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Oskarshamn site investigation

Hydraulic interference tests, pumping borehole KLX08

Subarea Laxemar

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December 2007

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Keywords: Site/project, Hydrogeology, Hydraulic tests, Pump tests, Interference tests, Hydraulic parameters, Transmissivity.

Abstract

Hydraulic interference tests have been performed at the Laxemar area in the active pumping borehole KLX08 in three different sections. During the pumping phase the pressure response in 19 observation boreholes was monitored in up to ten different intervals per borehole, which were separated with packers. 5 L water sample was taken by SKB at the end of each pumping phase. Theses samples were analysed according to the class 3 level. The tests are part of the general program for site investigations and specifically for the Laxemar subarea. Following the interference tests, hydraulic injection tests in 100 m and 20 m intervals were performed /Enachescu et al. 2007/. The hydraulic testing programme has the aim to characterise the rock with respect to its hydraulic properties and the interference tests have the purpose to resolve hydraulic connectivity in the fracture network, especially to the selected lineament EW007. Data is subsequently delivered for the site descriptive model.

This report describes the results and primary data evaluation of the interference tests in borehole KLX08 performed between 27th August and 27h of September 2006. The data of the observation boreholes were delivered by SKB.

The main objective of the interference testing was to characterize the rock around the borehole with special respect to connectivity of lineaments. Transient evaluation of the flow and recovery period of the constant rate interference pump tests provided additional information such as transmissivities, flow regimes and hydraulic boundaries.

Sammanfattning

Hydrauliska interferenstester har utförts i Laxemarområdet med pumpning i borrhål KLX08 i tre sektioner. Under pumpningen har tryckresponsen uppmätts i 19 observationshål i upp till tio sektioner per borrhål med dubbelmanschett. I slutet av varje pumpfas togs av SKB ett 5 liters vattenprov för klass 3 analys. Interferenstesterna är en del av platsundersökningarna och specifikt för Laxemar området. Före interferenstesterna utfördes hydrauliska injektionstester om 100 och 20 m sektioner /Enachescu m fl 2007/. Hydraultestprogrammet har som mål att karakterisera berget utifrån dess hydrauliska egenskaper och interferenstesterna har som syfte att undersöka konnektiviteten mellan sprickzoner, särskilt till lineament EW007. Erhållna data utgör sedan indata för den platsspecifika modellen.

Följande rapport redovisar resultaten och primärdata från utvärderingen av interferenstesterna i borrhål KLX08 utförda mellan den 27 augusti till den 27 september 2006. Data från observationshålen levererades av SKB.

Huvudsyftet med interferenstesterna var att karakterisera berget i anslutning till borrhålet med avseende på konnektivitet mellan olika lineament. Transient utvärdering av flödes- och återhämtningsfasen för pumptesterna utförda med konstant flöde vid interferenstesten har givit ytterligare information med avseende på transmissivitet, flödesregim och hydrauliska gränser.

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1 Introduction

A general program for site investigations presenting survey methods has been prepared /SKB 2001a/ as well as a site specific program for the investigations in the Laxemar area /SKB 2006/. The hydraulic interference tests form part of the site characterization program in the work breakdown structure of the execution program /SKB 2002/. The execution of the investigations is basically controlled through a general program /SKB 2001a/ and a program specifically for the Oskarshamn location /SKB 2001b/.

This document reports the results gained by the hydraulic interference tests (pumping tests) performed in borehole KLX08, which is one of the activities performed within the site investigation at Oskarshamn. The work was carried out in accordance with activity plan AP PS 400-06-001. In Table 1-1 controlling documents for performing this activity are listed. Both activity plan and method descriptions are SKB's internal controlling documents.

Hydraulic interference tests (pumping tests) have been performed in borehole KLX08 in three different sections with section lengths of 100 m and 140 m. Monitoring of pressure response was carried out by SKB in 19 additional boreholes (see Figure 1-1), monitoring data were delivered by SKB for further analyses.

Measurements were carried out between 27th August and 27th of September 2006 following the methodologies described in SKB MD 321.003 (pump tests), SKB MD 330.003 (interference tests), the activity plan AP PS 400-06-001 (SKB internal controlling documents) specifying in detail the interference tests campaign. Data and results were delivered to the SKB site characterization database SICADA where they are traceable by the activity plan number.

The hydraulic testing programme has the aim to characterise the rock with respect to its hydraulic properties of the fractured zones and rock mass between them. This report describes the results and primary data evaluation of the interference tests in borehole KLX08. The commission was conducted by Golder Associates AB and Golder Associates GmbH.

Difference flow logging was carried out in KLX08 from July to October 2005, including measurements of electric conductivity and temperature. After getting stuck in the borehole, parts of the flow logging device still remain in the borehole. Therefore the borehole was accessible only until a final depth of 970 m below TOC. The results of the difference flow logging were used to estimate the expected flow rate in the pump sections.

Table 1-1. Controlling documents for the performance of the activity.

Activity plan	Number	Version
Hydraulic pumping and injection tests in borehole KLX08	AP PS 400-06-001	1.0
Method descriptions	**Number**	**Version**
Analysis of injection and single-hole pumping tests	SKB MD 320.004e	1.0
Hydraulic injection tests	SKB MD 323.001	1.0
Metodbeskrivning för interferenstester	SKB MD 330.003	1.0
Metodbeskrivning för hydrauliska enhålspumptester	SKB MD 321.003	1.0
Instruktion för rengöring av borrhålsutrustning och viss markbaserad utrustning	SKB MD 600.004	1.0
Instruktion för längdkalibrering vid undersökningar i kärnborrhål	SKB MD 620.010	1.0
Allmäna ordning-, skydds- och miljöregler för platsundersökningar Oskarshamn	SKB SDPO-003	1.0
Miljökontrollprogram Platsundersökningar	SKB SDP-301	1.0
Hantering av primärdata vid platsundersökningar	SKB SDP-508	1.0

The pumping borehole KLX08 is situated in the Laxemar area approximately 4 km north-west of the nuclear power plant of Simpevarp, Figure 1-1. The borehole was drilled from January to June 2005 at 1,000.41 m length with an inner diameter of 76 mm and an inclination of –60.252°. The upper 12.20 m is cased with large diameter telescopic casing ranging from diameter (outer diameter) 208 mm–323 mm.

Most of the observation boreholes are located along the lineament EW007, which is located appr. 300 m south of the pumping hole and runs from west to east.

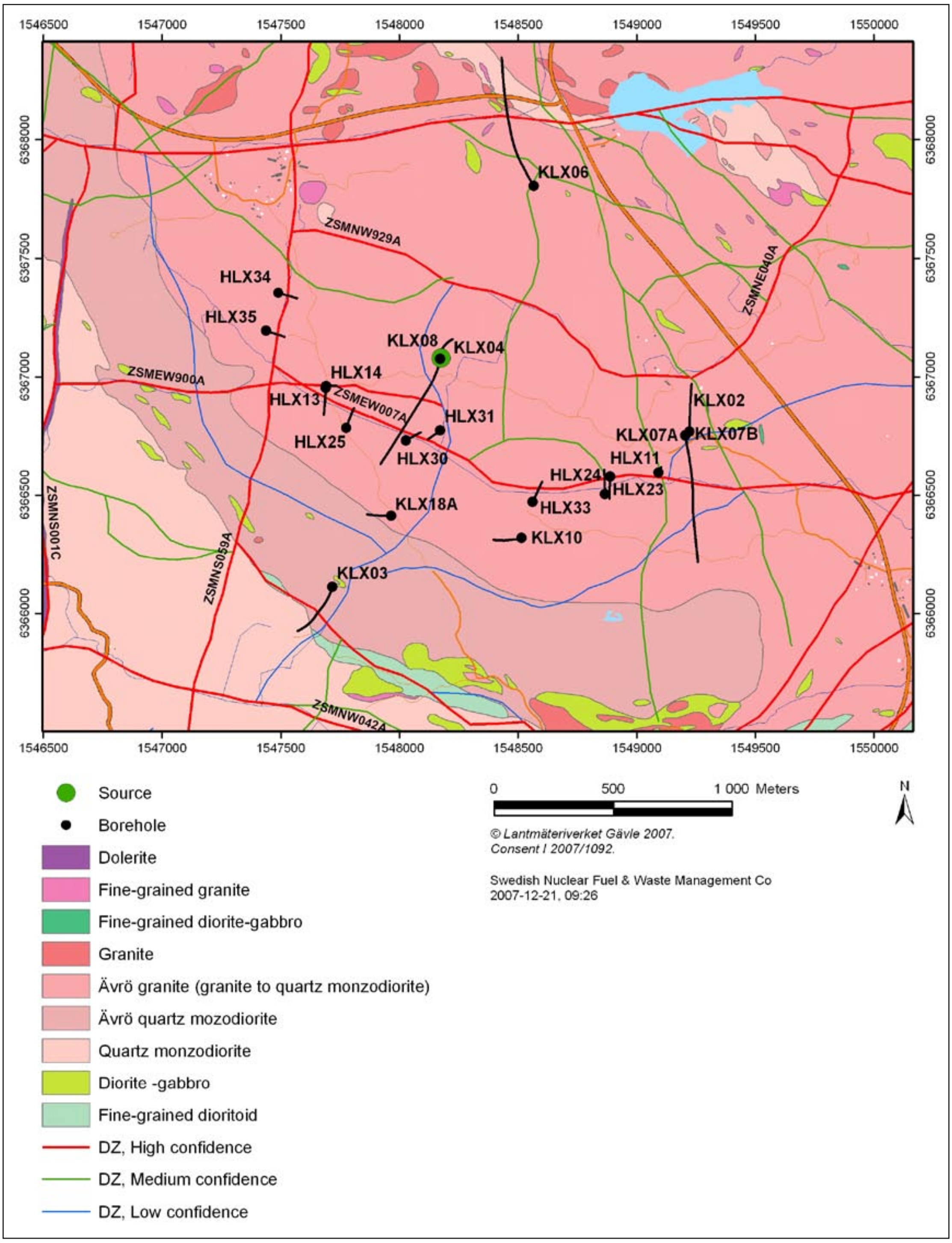

__Figure 1-1.__ The investigation area Laxemar showing the location of boreholes involved in the interference testing.

2 Objective and scope

The major objective of the performed testing program was the interference testing in order to resolve the hydraulic connectivity of and around deformation zone EW007.

Further objective of the pumping interference tests was to take water samples after each test. The water samples were taken and delivered by SKB to the chemistry laboratory at Äspö for class 3 analysis. In addition, both phases of each pump test (perturbation and recovery) were analysed to provide more information to characterize the rock around the borehole and the hydraulic properties of the tested lineament EW007.

The scope of work consisted of preparation of the PSS2 tool which included cleaning of the pump and the pump basket, calibration and functional checks and pumping tests in three different sections (100 m and 140 m section length). The required 80 m section length as specified in the activity plan for the section 241 m to 321 m was changed with agreement of SKB to a 100 m section length (241 m to 341 m) due to a lack of a 80 m long Multicable. The cleaning of the down-hole tools was done according to the required cleaning level 2 of SKB MD 600.004. The analysis and reporting for this report contains the measurements in KLX08, as well as the data of the observation boreholes, recorded, collected and delivered by SKB.

Preparation for testing was done according to the Quality plan. This step mainly consists of functions checks of the equipment to be used, the PSS2 tool. Calibration checks and function checks were documented in the daily log and/or relevant documents.

The following pump tests (Table 2-1) were performed between 27th August and 27th of September 2006.

2.1 Conditions that possibly affect the observed responses besides responses due to the source intended to study

Besides the response due to the pumping in KLX08 (source) the observed responses were influenced by earth-tidal effects.

2.2 Pumped borehole

Technical data of the borehole KLX08 is shown in Table 2-2. The reference point in the borehole is the centre of top of casing (ToC), given as Elevation in the table below. The Swedish National coordinate system (RT90) is used in the x-y direction and RHB70 in the z-direction. Northing and Easting refer to the top of the boreholes at the ground surface. Information to the observed boreholes was not presented.

Table 2-1. Performed test programme.

Borehole	Priority	Secup [mbToC]	Seclow [mbToC]	Seclen [m]	Duration Pumping [h]	Duration Recovery [h]
KLX08		102.0	242.0	140	73.3	60.1
KLX08		241.0	341.0	100	71.2	112.2
KLX08		357.0	497.0	140	72.6	93.9
Total:					217.1	266.2

Table 2-2. Information about KLX08 (from SICADA 2006-07-10).

Title	Value				
Old idcode name(s):	KLX08				
Comment:	No comment exists				
Borehole length (m):	1,000.410				
Reference level:	TOC				
Drilling period(s):	From date	To date	Secup (m)	Seclow (m)	Drilling type
	2005-01-12	2005-01-24	0.000	100.330	Percussion drilling
	2005-04-04	2005-06-13	100.330	1,000.410	Core drilling
Starting point coordinate:	Length (m)	Northing (m)	Easting (m)	Elevation (m.a.s.l.)	Coord system
(centerpoint of TOC)	0.000	6367079.103	1548176.713	24.314	RT90-RHB70 Measured
Angles:	Length (m)	Bearing	Inclination (– = down)		
	0.000	199.172	–60.252		RT90-RHB70 Measured
Borehole diameter:	Secup (m)	Seclow (m)	Hole diam (m)		
	0.300	12.200	0.343		
	12.200	100.200	0.197		
	100.200	100.330	0.165		
	100.330	101.010	0.086		
	101.010	1,000.410	0.076		
Core diameter:	Secup (m)	Seclow (m)	Core diam (m)		
	100.330	101.010	0.072		
	101.010	1,000.410	0.050		
Casing diameter:	Secup (m)	Seclow (m)	Case in (m)	Case out (m)	
	0.000				
	12.200	0.200	0.208		
	0.300	12.200	0.310	0.323	
Grove milling:	Length (m)	Trace detectable			
	111.000	YES			
	150.000	YES			
	200.000	YES			
	250.000	YES			
	300.000	YES			
	350.000	YES			
	400.000	YES			
	450.000	YES			
	500.000	YES			
	550.000	YES			
	600.000	YES			
	650.000	YES			
	700.000	YES			
	750.000	YES			
	800.000	YES			
	850.000	YES			
	900.000	YES			
	950.000	YES			
	980.000	YES			

2.3 Tests

The tests performed in KLX08 are listed in Table 2-4. They were conducted according to the Activity Plan AP PS 400-06-001 (SKB internal document). All tests were conducted as constant rate pump tests. Interference tests were carried out with additional installation of pressure transducers in selected monitoring boreholes. Groundwater data of further monitoring boreholes were provided by SKB.

At the end of each test, a 5 L water sample was taken by SKB and submitted to the SKB Äspö Laboratory for analysis.

Observations were made in the following boreholes (Table 2-3):

2.4 Control of equipment

Control of equipment was mainly performed according to the Quality plan. The basis for equipment handling is described in the "Mätssystembeskrivning" SKB MD 345.101–123 which is composed of two parts 1) management description, 2) drawings and technical documents of the modified PSS2 tool.

Function checks were performed before and during the tests. Among these pressure sensors were checked at ground level and while running in the hole calculated to the static head. Temperature was checked at ground level and while running in.

Any malfunction was recorded, and measures were taken accordingly for proper operation. Approval was made according to SKB site manager, or Quality plan and the "Mätssystem-beskrivning".

Table 2-3. Observation boreholes – see Table 5-2, 5-3 and 5-4 for distances and responses.

Bh ID	No of intervals monitored	Log time [s]	Bh ID	No of intervals monitored	Log time [s]	Bh ID	No of intervals monitored	Log time [s]
HLX11	2	60	HLX31	1	60	KLX06	8	60
HLX13	1	60	HLX33	2	60	KLX07A	8	60
HLX14	1	60	HLX34	1	60	KLX07B	2	60
HLX23	2	60	HLX35	2	60	KLX10	8	60
HLX24	2	60	KLX02	8	60	KLX18A	3	60
HLX25	2	60	KLX03	10	60			
HLX30	2	60	KLX04	8	10			

Table 2-4. Tests performed.

Bh ID	Test section (mbToC)	Test type*	Test no	Test start Date, time (yyyy-mm-dd hh:mm:ss)	Test stop Date, time (yyyy-mm-dd hh:mm:ss)
KLX08	241.0–341.0	1B	1	2006-08-30 15:02:00	2006-09-07 07:04:14
KLX08	357.0–497.0	1B	1	2006-09-11 13:47:09	2006-09-18 13:18:53
KLX08	102.0–242.0	1B	1	2006-09-21 16:17:00	2006-09-27 06:16:00

* 1B: pumping test-submersible pump.

3 Equipment

3.1 Description of equipment/interpretation tools

The equipment called PSS2 (Pipe String System 2) is a highly integrated tool for testing bore-holes at great depth (see conceptual drawing in the next Figure 3-1). The system is built inside a container suitable for testing at any weather. Briefly, the components consists of a hydraulic rig, down-hole equipment including packers, pressure gauges, shut-in tool and level indicator, racks for pump, gauge carriers, breakpins, etc. shelfs and drawers for tools and spare parts.

There are three spools for a multi-signal cable, a test valve hose and a packer inflation hose. There is a water tank for injection purposes, pressure vessels for injection of packers, to open test valve and for low flow injection. The PSS2 has been upgraded with a computerized flow regulation system. The office part of the container consists of a computer, regulation valves for the nitrogen system, a 24 V back-up system in case of power shut-offs and a flow regulation board.

PSS2 is documented in photographs 1–8.

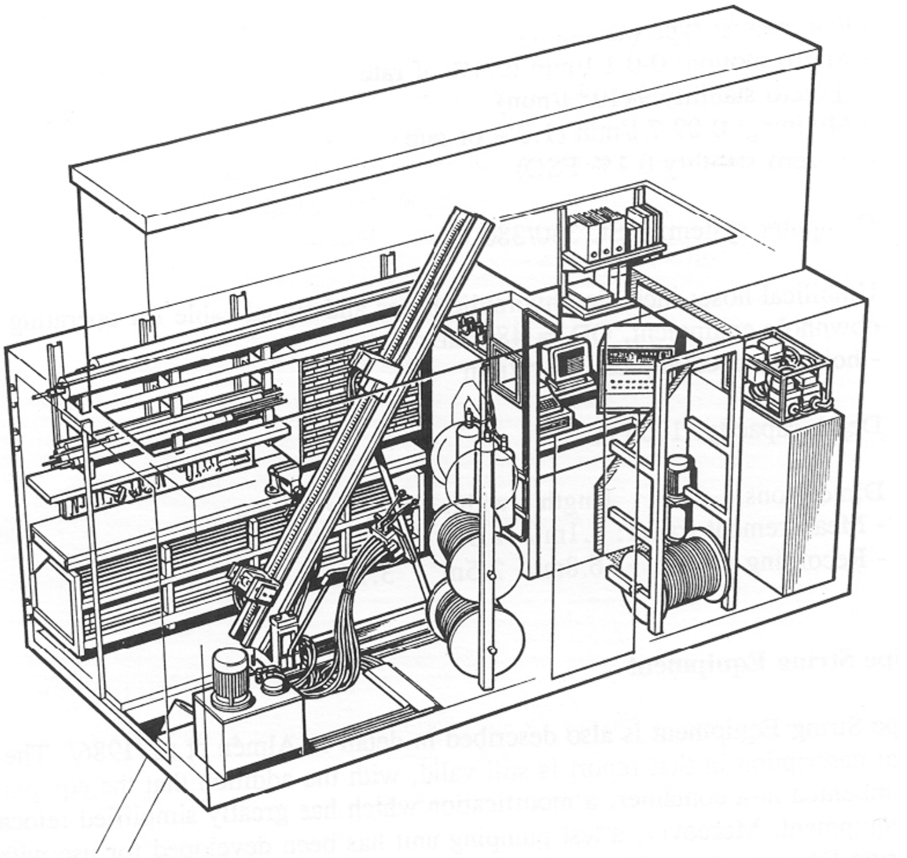

Figure 3-1. *A view of the layout and equipment of PSS2.*

Photo 1. *Hydraulic rig.*

Photo 2. *Rack for pump, down-hole equipment, workbench and drawers for tools.*

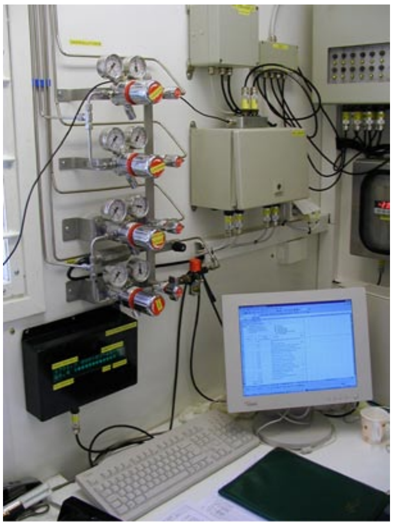

Photo 3. *Computer room, displays and gas regulators.*

Photo 4. *Pressure vessels for test valve, packers and injection.*

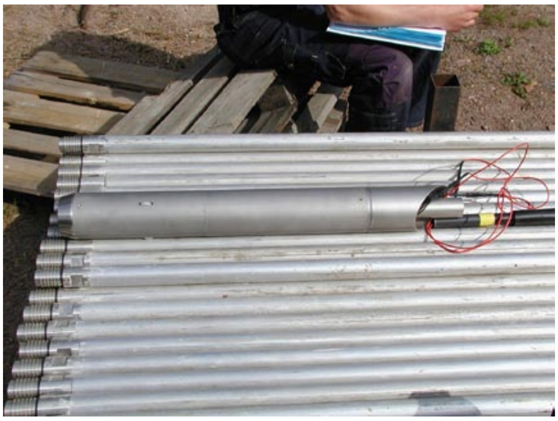

Photo 5. *Positioner, bottom end of down-in-hole string.*

Photo 6. *Packer and gauge carrier.*

Photo 7. *Top of test string with shunt valve and nylon line down to the pump basket.*

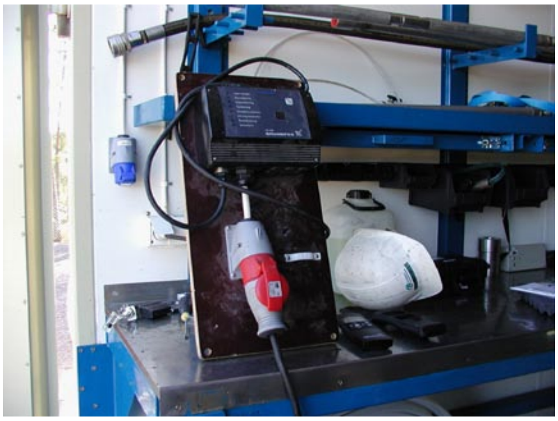

Photo 8. *Control board of the pump with remote control.*

The down-hole equipment consists from bottom to top of the following equipment:

- Level indicator – SS 630 mm pipe with OD 73 mm with 3 plastic wheels connected to a Hallswitch.
- Gauge carrier – SS 1.5 m carrying bottom section pressure transducer and connections from positioner.
- Lower packer – SS and PUR 1.5 m with OD 72 mm, stiff ends, tightening length 1.0 m, maximum pressure 6.5 MPa, working pressure 1.6 MPa.
- Gauge carrier with breakpin – SS 1.75 m carrying test section pressure transducer, temperature sensor and connections for sensors below. Breakpin with maximum load of 47.3 (± 1.0) kN. The gauge carrier is covered by split pipes and connected to a stone catcher on the top.
- Pop joint – SS 1.0 or 0.5 m with OD 33 mm and ID 21 mm, double O-ring fittings, trapezoid thread, friction loss of 3 kPa/m at 50 L/min.
- Pipe string – SS 3.0 m with OD 33 mm and ID 21 mm, double O-ring fittings, trapezoid thread, friction loss of 3 kPa/m at 50 L/min.
- Contact carrier – SS 1.0 m carrying connections for sensors below and
- Upper packer – SS and PUR 1.5 m with OD 72 mm, fixed ends, seal length 1.0 m, maximum pressure 6.5 MPa, working pressure 1.6 MPa.
- Breakpin – SS 250 mm with OD 33.7 mm. Maximum load of 47.3 (± 1.0) kN.
- Gauge carrier – SS 1.5 m carrying top section pressure transducer, connections from sensors below. Flow pipe is double bent at both ends to give room for sensor equipment. The pipe gauge carrier is covered by split pipes.
- Shut-in tool (test valve) – SS 1.0 m with a OD of 48 mm, Teflon coated valve piston, friction loss of 11 kPa at 10 L/min (260 kPa–50 L/min). Working pressure 2.8–4.0 MPa. Breakpipe with maximum load of 47.3 (± 1.0) kN. The shut-in tool is covered by split pipes and connected to a stone catcher on the top.

The 3”-pump is placed in a pump basket and connected to the test string at about 50–90 m below ToC. The pumping frequency of the pump is set with a remote control on surface. The flow can be regulated additionally with a shunt-valve on top of the test string, a nylon line connects the valve with the pump basket, so that the water can circulate and the pump cannot run out of water (photo 7).

The tool scheme is presented in Figure 3-2.

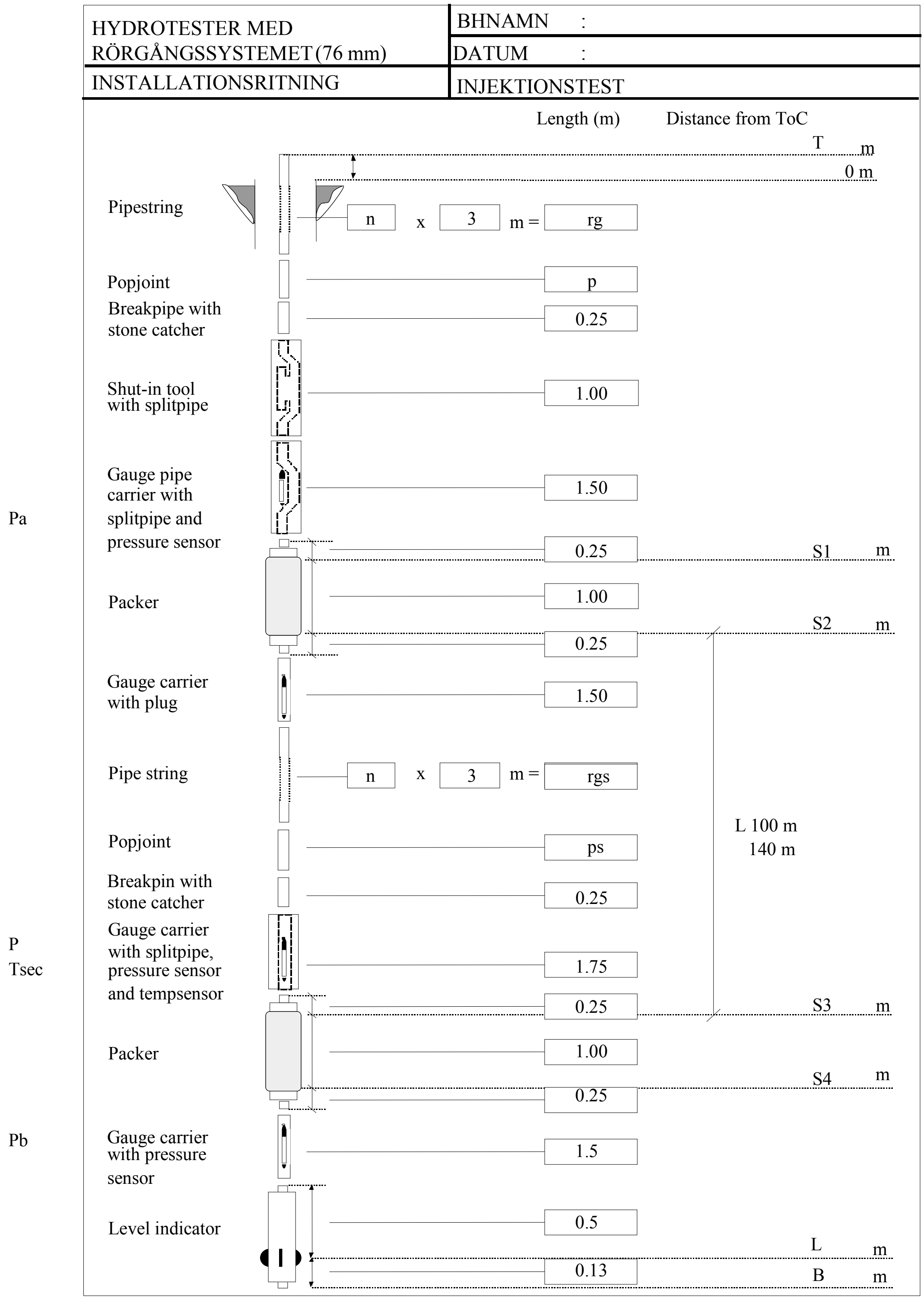

Figure 3-2. Schematic drawing of the down-hole equipment in the PSS2 system.

