P-05-67

Oskarshamn site investigation

Difference flow logging of borehole KLX03

Subarea Laxemar

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PRG-Tec Oy

February 2005

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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 method as well as results of measurements carried out in borehole KLX03 at Oskarshamn, Sweden, in November 2004, using Posiva flow log. The primary aim of the measurements was to determine the position and flow rate of flow yielding fractures in borehole KLX03.

The flow rate into or out of a 5 m long test section was measured between 101.30–992.37 m borehole lengths during natural (un-pumped) as well as pumped conditions. The flow measurements were repeated at the location of the detected flow anomalies using a 1 m long test section, successively transferred with an overlapping of 0.1 m.

Length calibration was made based on length marks milled into the borehole wall at accurately determined positions along the borehole. The length marks were detected by caliper measurements and by single point resistance measurements using sensors connected to the flow logging tool.

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.

Finally, EC of fracture-specific water was measured at chosen fractures.

Sammanfattning

Differensflödesloggning är en snabb metod för bestämning av transmissiviteten och hydraulisk head i borrhålssektioner och sprickor/sprickzoner i kärnborrhål. Denna rapport presenterar huvudprinciperna för metoden och resultat av mätningar utförda i borrhål KLX03 i Oskarshamn, Sverige, i november 2004 med Posiva flödesloggningsmetod. Det primära syftet med mätningarna var att bestämma läget och flödet för vattenförande sprickor i borrhål KLX03.

Flödet till eller från en 5 m lång testsektion mättes mellan 101,30–992,37 m borrhålslängd under såväl naturliga (icke-pumpade) som pumpade förhållanden. Flödesmätningarna upprepades vid lägena för de detekterade flödesanomalierna med en 1 m lång testsektion som förflyttades successivt med 0,1 m.

Längdkalibrering gjordes baserad på längdmärkerna som frästs in i borrhålsväggen vid noggrant bestämda positioner längs borrhålet. Längmärkena detekterades med caliper-mätningar och med punktresistansmätningar med hjälp av sensorer anslutna på flödesloggningssonden.

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

Till sist EC på vattnet i sprickor mättes för utvalda sprickor.

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 400-04-82. In Table 1-1 controlling documents for performing this activity are listed. Both activity plan and method descriptions are SKB's internal controlling documents.

Difference flow logging in the core drilled borehole KLX03 at Laxemar near Oskarshamn was conducted between November 4–18, 2004. The borehole is inclined c 75° from the horizontal direction, c 1,000.42 m long and performed with a telescopic drilling technique. The interval 0–100 m is percussion drilled with the diameter 200 mm. The interval 100–1,000.42 m is core drilled with the diameter 76 mm. The location of borehole KLX03 at the drill site within the Oskarshamn area is shown in Figure 1-1.

The field work and the subsequent interpretation were conducted by PRG-Tec Oy. 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. The commissions at the latter site included measurements in the 1,700 m long cored borehole KLX02 at Laxemar together with a methodology study /Ludvigson et al. 2002/.

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

Activity plan	Number	Version
Difference flow logging in borehole KLX04	AP PS 400-04-82	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	
Instruktion för längdkalibrering vid undersökningar i kärnborrhål	SKB MD 620.010	
Instruktion för analys av injektions- och enhålspumptester	SKB MD 320.004	

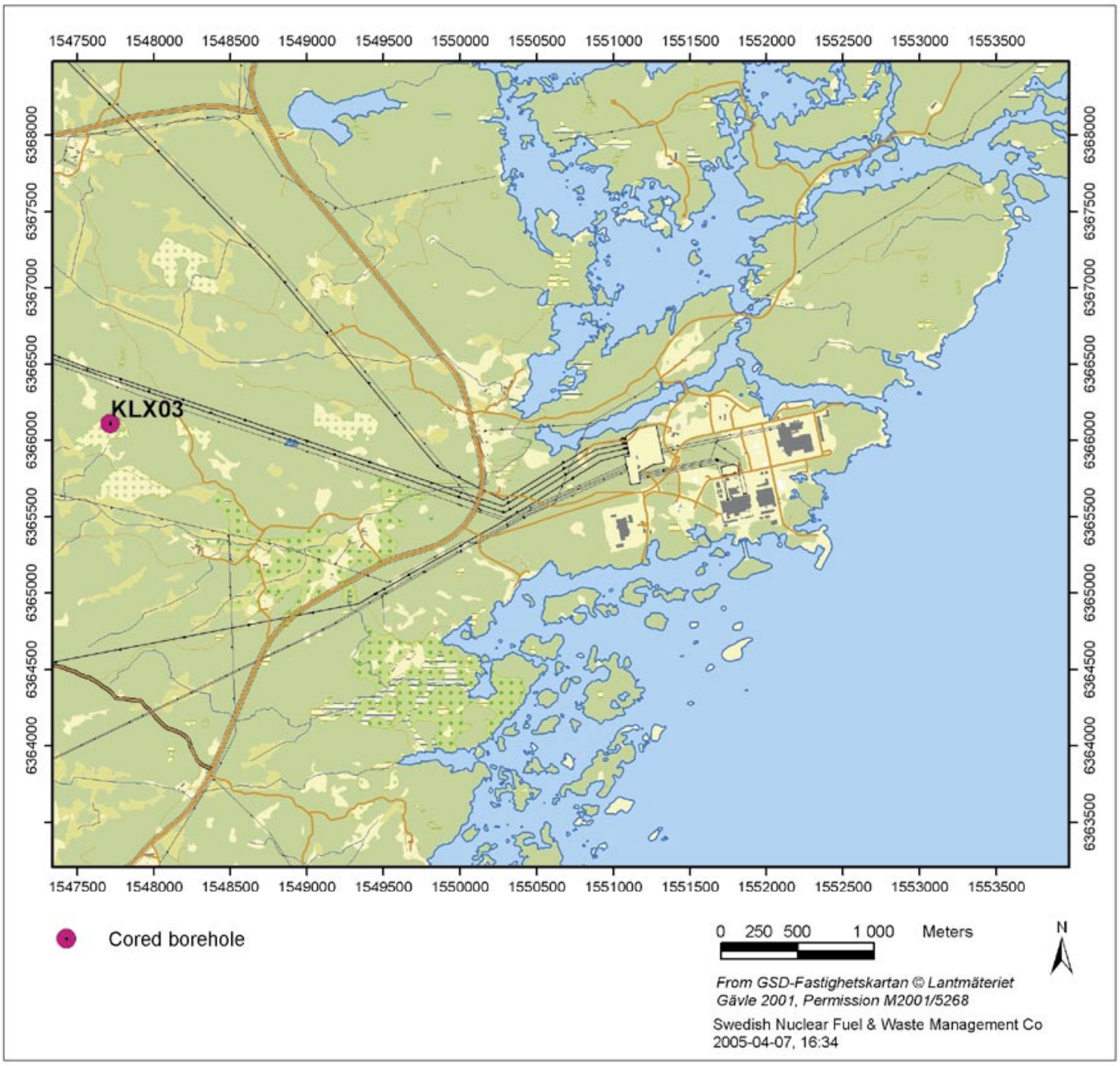

Figure 1-1. *Site map showing the location of borehole KLX03 situated in the subarea of Laxemar.*

2 Objective and scope

The main objective of the difference flow logging in KLX03 was to identify water-conductive sections/fractures. Secondly the results are utilised for selecting suitable sections along the borehole for the subsequent water sampling. These aim at a hydro-geological characterisation, including the prevailing water flow balance in the borehole. Based on the results of these investigations, a more detailed characterisation of flow anomalies along the hole, e.g. an estimate of the conductive fracture frequency (CFF), may be obtained.

Besides the difference flow logging, the measuring programme also included supporting measurements, performed for a better understanding of the overall hydrogeochemical conditions. These measurements included single-point resistance of the borehole wall and also the electric conductivity was measured for a number of selected high transmissive fractures in the borehole. Furthermore, the recovery of the groundwater level after pumping was registered and interpreted hydraulically.

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. The results are used in calculation of hydraulic head along the borehole.

Single point resistance measurements were also combined with caliper (borehole diameter) measurements for detection of length marks milled into the borehole wall at accurately determined positions along the borehole. This procedure was applied for length calibration of all results.

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.

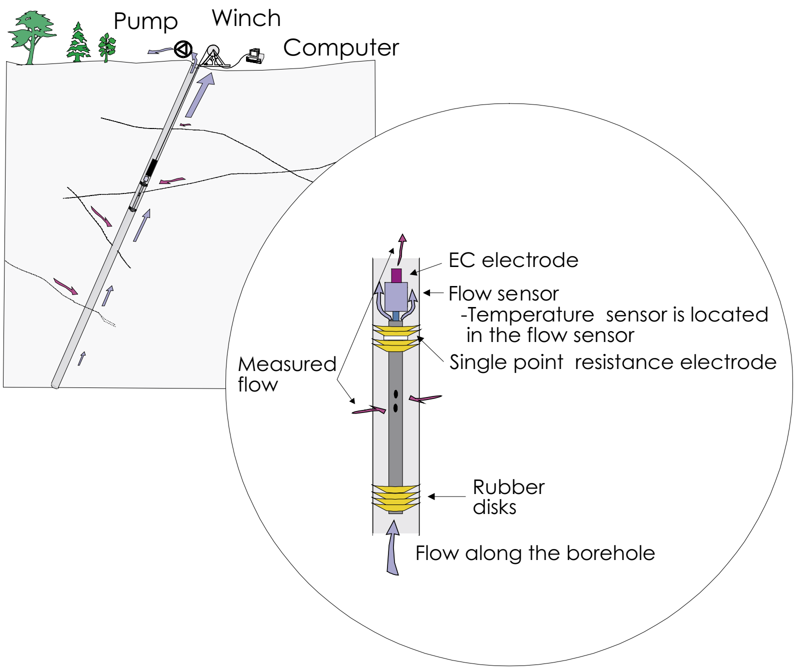

Figure 3-1. *Schematic of the downhole equipment used in the Difference flowmeter.*

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 borehole EC and temperature, were performed in KLX03.

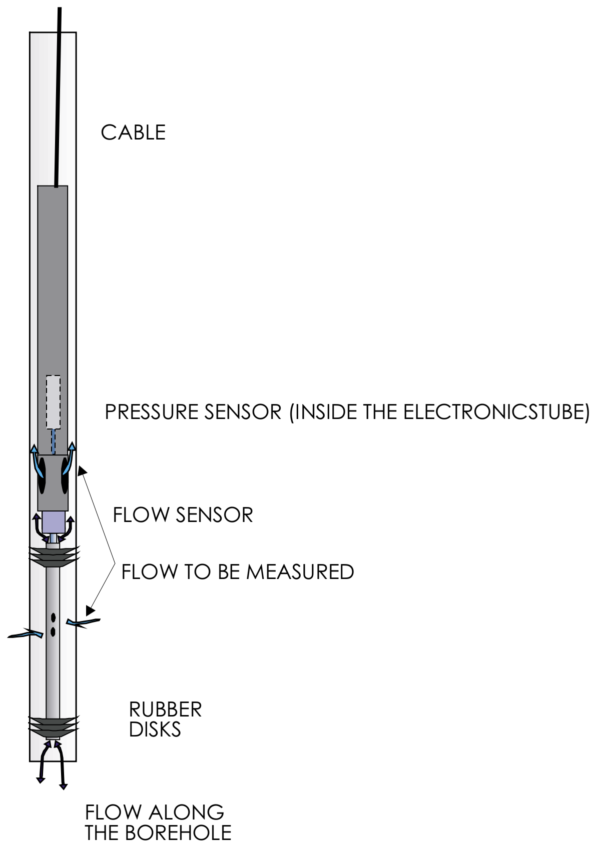

Figure 3-2. *The absolute pressure sensor is located inside the electronics tube and connected through a tube to the borehole water.*

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.

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 3-4a, 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 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.

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 floating 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.

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

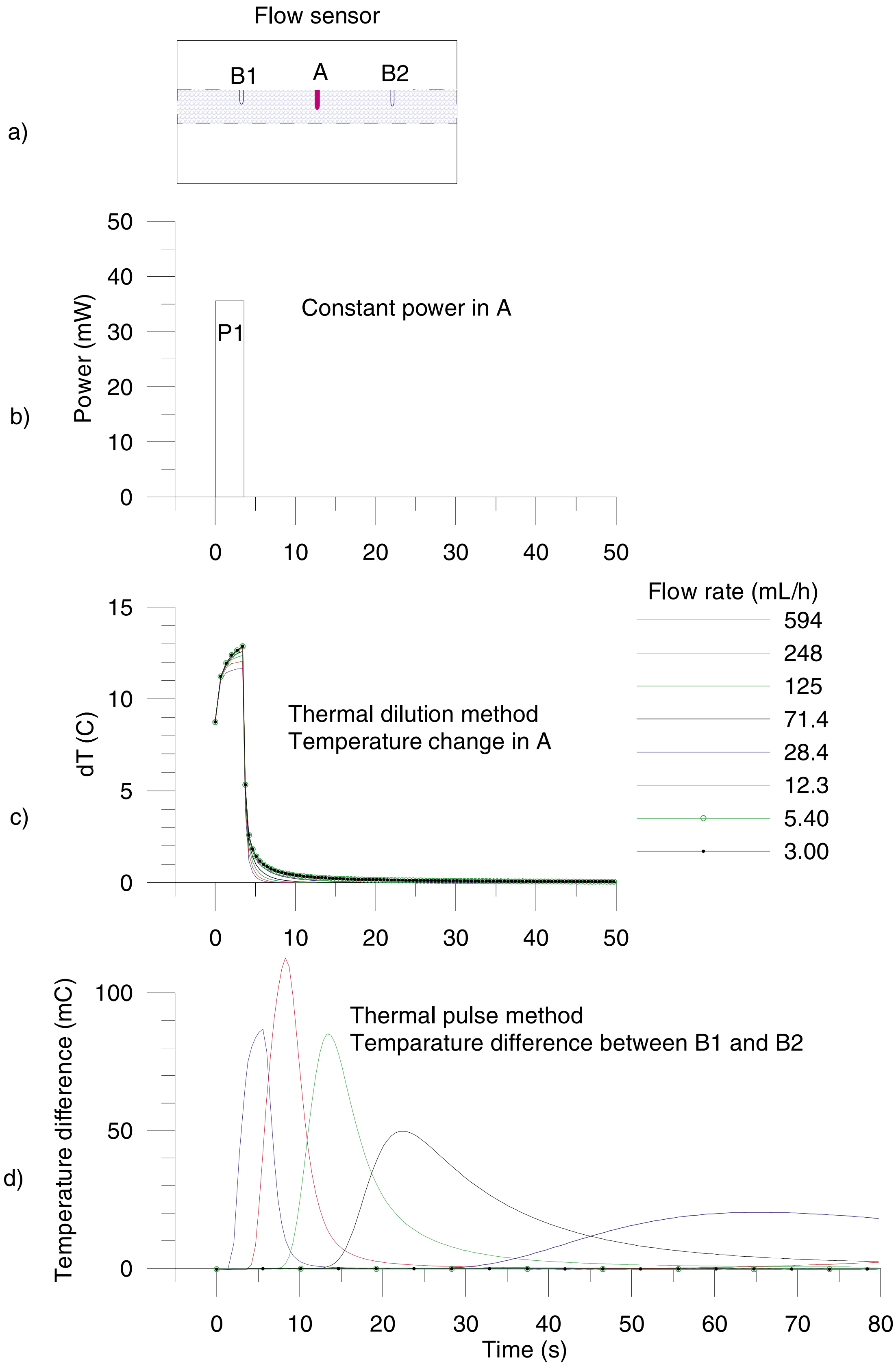

Figure 3-3. *Flow measurement, flow rate < 600 mL/h.*

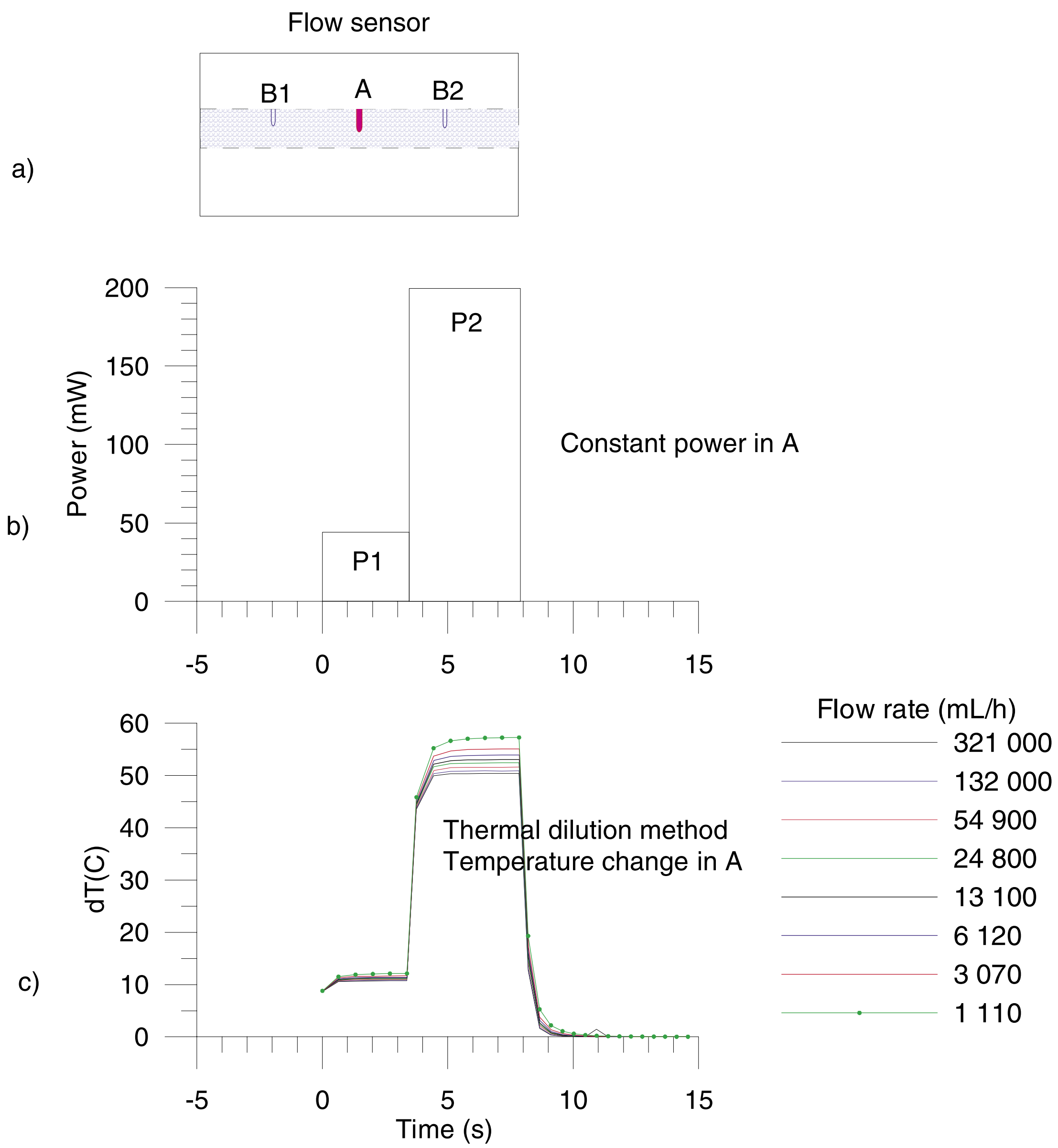

Figure 3-4. *Flow measurement, flow rate > 600 mL/h.*

3.2 Interpretation

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 borehole and $h = h_s$ at the radius of influence (R),
Q is flow rate into the borehole,
T is transmissivity of the test section,
a is a constant depending on the assumed flow geometry. For cylindrical flow, constant a is:

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

where

r_0 is 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 flows rates in the test section,
T_s is 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 the ends of the borehole.

The radial distance R to the undisturbed hydraulic head h_s is not known and it 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

$T_s = (1/a)\ (Q_{s0} – Q_{v1})/(h_1 – h_0)$ 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 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 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/.

Transmissivity of the entire borehole can be evaluated in several ways using the data of the pumping phase and of the recovery phase. The assumptions above (cylindrical and steady state flow) leads to Dupuits formula /Marsily, 1986/:

$$T = \frac{Q}{s2\pi}\ln\left(\frac{R}{r_0}\right) \qquad 3\text{-}9$$

where

s is drawdown and
Q is the pumping rate at the end of the pumping phase

In the Moye /Moye, 1967/ formula it is assumed the steady state flow is cylindrical near the borehole (to distance r = L/2, where L is the section under test) and spherical further away:

$$T = \frac{Q}{s2\pi}\cdot\left[1+\ln\left(\frac{L}{2r_0}\right)\right] \qquad 3\text{-}10$$

where

L is length of test section (m), in this case water filled uncased part of the borehole.

The transient recovery phase is analysed through a Jacob/Horner type of analysis following SKB MD 320.004 (SKB internal controlling document) with the purpose of calculating the transmissivity.

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, 220V/50Hz. 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 2000.
Software:	Based on MS Visual Basic.
Total power consumption:	1.5–2.5 kW depending on the pumps.
Calibrated:	August 2004.
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

The commission was performed according to Activity Plan AP PS 400-04-82 (SKB internal controlling document) following the SKB Method Description 322.010, Version 1.0 (Method description for difference flow logging). Prior to the measurements, the downhole tools and the measurement cable were disinfected. Time was synchronized to local Swedish 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. Immediately after completion of the drilling operations in borehole KLX03, length marks were milled into the borehole wall at certain intervals to be used for length calibration of various logging tools. By using the known positions of the length marks, logging cables etc can be calibrated in order to obtain an accurate length correction of the testing tool.

Table 5-1. Flow logging and testing in KLX03. Activity schedule.

Item	Activity	Explanation	Date
1	Mobilisation at site	Unpacking the trailer.	2004-11-04
7	Length calibration of the downhole tool	Dummy logging (SKB Caliper and SPR). Logging without the lower rubber discs, no pumping.	2004-11-04 2004-11-05
9	Borehole fluid logging	EC, Temp, P_{abs} measured without lower rubber disks, no pumping.	2004-11-05 2004-11-06
8	Overlapping flow logging	Section length L_w=5 m, Step length dL=0.5 m. No pumping.	2004-11-06 2004-11-08
10	Overlapping flow logging	Section length L_w=5 m, Step length dL=0.5 m at pumping (includes 1 day waiting after beginning of pumping).	2004-11-08 2004-11-10
11	Overlapping flow logging	Section length L_w=1 m, Step length dL=0.1 m, at pumping (only in conductive borehole intervals).	2004-11-10 2004-11-14
12	Fracture-specific EC-measurements in pre-selected fractures	Section length Lw=1 m, at pumping (in pre-selected fractures.	2004-11-14 2004-11-16
13	Borehole fluid logging	EC, Temp, P_{abs} measured without lower rubber disks, with pumping.	2004-11-16
14	Recovery transient	Measurement of water level and absolute pressure in the borehole after stopping of pumping.	2004-11-16 2004-11-17
11 extra	Flow measurement at smaller pumping	Length interval 194.93–195.93 m was measured at smaller pumping.	2004-11-17
14	Demobilisation	Uninstallation of the tool. Packing the trailer.	2004-11-17 2004-11-18
12	Delivery and filling of measured data	Delivering Daily logs, logging reports and raw data files for SKB.	2004-11-18

Each length mark includes two 20 mm wide tracks in the borehole wall. The distance between the marks is 100 mm. The upper track represents the reference level. An inevitable condition for a successful length calibration is that all length marks, or at least the major part of them, are detectable. The Difference flowmeter system uses caliper measurements in combination with single point resistance measurement (SPR) for this purpose, and these measurements were the first to be performed in borehole KLX03 (Item 7 in Table 5-1). These methods also reveal widened parts of the borehole.

The caliper- and SPR-measurements were preceded by measurements of electric conductivity (EC) of the borehole water (Item 9) during natural (un-pumped) conditions.

The flow measurements were performed firstly during natural (un-pumped) conditions (Item 8). Every tenth flow measurement 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 from it).

Pumping was started on November 8. The pump intake was at level 0.3 m (masl, RHB70), see Appendix 13.3. The groundwater level sensor (pressure transducer) was at –0.80 m (masl, RHB70). After 24 hours waiting time, the overlapping flow logging (Item 10) was carried out in the borehole interval 101.30–992.37 m. The section length was 5 m, and the length increment (step length) 0.5 m.

The overlapping flow logging was then continued in the way that previously measured flow anomalies were re-measured with 1 m section length and 0.1 m step length (Item 11). After that fracture specific EC was measured from some selected fractures (Item 12).

Still during pumped conditions, the EC of borehole water (Item 13) was measured. After this, the pump was stopped and the recovery of the groundwater level was monitored (Item 14).

Re-measurement was done at length interval 194.93–195.93 m using smaller drawdown since the flow rate was near the upper measurement limit at this interval. A section length of 1 m and a step length of 0.1 m were used here (Item 11 extra).

6 Results

6.1 Length calibration

6.1.1 Caliper and SPR measurement

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. In KLX03 the stretching of the cable was relatively high since the measurements were performed from the bottom of the borehole in the upward direction.

Length marks on the borehole wall can be used to minimise the length errors. The length marks are detected with the SKB caliper tool. The length scale is firstly corrected according to the length marks. Single point resistance is recorded simultaneously with the caliper logging. All flow measurement sequences can then be length corrected by synchronising the SPR results (SPR is recorded during all measurements) with the original caliper/SPR measurement.

The procedure of length correction was the following:

- Caliper+SPR measurement (Item 7) was initially length corrected in relation to the known length marks, Appendix 1.41 black curve. Corrections between the length marks were obtained for each length mark by linear interpolation.
- The SPR curve of Item 7 was then compared with the SPR curves of Items 8, 10, 11, 11 extra and 12 to obtain relative length errors of these measurement sequences.
- All SPR curves could then be synchronized, as can be seen in Appendices 1.2–1.40.

The results of the caliper and single point resistance measurements from all measurements in the entire borehole are presented in Appendix 1.1. five SPR-curves are plotted together with the SPR+caliper measurement. These measurements correspond to Items 8, 10, 11, 11 extra and 12 in Table 5-1.

Caliper tool shows low voltage when the borehole diameter is below 77 mm and high voltage when borehole diameter is over 77 mm.

Zoomed results of caliper and SPR are presented in Appendices 1.2–1.40. The length marks were detected at 110 m, 150 m, 200 m, 250 m, 300 m, 350 m, 399 m, 400 m, 450 m, 500 m, 550 m, 600 m, 650 m, 700 m, 750 m, 800 m, 850 m, and 900 m. The length marks were not detected at 950 m with the caliper tool. There was a large anomaly at this location, indicating widened borehole, see Appendix 1.39. The length correction was made using the detected length marks, which can also be seen in SPR results. However, the anomaly is complicated due to the four rubber disks used at the upper end of the section, two at the each side of the resistance electrode. A selection of length intervals where clear SPR-anomalies were found, are plotted as well.

The aim of the plots in Appendices 1.2–1.40 is to verify the accuracy of the length correction. The curves in these plots represent length corrected results.

The magnitude of length correction along the borehole is presented in Appendix 1.41. The error is negative, due to fact that the stretching extends the logging cable (i.e. the cable is longer than the nominal length marked on the cable).

6.1.2 Estimated error in location of detected fractures

In spite of the length correction described above, there are still length errors due to 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. Corrections between the length marks can be other than linear. This could cause error +/–0.1 m in the SPR+caliper measurement (Item 6).
4. SPR curves may be imperfectly synchronized. This could cause error +/–0.1 m.

In the worst case, the errors of points 1, 2, 3 and 4 are summed up. Then the total estimated error between the length marks would be +/–0.3 m.

Near the length marks the situation is slightly better. In the worst case, the errors of points 1, 2, and 4 are summed up. Then the total estimated error near the length marks would be +/–0.2 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.

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

6.2 EC of fracture-specific water

The flow direction is always from the fractures into the borehole if the borehole is pumped with a sufficiently large drawdown. This enables the determination of electric conductivity from fracture-specific water. Both electric conductivity and temperature of flowing water from the fractures were measured.

The flow measurement makes it possible to find the fractures for the EC measurement. The tool is moved so that the fracture to be tested will be located within the test section (L = 0.5 m). The EC measurements begin if the flow rate is larger than a predetermined limit. The tool is kept on the selected fracture. The measurement is continued at the given length allowing the fracture-specific water to enter the section. The waiting time for the EC measurement can be automatically calculated from the measured flow rate. The aim is to flush the water volume within the test section well enough. The measuring computer is programmed to change the water volume within the test section about three times. Also stabilization of measured EC values is monitored to ensure sufficient waiting time. The water volume in a one meter long test section was 1.8 L. In this case waiting times were selected to be much longer than calculated times.

Electric conductivity of fracture-specific water is presented on time scale, see Appendix 14.1. The blue symbol represents the value when tool was moved (half meter point interval) and the red symbol means that the tool was stopped on a fracture for a fracture specific EC measurement. The same fracture specific EC measurements are also presented on a zoomed time scale, see Appendices 14.2–14.3.

Borehole lengths at the upper and lower ends of the section, fracture locations as well as the final EC values are listed in Table 6-1.

Table 6-1. Fracture-specific EC.

Upper end of section (m)	Lower end of section (m)	Fractures measured (m)	EC (S/m) at 25°C
195.1	195.6	195.3	0.14
266.5	267.0	266.8	0.30
274.2	274.7	274.7	1.31
453.2	453.7	453.4	1.27
619.2	619.7	619.4	1.36
969.9	970.4	970.1	2.87

6.3 Pressure measurements

Absolute pressure was registered with the other measurements in Items 8, 9, 10, 11, 11 extra, 12, 13 and 14. The pressure sensor measures the sum of hydrostatic pressure in the borehole and air pressure. Air pressure was also registered, Appendix 13.2. 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 /SKB, 2002/:

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

where

h is the hydraulic head (masl) 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 9.80065 m/s^2 and

z is the elevation of measurement (masl) according to the RHB 70 reference system.

An offset of 2.46 kPa is subtracted from all absolute pressure results.

Exact z-coordinates are important in head calculation, 10 cm error in z-coordinate means 10 cm error in head. The calculated head results are presented in a graph in Appendix 13.1.

6.3 Flow logging

6.3.1 General comments on results

The flow results are presented together with single point resistance (right hand side) and caliper plot (in the middle), see Appendices 3.1–3.45. Single point resistance shows usually low resistance value on a fracture where flow is detected. There are also many other resistance anomalies from other fractures and geological features. The electrode of the Single point resistance tool is located within the upper rubber disks. Thus, the locations of the resistance anomalies of the leaky fractures fit with the lower end of the flow anomalies.

The flow logging was firstly performed with a 5 m section length and with 0.5 m length increments under natural conditions (no pumping), see Appendices 3.1–3.45 (blue curve). The method (overlapping flow logging) gives the length and the thickness of conductive zones with a length resolution of 0.5 m. To obtain quick results, only the thermal dilution method is used for flow determination. Thermal dilution method was used. However, every tenth flow measurement had a longer measurement time to ensure the direction of the flow (into the borehole or out of it). After that same depth intervals were measured under pumped conditions (red curve).

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. The overlapping flow logging was therefore repeated in the vicinity of identified flow anomalies using a 1 m long test section and 0.1 m length increments, see Appendices 3.1–3.45 (violet curve).

Detected fractures are shown on the caliper scale 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.

The table in Appendix 10 were used to calculate conductive fracture frequency (CFF). The number of conductive fractures was counted on the same 5 meter sections as in Appendix 6 before. The number of conductive fractures was sorted in six columns depending on their flow rate. The total conductive fracture frequency is presented graphically, see Appendix 11.

6.3.2 Transmissivity and hydraulic head of borehole sections

The entire borehole between 101.30 and 992.37 m was flow logged with a 5 m section length and with 0.5 m length increments. All the flow logging results presented in this report is derived from measurements with the thermal dilution method.

The results of the measurements with a 5 m section length are presented in tables, see Appendices 7.1–7.6. Only the results with a 5 m length increment are used. Secup presented in Appendices 7.1–7.6 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. Secup and seclow values for the two sequences (measurements at un-pumped and pumped conditions) are not exactly identical, due to a minor difference of the cable stretching. The difference between these two sequences was small. Secup and seclow given in Appendices 7.1–7.6 are calculated as an average of these two values. The same flow rates as in Appendix 7, are also plotted in Appendices 3.1–3.45.

Pressure was measured and calculated as described in Chapter 6.3. Borehole head dh_0 and borehole head dh_1 in Appendices 7.1–7.6 represent heads determined without respectively with pumping. Head in the borehole and calculated heads of borehole sections are given in RHB 70 scale.

The flow results presented in Appendices 7.1–7.6 (Q_0 and Q_1), representing flow rates derived from measurements during un-pumped respectively pumped conditions, are presented side by side to make comparison easier. Flow rates are positive if the flow direction is from the bedrock into the borehole and vice versa. With the borehole at rest, 13 sections were detected as flow yielding, of which 10 had a flow direction from the borehole into the bedrock (negative flow). During pumping, all 36 detected flows were directed towards the borehole.

The measurable flow range was exceeded at length of 195.3 m when the borehole was pumped. This location (length) was re-measured with smaller drawdown (with a section length of 1 m). Since all flow result was relatively consistent (see Appendix 3.46), transmissivities and heads of borehole sections presented in Appendices 7.6 and 4.2 are calculated from the original measurement with larger drawdown.

The flow data is presented as a plot, see Appendix 4.1. The left hand side of each diagram represents flow from the borehole into the bedrock for the respective test sections, whereas the right hand side represents the opposite. If the measured flow was zero (below the measurement limit), it is not visible in the logarithmic scale of the appendices.

In the plots (Appendix 4.1) and in the tables (Appendix 7), also the lower and upper measurement limits of flow are presented. There are theoretical and practical lower limits of flow, see Chapter 6.4.4.

Hydraulic head and transmissivity of borehole sections can be calculated from flow data using the method described in Chapter 3. Hydraulic head of sections is presented in the plots if none of the two flow values at the same length is equal to zero. Transmissivity is presented if none or just one of the flows is equal to zero, see Appendix 4.2. The measurement limits of transmissivity are also shown in Appendix 4.2 and in Appendix 7. All the measurement limit values of transmissivity are based on the actual pressure difference in the borehole (borehole head dh_0 and borehole head dh_1 in Appendix 7).

The sum of detected flows without pumping (Q_0) was –1.5 E–06 m^3/s (–5,000 mL/h). This sum should normally be zero if all the flows in the borehole are correctly measured, the borehole is not pumped, the water level is constant, the salinity distribution in the borehole is stabilized and the fractures are at steady state pressure. In this case the sum of inflows (into the borehole) was smaller than the sum of outflows.

6.3.3 Transmissivity and hydraulic head of fractures

An attempt was made to evaluate the magnitude of fracture-specific flow rates. The results for a 1 m section length and for 0.1 m length increments were used for this purpose. The first step in this procedure is to identify the locations of individual flowing fractures and then to evaluate their flow rates.

In cases where fracture distance is less than one meter, it may be difficult to evaluate the flow rate. There are such cases for instance in Appendix 3.29. Increase or decrease of flow anomaly at the fracture location (marked with the lines in Appendix 3) is used for determination of flow rate (filled triangles in Appendix 3).

Some fracture-specific results were rated to be "uncertain" results, see Appendix 8. The criterion of "uncertain" was in most cases a minor flow rate (< 30 mL/h). In some cases fracture anomalies were unclear, since the distance between them was less than one meter or since the form of anomaly was unclear because of noise.

Since a 1 m section length was not used at un-pumped conditions, the results for a 5 m section length were used instead. The fracture locations are important when evaluating flow rate at un-pumped conditions. The fracture locations are known on the basis of the measurements for a 1 m section length. Increase or decrease of flow anomaly at the fracture location determines the flow rate. The measurement for a 5 m section length at un-pumped conditions is used for the corresponding fracture flow rates. The flow direction is evaluated as well. The results of evaluation are plotted in Appendix 3, blue filled triangle.

Total amount of detected flowing fractures was 55, but only 5 could be defined without pumping. These 5 fractures could be used for head estimations and all 55 were used for transmissivity estimations, Appendix 8. Transmissivity and hydraulic head of fractures are plotted in Appendix 5.

Re-measurement was done around 195.3 m using smaller drawdown. The flow rate was near the measurement limit in these intervals. The used pumping rates are presented in Fracture-specific transmissivities were compared with transmissivities of borehole sections in Appendix 12. All fracture-specific transmisivities within each 5 m interval were first summed up to make them comparable with measurements with a 5 m section length. The results are, in most cases, consistent between the two types of measurements.

6.3.4 Theoretical and practical limits of flow measurements and transmissivity

Theoretical minimum of measurable flow rate in the overlapping results (thermal dilution method only) is about 30 mL/h. The upper limit of flow measurement is 300,000 mL/h. These limits are determined on the basis of flow calibration. It is assumed that flow can be reliably detected between the upper and lower theoretical limits in favourable borehole conditions.

The minimum measurable flow rate may be much higher in practice. Borehole conditions may increase the base level of flow (noise level). The noise level can be evaluated on such intervals of the borehole where there are no flowing fractures or other structures. The noise level may vary along the borehole.

There are several known reasons for increased noise in flow:

1. Rough borehole wall.
2. Solid particles in water such as clay or drilling mud.
3. Gas bubbles in water.
4. High flow rate along the borehole.

Rough borehole wall always causes high noise not only in flow but also in single point resistance results. Flow curve and SPR curves are typically spiky when borehole wall is rough.

Drilling mud usually increases noise level. Typically this kind of noise is seen both without pumping and with pumping.

Pumping causes pressure drop in borehole water and in water in fractures near the borehole. This may lead to release of gas from dissolved form to gas bubbles. Some fractures may produce more gas than others. Sometimes increased noise level is obtained just above certain fractures (when the borehole is measured upwards). The reason is assumed to be gas bubbles. Bubbles may cause decrease of average density of water and therefore also decrease of measured head in the borehole.

The effect of high flow rate along the borehole can often be seen above high flowing fractures. Any minor leak at the lower rubber disks is directly measured as increased noise in flow.

High noise level in flow masks "real" flow that is smaller than the noise. Real flows are totally invisible if they are about ten times smaller than the noise. Real flows are registered correctly if they are about ten times larger than noise. By experience, real flows between 1/10 times noise and 10 times noise are summed up with noise. Therefore noise level could be subtracted from the measured flow to get the real flow. This correction has not been done so far because it is not clear whether it is applicable in each case.

The practical minimum level of measurable flow rate is evaluated and presented in Appendices 3.1–3.45 using grey dashed line (Lower limit of flow rate). Below this line there may be fractures or structures that remain undetected.

Noise level in KLX03 was between 30–1,000 mL/h. A possible reason for noise could be drilling mud in the borehole water.

In some boreholes the upper limit of flow measurement (300,000 mL/h) may be exceeded. Such fractures or structures hardly remain undetected (as the fractures below the lower limit). High flow fractures can be measured separately at smaller drawdown. In KLX03 there was one which was re-measured using smaller drawdown.

Practical minimum of measurable flow rate is also presented in Appendix 7 (TD-measl_{LP}). It is taken from the plotted curve in Appendix 3 (Lower limit of flow rate). Practical minimum of measurable transmissivity can be evaluated using Q-lower limit and the head difference at each measurement, see Appendix 7. Theoretical minimum measurable transmissivity can also be evaluated using Q value of 30 mL/h (minimum theoretical flow rate with thermal dilution method) instead of Q-lower limit Practical, see Appendix 7 (TD-measl_{LT}). The upper measurement limit of transmissivity can be evaluated using the maximum flow rate (300,000 mL/h) at the actual head difference as above, see Appendix 7 (TD-measl_{U}).

All three flow limits are also plotted with measured flow rates, see Appendix 4.1. Theoretical minimum and maximum values are 30 mL/h and 300,000 mL/h, respectively.

The three transmissivity limits are also presented graphically, see Appendix 4.2.

Similar flow and transmissivity limits are not given for the fracture-specific results, Appendices 5 and 8. Approximately the same limits would be valid also for these results. The limits for fracture-specific results are more difficult to define. For instance, it may be difficult to see a small flow rate near (< 1 m) a high flowing fracture. The situation is similar for the upper flow limit. If there are several high flowing fractures nearer each other than one meter, the upper flow limit depends on the sum of flows which must be below 300,000 mL/h.

6.3.5 Transmissivity of the entire borehole

The pumping phase for the logging and its subsequent recovery is utilized to evaluate the transmissivity of the entire borehole. This is done with the two steady state methods and one transient analysis method, described in Chapter 3.

Steady state

For the Dupuit's formula (equation 3-9) R/r_0 is chosen to be 500, Q was 10.6 L/min, s (drawdown) was 10 m.

In the Moye's formula (equation 3-10) length of test section L is 898.6 m and borehole diameter $2r_0$ is 0.076 m.

Transient analysis (by M Morosini, SKB)

A Jacob type of analysis is done on the transient recovery phase following the methodology specified in SKB MD 320.004 (SKB internal controlling document). Briefly it specifies the utilization of the log-log plot and derivative method for the analsysis.

Furthermore, for an assumed storage coefficient $S = 4.0\times10^{-6}$ the recovery phase was simulated. The best fit simulation yield a transmissivity $T = 3.6\times10^{-5}$ m^2/s and a skin = 0.8.

Figure 6-1 show the semi-log and log-log plot of the recovery phase, this was utilised to extract the transmissivity.

The results of the three methods are given in Table 6-2 where for the steady-state analyses method of Dupuit and Moye, the flow was set to Q = 10.6 L/min and drawdown s = 10 m. Basic test data is in Appendix 13.

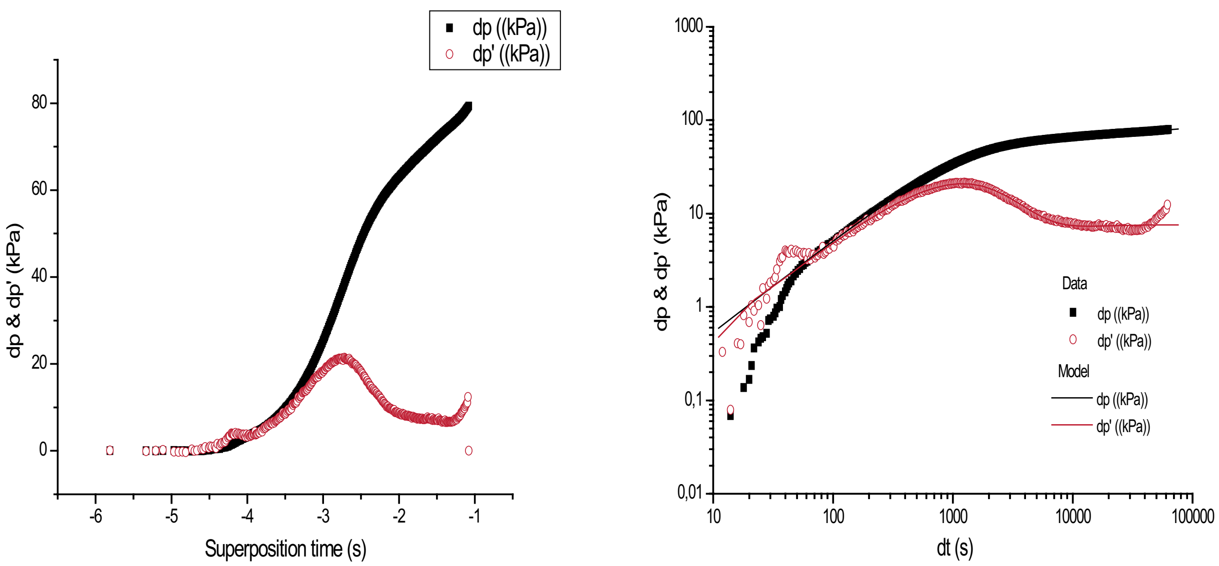

Figure 6-1. *Semi-log and log-log plot of recovery phase in KLX03 showing measured pressure dp (■) and pressure derivative dp' (o) along with simulated best fit curves (–) in the log-log plot.*

Table 6-2. Transmissivity of the entire borehole.

Method	Transmissivity (m^2/s)
Dupuit	1.8 E–05
Moye	2.9 E–05
Jacob/Horner	3.6 E–05

6.4 Groundwater level and pumping rate

The level of the groundwater table in the borehole during the measurement sequences is presented in Appendix 13.3. The borehole was pumped between November 8 and November 16 with a drawdown of about 10 meters. The pump intake was at level 0.3 m (masl, RHB70). The groundwater level sensor (pressure transducer) was at –0.80 m (masl, RHB70). Pumping rate was recorded, see Appendix 13.5.

The groundwater recovery was measured after the pumping period, November 16–17, Appendix 13.4. The recovery was measured with two sensors, using the water level sensor (pressure sensor for monitoring water level) and the absolute pressure sensor located in the flowmeter tool at the borehole length of 977.14 m.

7 Summary

In this study, the Posiva Flow Log/Difference Flow method has been used to determine the location and flow rate of flowing fractures or structures in borehole KLX03 at Oskarshamn. Measurements were carried out both when the borehole was at rest and during pumping. A 5 m section length with 0.5 m length increments was used firstly. The measurements were repeated using 1 m section length with 0.1 m length increments over the flow anomalies. After this electric conductivity was measured in selected flowing fractures.

Length calibration was made using the length marks on the borehole wall. The length marks were detected by caliper and in single point resistance logging. The latter method was also performed simultaneously with the flow measurements, and thus all flow results could be length calibrated by synchronising the single point resistance logs.

The total amount of detected flowing fractures in KLX03 was 55. Transmissivity and hydraulic head were calculated for borehole sections and fractures. The highest transmissivity was detected in a fracture at the length of 195.3 m. The lowest identified flowing fracture was at the length of 970.5 m.

