798	33980	5182	1.44	3917.8	3949.6
SW4		33992	34029	37	0.01	2175.0	2378.6
SWS4		34029	36262	2233	0.62	2378.6	3902.1
SW5		36267	36441	174	0.05	2198.4	2957.8
SWS5		36442	40299	3857	1.07	2957.8	3807.4
SW6		40303	46373	6070	1.69	2503.7	3683.8
SWS6		46373	48774	2401	0.67	3683.8	3698.1
SW7		48829	51578	2749	0.76	3098.7	3634.3
SWS7		51593	53268	1675	0.47	3634.3	3648.0
Pumping		53923	67221	13298	3.69	3656.7	3639.8
SW8	Air-lifts	68085	68816	731	0.20	3131.1	3535.5
SW9		68819	70373	1554	0.43	3074.1	3495.3
SW10		70383	71703	1320	0.37	3074.1	3449.6
SW11		71718	72913	1195	0.33	3048.0	3410.3
SW12		72923	74118	1195	0.33	2972.5	3377.3
SW13		74153	75333	1180	0.33	2962.3	3345.9
SW14		75343	76668	1325	0.37	2959.8	3320.8
SW15		76673	77778	1105	0.31	3080.4	3313.3
SW16		77788	78713	925	0.26	2998.7	3280.8
SW17		78873	80368	1495	0.42	3081.3	3268.0
SW18		80378	82218	1840	0.51	3137.9	3266.4
SW19		82228	87738	5510	1.53	2561.4	3244.2
SWS19		87738	99258	11520	3.20	3244.2	3333.8
SW20	Swabbing	99263	99918	655	0.18	1448.3	3004.0
SWS20		99918	100778	860	0.24	3004.0	3074.8
SW21		100788	101433	645	0.18	1648.8	2862.7
SWS21		101433	102333	900	0.25	2862.7	2941.5
SW22		102338	103003	665	0.18	1450.3	2738.5
SWS22		103003	103858	855	0.24	2738.5	2820.2
SW23		103863	104768	905	0.25	1739.2	2708.0
SWS23		104768	105483	715	0.20	2708.0	2761.2
SW24		105493	106348	855	0.24	1604.9	2626.9
SWS24		106348	112858	6510	1.81	2626.9	2873.7
SW25		112868	113623	755	0.21	1361.8	2641.8
SWS25		113623	114318	695	0.19	2641.8	2696.9
DEF		114318	117103	2785	0.77	2696.9	3820.7

Analysis

For the QLR analysis, the analytical and numerical methods were used for a standard analysis, which will be the basis for a possible detailed analysis depending on the test objectives and test results. Only the first test phases until SWS6 were investigated by the analytical analysis and by the nSights simulations (**Figure 3**).

Analytical Analysis

Type curve and straight-line fitting methods are applied. Effects of the borehole pressure history are not taken into account.

Slug Withdrawal Test (SW2)

The first slug test (SW) didn't show a significant pressure change and was not analyzed. Prior to start of the SW2 test, the water table in the 1.9” tubing was lowered to 35 m bgl (change of tubing water level does not affect the interval pressure while the shut-in tool is closed).

The SW2 test was started 0.6 hours after start of SW. The slug response was recorded with two pressure sensors at different depth positions: P2-sensor at 405.36 m bgl, and P4 at approximately 38 m bgl. The recorded pressure response of both sensors during SW2 is shown in **Figure 6**. The P4 values are shown with an additional offset value of 3600 kPa in order to enable comparison with P2. The pressure change during SW is larger for P4 than for P2. At end of SWS2, the difference in ΔP is 104 kPa. This difference might be due to the observed gas production or de-gassing in the water column of the tubing. If the water column in the 1.9" tubing was not solely displayed by the SW2 response but also by volume taken by gas bubbles, then the P4 sensor may "see" more pressure difference, assuming that the density of the water column above P4 remains constant.
The slug response was analyzed using CBP type-curves. The middle time fit using an α-type-curve of value 1.0E-05 provides a transmissivity estimate of 1.9E-06 m^2/s.

First Pulse Injection Test (PI)

The PI test was initiated at steady pressure conditions. At start of the pulse test the interval pressure was exposed to a differential pressure of 64 kPa. The shut-in valve was kept open during 47 seconds. After shut-in, a water level decrease equal to 1.3 m was measured in the 1.9” test string (P4 measurement), indicating a volume change of 1.67 liters due to compression of the test zone. The wellbore storage constant C ($\Delta V/\Delta P$) equals to 2.3E-07 m^3/Pa.

The pulse response was analyzed using CBP type-curves. As the final P2 pressure was higher than the initial pressure, only the early time fit is given in **Figure 9**, using an α-type-curve of value 1 which provides a transmissivity estimate of 7.0E-06 m^2/s.

Second Pulse Injection Test (PI2)

The PI2 test was initiated at steady pressure conditions. At start of the pulse test the interval pressure was exposed to a differential pressure of 113 kPa. The shut-in valve was kept open during 10 seconds. After shut-in, a water level decrease equal to 5.03 m was measured in the 1.9” test string (P4 measurement), indicating a volume change of 6.48 liters due to compression of the test zone. The wellbore storage constant C ($\Delta V/\Delta P$) equals to 5.7E-08 m^3/Pa.

The pulse response was analyzed using CBP type-curves. As the final P2 pressure was again higher than the initial pressure, only the early time fit is given in **Figure 10**, using an α-type-curve of value 1.0E-02 which provides a transmissivity estimate of 4.5E-05 m^2/s.

Third Pulse Injection Test (PI3)

The PI3 test was initiated at steady pressure conditions. From an assumed ΔP of 500 kPa and a water level decrease of 4.39 m measured in the 1.9” test string (P4 measurement), indicating a volume change of 5.66 liters due to compression of the test zone, the wellbore storage constant C (ΔV / ΔP) of 1.1E-08 m^3/Pa (Csc = 7.4E-08 1/Pa) was calculated.

Slug Withdrawal Test (SW3)

Prior to start of the SW3 test, the water table in the 1.9” tubing was lowered to 110 m bgl (change of tubing water level does not affect the interval pressure while the shut-in tool is closed).

The SW3 test was started 0.8 hours after start of PI3. The slug response was analyzed using CBP type-curves. The pressure response during the slug test was quick, with a distinct kink after about 400s and thereafter, a remarked flattening. Thus, two different fits are given. The early time fit using an α-type-curve of value 1.0E-06 provides a transmissivity estimate of 7.1E-06 m^2/s, the middle time fit using an α-type-curve of value 1.0E-06 provides a transmissivity estimate of 1.0E-05 m^2/s.

Slug Withdrawal Test (SW5)

The SW5 test was not analyzed due to its short duration of 174 s (**Figure 14**). The pressure recovery (SWS) was recorded for 1.1 hours. The early-time data of SWS5 were analyzed in a log-log plot to derive a rough estimate of the wellbore storage C. The estimate is based on the flow rate at the end of the SW5 flow phase and the ‘unit slope’ identifying the early-time pressure recovery phase with one log cycle pressure change per one log cycle of time (**Figure 15**). The result of 3.35E-09 m^3/Pa has to be considered as an indicative value.

The SWS5 phase was analyzed in an Agarwal plot using a corrected production time t_p*of 216 s, calculated from the flow rate at the end of the SW5 flow phase of 27.15 l/min and a total produced volume of 97.57 l (**Figure 16**). The SWS5 analysis provides a transmissivity estimate of 1.7E-05 m^2/s (**Figure 17**). However, the IARF phase is not clearly visible and the estimated transmissivity might be overestimating the real formation properties. The result is considered a rough estimate only.

Slug Withdrawal Test (SW6)

Prior to start of the SW6 test, the water table in the 1.9” tubing was lowered to 200 m bgl (change of tubing water level does not affect the interval pressure while the shut-in tool is closed).

The SW6 test was started 1.12 hours after start of SW5. The slug response was analyzed using CBP type-curves. The pressure during the slug recovered quickly, with a distinct kink after about 500s and thereafter, a remarked flattening. Thus, two different fits are given. The early time fit using an α-type-curve of value 1.0E-06 provides a transmissivity estimate of 4.4E-06 m^2/s, the middle time fit using an α-type-curve of value 1.0E-06 provides a transmissivity estimate of 6.0E-06 m^2/s.

nSights Analysis

In a first step, the diagnostic plots for the individual sequences were analyzed and fitted individually accounting for borehole history and taking into account of transient effects associated with the preceding test sequences. In a second step, the entire test sequence was simulated and fitted based on the Cartesian pressure plots.

For the Cartesian fit, the PSR, SW2, SWS2, PI, PI2, PI3, SW3, SWS3, SW4, SWS4, SW5, SWS5, SW6 and SWS6 phases were chosen and no weighting for individual events was applied. The so-called history periods BH, INF1, INF2 and COM were not fitted but incorporated as test events with defined pressure in the simulation process. Additionally, the SW and SWS phases were also included as history period because of the small pressure signal and the very short duration of these tests (see above). The transitional phases SW2_a, SW3_a, SW4_a, SW5_a and SW6_a denote very short events each of less than 0.0004 hrs duration and represent the transitional phases during initiation of the slug withdrawal tests (initial pressure decrease phase during start of slug withdrawal tests). The SW7 and SWS7 phases are relatively short and were not included in the simulation. The aim of the subsequent test sequences (pumping, airlift, swabbing) was to produce formation water samples. The test conditions were only summarily recorded during the sampling activities and therefore no nSights analyses were carried out for this period.

Please note that the fits of the Ramey plots for the analyzed pulse and slug sequences are the result of the inverse parameter estimation using nSights and represents a solution of a numeric process that includes the effects of potential transient effects of the preceding test phases and the borehole history.

A homogeneous model was assumed in this first evaluation for estimating formation parameters (i.e., K, S_s, and P_f). The analyses used a medium wellbore compressibility of 6E-8 m^3/Pa (c_{SC} = 4E-7 1/Pa) determined from the field measurements during PI2 and PI3, which is lower than the value determined from the first pulse test PI but higher than the value estimated from SWS5. During the parameter optimization, the specific storativity was allowed to vary within a plausible range from Ss = 1E-7 Pa^{-1} to1E-5 Pa^{-1}.

The SW2 test was the first test which could be numerically analyzed. The data fit of the SW2 sequences (**Figure 20**) is of relatively good quality and provides a K value which is similar to the analytical result together with low storativity (K = 2.5E-07 m/s, S_s= 1.0E-7 m^{-1}, P_f = 4016 kPa).

The data fit of the SW3 sequences (**Figure 21**) is relatively good for the early time data and provides a K value which corresponds to the early-middle-time analytical result (K = 7.4E-07 m/s, S_s= 1.0E-7 m^{-1}, P_f = 4283 kPa).

Additionally, the attempt was made to simulate the Horner fit of the SWS3 and SWS6 sequences. Both fits are of medium quality as well on the Horner plot (**Figure 23**, **Figure 25**) as in the Ramey plot (**Figure 22**, **Figure 24**). The formation parameters provided are very low for the conductivities (SWS3: K = 1.1E-08 m/s; SWS6: K = 1.04E-07 m/s) and for the static formation pressure (SWS3: P_f = 3883 kPa; SWS6: P_f = 3576 kPa). The storativity was fixed at the upper limit of the plausibility range (S_s= 1.0E-5 m^{-1}) after several simulations suggested higher Ss values.

With the current setup of the nSights simulation it was not possible to obtain a reasonable fit to all other phases, especially to the pulse test phases PI, PI2 and PI3.

The simulation of the entire test sequence on a Cartesian plot (**Figure 26**) produced the fitted parameters K = 5.22E-07 m/s and P_f = 3885.5 kPa with a storativity of S_s= 1.00E-5 m^{-1} which corresponds to the upper limit of the plausibility range. **Figure 26** shows the simulated pressure data which are lower than the measured data for the early sequences up to PI3 and higher for the late sequences from SW5. The best agreement between measured and simulated data in the Cartesian plot was found for SW3, SWS3, SW4 and SWS4. The sensitivity coefficients of the formation parameters during the different sequences are presented in **Figure 27**. The sensitivity to the storativity is very low except for the early-time data of the SW phases. The static formation pressure shows an increasing sensitivity with duration of individual phases. The definition of the sensitivity coefficient is given in the Chapter "Definitions".

The homogeneous model with single phase conditions does not satisfactorily reproduce the measured pressure data.

Results and Discussion

The shut-in wellbore storage constant value C=2.3E-07 m3/Pa obtained from the first pulse injection test PI corresponds to a system compressibility value (c_{SC}) of 1.5E-06 Pa^{-1}. This value is only slightly lower than the expected compressibility of gas at pressure conditions of the test zone.

The compressibility of gas at a depth of 4065 kPa equals to 2.46E-7 m^3/Pa. Dividing this value by the interval volume gives 1.6E-06 Pa^{-1} which marks the upper limit of the plausibility range for the c_{SC} parameter. The calculation of c_{SC} (c_{SC} = C / $V_{inteterval}$) assumes that all of the gas phase is restricted to the test zone and the no gas was present in the test string during the measurement of C which may be incorrect. If gas was present in the test tubing, the measured shut-in wellbore storage constant and the derived system compressibility would be overestimated. The shut-in wellbore storage constant values (C) obtained from the further pulse injection tests PI2 and PI3 are lower and correspond to system compressibility values (c_{SC}) of 3.8E-07 Pa^{-1} and 4.3E-07 Pa^{-1}, respectively. The system compressibility calculated from the SWS5 log-log plot (**Figure 15**) is 1.5 orders of magnitude lower with c_{SC} = 2.2E-08 Pa^{-1}. This value has to be considered with care because the calculation of C (and c_{SC}) from the unit-slope of a shut-in phase provides rough estimates only. However, the large range of measured compressibility values suggests that varying portions of gas were present in the test zone between packers and the test string. During the numerical simulations with nSights the Csc parameter was not varied with test time but a medium system compressibility of 4.0E-07 Pa^{-1} was used.

The series of pulse tests PI-PI2-PI3 showed increasing final pressures after each test event. The series of slug tests with shut-in phases, e.g. the series SW3-SWS3 to SW7-SWS7, showed decreasing final pressures after each test phase. This could indicate a reservoir of finite radial extent, limited by a no-flow type boundary. Additional nSights simulations were conducted (not shown) which included the optimization of the radius of an external no-flow boundary. These trials did not produce satisfactory fits and the bounded reservoir model is therefore discarded.

The estimated formation parameters for the different sequences vary considerably based on a homogeneous flow model. The range in K varies by more than two orders of magnitude between 1.1E-08 m/s (T=1.0E-07 m^2/s) and 4.9 E-06 m/s (T=4.5E-05 m^2/s). The range in calculated S_s varies between 1.0E-7 m^{-1} to 1.0E-5 m^{-1} and corresponds to the range in which the parameter was allowed to vary. The range in P_f is between 4283 kPa and 3576 kPa. This large range in properties is also reflected by the poor fit to the entire test sequence. This indicates that the homogeneous model may be inappropriate or other effects such as the presence of gas may have influenced the test. The sensitivities coefficients show that the storativity Ss has the lowest sensitivity among the fitted parameters. The later slug test events with larger differential drawdown could be influenced by increasing degassing effects in the formation. It would be expected that degassing effects in the formation would result in decreased permeability to water. As a general trend, the obtained T-/K- values are lower for the analyzed later test events (SWS3, SWS5, SW6) compared to the analyses of the earlier test events (**Figure 28**). The results of the earlier test events are considered to best represent the natural formation conditions. For the homogeneous model, the results of the SW2 analyses are preferred because of the relatively good fit in the Ramey plot.

The range in properties and the difficulty to fit the test sequences is probably due to changing occurrences of gas in the interval. Gas might have considerably changed the behavior between the individual test phases. A more accurate estimation of the formation properties would require an advanced model able to simulate variable gas and water saturations, and a test zone compressibility varying with test duration.

FIGURES

ABBREVIATIONS

NOMENCLATURE

DEFINITIONS

FIELD DOCUMENTATION

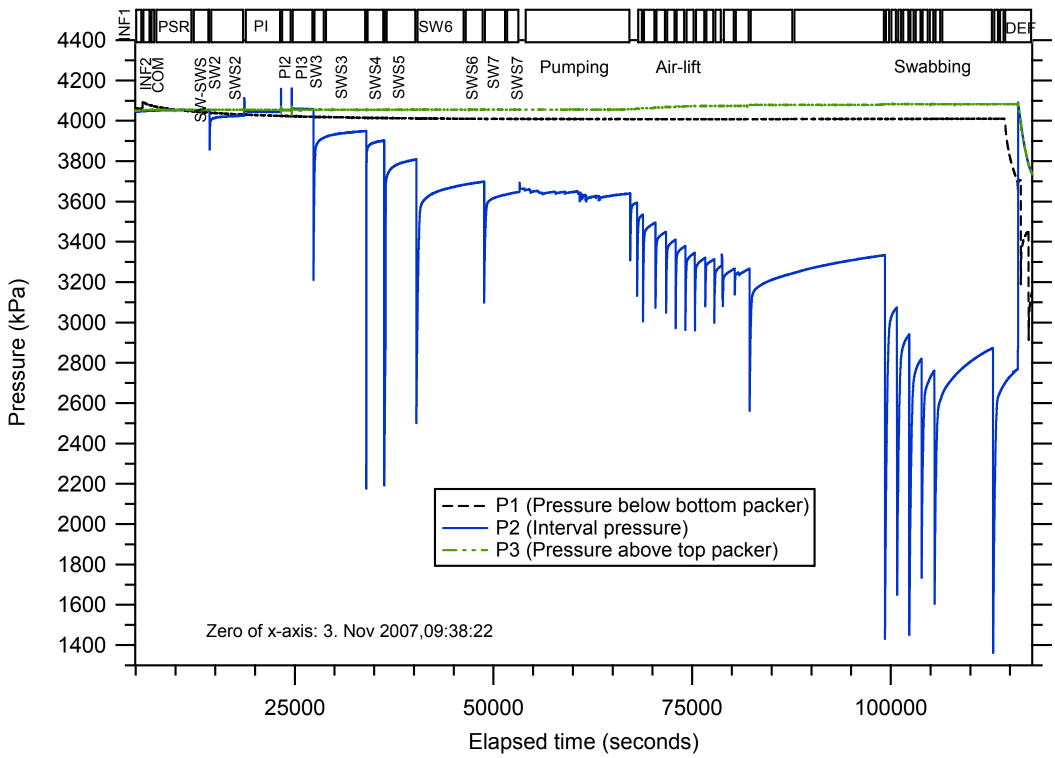


Figure 1: Oftr-i10: Overview plot

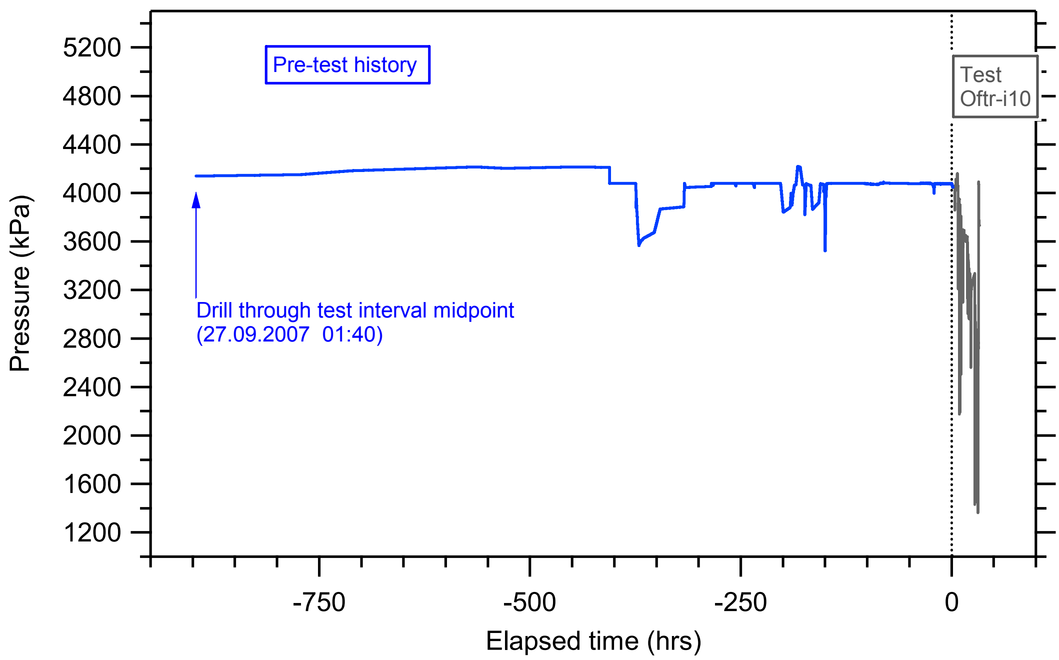


Figure 2: Oftr-i10: Borehole pressure history

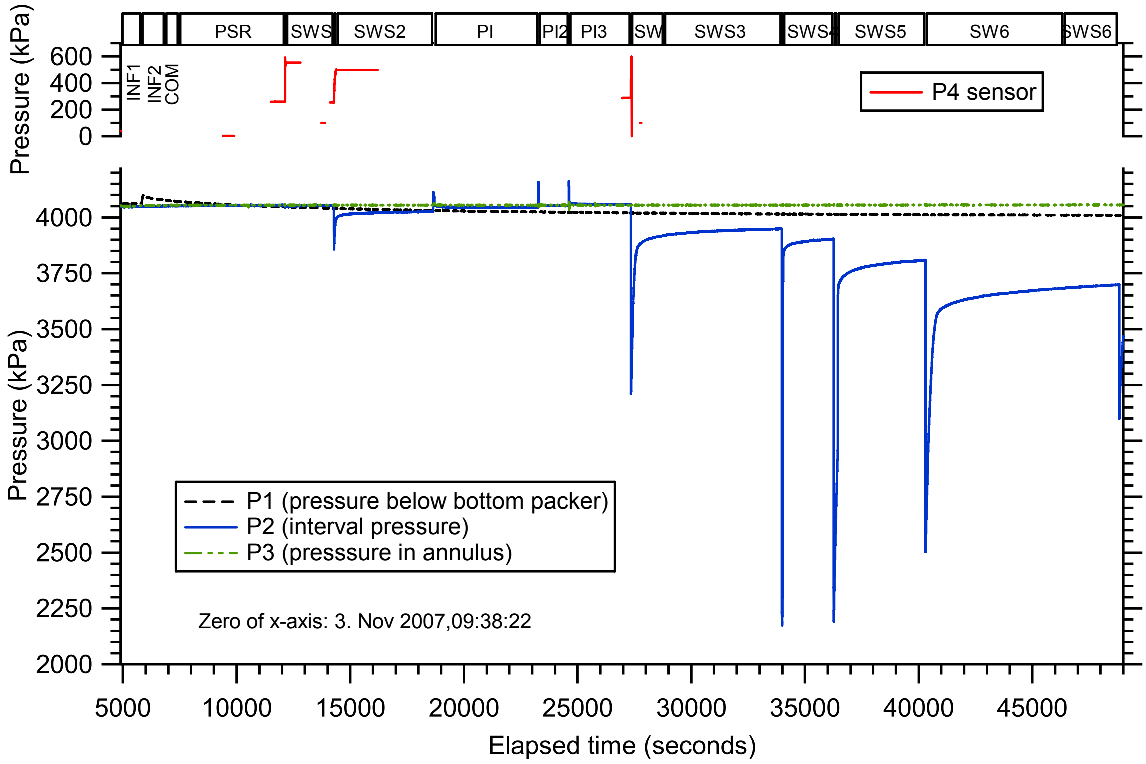


Figure 3: Oftr-i10: Overview plot showing test events from INF to SWS6

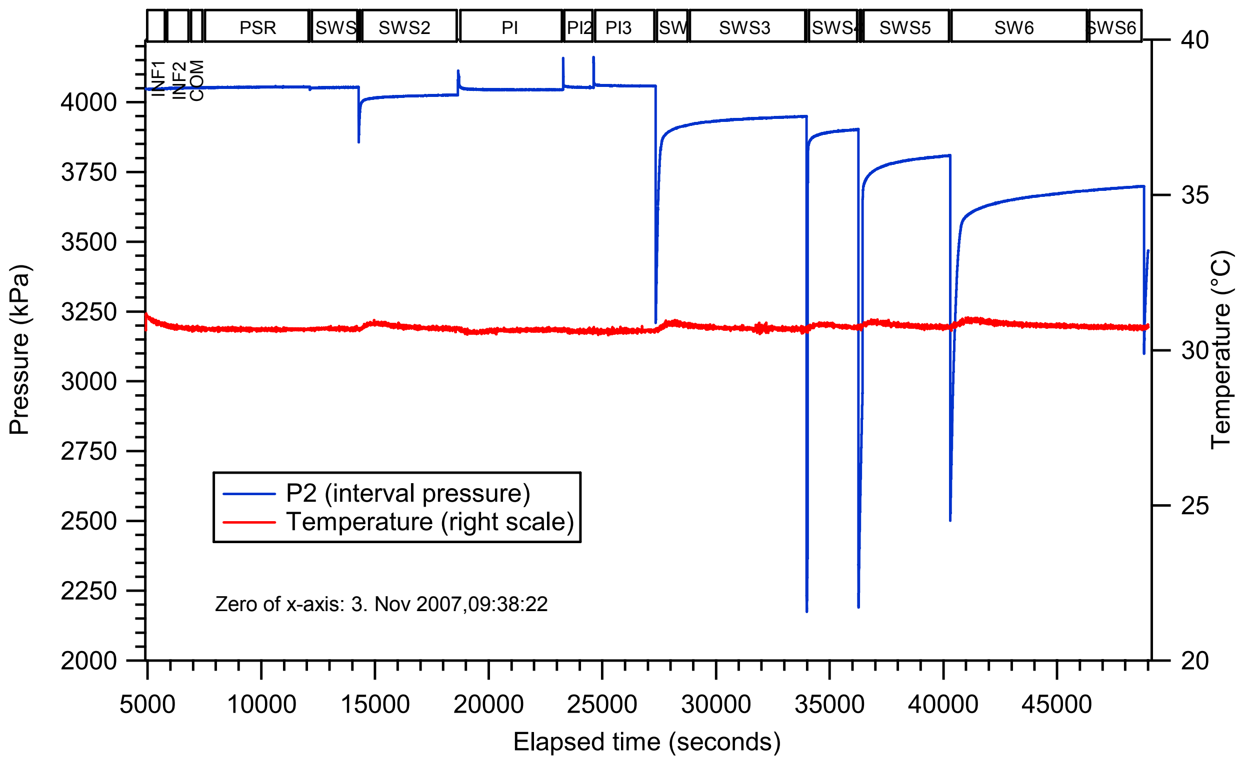


Figure 4: Oftr-i10: Measured downhole temperature for test events from INF to SWS6

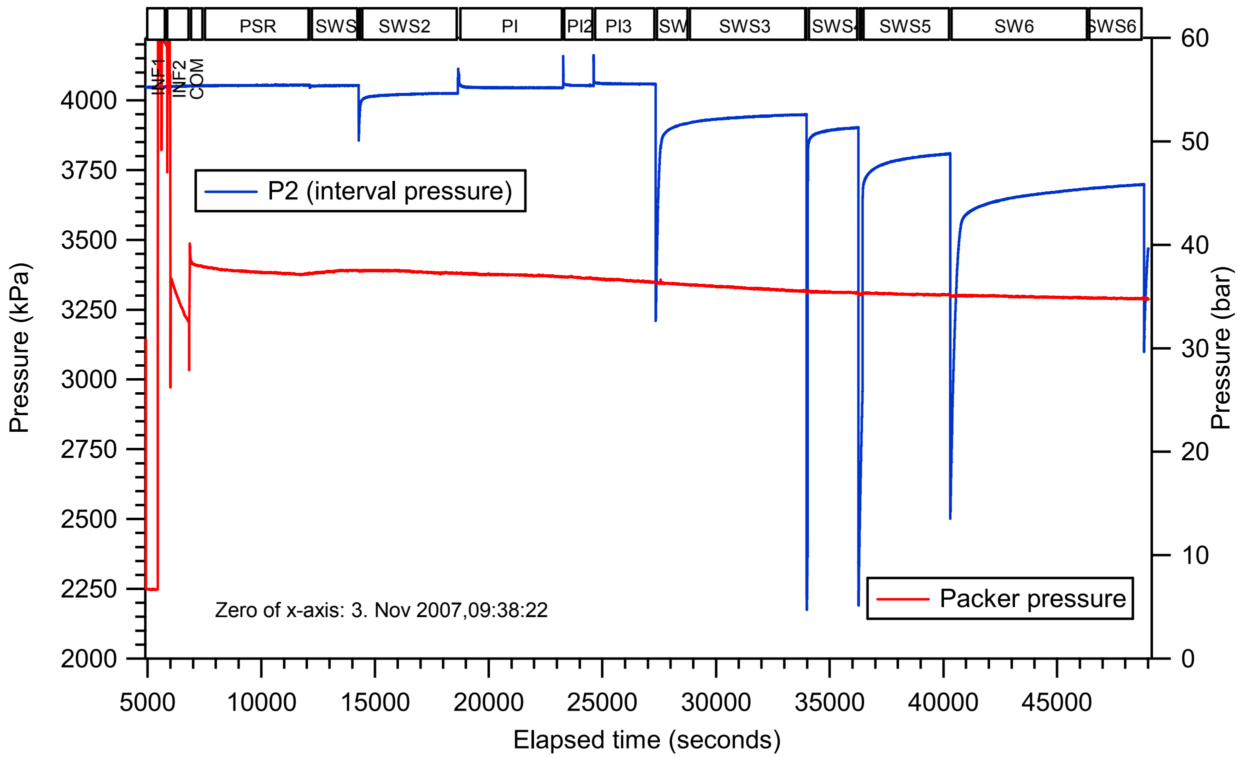


Figure 5: Oftr-i10: Measured packer pressure for test events from INF to SWS6

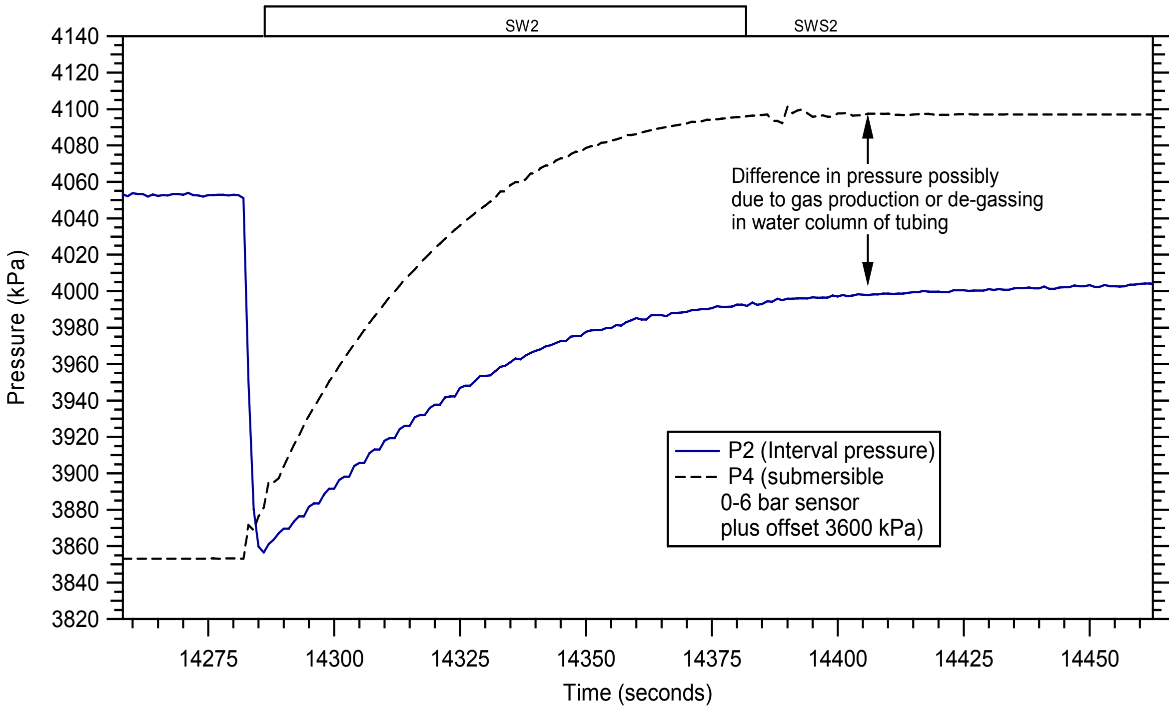


Figure 6: Oftr-i10: Detail of SW2

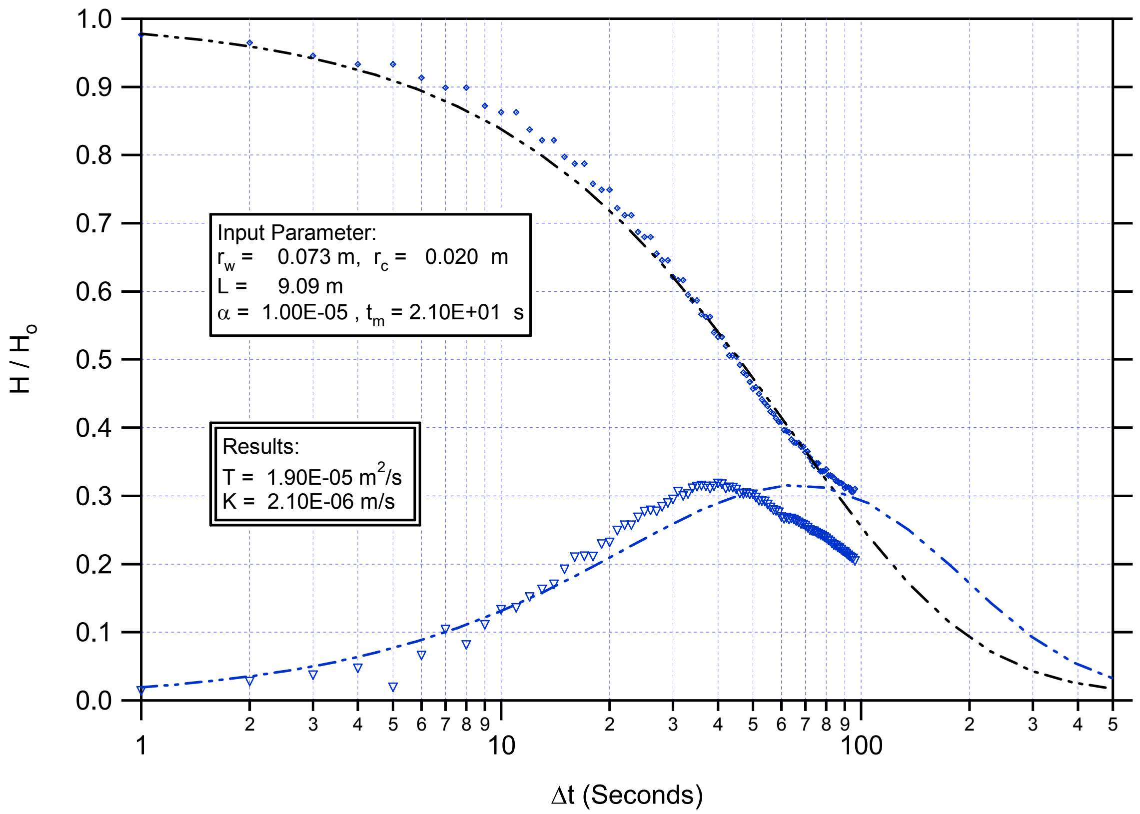


Figure 7: Oftr-i10: SW2 test analysis using CBP type-curves

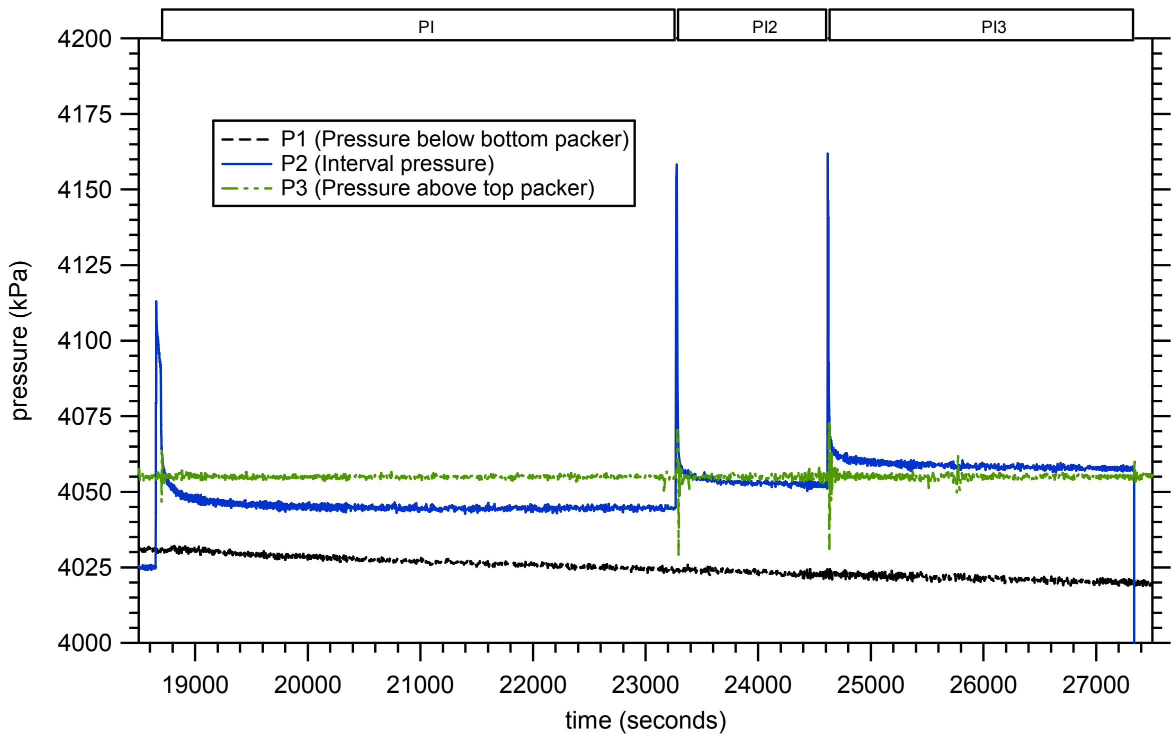


Figure 8: Ofrt-i10: Overview plot of pulse tests PI, PI2 and PI3

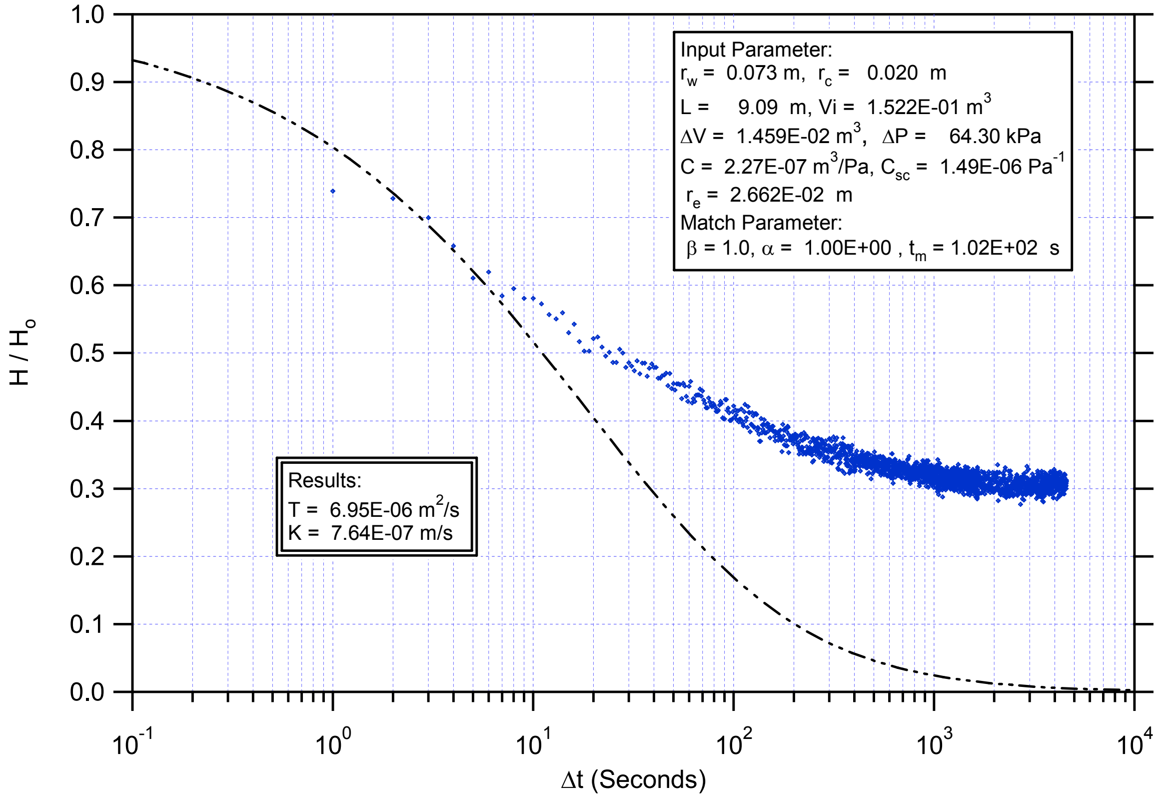


Figure 9: Oftr-i10: PI test analysis using CBP type-curves (early-time fit)