3.2 Sensors

Table 3-1. Technical specifications of sensors.

Keyword	Sensor	Name	Value/range	Unit	Comments
$P_{sec,a,b}$	Pressure	Druck PTX 162-1464abs	9–30 4–20 0–13.5 ± 0.1	VDC mA MPa % of FS	
$T_{sec,surf,air}$	Temperature	BGI	18–24 4–20 0–32 ± 0.1	VDC mA °C °C	
Q_{big}	Flow	Micro motion Elite sensor	0–100 ± 0.1	kg/min %	Massflow
Q_{small}	Flow	Micro motion Elite sensor	0–1.8 ± 0.1	kg/min %	Massflow
p_{air}	Pressure	Druck PTX 630	9–30 4–20 0–120 ± 0.1	VDC mA KPa % of FS	
p_{pack}	Pressure	Druck PTX 630	9–30 4–20 0–4 ± 0.1	VDC mA MPa % of FS	
$p_{in,out}$	Pressure	Druck PTX 1400	9–28 4–20 0–2.5 ± 0.15	VDC mA MPa % of FS	
L	Level indicator				Length correction

Calibration of the sensors was performed by Geosigma in December 2005. Actual calibration values were taken from the calibration protocols and inserted to the data acquisition system and the regulation unit as documented in the PSS protocol.

Table 3-2. Sensor positions and wellbore storage (WBS) controlling factors.

Borehole information			Sensors		Equipment affecting WBS coefficient			
ID	Test section (m)	Test no	Type	Position (m b ToC)	Position	Function	Outer diameter (mm)	Net water volume in test section (m³)
KLX08	102.00–242.00	2	p_a p T p_b L	100.11 241.37 241.20 244.01 247.25	Test section	Signal cable Pump string Packer line	9.1 33 6	0.502
KLX08	241.00–341.00	2	p_a p T p_b L	239.11 240.37 240.20 343.01 344.25	Test section	Signal cable Pump string Packer line	9.1 33 6	0.359
KLX08	357.00–497.00	2	p_a p T p_b L	355.11 356.37 356.20 499.01 500.25	Test section	Signal cable Pump string Packer line	9.1 33 6	0.502

3.3 Data acquisition system

The data acquisition system in the PSS2 container contains a stationary PC with the software Orchestrator, pump- and injection test parameters such as pressure, temperature and flow are monitored and sensor data collected. A second laptop PC is connected to the stationary PC through a network containing evaluation software, Flowdim. While testing, data from previously tested section is converted with IPPlot and entered in Flowdim for evaluation.

The data acquisition system starts and stops the test automatically or can be disengaged for manual operation of magnetic and regulation valves within the injection/pumping system. The flow regulation board is used for differential pressure and valve settings prior testing and for monitoring valves during actual test. An outline of the data acquisition system is outlined in Figure 3-3.

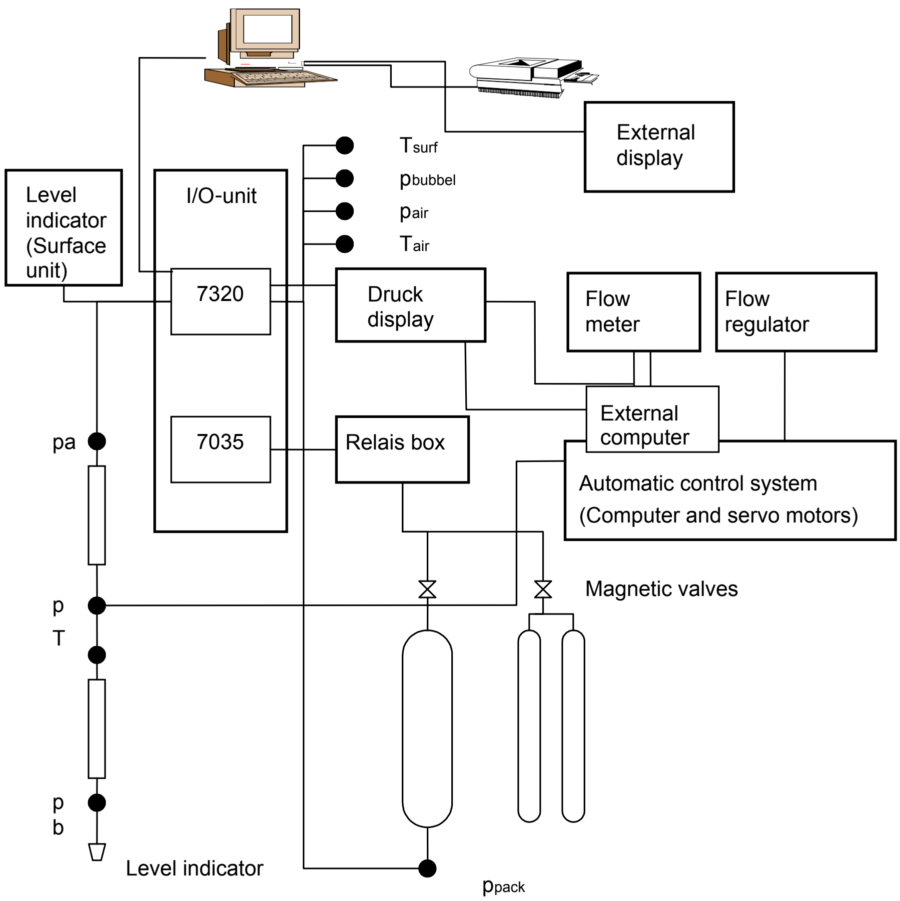

Figure 3-3. Schematic drawing of the data acquisition system and the flow regulation control system in PSS2.

4 Execution

4.1 General

Testing, analyses and reporting were carried out according to SKB's methodology as outlined in the internal SKB document SKB MD 330.003. The activity involves the following components:

- Prepararions
- Function control of transmitters and data system
- Pumping/interference testing
- Analyses of hydraulic tests
- Reporting

The basic testing sequence for the pumping tests was to perform a constant rate withdrawal followed by a pressure recovery.

4.2 Preparations

The container was placed on pallets with adjustments made according to the inclination of the borehole. Cables, hoses and down-hole equipment (including pump and pump basket) were cleaned with hot steam and disinfected with alcohol according to cleaning level 2. Calibration constants were entered in the data acquisition system and the regulation unit and function checks of the sensors, level indicator, shut in tool and flow meters were made. As result of the function checks, all sensors and components of the testing system worked well.

By running in with the test tool, a level indicator is incorporated at the bottom of the tool. The level indicator is able to record groves milled into the borehole wall. The depths of these groves are given by SKB in the activity plan (see Table 2-2) and the measured depth is counter checked against the number/length of the tubes build in. The achieved correction value, based on linear interpolation between the reference marks, is used to adjust the location of the packers for the test sections to avoid wrong placements and minimize elongation effects of the test string.

4.3 Execution of field work

4.3.1 Test principle

Pump tests

The pump tests were conducted as constant flow rate tests (CRw phase) followed by a pressure recovery period (CRwr phase). The intention was to achieve a drawdown as high as possible, which is limited by several factors like flow capacity of the valves at the regulation unit, maximum flow rate and depth of the pump, head loss due to friction inside the tubing, etc. According to the Activity Plan, the pump phase should have lasted 3 days and the recovery phase 4 days. The actual durations of the phases are shown in Table 2-1.

Observation wells

For evaluation as interference tests, several boreholes were used to monitor the pressure change in different intervals. Recording and data collection was done by SKB. SKB delivered the data as ASCII files (mio-format). An overview of the monitored boreholes and their intervals is given in Table 2-3.

4.3.2 Test procedure

A test cycle includes the following phases: 1) Transfer of down-hole equipment to the section. 2) Packer inflation. 3) Pressure stabilisation. 4) Constant rate withdrawal. 5) Pressure recovery. 6) Packer deflation. The pump tests in KLX08 have been carried out by applying a constant rate withdrawal with a drawdown as high as possible. The flow rates and resulting drawdowns are summarised in Table 4-1.

Before start of the pumping tests, approximately stable pressure conditions prevailed in the test section. After the perturbation period, the pressure recovery in the section was measured. Tidal effects were observed as disturbances of the pressure responses, no major rainfall happened during performance of the pump tests which may have disturbed the measurements.

The extracted water was collected in tanks, which were removed by SKB and discharged into the sea.

4.4 Data handling/post processing

Pump tests

The data handling followed several stages. The data acquisition software (Orchestrator) produced an ASCII raw data file (*.ht2) which contains the data in voltage and milliampere format plus calibration coefficients. The *.ht2 files were processed to *.dat files using the SKB program called IPPlot. These files contain the time, pressure, flow rate and temperature data. The *.dat files were synthesised in Excel to a *.xls file for plotting purposes. Finally, the test data to be delivered to SKB were exported from Excel in *.csv format. These files were also used for the subsequent test analysis.

Observation wells

SKB was responsible for recording and collecting the data of the observation boreholes. The sample rate in those boreholes was 1 minute, except for KLX04 where it was 10 seconds due its position close to KLX08. SKB delivered the ASCII data in mio-format. These files were imported and processed to Excel for further evaluation and analysis.

4.5 Analyses and interpretations

4.5.1 Analysis software

The pump tests were analysed using a type curve matching method. The analysis was performed using Golder's test analysis program FlowDim. FlowDim is an interactive analysis environment allowing the user to interpret constant pressure, constant rate and slug/pulse tests in source as well as observation boreholes. The program allows the calculation of type-curves for homogeneous, dual porosity and composite flow models in variable flow geometries from linear to spherical.

Table 4-1. Flow rate and drawdown of pumping tests.

Bh ID	Section [mbToC]	Flow rate [L/min]	Drawdown* [kPa]
KLX08	102.0–242.0	40.5	37
KLX08	241.0–341.0	5.1	453
KLX08	357.0–497.0	31.0	44

* Difference between pressure just before start and immediately before stop of pumping.

4.5.2 Analysis approach

Constant rate and pressure recovery tests are analysed using the method described by /Gringarten 1986/ and /Bourdet et al. 1989/ by using type curve derivatives calculated for different flow models.

4.5.3 Analysis methodology

Each of the relevant test phases is subsequently analyzed using the following steps:

- Identification of the flow model by evaluation of the derivative on the log-log diagnostic plot. Initial estimates of the model parameters are obtained by conventional straight-line analysis.
- Superposition type curve matching in log-log coordinates. A non-linear regression algorithm is used to provide optimized model parameters in the latter stages.
- Non-linear regression in semi-log coordinates (superposition HORNER plot; /Horner 1951/). In this stage of the analysis, the static formation pressure is selected for regression.

The test analysis methodology is best explained in /Horne 1990/.

4.5.4 Correlation between storativity and skin factor

For the analysis of the conducted hydraulic tests below 100 m depth a storativity of $1 \cdot 10^{-6}$ is assumed (SKB MD 320.004e). Based on this assumption the skin will be calculated. In the following the correlation between storativity and skin for the relevant test phases will be explained in greater detail.

Pump and recovery phase (CRw and CRwr)

The wellbore storage coefficient (C) is determined by matching the early time data with the corresponding type curve. The derived C-value is introduced in the equation of the type curve parameter:

$$(C_D e^{2s})_M = \frac{C \rho g}{2\pi r_w^2 S} e^{2s}$$

The equation above has two unknowns, the storativity (S) and the skin factor (s) which expresses the fact that for the case of constant rate and pressure recovery tests the storativity and the skin factor are 100% correlated. Therefore, the equation can only be either solved for skin by assuming that the storativity is known or solved for storativity by assuming the skin as known.

4.5.5 Steady state analysis

In addition to the type curve analysis, an interpretation based on the assumption of stationary conditions was performed as described by /Moye 1967/.

4.5.6 Flow models used for analysis

The flow models used in analysis were derived from the shape of the pressure derivative calculated with respect to log time and plotted in log-log coordinates.

In five cases a radial two shell composite flow model was used. One test phase was analysed using an infinite acting radial flow model.

If there were different flow models matching the data in comparable quality, the simplest model was preferred.

The flow dimension displayed by the test can be diagnosed from the slope of the pressure derivative. A slope of 0.5 indicates linear flow, a slope of 0 (horizontal derivative) indicates radial flow and a slope of –0.5 indicates spherical flow. The flow dimension diagnosis was commented for each of the tests. All tests were analysed using a flow dimension of two (radial flow).

4.5.7 Calculation of the static formation pressure and equivalent freshwater head

The static formation pressure (p*) measured at transducer depth, was derived from the pressure recovery (CRwr) following the constant pressure injection phase by using:

(1) straight line extrapolation in cases infinite acting radial flow (IARF) occurred,

(2) type curve extrapolation in cases infinite acting radial flow (IARF) is unclear or was not reached.

The equivalent freshwater head (expressed in meters above sea level) was calculated from the extrapolated static formation pressure (p*), corrected for atmospheric pressure measured by the surface gauge and corrected for the vertical depth considering the inclination of the borehole, by assuming a water density of 1,000 kg/m^3 (freshwater). The equivalent freshwater head is the static water level an individual test interval would show if isolated and connected to the surface by tubing full of freshwater. Figure 4-1 shows the methodology schematically.

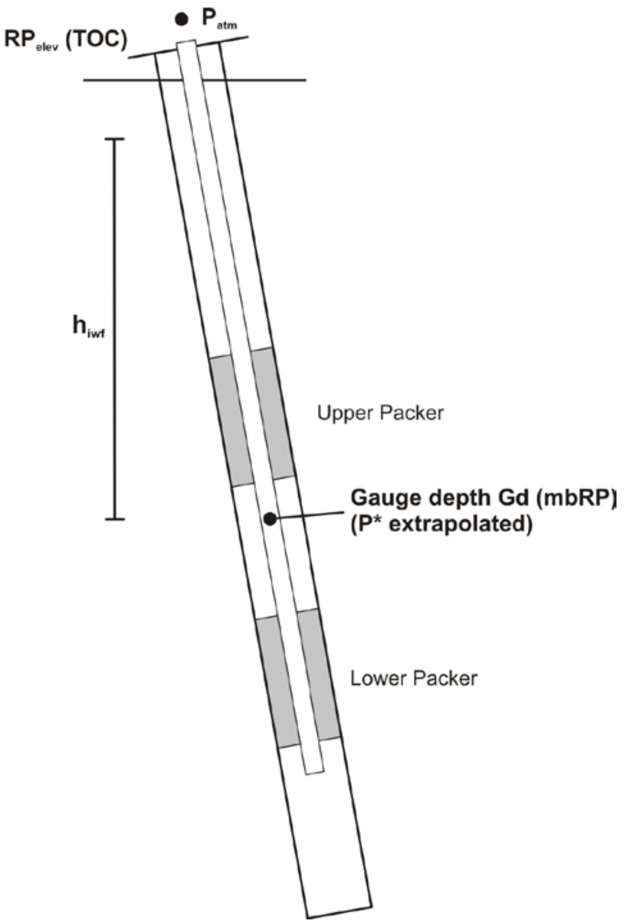

Figure 4-1. *Schematic methodologies for calculation of the freshwater head.*

The freshwater head in meters above sea level is calculated as following:

$$head = \frac{(p^* - p_{atm})}{\rho \cdot g}$$

which is the p* value expressed in a water column of freshwater.

With consideration of the elevation of the reference point (RP) and the gauge depth (Gd), the freshwater head h_{iwf} is:

$$h_{iwf} = RP_{elev} - Gd + \frac{(p^* - p_{atm})}{\rho \cdot g}$$

4.5.8 Calculation of the radius of the inner zone

All tests were analysed using a composite flow model. This chapter explain how the radius of influence of the inner zone (r_{inner}) was calculated.

$$ri = 1.89 * \sqrt{\frac{T_{s1}}{S_T} * t_2} \quad [\mathrm{m}]$$

T_{s1} recommended inner zone transmissivity of the recovery phase [m²/s]

t_2 time when hydraulic formation properties changes [s]

S_T for the calculation of the ri the storage coefficient (S) is estimated from the transmissivity /Rhen 2005/:
$S_T = 0.007 * T_T^{0.5}$ [–]

4.5.9 Derivation of the recommended transmissivity and the confidence range

In all cases both test phases were analysed (CRw and CRwr). The parameter sets (i.e. transmissivities) derived from the individual analyses of a specific test usually differ. In the case when the differences are small the recommended transmissivity value is chosen from the test phase that shows the best data and derivative quality, which is most of the cases at the CRwr phase. In cases when a composite flow model was deemed to be most representative for the hydraulic behaviour of the specific test section, than the most representative zone transmissivity was selected as recommended value.

The confidence range of the transmissivity was derived using expert judgement. Factors considered were the range of transmissivities derived from the individual analyses of the test as well as additional sources of uncertainty such as noise in the flow rate measurement, numeric effects in the calculation of the derivative or possible errors in the measurement of the wellbore storage coefficient. No statistical calculations were performed to derive the confidence range of transmissivity.

4.6 Analysis and interpretation of the response in the observation holes

In 19 boreholes with a total of 73 sections (Table 2-3) the responses were monitored during the pumping tests in KLX08. Those data were analysed according to the methodology description (SKB MD 330.003) to derive hydraulic connectivity parameters and by additional instructions from SKB (August 2006). Furthermore the data of the observation holes were analysed using a type curve matching method with Golder's test analysis program FlowDim.

4.6.1 Hydraulic connectivity parameters

Calculation of the indices

For the interference test analysis, the data of the pumping hole and the observation holes were compared. Therefore both data sets were plotted in one graph to decide if the observation borehole shows a response, which is related to the pumping. In case of a response in the observation sections due to pumping in KLX08, the response time (dt_L) and the maximum drawdown (s_p) in these sections were calculated. The 3D distance between the point of application in the pumping borehole and the observation borehole (r_s) was provided by SKB. These parameters combined with the pumping flow rate (Q_p) are the variables used to calculate the indices, which characterize the hydraulic connectivity between the pumping and the observed section. The parameters and the calculated hydraulic connectivity parameters are shown in the tables in Chapter 5 and Appendix 6. The indices are calculated as follows:

Index 1:

r_s^2/dt_L = normalised distance r_s with respect to the response time [m²/s].

Index 2:

s_p/Q_p = normalised drawdown with respect to the pumping rate [s/m²].

Additionally, a third index was calculated including drawdown and distance. This index is calculated as follows:

Index 2 new:

$(s_p/Q_p)*\ln(r_s/r_0)$ r_0=1 and for the pumped borehole $r_s=e^1$ (fictive borehole radius of 2.718).

The classification based on the indices is given as follows:

Index 1 (r_s^2/dt_L)		Index 2 (s_p/Q_p)		Colour code
r_s^2/dt_L > 100 m²/s	Excellent	$s_p/Q_p > 1\cdot10^5$ s/m²	Excellent	red
10 < r_s^2/dt_L ≤ 100 m²/s	High	$3\cdot10^4 < s_p/Q_p \le 1\cdot10^5$ s/m²	High	yellow
1 < r_s^2/dt_L ≤ 10 m²/s	Medium	$1\cdot10^4 < s_p/Q_p \le 3\cdot10^4$ s/m²	Medium	green
0.1 < r_s^2/dt_L ≤ 1 m²/s	Low	$s_p/Q_p \le 1\cdot10^4$ s/m²	Low	blue
		s_p < 0.1 m	No response	grey

Index 2 new $(s_p/Q_p)*\ln(r_s/r_0)$		Colour code
$(s_p/Q_p)*\ln(r_s/r_0) > 5\cdot10^5$ s/m²	Excellent	red
$5\cdot10^4 < (s_p/Q_p)*\ln(r_s/r_0) \le 5\cdot10^5$ s/m²	High	yellow
$5\cdot10^3 < (s_p/Q_p)*\ln(r_s/r_0) \le 5\cdot10^4$ s/m²	Medium	green
$5\cdot10^2 < (s_p/Q_p)*\ln(r_s/r_0) \le 5\cdot10^3$ s/m²	Low	blue
sp < 0.1 m	No response	grey

Calculated response indexes are given in Tables 5-2 to 5-4 and 6-3.

Derivation of the indices and limitations

To evaluate the hydraulic connectivity between the active and the observed section, the drawdown in the observation section (s_p) caused by pumping in the active section and the response time after start of pumping (dt_L) is needed.

To get these two values the data of both sections are plotted in one graph. The time, the observation hole needed to react to the pumping in KLX08 with a drawdown of at least 0.01 m and the amount of drawdown at the end of the pumping were taken out of the graph. Often it is not really clear if the section responds to the pumping or if the drawdown is based on natural processes exclusively. In unclear cases, the data sets were regarded in total to better differentiate between those effects. By looking at the pressure response of the days before and after the pumping phase, it is easier to distinguish between natural fluctuations and those induced by pumping. Furthermore it should be pointed out, that some of the responses could be caused by the drawdown in the section above or below of the same observation borehole.

All observation data are influenced by natural fluctuations of the groundwater level such as tidal effects. The pressure changes due to tidal effects are different for the observation boreholes and ranges between 0.01 m (e.g. HLX11) and 0.3 m (KLX04). The amplitudes of these tidal effects differ from borehole to borehole and between the different sections for each borehole. Regarding the deep boreholes KLX02, KLX03, KLX04, KLX06, KLX07A and KLX10, a correlation between the depth of the section and the amplitude could be derived. The deeper sections show a larger pressure difference between high tide and low tide.

The pressure changes in the observation sections generated by the pumping are often very marginal. In general, it is a combination of natural processes and the pumping in KLX08 producing the pressure changes in the monitored sections. If there is a reaction, it shows – in most of the cases – not a sharp but a smooth transition from undisturbed to disturbed (by pumping) behaviour, which makes it more difficult to determine the response time exactly. If neither start time nor stop time of pumping can provide reliable data for the response time Index 1 was not calculated. The second difficulty resulting out of the overlap of natural effects and those caused by the pumping is to determine the drawdown. In Figure 4-2, which shows the pressure in KLX08, section 357.00–497.00 m, and the response in KLX18A_3, the above mentioned uncertainties are shown.

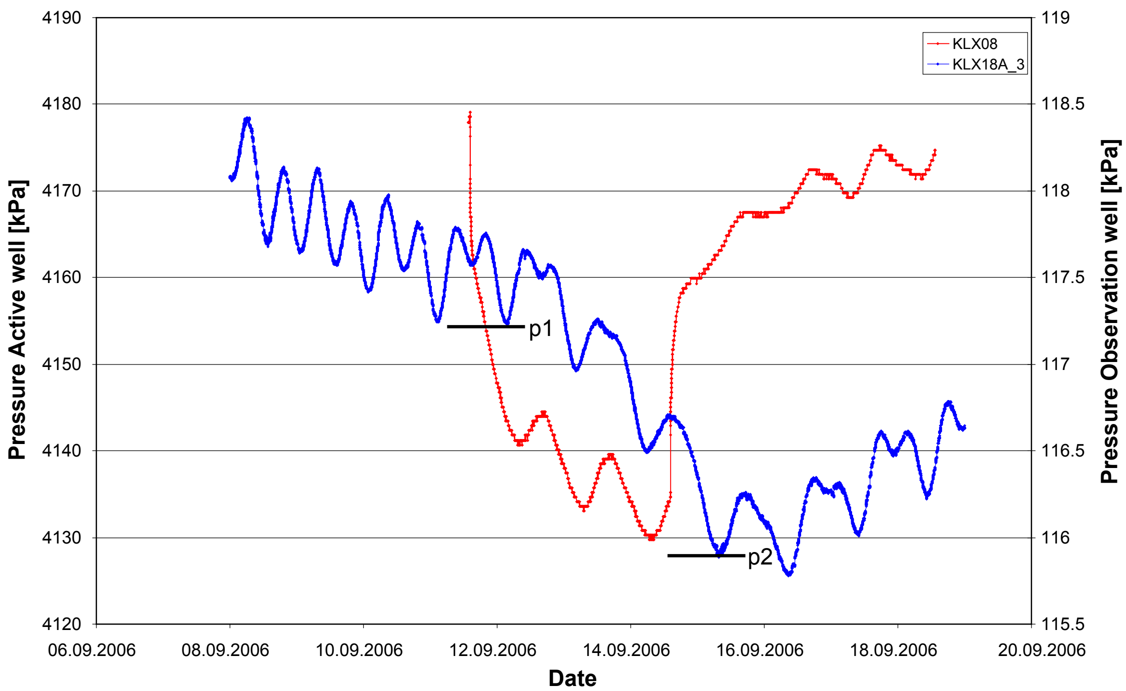

Figure 4-2. *Pumping section in KLX08 357.00–497.00 m bToC and Observation section KLX18A_3.*

The figure above explains the drawdown was calculated when the natural fluctuations preponderate the effects of pumping. In this example, the natural fluctuations are much larger than the influence of the pumping phase. Therefore, the pressure minima in the vicinity of start and stop of pumping were taken and the pressure difference was calculated (p2–p1), assuming that those pressure minima/maxima would have been the same value without pumping. This provides a value for the drawdown caused by pumping (s_p). The same calculation can be done with the maxima.

4.6.2 Approximate calculation of hydraulic diffusivity

The distance r_s between different borehole sections has been calculated as the spherical distance using co-ordinates for the mid-chainage of each section. The calculation of the hydraulic diffusivity is based on radial flow:

$$\eta = T / S = r_s^2 / [4 \cdot dt_L \cdot (1 + dt_L / tp) \cdot \ln(1 + tp / dt_L)]$$

The time lag dt_L is defined as the time when the pressure response in an observation section is greater than ca 0.01 metres (The time difference between a certain first observable response in the observation section and the stop of the pumping). The pumping time is included as tp /Streltsova 1988/.

The estimates of the hydraulic diffusivity according to above should be seen as indicative values of the hydraulic diffusivity. Observation sections straddling a planar, major conductive feature that also intersects the pumping section should provide reliable estimates of the hydraulic diffusivity, but these cases have to be judged based on the geological model of the site.

For the calculation of the hydraulic diffusivity the recommended transmissivity T_T and Storativity S derived from the transient type curve analysis were used. No calculation based on dt_L was done, because of the often poor quality of dt_L and to ensure the consistency between the calculated diffusivity values.

Values of the hydraulic diffusivity are shown in Tables 5-2 to 5-4 and 6-3.

4.6.3 Response analysis

To derive transmissivities and storativities from the sections of the observation boreholes Golder's analysis software FlowDim was used.

Analysis approach

The interference tests are analysed using cylindrical source type curves calculated for different flow models as identified from the log-log derivative of the pressure response.

Assumptions

To understand the assumption used in the analysis of observation zone data it is useful to imagine in a first instance a source zone connected with the observation zones through fractures of equal transmissivity (T_1 to T_4). In Figure 4-3 the case of a source zone connected with 4 observation zones is presented.

If we note the flow rate at the source as q, each of the response in each of the observation zones will be influenced by a flow rate of q/4 because the transmissivities of the 4 fractures are equal, so the rate will be evenly distributed between the fractures as well.

We complicate now the system by adding a new fracture of much higher transmissivity (T_5) to the system (see Figure 4-4).

