P-06-146

Oskarshamn site investigation

Interference difference flow logging of boreholes KLX09B–F

Subarea Laxemar

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May 2007

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Abstract

Difference flow logging is a swift method for determination of the transmissivity and the hydraulic head in borehole sections and fractures/fracture zones in core drilled boreholes. This report presents the main principles of the interference test as well as results of measurements carried out in five boreholes KLX09B–F at Oskarshamn, Sweden, in February, March and April 2006, using Posiva flow log. The primary aim of the measurements was to determine the position and flow rate of flow yielding fractures and the hydraulic connectivity between them in boreholes KLX09B–F.

The single hole difference flow logging results are reported in P-06-199. During these the flow rates into or out of 1 m and 5 m long test sections were measured in boreholes KLX09B–F during natural (un-pumped) as well as pumped conditions. To cover the upper part of the boreholes that was subjected to drawdown, the uppermost part were flow logged with injection, i.e. when water was pumped into the borehole.

The hydraulic cross hole interference was observed by pumping one borehole and measuring the flow responses in all the other four boreholes. The interference test was performed in all possible combinations, i.e. each of the five boreholes was pumped in turn. These results are presented in the present report.

The lengths of boreholes KLX09B–F are relatively short, between c. 100–150 m. No length calibration was made since there are no length marks milled into the borehole wall.

A high-resolution absolute pressure sensor was used to measure the total pressure along the borehole. These measurements were carried out together with the flow measurements.

Electric conductivity (EC) and temperature of borehole water was also measured. The EC measurements were conducted simultaneously with all flow logging measurements.

Sammanfattning

Differensflödesloggning är en snabb metod för bestämning av transmissivitet och hydraulisk head i borrhålssektioner och sprickor/sprickzoner i kärnborrhål. Denna rapport presenterar huvudprinciperna för metoden och resultat av mätningar utförda i fem borrhål KLX09B–F i Oskarshamn, Sverige, i februari, mars och april 2006 med Posiva flödesloggningsmetod. Det primära syftet med mätningarna var att bestämma läget och flödet för vattenförande sprickor i borrhålen och bestämma hydrauliska anslutningar mellan borrhål KLX09B–F.

Resultat ifrån enhåls differensflödesloggningen är rapporterat i P-06-199. Vid dessa tester mätts flödet till eller från 1 m och 5 m långa testsektioner i borrhål KLX09B–F under såväl naturliga (icke-pumpade) som pumpade förhållanden. Övre delen av borrhålen loggades med injektion.

Den hydrauliska interferensen var observerad med pumpning, när ett borrhål pumpades och andra fyra borrhål var under flödesmätning. Interferenstesten utfördes med alla möjliga kombinationer. Resultat från dessa mätningar redovisas i föreliggande rapport.

Borrhålen KLX09B–F är relativt korta, ca. 100–150 m. Ingen längdkalibrering har gjorts eftersom ingen spårfräsning var gjord i borrhålsväggen.

En högupplösande absoluttryckgivare användes för att mäta det absoluta totala trycket längs borrhålet. Dessa mätningar utfördes tillsammans med flödesmätningarna.

Elektrisk konduktivitet och temperatur på borrhålsvattnet mättes samtidigt med flödesmätningarna.

Contents

1 Introduction

This document reports the results gained by the difference flow logging, 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 400-05-106. The controlling documents for performing this activity are listed in Table 1-1. The list of controlling documents excludes the assignment specific quality plans. Both activity plan and method descriptions are SKB's internal controlling documents.

Two reports are produced concerning activity plan AP PS 400-05-106. One of the reports presents results of single hole tests, the other one of interference test. This document presents the results gained of the interference test in boreholes KLX09B–F.

The difference flow logging in the core drilled boreholes KLX09B–F at Oskarshamn were conducted between February 15–April 12, 2006. The detailed dimensions of the boreholes are presented in Table 1-2. The borehole diameter is 76 mm. The location of boreholes at the drill site within the subarea of Laxemar at Oskarshamn is shown in Figure 1-1.

The field work and the subsequent data processing were conducted by PRG-Tec Oy as Posiva Oy's subcontractor. The Posiva Flow Log/Difference Flow method has previously been employed in Posiva's site characterisation programme in Finland as well as at the Äspö Hard Rock Laboratory at Simpevarp, Sweden.

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

Activity plan	Number	Version
Interference difference flow logging in boreholes KLX09B–F	AP PS 400-05-106	1.0
Method descriptions	**Number**	**Version**
Method description for difference flow logging	SKB MD 322.010	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
Instruktion för analys av injektions- och enhåls-pumptester	SKB MD 320.004	1.0

Table 1-2. Borehole construction, KLX09B–F.

Borehole ID	Length (m)	Inclination (degrees)	Z coord. of top of casing (m.a.s.l.)
KLX09B	100.200	–89.540	23.615
KLX09C	120.050	–58.719	23.751
KLX09D	121.020	–59.621	23.101
KLX09E	120.000	–59.932	22.156
KLX09F	152.300	–59.144	19.571

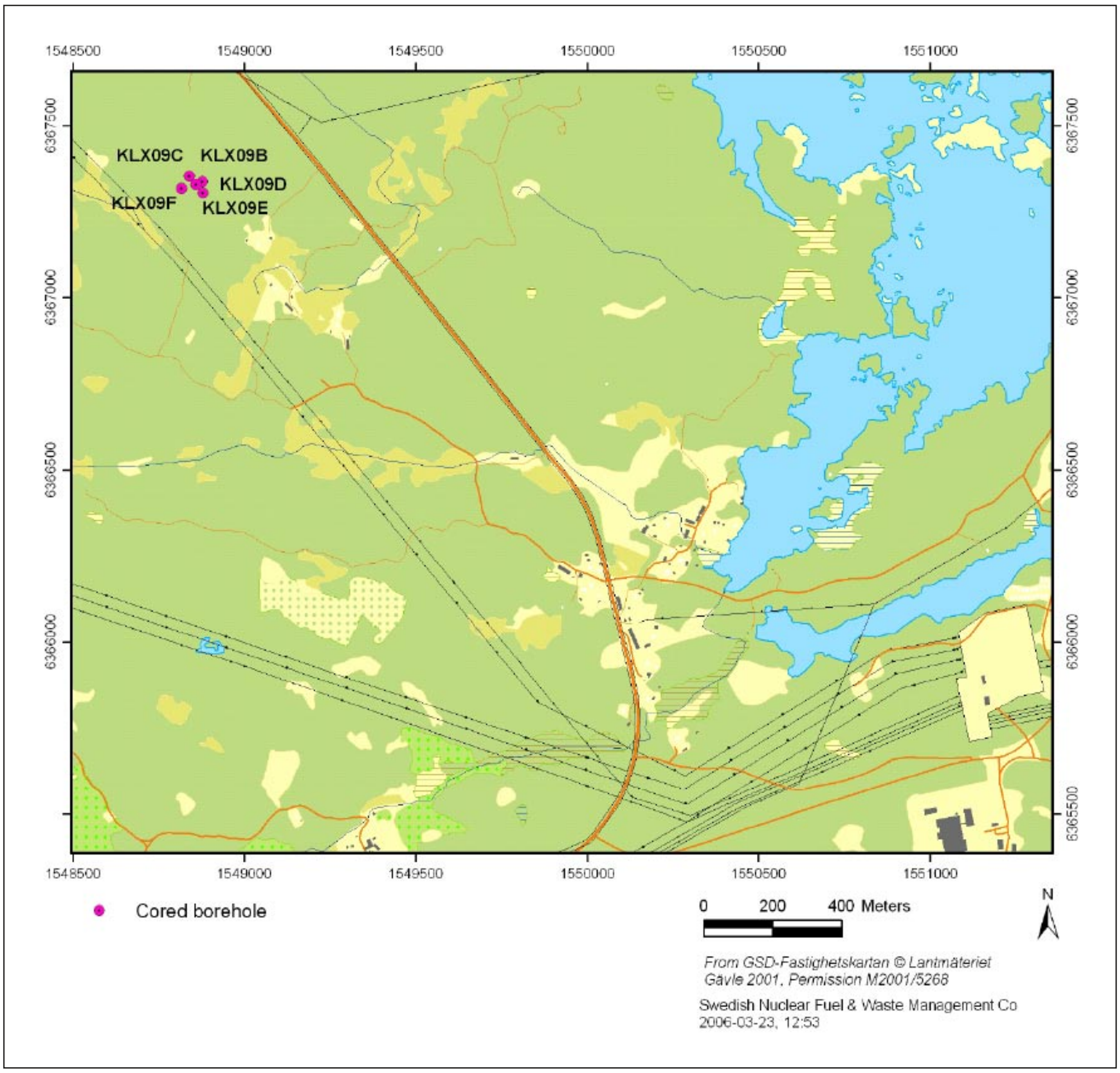

Figure 1-1. *Site map showing the locations of boreholes KLX09B–F situated in the subarea of Laxemar.*

2 Objective and scope

The objective with the present interference flow logging is to investigate the extent of hydraulically interconnected fractures or structures between the boreholes. For this purpose interference flow logging tests were conducted between five boreholes, where one borehole was pumped in turn and the flow responses were measured in the other four boreholes.

The report present flow responses in the different boreholes. No interpretation of the hydraulic interconnection or interpretation of the interference test is made as this is outside of the scope of works.

The testing programme was conducted according to activity plan AP PS 400-05-106. This activity plan includes both single hole tests and interference tests. The results of these two tests are reported separately. This document presents the results gained of the interference test in boreholes KLX09B–F. Single hole results are presented in report P-06-199.

3 Principles of measurement and interpretation

3.1 Measurements

Unlike traditional types of borehole flowmeters, the Difference flowmeter method measures the flow rate into or out of limited sections of the borehole instead of measuring the total cumulative flow rate along the borehole. The advantage of measuring the flow rate in isolated sections is a better detection of the incremental changes of flow along the borehole, which are generally very small and can easily be missed using traditional types of flowmeters.

Rubber disks at both ends of the downhole tool are used to isolate the flow rate in the test section from the flow rate in the rest of the borehole, see Figure 3-1. The flow rate along the borehole outside the isolated test section passes through the test section by means of a bypass pipe and is discharged at the upper end of the downhole tool.

The Difference flowmeter can be used in two modes, in a sequential mode and in an overlapping mode. In the sequential mode, the measurement increment is as long as the section length. It is used for determining the transmissivity and the hydraulic head /Öhberg and Rouhiainen 2000/. In the overlapping mode, the measurement increment is shorter than the section length. It is mostly used to determine the location of hydraulically conductive fractures and to classify them with regards to their flow rates.

The Difference flowmeter measures the flow rate into or out of the test section by means of thermistors, which track both the dilution (cooling) of a thermal pulse and transfer of thermal pulse with moving water. In the sequential mode, both methods are used, whereas in the overlapping mode, only the thermal dilution method is used because it is faster than thermal pulse method.

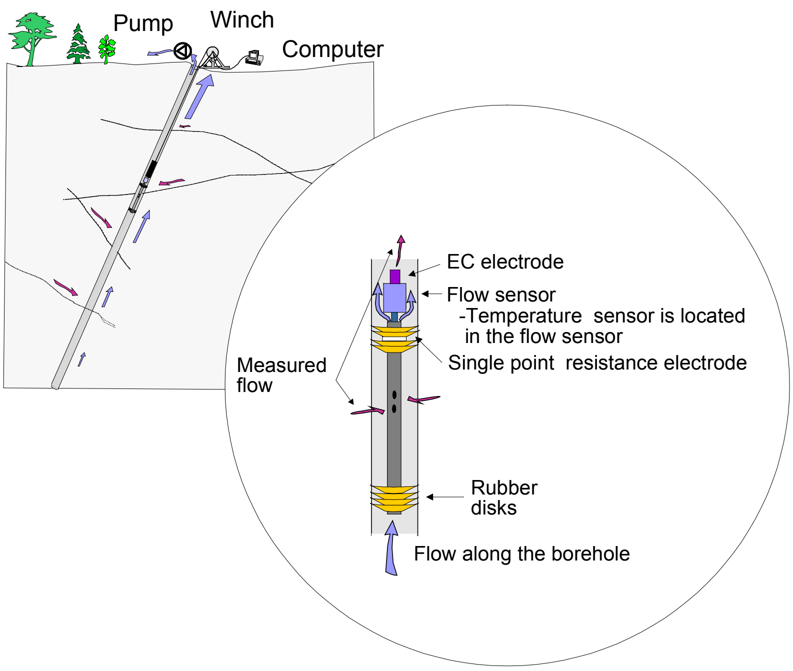

Figure 3-1. *Schematic of the downhole equipment used in the Difference flowmeter.*

Besides incremental changes of flow the downhole tool of the Difference flowmeter can also be used to measure:

- The electric conductivity (EC) of the borehole water and fracture-specific water. The electrode for the EC measurements is placed on the top of the flow sensor, Figure 3-1.
- The single point resistance (SPR) of the borehole wall (grounding resistance). The electrode of the Single point resistance tool is located in between the uppermost rubber disks, see Figure 3-1. This method is used for high-resolution depth/length determination of fractures and geological structures.
- The diameter of the borehole (caliper). The caliper tool, combined with SPR, is used for detection of the depth/length marks milled into the borehole wall. This enables an accurate depth/length calibration of the flow measurements.
- The prevailing water pressure profile in the borehole. The pressure sensor is located inside the electronics tube and connected through a tube to the borehole water, Figure 3-2.
- Temperature of the borehole water. The temperature sensor is placed in the flow sensor, Figure 3-1.

All of the above measurements, except fracture-specific EC and caliper, were performed in KLX09B–F. The hydraulic cross hole interference was observed by pumping one borehole and measuring the flow responses in all the other four boreholes. The interference test was performed in all possible combinations, i.e. each of the five boreholes was pumped in turn.

The principles of difference flow measurements are described in Figures 3-3 and 3-4. The flow sensor consists of three thermistors, see Figure 3-3a. The central thermistor, A, is used both as a heating element and for thermal pulse method and for registration of temperature changes in the thermal dilution method, Figures 3-3b and c. The side thermistors, B1 and B2, serve to detect the moving thermal pulse, Figure 3-3d, caused by the constant power heating in A, Figure 3-3b.

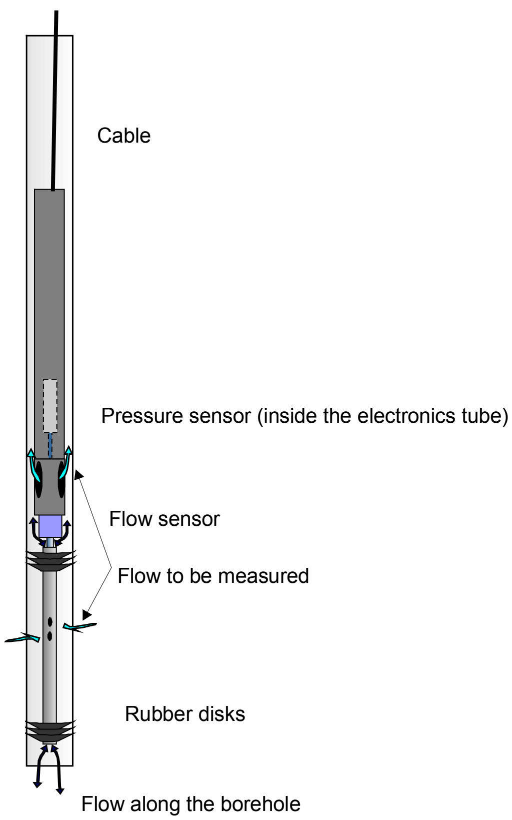

***Figure 3-2.** The absolute pressure sensor is located inside the electronics tube and connected through a tube to the borehole water.*

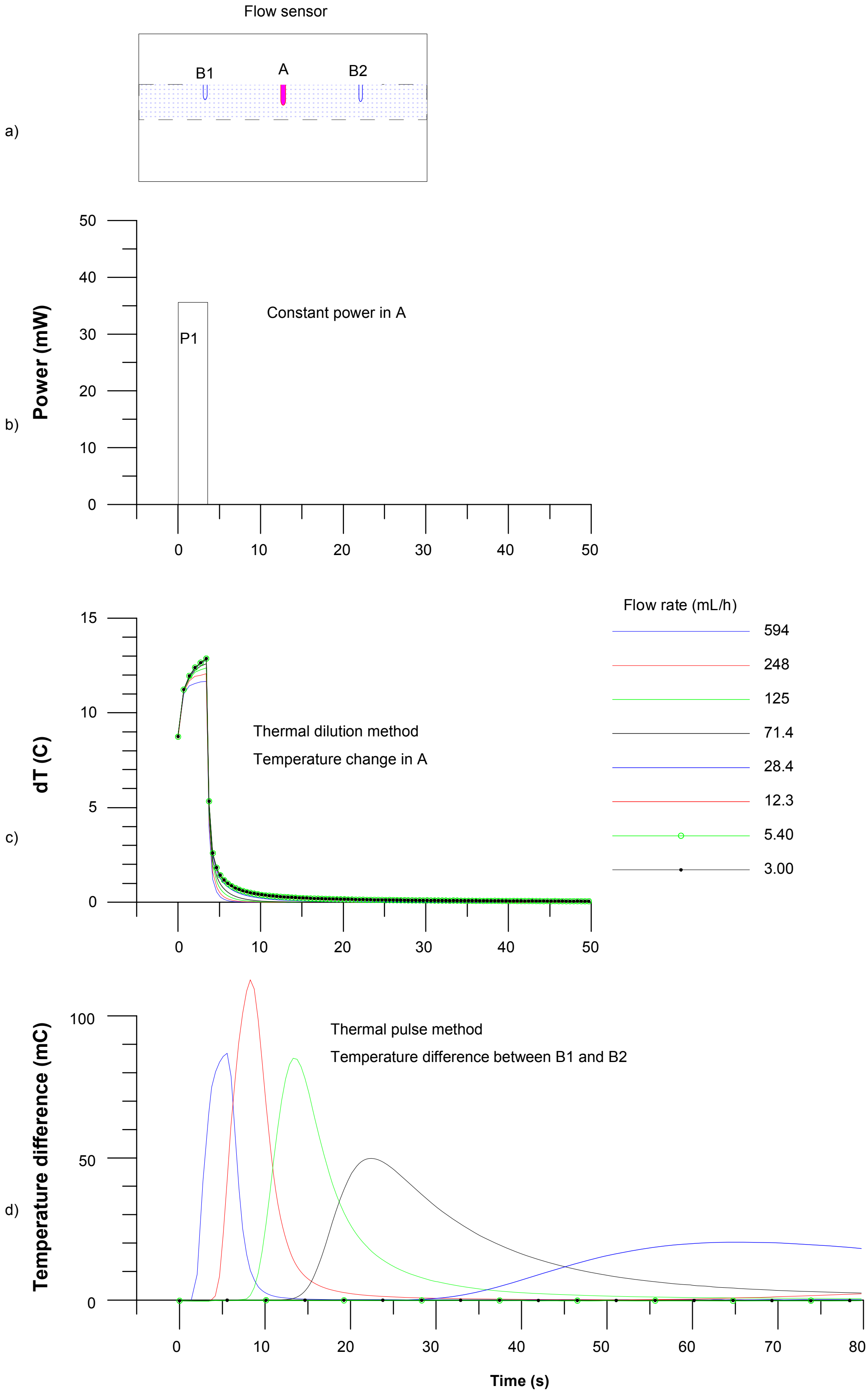

Figure 3-3. *Flow measurement, flow rate < 600 mL/h.*

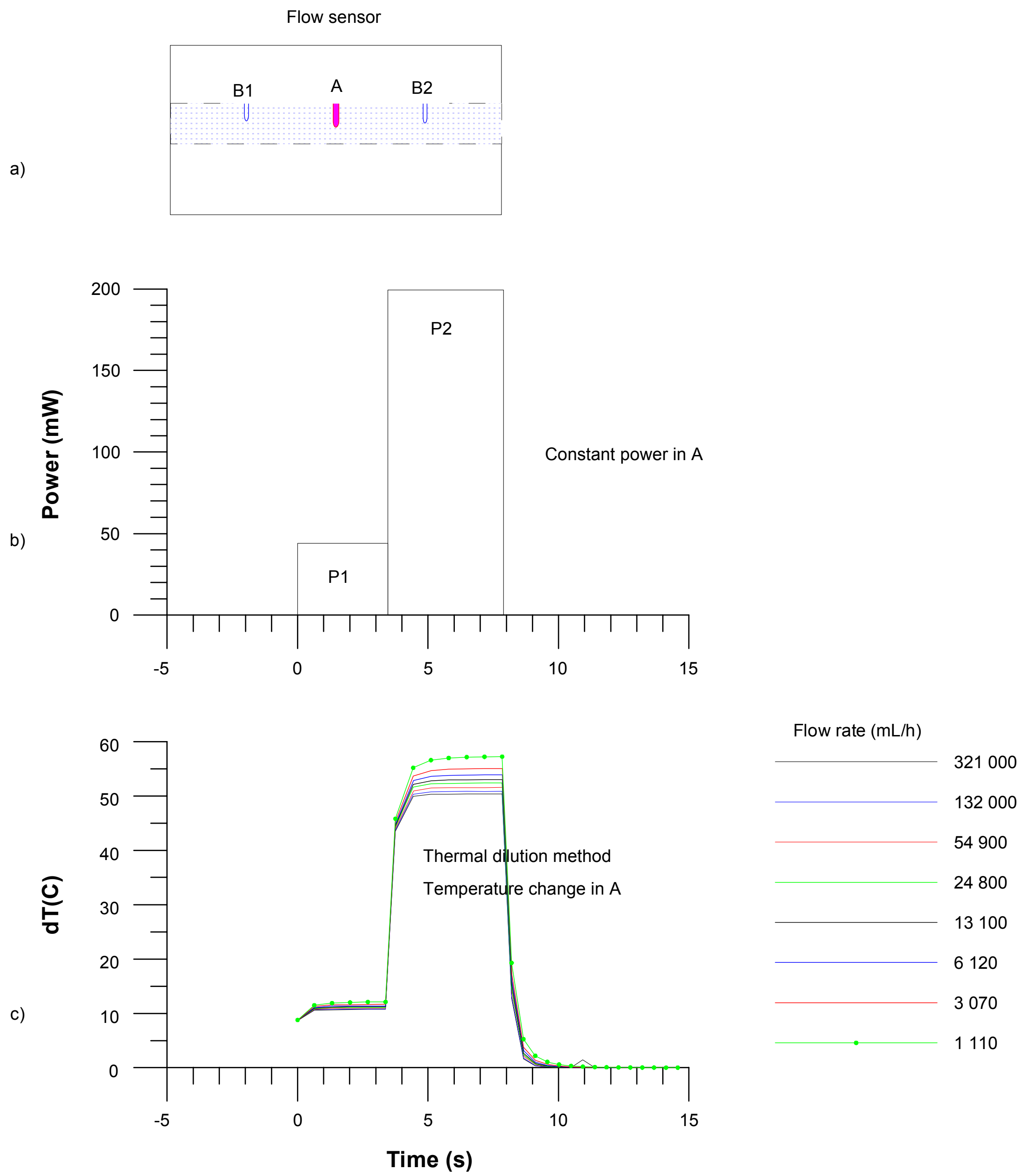

Figure 3-4. *Flow measurement, flow rate > 600 mL/h.*

Flow rate is measured during the constant power heating (Figure 3-3b). If the flow rate exceeds 600 mL/h, the constant power heating is increased, Figure 3-4b, and the thermal dilution method is applied.

If the flow rate during the constant power heating (Figure 3-3b) falls below 600 mL/h, the measurement continues with monitoring of thermal dilution transient (Figure 3-3c) and thermal pulse response (Figure 3-3d). When applying the thermal pulse method, also thermal dilution is always measured. The same heat pulse is used for the both methods.

Flow is measured when the tool is at rest. After transfer to a new position, there is a waiting time (the duration can be adjusted according to the prevailing circumstances) before the heat pulse (Figure 3-3b) is launched. The waiting time after the constant power thermal pulse can also be adjusted, but is normally 10 s long for thermal dilution and 300 s long for thermal pulse. The measuring range of each method is given in Table 3-1.

Table 3-1. Ranges of flow measurement.

Method	Range of measurement (mL/h)
Thermal dilution P1	30–6,000
Thermal dilution P2	600–300,000
Thermal pulse	6–600

The lower end limits of the thermal dilution and the thermal pulse methods in Table 3-1 are theoretical lowest measurable values. Depending on the borehole conditions these limits may not always prevail. Examples of disturbing conditions are suspended drilling debris in the borehole water, gas bubbles in the water and high flow rates (above about 30 L/min) along the borehole. If disturbing conditions are significant, a practical measurement limit is calculated for each set of data. When flow above the measurement limit is encountered a remeasurement is performed at the specific anomaly with a reduced pumping, typically about half the original drawdown.

3.2 Interpretation

3.2.1 Single hole tests

The interpretation is based on Thiems or Dupuits formula that describes a steady state and two dimensional radial flow into the borehole /Marsily 1986/:

$h_s – h = Q/(T \cdot a)$ 3-1

where

h is hydraulic head in the vicinity of the borehole and h_s at the radius of influence (R),

Q is the flow rate into the borehole,

T is the transmissivity of the test section,

a is a constant depending on the assumed flow geometry.

For cylindrical flow, the constant a is:

$a = 2 \cdot \pi / \ln(R/r_0)$ 3-2

where

r_0 is the radius of the well and

R is the radius of influence, i.e. the zone inside which the effect of the pumping is felt.

If flow rate measurements are carried out using two levels of hydraulic heads in the borehole, i.e. natural or pump-induced hydraulic heads, then the undisturbed (natural) hydraulic head and transmissivity of the tested borehole sections can be calculated. Two equations can be written directly from Equation 3-1:

$Q_{s0} = T_s \cdot a \cdot (h_s – h_0)$ 3-3

$Q_{s1} = T_s \cdot a \cdot (h_s – h_1)$ 3-4

where

h_0 and h_1 are the hydraulic heads in the borehole at the test level,

Q_{s0} and Q_{s1} are the measured flow rates in the test section,

T_s is the transmissivity of the test section and

h_s is the undisturbed hydraulic head of the tested zone far from the borehole.

Since, in general, very little is known of the flow geometry, cylindrical flow without skin zones is assumed. Cylindrical flow geometry is also justified because the borehole is at a constant head and there are no strong pressure gradients along the borehole, except at its ends.

The radial distance R to the undisturbed hydraulic head h_S is not known and must be assumed. Here a value of 500 is selected for the quotient R/r_0.

The hydraulic head and the test section transmissivity can be deduced from the two measurements:

$h_s = (h_0–b \cdot h_1)/(1–b)$ 3-5

$T_s = (1/a)\ (Q_{s0}–Q_{s1})/(h_1–h_0)$ 3-6

where

$b = Q_{s0}/Q_{s1}$

Transmissivity (T_f) and hydraulic head (h_f) of individual fractures can be calculated provided that the flow rates of individual fractures are known. Similar assumptions as above have to be used (a steady state cylindrical flow regime without skin zones).

$h_f = (h_0–b\ h_1)/(1–b)$ 3-7

$T_f = (1/a)\ (Q_{f0}–Q_{f1})/(h_1–h_0)$ 3-8

where

Q_{f0} and Q_{f1} are the flow rates at a fracture and

h_f and T_f are the hydraulic head (far away from borehole) and the transmissivity of a fracture, respectively. Since Q_{f0} is usually not measured, it is estimated from the Q_{s0} for some fractures, i.e. for those flowing fractures that are far away from the other flowing fractures or for the fractures that have much higher flow rate than surrounding fractures.

Since the actual flow geometry and the skin effects are unknown, transmissivity values should be taken as indicating orders of magnitude. As the calculated hydraulic heads do not depend on geometrical properties but only on the ratio of the flows measured at different heads in the borehole, they should be less sensitive to unknown fracture geometry. A discussion of potential uncertainties in the calculation of transmissivity and hydraulic head is provided in /Ludvigson et al. 2002/.

3.2.2 Interference tests

A reference flow (Q_x) is calculated for helping evaluation of degree of interconnection. It is a qualitative tool. Reference flow can be understood as a limit flow value when evaluating the flow results from interference test. If the measured flow rate and calculated reference flow are equal, there is no interconnection between the boreholes at all. In such a case flow rate in a fracture doesn't depend on pumping in other boreholes but only on water level in the borehole where the flow is measured. If the borehole is measured with two drawdowns as described above, any other flow rate into the borehole or out from it for any hydraulic head can be calculated with the assumptions above and with the assumption of laminar flow conditions.

Calculated reference flow in a measured borehole x can be written as follows:

$$Q_x = T_f \cdot a \cdot (h_f - h_x) \qquad 3\text{-}9$$

where

Q_x is the calculated reference flow in the measured borehole,

T_f is transmissivity of measured fracture,

a is a constant depending on the flow geometry,

h_x is the hydraulic head in the measured borehole at the test level. It is chosen to be the same as the hydraulic head in the measured borehole during the interference test when another borehole is pumped.

h_f is the static groundwater head of the measured zone far from the borehole, beyond the radius of influence R

Using Equations 3-7 and 3-8 Q_x can be solved:

$$Q_x = (Q_{f1} \cdot (h_x - h_0) - Q_{f0} \cdot (h_x - h_1))/(h_1 - h_0) \qquad 3\text{-}10$$

Q_x is a calculated reference of flow rate for hydraulic head of hx. Qx is also an interpolated value of the flow rates measured earlier. If $h_x = h_0$ then $Q_x = Q_{f0}$ and if $h_x = h_1$ then $Q_x = Q_{f1}$. It is assumed that there are the same flow conditions as during the two flow measurements Q_{f0} and Q_{f1} (no disturbance from outside, such as interference from boreholes nearby). Q_x can be therefore used as a reference value for interference test, giving the limit when there is no hydraulic connection between the observed hole and the pumped hole.

4 Equipment specifications

The Posiva Flow Log/Difference flowmeter monitors the flow of groundwater into or out from a borehole by means of a flow guide (rubber discs). The flow guide thereby defines the test section to be measured without altering the hydraulic head. Groundwater flowing into or out from the test section is guided to the flow sensor. Flow is measured using the thermal pulse and/or thermal dilution methods. Measured values are transferred in digital form to the PC computer.

Type of instrument:	Posiva Flow Log/Difference Flowmeter.
Borehole diameters:	56 mm, 66 mm and 76 mm.
Length of test section:	A variable length flow guide is used.
Method of flow measurement:	Thermal pulse and/or thermal dilution.
Range and accuracy of measurement:	Table 4-1.
Additional measurements:	Temperature, Single point resistance, Electric conductivity of water, Caliper, Water pressure.
Winch:	Mount Sopris Wna 10, 0.55 kW, 220 V/50 Hz. Steel wire cable 1,500 m, four conductors, Gerhard-Owen cable head.
Length determination:	Based on the marked cable and on the digital length counter.
Logging computer:	PC, Windows XP.
Software:	Based on MS Visual Basic.
Total power consumption:	1.5–2.5 kW depending on the pumps.
Calibrated:	November 2005.
Calibration of cable length:	Using length marks in the borehole.

Range and accuracy of sensors is presented in Table 4-1.

Table 4-1. Range and accuracy of sensors.

Sensor	Range	Accuracy
Flow	6–300,000 mL/h	± 10% curr.value
Temperature (middle thermistor)	0–50°C	0.1°C
Temperature difference (between outer thermistors)	–2 – +2°C	0.0001°C
Electric conductivity of water (EC)	0.02–11 S/m	± 5% curr.value
Single point resistance	5–500,000 Ω	± 10% curr.value
Groundwater level sensor	0–0.1 MPa	± 1% fullscale
Absolute pressure sensor	0–20 MPa	± 0.01% fullscale

5 Performance

5.1 Execution of the field work

The commission was performed according to Activity Plan AP PS 400-05-106 (SKB internal controlling document) following the SKB Method Description 322.010, Version 1.0 (Method description for difference flow logging). Two reports are produced concerning the activity plan. This document (P-06-146) presents the results gained of the interference test in boreholes KLX09B–F. Single hole results are presented separately in document P-06-199.

Prior to the measurements, the downhole tools and the measurement cable were disinfected. Clocks were synchronized to the official Swedish time (Clock time). The activity schedule of the borehole measurements is presented in Table 5-1. The items and activities in Table 5-1 are the same as in the Activity Plan.

Logging cables, wires, and pipe strings are exposed to stretching when lowered into a vertical or sub-vertical borehole. This will introduce a certain error in defining the position of a test tool connected to the end of e.g. a logging cable. Normally length calibration of logging tools is made by using the known positions of length marks milled into the borehole wall. Lengths of boreholes KLX09B–F are however relatively short, between c. 100–150 m, and no length marks were drilled on the borehole wall. Thereby no length calibration was applied in measurements in boreholes KLX09B–F.

The combined overlapping/sequential flow logging (Items 8–17) was carried out first in all the boreholes during natural (un-pumped) conditions. Both 1 m and 5 m section lengths were used. The length increment (step length) was 0.1 m with 1 m section length and 0.5 m with 5 m section length. Every tenth flow measurement (sequential mode) had a longer measurement time than normally in the overlapping mode. This was done to ensure the direction of the flow (into the borehole or out of it).

Pumping was started on February 22 in borehole KLX09B. Every borehole KLX09B–F were pumped, measured and waited for recovery in turn. The overlapping flow logging (Items 18–27) was carried out in all the boreholes during pumped conditions with 1 m and 5 m section lengths. The length increment (step length) was 0.1 m with 1 m section length and 0.5 m with 5 m section length. Measurement order was KLX09B, KLX09C, KLX09E, KLX09D and KLX09F. Pumping in borehole KLX09F was stopped on April 6. Water level in the boreholes are presented on the date scale, see Appendix 14.

The interference tests (Items 28–47 and 28A–47A) took place between February 26 and April 6. The same pumping sequences that were used for the single-hole tests were continued and all the other boreholes were flow logged using a 5 m section (0.5 m increments) and a 1 m section (0.1 m increments).

After the pumping of a certain borehole was stopped the recovery of the water level was recorded (Items 48–52).

The measurement programme was then continued with injection tests, which allow for a more complete characterization of the upper parts of the boreholes which were subjected to drawdown during pumping. The upper parts of the boreholes were now flow logged (overlapping flow logging) with 1 m section length and 0.1 m step length (Items 53–57)).

No separate activities were performed to measure the electric conductivity of borehole water. However, EC and temperature were obtained during flow loggings .

Table 5-1. Flow logging and testing in KLX09B–F. Activity schedule.

Item	Activity	Explanation	Date
1	Mobilisation at site	Unpacking the trailer	2006-02-15
8	Combined Overlapping/ Sequential flow logging, KLX09B	Section length L_w=5 m, Step length dL=0.5 m. No pumping	2006-02-21
9	Combined Overlapping/ Sequential flow logging, KLX09C	Section length L_w=5 m, Step length dL=0.5 m. No pumping	2006-02-16
10	Combined Overlapping/ Sequential flow logging, KLX09D	Section length L_w=5 m, Step length dL=0.5 m. No pumping	2006-02-17
11	Combined Overlapping/ Sequential flow logging, KLX09E	Section length L_w=5 m, Step length dL=0.5 m. No pumping	2006-02-18
12	Combined Overlapping/ Sequential flow logging, KLX09F	Section length L_w=5 m, Step length dL=0.5 m. No pumping	2006-02-20
13	Combined Overlapping/ Sequential flow logging, KLX09B	Section length L_w=1 m, Step length dL=0.1 m. No pumping	2006-02-21 2006-02-22
14	Combined Overlapping/ Sequential flow logging, KLX09C	Section length L_w=1 m, Step length dL=0.1 m. No pumping	2006-02-16 2006-02-17
15	Combined Overlapping/ Sequential flow logging, KLX09D	Section length L_w=1 m, Step length dL=0.1 m. No pumping	2006-02-17 2006-02-18
16	Combined Overlapping/ Sequential flow logging, KLX09E	Section length L_w=1 m, Step length dL=0.1 m. No pumping	2006-02-18 2006-02-19
17	Combined Overlapping/ Sequential flow logging, KLX09F	Section length L_w=1 m, Step length dL=0.1 m. No pumping	2006-02-20 2006-02-21
18	Overlapping flow logging, KLX09B	Section length L_w=5 m, Step length dL=0.5 m at pumping (includes 1 day waiting after beginning of pumping)	2006-02-23
19	Overlapping flow logging, KLX09C	Section length L_w=5 m, Step length dL=0.5 m at pumping (includes 1 day waiting after beginning of pumping)	2006-03-04
20	Overlapping flow logging, KLX09D	Section length L_w=5 m, Step length dL=0.5 m at pumping (includes 1 day waiting after beginning of pumping)	2006-03-23
21	Overlapping flow logging, KLX09E	Section length L_w=5 m, Step length dL=0.5 m at pumping (includes 1 day waiting after beginning of pumping)	2006-03-14
22	Overlapping flow logging, KLX09F	Section length L_w=5 m, Step length dL=0.5 m at pumping (includes 1 day waiting after beginning of pumping)	2006-04-01
23	Overlapping flow logging, KLX09B	Section length L_w=1 m, Step length dL=0.1 m at pumping	2006-02-23
24	Overlapping flow logging, KLX09C	Section length L_w=1 m, Step length dL=0.1 m at pumping	2006-03-04 2006-03-05
25	Overlapping flow logging, KLX09D	Section length L_w=1 m, Step length dL=0.1 m at pumping	2006-03-23 2006-03-24
26	Overlapping flow logging, KLX09E	Section length L_w=1 m, Step length dL=0.1 m at pumping	2006-03-14
27	Overlapping flow logging, KLX09F	Section length L_w=1 m, Step length dL=0.1 m at pumping	2006-04-01 2006-04-02
28A	Sequential flow logging/ Combined in KLX09C	Interference test. Section length L_w=5 m, Step length dL=0.5 m. KLX09B was pumped.	2006-02-26
28	Sequential flow logging/ Combined in KLX09C	Interference test. Section length L_w=1 m, Step length dL=0.1 m. KLX09B was pumped.	2006-02-26
29A	Sequential flow logging/ Combined in KLX09D	Interference test. Section length L_w=5 m, Step length dL=0.5 m. KLX09B was pumped.	2006-02-24
29	Sequential flow logging/ Combined in KLX09D	Interference test. Section length L_w=1 m, Step length dL=0.1 m. KLX09B was pumped.	2006-02-24 2006-02-25
30A	Sequential flow logging/ Combined in KLX09E	Interference test. Section length L_w=5 m, Step length dL=0.5 m. KLX09B was pumped.	2006-02-25

Item	Activity	Explanation	Date
30	Sequential flow logging/ Combined in KLX09E	Interference test. Section length L_w=1 m, Step length dL=0.1 m. KLX09B was pumped.	2006-02-25 2006-02-26
31A	Sequential flow logging/ Combined in KLX09F	Interference test. Section length L_w=5 m, Step length dL=0.5 m. KLX09B was pumped.	2006-02-27
31	Sequential flow logging/ Combined in KLX09F	Interference test. Section length L_w=1 m, Step length dL=0.1 m. KLX09B was pumped.	2006-02-27 2006-02-28
32A	Sequential flow logging/ Combined in KLX09B	Interference test. Section length L_w=5 m, Step length dL=0.5 m. KLX09C was pumped.	2006-03-05
32	Sequential flow logging/ Combined in KLX09B	Interference test. Section length L_w=1 m, Step length dL=0.1 m. KLX09C was pumped.	2006-03-05 2006-03-06
33A	Sequential flow logging/ Combined in KLX09D	Interference test. Section length L_w=5 m, Step length dL=0.5 m. KLX09C was pumped.	2006-03-07
33	Sequential flow logging/ Combined in KLX09D	Interference test. Section length L_w=1 m, Step length dL=0.1 m. KLX09C was pumped.	2006-03-07 2006-03-08
34A	Sequential flow logging/ Combined in KLX09E	Interference test. Section length L_w=5 m, Step length dL=0.5 m. KLX09C was pumped.	2006-03-08
34	Sequential flow logging/ Combined in KLX09E	Interference test. Section length L_w=1 m, Step length dL=0.1 m. KLX09C was pumped.	2006-03-08 2006-03-09
35A	Sequential flow logging/ Combined in KLX09F	Interference test. Section length L_w=5 m, Step length dL=0.5 m. KLX09C was pumped.	2006-03-06
35	Sequential flow logging/ Combined in KLX09F	Interference test. Section length L_w=1 m, Step length dL=0.1 m. KLX09C was pumped.	2006-03-06 2006-03-07
36A	Sequential flow logging/ Combined in KLX09B	Interference test. Section length L_w=5 m, Step length dL=0.5 m. KLX09D was pumped.	2006-03-24
36	Sequential flow logging/ Combined in KLX09B	Interference test. Section length L_w=1 m, Step length dL=0.1 m. KLX09D was pumped.	2006-03-24 2006-03-25
37A	Sequential flow logging/ Combined in KLX09C	Interference test. Section length L_w=5 m, Step length dL=0.5 m. KLX09D was pumped.	2006-03-26
37	Sequential flow logging/ Combined in KLX09C	Interference test. Section length L_w=1 m, Step length dL=0.1 m. KLX09D was pumped.	2006-03-26 2006-03-27
28A	Sequential flow logging/ Combined in KLX09C	Interference test. Section length L_w=5 m, Step length dL=0.5 m. KLX09B was pumped.	2006-02-26
28	Sequential flow logging/ Combined in KLX09C	Interference test. Section length L_w=1 m, Step length dL=0.1 m. KLX09B was pumped.	2006-02-26
29A	Sequential flow logging/ Combined in KLX09D	Interference test. Section length L_w=5 m, Step length dL=0.5 m. KLX09B was pumped.	2006-02-24
29	Sequential flow logging/ Combined in KLX09D	Interference test. Section length L_w=1 m, Step length dL=0.1 m. KLX09B was pumped.	2006-02-24 2006-02-25
30A	Sequential flow logging/ Combined in KLX09E	Interference test. Section length L_w=5 m, Step length dL=0.5 m. KLX09B was pumped.	2006-02-25
30	Sequential flow logging/ Combined in KLX09E	Interference test. Section length L_w=1 m, Step length dL=0.1 m. KLX09B was pumped.	2006-02-25 2006-02-26
31A	Sequential flow logging/ Combined in KLX09F	Interference test. Section length L_w=5 m, Step length dL=0.5 m. KLX09B was pumped.	2006-02-27
31	Sequential flow logging/ Combined in KLX09F	Interference test. Section length L_w=1 m, Step length dL=0.1 m. KLX09B was pumped.	2006-02-27 2006-02-28
32A	Sequential flow logging/ Combined in KLX09B	Interference test. Section length L_w=5 m, Step length dL=0.5 m. KLX09C was pumped.	2006-03-05
32	Sequential flow logging/ Combined in KLX09B	Interference test. Section length L_w=1 m, Step length dL=0.1 m. KLX09C was pumped.	2006-03-05 2006-03-06
33A	Sequential flow logging/ Combined in KLX09D	Interference test. Section length L_w=5 m, Step length dL=0.5 m. KLX09C was pumped.	2006-03-07
33	Sequential flow logging/ Combined in KLX09D	Interference test. Section length L_w=1 m, Step length dL=0.1 m. KLX09C was pumped.	2006-03-07 2006-03-08

Item	Activity	Explanation	Date
34A	Sequential flow logging/ Combined in KLX09E	Interference test. Section length L_w=5 m, Step length dL=0.5 m. KLX09C was pumped.	2006-03-08
34	Sequential flow logging/ Combined in KLX09E	Interference test. Section length L_w=1 m, Step length dL=0.1 m. KLX09C was pumped.	2006-03-08 2006-03-09
35A	Sequential flow logging/ Combined in KLX09F	Interference test. Section length L_w=5 m, Step length dL=0.5 m. KLX09C was pumped.	2006-03-06
35	Sequential flow logging/ Combined in KLX09F	Interference test. Section length L_w=1 m, Step length dL=0.1 m. KLX09C was pumped.	2006-03-06 2006-03-07
36A	Sequential flow logging/ Combined in KLX09B	Interference test. Section length L_w=5 m, Step length dL=0.5 m. KLX09D was pumped.	2006-03-24
36	Sequential flow logging/ Combined in KLX09B	Interference test. Section length L_w=1 m, Step length dL=0.1 m. KLX09D was pumped.	2006-03-24 2006-03-25
37A	Sequential flow logging/ Combined in KLX09C	Interference test. Section length L_w=5 m, Step length dL=0.5 m. KLX09D was pumped.	2006-03-26
37	Sequential flow logging/ Combined in KLX09C	Interference test. Section length L_w=1 m, Step length dL=0.1 m. KLX09D was pumped.	2006-03-26 2006-03-27
38A	Sequential flow logging/ Combined in KLX09E	Interference test. Section length L_w=5 m, Step length dL=0.5 m. KLX09D was pumped.	2006-03-25
38	Sequential flow logging/ Combined in KLX09E	Interference test. Section length L_w=1 m, Step length dL=0.1 m. KLX09D was pumped.	2006-03-25 2006-03-26
39A	Sequential flow logging/ Combined in KLX09F	Interference test. Section length L_w=5 m, Step length dL=0.5 m. KLX09D was pumped.	2006-03-27
39	Sequential flow logging/ Combined in KLX09F	Interference test. Section length L_w=1 m, Step length dL=0.1 m. KLX09D was pumped.	2006-03-27 2006-03-28
40A	Sequential flow logging/ Combined in KLX09B	Interference test. Section length L_w=5 m, Step length dL=0.5 m. KLX09E was pumped.	2006-03-15
40	Sequential flow logging/ Combined in KLX09B	Interference test. Section length L_w=1 m, Step length dL=0.1 m. KLX09E was pumped.	2006-03-15 2006-03-16
41A	Sequential flow logging/ Combined in KLX09C	Interference test. Section length L_w=5 m, Step length dL=0.5 m. KLX09E was pumped.	2006-03-18
41	Sequential flow logging/ Combined in KLX09C	Interference test. Section length L_w=1 m, Step length dL=0.1 m. KLX09E was pumped.	2006-03-18 2006-03-19
42A	Sequential flow logging/ Combined in KLX09D	Interference test. Section length L_w=5 m, Step length dL=0.5 m. KLX09E was pumped.	2006-03-16
42	Sequential flow logging/ Combined in KLX09D	Interference test. Section length L_w=1 m, Step length dL=0.1 m. KLX09E was pumped.	2006-03-16 2006-03-17
43A	Sequential flow logging/ Combined in KLX09F	Interference test. Section length L_w=5 m, Step length dL=0.5 m. KLX09E was pumped.	2006-03-17
43	Sequential flow logging/ Combined in KLX09F	Interference test. Section length L_w=1 m, Step length dL=0.1 m. KLX09E was pumped.	2006-03-17 2006-03-18
44A	Sequential flow logging/ Combined in KLX09B	Interference test. Section length L_w=5 m, Step length dL=0.5 m. KLX09F was pumped.	2006-04-02
44	Sequential flow logging/ Combined in KLX09B	Interference test. Section length L_w=1 m, Step length dL=0.1 m. KLX09F was pumped.	2006-04-02
45A	Sequential flow logging/ Combined in KLX09C	Interference test. Section length L_w=5 m, Step length dL=0.5 m. KLX09F was pumped.	2006-04-03
45	Sequential flow logging/ Combined in KLX09C	Interference test. Section length L_w=1 m, Step length dL=0.1 m. KLX09F was pumped.	2006-04-03 2006-04-04
46A	Sequential flow logging/ Combined in KLX09D	Interference test. Section length L_w=5 m, Step length dL=0.5 m. KLX09F was pumped.	2006-04-04
46	Sequential flow logging/ Combined in KLX09D	Interference test. Section length L_w=1 m, Step length dL=0.1 m. KLX09F was pumped.	2006-04-04 2006-04-05
47A	Sequential flow logging/ Combined in KLX09E	Interference test. Section length L_w=5 m, Step length dL=0.5 m. KLX09F was pumped.	2006-04-05

Item	Activity	Explanation	Date
47	Sequential flow logging/ Combined in KLX09E	Interference test. Section length L_w=1 m, Step length dL=0.1 m. KLX09F was pumped.	2006-04-05 2006-04-06
48	Recovery transient, KLX09B	Measurement of water level in the borehole after stopping of pumping.	2006-02-28 2006-03-03
49	Recovery transient, KLX09C	Measurement of water level in the borehole after stopping of pumping.	2006-03-09 2006-03-13
50	Recovery transient, KLX09D	Measurement of water level in the borehole after stopping of pumping.	2006-03-28 2006-03-31
51	Recovery transient, KLX09E	Measurement of water level in the borehole after stopping of pumping.	2006-03-19 2006-03-22
52	Recovery transient, KLX09F	Measurement of water level in the borehole after stopping of pumping.	2006-04-06 2006-04-08
55 Extra1	Overlapping flow logging, KLX09D	Section length L_w=1 m, Step length dL=0.1 m at smaller injection	2006-04-08
55 Extra2	Overlapping flow logging, KLX09D	Section length L_w=1 m, Step length dL=0.1 m at smaller injection	2006-04-08
55	Overlapping flow logging, KLX09D	Section length L_w=1 m, Step length dL=0.1 m at injection	2006-04-08
53	Overlapping flow logging, KLX09B	Section length L_w=1 m, Step length dL=0.1 m at injection	2006-04-09
56	Overlapping flow logging, KLX09E	Section length L_w=1 m, Step length dL=0.1 m at injection	2006-04-09
56 Extra1	Overlapping flow logging, KLX09E	Section length L_w=1 m, Step length dL=0.1 m at smaller injection	2006-04-10
56 Extra2	Overlapping flow logging, KLX09E	Section length L_w=1 m, Step length dL=0.1 m at smaller injection	2006-04-10
54 Extra1	Overlapping flow logging, KLX09C	Section length L_w=1 m, Step length dL=0.1 m at smaller injection	2006-04-10
54 Extra2	Overlapping flow logging, KLX09C	Section length L_w=1 m, Step length dL=0.1 m at smaller injection	2006-04-10
54	Overlapping flow logging, KLX09C	Section length L_w=1 m, Step length dL=0.1 m at injection	2006-04-10
57	Overlapping flow logging, KLX09F	Section length L_w=1 m, Step length dL=0.1 m at injection	2006-04-10
57 Extra1	Overlapping flow logging, KLX09F	Section length L_w=1 m, Step length dL=0.1 m at smaller injection	2006-04-11
57 Extra2	Overlapping flow logging, KLX09F	Section length L_w=1 m, Step length dL=0.1 m at smaller injection	2006-04-11

5.2 Nonconformities

The Activity Plan AP PS 400-05-106 was added with measurements with 5 m section length and 0.5 m step length during interference tests (Supplement to Activity Plan). These measurements are marked with “A” in Item column in Table 5-1.