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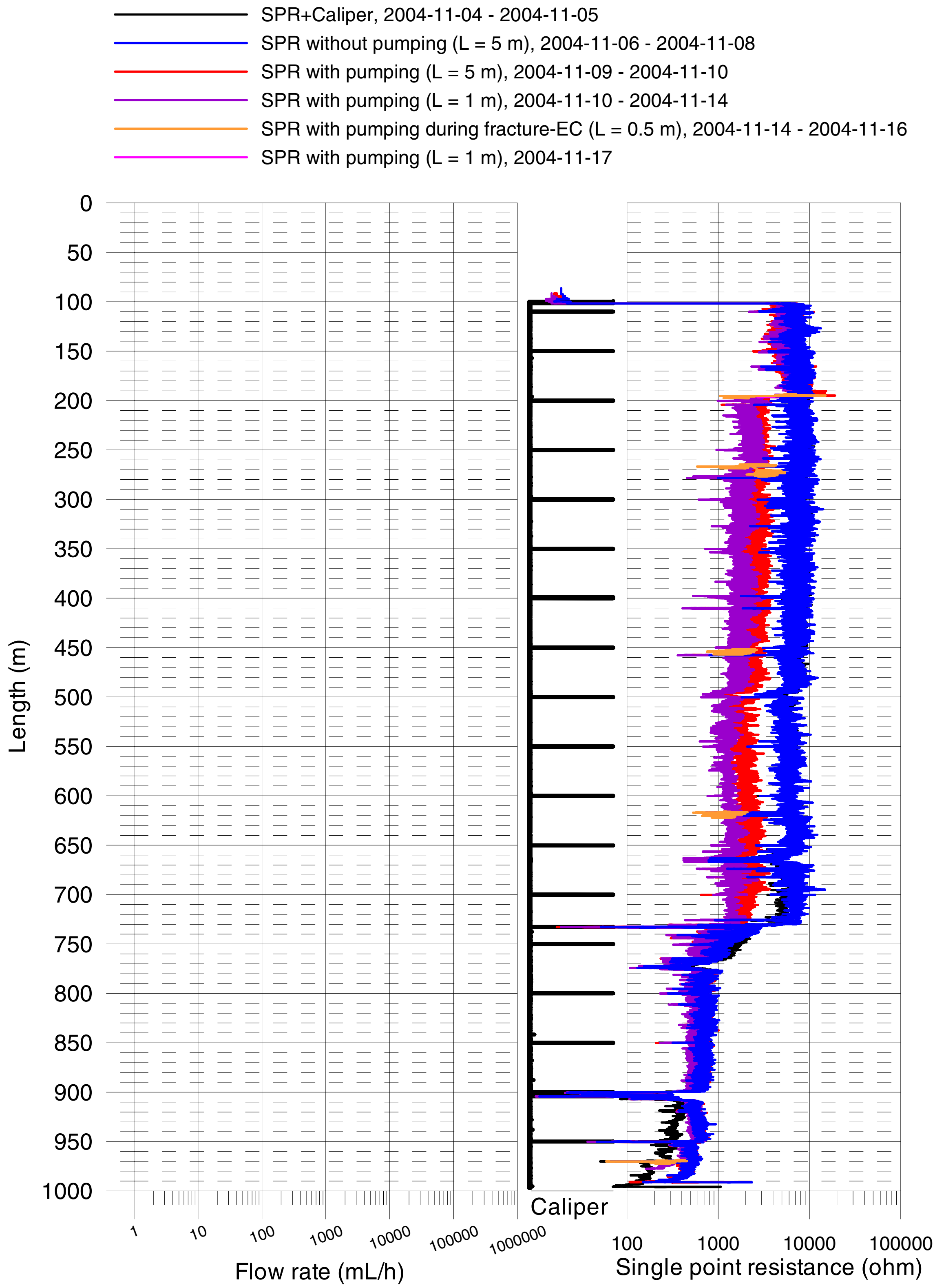
Appendices

Laxemar, KLX03
SPR and Caliper results after length correction



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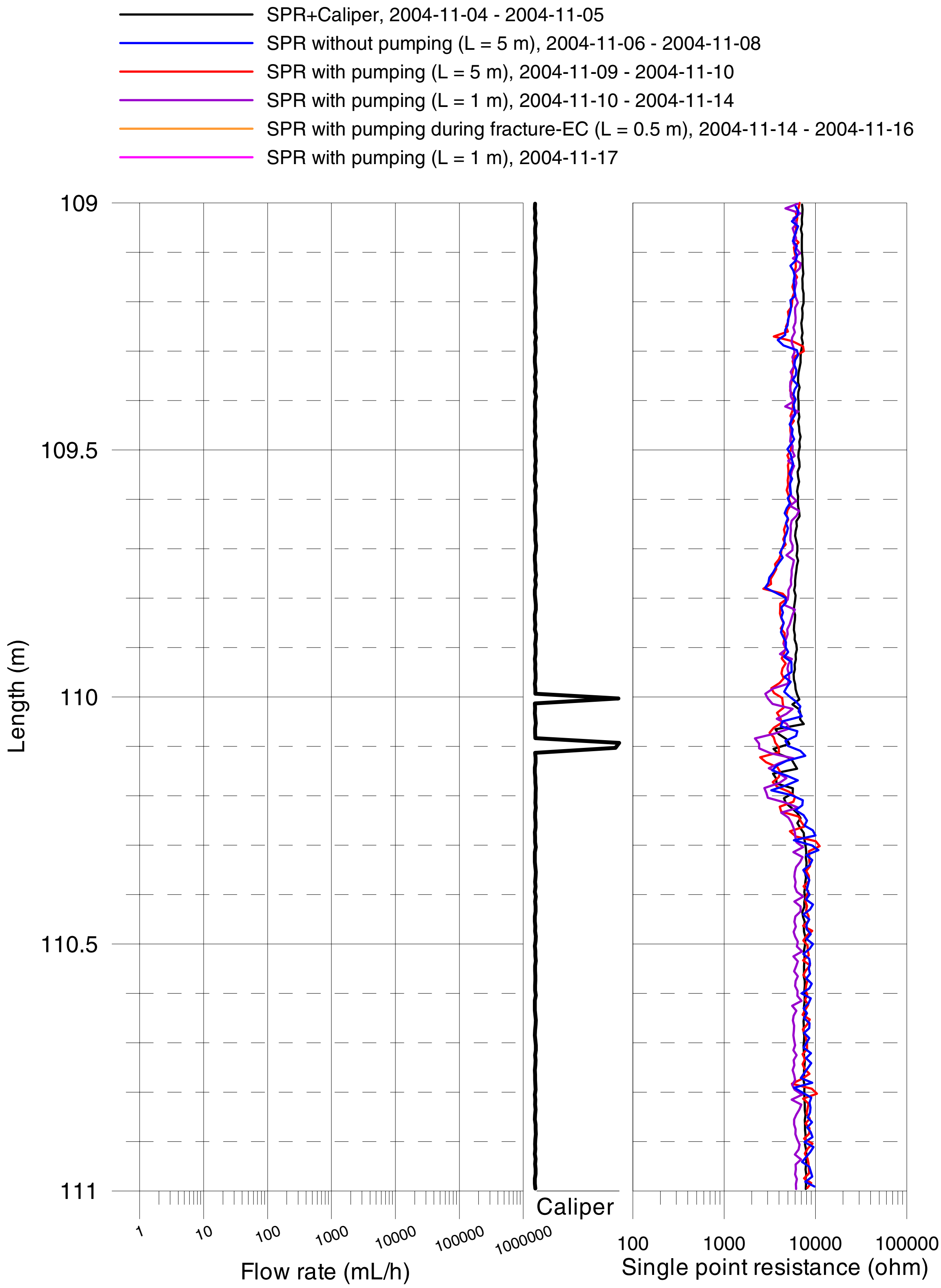

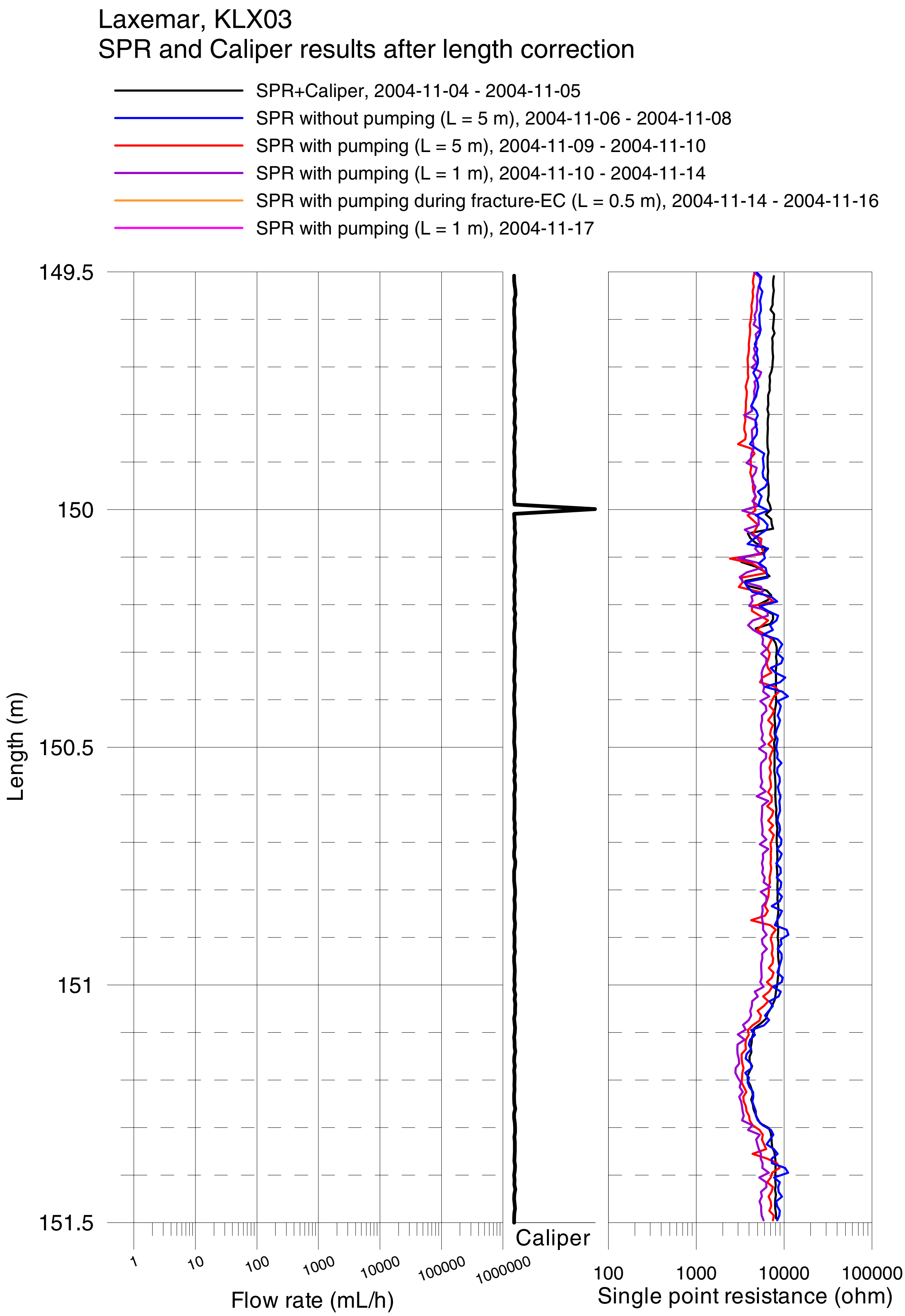
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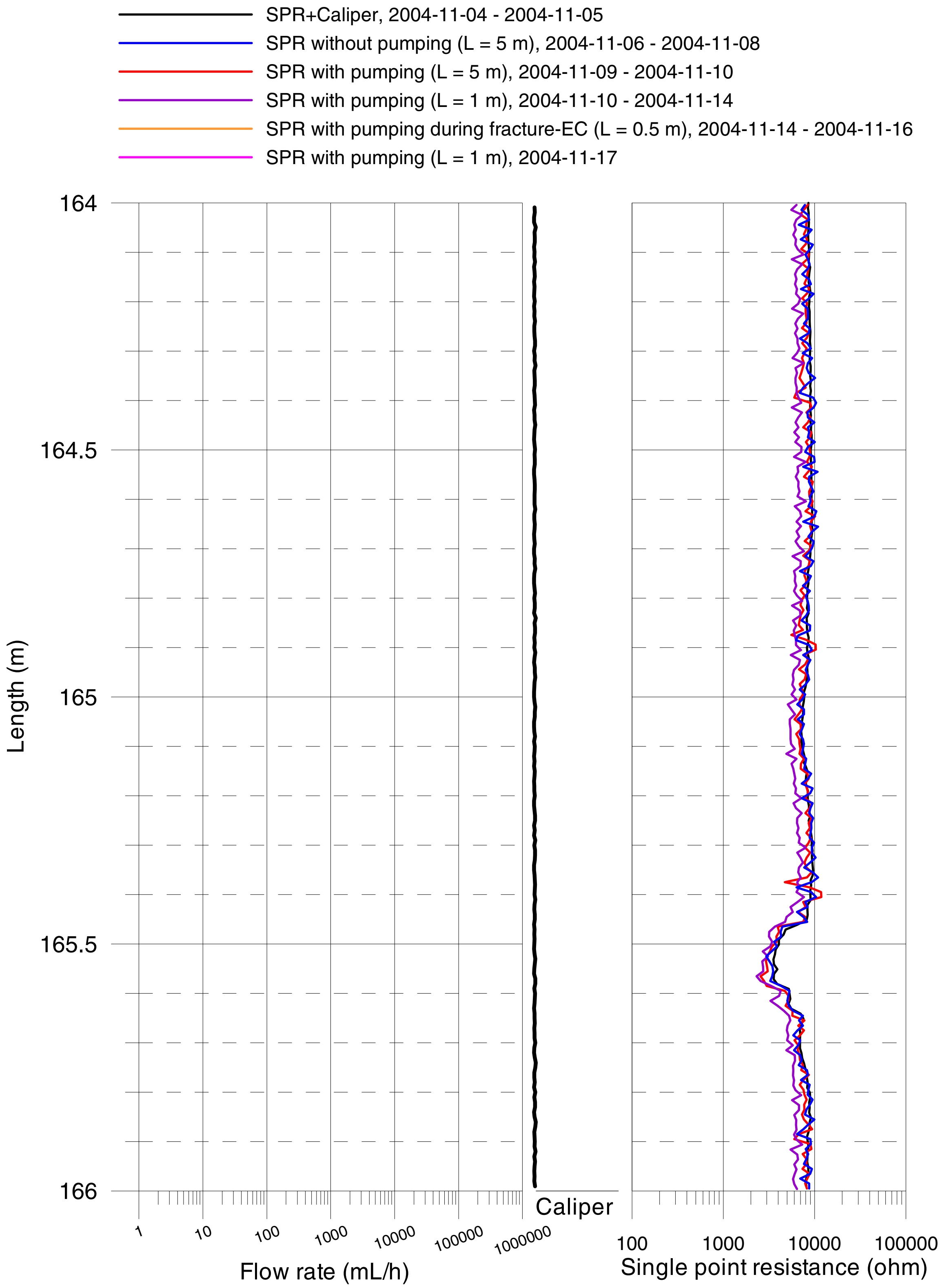
SPR with pumping (L = 1 m), 2004-11-10 - 2004-11-14
SPR with pumping during fracture-EC (L = 0.5 m), 2004-11-14 - 2004-11-16
SPR with pumping (L = 1 m), 2004-11-17
149.5
150
150.5
151
151.5
Length (m)
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)

Laxemar, KLX03
SPR and Caliper results after length correction



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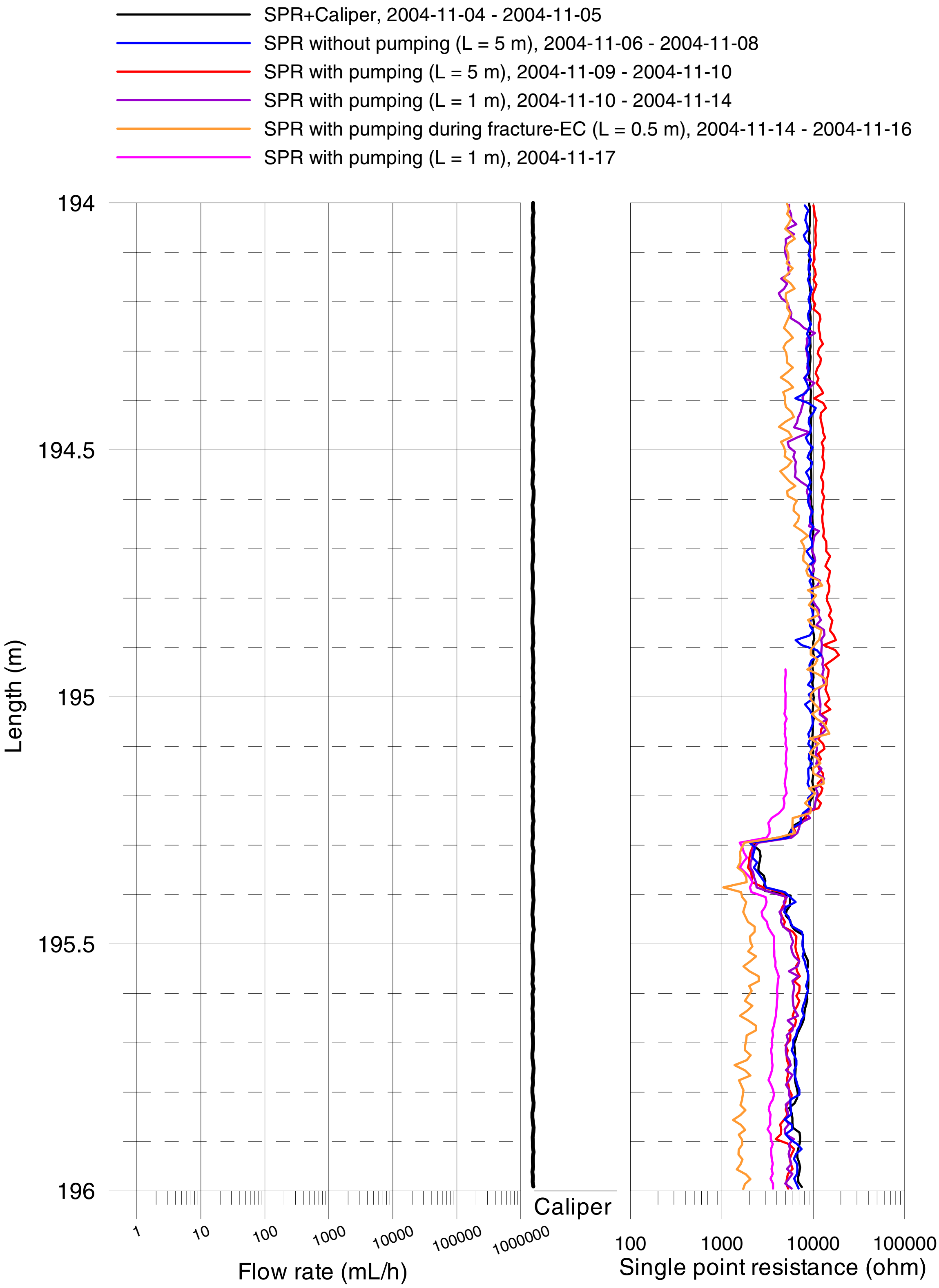

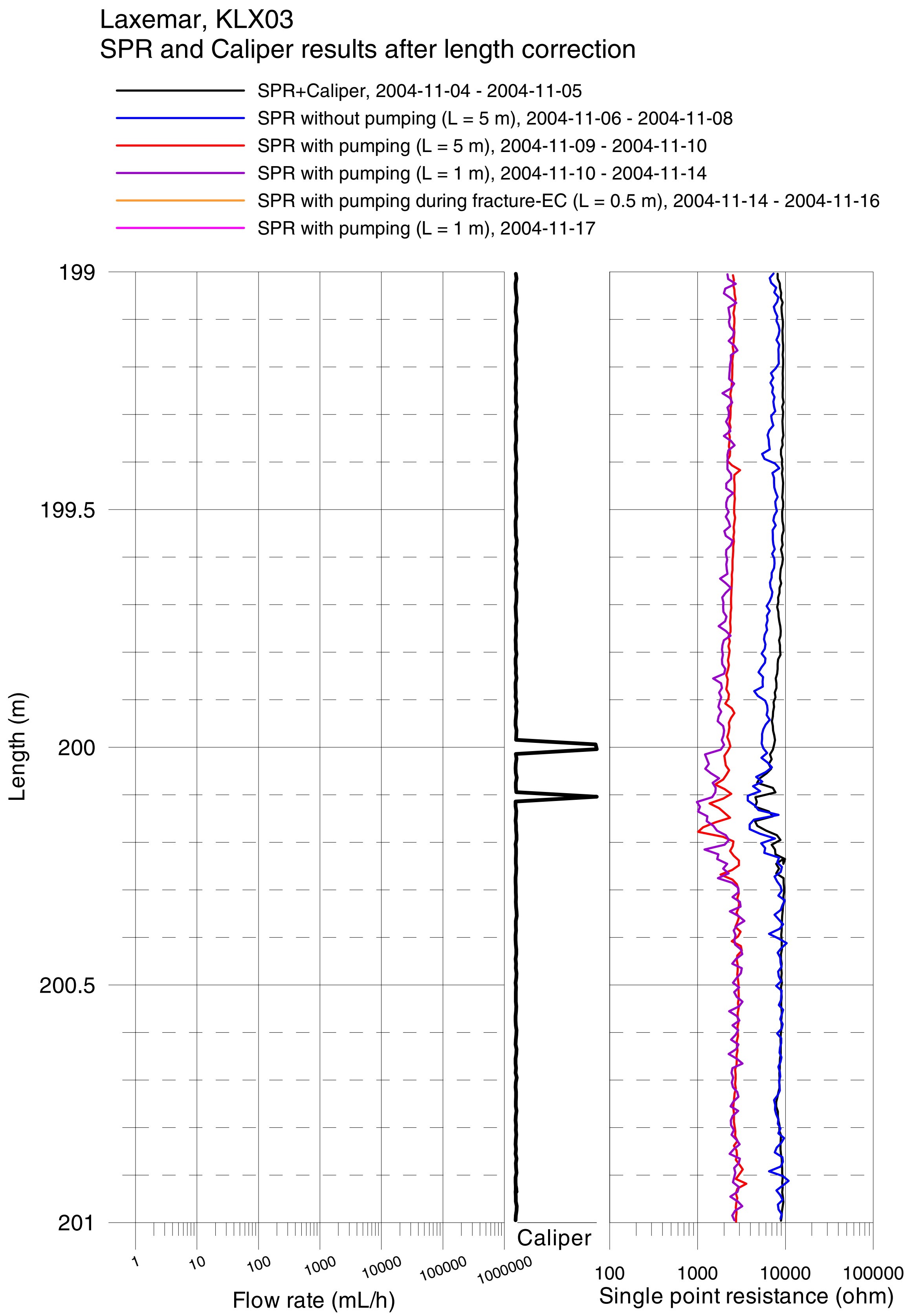

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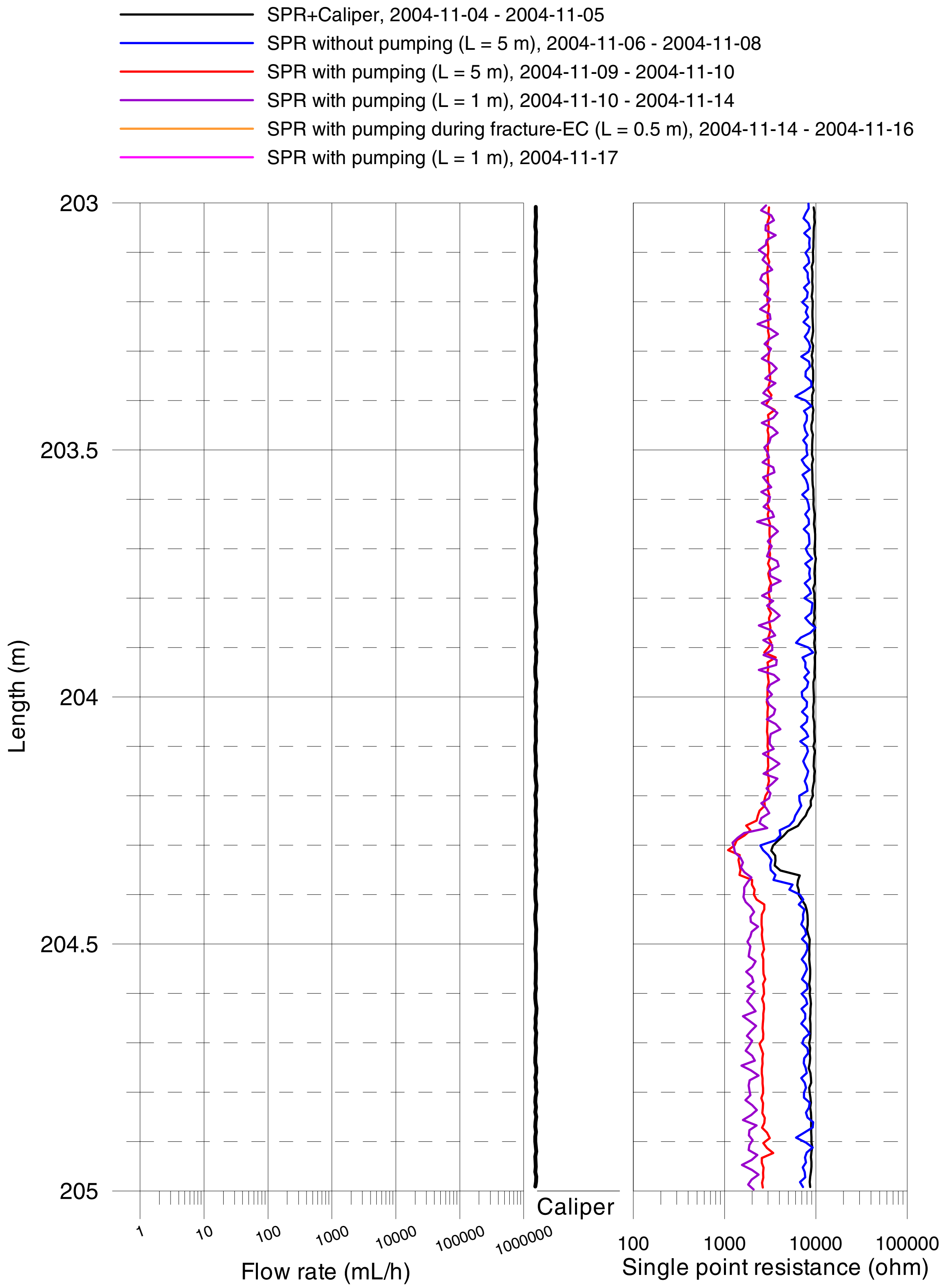
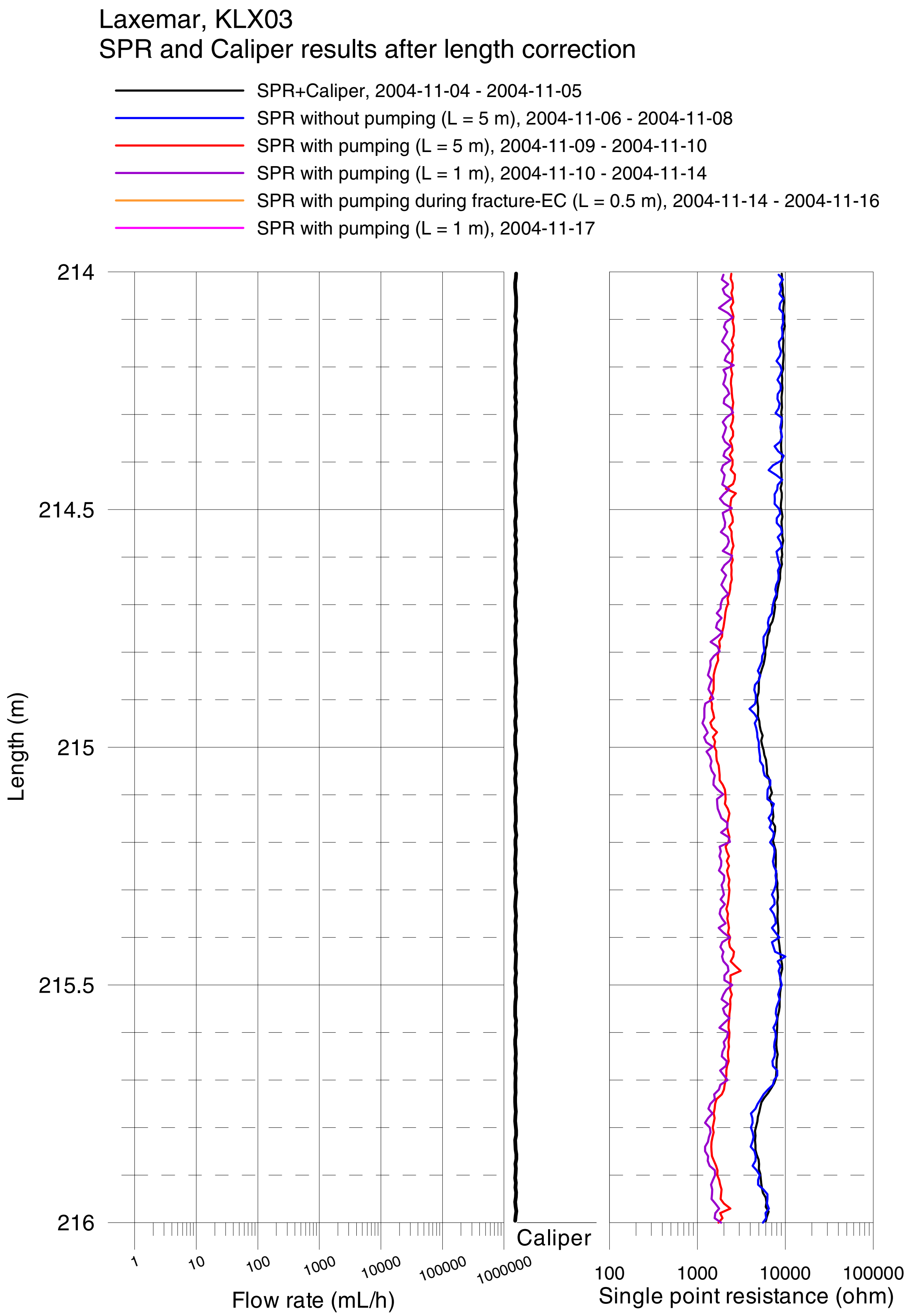
SPR with pumping during fracture-EC (L = 0.5 m), 2004-11-14 - 2004-11-16
SPR with pumping (L = 1 m), 2004-11-17
Length (m)
199
199.5
200
200.5
201
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)

Laxemar, KLX03
SPR and Caliper results after length correction

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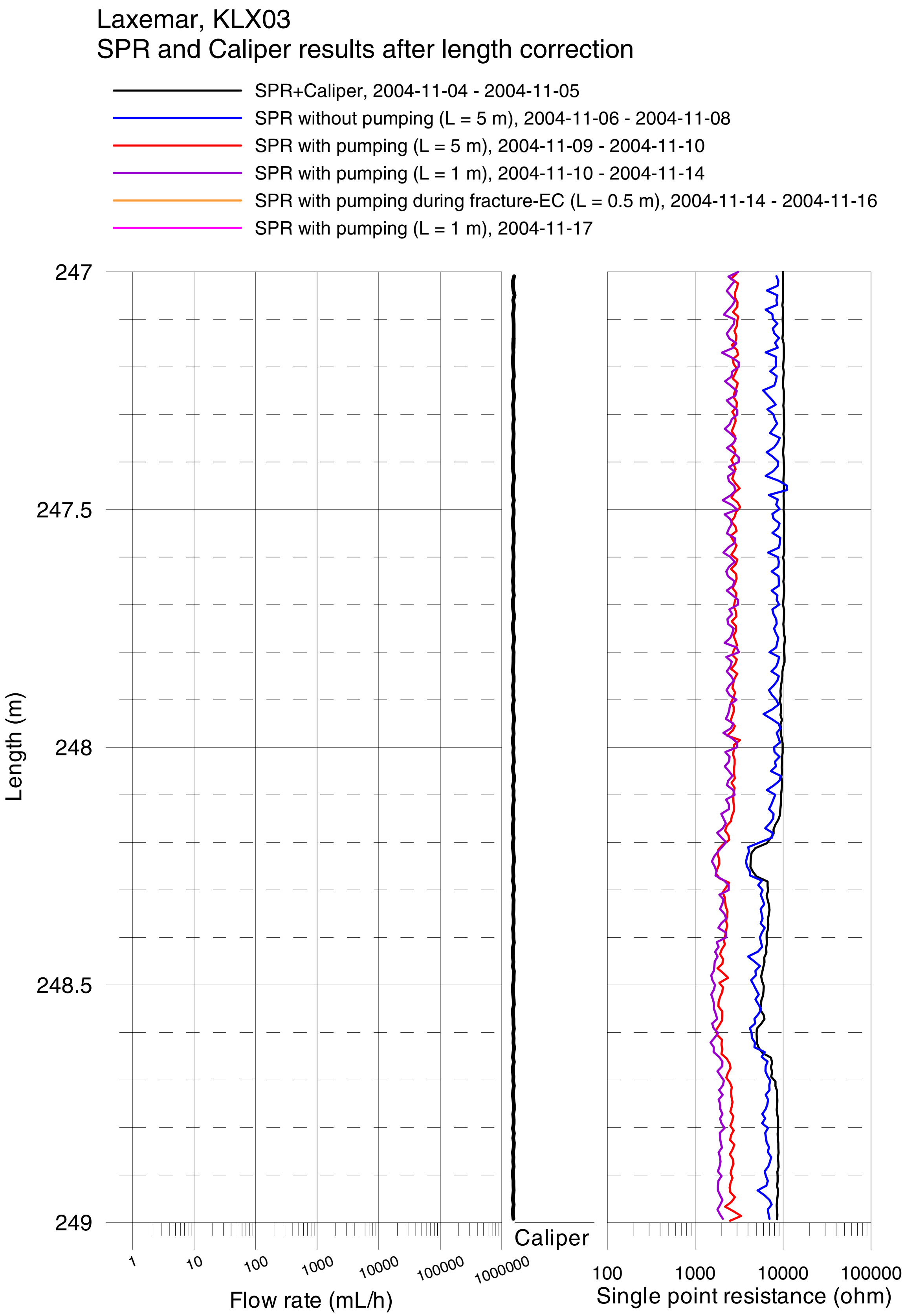
SPR with pumping (L = 1 m), 2004-11-10 - 2004-11-14
SPR with pumping during fracture-EC (L = 0.5 m), 2004-11-14 - 2004-11-16
SPR with pumping (L = 1 m), 2004-11-17
Length (m)
214
214.5
215
215.5
216
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)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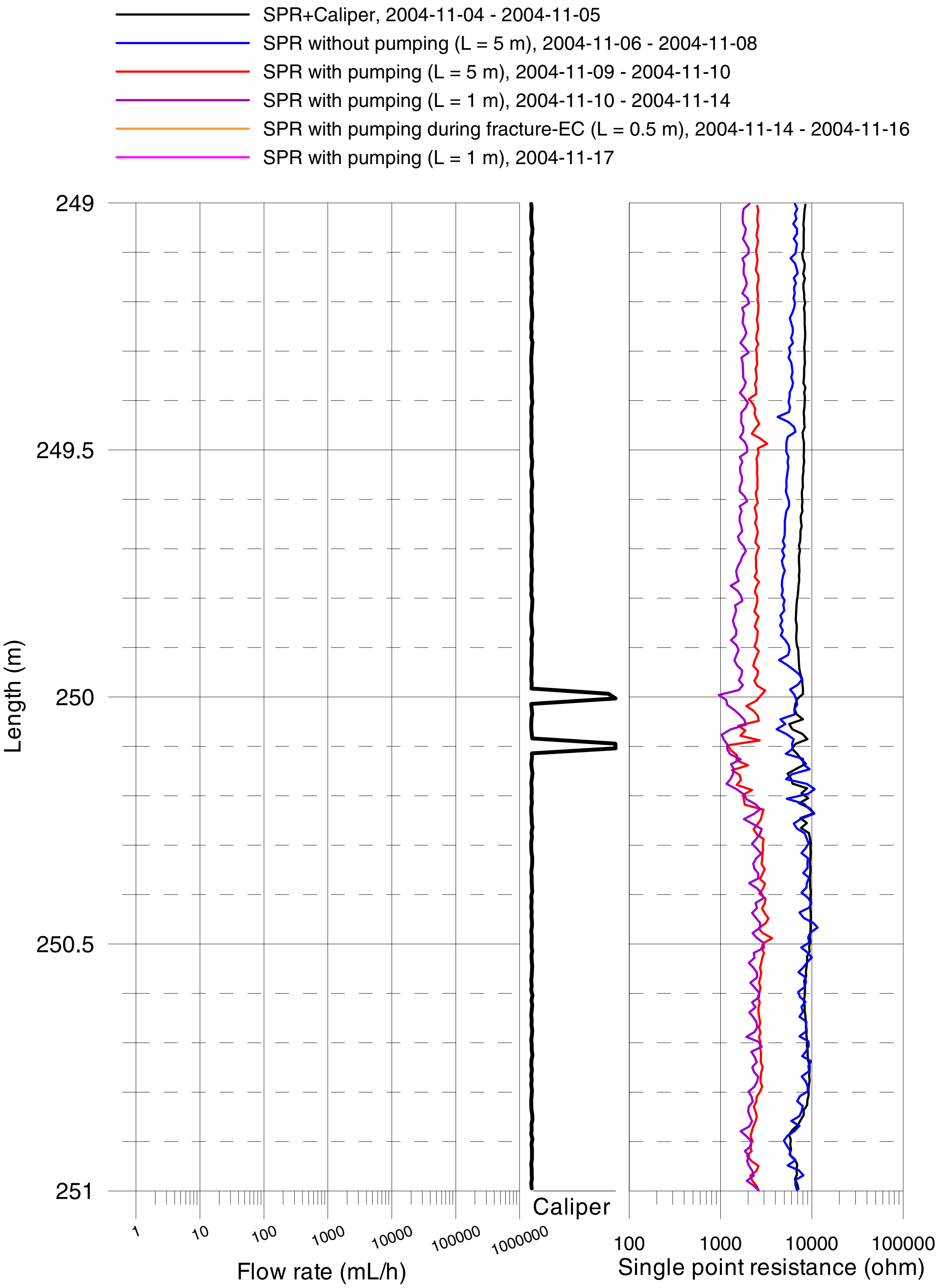
SPR with pumping during fracture-EC (L = 0.5 m), 2004-11-14 - 2004-11-16
SPR with pumping (L = 1 m), 2004-11-17
247
247.5
248
248.5
249
Length (m)
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)

Laxemar, KLX03
SPR and Caliper results after length correction



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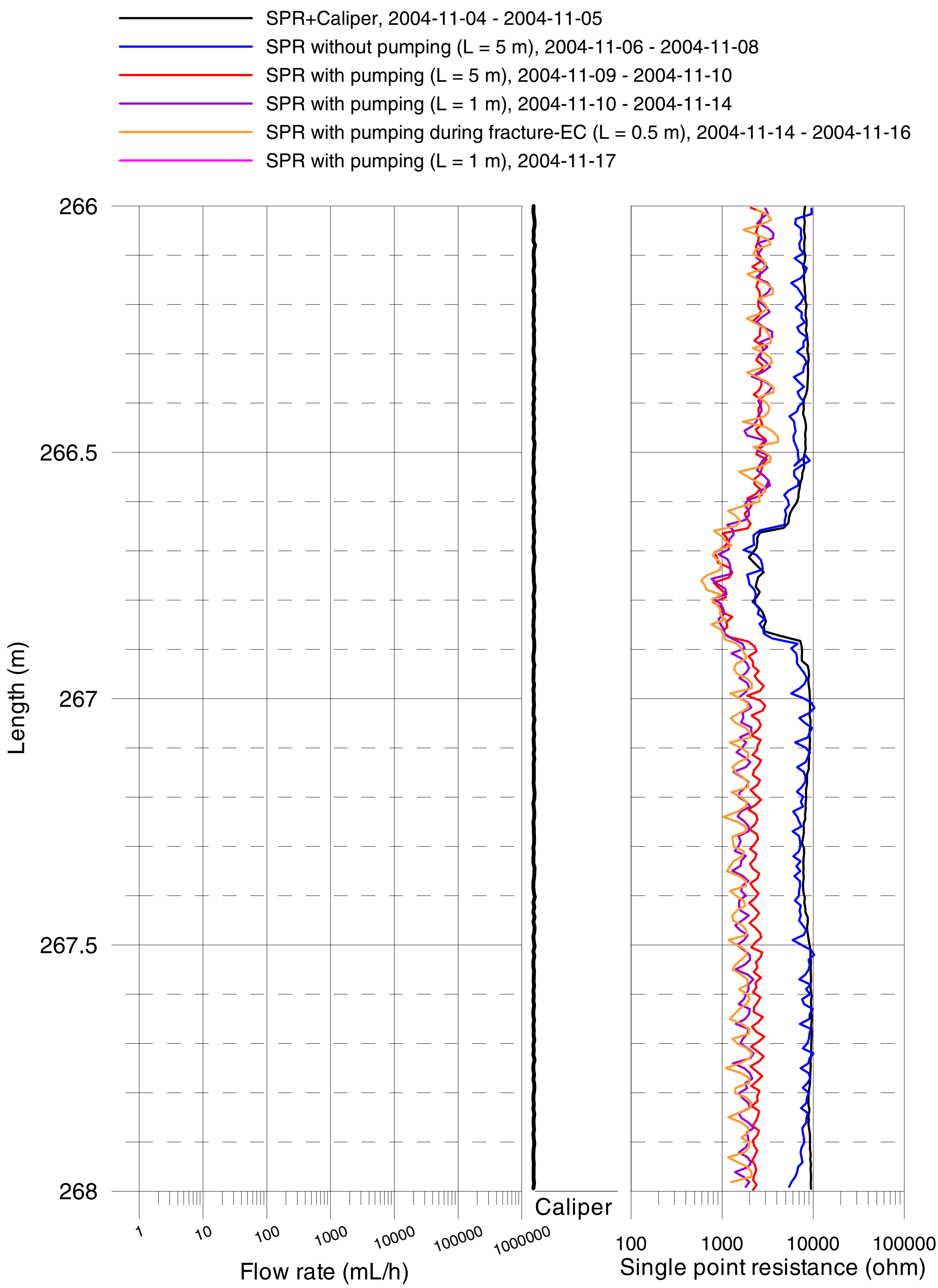

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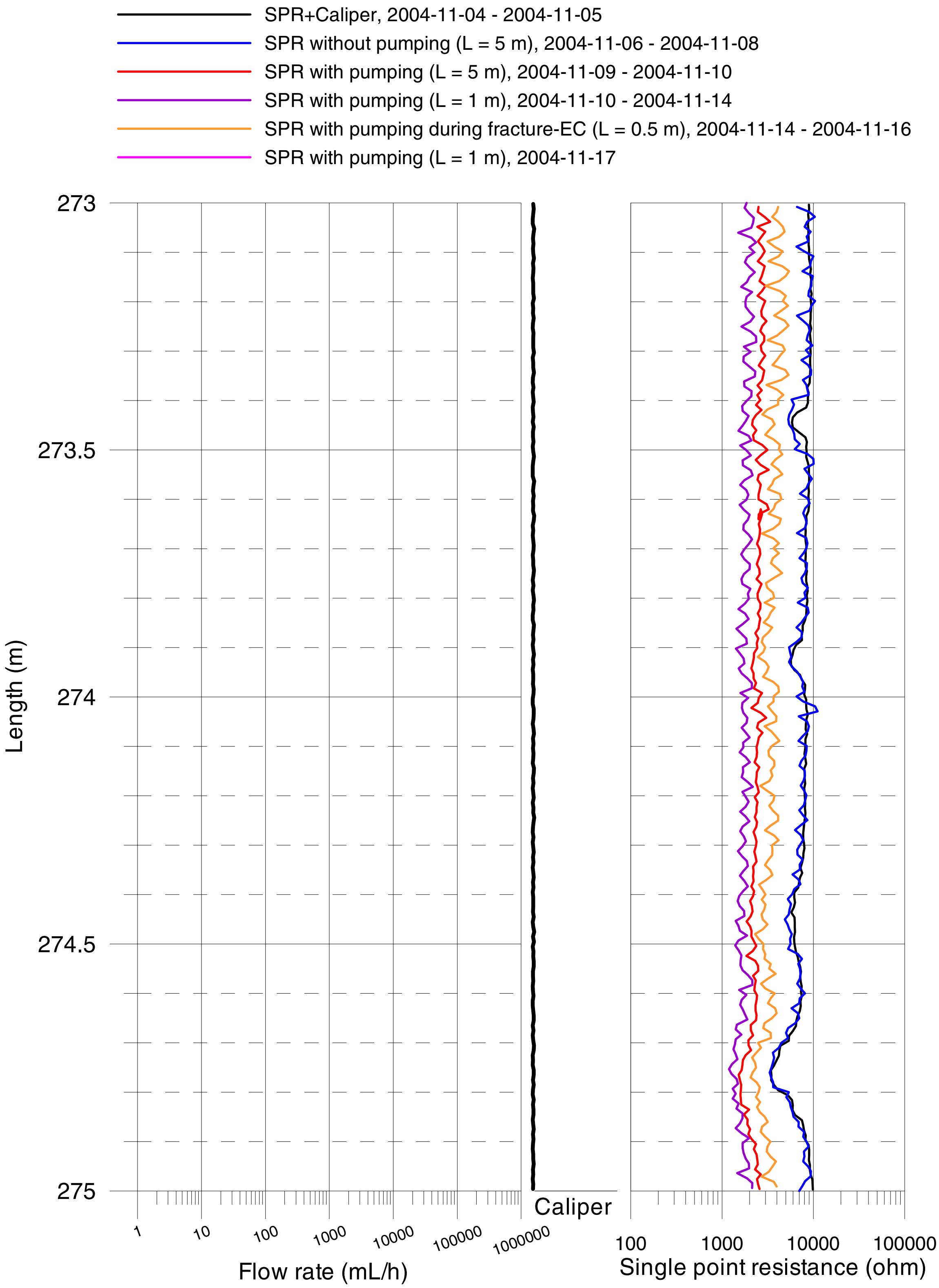

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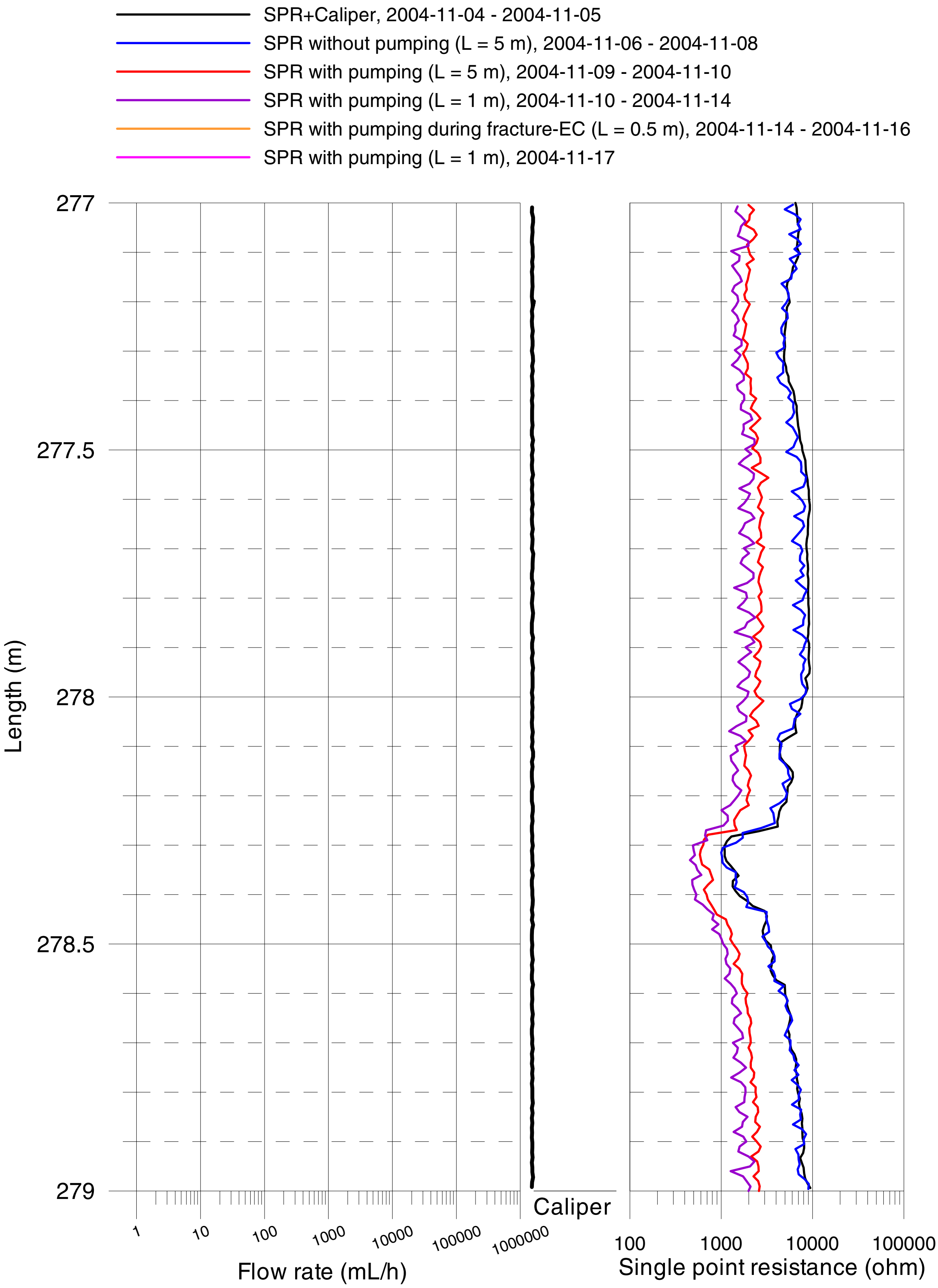

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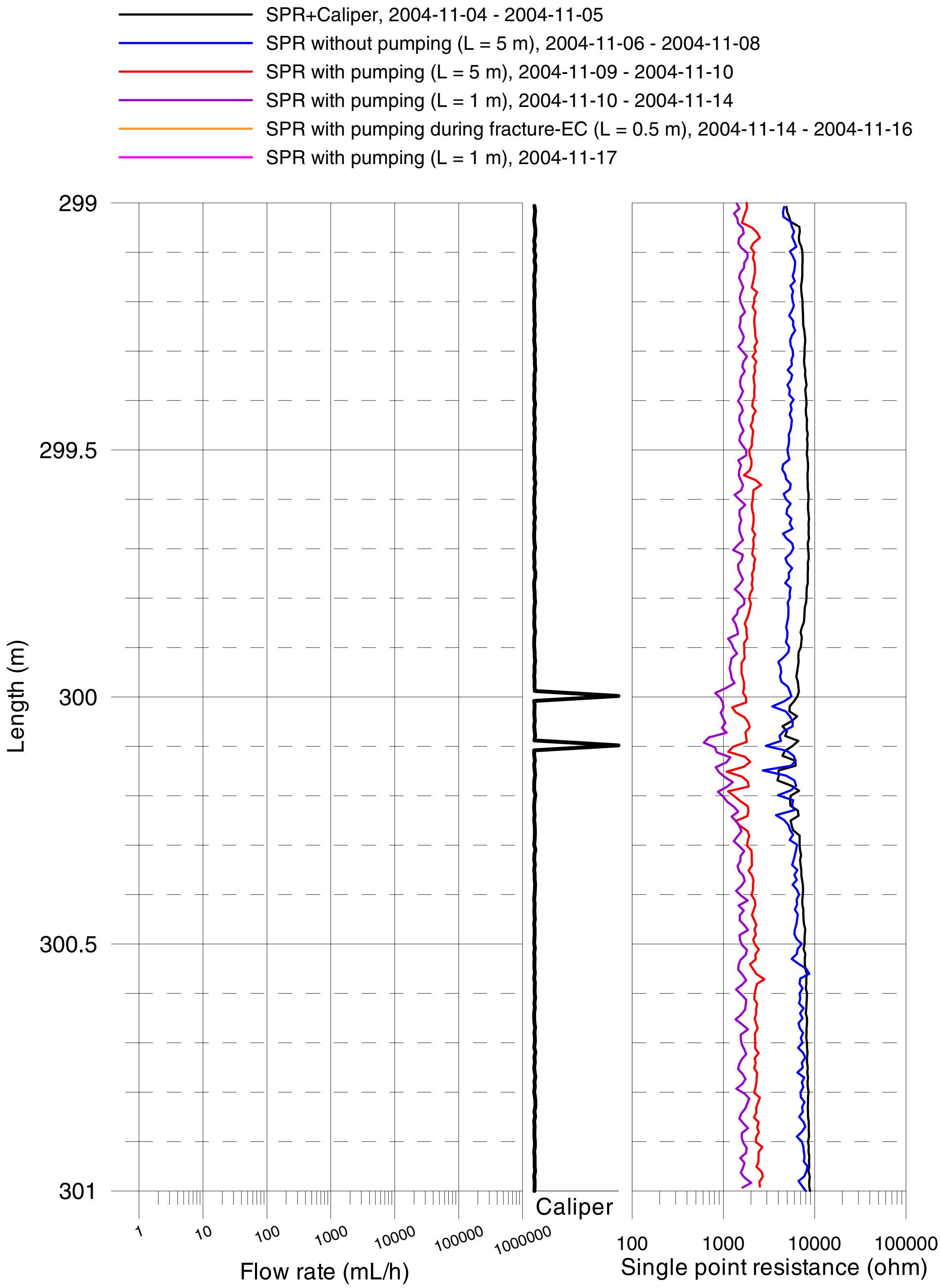

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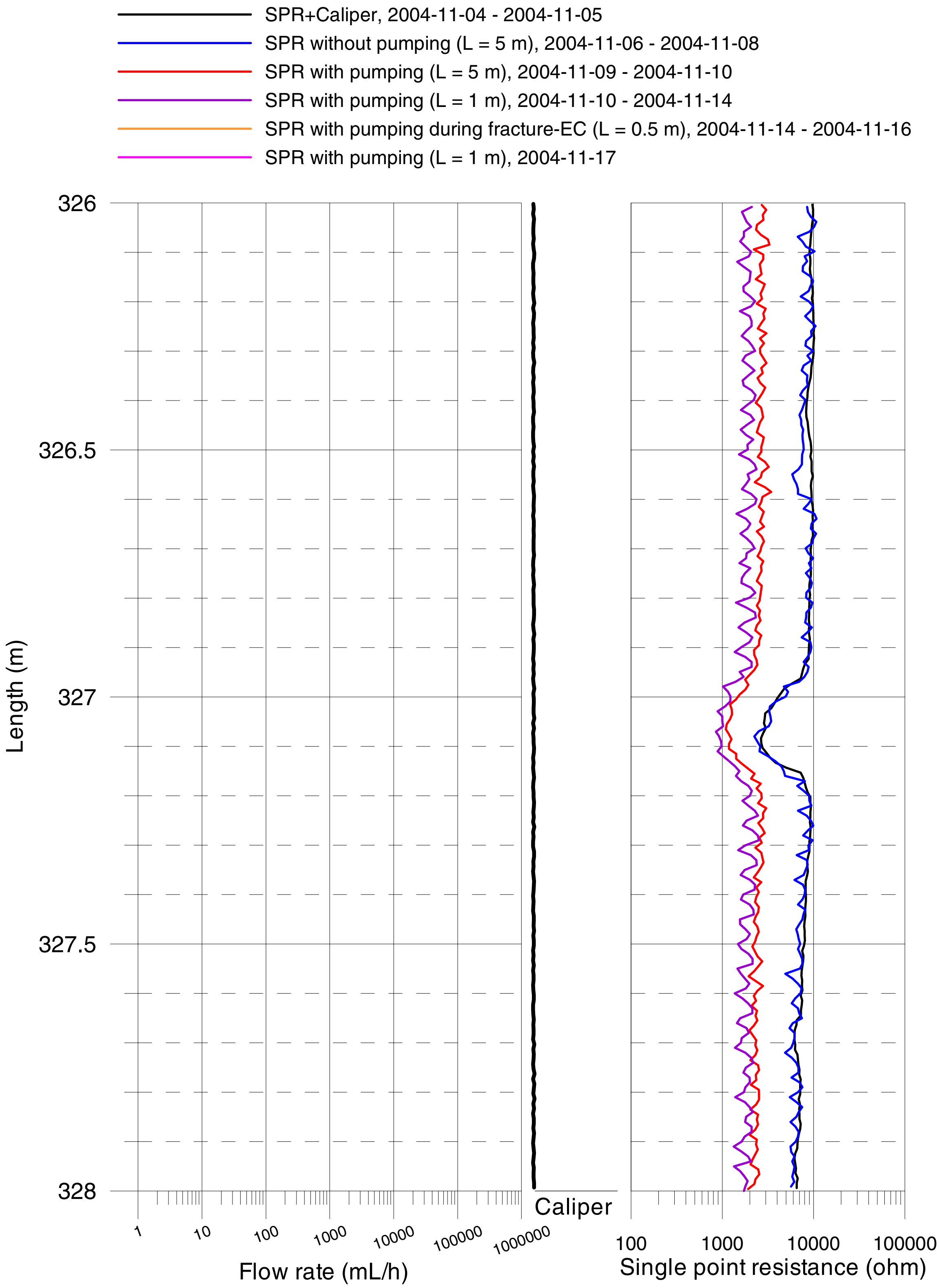

