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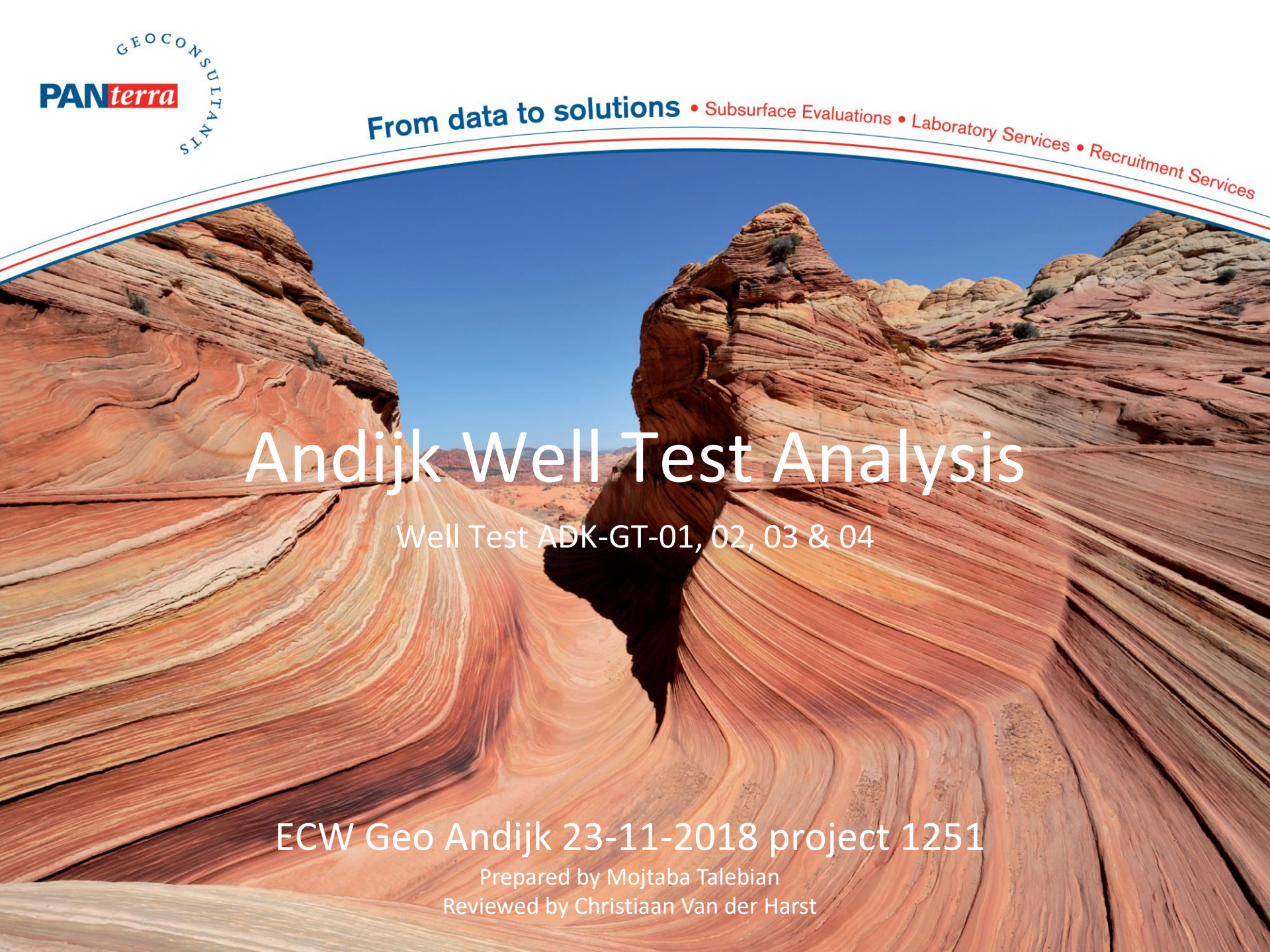

Andijk Well Test Analysis

Well Test ADK-GT-01, 02, 03 & 04

ECW Geo Andijk 23-11-2018 project 1251

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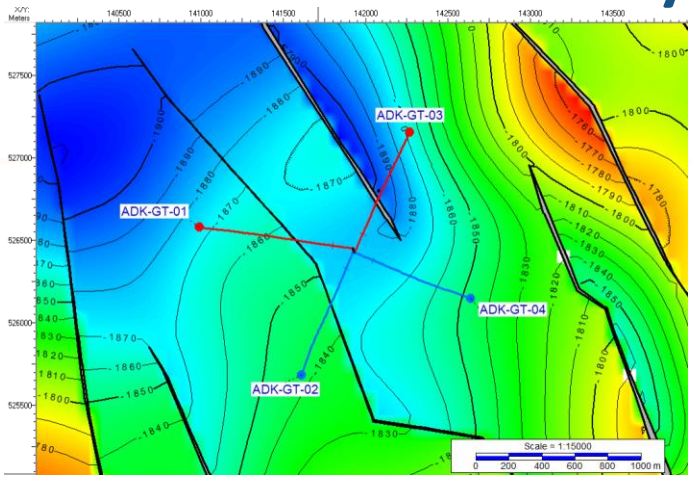
Reviewed by Christiaan Van der Harst

Content

Result Summary



	ADK-GT-01	ADK-GT-02	ADK-GT-03	ADK-GT-04
Top reservoir (m BGL)	1869	1783	1876	1802
Base reservoir (m BGL)	2050	1987	2040	1932
mid-res depth(m BGL)	1960	1885	1958	1867
Net thickness (mTV)	181	204	164	130
Phi	0.215	0.22	0.215	0.22
mid-res Pressure (bar)	212	205	212	203
Reservoir Temperature (°C)	84	81	82	81
Permeability (mD)	118-137	270-335	130-224	130-350
Skin (-) *	-2.5	-2	-2	-3
Productivity Index (transient PI @ Horner time) (m^3/hr/bar)	18	37	18	15

* Total final skin is surprisingly low at -2 or below. This might be the effect of well inclination or sand production

Data Standards

- The used coordinate system is RDnew “Rijks Driehoekstelsel”
- Presented parameters are in metric units
- Pressure data are absolute values
- IHS WellTest (Fekete), which is one of the technically advanced pressure transient analysis software packages is used for this analysis

ADK-GT-01 Test Analysis

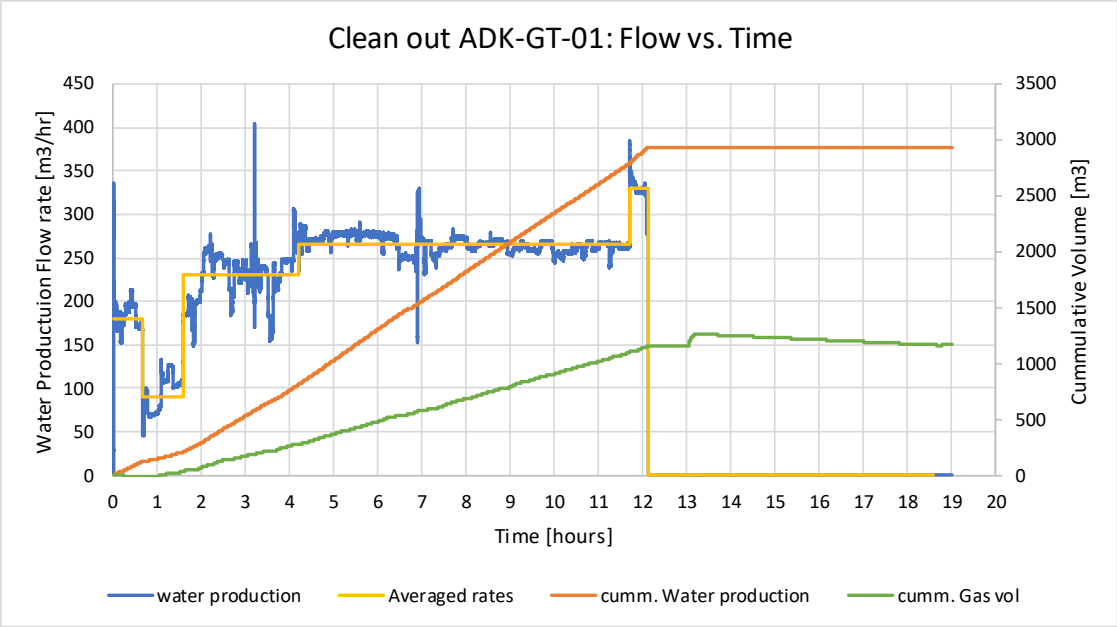
ADK-GT-01
Data for test interpretation

Data for test interpretation	Value	Dimension
Well location: X Coordinates Y Coordinates	 141,923.43 526,448.44	 RD RD
Well Total Depth	2349 2054	m BGL AH m BGL TVD
Aquifer top	2107 1869	M BGL (MD) M BGL (TVD)
Aquifer base	2347 2050	m BGL (MD) m BGL (TVD)
Aquifer thickness	181	m (TVD)
Aquifer Net/Gross (NTG)	98	%
Average aquifer porosity	21.5	%
Formation water salinity (TDS)	189000	ppm
Average initial reservoir pressure	212	bar @ 1960 m BGL TVD
Stabilized temperature of produced water	84	°C
Temperature gradient	3.5	° C/100m
Casing 28“	91	m BGL (TVD)
Casing 18 5/8”	500	M BGL (TVD)
Casing 13 3/8”	1289	m BGL(TVD)
Liner 9 5/8”	1865	M BGL (TVD)
Liner 7”	1844	m BGL(TVD)
Borehole diameter at aquifer	8.5	inch
Pump location	749.3	m BGL (TVD)
Shallow gauge location	n.a.	
Deep wireline gauge location	n.a.	

ADK-GT-01 Test Summary

- The ADK-GT-01 production well test started on 05-09-2018 and included a four-rate production test of 12.1 hours and a final build-up period of 6.6 hours.
- Reservoir fluid was produced with an Electric Submersible pump (ESP). The water production rates varied between 60 and 340 m3/hr with a cumulative production of 2934 m^3
- The pressure and temperature data from the well are only recorded by the ESP gauge (No downhole gauge).
- The maximum drawdown achieved was some 19 bar at an offtake of 330 m3/hr during flow period 5.
- The post-test reservoir pressure of the producing Slochteren sandstone derived from the final build-up is 212 bar at mid reservoir level (1960 m BGL TVD).
- Transient flow capacity (PI) after 11.7 hours flow for the longest flow period (flow 5) is 17.7 m3/hr/bar.

ADK-GT-01 Test Summary



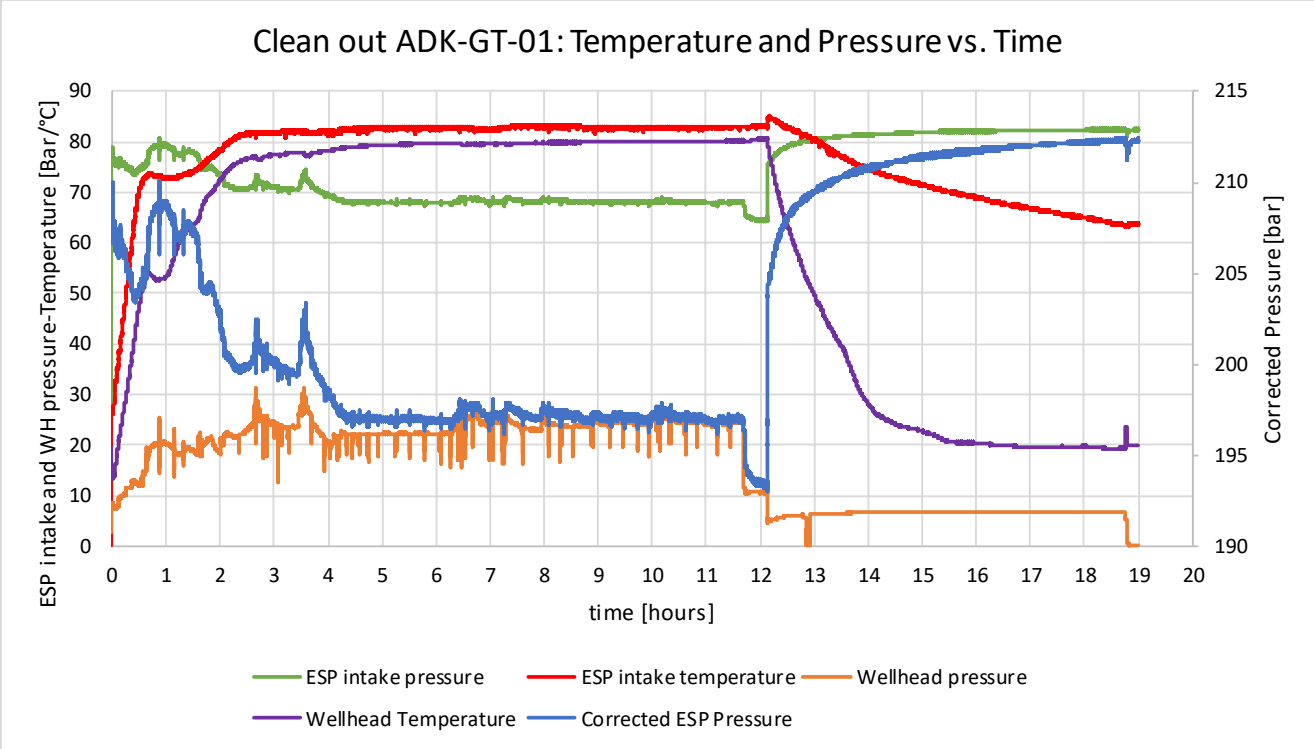
Start of event	Start time		Duration	Rate		Volume	Bottom hole pressure	Productivity Index
	(Days)	(Hours)	(Hours)	(m^3/d)	(m^3/hr)	(m^3)	(bar)	m^3/hr/bar
Flow 1	05-09-2018	22:00	0.67	4320	180	121	203.5	21
Flow 2	05-09-2018	22:40	0.92	2160	90	83	208.5	22
Flow 3	05-09-2018	23:35	2.63	5520	230	605	197.6	16
Flow 4	06-09-2018	02:13	7.50	6360	265	1988	197.0	18
Flow 5	06-09-2018	09:43	0.42	7920	330	139	193.4	18
BU	06-09-2018	10:08	6.48	0	0	0	n.a.	n.a.
					Total volume:	2934		

Pressure-Temperature correction

- The ESP pressure recording was extrapolated to the mid reservoir depth at 1964 m TVDSS in order to correct for the cooling of the water column within the wellbore, and depth gradient.
- The extrapolation function used to calculate the pressure difference between ESP (or gauges) depth and top reservoir depth, is very similar to that obtained from the test data of other Slochteren reservoir wells, including previous well test analysis of ADK-GT-01 (Dec. 2017).
- $DP = CDC*L*\{1089.5+0.4931*(83.5-T)-0.003*(83.5-T)^{2}\}$
- $\Delta p(bar) = C_1*L*\{\rho_w+C_a*(T_{max}-T_{top})-C_b*(T_{max}-T_{top})^2\}$

  Where,
  - C_1 =0.000098063 if pressure in bar
  - L is the m TVD difference to the mid reservoir
  - C_a = 0.4931 and C_b = 0.003
  - T_{max} is the maximum recorded temperature in °C
  - T_{top} is the current temperature at the recorded depth
- The water salinity ρ_w was first calculated from the pressure difference of ESP and bottom gauge in the first well test (2017). A pressure gradient of 0.1070 bar/m, or 1089 kg/m3 which indicates a salinity of 189 kg/m3 NaCl equivalent
- Extrapolation of the temperature recorded by the bottom gauge during flow period 5 indicates a final stabilized temperature of 84 °C of the produced water corresponding to a geothermal gradient of 3.6 °C /100m, assuming 15°C surface temperature.
- Total system compressibility was set to 8.3E-7 1/KPa, and the reservoir water viscosity to 0.5 cP.