Daylight saving time begun March 26 at 03:00 (at which time the clocks were moved one hour ahead to 04:00). The times in this report are given in standard Swedish time (GMT +1) before the change and in daylight saving time (GMT +2) after the change. The same also applies for the raw data since the measurement computer automatically changed the time to daylight saving time, i.e., there is a one hour “jump” ahead in the time columns in the data. The interference measurement of Item 38 was the only measurement affected by this.

Another nonconformity was the relatively high noise levels that were encountered under pumped conditions, except in the vertical borehole KLX09B. They were 10–100 times higher than what is usually measured for this method. See Section 6.4 for details.

Also, due to the length of the measuring probe it is not physically possible to measure all the way down to the bottom of the hole. The distance between measurement point and lower end of probe in borehole is presented in Table 5-2. Flow anomalies at the bottom will then not be detected.

Table 5-2. Unmeasured parts at bottom of boreholes.

KLX09B	KLX09C	KLX09D	KLX09E	KLX09F
2.25 m	2.25 m	2.25 m	3.65 m	3.65 m

6 Results

6.1 Length calibration

Accurate length scale of measurements is difficult to achieve in long boreholes. The main cause of inaccuracy is stretching of the logging cable. The stretching depends on the tension of the cable that in turn depends, among other things, on the inclination of the borehole and on friction of the borehole wall. The cable tension is higher when the borehole is measured upwards. The cables, especially new cables, may also stretch out permanently.

Length marks on the borehole wall can be used to minimise the length errors. Lengths of boreholes KLX09B–F are relatively short, between c. 100–150 m. Cable stretching is not significant at those lengths and no length marks were drilled on the borehole wall. Thereby no length calibration was applied in measurements in boreholes KLX09B–F.

Length errors in KLX09B–F are caused by following reasons:

1. Point interval in flow measurements is 0.1 m in overlapping mode. This could cause an error ± 0.05 m.
2. The length of the test section is not exact. The specified section length denotes the distance between the nearest upper and lower rubber disks. Effectively, the section length can be larger. At the upper end of the test section there are four rubber disks. The distance between these is 5 cm. This will cause rounded flow anomalies, there may be detected flow already when a fracture is between the upper rubber disks. These phenomena can only be seen with short step length (0.1 m). This could cause an error of ± 0.05 m.
3. Stretching of the logging cable. This could cause an error ± 0.2 m at the length of 150 m. The error is linear and goes to zero at the ground level.

In the worst case, the errors of points 1, 2 and 3 are summed up. Then the total estimated error for fracture locations at the length of c. 150 m would be ± 0.3 m.

Accurate location is important when different measurements are compared, for instance if the flow logging and borehole TV are compared. In that case the situation may not be as severe as the worst case above since part of the length errors are systematic and the length error is nearly constant in fractures near each other. However, the error of point 1 is of random type. Relative error in cable stretching between different flow measurements were max ± 0.1 m.

Fractures nearly parallel with the borehole may also be problematic. Fracture location may be difficult to accurately define in such cases.

The errors given above are estimations and are based on experiences and observations of earlier measurements.

6.2 Electric conductivity and temperature of borehole water

The electric conductivity of borehole water (EC) was measured simultaneously with all flow logging measurements. Normally EC is measured as a separate activity. Difference between the separate and the simultaneous EC measurement is, that in simultaneous measurement water changes slower in the test section. The measured EC value does not therefore represent the situation in borehole so accurately than it does in separate measurement that is performed without the lower rubber discs.

Temperature of borehole water was measured simultaneously with the EC measurements. The EC values are temperature corrected to 25°C to make them more comparable with other EC measurements /Heikkonen et al. 2002/. The temperature results in Appendix 11 correspond to the EC results in Appendix 10.

6.3 Pressure measurements

Absolute pressure was registered with the flow measurements in Items 8–27 and 55–57. The pressure sensor measures the sum of hydrostatic pressure in the borehole and air pressure. Air pressure was also registered, Appendices 13–14. Hydraulic head along the borehole is determined in the following way. Firstly, the monitored air pressure at the site is subtracted from the measured absolute pressure by the pressure sensor. The hydraulic head (h) at a certain elevation z is then calculated according to the following expression /Freeze and Cherry 1979/:

$$h_{fw} = (p_{abs} - p_b)/(\rho_{fw}\, g) + z \qquad (6\text{-}1)$$

where

h_{fw} is the hydraulic head (m.a.s.l.) according to the RHB 70 reference system,

p_{abs} is absolute pressure (Pa),

p_b is barometric (air) pressure (Pa),

ρ_{fw} is unit density 1,000 kg/m^3,

g is standard gravity 9.80665 m/s^2 and

z is the elevation of measurement (m.a.s.l.) according to the RHB 70 reference system.

A tool-specific offset of 2.46 kPa is subtracted from absolute pressure raw data.

Exact z-coordinates are important in head calculation, 10 cm error in z-coordinate means 10 cm error in head. Z-coordinates for boreholes KLX09B–F are calculated from the inclinations of borehole starting points. The calculated head results are presented in graphs in Appendix 12 h_{fw} is the head utilized in the calculations described in Equations 3-1 to 3-10.

6.4 Flow logging

Flow measurements were carried out in boreholes using five meters section length. A combined logging mode was used; thermal pulse (with 5 m length increments) and thermal dilution (with 0.5 m length increments) measurements were carried out during the same run.

Boreholes KLX09B–KLX09F were pumped in turn during the test and all other boreholes were measured during these pumping periods. The normal single hole measurements (flow measurements without pumping any borehole and with pumping the hole under test) were also carried out in each borehole. Therefore each borehole was measured several times. Single hole results are presented in more detail in separate report (P-06-199).

The combined plots of results are presented in Appendices 1–5. The calculated reference flow as defined in Section 3.2 (Equation 3-10) is also presented for comparison. Flow direction is shown with triangles. Fracture-specific flow rates during hydraulic crosshole interference test including calculated reference flows are also presented in Tables 8.1–8.5.

The results of the measurements with a 5 m section length are presented in tables, see Appendix 7. Only the results with a 5 m length increment are used. Secup presented in Appendix 7 is calculated as the distance along the borehole from the reference level (top of the casing tube) to the upper end of the test section. Seclow is calculated respectively to the lower end of the test section. The same flow rates as in Appendix 7 are also plotted in Appendix 6.

The test section length determines the width of a flow anomaly of a single fracture in the plots. If the distance between flow yielding fractures is less than the section length, the anomalies will be overlapped, resulting in a stepwise flow anomaly. To obtain quick results, only the thermal dilution method is used for flow determination.

Under natural conditions flow direction may be into the borehole or out from it. For small flow rates (< 100 ml/h) flow direction can not be seen in the normal overlapping mode (thermal dilution method). Therefore waiting time was longer for the thermal pulse method to determine flow direction at every 1 or 5 meter (sequential mode). The thermal pulse method was only used for flow direction, not for flow rate which would take even longer time. Longer flow direction measurement has to be done in un-pumped conditions and during the interference tests.

The noise levels were relatively high under pumped conditions, except in the vertical borehole KLX09B, see Table 6-1. Noise level was nearly the same with L=5 m and L=1 m during pumping. A probable reason for the high noise level is drilling debris that was known to exist on the wall of lower side of the inclined boreholes. The drilling debris can be seen in the BIPS-pictures of the boreholes. It could cause minor leaks at the rubber disks. Even minor leaks can increase noise level when the borehole is pumped and when there is high flowing fractures below the tool. In such cases there is high flow along the borehole (in upward direction) at the tool and minor leak flows at lower rubber disks enter into the test section and into the flow sensor increasing noise level.

Detected fractures are shown in Appendices 1–5 with their positions (borehole length). They are interpreted on the basis of the flow curves and represent therefore flowing fractures. A long line represents the location of a leaky fracture; short line denotes that the existence of a leaky fracture is uncertain. A short line is used if the flow rate is less than 30 mL/h or if the flow anomalies are overlapping or if they are unclear because of noise. If a fracture is not detected under pumped conditions (due to high noise level), the line is marked grey.

6.5 Groundwater level and pumping rate

Water levels were observed in all boreholes. Results are presented together with pumping rates and air pressure in Appendices 13–14. Time and name of pumped borehole is also presented in these plots. Table 6-2 is a summary of the obtained whole hole pumping rates and drawdowns. Drawdowns are calculated from average water levels during flow loggings with 1 m section length.

Table 6-1. Approximate noise level in flow in the pumped boreholes during pumping.

Borehole	Noise level in flow (mL/h)	Comments
KLX09B	< 30	Vertical borehole
KLX09C	500–1,000	
KLX09D	100	10 mL/h below 75 m
KLX09E	500	
KLX09F	1,000	

Table 6-2. Pumped flows and drawdown during the interference testing.

Pumped borehole		Observation hole				
Borehole	Pumping rate (L/min)	Drawdown KLX09B (m)	Drawdown KLX09C (m)	Drawdown KLX09D (m)	Drawdown KLX09E (m)	Drawdown KLX09F (m)
KLX09B	10	10.00	0.72	0.95	0.73	0.76
KLX09C	32	1.94	5.17	2.23	1.92	1.92
KLX09D	14	1.54	1.35	9.96	1.39	1.21
KLX09E	31	2.34	2.22	2.49	5.82	2.40
KLX09F	33	2.14	1.76	1.88	1.86	3.26

6.6 Evaluation of flow balances

In every borehole KLX09B–F the lowest parts could not be measured because of the physical restrictions of the measuring equipment, see Table 5-2. It is possible that these parts contain flowing fractures. Other reasons for unbalance outside of this explanation are mentioned in Comments-columns in Tables 6-3 to 6-6.

Flow balance in the pumped boreholes is presented in Table 6-3. Amount of water pumped out of the borehole is compared to the sum of measured fracture-specific flow rates during pumping. A probable reason for difference in most cases is exceeding of measurement limit at some fractures during flow logging. There were also identified fractures (found during injection) located above the flow logged borehole lengths in every borehole.

Borehole transmissivities gained from whole hole pumping tests are compared to the sum of fracture-specific transmissivities in Table 6-4. The fractures that exceeded the measurement limit were re-measured with a small injection and a correct T-value could be calculated. The transmissivity results in Table 6-4 are then more reliable than the flow results in Table 6-3. In all cases the detected fractures explain the transmissivity of the entire borehole (column A in Table 6-4) within factor of two or better. This would indicate that no major fracture remained undetected.

Table 6-3. Flow balance in pumped boreholes.

Borehole	A Pumping rate (L/min)	B Sum of measured flow rates in the borehole (L/min)	C Difference of pumping rate and sum of flows (L/min)	D Relative deviation (C/A·100%)	Comments
KLX09B	10	11	1	10	Flowing fractures above the measured borehole length
KLX09C	32	22	–10	–31	Flowing fractures above the measured borehole length, flows over meas. limit
KLX09D	14	16	2	14	Flowing fractures above the measured borehole length, flows over meas. limit
KLX09E	31	16	–15	–48	Flowing fractures above the measured borehole length, flows over meas. limit
KLX09F	33	20	–13	–39	Flowing fractures above the measured borehole length, flows over meas. limit

Table 6-4. Transmissivity comparison.

Borehole	A Entire borehole T (m^2/s)	B Sum of fracture TD (m^2/s)	C Relative deviation (B/A·100%)	Comments
KLX09B	1.6E–05	1.8E–05	113	Flowing fractures above the measured borehole length
KLX09C	1.0E–04	1.3E–04	132	Flowing fractures above the measured borehole length
KLX09D	2.3E–05	3.9E–05	170	Flowing fractures above the measured borehole length
KLX09E	8.7E–05	8.0E–05	92	Flowing fractures above the measured borehole length
KLX09F	1.6E–04	1.4E–04	86	Flowing fractures above the measured borehole length

Flow balances in the boreholes without pumping are valuated in Table 6-5. Relative deviation (column C) gives a ratio of flow balance (column B) and flow volume (column A). The nearer the ratio is to zero, the better the measured flows are in balance.

Small water level changes can have a big impact on flows. Variation of water level during the measurement with 1 m section length is presented in column D and it's theoretical maximum effect on total flow in column F. A complete balance is very difficult to achieve since in practice the water level can not be kept so stable that it would not have an impact on flow balance.

Flow balances in the boreholes during interference test are valuated in Table 6-6. The columns are the same as in Table 6-5. Correlation between flow balance and transmissivity can be seen. When borehole transmissivity is high, measured flows are not so well in balance (boreholes F, C and E). This suggest that the variation of water level during the measurement would explain the poor balance in high transmissive boreholes.

Table 6-5. Flow balance when no borehole is pumped.

Borehole	A (Sum of measured flow magnitudes)/2 (L/min)	B Sum of measured flow rates in the borehole (L/min)	C Relative deviation (B/A·100%)	D Variation of water level during meas. (m)	E Entire borehole T (m^2/s)	F Effect of water level variation to total flow (L/min)	Comments
KLX09B	0.0144	–0.0036	–24.82	0.07	1.6E–05	0.0679	
KLX09C	0.1268	0.0258	20.31	0.06	1.0E–04	0.3640	
KLX09D	0.0595	0.0030	5.04	0.08	2.3E–05	0.1116	
KLX09E	0.0364	0.0127	34.84	0.10	8.7E–05	0.5278	
KLX09F	0.3498	–0.0193	–5.51	0.08	1.6E–04	0.7765	

Table 6-6. Flow balance during interference test.

Measured borehole	Pumped borehole	A (Sum of measured flow magnitudes)/2 (L/min)	B Sum of measured flow rates in the borehole (L/min)	C Relative deviation (B/A·100%)	D Variation of water level during meas. (m)	E Entire borehole T (m^2/s)	F Effect of water level variation to total flow (L/min)	Comments
KLX09B	KLX09C	0.1266	–0.0029	–2	0.06	1.6E–05	0.0582	*
KLX09B	KLX09D	0.2183	–0.0186	–9	0.09	1.6E–05	0.0874	
KLX09B	KLX09E	0.0982	0.0047	5	0.11	1.6E–05	0.1068	
KLX09B	KLX09F	0.1834	–0.0077	–4	0.10	1.6E–05	0.0971	
KLX09C	KLX09B	0.7344	–0.3934	–54	0.13	1.0E–04	0.7886	
KLX09C	KLX09D	1.0257	–0.6616	–65	0.11	1.0E–04	0.6673	*
KLX09C	KLX09E	0.4941	–0.1702	–34	0.12	1.0E–04	0.7279	*
KLX09C	KLX09F	1.0971	–0.5894	–54	0.11	1.0E–04	0.6673	*
KLX09D	KLX09B	0.2517	0.0055	2	0.08	2.3E–05	0.1116	
KLX09D	KLX09C	0.3101	–0.0426	–14	0.08	2.3E–05	0.1116	
KLX09D	KLX09E	0.2249	–0.0098	–4	0.08	2.3E–05	0.1116	
KLX09D	KLX09F	0.2089	–0.0277	–13	0.11	2.3E–05	0.1535	
KLX09E	KLX09B	0.1731	–0.0905	–52	0.10	8.7E–05	0.5278	
KLX09E	KLX09C	0.0472	–0.0448	–95	0.10	8.7E–05	0.5278	
KLX09E	KLX09D	0.2554	–0.1097	–43	0.13	8.7E–05	0.6861	
KLX09E	KLX09F	0.0455	0.0128	28	0.11	8.7E–05	0.5805	
KLX09F	KLX09B	0.5882	–0.3099	–53	0.12	1.6E–04	1.1647	*
KLX09F	KLX09C	0.6962	–0.4283	–62	0.06	1.6E–04	0.5824	*
KLX09F	KLX09D	0.3846	–0.3144	–82	0.12	1.6E–04	1.1647	*
KLX09F	KLX09E	0.7479	–0.0089	–1	0.10	1.6E–04	0.9706	*

* Flowing fractures located above the measured borehole length.

7 Summary

In this study, the Posiva Flow Log/Difference Flow method has been used to determine hydraulic interferences between boreholes KLX09B–F at Oskarshamn. During the interference test, one of the boreholes was pumped in turn and the flow responses were measured in the other four boreholes. Pumping was done in all five boreholes.

Clear flow responses caused by pumping were detected. Interestingly in some boreholes flow anomalies were detected in the boreholes when it was utilized as an observation hole but not when it was being pumped. This feature is particulary frequent in KLX09C, KLX09E and KLX09F.

The distribution of saline water along the borehole was logged simultaneously with the flow measurements by electric conductivity and temperature measurements of the borehole water. Absolute pressure in boreholes was also registered.

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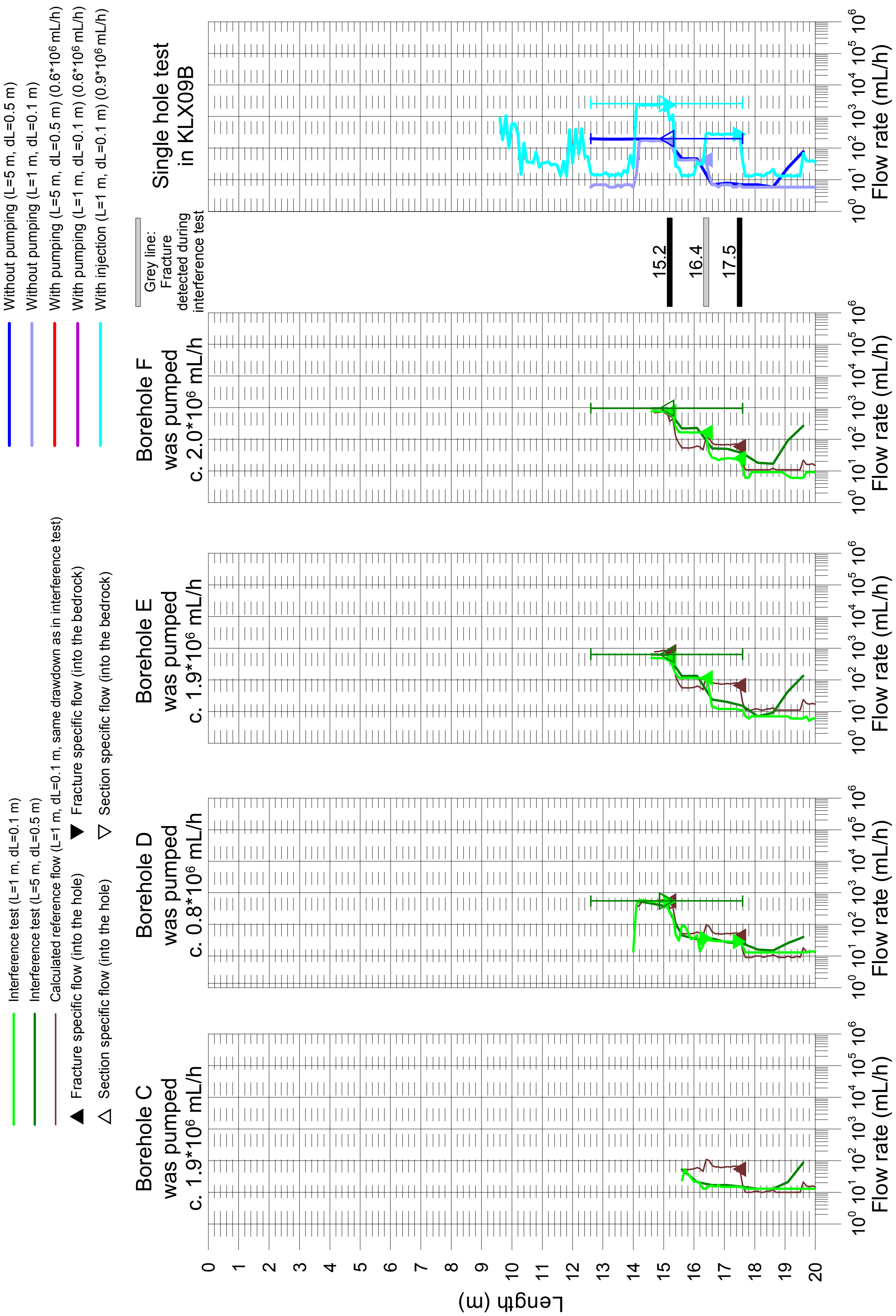
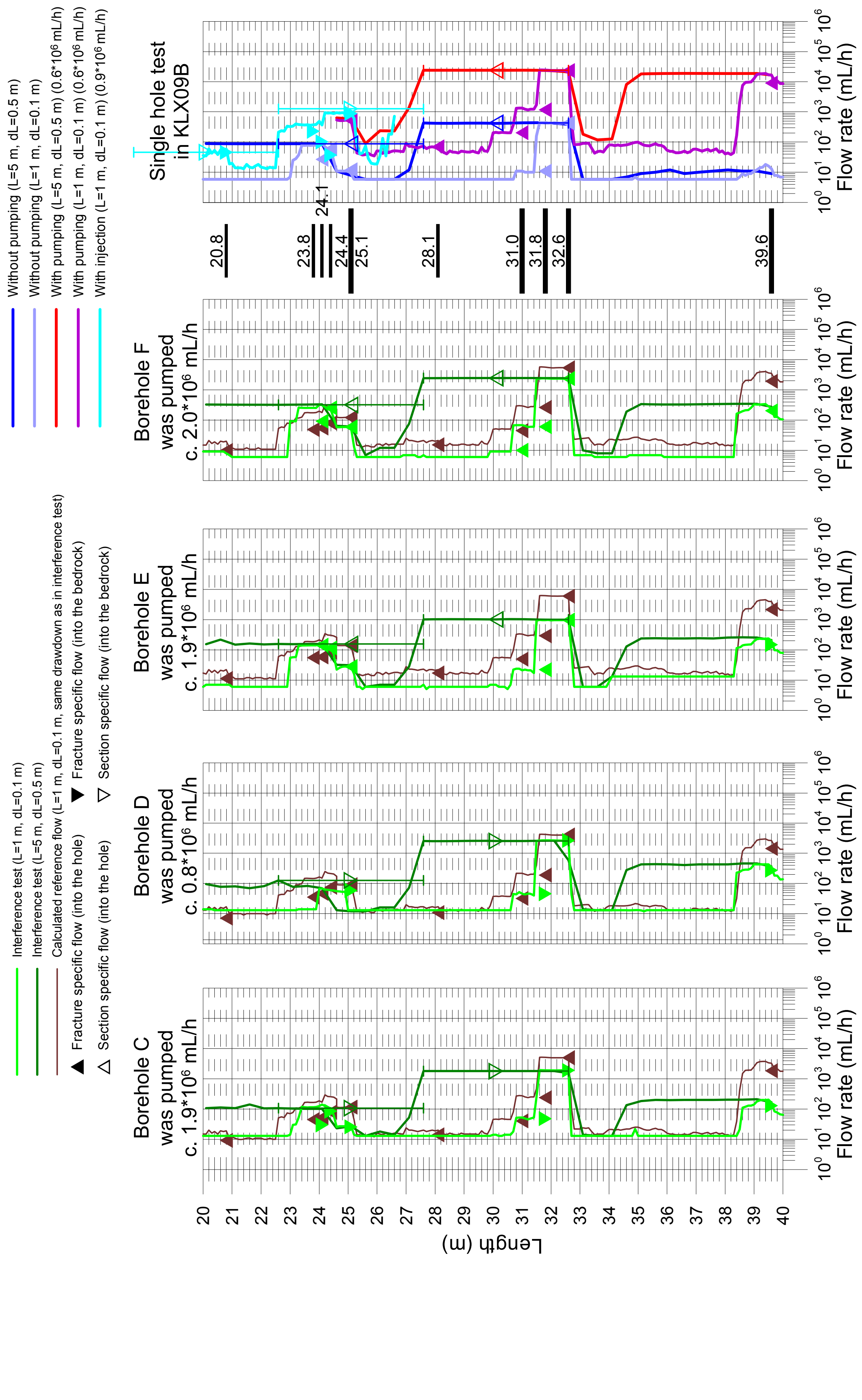
Marsily G, 1986. Quantitive Hydrology, Groundwater Hydrology for Engineers. Academic Press, Inc., London.

Freeze R A, Cherry J A, 1979. Groundwater. Prentice Hall, Inc., United States of America.

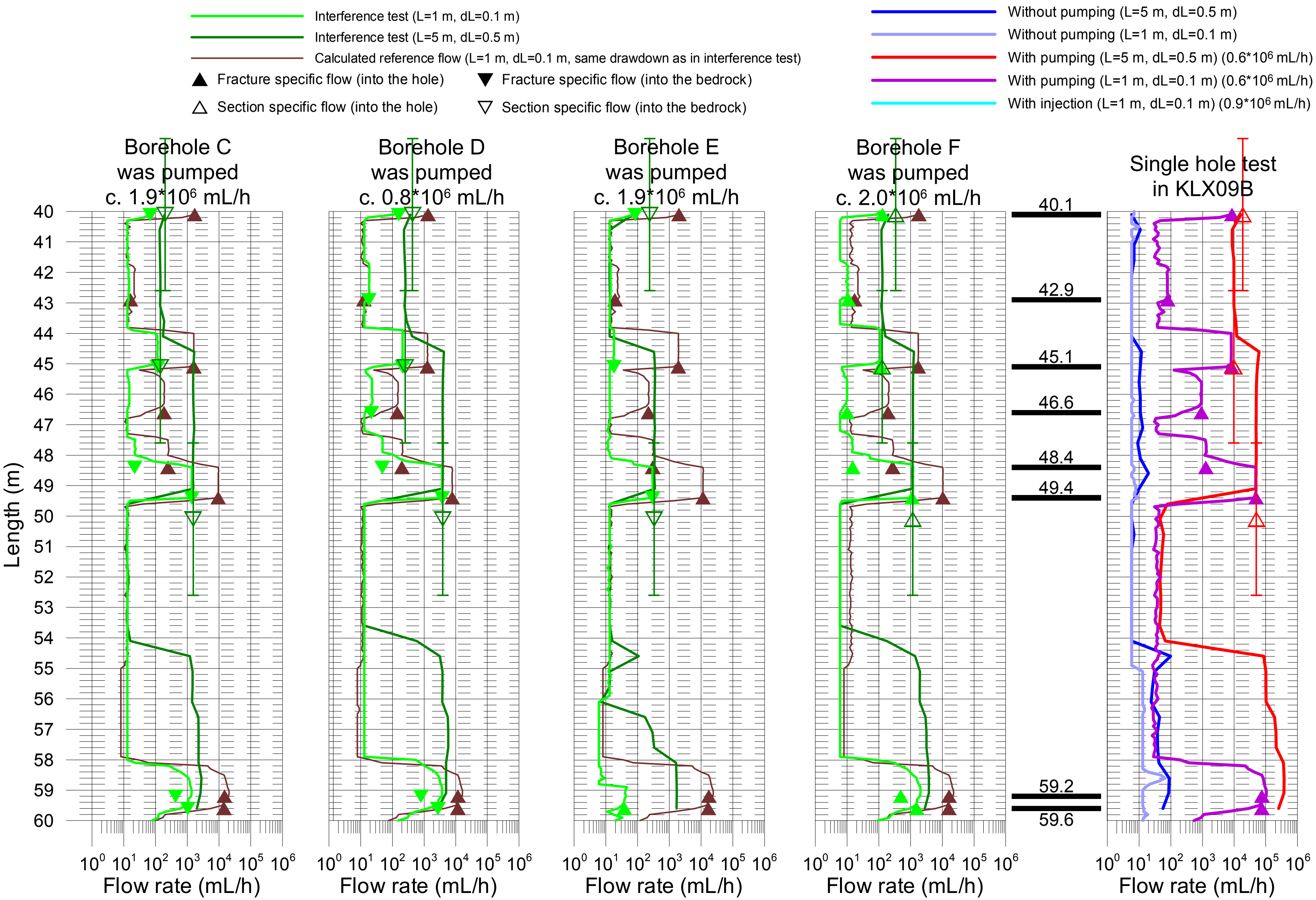
Öhberg A, Rouhiainen P, 2000. Posiva groundwater flow measuring techniques. Helsinki, Posiva Oy. Report POSIVA 2000-12.

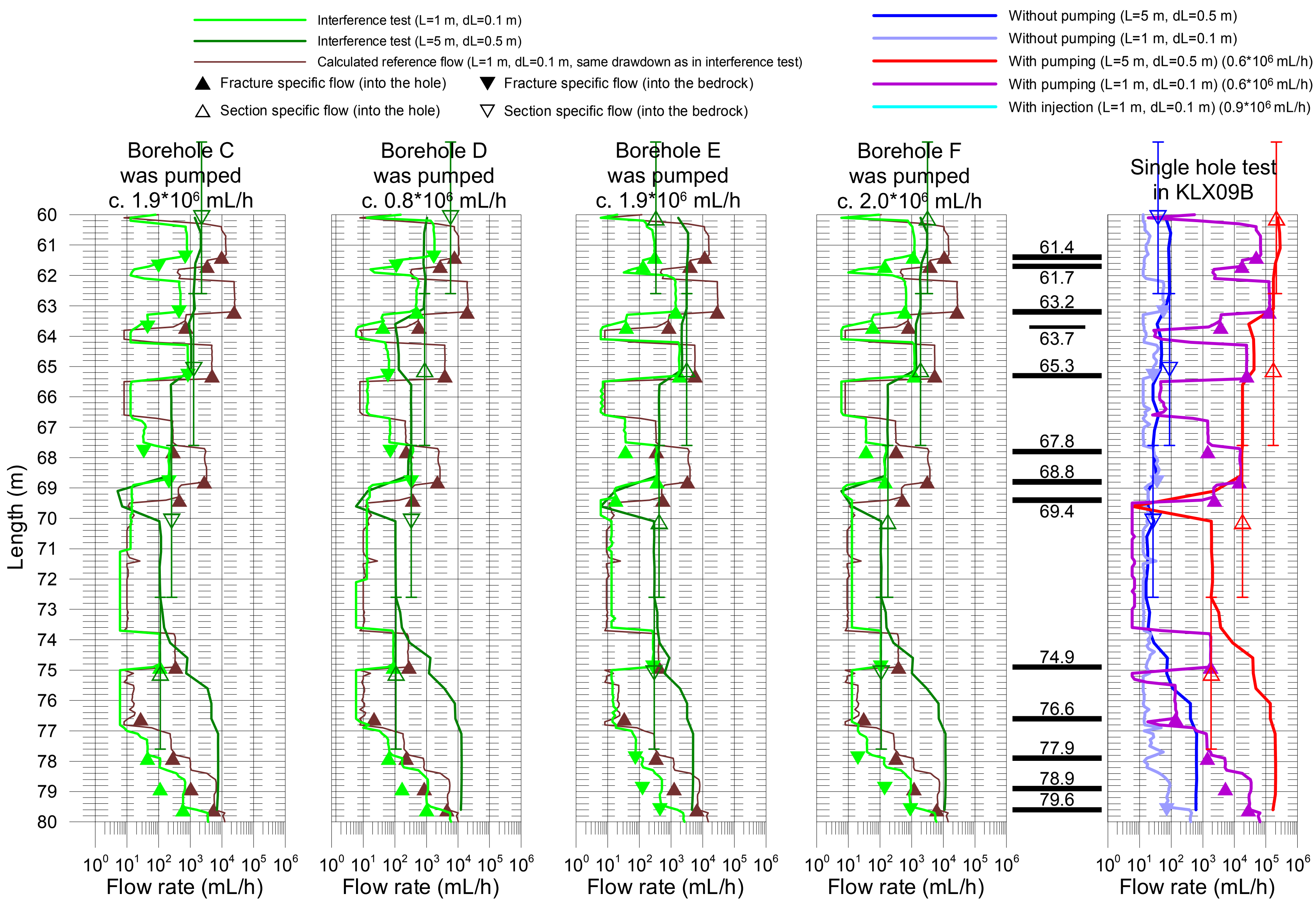
Hydraulic crosshole interference test, borehole KLX09B



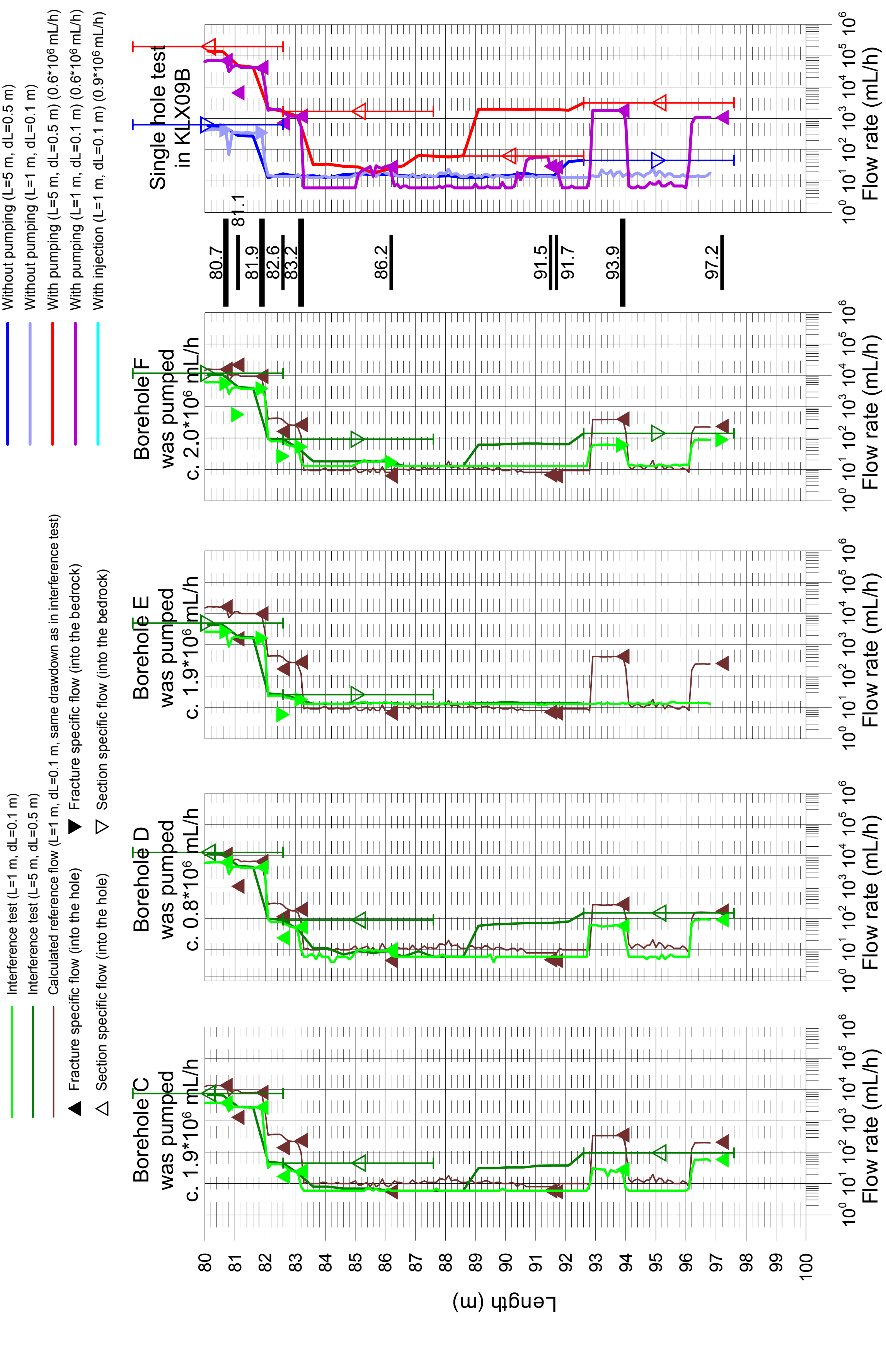


Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (0.6*10^6 mL/h)
With pumping (L=1 m, dL=0.1 m) (0.6*10^6 mL/h)
With injection (L=1 m, dL=0.1 m) (0.9*10^6 mL/h)
Borehole C was pumped c. 1.9*10^6 mL/h
Borehole D was pumped c. 0.8*10^6 mL/h
Borehole E was pumped c. 1.9*10^6 mL/h
Borehole F was pumped c. 2.0*10^6 mL/h
Single hole test in KLX09B
Length (m)
Flow rate (mL/h)
20.8
23.8
24.1
24.4
25.1
28.1
31.0
31.8
32.6
39.6


Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (0.6*10^6 mL/h)
With pumping (L=1 m, dL=0.1 m) (0.6*10^6 mL/h)
With injection (L=1 m, dL=0.1 m) (0.9*10^6 mL/h)
Borehole C was pumped c. 1.9*10^6 mL/h
Borehole D was pumped c. 0.8*10^6 mL/h
Borehole E was pumped c. 1.9*10^6 mL/h
Borehole F was pumped c. 2.0*10^6 mL/h
Single hole test in KLX09B
Length (m)
Flow rate (mL/h)
40.1
42.9
45.1
46.6
48.4
49.4
59.2
59.6

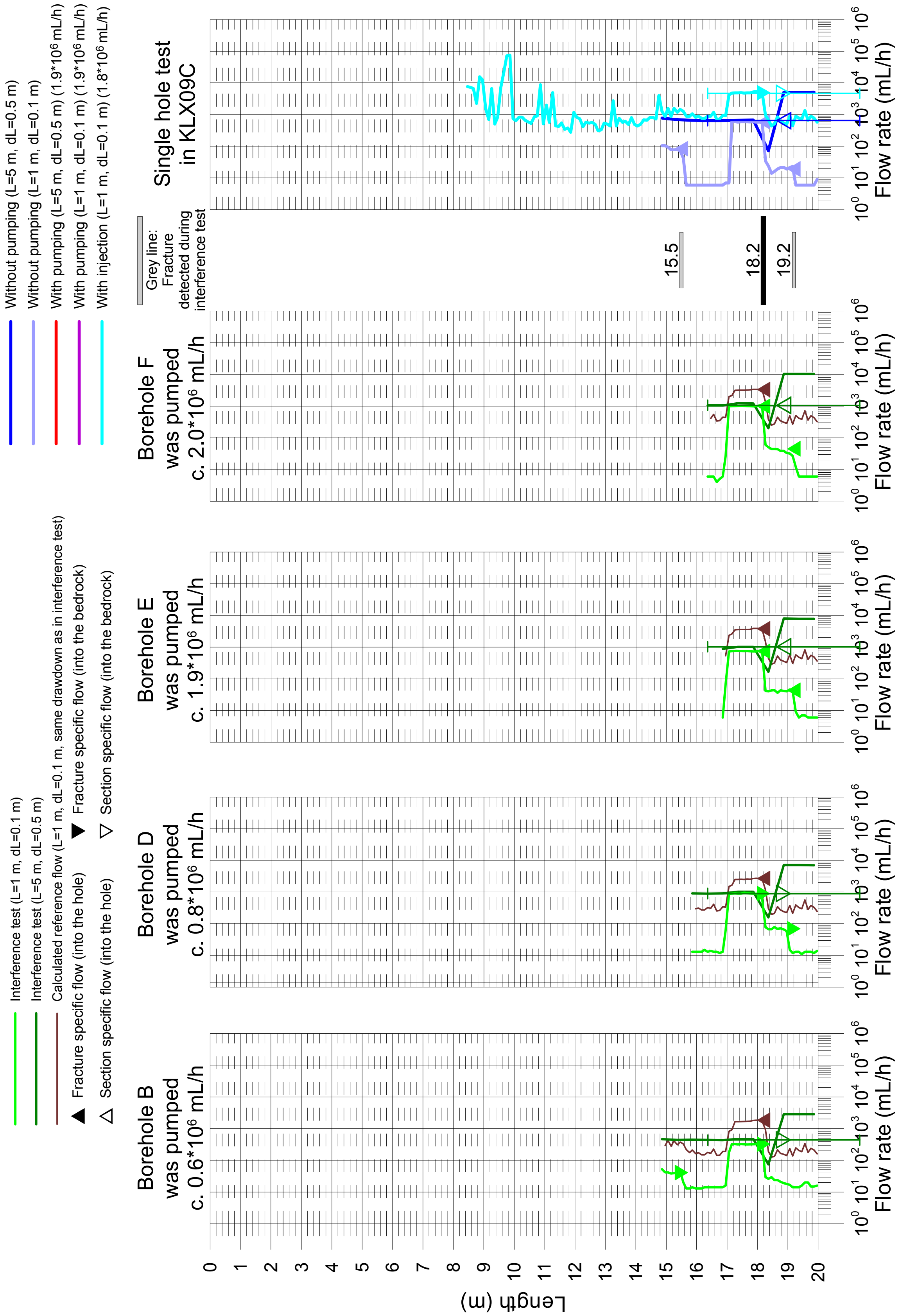


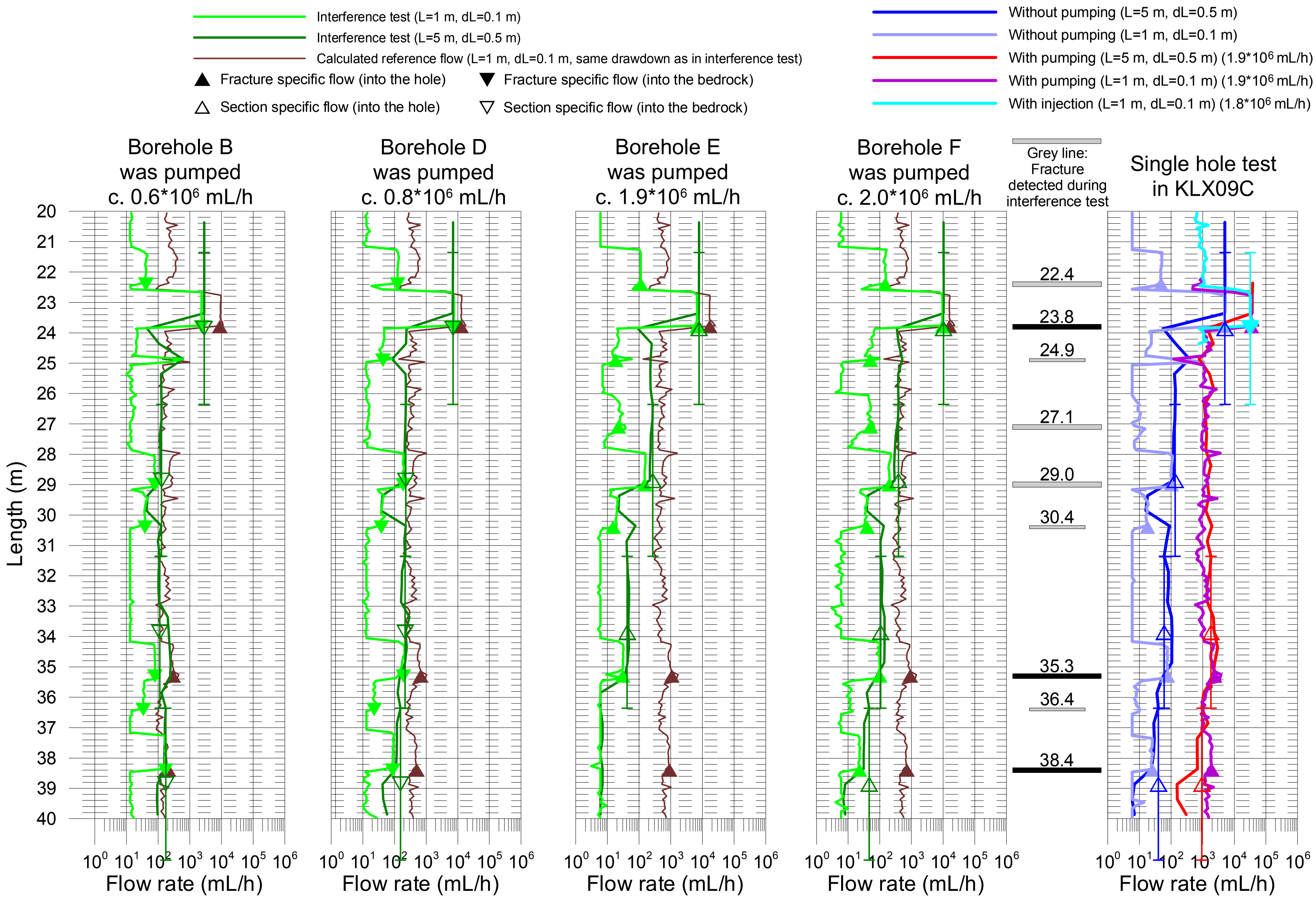
Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (0.6*10^6 mL/h)
With pumping (L=1 m, dL=0.1 m) (0.6*10^6 mL/h)
With injection (L=1 m, dL=0.1 m) (0.9*10^6 mL/h)
Borehole C was pumped c. 1.9*10^6 mL/h
Borehole D was pumped c. 0.8*10^6 mL/h
Borehole E was pumped c. 1.9*10^6 mL/h
Borehole F was pumped c. 2.0*10^6 mL/h
Single hole test in KLX09B
Length (m)
Flow rate (mL/h)
61.4
61.7
63.2
63.7
65.3
67.8
68.8
69.4
74.9
76.6
77.9
78.9
79.6