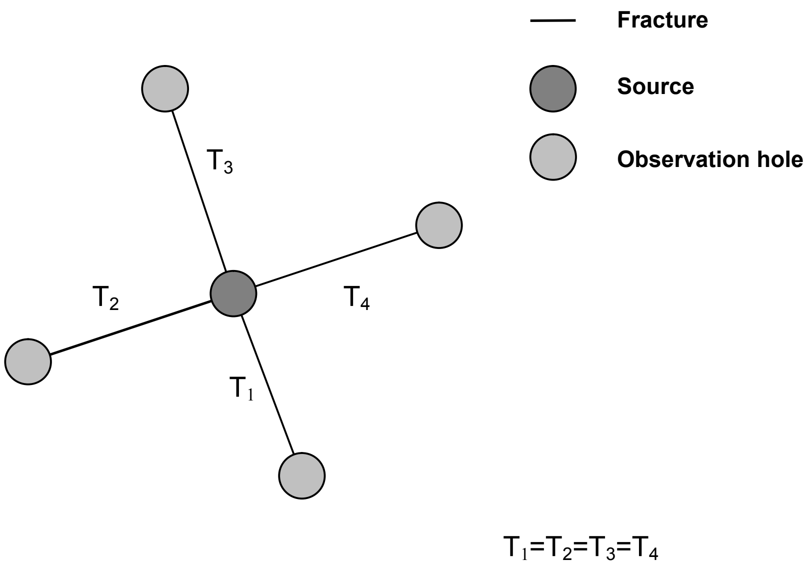

Figure 4-3. *Schematic sketch of a pumping hole (source) and observation holes.*

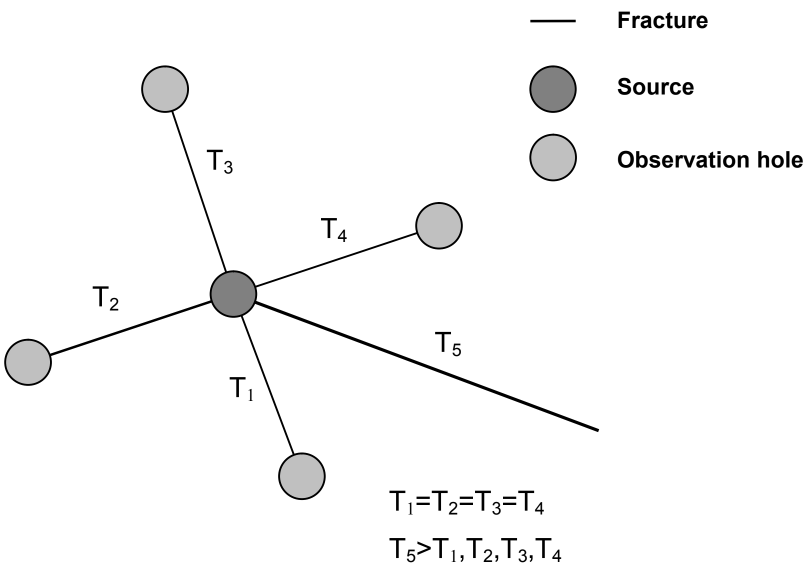

Figure 4-4. *Schematic sketch of a pumping hole (source) and observation holes with an added fracture.*

Because of the larger transmissivity, most of the flow rate of the source will be captured by this fracture, so the other 4 fractures will receive less flow. Because of this, the magnitude of the response at the 4 observation zones will be higher than in the first case. The pathway transmissivity derived from the analysis of the observation zones will be in the second case much higher than in the first case. However, the pathway transmissivity between source and any of the observation zones did not change. The transmissivity derived in the second case is false because the analysis is conducted under the assumption that the flow rate of the source is evenly distributed in space. This assumption is clearly not valid in the second case. In reality, the flow rate around the source will be distributed inversely proportional to the transmissivity of the individual pathways:

$q = q_1 + q_2 + \ldots. + q_n$

$$\frac{T_1}{q_1} = \frac{T_2}{q_2} = \ldots. = \frac{T_n}{q_n}$$

The analysis of observation zones (i.e. interference test analysis) assumes that:

$q_1 = q_2 = \ldots = q_n$

This assumption will typically result in similar transmissivities:

$T_1 = T_2 = \ldots = T_n$

The distance used for the analysis is the shortest way between the source and the observation hole and no pathway tortuosity was considered. This assumption influences the storativity derived from the transient analysis.

Methodology

Each of the relevant test phases is subsequently analyzed using the following steps:

- Identification of the flow model by evaluation of the derivative on the log-log diagnostic plot. Initial estimates of the model parameters are obtained by conventional straight-line analysis.
- Superposition type curve matching in log-log coordinates. The type curves are based on /Theis 1935/ calculated for a cylindrical source (i.e. finite wellbore radius).

Flow models used for analysis

The flow models used in analysis were derived from the shape of the pressure derivative calculated with respect to log time and plotted in log-log coordinates.

In the most cases a homogenous flow model was used, otherwise a two shell composite flow model was chosen for the analysis.

If there were different flow models matching the data in comparable quality, the simplest model was preferred.

The flow dimension displayed by the test can be diagnosed from the slope of the pressure derivative. A slope of 0.5 indicates linear flow, a slope of 0 (horizontal derivative) indicates radial flow and a slope of –0.5 indicates spherical flow. The flow dimension diagnosis was commented for each of the tests. All tests were analysed using a flow dimension of two (radial flow).

4.7 Nonconformities

A pump test with a section length of 80 m was requested by the activity plan AP PS 400-06-001 for the section 241–321 m. SKB provided three pieces of multicable which should be connected to the required section length. It was observed, that these three multicables fit not to the required section length and the needed pop joints for adjusting additionally gauge carriers in the section were not available. It was decided by SKB to perform a pump test of 100 m section length instead at the section 241–341 m.

5 Results

In the following, results of the pump tests conducted in KLX08 are presented and analysed. The results are given as general comments to test performance, the identified flow regimes and calculated parameters and finally the parameters which are considered as most representative are chosen and justification is given. All results are also summarized in the Tables 6-1 to 6-3 of the synthesis chapter and in the summary sheets (Appendix 3). No disturbing activities like heavy rainfall were observed during the pump tests in borehole KLX08. The only disturbing effects observed were caused by tidal influence. As at all performed pump tests the derivative is flat at late times, all pump tests were evaluated using a flow dimension of 2. In some cases, there was a flat derivative at middle times at a different level. In these cases, a composite model was chosen with a change of transmissivity in some distance from the borehole to match the different flat parts of the derivative and the connecting slope.

5.1 Results pump tests

5.1.1 Section 102–242 m, test no. 2, pumping

Comments to test

The test was composed of a constant rate pump test phase with a flow rate of 40.5 l/min and a pressure difference of 37 kPa, followed by a pressure recovery phase. A slightly hydraulic connection between the test interval and the adjacent zones was observed. The flow rate during the pumping phase was at about 40.5 l/min with a pressure drawdown of ca 37 kPa at the end of the perturbation phase, indicating a relatively high interval transmissivity. After approximate 73 hours of pumping, a water sample was taken by SKB. Both phases are a bit noisy but adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. In case of the present test the CRw and CRwr phases show a flat derivative at late times, which is indicative of a flow dimension of 2 (radial flow). A radial composite flow model was chosen for the analysis of the CRw and CRwr phases. The analysis is presented in Appendix 2-1.

Selected representative parameters

The recommended transmissivity of $1.3 \cdot 10^{-4}$ m^2/s was derived from the analysis of the CRwr phase (outer zone), which shows the best data and derivative quality. The confidence range for the interval transmissivity is estimated to be $5.0 \cdot 10^{-5}$ to $2.0 \cdot 10^{-4}$ m^2/s. The flow dimension displayed during the test is 2. The static pressure measured at transducer depth, was derived from the CRwr phase using straight line extrapolation in the Horner plot to a value of 2,011 kPa.

The analysis of the CRw and CRwr phases shows good consistency. No further analysis is recommended.

5.1.2 Section 241–341 m, test no. 2, pumping

Comments to test

The test was composed of a constant rate pump test phase with a rate of 5.1 l/min and a pressure difference of 453 kPa, followed by a pressure recovery phase. No hydraulic connection between test interval and the adjacent zones was observed. The pump rate control during the CRw phase was very good. But due to the small pump rates (low transmissivity) the rate measurements are relatively noisy. The pump rate was stable at around 5.1 l/min during the whole CRw phase, indicating a relatively low interval transmissivity. A sudden pressure uprise of 25 kPa was observed during the CRw phase without any change of the pump rate at around 12.8 h after pump start. This may be due to an opening of fractures during pumping. The pressure drawdown at the end of the pump phase was at about 453 kPa. After a pumping time of ca 71 hours, a water sample was taken by SKB. The perturbation phase (CRw) is quite noisy and of poor quality for analysis. The recovery phase (CRwr) shows no problems and is adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. In case of the present test the CRw and CRwr phases show a flat derivative at late times, which is indicative of a flow dimension of 2 (radial flow). Both phase derivatives show a downward trend at middle times indicating an increase of transmissivity at some distance from the borehole. For the analysis of the CRw and CRwr phases a radial composite flow model was chosen. The analysis is presented in Appendix 2-2.

Selected representative parameters

The recommended transmissivity of $2.29 \cdot 10^{-6}$ m^2/s was derived from the analysis of the CRwr phase (inner zone), which shows the best data and derivative quality. The confidence range for the interval transmissivity is estimated to be $1.0 \cdot 10^{-6}$ to $6.0 \cdot 10^{-5}$ m^2/s. The flow dimension displayed during the test is 2. The static pressure measured at transducer depth, was derived from the CRwr phase using straight line extrapolation in the Horner plot to a value of 2,848 kPa.

The analysis of the CRw and CRwr phases shows good consistency. No further analysis is recommended.

5.1.3 Section 357–497 m, test no. 2, pumping

Comments to test

The test was composed of a constant rate pump test phase with a rate of 31.0 l/min and a pressure difference of 44 kPa, followed by a pressure recovery phase. A slight hydraulic connection between test interval and the adjacent zones was observed. The pump rate control during the CRw phase was good. The pump rate was stable at around 31.0 l/min during the whole perturbation phase with a pressure drawdown of about 44 kPa at the end of the perturbation phase. After approximate 72 hours of pumping, a water sample was taken by SKB. Both phases are a bit noisy but show no problems and are adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. In case of the present test the CRw and CRwr phases show an upward trend of the derivative at middle times and a flat derivative at late times, which is indicative of a flow dimension of 2 (radial flow) and indicating a decrease of transmissivity at some distance from the borehole. For the analysis of the CRw and CRwr phases a radial composite flow model was chosen. The analysis is presented in Appendix 2-3.

__Selected representative parameters__

The recommended transmissivity of $1.21 \cdot 10^{-4}$ m^2/s was derived from the analysis of the CRwr phase (outer zone), which shows the best data and derivative quality. The confidence range for the interval transmissivity is estimated to be $1.0 \cdot 10^{-4}$ to $4.0 \cdot 10^{-4}$ m^2/s. The flow dimension displayed during the test is 2. The static pressure measured at transducer depth, was derived from the CRwr phase using straight line extrapolation in the Horner plot to a value of 4,174 kPa.

The analysis of the CRw and CRwr phases shows good consistency. No further analysis is recommended.

5.2 Results response analysis

In the following, the data of the observation zones which responded to pumping are presented and analysed. The results of the analysis are also summarized in the Table 6-3 of the summary chapter and the summary sheets (Appendix 6 and 8).

Table 5-1 summarises all the tests and the observed boreholes. Furthermore it shows the response matrix based on the calculated indices 1 (r_s^2/dt_L), 2 (s_p/Q_p) and 2 new (s_p/Q_p)*ln(r_s/r_0) (see Chapter 4.6.1).

Table 5-1. Response matrix with Index 1, Index 2 and Index 2 new.

		Pumping hole	KLX08			KLX08			KLX08		
		Section (m b TOC)	102.00–242.00			241.00–341.00			357.00–497.00		
		Flow rate (l/min)	40.5			5.1			31.0		
		Drawdown (kPa)	37			453			44		
Observation borehole	**Sec No**	**Section (m)**	**Response indices**								
			1	**2**	**2 new**	**1**	**2**	**2 new**	**1**	**2**	**2 new**
KLX08	Pa	101.00–102.00				n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
	Pb	243.00–1,000.41	H			n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
KLX08	Pa	101.00–240.00	n.o.	n.o.	n.o.	L			n.o.	n.o.	n.o.
	Pb	342.00–1,000.41	n.o.	n.o.	n.o.				n.o.	n.o.	n.o.
KLX08	Pa	101.00–356.00	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.	M		
	Pb	498.00–1,000.41	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.	H		
HLX11	1	17.00–70.00									
	2	6.00–16.00									
HLX13	1	12.00–200.20	H						H		
HLX14	1	12.00–115.90	n.c.						n.c.		
HLX23	1	61.00–160.20							n.c.		
	2	6.10–60.00									
HLX24	1	41.00–175.20									
	2	9.10–40.00									
HLX25	1	61.00–202.50	H			n.c.			H		
	2	6.12–60.00	H			n.c.			H		
HLX30	1	101.00–163.40	H			n.c.			M		
	2	9.10–100.00	H			n.c.			M		
HLX31	1	9.10–133.20	H			n.c.			H		
HLX33	1	31.00–202.10									
	2	9.10–30.00									

		Pumping hole	KLX08			KLX08			KLX08		
		Section (m b TOC)	102.00–242.00			241.00–341.00			357.00–497.00		
		Flow rate (l/min)	40.5			5.1			31.0		
		Drawdown (kPa)	37			453			44		
Observation borehole	**Sec No**	**Section (m)**	**Response indices**								
			1	**2**	**2 new**	**1**	**2**	**2 new**	**1**	**2**	**2 new**
HLX34	1	9.00–151.80									
HLX35	1	65.00–151.80									
	2	6.10–64.00									
KLX02	1	1,165.00–1,700.00									
	2	1,145.00 –1,164.00									
KLX02	3	718.00–1,144.00									
	4	495.00–717.00									
	5	452.00–494.00									
	6	348.00–451.00									
	7	209.00–347.00									
	8	100.35–208.00									
KLX03	1	965.00–971.00									
	2	830.00–964.00									
	3	752.00–829.00									
	4	729.00–751.00									
	5	652.00–728.00									
	6	465.00–651.00									
	7	349.00–464.00									
	8	199.00–348.00									
	9	193.00–198.00									
	X	100.05–192.00									
KLX04	1	898.00–1,000.00									
	2	870.00–897.00									
	3	686.00–869.00							n.c.		
	4	531.00–685.00	n.c.			n.c.			n.c.		
	5	507.00–530.00	E			E			E		
	6	231.00–506.00	n.c.			n.c.			n.c.		
	7	163.00–230.00	E			H			H		
	8	12.24–162.00	E			n.c.			n.c.		
KLX06	1	761.00–1,000.00									
	2	571.00–760.00									
	3	554.00–570.00									
	4	411.00–553.00									
	5	276.00–410.00									
	6	256.00–275.00									
	7	146.00–255.00									
	8	11.88–145.00									

		Pumping hole	KLX08			KLX08			KLX08		
		Section (m b TOC)	102.00–242.00			241.00–341.00			357.00–497.00		
		Flow rate (l/min)	40.5			5.1			31.0		
		Drawdown (kPa)	37			453			44		
Observation borehole	**Sec No**	**Section (m)**	**Response indices**								
			1	**2**	**2 new**	**1**	**2**	**2 new**	**1**	**2**	**2 new**
KLX07A	1	781.00–844.73									
	2	753.00–780.00									
	3	612.00–752.00									
	4	457.00–611.00									
	5	333.00–456.00									
	6	204.00–332.00									
	7	104.00–203.00									
	8	102.00–103.00									
KLX07B	1	95.00–200.00									
	2	9.64–94.00									
KLX10	1	711.00–1,001.00									
	2	689.00–710.00									
	3	465.00–688.00									
	4	369.00–464.00									
	5	351.00–368.00									
	6	291.00–350.00									
	7	131.00–290.00									
	8	9.20–130.00									
KLX18A	1	440.00–611.28							n.c.		
	2	241.00–439.00	n.c.			n.c.			H		
	3	11.83–240.00							n.c.		

Index 1 (r^2/t_L)

$r_s^2/dt_L > 100$ m²/s	Excellent	E
$10 < r_s^2/dt_L \leq 100$ m²/s	High	H
$1 < r_s^2/dt_L \leq 10$ m²/s	Medium	M
$0.1 < r_s^2/dt_L \leq 1$ m²/s	Low	L
Not calculated due to strong natural fluctuations		n.c.

Index 2 (s_p/Q_p)

$s_p/Q_p > 1 \cdot 10^5$ s/m²	Excellent
$3 \cdot 10^4 < s_p/Q_p \leq 1 \cdot 10^5$ s/m²	High
$1 \cdot 10^4 < s_p/Q_p \leq 3 \cdot 10^4$ s/m²	Medium
$s_p/Q_p \leq 1 \cdot 10^4$ s/m²	Low
$s_p < 0.1$ m	No response indices but analysed

Index 2 new ($(s_p/Q_p) \cdot \ln(r_s/r_0)$)

$(s_p/Q_p) \cdot \ln(r_s/r_0) > 5 \cdot 10^5$ s/m²	Excellent
$5 \cdot 10^4 < (s_p/Q_p) \cdot \ln(r_s/r_0) \leq 5 \cdot 10^5$ s/m²	High
$5 \cdot 10^3 < (s_p/Q_p) \cdot \ln(r_s/r_0) \leq 5 \cdot 10^4$ s/m²	Medium
$5 \cdot 10^2 < (s_p/Q_p) \cdot \ln(r_s/r_0) \leq 5 \cdot 10^3$ s/m²	Low
$s_p < 0.1$ m	No response indices but analysed

blank = observed but no response at all
n.o. = not observed

5.3 KLX08 Test section 102.00–242.00 m pumped

This interference test was conducted as constant rate pump test phase followed by a recovery pressure phase in the source section. The mean flow rate was 40.5 l/min with a drawdown of 37 kPa. In sum 16 observation sections responded due to the pumping. Table 5-2 summarizes the responding test sections and selected parameters. Figure 5-1 shows the drawdown of the observed sections related to the distance and Figure 5-2 a map with the borehole responses. The pumped borehole KLX08 is shown with consideration of the effective borehole radius r_{wf}, calculation based on the skin factor ξ.

$$r_{wf} = r_w \cdot e^{-\xi}$$

In the following chapters the response analysis of each responded section is presented.

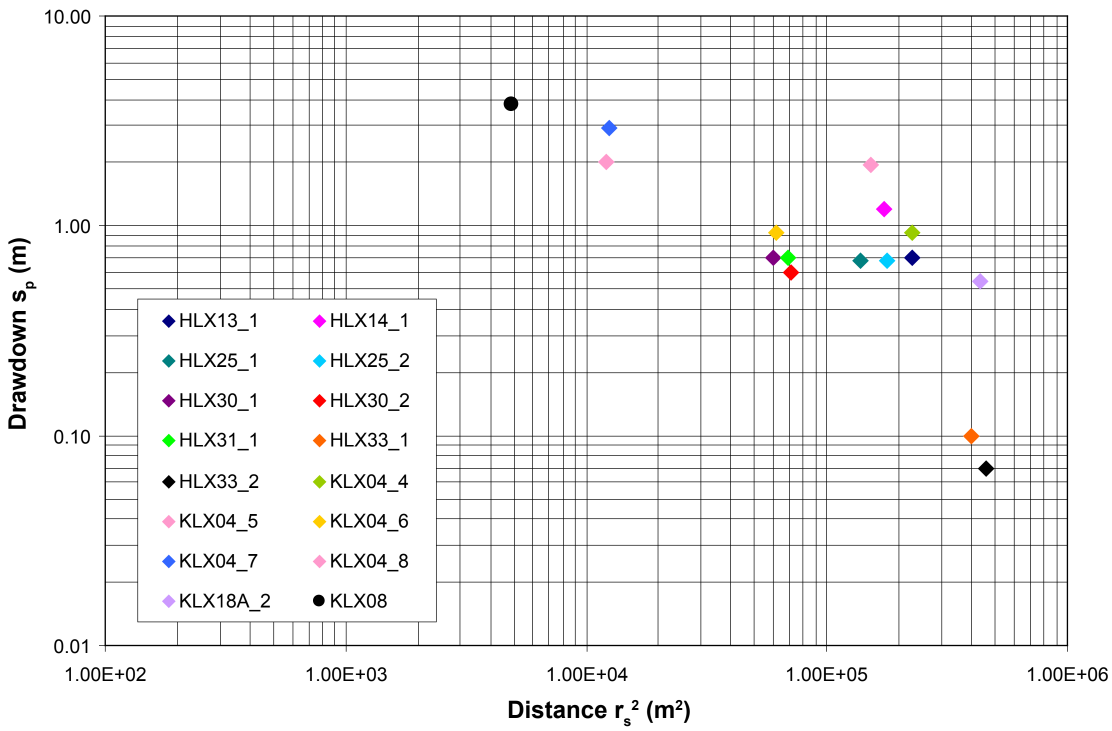

Figure 5-1. *Distance vs. drawdown for the responding test sections, KLX08 section 102.00–242.00 m pumped.*

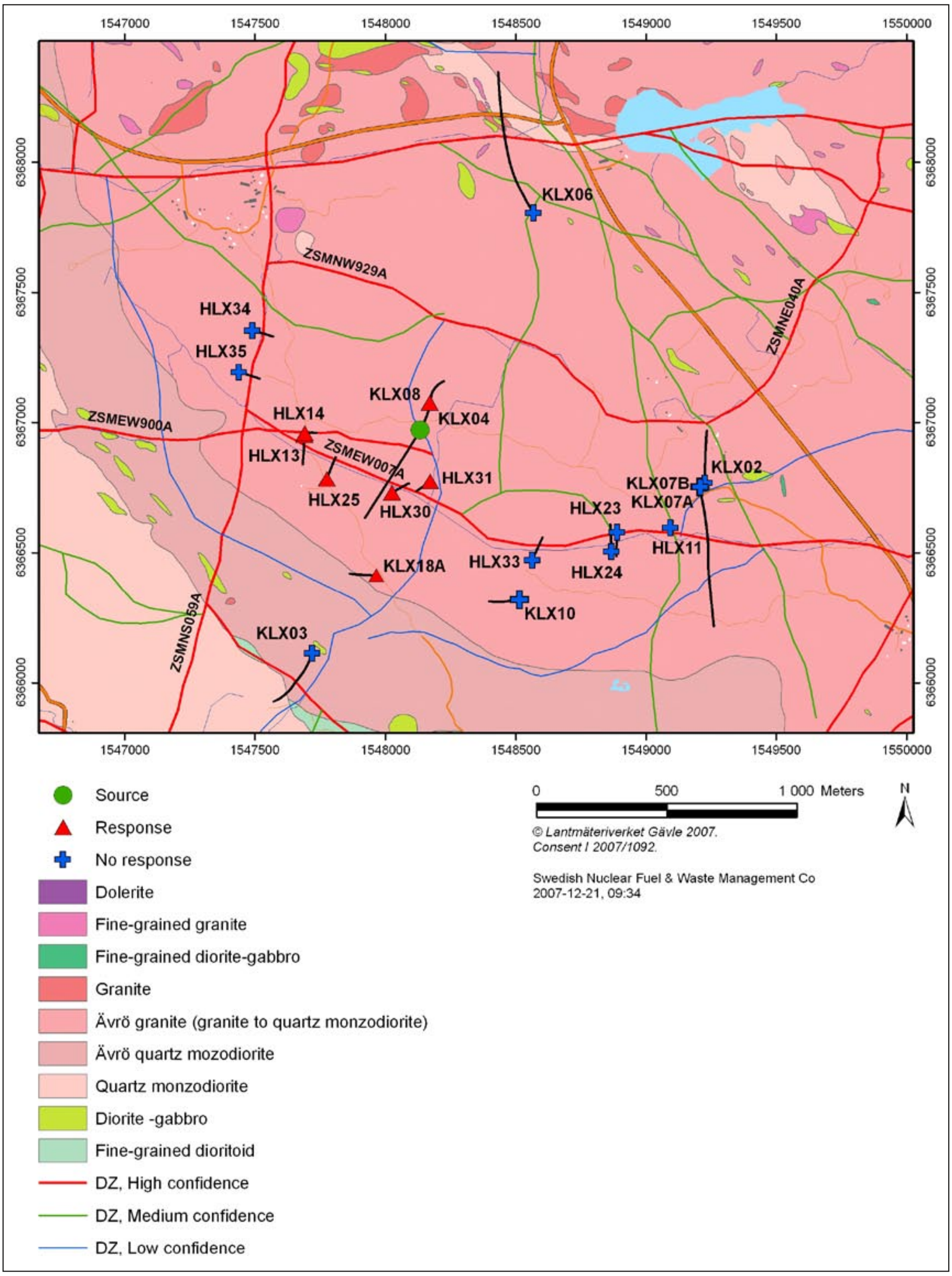

Figure 5-2. *Map showing the responses in the observation boreholes when pumping KLX08 section 102.00–242.00 m.*

Table 5-2. Observed test sections and selected parameters (section 102.00–242.00 m pumped).

Source borehole		Section (m)	Flow rate Qm (l/min)	Drawdown (m)	r_{wf} (m)				
KLX08		102.00–242.00	40.5	3.77	7.0E01				
Observation borehole	**Sec No**	**Section (m)**	**Distance r_s (m)**	**Drawdown s_p (m)**	**dt_L (s)**	**Index 1 r_s^2/dt_L (m^2/s)**	**Index 2 s_p/Q_p (s/m^2)**	**Index 2 New $(s_p/Q_p)^* \ln(r_s/r_0)$ (s/m^2)**	**Diffusivity η (m^2/s)**
KLX08	Pb	243.00–1,000.41	449.7	1.53	14,036	14.41 **H**	2,266.67	13,846.12	–
HLX11	1	17.00–70.00	1,032.1	n.r.	–	–	–	–	–
	2	6.00–16.00	–	n.r.	–	–	–	–	–
HLX13	1	12.00–200.20	475.4	0.70	3,672	61.55 **H**	1,042.02	6,423.18	2.36E02
HLX14	1	12.00–115.90	416.1	1.20	n.c.	n.c.	1,782.01	10,747.10	2.84E02
HLX23	1	61.00–160.20	872.8	n.r.	–	–	–	–	–
	2	6.10–60.00	869.5	n.r.	–	–	–	–	–
HLX24	1	41.00–175.20	834.00	n.r.	–	–	–	–	–
	2	9.10–40.00	878.60	n.r.	–	–	–	–	–
HLX25	1	61.00–202.50	370.3	0.68	3,515	39.01 **H**	1,011.82	5,984.20	1.00E02
	2	6.10–60.00	421.4	0.68	3,515	50.02 **H**	1,011.82	6,115.00	1.17E02
HLX30	1	101.00–163.40	244.9	0.70	3,507	17.10 **H**	1,042.02	5,732.00	3.79E01
	2	9.10–100.00	266.9	0.60	5,221	13.64 **H**	891.00	4,977.90	5.68E01
HLX31	1	9.10–133.20	263.2	0.70	3,306	20.95 **H**	1,042.02	5,807.10	4.73E01
HLX33	1	31.00–202.10	633.2	0.10	n.c.	n.c.	n.c.	n.c.	n.c.
	2	9.10–30.00	675.4	0.07)*	n.c.	n.c.	n.c.	n.c.	n.c.
HLX34	1	9.00–151.80	691.70	n.r.	–	–	–	–	–
HLX35	1	65.00–151.80	669.70	n.r.	–	–	–	–	–
	2	6.10–64.00	728.50	n.r.	–	–	–	–	–
KLX02	1	1,165.00–1,700.00	1,674.0	n.r.	–	–	–	–	–
	2	1,145.00–1,164.00	1,475.4	n.r.	–	–	–	–	–
	3	718.00–1,144.00	1,336.5	n.r.	–	–	–	–	–
	4	495.00–717.00	1,181.8	n.r.	–	–	–	–	–
	5	452.00–494.00	1,139.2	n.r.	–	–	–	–	–
	6	348.00–451.00	1,121.7	n.r.	–	–	–	–	–
	7	209.00–347.00	1,103.0	n.r.	–	–	–	–	–
	8	100.35–208.00	1,098.1	n.r.	–	–	–	–	–
KLX03	1	965.00–971.00	1,451.1	n.r.	–	–	–	–	–
	2	830.00–964.00	1,403.3	n.r.	–	–	–	–	–
	3	752.00–829.00	1,317.9	n.r.	–	–	–	–	–
	4	729.00–751.00	1,302.1	n.r.	–	–	–	–	–
	5	652.00–728.00	1,249.9	n.r.	–	–	–	–	–
	6	465.00–651.00	1,226.3	n.r.	–	–	–	–	–
	7	349.00–464.00	1,117.0	n.r.	–	–	–	–	–
	8	199.00–348.00	1,058.0	n.r.	–	–	–	–	–
	9	193.00–198.00	1,035.1	n.r.	–	–	–	–	–
	X	100.05–192.00	1,021.5	n.r.	–	–	–	–	–
KLX04	1	898.00–1,000.00	813.8	n.r.	–	–	–	–	–
	2	870.00–897.00	749.0	n.r.	–	–	–	–	–
	3	686.00–896.00	644.2	n.r.	–	–	–	–	–
	4	531.00–685.00	477.4	0.92	n.c.	n.c.	1,359.16	8,383.80	8.49E01
	5	507.00–530.00	390.3	1.96	669	227.70 **E**	2,899.54	17,301.30	1.98E02
	6	231.00–506.00	248.1	0.92	n.c.	n.c.	1,359.16	7,494.20	2.32E01
	7	163.00–230.00	111.6	2.93	69	180.50 **E**	4,334.20	20,435.40	5.84E01
	8	12.24–162.00	109.9	2.02	69	175.04 **E**	2,990.15	14,052.40	1.88E01

Source borehole		Section (m)	Flow rate Qm (l/min)	Drawdown (m)	r_{wf} (m)				
KLX08		102.00–242.00	40.5	3.77	7.0E01				
Observation borehole	**Sec No**	**Section (m)**	**Distance r_s (m)**	**Drawdown s_p (m)**	**dt_L (s)**	**Index 1 r_s^2/dt_L (m²/s)**	**Index 2 s_p/Q_p (s/m²)**	**Index 2 New (s_p/Q_p)* $\ln(r_s/r_0)$ (s/m²)**	**Diffusivity η (m²/s)**
KLX06	1	761.00–1,000.00	1,381.3	n.r.	–	–	–	–	–
	2	571.00–760.00	1,198.2	n.r.	–	–	–	–	–
	3	554.00–570.00	1,153.3	n.r.	–	–	–	–	–
	4	411.00–553.00	1,110.7	n.r.	–	–	–	–	–
	5	276.00–410.00	1,011.9	n.r.	–	–	–	–	–
	6	256.00–275.00	981.8	n.r.	–	–	–	–	–
	7	146.00–255.00	961.9	n.r.	–	–	–	–	–
	8	11.88–145.00	929.6	n.r.	–	–	–	–	–
KLX07A	1	781.00–844.73	1,435.0	n.r.	–	–	–	–	–
	2	753.00–780.00	1,399.9	n.r.	–	–	–	–	–
	3	612.00–752.00	1,325.9	n.r.	–	–	–	–	–
	4	457.00–611.00	1,248.5	n.r.	–	–	–	–	–
	5	333.00–456.00	1,202.4	n.r.	–	–	–	–	–
	6	204.00–332.00	1,154.9	n.r.	–	–	–	–	–
	7	104.00–203.00	1,127.1	n.r.	–	–	–	–	–
	8	102.00–103.00	1,111.4	n.r.	–	–	–	–	–
KLX07B	1	95.00–200.00	1,092.0	n.r.	–	–	–	–	–
	2	9.64–94.00	1,090.6	n.r.	–	–	–	–	–
KLX10	1	711.00–1,001.00	1,020.8	n.r.	–	–	–	–	–
	2	689.00–710.00	929.8	n.r.	–	–	–	–	–
	3	465.00–688.00	854.5	n.r.	–	–	–	–	–
	4	369.00–464.00	805.3	n.r.	–	–	–	–	–
	5	351.00–368.00	788.8	n.r.	–	–	–	–	–
	6	291.00–350.00	780.2	n.r.	–	–	–	–	–
	7	131.00–290.00	767.1	n.r.	–	–	–	–	–
	8	9.20–130.00	775.3	n.r.	–	–	–	–	–
KLX18A	1	440.00–611.28	693.4	n.r.	–	–	–	–	–
	2	241.00–439.00	657.0	0.54	n.c.	n.c.	800.39	5,192.70	1.71E02
	3	0.00–240.00	618.1	n.r.	–	–	–	–	–

* No response according to SKB 330.003 (Bilagor B); see Chapter 4.6.1 for greater detail.
n.c. Not calculated due to strong natural fluctuations (tidal effects).
n.r. No response due to pumping in source.
Key for Index 1, 2 and 2 New see Table 5-1.