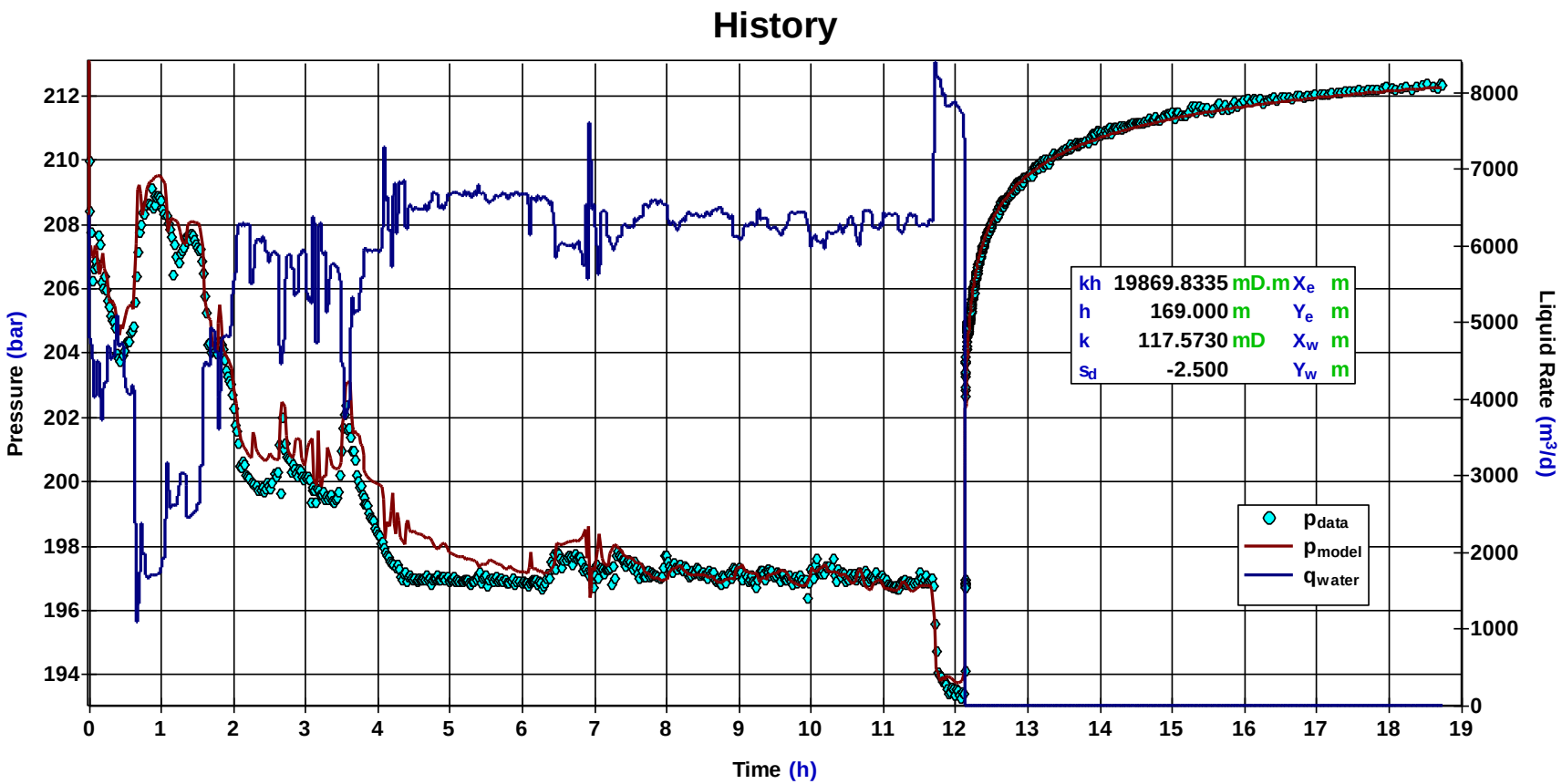
Pressure-Temperature correction



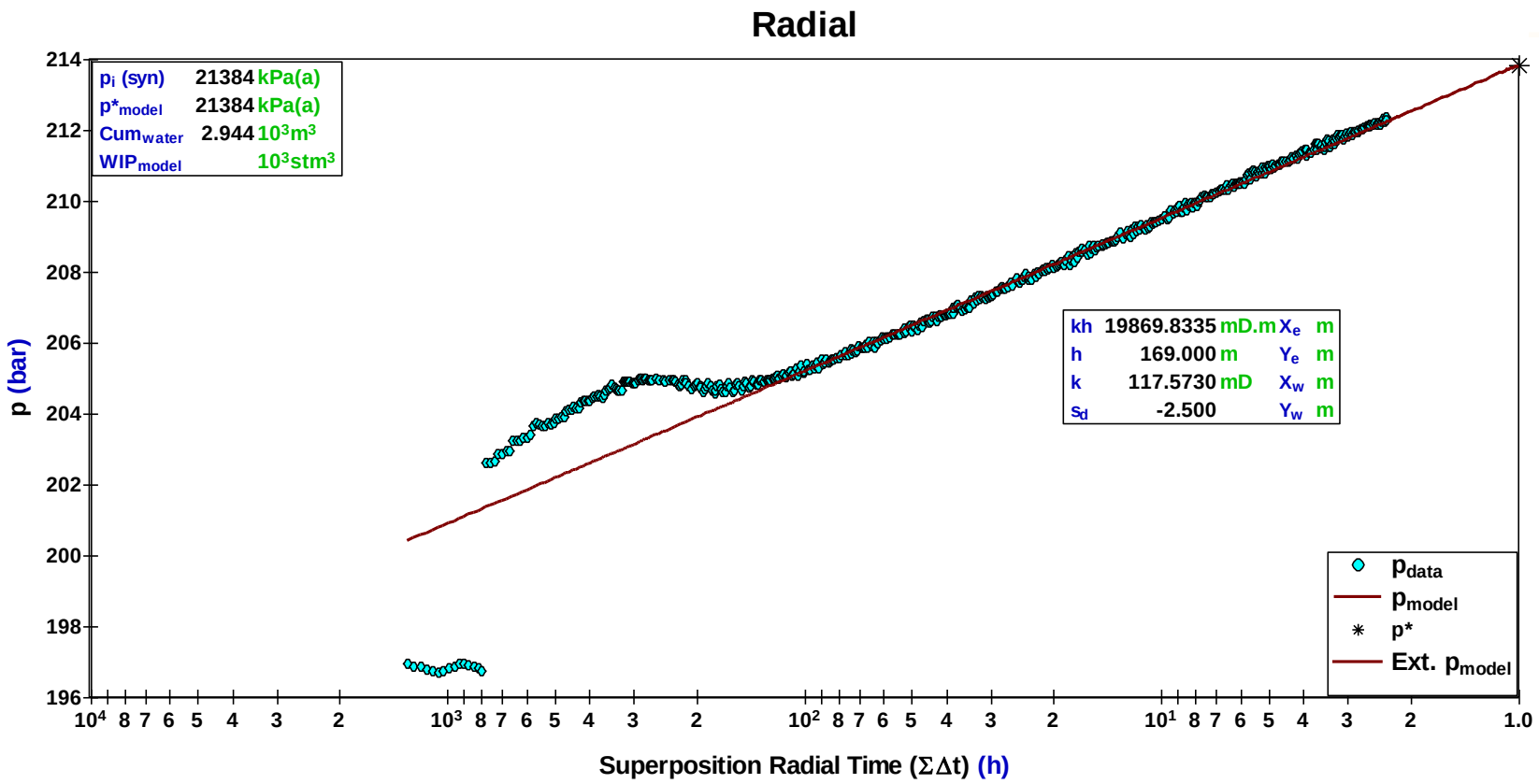
Analysis of corrected pressure data

- The large dataset within the gauges were reduced using a combination of time and resolution filters. An Arithmetic filter for flow periods, and a Logarithmic filter for shut-in periods were used.
- The average porosity has been estimated at 21.5%. Net thickness is 169 mtv. The water viscosity and water compressibility have been based on the salinity: μ_w = 0.5 cP and C_w = 3.2E-7 1/kPa respectively.
- Evaluation of the test indicated an average reservoir permeability of about 118 mD of the 170 m sand layer. This is comparable with the evaluation of the 2017 well test with an average reservoir permeability of about 128 mD
- Total final skin is low at -2.5
- The build-up period is too short to stablish a boundary effect
- The observed permeability is the radial permeability. The interference test showed an average permeability of 300-400 mD between the GT-01 and GT-02 wells. The estimated permeability (directional) from interference test is more in line with the permeabilities expected from the petrophysical data of the area.
- The static reservoir pressure at mid reservoir depth of 1964 mtv is 212 bara
- The reservoir temperature is about 84 °C.
- Transient flow capacity (PI) after 12 hours flow is 18 m3/hr/bar.

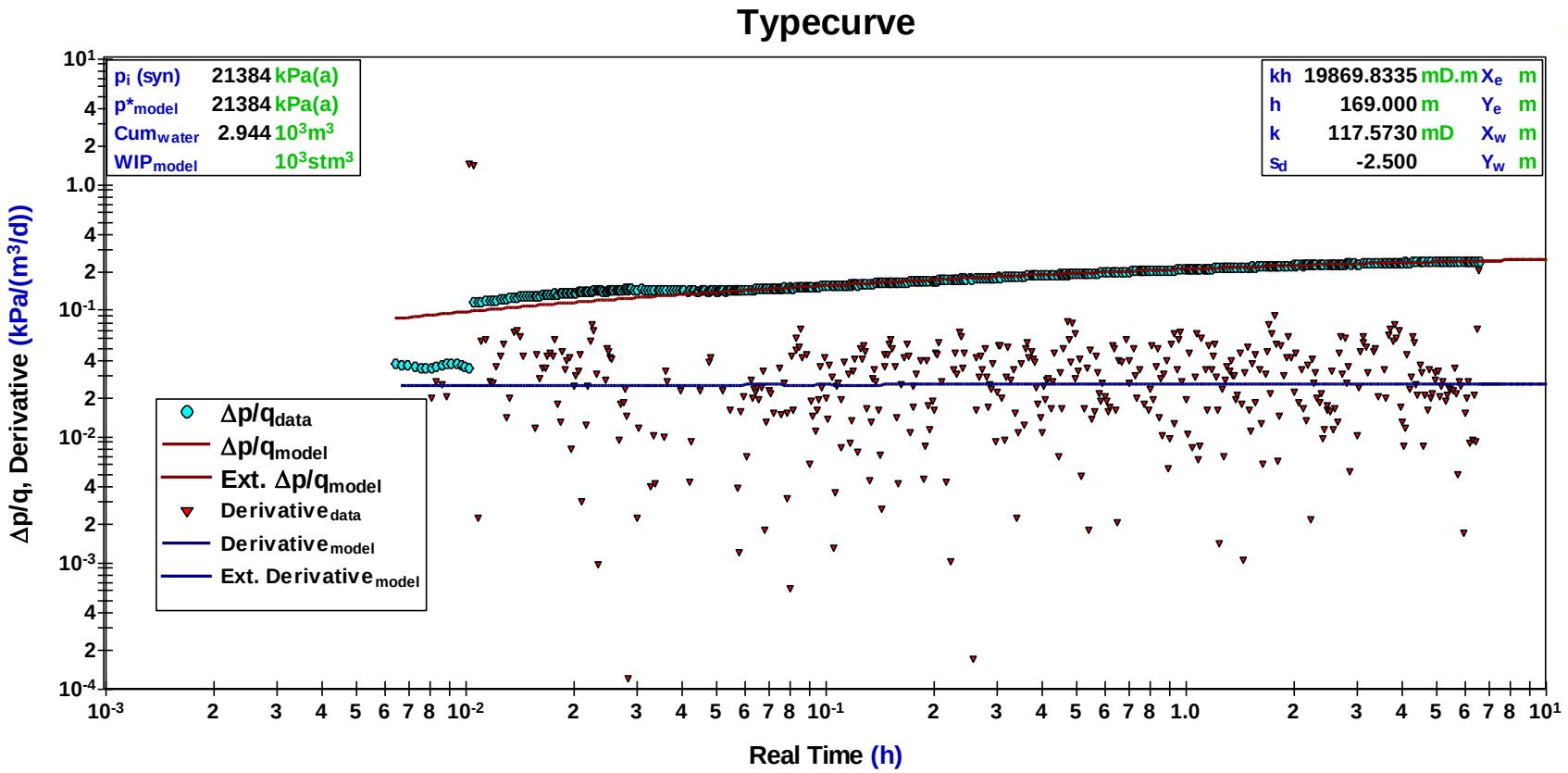
ADK-GT-01


History
Pressure (bar)
Liquid Rate (m3/d)
Time (h)
kh 19869.8335 mD.m Xe m
h 169.000 m Ye m
k 117.5730 mD Xw m
sd -2.500 Yw m
pdata
pmodel
qwater

ADK-GT-01 Build up – Radial (Horner) Plot



ADK-GT-01 Build up –Derivative plot



ADK-GT-02 Test Analysis

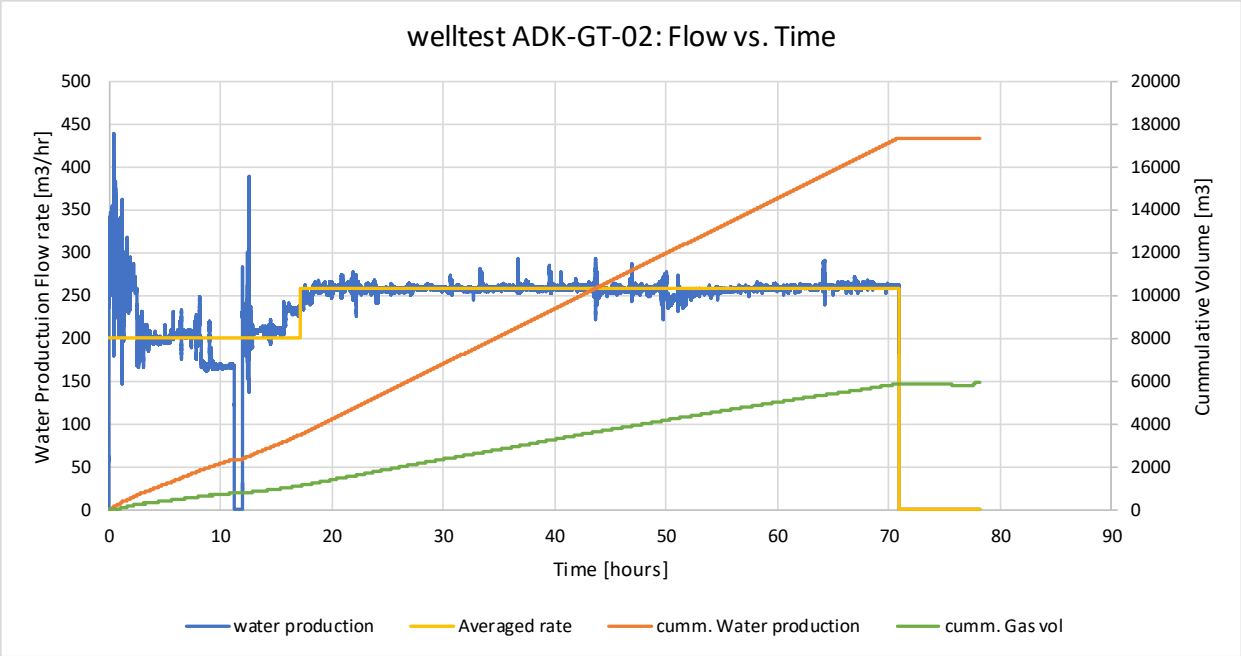
ADK-GT-02
Data for test interpretation

Data for test interpretation	Value	Dimension
Well location: X Coordinates Y Coordinates	 141,925.86 526,441.34	 RD RD
Well Total Depth	2244 1999	m BGL AH m BGL TVD
Aquifer top	1955 1783	M BGL (MD) M BGL (TVD)
Aquifer base	2228 1987	m BGL (MD) m BGL (TVD)
Aquifer thickness	204	m (TVD)
Aquifer Net/Gross (NTG)	98	%
Average aquifer porosity	22	%
Formation water salinity (TDS)	189000	ppm
Average initial reservoir pressure	197.7	bar @ 1960 m BGL TVD
Stabilized temperature of produced water	82	^{o}C
Temperature gradient	3.6	$^{\circ}$ C/100m
Casing 28“	91	m BGL (TVD)
Casing 18 5/8”	512	M BGL (TVD)
Casing 13 3/8”	1271	m BGL(TVD)
Liner 9 5/8”	1779	M BGL (TVD)
Liner 7”	1729	m BGL(TVD)
Borehole diameter at aquifer	8.5	inch
Pump location	749.3	m BGL (TVD)
Shallow gauge location	n.a.	
Deep wireline gauge location	n.a.	