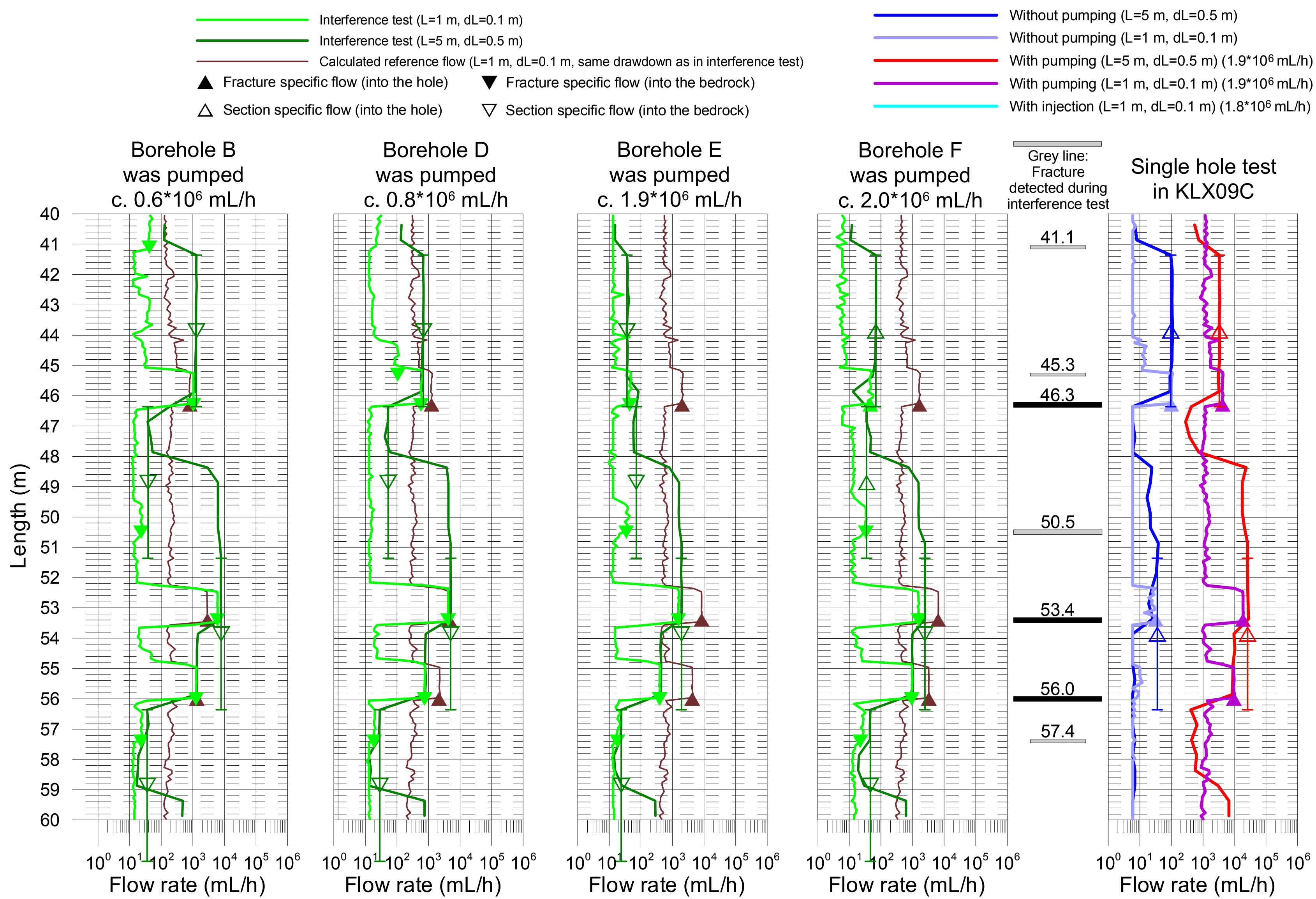


Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (0.6*10^6 mL/h)
With pumping (L=1 m, dL=0.1 m) (0.6*10^6 mL/h)
With injection (L=1 m, dL=0.1 m) (0.9*10^6 mL/h)
Borehole C was pumped c. 1.9*10^6 mL/h
Borehole D was pumped c. 0.8*10^6 mL/h
Borehole E was pumped c. 1.9*10^6 mL/h
Borehole F was pumped c. 2.0*10^6 mL/h
Single hole test in KLX09B
80.7
81.1
81.9
82.6
83.2
86.2
91.5
91.7
93.9
97.2
Length (m)
Flow rate (mL/h)

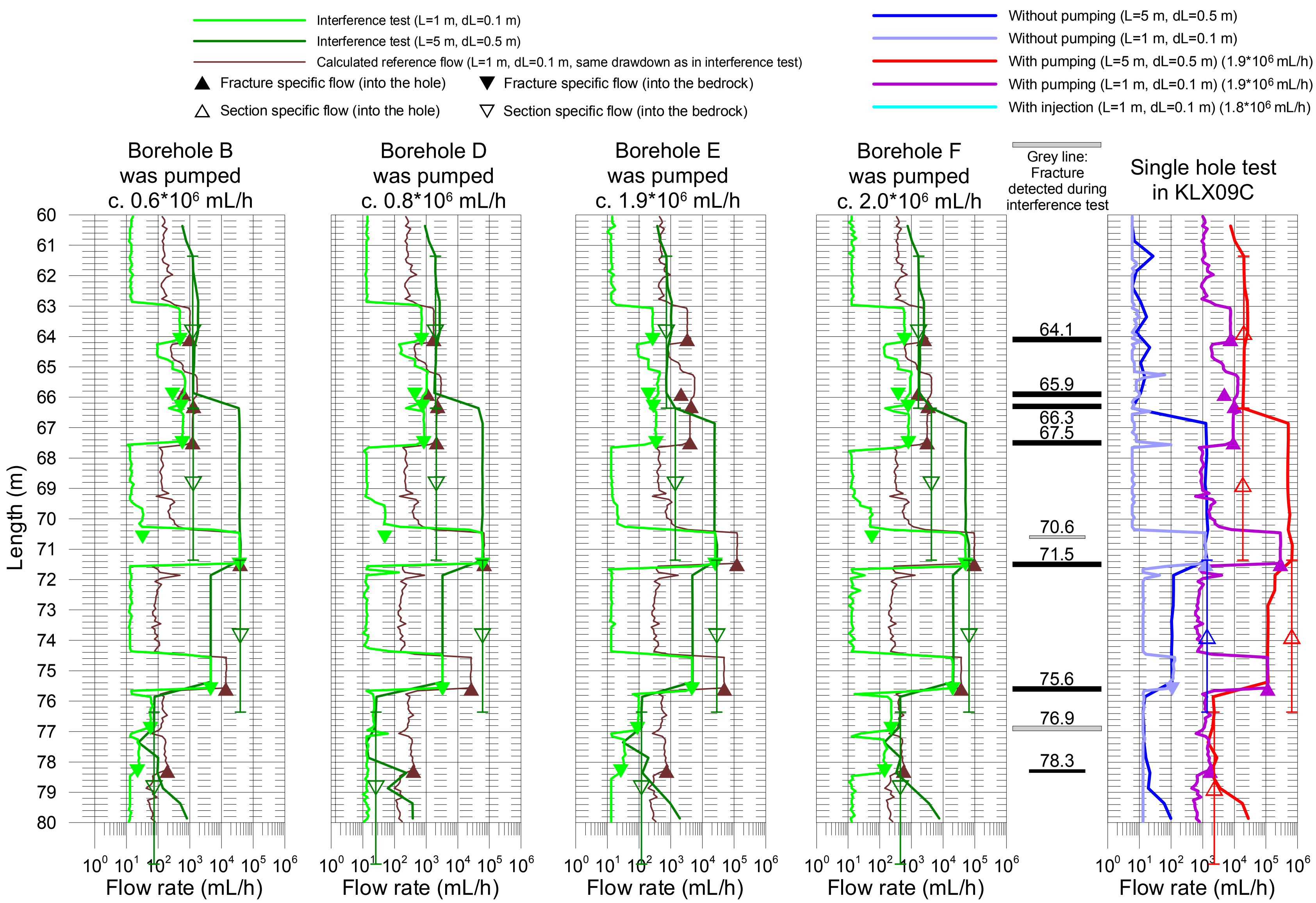
Hydraulic crosshole interference test, borehole KLX09C



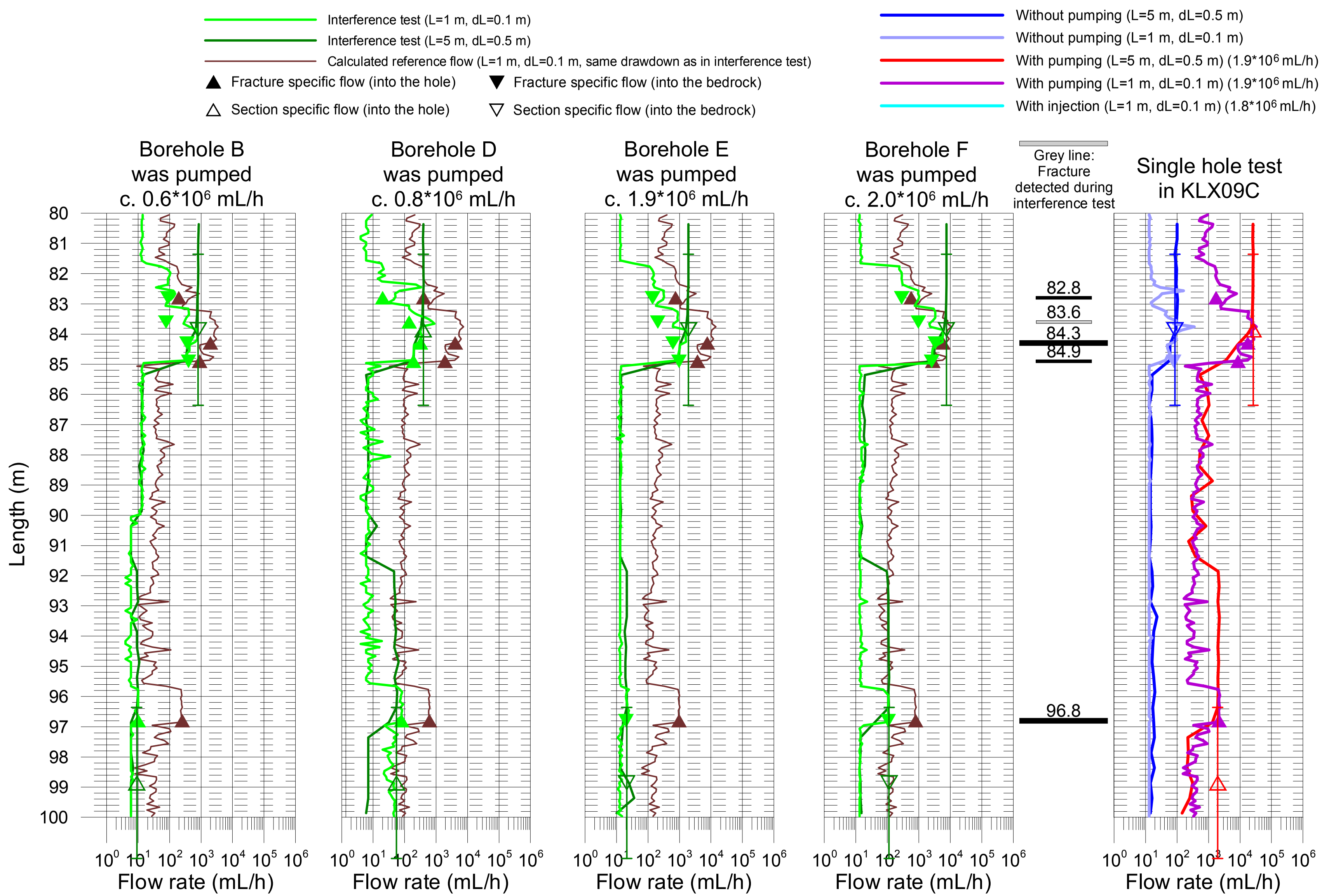

Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (1.9*10^6 mL/h)
With pumping (L=1 m, dL=0.1 m) (1.9*10^6 mL/h)
With injection (L=1 m, dL=0.1 m) (1.8*10^6 mL/h)
Borehole B was pumped c. 0.6*10^6 mL/h
Borehole D was pumped c. 0.8*10^6 mL/h
Borehole E was pumped c. 1.9*10^6 mL/h
Borehole F was pumped c. 2.0*10^6 mL/h
Grey line: Fracture detected during interference test
Single hole test in KLX09C
Length (m)
Flow rate (mL/h)
22.4
23.8
24.9
27.1
29.0
30.4
35.3
36.4
38.4

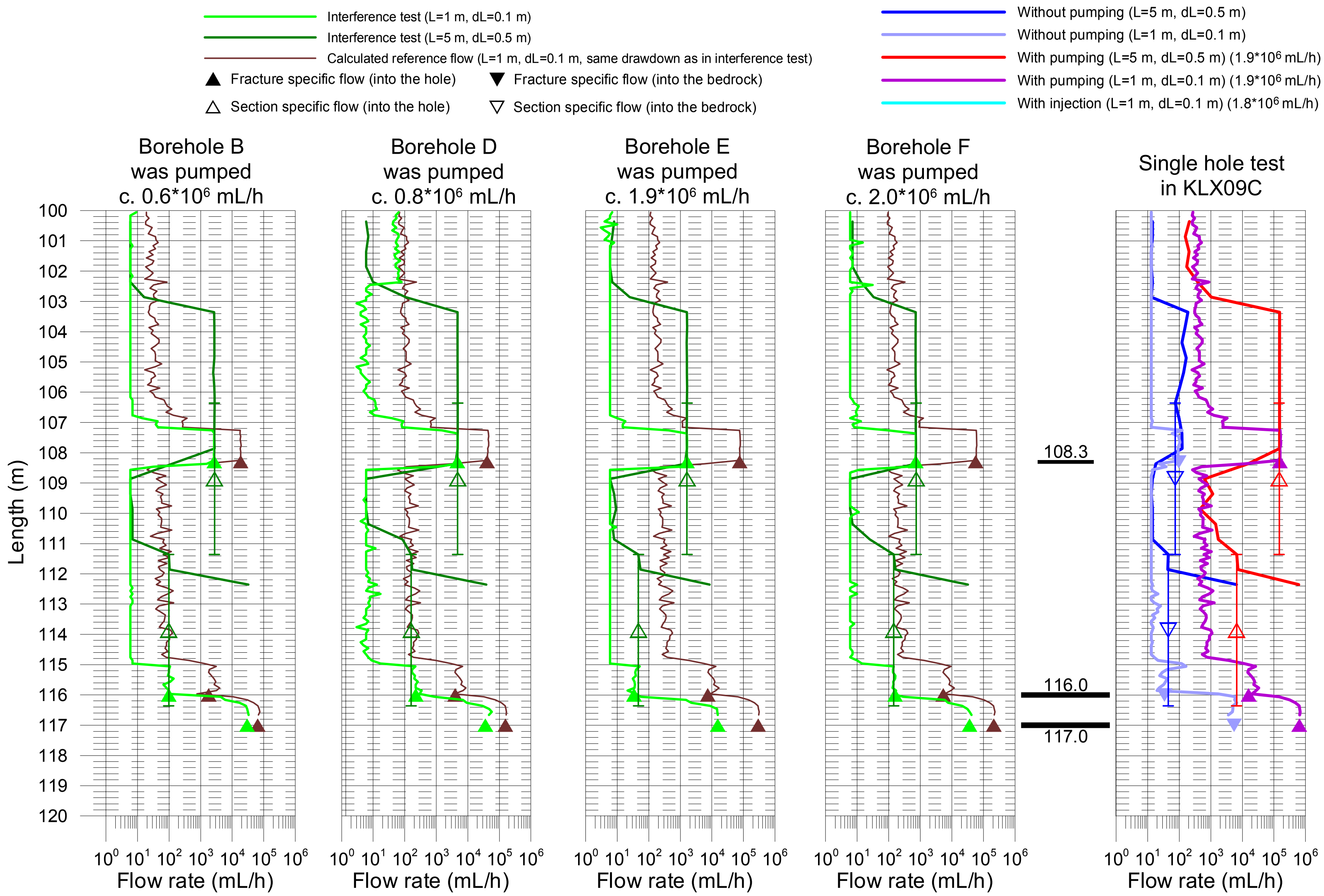


Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (1.9*10^6 mL/h)
With pumping (L=1 m, dL=0.1 m) (1.9*10^6 mL/h)
With injection (L=1 m, dL=0.1 m) (1.8*10^6 mL/h)
Borehole B was pumped c. 0.6*10^6 mL/h
Borehole D was pumped c. 0.8*10^6 mL/h
Borehole E was pumped c. 1.9*10^6 mL/h
Borehole F was pumped c. 2.0*10^6 mL/h
Grey line: Fracture detected during interference test
Single hole test in KLX09C
Length (m)
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
41.1
45.3
46.3
50.5
53.4
56.0
57.4
10^0 10^1 10^2 10^3 10^4 10^5 10^6
Flow rate (mL/h)



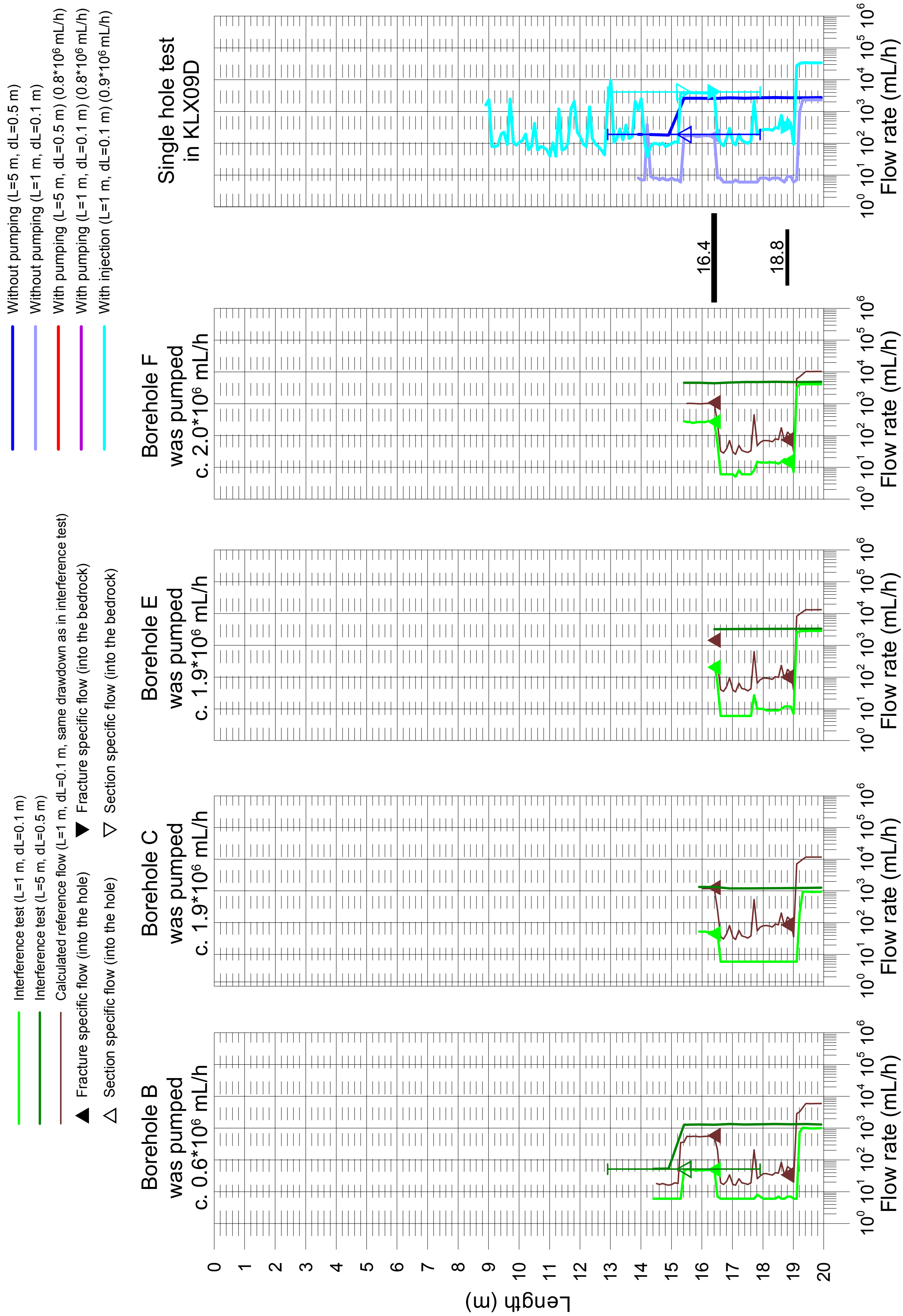
Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (1.9*10^6 mL/h)
With pumping (L=1 m, dL=0.1 m) (1.9*10^6 mL/h)
With injection (L=1 m, dL=0.1 m) (1.8*10^6 mL/h)
Borehole B was pumped c. 0.6*10^6 mL/h
Borehole D was pumped c. 0.8*10^6 mL/h
Borehole E was pumped c. 1.9*10^6 mL/h
Borehole F was pumped c. 2.0*10^6 mL/h
Grey line: Fracture detected during interference test
Single hole test in KLX09C
Length (m)
Flow rate (mL/h)
64.1
65.9
66.3
67.5
70.6
71.5
75.6
76.9
78.3

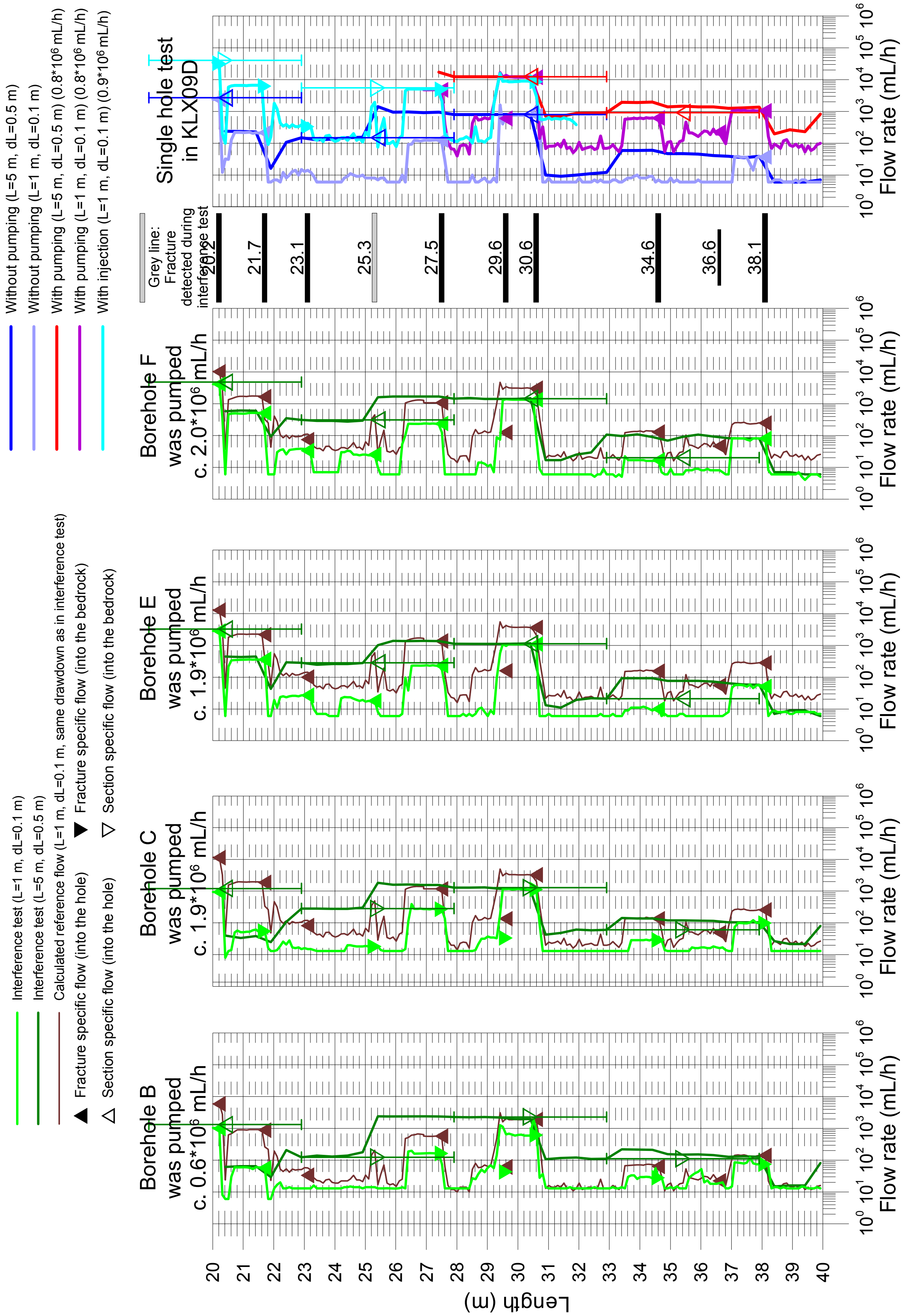

Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (1.9*10^6 mL/h)
With pumping (L=1 m, dL=0.1 m) (1.9*10^6 mL/h)
With injection (L=1 m, dL=0.1 m) (1.8*10^6 mL/h)
Borehole B was pumped c. 0.6*10^6 mL/h
Borehole D was pumped c. 0.8*10^6 mL/h
Borehole E was pumped c. 1.9*10^6 mL/h
Borehole F was pumped c. 2.0*10^6 mL/h
Grey line: Fracture detected during interference test
Single hole test in KLX09C
Length (m)
Flow rate (mL/h)
82.8
83.6
84.3
84.9
96.8

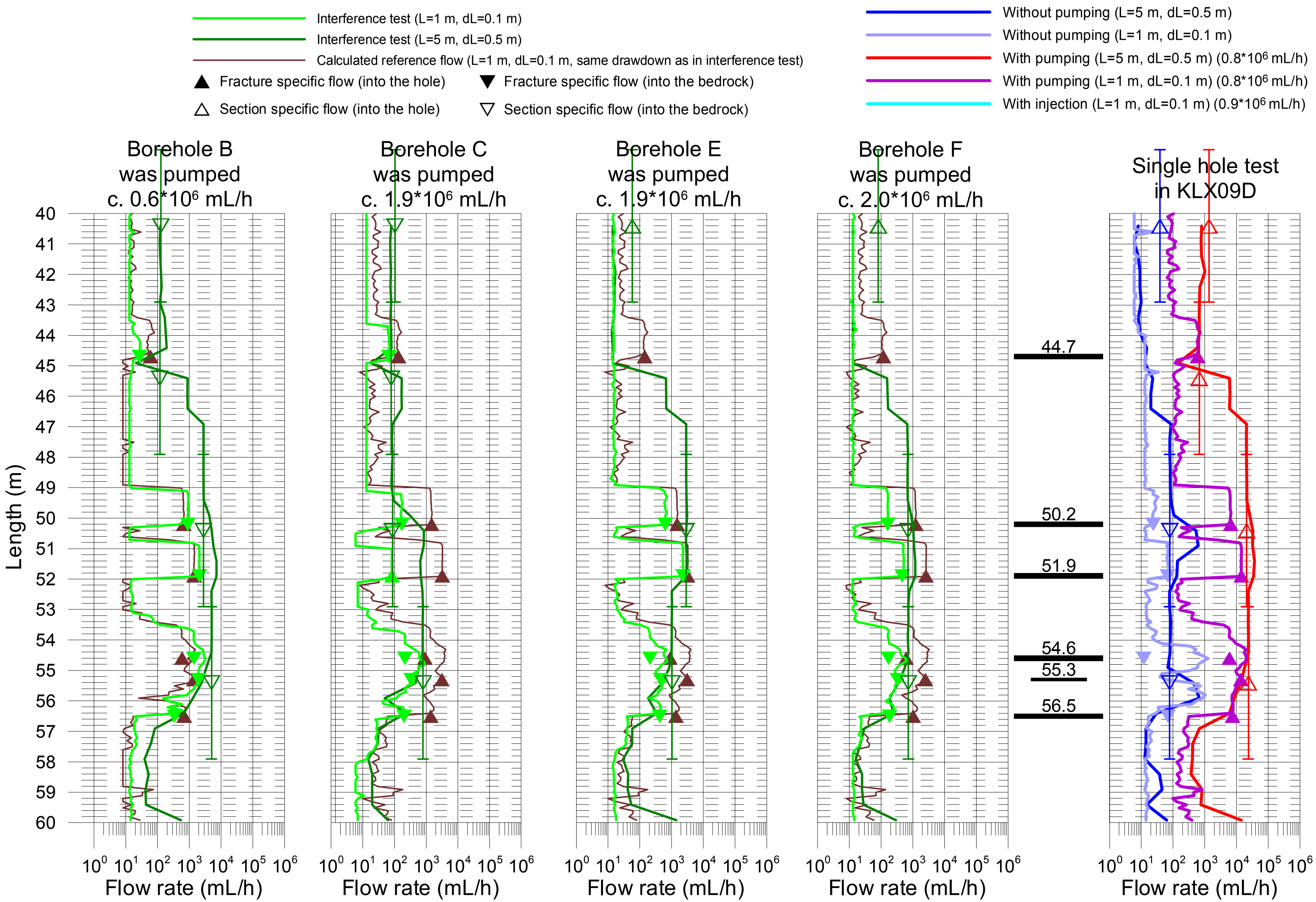


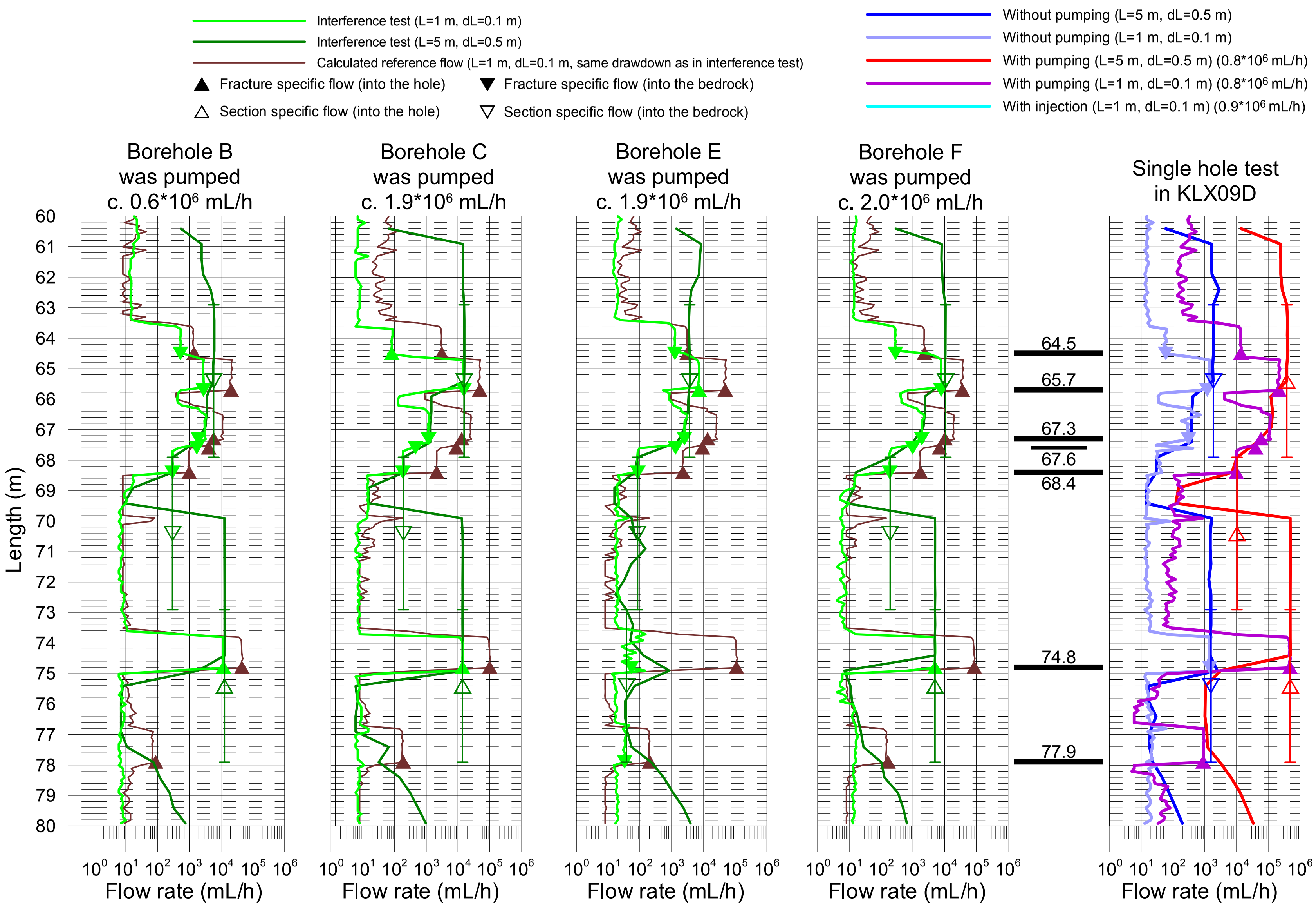
Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (1.9*10^6 mL/h)
With pumping (L=1 m, dL=0.1 m) (1.9*10^6 mL/h)
With injection (L=1 m, dL=0.1 m) (1.8*10^6 mL/h)
Borehole B was pumped c. 0.6*10^6 mL/h
Borehole D was pumped c. 0.8*10^6 mL/h
Borehole E was pumped c. 1.9*10^6 mL/h
Borehole F was pumped c. 2.0*10^6 mL/h
Single hole test in KLX09C
108.3
116.0
117.0
Length (m)
Flow rate (mL/h)

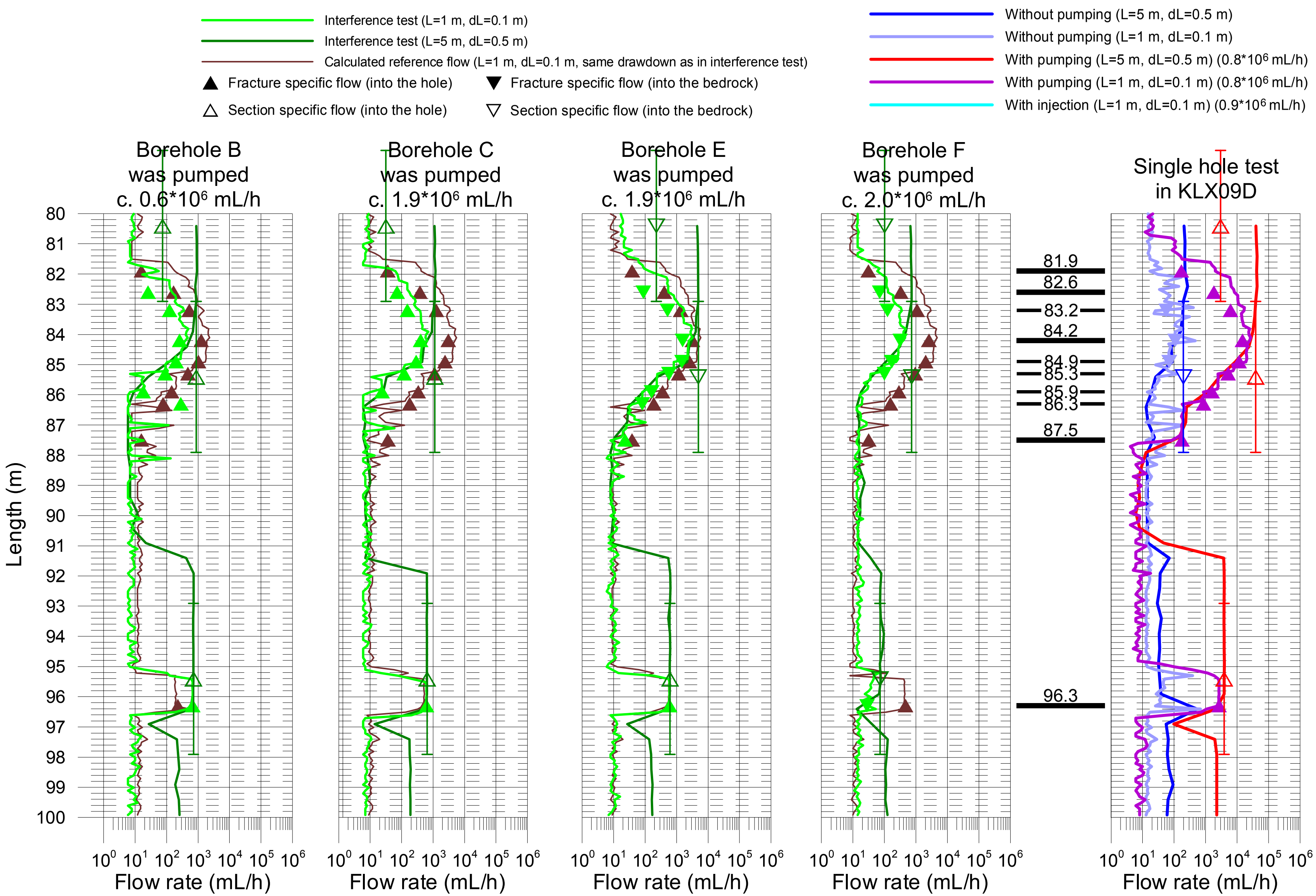
Hydraulic crosshole interference test, borehole KLX09D



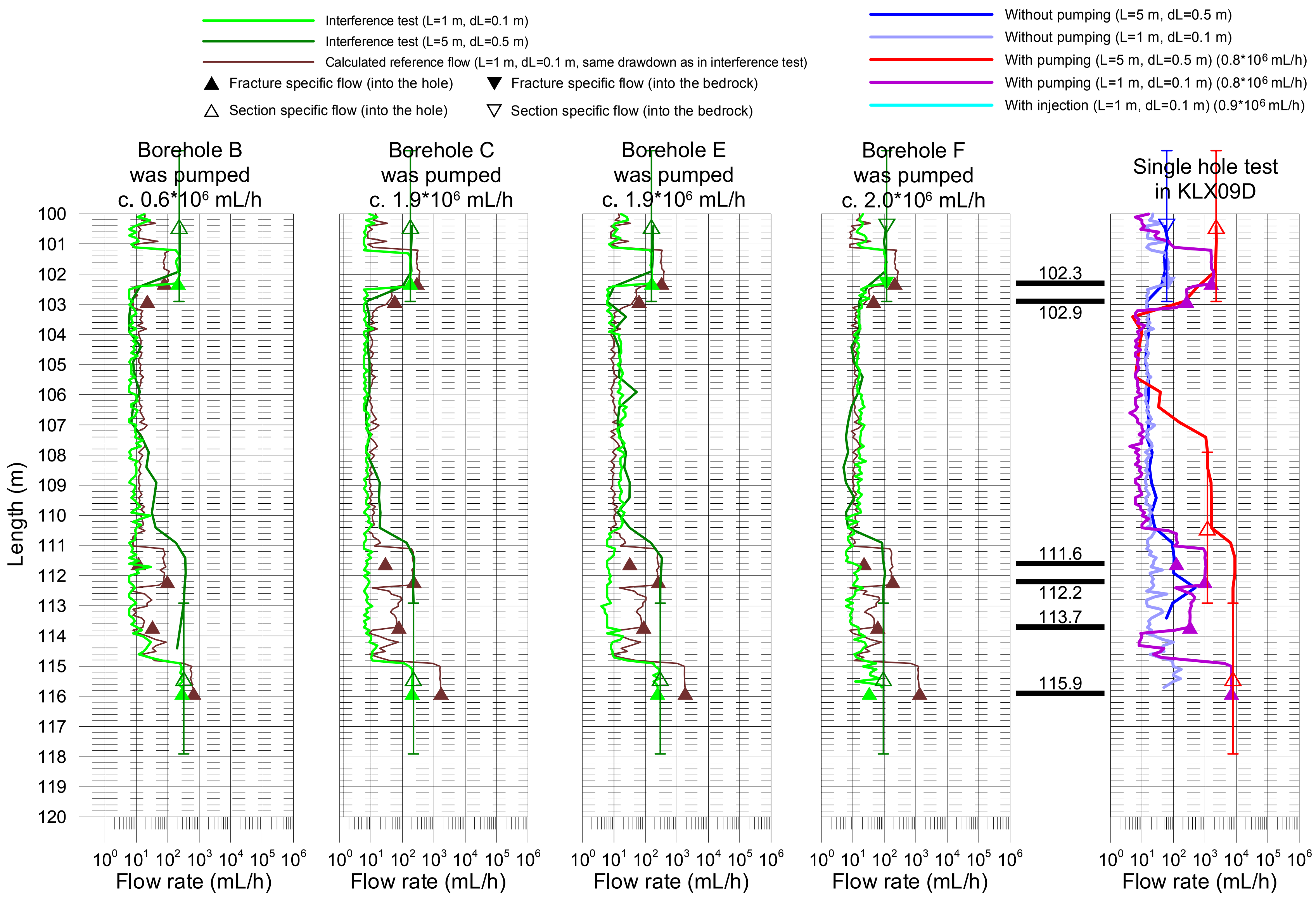

Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (0.8*10^6 mL/h)
With pumping (L=1 m, dL=0.1 m) (0.8*10^6 mL/h)
With injection (L=1 m, dL=0.1 m) (0.9*10^6 mL/h)
Borehole B was pumped c. 0.6*10^6 mL/h
Borehole C was pumped c. 1.9*10^6 mL/h
Borehole E was pumped c. 1.9*10^6 mL/h
Borehole F was pumped c. 2.0*10^6 mL/h
Grey line: Fracture detected during interference test
20.2
21.7
23.1
25.3
27.5
29.6
30.6
34.6
36.6
38.1
Single hole test in KLX09D
Length (m)
Flow rate (mL/h)


Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (0.8*10^6 mL/h)
With pumping (L=1 m, dL=0.1 m) (0.8*10^6 mL/h)
With injection (L=1 m, dL=0.1 m) (0.9*10^6 mL/h)
Borehole B was pumped c. 0.6*10^6 mL/h
Borehole C was pumped c. 1.9*10^6 mL/h
Borehole E was pumped c. 1.9*10^6 mL/h
Borehole F was pumped c. 2.0*10^6 mL/h
Single hole test in KLX09D
Length (m)
Flow rate (mL/h)
44.7
50.2
51.9
54.6
55.3
56.5


Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (0.8*10^6 mL/h)
With pumping (L=1 m, dL=0.1 m) (0.8*10^6 mL/h)
With injection (L=1 m, dL=0.1 m) (0.9*10^6 mL/h)
Borehole B was pumped c. 0.6*10^6 mL/h
Borehole C was pumped c. 1.9*10^6 mL/h
Borehole E was pumped c. 1.9*10^6 mL/h
Borehole F was pumped c. 2.0*10^6 mL/h
Single hole test in KLX09D
Length (m)
Flow rate (mL/h)
64.5
65.7
67.3
67.6
68.4
74.8
77.9