5.3.1 Response HLX13, Section 1 (12.00–200.20 m)

Comments to test

A total drawdown during the flow period of 6.9 kPa (0.70 m) was observed in this section. A recovery of 0.01 m was reached after appr. 61.2 min (3,672 s) after pump stop in KLX08 (102.00–242.00). The calculated index 1 (r_s^2/dt_L) is rated as "high response time", index 2 (s_p/Q_p) as "low response" and the new index 2 $(s_p/Q_p)\cdot\ln(r_s/r_0)$ as "medium response".

The CRw and CRwr phases show no problems and are adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. For the analysis of the CRw and CRwr phases a homogeneous radial flow model was chosen. The Analysis is presented in Appendix 7-1-1.

Selected representative parameters

The recommended transmissivity of $2.5 \cdot 10^{-4}$ m²/s was derived from the analysis of the CRw phase, which shows the best data and derivative quality. The confidence range for the borehole transmissivity is estimated to be $1.0 \cdot 10^{-4}$ m²/s to $5.0 \cdot 10^{-4}$ m²/s. The flow dimension during the test is 2. The static pressure measured at transducer depth, was derived from the CRwr phase using straight line extrapolation in the Horner plot to a value of 49.5 kPa.

The analyses of the CRw and CRwr phases show consistency. No further analysis recommended.

5.3.2 Response HLX14, Section 1 (12.00–115.90 m)

Comments to test

A total drawdown during the flow period of 11.8 kPa (1.20 m) was observed in this section. Due to the data quality a response time for a pressure change of 0.01 m was not possible to determine after pump start respectively pump stop in KLX08 (102.00–242.00). The index 1 (r_s^2/dt_L) was not possible to calculate, index 2 (s_p/Q_p) is rated as “low response” and the new index 2 $(s_p/Q_p) \cdot \ln(r_s/r_0)$ as “medium response”.

The CRw and CRwr phases show no problems and are adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. For the analysis of the CRw and CRwr phases a homogeneous radial flow model was chosen. The Analysis is presented in Appendix 7-1-2.

Selected representative parameters

The recommended transmissivity of $1.7 \cdot 10^{-4}$ m²/s was derived from the analysis of the CRw phase, which shows the best data and derivative quality. The confidence range for the borehole transmissivity is estimated to be $8.0 \cdot 10^{-5}$ m²/s to $4.0 \cdot 10^{-4}$ m²/s. The flow dimension during the test is 2. The static pressure measured at transducer depth, was derived from the CRwr phase using straight line extrapolation in the Horner plot to a value of 18.1 kPa.

The analyses of the CRw and CRwr phases show consistency. No further analysis recommended.

5.3.3 Response HLX25, Section 1 (61.00–202.50 m)

Comments to test

A total drawdown during the flow period of 6.7 kPa (0.68 m) was observed in this section. A recovery of 0.01 m was reached after appr. 58.6 min (3,515 s) after pump stop in KLX08 (102.00–242.00). The calculated index 1 (r_s^2/dt_L) is rated as “high response time”, index 2 (s_p/Q_p) as “low response” and the new index 2 $(s_p/Q_p) \cdot \ln(r_s/r_0)$ as “medium response”.

The CRw and CRwr phases show no problems and are adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. The CRw phase was analysed using a composite model, for the CRwr phase a homogeneous radial flow model was chosen. The Analysis is presented in Appendix 7-1-3.

Selected representative parameters

The recommended transmissivity of $2.1 \cdot 10^{-4}$ m²/s was derived from the analysis of the CRw phase (inner zone), which shows the best data and derivative quality. The confidence range for the borehole transmissivity is estimated to be $1.0 \cdot 10^{-4}$ m²/s to $5.0 \cdot 10^{-4}$ m²/s. The flow dimension during the test is 2. The static pressure measured at transducer depth, was derived from the CRwr phase using straight line extrapolation in the Horner plot to a value of 91.2 kPa.

The analyses of the CRw and CRwr phases show consistency. No further analysis recommended.

5.3.4 Response HLX25, Section 2 (6.12–60.00 m)

Comments to test

A total drawdown during the flow period of 6.7 kPa (0.68 m) was observed in this section. A recovery of 0.01 m was reached after appr. 58.6 min (3,515 s) after pump stop in KLX08 (102.00–242.00). The calculated index 1 (r_s^2/dt_L) is rated as "high response time", index 2 (s_p/Q_p) as "low response" and the new index 2 (s_p/Q_p)$\cdot$ln(r_s/r_0) as "medium response".

The CRw and CRwr phases show no problems and are adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. The CRw phase was analysed using a composite model, for the CRwr phase a homogeneous radial flow model was chosen. The Analysis is presented in Appendix 7-1-4.

Selected representative parameters

The recommended transmissivity of $2.1 \cdot 10^{-4}$ m²/s was derived from the analysis of the CRw phase (inner zone), which shows the best data and derivative quality. The confidence range for the borehole transmissivity is estimated to be $1.0 \cdot 10^{-4}$ m²/s to $4.0 \cdot 10^{-4}$ m²/s. The flow dimension during the test is 2. The static pressure measured at transducer depth, was derived from the CRwr phase using straight line extrapolation in the Horner plot to a value of 91.6 kPa.

The analyses of the CRw and CRwr phases show consistency. No further analysis recommended.

5.3.5 Response HLX30, Section 1 (101.00–163.40 m)

Comments to test

A total drawdown during the flow period of 6.9 kPa (0.70 m) was observed in this section. A recovery of 0.01 m was reached after appr. 58.5 min (3,507 s) after pump stop in KLX08 (102.00–242.00). The calculated index 1 (r_s^2/dt_L) is rated as "high response time", index 2 (s_p/Q_p) as "low response" and the new index 2 (s_p/Q_p)$\cdot$ln(r_s/r_0) as "medium response".

The CRw and CRwr phases show no problems and are adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. The CRw phase was analysed using a composite model, for the CRwr phase a homogeneous radial flow model was chosen. The Analysis is presented in Appendix 7-1-5.

Selected representative parameters

The recommended transmissivity of $1.9 \cdot 10^{-4}$ m²/s was derived from the analysis of the CRw phase (inner zone), which shows the best data and derivative quality. The confidence range for the borehole transmissivity is estimated to be $9.0 \cdot 10^{-5}$ m²/s to $5.0 \cdot 10^{-4}$ m²/s. The flow dimension during the test is 2. The static pressure measured at transducer depth, was derived from the CRwr phase using straight line extrapolation in the Horner plot to a value of 97.9 kPa.

The analyses of the CRw and CRwr phases show consistency. No further analysis recommended.

5.3.6 Response HLX30, Section 2 (9.10–100.00 m)

Comments to test

A total drawdown during the flow period of 5.9 kPa (0.60 m) was observed in this section. A recovery of 0.01 m was reached after appr. 87.0 min (5,221 s) after pump stop in KLX08 (102.00–242.00). The calculated index 1 (r_s^2/dt_L) is rated as "high response time", index 2 (s_p/Q_p) as "low response" and the new index 2 (s_p/Q_p)·ln(r_s/r_0) as "low response".

The CRw and CRwr phases show no problems and are adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. The CRw phase was analysed using a composite model, for the CRwr phase a homogeneous radial flow model was chosen. The Analysis is presented in Appendix 7-1-6.

Selected representative parameters

The recommended transmissivity of $2.6 \cdot 10^{-4}$ m²/s was derived from the analysis of the CRw phase (inner zone), which shows the best data and derivative quality. The confidence range for the borehole transmissivity is estimated to be $1.0 \cdot 10^{-4}$ m²/s to $6.0 \cdot 10^{-4}$ m²/s. The flow dimension during the test is 2. The static pressure measured at transducer depth, was derived from the CRwr phase using straight line extrapolation in the Horner plot to a value of 97.4 kPa.

The analyses of the CRw and CRwr phases show consistency. No further analysis recommended.

5.3.7 Response HLX31, Section 1 (9.10–133.20 m)

Comments to test

A total drawdown during the flow period of 6.9 kPa (0.70 m) was observed in this section. A recovery of 0.01 m was reached after appr. 55.1 min (3,306 s) after pump stop in KLX08 (102.00–242.00). The calculated index 1 (r_s^2/dt_L) is rated as "high response time", index 2 (s_p/Q_p) as "low response" and the new index 2 (s_p/Q_p)·ln(r_s/r_0) as "medium response".

The CRw and CRwr phases show no problems and are adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. The CRw phase was analysed using a composite model, for the CRwr phase a homogeneous radial flow model was chosen. The Analysis is presented in Appendix 7-1-7.

Selected representative parameters

The recommended transmissivity of $2.0 \cdot 10^{-4}$ m²/s was derived from the analysis of the CRw phase (inner zone), which shows the best data and derivative quality. The confidence range for the borehole transmissivity is estimated to be $1.0 \cdot 10^{-4}$ m²/s to $5.0 \cdot 10^{-4}$ m²/s. The flow dimension during the test is 2. The static pressure measured at transducer depth, was derived from the CRwr phase using straight line extrapolation in the Horner plot to a value of 97.6 kPa.

The analyses of the CRw and CRwr phases show consistency. No further analysis recommended.

5.3.8 Response HLX33, Section 1 (31.00–202.10 m)

Comments to test

A total drawdown during the flow period of 1.0 kPa (0.10 m) was observed in this section. Because of the low drawdown and the no clear reaction of the response, the indices are rated as "no response". Although the response is very low it is clearly caused by pumping in KLX08 (102.00–242.00) but due to major tidal effects, no transient analysis could be performed.

5.3.9 Response HLX33, Section 2 (9.10–30.00 m)

Comments to test

A total drawdown during the flow period of 0.7 kPa (0.07 m) was observed in this section. Because of the low drawdown and the no clear reaction of the response, the indices are rated as "no response". Although the response is very low it is clearly caused by pumping in KLX08 (102.00–242.00) but due to major tidal effects, no transient analysis could be performed.

5.3.10 Response KLX04, Section 4 (531.00–685.00 m)

Comments to test

A total drawdown during the flow period of 9.0 kPa (0.92 m) was observed in this section. Due to the data quality a response time for a pressure change of 0.01 m was not possible to determine after pump start respectively pump stop in KLX08 (102.00–242.00). The index 1 (r_s^2/dt_L) was not possible to calculate, index 2 (s_p/Q_p) is rated as "low response" and the new index 2 $(s_p/Q_p)\cdot\ln(r_s/r_0)$ as "medium response".

The CRw and CRwr phases show no problems and are adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. For the analysis of the CRw and CRwr phases a homogeneous radial flow model was chosen. The Analysis is presented in Appendix 7-1-8.

Selected representative parameters

The recommended transmissivity of $1.4\cdot10^{-4}$ m²/s was derived from the analysis of the CRw phase, which shows the best data and derivative quality. The confidence range for the borehole transmissivity is estimated to be $7.0\cdot10^{-5}$ m²/s to $4.0\cdot10^{-4}$ m²/s. The flow dimension during the test is 2. The static pressure measured at transducer depth, was derived from the CRwr phase using straight line extrapolation in the Horner plot to a value of 96.1 kPa.

The analyses of the CRw and CRwr phases show consistency. No further analysis recommended.

5.3.11 Response KLX04, Section 5 (507.00–530.00 m)

Comments to test

A total drawdown during the flow period of 19.2 kPa (1.96 m) was observed in this section. A recovery of 0.01 m was reached after appr. 11.2 min (669 s) after pump stop in KLX08 (102.00–242.00). The calculated index 1 (r_s^2/dt_L) is rated as "excellent response time", index 2 (s_p/Q_p) as "low response" and the new index 2 $(s_p/Q_p)\cdot\ln(r_s/r_0)$ as "high response".

The CRw and CRwr phases show no problems and are adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. For the analysis of the CRw and CRwr phases a homogeneous radial flow model was chosen. The Analysis is presented in Appendix 7-1-9.

Selected representative parameters

The recommended transmissivity of $1.0 \cdot 10^{-4}$ m²/s was derived from the analysis of the CRwr phase, which shows the best data and derivative quality. The confidence range for the borehole transmissivity is estimated to be $4.0 \cdot 10^{-5}$ m²/s to $2.0 \cdot 10^{-4}$ m²/s. The flow dimension during the test is 2. The static pressure measured at transducer depth, was derived from the CRwr phase using straight line extrapolation in the Horner plot to a value of 98.8 kPa.

The analyses of the CRw and CRwr phases show consistency. No further analysis recommended.

5.3.12 Response KLX04, Section 6 (231.00–506.00 m)

Comments to test

A total drawdown during the flow period of 9.0 kPa (0.92 m) was observed in this section. Due to the data quality a response time for a pressure change of 0.01 m was not possible to determine after pump start respectively pump stop in KLX08 (102.00–242.00). The index 1 (r_s^2/dt_L) was not possible to calculate, index 2 (s_p/Q_p) is rated as "low response" and the new index 2 $(s_p/Q_p) \cdot \ln(r_s/r_0)$ as "medium response".

The CRw and CRwr phases show no problems and are adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. For the analysis of the CRw and CRwr phases a composite radial flow model with a lower transmissivity in the outer zone was chosen. The Analysis is presented in Appendix 7-1-10.

Selected representative parameters

The recommended transmissivity of $1.6 \cdot 10^{-4}$ m²/s was derived from the analysis of the CRw phase (inner zone), which shows the best data and derivative quality. The confidence range for the borehole transmissivity is estimated to be $7.0 \cdot 10^{-5}$ m²/s to $6.0 \cdot 10^{-4}$ m²/s. The flow dimension during the test is 2. The static pressure measured at transducer depth, was derived from the CRwr phase using straight line extrapolation in the Horner plot to a value of 92.4 kPa.

The analyses of the CRw and CRwr phases show consistency. No further analysis recommended.

5.3.13 Response KLX04, Section 7 (163.00–230.00 m)

Comments to test

A total drawdown during the flow period of 28.7 kPa (2.93 m) was observed in this section. A recovery of 0.01 m was reached after appr. 1.2 min (69 s) after pump stop in KLX08 (102.00–242.00). The calculated index 1 (r_s^2/dt_L) is rated as "excellent response time", index 2 (s_p/Q_p) as "low response" and the new index 2 $(s_p/Q_p) \cdot \ln(r_s/r_0)$ as "medium response".

The CRw and CRwr phases show no problems and are adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. For the analysis of the CRw and CRwr phases a composite radial flow model with a higher transmissivity in the outer zone was chosen. The Analysis is presented in Appendix 7-1-11.

Selected representative parameters

The recommended transmissivity of $8.2 \cdot 10^{-5}$ m²/s was derived from the analysis of the CRwr phase (inner zone), which shows the best data and derivative quality. The confidence range for the borehole transmissivity is estimated to be $4.0 \cdot 10^{-5}$ m²/s to $2.0 \cdot 10^{-4}$ m²/s. The flow dimension during the test is 2. The static pressure measured at transducer depth, was derived from the CRwr phase using straight line extrapolation in the Horner plot to a value of 99.6 kPa.

The analyses of the CRw and CRwr phases show consistency. No further analysis recommended.

5.3.14 Response KLX04, Section 8 (12.24–162.00 m)

Comments to test

A total drawdown during the flow period of 19.8 kPa (2.02 m) was observed in this section. A recovery of 0.01 m was reached after appr. 1.2 min (69 s) after pump stop in KLX08 (102.00–242.00). The calculated index 1 (r_s^2/dt_L) is rated as “excellent response time”, index 2 (s_p/Q_p) as “low response” and the new index 2 $(s_p/Q_p) \cdot \ln(r_s/r_0)$ as “medium response”.

The CRw and CRwr phases show no problems and are adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. For the analysis of the CRw and CRwr phases a composite radial flow model with a higher transmissivity in the outer zone was chosen. The Analysis is presented in Appendix 7-1-12.

Selected representative parameters

The recommended transmissivity of $8.0 \cdot 10^{-5}$ m²/s was derived from the analysis of the CRw phase (inner zone), which shows the best data and derivative quality. The confidence range for the borehole transmissivity is estimated to be $4.0 \cdot 10^{-5}$ m²/s to $2.0 \cdot 10^{-4}$ m²/s. The flow dimension during the test is 2. The static pressure measured at transducer depth, was derived from the CRwr phase using straight line extrapolation in the Horner plot to a value of 103.6 kPa.

The analyses of the CRw and CRwr phases show consistency. No further analysis recommended.

5.3.15 Response KLX18A, Section 2 (241.00–439.00 m)

Comments to test

A total drawdown during the flow period of 5.3 kPa (0.54 m) was observed in this section. Due to the data quality a response time for a pressure change of 0.01 m was not possible to determine after pump start respectively pump stop in KLX08 (102.00–242.00). The index 1 (r_s^2/dt_L) was not possible to calculate, index 2 (s_p/Q_p) is rated as “low response” and the new index 2 $(s_p/Q_p) \cdot \ln(r_s/r_0)$ as “medium response”.

The CRw phase shows no problems and is adequate for quantitative analysis. The CRwr phase is of poor quality, a quantitative analysis was not possible for this test phase.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. For the analysis of the CRw phase a homogeneous radial flow model was chosen. The Analysis is presented in Appendix 7-1-13.

Selected representative parameters

The recommended transmissivity of $2.4 \cdot 10^{-4}$ m²/s was derived from the analysis of the CRw phase, which shows a good data and derivative quality. The confidence range for the borehole transmissivity is estimated to be $1.0 \cdot 10^{-4}$ m²/s to $5.0 \cdot 10^{-4}$ m²/s. The flow dimension during the test is 2. A static pressure was not possible to derive from the CRwr phase.

No further analysis recommended.

5.4 KLX08 Test section 241.00–341.00 m pumped

This interference test was conducted as constant rate pump test phase followed by a recovery pressure phase in the source section. The mean flow rate was 5.1 l/min with a drawdown of 453 kPa. In sum 13 observation sections responded due to the pumping. Table 5-3 summarizes the responding test sections and selected parameters. Figure 5-3 shows the drawdown of the observed sections related to the distance and Figure 5-4 a map the borehole resposnes. The pumped borehole KLX08 is shown with consideration of the effective borehole radius r_{wf}.
In the following chapters the response analysis of each responded section is presented.

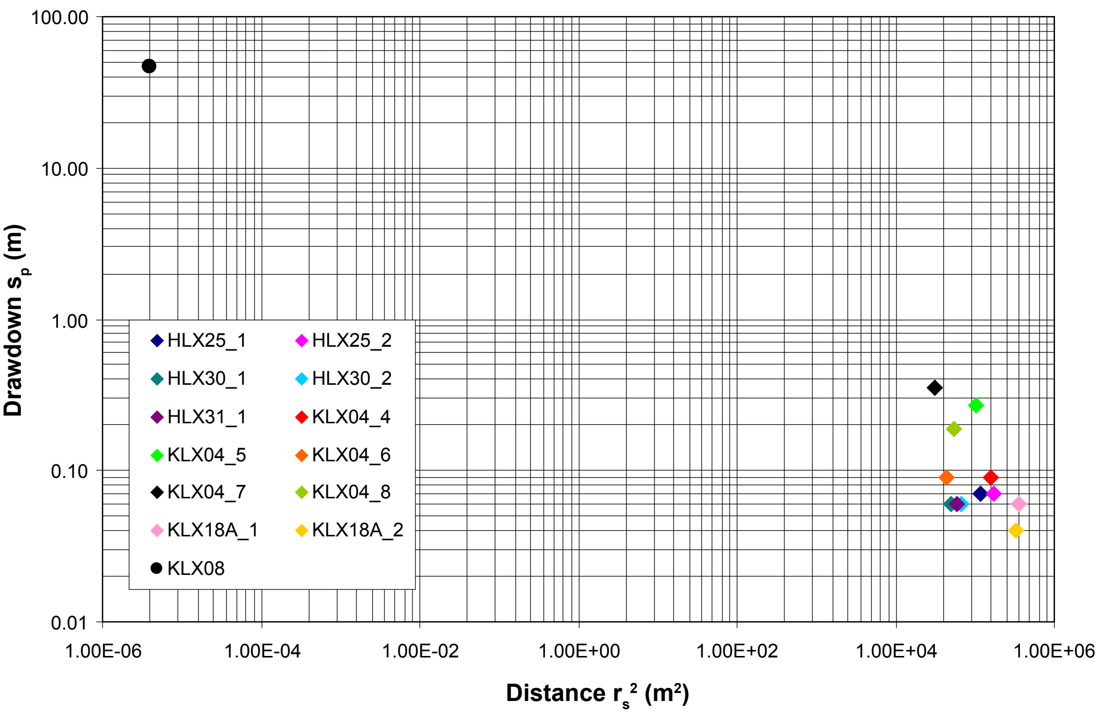

Figure 5-3. Distance vs. drawdown for the responding test sections, KLX08 section 241.00–341.00 m pumped.

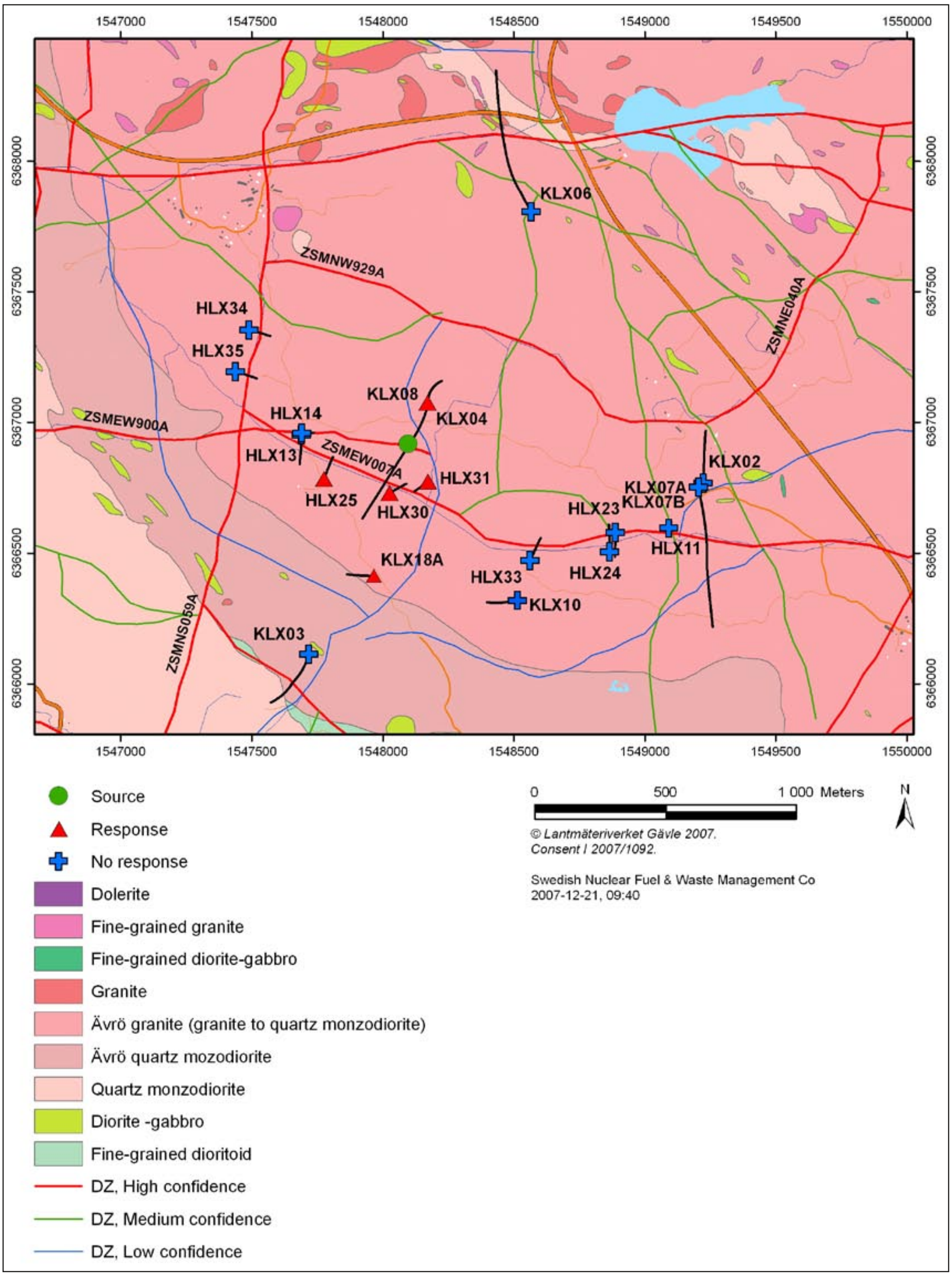

Figure 5-4. *Map showing the borehole responses when pumping KLX08 section 241.00–341.00 m.*

Table 5-3. Observed test sections and selected parameters (section 241.00–341.00 m pumped).