ADK-GT-02 Test Summary

- The ADK-GT-02 production well test started on 18-09-2018 and included a two-rate production test of 71 hours and a final build-up period of 7.1 hours.
- Reservoir fluid was produced with an Electric Submersible pump (ESP). The water production rates varied between 170 and 260 m3/hr with a cumulative production of 17376 m^3
- The pressure and temperature data from the well are only recorded by the ESP gauge (No downhole gauge).
- The maximum drawdown achieved was some 7.0 bar at an offtake of 260 m3/hr during flow period 2.
- The post-test reservoir pressure of the producing Slochteren sandstone derived from the final build-up is 205 bar at the mid reservoir (1885 m BGL TVD).
- Transient flow capacity (PI) after 70 hours flow is 37 m3/hr/bar.

ADK-GT-02 Test Summary



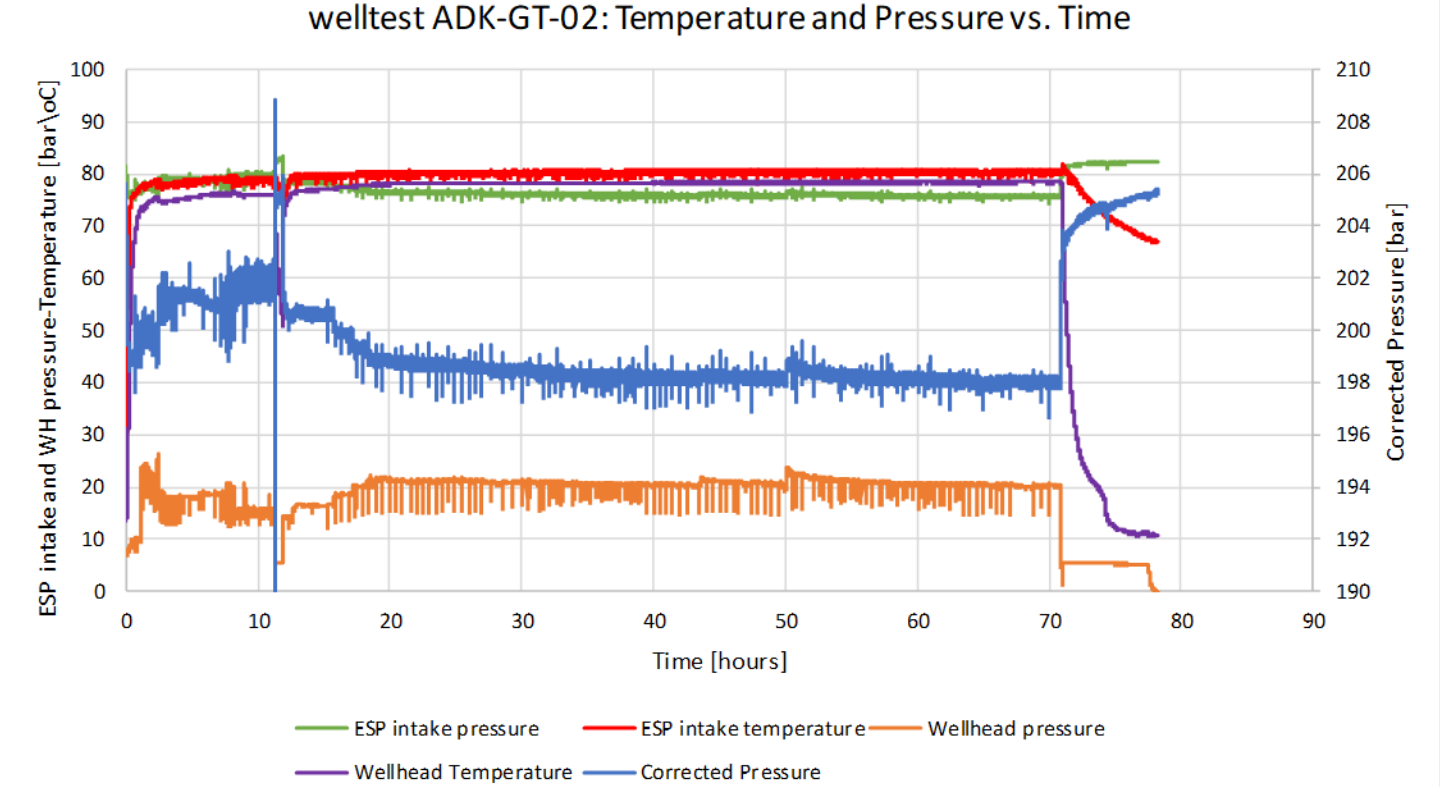
Start of event	Start time		Duration	Rate		Volume	Bottom hole pressure	Productivity Index
	(Days)	(Hours)	(Hours)	(m^3/d)	(m^3/hr)	(m^3)	(bar)	m^3/hr/bar
Flow 1	18-09-2018	15:35	17.2	4802	200	3440	200	40
Flow 2	19-09-2018	08:47	53.6	6221	260	13988	198	37
BU	21-09-2018	14:33	7.1	0	0	0	n.a	n.a
					Total volume:	17376		

Pressure-Temperature correction

- The ESP pressure recording was extrapolated to the mid reservoir depth at 1893 m TVD in order to correct for the cooling of the water column within the wellbore, and depth gradient.
- The extrapolation function used to calculate the pressure difference between ESP (or gauges) depth and top reservoir depth, is very similar to that obtained from the test data of other Slochteren reservoir wells, including previous well test analysis of ADK-GT-01 (Dec. 2017).
- DP = CDC*L*{1089.5+0.4931*(81. 5-T)-0.003*(81. 5-T) ^{2}}
- $\Delta p(bar) = C_1 * L * \{\rho_w + C_a * (T_{max} - T_{top}) - C_b * (T_{max} - T_{top})^2\}$

  Where,
  - C_1 =0.000098063 if pressure in bar
  - L is the m TVD difference to the mid reservoir
  - C_a = 0.4931 and C_b = 0.003
  - T_{max} is the maximum recorded temperature in °C
  - T_{top} is the current temperature at the recorded depth
- The water salinity ρ_w was first calculated from the pressure difference of ESP and bottom gauge in the first well test (2017). A pressure gradient of 0.1070 bar/m, or 1089 kg/m3 which indicates a salinity of 189 kg/m3 NaCl equivalent
- Extrapolation of the temperature recorded by the bottom gauge during flow period 2 indicates a final stabilized temperature of 81 °C of the produced water corresponding to a geothermal gradient of 3.5 °C /100m, assuming 15°C surface temperature.
- Total system compressibility was set to 8.3E-7 1/KPa, and the reservoir water viscosity to 0.54 cP.

Pressure-Temperature correction



Analysis of corrected pressure data

- The large dataset within the gauges were reduced using a combination of time and resolution filters. An Arithmetic filter for flow periods, and a Logarithmic filter for shut-in periods were used.
- The average porosity has been estimated at 22%. Net thickness is 200 mtv. The water viscosity and water compressibility have been based on the salinity: μ_w = 0.54 cP and C_w = 3.2E-7 1/kPa respectively.
- The build-up period is too short and the derivative plot is so scattered that it is not possible to make a conclusive diagnosis of a near well boundary. Two models were matched:
  - Model A: without a near well boundary (better match during the flow periods)
  - Model B: a fault at 150 m from the well (better match at late build-up)
- Model A: evaluation of the test indicates an average reservoir permeability of about 270 mD of the 200m sand layer. Total final skin is low at -2.0
- Model B: evaluation of the test indicates an average reservoir permeability of about 335 mD of the 200 m sand layer. Total final skin is low at -1.0
- In general Model A gives better overall match with the test data.
- The observed permeability is in line with the interference test between the GT-01 and GT-02.
- The static reservoir pressure at mid reservoir depth of 1893 mtv is 205 bara
- The reservoir temperature is about 81 °C.
- Transient flow capacity (PI) after about 70 hours flow is 37 m3/hr/bar.

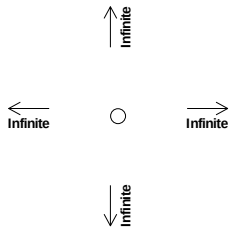
ADK-GT-02 Models

Model A

k = 270.0000 mD
s_d = -1.989

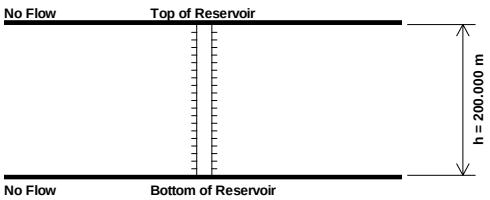
Plan View

(Not to scale)



Side View

(Not to scale)

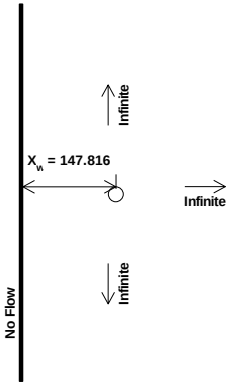


Model B

k = 335.2454 mD
s_d = -0.928
WIP_{model} = 10^3 stm^3

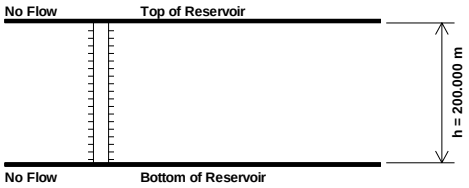
Plan View

(Not to scale)