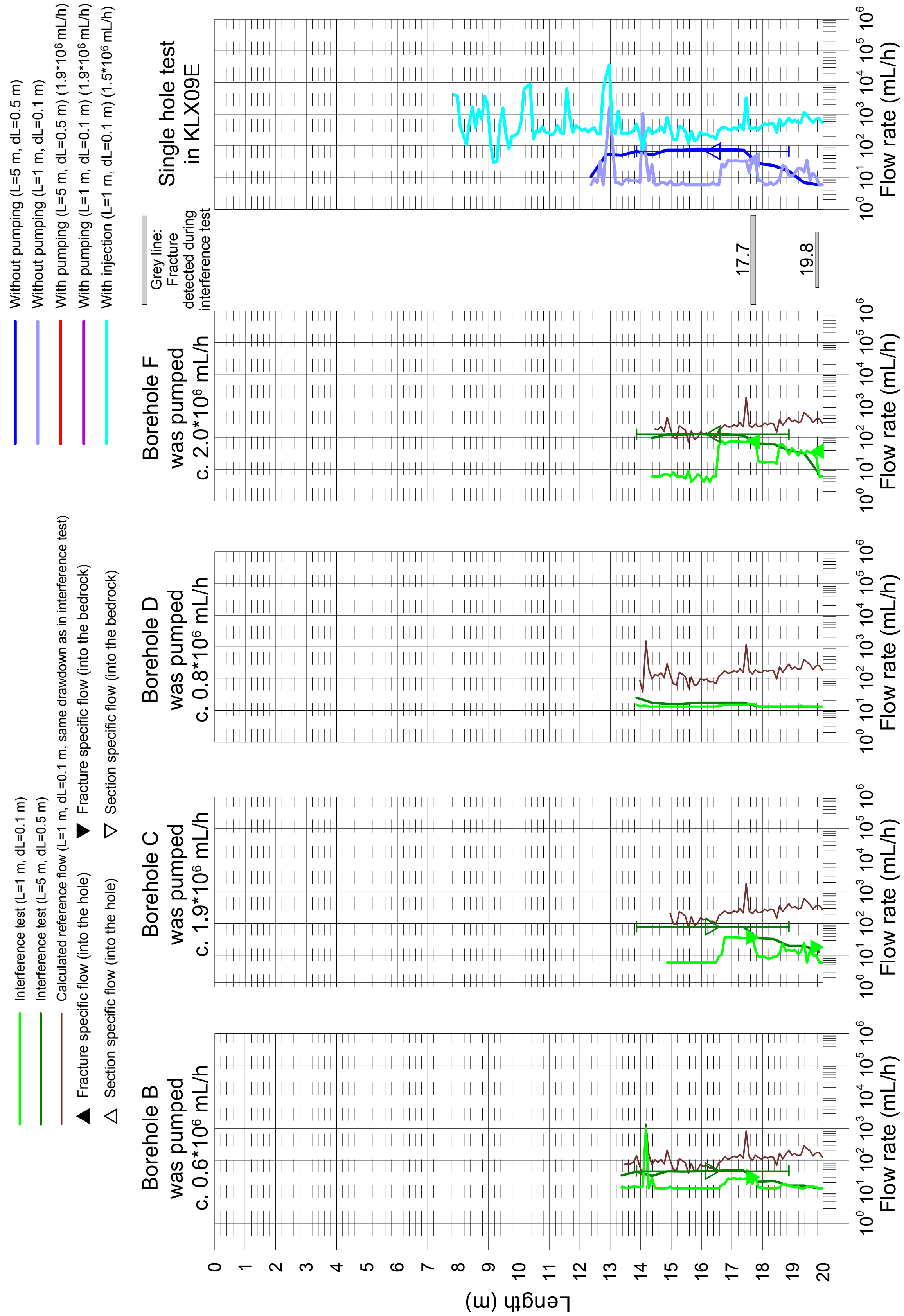


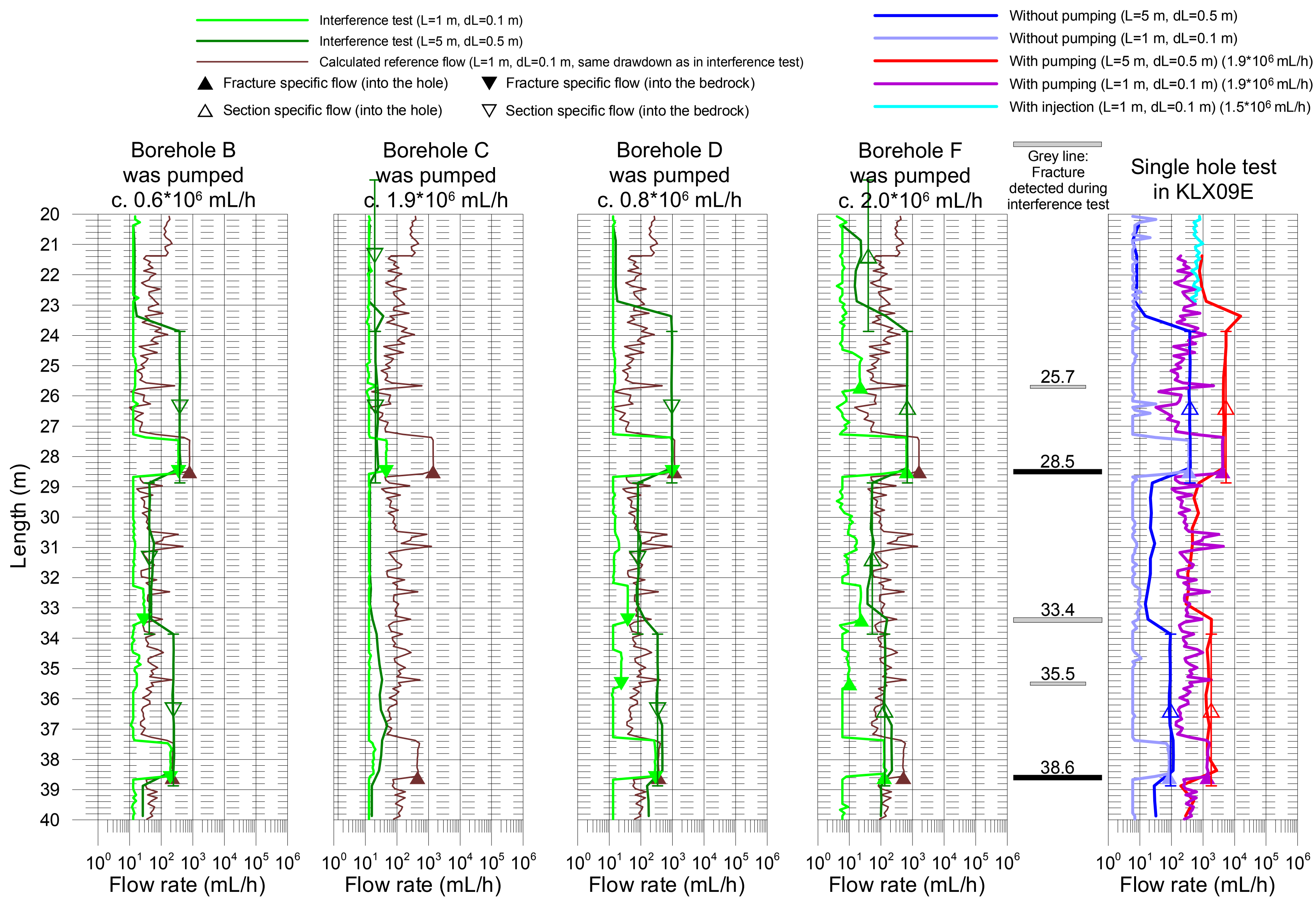
Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (0.8*10^6 mL/h)
With pumping (L=1 m, dL=0.1 m) (0.8*10^6 mL/h)
With injection (L=1 m, dL=0.1 m) (0.9*10^6 mL/h)
Borehole B was pumped c. 0.6*10^6 mL/h
Borehole C was pumped c. 1.9*10^6 mL/h
Borehole E was pumped c. 1.9*10^6 mL/h
Borehole F was pumped c. 2.0*10^6 mL/h
Single hole test in KLX09D
Length (m)
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
81.9
82.6
83.2
84.2
84.9
85.3
85.9
86.3
87.5
96.3
10^0 10^1 10^2 10^3 10^4 10^5 10^6
Flow rate (mL/h)

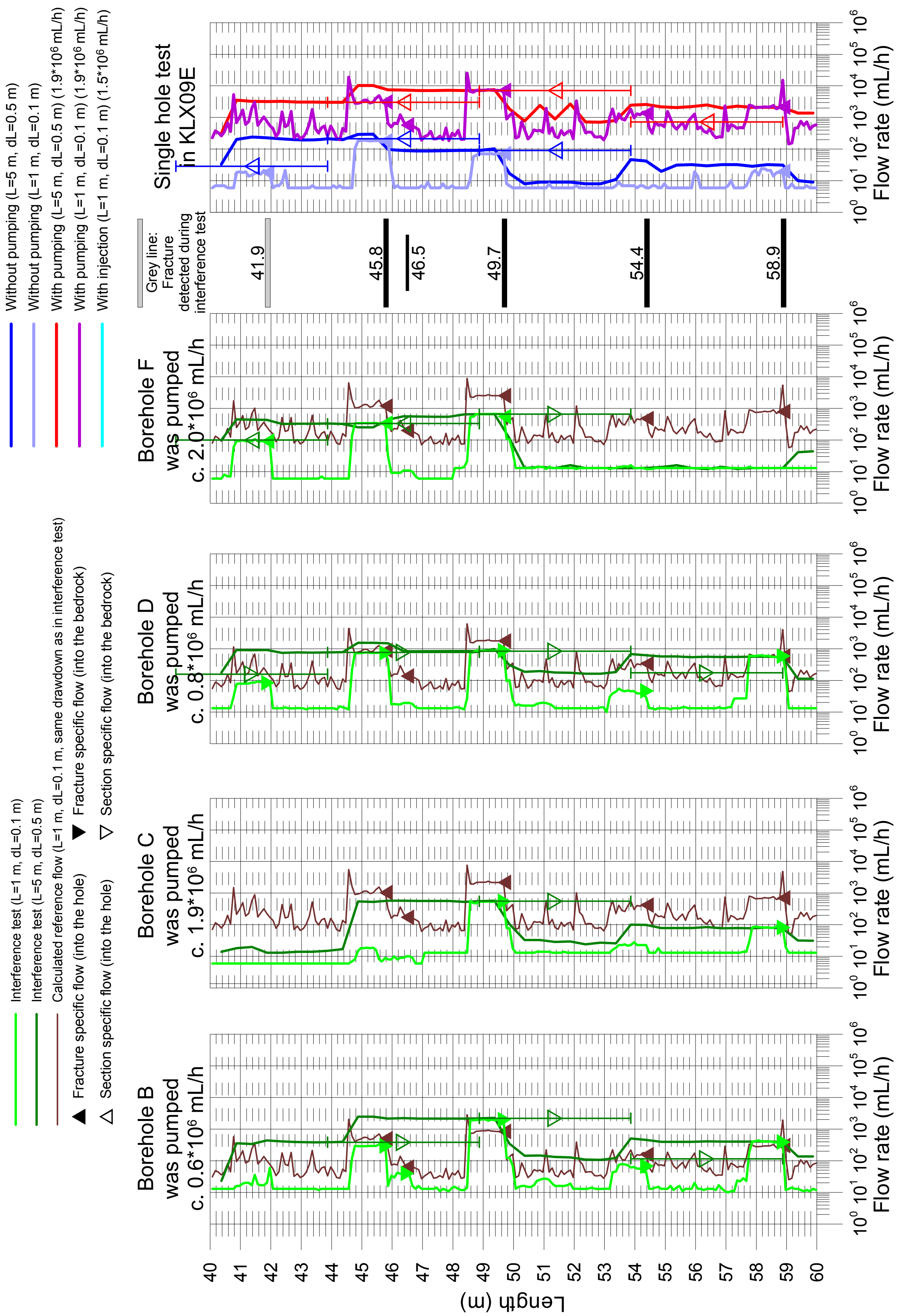


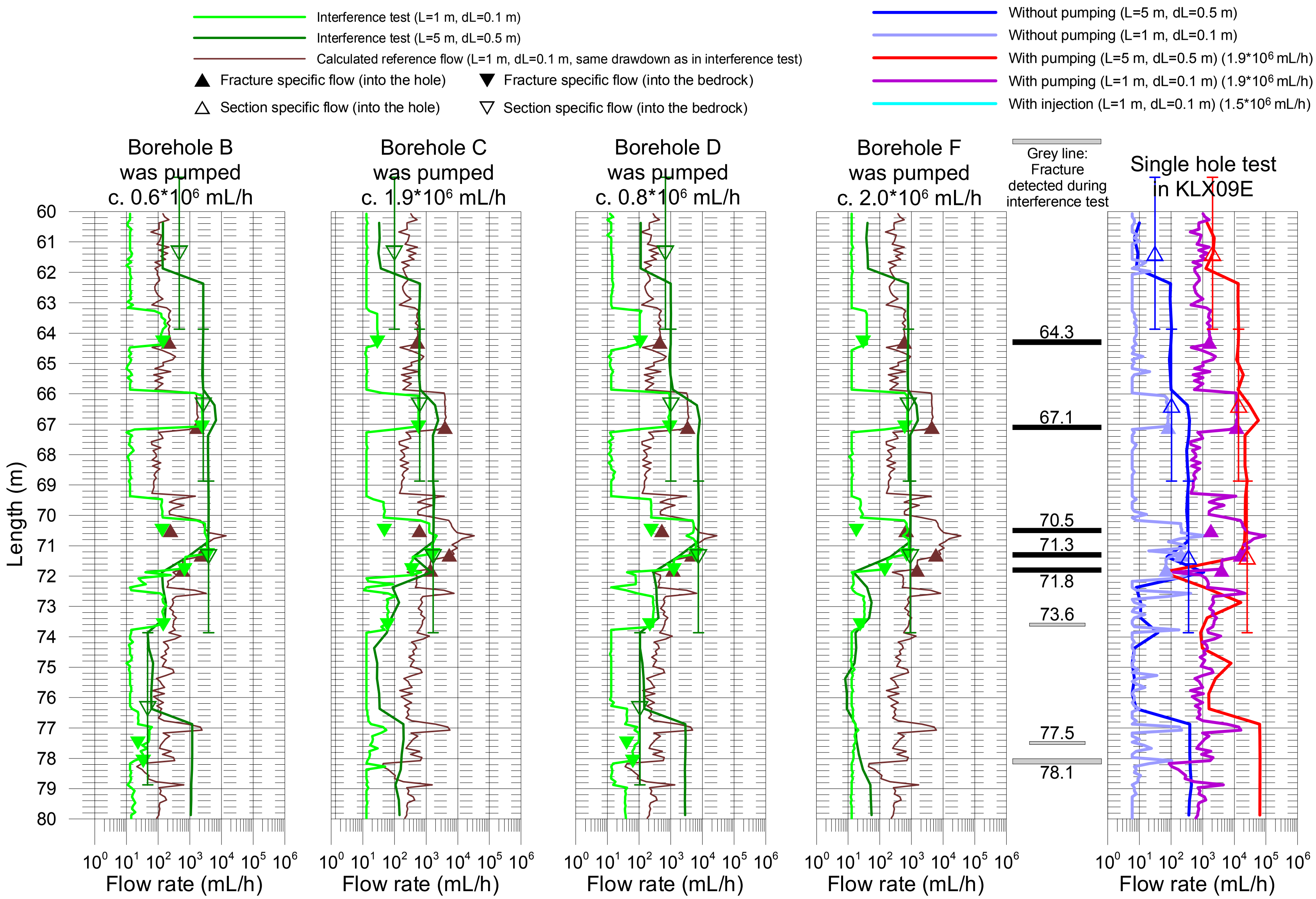
Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (0.8*10^6 mL/h)
With pumping (L=1 m, dL=0.1 m) (0.8*10^6 mL/h)
With injection (L=1 m, dL=0.1 m) (0.9*10^6 mL/h)
Borehole B was pumped c. 0.6*10^6 mL/h
Borehole C was pumped c. 1.9*10^6 mL/h
Borehole E was pumped c. 1.9*10^6 mL/h
Borehole F was pumped c. 2.0*10^6 mL/h
Single hole test in KLX09D
Length (m)
Flow rate (mL/h)
102.3
102.9
111.6
112.2
113.7
115.9

Hydraulic crosshole interference test, borehole KLX09E

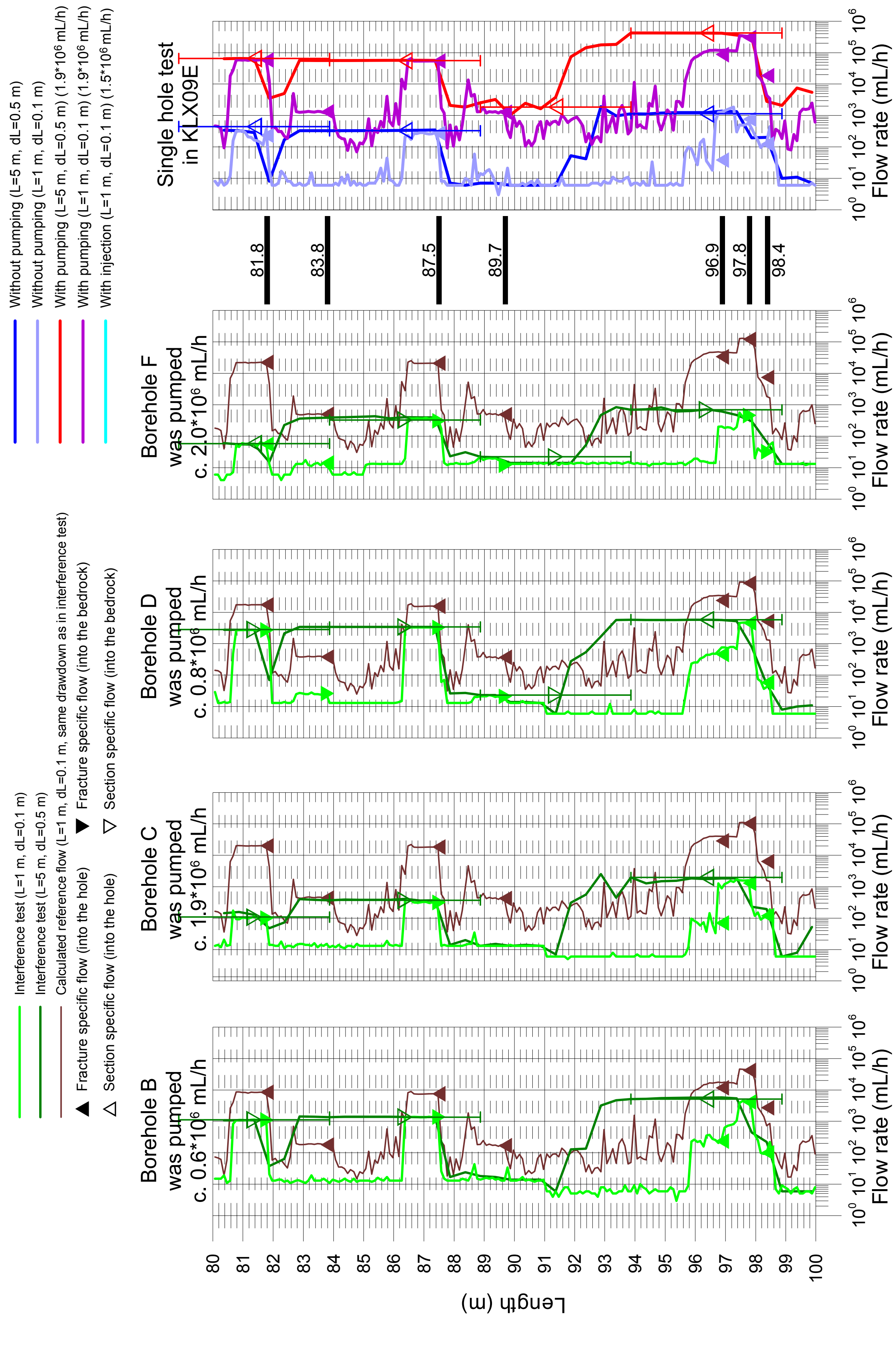



Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (1.9*10^6 mL/h)
With pumping (L=1 m, dL=0.1 m) (1.9*10^6 mL/h)
With injection (L=1 m, dL=0.1 m) (1.5*10^6 mL/h)
Borehole B was pumped c. 0.6*10^6 mL/h
Borehole C was pumped c. 1.9*10^6 mL/h
Borehole D was pumped c. 0.8*10^6 mL/h
Borehole F was pumped c. 2.0*10^6 mL/h
Grey line: Fracture detected during interference test
Single hole test in KLX09E
Length (m)
25.7
28.5
33.4
35.5
38.6
Flow rate (mL/h)

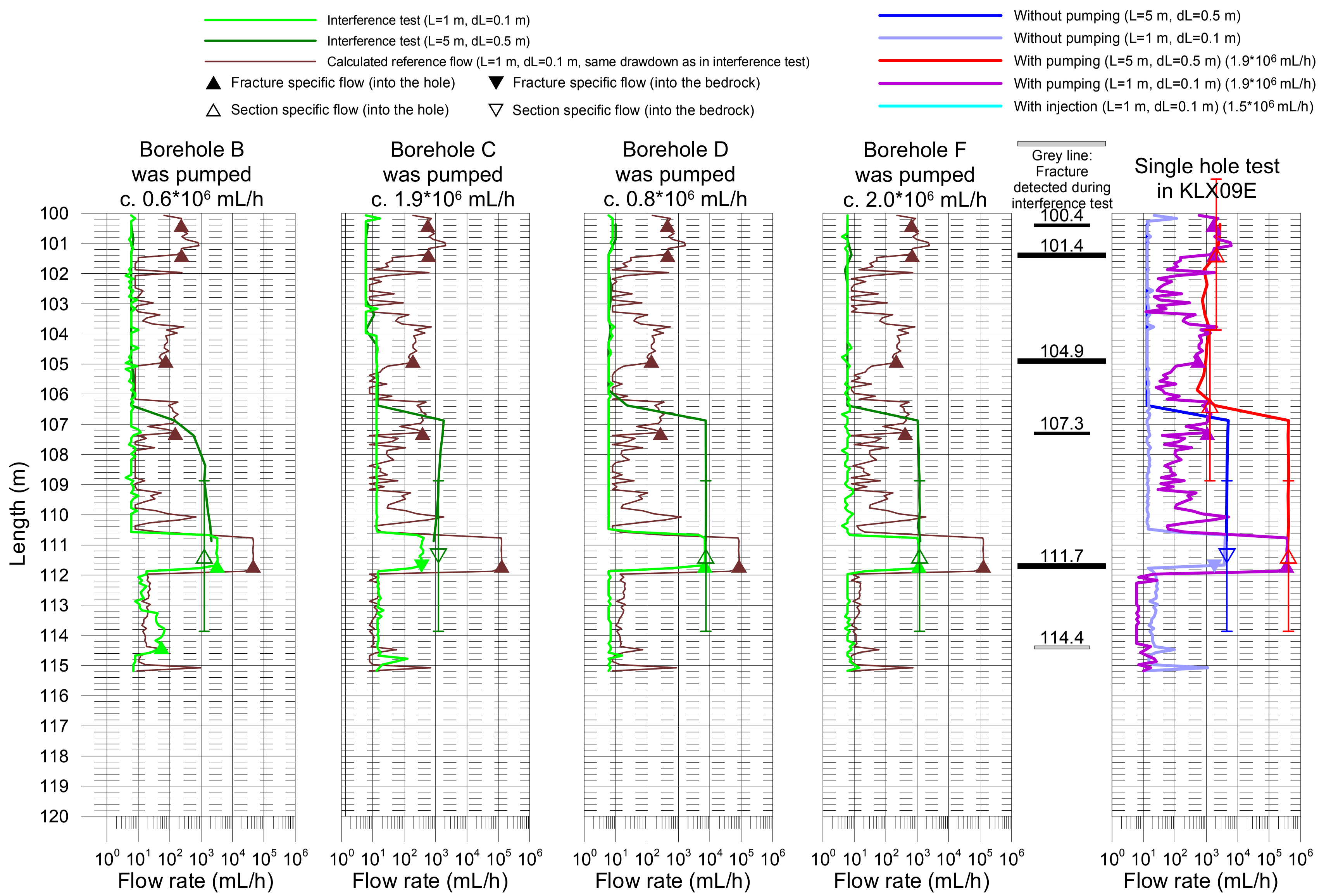

Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (1.9*10^6 mL/h)
With pumping (L=1 m, dL=0.1 m) (1.9*10^6 mL/h)
With injection (L=1 m, dL=0.1 m) (1.5*10^6 mL/h)
Borehole B was pumped c. 0.6*10^6 mL/h
Borehole C was pumped c. 1.9*10^6 mL/h
Borehole D was pumped c. 0.8*10^6 mL/h
Borehole F was pumped c. 2.0*10^6 mL/h
Grey line: Fracture detected during interference test
Single hole test in KLX09E
41.9
45.8
46.5
49.7
54.4
58.9
Length (m)
Flow rate (mL/h)



Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (1.9*10^6 mL/h)
With pumping (L=1 m, dL=0.1 m) (1.9*10^6 mL/h)
With injection (L=1 m, dL=0.1 m) (1.5*10^6 mL/h)
Borehole B was pumped c. 0.6*10^6 mL/h
Borehole C was pumped c. 1.9*10^6 mL/h
Borehole D was pumped c. 0.8*10^6 mL/h
Borehole F was pumped c. 2.0*10^6 mL/h
Grey line: Fracture detected during interference test
Single hole test in KLX09E
Length (m)
Flow rate (mL/h)
64.3
67.1
70.5
71.3
71.8
73.6
77.5
78.1

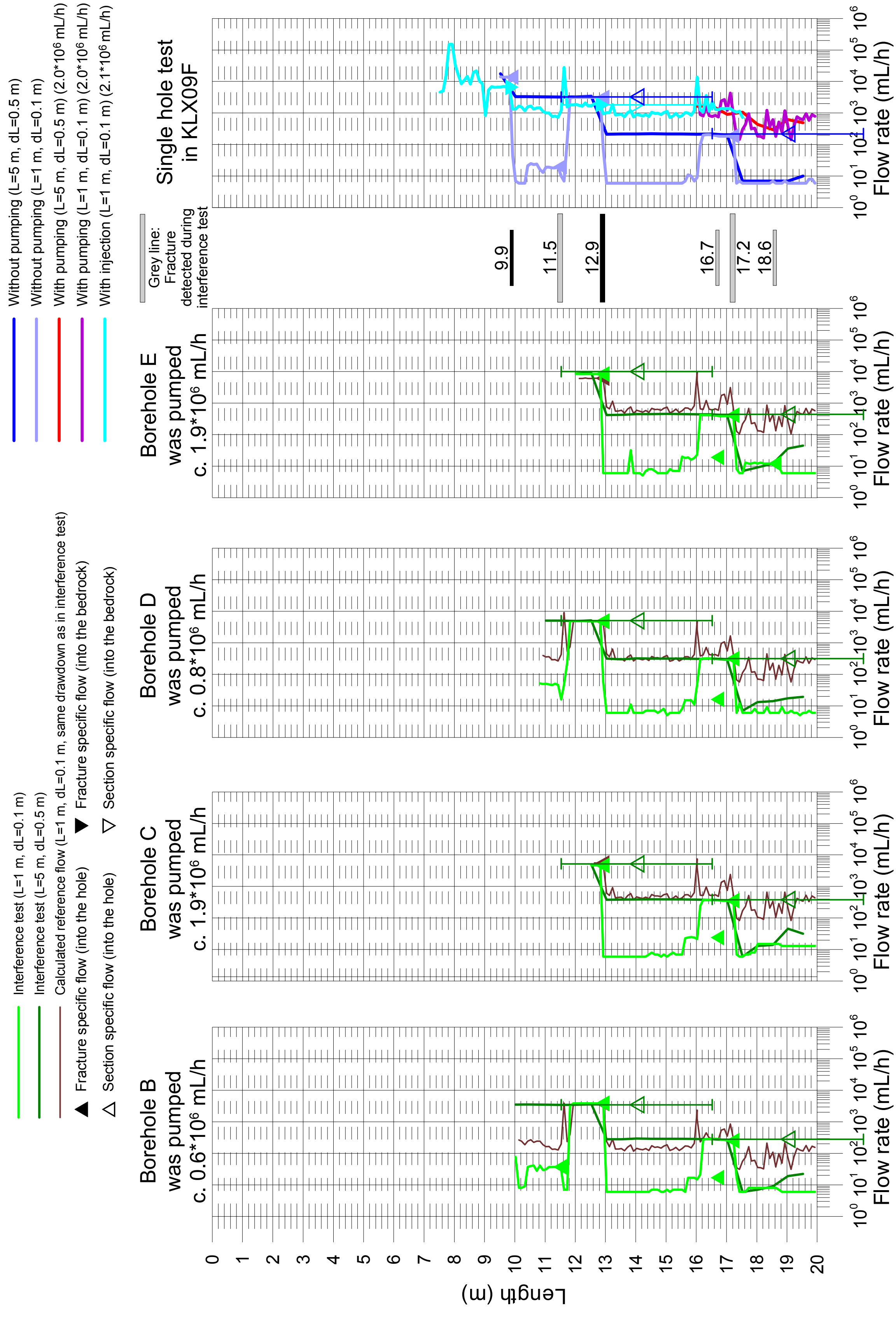


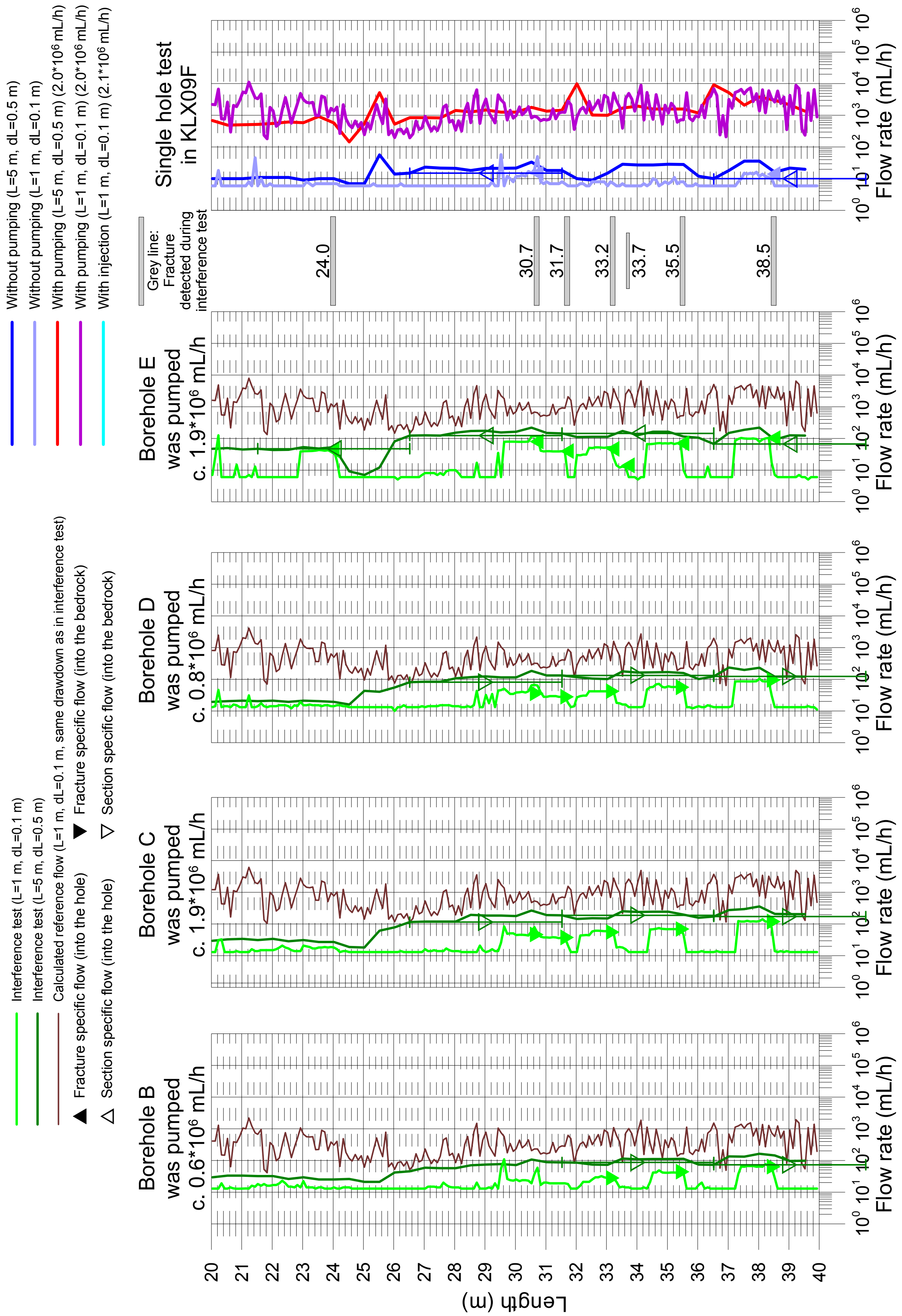
Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (1.9*10^6 mL/h)
With pumping (L=1 m, dL=0.1 m) (1.9*10^6 mL/h)
With injection (L=1 m, dL=0.1 m) (1.5*10^6 mL/h)
Borehole B was pumped c. 0.6*10^6 mL/h
Borehole C was pumped c. 1.9*10^6 mL/h
Borehole D was pumped c. 0.8*10^6 mL/h
Borehole F was pumped c. 2.0*10^6 mL/h
Single hole test in KLX09E
81.8
83.8
87.5
89.7
96.9
97.8
98.4
Length (m)
Flow rate (mL/h)



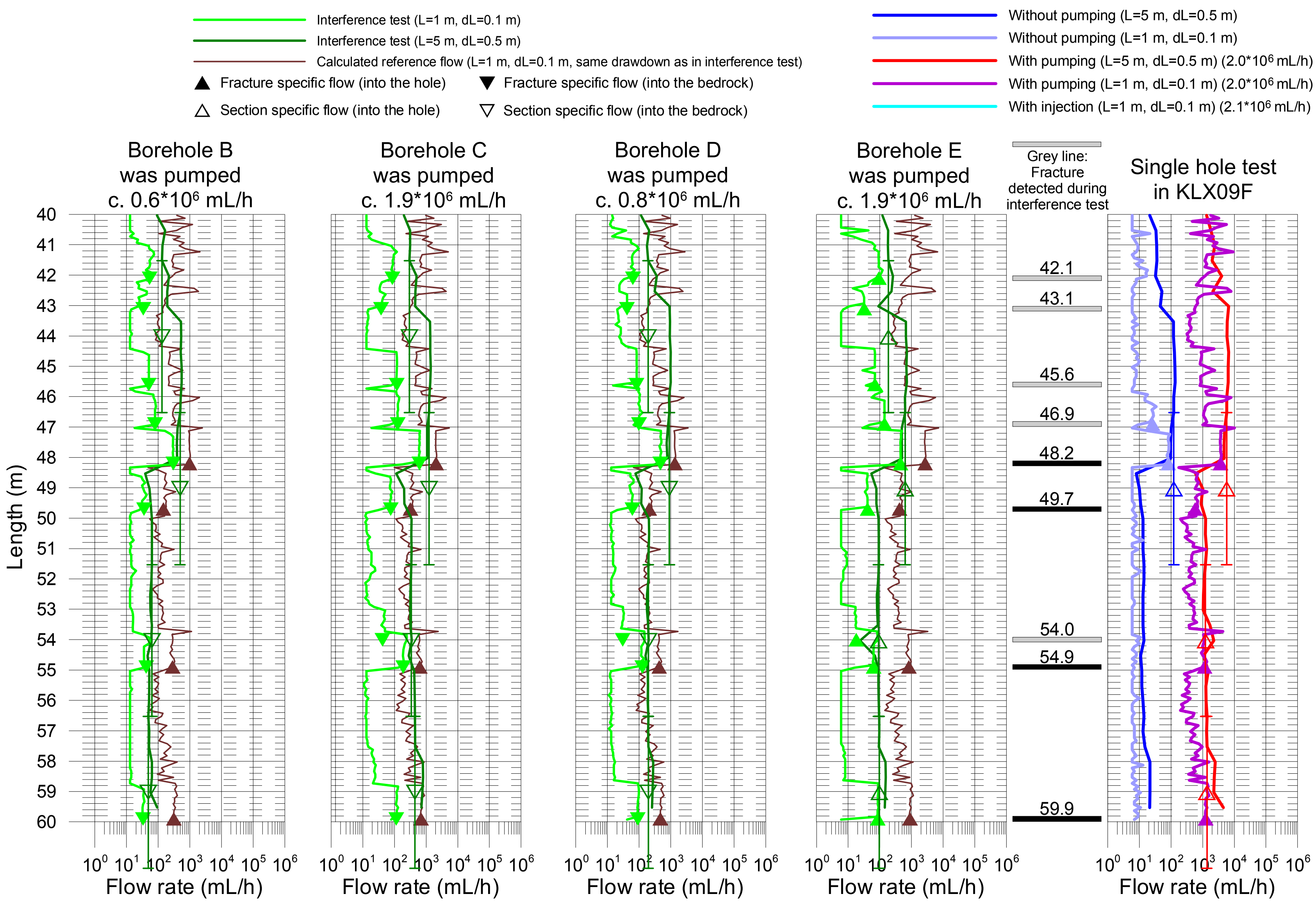
Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (1.9*10^6 mL/h)
With pumping (L=1 m, dL=0.1 m) (1.9*10^6 mL/h)
With injection (L=1 m, dL=0.1 m) (1.5*10^6 mL/h)
Borehole B was pumped c. 0.6*10^6 mL/h
Borehole C was pumped c. 1.9*10^6 mL/h
Borehole D was pumped c. 0.8*10^6 mL/h
Borehole F was pumped c. 2.0*10^6 mL/h
Grey line: Fracture detected during interference test
Single hole test in KLX09E
100.4
101.4
104.9
107.3
111.7
114.4
Length (m)
Flow rate (mL/h)

Hydraulic crosshole interference test, borehole KLX09F

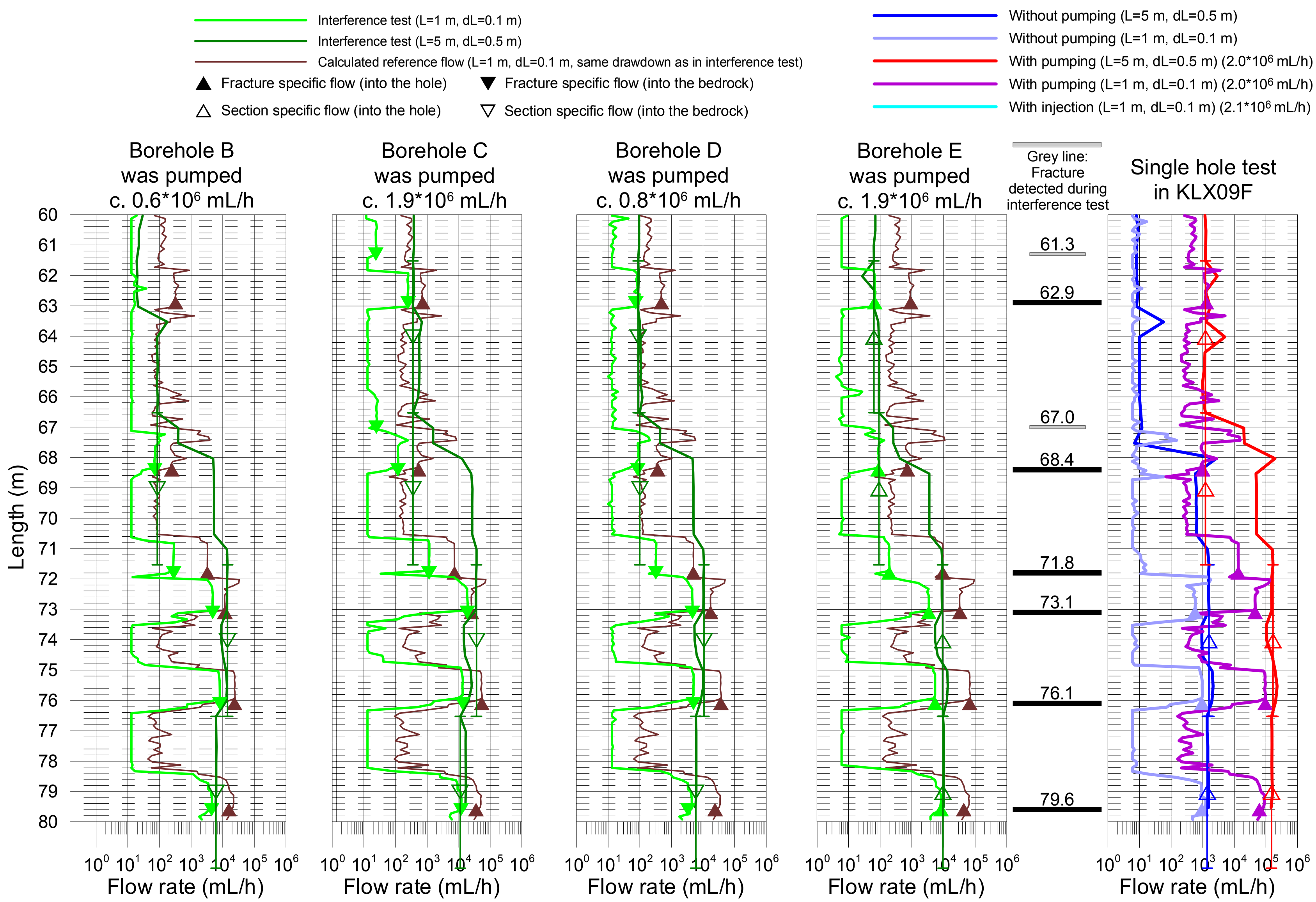




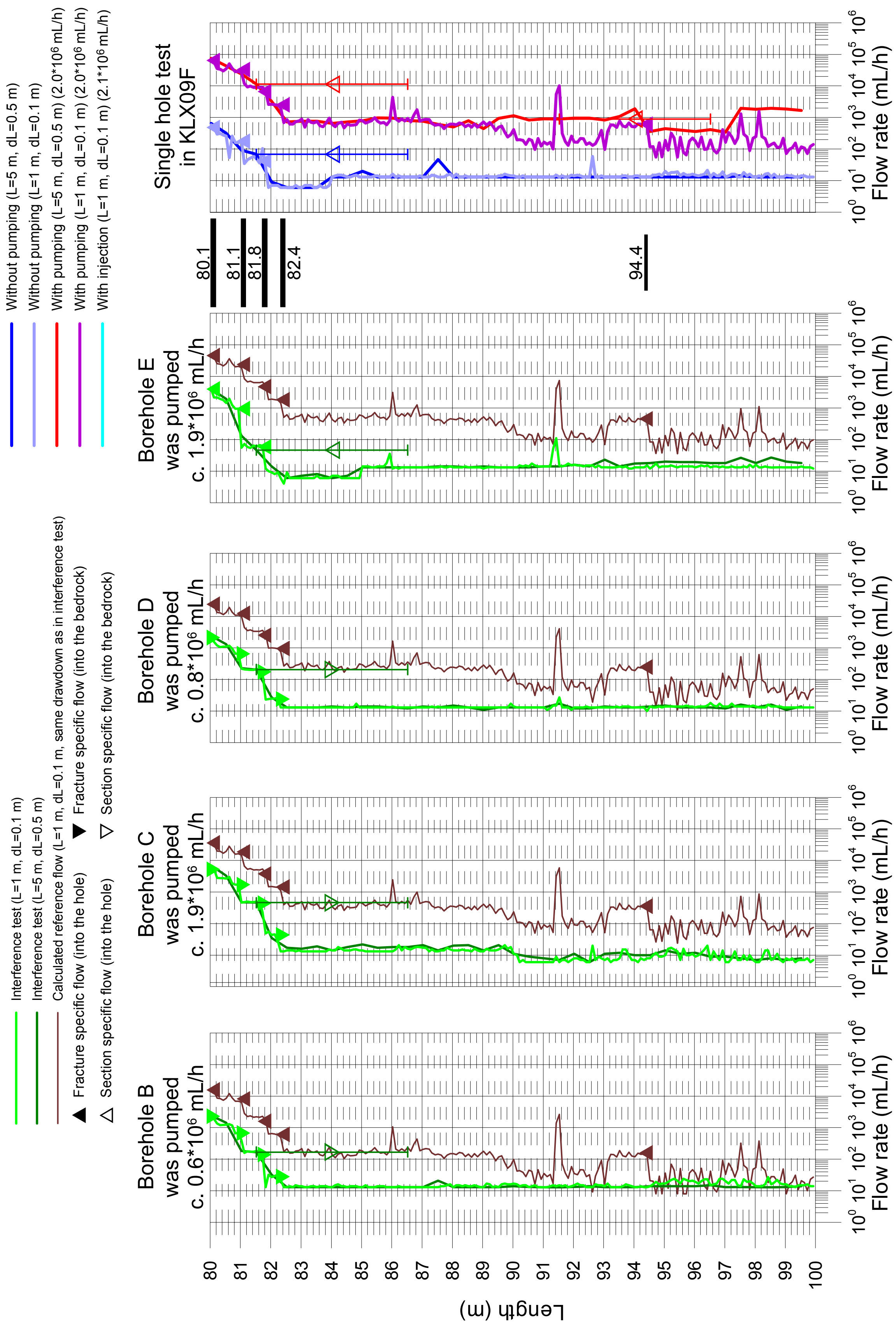
Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (2.0*10^6 mL/h)
With pumping (L=1 m, dL=0.1 m) (2.0*10^6 mL/h)
With injection (L=1 m, dL=0.1 m) (2.1*10^6 mL/h)
Borehole B was pumped c. 0.6*10^6 mL/h
Borehole C was pumped c. 1.9*10^6 mL/h
Borehole D was pumped c. 0.8*10^6 mL/h
Borehole E was pumped c. 1.9*10^6 mL/h
Grey line: Fracture detected during interference test
24.0
30.7
31.7
33.2
33.7
35.5
38.5
Single hole test in KLX09F
Length (m)
Flow rate (mL/h)



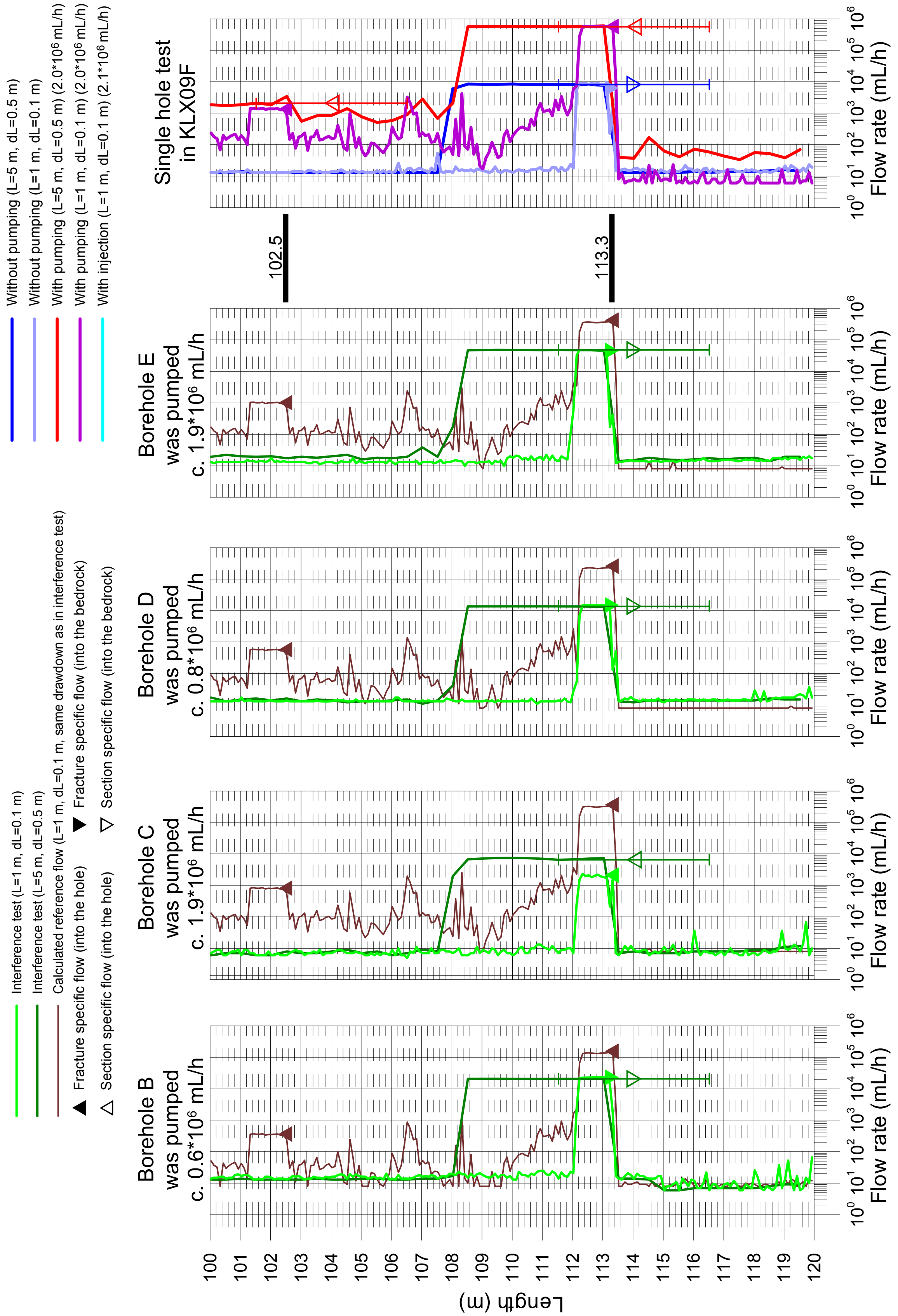
Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (2.0*10^6 mL/h)
With pumping (L=1 m, dL=0.1 m) (2.0*10^6 mL/h)
With injection (L=1 m, dL=0.1 m) (2.1*10^6 mL/h)
Borehole B was pumped c. 0.6*10^6 mL/h
Borehole C was pumped c. 1.9*10^6 mL/h
Borehole D was pumped c. 0.8*10^6 mL/h
Borehole E was pumped c. 1.9*10^6 mL/h
Grey line: Fracture detected during interference test
Single hole test in KLX09F
Length (m)
Flow rate (mL/h)
42.1
43.1
45.6
46.9
48.2
49.7
54.0
54.9
59.9