Source borehole		Section (m)	Flow rate Qm (l/min)	Drawdown (m)	r_{wf} (m)				
KLX08		241.00–341.00	5.1	46.18	2.0E–03				
Observation borehole	**Sec No**	**Section (m)**	**Distance r_s (m)**	**Drawdown s_p (m)**	**dt_L (s)**	**Index 1 r_s^2/dt_L (m²/s)**	**Index 2 s_p/Q_p (s/m²)**	**Index 2 New $(s_p/Q_p)^*\ln(r_s/r_0)$ (s/m²)**	**Diffusivity η (m²/s)**
KLX08	Pa	101.01–240.00	129.5	0.41	21,664	0.77 **L**	4,823.53	23,460.11	–
	Pb	342.00–1,000.41	499.2	n.r.	–	**–**	–	–	–
HLX11	1	17.00–70.00	1,056.3	n.r.	–	–	–	–	–
	2	6.00–16.00	–	n.r.	–	–	–	–	–
HLX13	1	12.00–200.20	463.1	n.r.	–	–	–	–	–
HLX14	1	12.00–115.90	411.9	n.r.	–	–	–	–	–
HLX23	1	61.00–160.20	887.5	n.r.	–	–	–	–	–
	2	6.10–60.00	886.8	n.r.	–	–	–	–	–
HLX24	1	41.00–175.20	845.0	n.r.	–	–	–	–	–
	2	9.10–40.00	896.1	n.r.	–	–	–	–	–
HLX25	1	61.00–202.50	339.8	0.07*	n.c.	n.c.	839.48	4,892.79	n.c.
	2	6.10–60.00	416.7	0.07*	n.c.	n.c.	839.48	5,064.05	n.c.
HLX30	1	101.00–163.40	220.9	0.06*	n.c.	n.c.	719.55	3,883.94	n.c.
	2	9.10–100.00	260.4	0.06*	n.c.	n.c.	719.55	4,002.32	n.c.
HLX31	1	9.10–133.20	244.2	0.06*	n.c.	n.c.	719.55	3,956.10	n.c.
HLX33	1	31.00–202.10	622.6	n.r.	–	–	–	–	–
	2	9.10–30.00	681.6	n.r.	–	–	–	–	–
HLX34	1	9.00–151.80	713.4	n.r.	–	–	–	–	–
HLX35	1	65.00–151.80	764.8	n.r.	–	–	–	–	–
	2	6.10–64.00	743.7	n.r.	–	–	–	–	–
KLX02	1	1,165.00–1,700.00	1,609.3	n.r.	–	–	–	–	–
	2	1,145.00–1,164.00	1,421.7	n.r.	–	–	–	–	–
	3	718.00–1,144.00	1,294.8	n.r.	–	–	–	–	–
	4	495.00–717.00	1,163.6	n.r.	–	–	–	–	–
	5	452.00–494.00	1,132.7	n.r.	–	–	–	–	–
	6	348.00–451.00	1,121.9	n.r.	–	–	–	–	–
	7	209.00–347.00	1,114.7	n.r.	–	–	–	–	–
	8	100.35–208.00	1,116.7	n.r.	–	–	–	–	–
KLX03	1	965.00–971.00	1,338.0	n.r.	–	–	–	–	–
	2	830.00–964.00	1,292.6	n.r.	–	–	–	–	–
	3	752.00–829.00	1,212.4	n.r.	–	–	–	–	–
	4	729.00–751.00	1,197.8	n.r.	–	–	–	–	–
	5	652.00–728.00	1,149.9	n.r.	–	–	–	–	–
	6	465.00–651.00	1,128.6	n.r.	–	–	–	–	–
	7	349.00–464.00	1,034.0	n.r.	–	–	–	–	–
	8	199.00–348.00	988.2	n.r.	–	–	–	–	–
	9	193.00–198.00	972.6	n.r.	–	–	–	–	–
	X	100.05–192.00	964.4	n.r.	–	–	–	–	–
KLX04	1	898.00–1,000.00	724.2	n.r.	–	–			
	2	870.00–897.00	660.7	n.r.	–	–	–	–	–
	3	686.00–869.00	559.0	n.r.	–	–	–	–	–
	4	531.00–685.00	400.8	0.09*	n.c.	n.c.	1,079.33	6,468.93	n.c.
	5	507.00–530.00	322.2	0.27	644	161.20 **E**	3,118.07	18,007.40	4.87E02
	6	231.00–506.00	210.6	0.09*	n.c.	n.c.	1,079.33	5,774.40	n.c.
	7	163.00–230.00	177.1	0.35	464	67.60 **H**	4,077.47	21,107.90	1.33E02
	8	12.24–162.00	231.5	0.19	n.c.	n.c.	2,278.59	12,406.00	n.c.

Source borehole		Section (m)	Flow rate Qm (l/min)	Drawdown (m)	r_{wf} (m)				
KLX08		241.00–341.00	5.1	46.18	2.0E–03				
Observation borehole	**Sec No**	**Section (m)**	**Distance r_s (m)**	**Drawdown s_p (m)**	**dt_L (s)**	**Index 1 r_s^2/dt_L (m²/s)**	**Index 2 s_p/Q_p (s/m²)**	**Index 2 New (s_p/Q_p)* $\ln(r_s/r_0)$ (s/m²)**	**Diffusivity η (m²/s)**
KLX06	1	761.00–1,000.00	1,398.1	n.r.	–	–	–	–	–
	2	571.00–760.00	1,226.9	n.r.	–	–	–	–	–
	3	554.00–570.00	1,186.1	n.r.	–	–	–	–	–
	4	411.00–553.00	1,148.2	n.r.	–	–	–	–	–
	5	276.00–410.00	1,064.5	n.r.	–	–	–	–	–
	6	256.00–275.00	1,041.3	n.r.	–	–	–	–	–
	7	146.00–255.00	1,027.5	n.r.	–	–	–	–	–
	8	11.88–145.00	1,008.5	n.r.	–	–	–	–	–
KLX07A	1	781.00–844.73	1,394.7	n.r.	–	–	–	–	–
	2	753.00–780.00	1,363.5	n.r.	–	–	–	–	–
	3	612.00–752.00	1,298.8	n.r.	–	–	–	–	–
	4	457.00–611.00	1,234.5	n.r.	–	–	–	–	–
	5	333.00–456.00	1,198.8	n.r.	–	–	–	–	–
	6	204.00–332.00	1,164.5	n.r.	–	–	–	–	–
	7	104.00–203.00	1,146.2	n.r.	–	–	–	–	–
	8	102.00–103.00	1,136.8	n.r.	–	–	–	–	–
KLX07B	1	95.00–200.00	1,115.2	n.r.	–	–	–	–	–
	2	9.64–94.00	1,122.7	n.r.	–	–	–	–	–
KLX10	1	711.00–1,001.00	917.0	n.r.	–	–	–	–	–
	2	689.00–710.00	835.0	n.r.	–	–	–	–	–
	3	465.00–688.00	772.7	n.r.	–	–	–	–	–
	4	369.00–464.00	738.2	n.r.	–	–	–	–	–
	5	351.00–368.00	729.6	n.r.	–	–	–	–	–
	6	291.00–350.00	726.6	n.r.	–	–	–	–	–
	7	131.00–290.00	731.4	n.r.	–	–	–	–	–
	8	9.20–130.00	761.3	n.r.	–	–	–	–	–
KLX18A	1	440.00–611.28	595.2	0.06*	n.c.	n.c.	n.c.	n.c.	n.c.
	2	241.00–439.00	570.9	0.04*	n.c.	n.c.	479.70	3,044.77	n.c.
	3	11.83–240.00	571.3	n.r.	–	–	–	–	–

* No response according to SKB 330.003 (Bilagor B); see Chapter 4.6.1 for greater detail.
n.c. Not calculated due to strong natural fluctuations (tidal effects).
n.r. No response due to pumping in source.
Key for Index 1, 2 and 2 New see Table 5-1.

5.4.1 Response HLX25, Section 1 (61.00–202.50 m)

Comments to test

A total drawdown during the flow period of 0.7 kPa (0.07 m) was observed in this section. Because of the low drawdown and the no clear reaction of the response, index 1 rated as “no response”. The calculated index 2 (s_p/Q_p) is rated as “low response” and the new index 2 (s_p/Q_p)·ln(r_s/r_0) as “low response”. Although the response is very low it is clearly caused by pumping in KLX08 (241.00–341.00) but due to major tidal effects, no transient analysis could be performed.

5.4.2 Response HLX25, Section 2 (6.10–60.00 m)

Comments to test

A total drawdown during the flow period of 0.7 kPa (0.07 m) was observed in this section. Because of the low drawdown and the no clear reaction of the response, index 1 rated as “no response”. The calculated index 2 (s_p/Q_p) is rated as “low response” and the new index 2 (s_p/Q_p)·ln(r_s/r_0) as “medium response”. Although the response is low it is clearly caused by pumping in KLX08 (241.00–341.00) but due to major tidal effects, no transient analysis could be performed.

5.4.3 Response HLX30, Section 1 (101.00–163.40 m)

Comments to test

A total drawdown during the flow period of 0.6 kPa (0.06 m) was observed in this section. Because of the low drawdown and the no clear reaction of the response, index 1 rated as “no response”. The calculated index 2 (s_p/Q_p) is rated as “low response” and the new index 2 (s_p/Q_p)·ln(r_s/r_0) as “low response”. Although the response is very low it is clearly caused by pumping in KLX08 (241.00–341.00) but due to major tidal effects, no transient analysis could be performed.

5.4.4 Response HLX30, Section 2 (9.10–100.00 m)

Comments to test

A total drawdown during the flow period of 0.6 kPa (0.06 m) was observed in this section. Because of the low drawdown and the no clear reaction of the response, index 1 rated as “no response”. The calculated index 2 (s_p/Q_p) is rated as “low response” and the new index 2 (s_p/Q_p)·ln(r_s/r_0) as “low response”. Although the response is very low it is clearly caused by pumping in KLX08 (241.00–341.00) but due to major tidal effects, no transient analysis could be performed.

5.4.5 Response HLX31, Section 1 (9.10–133.20 m)

Comments to test

A total drawdown during the flow period of 0.6 kPa (0.06 m) was observed in this section. Because of the low drawdown and the no clear reaction of the response, index 1 rated as “no response”. The calculated index 2 (s_p/Q_p) is rated as “low response” and the new index 2 (s_p/Q_p)·ln(r_s/r_0) as “low response”. Although the response is very low it is clearly caused by pumping in KLX08 (241.00–341.00) but due to major tidal effects, no transient analysis could be performed.

5.4.6 Response KLX04, Section 4 (531.00–685.00 m)

Comments to test

A total drawdown during the flow period of 0.9 kPa (0.09 m) was observed in this section. Because of the low drawdown and the no clear reaction of the response, index 1 rated as "no response". The calculated index 2 (s_p/Q_p) is rated as "low response" and the new index 2 $(s_p/Q_p)\cdot\ln(r_s/r_0)$ as "medium response". Although the response is low it is clearly caused by pumping in KLX08 (241.00–341.00) but due to major tidal effects, no transient analysis could be performed.

5.4.7 Response KLX04, Section 5 (507.00–530.00 m)

Comments to test

A total drawdown during the flow period of 2.6 kPa (0.27 m) was observed in this section. A recovery of 0.01 m was reached after appr. 10.7 min (644 s) after pump stop in KLX08 (241.00–341.00). The calculated index 1 (r_s^2/dt_L) is rated as "excellent response time", index 2 (s_p/Q_p) as "low response" and the new index 2 $(s_p/Q_p)\cdot\ln(r_s/r_0)$ as "medium response".

The CRw and CRwr phases show no problems and are adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. The CRw phase was analysed using a composite model, for the CRwr phase a homogeneous radial flow model was chosen. The Analysis is presented in Appendix 7-2-1.

Selected representative parameters

The recommended transmissivity of $1.7\cdot10^{-4}$ m²/s was derived from the analysis of the CRw phase (inner zone), which shows the best data and derivative quality. The confidence range for the borehole transmissivity is estimated to be $8.0\cdot10^{-5}$ m²/s to $4.0\cdot10^{-4}$ m²/s. The flow dimension during the test is 2. The static pressure measured at transducer depth, was derived from the CRwr phase using straight line extrapolation in the Horner plot to a value of 86.7 kPa.

The analyses of the CRw and CRwr phases show consistency. No further analysis recommended.

5.4.8 Response KLX04, Section 6 (231.00–506.00 m)

Comments to test

A total drawdown during the flow period of 0.9 kPa (0.09 m) was observed in this section. Because of the low drawdown and the no clear reaction of the response, index 1 rated as "no response". The calculated index 2 (s_p/Q_p) is rated as "low response" and the new index 2 $(s_p/Q_p)\cdot\ln(r_s/r_0)$ as "medium response". Although the response is low it is clearly caused by pumping in KLX08 (241.00–341.00) but due to major tidal effects, no transient analysis could be performed.

5.4.9 Response KLX04, Section 7 (163.00–230.00 m)

Comments to test

A total drawdown during the flow period of 3.4 kPa (0.35 m) was observed in this section. A recovery of 0.01 m was reached after appr. 7.7 min (464 s) after pump stop in KLX08 (241.00–341.00). The calculated index 1 (r_s^2/dt_L) is rated as "high response time", index 2 (s_p/Q_p) as "low response" and the new index 2 $(s_p/Q_p)\cdot\ln(r_s/r_0)$ as "medium response".

The CRw and CRwr phases show no problems and are adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. For the analysis of the CRw and CRwr phases a homogeneous radial flow model was chosen. The Analysis is presented in Appendix 7-2-2.

Selected representative parameters

The recommended transmissivity of $8.2 \cdot 10^{-5}$ m²/s was derived from the analysis of the CRwr phase, which shows the best data and derivative quality. The confidence range for the borehole transmissivity is estimated to be $4.0 \cdot 10^{-5}$ m²/s to $2.0 \cdot 10^{-4}$ m²/s. The flow dimension during the test is 2. The static pressure measured at transducer depth, was derived from the CRwr phase using straight line extrapolation in the Horner plot to a value of 87.8 kPa.

The analyses of the CRw and CRwr phases show consistency. No further analysis recommended.

5.4.10 Response KLX04, Section 8 (12.24–162.00 m)

Comments to test

A total drawdown during the flow period of 1.9 kPa (0.19 m) was observed in this section. Because of the low drawdown and the no clear reaction of the response, index 1 rated as "no response". The calculated index 2 (s_p/Q_p) is rated as "low response" and the new index 2 (s_p/Q_p)$\cdot$ln(r_s/r_0) as "medium response". Although the response is low it is clearly caused by pumping in KLX08 (241.00–341.00) but due to major tidal effects, no transient analysis could be performed.

5.4.11 Response KLX18A, Section 1 (440.00–611.28 m)

Comments to test

A total drawdown during the flow period of 0.6 kPa (0.06 m) was observed in this section. Because of the low drawdown and the no clear reaction of the response, index 1, index 2 and new index 2 are rated as "no response". Although the response is very low it is clearly caused by pumping in KLX08 (241.00–341.00) but due to major tidal effects, no transient analysis could be performed.

5.4.12 Response KLX18A, Section 2 (241.00–439.00 m)

Comments to test

A total drawdown during the flow period of 0.4 kPa (0.04 m) was observed in this section. Because of the low drawdown and the no clear reaction of the response, index 1 rated as "no response". The calculated index 2 (s_p/Q_p) is rated as "low response" and the new index 2 (s_p/Q_p)$\cdot$ln(r_s/r_0) as "low response". Although the response is very low it is clearly caused by pumping in KLX08 (241.00–341.00) but due to major tidal effects, no transient analysis could be performed.

5.5 KLX08 Test section 357.00–497.00 m pumped

This interference test was conducted as constant rate pump test phase followed by a recovery pressure phase in the source section. The mean flow rate was 31.0 l/min with a drawdown of 44 kPa. In sum 24 observation sections responded due to the pumping. Table 5-4 summarizes the responding test sections and selected parameters. Figure 5-5 shows the drawdown of the observed sections related to the distance and Figure 5-6 the map with the borehole responses. The pumped borehole KLX08 is shown with consideration of the effective borehole radius r_{wf}. For the calculation of r_{wf} the skin factor of the pump phase was taken into account. In the following chapters the response analysis of each responded section is presented.

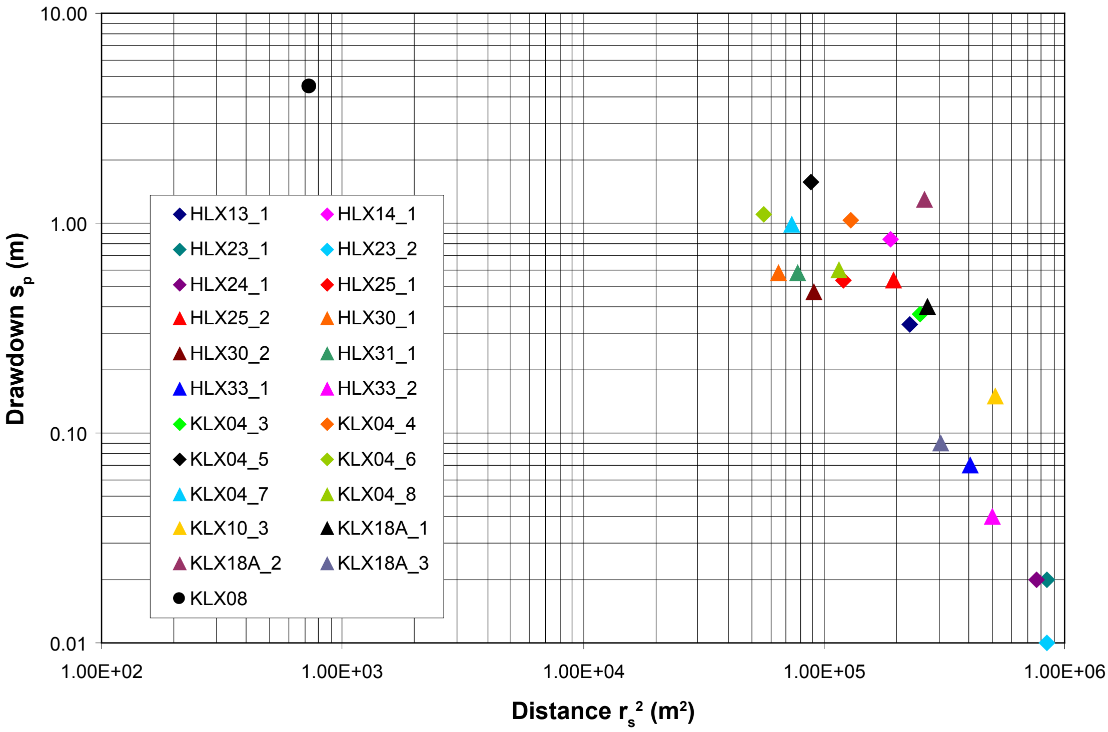

Figure 5-5. *Distance vs. drawdown for the responding test sections, KLX08 section 357.00–497.00 m pumped.*

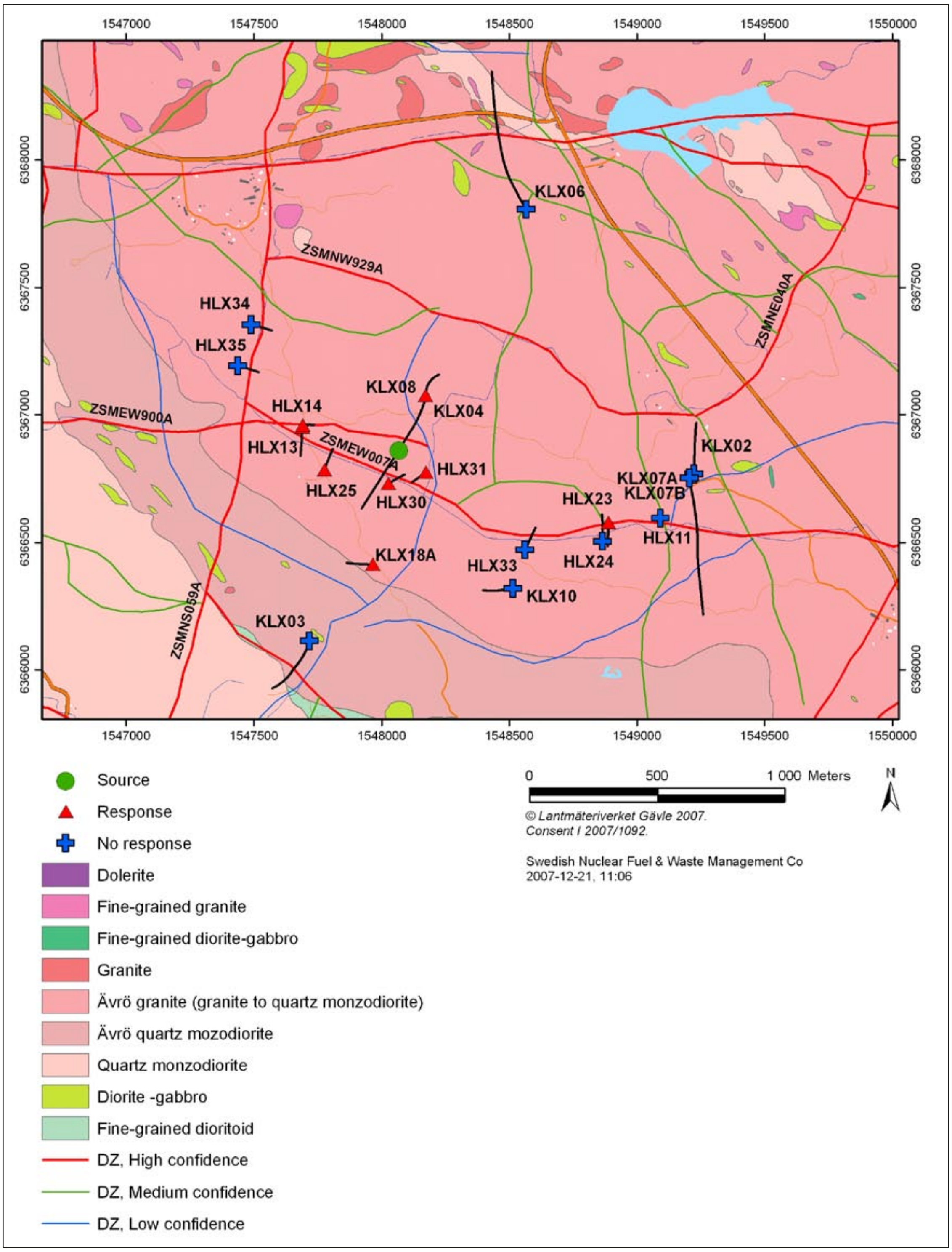

Figure 5-6. *Map showing borehole responses when pumping KLX08 section 241.00–341.00 m.*

Table 5-4. Observed test sections and selected parameters (section 357.00–497.00 m pumped).

Source borehole		Section (m)	Flow rate Qm (l/min)	Drawdown (m)	r_{wf} (m)				
KLX08		357.00–497.00	31.0	4.49	2.7E01				
Observation borehole	**Sec No**	**Section (m)**	**Distance r_s (m)**	**Drawdown s_p (m)**	**dt_L (s)**	**Index 1 r_s^2/dt_L (m^2/s)**	**Index 2 s_p/Q_p (s/m^2)**	**Index 2 New $(s_p/Q_p)^* \ln(r_s/r_0)$ (s/m^2)**	**Diffusivity η (m^2/s)**
KLX08	Pa	101.01–356.00	181.50	1.33	22,410	1.47 **M**	2,574.19	13,389.04	n.c.
	Pb	498.00–1,000.41	339.21	3.16	2,101	54.77 **H**	6,116.13	35,636.36	n.c.
HLX11	1	17.00–70.00	1,092.7	n.r.	–	–	–	–	–
	2	6.00–16.00	–	n.r.	–	–	–	–	–
HLX13	1	12.00–200.20	476.3	0.33	21,397	10.60 **H**	637.10	3,928.42	4.24E01
HLX14	1	12.00–115.90	435.2	0.84	n.c.	n.c.	1,632.58	9,919.25	n.c.
HLX23	1	61.00–160.20	918.2	0.02*	n.c.	n.c.	39.82	271.66	n.c.
	2	6.10–60.00	919.7	0.01*	n.c.	n.c.	n.c.	n.c.	n.c.
HLX24	1	41.00–175.20	873.4	0.02*	n.c.	n.c.	n.c.	n.c.	n.c.
	2	9.10–40.00	928.9	n.r.	–	–	–	–	–
HLX25	1	61.00–202.50	347.0	0.53	6,153	19.57 **H**	1,035.30	6,055.78	4.44E01
	2	6.10–60.00	440.1	0.53	6,407	30.23 **H**	1,035.30	6,301.85	6.32E01
HLX30	1	101.00–163.40	255.4	0.58	7,945	8.21 **M**	1,134.84	6,290.24	2.75E01
	2	9.10–100.00	301.2	0.47	12,959	7.00 **M**	915.84	5,227.40	2.89E01
HLX31	1	9.10–133.20	279.0	0.58	7,504	10.37 **H**	1,134.84	6,390.54	2.71E01
HLX33	1	31.00–202.10	638.0	0.07*	n.c.	n.c.	n.c.	n.c.	n.c.
	2	9.10–30.00	708.7	0.04*	n.c.	n.c.	n.c.	n.c.	n.c.
HLX34	1	9.00–151.80	745.2	n.r.	–	–	–	–	–
HLX35	1	65.00–151.80	693.8	n.r.	–	–	–	–	–
	2	6.10–64.00	769.5	n.r.	–	–	–	–	–
KLX02	1	1,165.00–1,700.00	1,563.4	n.r.	–	–	–	–	–
	2	1,145.00–1,164.00	1,387.1	n.r.	–	–	–	–	–
	3	718.00–1,144.00	1,272.3	n.r.	–	–	–	–	–
	4	495.00–717.00	1,163.5	n.r.	–	–	–	–	–
	5	452.00–494.00	1,142.9	n.r.	–	–	–	–	–
	6	348.00–451.00	1,138.0	n.r.	–	–	–	–	–
	7	209.00–347.00	1,140.5	n.r.	–	–	–	–	–
	8	100.35–208.00	1,148.2	n.r.	–	–	–	–	–
KLX03	1	965.00–971.00	1,242.6	n.r.	–	–	–	–	–
	2	830.00–964.00	1,199.6	n.r.	–	–	–	–	–
	3	752.00–829.00	1,124.9	n.r.	–	–	–	–	–
	4	729.00–751.00	1,111.4	n.r.	–	–	–	–	–
	5	652.00–728.00	1,068.0	n.r.	–	–	–	–	–
	6	465.00–651.00	1,049.0	n.r.	–	–	–	–	–
	7	349.00–464.00	969.6	n.r.	–	–	–	–	–
	8	199.00–348.00	937.1	n.r.	–	–	–	–	–
	9	193.00–198.00	928.7	n.r.	–	–	–	–	–
	X	100.05–192.00	925.7	n.r.	–	–	–	–	–
KLX04	1	898.00–1,000.00	658.2	n.r.	–	–	–	–	–
	2	870.00–897.00	597.5	n.r.	–	–	–	–	–.
	3	686.00–869.00	501.6	0.37	n.c.	n.c.	716.74	4,456.57	n.c.
	4	531.00–685.00	360.1	1.04	n.c.	n.c.	2,030.77	11,953.90	1.75E01
	5	507.00–530.00	298.0	1.56	607	146.30 **E**	3,046.16	17,354.20	1.25E02
	6	231.00–506.00	236.7	1.10	n.c.	n.c.	2,150.23	11,754.90	8.78E00
	7	163.00–230.00	271.8	0.98	4,747	15.56 **H**	1,911.31	10,713.00	2.67E01
	8	12.24–162.00	339.7	0.60	n.c.	n.c.	1,174.66	6,846.00	2.22E01

Source borehole		Section (m)	Flow rate Qm (l/min)	Drawdown (m)	r_{wf} (m)				
KLX08		357.00–497.00	31.0	4.49	2.7E01				
Observation borehole	**Sec No**	**Section (m)**	**Distance r_s (m)**	**Drawdown s_p (m)**	**dt_L (s)**	**Index 1 r_s^2/dt_L (m^2/s)**	**Index 2 s_p/Q_p (s/m^2)**	**Index 2 New $(s_p/Q_p)*\ln(r_s/r_0)$ (s/m^2)**	**Diffusivity η (m^2/s)**
KLX06	1	761.00–1,000.00	1,421.9	n.r.	–	–	–	–	–
	2	571.00–760.00	1,261.8	n.r.	–	–	–	–	–
	3	554.00–570.00	1,224.8	n.r.	–	–	–	–	–
	4	411.00–553.00	1,190.8	n.r.	–	–	–	–	–
	5	276.00–410.00	1,120.0	n.r.	–	–	–	–	–
	6	256.00–275.00	1,093.9	n.r.	–	–	–	–	–
	7	146.00–255.00	1,093.2	n.r.	–	–	–	–	–
	8	11.88–145.00	1,084.5	n.r.	–	–	–	–	–
KLX07A	1	781.00–844.73	1,373.0	n.r.	–	–	–	–	–
	2	753.00–780.00	1,345.5	n.r.	–	–	–	–	–
	3	612.00–752.00	1,289.9	n.r.	–	–	–	–	–
	4	457.00–611.00	1,237.4	n.r.	–	–	–	–	–
	5	333.00–456.00	1,211.0	n.r.	–	–	–	–	–
	6	204.00–332.00	1,188.1	n.r.	–	–	–	–	–
	7	104.00–203.00	1,177.8	n.r.	–	–	–	–	–
	8	102.00–103.00	1,173.6	n.r.	–	–	–	–	–
KLX07B	1	95.00–200.00	1,151.4	n.r.	–	–	–	–	–
	2	9.64–94.00	1,163.8	n.r.	–	–	–	–	–
KLX10	1	711.00–1,001.00	835.9	n.r.	–	–	–	–	–
	2	689.00–710.00	764.4	n.r.	–	–	–	–	–
	3	465.00–688.00	716.5	0.15	n.c.	n.c.	n.c.	n.c.	n.c.
	4	369.00–464.00	697.5	n.r.	–	–	–	–	–
	5	351.00–368.00	696.9	n.r.	–	–	–	–	–
	6	291.00–350.00	699.4	n.r.	–	–	–	–	–
	7	131.00–290.00	720.8	n.r.	–	–	–	–	–
	8	9.20–130.00	769.3	n.r.	–	–	–	–	–
KLX18A	1	440.00–611.28	520.7	0.40	–	–	776.47	4,857.00	n.c.
	2	241.00–439.00	510.7	1.29	7,267	35.89 **H**	2,528.51	15,767.20	1.23E02
	3	11.83–240.00	551.7	0.09*	–	–	179.19	1,131.20	n.c.