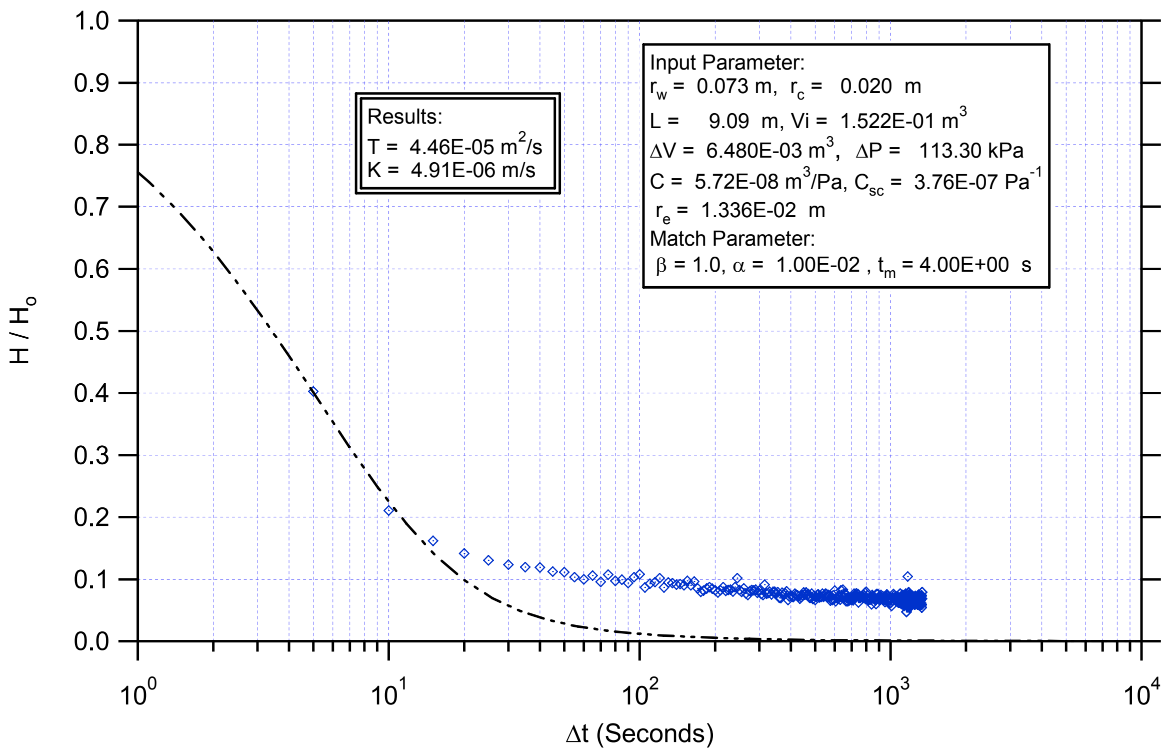


Figure 10: Oftr-i10: PI2 test analysis using CBP type-curves (early-time fit)

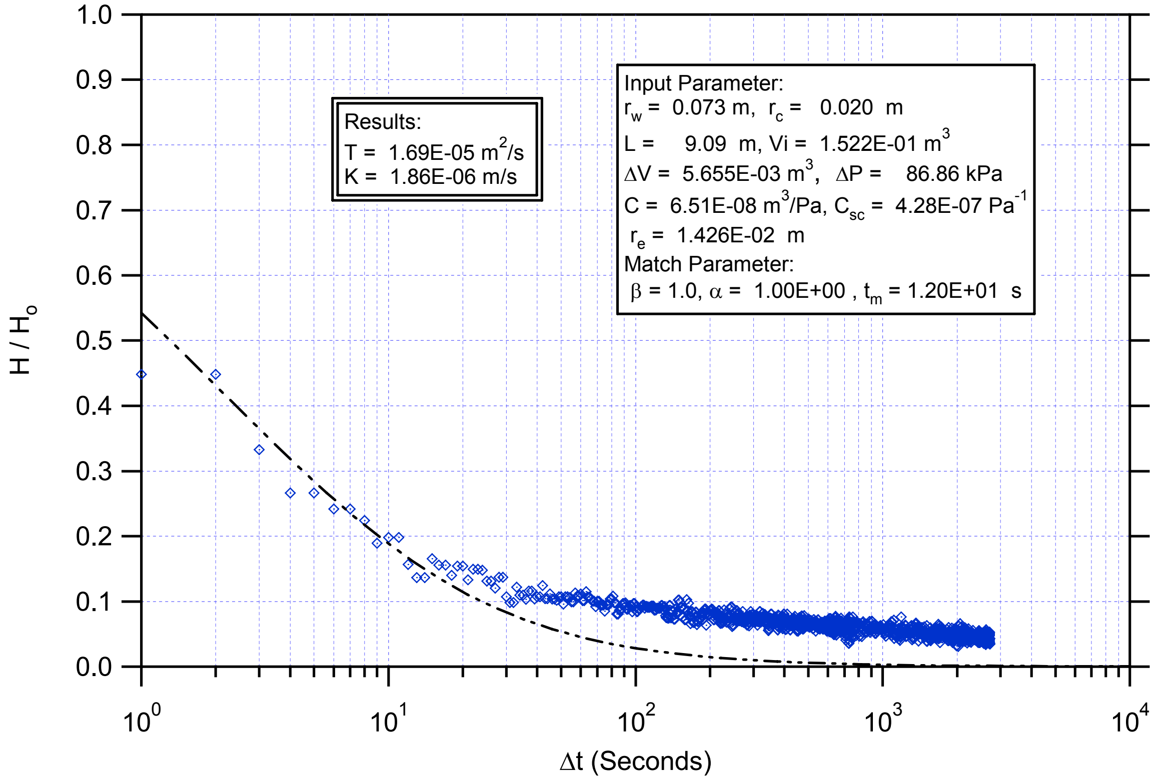


Figure 11: Oftr-i10: PI3 test analysis using CBP type-curves (early-time fit)

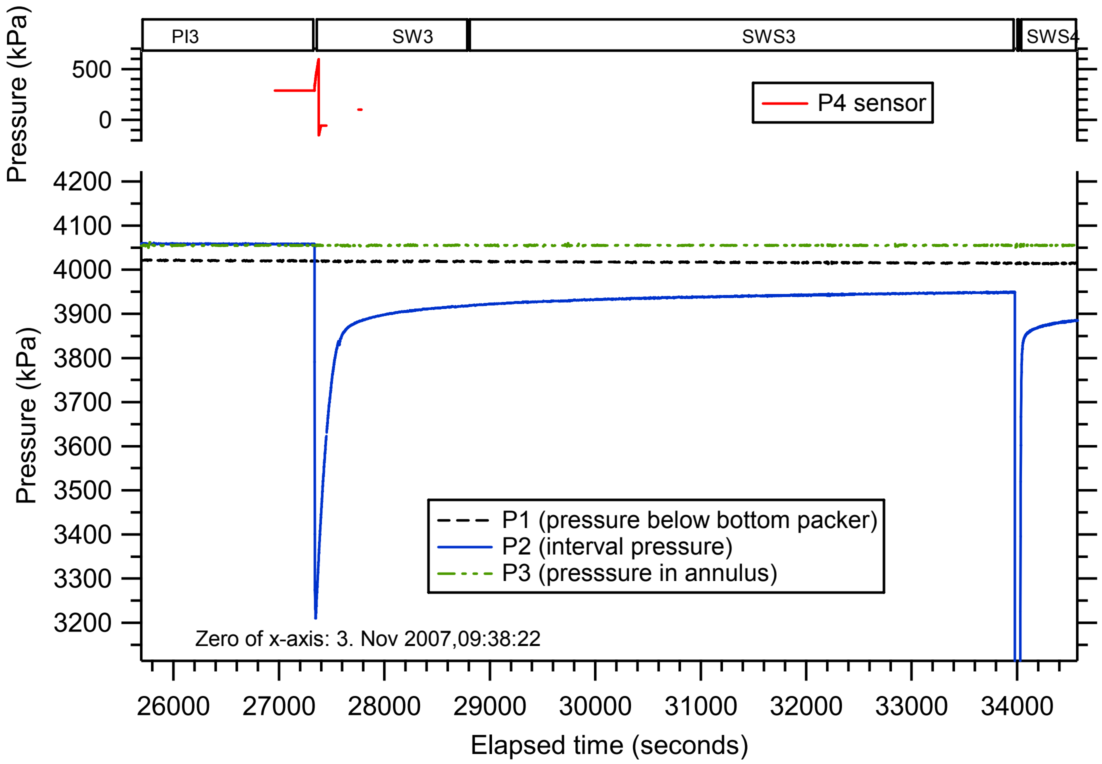


Figure 12: Ofrt-i10: Overview plot of test SW3

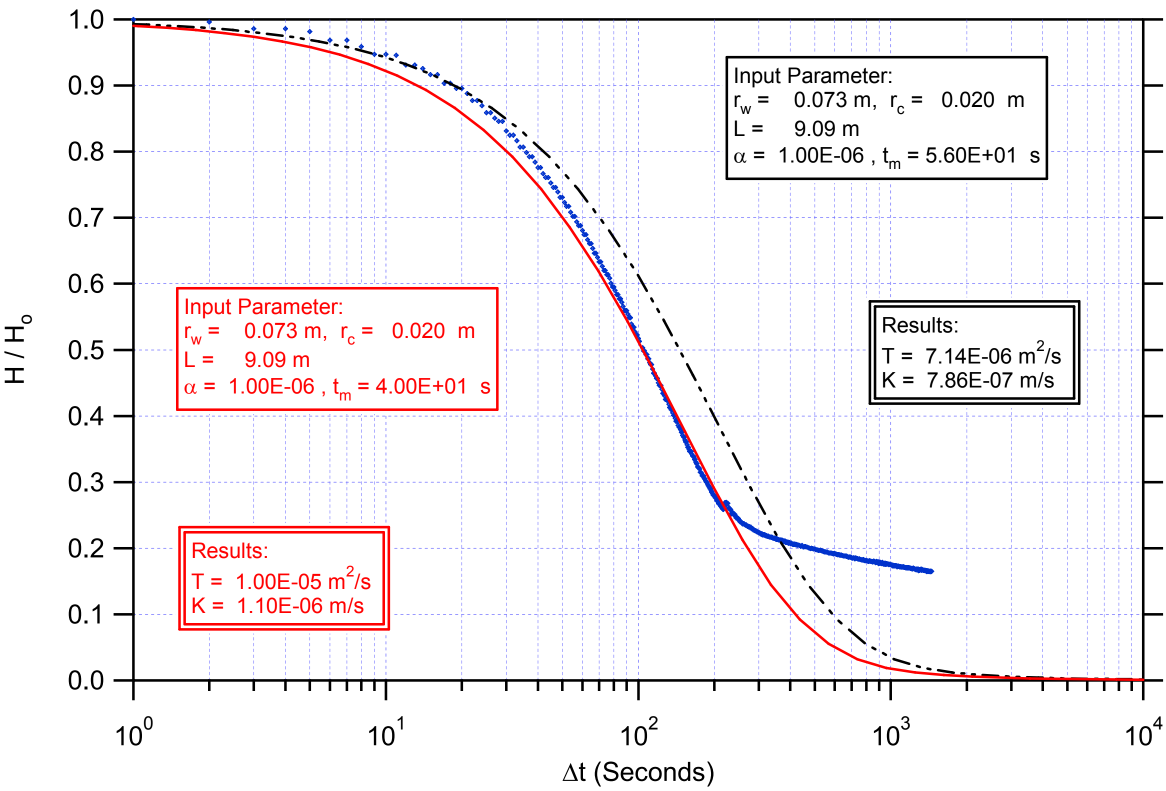


Figure 13: Oftr-i10: SW3 test analysis using CBP type-curves (early and middle time fit)

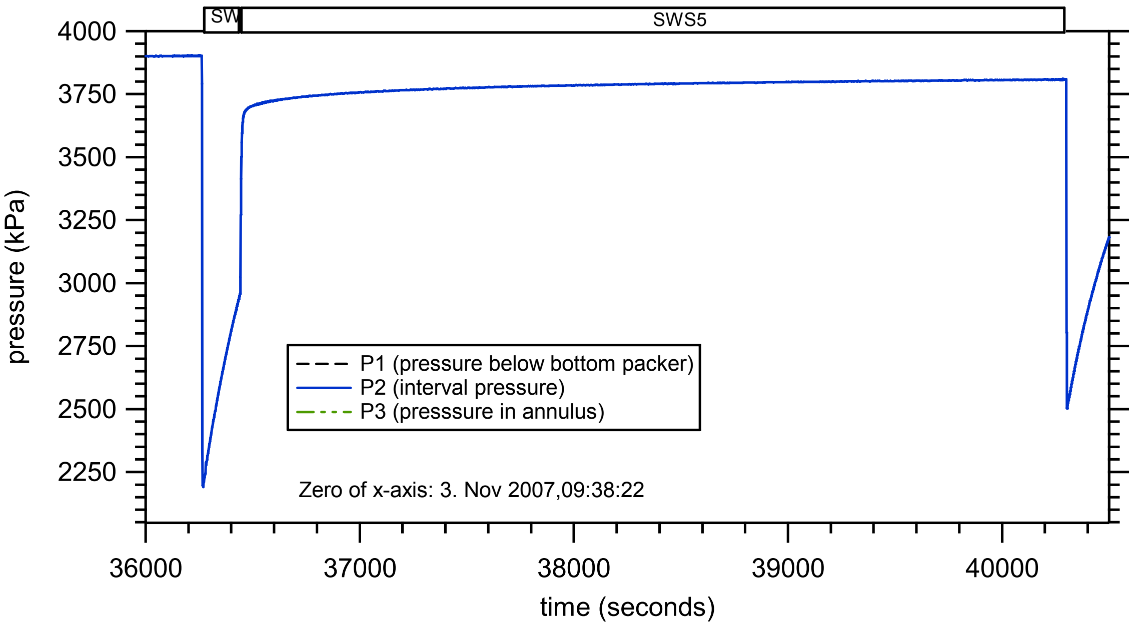


Figure 14: Ofrt-i10: Overview plot of test SW5

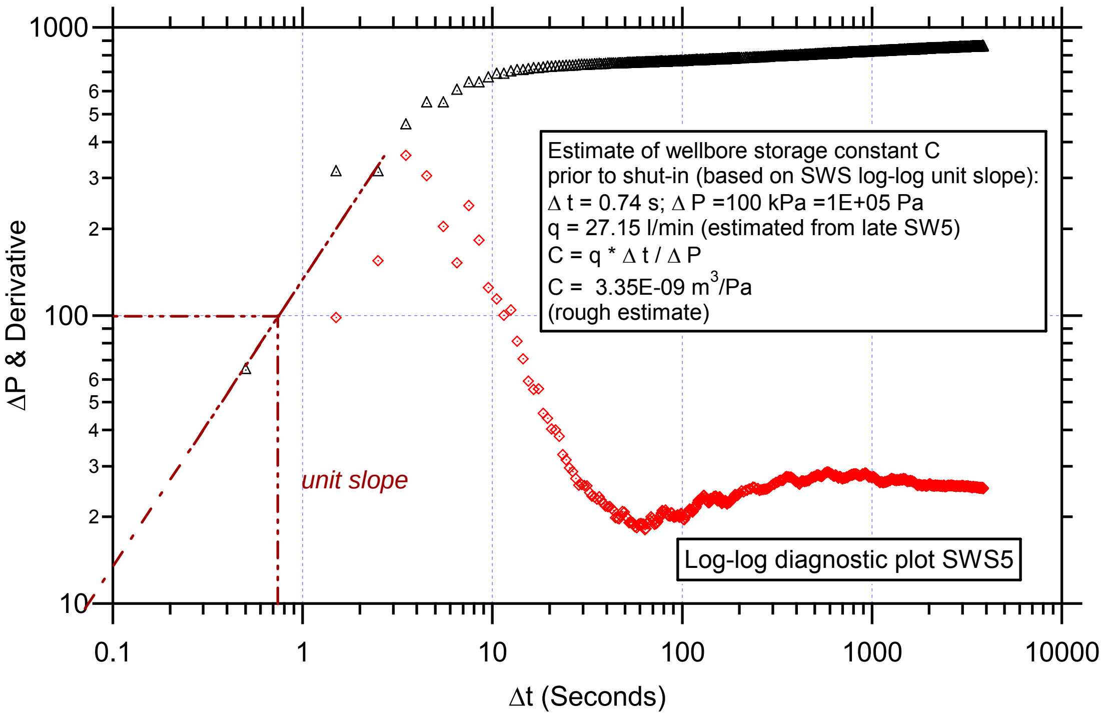


Figure 15: Oftr-i10: Estimate of C based on log-log unit slope of SWS5 and flow (q) at the end of SW5

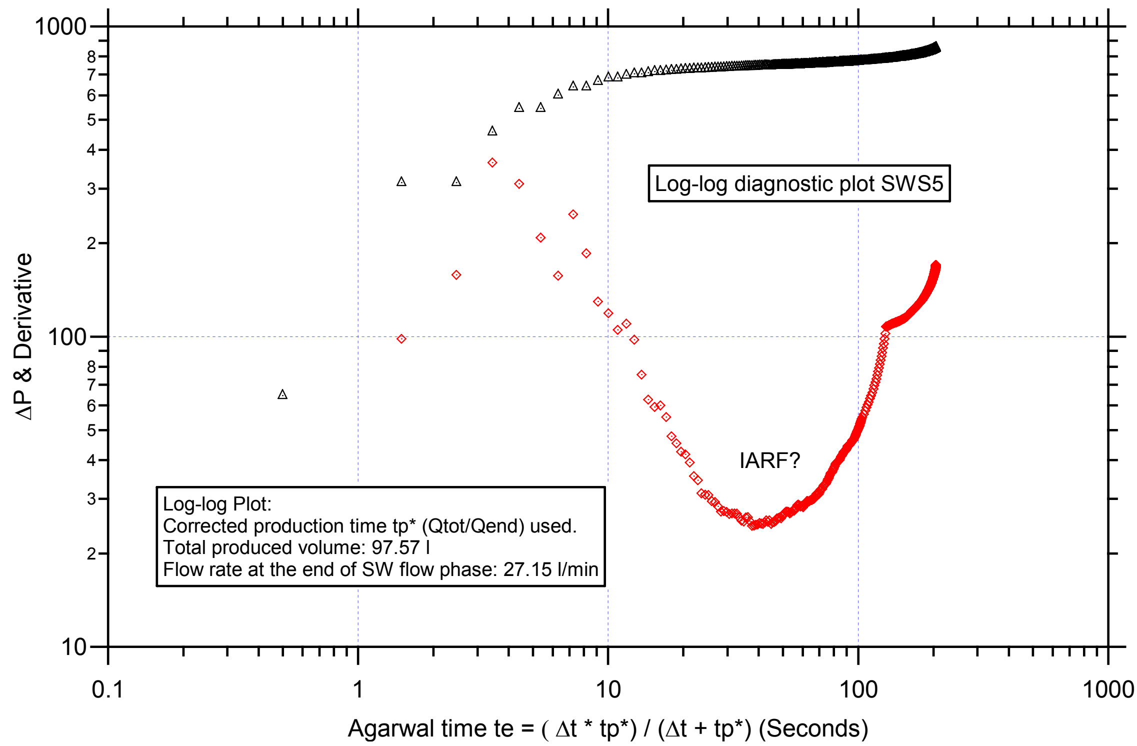


Figure 16: Oftr-i10: SWS5 log-log diagnostic plot (analytical analysis) using Agarwal time and corrected production time tp* of SW5

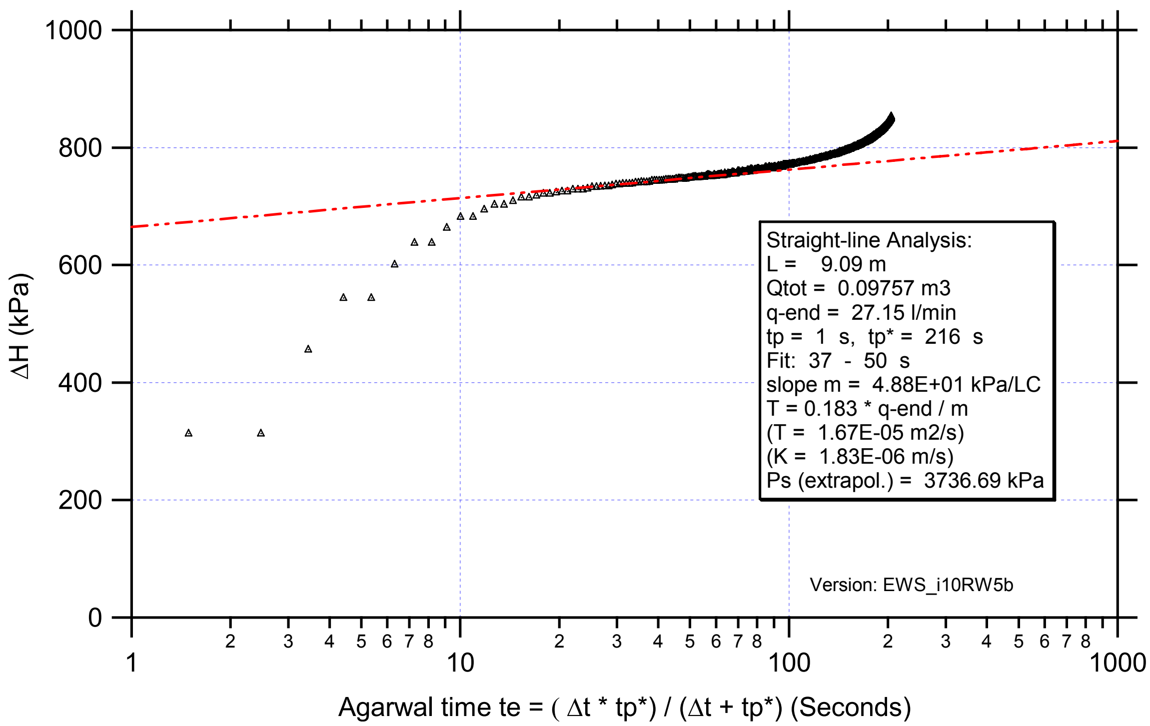


Figure 17: Oftr-i10: SWS5 analysis using Agarwal time

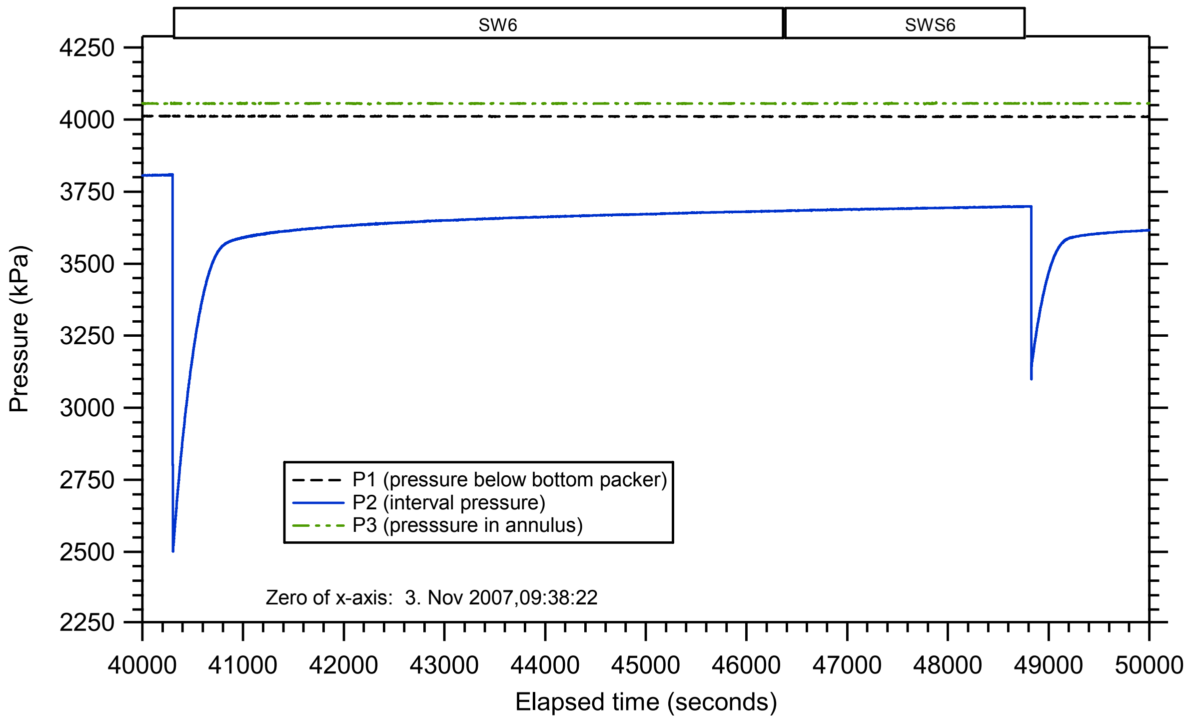


Figure 18: Ofrt-i10: Overview plot of test SW6

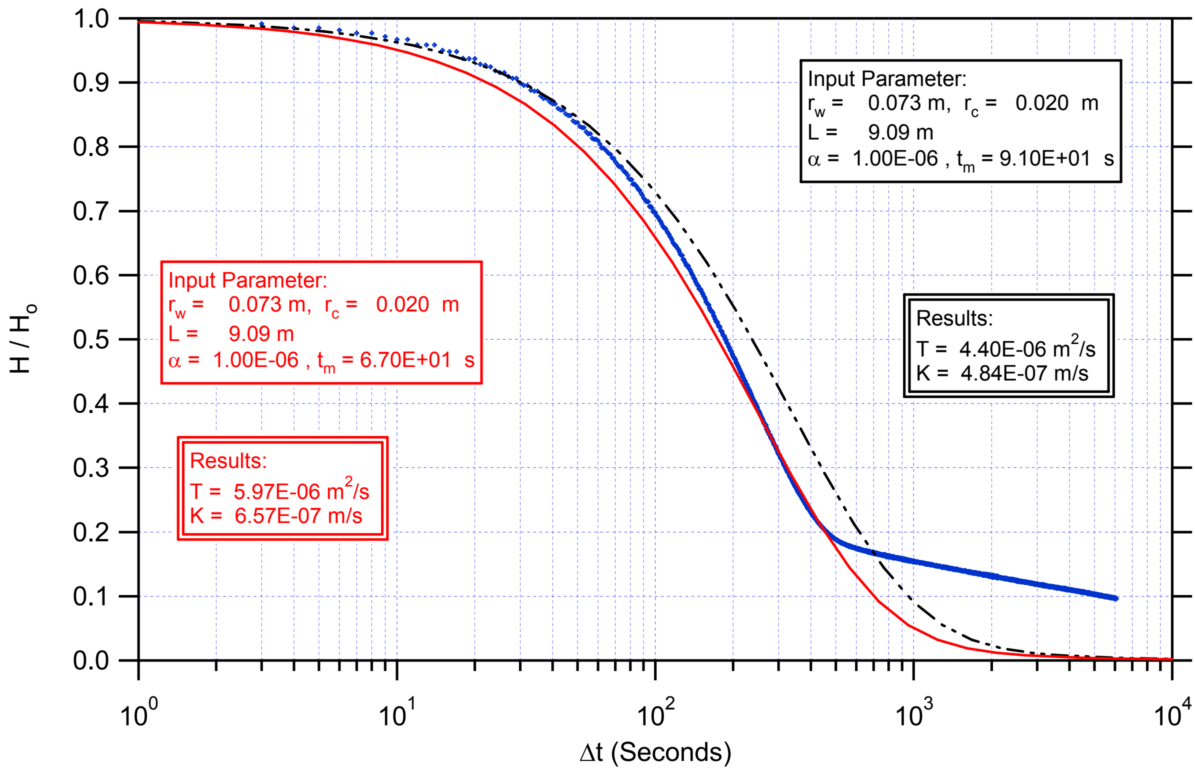


Figure 19: Oftr-i10: SW6 test analysis using CBP type-curves at early-time

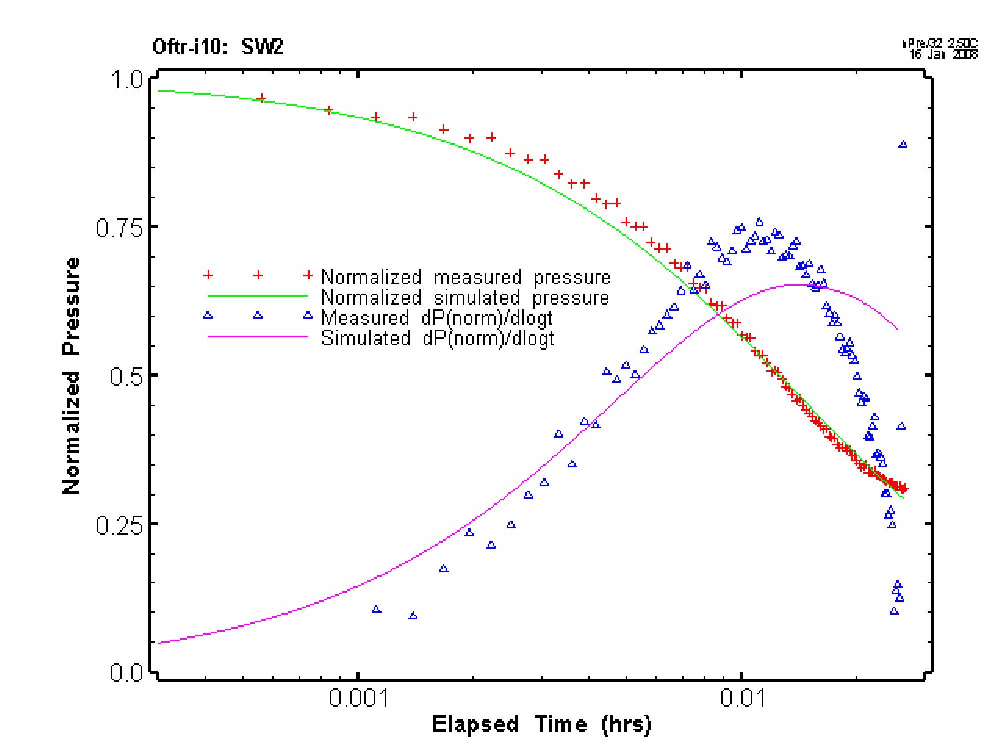


Figure 20: Oftr-i10: SW2 normalized pressure (Ramey A) plot

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_fm	[m/sec]	2.54E-06	9.16E-07	7.02E-05
P_fm	[kPa]	4016.2	3991.6	4040.9
ss_fm	[1/m]	1.00E-07	2.67E-12	3.74E-03

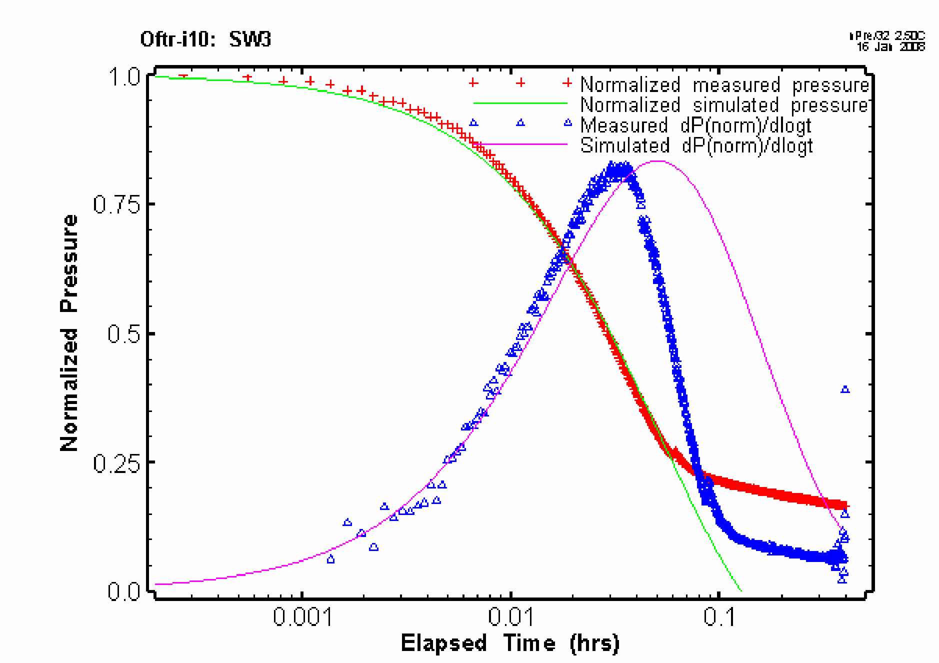


Figure 21: Oftr-i10: SW3 normalized pressure (Ramey A) plot

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_fm	[m/sec]	7.37E-07	2.77E-07	1.96E-06
P_fm	[kPa]	4282.7	4035.6	4530.0
ss_fm	[1/m]	1.00E-07	5.07E-12	1.97E-03

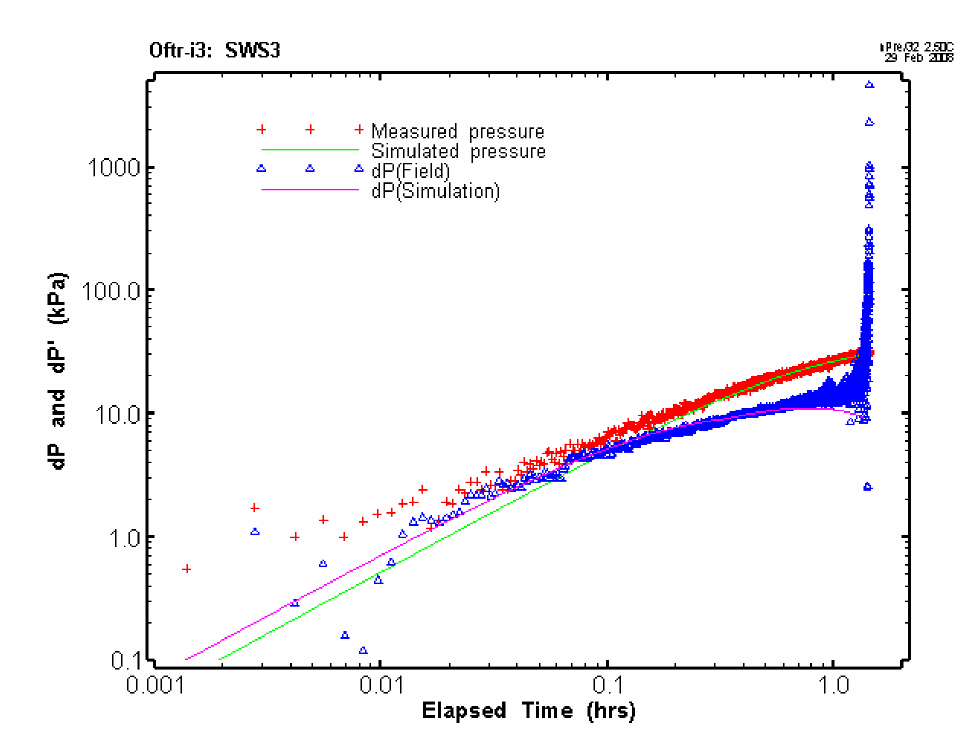


Figure 22: Oftr-i10: SWS3 normalized pressure (Ramey A) plot (for Horner fit)

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_fm	[m/sec]	1.12E-08	1.10E-08	1.14E-08
P_fm	[kPa]	3882.5	3882.0	3882.0
ss_fm	[1/m]	1.00E-05	Held constant	

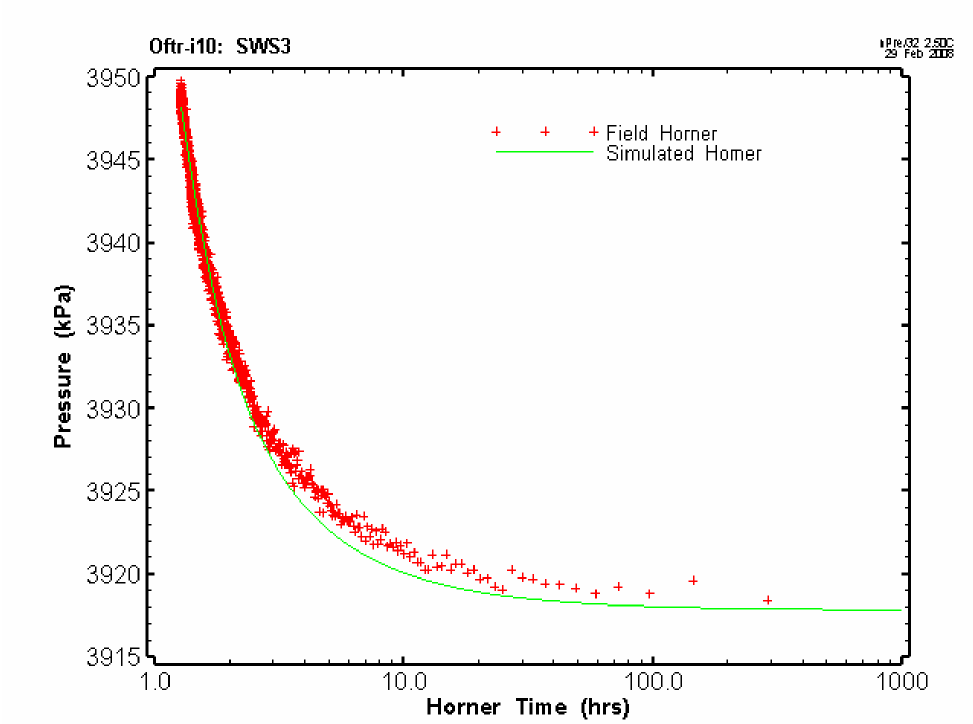


Figure 23: Oftr-i10: SWS3 Horner plot (for Horner fit)