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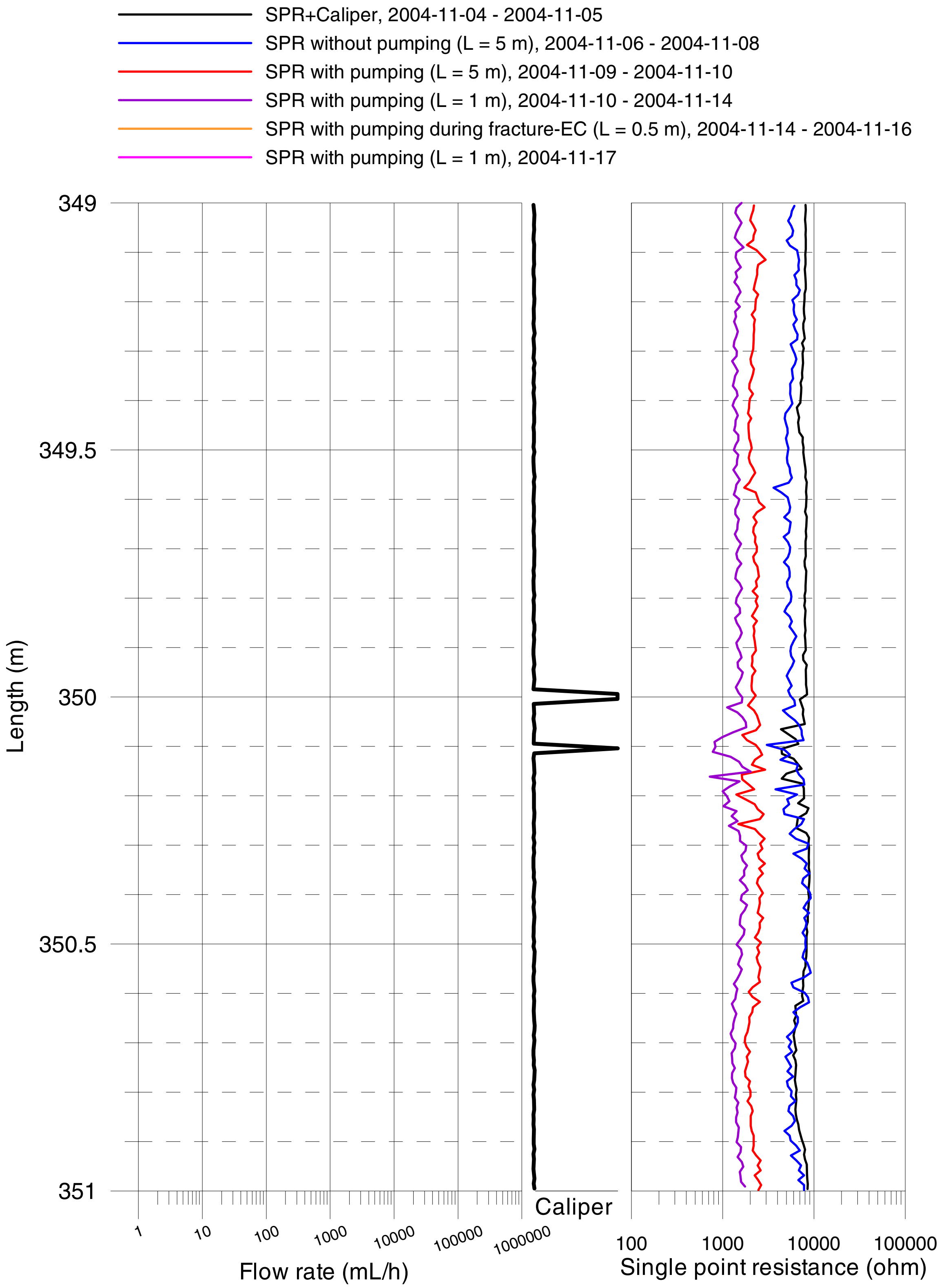

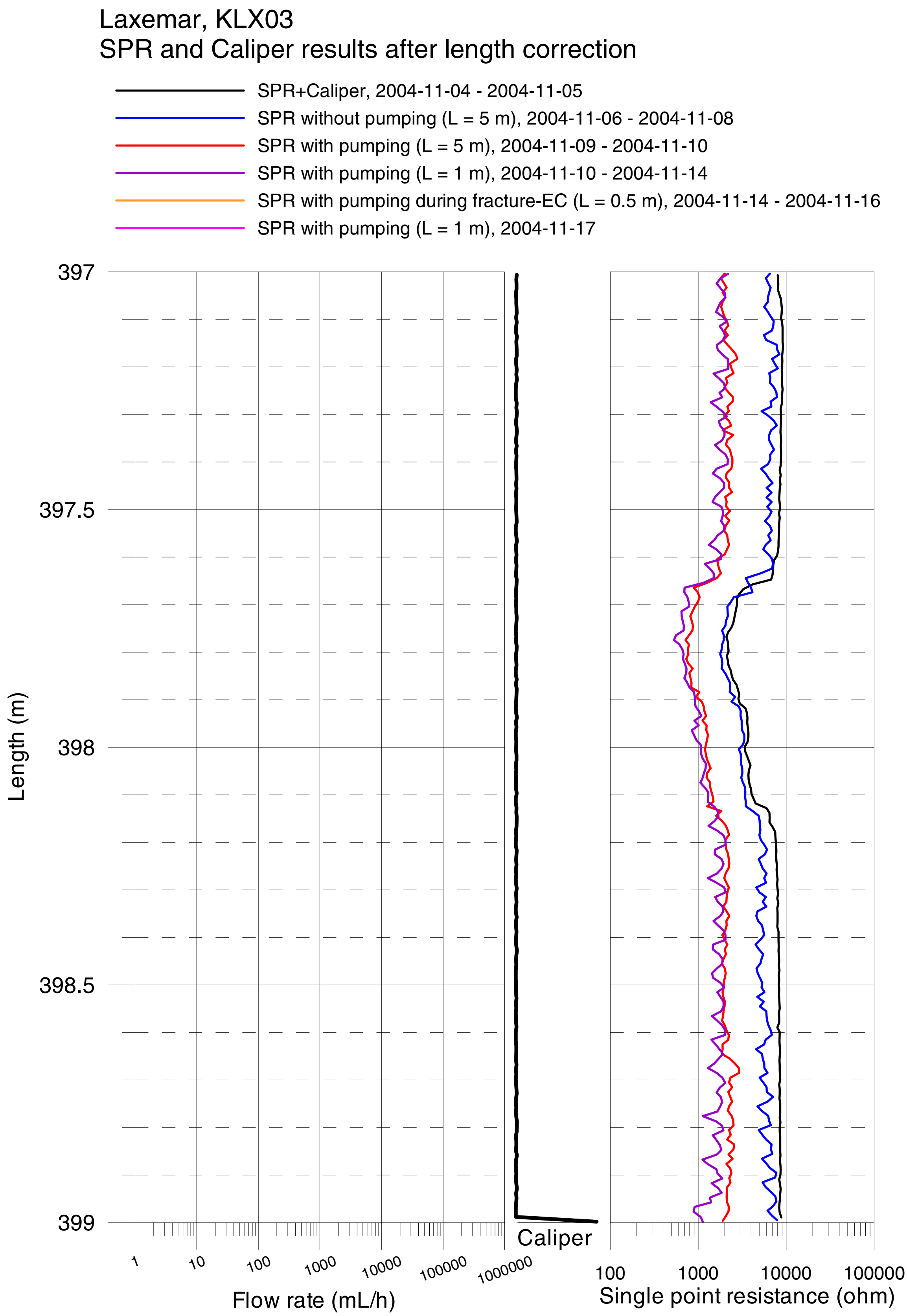
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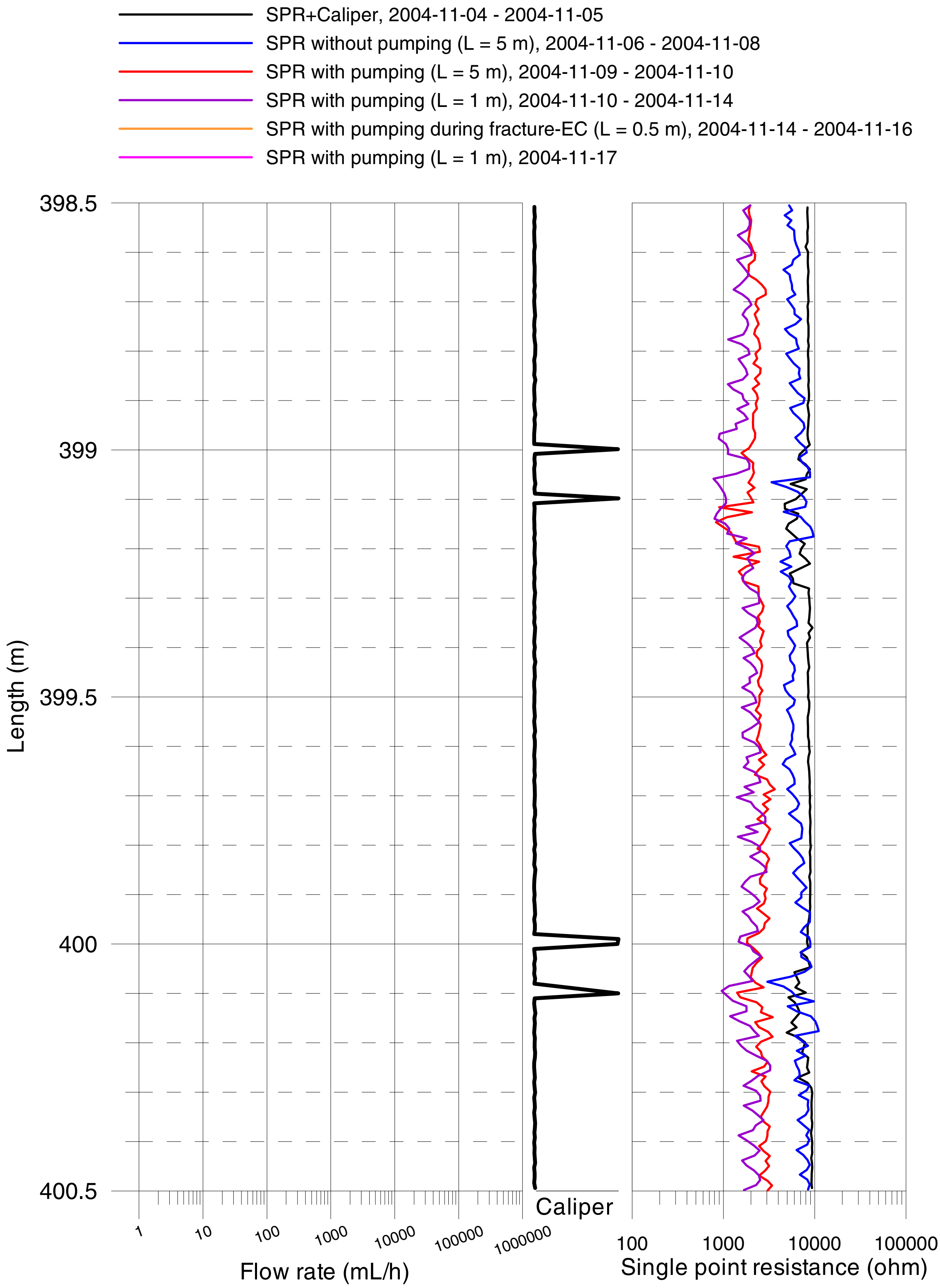
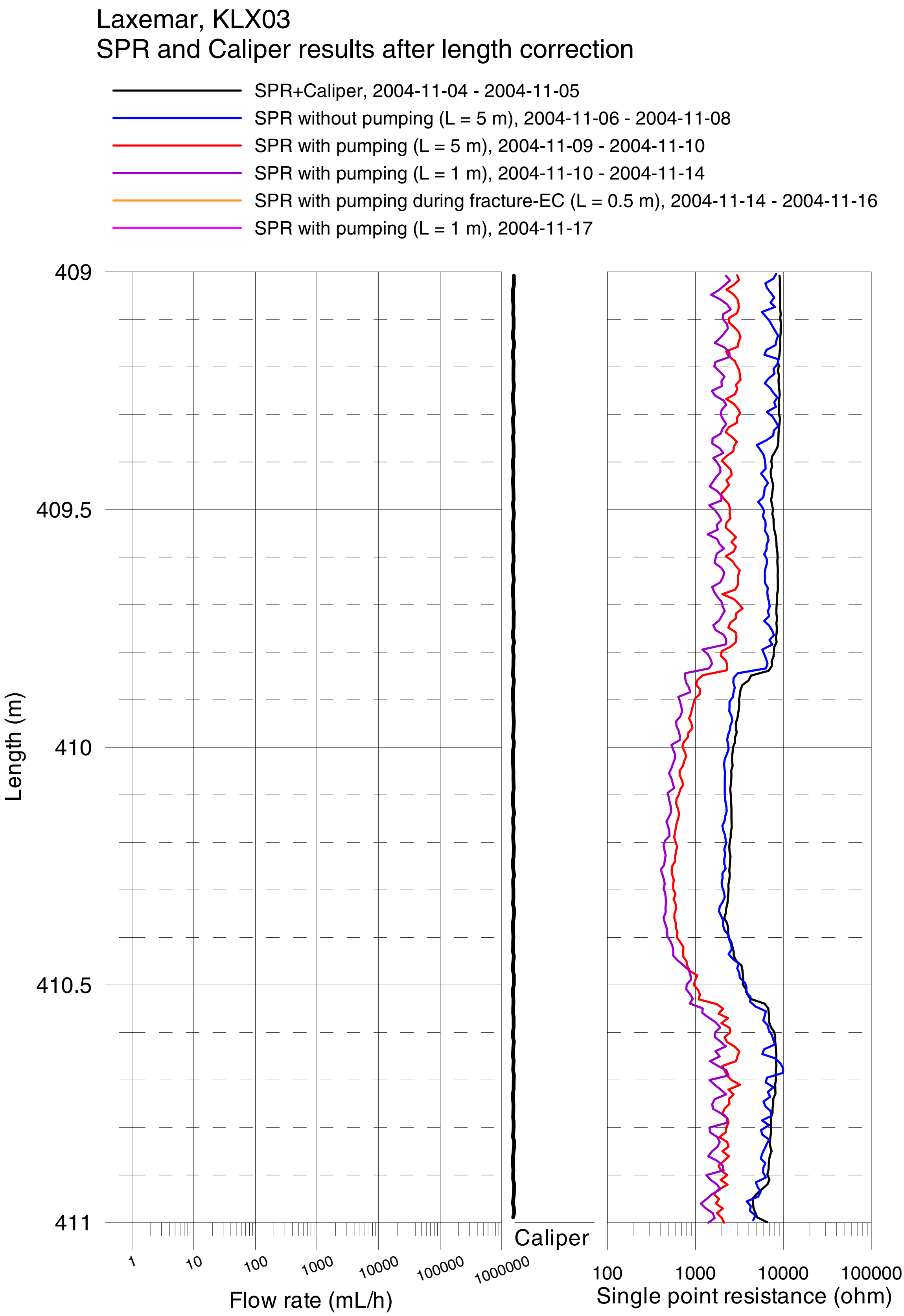
SPR with pumping (L = 1 m), 2004-11-17
Length (m)
397
397.5
398
398.5
399
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)

Laxemar, KLX03
SPR and Caliper results after length correction





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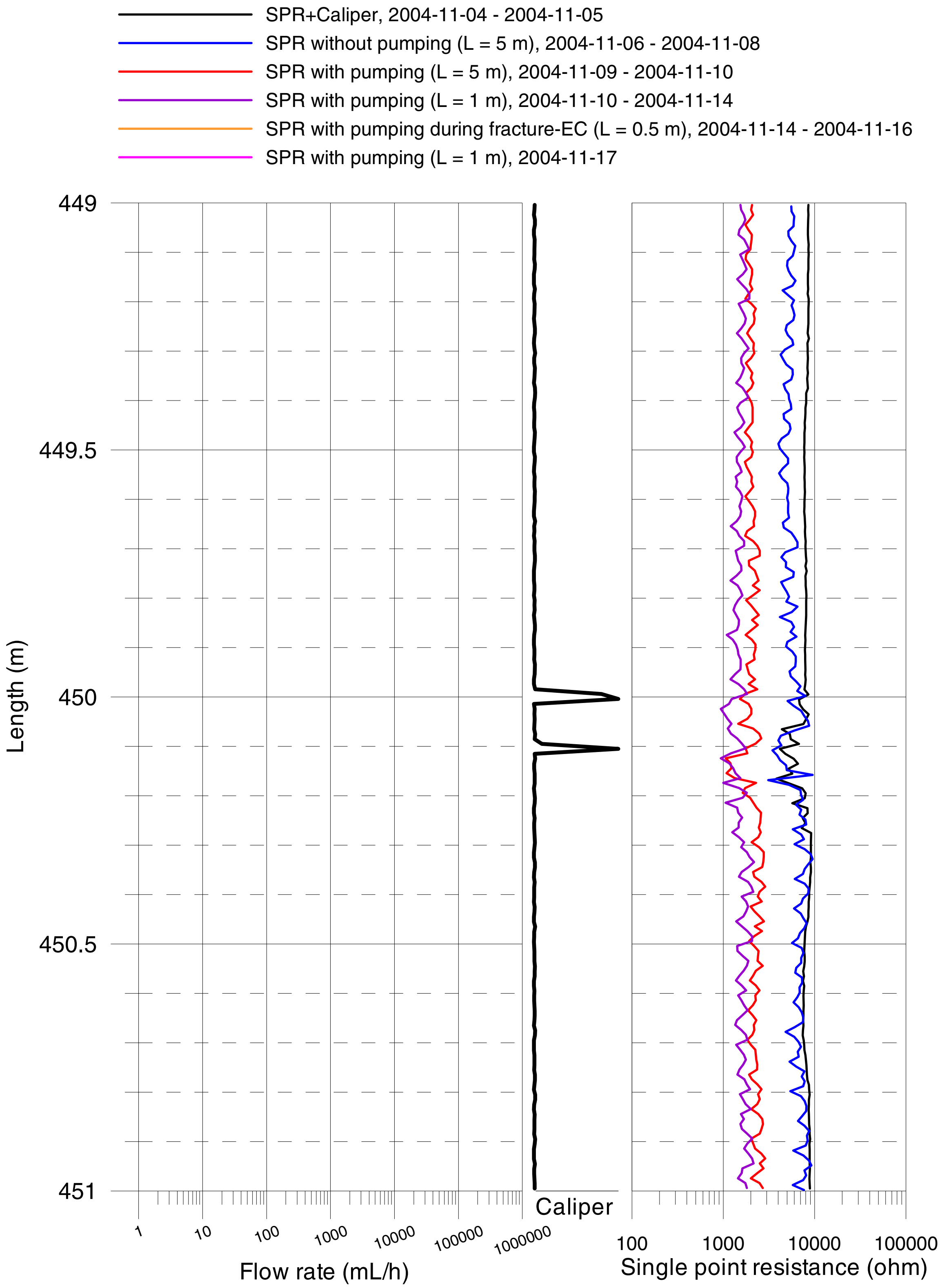
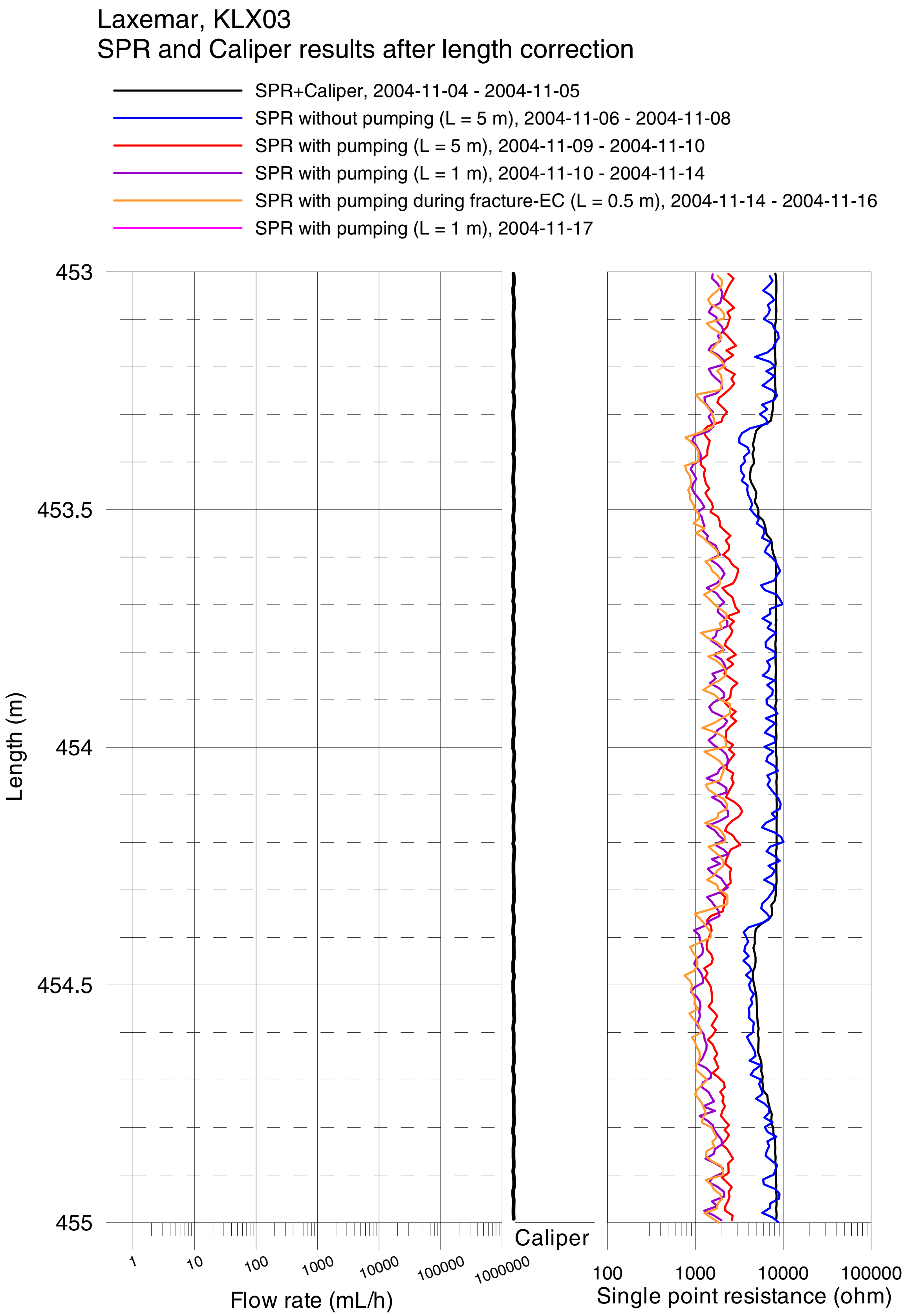
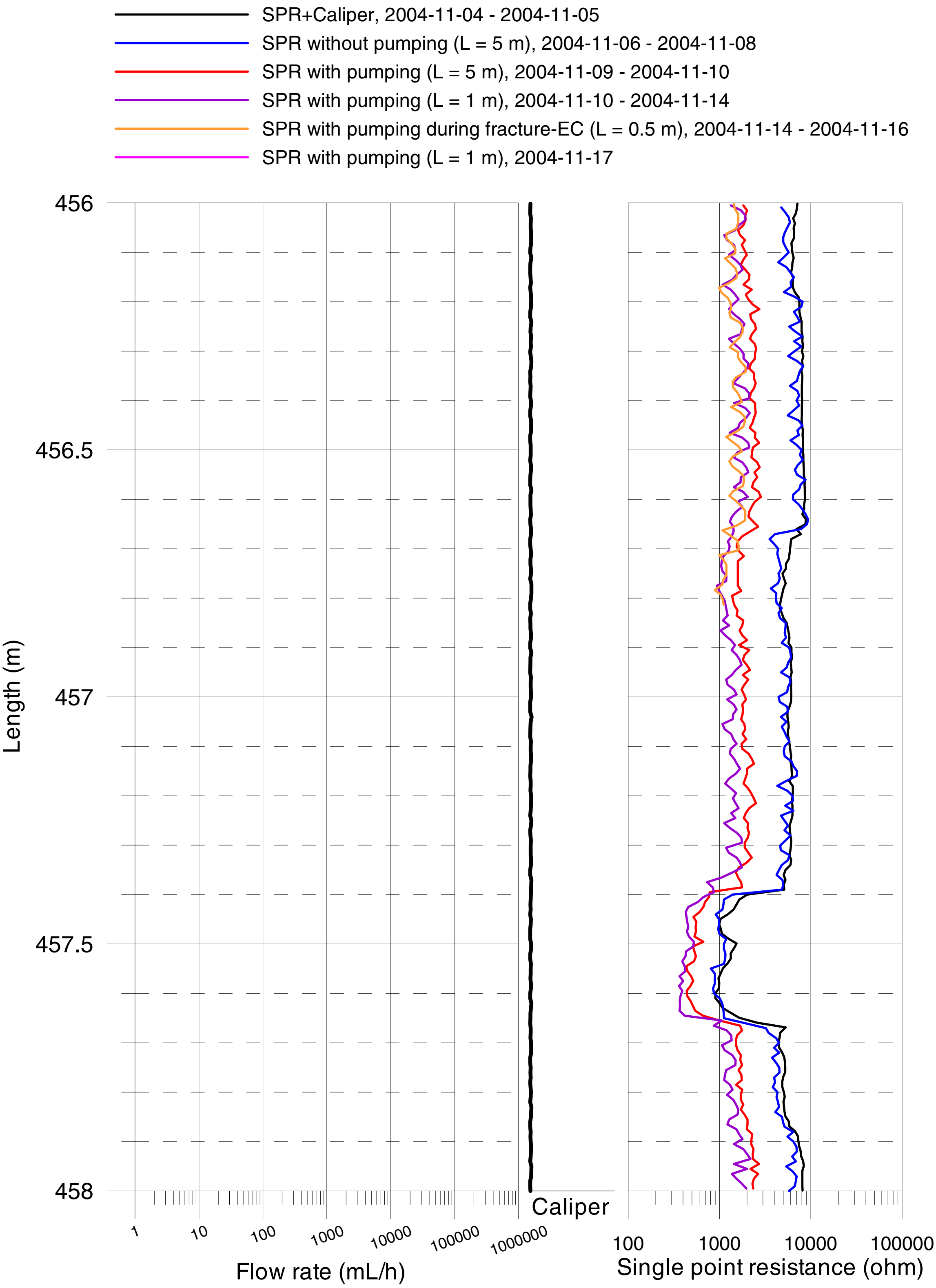
SPR with pumping (L = 1 m), 2004-11-10 - 2004-11-14
SPR with pumping during fracture-EC (L = 0.5 m), 2004-11-14 - 2004-11-16
SPR with pumping (L = 1 m), 2004-11-17
409
409.5
410
410.5
411
Length (m)
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)

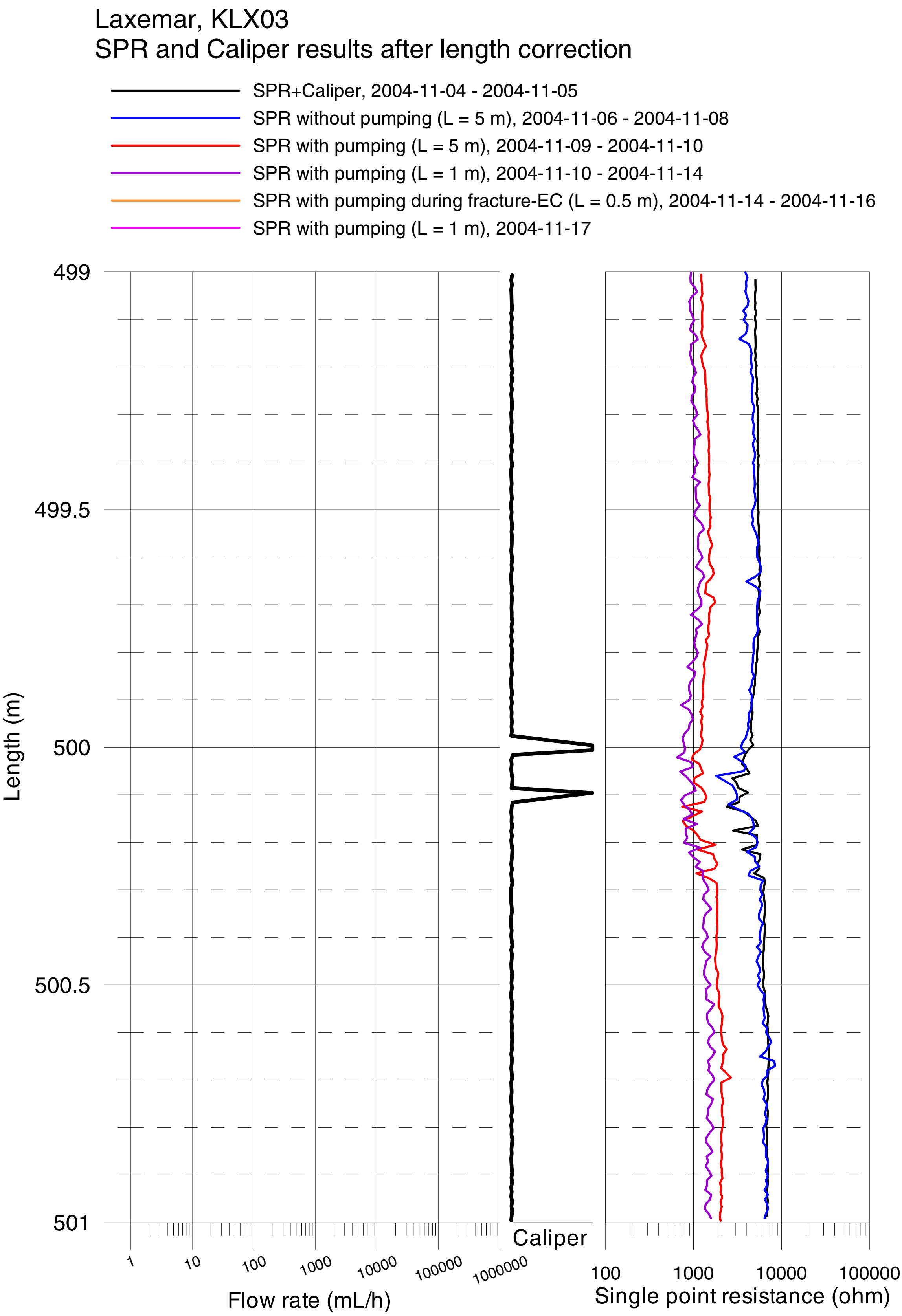
Laxemar, KLX03
SPR and Caliper results after length correction

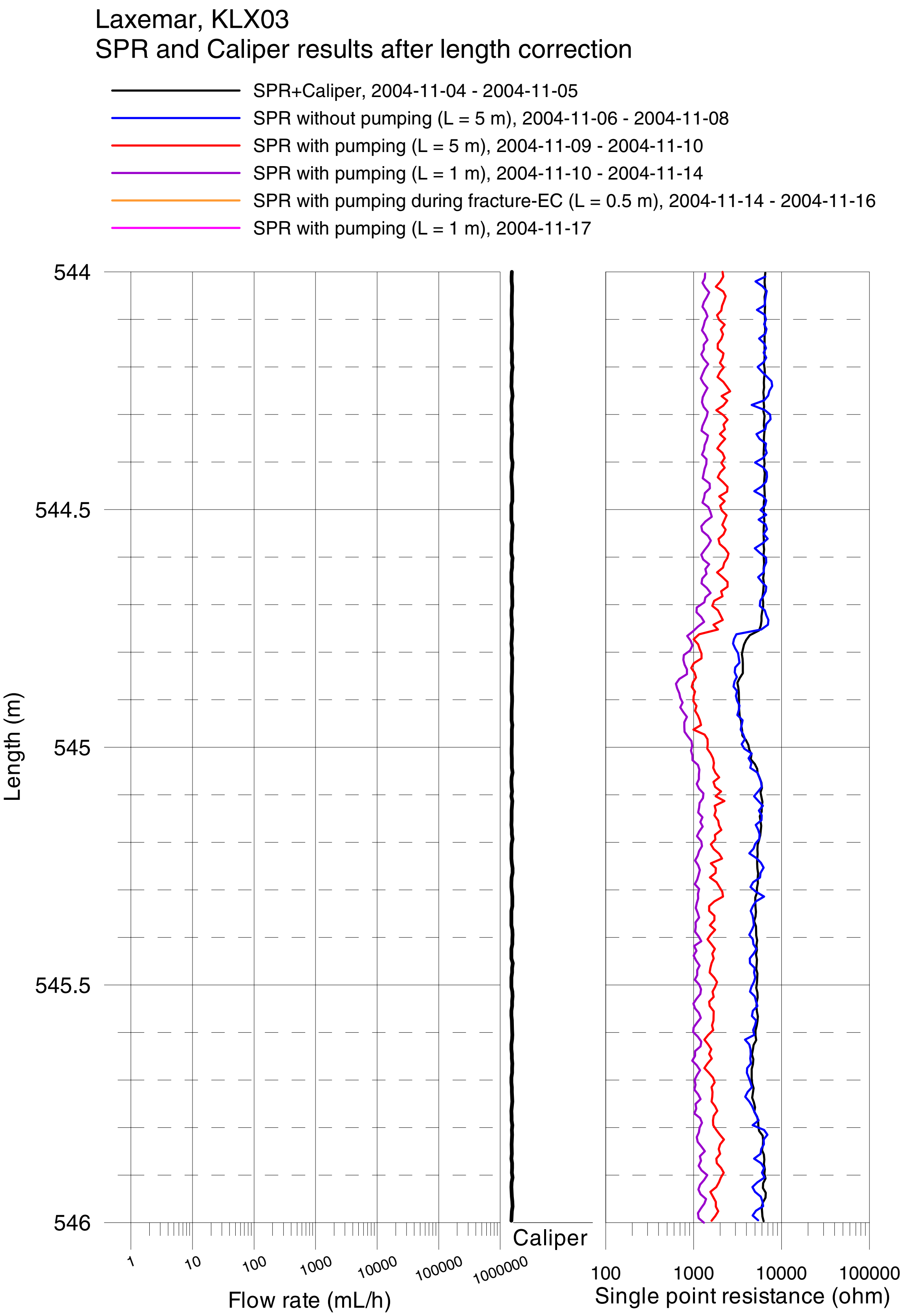


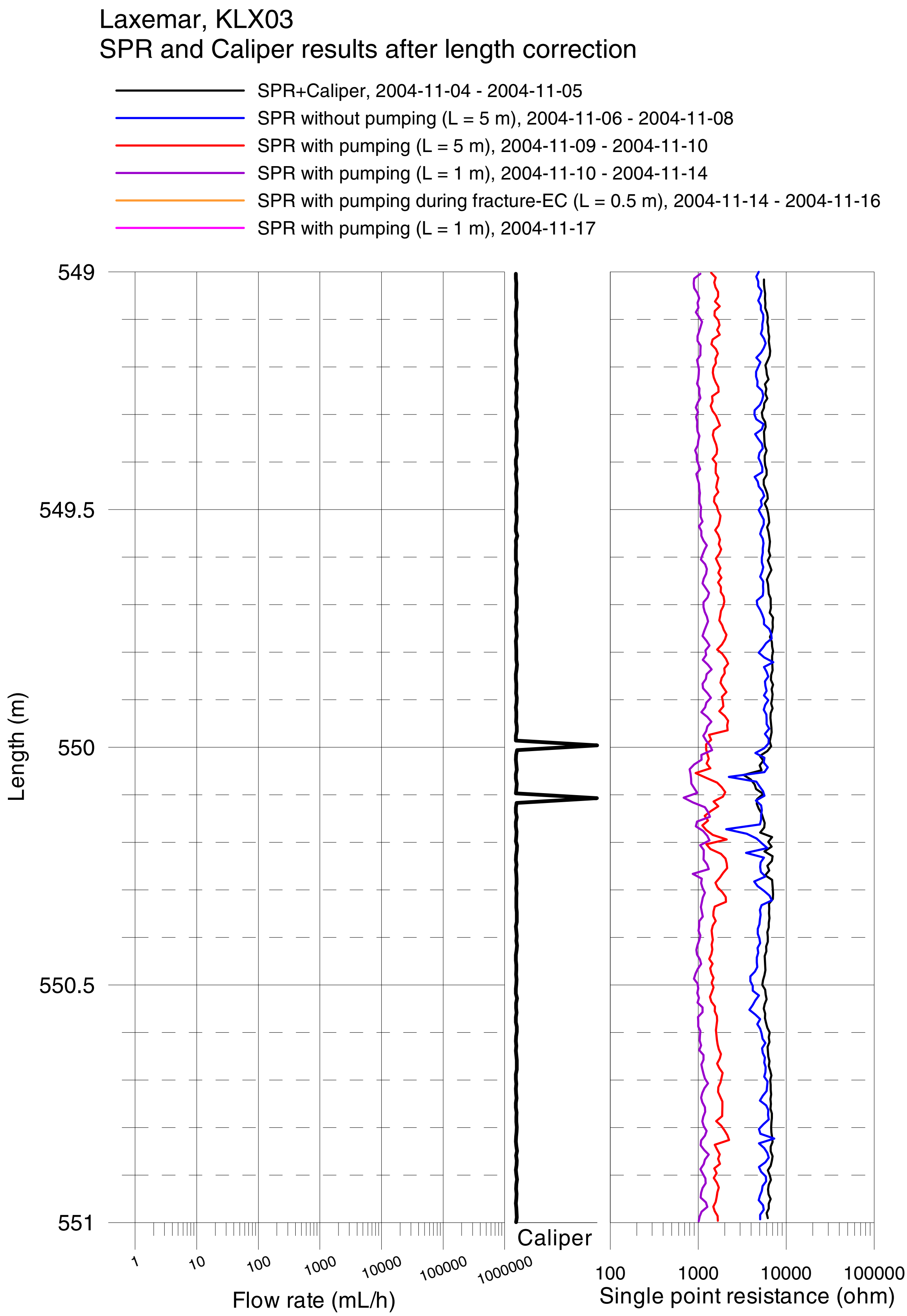

Laxemar, KLX03
SPR and Caliper results after length correction
SPR+Caliper, 2004-11-04 - 2004-11-05
SPR without pumping (L = 5 m), 2004-11-06 - 2004-11-08
SPR with pumping (L = 5 m), 2004-11-09 - 2004-11-10
SPR with pumping (L = 1 m), 2004-11-10 - 2004-11-14
SPR with pumping during fracture-EC (L = 0.5 m), 2004-11-14 - 2004-11-16
SPR with pumping (L = 1 m), 2004-11-17
Length (m)
453
453.5
454
454.5
455
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)

Laxemar, KLX03
SPR and Caliper results after length correction



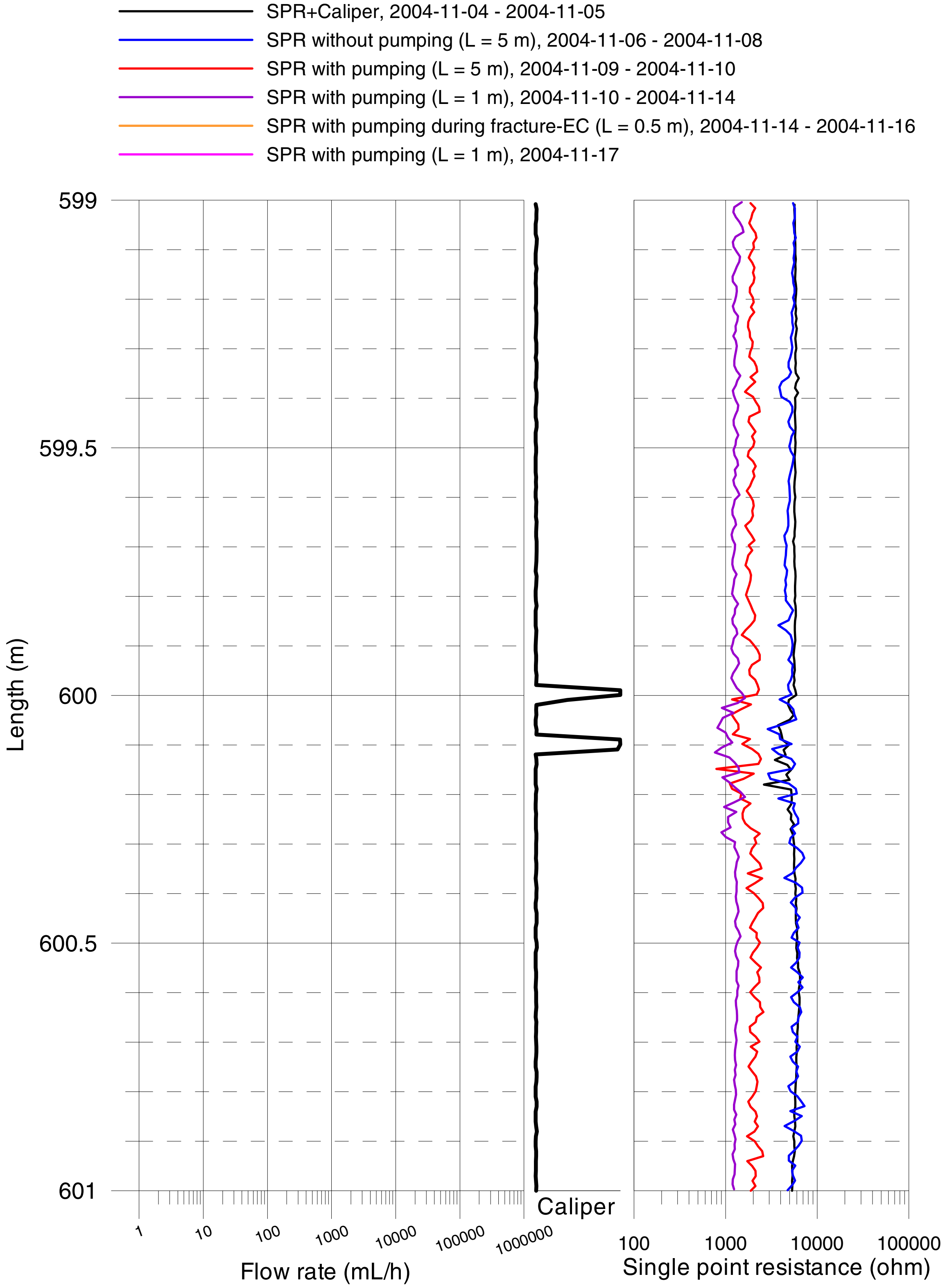

Laxemar, KLX03
SPR and Caliper results after length correction
SPR+Caliper, 2004-11-04 - 2004-11-05
SPR without pumping (L = 5 m), 2004-11-06 - 2004-11-08
SPR with pumping (L = 5 m), 2004-11-09 - 2004-11-10
SPR with pumping (L = 1 m), 2004-11-10 - 2004-11-14
SPR with pumping during fracture-EC (L = 0.5 m), 2004-11-14 - 2004-11-16
SPR with pumping (L = 1 m), 2004-11-17
499
499.5
500
500.5
501
Length (m)
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)


Laxemar, KLX03
SPR and Caliper results after length correction
SPR+Caliper, 2004-11-04 - 2004-11-05
SPR without pumping (L = 5 m), 2004-11-06 - 2004-11-08
SPR with pumping (L = 5 m), 2004-11-09 - 2004-11-10
SPR with pumping (L = 1 m), 2004-11-10 - 2004-11-14
SPR with pumping during fracture-EC (L = 0.5 m), 2004-11-14 - 2004-11-16
SPR with pumping (L = 1 m), 2004-11-17
Length (m)
544
544.5
545
545.5
546
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)

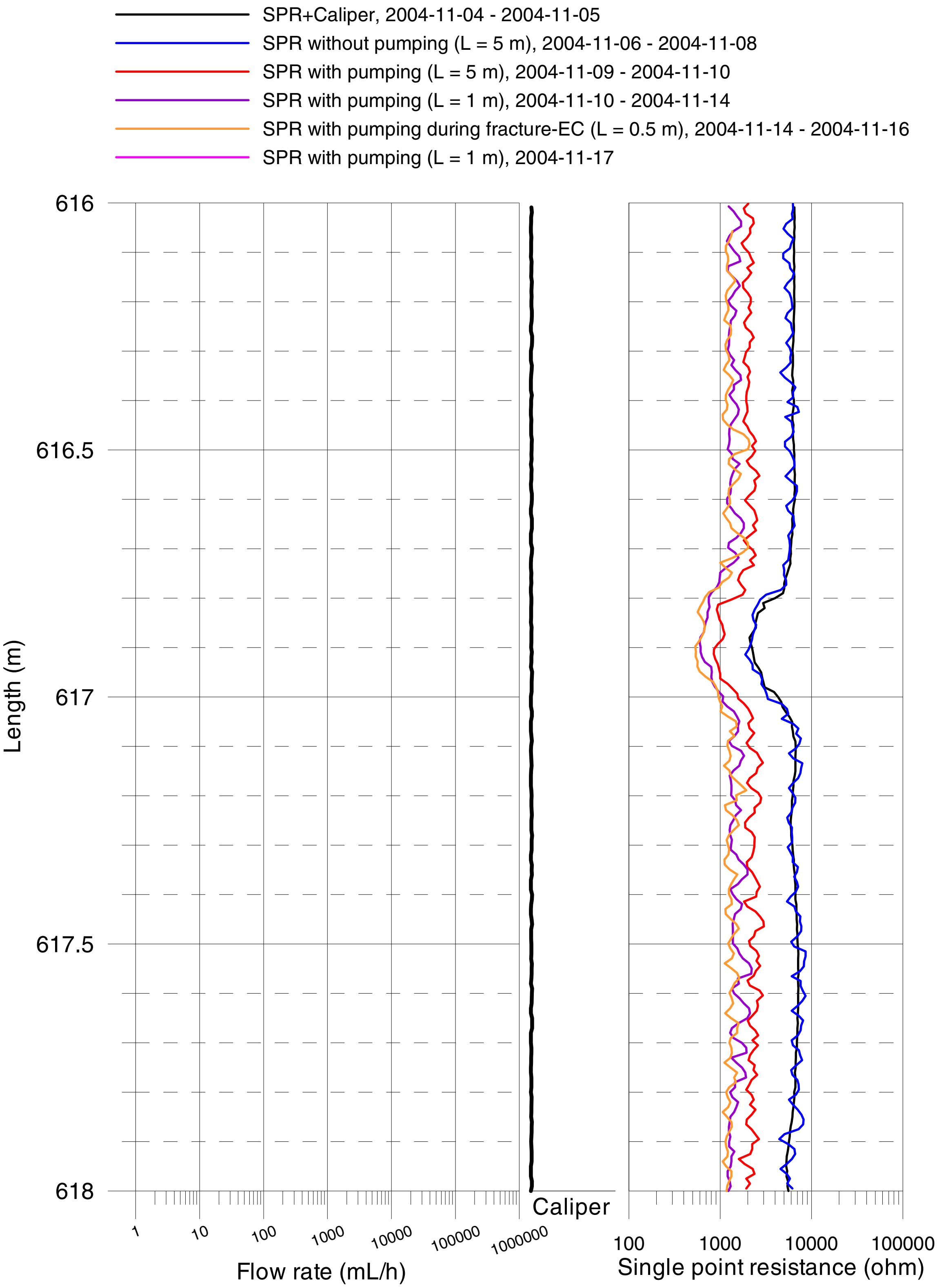


Laxemar, KLX03
SPR and Caliper results after length correction
SPR+Caliper, 2004-11-04 - 2004-11-05
SPR without pumping (L = 5 m), 2004-11-06 - 2004-11-08
SPR with pumping (L = 5 m), 2004-11-09 - 2004-11-10
SPR with pumping (L = 1 m), 2004-11-10 - 2004-11-14
SPR with pumping during fracture-EC (L = 0.5 m), 2004-11-14 - 2004-11-16
SPR with pumping (L = 1 m), 2004-11-17
549
549.5
550
550.5
551
Length (m)
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)