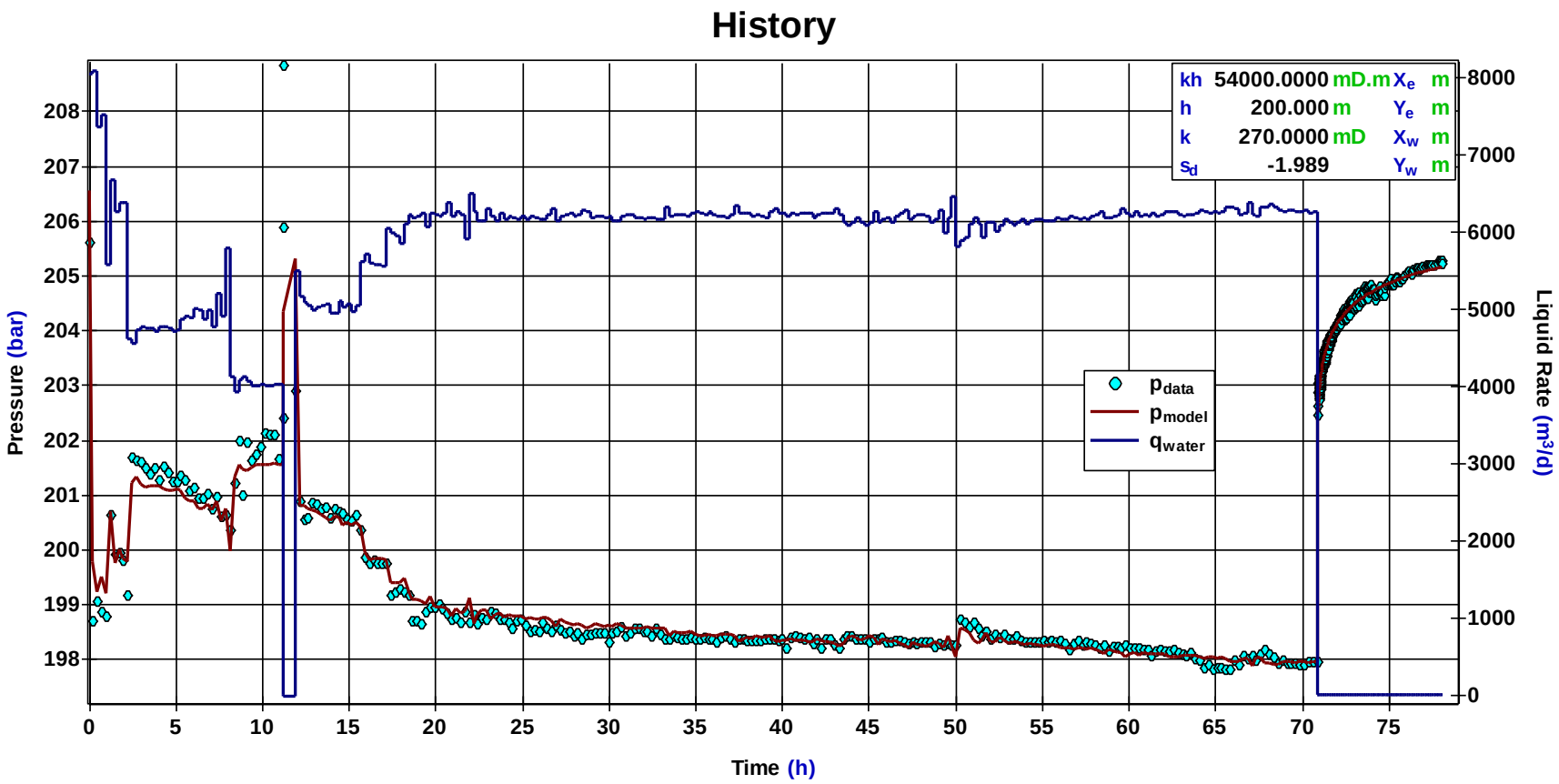


Side View

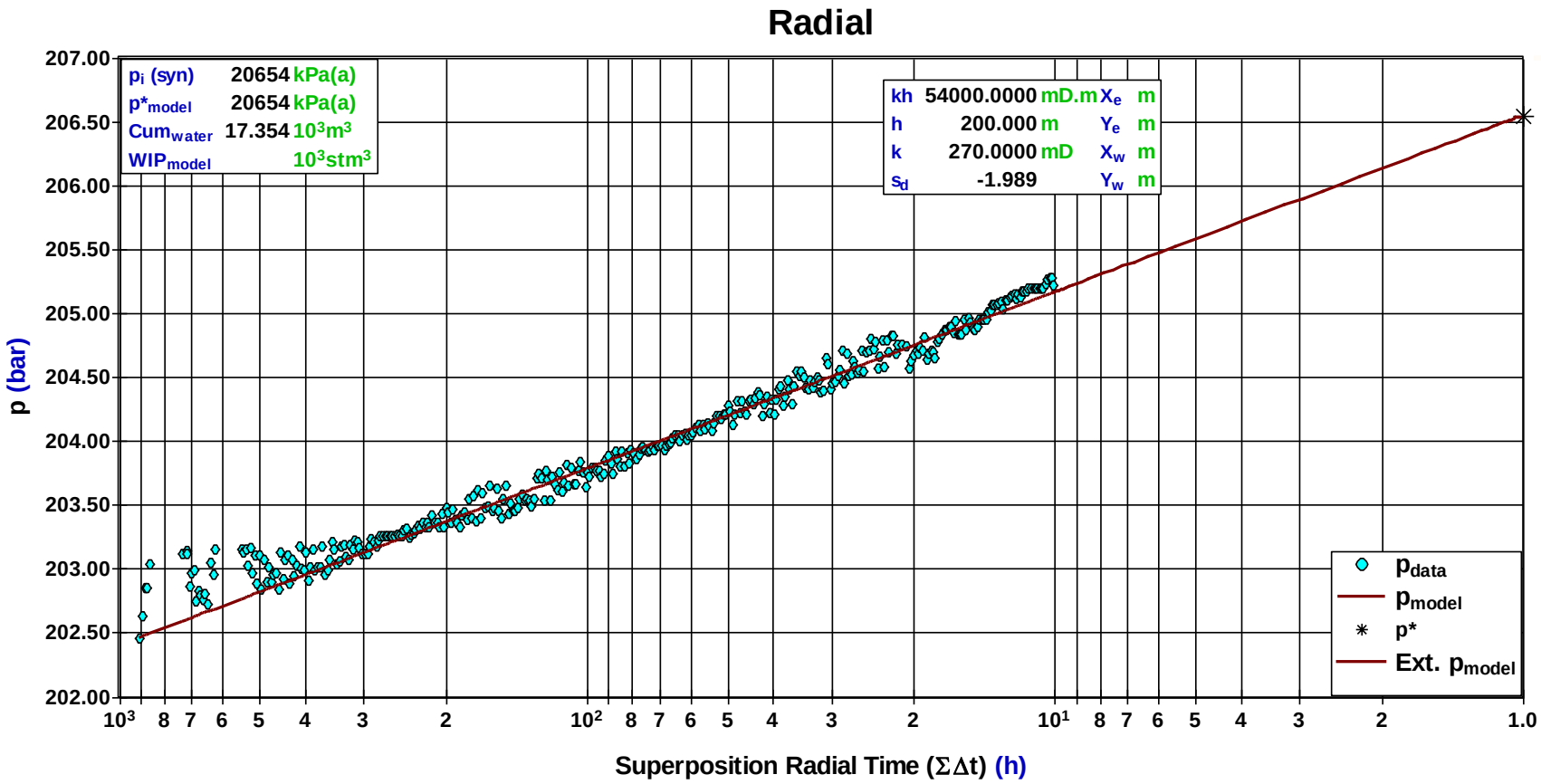
(Not to scale)



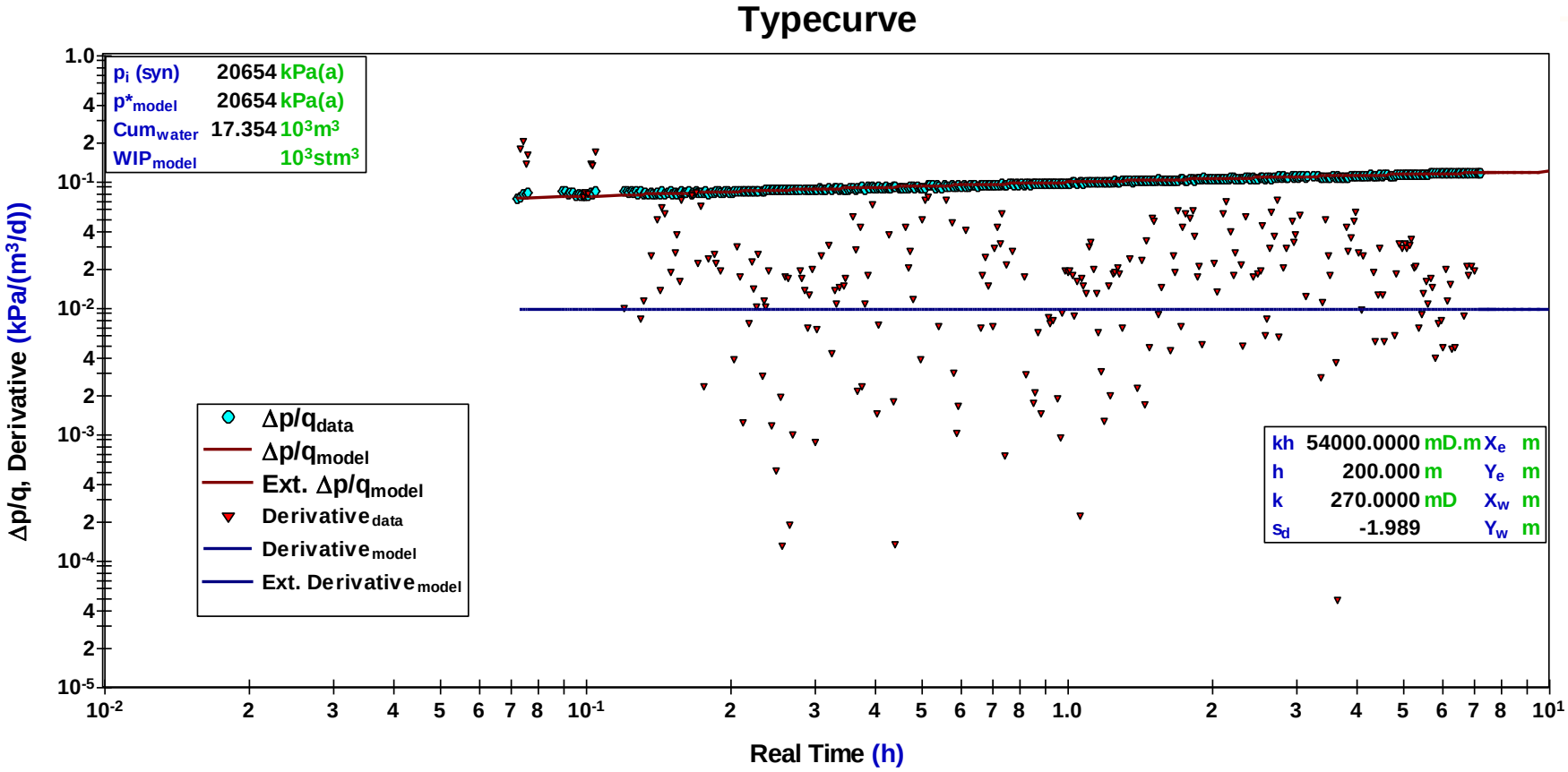
ADK-GT-02 – Model A



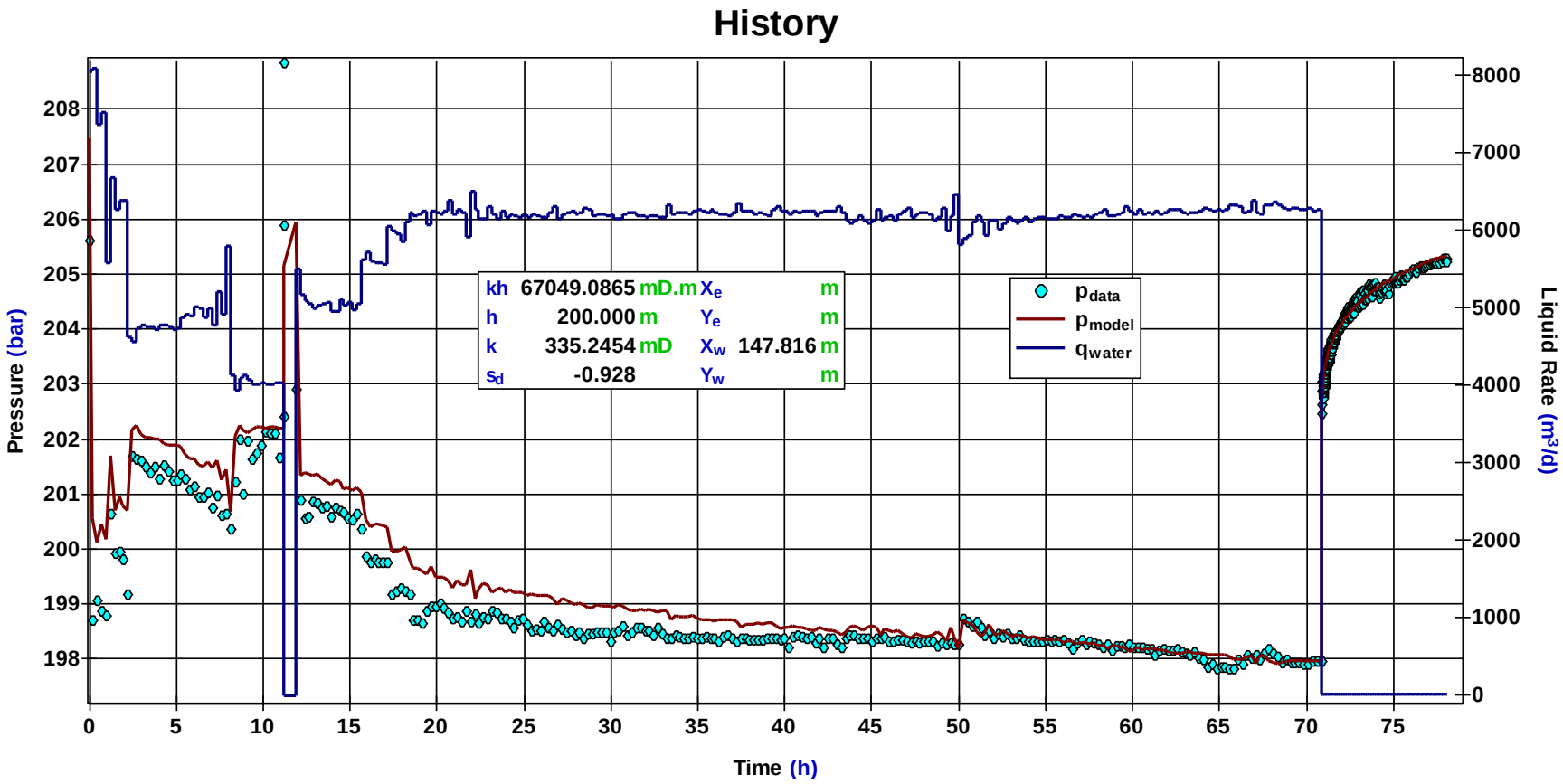
ADK-GT-02 – Model A– Radial (Horner) Plot