* No response according to SKB 330.003 (Bilagor B); see Chapter 4.6.1 for greater detail.
n.c. Not calculated due to strong natural fluctuations (tidal effects).
n.r. No response due to pumping in source.
Key for Index 1, 2 and 2 New see Table 5-1.

5.5.1 Response HLX13, Section 1 (12.00–200.20 m)

Comments to test

A total drawdown during the flow period of 3.2 kPa (0.33 m) was observed in this section. A recovery of 0.01 m was reached after appr. 356.6 min (21,397 s) after pump start in KLX08 (357.00–497.00). The calculated index 1 (r_s^2/dt_L) is rated as "high response time", index 2 (s_p/Q_p) as "low response" and the new index 2 $(s_p/Q_p)\cdot\ln(r_s/r_0)$ as "low response".

The CRw and CRwr phases show no problems and are adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. For the analysis of the CRw and CRwr phases a homogeneous radial flow model was chosen. The Analysis is presented in Appendix 7-3-1.

Selected representative parameters

The recommended transmissivity of $2.0·10^{-4}$ m²/s was derived from the analysis of the CRw phase, which shows the best data and derivative quality. The confidence range for the borehole transmissivity is estimated to be $1.0·10^{-4}$ m²/s to $5.0·10^{-4}$ m²/s. The flow dimension during the test is 2. The static pressure measured at transducer depth, was derived from the CRwr phase using straight line extrapolation in the Horner plot to a value of 48.2 kPa.

The analyses of the CRw and CRwr phases show consistency. No further analysis recommended.

5.5.2 Response HLX14, Section 1 (12.00–115.90 m)

Comments to test

A total drawdown during the flow period of 8.2 kPa (0.84 m) was observed in this section. Because of the low drawdown and the no clear reaction of the response, index 1 rated as "no response". The calculated index 2 (s_p/Q_p) is rated as "low response" and the new index 2 (s_p/Q_p)·ln(r_s/r_0) as "medium response". Although the response is low it is clearly caused by pumping in KLX08 (357.00–497.00) but due to major tidal effects and background noise, no transient analysis could be performed.

5.5.3 Response HLX23, Section 1 (61.00–160.20 m)

Comments to test

A total drawdown during the flow period of 0.2 kPa (0.02 m) was observed in this section. Because of the low drawdown and the no clear reaction of the response, index 1 rated as "no response". The calculated index 2 (s_p/Q_p) is rated as "low response" and the new index 2 (s_p/Q_p)·ln(r_s/r_0) as "low response". Although the response is low it is clearly caused by pumping in KLX08 (357.00–497.00) but due to major tidal effects, no transient analysis could be performed.

5.5.4 Response HLX23, Section 2 (6.10–60.00 m)

Comments to test

A total drawdown during the flow period of 0.1 kPa (0.01 m) was observed in this section. Because of the low drawdown and the no clear reaction of the response, index 1, index 2 and new index 2 are rated as "no response". Although the response is very low it is clearly caused by pumping in KLX08 (357.00–497.00) but due to major tidal effects, no transient analysis could be performed.

5.5.5 Response HLX24, Section 1 (41.00–175.20 m)

Comments to test

A total drawdown during the flow period of 0.2 kPa (0.02 m) was observed in this section. Because of the low drawdown and the no clear reaction of the response, index 1, index 2 and new index 2 are rated as "no response". Although the response is very low it is clearly caused by pumping in KLX08 (357.00–497.00) but due to major tidal effects, no transient analysis could be performed.

5.5.6 Response HLX25, Section 1 (61.00–202.50 m)

Comments to test

A total drawdown during the flow period of 5.2 kPa (0.53 m) was observed in this section. A recovery of 0.01 m was reached after appr. 102.6 min (6,153 s) after pump stop in KLX08 (357.00–497.00). The calculated index 1 (r_s^2/dt_L) is rated as "high response time", index 2 (s_p/Q_p) as "low response" and the new index 2 $(s_p/Q_p)\cdot\ln(r_s/r_0)$ as "medium response".

The CRw and CRwr phases show no problems and are adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. For the analysis of the CRw and CRwr phases a homogeneous radial flow model was chosen. The Analysis is presented in Appendix 7-3-2.

Selected representative parameters

The recommended transmissivity of $2.3\cdot10^{-4}$ m²/s was derived from the analysis of the CRwr phase, which shows the best data and derivative quality. The confidence range for the borehole transmissivity is estimated to be $8.0\cdot10^{-5}$ m²/s to $5.0\cdot10^{-4}$ m²/s. The flow dimension during the test is 2. The static pressure measured at transducer depth, was derived from the CRwr phase using straight line extrapolation in the Horner plot to a value of 90.6 kPa.

The analyses of the CRw and CRwr phases show consistency. No further analysis recommended.

5.5.7 Response HLX25, Section 2 (6.12–60.00 m)

Comments to test

A total drawdown during the flow period of 5.2 kPa (0.53 m) was observed in this section. A recovery of 0.01 m was reached after appr. 106.8 min (6,407 s) after pump stop in KLX08 (357.00–497.00). The calculated index 1 (r_s^2/dt_L) is rated as "high response time", index 2 (s_p/Q_p) as "low response" and the new index 2 $(s_p/Q_p)\cdot\ln(r_s/r_0)$ as "medium response".

The CRw and CRwr phases show no problems and are adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. For the analysis of the CRw and CRwr phases a homogeneous radial flow model was chosen. The Analysis is presented in Appendix 7-3-3.

Selected representative parameters

The recommended transmissivity of $1.7\cdot10^{-4}$ m²/s was derived from the analysis of the CRw phase, which shows the best data and derivative quality. The confidence range for the borehole transmissivity is estimated to be $8.0\cdot10^{-5}$ m²/s to $4.0\cdot10^{-4}$ m²/s. The flow dimension during the test is 2. The static pressure measured at transducer depth, was derived from the CRwr phase using straight line extrapolation in the Horner plot to a value of 90.7 kPa.

The analyses of the CRw and CRwr phases show consistency. No further analysis recommended.

5.5.8 Response HLX30, Section 1 (101.00–163.40 m)

Comments to test

A total drawdown during the flow period of 5.7 kPa (0.58 m) was observed in this section. A recovery of 0.01 m was reached after appr. 132.4 min (7,945 s) after pump stop in KLX08 (357.00–497.00). The calculated index 1 (r_s^2/dt_L) is rated as "medium response time", index 2 (s_p/Q_p) as "low response" and the new index 2 $(s_p/Q_p) \cdot \ln(r_s/r_0)$ as "medium response".

The CRw and CRwr phases show no problems and are adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. For the analysis of the CRw and CRwr phases a homogeneous radial flow model was chosen. The Analysis is presented in Appendix 7-3-4.

Selected representative parameters

The recommended transmissivity of $1.7 \cdot 10^{-4}$ m²/s was derived from the analysis of the CRw phase, which shows the best data and derivative quality. The confidence range for the borehole transmissivity is estimated to be $8.0 \cdot 10^{-5}$ m²/s to $5.0 \cdot 10^{-4}$ m²/s. The flow dimension during the test is 2. The static pressure measured at transducer depth, was derived from the CRwr phase using straight line extrapolation in the Horner plot to a value of 98.1 kPa.

The analyses of the CRw and CRwr phases show consistency. No further analysis recommended.

5.5.9 Response HLX30, Section 2 (9.10–100.00 m)

Comments to test

A total drawdown during the flow period of 4.6 kPa (0.47 m) was observed in this section. A recovery of 0.01 m was reached after appr. 216.0 min (12,959 s) after pump stop in KLX08 (357.00–497.00). The calculated index 1 (r_s^2/dt_L) is rated as "medium response time", index 2 (s_p/Q_p) as "low response" and the new index 2 $(s_p/Q_p) \cdot \ln(r_s/r_0)$ as "medium response".

The CRw and CRwr phases show no problems and are adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. For the analysis of the CRw and CRwr phases a homogeneous radial flow model was chosen. The Analysis is presented in Appendix 7-3-5.

Selected representative parameters

The recommended transmissivity of $1.9 \cdot 10^{-4}$ m²/s was derived from the analysis of the CRw phase, which shows the best data and derivative quality. The confidence range for the borehole transmissivity is estimated to be $9.0 \cdot 10^{-5}$ m²/s to $5.0 \cdot 10^{-4}$ m²/s. The flow dimension during the test is 2. The static pressure measured at transducer depth, was derived from the CRwr phase using straight line extrapolation in the Horner plot to a value of 97.3 kPa.

The analyses of the CRw and CRwr phases show consistency. No further analysis recommended.

5.5.10 Response HLX31, Section 1 (9.10–133.20 m)

Comments to test

A total drawdown during the flow period of 5.7 kPa (0.58 m) was observed in this section. A recovery of 0.01 m was reached after appr. 125.1 min (7,504 s) after pump stop in KLX08 (357.00–497.00). The calculated index 1 (r_s^2/dt_L) is rated as "high response time", index 2 (s_p/Q_p) as "low response" and the new index 2 $(s_p/Q_p)\cdot\ln(r_s/r_0)$ as "medium response".

The CRw and CRwr phases show no problems and are adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. For the analysis of the CRw and CRwr phases a homogeneous radial flow model was chosen. The Analysis is presented in Appendix 7-3-6.

Selected representative parameters

The recommended transmissivity of $1.6\cdot10^{-4}$ m²/s was derived from the analysis of the CRw phase, which shows the best data and derivative quality. The confidence range for the borehole transmissivity is estimated to be $7.0\cdot10^{-5}$ m²/s to $5.0\cdot10^{-4}$ m²/s. The flow dimension during the test is 2. The static pressure measured at transducer depth, was derived from the CRwr phase using straight line extrapolation in the Horner plot to a value of 97.7 kPa.

The analyses of the CRw and CRwr phases show consistency. No further analysis recommended.

5.5.11 Response HLX33, Section 1 (31.00–202.10 m)

Comments to test

A total drawdown during the flow period of 0.7 kPa (0.07 m) was observed in this section. Because of the low drawdown and the no clear reaction of the response, index 1, index 2 and new index 2 are rated as "no response". Although the response is very low it is clearly caused by pumping in KLX08 (357.00–497.00) but due to major tidal effects, no transient analysis could be performed.

5.5.12 Response HLX33, Section 2 (9.10–30.00 m)

Comments to test

A total drawdown during the flow period of 0.4 kPa (0.04 m) was observed in this section. Because of the low drawdown and the no clear reaction of the response, index 1, index 2 and new index 2 are rated as "no response". Although the response is very low it is clearly caused by pumping in KLX08 (357.00–497.00) but due to major tidal effects, no transient analysis could be performed.

5.5.13 Response KLX04, Section 3 (686.00–869.00 m)

Comments to test

A total drawdown during the flow period of 3.6 kPa (0.37 m) was observed in this section. Because of the low drawdown and the no clear reaction of the response, index 1 rated as "no response". The calculated index 2 (s_p/Q_p) is rated as "low response" and the new index 2 $(s_p/Q_p)\cdot\ln(r_s/r_0)$ as "low response". Although the response is low it is clearly caused by pumping in KLX08 (357.00–497.00) but due to major tidal effects, no transient analysis could be performed.

5.5.14 Response KLX04, Section 4 (531.00–685.00 m)

Comments to test

A total drawdown during the flow period of 10.2 kPa (1.04 m) was observed in this section. Due to the data quality a response time for a pressure change of 0.01 m was not possible to determine after pump start respectively pump stop in KLX08 (357.00–497.00). The index 1 (r_s^2/dt_L) was not possible to calculate, index 2 (s_p/Q_p) is rated as "low response" and the new index 2 (s_p/Q_p)·ln(r_s/r_0) as "medium response".

The CRw and CRwr phases show no problems and are adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. For the analysis of the CRw and CRwr phases a homogeneous radial flow model was chosen. The Analysis is presented in Appendix 7-3-7.

Selected representative parameters

The recommended transmissivity of $5.2 \cdot 10^{-5}$ m²/s was derived from the analysis of the CRw phase, which shows the best data and derivative quality. The confidence range for the borehole transmissivity is estimated to be $2.0 \cdot 10^{-5}$ m²/s to $2.0 \cdot 10^{-4}$ m²/s. The flow dimension during the test is 2. The static pressure measured at transducer depth, was derived from the CRwr phase using straight line extrapolation in the Horner plot to a value of 101.3 kPa.

The analyses of the CRw and CRwr phases show consistency. No further analysis recommended.

5.5.15 Response KLX04, Section 5 (507.00–530.00 m)

Comments to test

A total drawdown during the flow period of 15.3 kPa (1.56 m) was observed in this section. A recovery of 0.01 m was reached after appr. 10.1 min (607 s) after pump stop in KLX08 (357.00–497.00). The calculated index 1 (r_s^2/dt_L) is rated as "excellent response time", index 2 (s_p/Q_p) as "low response" and the new index 2 (s_p/Q_p)·ln(r_s/r_0) as "medium response".

The CRw and CRwr phases show no problems and are adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. For the analysis of the CRw and CRwr phases a composite radial flow model was chosen. The Analysis is presented in Appendix 7-3-8.

Selected representative parameters

The recommended transmissivity of $1.8 \cdot 10^{-4}$ m²/s was derived from the analysis of the CRwr phase (inner zone), which shows the best data and derivative quality. The confidence range for the borehole transmissivity is estimated to be $8.0 \cdot 10^{-5}$ m²/s to $4.0 \cdot 10^{-4}$ m²/s. The flow dimension during the test is 2. The static pressure measured at transducer depth, was derived from the CRwr phase using straight line extrapolation in the Horner plot to a value of 97.7 kPa.

The analyses of the CRw and CRwr phases show consistency. No further analysis recommended.

5.5.16 Response KLX04, Section 6 (231.00–506.00 m)

Comments to test

A total drawdown during the flow period of 10.8 kPa (1.10 m) was observed in this section. Due to the data quality a response time for a pressure change of 0.01 m was not possible to determine after pump start respectively pump stop in KLX08 (357.00–497.00). The index 1 (r_s^2/dt_L) was not possible to calculate, index 2 (s_p/Q_p) is rated as "low response" and the new index 2 $(s_p/Q_p)\cdot\ln(r_s/r_0)$ as "medium response".

The CRw and CRwr phases show no problems and are adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. For the analysis of the CRw and CRwr phases a homogeneous radial flow model was chosen. The Analysis is presented in Appendix 7-3-9.

Selected representative parameters

The recommended transmissivity of $5.2\cdot10^{-5}$ m²/s was derived from the analysis of the CRw phase, which shows the best data and derivative quality. The confidence range for the borehole transmissivity is estimated to be $2.0\cdot10^{-5}$ m²/s to $2.0\cdot10^{-4}$ m²/s. The flow dimension during the test is 2. The static pressure measured at transducer depth, was derived from the CRwr phase using straight line extrapolation in the Horner plot to a value of 100.8 kPa.

The analyses of the CRw and CRwr phases show consistency. No further analysis recommended.

5.5.17 Response KLX04, Section 7 (163.00–230.00 m)

Comments to test

A total drawdown during the flow period of 9.6 kPa (0.98 m) was observed in this section. A recovery of 0.01 m was reached after appr. 79.1 min (4,747 s) after pump stop in KLX08 (357.00–497.00). The calculated index 1 (r_s^2/dt_L) is rated as "high response time", index 2 (s_p/Q_p) as "low response" and the new index 2 $(s_p/Q_p)\cdot\ln(r_s/r_0)$ as "medium response".

The CRw and CRwr phases show no problems and are adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. For the analysis of the CRw and CRwr phases a homogeneous radial flow model was chosen. The Analysis is presented in Appendix 7-3-10.

Selected representative parameters

The recommended transmissivity of $9.2\cdot10^{-5}$ m²/s was derived from the analysis of the CRw phase, which shows the best data and derivative quality. The confidence range for the borehole transmissivity is estimated to be $4.0\cdot10^{-5}$ m²/s to $2.0\cdot10^{-4}$ m²/s. The flow dimension during the test is 2. The static pressure measured at transducer depth, was derived from the CRwr phase using straight line extrapolation in the Horner plot to a value of 94.1 kPa.

The analyses of the CRw and CRwr phases show consistency. No further analysis recommended.

5.5.18 Response KLX04, Section 8 (12.24–162.00 m)

Comments to test

A total drawdown during the flow period of 5.9 kPa (0.60 m) was observed in this section. Due to the data quality a response time for a pressure change of 0.01 m was not possible to determine after pump start respectively pump stop in KLX08 (357.00–497.00). The index 1 (r_s^2/dt_L) was not possible to calculate, index 2 (s_p/Q_p) is rated as "low response" and the new index 2 (s_p/Q_p)·ln(r_s/r_0) as "medium response".

The CRw and CRwr phases show no problems and are adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. For the analysis of the CRw and CRwr phases a homogeneous radial flow model was chosen. The Analysis is presented in Appendix 7-3-11.

Selected representative parameters

The recommended transmissivity of $1.2 \cdot 10^{-4}$ m²/s was derived from the analysis of the CRw phase, which shows the best data and derivative quality. The confidence range for the borehole transmissivity is estimated to be $4.0 \cdot 10^{-5}$ m²/s to $3.0 \cdot 10^{-4}$ m²/s. The flow dimension during the test is 2. The static pressure measured at transducer depth, was derived from the CRwr phase using straight line extrapolation in the Horner plot to a value of 101.6 kPa.

The analyses of the CRw and CRwr phases show consistency. No further analysis recommended.

5.5.19 Response KLX10, Section 3 (465.00–688.00 m)

Comments to test

A total drawdown during the flow period of 1.5 kPa (0.15 m) was observed in this section. Because of the low drawdown and the no clear reaction of the response, index 1, index 2 and new index 2 are rated as "no response". Although the response is very low it is clearly caused by pumping in KLX08 (357.00–497.00) but due to major tidal effects, no transient analysis could be performed.

5.5.20 Response KLX18A, Section 1 (440.00–611.28 m)

Comments to test

A total drawdown during the flow period of 3.9 kPa (0.40 m) was observed in this section. Because of the low drawdown and the no clear reaction of the response, index 1 rated as "no response". The calculated index 2 (s_p/Q_p) is rated as "low response" and the new index 2 (s_p/Q_p)·ln(r_s/r_0) as "low response". Although the response is low it is clearly caused by pumping in KLX08 (357.00–497.00) but due to major tidal effects, no transient analysis could be performed.

5.5.21 Response KLX18A, Section 2 (241.00–439.00 m)

Comments to test

A total drawdown during the flow period of 12.7 kPa (1.29 m) was observed in this section. A recovery of 0.01 m was reached after appr. 121.1 min (7,267 s) after pump stop in KLX08 (357.00–497.00). The calculated index 1 (r_s^2/dt_L) is rated as "high response time", index 2 (s_p/Q_p) as "low response" and the new index 2 (s_p/Q_p)·ln(r_s/r_0) as "medium response".

The CRw and CRwr phases show no problems and are adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. For the analysis of the CRw and CRwr phases a composite radial flow model was chosen. The Analysis is presented in Appendix 7-3-12.

Selected representative parameters

The recommended transmissivity of $1.7 \cdot 10^{-4}$ m^2/s was derived from the analysis of the CRwr phase (inner zone), which shows the best data and derivative quality. The confidence range for the borehole transmissivity is estimated to be $5.0 \cdot 10^{-5}$ m^2/s to $4.0 \cdot 10^{-4}$ m^2/s. The flow dimension during the test is 2. The static pressure measured at transducer depth, was derived from the CRwr phase using straight line extrapolation in the Horner plot to a value of 109.7 kPa.

The analyses of the CRw and CRwr phases show consistency. No further analysis recommended.

5.5.22 Response KLX18A, Section 3 (11.83–240.00 m)

Comments to test

A total drawdown during the flow period of 0.9 kPa (0.09 m) was observed in this section. Because of the low drawdown and the no clear reaction of the response, index 1 rated as "no response". The calculated index 2 (s_p/Q_p) is rated as "low response" and the new index 2 (s_p/Q_p)$\cdot$ln(r_s/r_0) as "low response". Although the response is low it is clearly caused by pumping in KLX08 (357.00–497.00) but due to major tidal effects, no transient analysis could be performed.

6 Summary and conclusions

The summary and conclusions chapter summarizes the basic test parameters and analysis results.

6.1 Location of responding test section

The following figures are showing the location of the responding test sections in relationship with the pumping section.

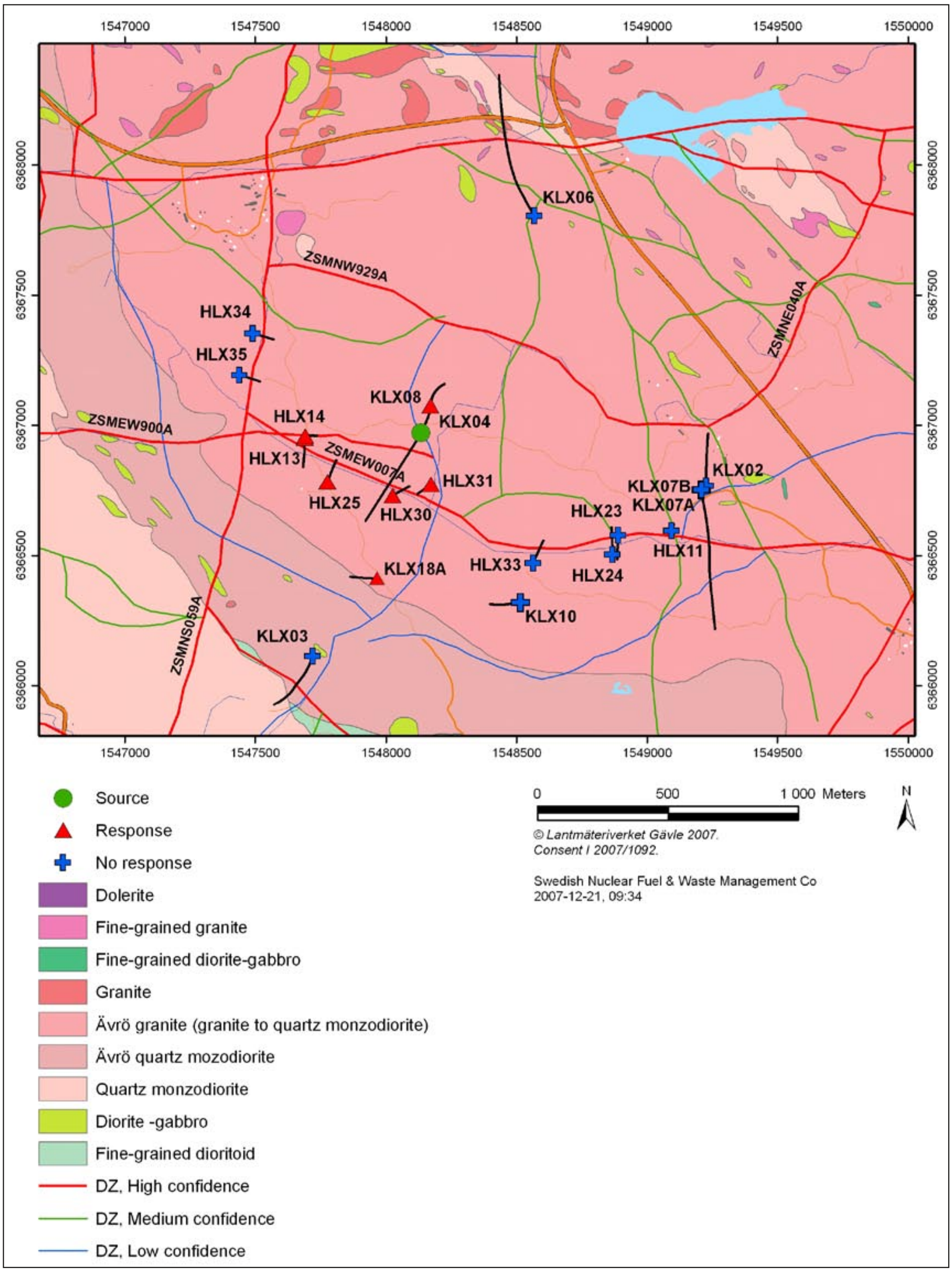

Figure 6-1. *Location of responding test sections while pumping in section 102.00–242.00 m.*

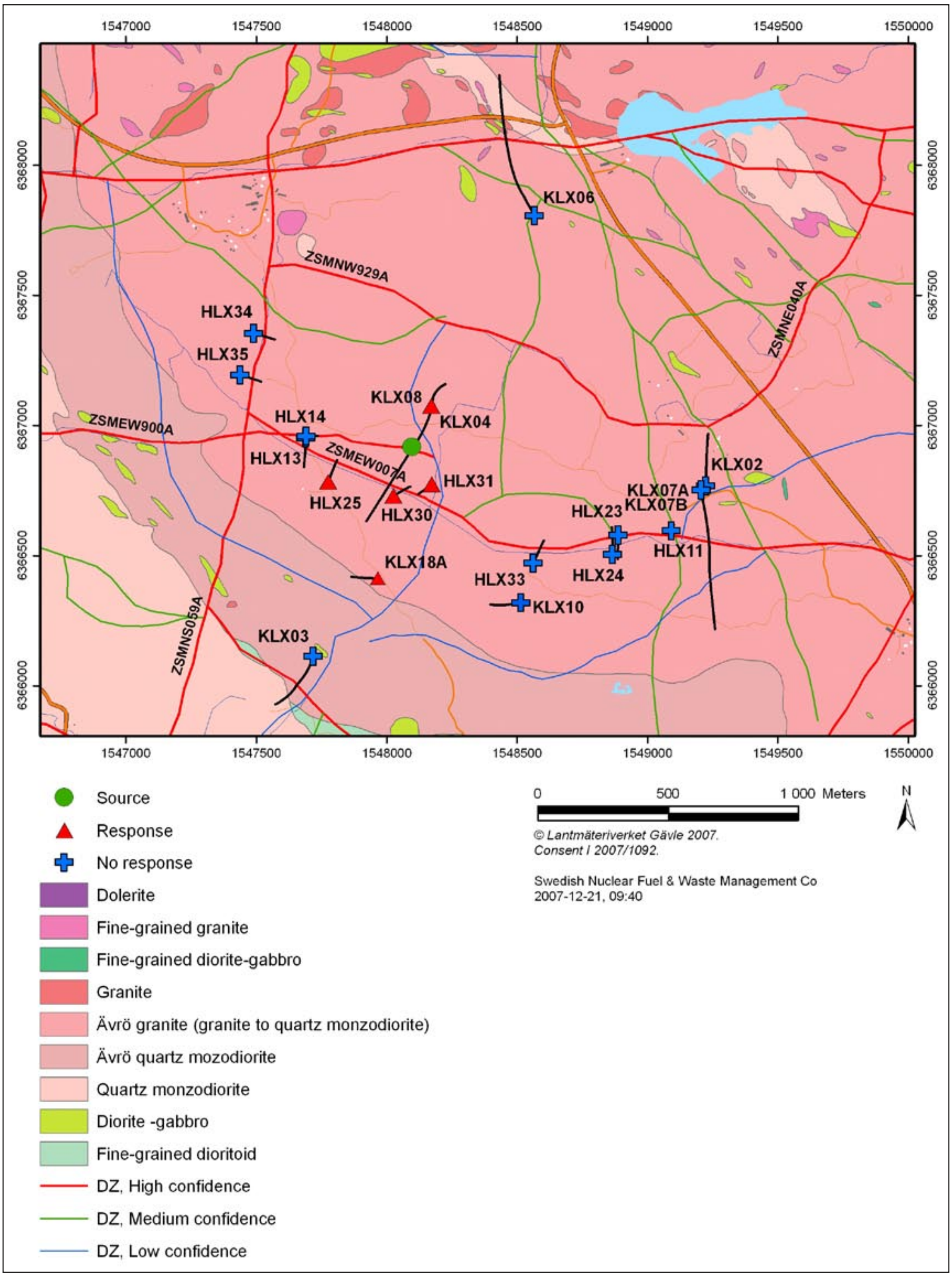

Figure 6-2. *Location of responding test sections while pumping in section 241.00–341.00 m.*