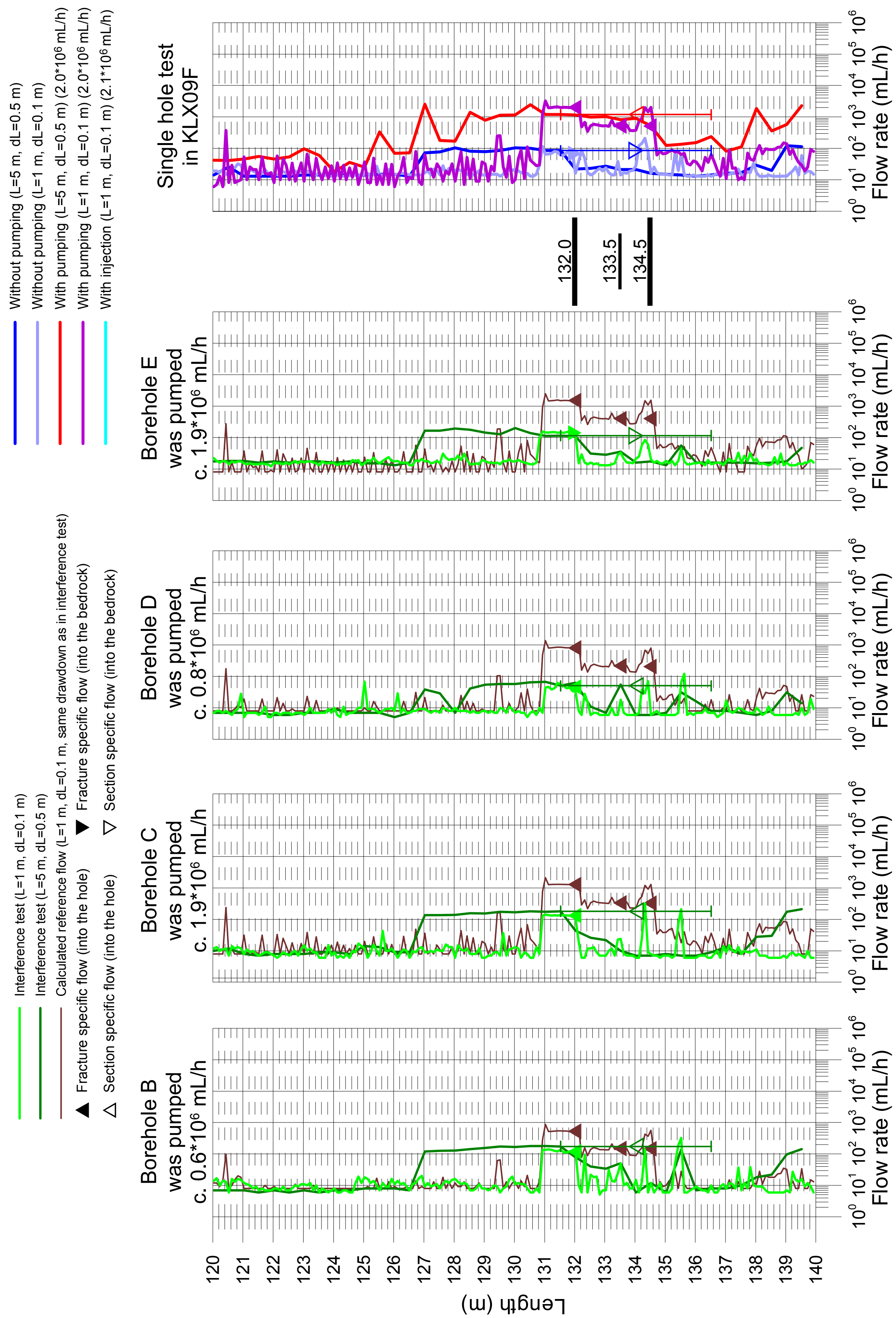
Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (2.0*10^6 mL/h)
With pumping (L=1 m, dL=0.1 m) (2.0*10^6 mL/h)
With injection (L=1 m, dL=0.1 m) (2.1*10^6 mL/h)
Borehole B was pumped c. 0.6*10^6 mL/h
Borehole C was pumped c. 1.9*10^6 mL/h
Borehole D was pumped c. 0.8*10^6 mL/h
Borehole E was pumped c. 1.9*10^6 mL/h
Grey line: Fracture detected during interference test
Single hole test in KLX09F
Length (m)
Flow rate (mL/h)
61.3
62.9
67.0
68.4
71.8
73.1
76.1
79.6



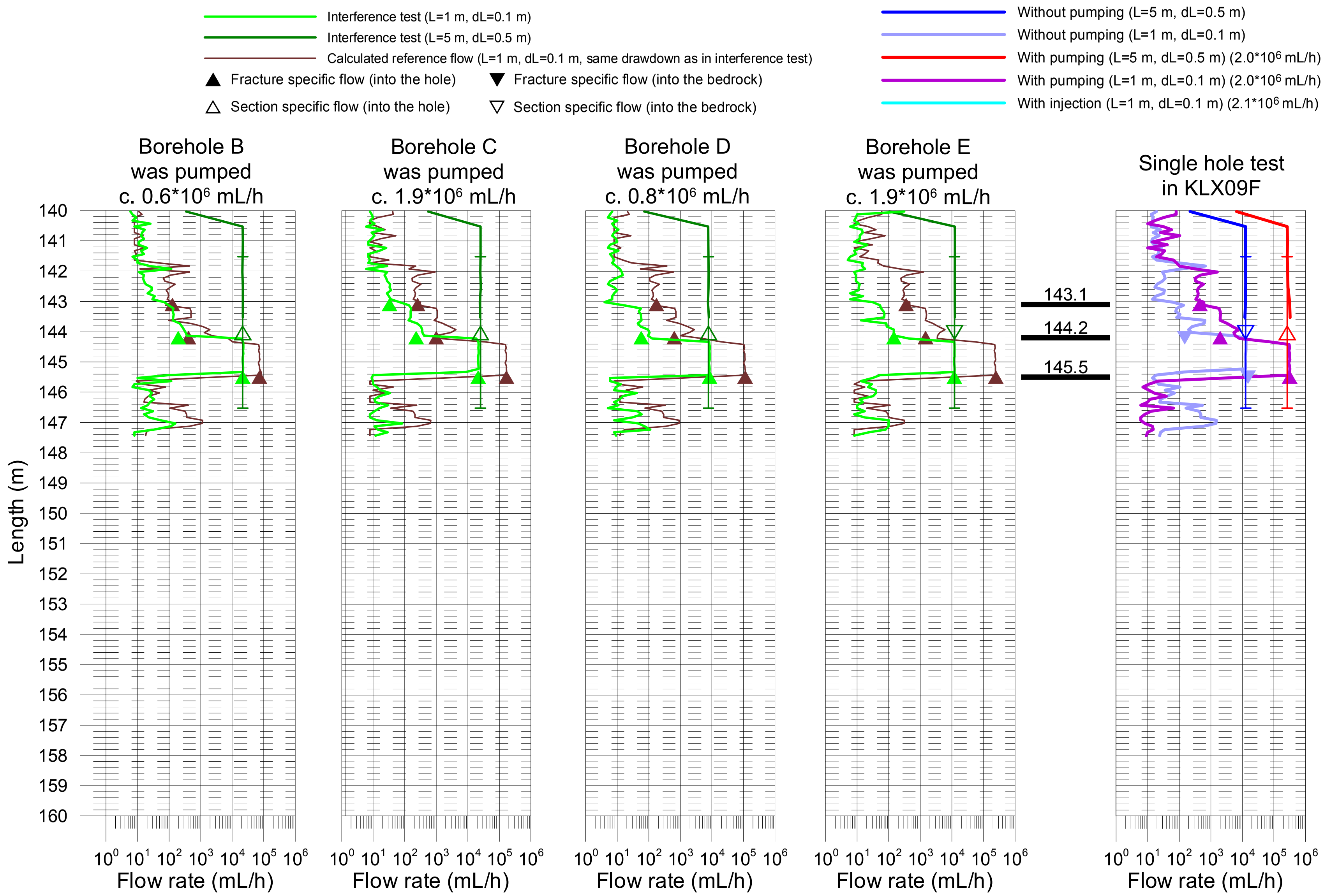
Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (2.0*10^6 mL/h)
With pumping (L=1 m, dL=0.1 m) (2.0*10^6 mL/h)
With injection (L=1 m, dL=0.1 m) (2.1*10^6 mL/h)
Borehole B was pumped c. 0.6*10^6 mL/h
Borehole C was pumped c. 1.9*10^6 mL/h
Borehole D was pumped c. 0.8*10^6 mL/h
Borehole E was pumped c. 1.9*10^6 mL/h
Single hole test in KLX09F
80.1
81.1
81.8
82.4
94.4
Length (m)
Flow rate (mL/h)



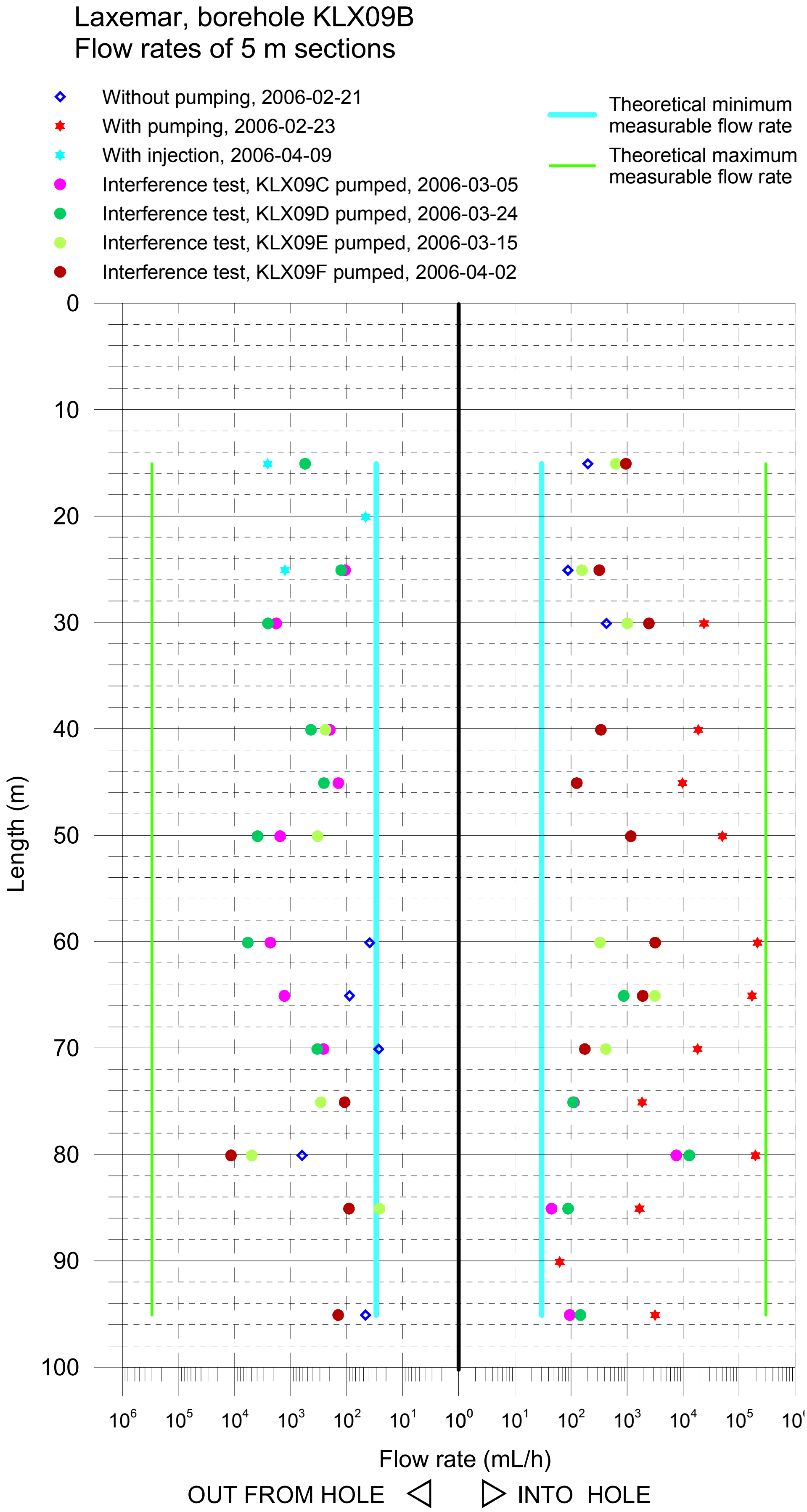
Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (2.0*10^6 mL/h)
With pumping (L=1 m, dL=0.1 m) (2.0*10^6 mL/h)
With injection (L=1 m, dL=0.1 m) (2.1*10^6 mL/h)
Borehole B was pumped c. 0.6*10^6 mL/h
Borehole C was pumped c. 1.9*10^6 mL/h
Borehole D was pumped c. 0.8*10^6 mL/h
Borehole E was pumped c. 1.9*10^6 mL/h
Single hole test in KLX09F
102.5
113.3
Length (m)
Flow rate (mL/h)

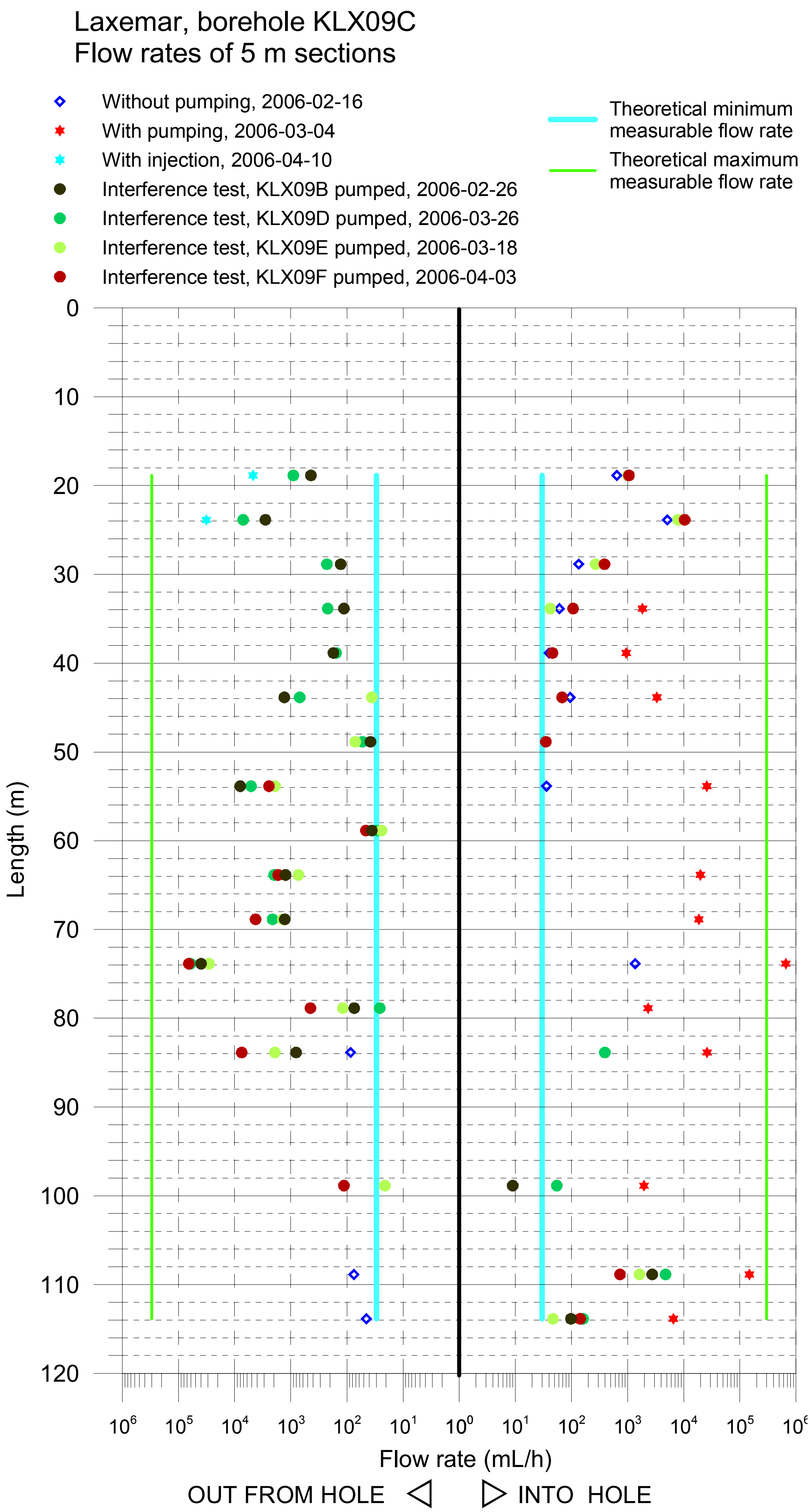


Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (2.0*10^6 mL/h)
With pumping (L=1 m, dL=0.1 m) (2.0*10^6 mL/h)
With injection (L=1 m, dL=0.1 m) (2.1*10^6 mL/h)
Borehole B was pumped c. 0.6*10^6 mL/h
Borehole C was pumped c. 1.9*10^6 mL/h
Borehole D was pumped c. 0.8*10^6 mL/h
Borehole E was pumped c. 1.9*10^6 mL/h
Single hole test in KLX09F
132.0
133.5
134.5
Length (m)
Flow rate (mL/h)

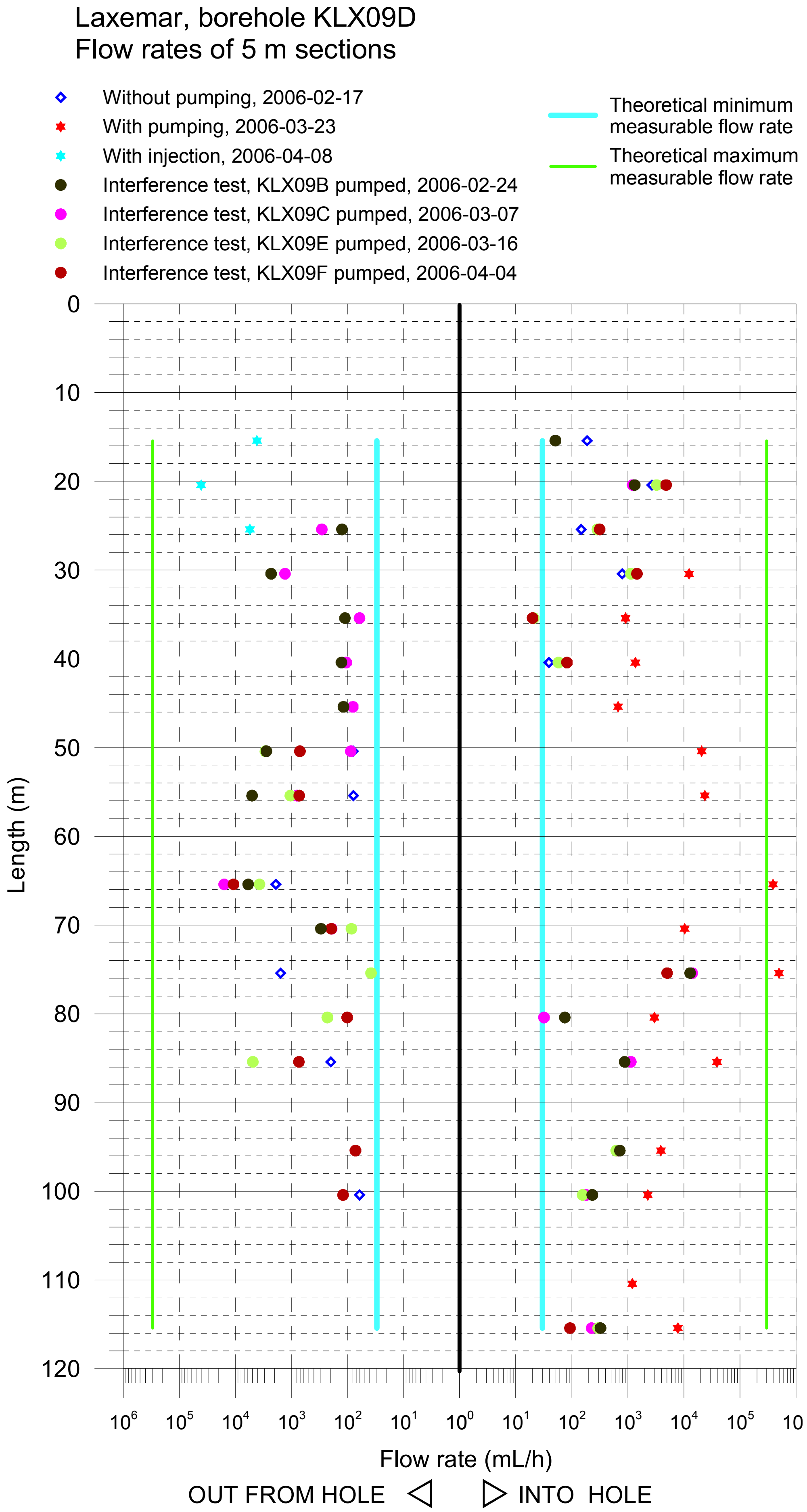

Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (2.0*10^6 mL/h)
With pumping (L=1 m, dL=0.1 m) (2.0*10^6 mL/h)
With injection (L=1 m, dL=0.1 m) (2.1*10^6 mL/h)
Borehole B was pumped c. 0.6*10^6 mL/h
Borehole C was pumped c. 1.9*10^6 mL/h
Borehole D was pumped c. 0.8*10^6 mL/h
Borehole E was pumped c. 1.9*10^6 mL/h
Single hole test in KLX09F
143.1
144.2
145.5
Length (m)
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
10^0 10^1 10^2 10^3 10^4 10^5 10^6
Flow rate (mL/h)

Flow rates of 5 m sections, boreholes KLX09B–KLX09F

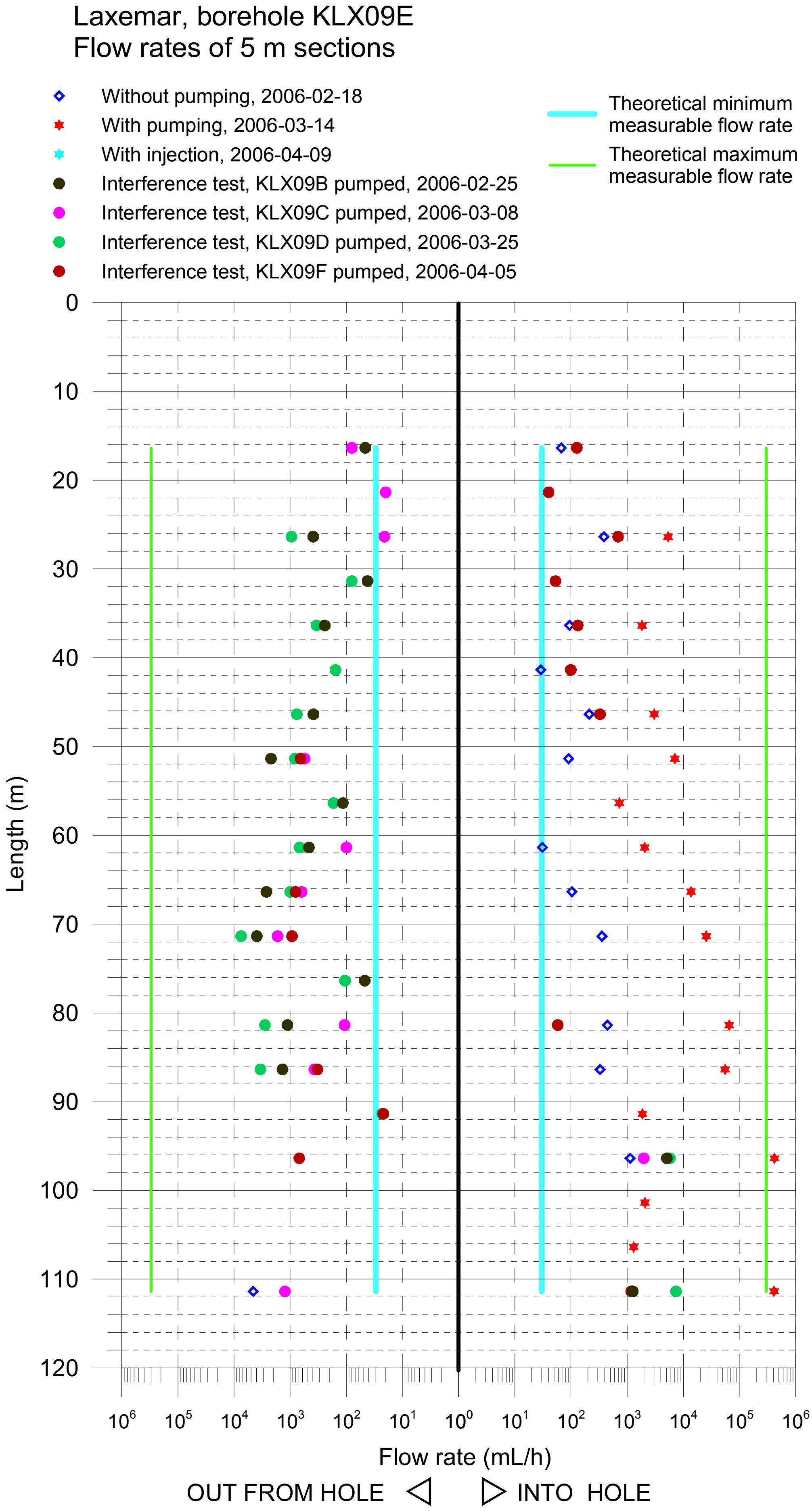


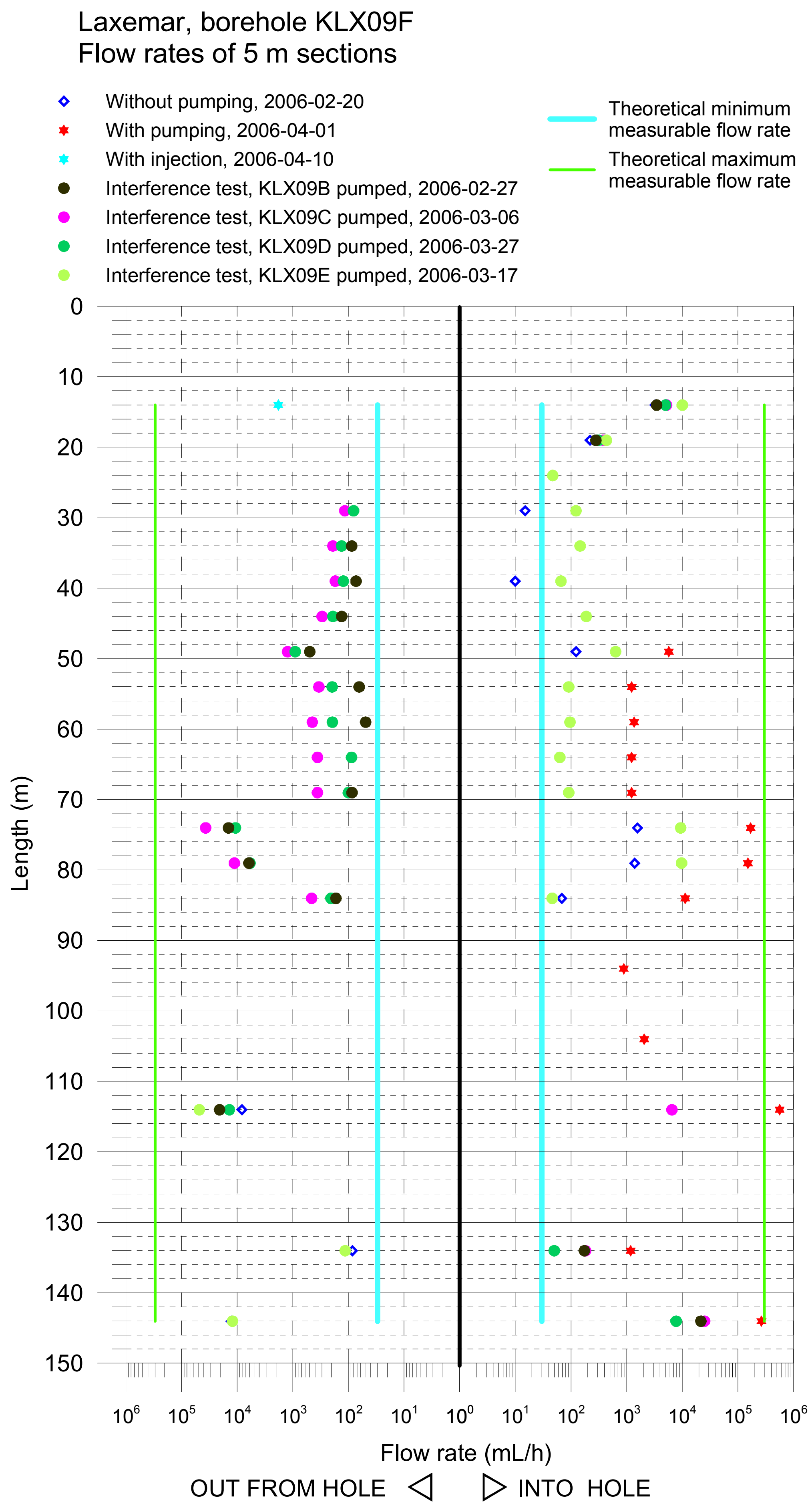


Laxemar, borehole KLX09C
Flow rates of 5 m sections
Without pumping, 2006-02-16
With pumping, 2006-03-04
With injection, 2006-04-10
Interference test, KLX09B pumped, 2006-02-26
Interference test, KLX09D pumped, 2006-03-26
Interference test, KLX09E pumped, 2006-03-18
Interference test, KLX09F pumped, 2006-04-03
Theoretical minimum measurable flow rate
Theoretical maximum measurable flow rate
Length (m)
Flow rate (mL/h)
OUT FROM HOLE
INTO HOLE



Laxemar, borehole KLX09D
Flow rates of 5 m sections
Without pumping, 2006-02-17
With pumping, 2006-03-23
With injection, 2006-04-08
Interference test, KLX09B pumped, 2006-02-24
Interference test, KLX09C pumped, 2006-03-07
Interference test, KLX09E pumped, 2006-03-16
Interference test, KLX09F pumped, 2006-04-04
Theoretical minimum measurable flow rate
Theoretical maximum measurable flow rate
Length (m)
Flow rate (mL/h)
OUT FROM HOLE
INTO HOLE


Laxemar, borehole KLX09E
Flow rates of 5 m sections
Without pumping, 2006-02-18
With pumping, 2006-03-14
With injection, 2006-04-09
Interference test, KLX09B pumped, 2006-02-25
Interference test, KLX09C pumped, 2006-03-08
Interference test, KLX09D pumped, 2006-03-25
Interference test, KLX09F pumped, 2006-04-05
Theoretical minimum measurable flow rate
Theoretical maximum measurable flow rate
Length (m)
0
10
20
30
40
50
60
70
80
90
100
110
120
10^6 10^5 10^4 10^3 10^2 10^1 10^0 10^1 10^2 10^3 10^4 10^5 10^6
Flow rate (mL/h)
OUT FROM HOLE
INTO HOLE



Laxemar, borehole KLX09F
Flow rates of 5 m sections
Without pumping, 2006-02-20
With pumping, 2006-04-01
With injection, 2006-04-10
Interference test, KLX09B pumped, 2006-02-27
Interference test, KLX09C pumped, 2006-03-06
Interference test, KLX09D pumped, 2006-03-27
Interference test, KLX09E pumped, 2006-03-17
Theoretical minimum measurable flow rate
Theoretical maximum measurable flow rate
Length (m)
Flow rate (mL/h)
OUT FROM HOLE
INTO HOLE

Results of sequential flow logging during hydraulic crosshole interference test, boreholes KLX09B–KLX09F

DIFFERENCE FLOW LOGGING – Sequential flow logging during hydraulic crosshole interference test

Borehole ID	SecUp L (m)	SecLow L (m)	L_w (m)	h_{CFW} (m.a.s.l.)	Q_C (m^3/s)	h_{DFW} (m.a.s.l.)	Q_D (m^3/s)	h_{EFW} (m.a.s.l.)	Q_E (m^3/s)	h_{FFW} (m.a.s.l.)	Q_F (m^3/s)
KLX09B	12.60	17.60	5.0	–	–	11.76	–1.53E–07	10.95	1.76E–07	11.18	2.65E–07
KLX09B	17.60	22.60	5.0	11.39	–	11.77	–	10.96	–	11.17	–
KLX09B	22.60	27.60	5.0	11.40	–2.97E–08	11.78	–3.50E–08	10.97	4.36E–08	11.16	8.89E–08
KLX09B	27.60	32.60	5.0	11.40	–5.03E–07	11.78	–7.06E–07	10.96	2.81E–07	11.16	6.83E–07
KLX09B	32.60	37.60	5.0	11.42	–	11.79	–	10.96	–	11.17	–
KLX09B	37.60	42.60	5.0	11.42	–5.56E–08	11.79	–1.21E–07	11.02	–6.67E–08	11.22	9.50E–08
KLX09B	42.60	47.60	5.0	11.42	–3.92E–08	11.80	–7.11E–08	11.02	–	11.23	3.53E–08
KLX09B	47.60	52.60	5.0	11.48	–4.28E–07	11.82	–1.08E–06	11.02	–9.17E–08	11.23	3.25E–07
KLX09B	52.60	57.60	5.0	11.48	–	11.81	–	11.03	–	11.24	–
KLX09B	57.60	62.60	5.0	11.49	–6.39E–07	11.84	–1.61E–06	11.09	9.17E–08	11.28	8.83E–07
KLX09B	62.60	67.60	5.0	11.51	–3.58E–07	11.86	2.43E–07	11.11	8.72E–07	11.30	5.31E–07
KLX09B	67.60	72.60	5.0	11.57	–7.22E–08	11.87	–9.28E–08	11.11	1.17E–07	11.31	4.92E–08
KLX09B	72.60	77.60	5.0	11.59	3.14E–08	11.88	3.03E–08	11.11	–8.06E–08	11.33	–3.03E–08
KLX09B	77.60	82.60	5.0	11.61	2.11E–06	11.87	3.58E–06	11.12	–1.38E–06	11.32	–3.22E–06
KLX09B	82.60	87.60	5.0	11.63	1.25E–08	11.89	2.47E–08	11.14	–7.22E–09	11.34	–2.53E–08
KLX09B	87.60	92.60	5.0	11.64	–	11.89	–	11.14	–	11.33	–
KLX09B	92.60	97.60	5.0	11.62	2.64E–08	11.89	4.11E–08	11.13	–	11.33	–3.94E–08
KLX09C	16.36	21.36	5.0	12.78	–1.22E–07	12.14	–2.50E–07	11.43	2.83E–07	11.76	2.94E–07
KLX09C	21.36	26.36	5.0	12.95	–7.86E–07	12.12	–1.96E–06	11.43	2.19E–06	11.93	2.89E–06
KLX09C	26.36	31.36	5.0	13.07	–3.58E–08	12.15	–6.33E–08	11.41	7.50E–08	11.93	1.08E–07
KLX09C	31.36	36.36	5.0	13.06	–3.14E–08	12.21	–6.11E–08	11.43	1.17E–08	11.78	2.97E–08

Borehole ID	SecUp L (m)	SecLow L (m)	L_w (m)	h_{CFW} (m.a.s.l.)	Q_C (m^3/s)	h_{DFW} (m.a.s.l.)	Q_D (m^3/s)	h_{EFW} (m.a.s.l.)	Q_E (m^3/s)	h_{FFW} (m.a.s.l.)	Q_F (m^3/s)
KLX09C	36.36	41.36	5.0	13.02	–4.83E–08	12.32	–4.33E–08	11.28	–	11.73	1.28E–08
KLX09C	41.36	46.36	5.0	12.85	–3.61E–07	12.34	–1.93E–07	11.22	–1.00E–08	11.73	1.89E–08
KLX09C	46.36	51.36	5.0	12.84	–1.06E–08	12.38	–1.47E–08	11.29	–1.97E–08	11.74	9.72E–09
KLX09C	51.36	56.36	5.0	12.83	–2.21E–06	12.39	–1.42E–06	11.31	–5.28E–07	11.76	–6.81E–07
KLX09C	56.36	61.36	5.0	12.88	–1.00E–08	12.42	–8.06E–09	11.31	–6.67E–09	11.83	–1.28E–08
KLX09C	61.36	66.36	5.0	12.87	–3.44E–07	12.29	–5.50E–07	11.30	–2.02E–07	11.83	–4.67E–07
KLX09C	66.36	71.36	5.0	12.95	–3.56E–07	12.24	–5.86E–07	11.32	–3.86E–07	11.83	–1.18E–06
KLX09C	71.36	76.36	5.0	12.94	–1.10E–05	12.19	–1.69E–05	11.31	–7.92E–06	11.81	–1.82E–05
KLX09C	76.36	81.36	5.0	12.91	–2.06E–08	12.15	–7.22E–09	11.30	–3.28E–08	11.80	–1.24E–07
KLX09C	81.36	86.36	5.0	12.89	–2.24E–07	12.19	1.09E–07	11.28	–5.33E–07	11.78	–2.08E–06
KLX09C	86.36	91.36	5.0	12.85	–	12.24	–	11.27	–	11.75	–
KLX09C	91.36	96.36	5.0	12.82	–	12.14	–	11.22	–	11.63	–
KLX09C	96.36	101.36	5.0	12.83	2.50E–09	11.97	1.53E–08	11.16	–5.83E–09	11.52	–3.14E–08
KLX09C	101.36	106.36	5.0	12.77	–	11.84	–	11.01	–	11.57	–
KLX09C	106.36	111.36	5.0	12.68	7.64E–07	11.88	1.32E–06	10.93	4.53E–07	11.61	2.04E–07
KLX09C	111.36	116.36	5.0	12.68	2.72E–08	11.88	4.47E–08	10.93	1.31E–08	11.61	3.97E–08
KLX09D	12.91	17.91	5.0	12.64	1.42E–08	11.20	–	11.19	–	11.64	–
KLX09D	17.91	22.91	5.0	12.68	3.67E–07	11.20	3.39E–07	11.19	9.06E–07	11.64	1.33E–06
KLX09D	22.91	27.91	5.0	12.70	–3.47E–08	11.15	–7.94E–08	11.08	7.94E–08	11.83	8.72E–08
KLX09D	27.91	32.91	5.0	12.73	–6.39E–07	11.20	–3.61E–07	10.94	3.14E–07	11.84	4.03E–07
KLX09D	32.91	37.91	5.0	12.82	–3.08E–08	11.26	–1.69E–08	11.02	5.83E–09	11.68	5.56E–09
KLX09D	37.91	42.91	5.0	12.83	–3.56E–08	11.34	–2.92E–08	11.20	1.61E–08	11.65	2.28E–08
KLX09D	42.91	47.91	5.0	12.86	–3.28E–08	11.40	–2.22E–08	11.24	–	11.62	–
KLX09D	47.91	52.91	5.0	12.88	–7.78E–07	11.44	–2.42E–08	11.19	–8.11E–07	11.60	–1.96E–07
KLX09D	52.91	57.91	5.0	12.87	–1.40E–06	11.36	–2.22E–07	11.16	–2.89E–07	11.61	–2.01E–07
KLX09D	57.91	62.91	5.0	12.82	–	11.32	–	11.10	–	11.64	–
KLX09D	62.91	67.91	5.0	12.80	–1.64E–06	11.30	–4.39E–06	11.01	–1.03E–06	11.70	–3.00E–06
KLX09D	67.91	72.91	5.0	12.78	–8.28E–08	11.28	–5.33E–08	10.91	–2.36E–08	11.68	–5.39E–08
KLX09D	72.91	77.91	5.0	12.74	3.58E–06	11.24	3.89E–06	10.89	–1.06E–08	11.66	1.39E–06

Borehole ID	SecUp L (m)	SecLow L (m)	L_w (m)	h_{CFW} (m.a.s.l.)	Q_C (m^3/s)	h_{DFW} (m.a.s.l.)	Q_D (m^3/s)	h_{EFW} (m.a.s.l.)	Q_E (m^3/s)	h_{FFW} (m.a.s.l.)	Q_F (m^3/s)
KLX09D	77.91	82.91	5.0	12.68	2.08E–08	11.18	8.89E–09	10.86	–6.33E–08	11.62	–2.81E–08
KLX09D	82.91	87.91	5.0	12.66	2.43E–07	11.13	3.14E–07	10.83	–1.35E–06	11.52	–2.03E–07
KLX09D	87.91	92.91	5.0	12.61	–	11.07	–	10.79	–	11.39	–
KLX09D	92.91	97.91	5.0	12.54	1.99E–07	11.03	1.81E–07	10.76	1.72E–07	11.43	–2.00E–08
KLX09D	97.91	102.91	5.0	12.47	6.44E–08	10.99	5.00E–08	10.72	4.33E–08	11.42	–3.33E–08
KLX09D	102.91	107.91	5.0	12.43	–	10.98	–	10.64	–	11.42	–
KLX09D	107.91	112.91	5.0	12.37	–	10.99	–	10.55	–	11.41	–
KLX09D	112.91	117.91	5.0	12.37	9.00E–08	10.99	6.28E–08	10.55	8.22E–08	11.41	2.58E–08
KLX09E	13.87	18.87	5.0	12.84	–1.28E–08	11.52	–2.22E–08	11.99	–	11.63	3.53E–08
KLX09E	18.87	23.87	5.0	12.89	–	11.47	–5.56E–09	12.12	–	11.52	1.11E–08
KLX09E	23.87	28.87	5.0	12.94	–1.08E–07	11.51	–5.83E–09	12.16	–2.63E–07	11.53	1.91E–07
KLX09E	28.87	33.87	5.0	12.95	–1.17E–08	11.55	–	12.24	–2.22E–08	11.50	1.47E–08
KLX09E	33.87	38.87	5.0	12.98	–6.72E–08	11.65	–	12.36	–9.39E–08	11.52	3.67E–08
KLX09E	38.87	43.87	5.0	13.10	–	11.72	–	12.33	–4.33E–08	11.54	2.75E–08
KLX09E	43.87	48.87	5.0	13.10	–1.07E–07	11.85	–	12.29	–2.12E–07	11.60	9.11E–08
KLX09E	48.87	53.87	5.0	13.10	–6.11E–07	11.82	–1.54E–07	12.27	–2.31E–07	11.67	–1.81E–07
KLX09E	53.87	58.87	5.0	13.08	–3.19E–08	11.82	–	12.23	–4.72E–08	11.75	–
KLX09E	58.87	63.87	5.0	13.07	–1.29E–07	11.81	–2.78E–08	12.10	–1.90E–07	11.79	–
KLX09E	63.87	68.87	5.0	13.08	–7.39E–07	11.79	–1.73E–07	12.11	–2.78E–07	11.81	–2.23E–07
KLX09E	68.87	73.87	5.0	13.06	–1.09E–06	11.76	–4.67E–07	12.15	–2.08E–06	11.79	–2.58E–07
KLX09E	73.87	78.87	5.0	13.04	–1.31E–08	11.73	–	12.16	–2.94E–08	11.75	–
KLX09E	78.87	83.87	5.0	13.00	–3.11E–07	11.69	–3.00E–08	12.14	–7.83E–07	11.72	1.61E–08
KLX09E	83.87	88.87	5.0	13.00	–3.81E–07	11.70	–1.03E–07	12.13	–9.44E–07	11.73	–9.06E–08
KLX09E	88.87	93.87	5.0	12.95	–	11.64	–	12.09	–6.39E–09	11.70	–6.11E–09
KLX09E	93.87	98.87	5.0	12.93	1.41E–06	11.60	5.47E–07	12.01	1.61E–06	11.66	–1.91E–07
KLX09E	98.87	103.87	5.0	12.88	–	11.54	–	11.96	–	11.58	–
KLX09E	103.87	108.87	5.0	12.80	–	11.51	–	11.91	–	11.46	–
KLX09E	108.87	113.87	5.0	12.80	3.50E–07	11.51	–3.44E–07	11.91	2.06E–06	11.46	3.28E–07
KLX09F	11.53	16.53	5.0	12.74	9.61E–07	11.59	1.45E–06	12.12	1.39E–06	11.03	2.78E–06