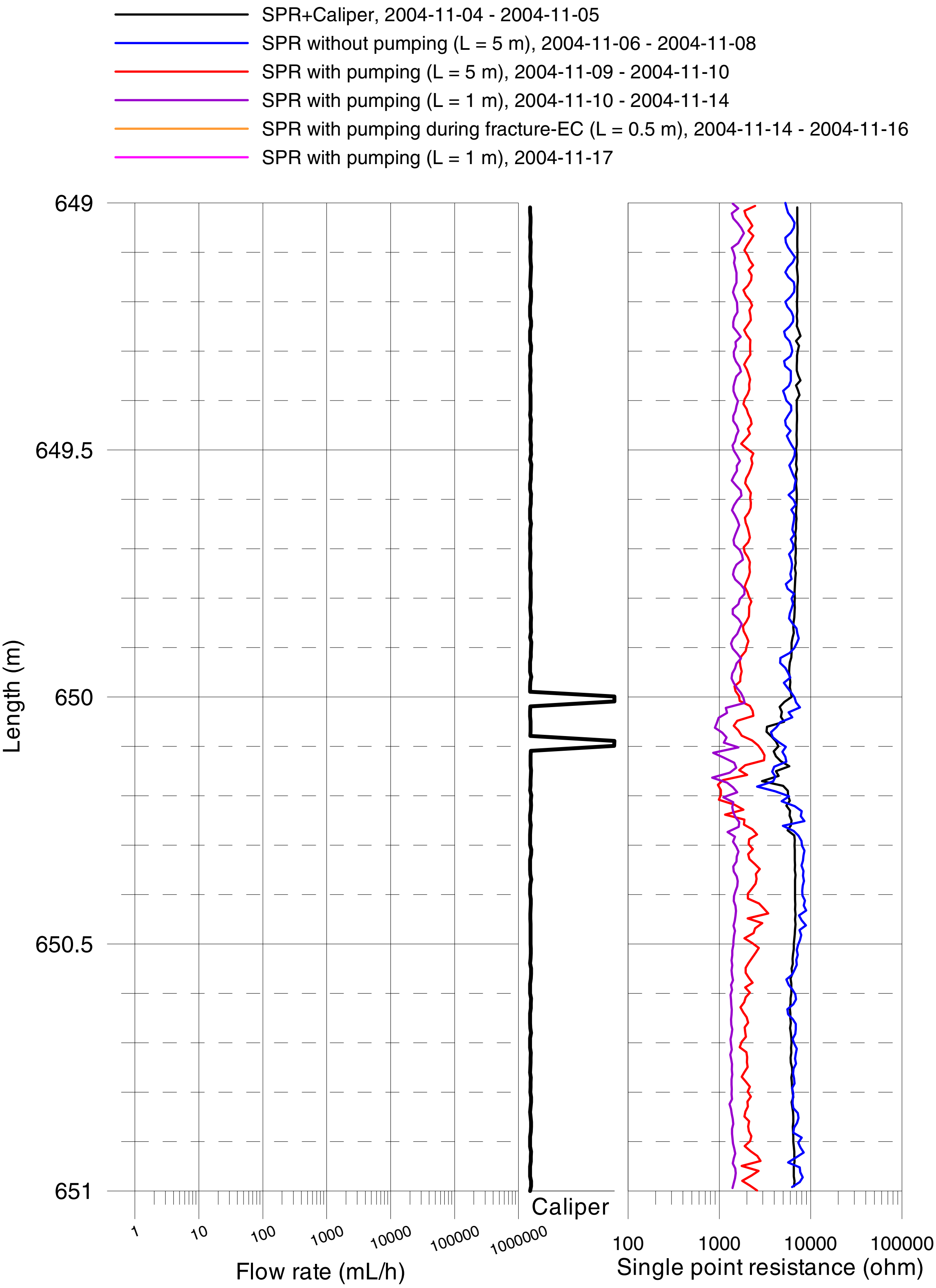
Laxemar, KLX03
SPR and Caliper results after length correction



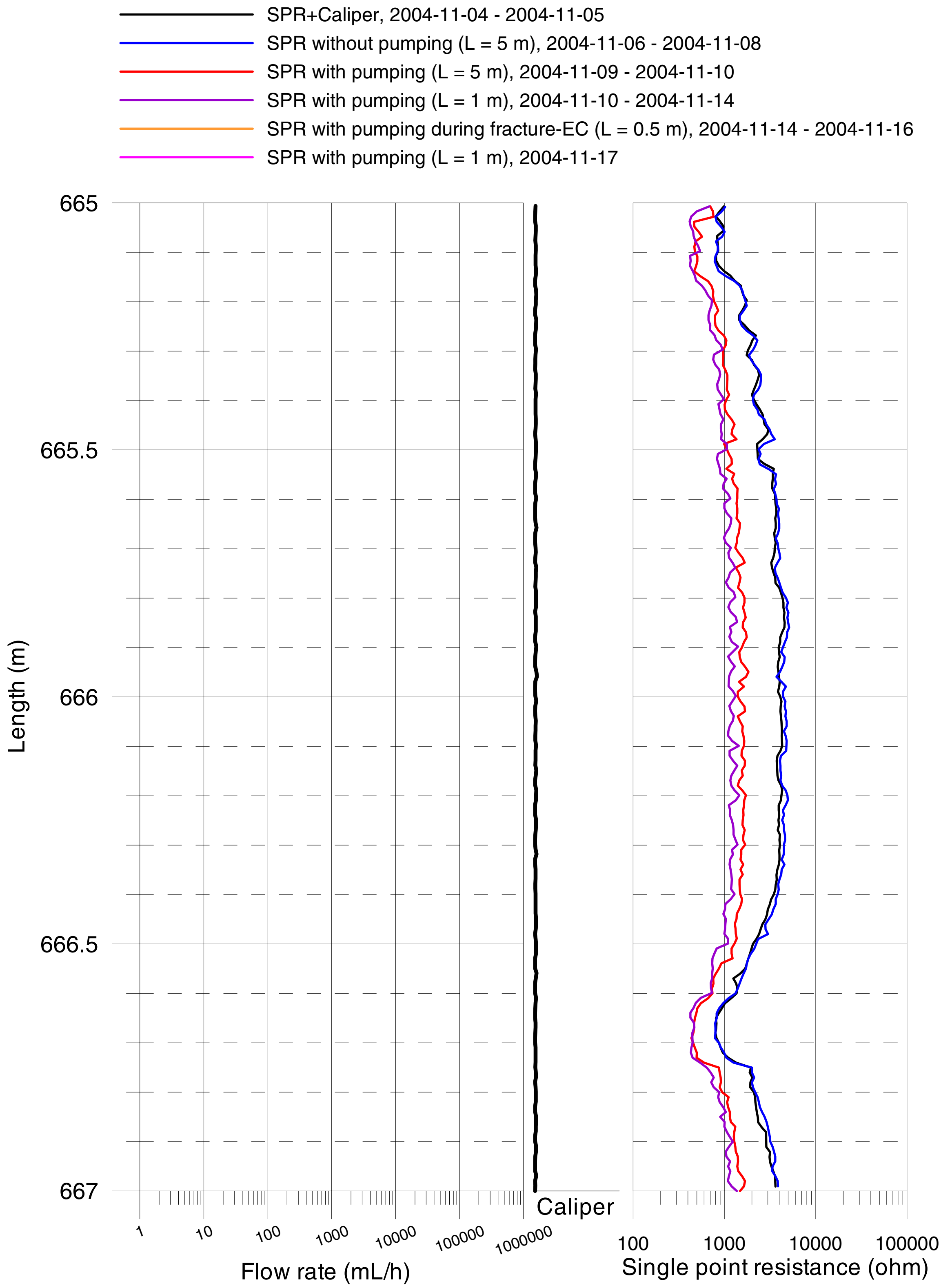
Laxemar, KLX03
SPR and Caliper results after length correction



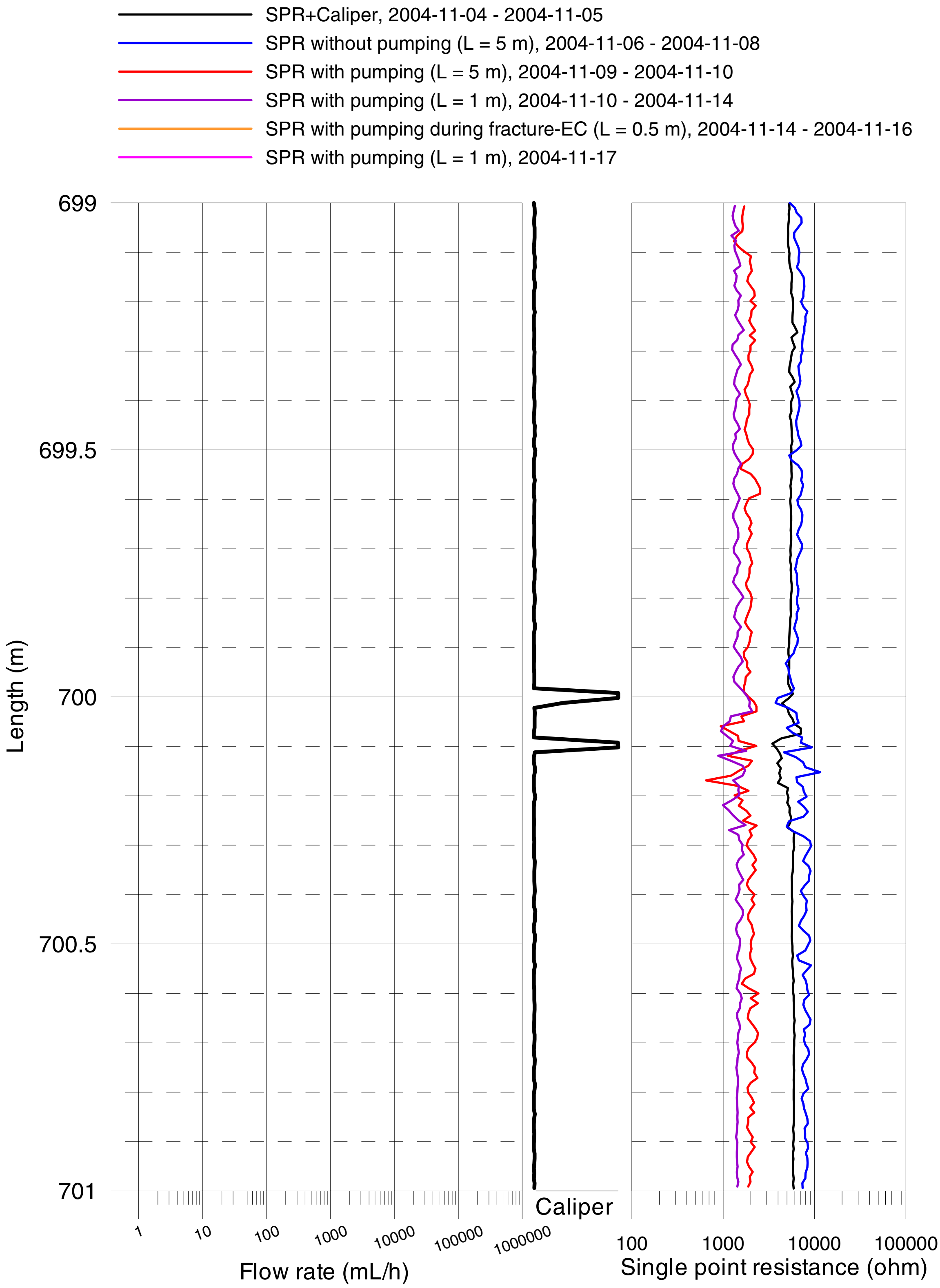
Laxemar, KLX03
SPR and Caliper results after length correction

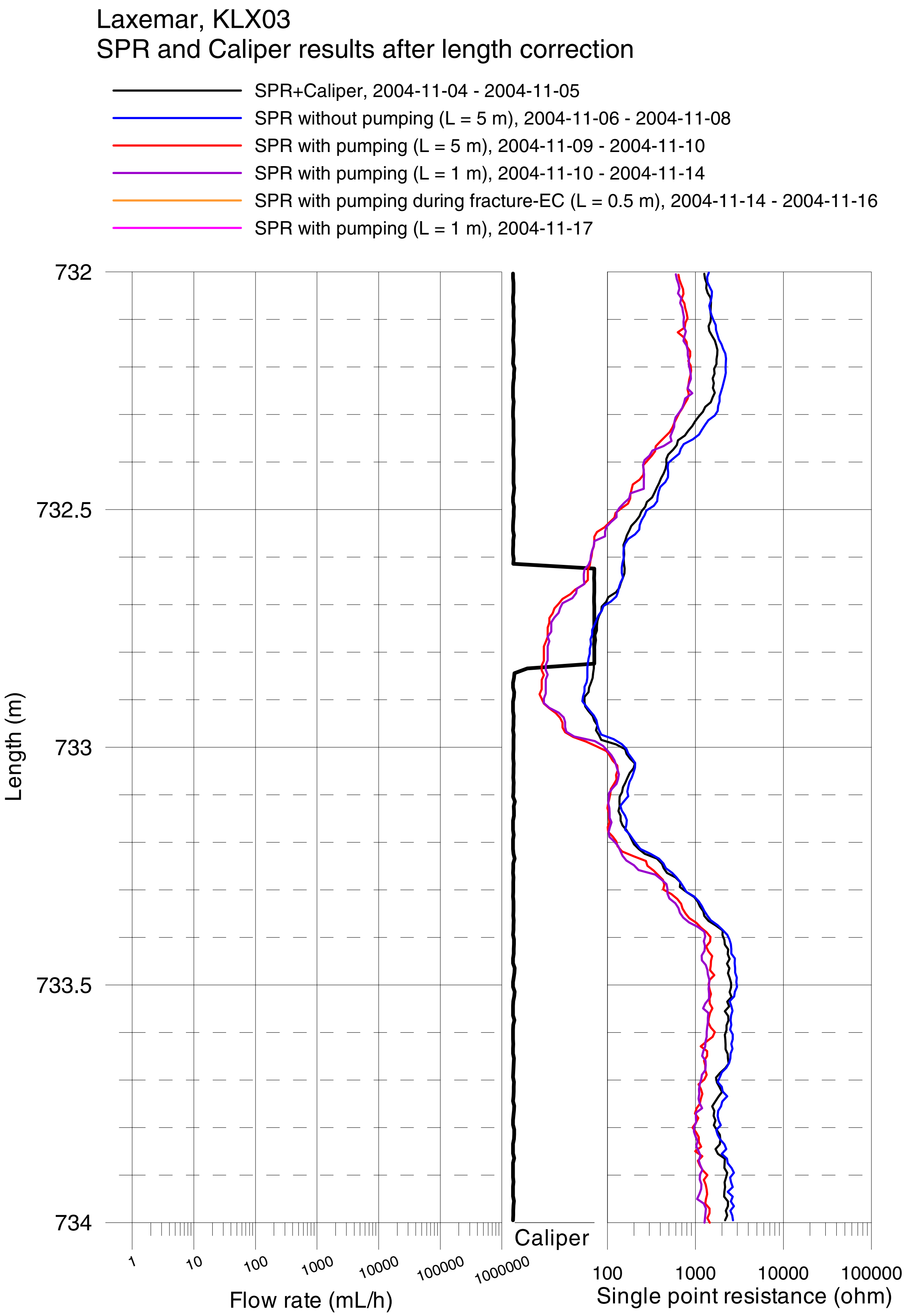


Laxemar, KLX03
SPR and Caliper results after length correction



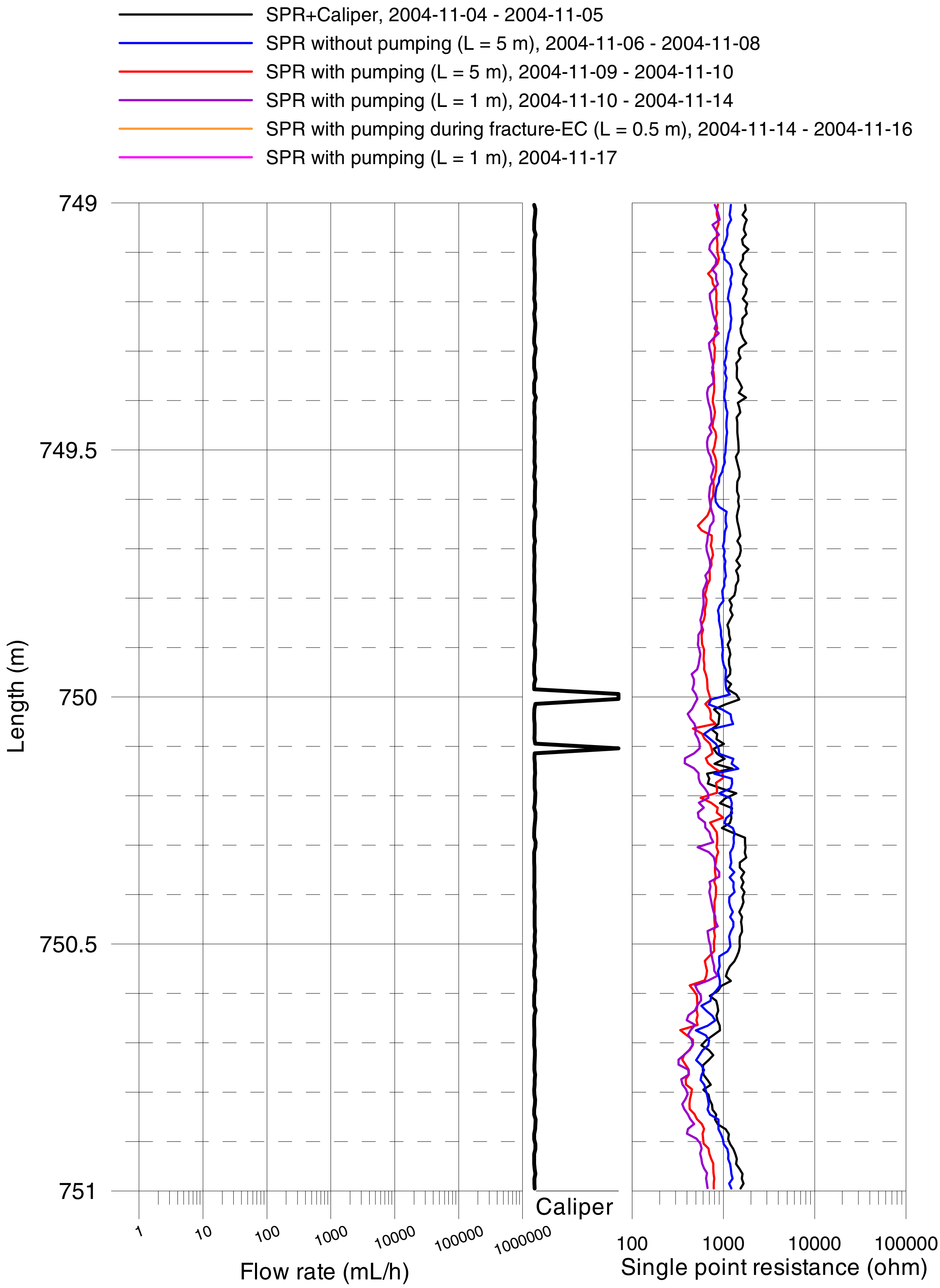
Laxemar, KLX03
SPR and Caliper results after length correction

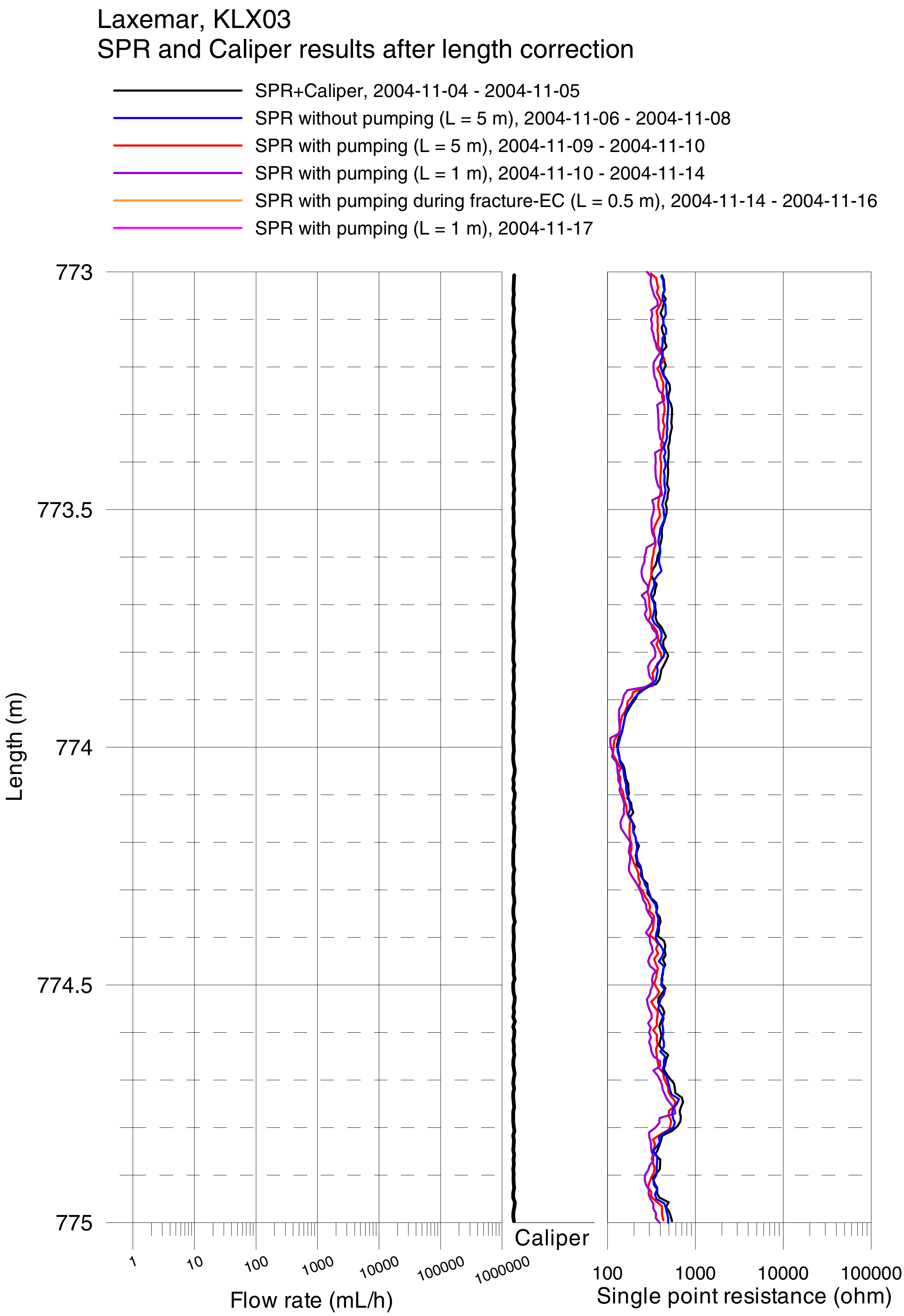




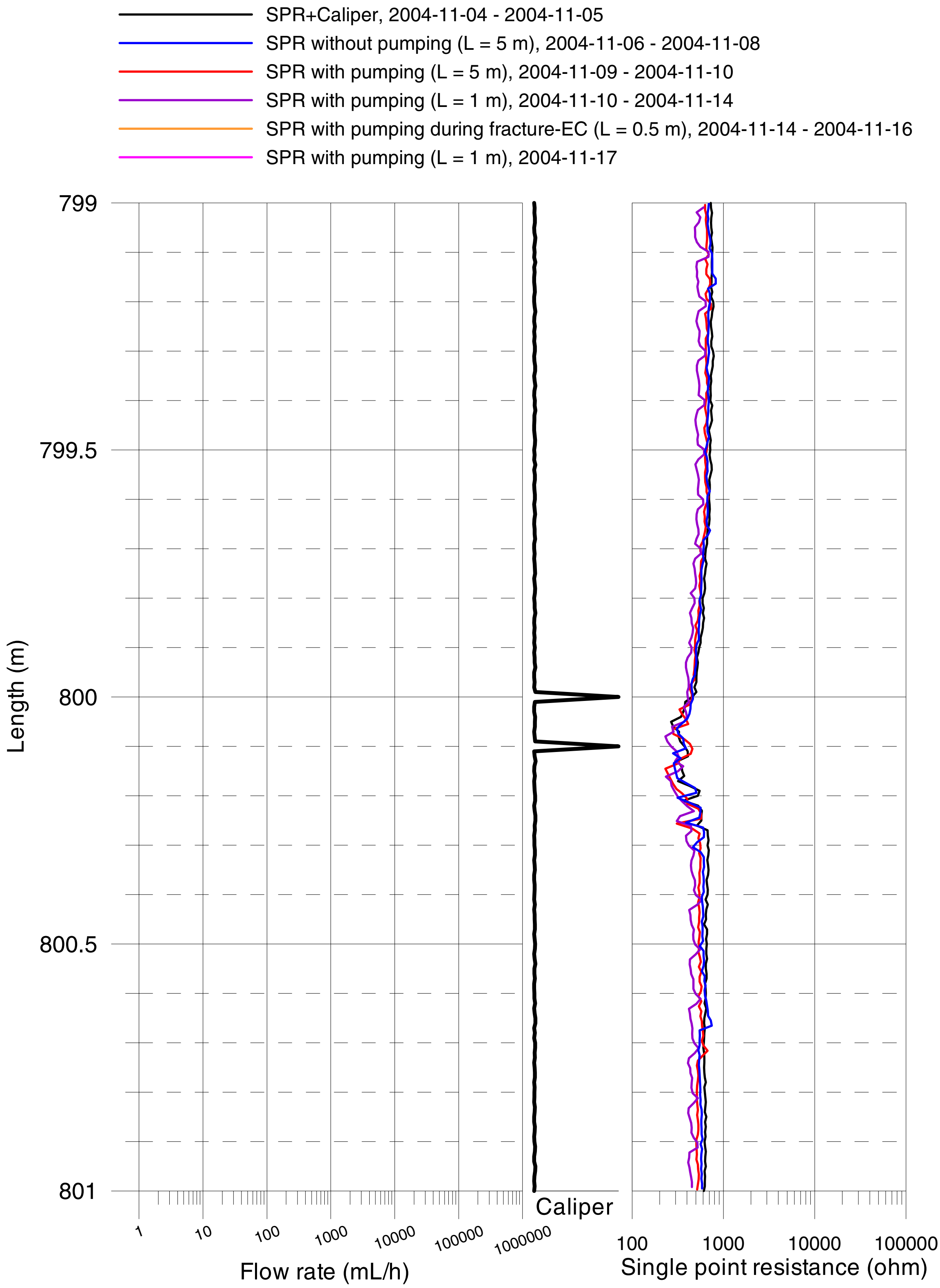
Laxemar, KLX03
SPR and Caliper results after length correction
SPR+Caliper, 2004-11-04 - 2004-11-05
SPR without pumping (L = 5 m), 2004-11-06 - 2004-11-08
SPR with pumping (L = 5 m), 2004-11-09 - 2004-11-10
SPR with pumping (L = 1 m), 2004-11-10 - 2004-11-14
SPR with pumping during fracture-EC (L = 0.5 m), 2004-11-14 - 2004-11-16
SPR with pumping (L = 1 m), 2004-11-17
Length (m)
732
732.5
733
733.5
734
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)

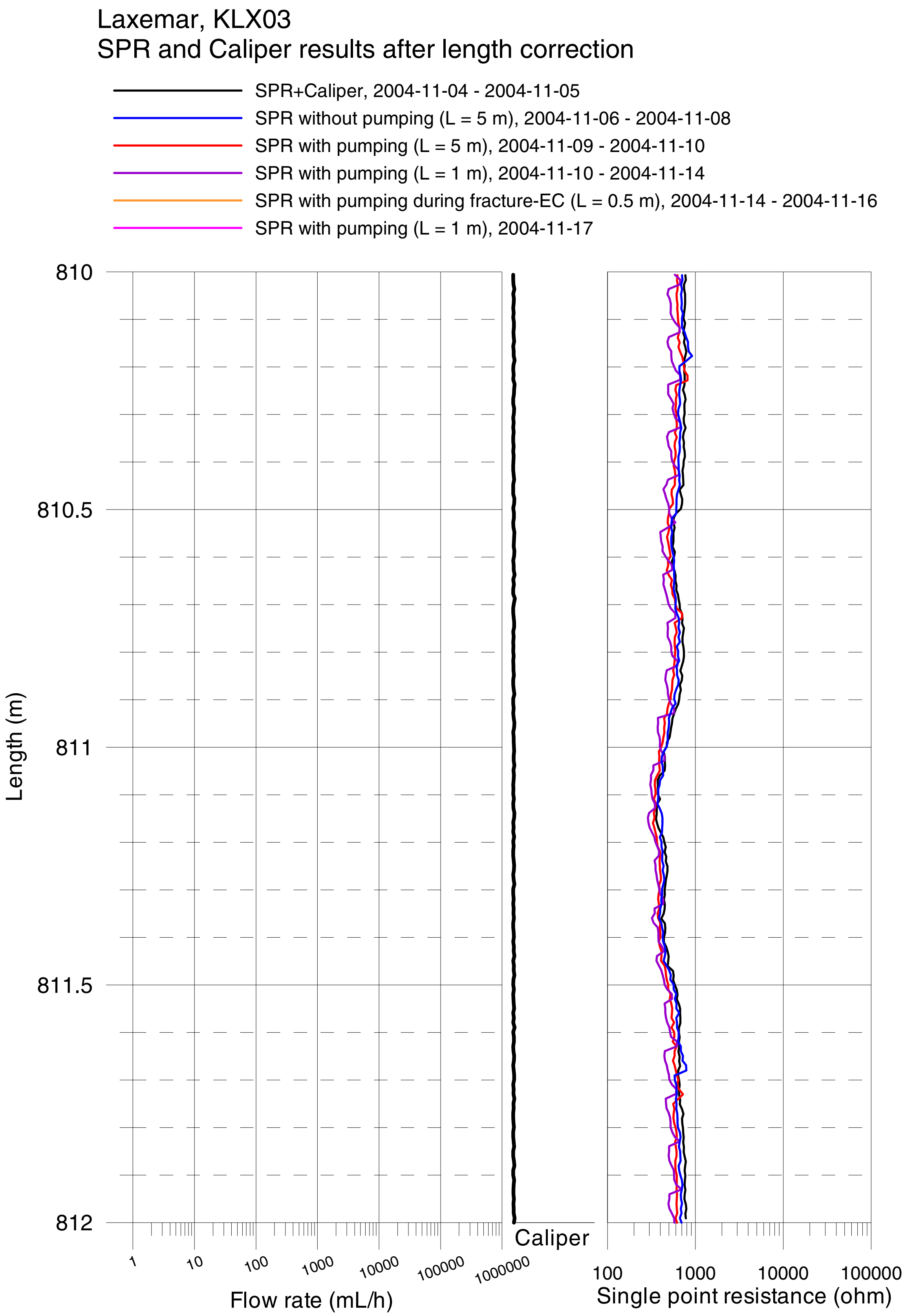
Laxemar, KLX03
SPR and Caliper results after length correction




Laxemar, KLX03
SPR and Caliper results after length correction
SPR+Caliper, 2004-11-04 - 2004-11-05
SPR without pumping (L = 5 m), 2004-11-06 - 2004-11-08
SPR with pumping (L = 5 m), 2004-11-09 - 2004-11-10
SPR with pumping (L = 1 m), 2004-11-10 - 2004-11-14
SPR with pumping during fracture-EC (L = 0.5 m), 2004-11-14 - 2004-11-16
SPR with pumping (L = 1 m), 2004-11-17
Length (m)
773
773.5
774
774.5
775
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)

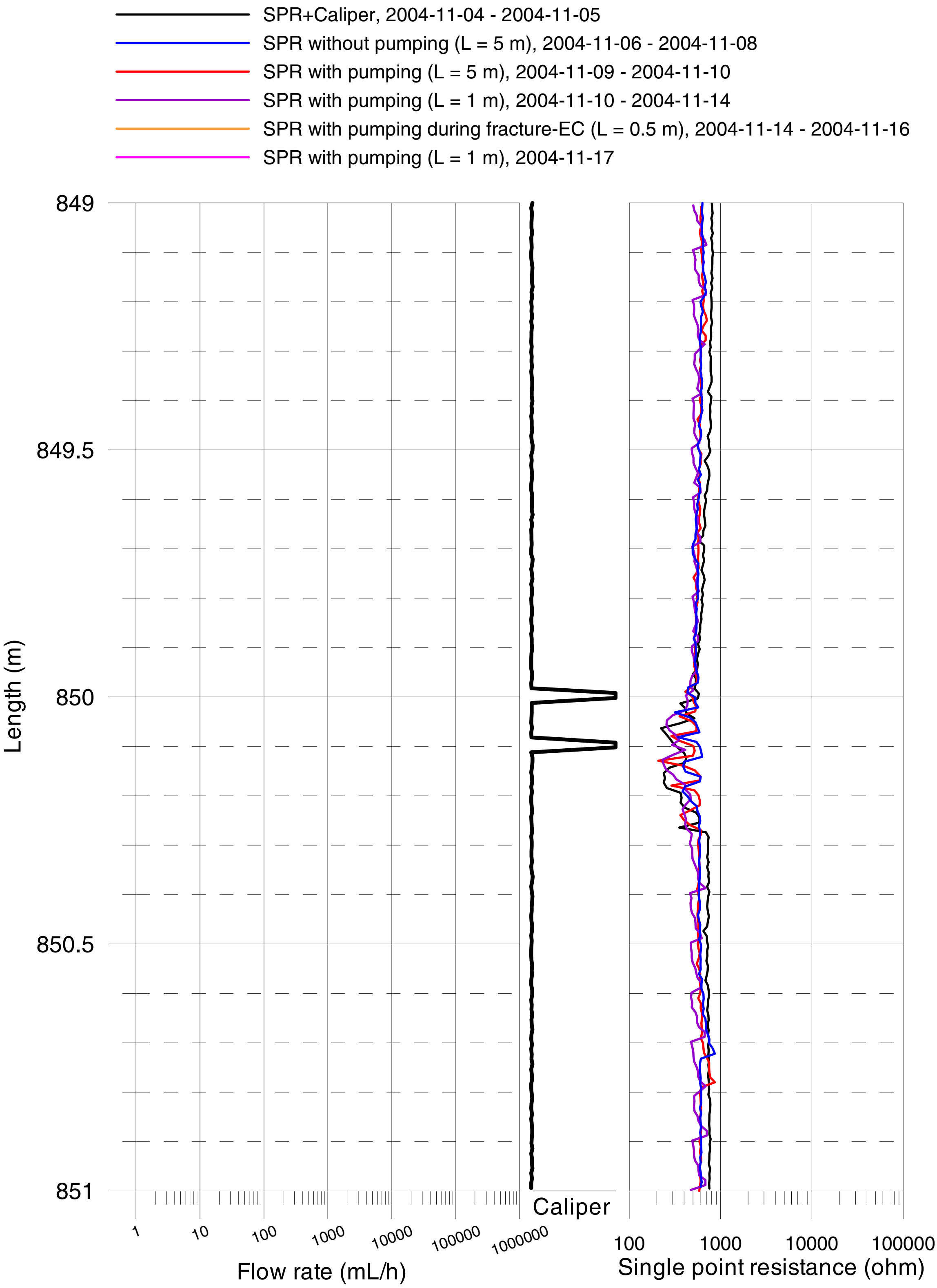
Laxemar, KLX03
SPR and Caliper results after length correction



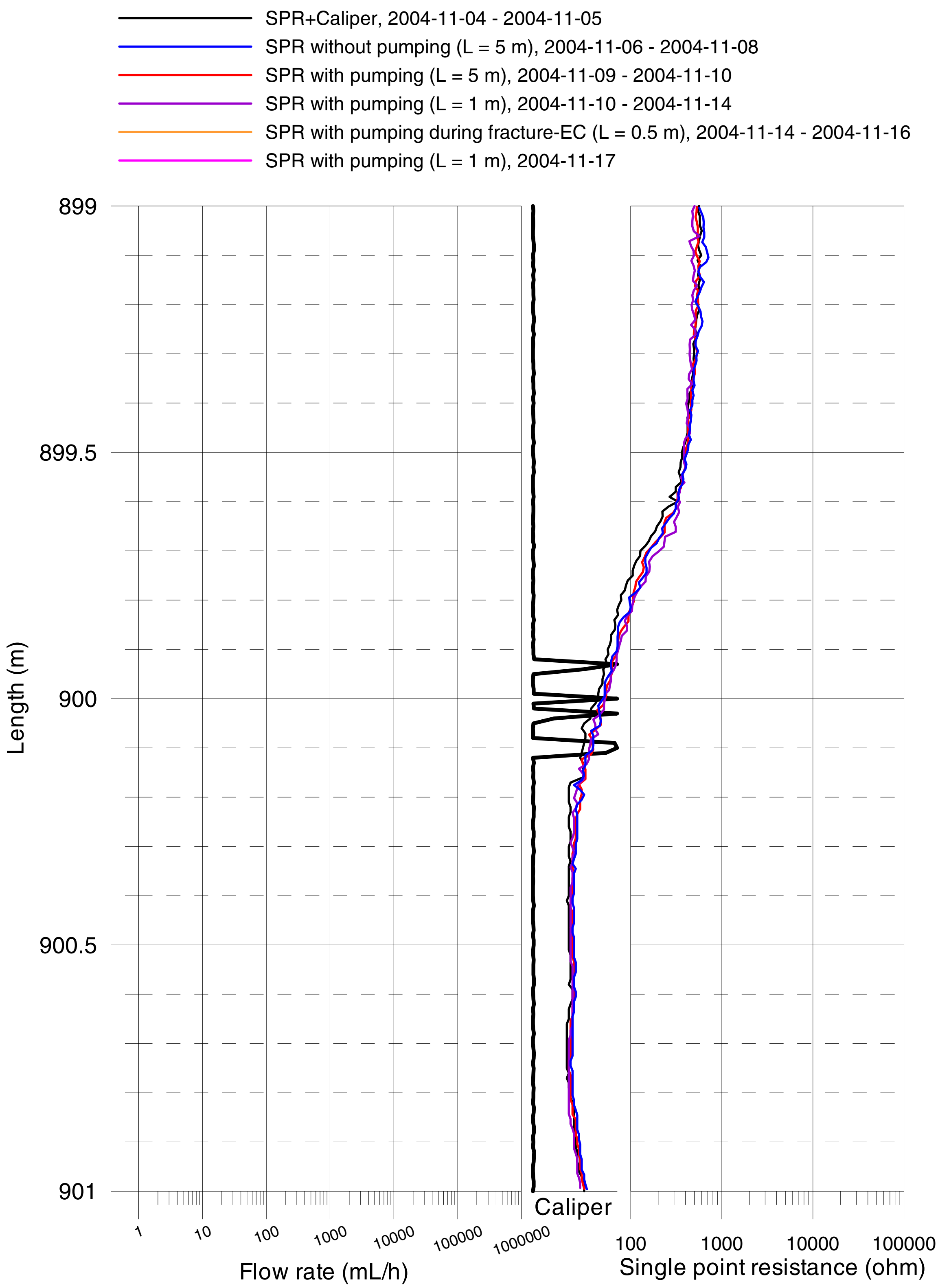


Laxemar, KLX03
SPR and Caliper results after length correction
SPR+Caliper, 2004-11-04 - 2004-11-05
SPR without pumping (L = 5 m), 2004-11-06 - 2004-11-08
SPR with pumping (L = 5 m), 2004-11-09 - 2004-11-10
SPR with pumping (L = 1 m), 2004-11-10 - 2004-11-14
SPR with pumping during fracture-EC (L = 0.5 m), 2004-11-14 - 2004-11-16
SPR with pumping (L = 1 m), 2004-11-17
810
810.5
811
811.5
812
Length (m)
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)

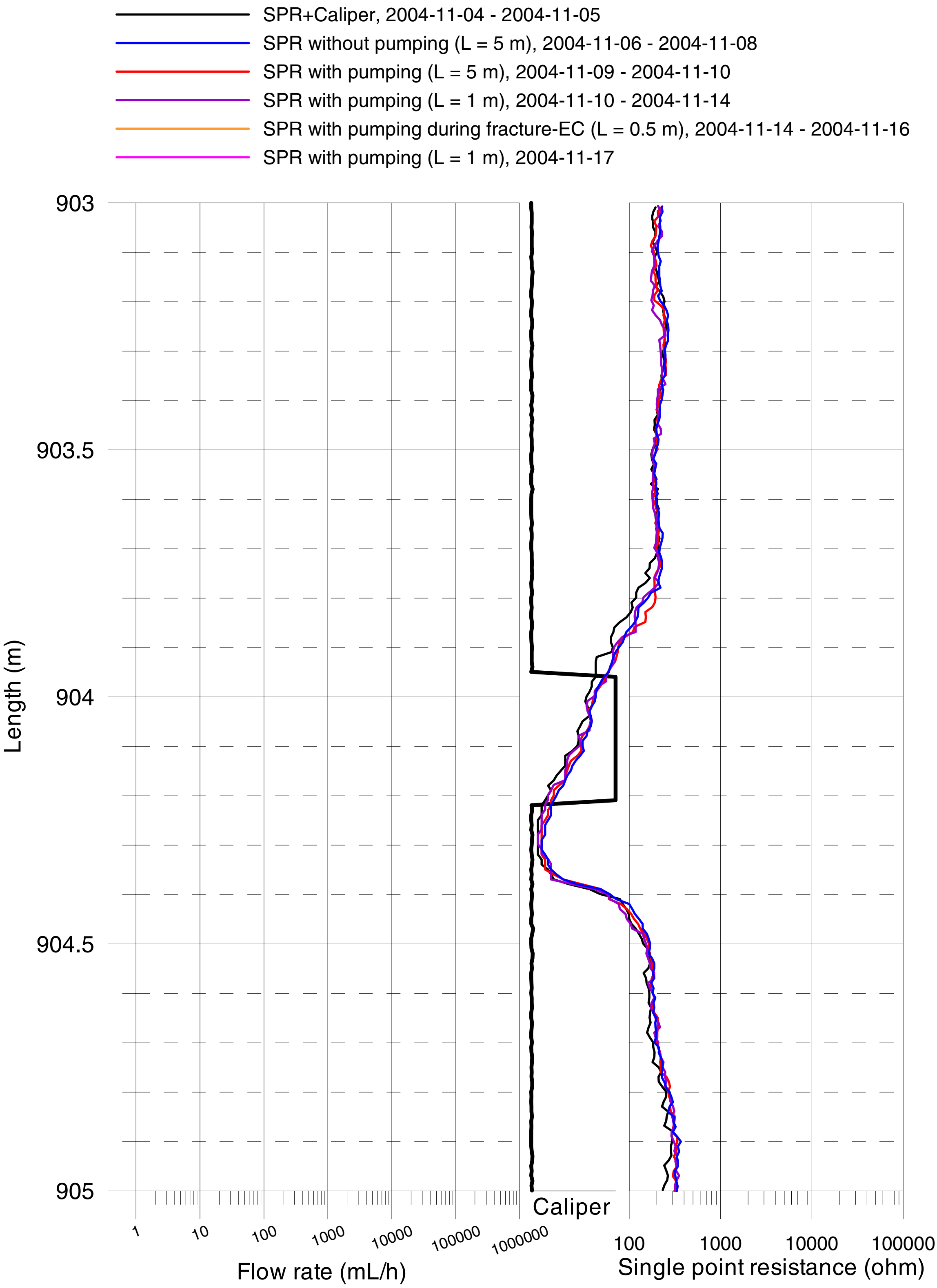
Laxemar, KLX03
SPR and Caliper results after length correction

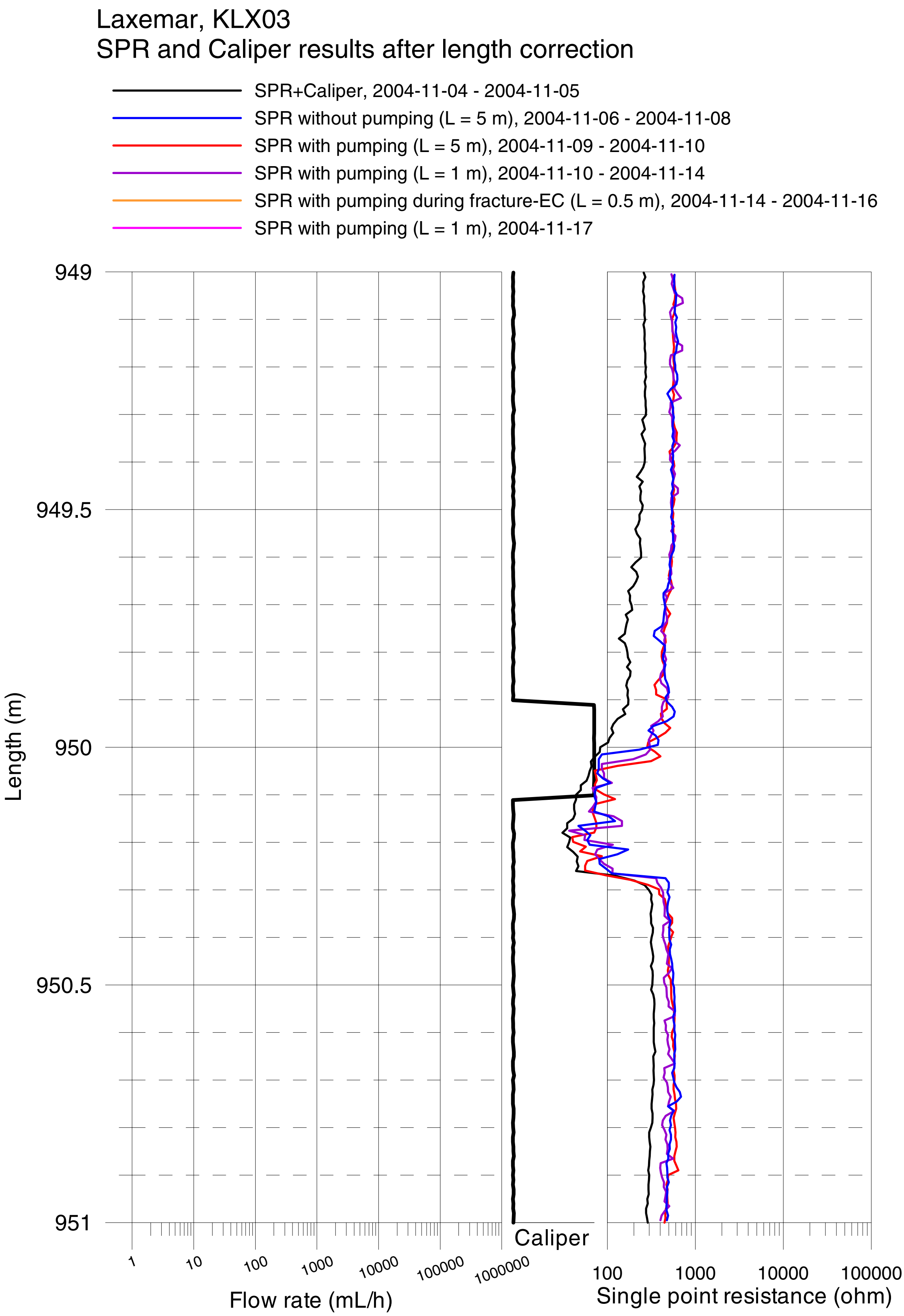


Laxemar, KLX03
SPR and Caliper results after length correction



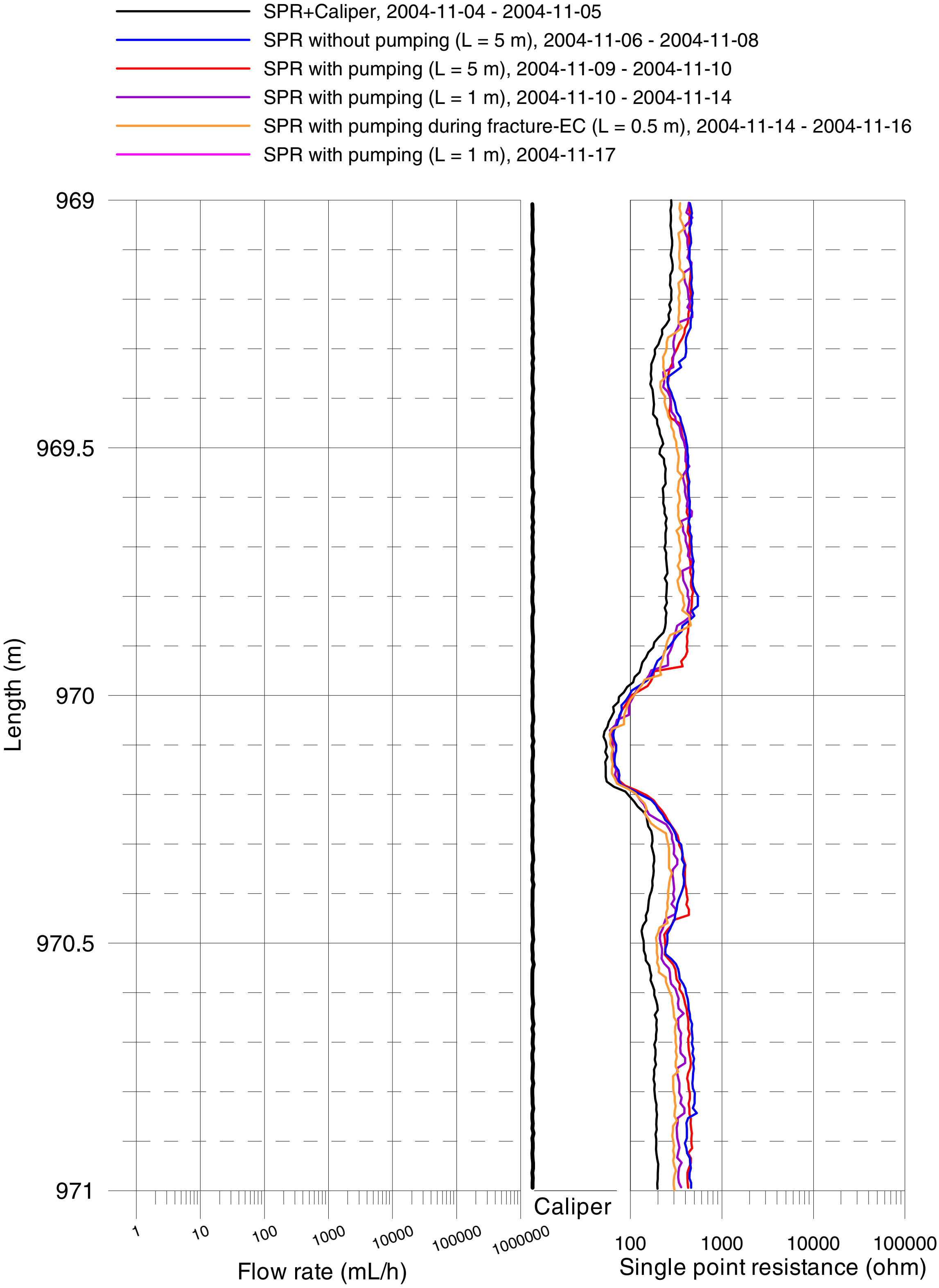
Laxemar, KLX03
SPR and Caliper results after length correction