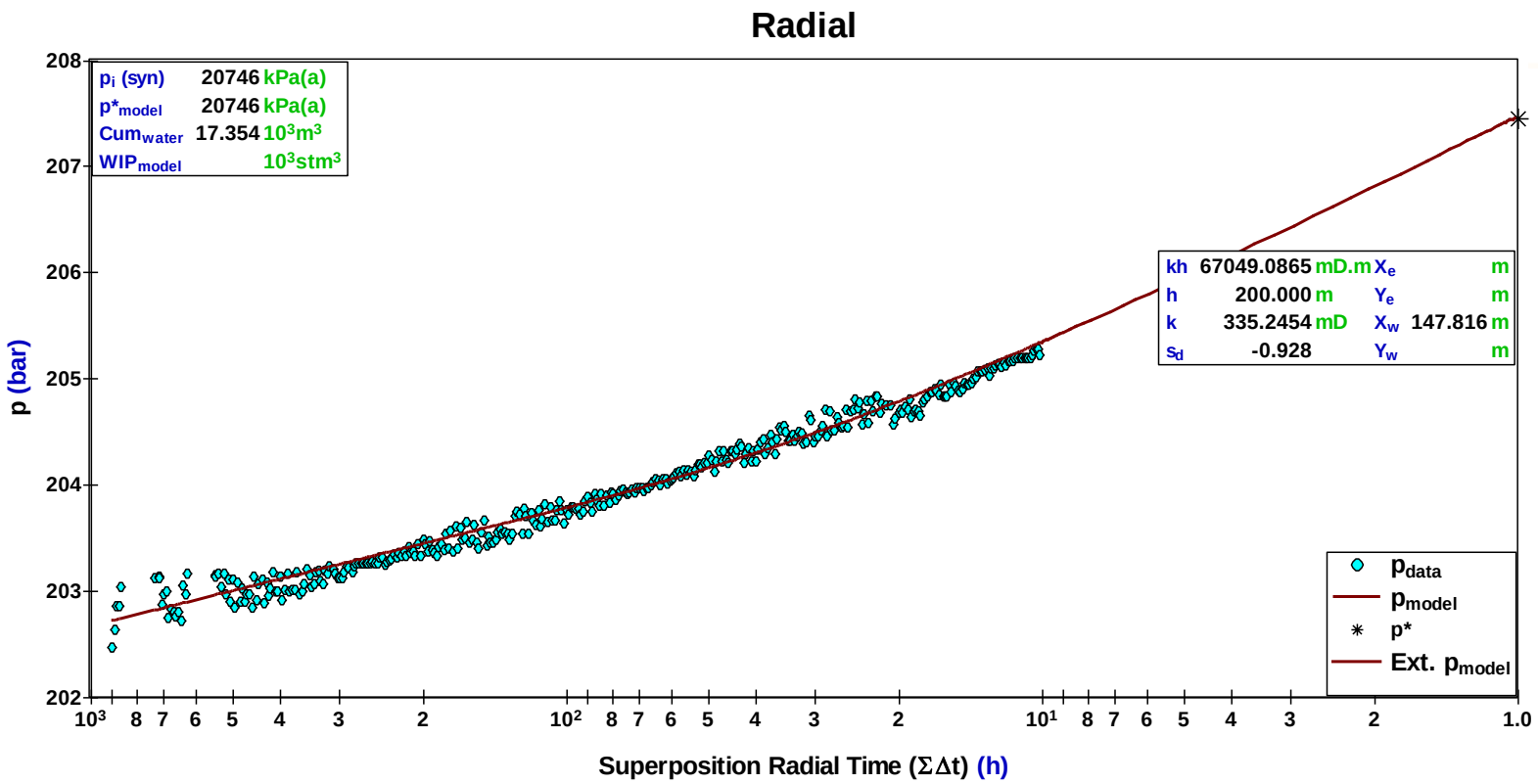
ADK-GT-02 – Model A Derivative plot



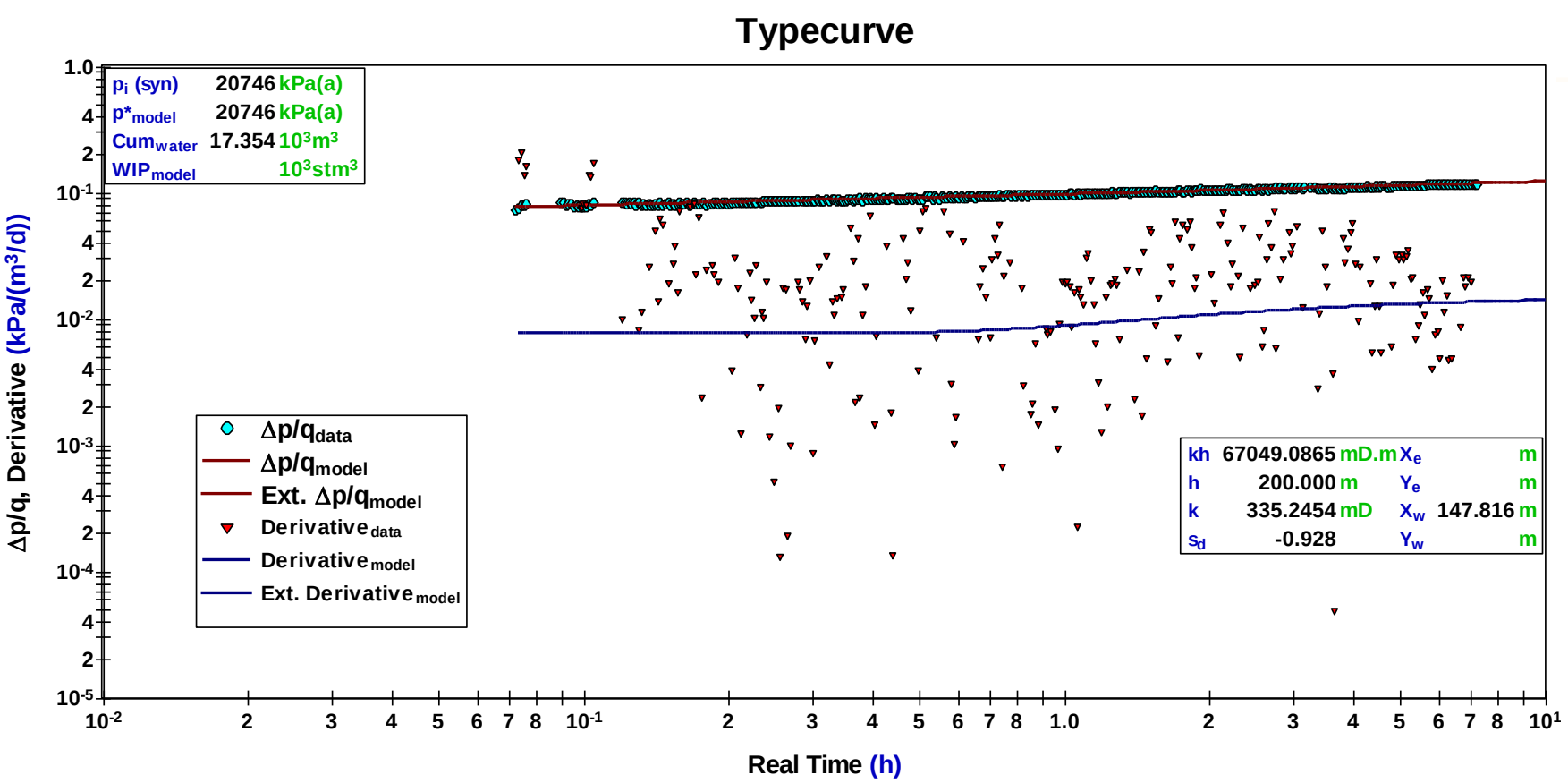
ADK-GT-02 – Model B



ADK-GT-02 – Model B– Radial (Horner) Plot



ADK-GT-02 – Model B Derivative plot



ADK-GT-03 Test Analysis

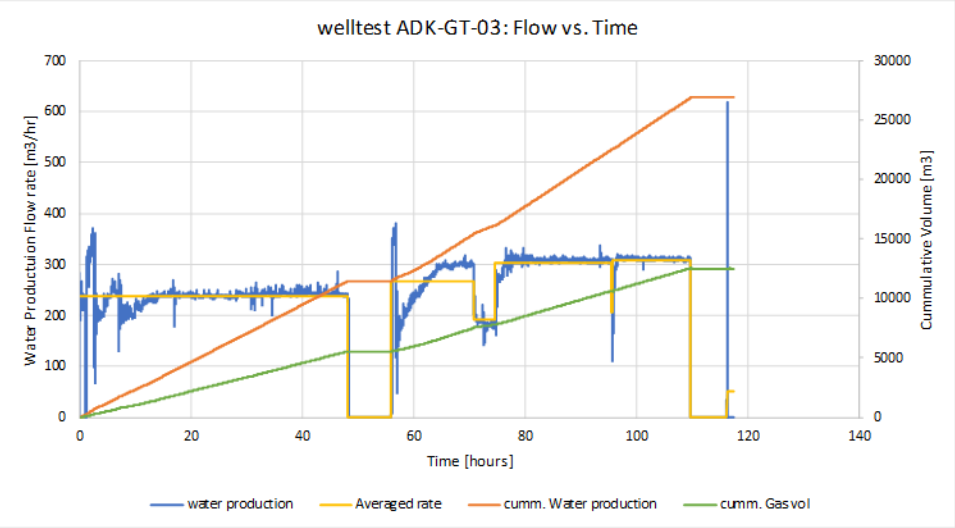
ADK-GT-03
Data for test interpretation

Data for test interpretation	Value	Dimension
Well location: X Coordinates Y Coordinates	 141,929.10 526,431.85	 RD RD
Well Total Depth	2275 2056	m BGL AH m BGL TVD
Aquifer top	2047 1876	M BGL (MD) M BGL (TVD)
Aquifer base	2255 2040	m BGL (MD) m BGL (TVD)
Aquifer thickness	164	m (TVD)
Aquifer Net/Gross (NTG)	98	%
Average aquifer porosity	21.5	%
Formation water salinity (TDS)	189000	ppm
Average initial reservoir pressure	205.5	bar @ 1960 m BGL TVD
Stabilized temperature of produced water	84	^{o}C
Temperature gradient	3.1	$^{\circ}$ C/100m
Casing 28“	90	m BGL (TVD)
Casing 18 5/8”	523	M BGL (TVD)
Casing 13 3/8”	1279	m BGL(TVD)
Liner 9 5/8”	1833	M BGL (TVD)
Liner 7”	1792	m BGL(TVD)
Borehole diameter at aquifer	8.5	inch
Pump location	797.9	m BGL (TVD)
Shallow gauge location	n.a.	
Deep wireline gauge location	n.a.	

ADK-GT-03 Test Summary

- The ADK-GT-03 production well test started on 06-10-2018 and included a first flow period of 48.2 hours, first build-up period of 7.8 hours, second flow period of 53.7 hours and a final build-up period of 6.5 hours.
- Reservoir fluid was produced with an Electric Submersible pump (ESP). The water production rates varied between 100 and 330 m3/hr with a cumulative production of 26892 m^3
- The pressure and temperature data from the well are only recorded by the ESP gauge (No downhole gauge).
- The maximum drawdown achieved was some 17.5 bar at an offtake of 310 m3/hr during the last flow period.
- The post-test reservoir pressure of the producing Slochteren sandstone derived from the first build-up is 212 bar at the mid reservoir (1958 m BGL TVD).
- Transient flow capacity (PI) after 87 hours flow is 18 m3/hr/bar.

ADK-GT-03 Test Summary



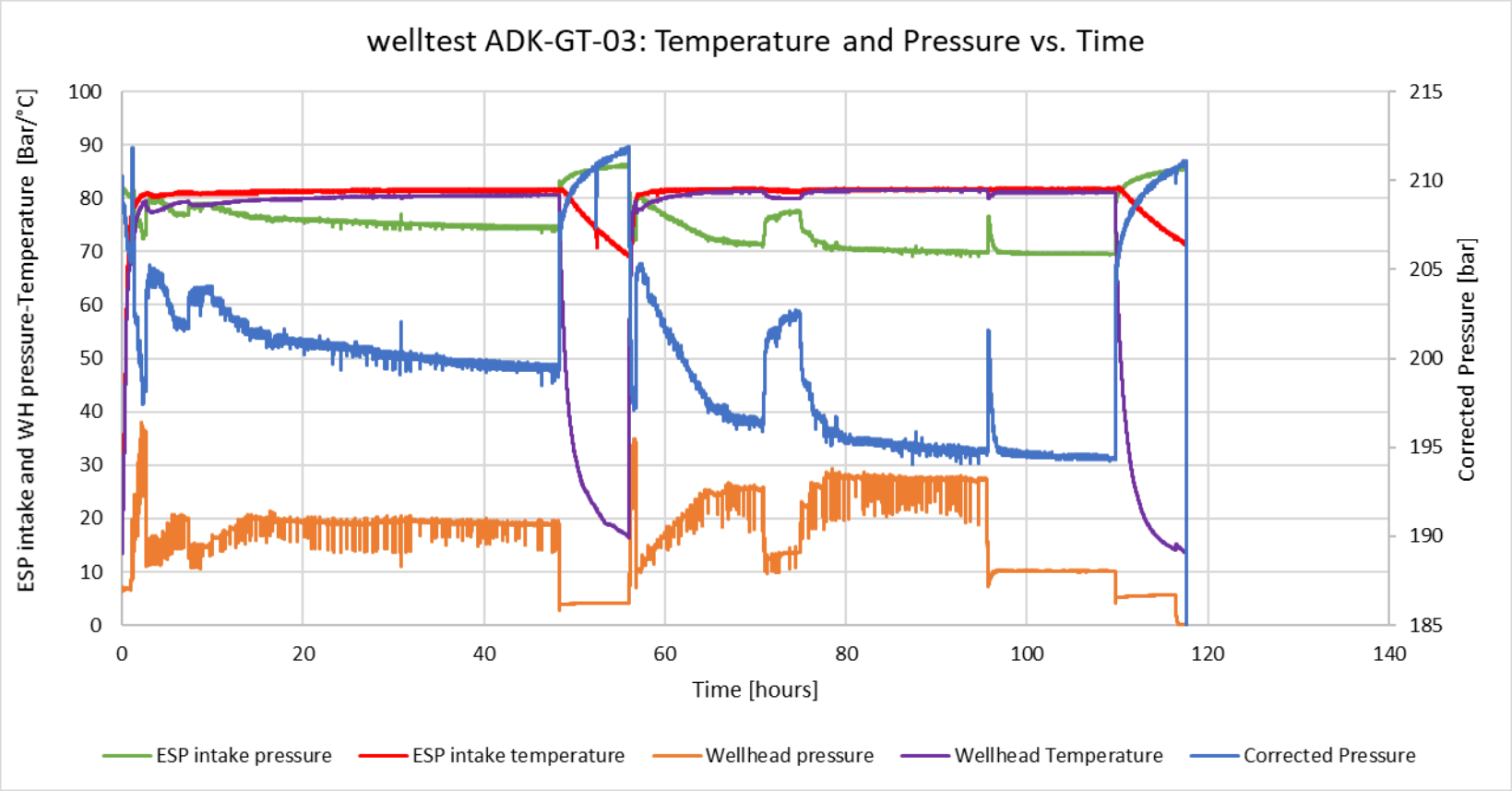
Start of event	Start time		Duration	Rate		Volume	Bottom hole pressure	Productivity Index
	(Days)	(Hours)	(Hours)	(m^3/d)	(m^3/hr)	(m^3)	(bar)	m^3/hr/bar
Flow 1	06-10-2018	15:35	48.2	5688	237	11423	199.4	18.8
BU 1	08-10-2018	08:47	7.8	0	0	0	n.a	n.a
Flow 2	08-10-2018	14:33	14.7	6456	269	3954	196.3	17.1
Flow 3	08-10-2018		3.7	4608	192	710	201.0	17.5
Flow 4	11-10-2018		35.2	7344	306	10771	194.4	17.4
BU 2	11-10-2018		6.5	0	0	0	n.a	n.a
					Total volume:	26859		

Pressure-Temperature correction

- The ESP pressure recording was extrapolated to the mid reservoir depth at 1966 m TVD in order to correct for the cooling of the water column within the wellbore, and depth gradient.
- The extrapolation function used to calculate the pressure difference between ESP (or gauges) depth and top reservoir depth, is very similar to that obtained from the test data of other Slochteren reservoir wells, including previous well test analysis of ADK-GT-01 (Dec. 2017).
- $DP = CDC*L*\{1089.5+0.4931*(82-T)-0.003*(82-T)^{2}\}$
- $\Delta p(bar) = C_1*L*\{\rho_w+C_a*(T_{max}-T_{top})-C_b*(T_{max}-T_{top})^2\}$

  Where,
  - C_1 =0.000098063 if pressure in bar
  - L is the m TVD difference to the mid reservoir
  - C_a = 0.4931 and C_b = 0.003
  - T_{max} is the maximum recorded temperature in °C
  - T_{top} is the current temperature at the recorded depth
- The water salinity ρ_w was first calculated from the pressure difference of ESP and bottom gauge in the first well test (2017). A pressure gradient of 0.1070 bar/m, or 1089 kg/m3 which indicates a salinity of 189 kg/m3 NaCl equivalent
- Extrapolation of the temperature recorded by the bottom gauge during flow period 4 indicates a final stabilized temperature of 82 °C of the produced water corresponding to a geothermal gradient of 3.4 °C /100m, assuming 15°C surface temperature.
- Total system compressibility was set to 8.3E-7 1/KPa, and the reservoir water viscosity to 0.53 cP.

Pressure-Temperature correction



Analysis of corrected pressure data

- The large dataset within the gauges were reduced using a combination of time and resolution filters. An Arithmetic filter for flow periods, and a Logarithmic filter for shut-in periods were used.
- The average porosity has been estimated at 21.5%. Net thickness is 160.2 mtv. The water viscosity and water compressibility have been based on the salinity: μ_w = 0.53 cP and C_w = 3.2E-7 1/kPa respectively.
- The build-up period is too short and the derivative plot is so scattered that it is not possible to make a conclusive diagnosis of a near well boundary. three models were matched:
  - Model A: a fault at 20 m from the well
  - Model B: without a near well boundary
  - Model C: Composite model with higher permeability at updip eastern area
- Model A gives a better match for the second build-up test, while model B & C give better matches for the first Build-up test. Model A and C give better match for the Horner plot of the Second Build-up. In general, permeability estimated from Model A is the most likely scenario.
- Model A: evaluation of the test indicates an average reservoir permeability of about 229 mD of the 160.2m sand layer. Total final skin is low at -2
- Model B: evaluation of the test indicates an average reservoir permeability of about 130 mD of the 160.2 m sand layer. Total final skin is low at -3
- Model C: evaluation of the test indicates an average reservoir permeability of about 120 mD at a radius of 272 m around the well and then higher permeability of 240 mD further from the well. Total final skin is low at -3
- The static reservoir pressure at mid reservoir depth of 1966 mtv is 212 bara
- The reservoir temperature is about 82 °C.
- Transient flow capacity (PI) is 17.5 m3/hr/bar.