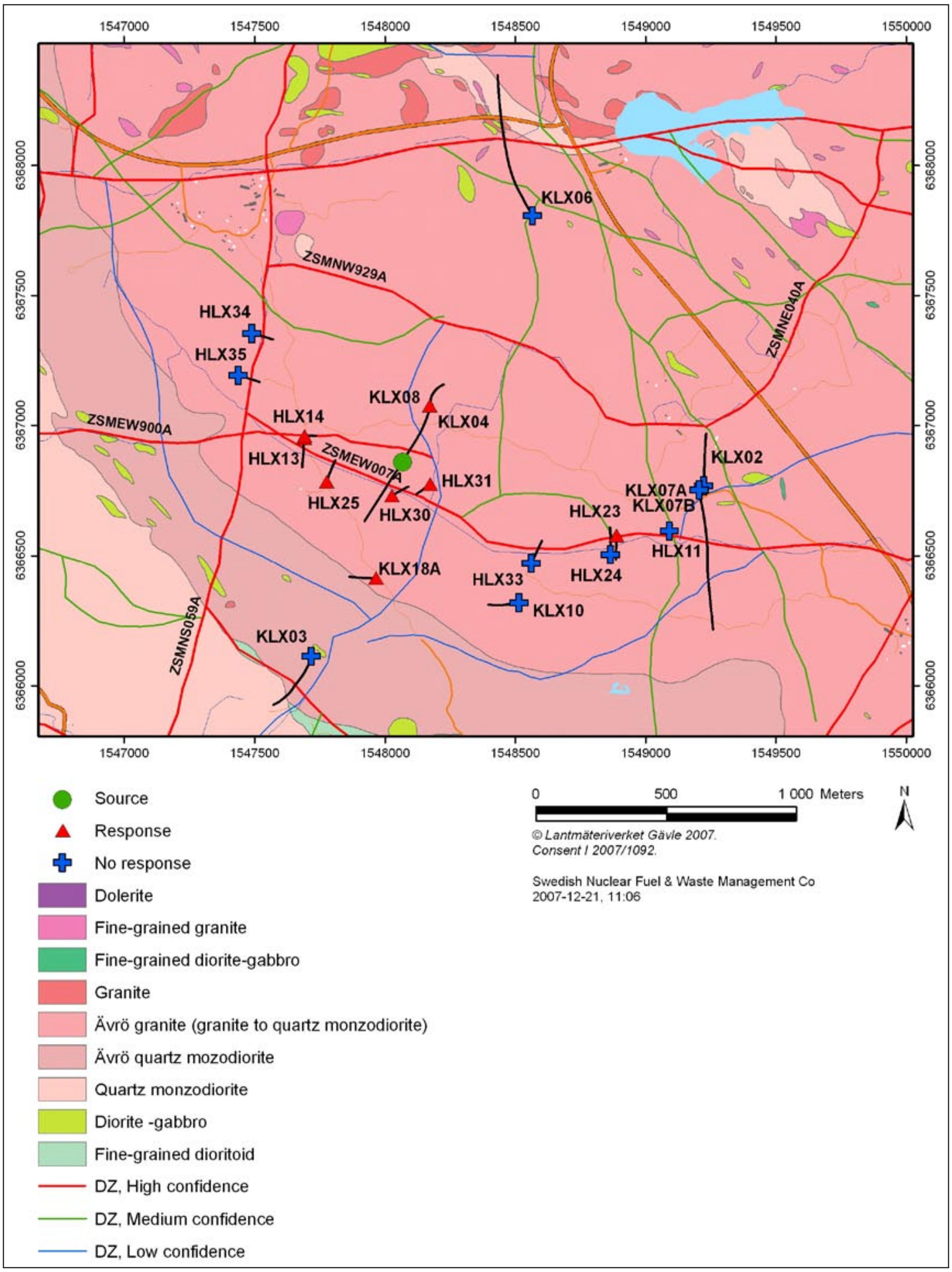

Figure 6-3. *Location of responding test sections while pumping in section 357.00–497.00 m.*

6.2 Summary of results

Table 6-1. General test data from constant rate pump tests.

Borehole ID	Borehole secup (m)	Borehole Seclow (m)	Date and time Test start YYYYMMDD hh:mm	Date and time Test stop YYYYMMDD hh:mm	Q_p (m^3/s)	Q_m (m^3/s)	tp (s)	t_F (s)	p_0 (kPa)	p_i (kPa)	p_p (kPa)	p_F (kPa)	Te_w (°C)	Test phases measured *Analysed test phases marked* ***bold***
KLX08	102.00	242.00	20060921 16:16	20060927 06:15	6.75E–04	6.83E–04	260,604	219,840	2,006	2,006	1,969	2,004	10.1	**CRw** **CRwr**
KLX08	241.00	341.00	20060830 15:02	20060907 07:04	8.50E–05	8.46E–05	262,152	400,440	2,847	2,847	2,394	2,846	11.3	**CRw** **CRwr**
KLX08	357.00	497.00	20060911 13:47	20060918 13:18	5.12E–04	5.17E–04	259,200	345,000	4,178	4,179	4,135	4,174	13.4	**CRw** **CRwr**

Nomenclature

Q_p	Flow in test section immediately before stop of flow [m³/s].
Q_m	Arithmetical mean flow during perturbation phase [m³/s].
t_p	Duration of perturbation phase [s].
t_f	Duration of recovery phase [s].
p_0	Pressure in borehole before packer inflation [kPa].
p_i	Pressure in test section before start of flowing [kPa].
p_p	Pressure in test section before stop of flowing [kPa].
p_F	Pressure in test section at the end of the recovery [kPa].
Te_w	Temperature in test section.
Test phases	CRw: constant rate pump (withdrawal) phase.
	CRwr: recovery phase following the constant rate pump (withdrawal) phase.

Table 6-2. Results from analysis of constant rate pump tests.

Interval position			Stationary flow parameters		Transient analysis Flow regime		Formation parameters												Static conditions	
Borehole ID	up m btoc	low m btoc	Q/s m^2/s	T_M m^2/s	Perturb. phase	Recovery phase	T_{f1} m^2/s	T_{f2} m^2/s	T_{s1} m^2/s	T_{s2} m^2/s	T_T m^2/s	T_{TMIN} m^2/s	T_{TMAX} m^2/s	C m^3/Pa	ξ –	dt_1 min	dt_2 min	r_{inner} m	p* kPa	h_{wif} masl
KLX08	102.00	242.00	1.8E–04	2.4E–04	WBS22	WBS22	1.2E–04	5.5E–05	2.8E–04	1.3E–04	1.3E–04	5.0E–05	4.0E–04	9.4E–07	–7.5	31	421	768.3	2,011.0	6.26
KLX08	241.00	341.00	1.8E–06	2.4E–06	WBS22	WBS22	3.2E–06	6.4E–06	2.3E–06	4.6E–05	2.3E–06	1.0E–06	6.0E–05	2.8E–09	2.9	5	183	50.1	2,848.3	7.49
KLX08	357.00	497.00	1.1E–04	1.6E–04	WBS22	WBS22	2.3E–04	7.6E–05	6.0E–04	1.2E–04	1.2E–04	1.0E–04	4.0E–04	1.1E–07	–1.2	16	326	764.9	4,173.8	6.45

Nomenclature

Q/s	Specific capacity.
T_M	Transmissivity according to /Moye 1967/.
Flow regime	The flow regime description refers to the recommended model used in the transient analysis. WBS denotes wellbore storage and skin and is followed by a set of numbers describing the flow dimension used in the analysis (1 = linear flow, 2 = radial flow, 3 = spherical flow). If only one number is used (e.g. WBS2 or 2) a homogeneous flow model (1 composite zone) was used in the analysis, if two numbers are given (WBS22 or 22) a 2 zones composite model was used.
T_f	Transmissivity derived from the analysis of the perturbation phase (CRw). In case a homogeneous flow model was used only one T_f value is reported, in case a two zone composite flow model was used both T_{f1} (inner zone) and T_{f2} (outer zone) are given.
T_s	Transmissivity derived from the analysis of the recovery phase (CRwr). In case a homogeneous flow model was used only one T_s value is reported, in case a two zone composite flow model was used both T_{s1} (inner zone) and T_{s2} (outer zone) are given.
T_T	Recommended transmissivity.
T_{TMIN} / T_{TMAX}	Confidence range lower/upper limit.
C	Wellbore storage coefficient.
ξ	Skin factor (calculated based on a Storativity of $1 \cdot 10^{-6}$).
dt_1 / dt_2	Estimated start/stop time of evaluation for the recommended transmissivity (T_T).
r_{inner}	Radius of the inner zone (see Chapter 4.5.8).
p*	The parameter p* denoted the static formation pressure (measured at transducer depth) and was derived from the HORNER plot of the CHir phase using straight line or type-curve extrapolation.
h_{wif}	Fresh-water head (based on transducer depth and p*).
#NV	Not analysed/no values.

Table 6-3. Results from analysis of the interference tests.

Pumped section		Observation borehole		Flow regime		Transient analysis Formation Parameter										Index calculation			
Borehole ID	Section m btoc	Borehole ID_Sec.	Section m btoc	Pertub. phase	Rec. phase	T_{f1} m^2/s	T_{f2} m^2/s	T_{s1} m^2/s	T_{s2} m^2/s	T_T m^2/s	T_{TMIN} m^2/s	T_{TMAX} m^2/s	S	dt_1 s	dt_2 s	Index 1 r_s^2/dt_L	Index 2 s_p/Q_p	Index 2 new $(sp/Qp)^* \ln(r_s/r_0)$	Diffusivity η (T/S)
KLX08	102.00–242.00	KLX08_Pb	243.00–1,000.41	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	44.88	2,266.67	15,133.9	n.a.
		HLX11_1	17.00–70.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		HLX11_2	6.00–16.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		HLX13_1	12.00–200.20	2	2	2.5E–04	–	2.5E–04	–	2.5E–04	1.0E–04	5.0E–04	1.1E–06	383	8,852	61.55	1,042.02	6,423.2	2.4E02
		HLX14_1	12.00–115.90	2	2	1.7E–04	–	1.9E–04	–	1.7E–04	8.0E–05	4.0E–04	5.9E–07	780	6,933	n.a.	1,782.01	10,747.1	2.8E02
		HLX23_1	61.00–160.20	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		HLX23_2	6.10–60.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			
		HLX24_1	41.00–175.20	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		HLX24_2	9.10–40.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		HLX25_1	61.00–202.50	22	2	2.1E–04	5.3E–04	2.4E–04	–	2.1E–04	1.0E–04	5.0E–04	2.1E–06	542	9,810	39.01	1,011.82	5,984.2	1.0E02
		HLX25_2	6.12–60.00	22	2	2.1E–04	7.0E–04	2.1E–04	–	2.1E–04	1.0E–04	4.0E–04	1.8E–06	275	9,823	50.52	1,011.82	6,115.0	1.2E02
		HLX30_1	101.00–163.40	22	2	1.9E–04	6.3E–04	2.6E–04	–	1.9E–04	9.0E–05	5.0E–04	5.1E–06	277	9,707	17.10	1,042.02	5,732.0	3.8E01
		HLX30_2	9.10–100.00	22	2	2.6E–04	6.5E–04	2.8E–04	–	2.6E–04	1.0E–04	6.0E–04	4.7E–06	422	10,147	13.64	891.00	4,977.9	5.7E01
		HLX31_1	9.10–133.20	22	2	2.0E–04	5.0E–04	2.4E–04	–	2.0E–04	1.0E–04	5.0E–04	4.2E–06	140	9,063	20.95	1,042.02	5,807.1	4.7E01
		HLX33_1	31.00–202.10	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
		HLX33_2	9.10–30.00	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
		HLX34_1	9.00–151.80	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		HLX35_1	65.00–151.80	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		HLX35_2	6.10–64.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX02_1	1,165.00–1,700.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX02_2	1,145.00–1,164.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX02_3	718.00–1,144.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–

Pumped section: Borehole ID	Pumped section: Section m btoc	Observation borehole: Borehole ID_Sec.	Observation borehole: Section m btoc	Flow regime: Pertub. phase	Flow regime: Rec. phase	Transient analysis, Formation Parameter: T_{f1} m²/s	T_{f2} m²/s	T_{s1} m²/s	T_{s2} m²/s	T_T m²/s	T_{TMIN} m²/s	T_{TMAX} m²/s	S	dt_1 s	dt_2 s	Index calculation: Index 1 r_s^2/dt_L	Index 2 s_p/Q_p	Index 2 new (sp/Qp)* $\ln(r_s/r_0)$	Diffusivity η (T/S)
KLX08	102.00–242.00	KLX02_4	495.00–717.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX02_5	452.00–494.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX02_6	348.00–451.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX02_7	209.00–347.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX02_8	100.35–208.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX03_1	965.00–971.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX03_2	830.00–964.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX03_3	752.00–829.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX03_4	729.00–751.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX03_5	652.00–728.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX03_6	465.00–651.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX03_7	349.00–464.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX03_8	199.00–348.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX03_9	193.00–198.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX03_X	100.05–192.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX04_1	898.00–1,000.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX04_2	870.00–897.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX04_3	686.00–869.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX04_4	531.00–685.00	2	2	1.4E–04	–	2.0E–04	–	1.4E–04	7.0E–05	4.0E–04	1.7E–06	471	9,513	n.a.	1,359.16	8,383.8	8.5E01
		KLX04_5	507.00–530.00	2	2	9.8E–05	–	1.0E–04	–	1.0E–04	4.0E–05	2.0E–04	5.2E–07	62	8,587	227.70	2,899.54	17,301.3	2.0E02
		KLX04_6	231.00–506.00	22	22	1.6E–04	7.8E–05	3.0E–04	1.5E–04	1.6E–04	7.0E–05	6.0E–04	6.7E–06	475	10,496	n.a.	1,359.16	7,494.2	2.3E01
		KLX04_7	163.00–230.00	22	22	8.2E–05	2.1E–04	8.2E–05	1.6E–04	8.2E–05	4.0E–05	2.0E–04	1.4E–06	50	8,438	180.50	4,334.20	20,435.4	5.8E01
		KLX04_8	12.24–162.00	22	22	8.0E–05	2.7E–04	9.4E–05	2.4E–04	8.0E–05	4.0E–05	2.0E–04	4.2E–06	50	9,025	175.04	2,990.15	14,052.4	1.9E01
		KLX06_1	761.00–1,000.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–

Pumped section		Observation borehole				Transient analysis										Index calculation			
				Flow regime		Formation Parameter													
Borehole ID	Section m btoc	Borehole ID_Sec.	Section m btoc	Pertub. phase	Rec. phase	T_{f1} m^2/s	T_{f2} m^2/s	T_{s1} m^2/s	T_{s2} m^2/s	T_T m^2/s	T_{TMIN} m^2/s	T_{TMAX} m^2/s	S	dt_1 s	dt_2 s	Index 1 r_s^2/dt_L	Index 2 s_p/Q_p	Index 2 new $(sp/Qp)^*$ $\ln(r_s/r_0)$	Diffusivity η (T/S)
KLX08	102.00–242.00	KLX06_2	571.00–760.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX06_3	554.00–570.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX06_4	411.00–553.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX06_5	276.00–410.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX06_6	256.00–275.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX06_7	146.00–255.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX06_8	11.88–145.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX07A_1	781.00–844.73	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX07A_2	753.00–780.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX07A_3	612.00–752.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX07A_4	457.00–611.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX07A_5	333.00–456.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX07A_6	204.00–332.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX07A_7	104.00–203.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX07A_8	102.00–103.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX07B_1	95.00–200.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX07B_2	9.64–94.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX10_1	711.00–1,001.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX10_2	689.00–710.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX10_3	465.00–688.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX10_4	369.00–464.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX10_5	351.00–368.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX10_6	291.00–350.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX10_7	131.00–290.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–

Pumped section		Observation borehole		Flow regime		Transient analysis Formation Parameter										Index calculation			
Borehole ID	Section m btoc	Borehole ID_Sec.	Section m btoc	Pertub. phase	Rec. phase	T_{f1} m^2/s	T_{f2} m^2/s	T_{s1} m^2/s	T_{s2} m^2/s	T_T m^2/s	T_{TMIN} m^2/s	T_{TMAX} m^2/s	S	dt_1 s	dt_2 s	Index 1 r_s^2/dt_L	Index 2 s_p/Q_p	Index 2 new (sp/Qp)* $\ln(r_s/r_0)$	Diffusivity η (T/S)
KLX08	102.00–242.00	KLX10_8	9.20–130.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX18A_1	440.00–611.28	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX18A_2	241.00–439.00	2	n.a.	2.4E–04	–	n.a.	n.a.	2.4E–04	1.0E–04	5.0E–04	1.4E–06	303	7,938	n.a.	800.39	5,192.7	1.7E02
		KLX18A_3	11.83–240.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
KLX08	241.00–341.00	KLX08_Pa	101.00–240.00	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0.77	4,823.53	23,460.1	n.a.
		KLX08_Pb	342.00–1,000.41	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		HLX11_1	17.00–70.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		HLX11_2	6.00–16.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		HLX13_1	12.00–200.20	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		HLX14_1	12.00–115.90	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		HLX23_1	61.00–160.20	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		HLX23_2	6.10–60.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		HLX24_1	41.00–175.20	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		HLX24_2	9.10–40.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		HLX25_1	61.00–202.50	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	839.48	4,892.8	n.a.
		HLX25_2	6.12–60.00	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	839.48	5,064.1	n.a.
		HLX30_1	101.00–163.40	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	719.55	3,883.9	n.a.
		HLX30_2	9.10–100.00	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	719.55	4,002.3	n.a.
		HLX31_1	9.10–133.20	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	719.55	3,956.1	n.a.
		HLX33_1	31.00–202.10	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		HLX33_2	9.10–30.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		HLX34_1	9.00–151.80	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		HLX35_1	65.00–151.80	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		HLX35_2	6.10–64.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–

Pumped section		Observation borehole		Flow regime		Transient analysis										Index calculation			
						Formation Parameter													
Borehole ID	Section m btoc	Borehole ID_Sec.	Section m btoc	Pertub. phase	Rec. phase	T_{f1} m^2/s	T_{f2} m^2/s	T_{s1} m^2/s	T_{s2} m^2/s	T_T m^2/s	T_{TMIN} m^2/s	T_{TMAX} m^2/s	S	dt_1 s	dt_2 s	Index 1 r_s^2/dt_L	Index 2 s_p/Q_p	Index 2 new (sp/Qp)* $\ln(r_s/r_0)$	Diffusivity η (T/S)
KLX08	241.00–341.00	KLX02_1	1,165.00–1,700.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX02_2	1,145.00–1,164.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX02_3	718.00–1,144.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX02_4	495.00–717.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX02_5	452.00–494.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX02_6	348.00–451.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX02_7	209.00–347.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX02_8	100.35–208.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX03_1	965.00–971.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX03_2	830.00–964.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX03_3	752.00–829.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX03_4	729.00–751.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX03_5	652.00–728.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX03_6	465.00–651.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX03_7	349.00–464.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX03_8	199.00–348.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX03_9	193.00–198.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX03_X	100.05–192.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX04_1	898.00–1,000.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX04_2	870.00–897.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX04_3	686.00–869.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX04_4	531.00–685.00	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1,079.33	6,468.9	n.a.
		KLX04_5	507.00–530.00	22	2	1.7E–04	8.4E–05	1.3E–04	–	1.7E–04	8.0E–05	4.0E–04	3.5E–07	21	7,192	161.20	3,118.07	18,007.4	4.9E02
		KLX04_6	231.00–506.00	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1,079.33	5,774.4	n.a.

Pumped section		Observation borehole		Flow regime		Transient analysis Formation Parameter										Index calculation			
Borehole ID	Section m btoc	Borehole ID_Sec.	Section m btoc	Pertub. phase	Rec. phase	T_{f1} m^2/s	T_{f2} m^2/s	T_{s1} m^2/s	T_{s2} m^2/s	T_T m^2/s	T_{TMIN} m^2/s	T_{TMAX} m^2/s	S	dt_1 s	dt_2 s	Index 1 r_s^2/dt_L	Index 2 s_p/Q_p	Index 2 new (sp/Qp)* $\ln(r_s/r_0)$	Diffusivity η (T/S)
KLX08	241.00–341.00	KLX04_7	163.00–230.00	2	2	9.0E–05	–	8.2E–05	–	8.2E–05	4.0E–05	2.0E–04	6.1E–07	33	12,621	67.60	4,077.47	21,107.9	1.3E02
		KLX04_8	12.24–162.00	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2,278.59	12,406.0	n.a.
		KLX06_1	761.00–1,000.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX06_2	571.00–760.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX06_3	554.00–570.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX06_4	411.00–553.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX06_5	276.00–410.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX06_6	256.00–275.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX06_7	146.00–255.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX06_8	11.88–145.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX07A_1	781.00–844.73	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX07A_2	753.00–780.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX07A_3	612.00–752.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX07A_4	457.00–611.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX07A_5	333.00–456.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX07A_6	204.00–332.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX07A_7	104.00–203.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX07A_8	102.00–103.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX07B_1	95.00–200.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX07B_2	9.64–94.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX10_1	711.00–1,001.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX10_2	689.00–710.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX10_3	465.00–688.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX10_4	369.00–464.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–

Pumped section		Observation borehole		Flow regime		Transient analysis Formation Parameter										Index calculation			
Borehole ID	Section m btoc	Borehole ID_Sec.	Section m btoc	Pertub. phase	Rec. phase	T_{f1} m^2/s	T_{f2} m^2/s	T_{s1} m^2/s	T_{s2} m^2/s	T_T m^2/s	T_{TMIN} m^2/s	T_{TMAX} m^2/s	S	dt_1 s	dt_2 s	Index 1 r_s^2/dt_L	Index 2 s_p/Q_p	Index 2 new (sp/Qp)* $\ln(r_s/r_0)$	Diffusivity η (T/S)
KLX08	241.00–341.00	KLX10_5	351.00–368.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX10_6	291.00–350.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX10_7	131.00–290.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX10_8	9.20–130.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX18A_1	440.00–611.28	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
		KLX18A_2	241.00–439.00	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	479.70	3,044.8	n.a.
		KLX18A_3	11.83–240.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
KLX08	357.00–497.00	KLX08_Pa	101.00–356.00	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1.47	2,547.19	13,389.0	n.a.
		KLX08_Pb	498.00–1,000.41	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	54.77	6,116.13	35,636.4	n.a.
		KLX11_1	17.00–70.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX11_2	6.00–16.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		HLX13_1	12.00–200.20	2	2	2.0E–04	–	2.9E–04	–	2.0E–04	1.0E–04	5.0E–04	4.7E–06	375	9,508	10.60	637.10	3,928.4	4.2E01
		HLX14_1	12.00–115.90	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1,632.58	9,919.3	n.a.
		HLX23_1	61.00–160.20	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	39.82	271.7	n.a.
		HLX23_2	6.10–60.00	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
		HLX24_1	41.00–175.20	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
		HLX24_2	9.10–40.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		HLX25_1	61.00–202.50	2	2	1.7E–04	–	2.3E–04	–	2.3E–04	8.0E–05	5.0E–04	5.1E–06	220	14,352	19.57	1,035.30	6,055.8	4.4E01
		HLX25_2	6.12–60.00	2	2	1.7E–04	–	2.0E–04	–	1.7E–04	8.0E–05	4.0E–04	2.7E–06	282	8,817	30.23	1,035.30	6,301.9	6.3E01
		HLX30_1	101.00–163.40	2	2	1.7E–04	–	2.2E–04	–	1.7E–04	8.0E–05	5.0E–04	6.2E–06	173	9,280	8.21	1,134.84	6,290.2	2.8E01
		HLX30_2	9.10–100.00	2	2	1.9E–04	–	2.6E–04	–	1.9E–04	9.0E–05	5.0E–04	6.5E–06	743	9,340	7.00	915.84	5,227.4	2.9E01
		HLX31_1	9.10–133.20	2	2	1.6E–04	–	2.1E–04	–	1.6E–04	7.0E–05	5.0E–04	5.8E–06	255	9,257	10.37	1,134.84	6,390.5	2.7E01
		HLX33_1	31.00–202.10	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
		HLX33_2	9.10–30.00	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Pumped section		Observation borehole		Flow regime		Transient analysis Formation Parameter										Index calculation			
Borehole ID	Section m btoc	Borehole ID_Sec.	Section m btoc	Pertub. phase	Rec. phase	T_{f1} m^2/s	T_{f2} m^2/s	T_{s1} m^2/s	T_{s2} m^2/s	T_T m^2/s	T_{TMIN} m^2/s	T_{TMAX} m^2/s	S	dt_1 s	dt_2 s	Index 1 r_s^2/dt_L	Index 2 s_p/Q_p	Index 2 new (sp/Qp)* $\ln(r_s/r_0)$	Diffusivity η (T/S)
KLX08	357.00–497.00	HLX34_1	9.00–151.80	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		HLX35_1	65.00–151.80	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		HLX35_2	6.10–64.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX02_1	1,165.00–1,700.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX02_2	1,145.00–1,164.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX02_3	718.00–1,144.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX02_4	495.00–717.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX02_5	452.00–494.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX02_6	348.00–451.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX02_7	209.00–347.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX02_8	100.35–208.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX03_1	965.00–971.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX03_2	830.00–964.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX03_3	752.00–829.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX03_4	729.00–751.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX03_5	652.00–728.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX03_6	465.00–651.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX03_7	349.00–464.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX03_8	199.00–348.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX03_9	193.00–198.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX03_X	100.05–192.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX04_1	898.00–1,000.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX04_2	870.00–897.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX04_3	686.00–869.00	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	716.74	4,456.6	n.a.