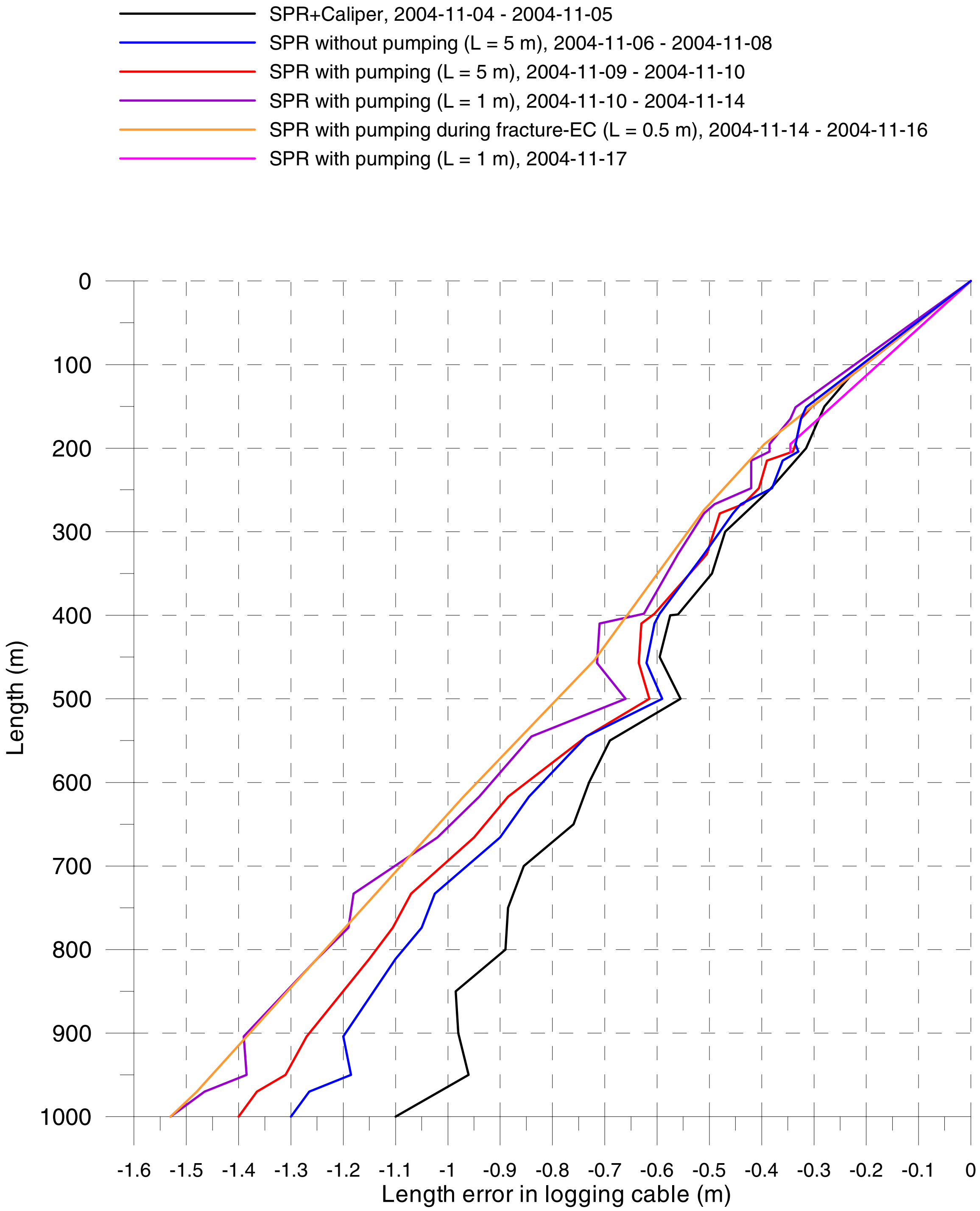


Laxemar, KLX03
SPR and Caliper results after length correction
SPR+Caliper, 2004-11-04 - 2004-11-05
SPR without pumping (L = 5 m), 2004-11-06 - 2004-11-08
SPR with pumping (L = 5 m), 2004-11-09 - 2004-11-10
SPR with pumping (L = 1 m), 2004-11-10 - 2004-11-14
SPR with pumping during fracture-EC (L = 0.5 m), 2004-11-14 - 2004-11-16
SPR with pumping (L = 1 m), 2004-11-17
949
949.5
950
950.5
951
Length (m)
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)

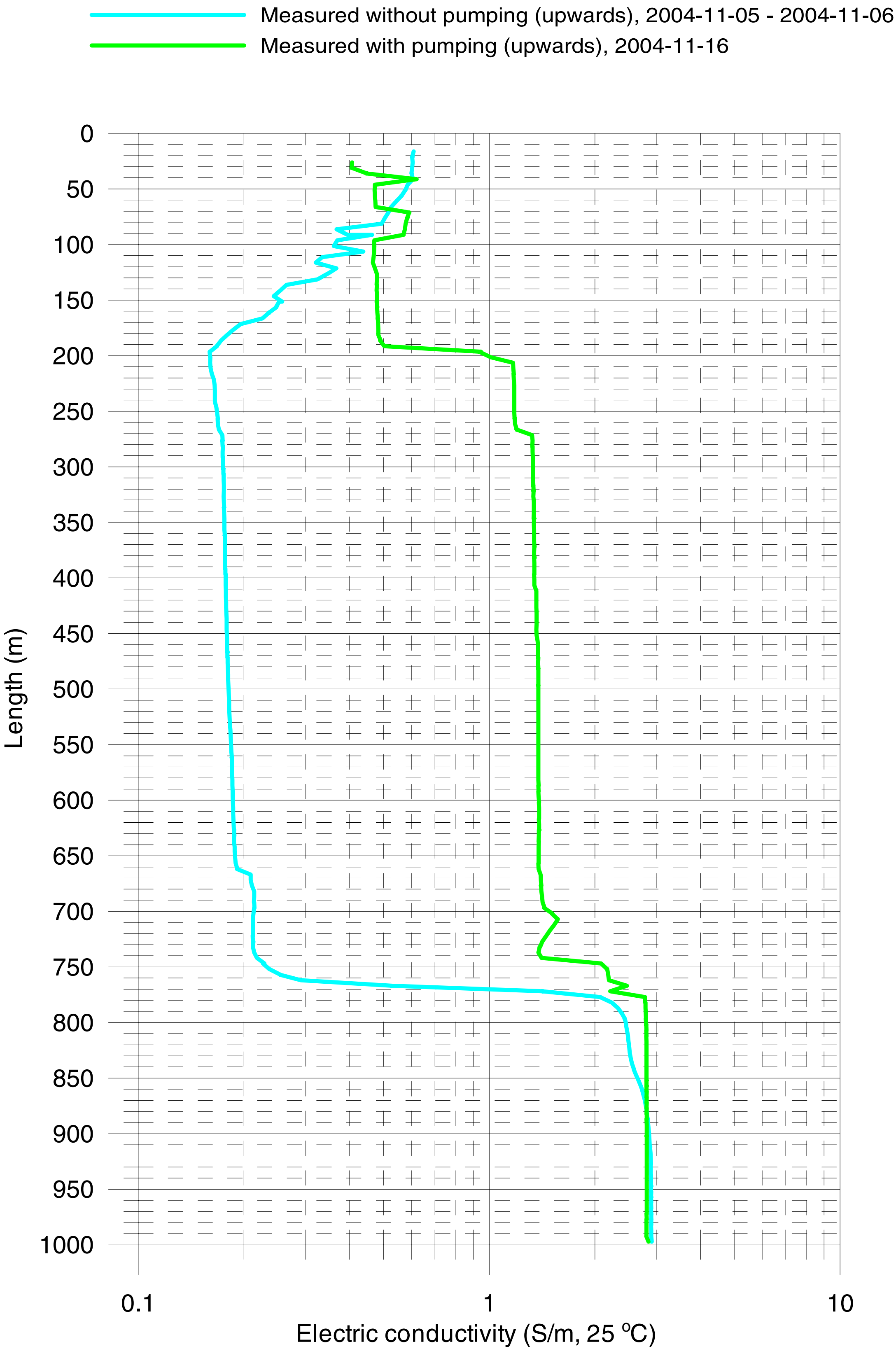
Laxemar, KLX03
SPR and Caliper results after length correction



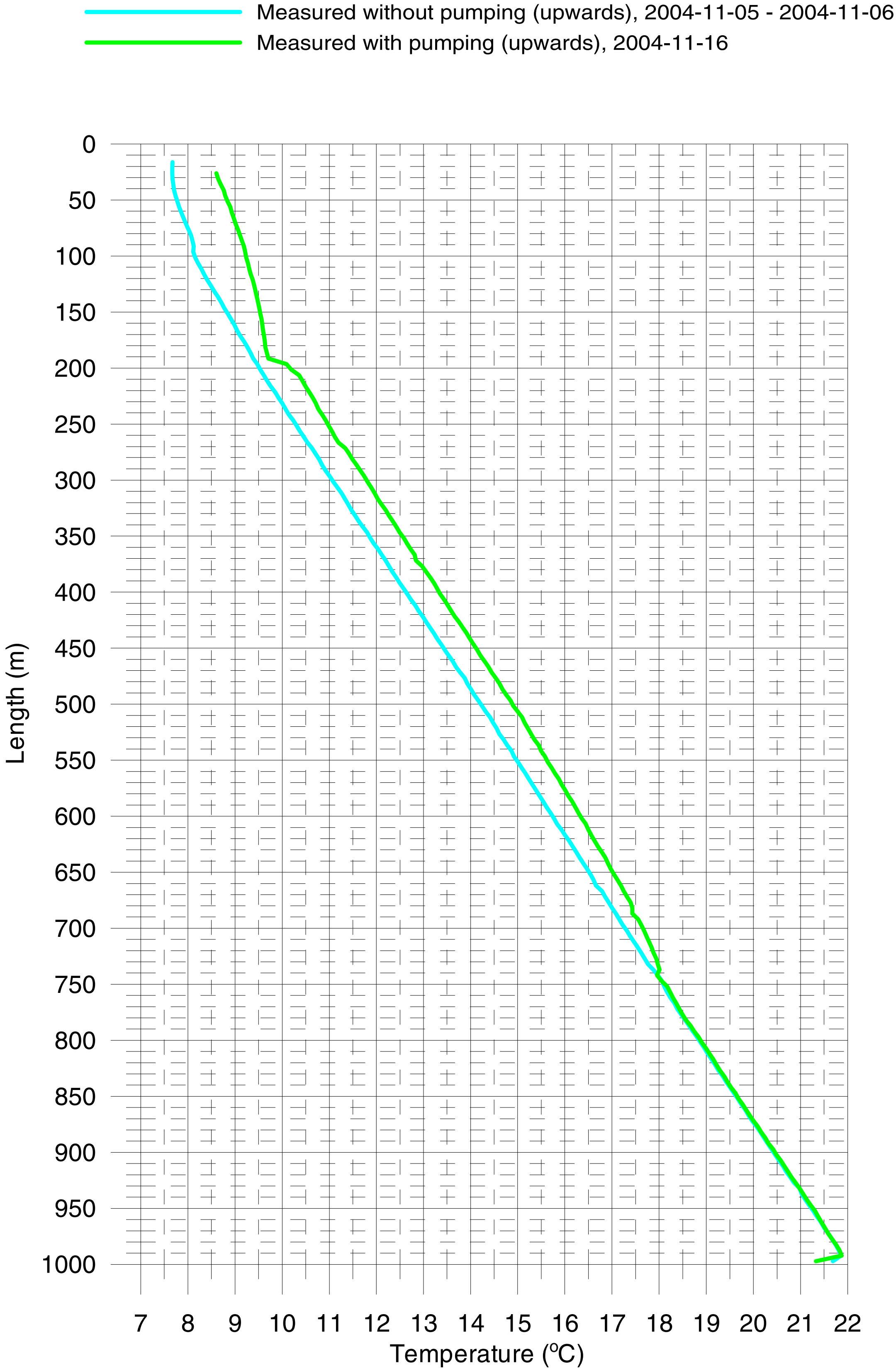
Laxemar, KLX03
Length correction



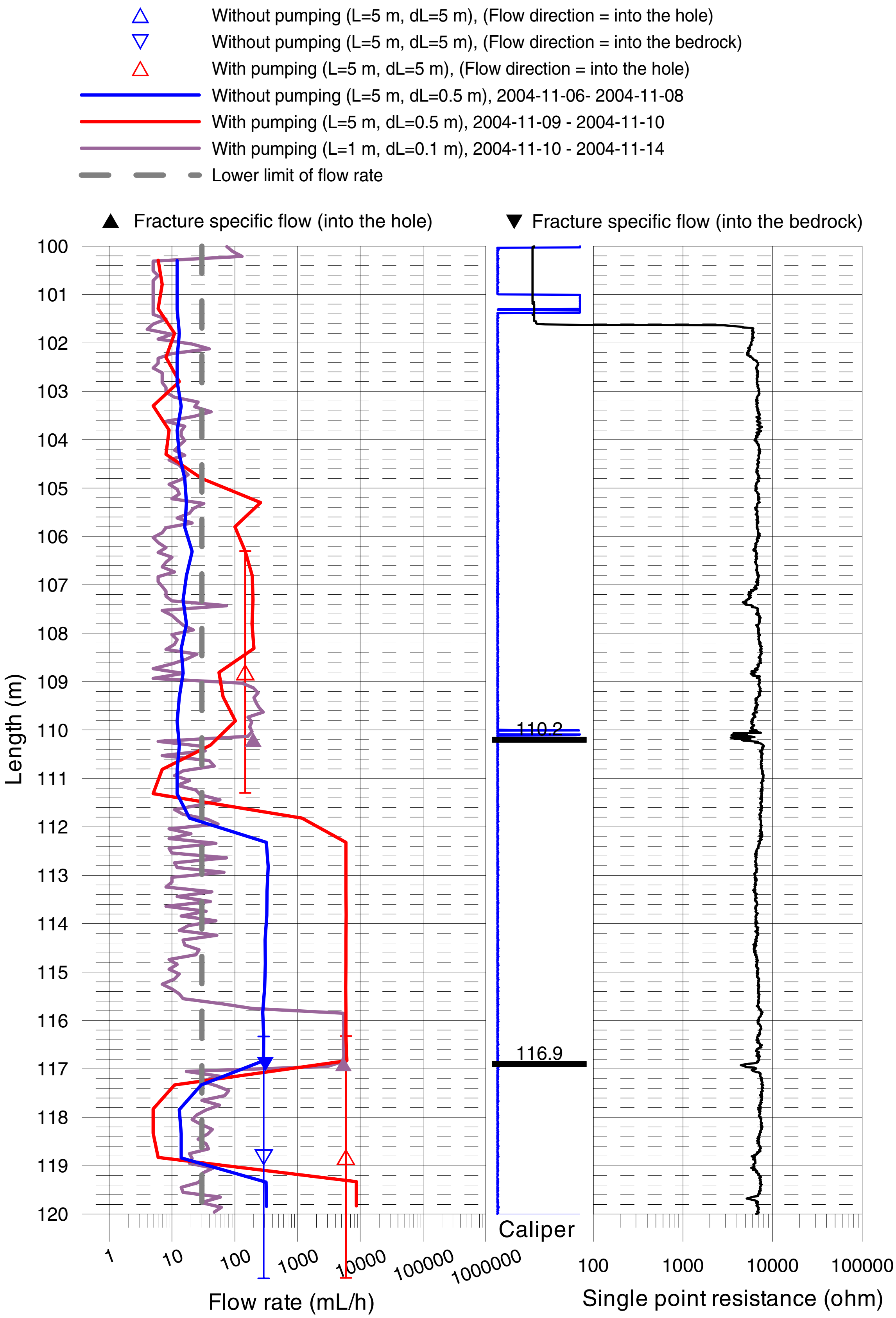
Laxemar, borehole KLX03
Electric conductivity of borehole water



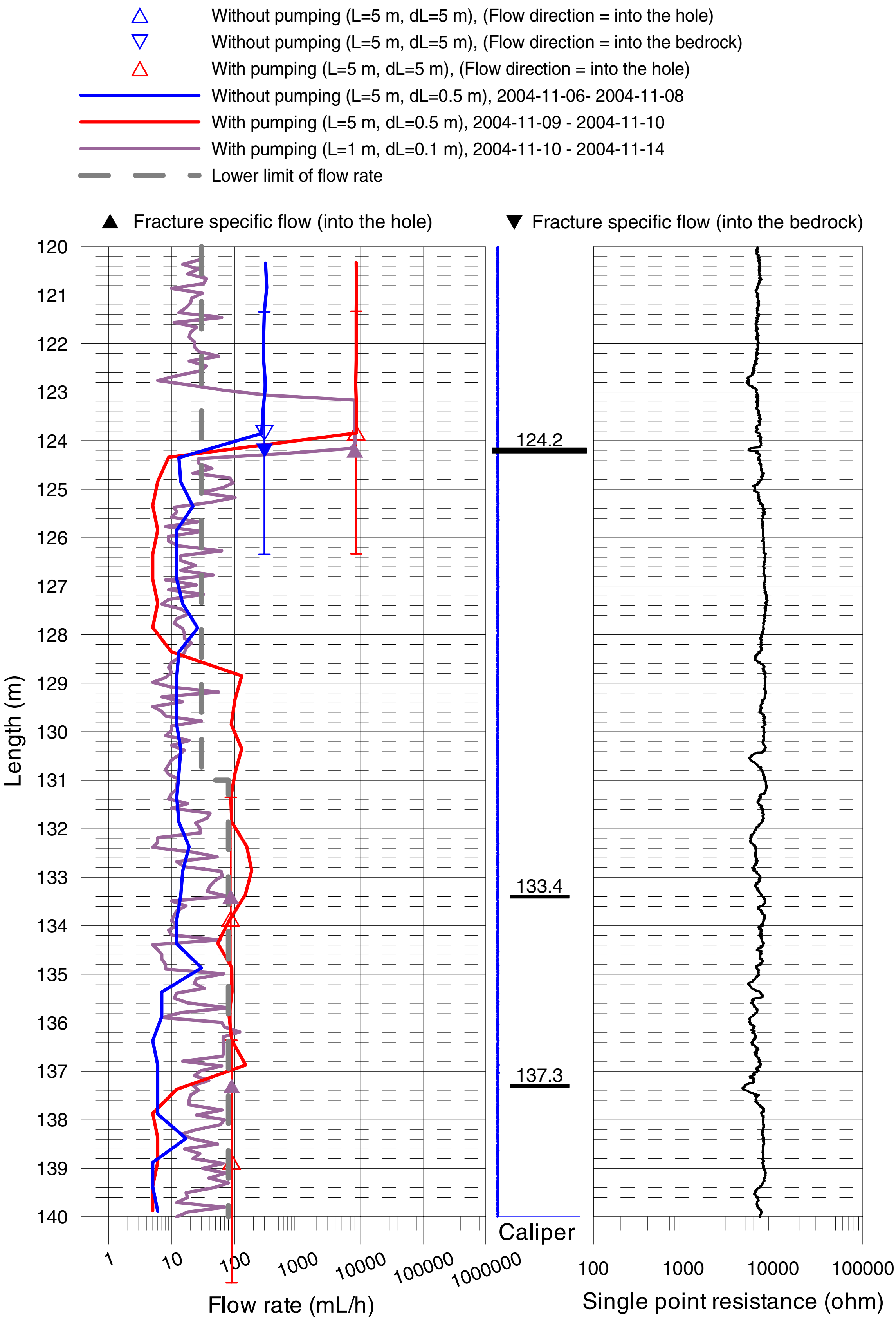
Laxemar, borehole KLX03
Temperature of borehole water



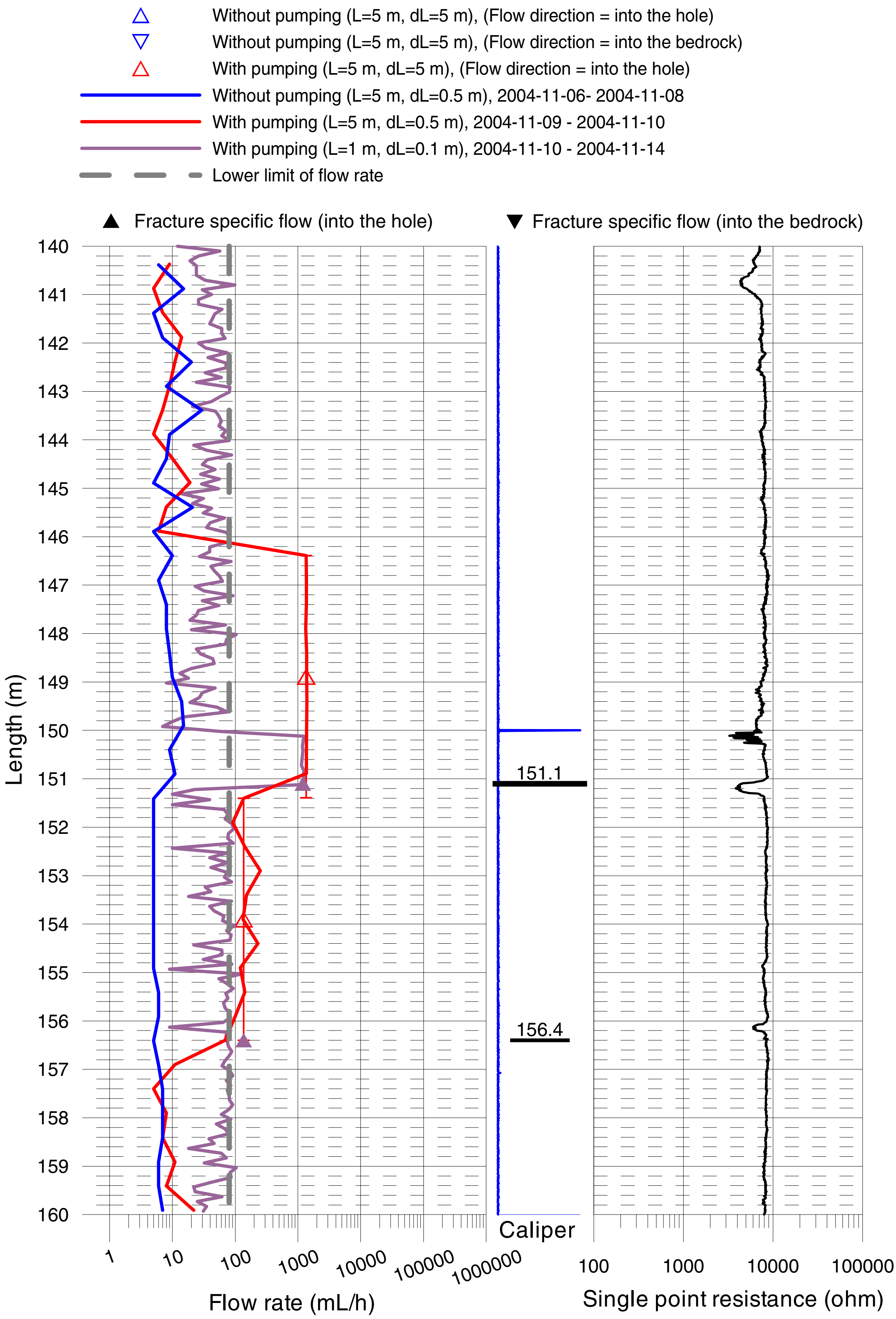
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



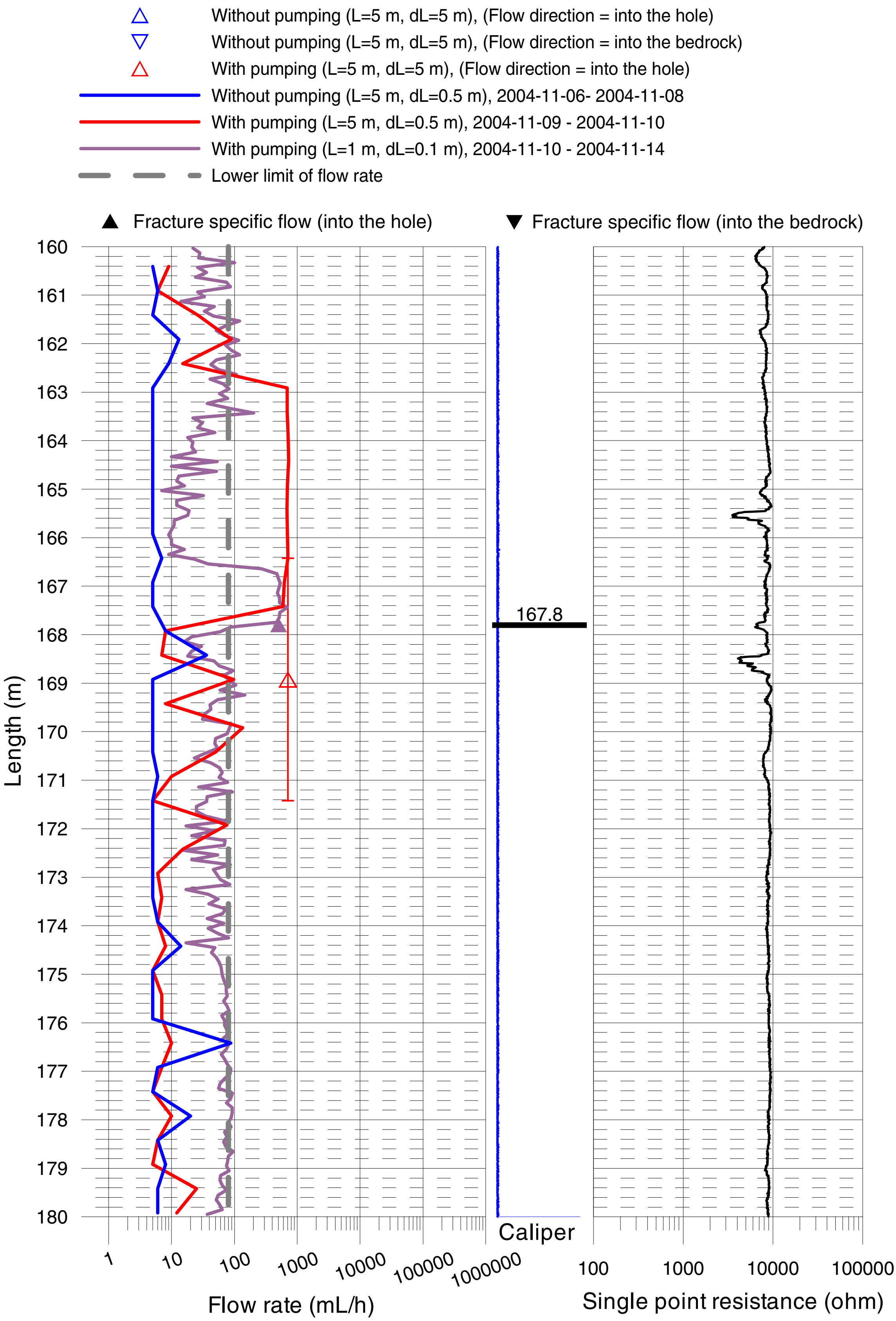
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



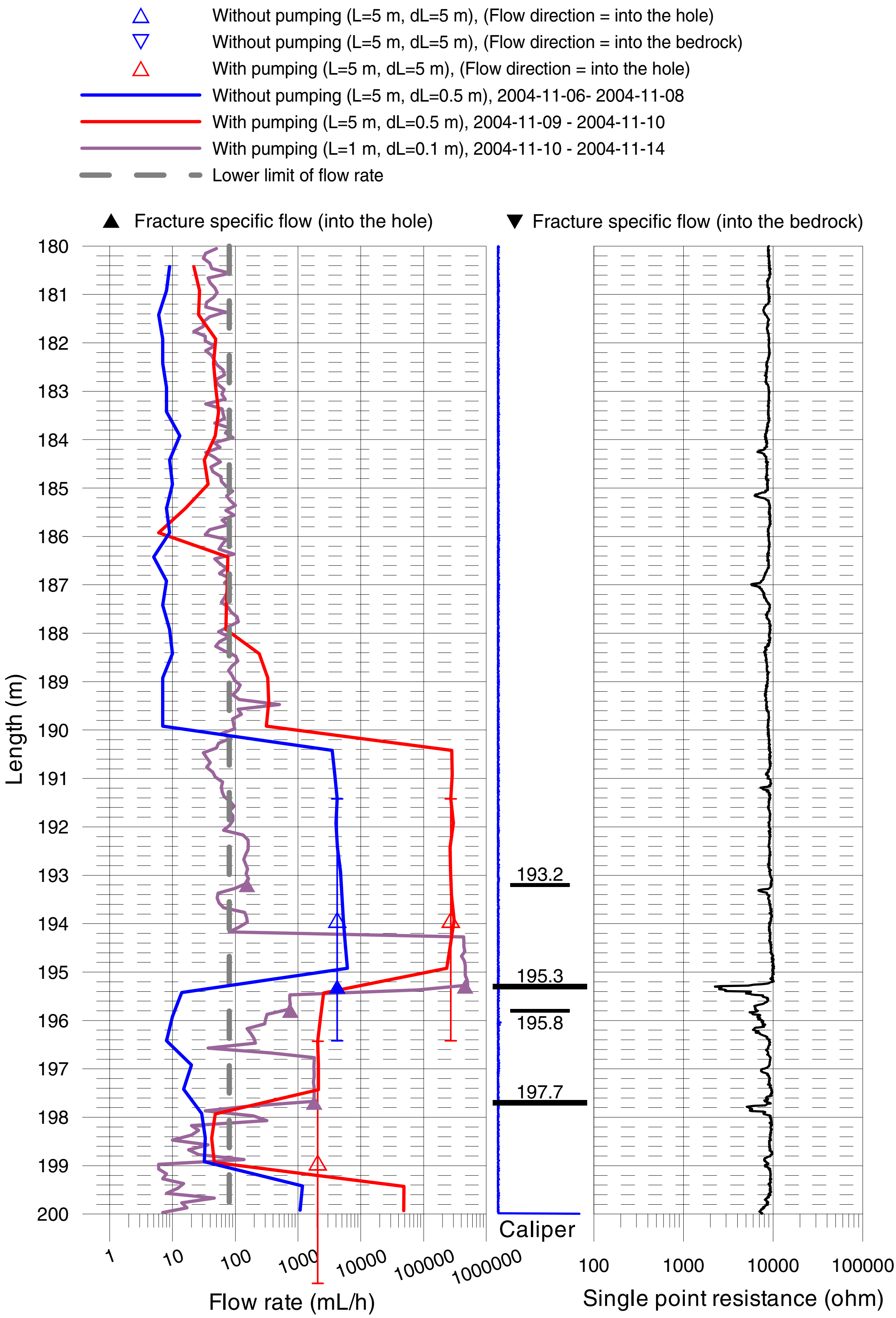
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



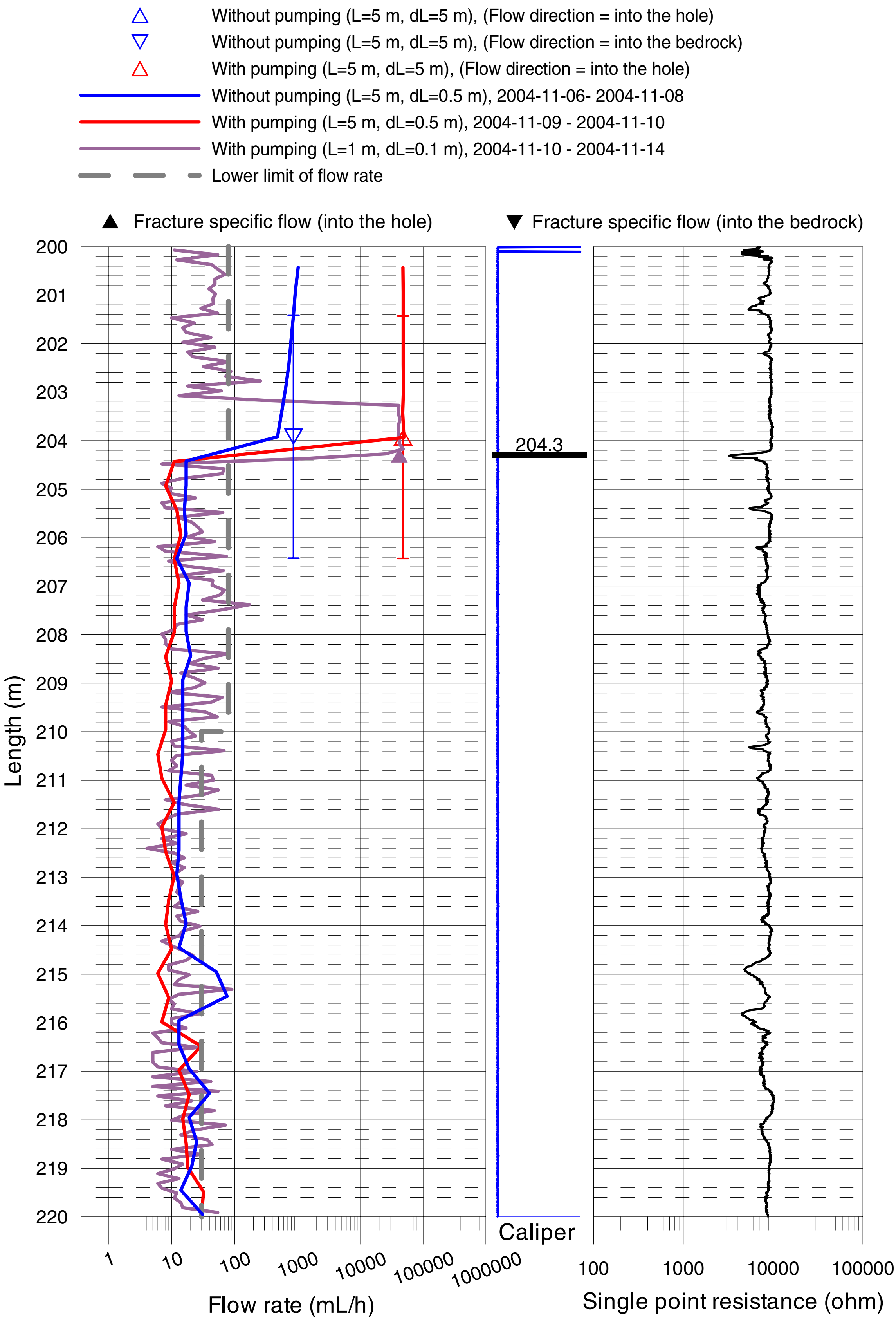
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



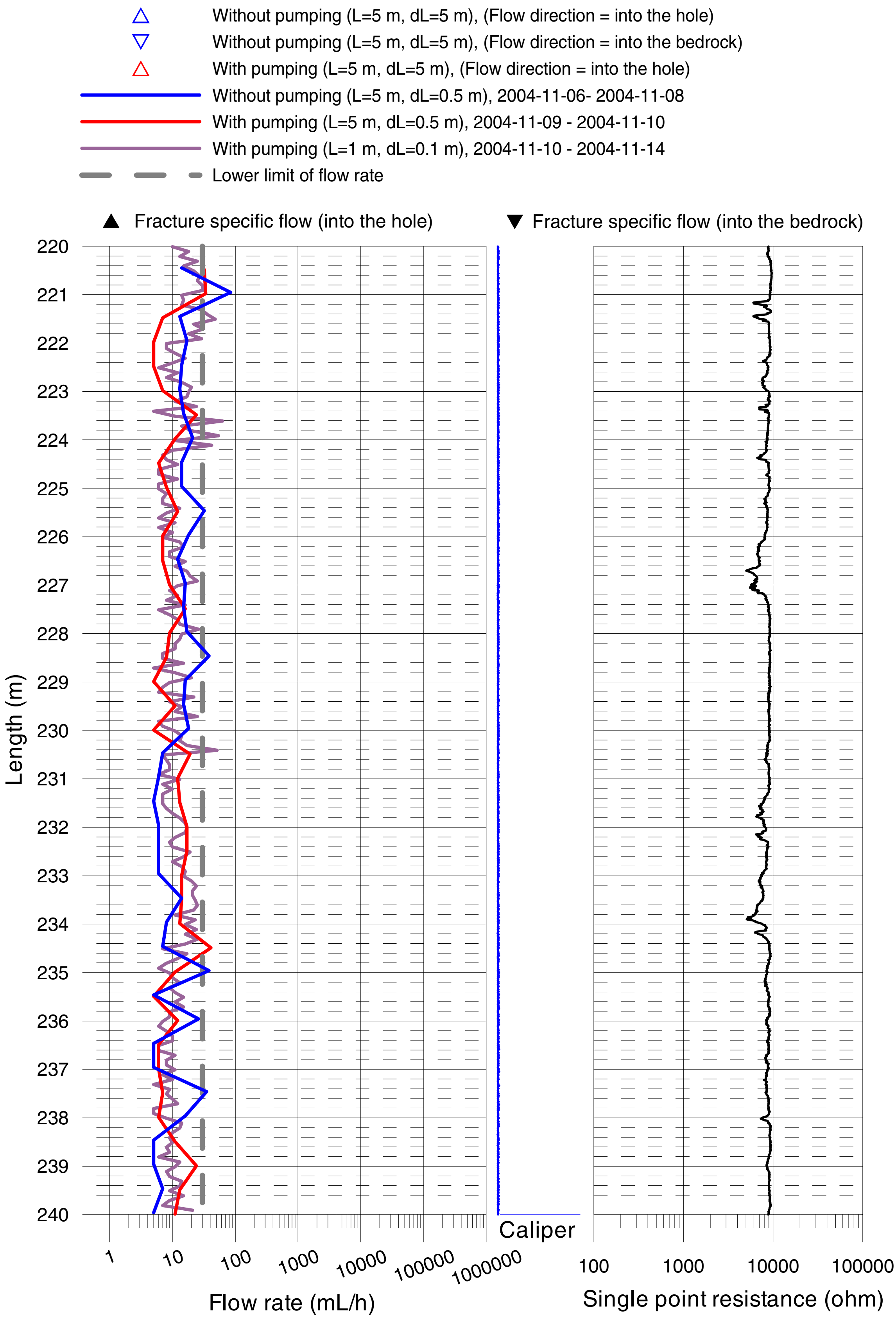
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



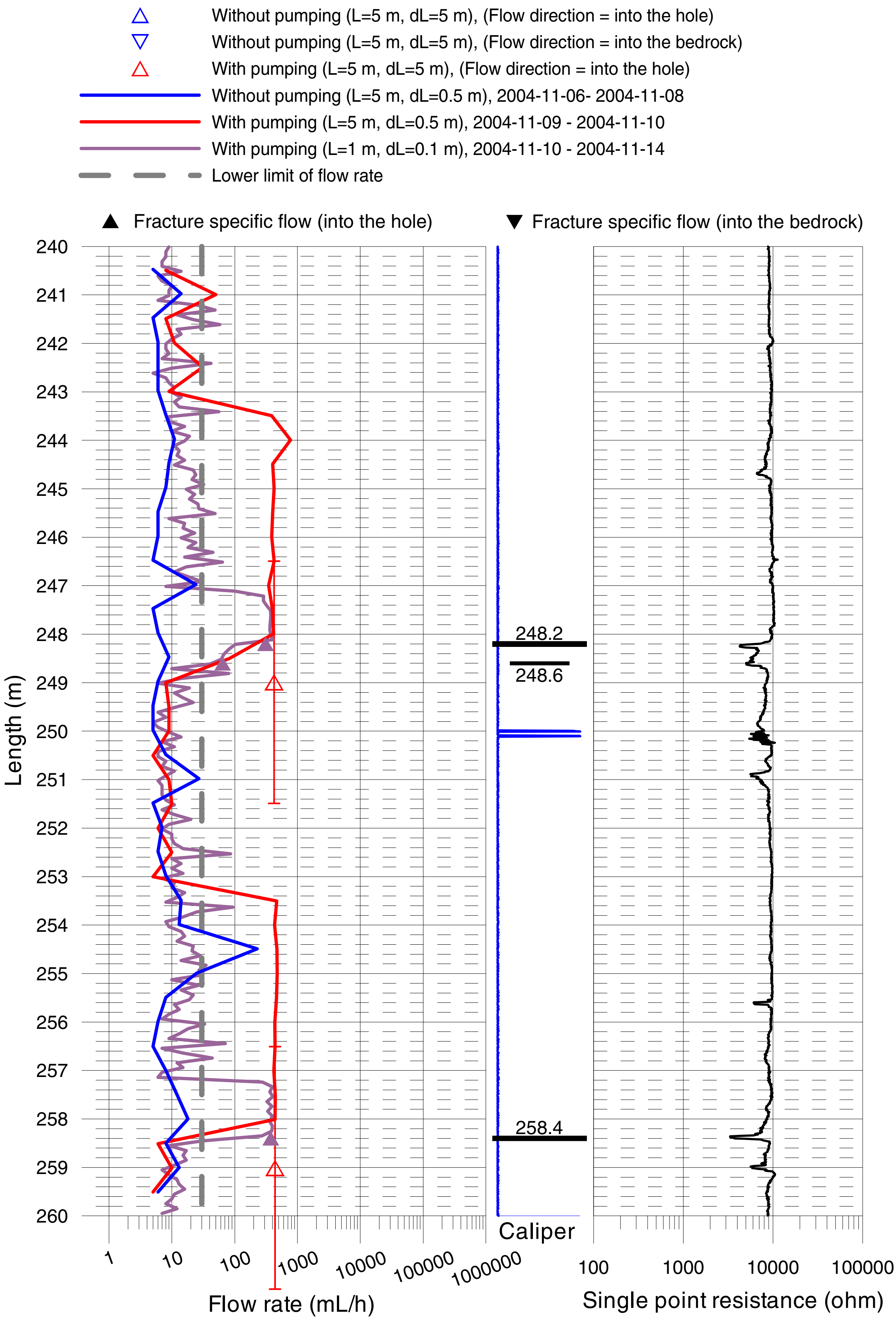
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



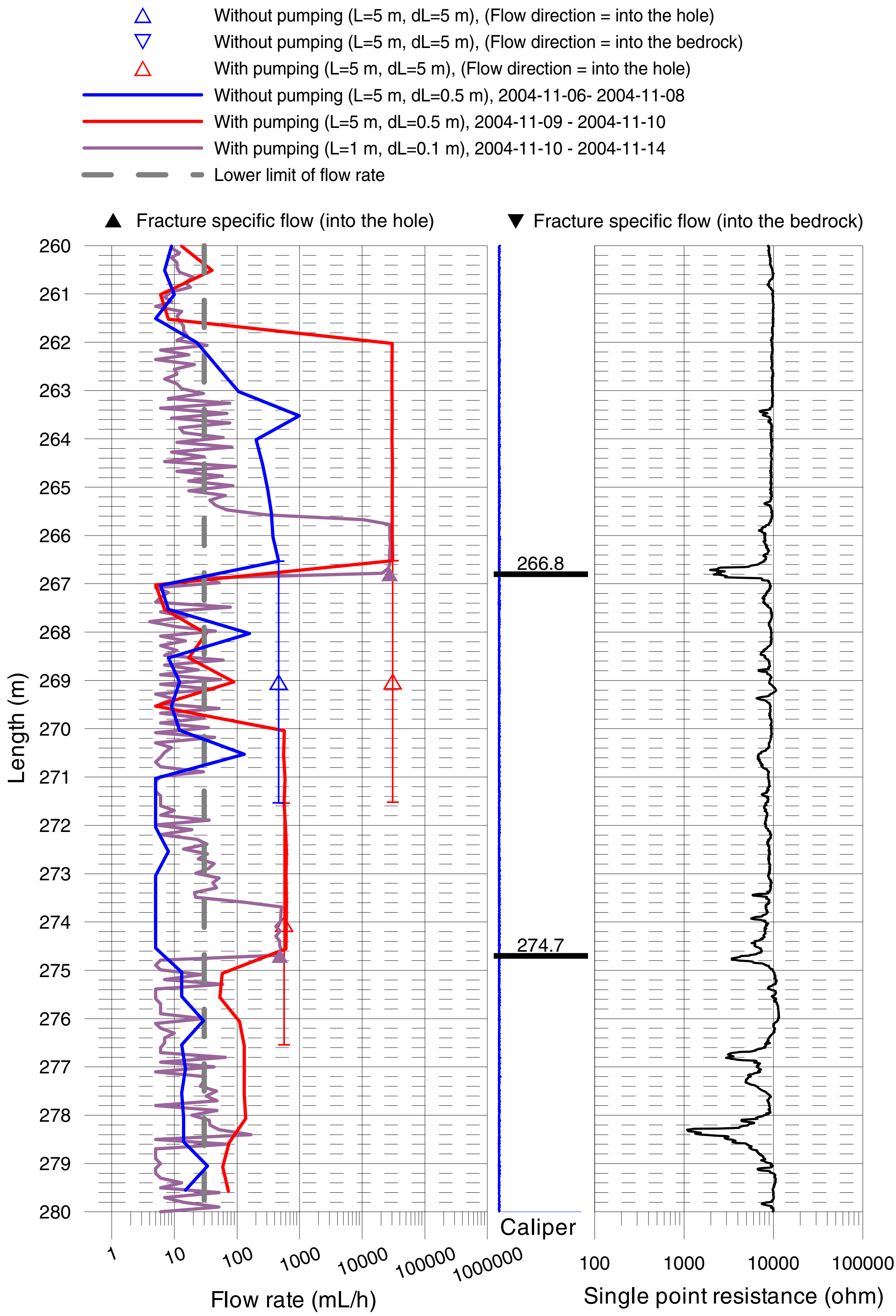
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



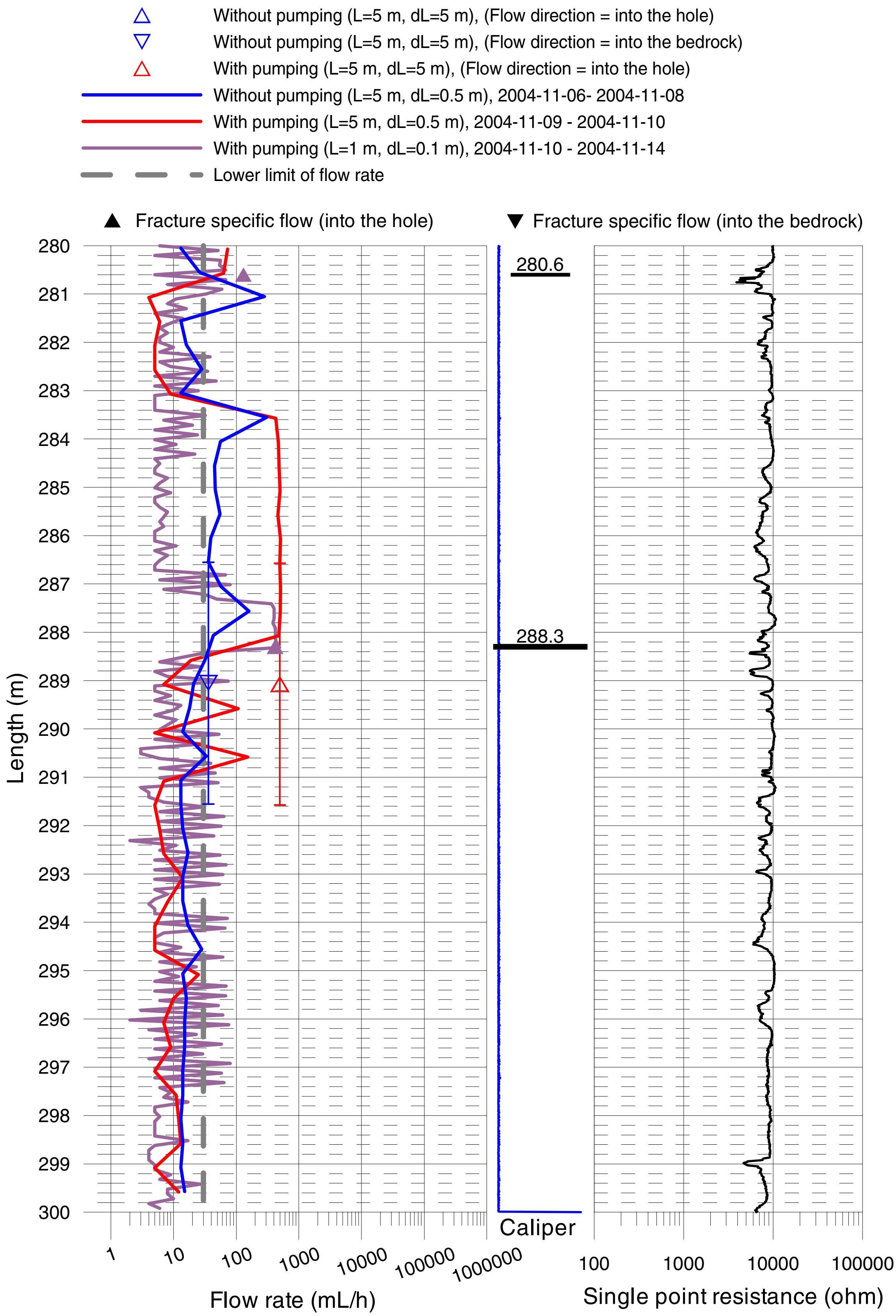
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



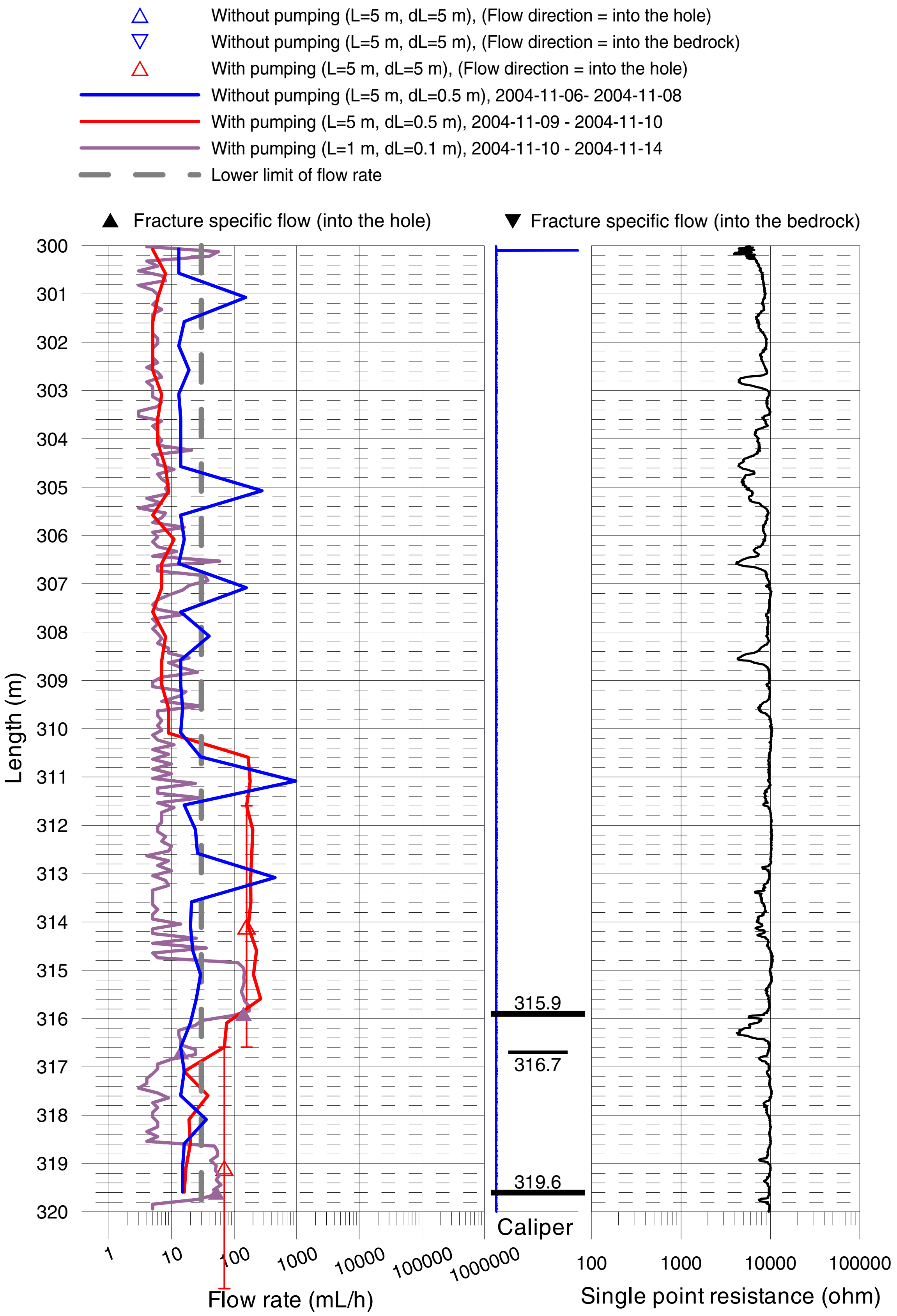
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