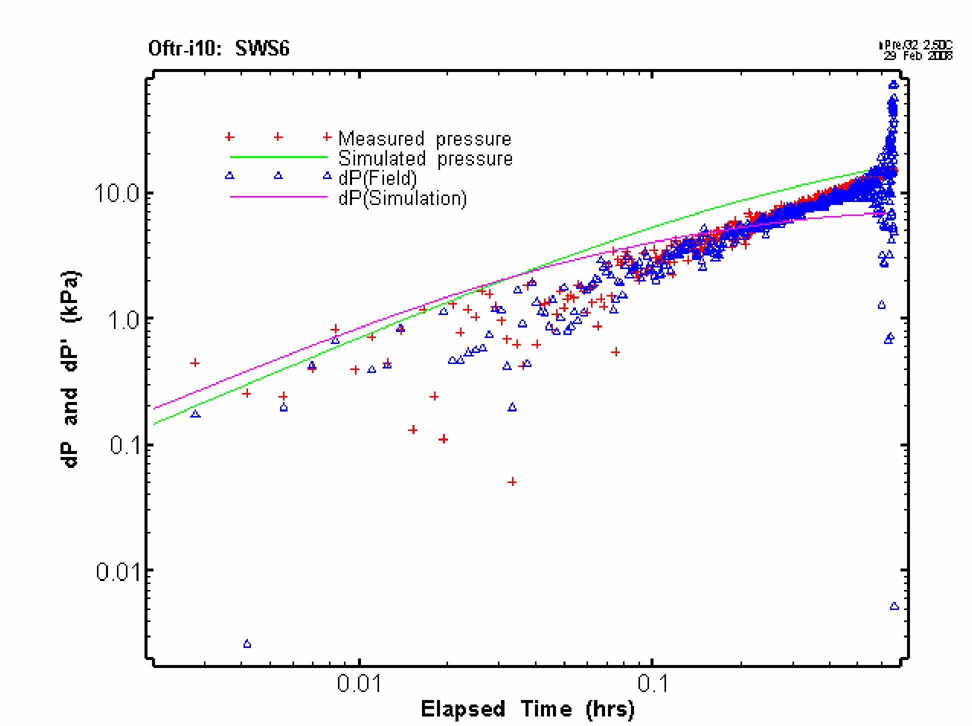


Figure 24: Oftr-i10: SWS6 normalized pressure (Ramey A) plot (for Horner fit)

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_fm	[m/sec]	1.04E-07	1.030E-07	1.05E-07
P_fm	[kPa]	3576.4	3575.9	3576.9
ss_fm	[1/m]	1.00E-05	Held constant	

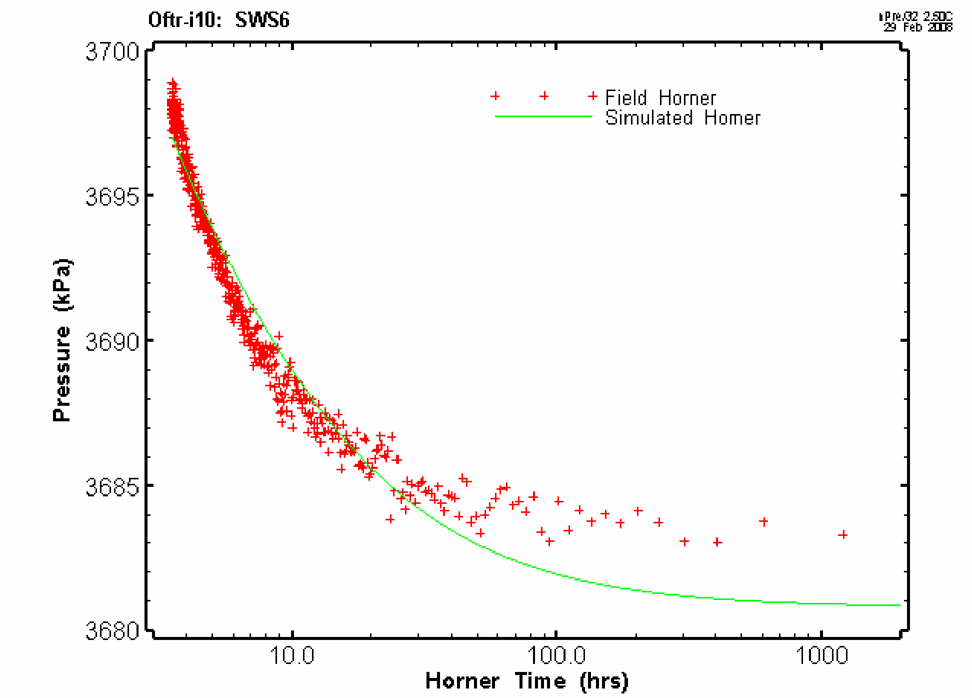


Figure 25: Oftr-i10: SWS6 Horner plot (for Horner fit)

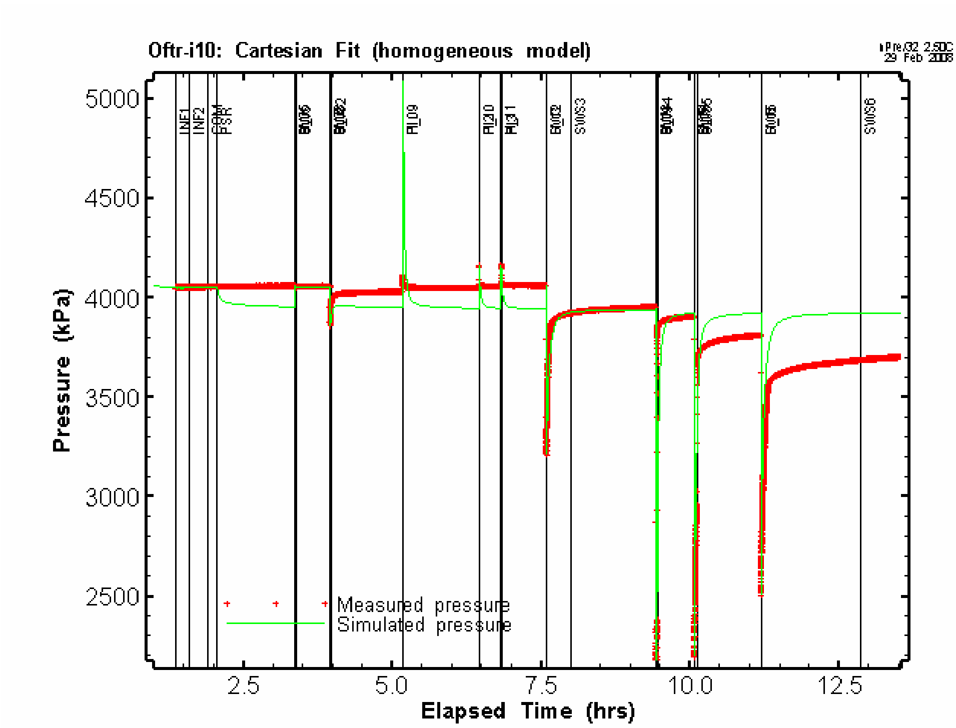


Figure 26: Oftr-i10: Cartesian fit of the entire test for homogeneous model

Fit Statistics:

95% Confidence Intervals				
Name	Units	FitValue	LowerValue	UpperValue
Est\Only				
K_fm	[m/sec]	5.22E-07	4.85E-07	5.60E-07
P_fm	[kPa]	3881.8	3877.5	3886.1
ss_fm	[1/m]	1.00E-05	5.49E-06	1.82E-05

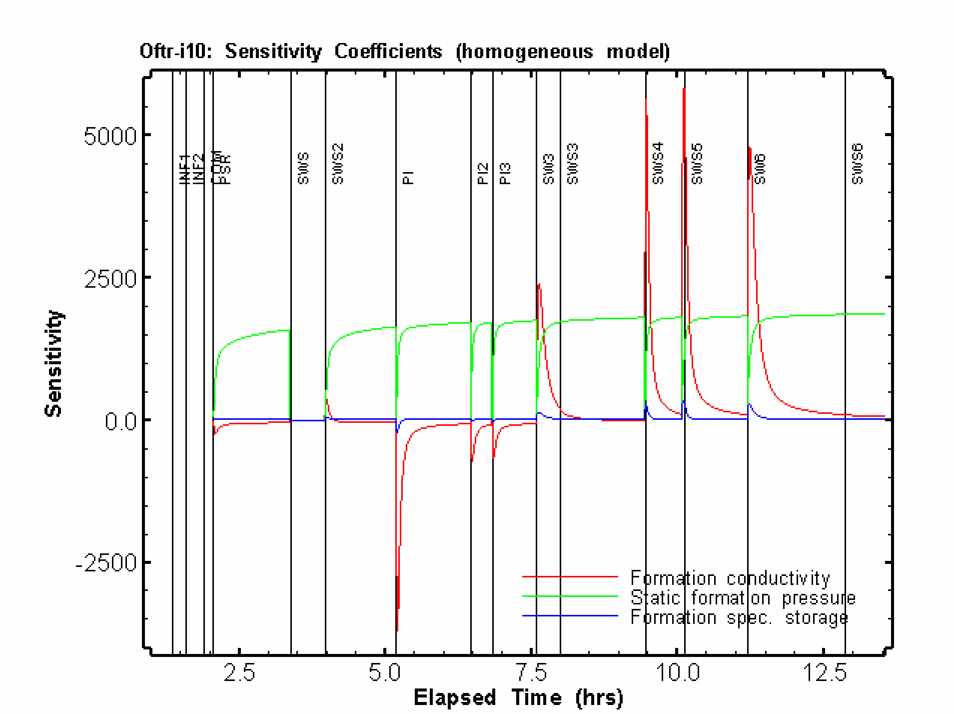


Figure 27: Oftr-i10: Sensitivity coefficients for the different formation parameters during the different sequences (homogenous model)

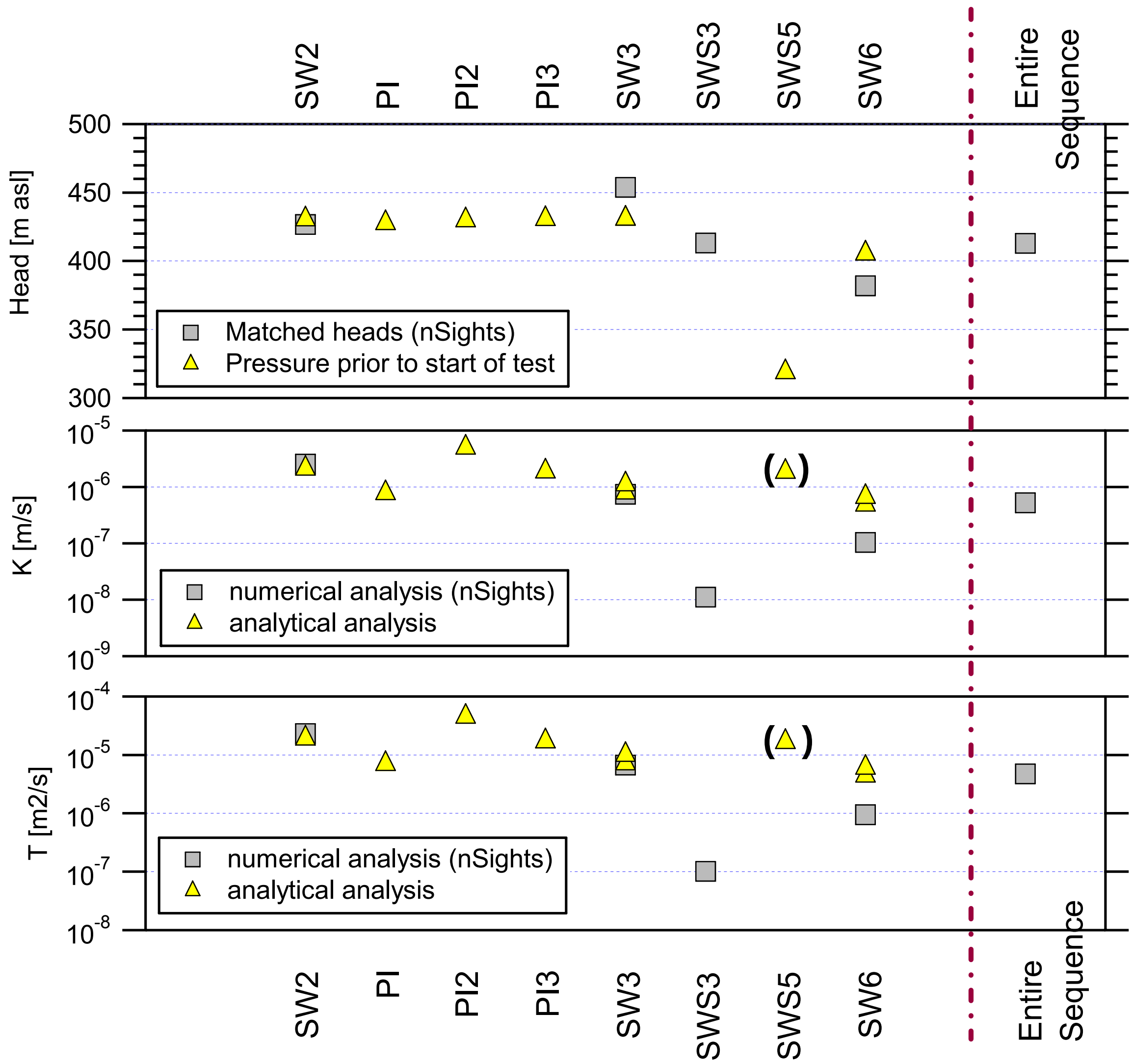


Figure 28: Oftr-i10: Comparison of T-, K- and h-results

Abbreviations

	Test phases
COM	Compliance
INF	Packer inflation
INF1	Inflation of lower packer (INF2 = Inflation of upper packer)
DEF	Packer deflation
DEF1	Deflation of lower packer (DEF2 = Deflation of upper packer)
PSR	Static pressure recovery (shut-in valve closed)
SI	Slug injection test
SIS	Pressure recovery after slug injection test (shut-in)
SW	Slug withdrawal test
SWS	Pressure recovery after slug withdrawal test (shut-in)
PI	Pulse injection test
PW	Pulse withdrawal test
HI	Constant head injection test (constant pressure difference)
HIS	Pressure recovery after constant head injection test (shut-in)
HW	Withdrawal test applying constant differential head
HWS	Pressure recovery after constant head withdrawal test (shut-in)
MR	Multi-rate test: Test with variable flow rate
MRS	Pressure recovery after test with variable flow rate
RW	Pump test with constant flow rate
RWS	Pressure recovery after pump test with constant flow rate (shut-in)
RI	Constant flow injection test
RIS	Pressure recovery after constant flow injection test (shut-in)
VC	Shut-in valve is closed
VO	Shut-in valve is open
	General
CBP	Cooper, Bredehoeft, Papadopulos (type-curve matching method)
DAS	Data acquisition system
FS	Full scale
IARF	Infinite Acting Radial Flow
LC	Log cycle
m agl	Meters above ground level
m bgl	Meters below ground level
m asl	Meters above sea level
OD	Outer diameter
PVT	Pressure volume temperature correlation
SLA	Straight-line analysis
TOC	Top of casing
WL	Water level (or WT = Water table)

Nomenclature

	Description	SI-Unit		Description	SI-Unit
b	Y-intercept of linear regression		S_S	Specific storativity	m^{-1}
C	Wellbore storage constant	$m^3\ Pa^{-1}$	S_{SS}	Specific storativity of skin zone	m^{-1}
C_S	Wellbore storage constant, shut-in	$m^3\ Pa^{-1}$	s	Skin factor	-
C_D	Dimensionless wellbore constant	-	t, Δt	Time, elapsed time	s
c_f	Pore volume based compressibility	Pa^{-1}	t_C	Critical time	s
c_r	Rock compressibility	Pa^{-1}	t_D	Dimensionless time	-
c_{SC}	System compressibility (= test zone compressibility c_{tz})	Pa^{-1}	Δt_e	Equivalent time (after Agarwal)	s
c_w	Water compressibility	Pa^{-1}	Δt_H	Horner time	-
Δh	Differential head	m	t_p	Production time	s
g	Acceleration of gravity (9.81)	$m\ s^{-2}$	t_p^*	Corrected production time	s
h_S	Static head	m	t_m	Match time	s
k	Intrinsic permeability	m^2	t_0	X-intercept of linear regression	s
K, K_f	Hydraulic conductivity of formation () special case	m/s	t_s	Thickness of skin zone	m
K_s	Hydraulic conductivity of skin zone () special case	m/s	T	Transmissivity	m^2/s
L	Interval length	m	T_W	Water temperature	°C
m	slope (regression)		z_1	P1 sensor depth	m
P	Pressure	Pa, kPa	z_2	P2 sensor depth	m
P_0	Minimal or maximal pressure	Pa, kPa	z_3	P3 sensor depth	m
P_{atm}	Probe signal at atmospheric pressure	Pa, kPa			
ΔP	Differential pressure, pressure change	Pa, kPa	α ,β	Type-curve match parameter	-
P_D	Dimensionless pressure	-	α	aquifer compressibility	Pa^{-1}
P_f	Static formation pressure	Pa, kPa	μ	Dynamic viscosity	Pa·s
P_i	Initial pressure	Pa, kPa	θ	Porosity	-
$P_{min/max}$	Minimal/maximal pressure	Pa, kPa	ρ_w	Density of fresh water	kg/m^3
P_{S1}	Static pressure in P1-Interval (below bottom packer)	Pa, kPa			
P_{S2}, P_f	Static pressure in test interval	Pa, kPa			
P_{S3}	Static pressure in annulus (above upper packer)	Pa, kPa			
q	Flow rate	$m^3\ s^{-1}$			
q_{end}, q_e	Last flow rate	$m^3\ s^{-1}$			
Q, Q_{tot}	Cumulative flow	m^3			
r_e	Effective radius (Slug, Pulse test)	m			
R_i	Radius of influence	m			
R^2	Correlation coefficient	-			
r_c	Tubing radius	m			
r_w	Wellbore radius	m			
R_1	Radius, composite model	m			
R_D	Dimensionless radius	-			
S	Storativity	-			
S_C	Sensitivity coefficient				
S_{SC}	Scaled sensitivity coefficient				

Definitions

$C_D = \frac{\rho\, g\, C}{2\pi\, S\, r_{w^2}}$	Wellbore constant, dimensionless
$H_D = \frac{P - P_i}{P_0 - P_i}$	Dimensionless pressure (slug und pulse tests)
$K = \frac{k\, \rho\, g}{\mu}$	Hydraulic conductivity
$P_D = \frac{2\pi\, T\, \Delta h}{q}$	Dimensionless pressure
$\Delta P = \rho\; g\, \Delta h$	Differential pressure
$q_D = \frac{q}{2\pi\, T\, \Delta h}$	Dimensionless flow
$t_D = \frac{t\, T}{r_w^2 S}$	Dimensionless time
$S = S_S\, L$	Storativity
$s = \left(\frac{K_f}{K_s} - 1\right) \ln\left(\frac{r_w + t_s}{r_w}\right)$	Skin factor
$S_S = \rho\, g\, (\alpha + \theta\, c_w)$	Specific storativity
$S_C = \frac{\partial P}{\partial r}$	Sensitivity coefficient.

where ∂P is the partial derivative of the calculated system response (i.e., pressure) with respect to a parameter varied by the derivative span ∂r .
For comparison of sensitivity coefficients for different parameters, the sensitivity coefficients are typically scaled by inverses of the respective standard deviations as follows:

$$S_{sc} = S\,\frac{\sigma_r}{\sigma_P} = \frac{\partial P}{\partial r} \cdot \frac{\sigma_r}{\sigma_P}$$

where S_{sc} is the scaled sensitivity coefficient, σ_r is the a priori standard deviation of the measurement error, and σ_P is the estimated standard deviation of the parameter.
If not otherwise stated, default values σ_r = 1 and σ_P = 1 were used.

Definitions (continued)

T = K L	Transmissivity
$\frac{t_D}{C_D} = \frac{2\pi T t}{\rho\ g C}$	Dimensionless time axis
$t_e = \frac{t_p \cdot \Delta t}{t_p + \Delta t}$	Dimensionless Agarwal time (Agarwal, 1980)
$t_e^* = \frac{t_P^* \cdot \Delta t}{t_P^* + \Delta t}$	Modified Agarwal time (using corrected production time)
$t_P^* = \frac{Q}{q_{end}}$	Modified production time (Ehlid-Economides and Ramey, 1980)

Form

DAILY LOG REPORT

SOLEXPERTS

Oftringen Hydraulic Testing: Interval 10: 408.5 – 417.59 m

Date	*Time*	*Activity*	*Who*
		Interval 10: 408.5 – 417.59 m	
03.11.07	*11:00*	*Start file: Oftr_2007_11_03_oftr_i10.dat P1 = 4061.89 kPa P2 = 4046.72 kPa P3 = 4050 kPa T1 = 31.03 °C T2 = 31.00 °C T3 = 31.01 °C Water table: 1.92 m bgl*	*SR, FP,*
	11:06	*Start inflation of packer 1 (PA1)*	
	11:18	*Start inflation of packer 2 (PA2)*	
	11:32	*Both packers are pressurized by pressure vessel at 38 bar (PA1 and PA2 pressure lines are interconnected)*	
	11:35	*Fix installation rods with clamp and tubing spider, tight movement of the rods*	
	11:41	*Shut-in (Start PSR)*	
	11:50	*Swabbing to 32 m below top of 1.9" tubing rods*	
	11:55	*Water table: 28.82 m bgl*	
	12:08	*Change swap cups*	
	12:15	*Recording slim tubing-sensor at atmospheric pressure Pslim = 2.44 kPa*	
	12:22	*Swabbing to 35 m below top of 1.9" tubing rods*	
	12:23	*Stop recording slim-tubing-sensor*	
	12:35	*Water table: 38.20 m bgl*	
	12:38	*Install slim tubing*	
	12:46	*Water table: 31.05 m bgl*	
	12:49	*Start recording slim-tubing-sensor*	
	12:53	*Inflate slim tubing packer to 25 bar*	
	12:56	*Scan rate 1 s*	
	13:00	*Start **SW**-test, pressure recovers quickly*	
	13:01	*Shut in*	
	13:11	*Stop scanning slim-tubing sensor*	
	13:12	*Scan rate 5 s*	
	13:13	*Deflate slim-packer*	
	13:21	*Swabbing to 35 m below top of 1.9" tubing rods*	
	13:27	*Recording P4-sensor at atmospheric pressure P4 = 100.60 kPa*	
	13:29	*Water table: 32.02 m bgl*	
	13:30	*Stop recording P4 -sensor*	
	13:31	*Install P4-sensor*	
	13:34	*Start recording P4 -sensor*	
	13:35	*Scan rate 1 s*	
	13:36	*Start **SW**-test*	
	13:38	*Shut in*	
	14:06	*Scan rate 5 s*	
	14:07	*Stop recording P4 -sensor*	
	14:15	*Remove P4 sensor*	
	14:25	*Start preparation for Pulse Injection Test (PI) Water table in test rod is top of tubing.*	
	14:35	*Install injection head on top of tubing rods with 6/4mm pressure line connected to nitrogen bottle, pressure 3 bars. P2 = 4024.45 kPa, scan rate set to 1 second*	
	14:49	*Start **PI**-test, valve open during 43 seconds*	

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DAILY LOG REPORT

SOLEXPERTS

Date	**Time**	**Activity**	**Who**
03.11.2007	14:52	Water table Water table in test rod is 12.62 m below top of rod => Δs = 12.62 m. 12.62 x 1.25 = 15.9 liters.	SR, FP
	15:17	Scan rate 5 s	
	15:20	Water table in test rod is top of tubing	
		Install injection head on top of tubing rods with 6/4mm pressure line connected to nitrogen bottle, pressure 3 bar, prepare pressure vessel to close shut-in tool	
	16:05	Start **PI**-test	
	16:10	Water table Water table in test rod is 5.03 m below top of rod => Δs = 5.03 m => dV = 6.48 l	
	16:20	Water table in test rod is top of tubing	
	16:24	Scan rate 1 s	
	16:28	Start PI-test	
		Water table Water table in test rod is 4.39 m below top of rod => Δs = 4.39 m => ΔV= 5.6552 l	
	16:41	Scan rate set to 5 s	
		Calculated compressibility with ΔP assumed 500 kPa (not recorded on plot): Csc = 7.4E-08 1/Pa	
	16:45	Start swabbing to a target level of 100 m bgl	
		Water table tubing: 110.32 m bgl	
	17:00	Install P4-sensor	
	17:08	Start P4-sensor, scan rate set to 1 s	
	17:13	Start **SW**-test	
		P4-sensor over pressure	
	17:19	Remove P4-sensor	
	17:41	Test P4-sensor => OK (100.65 kPa), scan rate: 5 s	
	17:38	Shut -in	
	17:40	Start swabbing to 200 m bgl	
	18:25	Scan rate 1 s	
	18:26	Preparing gas measuring at top of tubing	
	18:30	Water table tubing: 106 m	
	18:32	Change swab-caps	
	18:35	Swabbing to 200 m bgl	
	18:39	Scan rate 5 s	
	18:56	Water table tubing: 217 m	
	18:57	JH, Sti arrive on site	
	19:00	Scan rate 1 s	JH, Sti
	19:04	Start SW-test	
	19:05	Shut-in	
	19:21	Scan rate 5 s	
	19:25	Gas measurement top of tubing 6 % CO_2	
	19:30	SR, FP leave site	SR, FP
	19:31	Swabbing to 200 m bgl	
	19:39	Water table 209.80 m below top of tubing	
	19:42	Scan rate 1 s	
	19:44	Start SW-test shut-in after 76.10 m pressure recovery Q ca. 0.5 l/min	
	19:47	Shut-in	
	19:49	Scan rate 5 s	
	20:29	Swabbing to 200 m bgl	
	20:49	Scan rate 1 s	
	20:50	Start SW-test	
	21:10	Scan rate 5 s	
04.11.2007	22:08	Shut-in	SR, FP
	22:38	Swabbing to 100 m bgl	
	22:55	Swabbing to 260 m bgl	

Form

DAILY LOG REPORT

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Date	Time	Activity	Who
	22:56	Scan rate 1 s	
	23:00	Start SW-test	
	23:19	Scan rate 5 s	
	23:58	Shut-in	
	00:10	Install double valve pump at approximately 150 m bgl	
	00:28	Open valve	
	00:37	Start pumping, high gas production, recovery after pump-cycle 20 min duration. Gas production decreases after each cycle	
	02:35	Control visit and site inspection by Fbe	Fbe
	02:45	Stop pumping	
	03:00	Start pull-out double valve pump	
	03:23	Close shut-in valve	
	03:25	Disassembly double valve pump, install pressure hose from double valve-pump into tubing for air-lift	
	04:17	Air-lift 140 m below top of tubing	
	04:18	Open Shut-in valve	
	04:42	Close shut-in valve	
	04:44	Air-lift 145 m below top of Tubing	
	04:45	Open Shut-in valve	
	05:00	Close shut-in valve	
	05:05	Air-lift 145 m below top of tubing	
	05:08	B. Frieg leaves site to search nitrogen bottle in Nagra depot	
	05:10	Open Shut-in valve	
	05:30	Close shut-in valve	
	05:32	Air-lift 145 m below top of tubing	
	05:34	Open Shut-in valve	
	05:50	Close shut-in valve	
	05:52	Air-lift 145 m below top of tubing	
	05:55	Open Shut-in valve	
	06:10	Close shut-in valve	
	06:12	Air-lift 145 m below top of tubing	
	06:15	Open Shut-in valve	
	06:30	Close shut-in valve	
	06:32	Air-lift 145 m below top of tubing	
	06:35	Open Shut-in valve	
	06:50	Close shut-in valve	
	06:51	SR arrives on site	SR
	06:52	Air-lift 145 m below top of tubing	
	06:55	Open Shut-in valve	
	07:00	FP arrives on site	FP
	07:30	Air-lift 145 m below top of tubing (with shut in valve open)	
	07:48	Close shut-in valve	
	07:50	Air-lift 145 m below top of tubing	
	07:55	Open valve	
	08:00	Gasmeter measures just O2-Gas	
	08:05	Remove air-lift tubes	
	08:15	Close valve, swabbing to 200 m	
	08:20	Preparing downhole sampler	
	08:28	Open valve	
	08:50	JH arrives on site and leaves 10 min later	JH
	09:36	Adjust sampler for sampling: P2 = 3227 kPa, Psampler = 3227 kPa – 40.5 kPa (Shut-in tool above P2) = 3186.5 kPa (31 bar)	
	10:00	4% CH4	SR, FP
	10:01	Close valve (Total 990 l water removed)	
	10:05	Install sampler in 1.9" tubing	
	10:28	Sampler above shut in tool	

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DAILY LOG REPORT

Date	Time	Activity	Who
04.11.2007	10:38	Remove sampler, no water inside, reduce valve sensitivity from sampler to 29 bar	SR, FP
	10:45	Water table: ca. 86 m bgl	
	11:00	Install sampler in 1.9" tubing	
	11:19	Sampler above shut in tool	
	11:29	Remove sampler, no water inside, reduce valve sensitivity from sampler to 18 bar (cylinder in sampler requires extra 5 to 8 bar to overcome friction force)	
	11:50	Install sampler in 1.9" tubing	
	12:04	Sampler above shut in tool	
	12:15	Remove sampler	
	12:30	Prepare swabbing tool	
	12:31	Fill water sample in bottles (2 x 0.5 liter)	
	12:45	Start swabbing to 180 m	
	12:56	Change swabbing cups	
	12:03	Swabbing to 250 m	
	13:12	Open valve	
	13:24	Close valve	
	13:25	Start swabbing to 250 m (two tractions)	
	13:38	Open valve	
	13:48	Close valve	
	13:49	Start swabbing to 250 m (two tractions)	
	14:03	Open valve	
	14:15	Close valve	
	14:16	Start swabbing to 250 m (two tractions)	
	14:29	Open valve	
	14:30	Change swabbing cups	
	14:44	Close valve	
	14:46	Start swabbing to 250 m (two tractions)	
	14:56	Open valve	
	15:11	Close valve (total 1784 l water removed)	
	15:15	Prepare core cable to fix at downhole sampler	
	15:35	Install sampler in 1.9" tubing	
	15:43	Sampler above shut in tool	
	15:49	Remove sampler	
	15:54	Fill water sample in bottles (2 x 0.5 liter)	
	16:05	Prepare core cable to fix at swabbing tool	
	16:40	Start swabbing to 250 m (two tractions)	
	16:59	Open valve	
	17:12	Close valve	
	17:20	Deflate packers	
	18:15	Pull on system (3 tons overload), PA1 still inflated	
	18:23	Pull on system (3 tons overload), PA1 still inflated	
	18:25	JH, Sti arrive on site	JH, Sti
	18:25	Stop file	
	18:28	Start file: Oftr_2007_11_03_oftr_i10_test.dat	
	18:30	Try to release packer with pulling and lowering system	
	18:50	System free, start move out	
	18:55	Start move out system up to TU3	
	20:47	Start installation of Double Valve pump	
	21:00	Taking water samples (2x 250 ml, 3 x 5 l)	
	21:30	Start moving system out of borehole	FP, Sti
	21:35	Preparing tubing for transport, clean up trailer	SR, JH

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DAILY LOG REPORT

Date	***Time***	***Activity***	***Who***
04.11.2007	*22:50*	*System out of borehole*	*SR, JH, FP, Sti*
	23:20	*SR, JH, FP, Sti leave site*	
05.11.2007	*09:00*	*Disassemble System, clean up site, arm material for transport*	*SR,JH, FP, Sti*
	10:30	*JH leaves site*	
	11:00	*SR, Sti, FP leave site*	

SR Sacha Reinhardt
JH Jörg Hayer
AK Andreas Kern
FP Fredi Portmann
Sti Daniel Stillhard

Fbe Dr. Bernd Frieg (Nagra)

Form

INSTALLATION RECORD HDDP

SOLEXPERTS

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Oftringen NOK EWS Borehole: Hydraulic Testing

Date	03.11.2007	**Project Leader**	Fi/SR						
Borehole	NOK EWS 2007	**Direction**	vertical	**Reference point**	433.0	**JOB Nr**	1763	**Location**	Oftringen
Borehole Depth	719.0 m	**Casing depth**	376.5 m bgl	**Interval lenght**	9.09 m	**Test Name**	oftr_i10	**System**	**HDDP** 110
Borehole diameter	146 mm	**Stickup**	-3.18 m	**Water depth**	-1.42 m bgl	**Test depth (UPLS)**	408.50 m bgl	**Probe ID**	**TSSP** S1

Note: All depths shown are not correct for borehole deviation

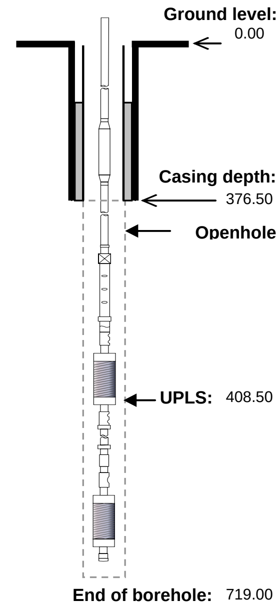
Component		Qty -	L unit m	L total m	Depth m	OD mm	ID mm	Wgt kg	Str t
Stickup	-3.18 m bgl								
Ground level					0.00				
Tubing 1.9" NU			404.41	404.41		56.1	40.3	1658	12.0
Pop joint			1.02		401.23	56.1	40.3	4.2	12
SIT Non Displacement Valve			0.84			79.0	24.0	20.6	15
Probe Shell Carrier mit Triple Sub	TSSP P3		1.97		405.06	70.0	10.9	48.0	25
	TSSP P2		0.30		405.36				
	TSSP P1		0.30		405.66				
			0.04						
X-Over	2"3/8 EU Pinx1.9" NU Box		0.51	7.27		66.0	40.0	2.1	16
Safety joint 3"1/16						78.0	50.5	5.5	24
Above Side Entry Sub (ASES)			0.52			66.0	32.0		24
Packer Stick Up			0.26			--	25.0		
Up. Packer Seal — Upper Packer	UPUS		0.26		407.25				
			1.25			108.0	32.0	82.4	17
	UPLS		0.24		408.50				
Straddle Length — Packer Stick Down			0.31			--	25.0		
Below Side Entry Sub (BSES)			0.52			66.0	32.0		24
X-Over	1.9" NU Pinx2"3/8 EU Box		0.26			--		3.0	16
Tubbing 1.9" NU			4.55			56.1	40.3	18.7	12
X-Over	2"3/8 EU Pinx1.9" NU Box		0.45	9.09		--		3.0	16
Filter			0.3						
	Screen		1.45			72.0	50.0	19.0	19
			0.3						
P1-Seal Sub			0.3			78.0	--		24
Packer Stick Up			0.16			--	32.0		
Lower Packer Seal — Lower Packer	LPUS		0.25		417.59				
			1.25	1.92		110.0	32.0	70.2	17
	LPLS		0.24		418.84				
Packer Stick Down			0.43			--	32.0		
End Cap					419.51	78.0	--		
End of Borehole					719.00				

Comments:

P4: submersible pressure transducer on cable; pressure at atmosphere measured on 03.11.07, 13:27

P_{SL}: submersible pressure transducer at bottom of slim tubing; pressure at atmosphere measured on 03.11.07, 12:15

Borehole configuration:



Probe	523 006.1	
values at atmosphere	P1	99.6
	P2	91.1
	P3	106.3
	P4/P_{SL}	100.6/2.4
	T1	14.3
	T2	14.2
	T3	14.0
Total Weight (kg)	1955.3	

Form

TALLY LIST

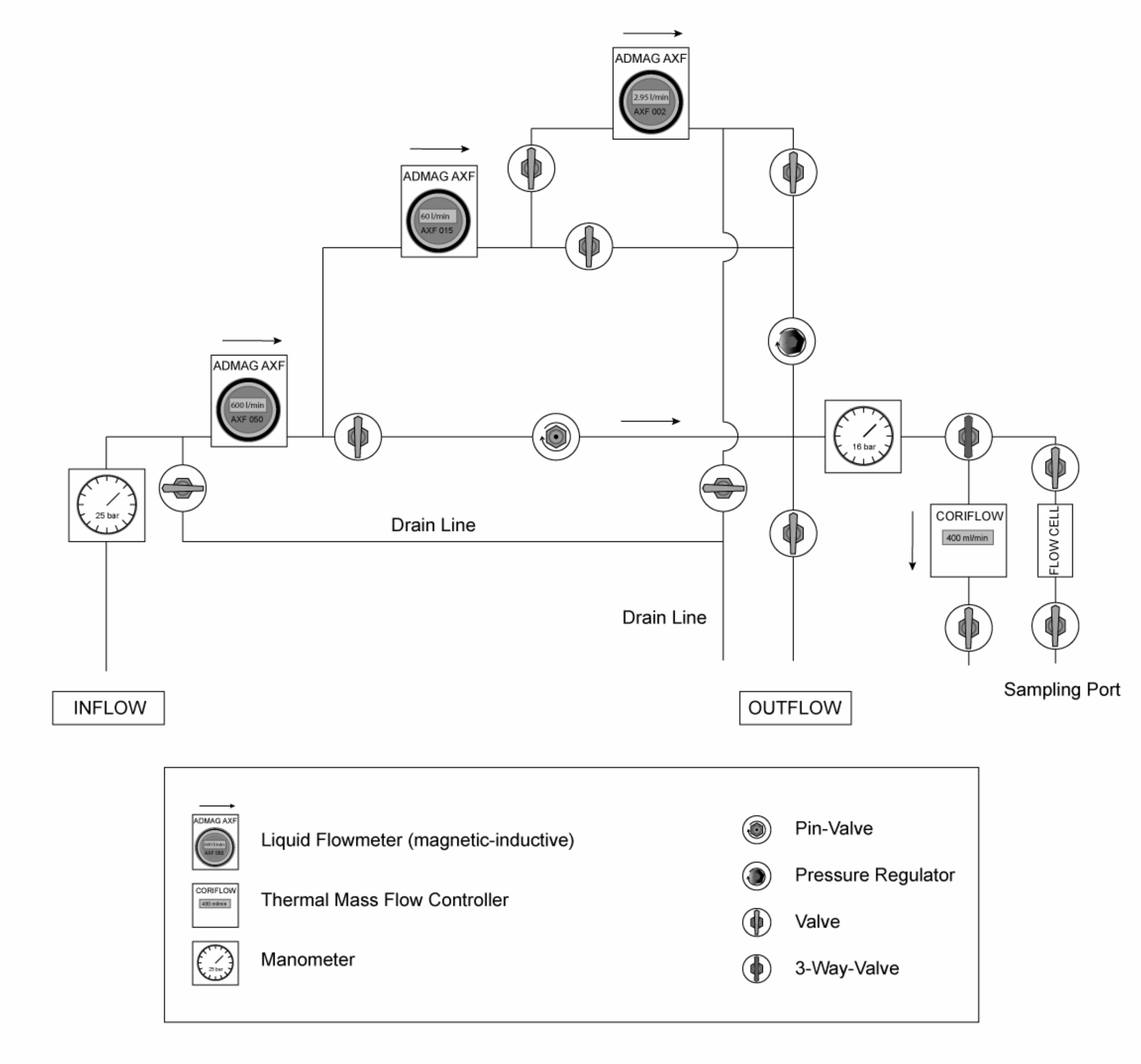
Borehole	NOK EWS 2007	Interval name	Test Oftr_i10	Date	03.11.2007
Depth	719.0 m	Interval depth	408.5 - 417.59 ı	Location	Oftringen