Pumped section		Observation borehole		Flow regime		Transient analysis Formation Parameter										Index calculation			
Borehole ID	Section m btoc	Borehole ID_Sec.	Section m btoc	Pertub. phase	Rec. phase	T_{f1} m²/s	T_{f2} m²/s	T_{s1} m²/s	T_{s2} m²/s	T_T m²/s	T_{TMIN} m²/s	T_{TMAX} m²/s	S	dt_1 s	dt_2 s	Index 1 r_s^2/dt_L	Index 2 s_p/Q_p	Index 2 new (sp/Qp)* $\ln(r_s/r_0)$	Diffusivity η (T/S)
KLX08	357.00–497.00	KLX04_4	531.00–685.00	2	2	5.2E–05	–	6.2E–05	–	5.2E–05	2.0E–05	2.0E–04	3.0E–06	617	9,554	n.a.	2,030.77	11,953.9	1.8E01
		KLX04_5	507.00–530.00	22	22	1.7E–04	6.9E–05	1.8E–04	7.2E–05	1.8E–04	8.0E–05	4.0E–04	1.5E–06	96	11,900	146.30	3,046.16	17,354.2	1.3E02
		KLX04_6	231.00–506.00	2	2	5.2E–05	–	5.9E–05	–	5.2E–05	2.0E–05	2.0E–04	6.0E–06	500	9,487	n.a.	2,150.23	11,754.9	8.8E00
		KLX04_7	163.00–230.00	2	2	9.2E–05	–	1.0E–04	–	9.2E–05	4.0E–05	2.0E–04	3.5E–06	829	9,321	15.56	1,911.31	10,713.0	2.7E01
		KLX04_8	12.24–162.00	2	2	1.2E–04	–	9.0E–05	–	1.2E–04	4.0E–05	3.0E–04	5.2E–06	375	9,450	n.a.	1,174.66	6,846.0	2.2E01
		KLX06_1	761.00–1,000.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX06_2	571.00–760.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX06_3	554.00–570.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX06_4	411.00–553.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX06_5	276.00–410.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX06_6	256.00–275.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX06_7	146.00–255.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX06_8	11.88–145.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX07A_1	781.00–844.73	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX07A_2	753.00–780.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX07A_3	612.00–752.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX07A_4	457.00–611.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX07A_5	333.00–456.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX07A_6	204.00–332.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX07A_7	104.00–203.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX07A_8	102.00–103.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX07B_1	95.00–200.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX07B_2	9.64–94.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX10_1	711.00–1,001.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–

Pumped section		Observation borehole		Flow regime		Transient analysis										Index calculation			
						Formation Parameter													
Borehole ID	Section m btoc	Borehole ID_Sec.	Section m btoc	Pertub. phase	Rec. phase	T_{f1} m^2/s	T_{f2} m^2/s	T_{s1} m^2/s	T_{s2} m^2/s	T_T m^2/s	T_{TMIN} m^2/s	T_{TMAX} m^2/s	S	dt_1 s	dt_2 s	Index 1 r_s^2/dt_L	Index 2 s_p/Q_p	Index 2 new $(sp/Qp)^* \ln(r_s/r_0)$	Diffusivity η (T/S)
KLX08	357.00–497.00	KLX10_2	689.00–710.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX10_3	465.00–688.00	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
		KLX10_4	369.00–464.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX10_5	351.00–368.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX10_6	291.00–350.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX10_7	131.00–290.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX10_8	9.20–130.00	–	–	–	–	–	–	–	–	–	–	–	–	No response due to pumping			–
		KLX18A_1	440.00–611.28	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	776.47	4,857.0	n.a.
		KLX18A_2	241.00–439.00	22	22	1.0E–04	6.9E–05	1.7E–04	9.3E–05	1.7E–04	5.0E–05	4.0E–04	1.4E–06	187	11,670	35.89	2,528.51	15,767.2	1.2E02
		KLX18A_3	11.83–240.00	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	179.19	1,131.2	n.a.

Nomenclature

Flow regime	The flow regime description refers to the recommended model used in the transient analysis. WBS denotes wellbore storage and skin and is followed by a set of numbers describing the flow dimension used in the analysis (1 = linear flow, 2 = radial flow, 3 = spherical flow). If only one number is used (e.g. WBS2 or 2) a homogeneous flow model (1 composite zone) was used in the analysis, if two numbers are given (WBS22 or 22) a 2 zones composite model was used.
T_f	Transmissivity derived from the analysis of the perturbation phase (CRw). In case a homogeneous flow model was used only one T_f value is reported, in case a two zone composite flow model was used both T_{f1} (inner zone) and T_{f2} (outer zone) are given.
T_s	Transmissivity derived from the analysis of the recovery phase (CRwr). In case a homogeneous flow model was used only one T_s value is reported, in case a two zone composite flow model was used both T_{s1} (inner zone) and T_{s2} (outer zone) are given.
T_T	Recommended transmissivity.
T_{TMIN} / T_{TMAX}	Confidence range lower/upper limit.
S	Storativity.
dt_1 / dt_2	Estimated start/stop time of evaluation for the recommended transmissivity (T_T).
Index 1	r_s^2/dt_L (m^2/s) normalised distance r_s with respect to the response time.
Index 2	sp/Qp (s/m^2) normalised drawdown with respect to the pumping rate.
Index 2 new	$(sp/Qp)^*\ln(r_s/r_0)$ (s/m^2) ormalised drawdown with respect to the pumping rate and distance.
Diffusivity η	T_T/S (m^2/s).
n.a.	Not analysed due to strong natural fluctuations (tidal effects).

The Figures 6-4 to 6-6 present the transmissivity and conductivity profiles.

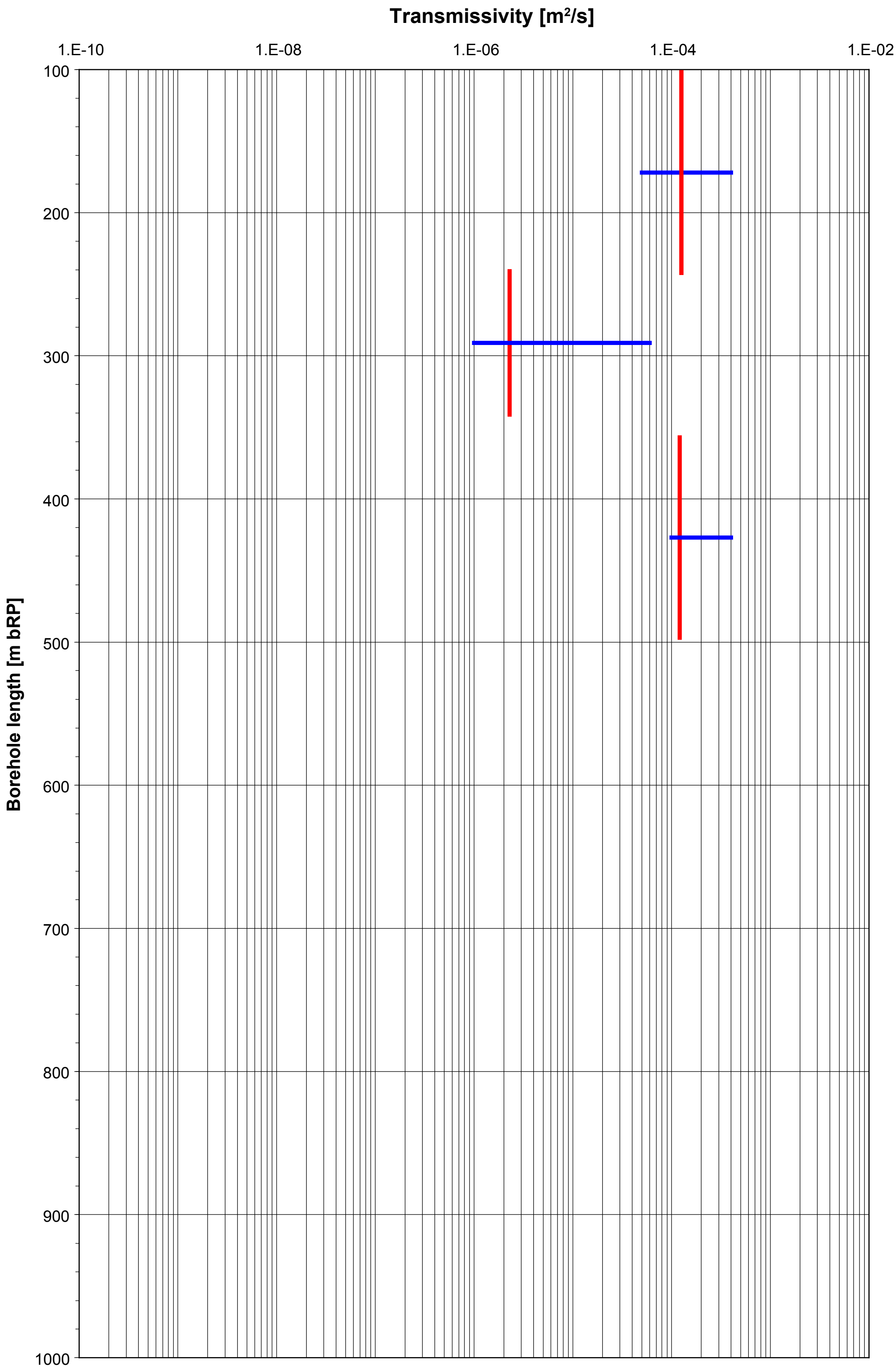

Figure 6-4. *Results summary of KLX08 – profile of transmissivity, transmissivities derived from the pump tests.*

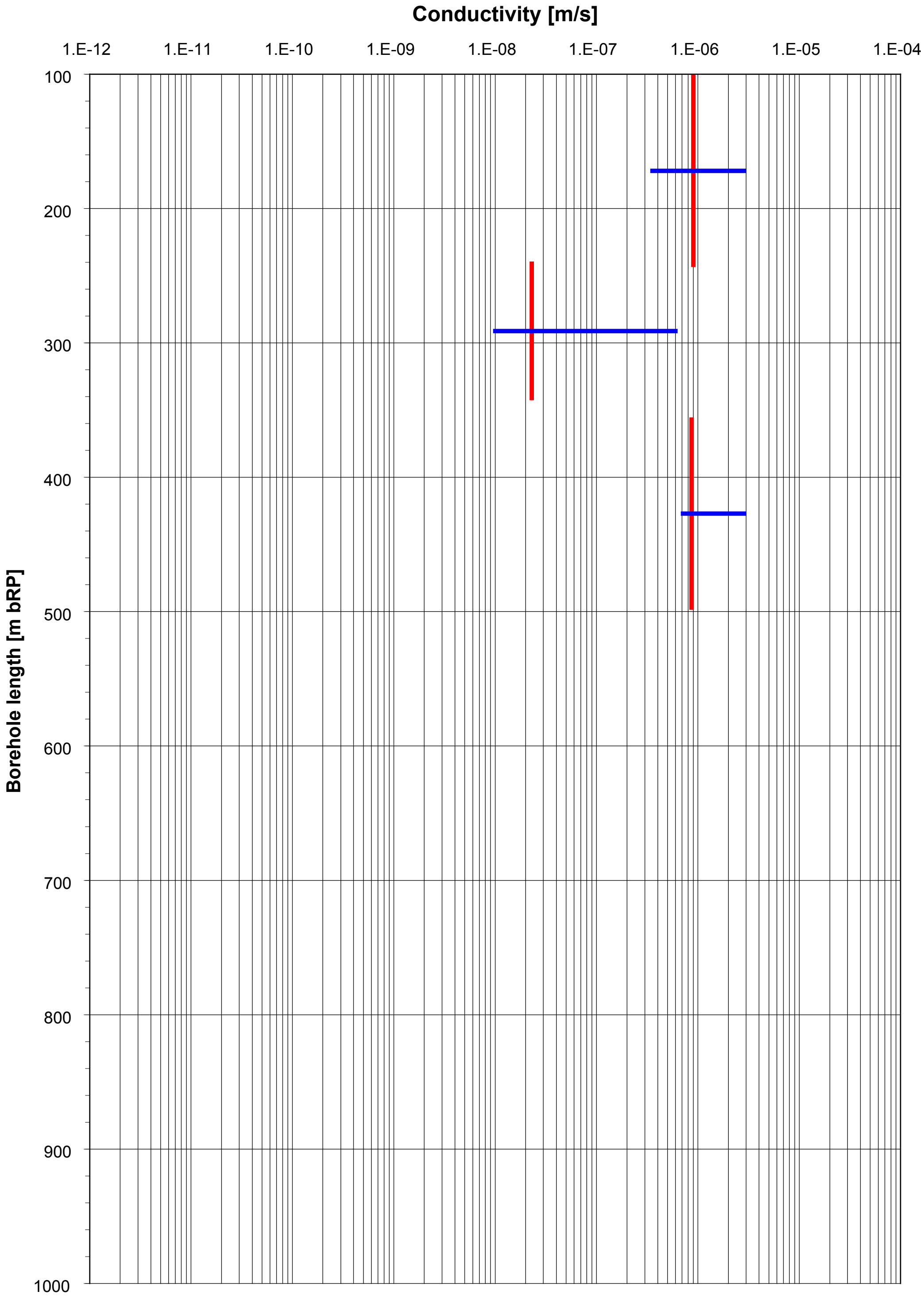

Figure 6-5. *Results summary of KLX08 – profile of hydraulic conductivity, conductivity derived from the pump tests.*

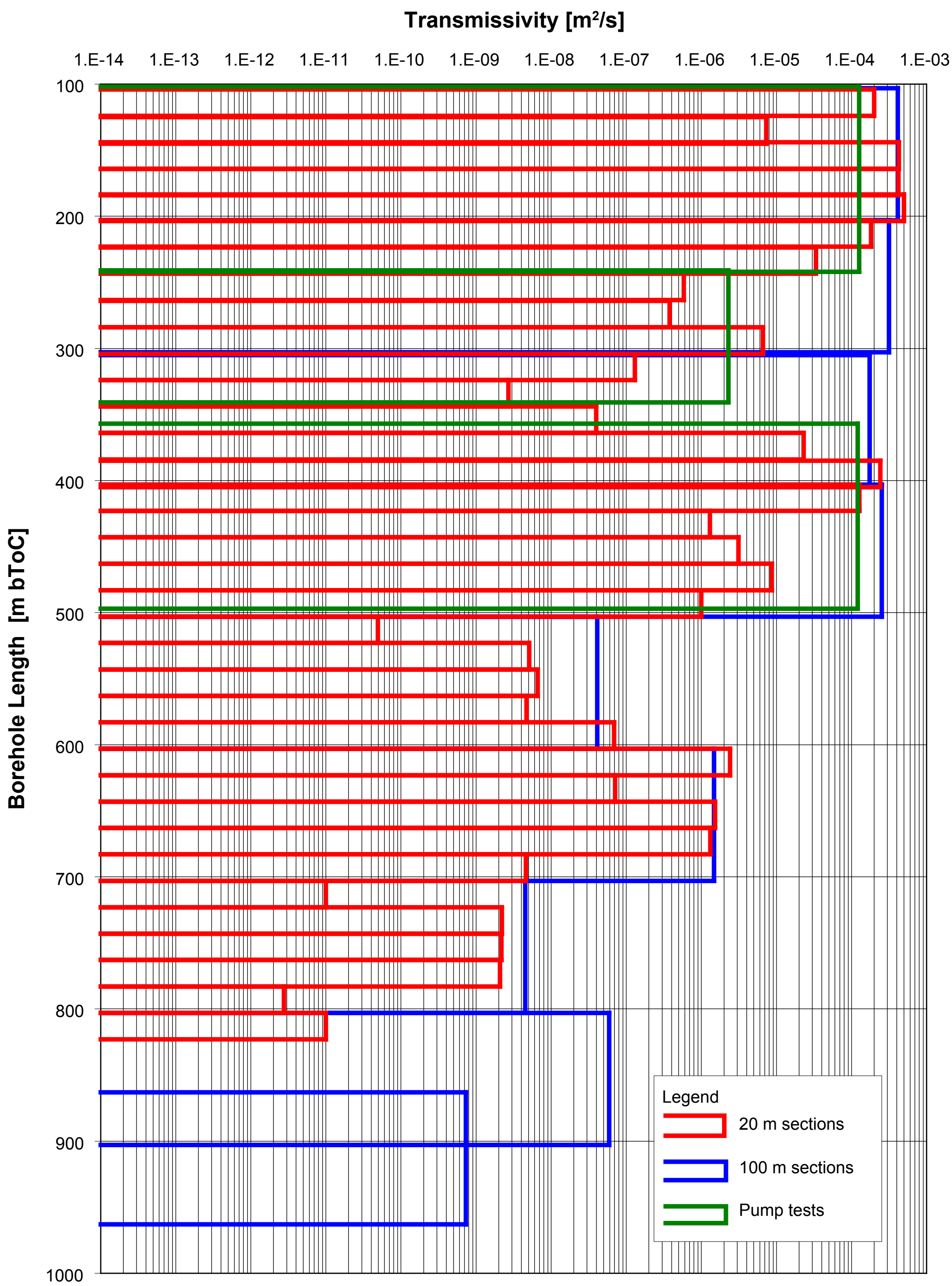

Figure 6-6. Results summary of KLX08 – comparison of the derived transmissivities of the injection and the pump tests.

6.3 Correlation analysis

A correlation analysis was used with the aim of examining the consistency of results and deriving general condlusion regarding the testing and analysis methods used.

6.3.1 Comparison of steady state and transient analysis results

The steady state derived transmissivities (T_M and Q/s) were compared in a cross-plot with the recommended transmissivity values derived from the transient analysis for the pump tests (see following Figure 6-7).

The correlation analysis shows that all of the steady state derived transmissivities differ by less than one order of magnitude from the transmissivities derived from the transient analysis.

6.3.2 Comparison between the matched and theoretical wellbore storage coefficient

The wellbore storage coefficient describes the capacity of the test interval to store fluid as result to an unit pressure change in the interval. For a closed system (i.e. closed downhole valve) the theoretical value of the wellbore storage coefficient is given by the product between the interval volume and the test zone compressibility. The interval volume is calculated from the borehole radius and interval length. There are uncertainties concerning the interval volume calculation. Cavities or high transmissivitiy fractures intersecting the interval may enlarge the effective volume of the interval.

The test zone compressibility is given by the sum of compressibilities of the individual components present in the interval (water, packer elements, other test tool components and the borehole wall). The water compressibility depends on the temperature and salinity. However, for temperature and salinity values as encountered at the Oskarshamn site the water compressibility varies only slightly between $4.6 \cdot 10^{-10}$ 1/Pa and $5.0 \cdot 10^{-10}$ 1/Pa.

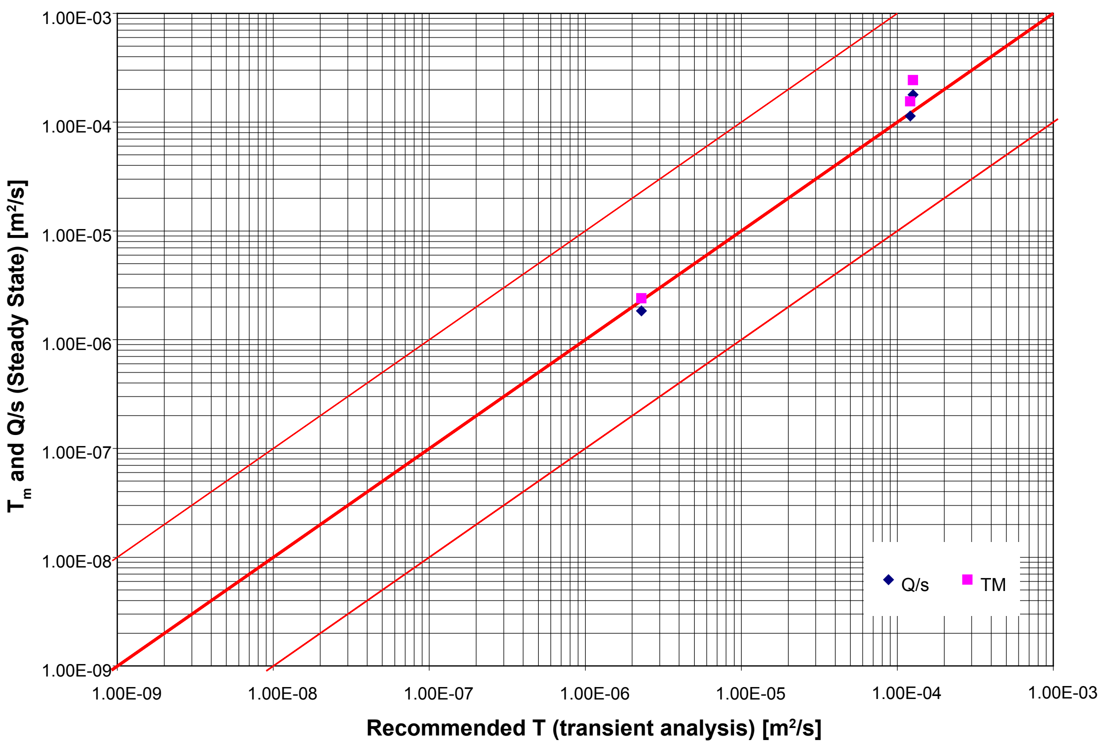

Figure 6-7. Correlation analysis of transmissivities derived by steady state and transient methods for the pump tests.

A water compressibility of $5 \cdot 10^{-10}$ 1/Pa and a rock compressibility of $1 \cdot 10^{-10}$ 1/Pa was assumed for the analysis. In addition, the test zone compressibility is influenced by the test tool (packer compliance). The test tool compressibility was calculated as follow:

$$c = \frac{\Delta V}{\Delta p} * \frac{1}{V} \quad [1/\mathrm{Pa}]$$

ΔV Volume change of 2 Packers (The volume change was estimated at $7 \cdot 10^{-7}$ m³/100 kPa based on the results of laboratory tests conducted by GEOSIGMA) [m³].

Δp Pressure change in test section (usually $2 \cdot 10^{5}$ Pa) [Pa].

V Volume in test section [m³].

The following Table 6-4 presents the calculated compressibilities for each relevant section length. The average value for the test tool compressibility based on different section length is $2 \cdot 10^{-11}$ 1/Pa.

The sum of the compressibilities (water, rock, test tool) leads to a test zone compressibility with a value of $6 \cdot 10^{-10}$ 1/Pa. This value is used for the calculation of the theoretical wellbore storage coefficient, which is $4 \cdot 10^{-10}$ m³/Pa for the 140 m test section and $3 \cdot 10^{-10}$ m³/Pa for the 100 m test section. The matched wellbore storage coefficient is derived from the transient type curve analysis by matching the unit slope early times derivative plotted in log-log coordinates.

The following Figure 6-8 presents a cross plot of the theoretical and matched wellbore storage coefficients derived by the pump tests.

It can be seen that the matched wellbore storage coefficients are up to one order of magnitude larger than the theoretical values for the 100 m test and up to three orders of magnitude larger for the 140 m tests. This phemomenon was already observed at the previous tested boreholes. A two or three orders of magnitude increase is difficult to explain by volume uncertainty. Even if large fractures are connected to the interval, a volume increase by three orders of magnitude does not seem probable. The discrepancy is not fully understood, but following hypothesis may be formulated:

- increased compressibility of the packer system,
- as shown by previous work /Böhner and Enachescu 2005/ conducted at the site, the phenomenon of increased wellbore storage coefficients can be explained by turbulent flow induced by the test in the vicinity of the borehole. Considering the fact that deviations concerning the wellbore storage rather occur in test sections with a higher transmissivity (which can lead to turbulent flow) seems to rest upon this hypothesis.

Table 6-4. Test tool compressibility values based on packer displacement.

Length of test section [m]	Volume in test section [m³]	Compressibility [1/Pa]
100	0.454	$2 \cdot 10^{-11}$
140	0.636	$1 \cdot 10^{-11}$
Average compressibility:		**$2 \cdot 10^{-11}$**

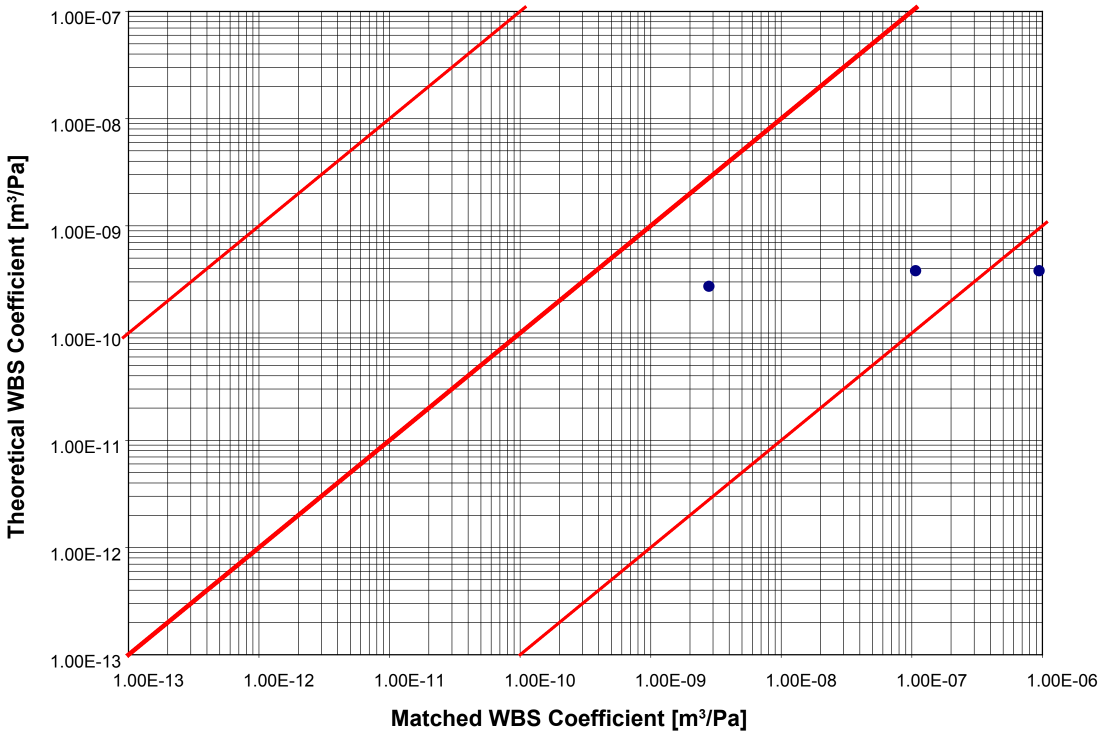

Figure 6-8. *Correlation analysis of theoretical and matched wellbore storage coefficients.*

6.4 Conclusions

6.4.1 Transmissivity derived from the pump tests

Figure 6-1 presents a profile of transmissivities, including the confidence range derived from the transient analysis. The method used for deriving the recommended transmissivity and its confidence range is described in Chapter 4.5.9.

Whenever possible, the transmissivities derived are representative for the "undisturbed formation" further away from the borehole. The borehole vicinity was typically described using a skin effect. A composite model was chosen for all three pump tests. Depending on the quality of the data, the inner zone transmissivity was recommended for the 100 m test and the outer zone transmissivity was recommended for the 140 m tests.

The transmissivity profile in Figure 6-1 shows transmissivities between $2.3 \cdot 10^{-06}$ m^2/s and $1.3 \cdot 10^{-04}$ m^2/s. The transmissivities derived from the pump tests are consistent with the results derived from the injection tests (see Figure 6-3).

6.4.2 Flow regimes encountered

The flow models used in the analysis were derived from the shape of the pressure derivative calculated with respect to log time and plotted in log-log coordinates.

In all three pump tests, the pressure derivative suggests a change of transmissivity with increased distance from the borehole. In these cases a composite flow model was used in the analysis.

The flow dimension displayed by the tests can be diagnosed from the slope of the pressure derivative. A slope of 0.5 indicates linear flow, a slope of 0 (horizontal derivative) indicates radial flow and a slope of –0.5 indicates spherical flow. The flow dimension diagnosis was commented for each of the tests. However, in all cases it was possible to achieve to acceptable analysis results (good match quality) by using radial flow geometry (flow dimension of 2).

6.4.3 Interference tests and hydraulic connectivity

For the interference tests three constant rate pump tests were performed in KLX08. 73 sections in 19 boreholes mainly along the lineament EW007 and northeast of KLX08 were monitored. 15 sections in 8 observation holes responded during the pump test in test section 102.00–242.00 m, 7 sections in 5 observation holes responded during the pump test in test section 241.00–341.00 m and altogether 22 sections in 11 observation holes responded during the pump test in test section 357.00–497.00 m.

The responding observation sections are located in boreholes along the lineament EW007 up to approximately 800 m away from KLX08. KLX04 is located adjacent to the pump hole KLX08 and KLX18A is located in a distance of approximately 600 m to KLX08 in a southwest direction.

In average, the highest drawdown in the observation holes was measured during the pump test in section 102.00–242.00 m and the lowest during pumping in test section 241.00–341.00 m. The evaluation of the interference test data shows a response time ranging from medium to excellent response time and a low to medium response drawdown.

The recommended transmissivities derived from the transient analysis ranges from $5.2 \cdot 10^{-5}$ m^2/s to $2.6 \cdot 10^{-4}$ m^2/s. Transmissivities of less than $1.0 \cdot 10^{-4}$ m^2/s were derived only in sections of KLX04, a borehole located adjacent to the pumped borehole KLX08.

Several observation boreholes showed some kind of response when pumping 357–497 m, but due to poor data quality caused by background noise and major tidal influence the data could not be ascertained that it was caused by pumping in KLX08. This happened mainly in the boreholes HLX23, HLX24, HLX33 and KLX10 which are all located in a distance of more than 600 m to the southeast of the pumped borehole KLX08.

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