Borehole ID	SecUp L (m)	SecLow L (m)	L_w (m)	h_{CFW} (m.a.s.l.)	Q_C (m^3/s)	h_{DFW} (m.a.s.l.)	Q_D (m^3/s)	h_{EFW} (m.a.s.l.)	Q_E (m^3/s)	h_{FFW} (m.a.s.l.)	Q_F (m^3/s)
KLX09F	16.53	21.53	5.0	12.78	7.78E–08	11.47	1.07E–07	12.21	8.67E–08	11.00	1.21E–07
KLX09F	21.53	26.53	5.0	12.84	–	11.43	–	12.33	–	11.03	1.31E–08
KLX09F	26.53	31.53	5.0	12.89	–	11.48	–3.22E–08	12.36	–2.25E–08	11.02	3.42E–08
KLX09F	31.53	36.53	5.0	12.92	–2.42E–08	11.54	–5.28E–08	12.37	–3.67E–08	10.98	4.06E–08
KLX09F	36.53	41.53	5.0	12.93	–2.03E–08	11.63	–4.78E–08	12.40	–3.42E–08	10.97	1.83E–08
KLX09F	41.53	46.53	5.0	12.91	–3.67E–08	11.72	–8.22E–08	12.24	–5.28E–08	10.96	5.22E–08
KLX09F	46.53	51.53	5.0	12.86	–1.38E–07	11.78	–3.44E–07	12.17	–2.51E–07	11.03	1.76E–07
KLX09F	51.53	56.53	5.0	12.71	–1.78E–08	11.68	–9.44E–08	12.17	–5.44E–08	11.08	2.53E–08
KLX09F	56.53	61.53	5.0	12.68	–1.36E–08	11.64	–1.24E–07	12.17	–5.39E–08	11.25	2.67E–08
KLX09F	61.53	66.53	5.0	12.76	–	11.61	–1.00E–07	12.29	–2.44E–08	11.26	1.75E–08
KLX09F	66.53	71.53	5.0	12.81	–2.39E–08	11.63	–1.00E–07	12.34	–2.78E–08	11.27	2.53E–08
KLX09F	71.53	76.53	5.0	12.81	–3.97E–06	11.58	–1.02E–05	12.34	–2.97E–06	11.26	2.60E–06
KLX09F	76.53	81.53	5.0	12.84	–1.70E–06	11.50	–3.11E–06	12.33	–1.63E–06	11.23	2.69E–06
KLX09F	81.53	86.53	5.0	12.82	–4.67E–08	11.48	–1.27E–07	12.32	–5.72E–08	11.22	1.28E–08
KLX09F	86.53	91.53	5.0	12.81	–	11.46	–	12.32	–	11.22	–
KLX09F	91.53	96.53	5.0	12.77	–	11.42	–	12.28	–	11.19	–
KLX09F	96.53	101.53	5.0	12.77	–	11.45	–	12.25	–	11.15	–
KLX09F	101.53	106.53	5.0	12.73	–	11.39	–	12.20	–	11.11	–
KLX09F	106.53	111.53	5.0	12.69	–	11.34	–	12.06	–	11.05	–
KLX09F	111.53	116.53	5.0	12.63	–5.75E–06	11.28	1.81E–06	11.90	–3.83E–06	10.96	–1.33E–05
KLX09F	116.53	121.53	5.0	12.57	–	11.21	–	11.79	–	10.89	–
KLX09F	121.53	126.53	5.0	12.50	–	11.17	–	11.71	–	10.78	–
KLX09F	126.53	131.53	5.0	12.43	–	11.15	–	11.68	–	10.61	–
KLX09F	131.53	136.53	5.0	12.31	4.83E–08	11.08	5.06E–08	11.73	1.39E–08	10.43	–3.17E–08
KLX09F	136.53	141.53	5.0	12.12	–	11.05	–	11.71	–	10.30	–
KLX09F	141.53	146.53	5.0	12.12	6.00E–06	11.05	6.97E–06	11.71	2.16E–06	10.30	–3.36E–06

Inferred flow anomalies from overlapping flow logging during hydraulic crosshole interference test, boreholes KLX09B–KLX09F

PFL – DIFFERENCE FLOW LOGGING – Inferred flow anomalies from overlapping flow logging during hydraulic crosshole interference test

Borehole ID	Length to flow anom. L (m)	L_w (m)	dL (m)	h_{CFW} (m.a.s.l.)	Calc Ref Q_C (m^3/s)	Q_C (m^3/s)	h_{DFW} (m.a.s.l.)	Calc Ref Q_D (m^3/s)	Q_D (m^3/s)	h_{EFW} (m.a.s.l.)	Calc Ref Q_E (m^3/s)	Q_E (m^3/s)	h_{FFW} (m.a.s.l.)	Calc Ref Q_F (m^3/s)	Q_F (m^3/s)	Comments
KLX09B	15.2	1.0	0.1	11.31	–	–	11.77	1.53E–07	–1.49E–07	10.86	2.14E–07	1.30E–07	11.16	1.94E–07	2.08E–07	
KLX09B	16.4	1.0	0.1	11.32	–	–	11.77	–	–1.00E–08	10.87	–	3.19E–08	11.16	–	4.61E–08	**
KLX09B	17.5	1.0	0.1	11.31	1.51E–08	–	11.77	1.17E–08	–8.06E–09	10.85	1.86E–08	–	11.16	1.63E–08	6.94E–09	
KLX09B	20.8	1.0	0.1	11.33	2.54E–09	–	11.78	1.98E–09	–	10.86	3.13E–09	–	11.17	2.74E–09	–	*
KLX09B	23.8	1.0	0.1	11.33	1.25E–08	–	11.77	9.79E–09	–	10.87	1.54E–08	–	11.16	1.36E–08	–	*
KLX09B	24.1	1.0	0.1	11.33	1.45E–08	–8.33E–09	11.77	1.30E–08	–	10.87	1.61E–08	3.92E–08	11.16	1.51E–08	2.58E–08	*
KLX09B	24.4	1.0	0.1	11.32	2.20E–08	–2.36E–08	11.77	2.08E–08	–	10.88	2.31E–08	3.22E–08	11.16	2.24E–08	7.11E–08	*
KLX09B	25.1	1.0	0.1	11.33	3.18E–08	–7.22E–09	11.77	2.55E–08	–1.64E–08	10.88	3.82E–08	7.78E–09	11.16	3.42E–08	1.64E–08	
KLX09B	28.1	1.0	0.1	11.32	3.90E–09	–	11.75	3.06E–09	–	10.88	4.75E–09	–	11.14	4.25E–09	–	*
KLX09B	31.0	1.0	0.1	11.33	1.13E–08	–	11.76	8.88E–09	–	10.89	1.38E–08	–	11.14	1.24E–08	2.78E–09	
KLX09B	31.8	1.0	0.1	11.33	6.65E–08	–1.33E–08	11.75	5.31E–08	–1.28E–08	10.89	8.05E–08	6.11E–09	11.14	7.26E–08	1.69E–08	
KLX09B	32.6	1.0	0.1	11.32	1.39E–06	–5.36E–07	11.74	1.12E–06	–7.33E–07	10.89	1.66E–06	2.69E–07	11.14	1.50E–06	6.58E–07	
KLX09B	39.6	1.0	0.1	11.33	5.10E–07	–3.61E–08	11.77	3.99E–07	–7.56E–08	10.97	6.00E–07	–4.17E–08	11.22	5.37E–07	5.67E–08	
KLX09B	40.1	1.0	0.1	11.33	4.77E–07	–1.89E–08	11.77	3.73E–07	–4.42E–08	10.97	5.62E–07	–2.33E–08	11.21	5.05E–07	3.61E–08	
KLX09B	42.9	1.0	0.1	11.34	4.50E–09	–	11.77	3.53E–09	–5.00E–09	10.97	5.33E–09	–	11.21	4.79E–09	3.06E–09	
KLX09B	45.1	1.0	0.1	11.35	4.49E–07	–3.19E–08	11.77	3.54E–07	–5.86E–08	10.98	5.33E–07	–5.00E–09	11.21	4.81E–07	3.11E–08	
KLX09B	46.6	1.0	0.1	11.35	5.10E–08	–	11.77	4.02E–08	–6.11E–09	10.99	6.03E–08	–	11.21	5.46E–08	2.78E–09	
KLX09B	48.4	1.0	0.1	11.40	6.87E–08	–6.11E–09	11.77	5.55E–08	–1.33E–08	10.99	8.33E–08	–	11.21	7.58E–08	4.17E–09	
KLX09B	49.4	1.0	0.1	11.40	2.65E–06	–3.89E–07	11.76	2.15E–06	–1.04E–06	10.99	3.21E–06	–8.22E–08	11.21	2.91E–06	3.11E–07	
KLX09B	59.2	1.0	0.1	11.40	4.14E–06	–1.18E–07	11.80	3.30E–06	–2.22E–07	11.06	4.85E–06	–	11.20	4.56E–06	1.36E–07	
KLX09B	59.6	1.0	0.1	11.40	4.05E–06	–2.86E–07	11.80	3.24E–06	–7.67E–07	11.06	4.75E–06	1.06E–08	11.19	4.49E–06	4.31E–07	

Borehole ID	Length to flow anom. L (m)	L_w (m)	dL (m)	h_{CFW} (m.a.s.l.)	Calc Ref Q_C (m^3/s)	Q_C (m^3/s)	h_{DFW} (m.a.s.l.)	Calc Ref Q_D (m^3/s)	Q_D (m^3/s)	h_{EFW} (m.a.s.l.)	Calc Ref Q_E (m^3/s)	Q_E (m^3/s)	h_{FFW} (m.a.s.l.)	Calc Ref Q_F (m^3/s)	Q_F (m^3/s)	Comments
KLX09B	61.4	1.0	0.1	11.40	2.72E–06	–1.95E–07	11.81	2.16E–06	–4.72E–07	11.06	3.19E–06	8.44E–08	11.20	2.99E–06	3.11E–07	
KLX09B	61.7	1.0	0.1	11.41	9.45E–07	–2.78E–08	11.82	7.48E–07	–3.11E–08	11.06	1.11E–06	3.61E–08	11.19	1.05E–06	3.94E–08	
KLX09B	63.2	1.0	0.1	11.40	6.77E–06	–1.23E–07	11.81	5.35E–06	1.35E–07	11.06	7.94E–06	3.89E–07	11.19	7.49E–06	1.70E–07	
KLX09B	63.7	1.0	0.1	11.40	2.02E–07	–1.25E–08	11.81	1.60E–07	1.17E–08	11.07	2.36E–07	1.06E–08	11.19	2.24E–07	1.64E–08	*
KLX09B	65.3	1.0	0.1	11.41	1.35E–06	–2.34E–07	11.81	1.07E–06	–1.69E–08	11.07	1.58E–06	5.14E–07	11.20	1.49E–06	3.42E–07	
KLX09B	67.8	1.0	0.1	11.44	7.96E–08	–9.44E–09	11.82	6.41E–08	–2.00E–08	11.06	9.52E–08	1.00E–08	11.19	8.99E–08	1.00E–08	
KLX09B	68.8	1.0	0.1	11.44	7.68E–07	–5.86E–08	11.81	6.20E–07	–9.22E–08	11.07	9.16E–07	9.97E–08	11.20	8.64E–07	4.03E–08	
KLX09B	69.4	1.0	0.1	11.45	1.27E–07	–	11.81	1.03E–07	–	11.06	1.53E–07	5.00E–09	11.19	1.44E–07	–	
KLX09B	74.9	1.0	0.1	11.45	9.61E–08	3.08E–08	11.82	7.77E–08	2.53E–08	11.07	1.15E–07	–7.44E–08	11.20	1.08E–07	–2.94E–08	
KLX09B	76.6	1.0	0.1	11.46	7.57E–09	–	11.82	6.15E–09	–	11.07	9.09E–09	–	11.21	8.55E–09	–	
KLX09B	77.9	1.0	0.1	11.46	7.71E–08	1.22E–08	11.81	6.33E–08	1.78E–08	11.07	9.24E–08	–2.08E–08	11.18	8.81E–08	–5.56E–09	
KLX09B	78.9	1.0	0.1	11.46	2.88E–07	3.11E–08	11.81	2.37E–07	4.75E–08	11.07	3.45E–07	–3.44E–08	11.18	3.28E–07	–3.94E–08	
KLX09B	79.6	1.0	0.1	11.46	1.52E–06	1.66E–07	11.81	1.24E–06	2.81E–07	11.07	1.82E–06	–1.23E–07	11.19	1.73E–06	–2.53E–07	
KLX09B	80.7	1.0	0.1	11.46	3.77E–06	1.05E–06	11.82	3.06E–06	1.69E–06	11.08	4.52E–06	–7.28E–07	11.19	4.31E–06	–1.53E–06	
KLX09B	81.1	1.0	0.1	11.47	3.59E–07	–	11.82	2.95E–07	–	11.08	4.31E–07	–	11.19	5.91E–06	–1.56E–07	*
KLX09B	81.9	1.0	0.1	11.47	2.26E–06	7.61E–07	11.81	1.85E–06	1.21E–06	11.07	2.74E–06	–4.58E–07	11.19	2.59E–06	–1.04E–06	
KLX09B	82.6	1.0	0.1	11.47	3.94E–08	4.72E–09	11.83	3.21E–08	6.67E–09	11.07	4.74E–08	–1.67E–09	11.19	4.50E–08	–7.22E–09	*
KLX09B	83.2	1.0	0.1	11.46	6.59E–08	6.94E–09	11.82	5.39E–08	1.50E–08	11.07	7.90E–08	–5.00E–09	11.19	7.50E–08	–1.44E–08	
KLX09B	86.2	1.0	0.1	11.47	1.53E–09	–	11.82	1.25E–09	2.78E–09	11.07	1.84E–09	–	11.21	1.73E–09	–4.72E–09	*
KLX09B	91.5	1.0	0.1	11.50	1.64E–09	–	11.88	1.32E–09	–	11.09	1.99E–09	–	11.26	1.84E–09	–	*
KLX09B	91.7	1.0	0.1	11.50	1.53E–09	–	11.87	1.24E–09	–	11.08	1.86E–09	–	11.26	1.72E–09	–	*
KLX09B	93.9	1.0	0.1	11.49	9.90E–08	7.78E–09	11.88	7.92E–08	1.61E–08	11.09	1.19E–07	–	11.26	1.11E–07	–1.67E–08	
KLX09B	97.2	1.0	0.1	11.44	5.90E–08	1.61E–08	11.84	4.69E–08	2.50E–08	11.05	7.08E–08	–	11.21	6.59E–08	–2.44E–08	*
KLX09C	15.5	1.0	0.1	12.74	–	–1.14E–08	12.11	–	–	11.32	–	–	11.64	–	–	**
KLX09C	18.2	1.0	0.1	12.71	5.12E–07	–9.06E–08	12.11	7.47E–07	–2.52E–07	11.36	1.04E–06	2.06E–07	11.65	9.27E–07	2.76E–07	
KLX09C	19.2	1.0	0.1	12.71	–	–	12.11	–	–1.94E–08	11.39	–	1.19E–08	11.66	–	1.25E–08	**
KLX09C	22.4	1.0	0.1	12.78	–	–1.14E–08	12.15	–	–3.50E–08	11.49	–	3.11E–08	11.68	–	4.11E–08	**
KLX09C	23.8	1.0	0.1	12.83	2.47E–06	–6.50E–07	12.19	3.53E–06	–2.06E–06	11.50	4.66E–06	1.82E–06	11.68	4.37E–06	2.66E–06	

Borehole ID	Length to flow anom. L (m)	L_w (m)	dL (m)	h_{CFW} (m.a.s.l.)	Calc Ref Q_C (m^3/s)	Q_C (m^3/s)	h_{DFW} (m.a.s.l.)	Calc Ref Q_D (m^3/s)	Q_D (m^3/s)	h_{EFW} (m.a.s.l.)	Calc Ref Q_E (m^3/s)	Q_E (m^3/s)	h_{FFW} (m.a.s.l.)	Calc Ref Q_F (m^3/s)	Q_F (m^3/s)	Comments
KLX09C	24.9	1.0	0.1	12.87	–	–	12.19	–	–1.19E–08	11.50	–	5.00E–09	11.69	–	1.39E–08	**
KLX09C	27.1	1.0	0.1	12.97	–	–	12.20	–	–	11.42	–	6.11E–09	11.69	–	1.39E–08	**
KLX09C	29.0	1.0	0.1	12.99	–	–2.19E–08	12.20	–	–5.28E–08	11.40	–	4.17E–08	11.70	–	5.53E–08	**
KLX09C	30.4	1.0	0.1	13.01	–	–1.06E–08	12.21	–	–1.08E–08	11.41	–	4.17E–09	11.70	–	1.11E–08	**
KLX09C	35.3	1.0	0.1	13.06	8.34E–08	–2.19E–08	12.23	1.89E–07	–5.33E–08	11.35	3.01E–07	8.33E–09	11.72	2.54E–07	2.75E–08	
KLX09C	36.4	1.0	0.1	13.07	–	–9.44E–09	12.28	–	–6.39E–09	11.28	–	–	11.72	–	–	**
KLX09C	38.4	1.0	0.1	13.05	5.90E–08	–4.72E–08	12.28	1.42E–07	–2.44E–08	11.25	2.53E–07	–	11.74	2.00E–07	6.39E–09	
KLX09C	41.1	1.0	0.1	13.01	–	–1.17E–08	12.29	–	–	11.26	–	–	11.75	–	–	**
KLX09C	45.3	1.0	0.1	12.88	–	–	12.29	–	–2.97E–08	11.26	–	–	11.77	–	–	**
KLX09C	46.3	1.0	0.1	12.87	2.26E–07	–2.89E–07	12.29	3.49E–07	–1.62E–07	11.31	5.57E–07	–1.22E–08	11.79	4.55E–07	1.28E–08	
KLX09C	50.5	1.0	0.1	12.86	–	–6.39E–09	12.34	–	–	11.31	–	–9.44E–09	11.82	–	–9.17E–09	**
KLX09C	53.4	1.0	0.1	12.81	8.06E–07	–1.69E–06	12.35	1.27E–06	–1.17E–06	11.31	2.32E–06	–4.25E–07	11.83	1.80E–06	–4.25E–07	
KLX09C	56.0	1.0	0.1	12.85	3.71E–07	–3.50E–07	12.41	6.01E–07	–2.08E–07	11.30	1.18E–06	–1.08E–07	11.82	9.09E–07	–2.63E–07	
KLX09C	57.4	1.0	0.1	12.85	–	–6.39E–09	12.39	–	–5.28E–09	11.30	–	–5.00E–09	11.83	–	–6.11E–09	**
KLX09C	64.1	1.0	0.1	12.83	2.77E–07	–1.35E–07	12.34	4.80E–07	–1.98E–07	11.29	9.15E–07	–7.44E–08	11.82	6.95E–07	–1.66E–07	
KLX09C	65.9	1.0	0.1	12.82	1.76E–07	–7.89E–08	12.33	3.06E–07	–1.24E–07	11.30	5.80E–07	–5.39E–08	11.82	4.42E–07	–1.05E–07	
KLX09C	66.3	1.0	0.1	12.83	3.63E–07	–1.47E–07	12.32	6.44E–07	–2.11E–07	11.30	1.20E–06	–7.83E–08	11.78	9.41E–07	–2.15E–07	
KLX09C	67.5	1.0	0.1	12.82	3.41E–07	–1.62E–07	12.31	6.00E–07	–2.36E–07	11.31	1.11E–06	–9.39E–08	11.79	8.65E–07	–2.22E–07	
KLX09C	70.6	1.0	0.1	12.82	–	–8.89E–09	12.30	–	–1.36E–08	11.29	–	–	11.79	–	–1.56E–08	**
KLX09C	71.5	1.0	0.1	12.80	1.09E–05	–1.02E–05	12.28	1.90E–05	–1.68E–05	11.29	3.46E–05	–6.92E–06	11.79	2.67E–05	–1.41E–05	
KLX09C	75.6	1.0	0.1	12.83	3.87E–06	–1.28E–06	12.26	7.41E–06	–9.25E–07	11.26	1.36E–05	–1.30E–06	11.77	1.04E–05	–5.56E–06	
KLX09C	76.9	1.0	0.1	12.85	–	–1.58E–08	12.24	–	–	11.25	–	–2.47E–08	11.76	–	–6.31E–08	**
KLX09C	78.3	1.0	0.1	12.85	5.47E–08	–6.11E–09	12.25	1.10E–07	–	11.25	2.03E–07	–7.22E–09	11.75	1.57E–07	–3.94E–08	*
KLX09C	82.8	1.0	0.1	12.84	5.47E–08	–2.44E–08	12.23	1.12E–07	5.56E–09	11.21	2.08E–07	–3.89E–08	11.73	1.59E–07	–7.83E–08	*
KLX09C	83.6	1.0	0.1	12.85	–	–2.14E–08	12.24	–	3.89E–08	11.21	–	–5.67E–08	11.73	–	–2.69E–07	**
KLX09C	84.3	1.0	0.1	12.84	5.48E–07	–9.94E–08	12.24	1.13E–06	8.97E–08	11.20	2.13E–06	–1.73E–07	11.73	1.62E–06	–9.19E–07	
KLX09C	84.9	1.0	0.1	12.83	2.52E–07	–1.11E–07	12.24	5.31E–07	5.28E–08	11.19	1.03E–06	–2.67E–07	11.73	7.72E–07	–7.11E–07	*
KLX09C	96.8	1.0	0.1	12.78	7.00E–08	2.78E–09	11.92	1.70E–07	2.22E–08	11.09	2.67E–07	–5.56E–09	11.51	2.18E–07	–2.94E–08	

Borehole ID	Length to flow anom. L (m)	L_w (m)	dL (m)	h_{CFW} (m.a.s.l.)	Calc Ref Q_C (m^3/s)	Q_C (m^3/s)	h_{DFW} (m.a.s.l.)	Calc Ref Q_D (m^3/s)	Q_D (m^3/s)	h_{EFW} (m.a.s.l.)	Calc Ref Q_E (m^3/s)	Q_E (m^3/s)	h_{FFW} (m.a.s.l.)	Calc Ref Q_F (m^3/s)	Q_F (m^3/s)	Comments
KLX09C	108.3	1.0	0.1	12.69	5.16E–06	7.42E–07	11.98	1.13E–05	1.31E–06	10.85	2.11E–05	4.53E–07	11.47	1.57E–05	1.99E–07	*
KLX09C	116.0	1.0	0.1	12.56	4.96E–07	2.69E–08	11.88	1.10E–06	6.22E–08	10.82	2.04E–06	9.44E–09	11.44	1.49E–06	4.36E–08	
KLX09C	117.0	1.0	0.1	12.57	1.78E–05	8.19E–06	11.86	4.32E–05	1.00E–05	10.81	8.08E–05	4.22E–06	11.42	5.90E–05	1.00E–05	
KLX09D	16.4	1.0	0.1	12.75	1.62E–07	1.36E–08	11.26	3.54E–07	1.25E–08	10.90	4.00E–07	5.64E–08	11.66	3.02E–07	7.58E–08	
KLX09D	18.8	1.0	0.1	12.77	9.35E–09	–	11.30	2.40E–08	–	10.91	2.78E–08	–	11.66	2.04E–08	4.17E–09	*
KLX09D	20.2	1.0	0.1	12.77	1.64E–06	2.76E–07	11.31	3.15E–06	2.62E–07	10.91	3.56E–06	7.86E–07	11.65	2.80E–06	1.15E–06	
KLX09D	21.7	1.0	0.1	12.78	2.44E–07	1.58E–08	11.35	5.19E–07	–1.53E–08	10.92	6.02E–07	1.00E–07	11.65	4.61E–07	1.40E–07	
KLX09D	23.1	1.0	0.1	12.78	9.23E–09	–	11.40	2.28E–08	–	10.90	2.77E–08	7.50E–09	11.62	2.06E–08	9.17E–09	
KLX09D	25.3	1.0	0.1	12.77	–	–	11.41	–	–5.00E–09	10.93	–	5.00E–09	11.60	–	6.94E–09	**
KLX09D	27.5	1.0	0.1	12.73	1.58E–07	–4.56E–08	11.40	3.26E–07	–7.56E–08	10.94	3.84E–07	6.44E–08	11.59	3.02E–07	6.64E–08	
KLX09D	29.6	1.0	0.1	12.67	1.70E–08	–1.19E–08	11.41	3.76E–08	–9.44E–09	11.02	4.40E–08	–	11.59	3.47E–08	–	
KLX09D	30.6	1.0	0.1	12.65	5.33E–07	–1.72E–07	11.42	9.07E–07	–3.14E–07	11.05	1.02E–06	3.06E–07	11.59	8.55E–07	3.72E–07	
KLX09D	34.6	1.0	0.1	12.66	1.77E–08	–7.78E–09	11.46	3.76E–08	–8.06E–09	11.16	4.26E–08	2.78E–09	11.57	3.58E–08	4.72E–09	
KLX09D	36.6	1.0	0.1	12.66	6.30E–09	–	11.45	1.36E–08	–	11.19	1.52E–08	–	11.56	1.30E–08	–	*
KLX09D	38.1	1.0	0.1	12.65	3.88E–08	–2.08E–08	11.46	7.12E–08	–2.75E–08	11.20	7.83E–08	1.42E–08	11.56	6.85E–08	2.22E–08	
KLX09D	44.7	1.0	0.1	12.63	1.68E–08	–7.50E–09	11.40	3.70E–08	–1.89E–08	11.24	3.97E–08	–	11.65	3.29E–08	–	
KLX09D	50.2	1.0	0.1	12.53	1.87E–07	–2.50E–07	11.28	4.12E–07	–4.72E–08	11.24	4.19E–07	–1.75E–07	11.67	3.42E–07	–4.44E–08	
KLX09D	51.9	1.0	0.1	12.50	3.93E–07	–5.78E–07	11.26	8.88E–07	2.33E–08	11.24	8.96E–07	–6.47E–07	11.68	7.20E–07	–1.31E–07	
KLX09D	54.6	1.0	0.1	12.52	1.67E–07	–3.89E–07	11.25	2.53E–07	–5.94E–08	11.27	2.50E–07	–5.83E–08	11.70	1.70E–07	–4.78E–08	
KLX09D	55.3	1.0	0.1	12.51	3.86E–07	–5.44E–07	11.25	8.67E–07	–9.50E–08	11.27	8.60E–07	–1.26E–07	11.71	6.92E–07	–9.25E–08	*
KLX09D	56.5	1.0	0.1	12.50	1.93E–07	–9.58E–08	11.23	3.90E–07	–5.53E–08	11.26	3.83E–07	–1.18E–07	11.71	2.83E–07	–5.11E–08	
KLX09D	64.5	1.0	0.1	12.47	3.92E–07	–1.47E–07	11.26	8.53E–07	2.31E–08	11.20	8.76E–07	–3.50E–07	11.79	6.51E–07	–7.83E–08	
KLX09D	65.7	1.0	0.1	12.47	5.79E–06	–7.75E–07	11.24	1.33E–05	–4.28E–06	11.19	1.36E–05	2.04E–06	11.76	1.01E–05	–2.15E–06	
KLX09D	67.3	1.0	0.1	12.46	1.63E–06	–5.42E–07	11.25	3.64E–06	–3.33E–07	11.16	3.79E–06	–7.08E–07	11.73	2.84E–06	–5.33E–07	
KLX09D	67.6	1.0	0.1	12.46	1.13E–06	–4.81E–07	11.26	2.48E–06	–1.29E–07	11.15	2.60E–06	–3.69E–07	11.73	1.95E–06	–2.75E–07	*
KLX09D	68.4	1.0	0.1	12.46	2.78E–07	–8.22E–08	11.28	6.03E–07	–5.11E–08	11.15	6.39E–07	–2.39E–08	11.72	4.82E–07	–5.22E–08	
KLX09D	74.8	1.0	0.1	12.46	1.26E–05	3.33E–06	11.32	2.81E–05	3.92E–06	11.10	3.11E–05	–1.50E–08	11.63	2.39E–05	1.39E–06	
KLX09D	77.9	1.0	0.1	12.44	2.41E–08	–	11.30	5.27E–08	–	11.10	5.77E–08	–9.17E–09	11.60	4.52E–08	–	

Borehole ID	Length to flow anom. L (m)	L_w (m)	dL (m)	h_{CFW} (m.a.s.l.)	Calc Ref Q_C (m^3/s)	Q_C (m^3/s)	h_{DFW} (m.a.s.l.)	Calc Ref Q_D (m^3/s)	Q_D (m^3/s)	h_{EFW} (m.a.s.l.)	Calc Ref Q_E (m^3/s)	Q_E (m^3/s)	h_{FFW} (m.a.s.l.)	Calc Ref Q_F (m^3/s)	Q_F (m^3/s)	Comments
KLX09D	81.9	1.0	0.1	12.42	4.40E–09	–	11.25	9.99E–09	–	11.09	1.08E–08	–	11.56	8.51E–09	–	
KLX09D	82.6	1.0	0.1	12.42	4.63E–08	7.22E–09	11.24	1.06E–07	2.00E–08	11.11	1.13E–07	–2.44E–08	11.54	9.10E–08	–1.94E–08	
KLX09D	83.2	1.0	0.1	12.41	1.47E–07	3.47E–08	11.24	3.52E–07	4.28E–08	11.11	3.75E–07	–1.44E–07	11.53	3.01E–07	–3.44E–08	
KLX09D	84.2	1.0	0.1	12.41	3.52E–07	7.22E–08	11.23	8.42E–07	1.11E–07	11.10	8.96E–07	–4.25E–07	11.53	7.18E–07	–8.78E–08	
KLX09D	84.9	1.0	0.1	12.40	2.85E–07	5.56E–08	11.24	6.61E–07	8.03E–08	11.10	7.07E–07	–4.11E–07	11.53	5.67E–07	–4.72E–08	
KLX09D	85.3	1.0	0.1	12.41	1.33E–07	2.50E–08	11.22	3.07E–07	3.36E–08	11.10	3.24E–07	–1.59E–07	11.52	2.63E–07	–2.78E–08	
KLX09D	85.9	1.0	0.1	12.40	4.05E–08	5.00E–09	11.21	9.34E–08	6.67E–09	11.09	9.88E–08	–4.47E–08	11.51	8.01E–08	–	
KLX09D	86.3	1.0	0.1	12.40	2.17E–08	7.94E–08	11.22	4.99E–08	–	11.10	5.28E–08	–2.28E–08	11.51	4.30E–08	–	
KLX09D	87.5	1.0	0.1	12.39	4.42E–09	–	11.20	1.03E–08	–	11.08	1.08E–08	6.39E–09	11.51	8.73E–09	–	
KLX09D	96.3	1.0	0.1	12.35	6.38E–08	1.88E–07	11.14	1.53E–07	1.71E–07	10.97	1.65E–07	1.67E–07	11.47	1.28E–07	–7.78E–09	
KLX09D	102.3	1.0	0.1	12.28	2.18E–08	5.92E–08	11.01	8.07E–08	5.00E–08	10.80	9.04E–08	4.44E–08	11.46	5.98E–08	–3.22E–08	
KLX09D	102.9	1.0	0.1	12.28	6.28E–09	–	10.99	1.58E–08	–	10.76	1.75E–08	–	11.43	1.26E–08	–	
KLX09D	111.6	1.0	0.1	12.15	3.27E–09	–	10.79	7.99E–09	–	10.53	8.90E–09	–	11.28	6.29E–09	–	
KLX09D	112.2	1.0	0.1	12.13	2.69E–08	–	10.78	6.48E–08	–	10.52	7.21E–08	–	11.27	5.11E–08	–	
KLX09D	113.7	1.0	0.1	12.10	9.01E–09	–	10.73	2.17E–08	–	10.45	2.43E–08	–	11.23	1.71E–08	–	
KLX09D	115.9	1.0	0.1	12.09	1.85E–07	8.00E–08	10.62	4.75E–07	5.78E–08	10.42	5.14E–07	6.75E–08	11.15	3.70E–07	9.17E–09	
KLX09E	17.7	1.0	0.1	12.61	–	–8.33E–09	11.53	–	–1.03E–08	12.24	–	–	11.52	–	2.08E–08	**
KLX09E	19.8	1.0	0.1	12.63	–	–	11.59	–	–5.00E–09	12.19	–	–	11.48	–	1.03E–08	**
KLX09E	25.7	1.0	0.1	12.72	–	–	11.75	–	–	12.18	–	–	11.50	–	6.11E–09	**
KLX09E	28.5	1.0	0.1	12.75	2.16E–07	–9.86E–08	11.77	3.93E–07	–1.28E–08	12.17	3.21E–07	–2.72E–07	11.49	4.44E–07	1.79E–07	
KLX09E	33.4	1.0	0.1	12.79	–	–7.78E–09	11.78	–	–	12.20	–	–1.06E–08	11.52	–	6.67E–09	**
KLX09E	35.5	1.0	0.1	12.81	–	–	11.80	–	–	12.21	–	–6.67E–09	11.52	–	2.78E–09	**
KLX09E	38.6	1.0	0.1	12.83	6.26E–08	–5.44E–08	11.79	1.26E–07	–	12.20	1.01E–07	–8.00E–08	11.54	1.41E–07	3.53E–08	
KLX09E	41.9	1.0	0.1	12.84	–	–	11.80	–	–	12.21	–	–2.31E–08	11.54	–	2.53E–08	**
KLX09E	45.8	1.0	0.1	12.90	1.40E–07	–8.17E–08	11.83	2.90E–07	–	12.18	2.41E–07	–2.06E–07	11.56	3.27E–07	9.47E–08	
KLX09E	46.5	1.0	0.1	12.91	1.76E–08	–1.11E–08	11.83	4.77E–08	–	12.18	3.79E–08	–	11.55	5.55E–08	0.00E+00	*
KLX09E	49.7	1.0	0.1	12.92	2.36E–07	–5.56E–07	11.83	6.08E–07	–1.53E–07	12.17	4.92E–07	–2.43E–07	11.55	7.04E–07	1.53E–07	
KLX09E	54.4	1.0	0.1	12.92	4.32E–08	–1.89E–08	11.81	1.16E–07	–	12.16	9.29E–08	–1.28E–08	11.56	1.32E–07	–	

Borehole ID	Length to flow anom. L (m)	L_w (m)	dL (m)	h_{CFW} (m.a.s.l.)	Calc Ref Q_C (m^3/s)	Q_C (m^3/s)	h_{DFW} (m.a.s.l.)	Calc Ref Q_D (m^3/s)	Q_D (m^3/s)	h_{EFW} (m.a.s.l.)	Calc Ref Q_E (m^3/s)	Q_E (m^3/s)	h_{FFW} (m.a.s.l.)	Calc Ref Q_F (m^3/s)	Q_F (m^3/s)	Comments
KLX09E	58.9	1.0	0.1	12.91	8.36E–08	–1.09E–07	11.80	1.96E–07	–2.28E–08	12.12	1.64E–07	–1.63E–07	11.57	2.19E–07	–	
KLX09E	64.3	1.0	0.1	12.91	5.98E–08	–3.92E–08	11.78	1.48E–07	–8.06E–09	12.08	1.24E–07	–3.00E–08	11.56	1.65E–07	–8.33E–09	
KLX09E	67.1	1.0	0.1	12.90	4.67E–07	–6.81E–07	11.77	1.10E–06	–1.60E–07	12.06	9.39E–07	–2.55E–07	11.55	1.23E–06	–1.71E–07	
KLX09E	70.5	1.0	0.1	12.91	6.78E–08	–3.72E–08	11.75	1.70E–07	–1.33E–08	12.04	1.44E–07	–6.72E–08	11.55	1.88E–07	–5.00E–09	
KLX09E	71.3	1.0	0.1	12.90	6.44E–07	–9.94E–07	11.74	1.51E–06	–4.44E–07	12.03	1.30E–06	–1.69E–06	11.56	1.65E–06	–1.96E–07	
KLX09E	71.8	1.0	0.1	12.91	1.64E–07	–1.91E–07	11.75	3.82E–07	–9.78E–08	12.04	3.27E–07	–3.44E–07	11.56	4.17E–07	–4.03E–08	
KLX09E	73.6	1.0	0.1	12.91	–	–4.03E–08	11.73	–	–1.69E–08	12.02	–	–5.97E–08	11.55	–	–6.67E–09	**
KLX09E	77.5	1.0	0.1	12.90	–	–6.39E–09	11.71	–	–	12.01	–	–1.11E–08	11.53	–	–	**
KLX09E	78.1	1.0	0.1	12.90	–	–9.44E–09	11.71	–	–	12.00	–	–1.75E–08	11.53	–	–	**
KLX09E	81.8	1.0	0.1	12.88	2.34E–06	–3.08E–07	11.70	5.58E–06	–2.83E–08	11.99	4.78E–06	–7.53E–07	11.50	6.13E–06	1.53E–08	
KLX09E	83.8	1.0	0.1	12.90	4.92E–08	–	11.72	1.22E–07	–	12.00	1.04E–07	–7.22E–09	11.46	1.38E–07	3.89E–09	
KLX09E	87.5	1.0	0.1	12.87	2.09E–06	–3.86E–07	11.68	5.09E–06	–8.83E–08	11.98	4.34E–06	–9.14E–07	11.41	5.77E–06	–8.56E–08	
KLX09E	89.7	1.0	0.1	12.86	4.66E–08	–	11.67	1.19E–07	–	11.96	1.01E–07	–5.83E–09	11.39	1.35E–07	–3.33E–09	
KLX09E	96.9	1.0	0.1	12.76	3.25E–06	6.50E–08	11.58	8.03E–06	1.94E–08	11.94	6.57E–06	1.27E–07	11.26	9.33E–06	–	
KLX09E	97.8	1.0	0.1	12.75	1.17E–05	1.13E–06	11.59	2.84E–05	3.61E–07	11.95	2.32E–05	1.27E–06	11.26	3.31E–05	–1.26E–07	
KLX09E	98.4	1.0	0.1	12.75	7.46E–07	2.78E–08	11.59	1.78E–06	3.33E–08	11.97	1.44E–06	1.61E–08	11.27	2.06E–06	–8.89E–09	
KLX09E	100.4	1.0	0.1	12.73	6.43E–08	–	11.57	1.58E–07	–	11.98	1.25E–07	–	11.26	1.83E–07	–	*
KLX09E	101.4	1.0	0.1	12.72	6.69E–08	–	11.55	1.65E–07	–	12.00	1.27E–07	–	11.26	1.89E–07	–	
KLX09E	104.9	1.0	0.1	12.68	2.08E–08	–	11.47	5.23E–08	–	12.01	3.82E–08	–	11.19	5.96E–08	–	
KLX09E	107.3	1.0	0.1	12.63	4.20E–08	–	11.38	1.07E–07	–	12.01	7.41E–08	–	11.24	1.14E–07	–	*
KLX09E	111.7	1.0	0.1	12.58	1.27E–05	8.92E–07	11.28	3.56E–05	–1.00E–07	11.97	2.35E–05	1.93E–06	11.29	3.54E–05	3.11E–07	
KLX09E	114.4	1.0	0.1	12.50	–	1.53E–08	11.14	–	–	11.91	–	–	11.29	–	–	**
KLX09F	9.9	1.0	0.1	12.84	–	–	11.57	–	–	12.13	–	–	11.10	–	–	*
KLX09F	11.5	1.0	0.1	12.85	–	1.03E–08	11.56	–	–	12.14	–	–	11.09	–	–	**
KLX09F	12.9	1.0	0.1	12.88	1.06E–06	1.08E–06	11.55	1.55E–06	1.29E–06	12.16	1.32E–06	1.34E–06	11.11	1.71E–06	2.32E–06	
KLX09F	16.7	1.0	0.1	12.94	–	4.72E–09	11.56	–	6.67E–09	12.25	–	4.44E–09	10.97	–	5.28E–09	**
KLX09F	17.2	1.0	0.1	12.94	–	6.94E–08	11.57	–	9.83E–08	12.26	–	8.72E–08	10.97	–	1.14E–07	**
KLX09F	18.6	1.0	0.1	12.94	–	–	11.57	–	–	12.26	–	–	10.98	–	3.33E–09	**

Borehole ID	Length to flow anom. L (m)	L_w (m)	dL (m)	h_{CFW} (m.a.s.l.)	Calc Ref Q_C (m^3/s)	Q_C (m^3/s)	h_{DFW} (m.a.s.l.)	Calc Ref Q_D (m^3/s)	Q_D (m^3/s)	h_{EFW} (m.a.s.l.)	Calc Ref Q_E (m^3/s)	Q_E (m^3/s)	h_{FFW} (m.a.s.l.)	Calc Ref Q_F (m^3/s)	Q_F (m^3/s)	Comments
KLX09F	24.0	1.0	0.1	12.86	–	–	11.57	–	–	12.33	–	–	10.98	–	1.17E–08	**
KLX09F	30.7	1.0	0.1	12.80	–	–	11.57	–	–1.31E–08	12.44	–	–1.00E–08	10.99	–	2.22E–08	**
KLX09F	31.7	1.0	0.1	12.79	–	–	11.58	–	–1.06E–08	12.47	–	–7.78E–09	10.98	–	1.11E–08	*'
KLX09F	33.2	1.0	0.1	12.77	–	–7.78E–09	11.59	–	–1.56E–08	12.47	–	–1.17E–08	10.98	–	1.31E–08	**
KLX09F	33.7	1.0	0.1	12.77	–	–	11.59	–	–	12.45	–	–	10.98	–	3.89E–09	**
KLX09F	35.5	1.0	0.1	12.74	–	–1.22E–08	11.57	–	–1.94E–08	12.46	–	–1.56E–08	10.98	–	1.94E–08	**
KLX09F	38.5	1.0	0.1	12.73	–	–1.78E–08	11.60	–	–3.36E–08	12.49	–	–2.61E–08	11.01	–	2.83E–08	**
KLX09F	42.1	1.0	0.1	12.66	–	–1.50E–08	11.61	–	–2.39E–08	12.42	–	–1.78E–08	11.01	–	2.58E–08	**
KLX09F	43.1	1.0	0.1	12.62	–	–9.44E–09	11.61	–	–1.06E–08	12.41	–	–1.14E–08	11.01	–	8.89E–09	**
KLX09F	45.6	1.0	0.1	12.61	–	–1.39E–08	11.61	–	–3.28E–08	12.34	–	–2.28E–08	11.01	–	1.94E–08	**
KLX09F	46.9	1.0	0.1	12.64	–	–2.22E–08	11.64	–	–3.56E–08	12.30	–	–2.72E–08	11.04	–	3.94E–08	**
KLX09F	48.2	1.0	0.1	12.64	2.72E–07	–8.39E–08	11.64	5.69E–07	–1.71E–07	12.29	3.76E–07	–1.31E–07	11.04	7.46E–07	1.27E–07	
KLX09F	49.7	1.0	0.1	12.63	4.06E–08	–1.00E–08	11.63	8.84E–08	–2.11E–08	12.27	5.78E–08	–1.69E–08	11.04	1.17E–07	1.14E–08	
KLX09F	54.0	1.0	0.1	12.63	–	–	11.63	–	–1.17E–08	12.21	–	–8.33E–09	11.04	–	5.00E–09	**
KLX09F	54.9	1.0	0.1	12.64	7.92E–08	–1.17E–08	11.62	1.75E–07	–5.28E–08	12.21	1.20E–07	–3.50E–08	11.03	2.31E–07	1.78E–08	
KLX09F	59.9	1.0	0.1	12.63	8.71E–08	–9.17E–09	11.61	1.93E–07	–3.17E–08	12.22	1.30E–07	–2.50E–08	11.08	2.48E–07	2.39E–08	
KLX09F	61.3	1.0	0.1	12.63	–	–	11.60	–	–6.67E–09	12.21	–	–	11.08	–	–	**
KLX09F	62.9	1.0	0.1	12.63	8.97E–08	–	11.60	2.01E–07	–7.00E–08	12.22	1.34E–07	–2.06E–08	11.07	2.58E–07	1.86E–08	
KLX09F	67.0	1.0	0.1	12.65	–	–	11.65	–	–6.94E–09	12.24	–	–	11.08	–	–	**
KLX09F	68.4	1.0	0.1	12.66	6.84E–08	–2.00E–08	11.65	1.52E–07	–3.36E–08	12.25	1.02E–07	–2.39E–08	11.07	1.99E–07	2.39E–08	
KLX09F	71.8	1.0	0.1	12.66	9.04E–07	–7.89E–08	11.64	2.03E–06	–3.22E–07	12.24	1.37E–06	–8.94E–08	11.08	2.65E–06	5.33E–08	
KLX09F	73.1	1.0	0.1	12.64	3.29E–06	–1.33E–06	11.62	7.09E–06	–5.22E–06	12.24	4.78E–06	–1.26E–06	11.06	9.17E–06	9.56E–07	
KLX09F	76.1	1.0	0.1	12.67	6.57E–06	–2.26E–06	11.61	1.49E–05	–3.67E–06	12.22	1.01E–05	–1.38E–06	11.10	1.90E–05	1.50E–06	
KLX09F	79.6	1.0	0.1	12.67	4.34E–06	–1.25E–06	11.59	9.78E–06	–3.31E–06	12.21	6.66E–06	–9.19E–07	11.09	1.23E–05	2.32E–06	
KLX09F	80.1	1.0	0.1	12.67	4.35E–06	–6.39E–07	11.59	1.00E–05	–1.44E–06	12.21	6.77E–06	–5.94E–07	11.08	1.27E–05	1.09E–06	
KLX09F	81.1	1.0	0.1	12.66	2.25E–06	–1.88E–07	11.57	5.22E–06	–4.75E–07	12.21	3.48E–06	–1.81E–07	11.08	6.55E–06	2.62E–07	
KLX09F	81.8	1.0	0.1	12.67	4.45E–07	–3.94E–08	11.58	1.04E–06	–1.23E–07	12.20	7.00E–07	–4.83E–08	11.08	1.31E–06	1.61E–08	
KLX09F	82.4	1.0	0.1	12.67	1.70E–07	–7.78E–09	11.57	4.03E–07	–1.22E–08	12.22	2.65E–07	–6.67E–09	11.08	5.07E–07	–	
KLX09F	94.4	1.0	0.1	12.62	4.42E–08	–	11.48	9.90E–08	–	12.11	6.87E–08	–	10.95	1.24E–07	–	**

Borehole ID	Length to flow anom. L (m)	L_w (m)	dL (m)	h_{CFW} (m.a.s.l.)	Calc Ref Q_C (m^3/s)	Q_C (m^3/s)	h_{DFW} (m.a.s.l.)	Calc Ref Q_D (m^3/s)	Q_D (m^3/s)	h_{EFW} (m.a.s.l.)	Calc Ref Q_E (m^3/s)	Q_E (m^3/s)	h_{FFW} (m.a.s.l.)	Calc Ref Q_F (m^3/s)	Q_F (m^3/s)	Comments
KLX09F	102.5	1.0	0.1	12.60	1.02E–07	–	11.44	2.26E–07	–	12.06	1.60E–07	–	10.93	2.80E–07	–	
KLX09F	113.3	1.0	0.1	12.50	4.36E–05	–6.36E–06	11.31	1.01E–04	5.89E–07	11.92	7.14E–05	–4.14E–06	10.98	1.16E–04	–1.25E–05	
KLX09F	132.0	1.0	0.1	12.21	1.47E–07	3.28E–08	10.99	3.57E–07	3.72E–08	11.76	2.24E–07	1.28E–08	10.63	4.19E–07	–3.89E–08	
KLX09F	133.5	1.0	0.1	12.18	4.14E–08	–	10.97	9.30E–08	–	11.75	5.97E–08	–	10.57	1.10E–07	–	**
KLX09F	134.5	1.0	0.1	12.16	4.09E–08	–	10.96	9.15E–08	–	11.77	5.73E–08	–	10.53	1.10E–07	–	
KLX09F	143.1	1.0	0.1	11.94	3.53E–08	–	10.93	7.09E–08	9.17E–09	11.57	4.83E–08	–	10.15	9.84E–08	–	
KLX09F	144.2	1.0	0.1	11.94	1.14E–07	5.44E–08	10.92	2.77E–07	6.39E–08	11.54	1.78E–07	1.58E–08	10.11	4.06E–07	4.00E–08	
KLX09F	145.5	1.0	0.1	11.92	2.02E–05	5.97E–06	10.88	4.70E–05	5.94E–06	11.49	3.13E–05	2.33E–06	10.06	6.82E–05	3.28E–06	

* Uncertain = The flow rate is less than 30 mL/h or the flow anomalies are overlapping or they are unclear because of noise.