TU	1	6.51	TU	51	6.50				
TU	2	6.51	TU	52	6.51				
TU	3	6.51	TU	53	6.51				
TU	4	6.51	TU	54	6.51				
TU	5	6.51	TU	55	6.51				
TU	6	6.51	TU	56	6.51				
TU	7	6.51	TU	57	6.50				
TU	8	6.51	TU	58	6.51				
TU	9	6.51	TU	59	6.51				
TU	10	6.50	TU	60	6.51				
TU	11	6.50	TU	61	6.50				
TU	12	6.51	TU	62	6.50				
TU	13	6.50	Pop Joint		1.05				
TU	14	6.51							
TU	15	6.51							
TU	16	6.51							
TU	17	6.51							
TU	18	6.51							
TU	19	6.50							
TU	20	6.51							
TU	21	6.51							
TU	22	6.50							
TU	23	6.51							
TU	24	6.50							
TU	25	6.50							
TU	26	6.50							
TU	27	6.50							
TU	28	6.50							
TU	29	6.50							
TU	30	6.50							
TU	31	6.50							
TU	32	6.50							
TU	33	6.51							
TU	34	6.51							
TU	35	6.50							
TU	36	6.51							
TU	37	6.50							
TU	38	6.50							
TU	39	6.51							
TU	40	6.50							
TU	41	6.51							
TU	42	6.51							
TU	43	6.50							
TU	44	6.50							
TU	45	6.50							
TU	46	6.50							
TU	47	6.51							
TU	48	6.51							
TU	49	6.51							
TU	50	6.51							
		325.28			79.13		0.00		0.00

Total string length:	404.41

Form

SURFACE EQUIPMENT LAYOUT



Flow meter	Lower limit of measuring range	(% of FS)	Upper limit of measuring range (l/min)	Accuracy between 3% and 100% of FS (% of rate)	Accuracy between 1% and 3% of FS (% of rate)	Equipment used
AXF DN2	0.030 l/min	1 %	2.95 l/min	0.35	0.5	no
AXF DN15	0.6 l/min	1 %	60 l/min	0.35	0.5	no
AXF DN50	11.78 l/min	1 %	1178.10 l/min	0.35	0.5	no
Coriflow	0.50 kg/h	2 %	25.00 kg/h	1	1	no

Form

BENCH TEST

SOLEXPERTS

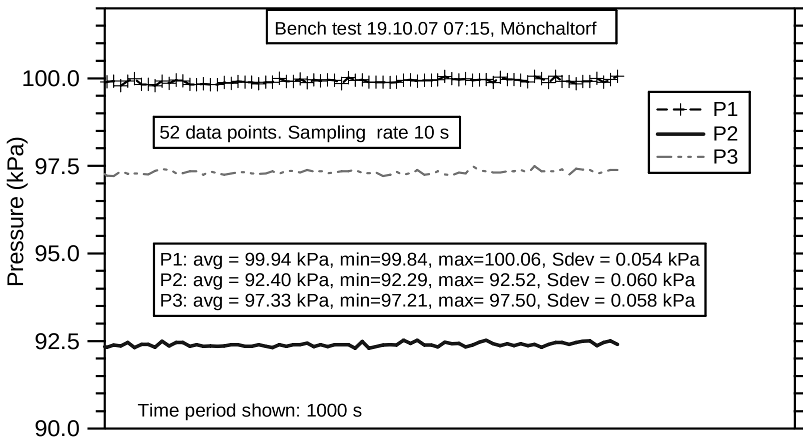
Project	Location	Date
Oftringen NOK EWS Borehole	Oftringen	20.12.2007
Well name	**Test name**	**Engineer**
NOK EWS 2007	Oftri-i10	Fi/SR

Transducer describtion	Output units
P1, P2, P3: 0-206.84 bar (3000 Psi), P4: 0-6 bar, P_{ST} = 0-10 bar	kPa, °C

P1#	P2#	P3#	P4#
43224	50370	43231	591.001.027

Offsite pretest bench test (Date: 19.10.07)

Measurement conditions (P, T and position)			Sampling rate
	97.7 kPa	5.6 °C	10 s
( ) direct	(x) vertical	( ) horizontal	

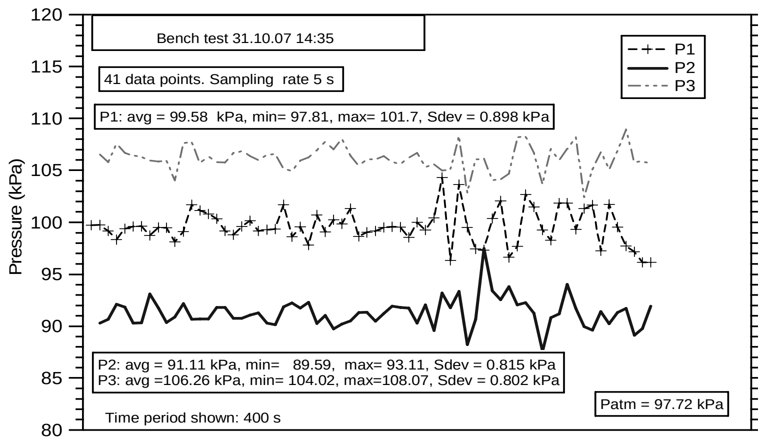


P1 average:	99.84	kPa
P2 average:	92.29	kPa
P3 average:	97.33	kPa
P4 average:	n.m.	kPa
P_{SL} average:	n.m.	kPa
P1 Sdev	0.054	kPa
P2 Sdev	0.060	kPa
P3 Sdev	0.058	kPa

File: TestData24.DAT

Onsite pretest bench test (Date: 31.10.07)

Measurement conditions (P, T and position)			Sampling rate
	97.4 kPa	14.2 °C	5 s
( ) direct	(x) vertical	( ) horizontal	



P1 average:	99.58	kPa	
P2 average:	91.11	kPa	
P3 average:	106.26	kPa	
P4 average:	101.36	kPa	1)
P_{SL} average:	n.m	kPa	
P1 Sdev	0.898	kPa	
P2 Sdev	0.815	kPa	
P3 Sdev	0.815	kPa	
P4 Sdev	0.0085	kPa	1)
P_{SL} Sdev	n.m	kPa	

1) Data not shown, 01.11.07, 20:50
Oftr_2007_11_01_oftr_i8.DAT, Patm=98.2 kPa

File: Oftr_2007_10_31_atm1.DAT

Form

BENCH TEST

SOLEXPERTS

Project	Location	Date
Oftringen NOK EWS Borehole	Oftringen	20.12.2007
Well name	**Test name**	**Engineer**
NOK EWS 2007	Oftri-i10	Fi/SR

Transducer describtion	Output units
P1, P2, P3: 0-206.84 bar (3000 Psi), P4: 0-6 bar, P_{ST} = 0-10 bar	kPa, °C

P1#	P2#	P3#	P4#
43224	50370	43231	591.001.027

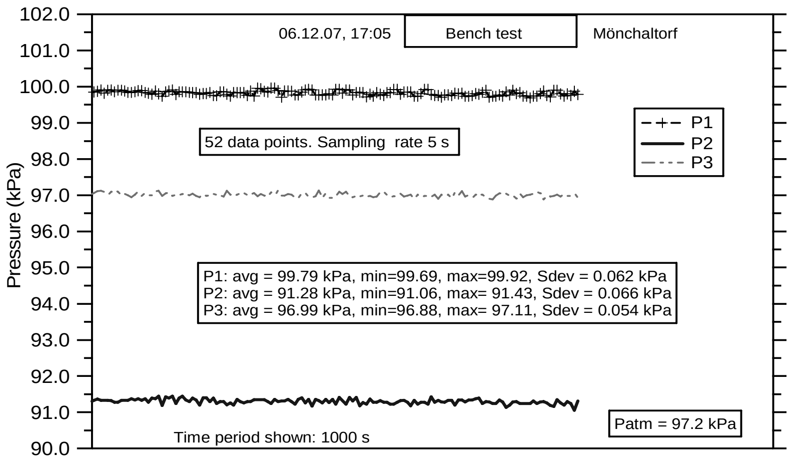
Onsite after test bench test (Date: -)

Measurement conditions (P, T and position)	Sampling rate
( ) direct ( ) vertical ( ) horizontal	

No onsite after test bench test was carried out

Offsite after test bench test (Date: 06.12.07)

Measurement conditions (P, T and position)	Sampling rate
96.6 kPa 9.6 °C	5 s
( ) direct (x) vertical ( ) horizontal	



P1 average:	99.69 kPa
P2 average:	91.28 kPa
P3 average:	96.99 kPa
P4 average: [1)]	101.44 kPa
P_{SL} average:	n.m. kPa
P1 Sdev	0.062 kPa
P1 Sdev	0.062 kPa
P2 Sdev	0.066 kPa
P3 Sdev	0.054 kPa
P4 Sdev	0.007 kPa

[1)] not shown on graph

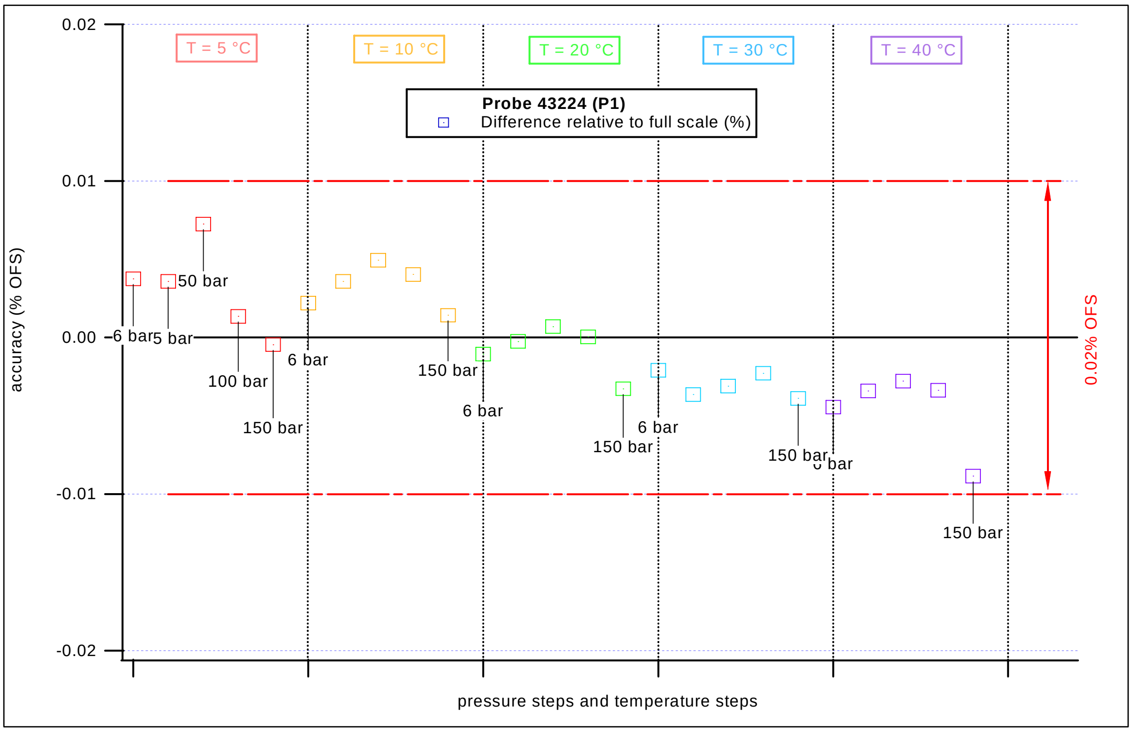
File: test8.dat

Appendix K

Verification of the TSSP Pressure Transducers

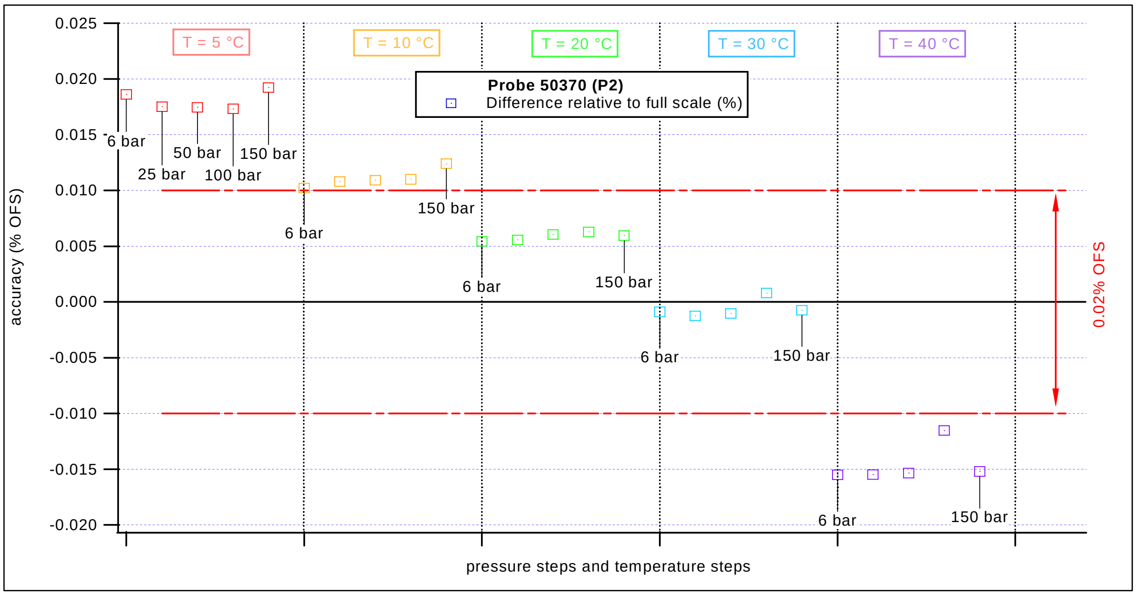
Probe No.: 43224	TSSP S1					16.10.2007
applied temp °C	***measured temp* °C***	***difference °C***	***applied pressure bar***	***measured pressure* bar***	***difference bar***	***pressure accuracy % OFS***
5	5.2681	0.2681	5.9817	5.9432	-0.0385	-0.0186
5	5.1188	0.1188	24.9817	24.9454	-0.0363	-0.0175
5	5.0916	0.0916	49.9817	49.9456	-0.0361	-0.0174
5	5.0916	0.0916	99.9817	99.9458	-0.0359	-0.0173
5	5.0916	0.0916	149.9820	149.9420	-0.0400	-0.0193
10	9.7927	-0.2073	5.9817	5.9605	-0.0212	-0.0102
10	9.8196	-0.1804	24.9817	24.9593	-0.0224	-0.0108
10	9.8330	-0.1670	49.9817	49.9591	-0.0226	-0.0109
10	9.8465	-0.1535	99.9817	99.9589	-0.0228	-0.0110
10	9.8465	-0.1535	149.9820	149.9560	-0.0260	-0.0126
20	19.9321	-0.0679	5.9817	5.9705	-0.0112	-0.0054
20	19.9584	-0.0416	24.9817	24.9701	-0.0116	-0.0056
20	19.9584	-0.0416	49.9817	49.9692	-0.0125	-0.0060
20	19.9715	-0.0285	99.9317	99.9187	-0.0130	-0.0063
20	19.9715	-0.0285	149.9820	149.9690	-0.0130	-0.0063
30	30.1751	0.1751	5.9817	5.9835	0.0018	0.0009
30	30.1366	0.1366	24.9817	24.9842	0.0025	0.0012
30	30.1238	0.1238	49.9817	49.9838	0.0021	0.0010
30	30.1366	0.1366	99.9817	99.9800	-0.0017	-0.0008
30	30.1494	0.1494	149.9820	149.9830	0.0010	0.0005
40	39.8722	-0.1278	5.9817	6.0138	0.0321	0.0155
40	39.9223	-0.0777	24.9817	25.0137	0.0320	0.0155
40	39.9598	-0.0402	49.9817	50.0134	0.0317	0.0153
40	39.9598	-0.0402	99.9817	100.0060	0.0243	0.0117
40	39.9724	-0.0276	149.9820	150.0130	0.0310	0.0150

*) raw values see report from the 14th of September 2006 ('Messbericht Nr. 133-03782, METAS Bern')



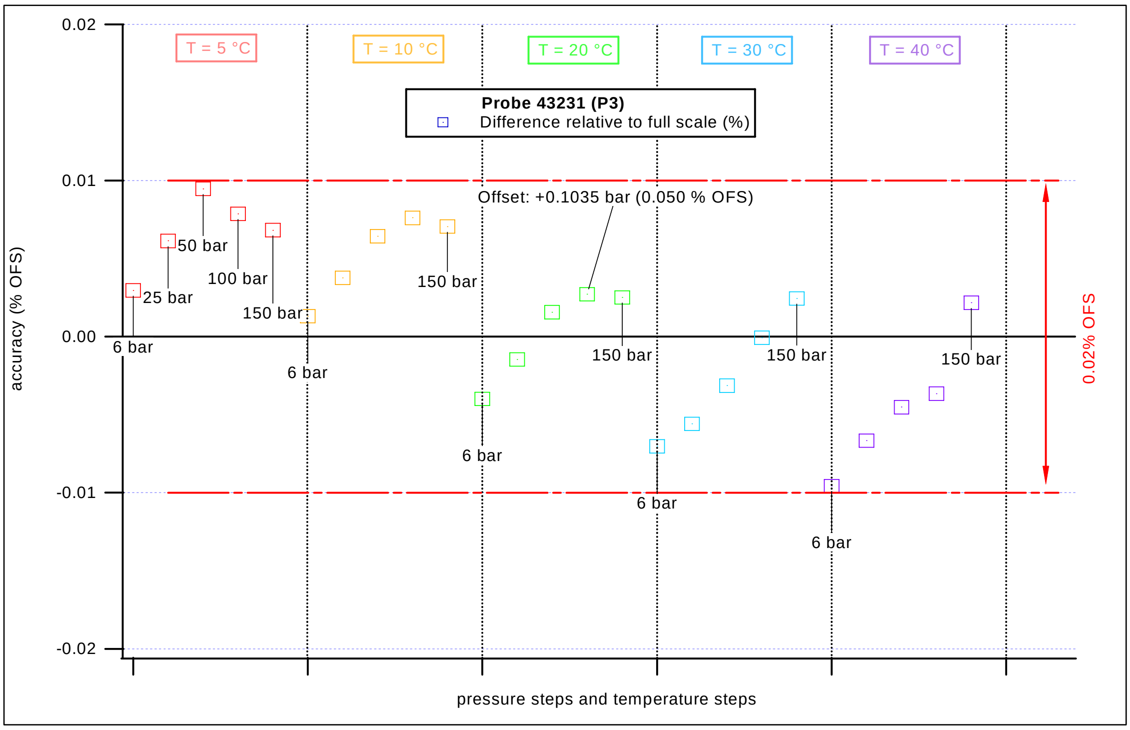
Probe No.: 50370		TSSP S1				16.10.2007
applied temp	*measured temp**	*difference*	*applied pressure*	*measured pressure**	*difference*	*pressure accuracy*
°C	*°C*	*°C*	*bar*	*bar*	*bar*	*% OFS*
5	5.3386	0.3386	5.98169	5.94317	-0.038520	-0.0186
5	5.1268	0.1268	24.9817	24.9454	-0.036300	-0.0175
5	5.0473	0.0473	49.9817	49.9456	-0.036100	-0.0174
5	5.0209	0.0209	99.9817	99.9458	-0.035900	-0.0173
5	5.0076	0.0076	149.982	149.942	-0.040000	-0.0193
10	9.7965	-0.2035	5.98169	5.96054	-0.021150	-0.0102
10	9.8360	-0.1640	24.9817	24.9593	-0.022400	-0.0108
10	9.8623	-0.1378	49.9817	49.9591	-0.022600	-0.0109
10	9.8754	-0.1246	99.9817	99.9589	-0.022800	-0.0110
10	9.8885	-0.1115	149.982	149.956	-0.026000	-0.0126
20	19.9687	-0.0313	5.98169	5.97045	-0.011240	-0.0054
20	19.9816	-0.0184	24.9817	24.9701	-0.011600	-0.0056
20	19.9816	-0.0184	49.9817	49.9692	-0.012500	-0.0060
20	19.9945	-0.0055	99.9317	99.9187	-0.013000	-0.0063
20	19.9945	-0.0055	149.982	149.969	-0.013000	-0.0063
30	30.0946	0.0946	5.98169	5.98354	0.001850	0.0009
30	30.0946	0.0946	24.9817	24.9842	0.002500	0.0012
30	30.0946	0.0946	49.9817	49.9838	0.002100	0.0010
30	30.1073	0.1073	99.9817	99.98	-0.001700	-0.0008
30	30.1200	0.1200	149.982	149.983	0.001000	0.0005
40	39.8309	-0.1691	5.98169	6.01375	0.032060	0.0155
40	39.9311	-0.0689	24.9817	25.0137	0.032000	0.0155
40	39.9812	-0.0188	49.9817	50.0134	0.031700	0.0153
40	40.0062	0.0062	99.9817	100.006	0.024300	0.0117
40	40.0188	0.0188	149.982	150.013	0.031000	0.0150

*) raw values see report from the 14th of September 2006 ('Messbericht Nr. 133-03782, METAS Bern')



Probe No.: 43231		TSSP S1				16.10.2007
applied temp	***measured temp****	***difference***	***applied pressure***	***measured pressure****	***difference***	***pressure accuracy***
°C	***°C***	***°C***	***bar***	***bar***	***bar***	***% OFS***
5	5.2826	0.2826	5.96634	5.97057	0.004230	0.0020
5	5.1457	0.1457	24.9663	24.964	-0.002300	-0.0011
5	5.0909	0.0909	49.9663	49.9571	-0.009200	-0.0044
5	5.0909	0.0909	99.9663	99.9604	-0.005900	-0.0029
5	5.0909	0.0909	149.966	149.963	-0.003000	-0.0014
10	9.7700	-0.2300	5.96634	5.97399	0.007650	0.0037
10	9.7972	-0.2028	24.9663	24.9689	0.002600	0.0013
10	9.8244	-0.1756	49.9663	49.9634	-0.002900	-0.0014
10	9.8379	-0.1621	99.9663	99.9609	-0.005400	-0.0026
10	9.8379	-0.1621	149.966	149.962	-0.004000	-0.0019
20	19.9370	-0.0630	5.96634	5.98493	0.018590	0.0090
20	19.9638	-0.0362	24.9663	24.9797	0.013400	0.0065
20	19.9771	-0.0229	49.9663	49.9735	0.007200	0.0035
20	19.9771	-0.0229	99.9163	99.9211	0.004800	0.0023
20	19.9771	-0.0229	149.966	149.971	0.005000	0.0024
30	30.1518	0.1518	5.96634	5.99123	0.024890	0.0120
30	30.1387	0.1387	24.9663	24.9883	0.022000	0.0106
30	30.1255	0.1255	49.9663	49.9832	0.016900	0.0082
30	30.1387	0.1387	99.9663	99.9768	0.010500	0.0051
30	30.1650	0.1650	149.966	149.972	0.006000	0.0029
40	39.8738	-0.1262	5.96634	5.99651	0.030170	0.0146
40	39.9256	-0.0744	24.9663	24.9905	0.024200	0.0117
40	39.9515	-0.0485	49.9663	49.986	0.019700	0.0095
40	39.9644	-0.0356	99.9663	99.9843	0.018000	0.0087
40	39.9644	-0.0356	149.966	149.972	0.006000	0.0029

*) raw values see report from the 14th of September 2006 ('Messbericht Nr. 133-03782, METAS Bern')



Appendix L

Reviews and Comments
(AF-Colenco)

- **Replies (Solexperts) on review comments Memo 1190/12 (AF-Colenco)**
- **Memo 1190/12 (10.09.2008); Review NAB 08-15 (AF-Colenco)**
- **Replies (Solexperts and Intera) on review comments Memoranda (AF-Colenco)**
- **Memoranda 1190/2 to 1190/11 on QLRs (AF-Colenco)**

Chapter/ Interval	**Comment Memo 1190/12**	**Review comments**
All	General	The analyses of the hydraulic tests do not always conform to the contents of the analysis levels as defined by NAGRA. In some cases more details are provided than demanded by NAGRA, in one case the analysis seems not to reach the level of analysis. In general the analyses of the standard level are more comprehensive than required by NAGRA.
All	General	The assessment of the flow model using residual plots is a suitable method. This method in combination with the SSE value can also be used to evaluate the quality of a match. However, these methods can't replace the classical diagnostic plots (comparison of the data with the simulation). The diagnostic plots should always be provided.
Addressed in specific sections		
8 / Oftr-i1	8.1	It is known that the PSR and PW phases are disturbed. Why are they not included in the pressure history like in the homogeneous case. They have a direct impact on the following phases.
The impact is very small. It was decided to show the discrepancy of the model with respect to PSR and PW, even though the incorporation of PSR and PW as pressure history would have been appropriate		
8 / Oftr-i1	8.2	The recommended parameter range is missing.
The summary chapter is completed to address the issue above		
8 / Oftr-i1	8.3	The mismatch of the early time derivatives of phases PW and PI seems to result from a wrong fit of the inner zone parameters or the wellbore storage (c_{tz}-value). A variation / fitting of the wellbore storage in an acceptable range might lead to a better solution of this fitting problem.
A variation of the c_{tz} *would improve the the fit for the PW and PI sequences but compromise the fit of the SWS log-log-diagnostic plot (The plots show the result of a multiple sequence Cartesian fit to the individual test sequences)*		
8 / Oftr-i2	9.2	The upper limit of the parameter value is defined in chapter 7.3.2 as 2E-5 m^{-1}. What is the explanation for the larger maximum value chosen at 5E-5 m^{-1}?
The detailed analysis for Oftr-i2 was completed before the plausibility ranges for P_f *and* S_S *were reconsidered*		

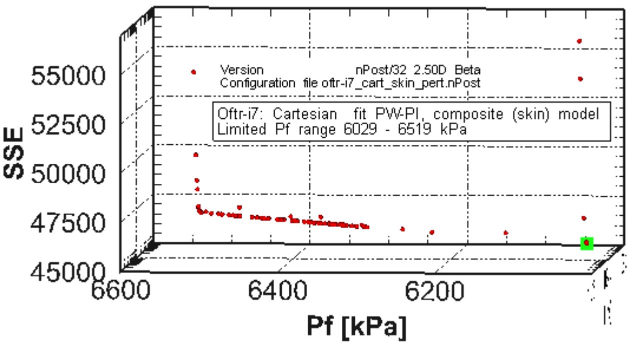
(Continuation)

Chapter	Comment	Review comments[1)]
9 / Oftr-i2	9.3	The simulation seems not to represent the formation behaviour very well with respect to the late times of the derivative of phase PI_b shown in figure 9.4
Agreed, no action taken (note that Fig. 9.4 changed to Fig 9.7 during report revision)		
9/ Oftr-i2	9.4	The given estimation of the formation equivalent fresh water head is based on a model which excludes the borehole history. This has to be taken into account when using this result.
Agreed, no action taken		
9 / Oftr-i2	9.5	This result is well known and needs no detailed analysis. Instead, an analysis of the complete test sequence (PI_b + SWS phases) is missing. A recommendation range for the parameter values should also be provided. The comprehensiveness of the analysis seems therefore to be lower than that of the standard analyses presented in this report. As the detailed analysis should include a fit of the entire sequence (already performed in the QLR), this should be included in the report.
The QLR fit of the entire sequence is added during revison and two additional Cartesian multiple fits are presented: PSR-PI-(SW)-SWS-PI2 (now Section 9.2) and PI-(SW)-SWS-PI (now Section 9.3). The latter case assumes that the PSR-period was affected by ongoing compliance effects.		
10 / Oftr-i3 11 / Oftr-i4	10.1 11.1	The high degree of interdependence between the estimation of the formation storativity and the transmissivity of a single borehole test is not understandable, especially as it is not observed amongst the further analysis presented in this report. During the analysis typically a high correlation between these parameters is observed with respect to the tables of the covariance-correlation matrix presented.
The interpendence is documented in the covariance/correlation matrix tables for a number of analyses: Tab. 10.3, Tab. 10.5, Tab. 10.7 (all homogeneous model) and Tab. 10.10 (composite skin model). Table numbers refer to the revised report.		
10 / Oftr-i3	10.3	In this place (mid-left) a diagnostic plot of the SW phase (and not PI2) as in figure 10.3 should be given.
The plots are revised as suggested (now referenced as Fig. 10.11)		

(Continuation)

Chapter	Comment	Review comments [1)]
11 / Oftr-i4	11.2	This range is not traceable with respect to the QLR presented in Appendix D.
The range values were wrong and have been corrected		
11 / Oftr-i4	11.4	At the beginning of section 11.6 it seems that the best match is found and the author starts the evaluation of the parameter ranges. Up to this point no diagnostic plot is presented to show the quality of the estimation. The use of the residual plots and SSE values to evaluate the correctness of the flow model as well as the parameters is possible, but the classical methods of fit quality control using diagnostic plots should also be carried out by the authors, in the same way it was provided in the preceding chapters.
New Fig. 11.7 with two SWS diagnostic plots was added. Note that the diagnostic plots for the two simulations show near perfect fits which makes selecting of the appropriate model difficult.		
11 / Oftr-i4	11.5	It is well known that the c_{tz} parameter constrains the estimation of the parameters P_f and K by usage of shut-in phases. Therefore the concluded correlation is obvious. In contrast, the only little influence of the wellbore radius is more remarkable as the radius has a direct influence on the interval volume and hence on the wellbore storage.
During the pulse tests very low test zone compressibilities were measured: 4.3E-10 Pa^{-1} for PI and 4.2E-10 Pa^{-1} for PI2 (see Appendix D). These values were considered too low as they are similar or slightly lower than the expected water compressibility at interval depth and temperature conditions (see Appendix D). Therefore, c_{tz} was set to a value of 8E-9 Pa^{-1}. The influence of radius is small because it has little effect on the C parameter using the prescribed range (sampling of r_w parameter within 0.07 - 0.08 m)		
11 / Oftr-i4	11.7	The use of the residual plots and SSE values to evaluate the correctness of the flow model and parameters is possible, but also limited. The classical methods of fit quality control using diagnostic plots should also be provided by the authors as it was done in the preceding chapters.
The limited use of the diagnostic plots is shown with the additionally provided plots in reply to Comment 11.4. Additional log-log plots are nonetheless desirable. No action taken due to time constraints.		
12 / Oftr-i5	12.1	The observed sensitivities indicating the high degree of uncertainty are based on the short test duration. Therefore this remark offers no new evidence to the analysis.
The rated remark is of descriptive (and not deductive) character -- as stated in the comment		
12 / Oftr-i5	12.2	Figure 12.1 indicates that during phase PW1 the sensitivity of the formation conductivity is lower than in phase PW2. In addition, the sensitivity of the formation pressure in phase PW1 is in the same order of magnitude as the sensitivity of the conductivity. This offers the possibility to use PW1 for the estimation of the formation pressure. The zero sensitivity of the formation parameters obtained during the slug phase SW, as a flow phase, is not typical, It is most probably due to the very low permeability and therefore associated very low pressure changes during the SW-phase.
Agreed but no action taken due to time constraints		

(Continuation)

<table>
<tr><th>Chapter</th><th>Comment</th><th>Review comments [1)]</th></tr>
<tr><td>14 /Oftr-i7</td><td>14.1</td><td>The values in brackets indicating the lowest/highest estimation are not consistent with the values given in the summary table of the QLR (cf. appendix G). The highest conductivity value is 3.2E-13 m/s and the lowest formation pressure is estimated to 4795 kPa according to appendix G.</td></tr>
<tr><td colspan="3">Part of the review comment refers to a K-value which was presented in brackets. Values in brackets were considered highly unreliable and not included in the results. The lowest P_f value is corrected as suggested</td></tr>
<tr><td>14 /Oftr-i7</td><td>14.2</td><td>We can not see the event which could either remove an existing skin or change the borehole conditions. The interval i7 covers 7.5 m of interval i2. The conclusion of the detailed analysis of i2 was that the best description for the flow behaviour in interval i2 is a homogeneous flow model. Therefore, there is no indication of any positive skin. Furthermore the suitable flow model for i7 is a homogeneous flow model. The reason for the choice of neglecting the borehole history should be more obvious.</td></tr>
<tr><td colspan="3">Test interval Oftr-i2 covers a borehole section of 50 m whereas Oftr-i7 represents a subsection of Oftr-i2 with a length of 9.1 m. The review comment implies the assumption of a homogeneous distribution of borhole (skin/no skin) properties along the borehole axis within the mentioned intervals. To the authors it seems plausible that a specific feature (e.g. skin) could be detecable in the test response of interval Oftr-i7 whereas it would be masked (or less dominant) in the the test response of the the 5 times longer interval Oftr-i2.</td></tr>
<tr><td>14 /Oftr-i7</td><td>14.3/14.4</td><td>The meaning of a bi-modal distribution of the formation pressure is not clear. The distribution might be an artefact of the inverse modelling procedure (one of the peak representing local minima?).</td></tr>
<tr><td colspan="3">The peak represents a number of solutions at the upper P_f range limit (P_f at 6519 kPa, as shown below) but associated with very low K-values <1E-14 m/s (not visible from the perspective of the 3D plot below). The peak is not representing a local minima.

</td></tr>
<tr><td>14 /Oftr-i7</td><td>14.5</td><td>The change of the interval length influences the interval volume and therefore affects the wellbore storage. Do the measured c_{tz}-values, estimated using a stable interval volume, support this assumption?</td></tr>
<tr><td colspan="3">The simulated change in interval volume (in total about 25 ml) is very small compared to the nominal interval volume 152'180 ml (ratio 1 : 6000). Therefore, (and because $V_{interval}$ contributes only in part to C) a potential effect on the wellbore storage can be excluded.</td></tr>
<tr><td>14 /Oftr-i7</td><td>14.6</td><td>A discussion of the results including comparison with the parameter range and the values estimated for interval i2 is missing.</td></tr>
<tr><td colspan="3">The summary chapter was completed to address the issues above</td></tr>
</table>

(Continuation)

<table>
<tr><th>Chapter</th><th>Comment</th><th>Review comments [1)]</th></tr>
<tr><td>15 /Oftr-i8</td><td>15.3</td><td>The best fit value at the upper limit indicates a lower value for the formation conductivity.</td></tr>
<tr><td colspan="3">This comment is not understood. We assume that it should say "The best fit value at the <u>lower</u> limit indicates a lower formation conductivity". K-values lower than 1.0E-14 are considered unrealistic.</td></tr>
<tr><td>15 /Oftr-i8</td><td>15.4</td><td>The reason for the large range for the formation conductivity is not conclusive. All presented matches using conductivity values greater then 5E-14 m/s show a significant mismatch of the slope at late times.</td></tr>
<tr><td colspan="3">No action taken</td></tr>
<tr><td>15 /Oftr-i8</td><td>15.5</td><td>A discussion of the results including comparison with the parameter range and the values estimated for interval i2 is missing.</td></tr>
<tr><td colspan="3">The summary chapter was completed to address the issues above</td></tr>
<tr><td>16 /Oftr-i9</td><td>16.3</td><td>The intervals i2 and i3 are relevant for a comparison between the results. The interval i1 is situated in the deeper parts of the borehole.</td></tr>
<tr><td colspan="3">Interval i1 has a higher T/K-values than interval i2 and could play the role of a dominant zone with an imposing head (to a certain degree) to the less permeable zones i2 and indirectly also to i3. Given the higher T/K-values of interval i1, the head estimate for i1 has a higher level of confidence.</td></tr>
<tr><td>16 /Oftr-i9</td><td>16.4</td><td>The table presents the best simulation of the perturbation analysis used for the improvement of a composite model. Therefore, it presents the matrix of a composite model and not that of a homogeneous model.</td></tr>
<tr><td colspan="3">Error corrected</td></tr>
<tr><td>16 /Oftr-i9</td><td>16.6</td><td>The evaluation of the influence of the temperature on the parameter estimation can only be estimated by an ongoing match. It is not clear how the influence was estimated, but the new parameters are not presented. Therefore, it has to be assumed that no new parameter estimation was done including the temperature effect. The conclusion that the temperature has no significant impact is hence not proven.</td></tr>
<tr><td colspan="3">The parameters were re-optimized with inclusion of the temperature history (ongoing match). For the homogeneous model, the resulting optimized pressure is at lower limit of the plausible range (P_f = 5300 kPa, K=1.69E-11 m/s, S_S = 1.90E-05). For the composite skin model, the following parameter were obtained:
K = 1.9E-12 m/s
K_S = 1.2E-10
Pf = 5933 kPa
S_S= 1.89E-05
S_S = 3.46E-06
t_S = 0.19 m
The aim of including the temperature effects was to see if higher formation pressures would be obtained. This was not the case. The model was not further investigated because modelling of varying test zone conditions is beyond what is requested for Standard analysis.</td></tr>
</table>

(Continuation)

Chapter	Comment	Review comments [1)]
16 /Oftr-i9	16.7	A discussion of the results including comparison with the parameter range and the values estimated for interval i3 and i2 is missing.
The summary chapter was completed to address the issues above		
19 / Summary	19.1	The ranges for the formation conductivity and the static formation pressure are not presented in the interval chapter. The evaluation is not described and not traceable.
The summary chapter was completed to address the issues above		
19 / Summary	19.2	The position of the interval differs from the position given in chapter 3, table 3.1, which refers to the same interval position as in the QLR.
Corrected		
19 / Summary	19.3	The value given as the best estimation for the formation pressure is equal to the boundary value of the inverse fitting procedure. Is it really the best estimation?
It is rated as best estimate using the predescribed working hypothesis with plausible head ranges +/- 50 m asl.		
19 / Summary	19.4	The value range given is not equal to the values presented in the interval chapter.
Parameter ranges were revised based on a consistent procedure specified in the test interval chapters		
19 / Summary	19.5	The value given as the best estimation is not traceable with respect to the interval chapter.
This comment was addressed by completing the test interval chapters with additional text, graphs and summary tables		

1) Review comments considering small changes in the text have been corrected as suggested and are not mentioned in this table.

MEMO
10.09.2008

An: NAGRA
Dr. B. Frieg

Von: AF-Colenco AG
Dr. R. Schwarz, Dr. J. Croisé

zur Kenntnis: AF-Colenco AG
J.-M. Lavanchy

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Review: NAB 08-15 Oftringen Borehole – Hydraulic Packer Testing

Contents

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1 Intention

Between 19.10.2007 and 05.11.2007 10 hydraulic packer tests were performed at the borehole NOK-EWS 2007. The analyses of these hydraulic tests are presented in the NAGRA NAB 08-15. This memo documents the review of the draft version of the NAGRA NAB 08-15. It has a general section and a section focusing on each chapter of the NAB. The text passages to which the comments in this memo refer to are marked in a pdf copy of the NAGRA NAB 08-15.

2 Comments

2.1 General

The analyses of the hydraulic tests do not always conform to the contents of the analysis levels as defined by NAGRA. In some cases more details are provided than demanded by NAGRA, in one case the analysis seems not to reach the level of analysis. In general the analyses of the standard level are more comprehensive than required by NAGRA.

The assessment of the flow model using residual plots is a suitable method. This method in combination with the SSE value can also be used to evaluate the quality of a match. However, these methods can't replace the classical diagnostic plots (comparison of the data with the simulation). The diagnostic plots should always be provided.

The structure between the different test interval chapters is not consistent. The summary of each chapter either gives only the recommendation ranges or only the recommended reference parameter values. Both, reference values and ranges, should be given in every chapter summary. Further, for some intervals the synthesis of the values is not traceable. The graphical presentation of the results as done in chapter 8, figure 8.12 would be helpful for all other test intervals. The tabular presentation of the results, including an assessment of the fit quality, as done in table 16.11 for a part of the analysis of the interval Oftr-i9 would be desirable for all test intervals.

2.2 Chapter 1

Comment 1.1 The two marked persons are to be deleted. They are not responsible for the analysis of the hydraulic tests.
Comment 1.2 Replace "Colenco" by "AF-Colenco"

2.3 Chapter 2 – Chapter 5

No comments

2.4 Chapter 6: Analysis Methods

Comment 6.1 The reference should be to Agarwal (1980)
Comment 6.2 The reference should be to Horne (1995), and the reference Peres at al. (1989) is missing in the list of references.

Comment 6.3 Replace “6.5.1 Multi-component object function” by “6.5.1 Multi-component objective function”?