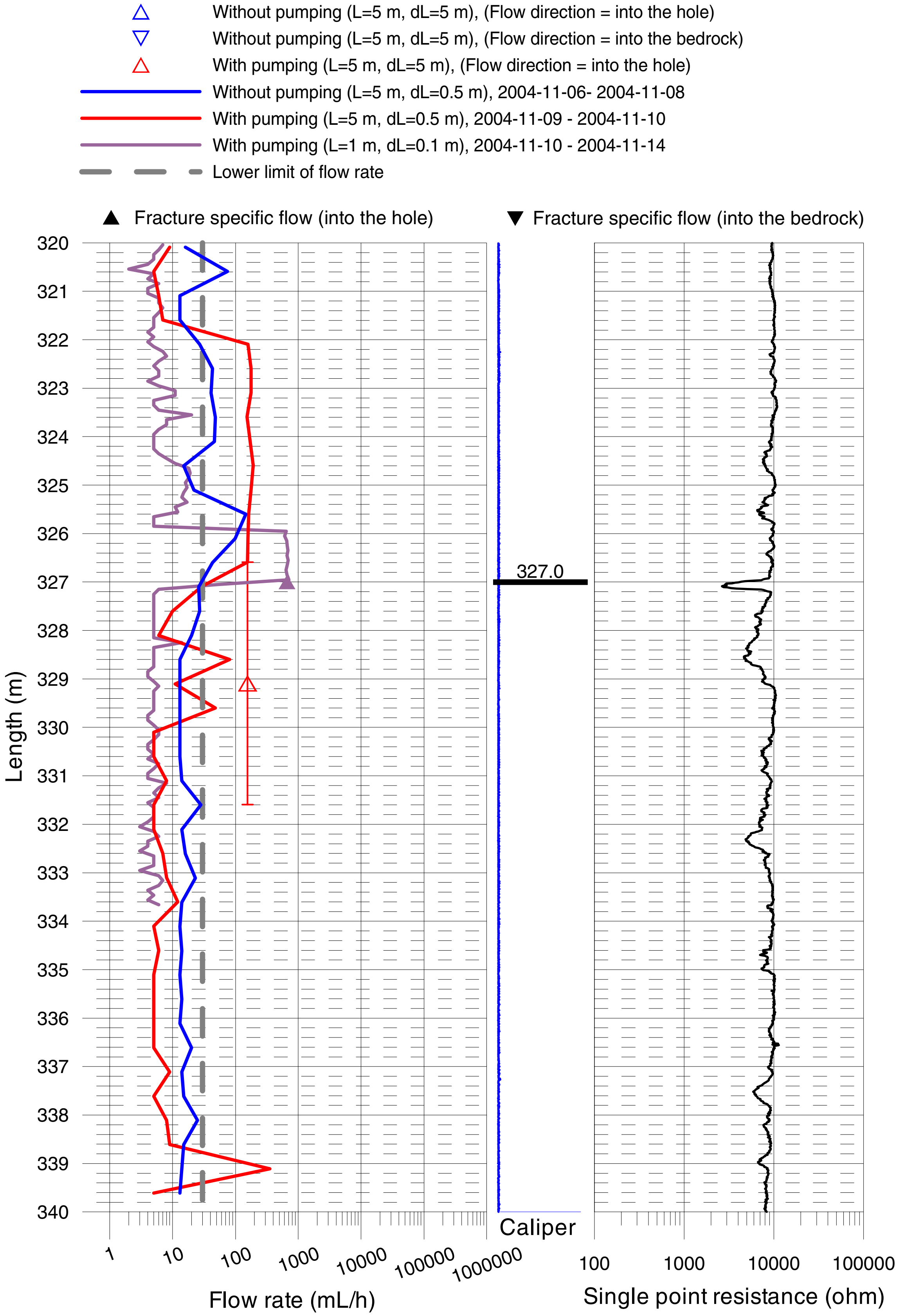
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



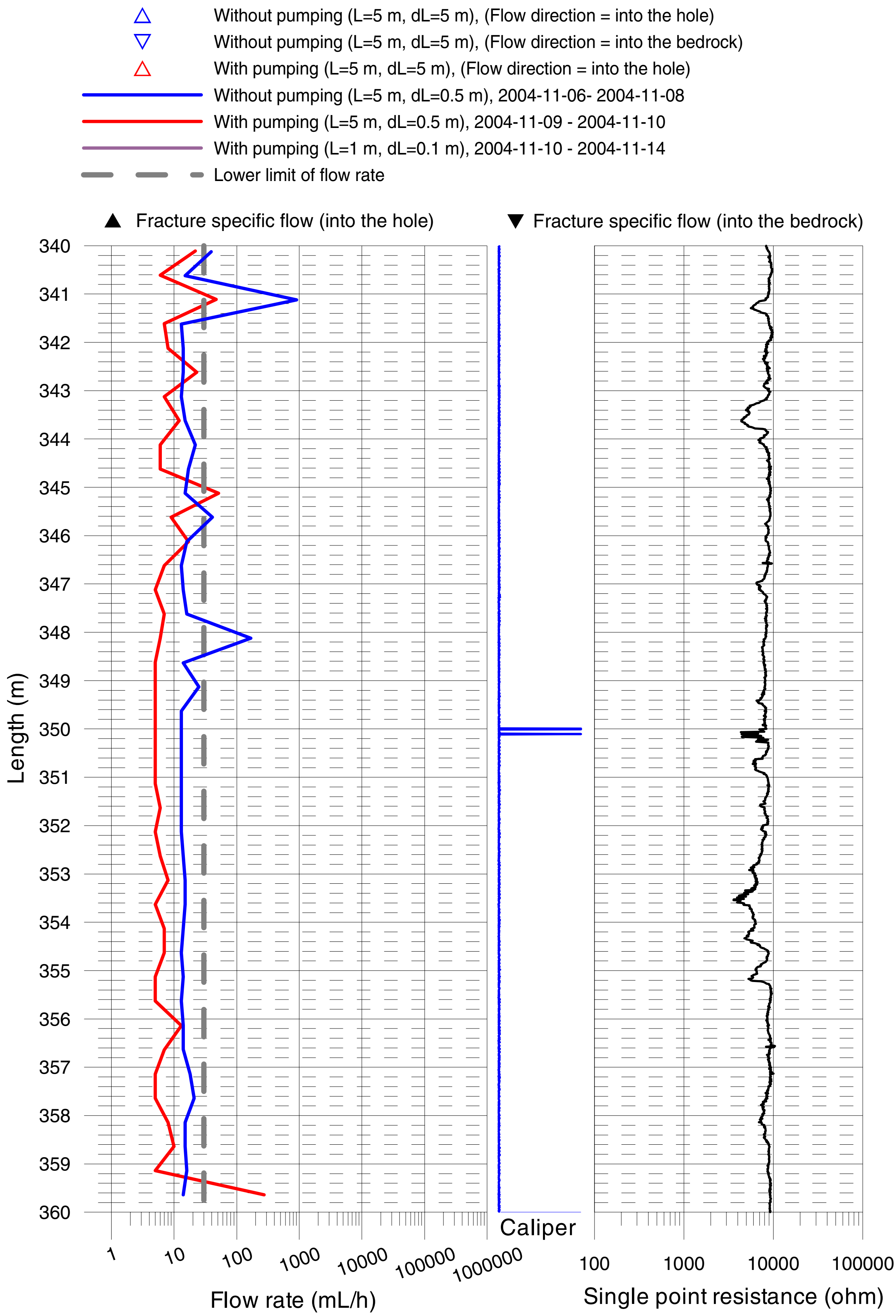
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



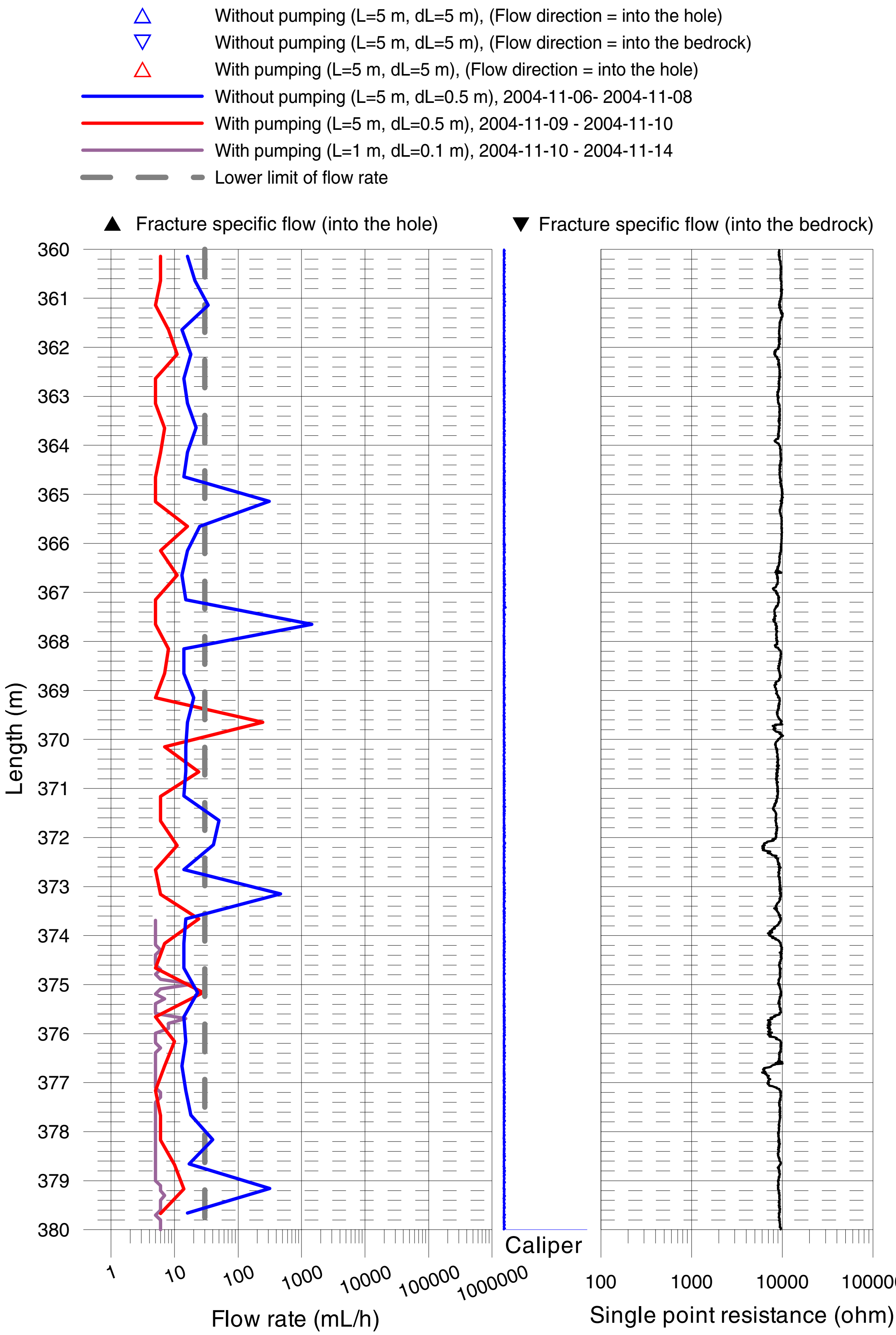
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



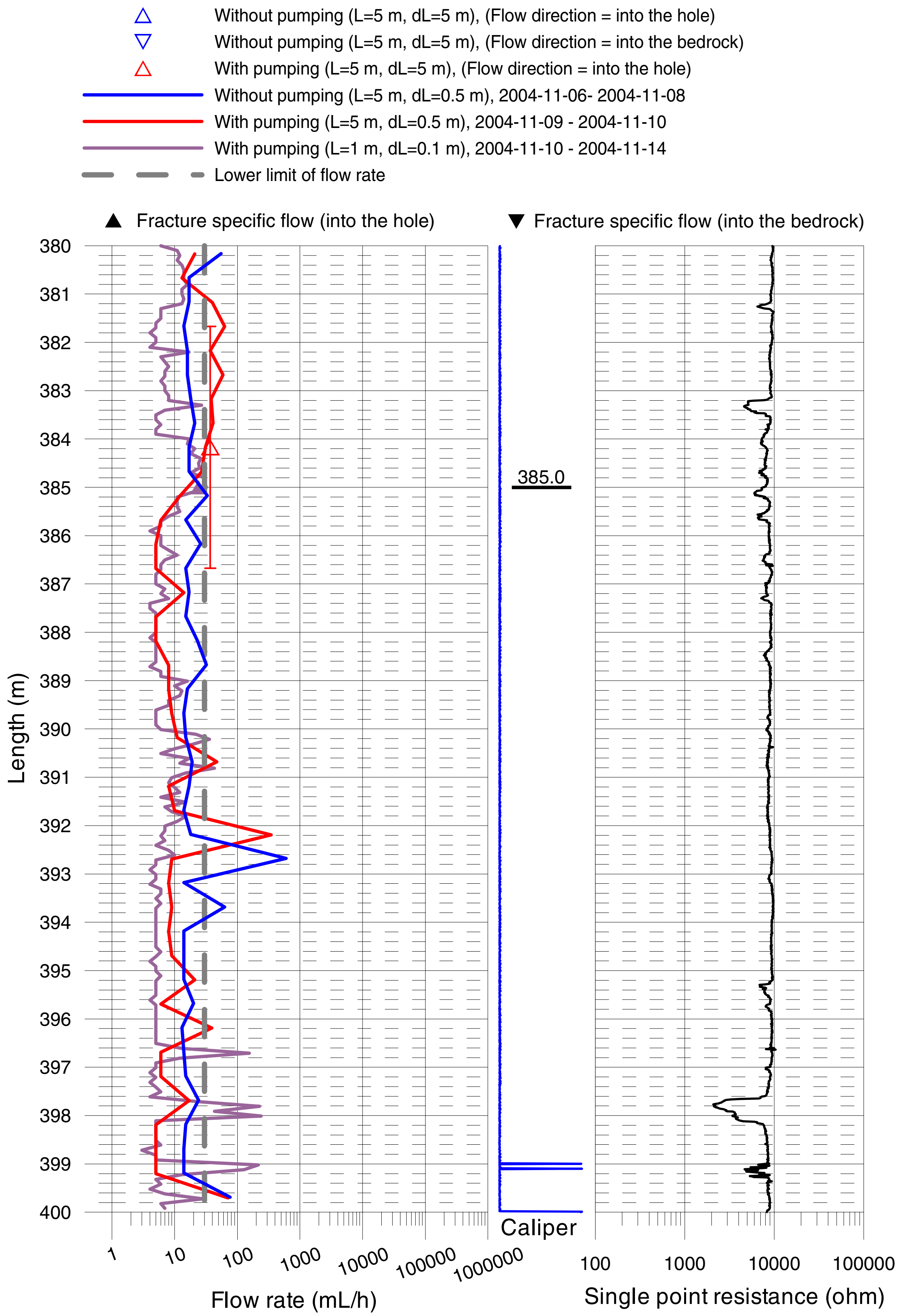
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



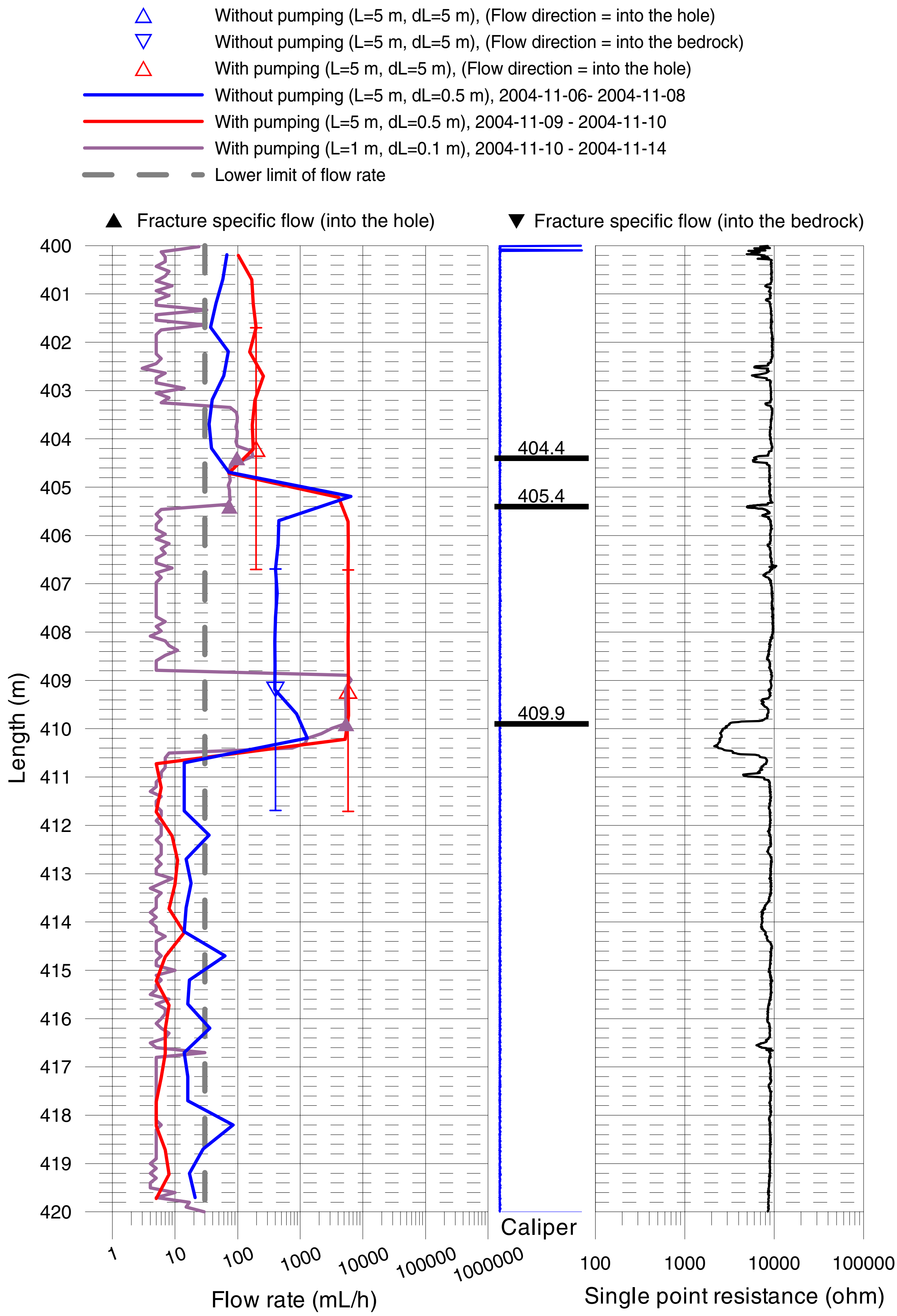
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



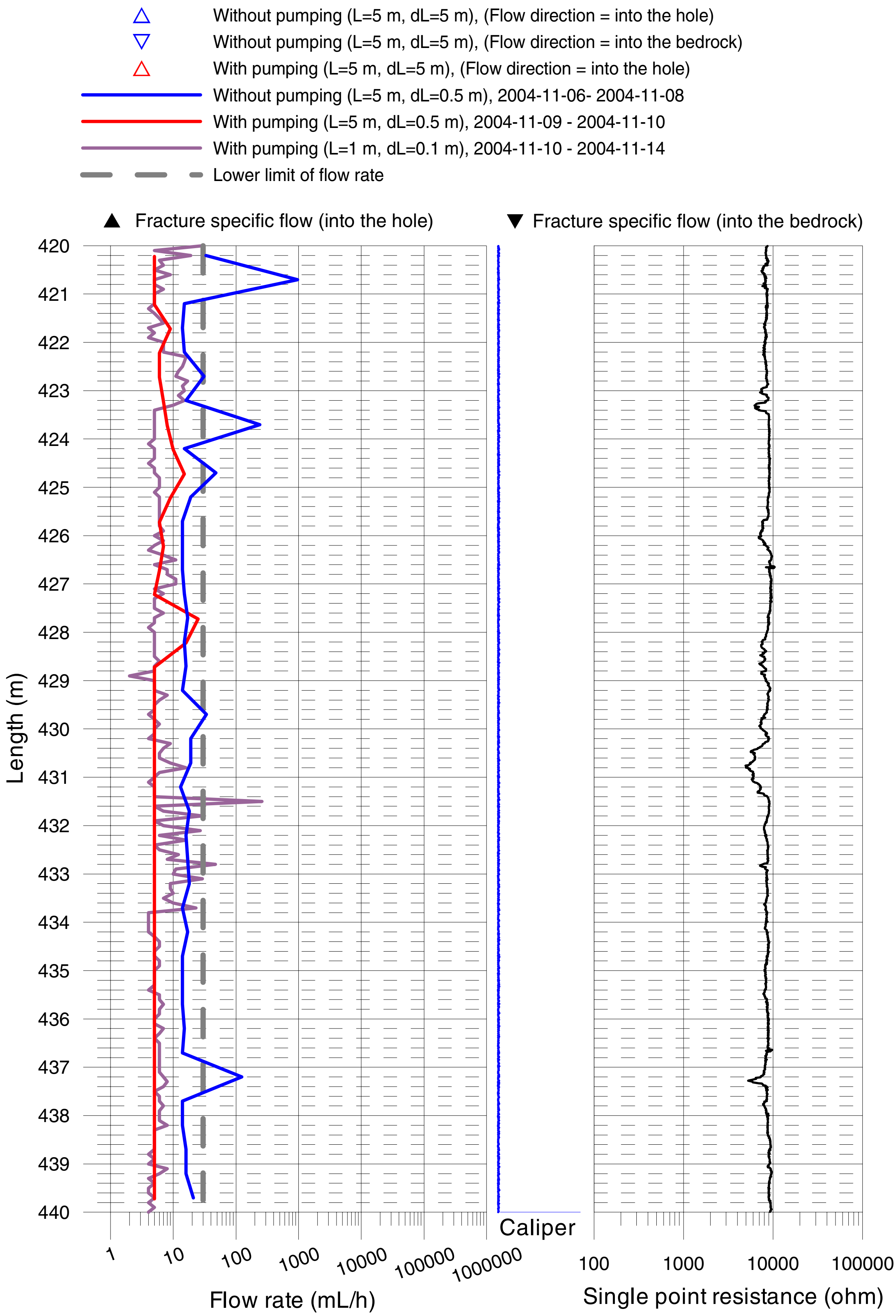
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



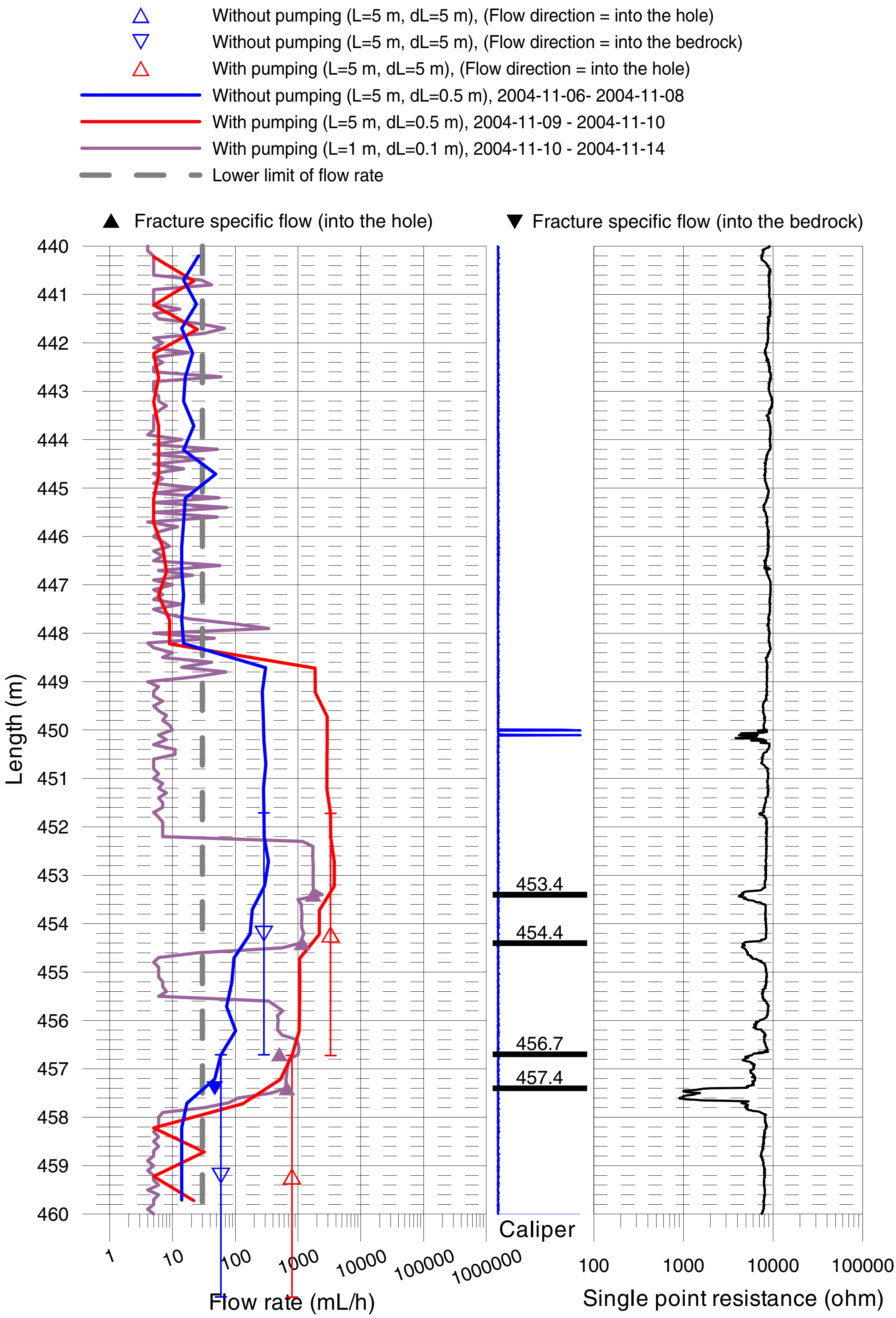
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



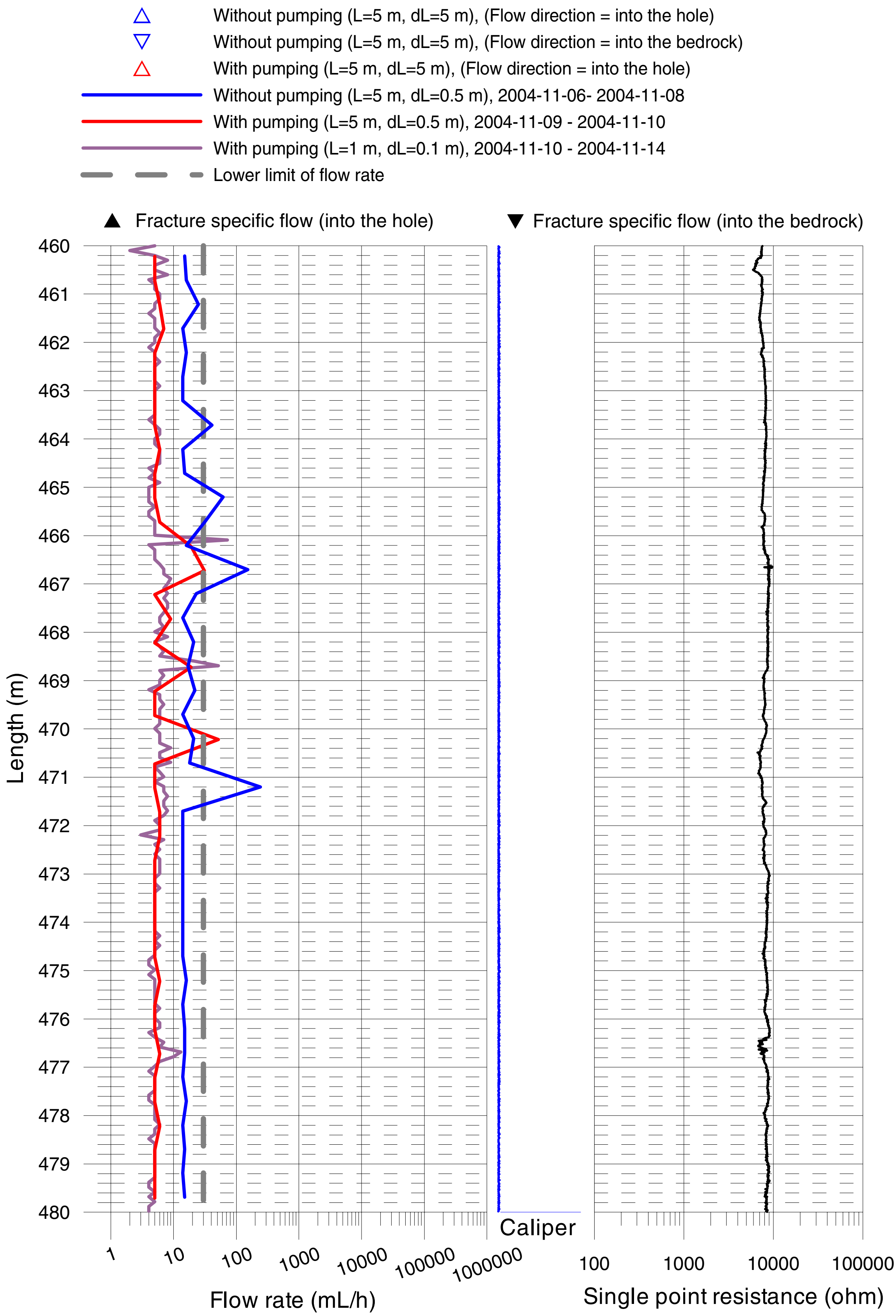
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



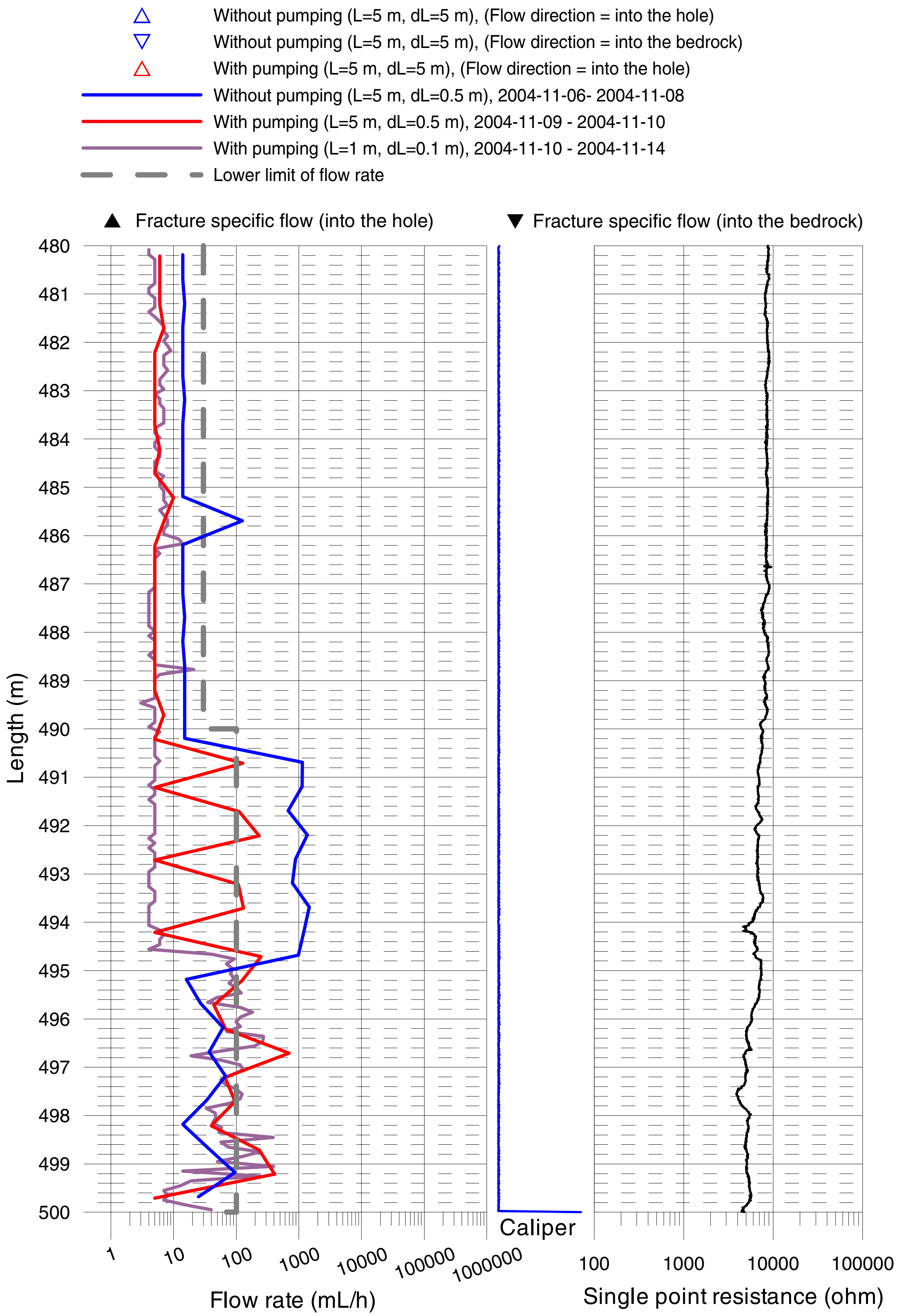
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



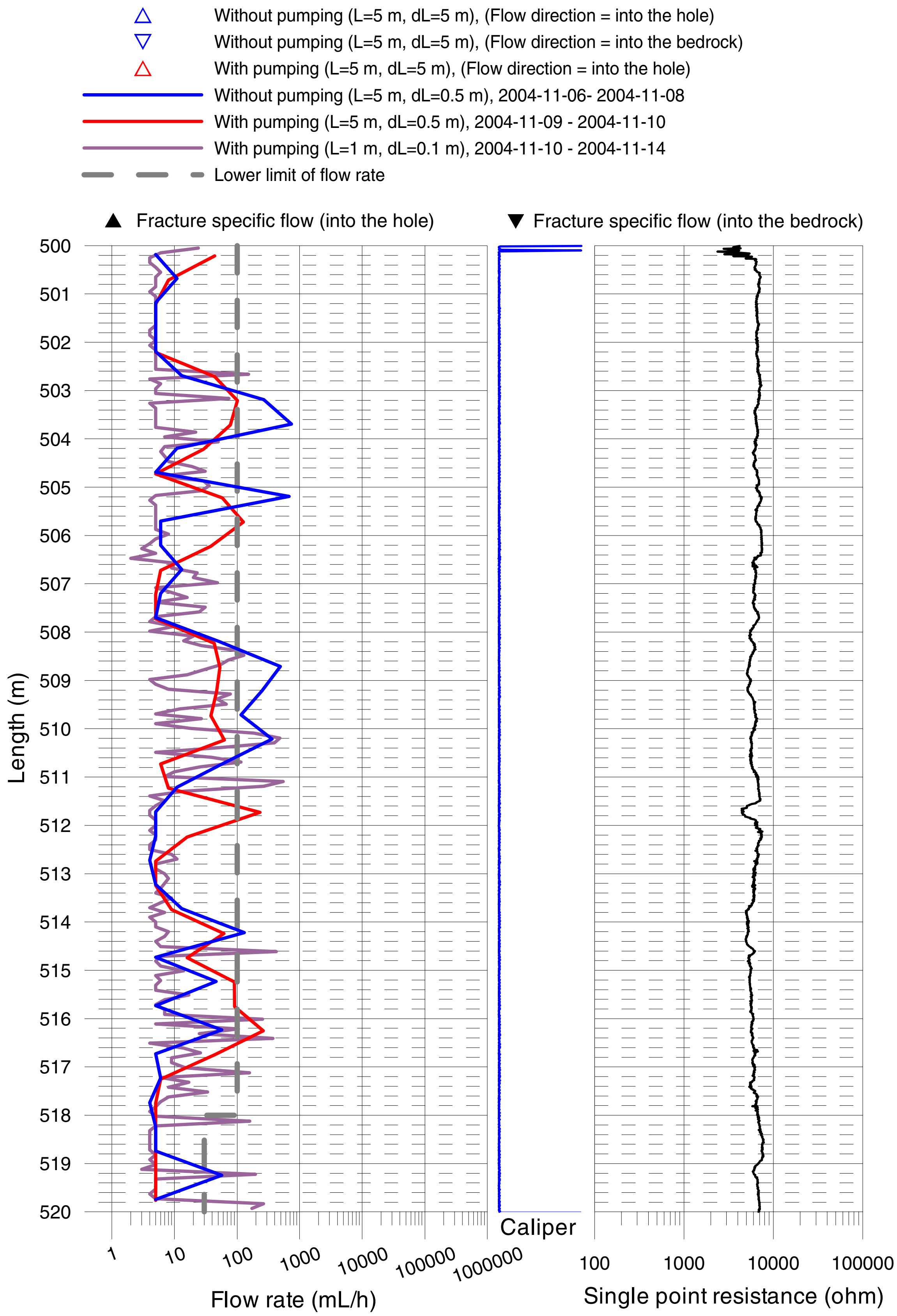
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



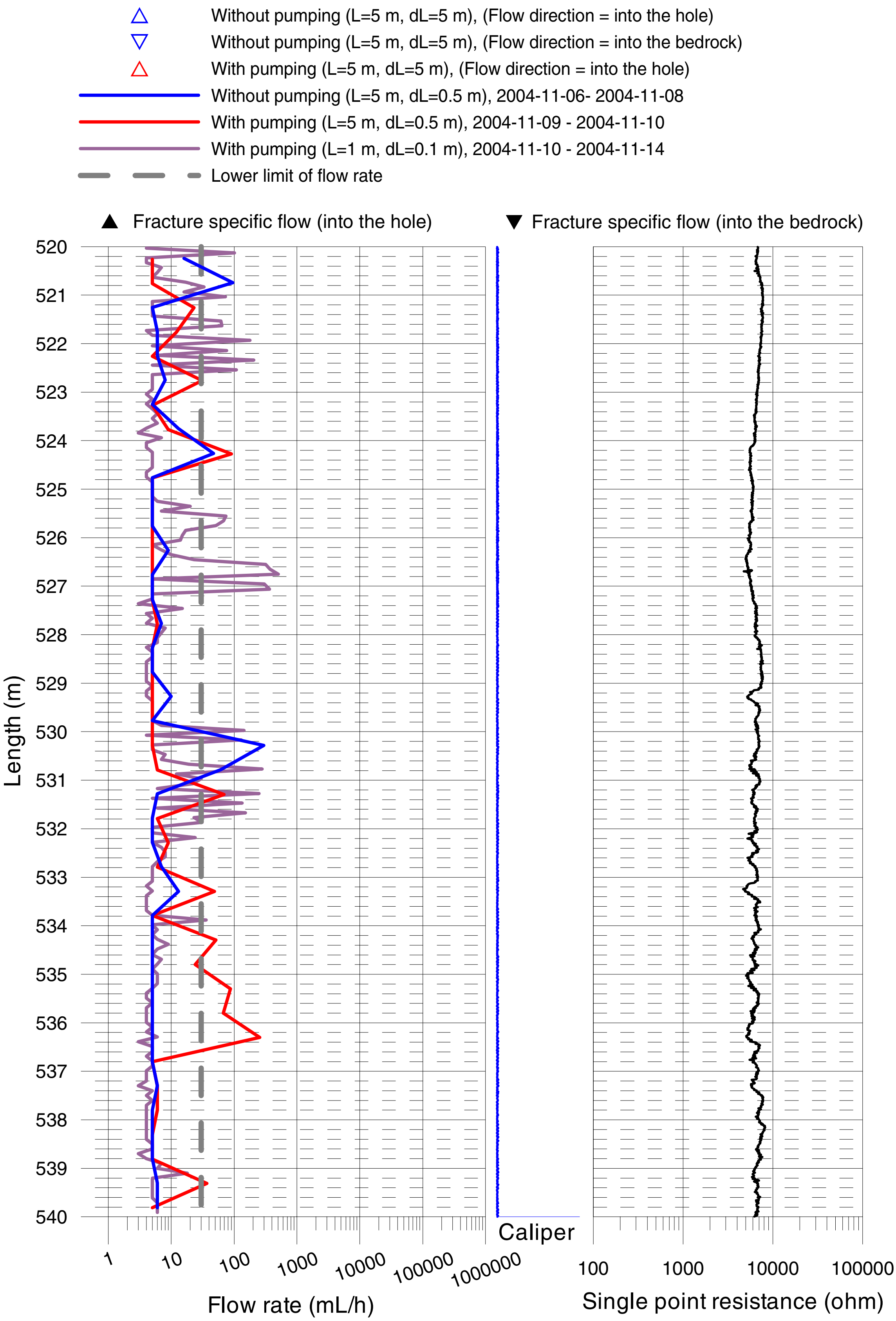
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



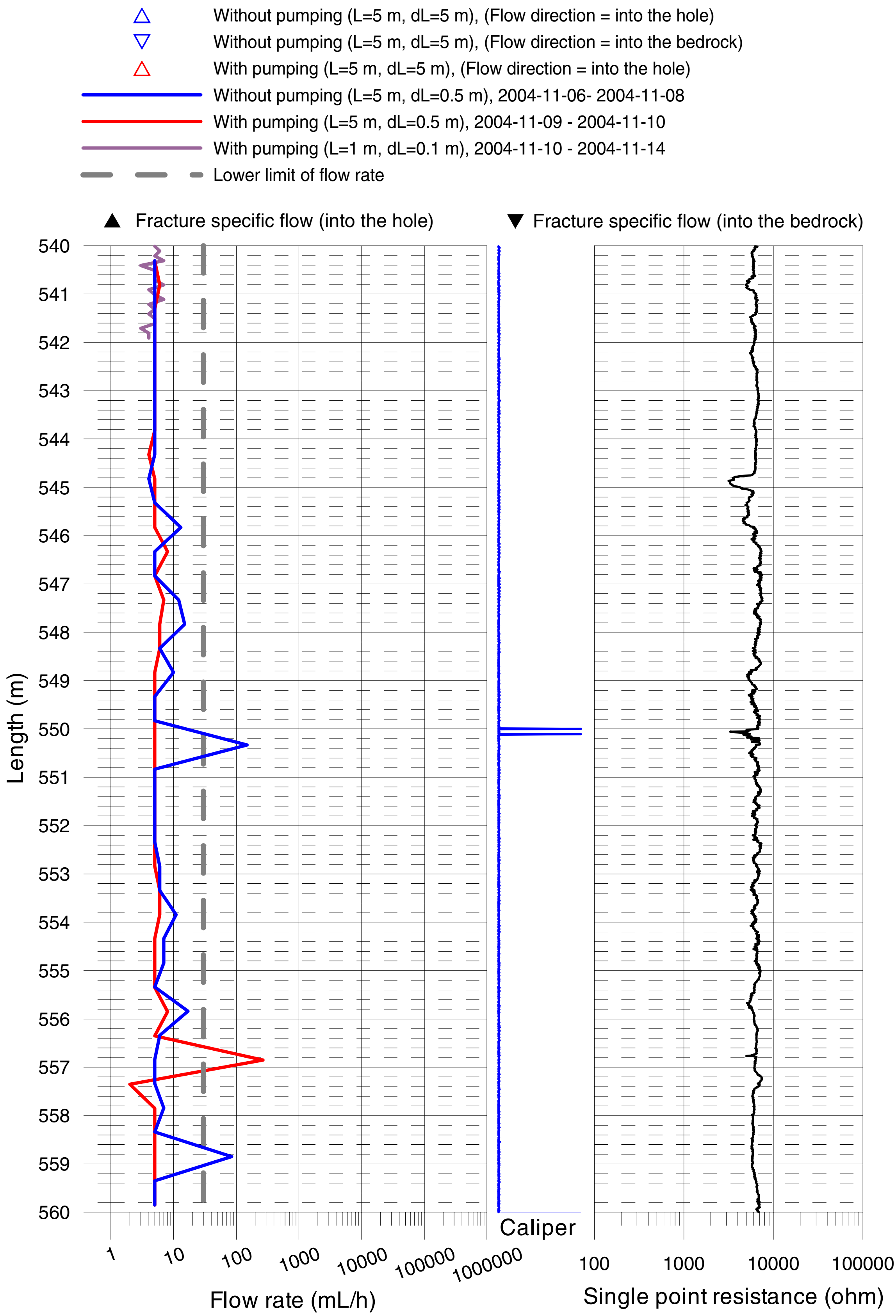
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



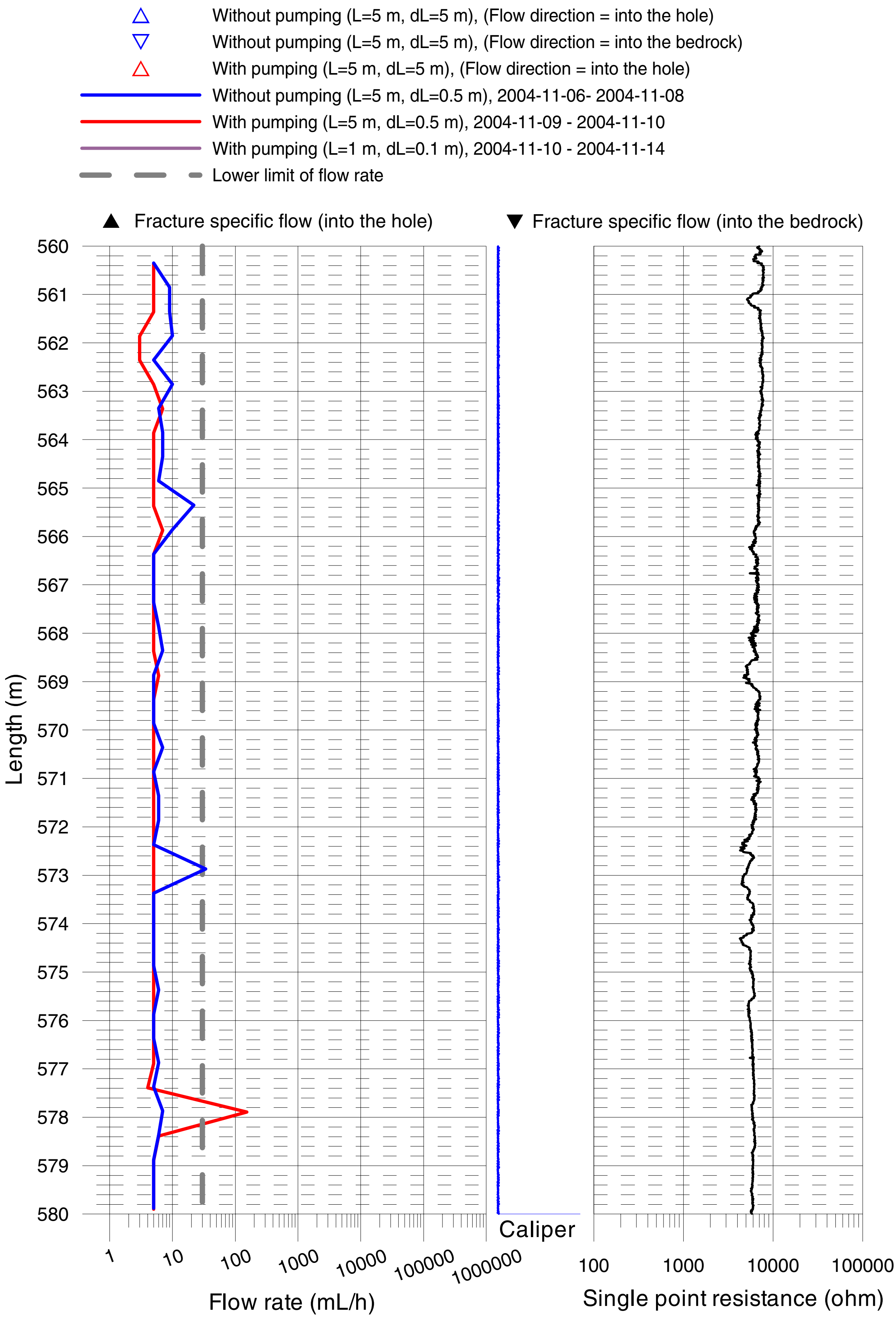
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



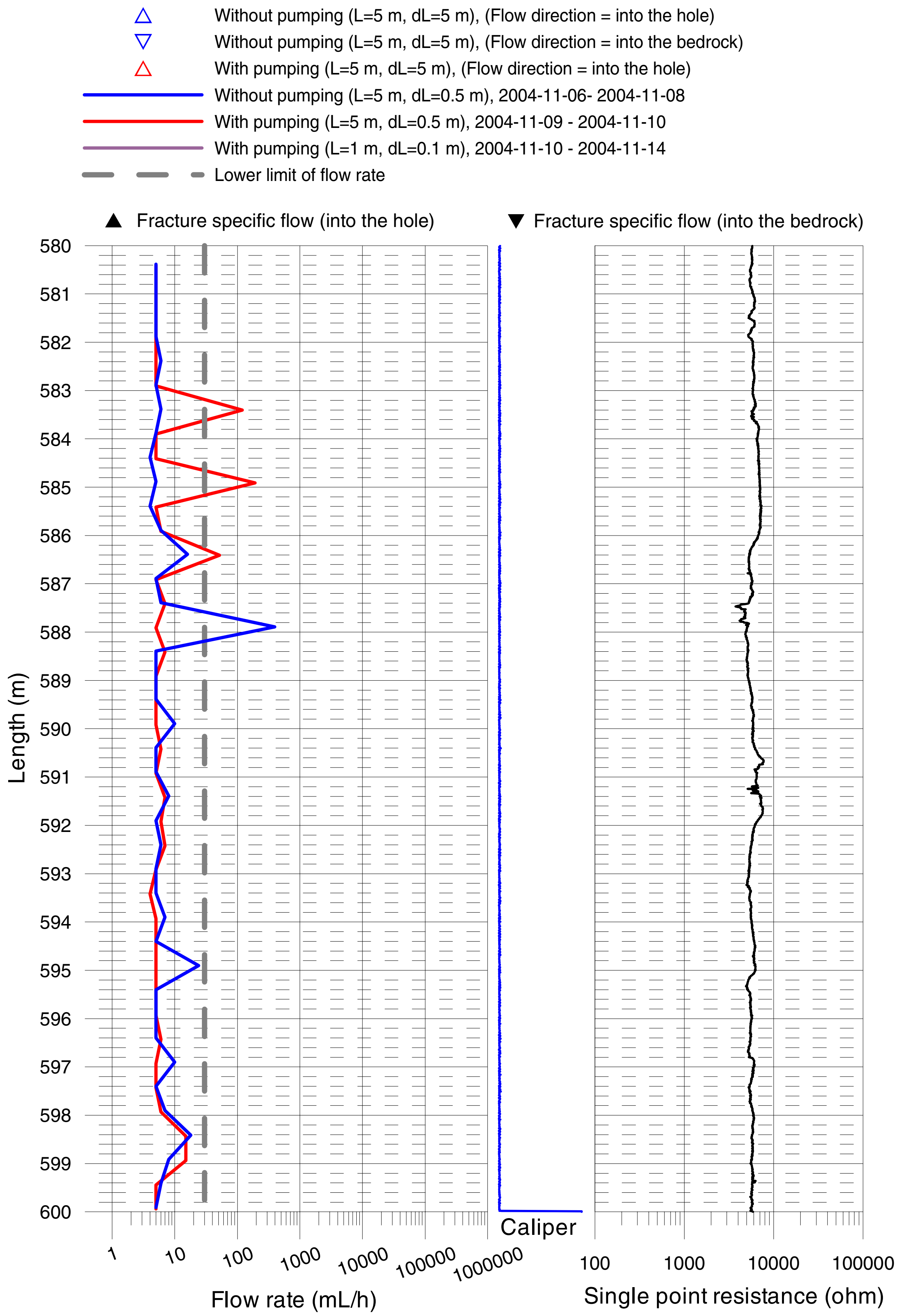
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