** Found only during hydraulic crosshole interference test

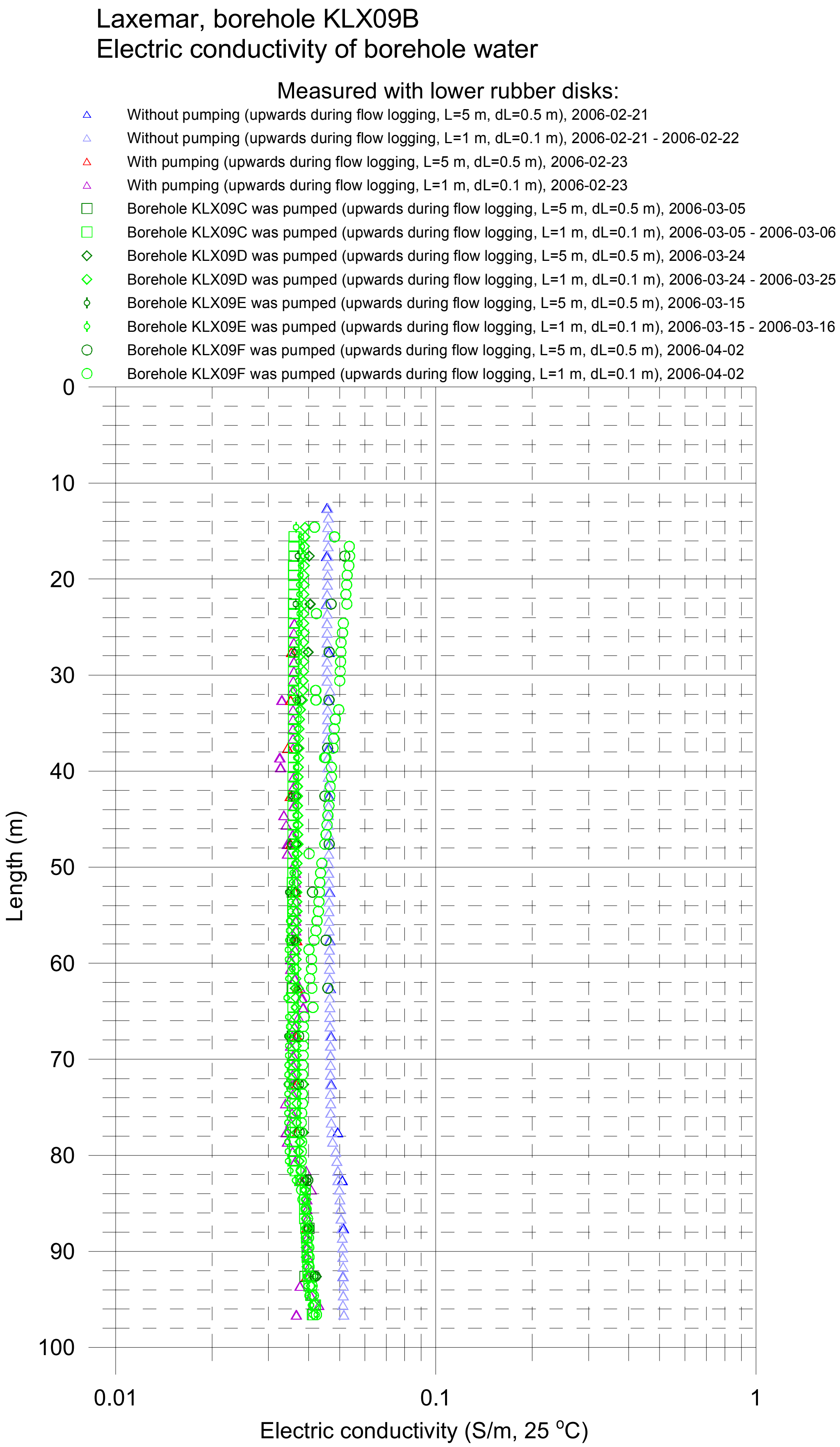
Appendix 9

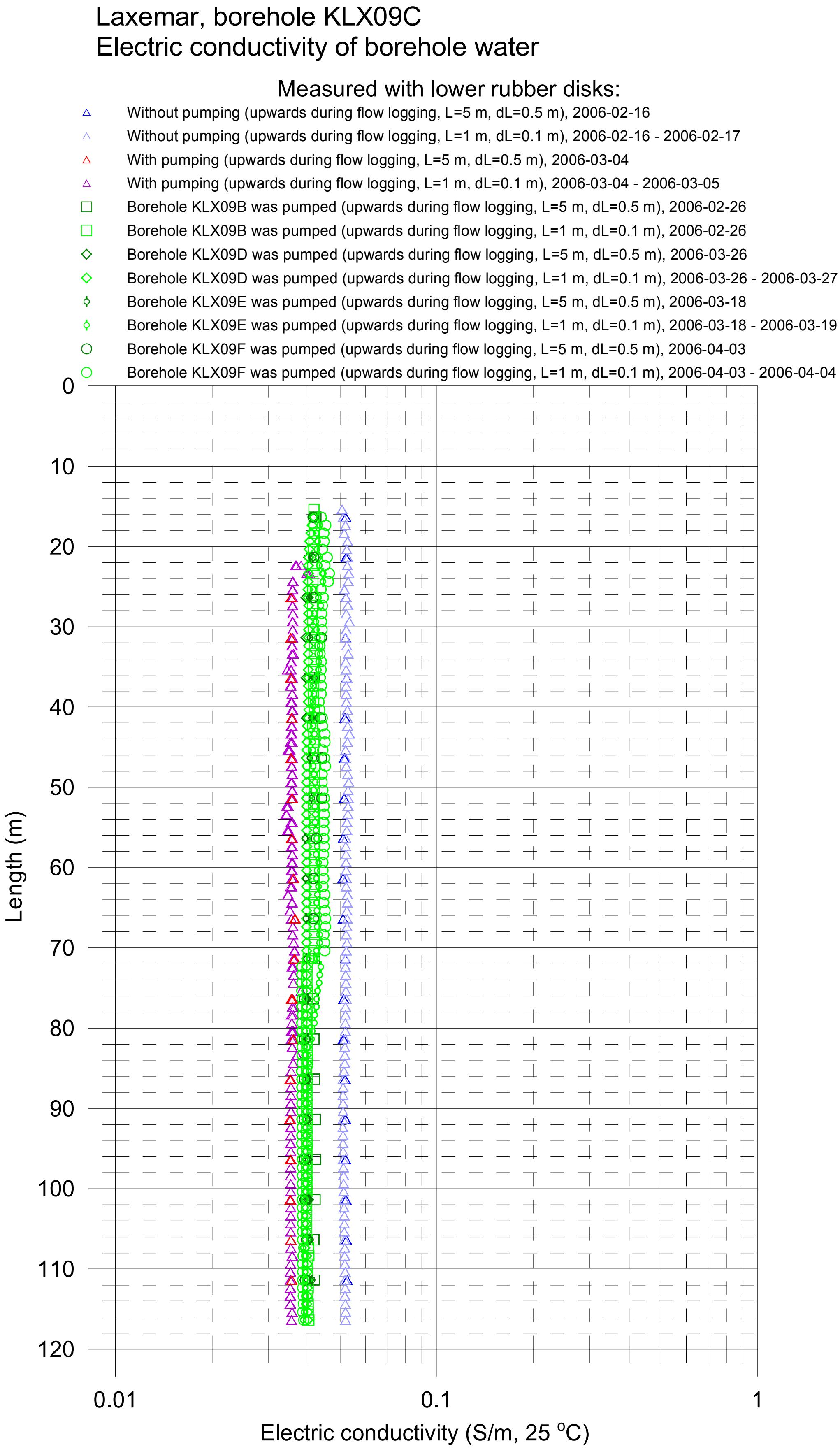
Explanations for the tables in Appendices 7 and 8

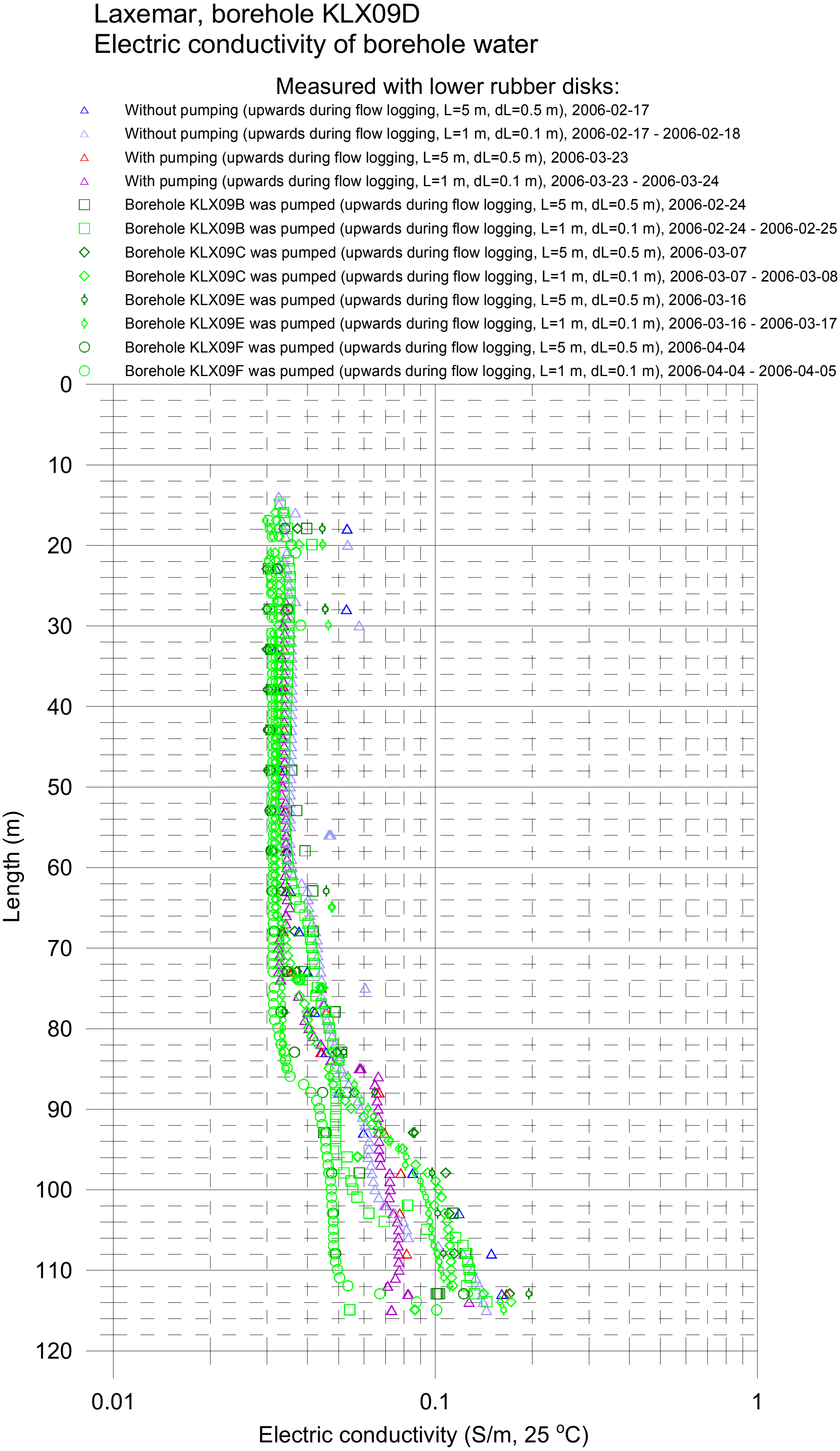
Header	Unit	Explanations
Borehole		ID for borehole
Secup	m	Length along the borehole for the upper limit of the test section (based on corrected length L)
Seclow	m	Length along the borehole for the lower limit of the test section (based on corrected length L)
L	m	Corrected length along borehole based on SKB procedures for length correction.
Length to flow anom.	m	Length along the borehole to inferred flow anomaly during overlapping flow logging
L_w	m	Section length used in the difference flow logging
dL	m	Step length (increment) used in the difference flow logging
Q_B	m^3/s	Measured flow rate through the test section or flow anomaly during hydraulic crosshole interference test (Borehole KLX09B was pumped)
Q_C	m^3/s	Measured flow rate through the test section or flow anomaly during hydraulic crosshole interference test (Borehole KLX09C was pumped)
Q_D	m^3/s	Measured flow rate through the test section or flow anomaly during hydraulic crosshole interference test (Borehole KLX09D was pumped)
Q_E	m^3/s	Measured flow rate through the test section or flow anomaly during hydraulic crosshole interference test (Borehole KLX09E was pumped)
Q_F	m^3/s	Measured flow rate through the test section or flow anomaly during hydraulic crosshole interference test (Borehole KLX09F was pumped)
Calc Ref Q_B	m^3/s	Calculated reference flow rate through the test section or flow anomaly during hydraulic crosshole interference test (Borehole KLX09B was pumped)
Calc Ref Q_C	m^3/s	Calculated reference flow rate through the test section or flow anomaly during hydraulic crosshole interference test (Borehole KLX09C was pumped)
Calc Ref Q_D	m^3/s	Calculated reference flow rate through the test section or flow anomaly during hydraulic crosshole interference test (Borehole KLX09D was pumped)
Calc Ref Q_E	m^3/s	Calculated reference flow rate through the test section or flow anomaly during hydraulic crosshole interference test (Borehole KLX09E was pumped)
Calc Ref Q_F	m^3/s	Calculated reference flow rate through the test section or flow anomaly during hydraulic crosshole interference test (Borehole KLX09F was pumped)
h_{BFW}	m.a.s.l.	Corrected initial hydraulic head along the hole due to e.g. varying salinity conditions of the borehole fluid during hydraulic crosshole interference test (Borehole KLX09B was pumped)
h_{CFW}	m.a.s.l.	Corrected initial hydraulic head along the hole due to e.g. varying salinity conditions of the borehole fluid during hydraulic crosshole interference test (Borehole KLX09C was pumped)
h_{DFW}	m.a.s.l.	Corrected initial hydraulic head along the hole due to e.g. varying salinity conditions of the borehole fluid during hydraulic crosshole interference test (Borehole KLX09D was pumped)
h_{EFW}	m.a.s.l.	Corrected initial hydraulic head along the hole due to e.g. varying salinity conditions of the borehole fluid during hydraulic crosshole interference test (Borehole KLX09E was pumped)
h_{FFW}	m.a.s.l.	Corrected initial hydraulic head along the hole due to e.g. varying salinity conditions of the borehole fluid during hydraulic crosshole interference test (Borehole KLX09F was pumped)

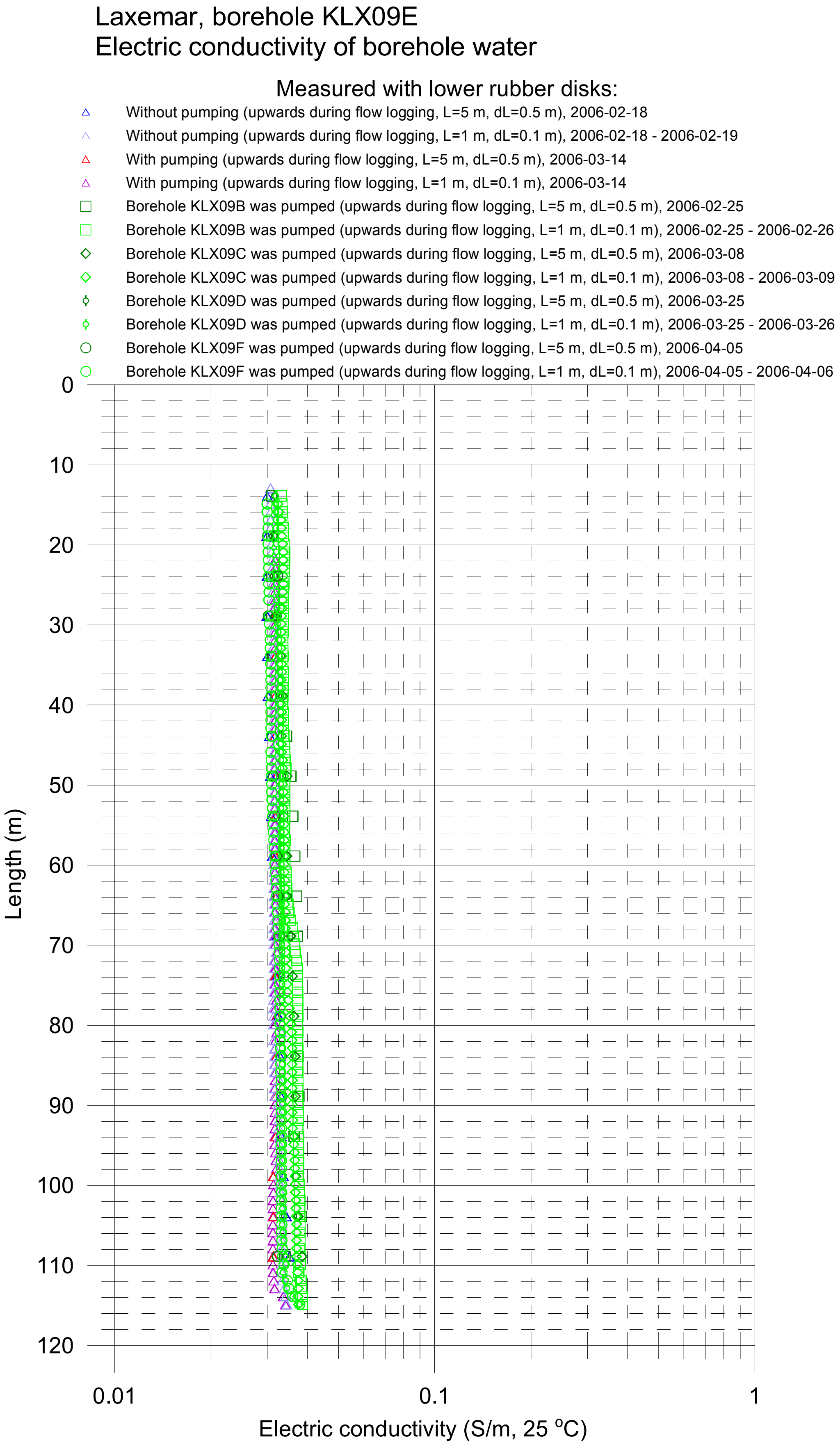
Appendix 10

Electric conductivity of borehole water, boreholes KLX09B–KLX09F



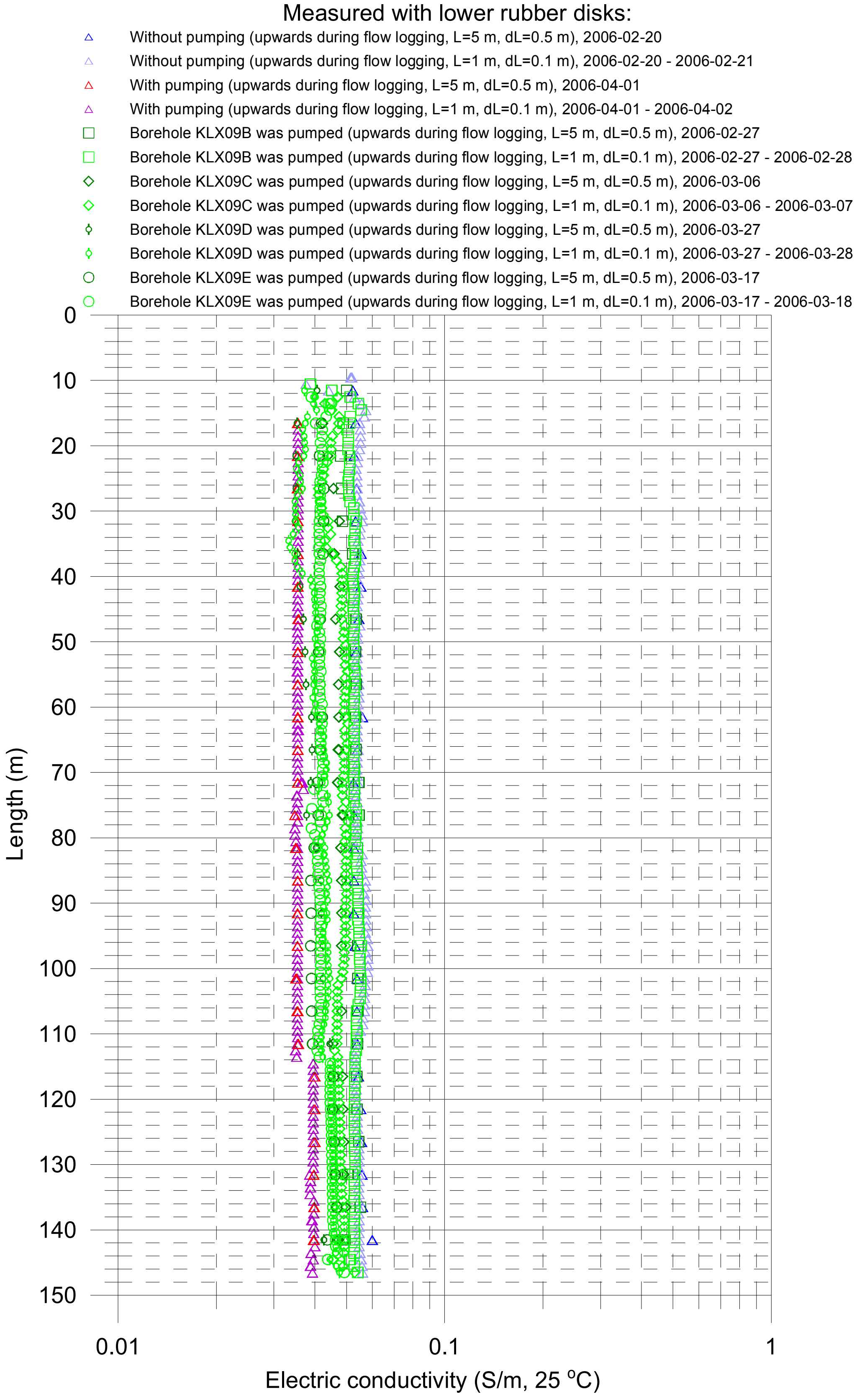

Laxemar, borehole KLX09C
Electric conductivity of borehole water
Measured with lower rubber disks:
Without pumping (upwards during flow logging, L=5 m, dL=0.5 m), 2006-02-16
Without pumping (upwards during flow logging, L=1 m, dL=0.1 m), 2006-02-16 - 2006-02-17
With pumping (upwards during flow logging, L=5 m, dL=0.5 m), 2006-03-04
With pumping (upwards during flow logging, L=1 m, dL=0.1 m), 2006-03-04 - 2006-03-05
Borehole KLX09B was pumped (upwards during flow logging, L=5 m, dL=0.5 m), 2006-02-26
Borehole KLX09B was pumped (upwards during flow logging, L=1 m, dL=0.1 m), 2006-02-26
Borehole KLX09D was pumped (upwards during flow logging, L=5 m, dL=0.5 m), 2006-03-26
Borehole KLX09D was pumped (upwards during flow logging, L=1 m, dL=0.1 m), 2006-03-26 - 2006-03-27
Borehole KLX09E was pumped (upwards during flow logging, L=5 m, dL=0.5 m), 2006-03-18
Borehole KLX09E was pumped (upwards during flow logging, L=1 m, dL=0.1 m), 2006-03-18 - 2006-03-19
Borehole KLX09F was pumped (upwards during flow logging, L=5 m, dL=0.5 m), 2006-04-03
Borehole KLX09F was pumped (upwards during flow logging, L=1 m, dL=0.1 m), 2006-04-03 - 2006-04-04
Length (m)
0
10
20
30
40
50
60
70
80
90
100
110
120
0.01
0.1
1
Electric conductivity (S/m, 25 °C)


Laxemar, borehole KLX09D
Electric conductivity of borehole water
Measured with lower rubber disks:
Without pumping (upwards during flow logging, L=5 m, dL=0.5 m), 2006-02-17
Without pumping (upwards during flow logging, L=1 m, dL=0.1 m), 2006-02-17 - 2006-02-18
With pumping (upwards during flow logging, L=5 m, dL=0.5 m), 2006-03-23
With pumping (upwards during flow logging, L=1 m, dL=0.1 m), 2006-03-23 - 2006-03-24
Borehole KLX09B was pumped (upwards during flow logging, L=5 m, dL=0.5 m), 2006-02-24
Borehole KLX09B was pumped (upwards during flow logging, L=1 m, dL=0.1 m), 2006-02-24 - 2006-02-25
Borehole KLX09C was pumped (upwards during flow logging, L=5 m, dL=0.5 m), 2006-03-07
Borehole KLX09C was pumped (upwards during flow logging, L=1 m, dL=0.1 m), 2006-03-07 - 2006-03-08
Borehole KLX09E was pumped (upwards during flow logging, L=5 m, dL=0.5 m), 2006-03-16
Borehole KLX09E was pumped (upwards during flow logging, L=1 m, dL=0.1 m), 2006-03-16 - 2006-03-17
Borehole KLX09F was pumped (upwards during flow logging, L=5 m, dL=0.5 m), 2006-04-04
Borehole KLX09F was pumped (upwards during flow logging, L=1 m, dL=0.1 m), 2006-04-04 - 2006-04-05
Length (m)
0
10
20
30
40
50
60
70
80
90
100
110
120
0.01
0.1
1
Electric conductivity (S/m, 25 °C)



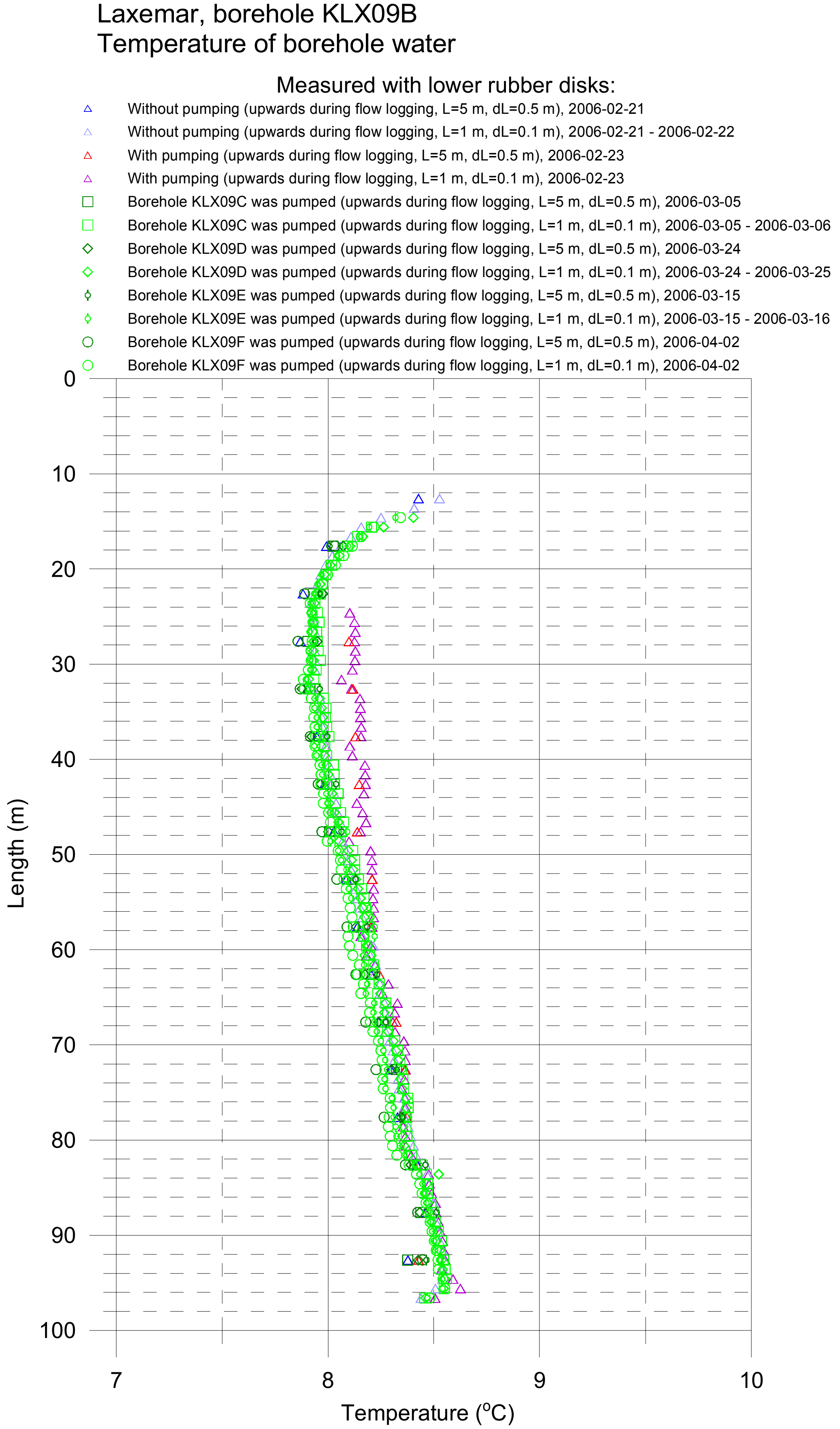
Laxemar, borehole KLX09E
Electric conductivity of borehole water
Measured with lower rubber disks:
Without pumping (upwards during flow logging, L=5 m, dL=0.5 m), 2006-02-18
Without pumping (upwards during flow logging, L=1 m, dL=0.1 m), 2006-02-18 - 2006-02-19
With pumping (upwards during flow logging, L=5 m, dL=0.5 m), 2006-03-14
With pumping (upwards during flow logging, L=1 m, dL=0.1 m), 2006-03-14
Borehole KLX09B was pumped (upwards during flow logging, L=5 m, dL=0.5 m), 2006-02-25
Borehole KLX09B was pumped (upwards during flow logging, L=1 m, dL=0.1 m), 2006-02-25 - 2006-02-26
Borehole KLX09C was pumped (upwards during flow logging, L=5 m, dL=0.5 m), 2006-03-08
Borehole KLX09C was pumped (upwards during flow logging, L=1 m, dL=0.1 m), 2006-03-08 - 2006-03-09
Borehole KLX09D was pumped (upwards during flow logging, L=5 m, dL=0.5 m), 2006-03-25
Borehole KLX09D was pumped (upwards during flow logging, L=1 m, dL=0.1 m), 2006-03-25 - 2006-03-26
Borehole KLX09F was pumped (upwards during flow logging, L=5 m, dL=0.5 m), 2006-04-05
Borehole KLX09F was pumped (upwards during flow logging, L=1 m, dL=0.1 m), 2006-04-05 - 2006-04-06
Length (m)
0
10
20
30
40
50
60
70
80
90
100
110
120
0.01
0.1
1
Electric conductivity (S/m, 25 °C)

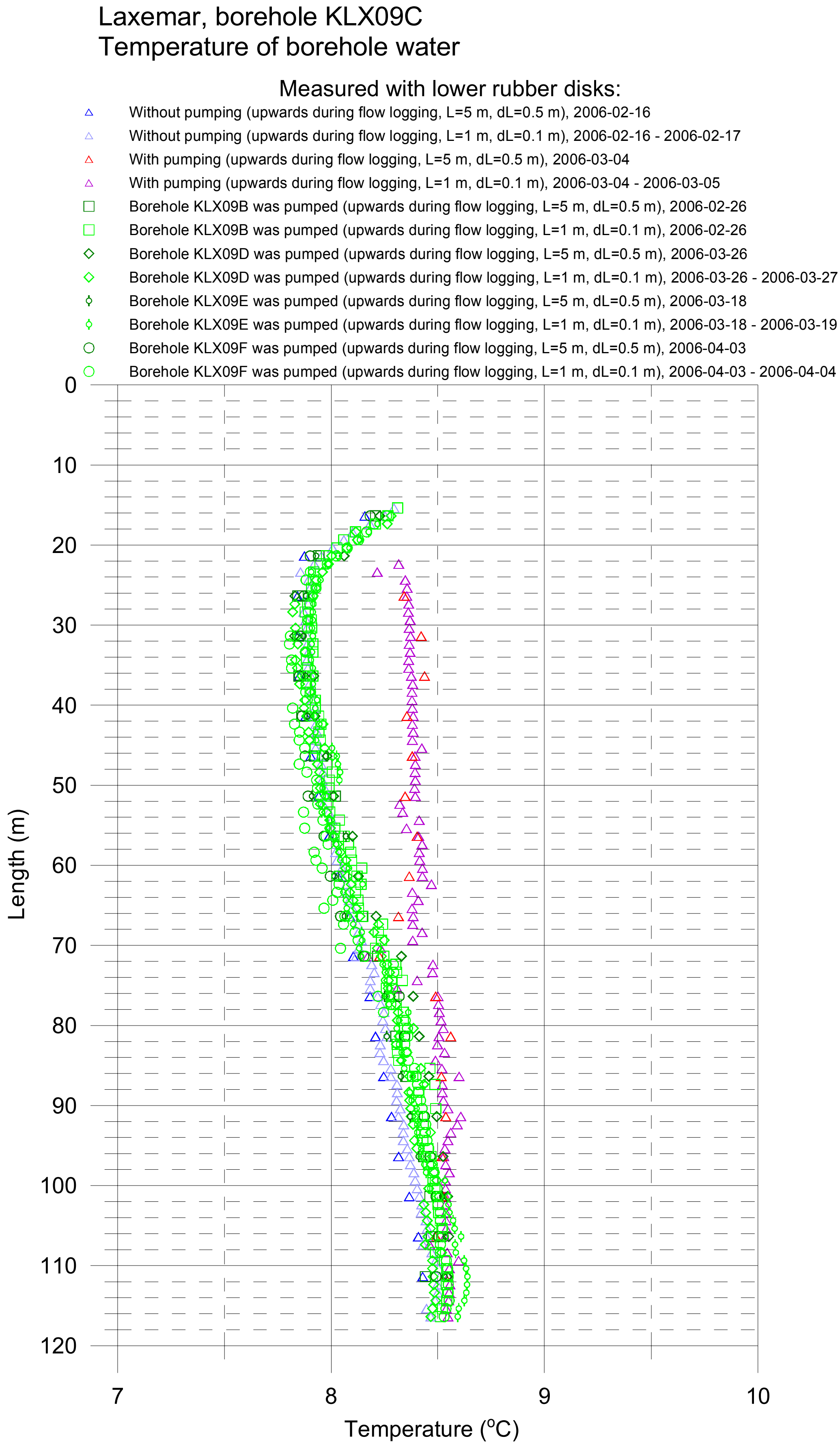
Laxemar, borehole KLX09F
Electric conductivity of borehole water



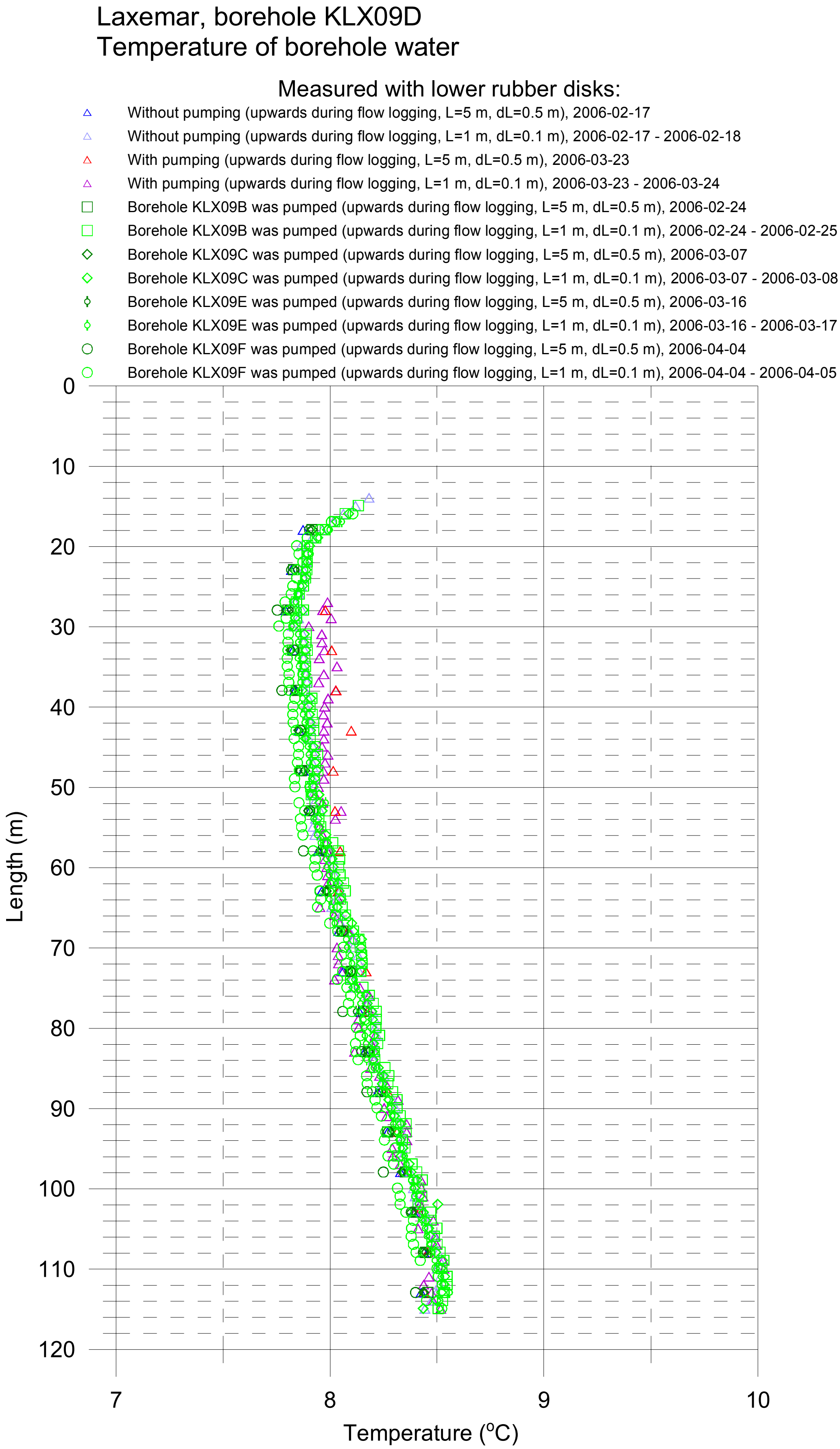
Appendix 11

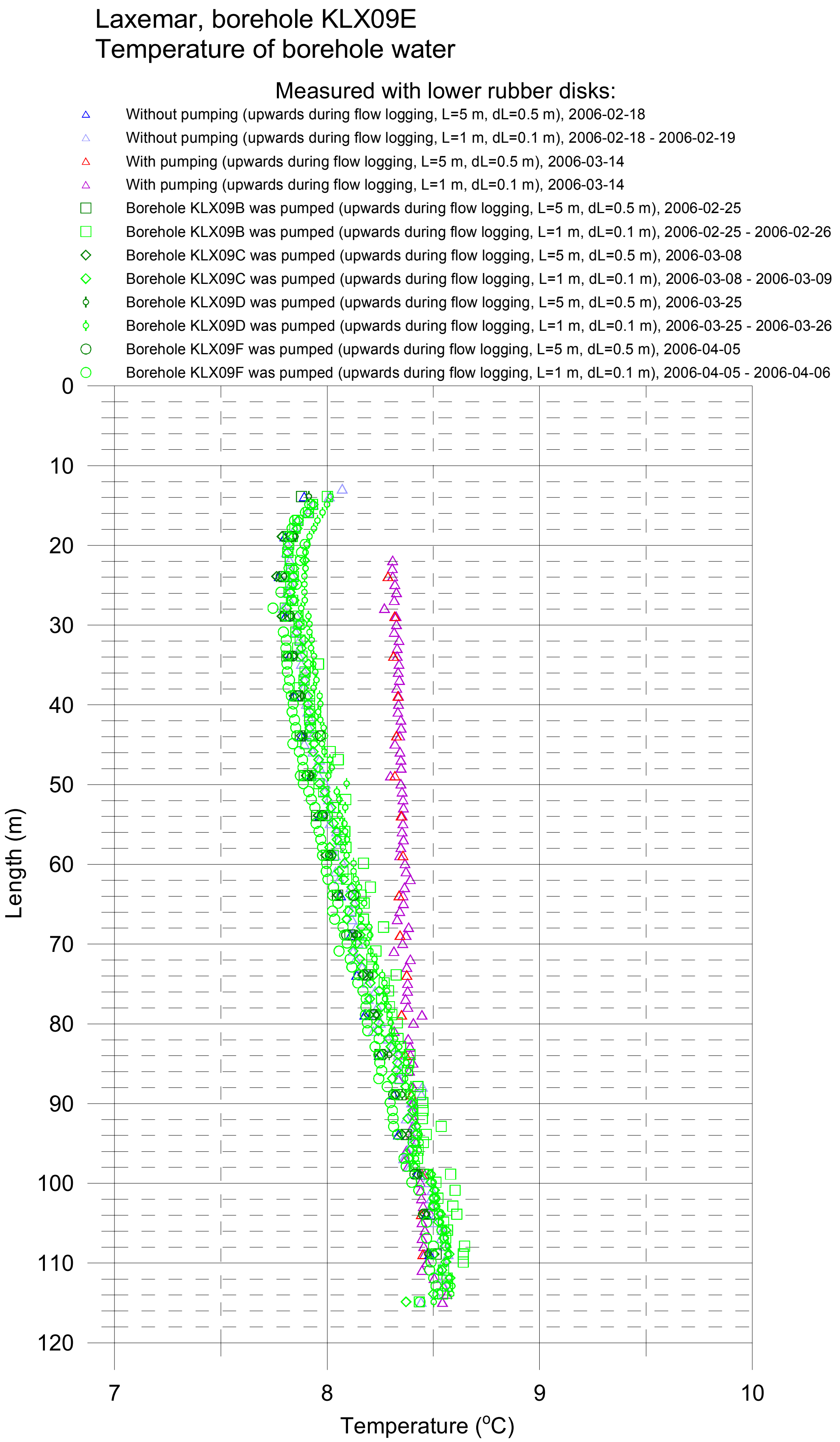
Temperature of borehole water, boreholes KLX09B–KLX09F



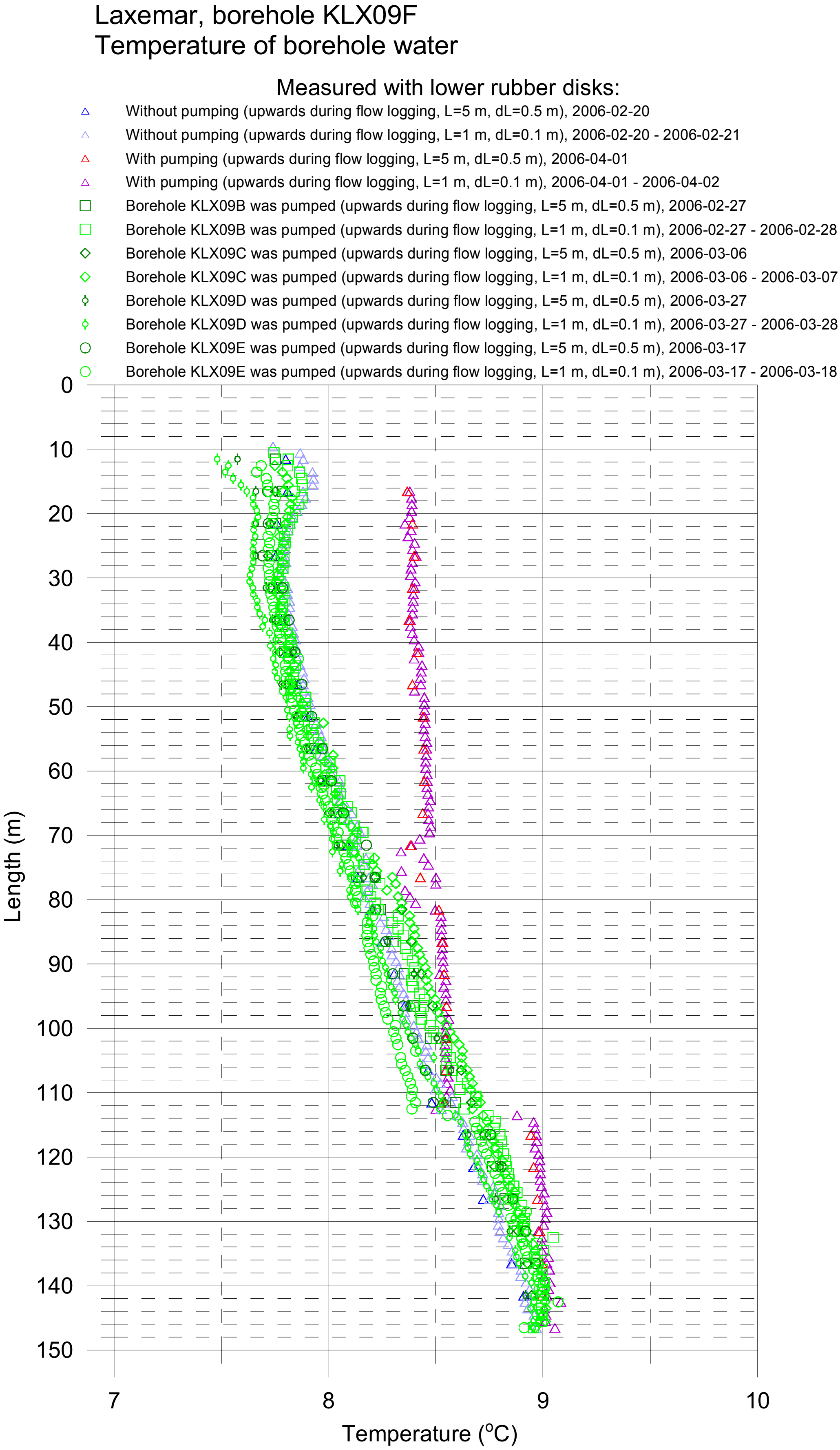


Laxemar, borehole KLX09C
Temperature of borehole water
Measured with lower rubber disks:
Without pumping (upwards during flow logging, L=5 m, dL=0.5 m), 2006-02-16
Without pumping (upwards during flow logging, L=1 m, dL=0.1 m), 2006-02-16 - 2006-02-17
With pumping (upwards during flow logging, L=5 m, dL=0.5 m), 2006-03-04
With pumping (upwards during flow logging, L=1 m, dL=0.1 m), 2006-03-04 - 2006-03-05
Borehole KLX09B was pumped (upwards during flow logging, L=5 m, dL=0.5 m), 2006-02-26
Borehole KLX09B was pumped (upwards during flow logging, L=1 m, dL=0.1 m), 2006-02-26
Borehole KLX09D was pumped (upwards during flow logging, L=5 m, dL=0.5 m), 2006-03-26
Borehole KLX09D was pumped (upwards during flow logging, L=1 m, dL=0.1 m), 2006-03-26 - 2006-03-27
Borehole KLX09E was pumped (upwards during flow logging, L=5 m, dL=0.5 m), 2006-03-18
Borehole KLX09E was pumped (upwards during flow logging, L=1 m, dL=0.1 m), 2006-03-18 - 2006-03-19
Borehole KLX09F was pumped (upwards during flow logging, L=5 m, dL=0.5 m), 2006-04-03
Borehole KLX09F was pumped (upwards during flow logging, L=1 m, dL=0.1 m), 2006-04-03 - 2006-04-04
Length (m)
0
10
20
30
40
50
60
70
80
90
100
110
120
7
8
9
10
Temperature (°C)