2.5 Chapter 7: Hydraulic Parameters and Plausibility Ranges

Comment 7.1 The referred interval depths differ from table 3.1, which refers to the same interval positions as the QLR does. The interval depths should be corrected.

Comment 7.2 C=delta (greek letter missing) V/ delta (greek letter missing) P

2.6 Chapter 8: Test Interval Oftr-i1

Comment 8.1 It is known that the PSR and PW phases are disturbed. Why are they not included in the pressure history like in the homogeneous case. They have a direct impact on the following phases.

Comment 8.2 The recommended parameter range is missing.

Comment 8.3 The mismatch of the early time derivatives of phases PW and PI seems to result from a wrong fit of the inner zone parameters or the wellbore storage (c_{sc}-value). A variation / fitting of the wellbore storage in an acceptable range might lead to a better solution of this fitting problem.

2.7 Chapter 9: Test Interval Oftr-i2

Comment 9.1 wrong reference: Oftr-i2 instead of Qftr-i1.

Comment 9.2 The upper limit of the parameter value is defined in chapter 7.3.2 as 2E-5 m^{-1}. What is the explanation for the larger maximum value chosen at 5E-5 m^{-1}?

Comment 9.3 The simulation seems not to represent the formation behaviour very well with respect to the late times of the derivative of phase PI_b shown in figure 9.4.

Comment 9.4 The given estimation of the formation equivalent fresh water head is based on a model which excludes the borehole history. This has to be taken into account when using this result.

Comment 9.5 This result is well known and needs no detailed analysis. Instead, an analysis of the complete test sequence (PI_b + SWS phases) is missing. A recommendation range for the parameter values should also be provided. The comprehensiveness of the analysis seems therefore to be lower than that of the standard analyses presented in this report. As the detailed analysis should include a fit of the entire sequence (already performed in the QLR), this should be included in the report.

2.8 Chapter 10: Test Interval Oftr-i3

Comment 10.1 The high degree of interdependence between the estimation of the formation storativity and the transmissivity of a single borehole test is not understandable, especially as it is not observed amongst the further analysis presented in this report. During the analysis typically a high correlation between these parameters is observed with respect to the tables of the covariance-correlation matrix presented.

Comment 10.2 wrong reference: Oftr-i3 instead of Oftr-i1.

Comment 10.3 In this place (mid-left) a diagnostic plot of the SW phase (and not PI2) as in figure 10.3 should be given.

Comment 10.4 The demands of a detailed analysis are well fulfilled. A discussion of the estimated formation equivalent fresh water head in comparison to the interval Oftr-i9 is missing.

2.9 Chapter 11: Test Interval Oftr-i4

Comment 11.1 see comment 10.1

Comment 11.2 This range is not traceable with respect to the QLR presented in Appendix D.

Comment 11.3 The plots at the bottom of figure 11.4 and 11.5 are swapped.

Comment 11.4 At the beginning of section 11.6 it seems that the best match is found and the author starts the evaluation of the parameter ranges. Up to this point no diagnostic plot is presented to show the quality of the estimation. The use of the residual plots and SSE values to evaluate the correctness of the flow model as well as the parameters is possible, but the classical methods of fit quality control using diagnostic plots should also be carried out by the authors, in the same way it was provided in the preceding chapters.

Comment 11.5 It is well known that the c_{sc} parameter constrains the estimation of the parameters P_f and K by usage of shut-in phases. Therefore the concluded correlation is obvious. In contrast, the only little influence of the wellbore radius is more remarkable as the radius has a direct influence on the interval volume and hence on the wellbore storage.

Comment 11.6 With respect to figure 11.11 it should be 0.3 hours.

Comment 11.7 The use of the residual plots and SSE values to evaluate the correctness of the flow model and parameters is possible, but also limited. The classical methods of fit quality control using diagnostic plots should also be provided by the authors as it was done in the preceding chapters.

2.10 Chapter 12: Test Interval Oftr-i5

Comment 12.1 The observed sensitivities indicating the high degree of uncertainty are based on the short test duration. Therefore this remark offers no new evidence to the analysis.

Comment 12.2 Figure 12.1 indicates that during phase PW1 the sensitivity of the formation conductivity is lower than in phase PW2. In addition, the sensitivity of the formation pressure in phase PW1 is in the same order of magnitude as the sensitivity of the conductivity. This offers the possibility to use PW1 for the estimation of the formation pressure. The zero sensitivity of the formation parameters obtained during the slug phase SW, as a flow phase, is not typical, It is most probably due to the very low permeability and therefore associated very low pressure changes during the SW-phase.

Comment 12.3 It should be documented which PW phase is shown. It seems to be the phase PW2.

2.11 Chapter 13: Test Interval Oftr-i6

No comments

2.12 Chapter 14: Test Interval Oftr-i7

Comment 14.1 The values in brackets indicating the lowest/highest estimation are not consistent with the values given in the summary table of the QLR (cf. appendix G). The highest conductivity value is 3.2E-13 m/s and the lowest formation pressure is estimated to 4795 kPa according to appendix G.

Comment 14.2 We can not see the event which could either remove an existing skin or change the borehole conditions. The interval i7 covers 7.5 m of interval i2. The conclusion of the detailed analysis of i2 was that the best description for the flow behaviour in interval i2 is a homogeneous flow model. Therefore, there is no indication of any positive skin. Furthermore the suitable flow model for i7 is a homogeneous flow model. The reason for the choice of neglecting the borehole history should be more obvious..

Comment 14.3 The meaning of a bi-modal distribution of the formation pressure is not clear. The distribution might be an artefact of the inverse modelling procedure (one of the peak representing local minima?).

Comment 14.4 see comment 14.3

Comment 14.5 The change of the interval length influences the interval volume and therefore affects the wellbore storage. Do the measured c_{sc}-values, estimated using a stable interval volume, support this assumption?

Comment 14.6 A discussion of the results including comparison with the parameter range and the values estimated for interval i2 is missing.

2.13 Chapter 15: Test Interval Oftr-i8

Comment 15.1 The referred value for the specific storage is not traceable with respect to the QLR presented in appendix H.

Comment 15.2 The lower limit of the parameter range seems to be wrong. It is described to be 5784 kPa but also referred with 5676 kPa later on.

Comment 15.3 The best fit value at the upper limit indicates a lower value for the formation conductivity.

Comment 15.4 The reason for the large range for the formation conductivity is not conclusive. All presented matches using conductivity values greater then 5E-14 m/s show a significant mismatch of the slope at late times.

Comment 15.5 A discussion of the results including comparison with the parameter range and the values estimated for interval i2 is missing.

2.14 Chapter 16: Test Interval Oftr-i9

Comment 16.1 temperature salinity logging: BLM

Comment 16.2 The presented formation pressure is not consistent with the value of the QLR given in appendix I.

Comment 16.3 The intervals i2 and i3 are relevant for a comparison between the results. The interval i1 is situated in the deeper parts of the borehole.

Comment 16.4 The table presents the best simulation of the perturbation analysis used for the improvement of a composite model. Therefore, it presents the matrix of a composite model and not that of a homogeneous model.

Comment 16.5 The plots presented are not consistent with the caption of the figure.

Comment 16.6 The evaluation of the influence of the temperature on the parameter estimation can only be estimated by an ongoing match. It is not clear how the influence was estimated, but the new parameters are not presented. Therefore, it has to be assumed that no new parameter estimation was done including the temperature effect. The conclusion that the temperature has no significant impact is hence not proven.

Comment 16.7 A discussion of the results including comparison with the parameter range and the values estimated for interval i3 and i2 is missing.

2.15 Chapter 17: Test Interval Oftr-i10

No comments

2.16 Chapter 18: Quality Assurance

Comment 18.1 replace Colenco Power Engineering AG by AF-Colenco.

2.17 Chapter 19: Summary and Conclusions

Comment 19.1 The ranges for the formation conductivity and the static formation pressure are not presented in the interval chapter. The evaluation is not described and not traceable.

Comment 19.2 The position of the interval differs from the position given in chapter 3, table 3.1, which refers to the same interval position as in the QLR.

Comment 19.3 The value given as the best estimation for the formation pressure is equal to the boundary value of the inverse fitting procedure. Is it really the best estimation?

Comment 19.4 The value range given is not equal to the values presented in the interval chapter.

Comment 19.5 The value given as the best estimation is not traceable with respect to the interval chapter.

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<table>
<tr><th>Issue</th><th>QLR/
Memo</th><th>Review comments[1)]</th></tr>
<tr><td>Flow model</td><td>QLR-i1
1190/02</td><td>The results of the numerical analysis focus on the homogeneous flow model presented in the table “Summary of Test Data”. However, the match of the parameters of the composite flow model is in general better (compare Figure 20 and 23). The results are only presented in the numerical analysis chapter and should be added to the table “Summary of Test Data”.</td></tr>
<tr><td colspan="3">A composite model typically produces a better fit than a homogeneous model, because of the greater number of fitting parameters (i.e., greater degree of freedom) compared to the homogeneous model. The fit quality alone is not sufficient to postulate a composite model. The composite model indicates estimates for P_f and for t_s at the upper bound of realistic values. Even though the estimate for Ss_f (formation specific storage) is in the expected range, compared to the high value obtained from the homogeneous model, the composite model yields parameter estimates for P_f and t_s at the upper bound. The resulting diagnostic plots for PW and SW indicate that distinct features in the simulated response which are not observed in the data (may need to add the diagnostic plots). In case of doubt, it is more appropriate to apply the simpler model (i.e., homogeneous model), and consider the more complex model as alternative. Additional analyses should then be used to support or refute the alternative model.</td></tr>
<tr><td>Sensitivity Coefficient</td><td>QLR-i1
190/02</td><td>The sensitivities of the fitting parameters are presented for both flow models. However the definition of the sensitivity coefficients is missing.</td></tr>
<tr><td colspan="3">To be added to definition section and referenced in the text (same as in QLR-i4)</td></tr>
<tr><td>Sensitivity Coefficient</td><td>QLR-i7
1190/08</td><td>For the sensitivity coefficients shown, the σr and σP values chosen should also be provided.</td></tr>
<tr><td colspan="3">Default values $\sigma_r = 1$ and $\sigma_P =1$ were used</td></tr>
<tr><td>Analysis procedure</td><td>QLR-i1
1190/02</td><td>The first step also provides a discussion of the flow model and the estimation of the parameter ranges for each individual test phase by taking into account the borehole history. However, the analysis procedure is not explained (prescribed measured pressure prior to the test sequence analysed?). The use of the specific storage as fitting parameter doesn’t lead to reasonable results (often very high specific storage values 1E-4 1/m) as the permeability is the dominating parameter (see Figure 21).</td></tr>
<tr><td colspan="3">Figure 21 still shows significant sensitivity for S_S indicating a reasonably well-constrained parameter. Compared to P_f, the sensitivities for Ss are greatest at the beginning of SWS, whereas the sensitivities P_f increase during SWS.</td></tr>
<tr><td>Analysis procedure</td><td>All</td><td>The first part also provides a discussion of the flow model and the estimation of the parameter ranges for each individual test phase by taking into account the borehole history. However, the analysis procedure is not explained sufficiently. It can only be supposed that the matching was carried out for each phase individually.</td></tr>
<tr><td colspan="3">In a first step, the diagnostic plots or Ramey graphs for the individual sequences were analyzed and fitted individually accounting for borehole history and taking into account of transient effects associated with the preceding test sequences.</td></tr>
<tr><td>Specific storage</td><td>QLR-i4
1190/05</td><td>The fitted specific storage values for the PI1- und PI2-phase seem to be too low, caused by the fixed formation pressure and maybe a skin effect.</td></tr>
<tr><td colspan="3">The PI tests show less than 10% recovery, indicating that the estimated parameters are not well constrained, and have limited reliability (results are included for completeness).</td></tr>
</table>

(Continuation)

<table>
<tr><th>Issue</th><th>QLR/
Memo</th><th>Review comments[1)]</th></tr>
<tr><td>Specific storage</td><td>QLR-i7
1190/07</td><td>The lower range of the fitted specific storage values for the phases PW seem to be slightly below the physical range. The reason why the authors never use the preliminary information about the formation specific storage is not discussed.</td></tr>
<tr><td colspan="3">The preliminary information is based on assumed formation properties without supporting results from core or in-situ measurements. Therefore, the parameters were allowed to vary within a relatively wide range.</td></tr>
<tr><td>Specific storage</td><td>QLR-i8c
1190/08</td><td>(1) The fitted specific storage values for the phases PSR and PI seem to be too low, maybe caused by incorrect inner boundary conditions or possible skin effects.
(2) In general, the term specific storage Ss should be used (unit m-1) and not storativity (dimensionless).</td></tr>
<tr><td colspan="3">(1) The PSR is more likely to respond to potential non-ideal conditions (transient effects from borehole history, packer “squeeze”) creating some pressurization mechanisms resulting in a particular pressure response. SS of PI is only a factor 2 below value of preliminary information.
(2) Agreed</td></tr>
<tr><td>Fitting parameters</td><td>QLR-i4
1190/05</td><td>However, the slopes of the PSR phase are not (represented) reproduced by the simulation. This seems to be affected by the choice of the fitting parameters. A better choice would be the formation pressure and hydraulic conductivity using a formation storage fixed to the theoretical value (given as preliminary information).</td></tr>
<tr><td colspan="3">The PSR is more likely to respond to potential non-ideal conditions (transient effects from borehole history, packer “squeeze”, or borehole closure) creating some pressurization mechanisms resulting in a particular pressure response. The PSR is dominated by wellbore storage and is therefore not well suited for parameter estimation; focus should be on the SWS response, which indicates greater parameter sensitivity</td></tr>
<tr><td>Fitting parameters</td><td>QLR-i5
1190/06</td><td>Concerning the estimated formation parameter ranges, the analyses state some significant uncertainties with respect to the specific storage and the static pressure. The given parameter ranges seem to be affected by the interpretation procedure, in particular by the choice of the fitting parameter. The interpretation of the SW-phase is not reliable.</td></tr>
<tr><td colspan="3">The test sequence consists mainly of two PW phase with very little recovery followed by a very short SW. The aim of the short SW phase was to confirm roughly the PW and PW2 results. Pressure recovery during was less than 2% indicating that the estimated parameters are not well constrained, and have limited reliability => results should be shown between brackets, or, the Ramey plot can be removed. The total water level change measured during SW could provide a rough estimate of average flow.</td></tr>
<tr><td>Wellbore storage</td><td>QLR-i4
1190/05
QLR-i8c
1190/08</td><td>The wellbore storage was estimated based on the early time measurements of the phases PW and PI (..... m3/Pa). In comparison with the theoretical value of ....m3/Pa the value seems to be low – very close to the water compressibility ...</td></tr>
<tr><td colspan="3">(1) i4: The measured low c_{SC} values can be explained by the relatively large water volume in the 50 m long interval section diminishing the effect of the elastic behavior of the packer on this parameter (c_{SC} = C / Vinterval).
(2) For all intervals: The measured system compressibilities are to be considered as approximate values because of the limited accuracy inherent to this type of field measurement.</td></tr>
</table>

(Continuation)

<table>
<tr><th>Issue</th><th>QLR/
Memo</th><th>Review comments[1)]</th></tr>
<tr><td>General</td><td>QLR-i4
1190/05</td><td>The discussion of the log-log plots could be extended to early time effects like changing wellbore conditions (e.g. to observe in Figure 13) and maybe to possible boundary or history effects (e.g. to observe in Figure 9).</td></tr>
<tr><td colspan="3">Figure 9 does not show a boundary effect, but an artifact of the derivative calculation of the field data (note, this can be adjusted by modifying the derivative span or spline the data). The particular early-time response in Figure 13 is caused by a change in the packer pressure and does not represent changing wellbore storage conditions.</td></tr>
<tr><td>General</td><td>QLR-i4
1190/05
QLR-i7
1190/07
QLR-i8c
1190/08</td><td>No diagnostic plots are presented for the match of the entire test sequence. They should be presented for the main sequences of a test.</td></tr>
<tr><td colspan="3">Because simulation uses a Cartesian fit of the entire test sequence, the simulated response should be compared to the Cartesian pressure response. Additional diagnostic plots for individual sequences could be included in support of a particular flow model, which can be discussed further in the detailed report.</td></tr>
<tr><td>General</td><td>QLR-i5
1190/06</td><td>The pressure signal in one well is determined by the diffusivity and the pressure and only these two values are possible to estimate. Therefore a range for the pressure can be estimated and either the formation conductivity or the storativity can be matched.</td></tr>
<tr><td colspan="3">The interdependence of different parameters can be assessed from the covariance matrix which can be obtained, in addition to the sensitivity coefficients, from the nSights optimization. Generally, S and T can be highly correlated in a single well test; however, depending on the test sequence, reasonably well constrained parameter estimates can be obtained for S, T, and P_f, which is quantifiable by the computed uncertainty range of the estimated parameters (95th percentile confidence interval). Highly correlated parameters would indicate a large uncertainty range.</td></tr>
</table>

[1)] Figures mentioned in comment can be found in the corresponding QLRs

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M E M O R A N D U M 1 1 9 0 / 0 2 22.11.2007

To:	NAGRA Dr. B. Frieg
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Review: QLR Oftringen Test OFTR-i1 by Solexperts

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Contents

1. Test design – test implementation

The test T1 was performed from 20/10/2007 till 21/10/2007, lasted for 28 hours including 9 different phases, which can be divided as follows:

- Phase 1 (INF): Packer inflation
- Phase 2 (COM): Packer compliance
- Phase 3 (PSR): Pressure recovery, enabling a preliminary estimate of the formation parameters
- Phase 4 (PW): Direct determination of the test zone compressibility (by measuring the volume of water associated with a pressure change) for comparison with the formation response of the previous phases
- Phase 5 (SW): Estimation of the formation parameters under flowing conditions
- Phase 6 (SWS): Repeated determination of the test zone compressibility in 2nd pressure recovery sequence; comparison with the formation response of the previous phases
- Phase 7 (PI): Repeated direct determination of the test zone compressibility (by measuring the volume of water associated with a pressure change) and further check of the formation properties.

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- Phase 8 (HI): Repeated parameter determination under flowing conditions
- Phase 9 (HIS): Pressure recovery for the determination of the test zone compressibility and for comparison with the formation response of the previous phases.

All phases are considered to be adequate for reaching the test objectives.

The middle of the interval was drilled at approximately 18:30 on October 15th 2007.

2. Hardware performance

A straddle-packer was used. Pressure and temperature were measured in the test interval as well as below the lower packer and above the upper packer (annulus). In addition the pressure was measured in the tubing above the upper packer.

The measurements were influenced by the adjacent high voltage current transformer facility (NOK). Therefore the pressure and temperature signals of the downhole triple probe were noisy throughout the whole test sequence.

3. Completeness and consistency of the field documentation

The QLR for test OFTR-i1 includes the following documents.

Document	Status	Comments
Summary page	Provided	See below
Comments page	Provided	See below
Figures and related documents	Provided	A figure of the temperature measurement is missing.
Testing logbook	Provided	Complete
Tool Configuration	Provided	
Surface equipement	Provided	
Transducer bench test	Not provided	
Flowmeter bench test	Not provided	
Tally list	Provided	
Glossary	Provided	Complete (except “Cs-“ and “Cf-value”)

Additional comments related to the specific QLR documents are addressed below.

“Summary page”

The information provided on the front page gives an overview of the basic test conditions (“Test Interval Information”), the initial analysis assumptions (“Preliminary Information”) and a summary of the test (“Test Summary”) including the borehole history information.
The comments related to this section of the QLR can be summarised as follows:

- The theoretical values for Cs and Cf are given. However, the Cs- and Cf-values are not defined in the glossary (“Nomenclature”).
- In the borehole history section, the date for the end of drilling should be given, not only the total duration of the history period.
- The names of all participants in the field test and in the analysis should be given.

“Summary of Test Data”

- The transmissivity value of the analytical interpretation of the PW-phase should be corrected to 3.00E-8 m^2/s.
- The given values in row “storativity” (S) seem to refer to the specific storage value (row below, compare with section “nSights Analysis”).
- Wrong gravitational constant under comment C.

“Comments” section (“Test overview”)

The “comments” section provides pertinent information related to the activities and the observations during testing as well as a documentation of the test equipment and the pre-test information. The section especially contains the following information:

- The borehole history contains three phases: The period after drilling through the midpoint of the interval, followed by a period after the flushing of the borehole with fresh water and finally a period of geophysical logging and fluid-logging.
- The measurements of downhole pressure and temperature signals are influenced by the adjacent high voltage current transformer facility (NOK).
- The test interval consists of a sequence of carbonates and marls (Eisenoolith, Kalksteine, Mergel).

4. Quick look analysis

Analytical analysis

Type curve and straight-line fitting methods are applied. Effects of the borehole pressure history are not taken into account. The following methods were used:

- PW-phase: Cooper-Bredehoeft-Papadopulos (CBP) type-curve (with and without correction of the pressure trend)
- SW-phase: CPB type-curves
- SWS-phase: no analysis
- PI-phase: CPB type-curves (with correction of the pressure trend)
- HI-phase: normalized semi-log constant head analysis
- HIS-phase: Agarwal plot

The comments for the analytical analysis of the test can be summarized as follows:

- The wellbore storage was estimated based on the early time measurements of the PW- and the PI-phase (2.3 – 2.7E-9 m^3/Pa). The values show good consistency with the theoretical value of 1.7E-9 m^3/Pa.
- The reasons and the circumstances leading to different estimates of the formation parameters beween different phases are not discussed, i.e. changes of the radius of influence, changes of the skin or a transmissivity normalized plot
- The SWS-phase is not used in the analysis without any comment
- The correct unit of the wellbore storage constant C is m^3/Pa.

Numerical Analysis (“nSights Analysis”)

The numerical analysis consists of two steps:

- A diagnostic step of each individual phase (like the analytical analysis).
- Simulation of the entire test sequence.

A summary and some comments to this section:

- The first step of the numerical analysis completes the analytical analysis by log-log diagnostics of the PSR-phase, SWS-phase and HIS-phase and Ramey-plots of the PW-phase, SW-phase and PI-phase and Horner-plots of the SWS-phase and HIS-phase.
- The first step also provides a discussion of the flow model and the estimation of the parameter ranges for each individual test phase by taking into account the borehole his-

tory. However, the analysis procedure is not explained (prescribed measured pressure prior to the test sequence analysed?). The use of the specific storage as fitting parameter doesn't lead to reasonable results (often very high specific storage values 1E-4 1/m) as the permeability is the dominating parameter (see Figure 21).

- Two flow models are used to match the entire test sequence: Homogeneous model and composite model with an infinite lateral extent of the outer boundary. The test phases used by the matching algorithm are not provided.
- The sensitivities of the fitting parameters are presented for both flow models. However the definition of the sensitivity coefficients is missing.
- The results of the numerical analysis focus on the homogeneous flow model presented in the table "Summary of Test Data". However, the match of the parameters of the composite flow model is in general better (compare Figure 20 and 23). The results are only presented in the numerical analysis chapter and should be added to the table "Summary of Test Data".
- The figures 21 – 24 are not represented in the table "Summary of Test Data".

5. Conclusions

The test OFTR-i1 was successful in collecting good data which allows a reliable identification of the flow model and an estimation of the formation parameters. The results issued from the preliminary analysis presented in the QLR are still affected by uncertainties concerning the flow model, the test zone compressibility, the specific storage of the formation and the possible impact of skin effects.

The documentation and the analysis fullfill the standards of the QLR. However, a discussion of different aspects or existing changes between resulting formation parameter values of different phases, i.e. using a transmissivity normalized plot, are missing. The first part of the numerical analysis is addressed to finalize the analytical analysis and could be moved to the corresponding chapter. The numerical analysis mentions two flow models. In the conclusions the authors only focus on the homogeneous model even though a composite model in general leads to a better match of the entire test sequence in comparison to a homogeneous model. The reasons therefore are not discussed. The sensitivity analysis completes the numerical analysis.

Concerning the estimated formation parameter ranges, the analyses suggest some significant uncertainties with respect to the static pressure and to the storativity. However it can be considered that the provided transmissivity and hydraulic head ranges are reasonable estimates:

- The transmissivity range is 2.8E-12 - 5.1E-11 m^2/s
- The equivalent head range is 455 - 490 m asl

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M E M O R A N D U M 1 1 9 0 / 0 3 04.12.2007

To:	NAGRA Dr. B. Frieg
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Review: QLR Oftringen Test OFTR-i2 by Solexperts

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Contents

1. Test design – test implementation

The test OFTR-i2 was performed from 21/10/2007 till 22/10/2007, lasted for 31.7 hours including 7 different phases, which can be divided as follows:

- Phase 1 (INF): Packer inflation
- Phase 2 (COM): Packer compliance
- Phase 3 (PSR): Pressure recovery, enabling a preliminary estimate of the formation parameters
- Phase 4 (PI1): Direct determination of the test zone compressibility (by measuring the volume of water associated with a pressure change) for comparison with the formation response of the previous phases
- Phase 5 (SW): Estimation of the formation parameters under flowing conditions
- Phase 6 (SWS): Repeated determination of the test zone compressibility in 2nd pressure recovery sequence; comparison with the formation response of the previous phases and continued estimation of the formation parameters and the corresponding flow model.

- Phase 7 (PI2): Repeated direct determination of the test zone compressibility (by measuring the volume of water associated with a pressure change) and further check of the formation properties.

All phases are considered to be adequate for reaching the test objectives.

The middle of the interval was drilled at approximately 08:00 on October 12th 2007.

2. Hardware performance

A straddle-packer was used. Pressure and temperature were measured in the test interval as well as below the lower packer and above the upper packer (annulus). In addition the pressure was measured in the tubing above the upper packer.

The measurements were influenced by the adjacent high voltage current transformer facility (NOK). Therefore the pressure and temperature signals of the downhole triple probe were noisy throughout the whole test sequence. The slug withdrawal test phase (SW) had to be terminated caused by a water bypass between the slim-line packer and the entering of the annulus of the test tubing.

3. Completeness and consistency of the field documentation

The QLR for test OFTR-i2 includes the following documents.

Document	**Status**	**Comments**
Summary page	Provided	See below
Comments page	Provided	See below
Figures and related documents	Provided	A figure of the temperature measurement is missing.
Testing logbook	Provided	Complete
Tool Configuration	Provided	
Surface equipement	Provided	
Transducer bench test	Not provided	
Flowmeter bench test	Not provided	
Tally list	Provided	
Glossary	Provided	Complete (except “Cs-“ and “Cf-value”)

Additional comments related to the specific QLR documents are addressed below.

“Summary page”

The information provided on the front page gives an overview of the basic test conditions (“Test Interval Information”), the initial analysis assumptions (“Preliminary Information”) and a summary of the test (“Test Summary”) including the borehole history information. The test objectives are the estimation of the transmissivity, the static formation pressure and the flow model. The comments related to this section of the QLR can be summarised as follows:

- The theoretical values for Cs and Cf are given. However, the Cs- and Cf-values are not defined in the glossary (“Nomenclature”).
- In the borehole history section, the date of drilling through the midpoint of the interval should be given, not only the total duration of the history period.
- Is it correct that the specific storativity was estimated by the mud engineer?
- The names of all participants in the field test and in the analysis should be given.
- The interval position given at “QLR results” is incorrect.

“Summary of Test Data”

- Why do the given values in row “storativity” never equal the given value of 1.1E-4 as denoted in the table “Preliminary information”? The given values seem to be too high.
- The simulation of the entire test sequence was carried out using a homogeneous flow model without skin effect (see section “nSights Analysis”). However, in the summary only a homogeneous model with skin effect is mentioned.
- Wrong gravitational constant under comment C.
- The PI2-phase is presented in figure 1 and 7.

“Comments” section (“Test overview”)

The “comments” section provides pertinent information related to the activities and the observations during testing as well as a documentation of the test equipment and the pre-test information. The section especially contains the following information:

- The borehole history contains three phases: The period after drilling through the midpoint of the interval, followed by a period after the flushing of the borehole with fresh water and finally a period of geophysical logging and fluid-logging.
- The measurements of downhole pressure and temperature signals are influenced by the adjacent high voltage current transformer facility (NOK).
- The slug withdrawal (SW) test phase is influenced by a water bypass between the slimline packer and the entering of the annulus of the test tubing.
- The test interval consists of a sequence of marls with interbedded limestone layers.

- The test objectives mentioned in this section specify a further parameter (formation storativity) in comparison to those mentioned on the "Summary page". The determination of the formation storativity is not a test objective.

4. Quick look analysis

Analytical analysis

Type curve and straight-line fitting methods are applied. Effects of the borehole pressure history are not taken into account. The following methods were used:

- PI1-phase: Cooper-Bredehoeft-Papadopulos (CBP) type-curve (with and without correction of the pressure trend)
- SW-phase: no analysis
- SWS-phase: log-log analysis
- PI2-phase: CPB type-curves (with correction of the pressure trend)

The comments for the analytical analysis of the test can be summarized as follows:

- The analysis of SW was not possible as the water level rise in the annulus, between the slim tubing and the 1.9" tubing, was not measured. Hence an equivalent radius is not deducible.
- The wellbore storage was estimated based on the early time measurements of the PI1- and the PI2-phase (8.5 – 9.4E-10 m^3/Pa). The values show good consistency with the theoretical value of 1.7E-9 m^3/Pa.
- The reasons and the circumstances leading to different estimates of the formation parameters beween different phases are not discussed, i.e. changes of the radius of influence, changes of the skin or a transmissivity normalized plot
- The SWS-phase is not considered in the discussion of the flow model
- The correct unit of the wellbore storage constant C is m^3/Pa.

Numerical Analysis ("nSights Analysis")

The numerical analysis consists of two steps:

- A diagnostic step of each individual phase (like the analytical analysis).
- Simulation of the entire test sequence.

A summary and some comments to this section:

- The first step of the numerical analysis completes the analytical analysis by log-log diagnostics of the PSR- and the SWS-phase and Ramey-plots of the PI1-phase and Horner-plots of the PSR- and the SWS-phase.
- The first step also provides a discussion of the flow model and the estimation of the parameter ranges for each individual test phase by taking into account the borehole history. However, the analysis procedure is not explained.
- Two flow models are used to match the entire test sequence: Homogeneous model and composite model with an infinite lateral extent of the outer boundary. The test phases used by the matching algorithm are not provided.
- Inconsistency between the used and the described flow model: with-/without skin effect (cf. this section vs. “Summary of Test Data”)
- The sensitivities of the fitting parameters are presented for the homogeneous flow model. However the definition of the sensitivity coefficients is missing.
- The given skin radius seems to be the difference between the effective wellbore radius and the wellbore radius. However, this is not clearly defined. r_s should be documented in the nomenclature section and a value for the radius of discontinuity should be given.
- The PI2-phase is not used without any explanation.

5. Conclusions

The test OFTR-i2 was successful in collecting good data which allows a reliable identification of the flow model and an estimation of the formation parameters. Only the SW-phase could not be used caused by a water bypass between the slim-line packer and the entering of the test tubing. However, the results issued from the preliminary analysis presented in the QLR are still affected by uncertainties concerning the flow model, the test zone compressibility, the specific storage of the formation and the possible impact of skin effects.

The test objectives should be defined consistently (cf. section “Test overview” vs. “Summary of Test Data”).

The documentation and the analysis fullfill the standards of the QLR. The first part of the numerical analysis is addressed to finalize the analytical analysis and could be moved to the corresponding chapter. The numerical analysis mentions two flow models. In the conclusions the authors focus on the homogeneous model. The sensitivity analysis completes the numerical analysis.

Concerning the estimated formation parameter ranges, the analyses state some significant uncertainties with respect to the static pressure and to the storativity. The given value for the specific storativity in the section “Preliminary information” doesn’t lay in the proposed range in the section “Results and Discussion”. The given uncertainty ranges are significantly greater than in the test OFTR-i1, caused by the uncertainty of the flow rate of the SW-phase.

The provided transmissivity and hydraulic head ranges are estimated to:

- The transmissivity range is 1.2E-11 - 1.4E-09 m^2/s
- The equivalent head range is 452 - 478 m asl

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MEMORANDUM 1190/04 09.01.2008

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Review: QLR Oftringen Test OFTR-i3 by Solexperts

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Contents

1. Test design – test implementation

The test OFTR-i3 was performed from 22/10/2007 till 23/10/2007, lasted for 25.15 hours including 7 different phases, which can be divided as follows:

- Phase 1 (INF): Packer inflation
- Phase 2 (COM): Packer compliance
- Phase 3 (PSR): Pressure recovery, enabling a preliminary estimate of the formation parameters
- Phase 4 (PI1): Direct determination of the test zone compressibility (by measuring the volume of water associated with a pressure change) for comparison with the formation response of the previous phases
- Phase 5 (SW): Estimation of the formation parameters under flowing conditions
- Phase 6 (SWS): Repeated determination of the test zone compressibility in 2nd pressure recovery sequence; comparison with the formation response of the previous phases and continued estimation of the formation parameters and the corresponding flow model.

- Phase 7 (PI2): Repeated direct determination of the test zone compressibility (by measuring the volume of water associated with a pressure change) and further check of the formation properties.

All phases are considered to be adequate for reaching the test objectives.

The midpoint of the interval was drilled at approximately 21:30 on October 10th 2007.

2. Hardware performance

A straddle-packer was used. Pressure and temperature were measured in the test interval as well as below the lower packer and above the upper packer (annulus). In addition the pressure was measured in the tubing above the upper packer.

The measurements were influenced by the adjacent high voltage current transformer facility (NOK). Therefore the pressure and temperature signals of the downhole triple probe were noisy throughout the whole test sequence.

3. Completeness and consistency of the field documentation

The QLR for test OFTR-i3 includes the following documents.

Document	Status	Comments
Summary page	Provided	See below
Comments page	Provided	See below
Figures and related documents	Provided	See below
Testing logbook	Provided	Complete
Tool Configuration	Provided	
Surface equipement	Provided	
Transducer bench test	Provided	
Flowmeter bench test	Not provided	
Tally list	Provided	
Glossary	Provided	

Additional comments related to the specific QLR documents are addressed below.

“Summary page”

The information provided on the front page gives an overview of the basic test conditions (“Test Interval Information”), the initial analysis assumptions (“Preliminary Information”) and a summary of the test (“Test Summary”) including the borehole history information. The test objectives are the estimation of the transmissivity, the static formation pressure and the flow model. The comments related to this section of the QLR can be summarised as follows:

- In the borehole history section, the date of drilling through the midpoint of the interval should be given, not only the total duration of the history period.
- The total duration of the history is 281.35 hours; the time span between midpoint drilling (10/10/07, 21:30) and test start (22/10/07, 14:51)

“Summary of Test Data”

- Why do the given values in rows “storativity” and “specific storativity” never equal the given value of 1.1E-4 respectively 2.19E-6 1/m as denoted in the table “Preliminary information”?
- Figure 6 presents a log-log plot of the SWS-phase. A reference should be given in row “figures” of the SWS- phase.

“Comments” section (“Test overview”)

The “comments” section provides pertinent information related to the activities and the observations during testing as well as a documentation of the test equipment and the pre-test information. The section especially contains the following information:

- The borehole history contains three phases: The period after drilling through the midpoint of the interval, followed by a period after the flushing of the borehole with fresh water and finally a period with measured pressures (geophysical loggings, fluid-logging and previous hydraulic tests)
- The measurements of downhole pressure and temperature signals (temperature signal presented graphically only for T2) are influenced by the adjacent high voltage current transformer facility (NOK).
- The test interval consists of a sequence of marls with an interbedded carbonate layer.
- The test objectives mentioned in this section specify a further parameter (formation storativity) in comparison to those mentioned on the “Summary page”. The determination of the formation storativity is not a test objective.
- Temperature effects are neglectable for the analyses of the test phases.

4. Quick look analysis

Analytical analysis

Type curve and straight-line fitting methods are applied. Effects of the borehole pressure history are not taken into account. The following methods were used:

- PI1-phase: Cooper-Bredehoeft-Papadopulos (CBP) type-curve
- SW-phase: CBP type-curve
- SWS-phase: log-log analysis (Agarwal-plot)
- PI2-phase: CPB type-curves

The comments for the analytical analysis of the test can be summarized as follows:

- The wellbore storage was estimated based on the early time measurements of the PI1- and the PI2-phase (1.5 – 1.4E-09 m^3/Pa). The values show good consistency with the theoretical value of 1.7E-9 m^3/Pa.
- The reasons and the circumstances leading to different estimates of the formation parameters between different phases are discussed in brief, i.e. changes of the radius of influence, …
- The figure reference "figure 4" should be corrected to figure 5 (analogous for figure 5 and 6).
- Pages 7 and 8 are identical.

Numerical Analysis (“nSights Analysis”)

The numerical analysis consists of two parts:

- A diagnostic step of each individual phase (like the analytical analysis).
- The simulation of the entire test sequence.

A summary and some comments to this section:

- The first part of the numerical analysis completes the analytical analysis by Ramey-plots of the phases PI1, SW and the PI2 as well as a log-log- and Horner-plot of the SWS-phase.
- The first part also provides a short description of the flow model and an estimation of the parameter ranges for each individual test phase by taking into account the borehole history. However, the analysis procedure is not explained sufficiently. It can only be supposed that the matching was carried out for each phase individually.

- A homogeneous flow model without skin was used to match the entire test sequence. It seems that all phases were chosen for the fitting procedure and no weighting between the different phases was applied.
- No diagnostic plots are presented for the matching results of the entire test sequence. To assess the quality of the matching results such plots should be presented for the main phases of the test sequence.
- The sensitivities of the fitting parameters are presented for the homogeneous flow model. However, a definition of the sensitivity coefficients is missing.

5. Conclusions

The test OFTR-i3 was successful in collecting good data which allows a reliable identification of the flow model and an estimation of the formation parameters. The results issued from the preliminary analysis presented in the QLR are still affected by uncertainties concerning the flow model, a possible inner zone or a changing skin effect and the specific storage of the formation.

The test objectives should be defined consistently (cf. section “Test overview” vs. “Summary of Test Data”).

The documentation and the analysis fullfill the standards of the QLR. The first part of the numerical analysis is addressed to finalize the analytical analysis and could be moved to the corresponding chapter. The numerical analysis mentions a homogeneous flow model. The sensitivity analysis completes the numerical analysis. As expected, the sensitivity analysis presents a domination of the SWS-phase. This results from the greatest duration (= greatest radius of influence) of this test phase.

Concerning the estimated formation parameter ranges, the analyses state some significant uncertainties with respect to the static pressure and to the storativity. Taking into account the given geological formation, the upper limit of the given uncertainty range for the storativity seems to be too large.

The stated consistency between the fitted formation parameter values obtained form the fitting of the SWS-phase and the fitting of the whole test phases can't be interpreted as "most representative" evaluation of the formation conditions but rather source from the used fitting procedure.

The provided transmissivity and hydraulic head ranges are estimated to:

- The transmissivity range is 6.5E-11 – 3.3E-10 m^2/s
- The equivalent head range is 335 - 488 m asl

Colenco Power Engineering Ltd

M E M O R A N D U M 1 1 9 0 / 0 5 11.01.2008

To:	NAGRA Dr. B. Frieg
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Review: QLR Oftringen Test OFTR-i4 by Solexperts

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Contents

1. Test design – test implementation

The test OFTR-i4 was performed from 23/10/2007 until 24/10/2007, lasted for 19.77 hours including 7 different phases, which can be divided as follows:

- Phase 1 (INF): Packer inflation
- Phase 2 (COM): Packer compliance
- Phase 3 (PSR): Pressure recovery, to dissipate history and temperature effects and enabling a preliminary estimate of the formation parameters
- Phase 4 (PI1): Direct determination of the test zone compressibility (by measuring the volume of water associated with a pressure change) for comparison with the formation response of the previous phases
- Phase 5 (SW): Estimation of the formation parameters under flowing conditions
- Phase 6 (SWS): Repeated determination of the test zone compressibility in 2nd pressure recovery sequence; comparison with the formation response of the previous phases and continued estimation of the formation parameters and the corresponding flow model.