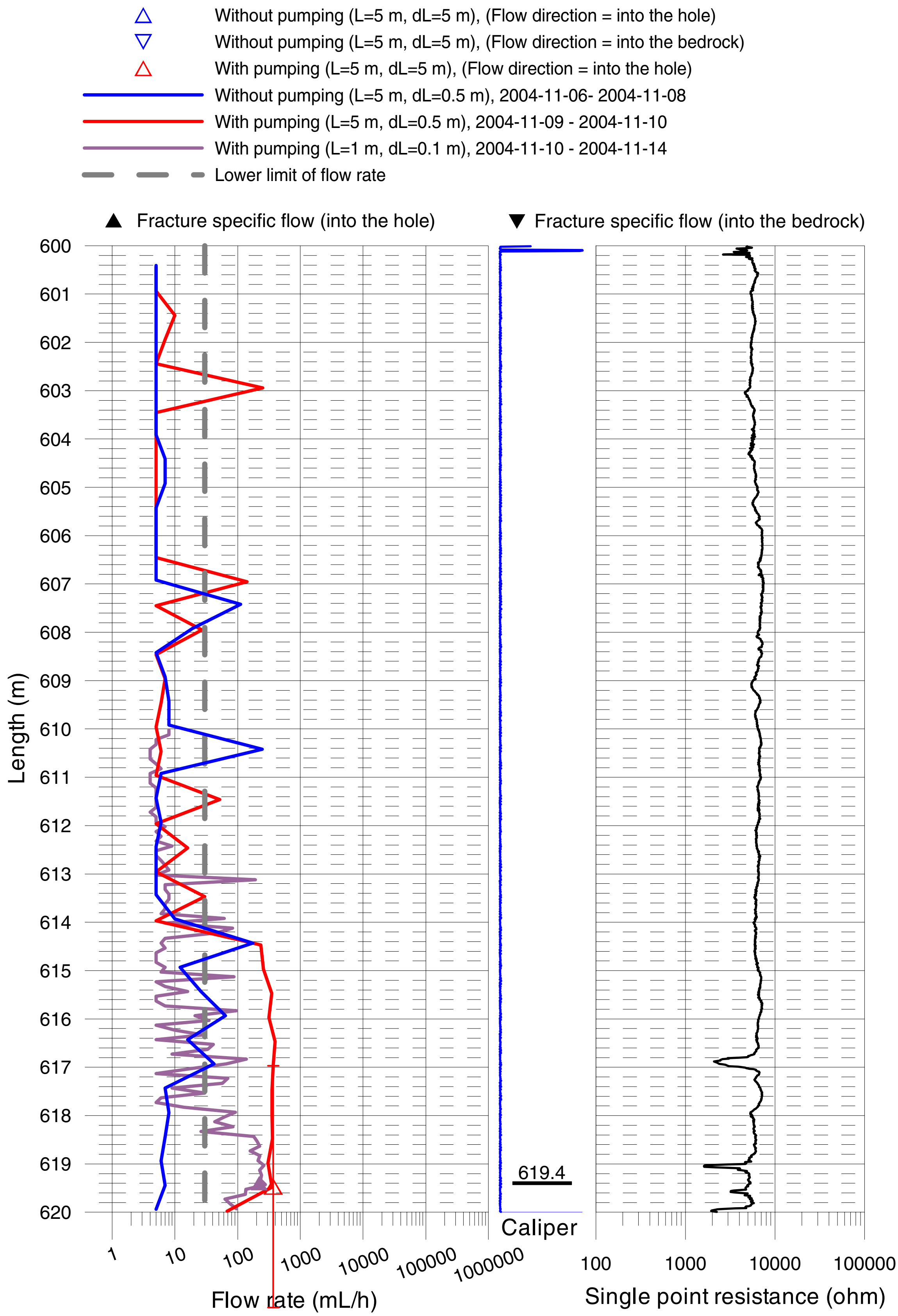
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



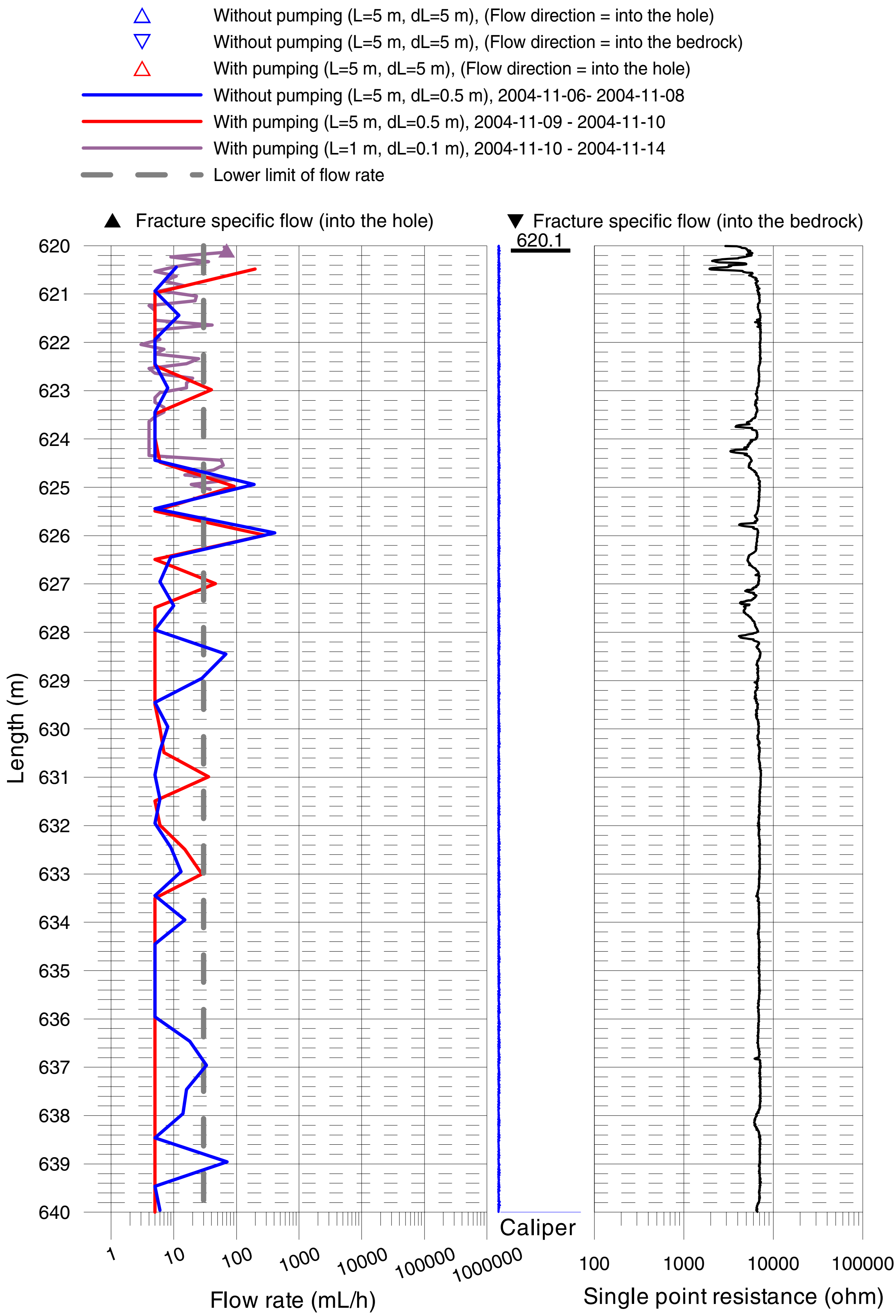
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



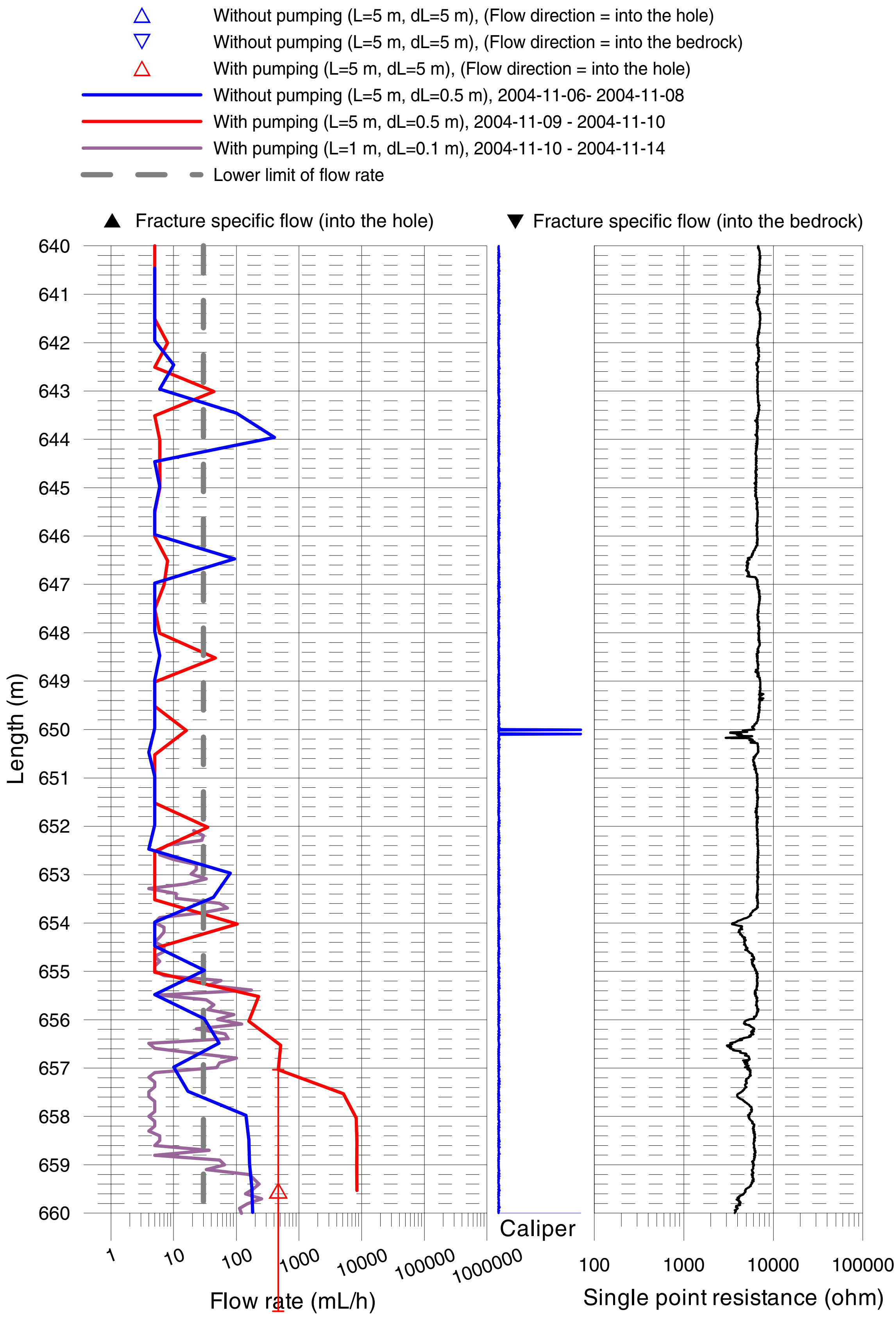
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



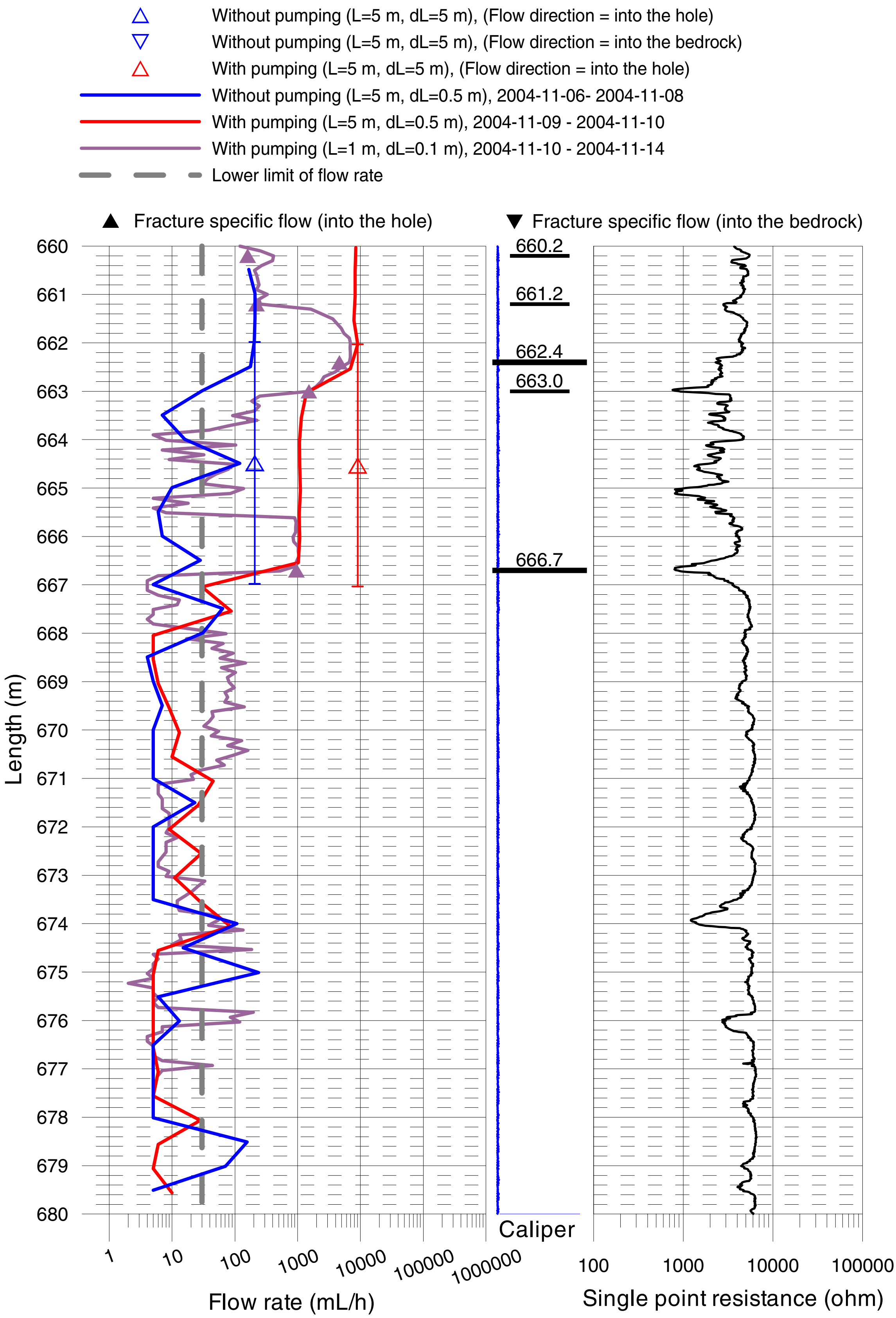
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



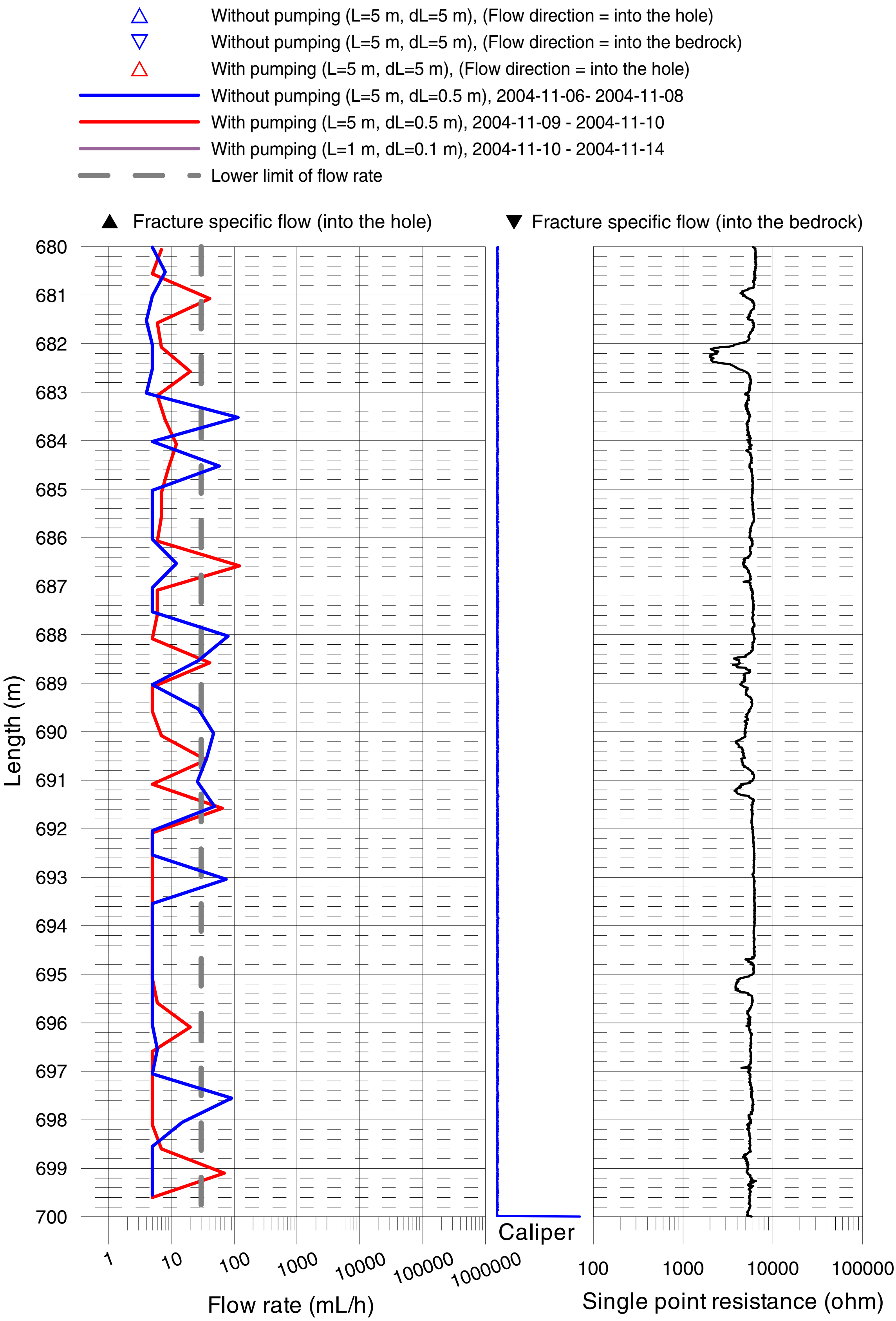
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



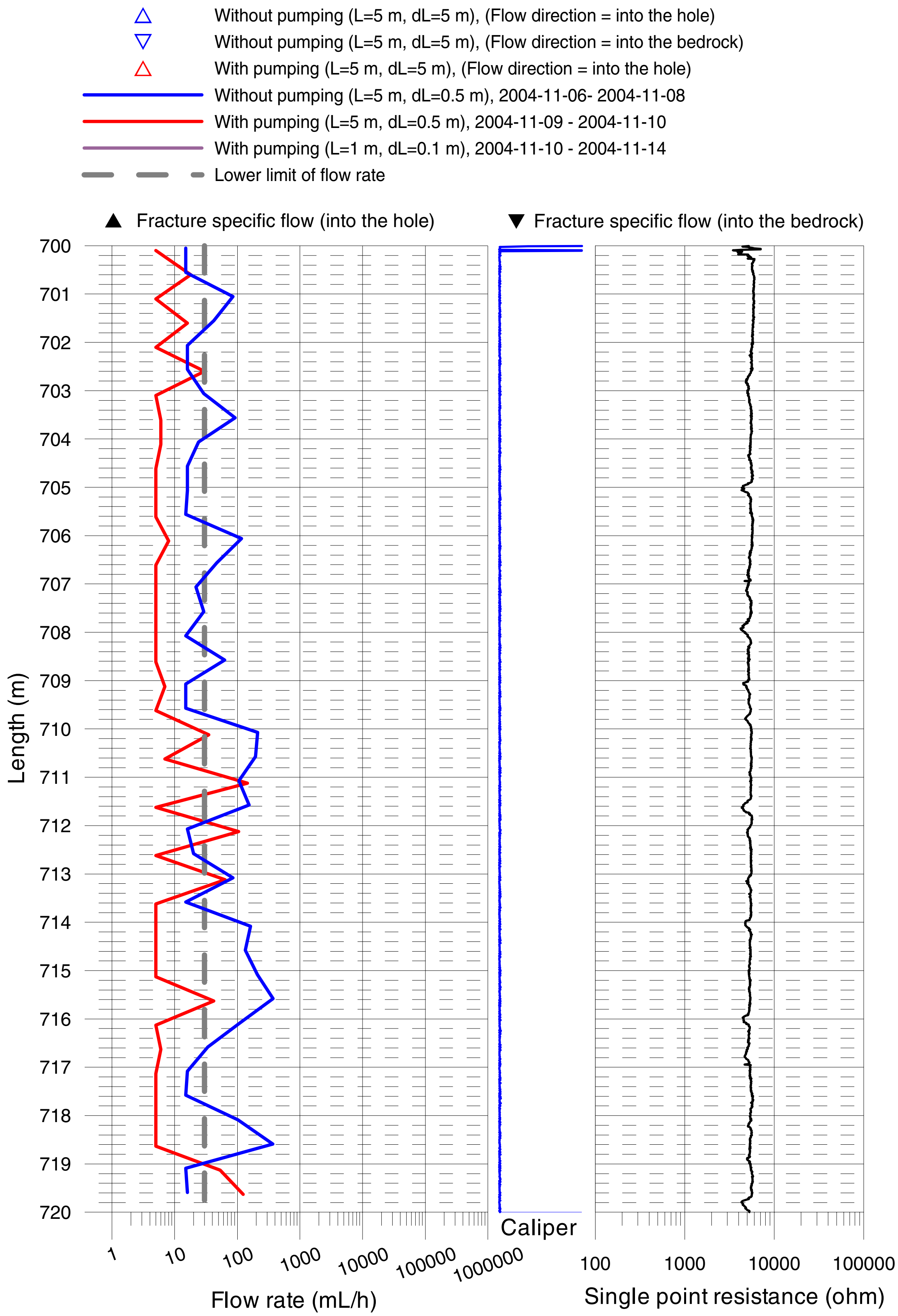
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



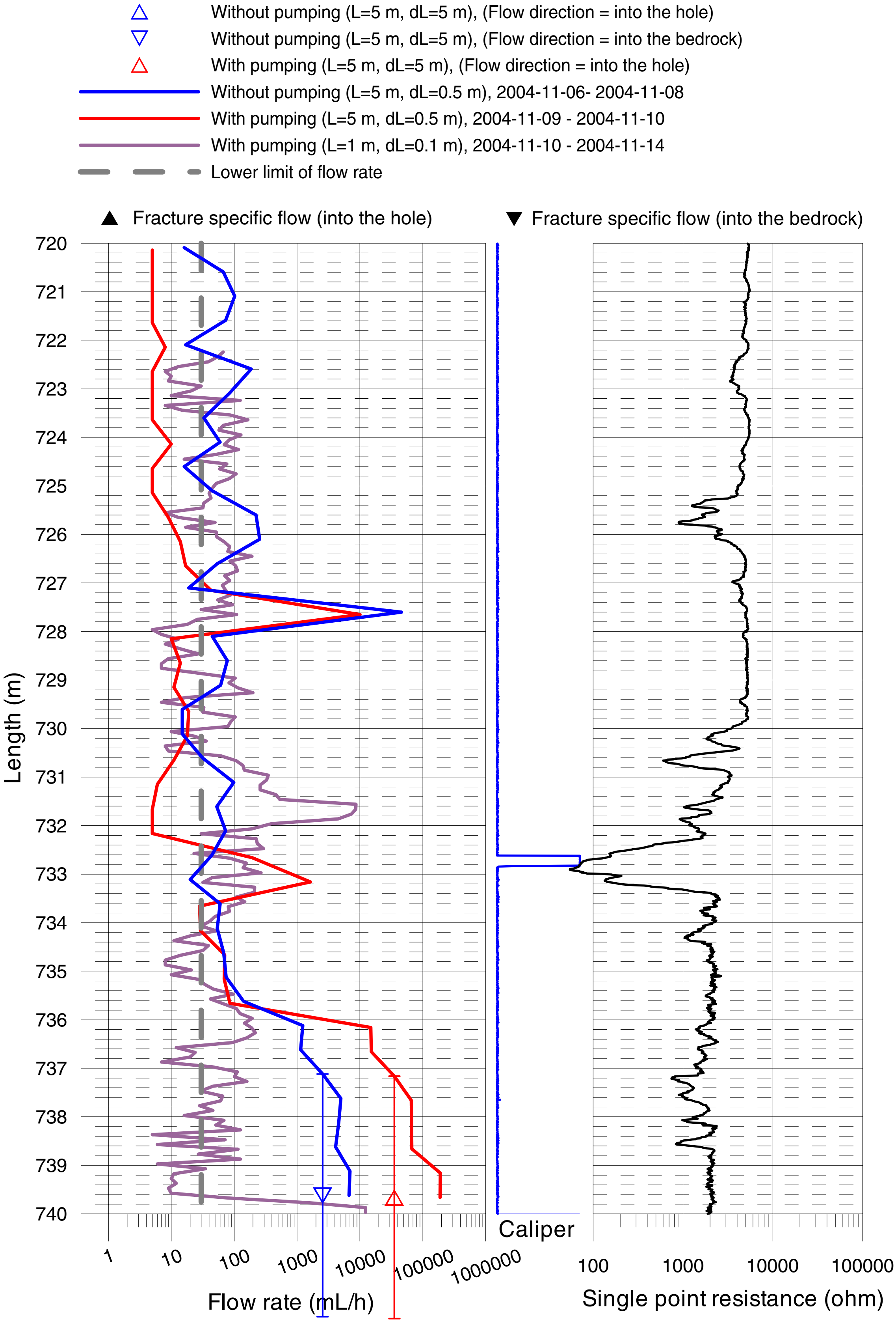
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



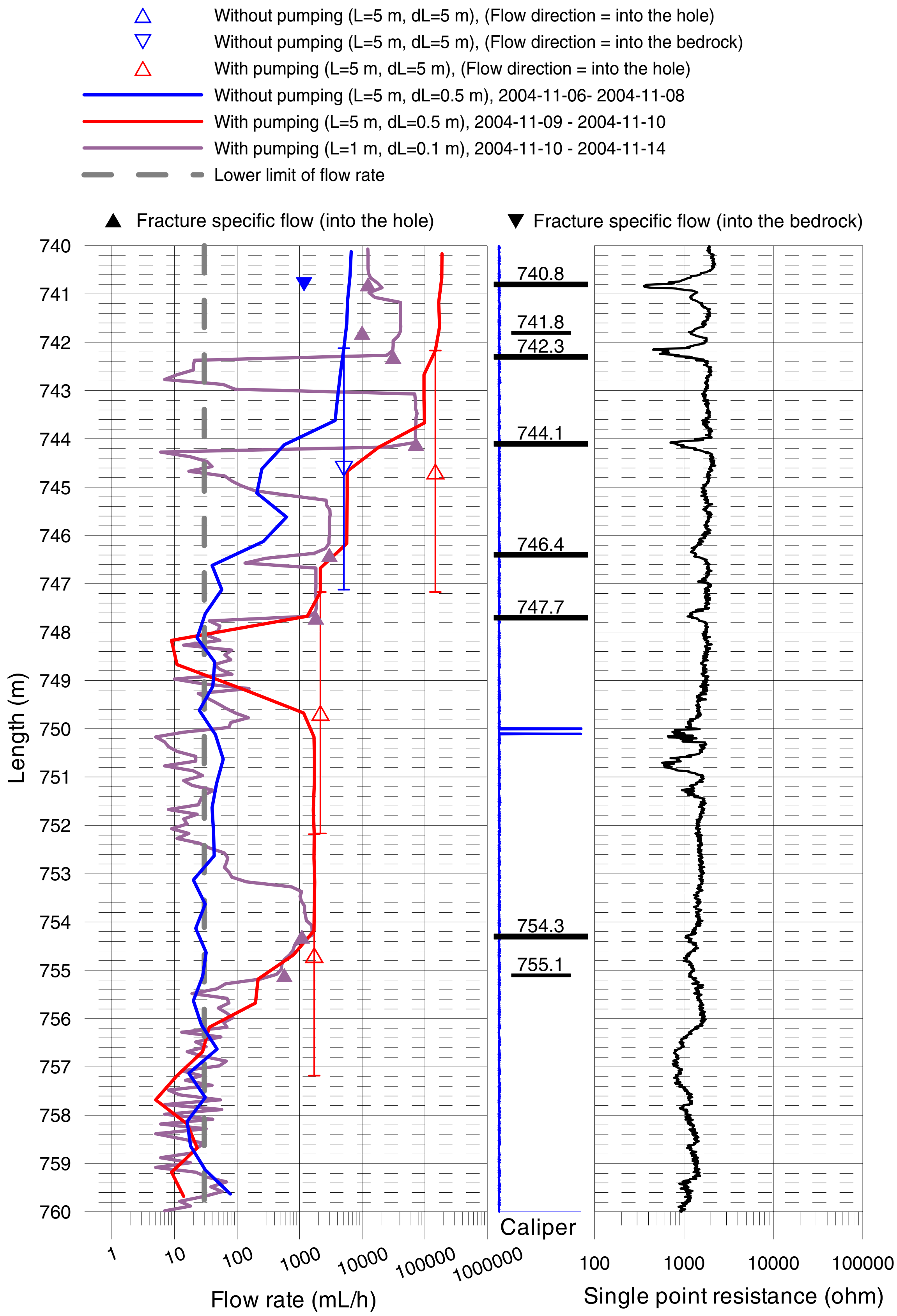
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



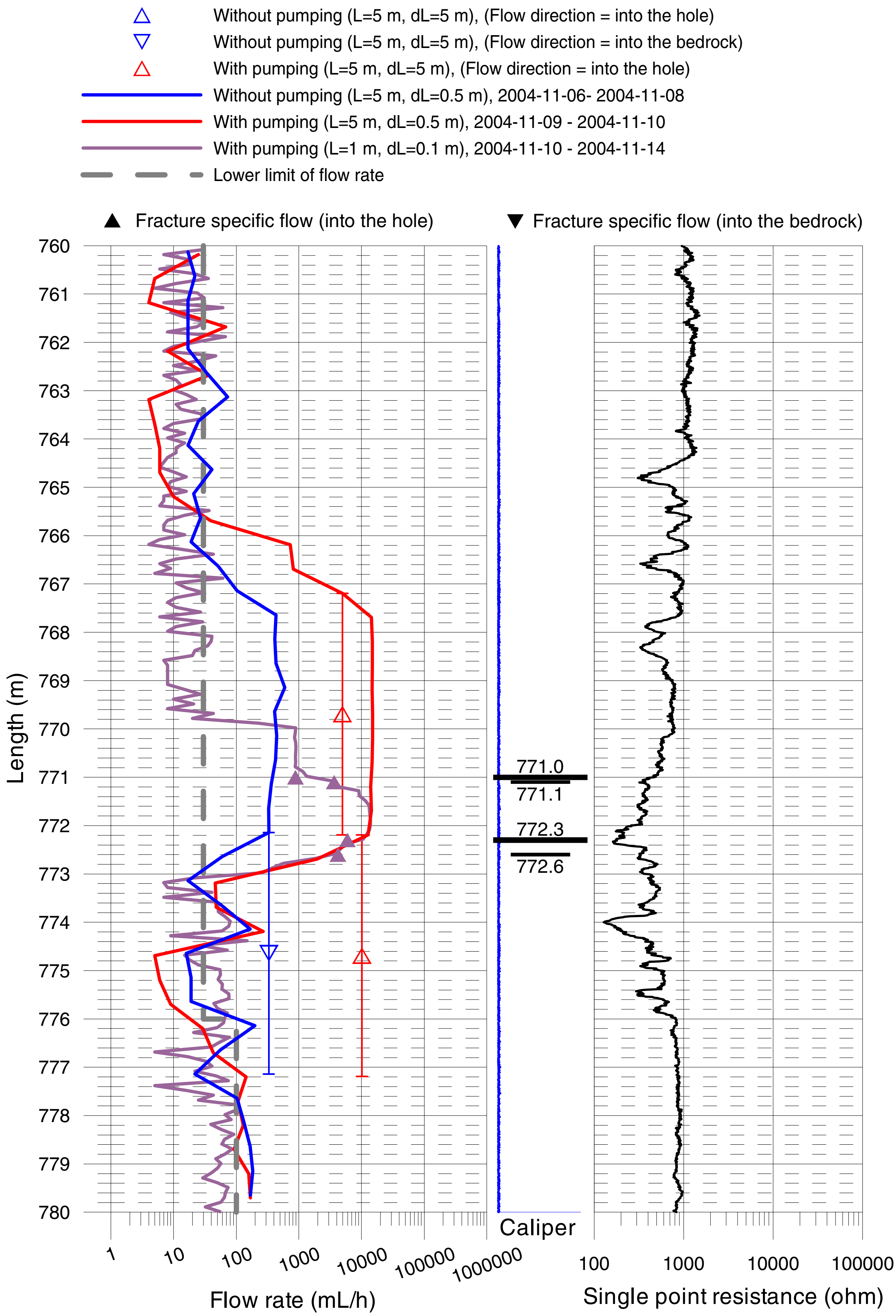
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



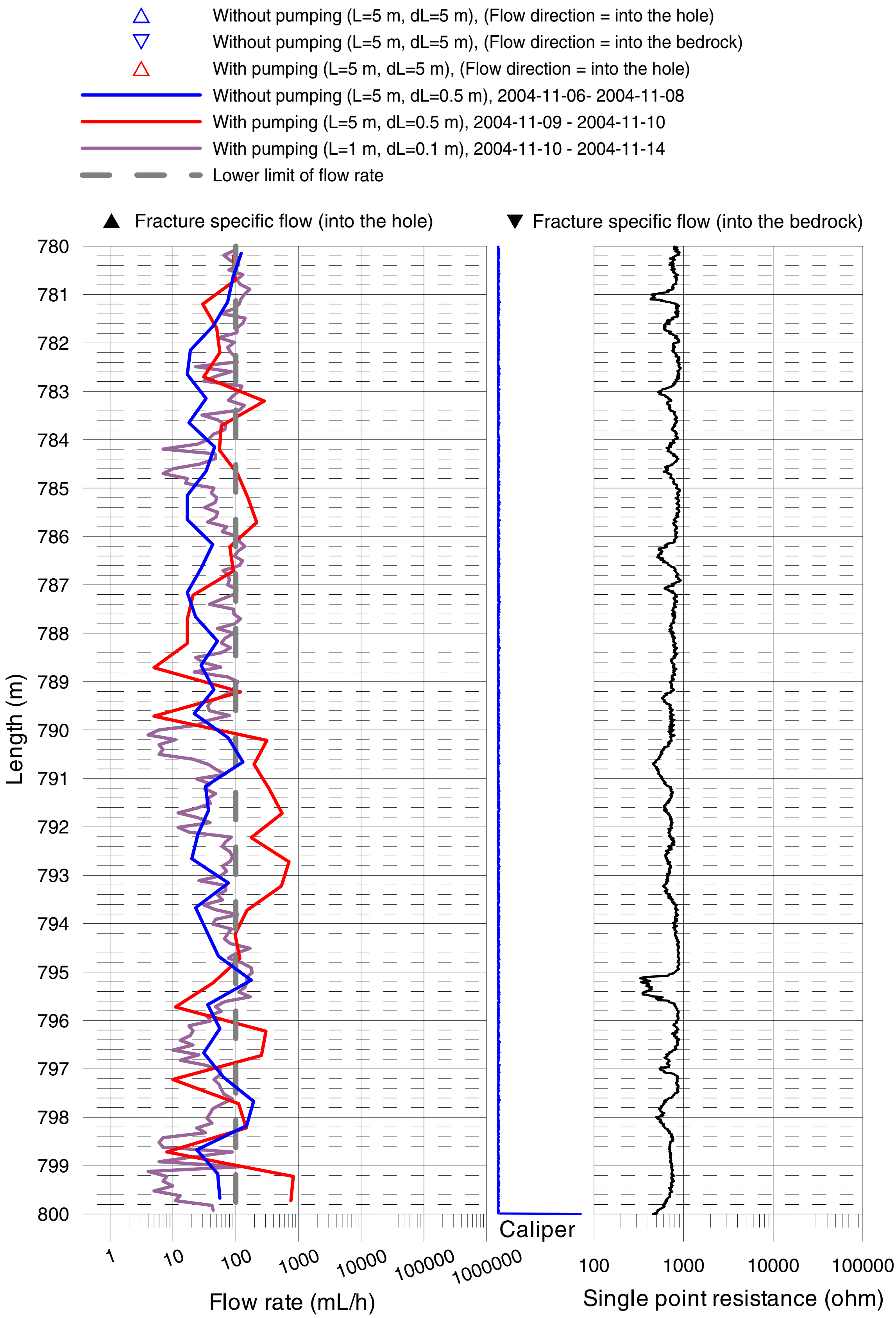
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



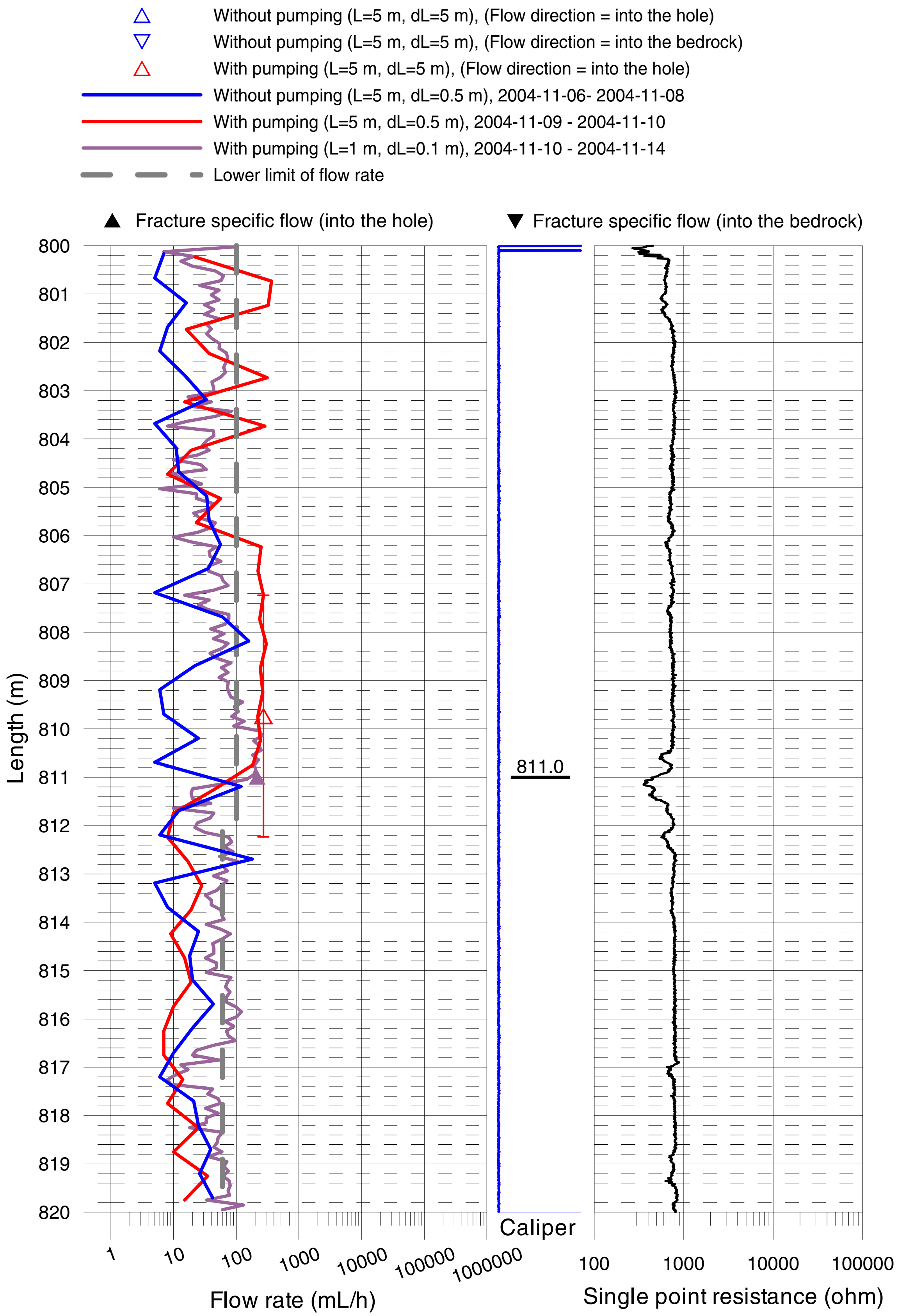
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



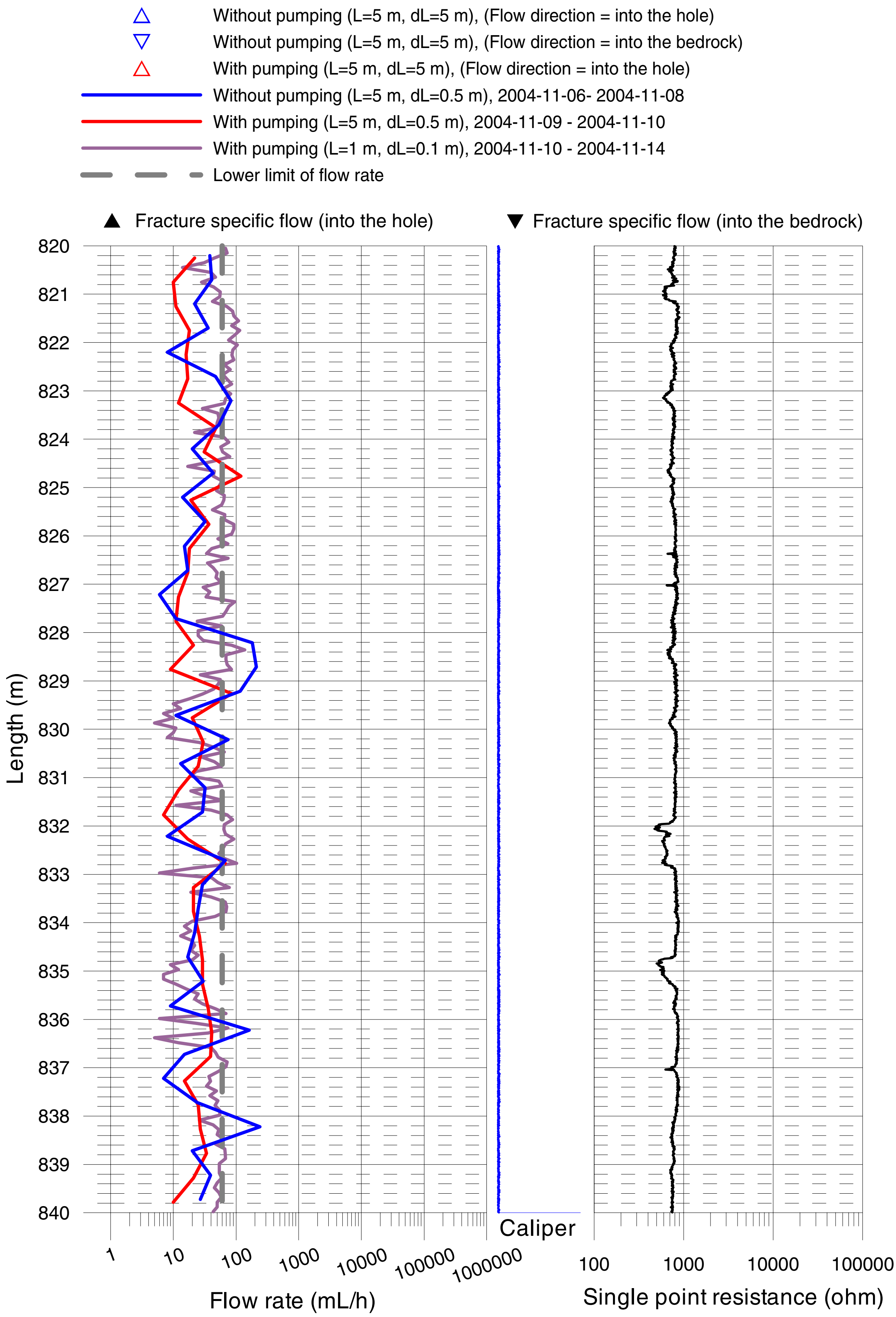
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



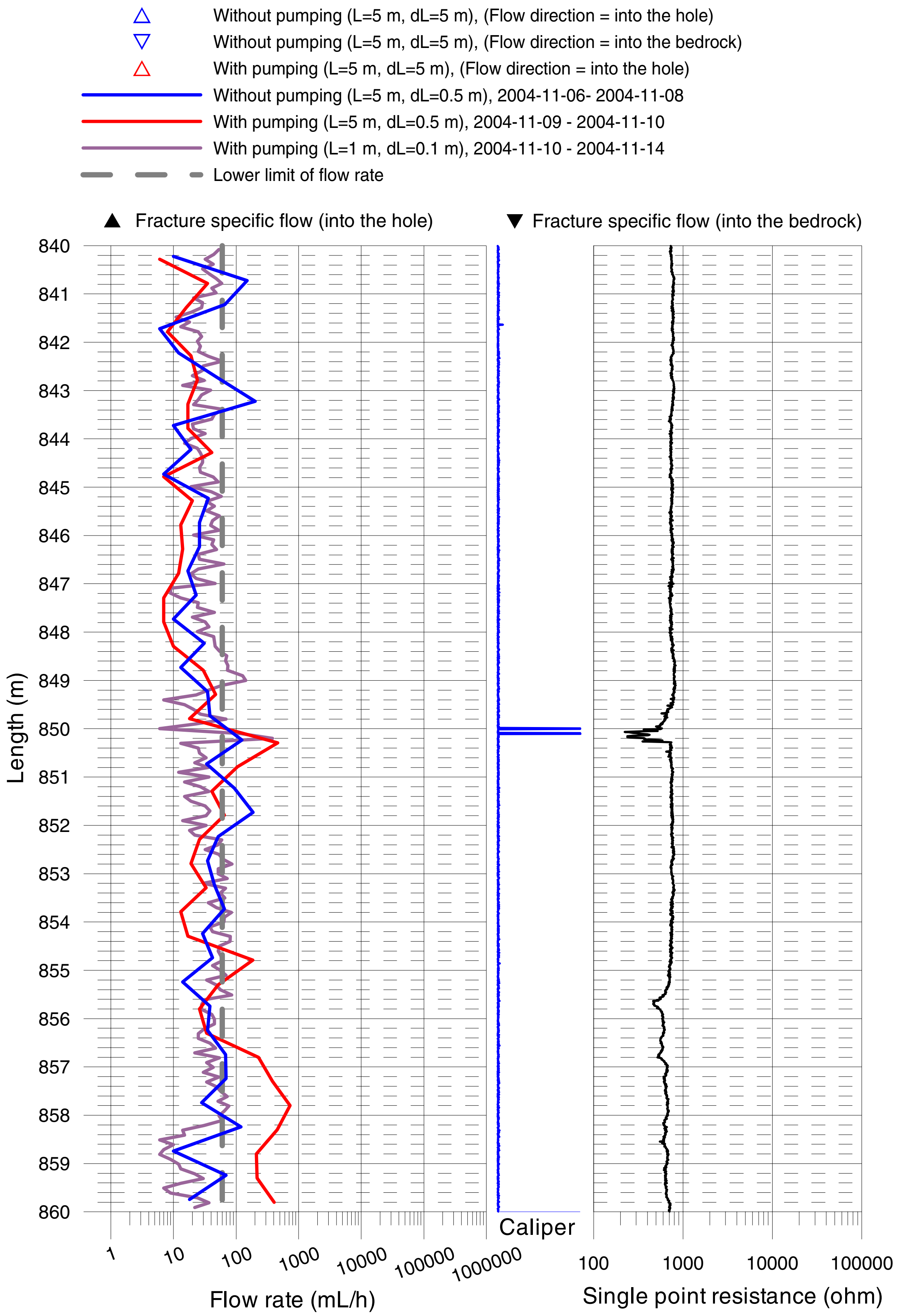
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