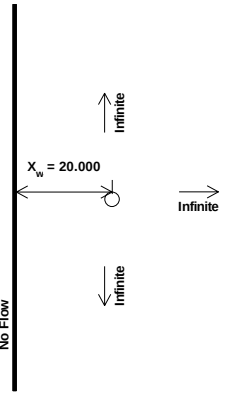
ADK-GT-03 Models

Model A

k = 229.0406 mD
s_d = -2.063

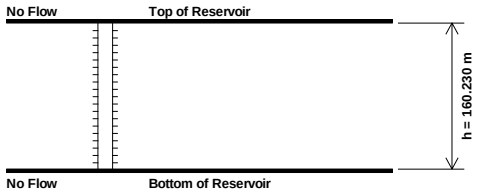
Plan View

(Not to scale)



Side View

(Not to scale)

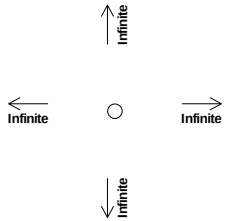


Model B

k = 130.0000 mD
s_d = -3.233

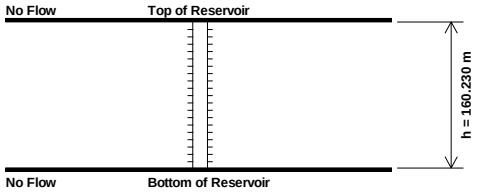
Plan View

(Not to scale)



Side View

(Not to scale)

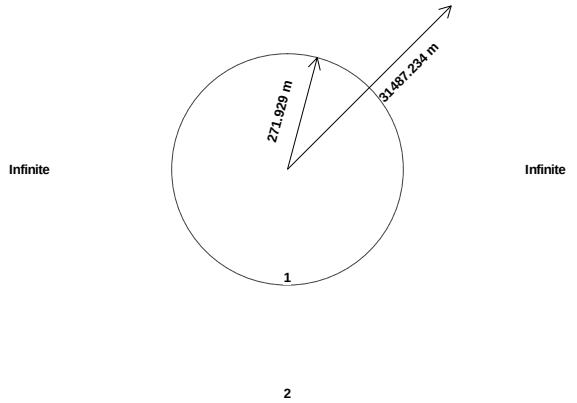


Model C

s_d = -3.523
k_1 = 120.0000 mD
k_2 = 240.0000 mD

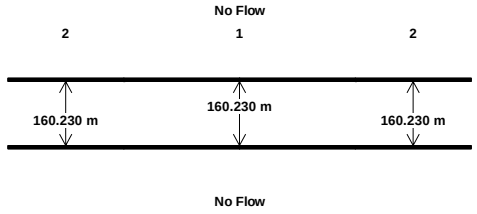
Plan View

(Not to scale)

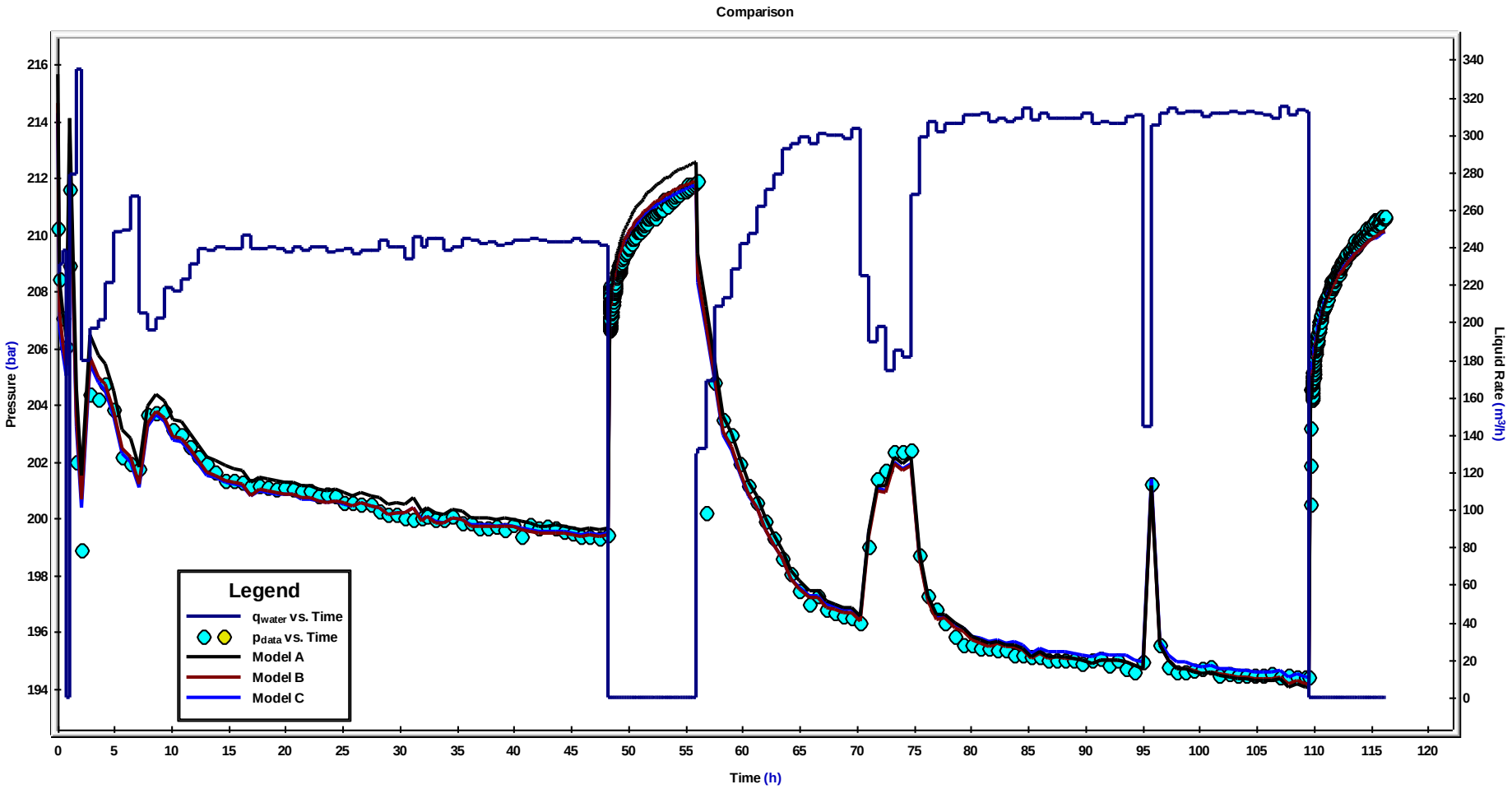


Side View

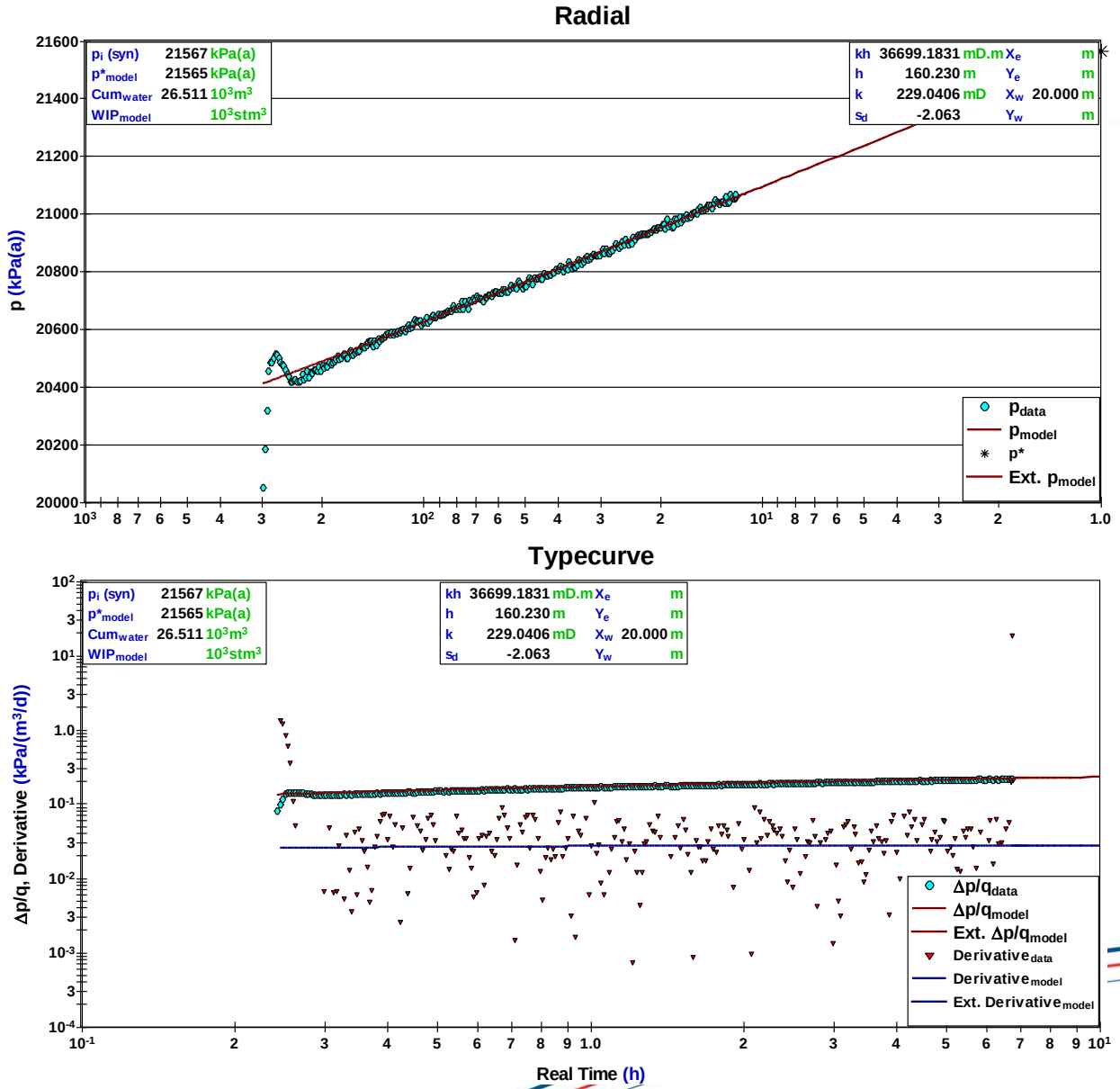
(Not to scale)