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- Phase 7 (PI2): Repeated direct determination of the test zone compressibility (by measuring the volume of water associated with a pressure change) and further check of the formation properties.

All phases are considered to be adequate for reaching the test objectives.

The middle of the interval was drilled approximately 17:30 on October 4th 2007.

2. Hardware performance

A straddle-packer was used. Pressure and temperature were measured in the test interval as well as below the lower packer and above the upper packer (annulus). In addition the pressure was measured in the tubing above the upper packer.

The measurements were influenced by the adjacent high voltage current transformer facility (NOK). Therefore the pressure and temperature signals of the downhole triple probe were noisy throughout the whole test sequence. The slug withdrawal test phase (SW) and the following shut-in phase (SWS) seem to be influenced by changing wellbore conditions corresponding to small changes in the packer pressure.

3. Completeness and consistency of the field documentation

The QLR for test OFTR-i4 includes the following documents.

Document	Status	Comments
Summary page	Provided	See below
Comments page	Provided	See below
Figures and related documents	Provided	See below
Testing logbook	Provided	Complete
Tool Configuration	Provided	
Surface equipement	Provided	
Transducer bench test	Provided	
Flowmeter bench test	Not provided	
Tally list	Provided	
Glossary	Provided	

Additional comments related to the specific QLR documents are addressed below. The page numbers 4 to 15 are missing

“Summary page”

The information provided on the front page gives an overview of the basic test conditions (“Test Interval Information”), the initial analysis assumptions (“Preliminary Information”) and a summary of the test (“Test Summary”) including the borehole history information. The test objectives are the estimation of the transmissivity, the static formation pressure and the flow model. The comments related to this section of the QLR can be summarised as follows:

- In the borehole history section, the date of drilling through the midpoint of the interval should be given, not only the total duration of the history period.
- A note should be added to explain the meaning of in-brackets-presented fresh water heads.

“Summary of Test Data”

- Why do the given values in row “storativity” never equal the given value of 1.1E-4 as denoted in the table “Preliminary information”?
- Wrong gravitational constant under comment C.
- The calculated fresh water head does not correspond to the formation pressure of the SW-Phase.
- Phases PI1, PI2a and PI2b are parts of Figure 1. A reference should be given in row “figures” for these phases.
- Figure 6 presents a log-log plot of the SWS-phase. The reference is wrong (column SWS instead of column SW).

“Comments” section (“Test overview”)

The “comments” section provides pertinent information related to the activities and the observations during testing as well as a documentation of the test equipment and the pre-test information. The section especially contains the following information:

- The borehole history contains three phases: The period after drilling through the midpoint of the interval, followed by a period after the flushing of the borehole with fresh water and finally a period with measured pressures (geophysical loggings, fluid-logging and previous hydraulic tests).
- The measurements of downhole pressure and temperature signals (temperature signal presented graphically only for T2) are influenced by the adjacent high voltage current transformer facility (NOK).
- The test interval consists of a sequence of marls with interbedded limestone layers.

- The test objectives mentioned in this section specify a further parameter (formation storativity) in comparison to those mentioned on the "Summary page". The determination of the formation storativity can not be a test objective.
- Temperature effects are neglectable for the analyses of the test phases.
- The test name has to be corrected to OFTR-i4.

4. Quick look analysis

Analytical analysis

Type curve and straight-line fitting methods are applied. Effects of the borehole pressure history are not taken into account. The following methods were used:

- PI1-phase: Cooper-Bredehoeft-Papadopulos (CBP) type-curve
- SW-phase: no analysis
- SWS-phase: log-log analysis
- PI2-phase: CPB type-curves

The comments for the analytical analysis of the test can be summarized as follows:

- The analysis of the SW-phase was not possible due to small changes in the packer pressure. Changing borehole conditions can also be detected using the log-log of the SWS-phase (provided in Figure 6).
- The wellbore storage was estimated based on the early time measurements of the PI1- and the PI2-phases (3.6 – 4.2E-10 m^3/Pa). In comparison with the theoretical value of 1.7E-9 m^3/Pa the value seems to be too low – very close to the water compressibility. The reasons herefore are not discussed.
- The reasons and the circumstances leading to different estimates of the formation parameters between different phases are discussed in brief.
- The durations of the SW- and SWS-phases differ from the durations given in the section "Summary of Test Data"

Numerical Analysis ("nSights Analysis")

The numerical analysis consists of two parts:

- A diagnostic step of each individual phase (like the analytical analysis).
- The simulation of the entire test sequence.

A summary and some comments to this section:

- The first part of the numerical analysis completes the analytical analysis by log-log diagnostics of the PSR- and the SWS-phase and Ramey-plots of the PI1- and PI2-phase. Horner-plots of the PSR- and the SWS-phase are also provided.
- The first part also provides a discussion of the flow model and the estimation of the parameter ranges for each individual test phase by taking into account the borehole history.
- The discussion of the log-log plots could be extended to early time effects like changing wellbore conditions (e.g. to observe in Figure 13) and maybe to possible boundary or history effects (e.g. to observe in Figure 9).
- A homogeneous flow model without skin is used to match the entire test sequence. It seems that all phases were chosen for the fitting procedure and no weighting between the different phases was applied.
- No diagnostic plots are presented for the match of the entire test sequence. They should be presented for the main sequences of a test. However, the slopes of the PSR-phase are not represented by the simulation. This seems to be affected by the choice of the fitting parameters. A better choice would be the formation pressure and hydraulic conductivity using a formation storativity fixed to the theoretical value (given as preliminary information).
- The sensitivities of the fitting parameters are presented for the homogeneous flow model. However the definition of the sensitivity coefficients is missing.
- The fitted specific storativity values for the PI1- und PI2-phase seem to be too low, caused by the fixed formation pressure and maybe a skin effect.

5. Conclusions

The test OFTR-i4 was successful in collecting good data which allows a reliable identification of the flow model and an estimation of the formation parameters. However, the results issued from the preliminary analysis presented in the QLR are still affected by uncertainties concerning the flow model, the inner and outer boundary conditions, the specific storage of the formation and the possible impact of skin effects. The ongoing interpretation should focus upon the accurate choice of the fitting parameters.

The test objectives should be defined consistently (cf. section “Test overview” vs. “Summary of Test Data”).

The documentation fullfills the standards of the QLR. The analysis is only interpretable as a basic preliminary estimation. The first part of the numerical analysis is addressed to finalize the analytical analysis and could be moved to the corresponding chapter. The numerical analysis mentions a homogeneous flow model. The sensitivity analysis completes the numerical analysis.

Concerning the estimated formation parameter ranges, the analyses state some significant uncertainties with respect to the storativity and the static formation pressure. The given value for the specific storativity in the section “Preliminary information” lies on the upper limit of the proposed range in the section “Results and Discussion” which presumably sources from the choice of the fitting parameters.

The conclusion that the sensitivity of the formation pressure is very low is correct, but it is a failure to fix the pressure in order to estimate a range of the formation storativity and conductivity. The pressure signal observed in a single well is determined by the diffusivity and the pressure. Therefore, only these two values are possible to be estimated. A range for the pressure can be estimated and either the formation conductivity or the storativity can be matched.

The test objective to determine the static formation pressure is not achieved du to the misleading choice of the fitting parameters.

The provided transmissivity range is estimated to:

- The transmissivity range is 3.8E-13 - 2.7E-11 m^2/s

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M E M O R A N D U M 1 1 9 0 / 0 6 09.01.2008

To:	NAGRA Dr. B. Frieg
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Review: QLR Oftringen Test OFTR-i5 by Solexperts

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Contents

1. Test design – test implementation

The test OFTR-i5 was performed from 24/10/2007 until 25/10/2007, lasted for 28.55 hours including 6 different phases, which can be divided as follows:

- Phase 1 (INF): Packer inflation
- Phase 2 (COM): Packer compliance
- Phase 3 (PSR): Pressure recovery, to dissipate history and temperature effects and enabling a preliminary estimate of the formation parameters
- Phase 4 (PW1): Direct determination of the test zone compressibility (by measuring the volume of water associated with a pressure change) and estimation of the formation parameters for comparison with the formation response of the previous phases
- Phase 5 (PW2): Second direct determination of the test zone compressibility (by measuring the volume of water associated with a pressure change) and estimation of the formation parameters for comparison with the formation response of the previous phases
- Phase 6 (SW): Estimation of the formation parameters under flowing conditions

All phases are considered to be adequate for reaching the test objectives.

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The middle of the interval was drilled at approximately 05:30 on October 2nd 2007.

2. Hardware performance

A straddle-packer was used. Pressure and temperature were measured in the test interval as well as below the lower packer and above the upper packer (annulus). In addition the pressure was measured in the tubing above the upper packer.

The measurements were influenced by the adjacent high voltage current transformer facility (NOK). Therefore the pressure and temperature signals of the downhole triple probe were noisy throughout the whole test sequence.

3. Completeness and consistency of the field documentation

The QLR for test OFTR-i5 includes the following documents.

Document	Status	Comments
Summary page	Provided	See below
Comments page	Provided	See below
Figures and related documents	Provided	See below
Testing logbook	Provided	Complete
Tool Configuration	Provided	
Surface equipement	Provided	
Transducer bench test	Provided	
Flowmeter bench test	Not provided	
Tally list	Provided	
Glossary	Provided	

Additional comments related to the specific QLR documents are addressed below.

In general, the term of specific storage S_s should be used (unit m^{-1}) and not storativity (dimensionless).

“Summary page”

The information provided on the front page gives an overview of the basic test conditions (“Test Interval Information”), the initial analysis assumptions (“Preliminary Information”) and a summary of the test (“Test Summary”) including the borehole history information. The test objectives are the estimation of the transmissivity, the static formation pressure and the flow model. The comments related to this section of the QLR can be summarised as follows:

- In the borehole history section, the date of drilling through the midpoint of the interval should be given, not only the total duration of the history period.
- The unit of the borehole system compressibility should be corrected to [1/Pa].

“Summary of Test Data”

- The permeability is related to the hydraulic conductivity, therefore the same footnote as for the hydraulic conductivity should be added.
- Wrong figure references in row “figures”: all numbers, apart from figure number 1, have to be increased by 1 (3-> 4, 4->5, etc.).
- According to the footnotes, the static formation pressure was only used as a matching parameter in phase SW as well as in the simulation of the entire sequence. Why was the static formation pressure set fixed in the other phases?

“Comments” section (“Test overview”)

The “comments” section provides pertinent information related to the activities and the observations during testing as well as a documentation of the test equipment and the pre-test information. The section especially contains the following information:

- The borehole history contains three phases: The period after drilling through the midpoint of the interval, followed by a period after the flushing of the borehole with fresh water and finally a period with measured pressures (geophysical loggings, fluid-logging and previous hydraulic tests).
- The measurements of downhole pressure and temperature signals (temperature signal presented graphically only for T2) are influenced by the adjacent high voltage current transformer facility (NOK).
- The test interval consists of a sequence of marls and argillaceous marls with interbedded limestone layers.
- The test objectives mentioned in this section specify a further parameter (formation storativity) in comparison to those mentioned on the “Summary page”. The determination of the formation storativity can not be a test objective.
- Wrong date: The test ends on 25th of October (as reported on the “Summary page”)

- The presented intention of the second pulse-phase (PW2) is an estimation of the wellbore compressibility. If so, what's the reason for such a long duration?

4. Quick look analysis

Analytical analysis

Type curve and straight-line fitting methods are applied. Effects of the borehole pressure history are not taken into account. The following methods were used:

- PW1-phase: Cooper-Bredehoeft-Papadopulos (CBP) type-curve
- PW2-phase: CPB type-curves
- SW-phase: no analysis

The comments for the analytical analysis of the test can be summarized as follows:

- The wellbore storage was estimated based on the early time measurements of the PW1- and the PW2-phases (6.1 – 5.2E-10 m^3/Pa). In comparison with the theoretical value of 1.7E-9 m^3/Pa the value range is at its lower physical bound.
- The correct unit of the wellbore storage constant C is m^3/Pa.
- There is no analysis of the SW-phase.
- The SW-phase followed on the PW2-phase. Therefore, the SW-phase started 12.8 hours after the start of the PW2-phase (not the PW-phase).

Numerical Analysis ("nSights Analysis")

The numerical analysis consists of two parts:

- A diagnostic step of each individual phase (like the analytical analysis).
- The simulation of the entire test sequence.

A summary and some comments to this section:

- The first part of the numerical analysis completes the analytical analysis by log-log diagnostics as well as a Horner-plot of the PSR-phase and Ramey-plots of the phases PW1, PW2 and SW.
- The first part also provides a discussion of the flow model and the estimation of the parameter ranges for each individual test phase by taking into account the borehole history. However, the analysis procedure is not explained sufficiently. It can only be supposed that the matching was carried out for each phase individually.

- In this test the second part of the analysis can only be based on the pressure measurement, As no HI-phase was performed, and no flow rates were measured.
- The fit obtained on the very short SW sequence only, does not seem to make any sense (the lower bound of the specific storage is not physical). It should be removed from the analysis.
- A homogeneous flow model without skin was used to match the entire test sequence. It seems that all phases were chosen for the fitting procedure and no weighting between the different phases was applied. However, the value for the specific storativity is close to the theoretical value though the theoretical value is outside the given uncertainty range.
- No diagnostic plots are presented for the matching of the entire test sequence. They should be presented for the main sequences of a test.
- The sensitivities of the fitting parameters are presented for the homogeneous flow model. For the sensitivity coefficients provided, the σ_r and σ_P values chosen should also be provided .

5. Conclusions

The test OFTR-i5 was successful in collecting good data which allows a reliable identification of the flow model and an estimation of the formation parameters. However, the results issued from the preliminary analysis presented in the QLR are still affected by uncertainties concerning the flow model, the specific storage of the formation and the possible impact of skin effects.

The test objectives should be defined consistently (cf. section “Test overview” vs. “Summary of Test Data”).

The documentation and the analysis fullfill the standards of the QLR. The first part of the numerical analysis is addressed to finalize the analytical analysis and could be moved to the corresponding chapter. The numerical analysis mentions a homogeneous flow model. The sensitivity analysis completes the numerical analysis.

Concerning the estimated formation parameter ranges, the analyses state some significant uncertainties with respect to the specific storage and the static pressure. The given parameter ranges seem to be affected by the interpretation procedure, in particular by the choice of the fitting parameter. The interpretation of the SW-phase is not reliable.

The pressure signal in one well is determined by the diffusivity and the pressure and only these two values are possible to estimate. Therefore a range for the pressure can be estimated and either the formation conductivity or the storativity can be matched.

The conclusion that the most representative parameter values for the formation are obtained from the matching of the entire sequence seems plausible. However, the matched value of PW2 seems far too high and calls for further investigation.

The provided parameter ranges are estimated to:

- The transmissivity range is 1.1E-13 - 7.0E-10 m^2/s
- The equivalent head range is 257 - 305 m asl

The upper transmissivity value seems to be overestimated (artefact of interpretation of SW-phase).

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MEMORANDUM 1190/07 10.01.2008

To: NAGRA
Dr. B. Frieg

From: Colenco Power Engineering AG
Dr. R. Schwarz

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J.-M. Lavanchy, Dr. J. Croisé

Review: QLR Oftringen Test OFTR-i7 by Solexperts

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Contents

1. Test design – test implementation

The test OFTR-i7 was performed on 30/10/2007, lasted for 15.67 hours including 5 different phases, which can be divided as follows:

- Phase 1 (INF): Packer inflation
- Phase 2 (COM): Packer compliance
- Phase 3 (PSR): Pressure recovery, to dissipate history and temperature effects and enabling a preliminary estimate of the formation parameters
- Phase 4 (PW): Direct determination of the test zone compressibility (by measuring the volume of water associated with a pressure change) and estimation of the formation parameters in comparison with the formation response of the previous phases
- Phase 5 (PI): Repeated direct determination of the test zone compressibility (by measuring the volume of water associated with a pressure change) and estimation of the formation parameters in comparison with the results of the previous phases.

All phases are considered to be adequate for reaching the test objectives.

The midpoint of the interval was drilled at approximately 23:46 on 12/10/2007.

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2. Hardware performance

A straddle-packer was used. Pressure and temperature were measured in the test interval as well as below the lower packer and above the upper packer (annulus). In addition the pressure was measured in the tubing above the upper packer.

The measurements were influenced by the adjacent high voltage current transformer facility (NOK). Therefore the pressure and temperature signals of the downhole triple probe were noisy throughout the whole test sequence.

3. Completeness and consistency of the field documentation

The QLR for test OFTR-i7 includes the following documents.

Document	Status	Comments
Summary page	Provided	See below
Comments page	Provided	See below
Figures and related documents	Provided	See below
Testing logbook	Provided	Complete
Tool Configuration	Provided	
Surface equipement	Provided	
Transducer bench test	Provided	
Flowmeter bench test	Not provided	
Tally list	Provided	
Glossary	Provided	

Additional comments related to the specific QLR documents are addressed below.

"Summary page"

The information provided on the front page gives an overview of the basic test conditions ("Test Interval Information"), the initial analysis assumptions ("Preliminary Information") and a summary of the test ("Test Summary") including the borehole history information. The test objectives are the estimation of the transmissivity, the static formation pressure and the flow model. The comments related to this section of the QLR can be summarised as follows:

- In the borehole history section, the date of drilling through the midpoint of the interval should be given, not only the total duration of the history period.
- The duration of the borehole history is 410.23 hours, based on the time of drilling through the midpoint of the interval at approximately 23:46 on 12/10/2007 and the start of the test at 02:00 on 30/10/2007. This should be corrected.

"Summary of Test Data"

- References to the figures should be given in row "figures".
- The permeability is calculated for all columns where the conductivity is known apart from column "Simulation entire Seq.". Why not?
- The value for Ss in column "PI[2)]" differs from the corresponding value given in section "Numerical Analysis using nSights". Which one is correct?

"Comments" section ("Test overview")

The "comments" section provides pertinent information related to the activities and the observations during testing as well as a documentation of the test equipment and the pre-test information. The section especially contains the following information:

- The borehole history contains three phases: The period after drilling through the midpoint of the interval, followed by a period after the flushing of the borehole with fresh water and finally a period with measured pressures (from geophysical loggings, fluid-logging and previous hydraulic tests).
- The measurements of downhole pressure and temperature signals (temperature signal presented graphically only for T2) are influenced by the adjacent high voltage current transformer facility (NOK).
- The test interval consists of a sequence of marls which varies between clay-marls and carbonate-marls.
- The test objectives mentioned in this section specify a further parameter (formation storativity) in comparison to those mentioned on the "Summary page". The determination of the formation storativity can not be a test objective.
- Temperature effects are negligible for the analyses of the test phases.

In general, the term specific storage S_s should be used (unit m^{-1}) and not storativity (dimensionless).

4. Quick look analysis

Analytical analysis

Type curve and straight-line fitting methods are applied. Effects of the borehole pressure history are not taken into account. The following methods were used:

- PW-phase: Cooper-Bredehoeft-Papadopulos (CBP) type-curve
- PI-phase: CPB type-curves

The comments for the analytical analysis of the test can be summarised as follows:

- The wellbore storage was estimated based on the early time measurements of the phases PW and the PI (9.2 – 8.6E-11 m^3/Pa). In comparison with the theoretical value of 3.04E-10 m^3/Pa the values islow – close to the water compressibility (6.5E-11 m^3/Pa).
- The wellbore storage calculation presented for the PI-phase is based on a volume change of 0.055 liters. The logbook gives two values, 0.049 liters and 0.055 liters (5 minutes later). Why was the early time volume change (0.049 l) not used? For a better understanding, the underlying pressure change which was used should also be provided.
- The reasons and the circumstances leading to different estimates of the formation parameters between different phases are discussed in brief.

Numerical Analysis ("nSights Analysis")

The numerical analysis consists of two parts:

- A diagnostic step of each individual phase (like the analytical analysis).
- The simulation of the entire test sequence.

A summary and some comments to this section:

- The first part of the numerical analysis completes the analytical analysis by a log-log diagnostic of the PSR-phase and Ramey-plots of the phases PW and PI.
- The first part also provides a discussion of the flow model and the estimation of the parameter ranges for each individual test phase by taking into account the borehole history.

- A homogeneous flow model without skin is used to match the entire test sequence. It seems that all phases were chosen for the fitting procedure and no weighting between the different phases was applied.
- No diagnostic plots are presented for the match of the entire test sequence. They should be presented for the main sequences of a test.
- The sensitivities of the fitting parameters are presented for the homogeneous flow model. For the sensitivity coefficients shown, the σ_r and σ_P values chosen should also be provided
- The lower range of the fitted specific storage values for the phases PW seem to be slightly below the physical range. The reason why the authors never use the preliminary information about the formation specific storage is not discussed.

5. Conclusions

The test OFTR-i7 was successful in collecting good data which allows an estimation of the formation parameters. However, the results issued from the preliminary analysis presented in the QLR are still affected by uncertainties concerning the flow model, the inner and outer boundary conditions, the specific storage of the formation and the possible impact of skin effects. The ongoing interpretation should focus upon an understanding of these results in comparison with the test sequence QFTR-i2, which includes this interval.

The test objectives should be defined consistently (cf. section “Test overview” vs. “Summary of Test Data”).

The documentation and analysis fullfill the standards of the QLR. The first part of the numerical analysis is addressed to finalize the analytical analysis and could be moved to the corresponding chapter. The numerical analysis mentions a homogeneous flow model. The sensitivity analysis completes the numerical analysis.

Concerning the estimated formation parameter ranges, the analyses state some significant uncertainties with respect to the storativity and the static formation pressure.

The provided parameter ranges are estimated to:

- The transmissivity range is 5.6E-13 - 2.9E-12 m^2/s
- The equivalent head range is 310 - 438 m asl.

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M E M O R A N D U M 1 1 9 0 / 0 8 23.01.2008

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Review: QLR Oftringen Test OFTR-i8c by Solexperts

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Contents

1. Test design – test implementation

The test OFTR-i8c was performed from 01/11/2007 until 02/11/2007, lasted for 11.25 hours including 5 different phases, which can be divided as follows:

- Phase 1 (INF): Packer inflation
- Phase 2 (COM): Packer compliance
- Phase 3 (PSR): Pressure recovery, to dissipate history and temperature effects and enabling a preliminary estimate of the formation parameters
- Phase 4 (PW): Direct determination of the test zone compressibility (by measuring the volume of water associated with a pressure change) and estimation of the formation parameters in comparison with the formation response of the previous phases
- Phase 5 (PI): Repeated direct determination of the test zone compressibility (by measuring the volume of water associated with a pressure change) and estimation of the formation parameters in comparison with the results of the previous phases.

All phases are considered to be adequate for reaching the test objectives.

The midpoint of the interval was drilled at approximately 17:00 on 12/10/2007.

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2. Hardware performance

A straddle-packer was used. Pressure and temperature were measured in the test interval as well as below the lower packer and above the upper packer (annulus). In addition the pressure was measured in the tubing above the upper packer.

The measurements were influenced by the adjacent high voltage current transformer facility (NOK). Therefore the pressure and temperature signals of the downhole triple probe were noisy throughout the whole test sequence.

3. Completeness and consistency of the field documentation

The QLR for test OFTR-i4 includes the following documents.

Document	Status	Comments
Summary page	Provided	See below
Comments page	Provided	See below
Figures and related documents	Provided	See below
Testing logbook	Provided	Complete
Tool Configuration	Provided	
Surface equipement	Provided	
Transducer bench test	Provided	
Flowmeter bench test	Not provided	
Tally list	Provided	
Glossary	Provided	

Additional comments related to the specific QLR documents are addressed below.

“Summary page”

The information provided on the front page gives an overview of the basic test conditions (“Test Interval Information”), the initial analysis assumptions (“Preliminary Information”) and a summary of the test (“Test Summary”) including the borehole history information. The test objectives are the estimation of the transmissivity, the static formation pressure and the flow model. The comments related to this section of the QLR can be summarised as follows:

- In the borehole history section, the date of drilling through the midpoint of the interval should be given, not only the total duration of the history period.
- The interval position given at “QLR results” is not correct.
- The unit of the borehole system compressibility should be corrected to [1/Pa].

“Summary of Test Data”

- References to the figures should be given in row “figures”.
- The duration of the test phases should be presented in row “duration”.
- The permeability is related to the hydraulic conductivity; therefore the same footnote as for the hydraulic conductivity should be added.
- The row of the skin values (named “s”) seems to give the values of the specific storage. Either the row has to be renamed to “S_s” or the values have to be deleted.

“Comments” section (“Test overview”)

The “comments” section provides pertinent information related to the activities and the observations during testing as well as a documentation of the test equipment and the pre-test information. The section especially contains the following information:

- The borehole history contains three phases: The period after drilling through the midpoint of the interval, followed by a period after the flushing of the borehole with fresh water and finally a period with measured pressures (geophysical loggings, fluid-logging and previous hydraulic tests).
- The measurements of downhole pressure and temperature signals (temperature signal presented graphically only for T2) are influenced by the adjacent high voltage current transformer facility (NOK).
- The test interval consists of a sequence of marls with interbedded limestone layers.
- The test objectives mentioned in this section specify a further parameter (formation storativity) in comparison to those mentioned on the “Summary page”. The determination of the formation storativity can not be a test objective.

- Temperature effects are negligible for the analyses of the test phases.

In general, the term specific storage S_s should be used (unit m^{-1}) and not storativity (dimensionless).

4. Quick look analysis

Analytical analysis

Type curve and straight-line fitting methods are applied. Effects of the borehole pressure history are not taken into account. The following methods were used:

- PW-phase: Cooper-Bredehoeft-Papadopulos (CBP) type-curve
- PI-phase: CPB type-curves

The comments for the analytical analysis of the test can be summarized as follows:

- The wellbore storage was estimated based on the early time measurements of the phases PW and PI (1.2E-10 – 6.64E-11 m^3/Pa). In comparison with the theoretical value of 3E-10 m^3/Pa the value seems to be low – very close to the water compressibility (6.5E-11 m^3/Pa). For a better understanding the pressure change which was measured and which was used for the calculation should be provided. The reasons for the very low values are not discussed.

Numerical Analysis (“nSights Analysis”)

The numerical analysis consists of two parts:

- A diagnostic step of each individual phase (like the analytical analysis).
- The simulation of the entire test sequence.

A summary and some comments to this section:

- The first part of the numerical analysis completes the analytical analysis by a log-log diagnostic as well as a Horner-plot of the PSR-phase and Ramey-plots of the PW- and PI-phases.
- The first part also provides a discussion of the flow model and the estimation of the parameter ranges for each individual test phase by taking into account the borehole history.
- The discussion of the log-log plots could be extended to “late” time maybe to possible boundary or more realistic history effects (e.g. to observe in Figure 6).

- A homogeneous flow model without skin is used to match the entire test sequence. It seems that all phases were chosen for the fitting procedure and no weighting between the different phases was applied.
- No diagnostic plots are presented for the match of the entire test sequence. They should be presented for the main sequences of a test.
- The sensitivities of the fitting parameters are presented for the homogeneous flow model. However the definition of the sensitivity coefficients is missing.
- The fitted specific storativity values for the phases PSR and PI seem to be too low, maybe caused by incorrect inner boundary conditions or possible skin effects.

5. Conclusions

The test OFTR-i8c was successful in collecting good data which allows an estimation of the formation parameters. However, the results issued from the preliminary analysis presented in the QLR are still affected by uncertainties concerning the flow model, the inner and outer boundary conditions, the specific storage of the formation and the possible impact of skin effects. The ongoing interpretation should focus upon an understanding of these results in comparison with the test sequence QFTR-i2, which includes this interval.

The test objectives should be defined consistently (cf. section “Test overview” vs. “Summary of Test Data”).

The documentation and analyses fullfill the standards of the QLR. The first part of the numerical analysis is addressed to finalize the analytical analysis and could be moved to the corresponding chapter. The numerical analysis mentions a homogeneous flow model. The sensitivity analysis completes the numerical analysis.

Concerning the estimated formation parameter ranges, the analyses state some significant uncertainties with respect to the flow model, the storativity and the static formation pressure. The range of the static formation pressure could be limited in a further analysis concerning the test sequence OFTR-i2.

The provided parameter ranges are estimated to:

- The transmissivity range is 1.4E-12 - 4.8E-12 m^2/s
- The equivalent head range is 197 - 486 m asl

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M E M O R A N D U M 1 1 9 0 / 0 9 23.01.2008

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Review: QLR Oftringen Test OFTR-i9 by Solexperts

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Contents

1. Test design – test implementation

The test OFTR-i9 was performed from 02/11/2007 until 03/11/2007, lasted for 19.08 hours including 7 different phases, which can be divided as follows:

- Phase 1 (INF): Packer inflation
- Phase 2 (COM): Packer compliance
- Phase 3 (PSR): Pressure recovery, to dissipate history and temperature effects and enabling a preliminary estimate of the formation parameters
- Phase 4 (PW): Direct determination of the test zone compressibility (by measuring the volume of water associated with a pressure change) for comparison with the formation response of the previous phases
- Phase 5 (SW): Estimation of the formation parameters under flowing conditions
- Phase 6 (SWS): Repeated determination of the test zone compressibility in 2nd pressure recovery sequence; comparison with the formation response of the previous phases and continued estimation of the formation parameters and the corresponding flow model.

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- Phase 7 (PI): Repeated direct determination of the test zone compressibility (by measuring the volume of water associated with a pressure change) and further check of the formation properties.

All phases are considered to be adequate for reaching the test objectives.

The midpoint of the interval was drilled at approximately 7:45 on 11/10/2007.

2. Hardware performance

A straddle-packer was used. Pressure and temperature were measured in the test interval as well as below the lower packer and above the upper packer (annulus). In addition the pressure was measured in the tubing above the upper packer.

The measurements were influenced by the adjacent high voltage current transformer facility (NOK). Therefore the pressure and temperature signals of the downhole triple probe were noisy throughout the whole test sequence.

3. Completeness and consistency of the field documentation

The QLR for test OFTR-i9 includes the following documents.

Document	Status	Comments
Summary page	Provided	See below
Comments page	Provided	See below
Figures and related documents	Provided	See below
Testing logbook	Provided	Complete
Tool Configuration	Provided	
Surface equipement	Provided	
Transducer bench test	Provided	
Flowmeter bench test	Not provided	
Tally list	Provided	
Glossary	Provided	

Additional comments related to the specific QLR documents are addressed below.

“Summary page”

The information provided on the front page gives an overview of the basic test conditions (“Test Interval Information”), the initial analysis assumptions (“Preliminary Information”) and a summary of the test (“Test Summary”) including the borehole history information. The test objectives are the estimation of the transmissivity, the static formation pressure and the flow model. The comments related to this section of the QLR can be summarised as follows:

- In the borehole history section, the date of drilling through the midpoint of the interval should be given, not only the total duration of the history period.
- The interval position given at “QLR results” is not correct.

“Summary of Test Data”

- The table seems to be completely wrong. The given entries in the table do neither correspond to the referred values nor to figures in the following chapters of the QLR.

“Comments” section (“Test overview”)

The “comments” section provides pertinent information related to the activities and the observations during testing as well as a documentation of the test equipment and the pre-test information. The section especially contains the following information:

- The borehole history contains three phases: The period after drilling through the midpoint of the interval, followed by a period after the flushing of the borehole with fresh water and finally a period with measured pressures (geophysical loggings, fluid-logging and previous hydraulic tests).
- The measurements of downhole pressure and temperature signals (temperature signal presented graphically only for T2) are influenced by the adjacent high voltage current transformer facility (NOK).
- The test interval consists of a sequence of marls with interbedded limestone layers.
- The test objectives mentioned in this section specify a further parameter (formation storativity) in comparison to those mentioned on the “Summary page”. The determination of the formation storativity can not be a test objective.

4. Quick look analysis

Analytical analysis

Type curve and straight-line fitting methods are applied. Effects of the borehole pressure history are not taken into account. The following methods were used:

- PW-phase: Cooper-Bredehoeft-Papadopulos (CBP) type-curve

- SW-phase: CPB type-curves
- SWS-phase: no analysis
- PI-phase: CPB type-curves

The comments for the analytical analysis of the test can be summarized as follows:

- The analysis of the SWS-phase was not possible as there was no IAFR, due to the duration of the test phase.
- The wellbore storage was estimated based on the early time measurements of the PW- and the PI-phases (8.0 and 9.6E-10 m^3/Pa). The theoretical value is 3.04E-10 m^3/Pa. For a better understanding, the underlying pressure change which was used should also be given.
- The reasons and the circumstances leading to different estimates of the formation parameters between different phases are discussed in brief.

Numerical Analysis (“nSights Analysis”)

The numerical analysis consists of two parts:

- A diagnostic step of each individual phase (like the analytical analysis).
- The simulation of the entire test sequence.

A summary and some comments to this section:

- The first part of the numerical analysis completes the analytical analysis by log-log diagnostics of the PSR- and the SWS-phase as well as a Horner-plot of the SWS-phase and Ramey-plots of the PW-, SW- and PI-phase.
- The first part also provides a discussion of the flow model and the estimation of the parameter ranges for each individual test phase by taking into account the borehole history.
- A homogeneous flow model without skin is used to match the entire test sequence. It seems that all phases were chosen for the fitting procedure and no weighting between the the different phases was applied.
- No diagnostic plots are presented for the match of the entire test sequence. They should be presented for the main sequences of a test. Remarquably, none of the slopes of the different test phases is reproduced by the simulations. This seems to be caused by the choice of the flow model, partly by the choice of the fitting parameters and by the changing temperature conditions. A better choice would be the formation pressure and the hydraulic conductivity using a formation storativity fixed to the theoretical value (given as preliminary information).

- The sensitivities of the fitting parameters are presented for the homogeneous flow model. However the definition of the sensitivity coefficients is missing.
- The fitted specific storativity values seem to be too high, may be caused by skin effects which are compensated by a higher storativity values using a homogenous model without skins. The fitted specific storativity values seem to be too high (~1E-4 1/m). This might be caused by the usage of a homogeneous flow model without a skin effect. In this case the high Ss value leads to rather high estimates of the permeability.

5. Conclusions

The test OFTR-i9 was successful in collecting good data which should allow a reliable identification of the flow model and an estimation of the formation parameters. However, the results issued from the preliminary analysis presented in the QLR are still affected by uncertainties concerning the flow model, the inner and outer boundary conditions, the specific storage of the formation and the possible impact of skin effects. The ongoing interpretation should focus upon the accurate choice of the fitting parameters.

The test objectives should be defined consistently (cf. section “Test overview” vs. “Summary of Test Data”).

Due to the completely wrong summary of test data, the documentation does not fulfill the standards of the QLR. The analysis is only interpretable as a basic preliminary estimation. The first part of the numerical analysis is addressed to finalize the analytical analysis and could be moved to the corresponding chapter. The numerical analysis mentions a homogeneous flow model. The sensitivity analysis completes the numerical analysis.

Concerning the estimated formation parameter ranges, the analyses state some significant uncertainties with respect to the storativity and the static formation pressure. The given value for the specific storativity in the section “Preliminary information” lies near by – but outside - the lower limit of the proposed range in the section “Results and Discussion” which presumably sources from the choice of the fitting parameters. In comparison with the theoretical value of the storativity (given as preliminary information) the range of the storativity seems to be unrealistic. Caused by the great impact of the storativity value on the results, the presented values of the formation parameters cannot be interpreted in terms of representing the realistic conditions.

The provided parameter ranges are strongly influenced by the misleading storativity values and have to be handled with care:

- The transmissivity range is 4.9E-11 - 2.0E-10 m^2/s
- The equivalent head range is 338 - 452 m asl

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Colenco Power Engineering Ltd

M E M O R A N D U M 1 1 9 0 / 1 0 28.01.2008

To:	NAGRA Dr. B. Frieg
From:	Colenco Power Engineering AG Dr. J. Croisé, Dr. R. Schwarz
Copy to:	Colenco Power Engineering AG J.-M. Lavanchy

Review: QLR Oftringen Test OFTR-i6d by Solexperts

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Contents

1. Test design – test implementation

The test OFTR-i6d was performed from 28/10/2007 until 29/10/2007, lasted for 28.9 hours including 11 main different phases[1], which can be divided as follows:

- Phase 1 (INF): Packer inflation
- Phase 2 (COM): Packer compliance
- Phase 3 (PSR): Pressure recovery, to dissipate history and temperature effects and enabling a preliminary estimate of the formation parameters
- Phase 4 (PW): Determination of the test zone compressibility (by measuring the volume of water associated with a pressure change)
- Phase 5 and 6 (HW-HWS): Estimation of the formation parameters under flowing and recovery conditions
- Phases 7 and 8 (DEF2 and INF2): Due to suspicion of gas in the testing interval: deflation and inflation
- Phase 9 (PSR2): Pressure recovery.

[1] Other intermediate phases see QLR

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- Phase 10 (RW2): Determination of the formation parameters and the corresponding flow model.
- Phase 11 (Sampling): Sampling from the test interval by alternate pumping scheme.

This test was performed after several attempts (i6, b and c) were performed to test this part of the borehole but had to be interrupted due to leakage at the packer seats (see logbook).

All phases are considered to be adequate for reaching the test objectives. The major handicap of this test is the invoked presence of gas in the test interval.

The midpoint of the interval was drilled at approximately 01:40 on the 27/09/2007.

2. Hardware performance

A straddle-packer was used. Pressure and temperature were measured in the test interval as well as below the lower packer and above the upper packer (annulus). In addition the pressure was measured in the tubing above the upper packer.

The measurements were influenced by the adjacent high voltage current transformer facility (NOK). Therefore the pressure and temperature signals of the downhole triple probe were noisy throughout the whole test sequence.

The functioning of the 3” pump was affected during the test, presumably due to the presence of gas.

3. Completeness and consistency of the field documentation

The QLR for test OFTR-i6d includes the following documents.

Document	Status	Comments
Summary page	Provided	See below
Comments page	Provided	See below
Figures and related documents	Provided	See below
Testing logbook	Provided	Complete
Tool Configuration	Provided	
Surface equipement	Provided	
Transducer bench test	Provided	
Flowmeter bench test	Not provided	
Tally list	Provided	
Glossary	Provided	

Additional comments related to the specific QLR documents are addressed below.

“Summary page”

The information provided on the front page gives an overview of the basic test conditions (“Test Interval Information”), the initial analysis assumptions (“Preliminary Information”) and a summary of the test (“Test Summary”) including the borehole history information. The test objectives are the estimation of the transmissivity, the static formation pressure and the flow model. Furthermore water sampling is to be performed.

The comments related to this section of the QLR can be summarised as follows:

- In the borehole history section, the date of drilling through the midpoint of the interval should be given, not only the total duration of the history period.
- In the section “QLR results”, the transmissivity and K-value reported under the row “Numerical simulation seem to be errors, they should be corrected to T=3.39E-7 and K=3.73E-8 (according to the “Summary of Test Data”).
- The unit of the borehole system compressibility should be corrected to [1/Pa] (below bloc “Test Interval Information”).
- The total pressure history is 750.45 hours (according to a test start at 08:07 of 28th of October 2007 and a drilling thought the midpoint of the interval 01:40 of 27th of September 2007).

“Summary of Test Data”

On page 3/3, the test phase should be RW2 in order to be consistent with the logbook and the comments in the section “Test overview”.

“Comments” section (“Test overview”)

The “comments” section provides pertinent information related to the activities and the observations during testing as well as a documentation of the test equipment and the pre-test information. The section especially contains the following information:

- The measurements of downhole pressure and temperature signals (temperature signal presented graphically only for T2) are influenced by the adjacent high voltage current transformer facility (NOK).
- The test interval consists of a sequence of limestones of the Geissberg Member.
- The test objectives mentioned in this section specify a further parameter (formation storativity) in comparison to those mentioned on the “Summary page”. The determination of the formation storativity can not be a test objective.