Laxemar, borehole KLX09D
Temperature of borehole water
Measured with lower rubber disks:
Without pumping (upwards during flow logging, L=5 m, dL=0.5 m), 2006-02-17
Without pumping (upwards during flow logging, L=1 m, dL=0.1 m), 2006-02-17 - 2006-02-18
With pumping (upwards during flow logging, L=5 m, dL=0.5 m), 2006-03-23
With pumping (upwards during flow logging, L=1 m, dL=0.1 m), 2006-03-23 - 2006-03-24
Borehole KLX09B was pumped (upwards during flow logging, L=5 m, dL=0.5 m), 2006-02-24
Borehole KLX09B was pumped (upwards during flow logging, L=1 m, dL=0.1 m), 2006-02-24 - 2006-02-25
Borehole KLX09C was pumped (upwards during flow logging, L=5 m, dL=0.5 m), 2006-03-07
Borehole KLX09C was pumped (upwards during flow logging, L=1 m, dL=0.1 m), 2006-03-07 - 2006-03-08
Borehole KLX09E was pumped (upwards during flow logging, L=5 m, dL=0.5 m), 2006-03-16
Borehole KLX09E was pumped (upwards during flow logging, L=1 m, dL=0.1 m), 2006-03-16 - 2006-03-17
Borehole KLX09F was pumped (upwards during flow logging, L=5 m, dL=0.5 m), 2006-04-04
Borehole KLX09F was pumped (upwards during flow logging, L=1 m, dL=0.1 m), 2006-04-04 - 2006-04-05
Length (m)
0
10
20
30
40
50
60
70
80
90
100
110
120
7
8
9
10
Temperature (°C)

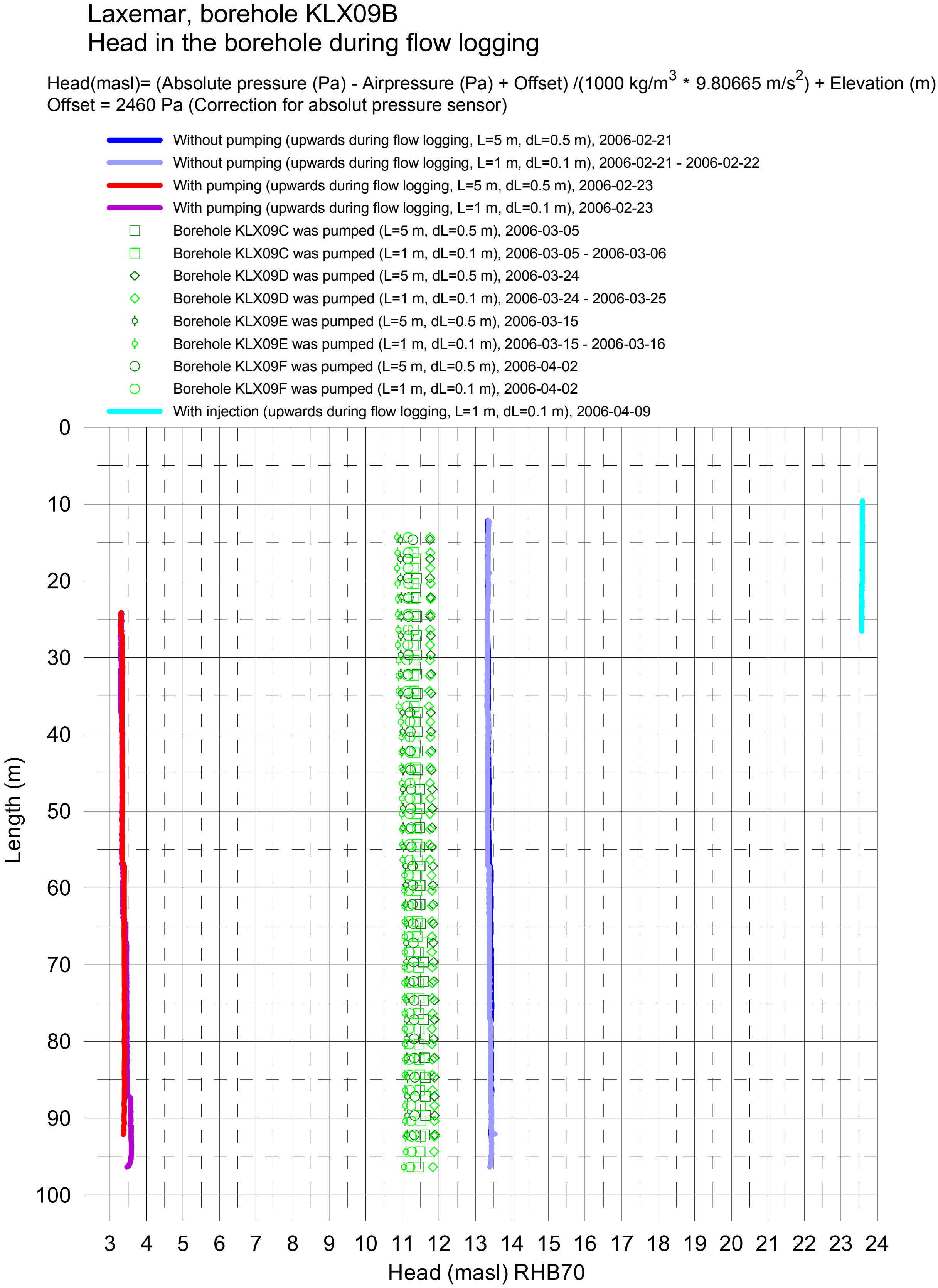


Laxemar, borehole KLX09E
Temperature of borehole water
Measured with lower rubber disks:
Without pumping (upwards during flow logging, L=5 m, dL=0.5 m), 2006-02-18
Without pumping (upwards during flow logging, L=1 m, dL=0.1 m), 2006-02-18 - 2006-02-19
With pumping (upwards during flow logging, L=5 m, dL=0.5 m), 2006-03-14
With pumping (upwards during flow logging, L=1 m, dL=0.1 m), 2006-03-14
Borehole KLX09B was pumped (upwards during flow logging, L=5 m, dL=0.5 m), 2006-02-25
Borehole KLX09B was pumped (upwards during flow logging, L=1 m, dL=0.1 m), 2006-02-25 - 2006-02-26
Borehole KLX09C was pumped (upwards during flow logging, L=5 m, dL=0.5 m), 2006-03-08
Borehole KLX09C was pumped (upwards during flow logging, L=1 m, dL=0.1 m), 2006-03-08 - 2006-03-09
Borehole KLX09D was pumped (upwards during flow logging, L=5 m, dL=0.5 m), 2006-03-25
Borehole KLX09D was pumped (upwards during flow logging, L=1 m, dL=0.1 m), 2006-03-25 - 2006-03-26
Borehole KLX09F was pumped (upwards during flow logging, L=5 m, dL=0.5 m), 2006-04-05
Borehole KLX09F was pumped (upwards during flow logging, L=1 m, dL=0.1 m), 2006-04-05 - 2006-04-06
Length (m)
0
10
20
30
40
50
60
70
80
90
100
110
120
7
8
9
10
Temperature (°C)



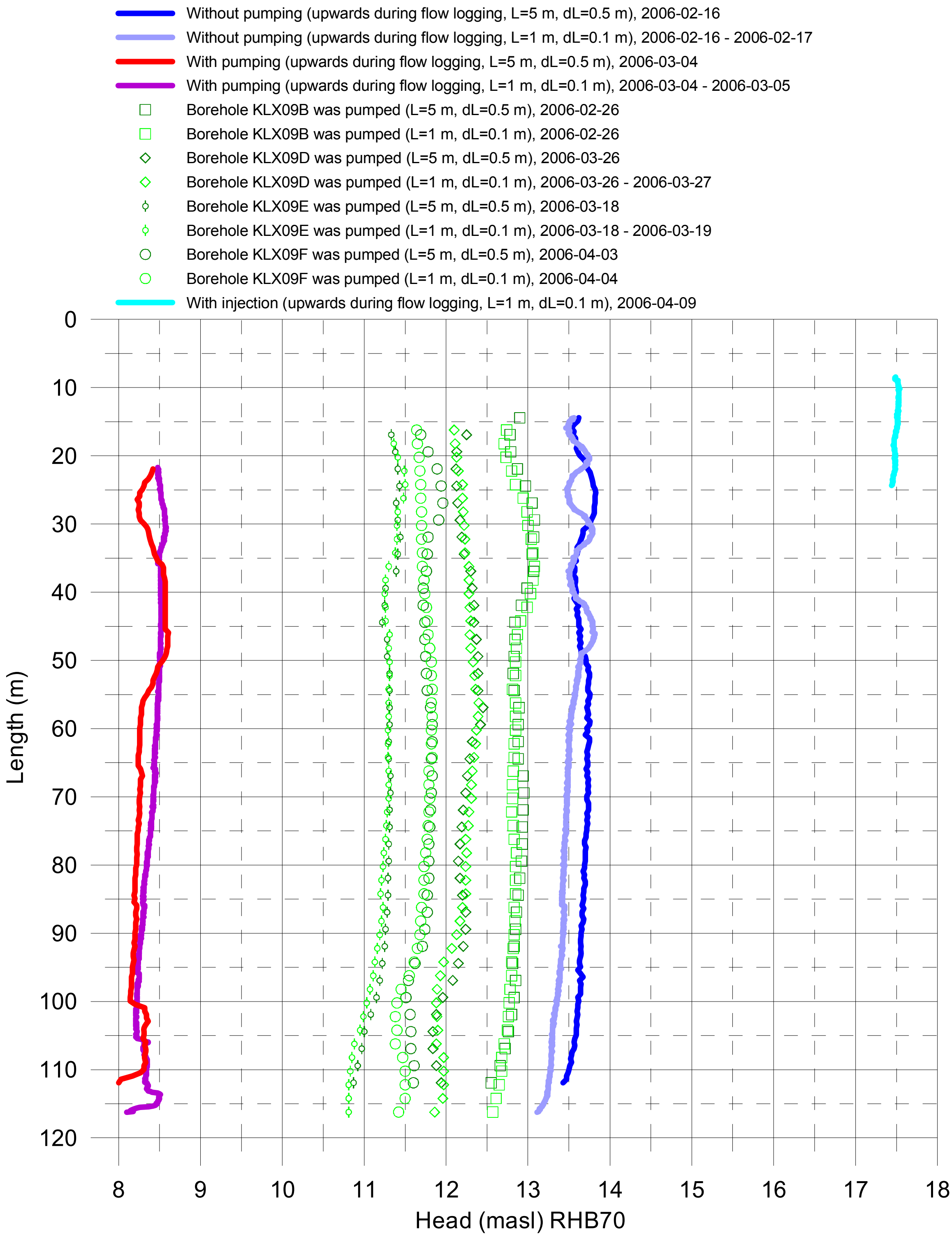
Laxemar, borehole KLX09F
Temperature of borehole water
Measured with lower rubber disks:
Without pumping (upwards during flow logging, L=5 m, dL=0.5 m), 2006-02-20
Without pumping (upwards during flow logging, L=1 m, dL=0.1 m), 2006-02-20 - 2006-02-21
With pumping (upwards during flow logging, L=5 m, dL=0.5 m), 2006-04-01
With pumping (upwards during flow logging, L=1 m, dL=0.1 m), 2006-04-01 - 2006-04-02
Borehole KLX09B was pumped (upwards during flow logging, L=5 m, dL=0.5 m), 2006-02-27
Borehole KLX09B was pumped (upwards during flow logging, L=1 m, dL=0.1 m), 2006-02-27 - 2006-02-28
Borehole KLX09C was pumped (upwards during flow logging, L=5 m, dL=0.5 m), 2006-03-06
Borehole KLX09C was pumped (upwards during flow logging, L=1 m, dL=0.1 m), 2006-03-06 - 2006-03-07
Borehole KLX09D was pumped (upwards during flow logging, L=5 m, dL=0.5 m), 2006-03-27
Borehole KLX09D was pumped (upwards during flow logging, L=1 m, dL=0.1 m), 2006-03-27 - 2006-03-28
Borehole KLX09E was pumped (upwards during flow logging, L=5 m, dL=0.5 m), 2006-03-17
Borehole KLX09E was pumped (upwards during flow logging, L=1 m, dL=0.1 m), 2006-03-17 - 2006-03-18
Length (m)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
7
8
9
10
Temperature (°C)

Head in the borehole during flow logging, boreholes KLX09B–KLX09F



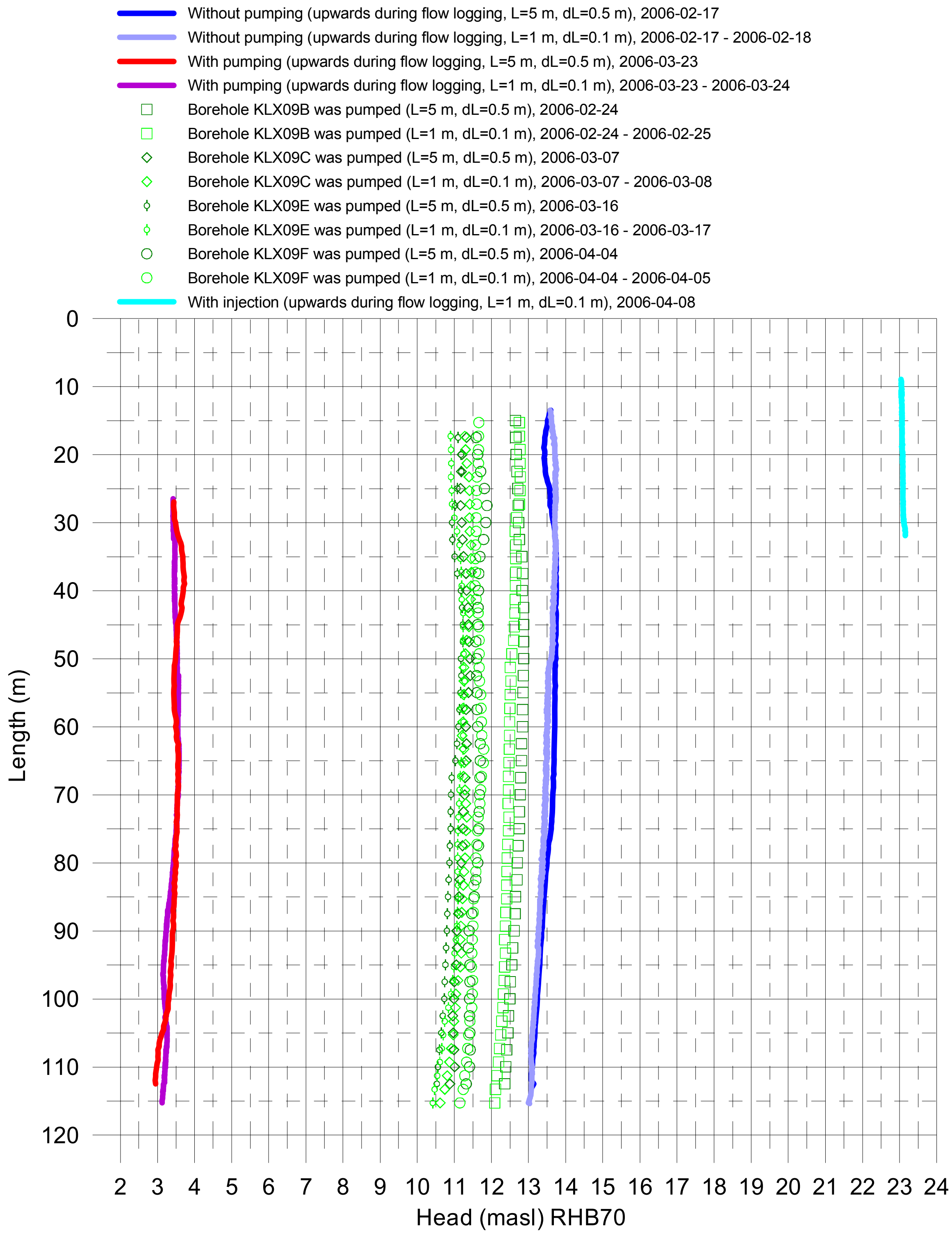
Laxemar, borehole KLX09C
Head in the borehole during flow logging

Head(masl)= (Absolute pressure (Pa) - Airpressure (Pa) + Offset) /(1000 kg/m^3 * 9.80665 m/s^2) + Elevation (m)
Offset = 2460 Pa (Correction for absolut pressure sensor)



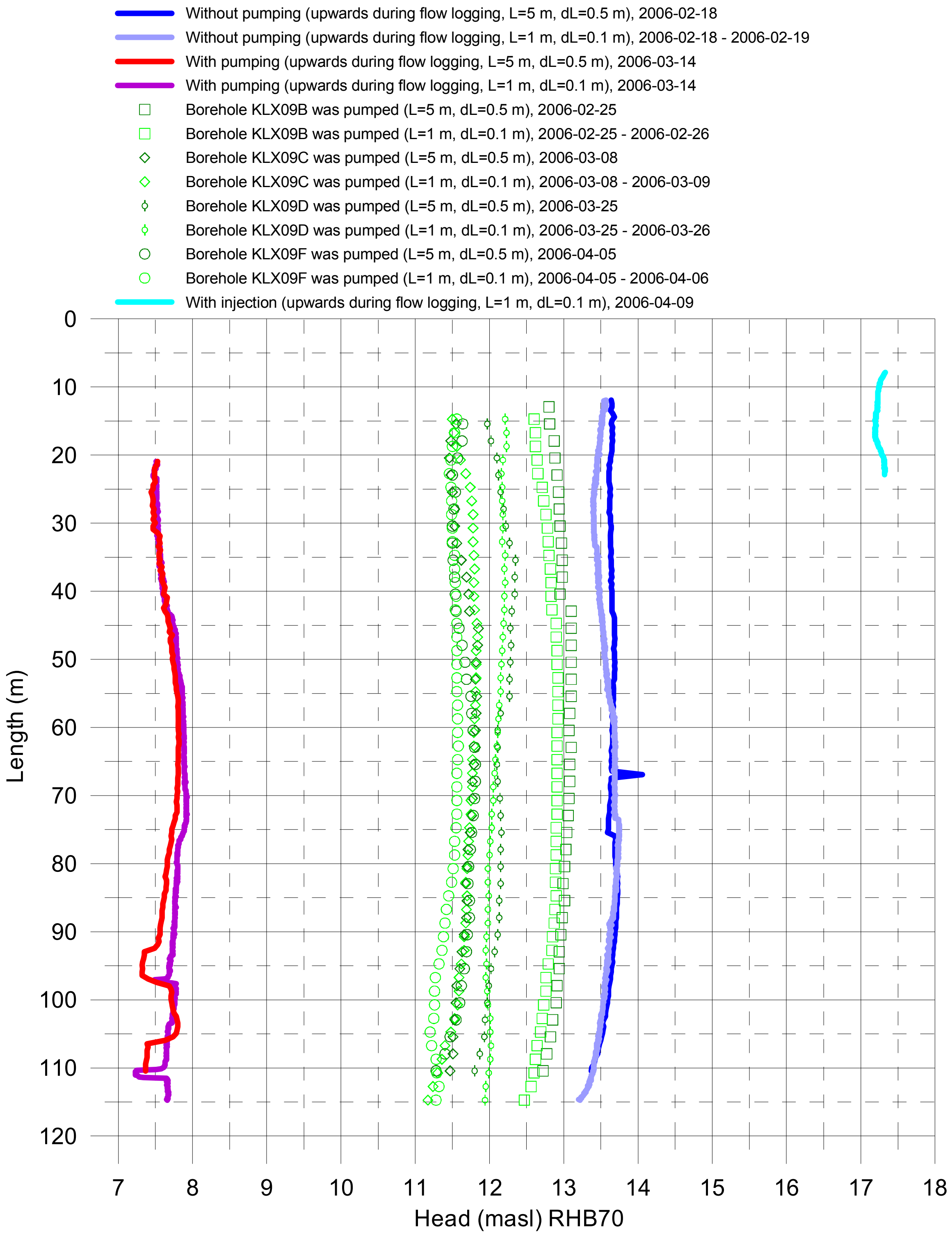
Laxemar, borehole KLX09D
Head in the borehole during flow logging

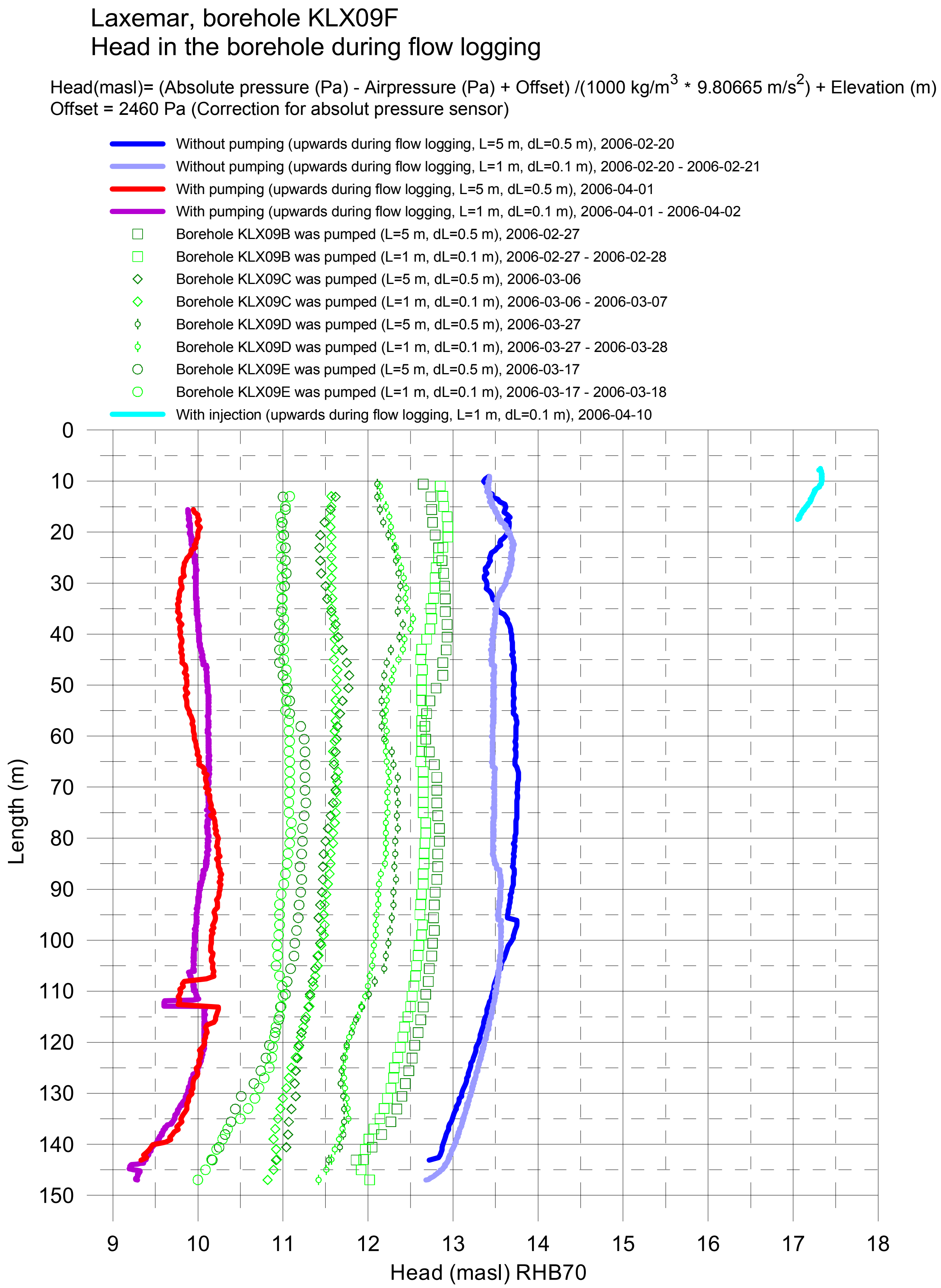
Head(masl)= (Absolute pressure (Pa) - Airpressure (Pa) + Offset) /(1000 kg/m^3 * 9.80665 m/s^2) + Elevation (m)
Offset = 2460 Pa (Correction for absolut pressure sensor)



Laxemar, borehole KLX09E
Head in the borehole during flow logging

Head(masl)= (Absolute pressure (Pa) - Airpressure (Pa) + Offset) /(1000 kg/m^3 * 9.80665 m/s^2) + Elevation (m)
Offset = 2460 Pa (Correction for absolut pressure sensor)



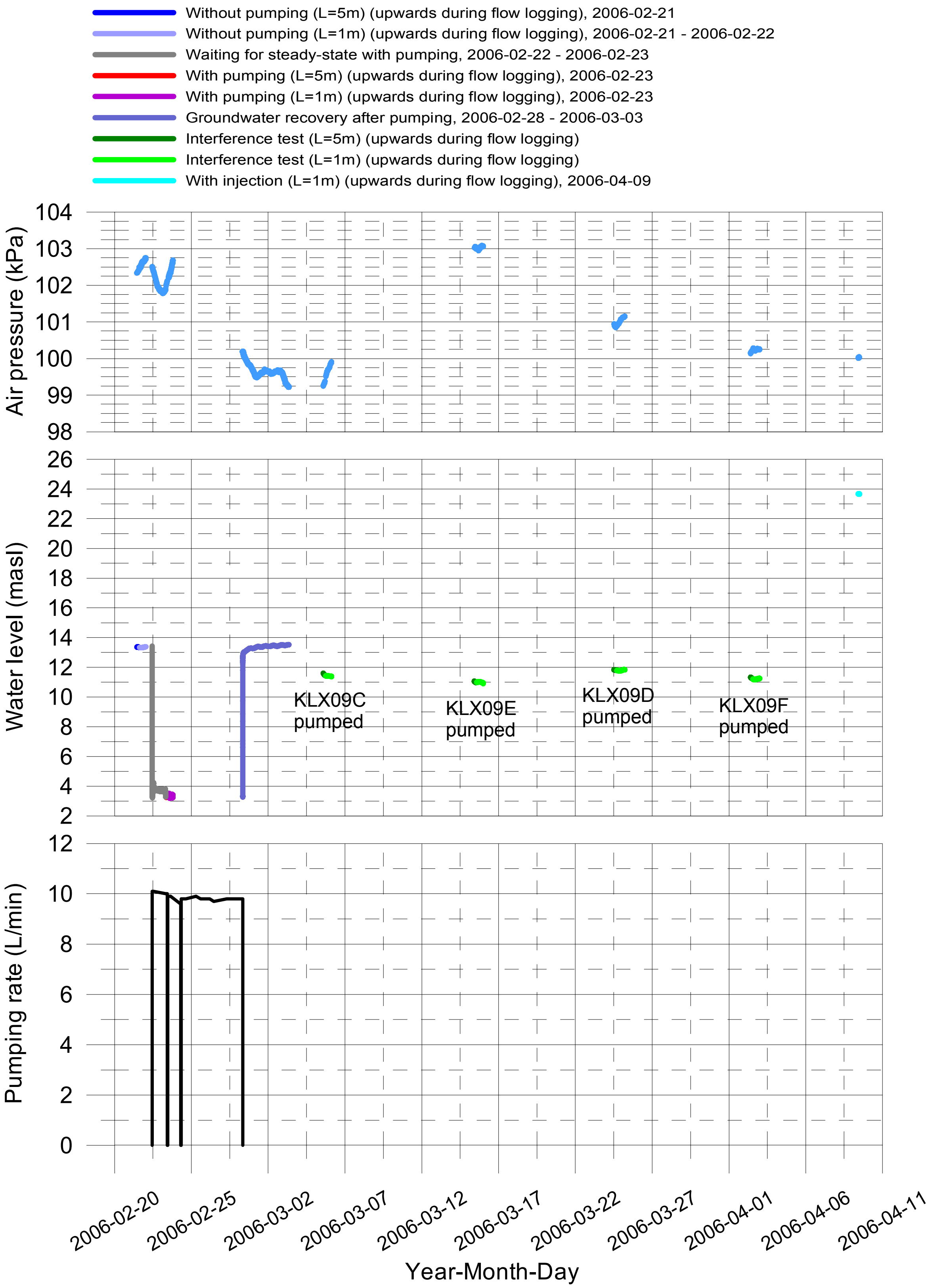


Laxemar, borehole KLX09F
Head in the borehole during flow logging
Head(masl)= (Absolute pressure (Pa) - Airpressure (Pa) + Offset) /(1000 kg/m3 * 9.80665 m/s2) + Elevation (m)
Offset = 2460 Pa (Correction for absolut pressure sensor)
Without pumping (upwards during flow logging, L=5 m, dL=0.5 m), 2006-02-20
Without pumping (upwards during flow logging, L=1 m, dL=0.1 m), 2006-02-20 - 2006-02-21
With pumping (upwards during flow logging, L=5 m, dL=0.5 m), 2006-04-01
With pumping (upwards during flow logging, L=1 m, dL=0.1 m), 2006-04-01 - 2006-04-02
Borehole KLX09B was pumped (L=5 m, dL=0.5 m), 2006-02-27
Borehole KLX09B was pumped (L=1 m, dL=0.1 m), 2006-02-27 - 2006-02-28
Borehole KLX09C was pumped (L=5 m, dL=0.5 m), 2006-03-06
Borehole KLX09C was pumped (L=1 m, dL=0.1 m), 2006-03-06 - 2006-03-07
Borehole KLX09D was pumped (L=5 m, dL=0.5 m), 2006-03-27
Borehole KLX09D was pumped (L=1 m, dL=0.1 m), 2006-03-27 - 2006-03-28
Borehole KLX09E was pumped (L=5 m, dL=0.5 m), 2006-03-17
Borehole KLX09E was pumped (L=1 m, dL=0.1 m), 2006-03-17 - 2006-03-18
With injection (upwards during flow logging, L=1 m, dL=0.1 m), 2006-04-10
Length (m)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
9
10
11
12
13
14
15
16
17
18
Head (masl) RHB70

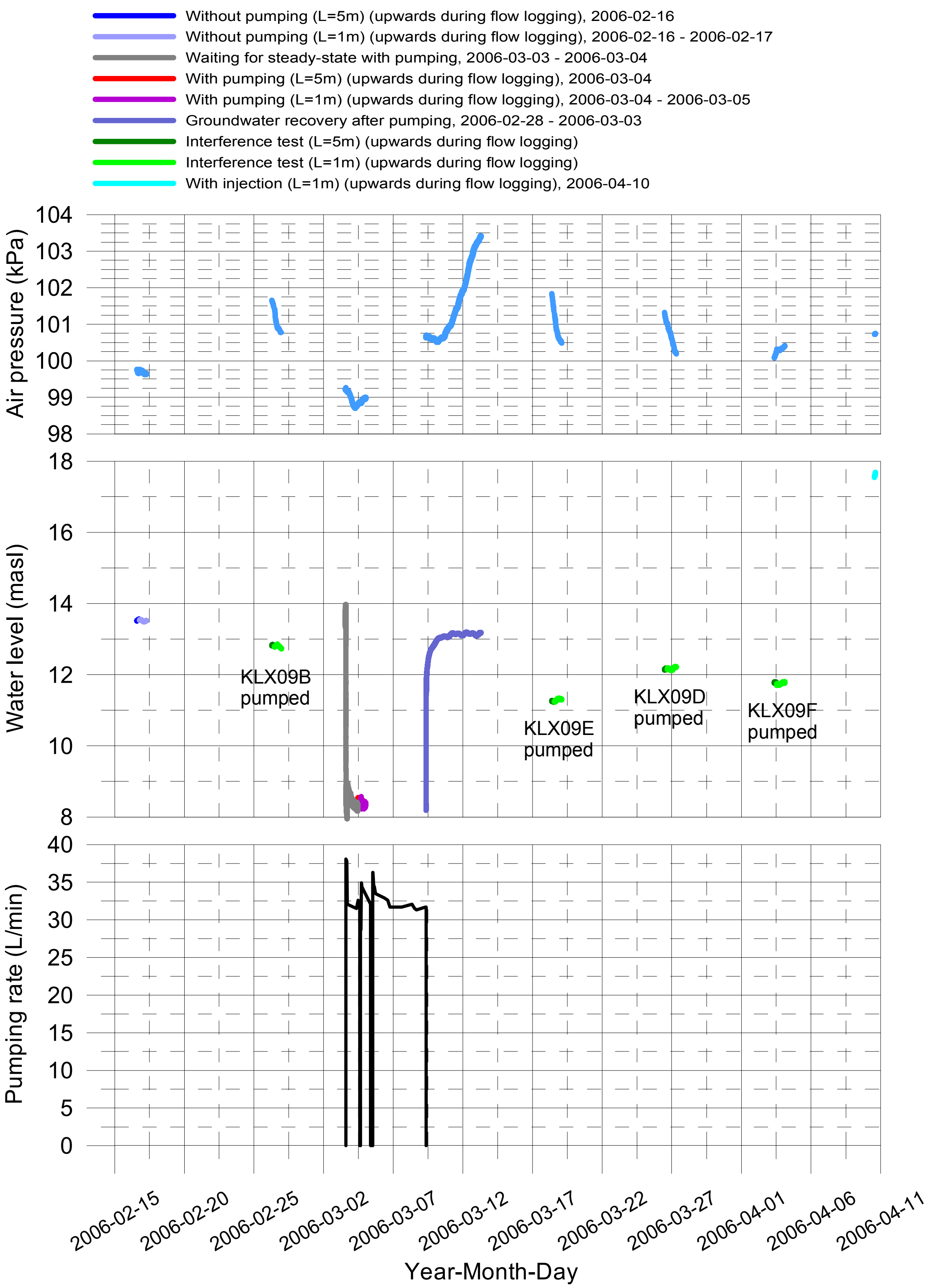
Appendix 13

Air pressure, water level in the borehole and pumping rate during flow logging, boreholes KLX09B–KLX09F

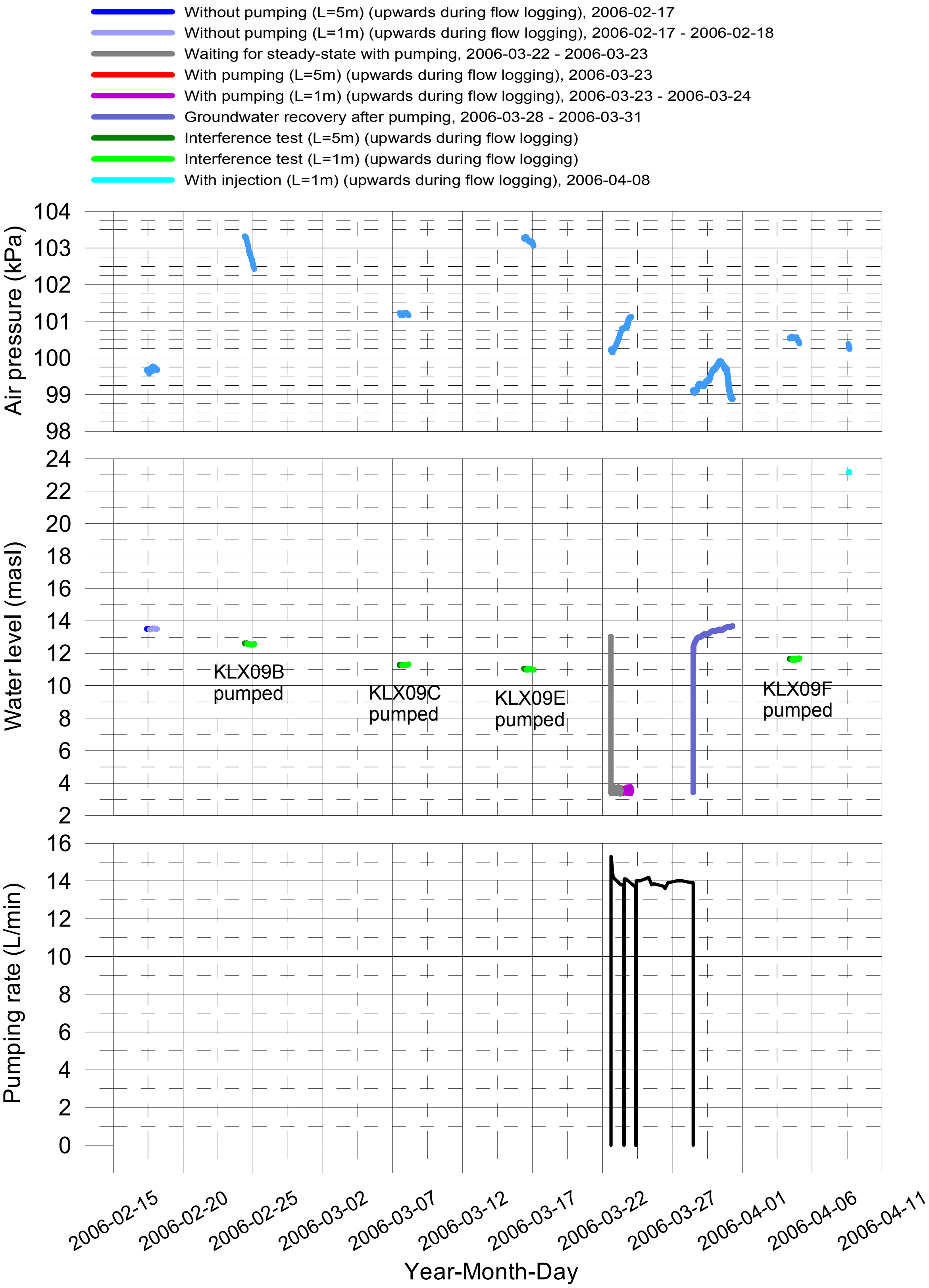
Laxemar, borehole KLX09B
Air pressure, water level in the borehole and pumping rate during flow logging



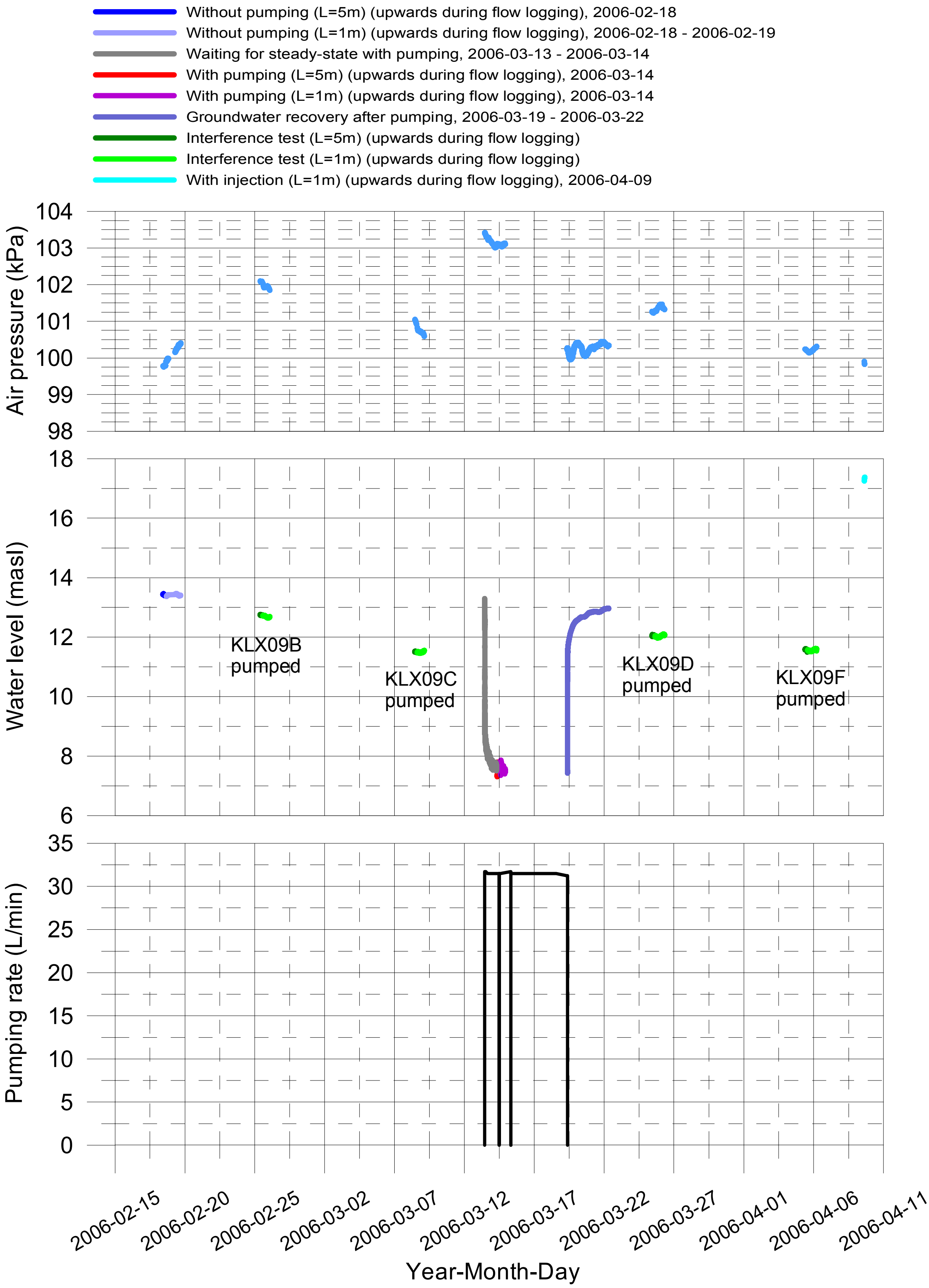
Laxemar, borehole KLX09C
Air pressure, water level in the borehole and pumping rate during flow logging



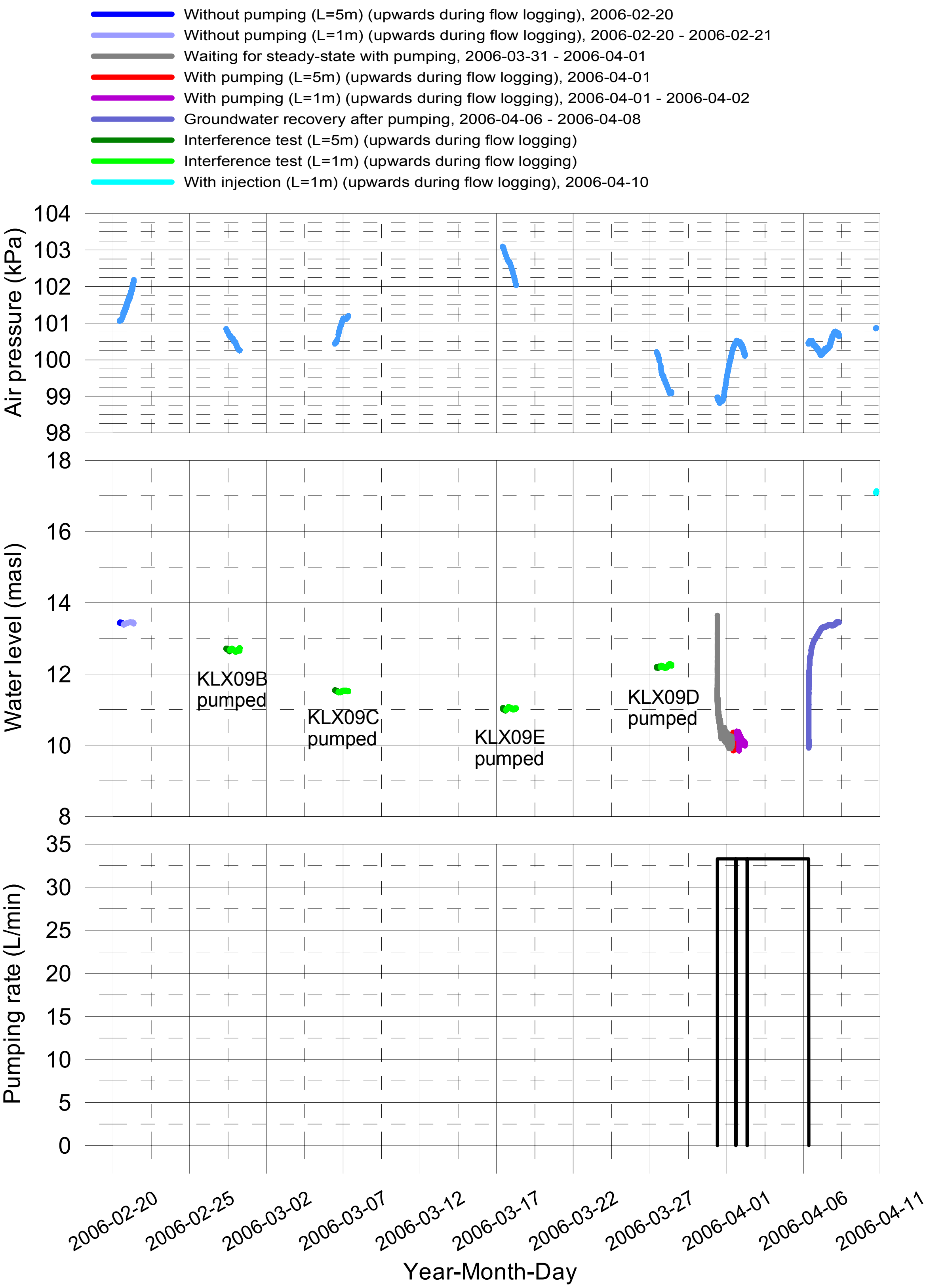
Laxemar, borehole KLX09D
Air pressure, water level in the borehole and pumping rate during flow logging



Laxemar, borehole KLX09E
Air pressure, water level in the borehole and pumping rate during flow logging



Laxemar, borehole KLX09F
Air pressure, water level in the borehole and pumping rate during flow logging



Appendix 14

Water level and air pressure during whole test period, boreholes KLX09B–KLX09F