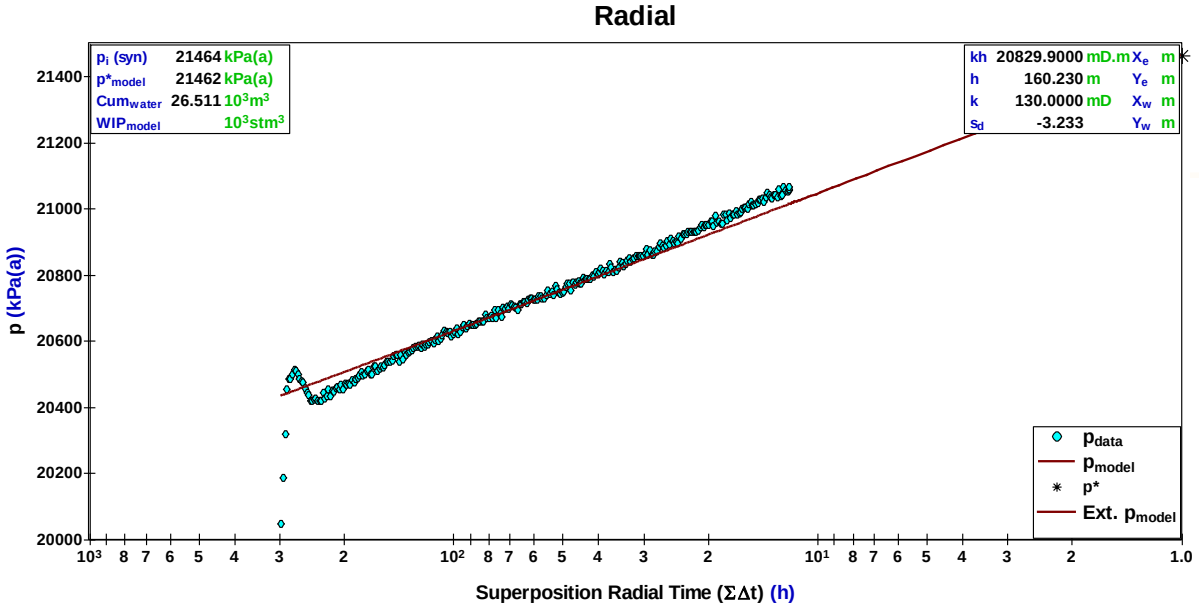
ADK-GT-03 –Comparison of three models

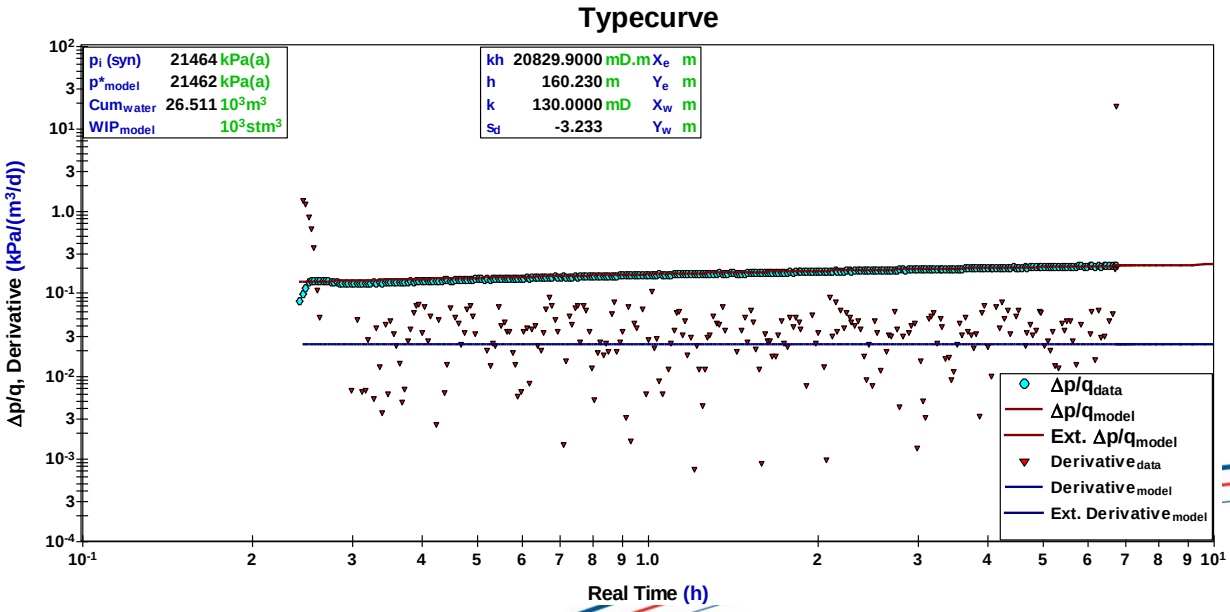


ADK-GT-03 Model A – Radial and derivative plots

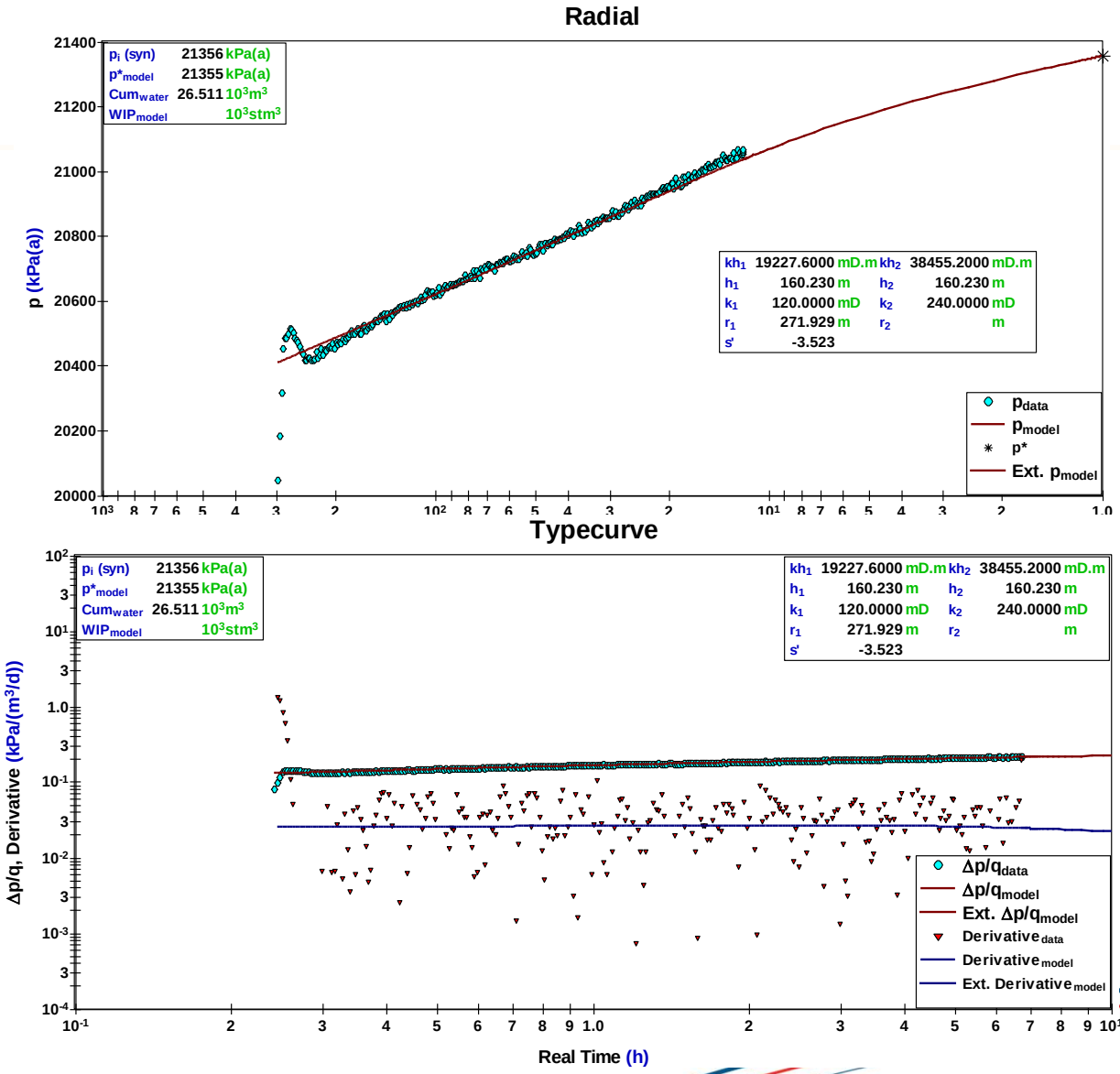


ADK-GT-03 Model B





ADK-GT-03 Model C



ADK-GT-04 Test Analysis

ADK-GT-04

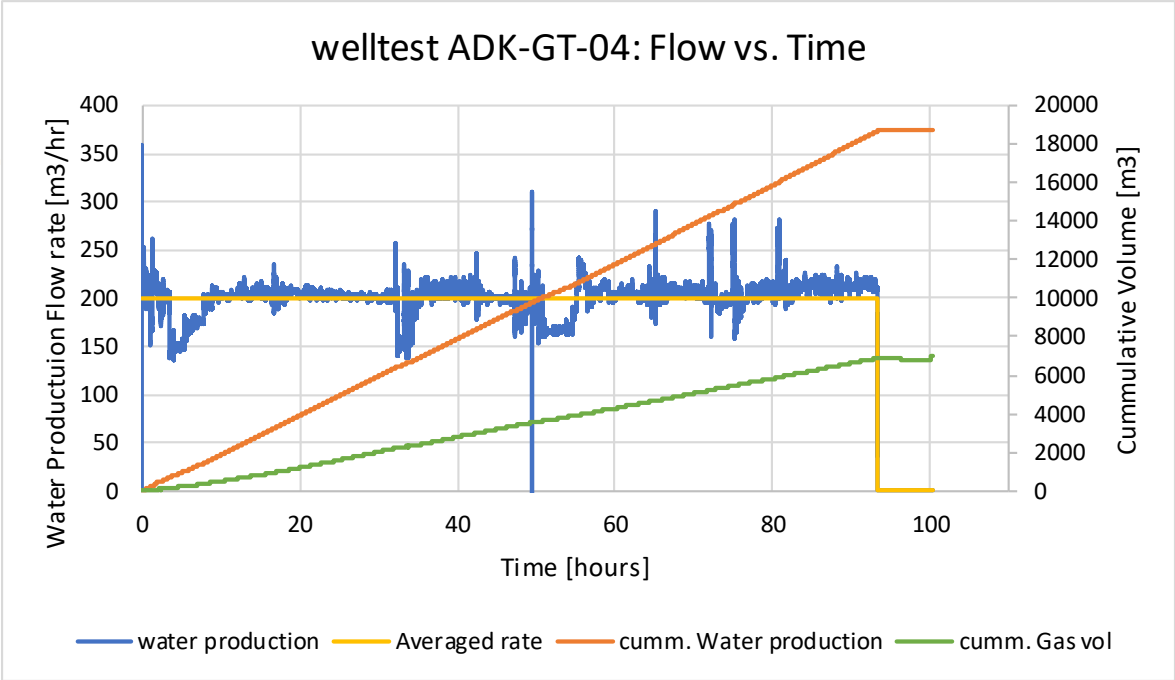
Data for test interpretation

Data for test interpretation	Value	Dimension
Well location: X Coordinates Y Coordinates	 141,931.52 526,424.71	 RD RD
Well Total Depth	2159 1949	m BGL AH m BGL TVD
Aquifer top	1979 1802	M BGL (MD) M BGL (TVD)
Aquifer base	2138 1932	m BGL (MD) m BGL (TVD)
Aquifer thickness	130	m (TVD)
Aquifer Net/Gross (NTG)	98	%
Average aquifer porosity	22	%
Formation water salinity (TDS)	189000	ppm
Average initial reservoir pressure	196	bar @ 1960 m BGL TVD
Stabilized temperature of produced water	80	^{o}C
Temperature gradient	3.1	$^{\circ}$ C/100m
Casing 28“	92	m BGL (TVD)
Casing 18 5/8”	523	M BGL (TVD)
Casing 13 3/8”	1268	m BGL(TVD)
Liner 9 5/8”	1798	M BGL (TVD)
Liner 7”	1755	m BGL(TVD)
Borehole diameter at aquifer	8.5	inch
Pump location	750.3	m BGL (TVD)
Shallow gauge location	n.a.	
Deep wireline gauge location	n.a.	

ADK-GT-04 Test Summary

- The ADK-GT-04 production well test started on 24-09-2018 and included a single rate production test of 93.3 hours and a final build-up period of 7.0 hours.
- Reservoir fluid was produced with an Electric Submersible pump (ESP). The water production rates varied between 150 and 250 m3/hr with a cumulative production of 18660 m^3
- The pressure and temperature data from the well are only recorded by the ESP gauge (No downhole gauge).
- The maximum drawdown achieved was some 14 bar at an offtake of 210 m3/hr during the last flow period.
- The post-test reservoir pressure of the producing Slochteren sandstone derived from the build-up is 203 bar at the mid reservoir (1867 m BGL TVD).
- Transient flow capacity (PI) after 90 hours flow is 15 m3/hr/bar.

ADK-GT-04 Test Summary



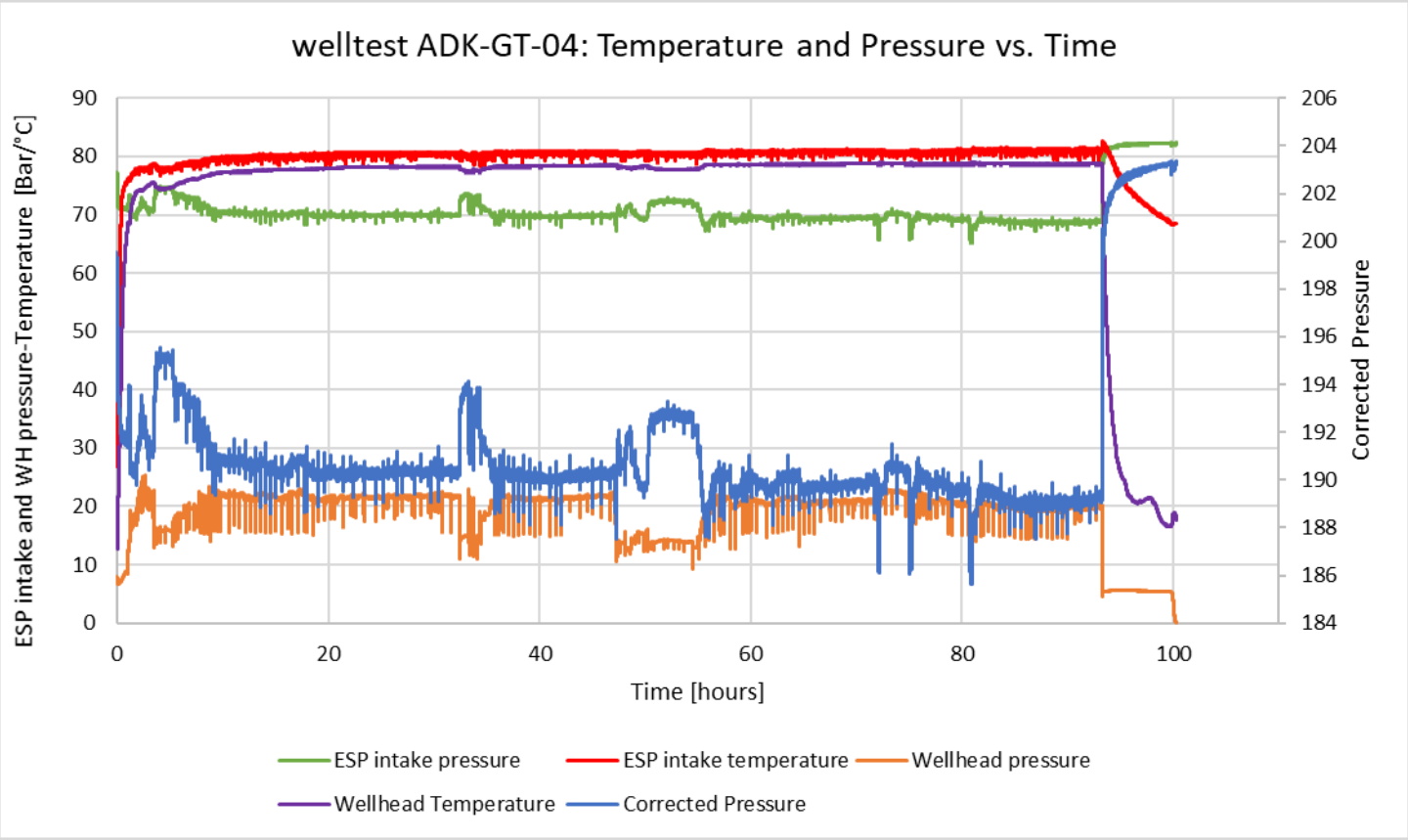
Start of event	Start time		Duration	Rate		Volume	Bottom hole pressure	Productivity Index
	(Days)	(Hours)	(Hours)	(m^3/d)	(m^3/hr)	(m^3)	(bar)	m^3/hr/bar
Flow	24-09-2018	12:29	93.3	4800	200	18660	189.6	15
BU	28-09-2018	09:47	7	0	0	0	n.a	n.a
					Total volume:	18660		

Pressure-Temperature correction

- The ESP pressure recording was extrapolated to the mid reservoir depth at 1876 m TVD in order to correct for the cooling of the water column within the wellbore, and depth gradient.
- The extrapolation function used to calculate the pressure difference between ESP (or gauges) depth and top reservoir depth, is very similar to that obtained from the test data of other Slochteren reservoir wells, including previous well test analysis of ADK-GT-01 (Dec. 2017).
- $DP = CDC*L*\{1089.5+0.4931*(81.5-T)-0.003*(81.5-T)^{2}\}$
- $\Delta p(bar) = C_1*L*\{\rho_w+C_a*(T_{max}-T_{top})-C_b*(T_{max}-T_{top})^2\}$

  Where,
  - C_1 =0.000098063 if pressure in bar
  - L is the m TVD difference to the mid reservoir
  - C_a = 0.4931 and C_b = 0.003
  - T_{max} is the maximum recorded temperature in °C
  - T_{top} is the current temperature at the recorded depth
- The water salinity ρ_w was first calculated from the pressure difference of ESP and bottom gauge in the first well test (2017). A pressure gradient of 0.1070 bar/m, or 1089 kg/m3 which indicates a salinity of 189 kg/m3 NaCl equivalent
- Extrapolation of the temperature recorded by the bottom gauge during flow period indicates a final stabilized temperature of 81.5 °C of the produced water corresponding to a geothermal gradient of 3.54 °C /100m, assuming 15°C surface temperature.
- Total system compressibility was set to 8.3E-7 1/KPa, and the reservoir water viscosity to 0.55 cP.

Pressure-Temperature correction



Analysis of corrected pressure data

- The large dataset within the gauges were reduced using a combination of time and resolution filters. An Arithmetic filter for flow periods, and a Logarithmic filter for shut-in periods were used.
- The average porosity has been estimated at 22%. Net thickness is 127.4 mtv. The water viscosity and water compressibility have been based on the salinity: μ_w = 0.55 cP and C_w = 3.2E-7 1/kPa respectively.
- The build-up period is too short to establish a boundary effect. A permeability variation can be seen in the Horner plot. Two models were matched:
  - Model A: A constant permeability without boundaries
  - Model B: A Composite model with higher permeability at updip south east area
- Model B gives a very good match for the Horner plot and is in line with the geological understanding.
- Model A: evaluation of the test indicates an average reservoir permeability of about 266 mD of the 127.4 m sand layer. Total final skin is low at 1
- Model B: evaluation of the test indicates an average reservoir permeability of about 130 mD at a radius of 75 m around the well and then higher permeability of 350 mD further from the well. Total final skin is low at -2.5
- The static reservoir pressure at mid reservoir depth of 1876 mtv is 203 bara
- The reservoir temperature is about 81 °C.
- Transient flow capacity (PI) is 15 m3/hr/bar.

ADK-GT-04 Models

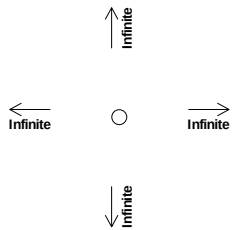
Model A

Vertical 1

$k = 266.1882$ mD
$s_d = 1.252$

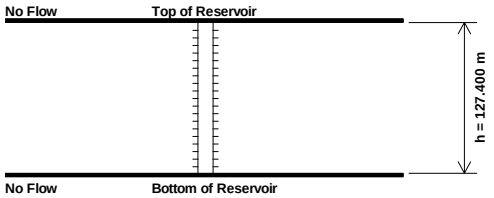
Plan View

(Not to scale)



Side View

(Not to scale)



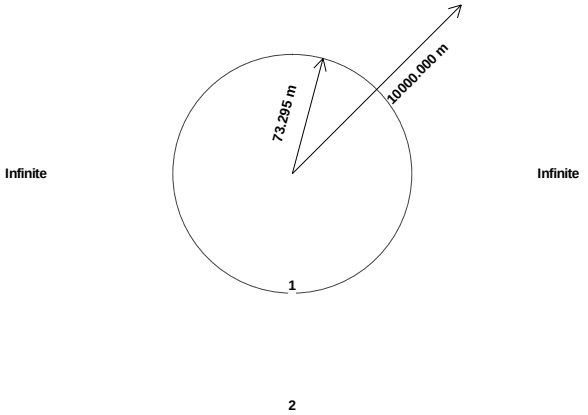
Model B

Composite 1

$s_d = -2.660$
$k_1 = 130.0000$ mD
$k_2 = 350.0000$ mD

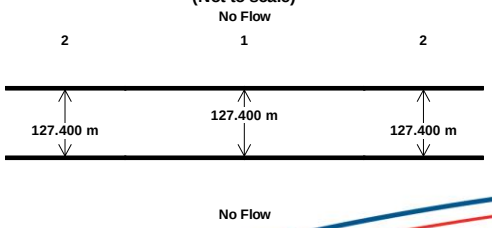
Plan View

(Not to scale)