Some comments:

- Apart from the point that the flow observed at the pump stopped, more details should be given on the observation of gas, if any additional observations are available. Alternatively: Was there any equipment problem with the pump? It seems that the pump does work well as long as the drawdown in the interval is less than around 40m (i.e. pressure differential of less than 40 m see RW2).
- In general, the term specific storage S_s should be used (unit m^{-1}) and not storativity (dimensionless).

4. Quick look analysis

Analytical analysis

Type curve and straight-line fitting methods are applied. Effects of the borehole pressure history are not taken into account. The following methods were used:

- PW-phase: Cooper-Bredehoeft-Papadopulos (CBP) type-curve

The comments for the analytical analysis of the test can be summarized as follows:

- The wellbore storage coefficient of the PW-phase was calculated based on the measurements. It should be mentioned that it is very large, (1 order of magnitude higher than the gas compressibility at the given pressure level!). Furthermore it should be mentioned that the period of time during which the valve was opened was high (90s, see logbook).
- The 75 seconds are wrong (90s in the logbook).
- The correct unit of the wellbore storage coefficient is m^3/Pa.

Numerical Analysis (“nSights Analysis”)

The numerical analysis consists of two parts:

- A diagnostic step of each individual phase (like the analytical analysis but taking into account the preceding test sequences).
- The simulation of the entire test sequence.

A summary and some comments to this section:

- The first part of the numerical analysis completes the analytical analysis and provides also ranges for the parameter estimates. In general the fit obtained are poor. The test interval compressibility value used for the fits is not provided.
- The PSR2 diagnostic plot presents a “normal shape”, without indication of gas conditions in the interval. Unfortunately, the RW2 phase does not provide a clear response

for the identification of the flow model (the strange shape of the log-log diagnostic is not discussed in the QLR). The almost linear decrease of pressure during the RW2 should be explained.

- A homogeneous flow model without skin is used to match the entire test sequence. The fit obtained is highly questionable. The results of the parameter estimates are therefore to be considered with caution. The test interval compressibility value used for the fits is not provided.
- The sensitivities of the fitting parameters are presented for the homogeneous flow model. However the definition of the sensitivity coefficients is missing.

5. Conclusions

The test OFTR-i6d was successful in collecting good data. It is however not clear if they allow a reliable identification of the flow model and a precise estimate of the formation parameters. The large test interval compressibility values obtained during the initial PW phase indicated that gas might have been trapped in the interval. The authors of the QLR seem to assume that gas has affected the entire test sequence, this is not proven. Additional interpretation should focus also on flow model effects.

The documentation fulfills the standards of the QLR. The analysis is only interpretable as a basic preliminary estimation. The first part of the numerical analysis is addressed to finalize the analytical analysis and could be moved to the corresponding chapter. The numerical analysis mentions a homogeneous flow model. The sensitivity analysis completes the numerical analysis.

The provided parameter ranges are strongly influenced by non-ideal test conditions (presence of gas and potentially pump characteristics) and have to be considered as preliminary estimates:

- The provided transmissivity range is 2.1E-07 - 9.6E-06 m^2/s
- The provided equivalent head range is 417 - 477 m asl

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MEMORANDUM 1190/11 04.02.2008

To:	NAGRA Dr. B. Frieg
From:	Colenco Power Engineering AG Dr. R. Schwarz
Copy to:	Colenco Power Engineering AG Dr. J. Croisé, J.-M. Lavanchy

Review: QLR Oftringen Test OFTR-i10 by Solexperts

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Contents

1. Test design – test implementation

The test OFTR-i10 was performed from 03/11/2007 until 04/11/2007, lasted for 31.75 hours including a series of different phases[1], which can be divided as follows:

- Phase 1 (INF): Packer inflation
- Phase 2 (COM): Packer compliance
- Phase 3 (PSR): Pressure recovery, to dissipate history and temperature effects and enabling a preliminary estimate of the formation parameters
- Phase 4 (SW1 – SWS1): Estimation of the formation parameters under flowing conditions using the slim tubing and the recovery conditions
- Phase 5 (SW2 – SWS2): 2nd estimation of the formation parameters under flowing conditions without using a slim tubing and the recovery conditions
- Phase 6 (PI1): Direct determination of the test zone compressibility (by measuring the volume of water associated with a pressure change) for comparison with the formation response of the previous phases

[1] Other intermediate phases see QLR (Table 1)

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- Phase 7 (PI2): Repeated direct determination of the test zone compressibility (by measuring the volume of water associated with a pressure change) for comparison with the formation response of the previous phases
- Phase 8 (PI3): Repeated direct determination of the test zone compressibility (by measuring the volume of water associated with a pressure change) for comparison with the formation response of the previous phases
- Phase 9 (SW3 – SWS3): 3rd estimation of the formation parameters under flowing conditions and under recovery conditions
- Phase 10 (SW4 – SWS4): 4th estimation of the formation parameters under flowing conditions and under recovery conditions
- Phase 11 (SW5 – SWS5): 5th estimation of the formation parameters under flowing conditions and under recovery conditions
- Phase 12 (SW6 – SWS6): 6th estimation of the formation parameters under flowing conditions and under recovery conditions
- Phase 13 (SW7 – SWS7): 7th estimation of the formation parameters under flowing conditions and under recovery conditions
- Phase 14: A pumping phase, not used for the estimation of the formation parameters
- Phase 15: A series of air-lifts and a pressure recovery phase to increase the formation production rate in order to sample the formation water.
- Phase 16: A series of swabbing events in order to increase the formation flow rate followed by a pressure recovery phase and water sampling.

This test i10 was performed at exactly the same position as test i6. All phases are considered to be adequate for reaching the test objectives. The major handicap of this test is the possible presence of gas in the test interval. Water sampling seems to be the only objective for the execution of phases 14 to 16.

The midpoint of the interval was drilled at approximately 01:40 on 27/09/2007.

2. Hardware performance

A straddle-packer was used. Pressure and temperature were measured in the test interval as well as below the lower packer and above the upper packer (annulus). In addition, the pressure was also measured in the tubing above the upper packer.

The measurements were influenced by the adjacent high voltage current transformer facility (NOK). Therefore the pressure and temperature signals of the downhole triple probe were noisy throughout the whole test sequence.

The faulty operation of the 3" pump was presumably caused by the presence of gas or the decrease of the water level.

3. Completeness and consistency of the field documentation

The QLR for test OFTR-i10 includes the following documents.

Document	Status	Comments
Summary page	Provided	See below
Comments page	Provided	See below
Figures and related documents	Provided	See below
Testing logbook	Provided	Complete
Tool Configuration	Provided	
Surface equipement	Provided	
Transducer bench test	Provided	
Flowmeter bench test	Not provided	
Tally list	Provided	
Glossary	Provided	

Additional comments related to the specific QLR documents are addressed below.

"Summary page"

The information provided on the front page gives an overview of the basic test conditions ("Test Interval Information"), the initial analysis assumptions ("Preliminary Information") and a summary of the test ("Test Summary") including the borehole history information. The test objectives are the estimation of the transmissivity, the static formation pressure and the flow model. Furthermore water sampling is to be performed.

The comments related to this section of the QLR can be summarised as follows:

- In the borehole history section, the date of drilling through the midpoint of the interval should be given, not only the total duration of the history period.
- In the section "QLR results", the transmissivity and K-value given in row "Analytical interpretation" seem to refer to the results of the interpretation of phase SW2 (according to the "Summary of Test Data").

"Summary of Test Data"

On page 3/5, figure 19 should also be referenced for the numerical simulation of phase SW3.

“Comments” section (“Test overview”)

The “comments” section provides pertinent information related to the activities and the observations during testing as well as a documentation of the test equipment and the pre-test information. The section especially contains the following information:

- The measurements of downhole pressure and temperature signals (temperature signal presented graphically only for T2) are influenced by the adjacent high voltage current transformer facility (NOK).
- The temperature is systematically affected by the start of a slug phase.
- The test interval consists of a sequence of limestones of the Geissberg Member.
- The test objectives mentioned in this section specify a further parameter (formation storativity) in comparison to those mentioned on the “Summary page”. The determination of the formation storativity cannot be a test objective.

Some comments:

- The temperature effects observed at the beginning of all slug phases are not understood up to now.
- The interpretation of the pulse injection tests shows a trend of an increasing formation pressure. This could indicate bounded reservoir conditions or strong history effects, which however are inadequate seeing the observed transimissivity values. This should be discussed.
- The reason for omitting the pumping phase in the analysis is not discussed. The rates, if measured at all, are not presented.

4. Quick look analysis

Analytical analysis

Type curve and straight-line fitting methods are applied. Effects of the borehole pressure history are not taken into account. The following methods were used:

- SW2-phase: Cooper-Bredehoeft-Papadopulos (CBP) type-curve
- PI1-phase: CBP type-curve
- PI2-phase: CBP type-curve
- PI3-phase: CBP type-curve
- SW3-phase: CBP type-curve
- SWS5-phase: Agarwal-plot
- SW6-phase: CBP type-curve

The pressure difference observed between P4 and P2 (shown in figure 5 for the SW2 phase) are attributed to the observed gas production or de-gassing in the water column of the tubing.

The comments for the analytical analysis of the test can be summarized as follows:

- The transmissivity estimation of the SW2 phase leads to a value of 1.9E-05 m^2/s (see figure 6 and section “Summary of Test Data”)
- The log-log plot of SWS5 phase presented in figure 14 should be discussed. Only in figure 14 the possible IAFR is referred with a question mark, but used in figure 15 for a straight-line analysis.
- The discussion of the slug and slug-withdrawal phase SW6 and SWS6 refers to a pulse phase PI5 which does not exist. The given duration of 1.2 hours does not equal the time difference to PI3 and therefore is wrongly interpreted. In comparison with figure 17 the given value for the transmissivity estimation seems also to be wrong.

Numerical Analysis (“nSights Analysis”)

The numerical analysis consists of two parts:

- A diagnostic step of each individual phase (like the analytical analysis but taking into account the preceding test sequences).
- The simulation of the entire test sequence.

A summary and some comments to this section:

- The first part of the numerical analysis completes the analytical analysis and also provides ranges for the parameter estimates. In general the obtained quality of the fits is poor. The test interval compressibility value used for the fits is not provided.
- The first test phase is SW2 which could be numerically analysed. Why were the phases SW and SWS not analysed?
- Both a homogeneous flow model without skin and a composite flow model are used to match the entire test sequence. The credibility of the obtained fits is highly questionable. The results of the parameter estimates are therefore to be considered with caution.
- The sensitivities of the fitting parameters are presented for the homogeneous flow model. However the definition of the sensitivity coefficients is missing.

5. Conclusions

The test OFTR-i10 was successful in collecting good data. It is however not clear if they allow a reliable identification of the flow model and a precise estimate of the formation parameters. The large values for the test zone compressibility obtained during phase PI indicate that gas might have been trapped in the interval. The authors of the QLR seem to assume that gas has affected the entire test sequence. However this is not doubtlessly proven. An argument against this conclusion might be drawn from the evolution of the values for the test zone compressibility which decrease with each pulse phase. It is suggested that additional interpretation should also focus on flow model effects and provide an interpretation covering the whole test sequence.

The documentation fulfills the standards of the QLR. The analysis is only interpretable as a basic preliminary estimation. The first part of the numerical analysis is addressed to finalize the analytical analysis and could be moved to the corresponding chapter. The numerical analysis mentions a homogeneous flow model. The sensitivity analysis completes the numerical analysis.

The provided parameter ranges are strongly influenced by an up to now not understood flow model (presence of gas and may be boundary conditions) and have to be considered as preliminary estimates:

- The provided transmissivity range is 1.1E-06 - 4.5E-05 m^2/s
- The provided equivalent head range is 405 - 454 m asl

Appendix M

Master Testing Data Forms (MTDF)

Project / Borehole	Test	Test Start Date	Test Completion Date
Nagra / NOK EWS Oftringen	OFTR-11	20.10.07	21.10.07

Task	Subtask	Completed / Date	Signature	Checked / Date	Signature
A - Field Operation	**NAGRA and Solexperts**				
A1	Test objectives Personal communication by Nagra	B. Frieg 19.10.07	B. Frieg	—	—
A2	Pressure transducer bench test Solexperts	H.R. Fisch 19.10.07	H. Fisch	S. Reinhardt 19.10.07	S. Reinhardt
A3	Surface equipment Solexperts	H.R. Fisch 19.10.07	H. Fisch	S. Reinhardt 19.10.07	S. Reinhardt
A4	Tally list Solexperts	H.R. Fisch 19.10.07	H. Fisch	S. Reinhardt 19.10.07	S. Reinhardt
A5	Tool layout Solexperts	H.R. Fisch 19.10.07	H. Fisch	S. Reinhardt 19.10.07	S. Reinhardt
A6	On site analysis Solexperts	S. Reinhardt 21.10.07	S. Reinhardt	H.R. Fisch 21.10.07	H. Fisch
A7	Testing log book Solexperts	S. Reinhardt 21.10.07	S. Reinhardt	H.R. Fisch 21.10.07	H. Fisch
A8	Data back-up Solexperts	S. Reinhardt 21.10.07	S. Reinhardt	H.R. Fisch 21.10.07	H. Fisch
B - Quick Look Report	**Solexperts and Intera (offsite)**				
B1	Input parameters & borehole history Solexperts and Intera	H.R. Fisch 2.11.07	H. Fisch	U. Rösli 3.11.07	U. Rösli
B2	Analytical test analysis Solexperts	H.R. Fisch 14.11.07	H. Fisch	U. Rösli 14.11.07	U. Rösli
B3	Numerical analysis Solexperts and Intera	R. Senger 14.11.07	R. Senger	Tim Dale 14.11.07	Tim Dale
B4	Data back-up Solexperts	H.R. Fisch 15.11.07	H. Fisch	U. Rösli 15.11.07	U. Rösli
B5	Drafting and reporting Solexperts and Intera	H.R. Fisch 15.11.07	H. Fisch	U. Rösli 15.11.07	U. Rösli
B6	Copy sent to Nagra Solexperts	H.R. Fisch 15.11.07	H. Fisch	U. Rösli 15.11.07	U. Rösli

Project / Borehole		Test		Test Start Date	Test Completion Date
Nagra / NOK EWS Oftringen		Oftr_i1		20.10.07	21.10.07
Task	**Subtask**	**Completed / Date**	**Signature**	**Checked / Date**	**Signature**
C - QLR QC Notes	**Colenco (offsite)**				
C1	Test implementation / Colenco	R. Schwarz 20.11.07	R. Schwarz	J. Croisé 21.11.07	J. Croisé
C2	Hardware performance / Colenco	20.11.07 R. Schwarz	R. Schwarz	J. Croisé 21.11.07	J. Croisé
C3	Field documentation / Colenco	R. Schwarz 20.11.07	R. Schwarz	J. Croisé 21.11.07	J. Croisé
C4	Completeness of report / Colenco	R. Schwarz 20.11.07	R. Schwarz	J. Croisé 21.11.07	J. Croisé
C5	Review of analysis / Colenco	R. Schwarz 20.11.07	R. Schwarz	J. Croisé 21.11.07	J. Croisé
C6	Consistency of results / Colenco	R. Schwarz 20.11.07	R. Schwarz	J. Croisé 21.11.07	J. Croisé
C7	Suggestions for future analysis / Colenco	R. Schwarz 20.11.07	R. Schwarz	J. Croisé 21.11.07	J. Croisé
D - Incorporate QC comments / Re-issue QLR as Revision 1	**Solexperts (offsite)**				
D1	Incorporate QC comments / Solexperts	H. Fisch 6.3.08	H. Fisch	U. Rösli 06.03.08	U. Rösli
D2	Re-issue QLR as Revision 1 / Solexperts	H. Fisch 6.3.08	H. Fisch	U. Rösli 06.03.08	U. Rösli
E- QLR accepted / Test classification	**Nagra**				
E1	QLR accepted / Nagra	B. Frieg 14.8.08	B. Frieg		
E2	Test classification / Nagra	B. Frieg 14.3.08	B. Frieg		
	Level of interpretation (circle one)	Standard Interpretation		Detailed Interpretation	

Project / Borehole	Test	Test Start Date	Test Completion Date
Nagra / NOK EWS Oftringen	OFTR-11	20.10.07	21.10.07

Task	Subtask	Completed Date	Signature	Checked Date	Signature
F - Additional Interpretation (off site)	**Nagra + Solexperts + Intera**				
F1	Additional analyses required Nagra	B. Frieg 14/3/08	B. Frieg	–	
	Circle one	YES		NO	
	Type (Circle one)	Standard Minus	Standard	Standart Plus	Detailed
F2	Select input parameters & check detailed borehole history Solexperts/Intera	H. Fisch 27.06.08	H. Fisch	R. Senger 30.06.08	R. Senger
F3	Additional numerical analysis Solexperts/Intera	H. Fisch	H. Fisch	R. Senger 30.06.08	R. Senger
F4	Sensitivity analysis Solexperts/Intera	H. Fisch 27.06.08	H. Fisch	R. Senger 30.06.08	R. Senger
F5	Residual analysis Solexperts/Intera	H. Fisch 02.07.08	H. Fisch	R. Senger 30.06.08	R. Senger
F6	Perturbation analysis Solexperts/Intera				
F7	Influence of non-fitting parameters Solexperts/Intera				
F8	Check for alternative flow models Solexperts/Intera	H. Fisch 04.07.08	H. Fisch	R. Senger 30.06.08	R. Senger
F9	Document analysis in NAB 08-15, Chapter ....8.... Solexperts	H. Fisch 10.07.08	H. Fisch	U. Rösli 10.07.08	U. Rösli
F10	Send report to Nagra Solexperts	H. Fisch 04.08.08	H. Fisch	U. Rösli 10.07.08	U. Rösli
G - NAB Report Review	**Colenco + Nagra**				
G1	External review of standard or detailed analysis (see Appendix L) Colenco	26.08.08 R. Schwarz	R. Schwarz	J. Croisé 25.08.08	J. Croisé
G2	NAGRA review Nagra	B. Frieg 8/9/08	B. Frieg		
H - Address Review Comments	**Solexperts/Intera**				
H1	Incorporate Review Comments Solexperts/Intera	H. Fisch 28.10.08	H. Fisch	U. Rösli 28.10.08	U. Rösli
H2	Data back-up Solexperts/Intera	H. Fisch 28.10.08	H. Fisch	U. Rösli 28.10.08	U. Rösli
H3	Copy sent to Nagra Solexperts	H. Fisch 28.10.08	H. Fisch	U. Rösli 28.10.08	U. Rösli
I - Report approved and accepted	**Nagra**	B. Frieg 30/10/08	B. Frieg		

Project / Borehole		Test		Test Start Date	Test Completion Date
Nagra / NOK EWS Oftringen		OFTR-i2		21.10.07	22.10.07
Task	**Subtask**	**Completed Date**	**Signature**	**Checked Date**	**Signature**
A - Field Operation	**NAGRA and Solexperts**				
A1	Test objectives Personal communication by Nagra	B. Frieg 20.10.07	B. Frieg	—	
A2	Pressure transducer bench test Solexperts	H. FISCH 19.10.07	H. Fisch	S. Reinhardt 19.10.07	S. Reinhardt
A3	Surface equipment Solexperts	S. Reinhardt 21.10.07	S. Reinhardt	H. FISCH 21.10.07	H. Fisch
A4	Tally list Solexperts	S. Reinhardt 21.10.07	S. Reinhardt	H. FISCH 21.10.07	H. Fisch
A5	Tool layout Solexperts	S. Reinhardt 21.10.07	S. Reinhardt	H. FISCH 21.10.07	H. Fisch
A6	On site analysis Solexperts	H. FISCH 22.10.07	H. Fisch	S. Reinhardt 22.10.07	S. Reinhardt
A7	Testing log book Solexperts	H. FISCH 22.10.07	H. Fisch	S. Reinhardt 22.10.07	S. Reinhardt
A8	Data back-up Solexperts	H. FISCH 22.10.07	H. Fisch	S. Reinhardt 22.10.07	S. Reinhardt
B - Quick Look Report	**Solexperts and Intera (offsite)**				
B1	Input parameters & borehole history Solexperts and Intera	H. FISCH 2.11.07	H. Fisch	U. Rösli 3.11.07	U. Rösli
B2	Analytical test analysis Solexperts	H. FISCH 19.11.07	H. Fisch	U. Rösli 19.11.07	U. Rösli
B3	Numerical analysis Solexperts and Intera	T. DALE 8.11.07	Tim Dale	R. Senger 18.11.07	R. Senger
B4	Data back-up Solexperts	H. FISCH 21.11.07	H. Fisch	U. Rösli 21.11.07	U. Rösli
B5	Drafting and reporting Solexperts and Intera	H. FISCH 21.11.07	H. Fisch	U. Rösli 21.11.07	U. Rösli
B6	Copy sent to Nagra Solexperts	H. FISCH 21.11.07	H. Fisch	U. Rösli 21.11.07	U. Rösli

Project / Borehole		Test		Test Start Date	Test Completion Date
Nagra / NOK EWS Oftringen		OFTR-12		21.10.07	22.10.07
Task	**Subtask**	**Completed Date**	**Signature**	**Checked Date**	**Signature**
C - QLR QC Notes	**Colenco (offsite)**				
C1	Test implementation Colenco	R. Schwarz 03.12.07	R. Schwarz	J. Croisé 04.12.07	J. Croisé
C2	Hardware performance Colenco	R. Schwarz 03.12.07	R. Schwarz	J. Croisé 04.12.07	J. Croisé
C3	Field documentation Colenco	R. Schwarz 03.12.07	R. Schwarz	J. Croisé 04.12.07	J. Croisé
C4	Completeness of report Colenco	R. Schwarz 03.12.07	R. Schwarz	J. Croisé 04.12.07	J. Croisé
C5	Review of analysis Colenco	R. Schwarz 03.12.07	R. Schwarz	J. Croisé 04.12.07	J. Croisé
C6	Consistency of results Colenco	R. Schwarz 03.12.07	R. Schwarz	J. Croisé 04.12.07	J. Croisé
C7	Suggestions for future analysis Colenco	R. Schwarz 03.12.07	R. Schwarz	J. Croisé 04.12.07	J. Croisé
D - Incorporate QC comments / Re-issue QLR as Revision 1	**Solexperts (offsite)**				
D1	Incorporate QC comments Solexperts	H. Fisch 08.03.08	H. Fisch	U. Rösli 08.03.08	U. Rösli
D2	Re-issue QLR as Revision 1 Solexperts	H. Fisch 08.03.08	H. Fisch	U. Rösli 08.03.08	U. Rösli
E- QLR accepted / Test classification	**Nagra**				
E1	QLR accepted Nagra	B. Frieg 14/3/08	B. Frieg		
E2	Test classification Nagra	B. Frieg 14/3/08	B. Frieg		
	Level of interpretation (circle one)	**Standard Interpretation**		**Detailed Interpretation**	

Project / Borehole	Test	Test Start Date	Test Completion Date
Nagra / NOK EWS Oftringen	OFTR-12	21.10.07	22.10.07

Task	Subtask	Completed Date	Signature	Checked Date	Signature
F - Additional Interpretation (off site)	**Nagra + Solexperts + Intera**				
F1	Additional analyses required Nagra	B. Frieg 14.3.08	B. Frieg		
	Circle one	YES		NO	
	Type (Circle one)	Standard Minus	Standard	Standart Plus	Detailed
F2	Select input parameters & check detailed borehole history Solexperts/Intera	T. Dale 27.05.08	Tim Dale	R. Senger 30.05.08	R. Senger
F3	Additional numerical analysis Solexperts/Intera	T. Dale 27.05.08	Tim Dale	R. Senger 30.05.08	R. Senger
F4	Sensitivity analysis Solexperts/Intera	T. Dale 27.05.08	Tim Dale	R. Senger 30.05.08	R. Senger
F5	Residual analysis Solexperts/Intera	T. Dale 27.05.08	Tim Dale	R. Senger 30.05.08	R. Senger
F6	Perturbation analysis Solexperts/Intera	T. Dale 27.05.08	Tim Dale	R. Senger 30.05.08	R. Senger
F7	Influence of non-fitting parameters Solexperts/Intera	T. Dale 27.05.08	Tim Dale	R. Senger 30.05.08	R. Senger
F8	Check for alternative flow models Solexperts/Intera	T. Dale 02.06.08	Tim Dale	H. Fisch 08.07.08	H. Fisch
F9	Document analysis in NAB 08-15, Chapter ......9.......... Solexperts	T. Dale 02.06.08	Tim Dale	H. Fisch 08.07.08	H. Fisch
F10	Send report to Nagra Solexperts	H. Fisch 04.08.08	H. Fisch	U. Rösli 04.08.08	U. Rösli
G - NAB Report Review	**Colenco + Nagra**				
G1	External review of standard or detailed analysis (see Appendix L) Colenco	27.08.08 R. Schwarz	R. Schwarz	J. Croisé 28.08.08	J. Croisé
G2	NAGRA review Nagra	B. Frieg 16/9/08	B. Frieg		
H - Address Review Comments	**Solexperts/Intera**				
H1	Incorporate Review Comments Solexperts/Intera	H. Fisch 28.10.08	H. Fisch	U. Rösli 28.10.08	U. Rösli
H2	Data back-up Solexperts/Intera	H. Fisch 28.10.08	H. Fisch	U. Rösli 28.10.08	U. Rösli
H3	Copy sent to Nagra Solexperts	H. Fisch 28.10.08	H. Fisch	U. Rösli 28.10.08	U. Rösli
I - Report approved and accepted	**Nagra**	B. Frieg 30.10.08	B. Frieg		

Project / Borehole		Test		Test Start Date	Test Completion Date
Nagra / NOK EWS Oftringen		OFTR-13		22.10.07	23.10.07
Task	**Subtask**	**Completed Date**	**Signature**	**Checked Date**	**Signature**
A - Field Operation NAGRA and Solexperts					
A1	Test objectives Personal communication by Nagra	B. Frieg 22/10/07	B. Frieg		
A2	Pressure transducer bench test Solexperts	H. Fisch 19.10.07	H. Fisch	S. Reinhardt 19.10.07	S. Reinhardt
A3	Surface equipment Solexperts	S. Reinhardt 22.10.07	S. Reinhardt	H. Fisch 22.10.07	H. Fisch
A4	Tally list Solexperts	S. Reinhardt 22.10.07	S. Reinhardt	H. Fisch 22.10.07	H. Fisch
A5	Tool layout Solexperts	S. Reinhardt 22.10.07	S. Reinhardt	H. Fisch 22.10.07	H. Fisch
A6	On site analysis Solexperts	S. Reinhardt 23.10.07	S. Reinhardt	H. Fisch 23.10.07	H. Fisch
A7	Testing log book Solexperts	S. Reinhardt 23.10.07	S. Reinhardt	H. Fisch 23.10.07	H. Fisch
A8	Data back-up Solexperts	S. Reinhardt 23.10.07	S. Reinhardt	H. Fisch 23.10.07	H. Fisch
B - Quick Look Report Solexperts and Intera (offsite)					
B1	Input parameters & borehole history Solexperts and Intera	H. Fisch 2.11.07	H. Fisch	T. Thiel 30.11.07	D. Thiel
B2	Analytical test analysis Solexperts	D. Thiel 30.11.07	D. Thiel	H. Fisch 16.12.07	H. Fisch
B3	Numerical analysis Solexperts and Intera	T. Thiel 4.12.07	D. Thiel	H. Fisch 18.12.07	H. Fisch
B4	Data back-up Solexperts	T. Thiel 18.12.07	D. Thiel	H. Fisch 18.12.07	H. Fisch
B5	Drafting and reporting Solexperts and Intera	T. Thiel 4.12.07	D. Thiel	H. Fisch 18.12.07	H. Fisch
B6	Copy sent to Nagra Solexperts	H. Fisch 18.12.07	H. Fisch	T. Thiel 18.12.07	D. Thiel

Project / Borehole		Test		Test Start Date	Test Completion Date
Nagra / NOK EWS Oftringen		Oftr-i3		22.10.07	23.10.07
Task	**Subtask**	**Completed Date**	**Signature**	**Checked Date**	**Signature**
C - QLR QC Notes Colenco (offsite)					
C1	Test implementation Colenco	R. Schwarz 07.01.08	R. Schwarz	J. Croisé 08.01.08	J Croisé
C2	Hardware performance Colenco	07.01.08 R. Schwarz	R. Schwarz	J. Croisé 08.01.08	J Croisé
C3	Field documentation Colenco	07.01.08 R. Schwarz	R. Schwarz	J. Croisé 08.01.08	J Croisé
C4	Completeness of report Colenco	R. Schwarz 07.01.08	R. Schwarz	J. Croisé 08.01.08	J Croisé
C5	Review of analysis Colenco	R. Schwarz 07.01.08	R. Schwarz	J. Croisé 08.01.08	J Croisé
C6	Consistency of results Colenco	R. Schwarz 07.01.08	R. Schwarz	J. Croisé 08.01.08	J Croisé
C7	Suggestions for future analysis Colenco	R. Schwarz 07.01.08	R. Schwarz	J. Croisé 08.01.08	J Croisé
D - Incorporate QC comments / Re-issue QLR as Revision 1 Solexperts (offsite)					
D1	Incorporate QC comments Solexperts	H. Fisch 08.02.08	H. Fisch	U. Rösli 08.02.08	U. Rösli
D2	Re-issue QLR as Revision 1 Solexperts	H. Fisch 08.02.08	H. Fisch	U. Rösli 08.02.08	U. Rösli
E- QLR accepted / Test classification Nagra					
E1	QLR accepted Nagra	B. Frieg 7/8/08	B. F		
E2	Test classification Nagra	B. Frieg 14.3.08	B. F		
	Level of interpretation (circle one)	Standard Interpretation		Detailed Interpretation	

Project / Borehole		Test		Test Start Date	Test Completion Date
Nagra / NOK EWS Oftringen		OFTR-i3		22.10.07	23.10.07
Task	**Subtask**	**Completed Date**	**Signature**	**Checked Date**	**Signature**
F - Additional Interpretation (off site)	**Nagra + Solexperts + Intera**				
F1	Additional analyses required Nagra	B. Frieg 14.3.08	B. F.		
	Circle one	YES		NO	
	Type (Circle one)	Standard Minus	Standard	Standart Plus	Detailed
F2	Select input parameters & check detailed borehole history Solexperts/Intera	R. Senger 30.04.08	R. Senger	H. Fisch 07.07.08	H. Fisch
F3	Additional numerical analysis Solexperts/Intera	R. Senger 30.04.08	R. Senger	H. Fisch 07.07.08	H. Fisch
F4	Sensitivity analysis Solexperts/Intera	R. Senger 30.04.08	R. Senger	H. Fisch 07.07.08	H. Fisch
F5	Residual analysis Solexperts/Intera	R. Senger 30.04.08	R. Senger	H. Fisch 07.07.08	H. Fisch
F6	Perturbation analysis Solexperts/Intera	R. Senger 30.04.08	R. Senger	H. Fisch 07.07.08	H. Fisch
F7	Influence of non-fitting parameters Solexperts/Intera	R. Senger 30.04.08	R. Senger	H. Fisch 07.07.08	H. Fisch
F8	Check for alternative flow models Solexperts/Intera	R. Senger 30.04.08	R. Senger	H. Fisch 07.07.08	H. Fisch
F9	Document analysis in NAB 08-15, Chapter 10 Solexperts	R. Senger 30.04.08	R. Senger	H. Fisch 07.07.08	H. Fisch
F10	Send report to Nagra Solexperts	H. Fisch 04.08.08	H. Fisch	U. Rösli 04.08.08	U. Rösli
G - NAB Report Review	**Colenco + Nagra**				
G1	External review of standard or detailed analysis (see Appendix L) Colenco	23.08.08 R. Schwarz	R. Schwarz	J. Croisé 24.08.08	J. Croisé
G2	NAGRA review Nagra	28.8.08 B. Frieg	B. F.		
H - Address Review Comments	**Solexperts/Intera**				
H1	Incorporate Review Comments Solexperts/Intera	H. Fisch 28.10.08	H. Fisch	U. Rösli 28.10.08	U. Rösli
H2	Data back-up Solexperts/Intera	H. Fisch 28.10.08	H. Fisch	U. Rösli 28.10.08	U. Rösli
H3	Copy sent to Nagra Solexperts	H. Fisch 28.10.08	H. Fisch	U. Rösli 28.10.08	U. Rösli
I - Report approved and accepted	**Nagra**	B. Frieg 30/10/08	B. F.		

Project / Borehole		Test		Test Start Date	Test Completion Date
Nagra / NOK EWS Oftringen		OFTR-i4		23.10.07	24.10.07
Task	**Subtask**	**Completed Date**	**Signature**	**Checked Date**	**Signature**
A - Field Operation NAGRA and Solexperts					
A1	Test objectives Personal communication by Nagra	B. Frieg 23/10/07	B. Frieg	–	
A2	Pressure transducer bench test Solexperts	H. Fisch 19.10.07	H. Fisch	S. Reinhardt 19.10.07	S. Reinhardt
A3	Surface equipment Solexperts	H. Fisch 23.10.07	H. Fisch	S. Reinhardt 23.10.07	S. Reinhardt
A4	Tally list Solexperts	H. Fisch 23.10.07	H. Fisch	S. Reinhardt 23.10.07	S. Reinhardt
A5	Tool layout Solexperts	H. Fisch 23.10.07	H. Fisch	S. Reinhardt 23.10.07	S. Reinhardt
A6	On site analysis Solexperts	S. Reinhardt 23.10.07	S. Reinhardt	H. Fisch 24.10.07	H. Fisch
A7	Testing log book Solexperts	S. Reinhardt 24.10.07	S. Reinhardt	H. Fisch 24.10.07	H. Fisch
A8	Data back-up Solexperts	S. Reinhardt 24.10.07	S. Reinhardt	H. Fisch 24.10.07	H. Fisch
B - Quick Look Report Solexperts and Intera (offsite)					
B1	Input parameters & borehole history Solexperts and Intera	H. Fisch 2.11.07	H. Fisch	U. Rösli 06.12.07	U. Rösli
B2	Analytical test analysis Solexperts	U. Rösli 06.12.07	U. Rösli	H. Fisch 17.12.07	H. Fisch
B3	Numerical analysis Solexperts and Intera	U. Rösli 07.12.07	U. Rösli	H. Fisch 17.12.07	H. Fisch
B4	Data back-up Solexperts	U. Rösli 14.12.07	U. Rösli	H. Fisch 17.12.07	H. Fisch
B5	Drafting and reporting Solexperts and Intera	14.12.07 U. Rösli	U. Rösli	17.12.07 H. Fisch	H. Fisch
B6	Copy sent to Nagra Solexperts	17.12.07 H. Fisch	H. Fisch	17.12.07 U. Rösli	U. Rösli

Project / Borehole		Test		Test Start Date	Test Completion Date
Nagra / NOK EWS Oftringen		Oftr-i4		23.10.07	24.10.07
Task	**Subtask**	**Completed Date**	**Signature**	**Checked Date**	**Signature**
C - QLR QC Notes Colenco (offsite)					
C1	Test implementation Colenco	R. Schwarz 09.01.08	R. Schwarz	J. Croisé 10.01.08	J Croisé
C2	Hardware performance Colenco	R. Schwarz 09.01.08	R. Schwarz	J. Croisé 10.01.08	J Croisé
C3	Field documentation Colenco	R. Schwarz 09.01.08	R. Schwarz	J. Croisé 10.01.08	J Croisé
C4	Completeness of report Colenco	R. Schwarz 09.01.08	R. Schwarz	J. Croisé 10.01.08	J Croisé
C5	Review of analysis Colenco	R. Schwarz 09.01.08	R. Schwarz	J. Croisé 10.01.08	J Croisé
C6	Consistency of results Colenco	R. Schwarz 09.01.08	R. Schwarz	J. Croisé 10.01.08	J Croisé
C7	Suggestions for future analysis Colenco	R. Schwarz 09.01.08	R. Schwarz	J. Croisé 10.01.08	J Croisé
D - Incorporate QC comments / Re-issue QLR as Revision 1 Solexperts (offsite)					
D1	Incorporate QC comments Solexperts	U. Rösli 31.01.08	U. Rösli	H. Fisch 31.01.08	H. Fisch
D2	Re-issue QLR as Revision 1 Solexperts	U. Rösli 31.01.08	U. Rösli	H. Fisch 31.01.08	H. Fisch
E- QLR accepted / Test classification Nagra					
E1	QLR accepted Nagra	B. Frieg 28/8/08	B. F		
E2	Test classification Nagra	B. Frieg 14/3/08	B. F		
	Level of interpretation (circle one)	**Standard Interpretation**		**Detailed Interpretation**	

Project / Borehole	Test	Test Start Date	Test Completion Date
Nagra / NOK EWS Oftringen	OFTR-i4	23.10.07	24.10.07

Task	Subtask	Completed Date	Signature	Checked Date	Signature
F - Additional Interpretation (off site) Nagra + Solexperts + Intera					
F1	Additional analyses required — Nagra	B. Frieg 14/3/08	B. F.	–	
	Circle one	YES		NO	
	Type (Circle one)	Standard Minus	Standard	Standart Plus	Detailed
F2	Select input parameters & check detailed borehole history — Solexperts/Intera	H. Fisch 10.07.08	H. Fisch	R. Senger 20.07.08	R. Senger
F3	Additional numerical analysis — Solexperts/Intera	H. Fisch 10.07.08	H. Fisch	R. Senger 20.07.08	R. Senger
F4	Sensitivity analysis — Solexperts/Intera	H. Fisch 11.07.08	H. Fisch	R. Senger 20.07.08	R. Senger
F5	Residual analysis — Solexperts/Intera	H. Fisch 11.07.08	H. Fisch	R. Senger 20.07.08	R. Senger
F6	Perturbation analysis — Solexperts/Intera	H. Fisch 13.07.08	H. Fisch	R. Senger 20.07.08	R. Senger
F7	Influence of non-fitting parameters — Solexperts/Intera	H. Fisch 14.07.08	H. Fisch	R. Senger 20.07.08	R. Senger
F8	Check for alternative flow models — Solexperts/Intera	H. Fisch 15.07.08	H. Fisch	R. Senger 20.07.08	R. Senger
F9	Document analysis in NAB 08-15, Chapter ...11........ — Solexperts	H. Fisch 19.07.08	H. Fisch	R. Senger 20.07.08	R. Senger
F10	Send report to Nagra — Solexperts	H. Fisch 04.08.08	H. Fisch	U. Rösli 04.08.08	U. Rösli
G - NAB Report Review Colenco + Nagra					
G1	External review of standard or detailed analysis (see Appendix L) — Colenco	R. Schwarz 22.08.08	R. Schwarz	J. Croisé 23.08.08	J. Croisé
G2	NAGRA review — Nagra	B. Frieg 28/8/08	B. F.	–	
H - Address Review Comments Solexperts/Intera					
H1	Incorporate Review Comments — Solexperts/Intera	H. Fisch 28.10.08	H. Fisch	U. Rösli 28.10.08	U. Rösli
H2	Data back-up — Solexperts/Intera	H. Fisch 28.10.08	H. Fisch	U. Rösli 28.10.08	U. Rösli
H3	Copy sent to Nagra — Solexperts	H. Fisch 28.10.08	H. Fisch	U. Rösli 28.10.08	U. Rösli
I - Report approved and accepted — Nagra		B. Frieg 30/10/08	B. F.	–	

Project / Borehole		Test		Test Start Date	Test Completion Date
Nagra / NOK EWS Oftringen		OFTR-i5		24.10.07	25.10.07
Task	**Subtask**	**Completed Date**	**Signature**	**Checked Date**	**Signature**
A - Field Operation	**NAGRA and Solexperts**				
A1	Test objectives Personal communication by Nagra	B. Frieg 24.10.07	B. F.		
A2	Pressure transducer bench test Solexperts	H.R. Fisch 19.10.07	H. Fisch	Hager 19.10.07	Hag
A3	Surface equipment Solexperts	H.R. Fisch 19.10.07	H. Fisch	Hager 19.10.07	Hag
A4	Tally list Solexperts	H.R. Fisch 24.10.07	H. Fisch	Hager 24.10.07	Hag
A5	Tool layout Solexperts	H.R. Fisch 24.10.07	H. Fisch	Hager 24.10.07	Hag
A6	On site analysis Solexperts	Hager 25.10.07	Hag	S. Reinhardt 25.10.07	S. Reinhardt
A7	Testing log book Solexperts	Hager 25.10.07	Hag	S. Reinhardt 25.10.07	S. Reinhardt
A8	Data back-up Solexperts	Hager 25.10.07	Hag	S. Reinhardt 25.10.07	S. Reinhardt
B - Quick Look Report	**Solexperts and Intera (offsite)**				
B1	Input parameters & borehole history Solexperts and Intera	H.R. Fisch 2.11.07	H. Fisch	U. Rösli 20.12.07	U. Rösli
B2	Analytical test analysis Solexperts	U. Rösli 20.12.07	U. Rösli	H.R. Fisch 21.12.07	H. Fisch
B3	Numerical analysis Solexperts and Intera	U. Rösli 20.12.07	U. Rösli	H.R. Fisch 21.12.07	H. Fisch
B4	Data back-up Solexperts	U. Rösli 20.12.07	U. Rösli	H.R. Fisch 21.12.07	H. Fisch
B5	Drafting and reporting Solexperts and Intera	U. Rösli 20.12.07	U. Rösli	H.R. Fisch 21.12.07	H. Fisch
B6	Copy sent to Nagra Solexperts	H.R. Fisch 21.12.07	H. Fisch	U. Rösli 21.12.07	U. Rösli

Project / Borehole		Test		Test Start Date	Test Completion Date
Nagra / NOK EWS Oftringen		Oftr-i5		24.10.07	25.10.07
Task	**Subtask**	**Completed Date**	**Signature**	**Checked Date**	**Signature**
C - QLR QC Notes	**Colenco (offsite)**				
C1	Test implementation — Colenco	R. Schwarz 09.01.08	R. Schwarz	J. Croisé 10.01.08	J. Croisé
C2	Hardware performance — Colenco	R. Schwarz 09.01.08	R. Schwarz	J. Croisé 10.01.08	J. Croisé
C3	Field documentation — Colenco	R. Schwarz 09.01.08	R. Schwarz	J. Croisé 10.01.08	J. Croisé
C4	Completeness of report — Colenco	R. Schwarz 09.01.08	R. Schwarz	J. Croisé 10.01.08	J. Croisé
C5	Review of analysis — Colenco	R. Schwarz 09.01.08	R. Schwarz	J. Croisé 10.01.08	J. Croisé
C6	Consistency of results — Colenco	R. Schwarz 09.01.08	R. Schwarz	J. Croisé 10.01.08	J. Croisé
C7	Suggestions for future analysis — Colenco	R. Schwarz 09.01.08	R. Schwarz	J. Croisé 10.01.03	J. Croisé
D - Incorporate QC comments / Re-issue QLR as Revision 1	**Solexperts (offsite)**				
D1	Incorporate QC comments — Solexperts	U. Rösli 7.02.08	U. Rösli	H. Fisch 8.02.08	H. Fisch
D2	Re-issue QLR as Revision 1 — Solexperts	U. Rösli 07.02.08	U. Rösli	H. Fisch 8.02.08	H. Fisch
E- QLR accepted / Test classification	**Nagra**				
E1	QLR accepted — Nagra	B. Frieg 4.8.08	B. Frieg		
E2	Test classification — Nagra	B. Frieg 14/3/08	B. Frieg		
	Level of interpretation (circle one)	**Standard Interpretation**		**Detailed Interpretation**	

Project / Borehole		Test		Test Start Date	Test Completion Date
Nagra / NOK EWS Oftringen		OFTR-15		24.10.07	25.10.07
Task	**Subtask**	**Completed** Date	**Signature**	**Checked** Date	**Signature**
F - Additional Interpretation (off site) Nagra + Solexperts + Intera					
F1	Additional analyses required Nagra	B. Frieg 14/3/08	B. Frieg		
	Circle one	YES		NO	
	Type (Circle one)	Standard Minus	Standard	Standart Plus	Detailed
F2	Select input parameters & check detailed borehole history Solexperts/Intera	H. Fisch 19.07.08	H. Fisch	R. Senger 23.07.08	R. Senger
F3	Additional numerical analysis Solexperts/Intera	H. Fisch 21.07.08	H. Fisch	R. Senger 23.07.08	R. Senger
F4	Sensitivity analysis Solexperts/Intera	H. Fisch 21.07.08	H. Fisch	R. Senger 23.07.08	R. Senger
F5	Residual analysis Solexperts/Intera	H. Fisch 21.07.08	H. Fisch	R. Senger 28.07.08	R. Senger
F6	Perturbation analysis Solexperts/Intera	H. Fisch			
F7	Influence of ~~non fitting parameters~~ varying test zone volume Solexperts/Intera	H. Fisch 22.07.08	H. Fisch	R. Senger 23.07.08	R. Senger
F8	Check for alternative flow models Solexperts/Intera	H. Fisch			
F9	Document analysis in NAB 08-15, Chapter ...12....... Solexperts	H. Fisch 23.07.08	H. Fisch	R. Senger 23.07.08	R. Senger
F10	Send report to Nagra Solexperts	H. Fisch 04.08.08	H. Fisch	U. Rösli 04.08.08	U. Rösli
G - NAB Report Review Colenco + Nagra					
G1	External review of standard or detailed analysis (see Appendix L) Colenco	23.08.08 R. Schwarz	R. Schwarz	J. Croisé 24.08.08	J. Croisé
G2	NAGRA review Nagra	28.8.08 B. Frieg	B. Frieg		
H - Address Review Comments Solexperts/Intera					
H1	Incorporate Review Comments Solexperts/Intera	H. Fisch 28.10.08	H. Fisch	U. Rösli 28.10.08	U. Rösli
H2	Data back-up Solexperts/Intera	H. Fisch 28.10.08	H. Fisch	U. Rösli 28.10.08	U. Rösli
H3	Copy sent to Nagra Solexperts	H. Fisch 28.10.08	H. Fisch	U. Rösli 28.10.08	U. Rösli
I - Report approved and accepted Nagra		B. Frieg 30/10/08	B. Frieg		

Project / Borehole		Test		Test Start Date	Test Completion Date
Nagra / NOK EWS Oftringen		OFTR-16		28.10.07	29.10.07
Task	**Subtask**	**Completed Date**	**Signature**	**Checked Date**	**Signature**
A - Field Operation	**NAGRA and Solexperts**				
A1	Test objectives Personal communication by Nagra	B. Frieg 25/10/07	B. Frieg	—	
A2	Pressure transducer bench test Solexperts	S. Reinhardt 26.10.07	S. Reinhardt	Hager 26/10.07	Hager
A3	Surface equipment Solexperts	S. Reinhardt 28.10.07	S. Reinhardt	Hager 28/10.07	Hager
A4	Tally list Solexperts	S. Reinhardt 28.10.07	S. Reinhardt	Hager 28.10.07	Hager
A5	Tool layout Solexperts	S. Reinhardt 28.10.07	S. Reinhardt	Hager 28/10.07	Hager
A6	On site analysis Solexperts	S. Reinhardt 29.10.07	S. Reinhardt	Hager 29/10.07	Hager
A7	Testing log book Solexperts	S. Reinhardt 29.10.07	S. Reinhardt	Hager 29/10.07	Hager
A8	Data back-up Solexperts	S. Reinhardt 29.10.07	S. Reinhardt	Hager 29.10.07	Hager
B - Quick Look Report	**Solexperts and Intera (offsite)**				
B1	Input parameters & borehole history Solexperts and Intera	U. Rösli 16.01.08	U. Rösli	H. Fivel 16.1.08	H. Fivel
B2	Analytical test analysis Solexperts	U. Rösli 16.01.08	U. Rösli	K. Kontar 18.01.08	Koray Kontar
B3	Numerical analysis Solexperts and Intera	U. Rösli 18.01.08	U. Rösli	K. Kontar 18.01.08	Koray Kontar
B4	Data back-up Solexperts	U. Rösli 18.01.08	U. Rösli	K. Kontar 18.01.08	Koray Kontar
B5	Drafting and reporting Solexperts and Intera	U. Rösli 18.01.08	U. Rösli	K. Kontar 18.01.08	Koray Kontar
B6	Copy sent to Nagra Solexperts	U. Rösli 23.01.08	U. Rösli	H. Fivel 23.01.08	H. Fivel

Project / Borehole		Test		Test Start Date	Test Completion Date
Nagra / NOK EWS Oftringen		Oftr-i6		28.10.07	29.10.07
Task	**Subtask**	**Completed Date**	**Signature**	**Checked Date**	**Signature**
C - QLR QC Notes	**Colenco (offsite)**				
C1	Test implementation Colenco	R. Schwarz 08.01.08	R. Schwarz	J. Croisé 09.01.08	J. Croisé
C2	Hardware performance Colenco	R. Schwarz 08.01.08	R. Schwarz	J. Croisé 09.01.08	J. Croisé
C3	Field documentation Colenco	R. Schwarz 08.01.08	R. Schwarz	J. Croisé 09.01.08	J. Croisé
C4	Completeness of report Colenco	R. Schwarz 08.01.08	R. Schwarz	J. Croisé 09.01.08	J. Croisé
C5	Review of analysis Colenco	R. Schwarz 08.01.08	R. Schwarz	J. Croisé 09.01.08	J. Croisé
C6	Consistency of results Colenco	R. Schwarz 08.01.08	R. Schwarz	J. Croisé 09.01.08	J. Croisé
C7	Suggestions for future analysis Colenco	R. Schwarz 08.01.08	R. Schwarz	J. Croisé 09.01.08	J. Croisé
D - Incorporate QC comments / Re-issue QLR as Revision 1	**Solexperts (offsite)**				
D1	Incorporate QC comments Solexperts	U. Rösli 13.03.08	U. Rösli	H. Fisch 13.03.08	H. Fisch
D2	Re-issue QLR as Revision 1 Solexperts	U. Rösli 13.03.08	U. Rösli	H. Fisch 13.03.08	H. Fisch
E- QLR accepted / Test classification	**Nagra**				
E1	QLR accepted Nagra	B. Frieg 14/3/08	B. Frieg		
E2	Test classification Nagra	B. Frieg 14/3/08	B. Frieg		
	Level of interpretation (circle one)	~~Standard Interpretation~~		~~Detailed Interpretation~~	

Project / Borehole		Test		Test Start Date	Test Completion Date
Nagra / NOK EWS Oftringen		OFTR-i6		28.10.07	29.10.07
Task	**Subtask**	**Completed Date**	**Signature**	**Checked Date**	**Signature**
F - Additional Interpretation (off site)	**Nagra + Solexperts + Intera**				
F1	Additional analyses required Nagra	B. Frieg 14/3/08	B. Frieg		
	Circle one	YES		NO	
	Type (Circle one)	Standard Minus	Standard	Standart Plus	Detailed
F2	Select input parameters & check detailed borehole history Solexperts/Intera				
F3	Additional numerical analysis Solexperts/Intera				
F4	Sensitivity analysis Solexperts/Intera				
F5	Residual analysis Solexperts/Intera				
F6	Perturbation analysis Solexperts/Intera				
F7	Influence of non-fitting parameters Solexperts/Intera				
F8	Check for alternative flow models Solexperts/Intera				
F9	Document analysis in NAB 08-15, Chapter ....13....... Solexperts	H. Fisch 27.07.08	H. Fisch	U. Rösli 27.07.08	U. Rösli
F10	Send report to Nagra Solexperts	H. Fisch 04.08.08	H. Fisch	U. Rösli 04.08.08	U. Rösli
G - NAB Report Review	**Colenco + Nagra**				
G1	External review of standard or detailed analysis (see Appendix L) Colenco	23.08.08 R. Schwarz	R. Schwarz	J. Croisé 24.08.08	J. Croisé
G2	NAGRA review Nagra	B. Frieg 14/8/08	B. Frieg		
H - Address Review Comments	**Solexperts/Intera**				
H1	Incorporate Review Comments Solexperts/Intera	H. Fisch 28.10.08	H. Fisch	U. Rösli 28.10.08	U. Rösli
H2	Data back-up Solexperts/Intera	H. Fisch 28.10.08	H. Fisch	U. Rösli 28.10.08	U. Rösli
H3	Copy sent to Nagra Solexperts	H. Fisch 28.10.08	H. Fisch	U. Rösli 28.10.08	U. Rösli
I - Report approved and accepted	**Nagra**	B. Frieg 30/10/08	B. Frieg		

Project / Borehole		Test		Test Start Date	Test Completion Date
Nagra / NOK EWS Oftringen		OFTR-17		30.10.07	30.10.07
Task	**Subtask**	**Completed Date**	**Signature**	**Checked Date**	**Signature**
A - Field Operation	**NAGRA and Solexperts**				
A1	Test objectives Personal communication by Nagra	B. Frieg 29/10/07	B. Fr	–	
A2	Pressure transducer bench test Solexperts	S. Reinhardt 26.10.07	S. Reinhardt	J. Hayer 26.10.07	J. Hayer
A3	Surface equipment Solexperts	S. Reinhardt 29.10.07	S. Reinhardt	Hayer 29.10.07	J. Hayer
A4	Tally list Solexperts	S. Reinhardt 29.10.07	S. Reinhardt	Hayer 29.10.07	Hayer
A5	Tool layout Solexperts	S. Reinhardt 29.10.07	S. Reinhardt	Hayer 29.10.07	Hayer
A6	On site analysis Solexperts	S. Reinhardt 30.10.07	S. Reinhardt	Hayer 30.11.07	Hayer
A7	Testing log book Solexperts	S. Reinhardt 30.10.07	S. Reinhardt	Hayer 30.11.07	Hayer
A8	Data back-up Solexperts	S. Reinhardt 30.10.07	S. Reinhardt	Hayer 30.11.07	Hayer
B - Quick Look Report	**Solexperts and Intera (offsite)**				
B1	Input parameters & borehole history Solexperts and Intera	H.R. Fisch 2.11.07	H. Fisch	U. Rösli 03.11.07	U. Rösli
B2	Analytical test analysis Solexperts	TRICK 24.12.07		H.R. Fisch 28.12.07	H. Fisch
B3	Numerical analysis Solexperts and Intera	TRICK 24.12.07		H.R. Fisch 29.12.07	H. Fisch
B4	Data back-up Solexperts	TRICK 24.12.07		H.R. Fisch 29.12.07	H. Fisch
B5	Drafting and reporting Solexperts and Intera	TRICK 24.12.07		H.R. Fisch 29.12.07	H. Fisch
B6	Copy sent to Nagra Solexperts	TRICK 24.12.07		H.R. Fisch 29.12.07	H. Fisch

Project / Borehole		Test		Test Start Date	Test Completion Date
Nagra / NOK EWS Oftringen		Oftr-i7		30.10.07	30.10.07
Task	**Subtask**	**Completed Date**	**Signature**	**Checked Date**	**Signature**
C - QLR QC Notes	**Colenco (offsite)**				
C1	Test implementation Colenco	R. Schwarz 08.01.08	R. Schwarz	J. Croisé 09.01.08	J. Croisé
C2	Hardware performance Colenco	R. Schwarz 08.01.08	R. Schwarz	J. Croisé 09.01.08	J. Croisé
C3	Field documentation Colenco	R. Schwarz 08.01.08	R. Schwarz	J. Croisé 09.01.08	J. Croisé
C4	Completeness of report Colenco	R. Schwarz 08.01.08	R. Schwarz	J. Croisé 09.01.08	J. Croisé
C5	Review of analysis Colenco	R. Schwarz 08.01.08	R. Schwarz	J. Croisé 09.01.08	J. Croisé
C6	Consistency of results Colenco	R. Schwarz 08.01.08	R. Schwarz	J. Croisé 09.01.08	J. Croisé
C7	Suggestions for future analysis Colenco	R. Schwarz 08.01.08	R. Schwarz	J. Croisé 09.01.08	J. Croisé
D - Incorporate QC comments / Re-issue QLR as Revision 1	**Solexperts (offsite)**				
D1	Incorporate QC comments Solexperts	U. Rösli 27.02.08	U. Rösli	H. Fivel 27.02.08	H. Fivel
D2	Re-issue QLR as Revision 1 Solexperts	U. Rösli 27.02.08	U. Rösli	H. Fivel 27.02.08	H. Fivel
E- QLR accepted / Test classification	**Nagra**				
E1	QLR accepted Nagra	B. Frieg 12/3/08	B. Frieg		
E2	Test classification Nagra	B. Frieg 14/3/08	B. Frieg		
	Level of interpretation (circle one)	**Standard Interpretation**		**Detailed Interpretation**	

Project / Borehole		Test		Test Start Date	Test Completion Date
Nagra / NOK EWS Oftringen		OFTR-17		30.10.07	30.10.07
Task	**Subtask**	**Completed Date**	**Signature**	**Checked Date**	**Signature**
F - Additional Interpretation (off site)	**Nagra + Solexperts + Intera**				
F1	Additional analyses required Nagra	B. Frieg 14/3/08	B. Frieg		
	Circle one	YES		NO	
	Type (Circle one)	Standard Minus	Standard	Standart Plus	Detailed
F2	Select input parameters & check detailed borehole history Solexperts/Intera	H. Fisch 23.07.08	H. Fisch	R. Senger 28.07.08	R. Senger
F3	Additional numerical analysis Solexperts/Intera	H. Fisch 23.07.08	H. Fisch	R. Senger 28.07.08	R. Senger
F4	Sensitivity analysis Solexperts/Intera	H. Fisch 23.07.08	H. Fisch	R. Senger 28.07.08	R. Senger
F5	Residual analysis Solexperts/Intera	H. Fisch 24.07.08	H. Fisch	R. Senger 28.07.08	R. Senger
F6	Perturbation analysis Solexperts/Intera	H. Fisch 26.07.08	H. Fisch	R. Senger 28.07.08	R. Senger
F7	Influence of ~~non-fitting parameters~~ varying test zone volume Solexperts/Intera	H. Fisch 27.07.08	H. Fisch	R. Senger 28.07.08	R. Senger
F8	Check for alternative flow models Solexperts/Intera	H. Fisch 26.07.08	H. Fisch	R. Senger 28.07.08	R. Senger
F9	Document analysis in NAB 08-15, Chapter ...14....... Solexperts	H. Fisch 27.07.08	H. Fisch	R. Senger 28.07.08	R. Senger
F10	Send report to Nagra Solexperts	H. Fisch 04.08.08	H. Fisch	R. Senger 28.07.08	R. Senger
G - NAB Report Review	**Colenco + Nagra**				
G1	External review of standard or detailed analysis (see Appendix L) Colenco	24.08.2008 R. Schwooz	R. Schwooz	J. Croisé 24.08.08	J. Croisé
G2	NAGRA review Nagra	18/9/08 B. Frieg	B. Frieg		
H - Address Review Comments	**Solexperts/Intera**				
H1	Incorporate Review Comments Solexperts/Intera	H. Fisch 28.10.08	H. Fisch	U. Rösli 28.10.08	U. Rösli
H2	Data back-up Solexperts/Intera	H. Fisch 28.10.08	H. Fisch	U. Rösli 28.10.08	U. Rösli
H3	Copy sent to Nagra Solexperts	H. Fisch 28.10.08	H. Fisch	U. Rösli 28.10.08	U. Rösli
I - Report approved and accepted	**Nagra**	30/10/08 B. Frieg	B. Frieg		

Project / Borehole		Test		Test Start Date	Test Completion Date
Nagra / NOK EWS Oftringen		OFTR-i8		01.11.07	02.11.07
Task	**Subtask**	**Completed Date**	**Signature**	**Checked Date**	**Signature**
A - Field Operation	**NAGRA and Solexperts**				
A1	Test objectives Personal communication by Nagra	B. Frieg 30/10/07	B. Frieg		
A2	Pressure transducer bench test Solexperts	S. Reinhardt 31.10.07	S. Reinhardt	Hayer 31.10.07	Hayer
A3	Surface equipment Solexperts	S. Reinhardt 30.10.07	S. Reinhardt	Hayer 30.10.07	Hayer
A4	Tally list Solexperts	S. Reinhardt 30.10.07	S. Reinhardt	Hayer 30.10.07	Hayer
A5	Tool layout Solexperts	S. Reinhardt 30.10.07	S. Reinhardt	Hayer 30.10.07	Hayer
A6	On site analysis Solexperts	S. Reinhardt 02.11.07	S. Reinhardt	Hayer 02.11.07	Hayer
A7	Testing log book Solexperts	S. Reinhardt 02.11.07	S. Reinhardt	Hayer 02.11.07	Hayer
A8	Data back-up Solexperts	S. Reinhardt 02.11.07	S. Reinhardt	Hayer 02.11.07	Hayer
B - Quick Look Report	**Solexperts and Intera (offsite)**				
B1	Input parameters & borehole history Solexperts and Intera	H.R. Fisch 2.11.07	H. Fisch	U. Rösli 24.12.07	U. Rösli
B2	Analytical test analysis Solexperts	U. Rösli 24.12.07	U. Rösli	H.R. Fisch 29.12.07	H. Fisch
B3	Numerical analysis Solexperts and Intera	U. Rösli 24.12.07	U. Rösli	H.R. Fisch 29.12.07	H. Fisch
B4	Data back-up Solexperts	U. Rösli 24.12.07	U. Rösli	H.R. Fisch 29.12.07	H. Fisch
B5	Drafting and reporting Solexperts and Intera	U. Rösli 26.12.07	U. Rösli	H.R. Fisch 29.12.07	H. Fisch
B6	Copy sent to Nagra Solexperts	U. Rösli 29.12.07	U. Rösli	H.R. Fisch 29.12.07	H. Fisch

Project / Borehole		Test		Test Start Date	Test Completion Date
Nagra / NOK EWS Oftringen		Oftr-i8		01.11.07	02.11.07
Task	**Subtask**	**Completed** Date	**Signature**	**Checked** Date	**Signature**
C - QLR QC Notes Colenco (offsite)					
C1	Test implementation Colenco	R. Schwarz 19.01.2008	R. Schwarz	J. Croisé 20.01.08	J. Croisé
C2	Hardware performance Colenco	R. Schwarz 19.01.2008	R. Schwarz	J. Croisé 20.01.08	J. Croisé
C3	Field documentation Colenco	R. Schwarz 19.01.2008	R. Schwarz	J. Croisé 20.01.08	J. Croisé
C4	Completeness of report Colenco	R. Schwarz 19.01.2008	R. Schwarz	J. Croisé 20.01.08	J. Croisé
C5	Review of analysis Colenco	R. Schwarz 19.01.2008	R. Schwarz	J. Croisé 20.01.08	J. Croisé
C6	Consistency of results Colenco	R. Schwarz 19.01.2008	R. Schwarz	J. Croisé 20.01.08	J. Croisé
C7	Suggestions for future analysis Colenco	R. Schwarz 19.01.2008	R. Schwarz	J. Croisé 20.01.08	J. Croisé
D - Incorporate QC comments / Re-issue QLR as Revision 1 Solexperts (offsite)					
D1	Incorporate QC comments Solexperts	U. Rösli 07.03.08	U. Rösli	H. Fisch 07.03.08	H. Fisch
D2	Re-issue QLR as Revision 1 Solexperts	U. Rösli 07.03.08	U. Rösli	H. Fisch 07.03.08	H. Fisch
E- QLR accepted / Test classification Nagra					
E1	QLR accepted Nagra	B. Frieg 15/8/08	B. Frieg		
E2	Test classification Nagra	B. Frieg 14.3.08	B. Frieg		
	Level of interpretation (circle one)	**Standard Interpretation**		**Detailed Interpretation**	

Project / Borehole		Test		Test Start Date	Test Completion Date
Nagra / NOK EWS Oftringen		OFTR-i8c		01.11.07	02.11.07
Task	**Subtask**	**Completed Date**	**Signature**	**Checked Date**	**Signature**
F - Additional Interpretation (off site) Nagra + Solexperts + Intera					
F1	Additional analyses required Nagra	B. Frieg 14/3/08	B Frieg		
	Circle one	YES		NO	
	Type (Circle one)	Standard Minus	Standard	Standart Plus	Detailed
F2	Select input parameters & check detailed borehole history Solexperts/Intera	H. Fisch 28.07.08	H. Fisch	U. Rösli 28.07.08	U. Rösli
F3	Additional numerical analysis Solexperts/Intera	H. Fisch 28.07.08	H. Fisch	R. Senger 1.08.08	R. Senger
F4	Sensitivity analysis Solexperts/Intera	H. Fisch 28.07.08	H. Fisch	R. Senger 1.08.08	R. Senger
F5	Residual analysis Solexperts/Intera	H. Fisch 28.07.08	H. Fisch	R. Senger 1.08.08	R. Senger
F6	Perturbation analysis Solexperts/Intera	H. Fisch 29.07.08	H. Fisch	R. Senger 1.08.08	R. Senger
F7	Influence of non-fitting parameters TR Solexperts/Intera				
F8	Check for alternative flow models Solexperts/Intera	H. Fisch 28.07.08	H. Fisch	R. Senger 01.08.08	R. Senger
F9	Document analysis in NAB 08-15, Chapter ...15... Solexperts	H. Fisch 30.07.08	H. Fisch	R. Senger 01.08.08	R. Senger
F10	Send report to Nagra Solexperts	H. Fisch 04.08.08	H. Fisch	U. Rösli 04.08.08	U. Rösli
G - NAB Report Review Colenco + Nagra					
G1	External review of standard or detailed analysis (see Appendix L) Colenco	R. Schwarz 27.08.2008	R. Schwarz	J. Croisé 27.08.08	J. Croisé
G2	NAGRA review Nagra	B. Frieg 16.10.08	B Frieg		
H - Address Review Comments Solexperts/Intera					
H1	Incorporate Review Comments Solexperts/Intera	H. Fisch 28.10.08	H. Fisch	U. Rösli 28.10.08	U. Rösli
H2	Data back-up Solexperts/Intera	H. Fisch 28.10.08	H. Fisch	U. Rösli 28.10.08	U. Rösli
H3	Copy sent to Nagra Solexperts	H. Fisch 28.10.08	H. Fisch	U. Rösli 28.10.08	U. Rösli
I - Report approved and accepted Nagra		B. Frieg 30/10/08	B Frieg		

Project / Borehole		Test		Test Start Date	Test Completion Date
Nagra / NOK EWS Oftringen		OFTR-19		02.11.07	03.11.07
Task	**Subtask**	**Completed** Date	**Signature**	**Checked** Date	**Signature**
A - Field Operation	**NAGRA and Solexperts**				
A1	Test objectives Personal communication by Nagra	B. Frieg 2.11.07	B. Frieg		
A2	Pressure transducer bench test Solexperts	S. Reinhardt 31.10.07	S. Reinhardt	Hayer 26.10.07	Hayer
A3	Surface equipment Solexperts	S. Reinhardt 02.11.07	S. Reinhardt	Kem 02.11.08	Kem
A4	Tally list Solexperts	S. Reinhardt 02.11.07	S. Reinhardt	Kem 02.11.08	Kem
A5	Tool layout Solexperts	S. Reinhardt 02.11.07	S. Reinhardt	Kem 02.11.08	Kem
A6	On site analysis Solexperts	S. Reinhardt 03.11.07	S. Reinhardt	Hayer 03.11.07	Hayer
A7	Testing log book Solexperts	S. Reinhardt 03.11.07	S. Reinhardt	Hayer 03.11.07	Hayer
A8	Data back-up Solexperts	S. Reinhardt 03.11.07	S. Reinhardt	Hayer 03.11.07	Hayer
B - Quick Look Report	**Solexperts and Intera (offsite)**				
B1	Input parameters & borehole history Solexperts and Intera	H.R. Fisch 2.11.07	H. Fisch	U. Rösli 2.11.07	U. Rösli
B2	Analytical test analysis Solexperts	U. Rösli 20.12.07	U. Rösli	H. Fisch 20.12.07	H. Fisch
B3	Numerical analysis Solexperts and Intera	U. Rösli 23.12.07	U. Rösli	H. Fisch 23.12.07	H. Fisch
B4	Data back-up Solexperts	U. Rösli 23.12.07	U. Rösli	H. Fisch 23.12.07	H. Fisch
B5	Drafting and reporting Solexperts and Intera	U. Rösli 23.12.07	U. Rösli	23.12.07 H. Fisch	H. Fisch
B6	Copy sent to Nagra Solexperts	U. Rösli 23.12.07	U. Rösli	H.R. Fisch 23.12.07	H. Fisch

Project / Borehole		Test		Test Start Date	Test Completion Date
Nagra / NOK EWS Oftringen		Oftr-i9		02.11.07	03.11.07
Task	**Subtask**	**Completed** Date	**Signature**	**Checked** Date	**Signature**
C - QLR QC Notes	**Colenco (offsite)**				
C1	Test implementation Colenco	R. Schwarz 22.01.08	R. Schwarz	J. Croisé 23.01.08	J. Croisé
C2	Hardware performance Colenco	R. Schwarz 22.01.08	R. Schwarz	J. Croisé 23.01.08	J. Croisé
C3	Field documentation Colenco	R. Schwarz 22.01.08	R. Schwarz	J. Croisé 23.01.08	J. Croisé
C4	Completeness of report Colenco	R. Schwarz 22.01.08	R. Schwarz	J. Croisé 23.01.08	J. Croisé
C5	Review of analysis Colenco	R. Schwarz 22.01.08	R. Schwarz	J. Croisé 23.01.08	J. Croisé
C6	Consistency of results Colenco	R. Schwarz 22.01.08	R. Schwarz	J. Croisé 23.01.08	J. Croisé
C7	Suggestions for future analysis Colenco	22.01.08 R. Schwarz	R. Schwarz	J. Croisé 23.01.08	J. Croisé
D - Incorporate QC comments / Re-issue QLR as Revision 1	**Solexperts (offsite)**				
D1	Incorporate QC comments Solexperts	U. Rösli 03.03.08	U. Rösli	H. Fisch 3.3.08	H. Fisch
D2	Re-issue QLR as Revision 1 Solexperts	U. Rösli 03.03.08	U. Rösli	H. Fisch 3.3.08	H. Fisch
E- QLR accepted / Test classification	**Nagra**				
E1	QLR accepted Nagra	B. Frieg 14/8/08	B. Frieg		
E2	Test classification Nagra	B. Frieg 14.3.08	B. Frieg		
	Level of interpretation (circle one)	Standard Interpretation		Detailed Interpretation	

Project / Borehole		Test		Test Start Date	Test Completion Date
Nagra / NOK EWS Oftringen		Oftr-i9		02.11.07	03.11.07
Task	**Subtask**	**Completed Date**	**Signature**	**Checked Date**	**Signature**
F - Additional Interpretation (off site)	**Nagra + Solexperts + Intera**				
F1	Additional analyses required Nagra	B. Frieg 14.3.08	B. Frieg		
	Circle one	YES		NO	
	Type (Circle one)	Standard Minus	Standard	Standart Plus	Detailed
F2	Select input parameters & check detailed borehole history Solexperts/Intera	H. Fisch 30.07.08	H. Fisch	R. Senger 2.08.08	R. Senger
F3	Additional numerical analysis Solexperts/Intera	H. Fisch 30.07.08	H. Fisch	R. Senger 2.08.08	R. Senger
F4	Sensitivity analysis Solexperts/Intera	H. Fisch 30.07.08	H. Fisch	R. Senger 2.08.08	R. Senger
F5	Residual analysis Solexperts/Intera	H. Fisch 31.07.08	H. Fisch	R. Senger 2.08.08	R. Senger
F6	Perturbation analysis Solexperts/Intera	H. Fisch 01.08.08	H. Fisch	R. Senger 02.08.08	R. Senger
F7	Influence of non-fitting parameters Varying internal temperature Solexperts/Intera	H. Fisch 02.08.08	H. Fisch	R. Senger 2.08.08	R. Senger
F8	Check for alternative flow models Solexperts/Intera	H. Fisch 31.07.08	H. Fisch	R. Senger 2.08.08	R. Senger
F9	Document analysis in NAB 08-15, Chapter 16 Solexperts	H. Fisch 02.08.08	H. Fisch	R. Senger 2.08.08	R. Senger
F10	Send report to Nagra Solexperts	H. Fisch 04.08.08	H. Fisch	U. Rösli 04.08.08	U. Rösli
G - NAB Report Review	**Colenco + Nagra**				
G1	External review of standard or detailed analysis (see Appendix L) Colenco	27.08.08 R. Schwarz	R. Schwarz	J. Croisé 28.08.08	J. Croisé
G2	NAGRA review Nagra	B. Frieg 30/10/08	B. Frieg		
H - Address Review Comments	**Solexperts/Intera**				
H1	Incorporate Review Comments Solexperts/Intera	H. Fisch 28.10.08	H. Fisch	U. Rösli 28.10.08	U. Rösli
H2	Data back-up Solexperts/Intera	H. Fisch 28.10.08	H. Fisch	U. Rösli 28.10.08	U. Rösli
H3	Copy sent to Nagra Solexperts	H. Fisch 28.10.08	H. Fisch	U. Rösli 28.10.08	U. Rösli
I - Report approved and accepted	**Nagra**	B. Frieg 30/10/08	B. Frieg		

Project / Borehole		Test		Test Start Date	Test Completion Date
Nagra / NOK EWS Oftringen		OFTR-i10		03.11.07	04.11.07
Task	**Subtask**	**Completed Date**	**Signature**	**Checked Date**	**Signature**
A - Field Operation	**NAGRA and Solexperts**				
A1	Test objectives Personal communication by Nagra	B. Frieg 2/11/07	B. Frieg		
A2	Pressure transducer bench test Solexperts	S. Reinhardt 31.10.07	S. Reinhardt	Hayer 30.10.07	Hayer
A3	Surface equipment Solexperts	S. Reinhardt 03.11.07	S. Reinhardt	Hayer 03.11.07	Hayer
A4	Tally list Solexperts	S. Reinhardt 03.11.07	S. Reinhardt	Hayer 03.11.07	Hayer
A5	Tool layout Solexperts	S. Reinhardt 03.11.07	S. Reinhardt	Hayer 03.11.07	Hayer
A6	On site analysis Solexperts	S. Reinhardt 04.11.07	S. Reinhardt	Hayer 04.11.07	Hayer
A7	Testing log book Solexperts	S. Reinhardt 04.11.07	S. Reinhardt	Hayer 04.11.07	Hayer
A8	Data back-up Solexperts	S. Reinhardt 04.11.07	S. Reinhardt	Hayer 04.11.07	Hayer
B - Quick Look Report	**Solexperts and Intera (offsite)**				
B1	Input parameters & borehole history Solexperts and Intera	H. Fisch 2.11.07	H. Fisch	U. Rösli 08.01.08	U. Rösli
B2	Analytical test analysis Solexperts	U. Rösli 08.01.08	U. Rösli	H. Fisch 12.1.08	H. Fisch
B3	Numerical analysis Solexperts and Intera	U. Rösli 09.01.08	U. Rösli	H. Fisch 12.1.08	H. Fisch
B4	Data back-up Solexperts	H. Fisch 12.01.08	H. Fisch	U. Rösli 12.1.08	U. Rösli
B5	Drafting and reporting Solexperts and Intera	U. Rösli 10.01.08	U. Rösli	H. Fisch 12.1.08	H. Fisch
B6	Copy sent to Nagra Solexperts	H. Fisch 12.01.08	H. Fisch	U. Rösli 12.01.08	U. Rösli

Project / Borehole	Test	Test Start Date	Test Completion Date
Nagra / NOK EWS Oftringen	Oftr-i10	03.11.07	04.11.07

Task	Subtask	Completed Date	Signature	Checked Date	Signature
C - QLR QC Notes	Colenco (offsite)				
C1	Test implementation Colenco	04.02.2008 R. Schwarz	R. Schwarz	04.02.08 J. Croisé	J. Croisé
C2	Hardware performance Colenco	R. Schwarz 04.02.2008	R. Schwarz	J. Croisé 04.02.08	J. Croisé
C3	Field documentation Colenco	R. Schwarz 04.02.2008	R. Schwarz	J. Croisé 04.02.08	J. Croisé
C4	Completeness of report Colenco	R. Schwarz 04.02.2008	R. Schwarz	J. Croisé 04.02.08	J. Croisé
C5	Review of analysis Colenco	R. Schwarz 04.02.2008	R. Schwarz	J. Croisé 04.02.08	J. Croisé
C6	Consistency of results Colenco	R. Schwarz 04.02.2008	R. Schwarz	J. Croisé 04.02.08	J. Croisé
C7	Suggestions for future analysis Colenco	R. Schwarz 04.02.2008	R. Schwarz	J. Croisé 04.02	J. Croisé
D - Incorporate QC comments / Re-issue QLR as Revision 1	Solexperts (offsite)				
D1	Incorporate QC comments Solexperts	U. Rösli 04.03.08	U. Rösli	H. Fisch 4.3.08	H. Fisch
D2	Re-issue QLR as Revision 1 Solexperts	U. Rösli 04.03.08	U. Rösli	H. Fisch 4.3.08	H. Fisch
E- QLR accepted / Test classification	Nagra				
E1	QLR accepted Nagra	B. Frieg 14/3/08	B. Frieg		
E2	Test classification Nagra	B. Frieg 14/3/08	B. Frieg		
	Level of interpretation (circle one)	Standard Interpretation		Detailed Interpretation	

Project / Borehole Nagra / NOK EWS Oftringen	Test OFTR-i10		Test Start Date 03.11.07	Test Completion Date 04.11.07
Task / Subtask	**Completed Date**	**Signature**	**Checked Date**	**Signature**
F - Additional Interpretation (off site) Nagra + Solexperts + Intera				
F1 Additional analyses required — Nagra	B. Frieg 14.3.08	B. F.		
Circle one	YES		NO (circled)	
Type (Circle one)	Standard Minus	Standard	Standart Plus	Detailed
F2 Select input parameters & check detailed borehole history — Solexperts/Intera				
F3 Additional numerical analysis — Solexperts/Intera				
F4 Sensitivity analysis — Solexperts/Intera				
F5 Residual analysis — Solexperts/Intera				
F6 Perturbation analysis — Solexperts/Intera				
F7 Influence of non-fitting parameters — Solexperts/Intera				
F8 Check for alternative flow models — Solexperts/Intera				
F9 Document analysis in NAB 08-15, Chapter 17 — Solexperts	H. Fisch 02.08.08	H. Fisch	U. Rösli 02.08.08	U. Rösli
F10 Send report to Nagra — Solexperts	H. Fisch 04.08.08	H. Fisch	U. Rösli 04.08.08	U. Rösli
G - NAB Report Review Colenco + Nagra				
G1 External review of standard or detailed analysis (see Appendix L) — Colenco	R. Schwarz 08.09.2008	R. Schwarz	J. Croisé 09.09.08	J. Croisé
G2 NAGRA review — Nagra	B. Frieg 16/10/08	B. F.		
H - Address Review Comments Solexperts/Intera				
H1 Incorporate Review Comments — Solexperts/Intera	H. Fisch 28.10.08	H. Fisch	U. Rösli 28.10.08	U. Rösli
H2 Data back-up — Solexperts/Intera	H. Fisch 28.10.08	H. Fisch	U. Rösli 28.10.08	U. Rösli
H3 Copy sent to Nagra — Solexperts	H. Fisch 28.10.08	H. Fisch	U. Rösli 28.10.08	U. Rösli
I - Report approved and accepted Nagra	B. Frieg 30/10/08	B. F.		