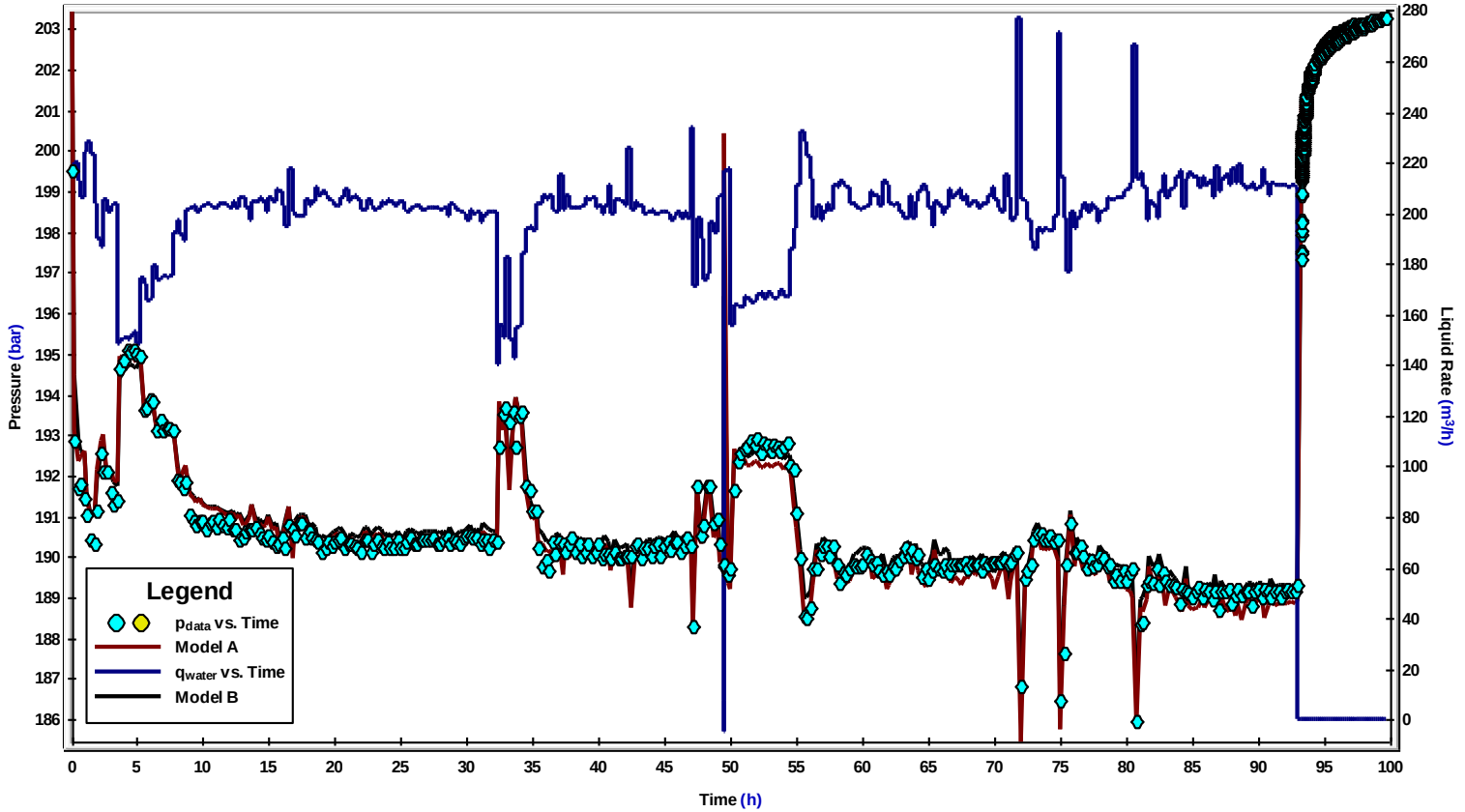


Side View

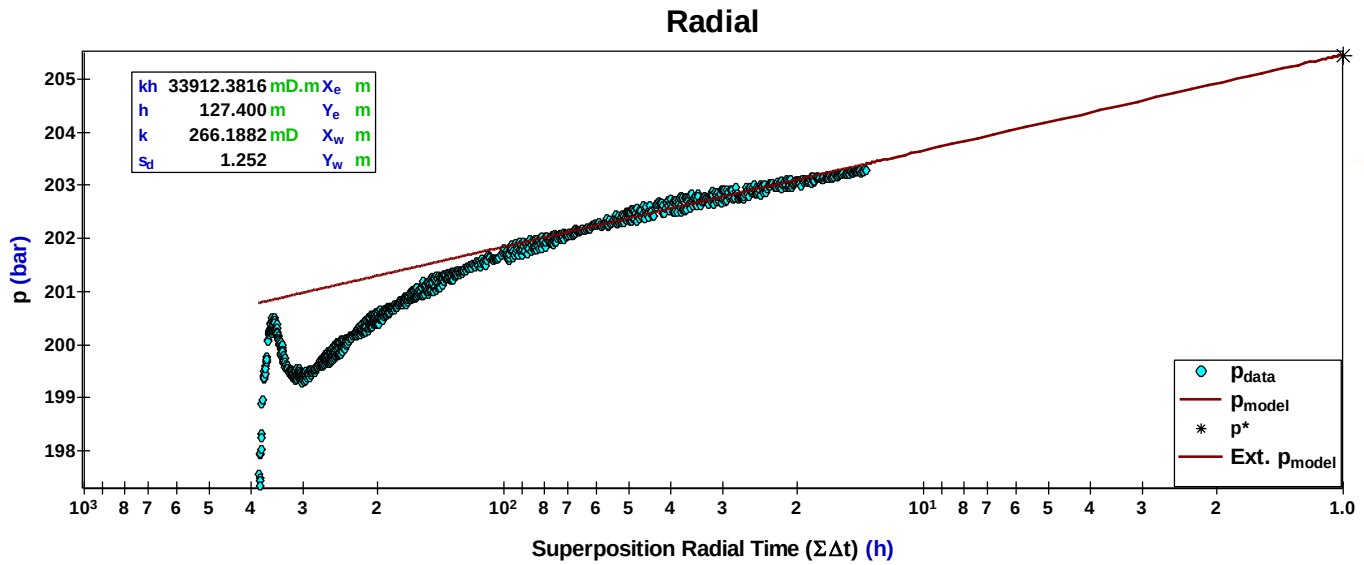
(Not to scale)

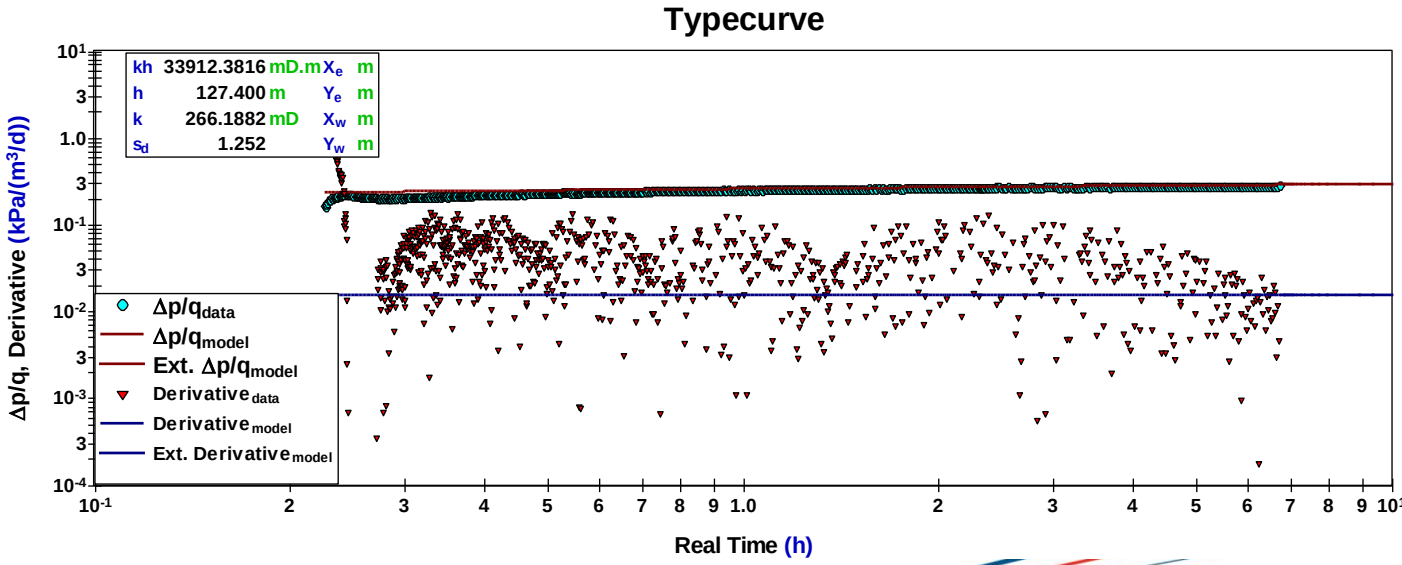


ADK-GT-04 –Comparison of three models

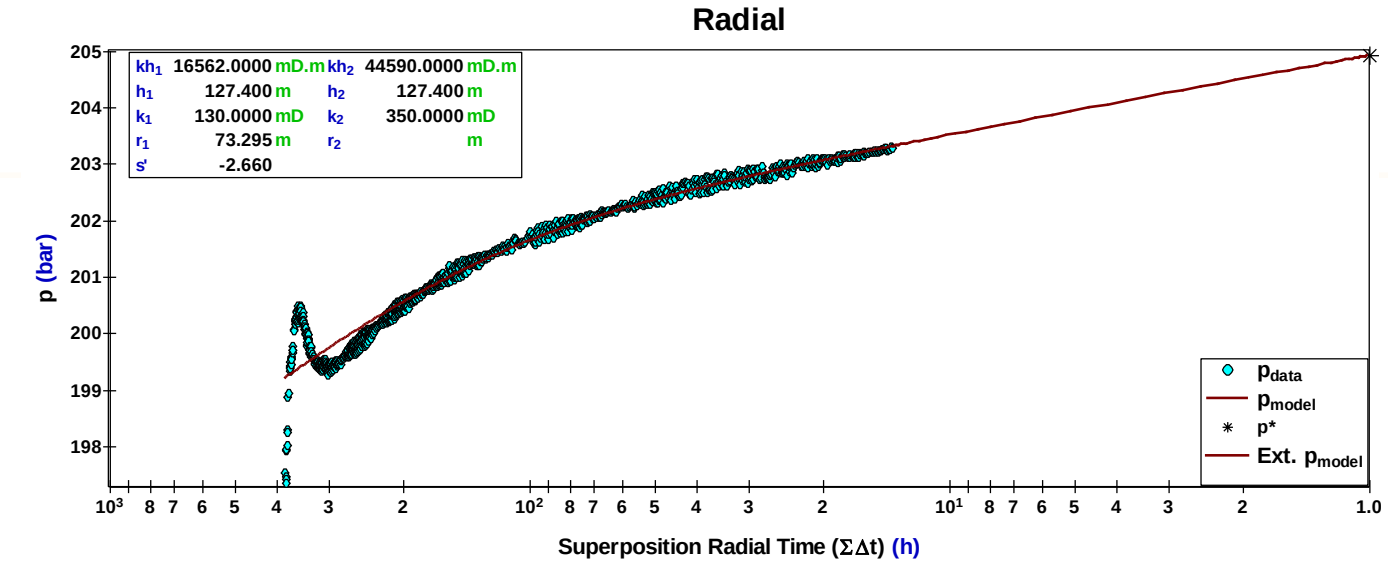


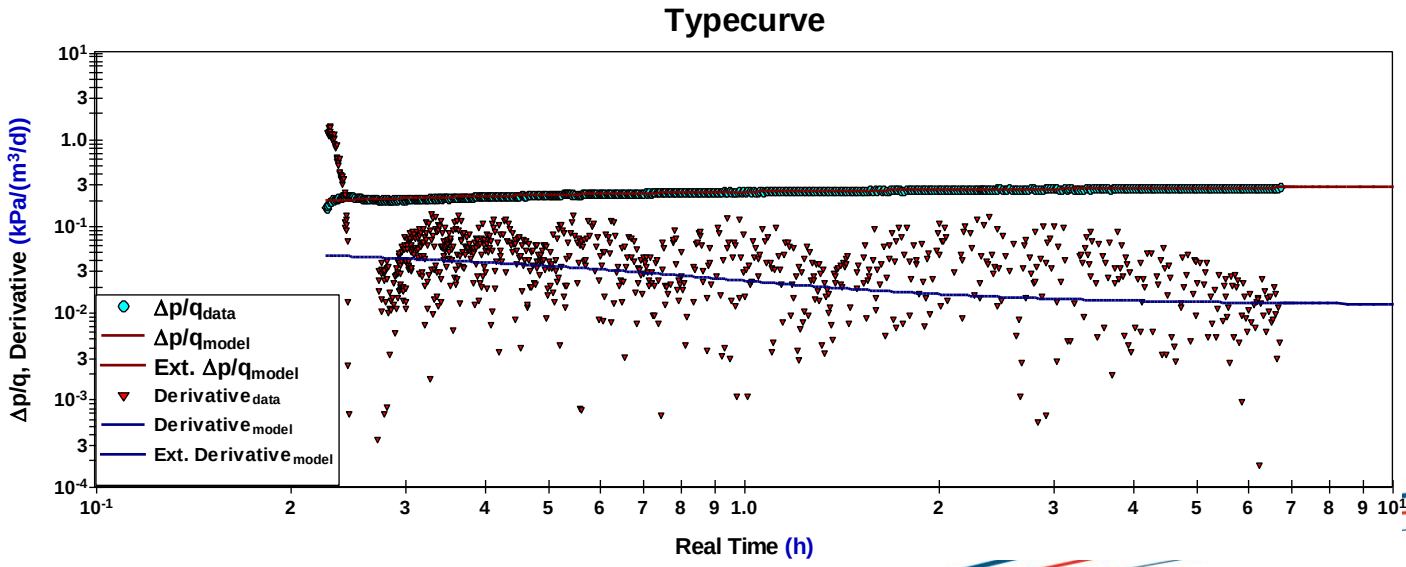
ADK-GT-04 Model A





ADK-GT-04 Model B





Injection Effect

- During the well tests GT-02/03/04; the remainder of the produced water (after producing approximately 750 m^3) was directly injected via a closed loop into GT-01
- It is believed that this injection into GT-01 has no noticeable effect on pressure derivative and consequently on well test analysis of other wells.
- Injection into GT-01 has no noticeable effect on estimated drawdown and PI for GT-03&4 due to the flow barrier (faults) between them. Though, the interference test indicates a small communication
- The interference test indicates an excellent communication between GT-01 and GT-02. Assuming the injection rate of 200 m3/hr for 100 hrs and a cumulative water injection of 20k m3 in GT-02, the model shows that the maximum pressure increase in GT-02 is about 0.8 bar. Based on this, It is expected that the injection into GT-01, could only have limited effect (less than 5%) on estimation of productivity index (PI) in well GT-02

GT-01&04 Injectivity

- During the GT-03 production test, the water was injected into GT-01 during the first flow period and then into GT-04 during the second flow period.
- GT-01 could not take more than 210 m3/hr with 50 bar injection pressure (Injectivity index of about 3.8 m3/hr/bar)
- GT-04 could take 300 m3/hr with 35 bar injection pressure (Injectivity index of about 7.3 m3/hr/bar)
- The estimated initial injectivity index of GT-01 (from the model) is 10 m3/hr/bar and then it decreases to 5 over time
- The estimated initial injectivity index of GT-04 is 9 m3/hr/bar and it decreases to 7 m3/hr/bar over time
- Over time, The injectivity of the injector will decline due to the expansion of the area of cold, more viscous, water around the well. Injectivity is strongly temperature-dependent, decreasing greatly with decreased temperature difference between injectate and reservoir fluid. The injectivity is inversely related to the water viscosity.

Conclusions

- The Clean-out / Well Test ADK-GT-01, 02, 03 & 04 have been successful in establishing an accurate estimate of reservoir permeability of about 120 - 350 mD at different wells and demonstrates that there is a low skin factor and no severe formation damage in the wells.
- In general, Well ADK-GT-02 shows better reservoir quality and productivity index compared to other wells. The PI of the well GT-02 is high at 37 m3/hr/bar
- The observed total net sand thickness ranges from 130 m (in GT-04) to 204 m (GT-02).
- The reservoir pressure and temperature are in line with expectations.
- In general, the pressure build-up periods were too short to derive the position of no flow boundaries. In future flow tests it is recommended to extend the shut in period.
- A better definition of the boundaries around these wells and the long-term steady-state PI were obtained from the interference tests (see Andijk Wells Interference Test report, 20-09-2018 project 1251)