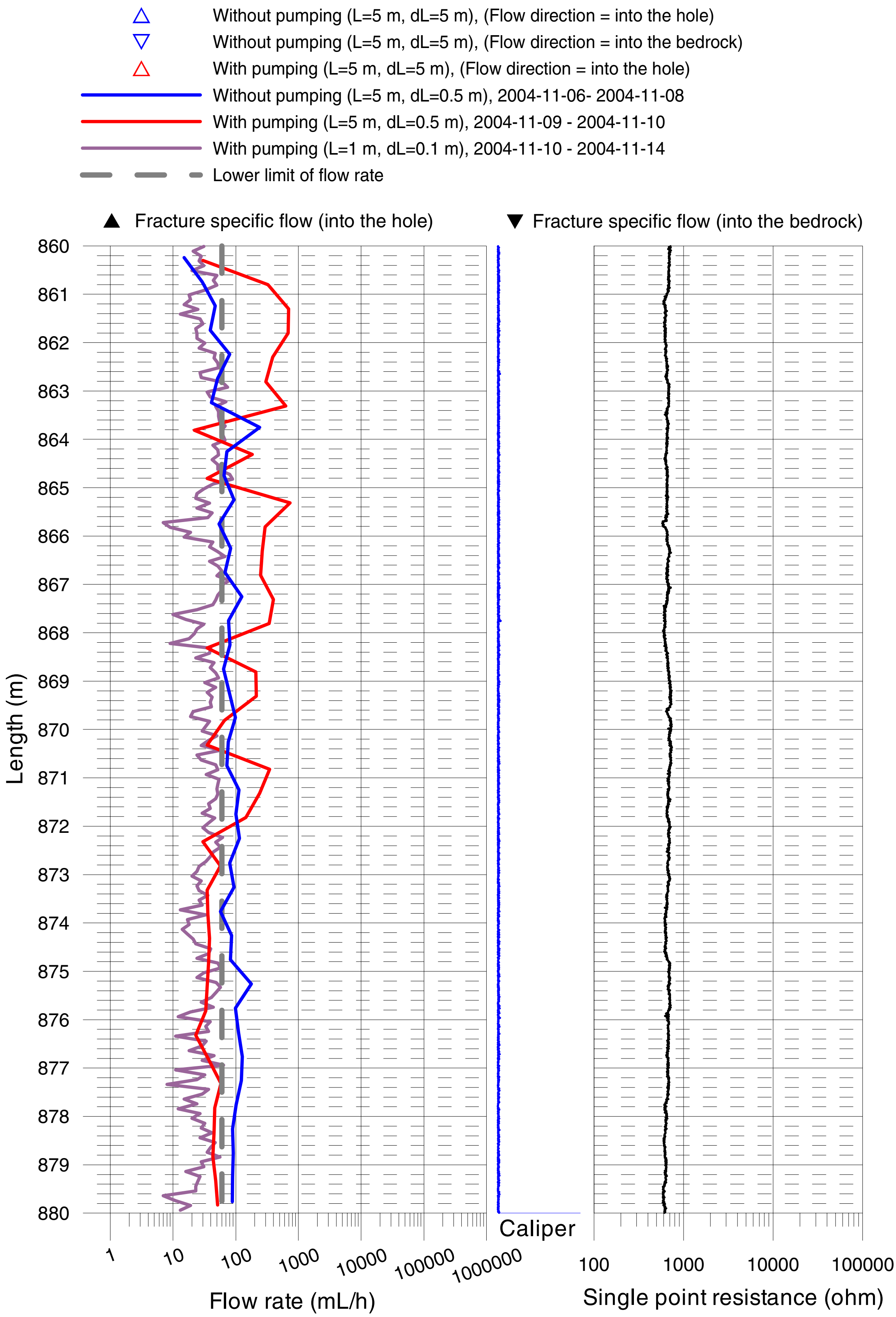
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



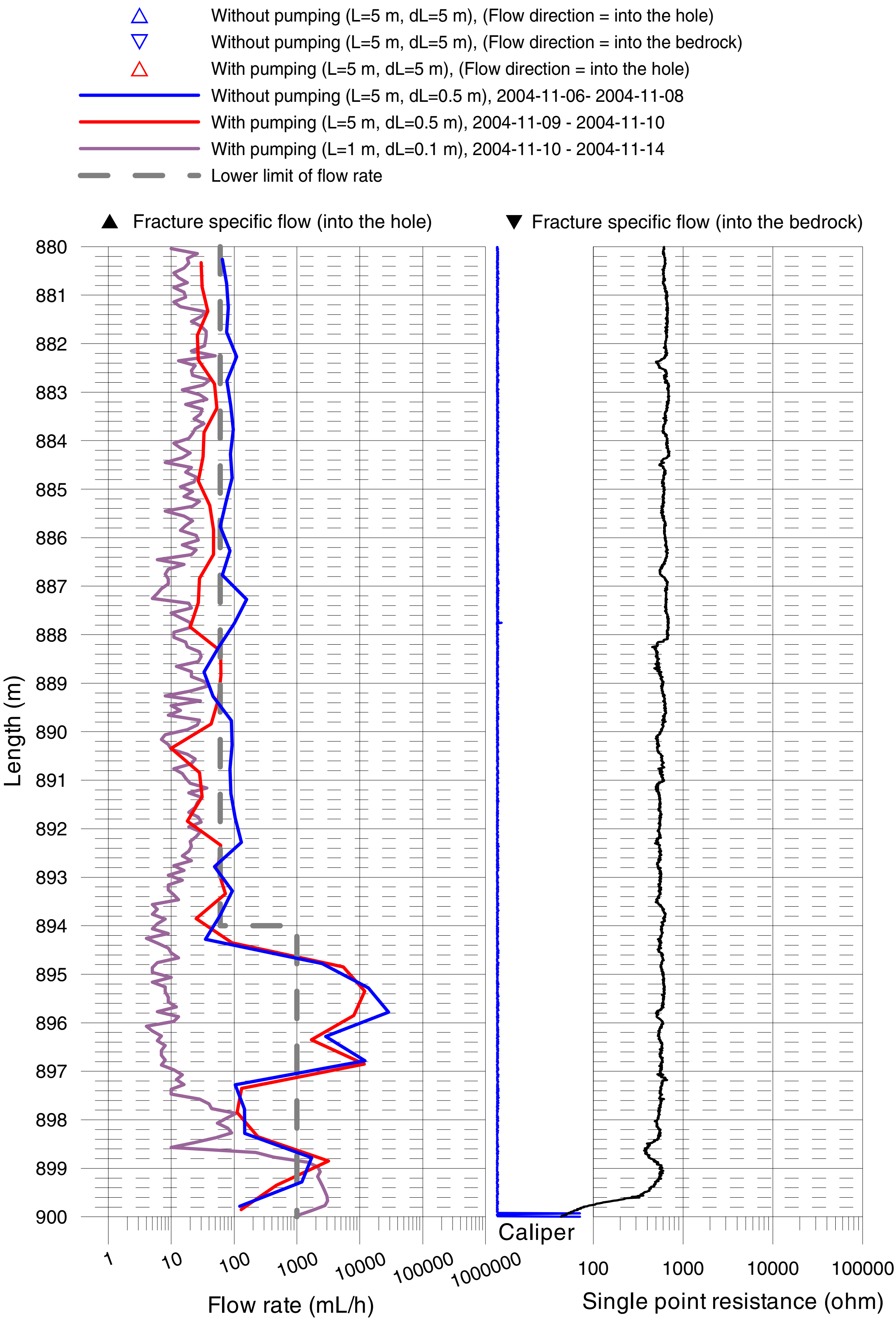
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



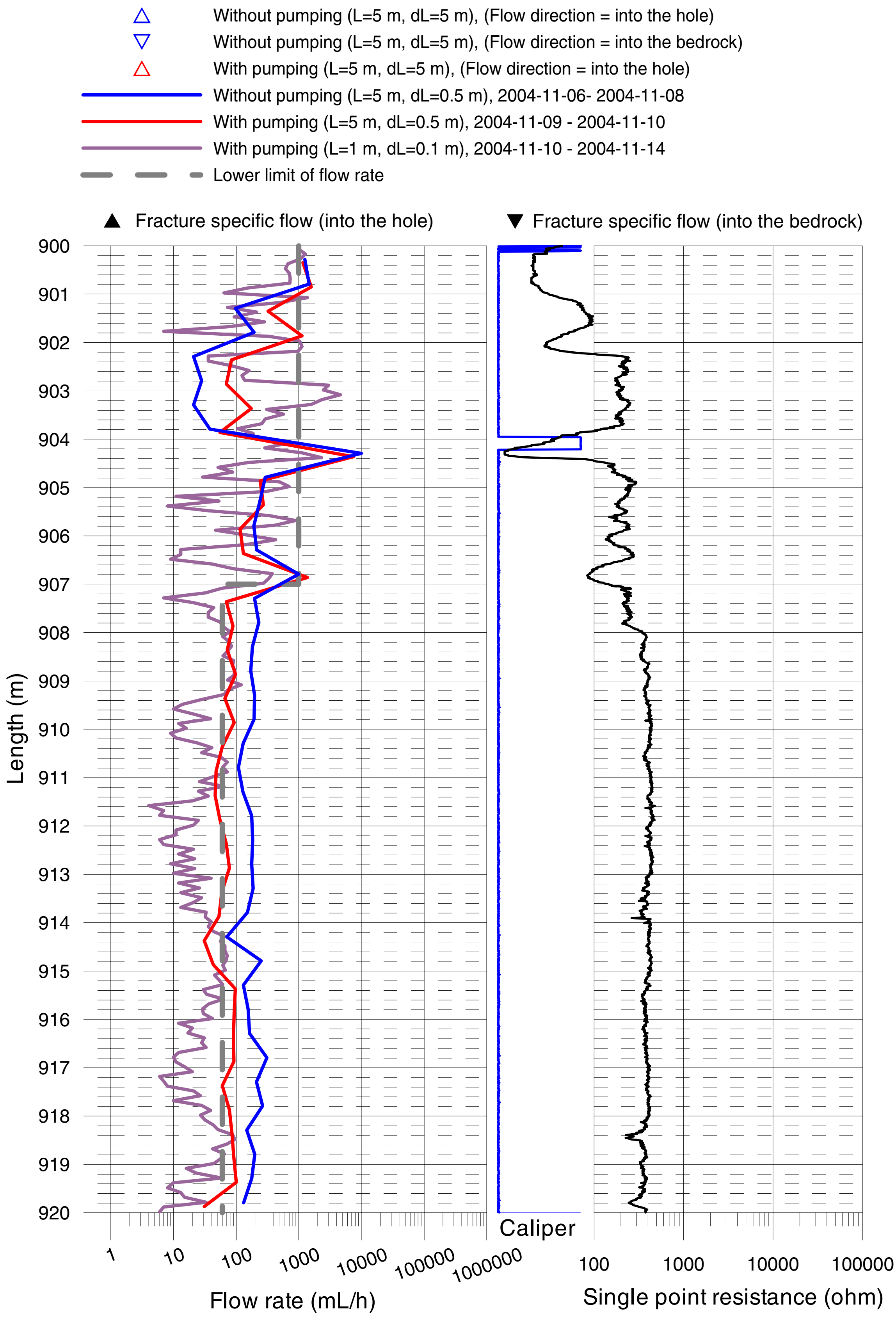
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



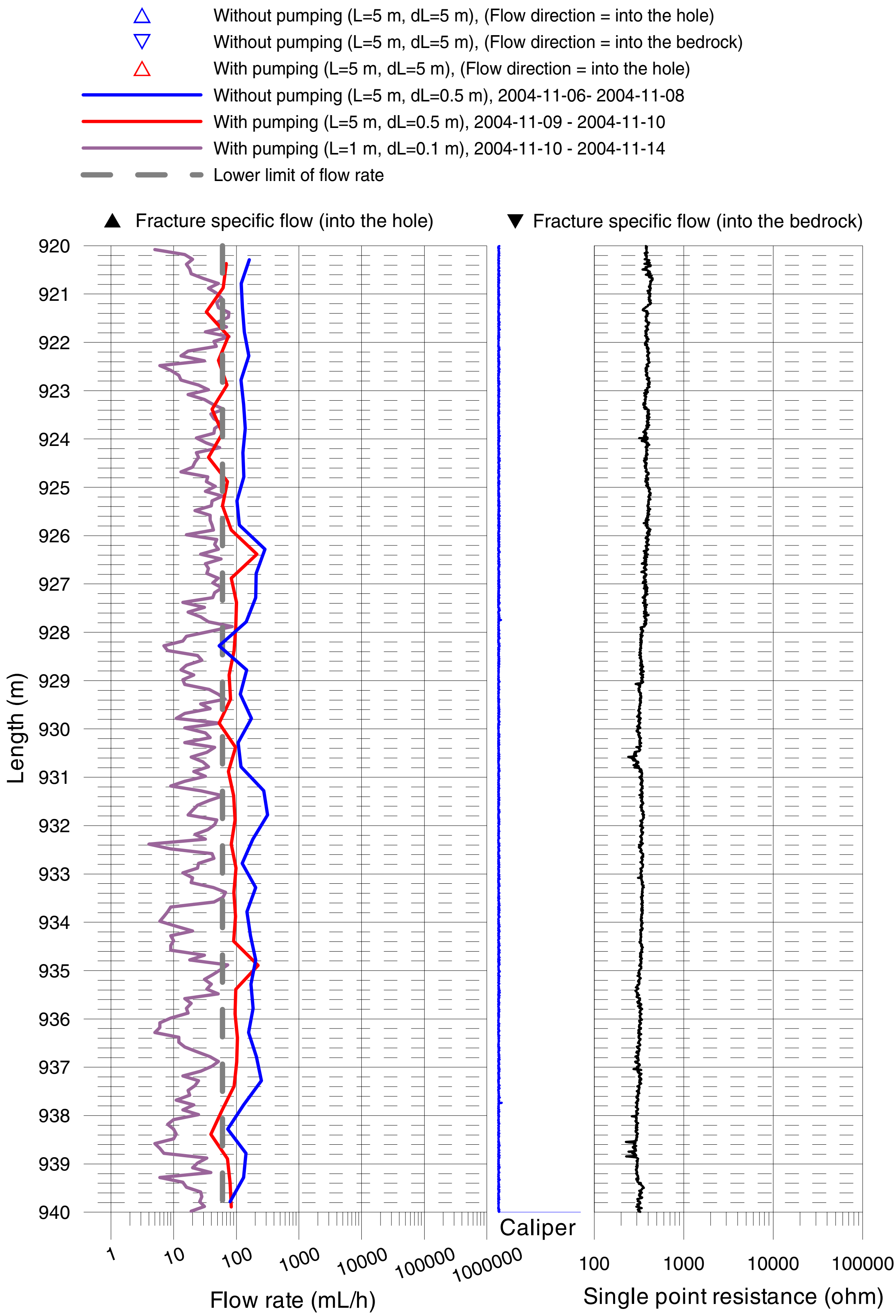
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



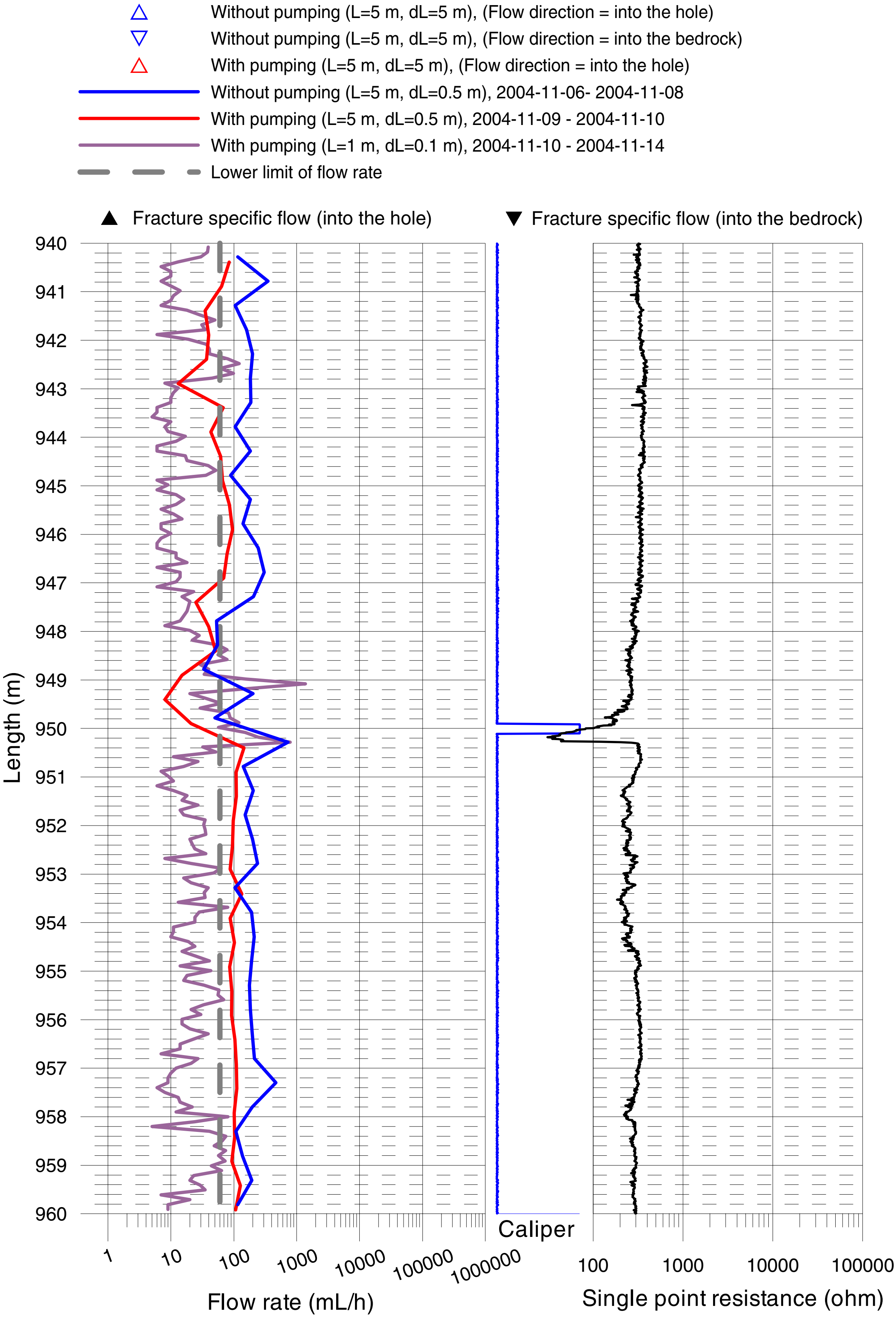
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



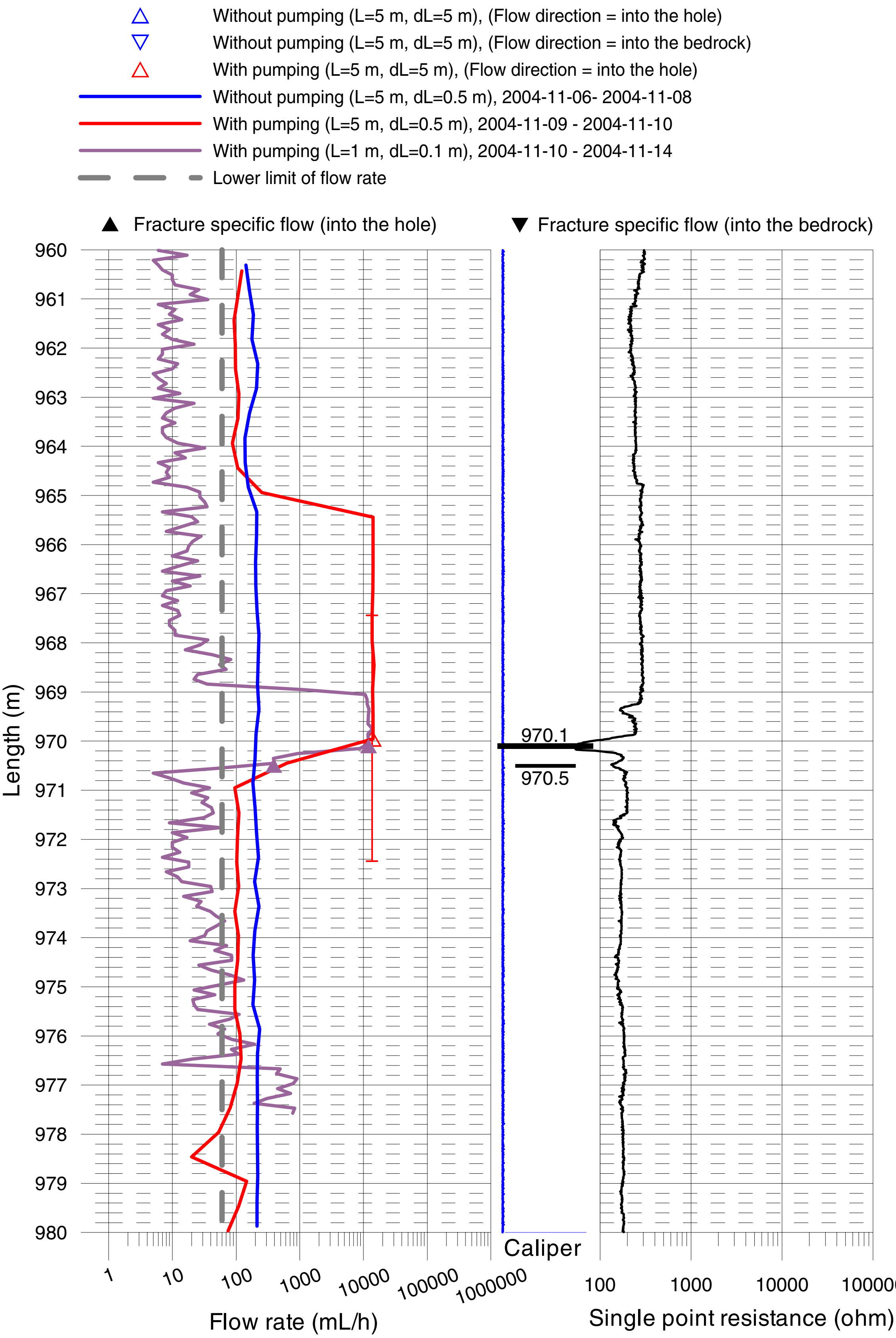
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



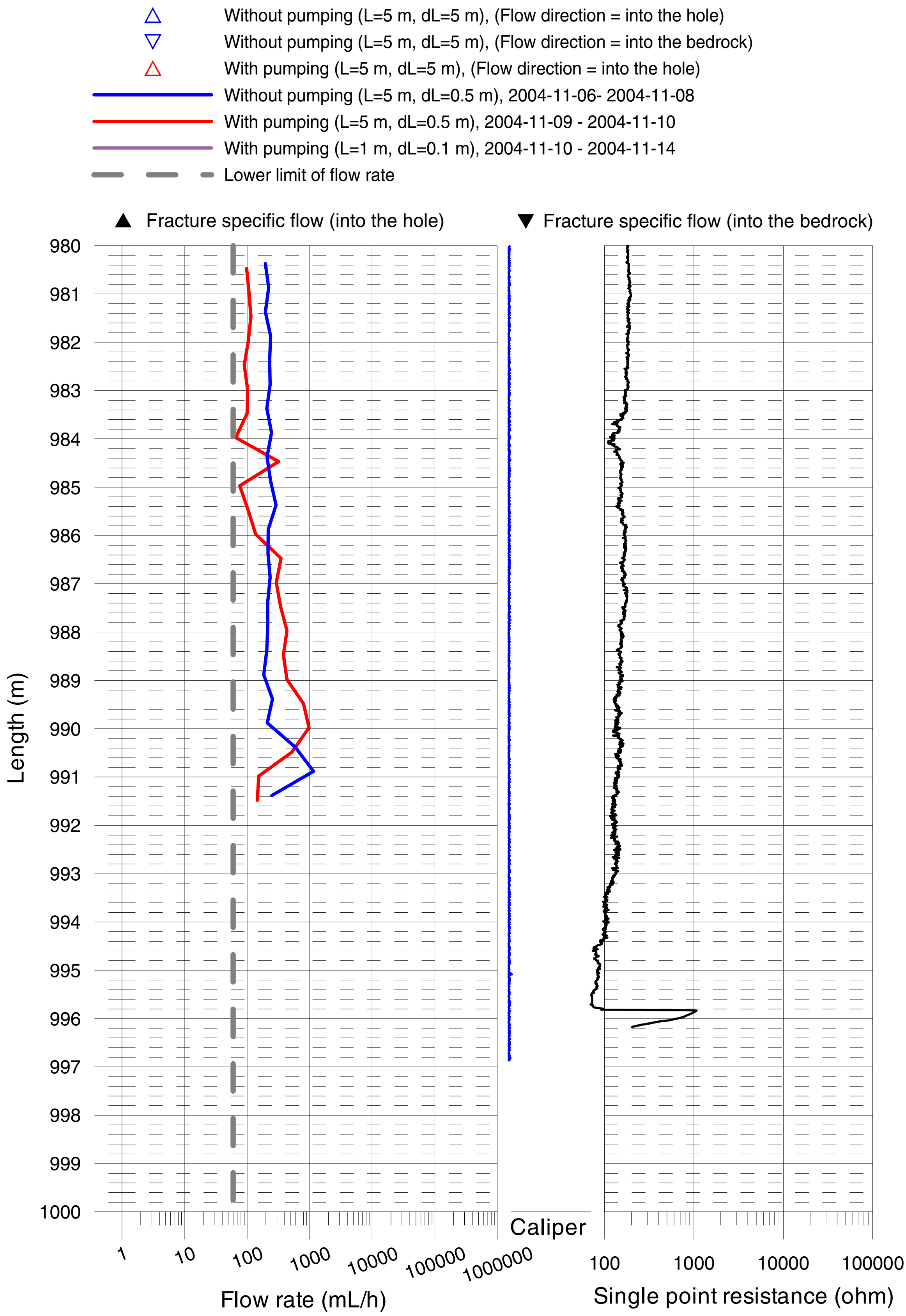
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance



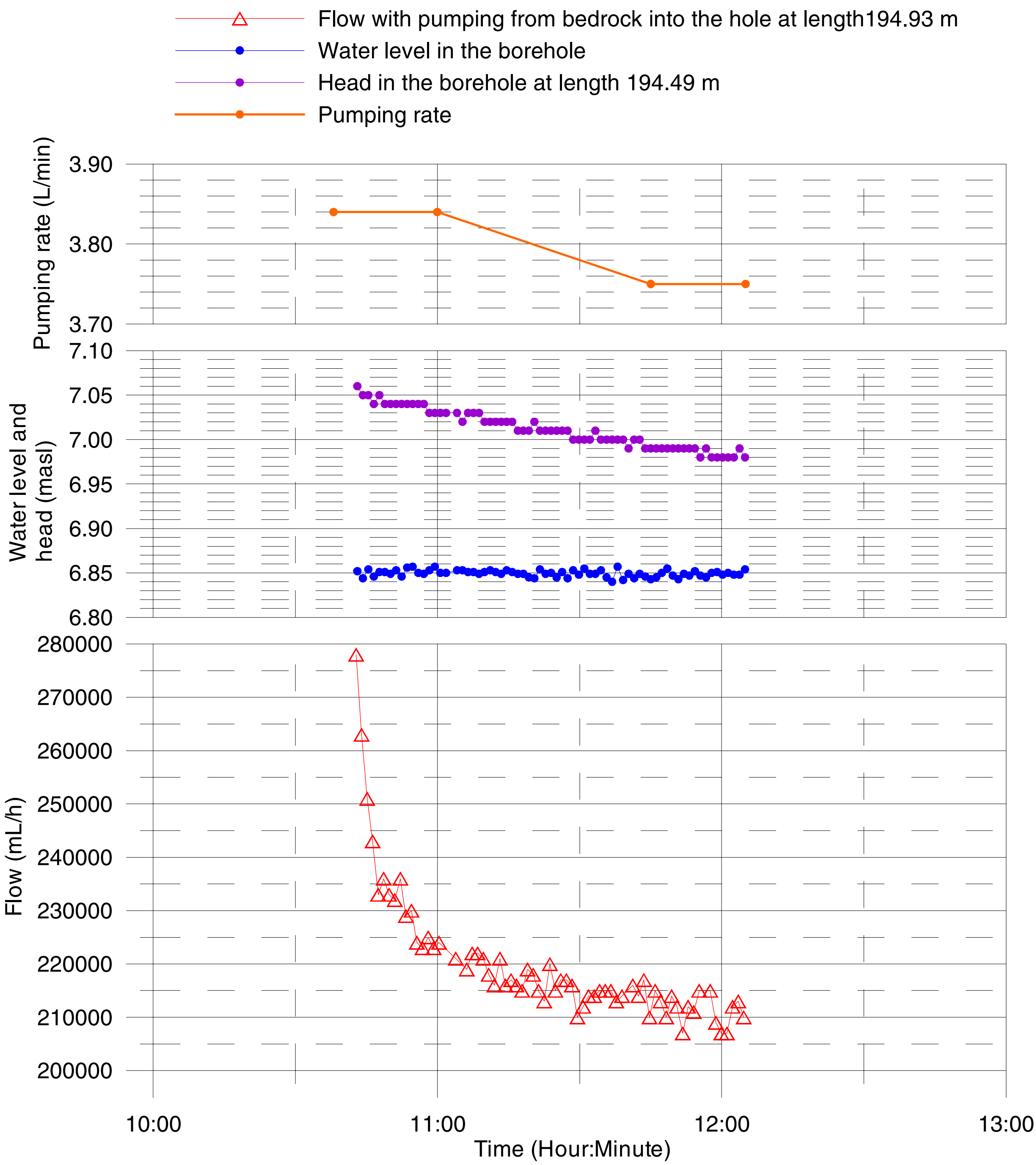
Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance

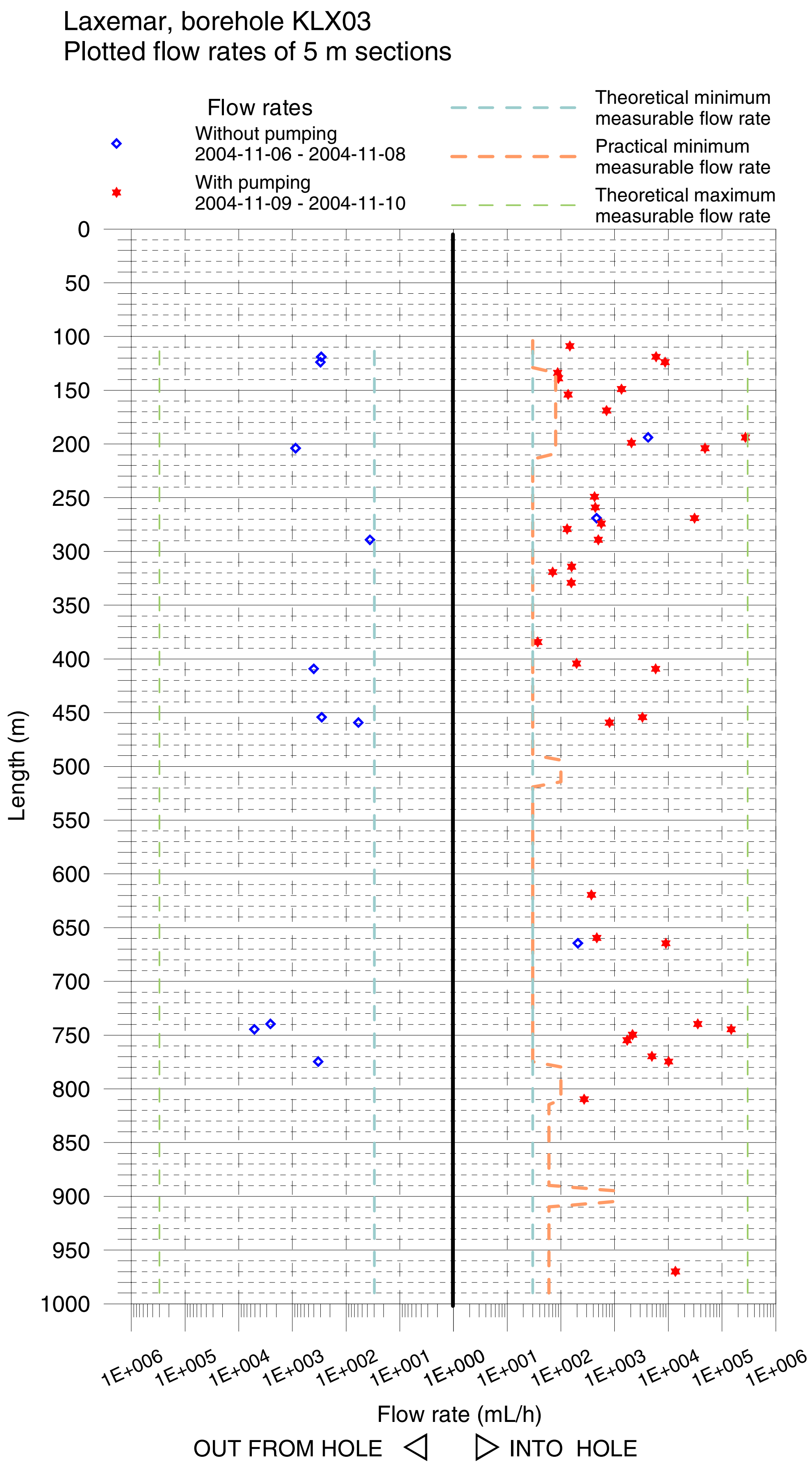


Laxemar, borehole KLX03
Measured flow rates, caliper and single point resistance

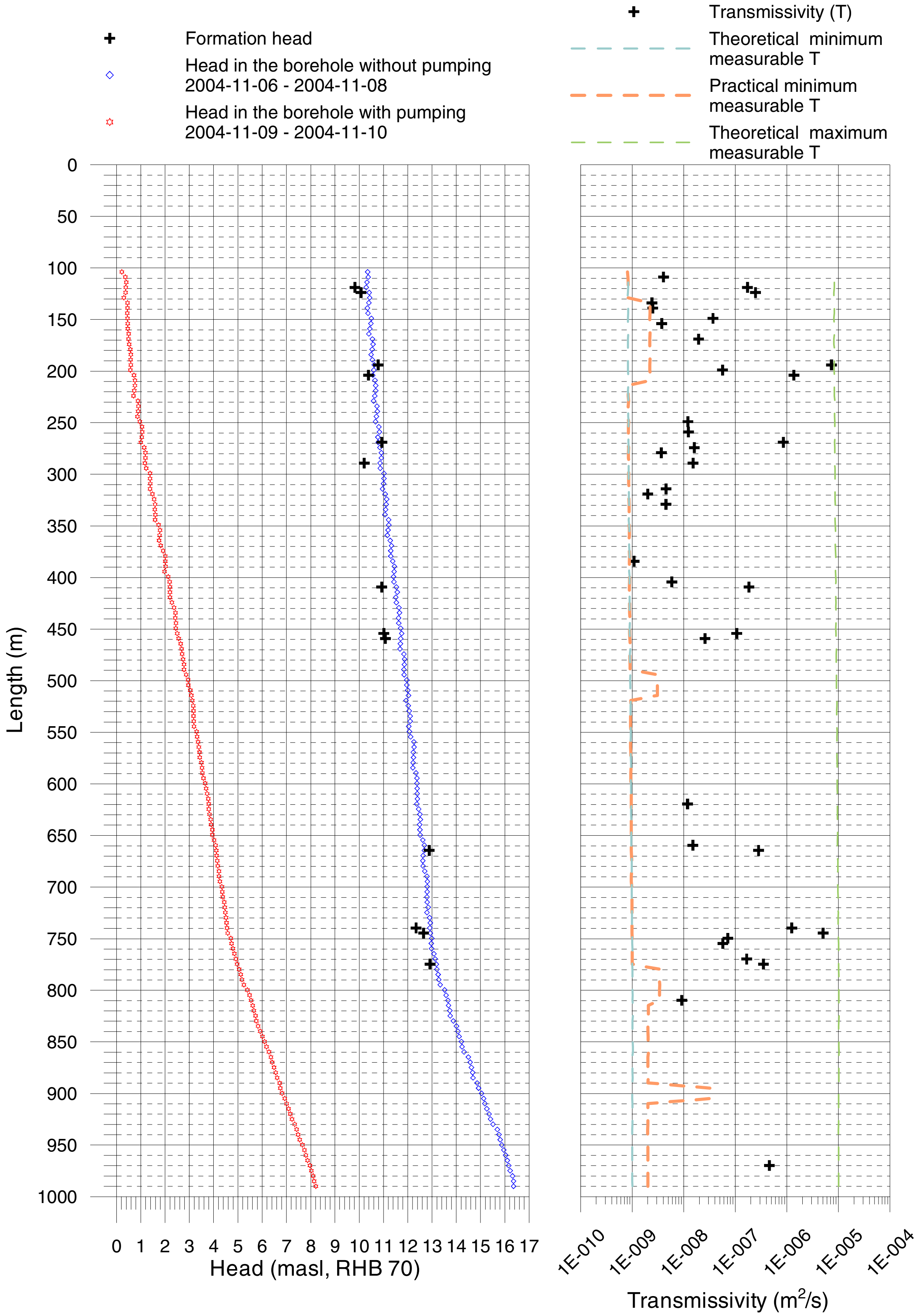


Laxemar KLX03
Extra flow measurements at the length of 194.93 m
2004-11-17

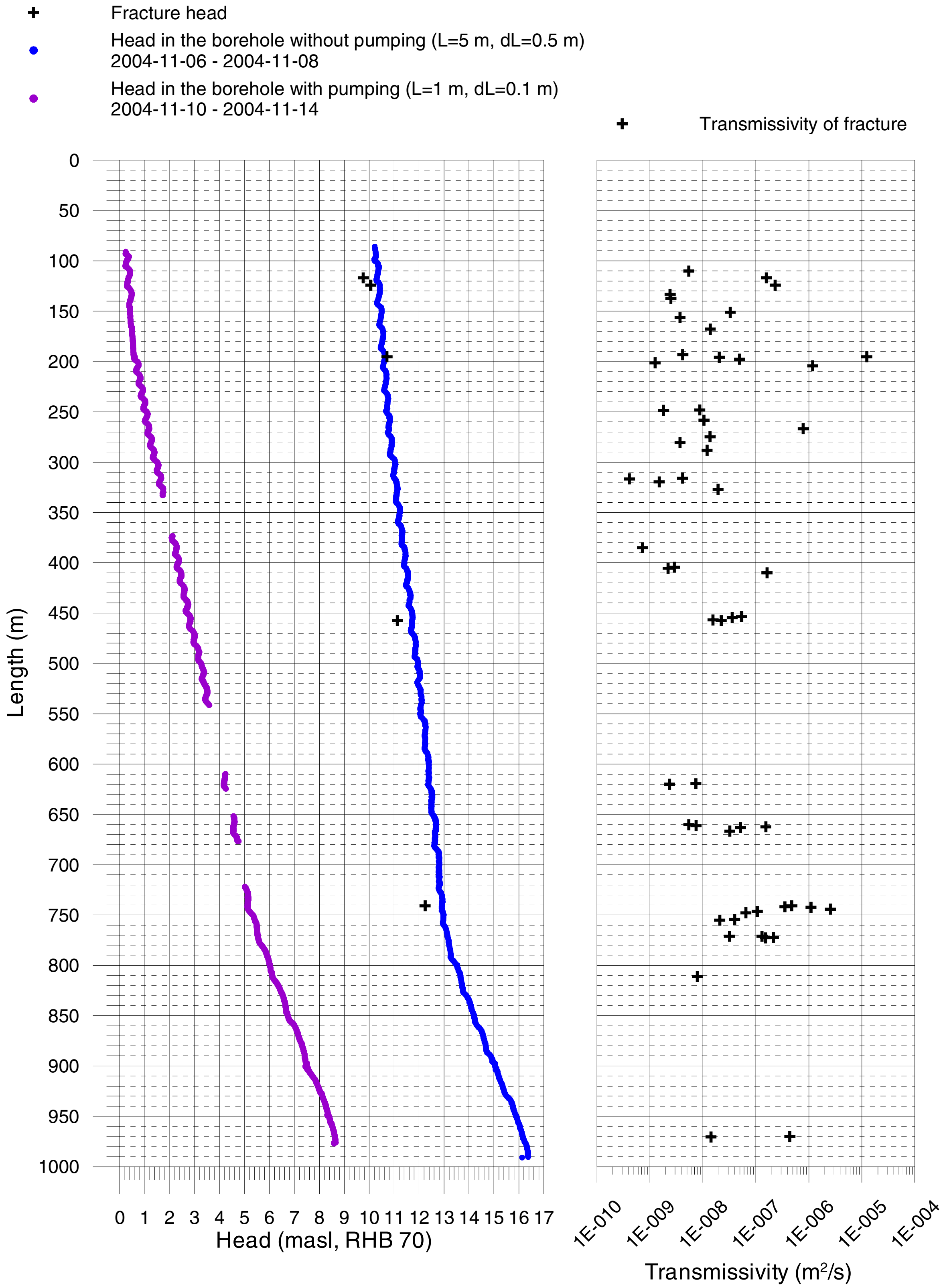



Laxemar, borehole KLX03
Plotted flow rates of 5 m sections
Flow rates
Without pumping
2004-11-06 - 2004-11-08
With pumping
2004-11-09 - 2004-11-10
Theoretical minimum measurable flow rate
Practical minimum measurable flow rate
Theoretical maximum measurable flow rate
Length (m)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900
950
1000
1E+006
1E+005
1E+004
1E+003
1E+002
1E+001
1E+000
1E+001
1E+002
1E+003
1E+004
1E+005
1E+006
Flow rate (mL/h)
OUT FROM HOLE
INTO HOLE

Laxemar, borehole KLX03
Plotted head and transmissivity of 5 m sections



Laxemar, borehole KLX03
Plotted head and transmissivity of detected fractures



PFL – DIFFERENCE FLOW LOGGING – Basic test data

Borehole ID	Logged interval Secup (m)	Seclow (m)	Test type (1–6)	Date of test, start YYYYMMDD	Time of test, start hh:mm	Date of flowl., start YYYYMMDD	Time of flowl., start hh:mm	Date of test, stop YYYYMMDD	Time of test, stop hh:mm	L_w (m)	dL (m)	Q_{p1} (m^3/s)	Q_{p2} (m^3/s)
KLX03	101.30	992.42	5A	20041108	08:27	20041109	09:46	20041116	13:36	5	5	1.77E–4	

PFL – DIFFERENCE FLOW LOGGING – Basic test data

t_{p1} (s)	t_{p2} (s)	t_{F1} (s)	t_{F2} (s)	h_0 (m)	h_1 (m)	h_2 (m)	s_1 (m)	s_2 (m)	T Entire hole (m^2/s)	Reference (–)	Comments (–)
709,740		64,620		10.29	0.26		–10.03		1.75E–5		

DIFFERENCE FLOW LOGGING – Sequential flow logging

Borehole ID	Secup L(m)	Seclow L(m)	Lw (m)	Q0 (m^3/s)	dh0 (m)	Q1 (m^3/s)	dh1 (m)	TD (m^2/s)	hi (m)	TD-measl$_{LT}$ (m^2/s)	TD-measl$_{LP}$ (m^2/s)	TD-measl$_{U}$ (m^2/s)	EC$_{w0}$ (S/m)	Te$_{w0}$ (°C)	EC$_{w1}$ (S/m)	Te$_{w1}$ (°C)	Comments
KLX03	987.42	992.42	5	–	16.36	–	8.21	–	–	1.01E–09	2.02E–09	1.01E–05	2.86	21.84	2.86	21.86	
KLX03	982.42	987.42	5	–	16.36	–	8.14	–	–	1.00E–09	2.01E–09	1.00E–05	2.88	21.79	2.86	21.81	
KLX03	977.41	982.41	5	–	16.32	–	8.10	–	–	1.00E–09	2.01E–09	1.00E–05	2.89	21.72	2.86	21.75	
KLX03	972.41	977.41	5	–	16.22	–	8.03	–	–	1.01E–09	2.01E–09	1.01E–05	2.89	21.63	2.86	21.66	
KLX03	967.39	972.39	5	–	16.16	3.78E–06	7.97	4.56E–07	–	1.01E–09	2.01E–09	1.01E–05	2.89	21.55	2.61	21.52	
KLX03	962.38	967.38	5	–	16.1	–	7.87	–	–	1.00E–09	2.00E–09	1.00E–05	2.90	21.47	2.89	21.53	
KLX03	957.36	962.36	5	–	16.03	–	7.80	–	–	1.00E–09	2.00E–09	1.00E–05	2.90	21.39	2.89	21.45	
KLX03	952.34	957.34	5	–	15.96	–	7.74	–	–	1.00E–09	2.01E–09	1.00E–05	2.91	21.32	2.89	21.38	
KLX03	947.34	952.34	5	–	15.87	–	7.66	–	–	1.00E–09	2.01E–09	1.00E–05	2.92	21.24	2.90	21.31	
KLX03	942.34	947.34	5	–	15.81	–	7.55	–	–	9.98E–10	2.00E–09	9.98E–06	2.92	21.15	2.90	21.21	
KLX03	937.34	942.34	5	–	15.76	–	7.48	–	–	9.95E–10	1.99E–09	9.95E–06	2.89	21.06	2.87	21.14	
KLX03	932.33	937.33	5	–	15.69	–	7.42	–	–	9.97E–10	1.99E–09	9.97E–06	2.87	20.98	2.87	21.07	
KLX03	927.33	932.33	5	–	15.51	–	7.34	–	–	1.01E–09	2.02E–09	1.01E–05	2.86	20.91	2.87	20.98	
KLX03	922.33	927.33	5	–	15.41	–	7.23	–	–	1.01E–09	2.02E–09	1.01E–05	2.87	20.83	2.86	20.91	
KLX03	917.33	922.33	5	–	15.35	–	7.16	–	–	1.01E–09	2.01E–09	1.01E–05	2.88	20.75	2.89	20.82	
KLX03	912.33	917.33	5	–	15.26	–	7.09	–	–	1.01E–09	2.02E–09	1.01E–05	2.90	20.67	2.88	20.74	
KLX03	907.33	912.33	5	–	15.18	–	7.01	–	–	1.01E–09	2.02E–09	1.01E–05	2.88	20.61	2.87	20.66	
KLX03	902.33	907.33	5	–	15.13	–	6.93	–	–	1.01E–09	3.35E–08	1.01E–05	2.76	20.53	2.88	20.56	
KLX03	897.32	902.32	5	–	15.04	–	6.82	–	–	1.00E–09	3.34E–08	1.00E–05	2.78	20.43	2.83	20.46	
KLX03	892.31	897.31	5	–	14.92	–	6.75	–	–	1.01E–09	3.36E–08	1.01E–05	2.79	20.36	2.82	20.40	
KLX03	887.31	892.31	5	–	14.86	–	6.72	–	–	1.01E–09	2.03E–09	1.01E–05	2.76	20.28	2.82	20.33	
KLX03	882.30	887.30	5	–	14.69	–	6.62	–	–	1.02E–09	2.04E–09	1.02E–05	2.80	20.21	2.85	20.27	
KLX03	877.29	882.29	5	–	14.67	–	6.56	–	–	1.02E–09	2.03E–09	1.02E–05	2.82	20.13	2.86	20.19	
KLX03	872.29	877.29	5	–	14.62	–	6.49	–	–	1.01E–09	2.03E–09	1.01E–05	2.80	20.06	2.84	20.13	
KLX03	867.28	872.28	5	–	14.57	–	6.41	–	–	1.01E–09	2.02E–09	1.01E–05	2.77	19.98	2.82	20.05	
KLX03	862.27	867.27	5	–	14.5	–	6.36	–	–	1.01E–09	2.03E–09	1.01E–05	2.74	19.89	2.80	19.95	
KLX03	857.27	862.27	5	–	14.32	–	6.28	–	–	1.03E–09	2.05E–09	1.03E–05	2.71	19.83	2.82	19.92	
KLX03	852.26	857.26	5	–	14.24	–	6.18	–	–	1.02E–09	2.05E–09	1.02E–05	2.69	19.74	2.82	19.79	

Borehole ID	Secup L(m)	Seclow L(m)	Lw (m)	Q0 (m^3/s)	dh0 (m)	Q1 (m^3/s)	dh1 (m)	TD (m^2/s)	hi (m)	TD-measl$_{LT}$ (m^2/s)	TD-measl$_{LP}$ (m^2/s)	TD-measl$_{U}$ (m^2/s)	EC$_{w0}$ (S/m)	Te$_{w0}$ (°C)	EC$_{w1}$ (S/m)	Te$_{w1}$ (°C)	Comments
KLX03	847.26	852.26	5	–	14.21	–	6.10	–	–	1.02E–09	2.03E–09	1.02E–05	2.67	19.67	2.82	19.69	
KLX03	842.25	847.25	5	–	14.12	–	6.01	–	–	1.02E–09	2.03E–09	1.02E–05	2.61	19.62	2.82	19.65	
KLX03	837.25	842.25	5	–	14.07	–	5.92	–	–	1.01E–09	2.02E–09	1.01E–05	2.58	19.54	2.80	19.56	
KLX03	832.24	837.24	5	–	14.01	–	5.83	–	–	1.01E–09	2.02E–09	1.01E–05	2.55	19.46	2.81	19.49	
KLX03	827.24	832.24	5	–	13.88	–	5.76	–	–	1.02E–09	2.03E–09	1.02E–05	2.53	19.38	2.82	19.41	
KLX03	822.23	827.23	5	–	13.75	–	5.73	–	–	1.03E–09	2.06E–09	1.03E–05	2.51	19.31	2.82	19.32	
KLX03	817.23	822.23	5	–	13.73	–	5.66	–	–	1.02E–09	2.04E–09	1.02E–05	2.50	19.22	2.81	19.23	
KLX03	812.22	817.22	5	–	13.68	–	5.61	–	–	1.02E–09	2.04E–09	1.02E–05	2.48	19.14	2.80	19.16	
KLX03	807.21	812.21	5	–	13.66	7.53E–08	5.54	9.17E–09	–	1.02E–09	3.38E–09	1.02E–05	2.47	19.07	2.76	19.04	
KLX03	802.21	807.21	5	–	13.58	–	5.48	–	–	1.02E–09	3.39E–09	1.02E–05	2.45	18.96	2.74	18.99	
KLX03	797.20	802.20	5	–	13.52	–	5.39	–	–	1.01E–09	3.38E–09	1.01E–05	2.44	18.87	2.72	18.90	
KLX03	792.19	797.19	5	–	13.34	–	5.25	–	–	1.02E–09	3.40E–09	1.02E–05	2.43	18.80	2.71	18.81	
KLX03	787.19	792.19	5	–	13.28	–	5.17	–	–	1.02E–09	3.39E–09	1.02E–05	2.38	18.72	2.72	18.75	
KLX03	782.18	787.18	5	–	13.25	–	5.12	–	–	1.01E–09	3.38E–09	1.01E–05	2.32	18.63	2.71	18.65	
KLX03	777.17	782.17	5	–	13.2	–	5.05	–	–	1.01E–09	3.37E–09	1.01E–05	2.22	18.53	2.69	18.55	
KLX03	772.17	777.17	5	–9.19E–08	13.18	2.82E–06	4.97	3.51E–07	12.92	1.00E–09	1.00E–09	1.00E–05	1.98	18.42	2.53	18.51	
KLX03	767.17	772.17	5	–	13.13	1.38E–06	4.92	1.66E–07	–	1.00E–09	1.00E–09	1.00E–05	1.18	18.36	2.53	18.42	
KLX03	762.16	767.16	5	–	13.08	–	4.86	–	–	1.00E–09	1.00E–09	1.00E–05	0.45	18.31	2.19	18.36	
KLX03	757.16	762.16	5	–	12.98	–	4.80	–	–	1.01E–09	1.01E–09	1.01E–05	0.30	18.26	2.19	18.32	
KLX03	752.16	757.16	5	–	12.97	4.75E–07	4.74	5.71E–08	–	1.00E–09	1.00E–09	1.00E–05	0.27	18.18	2.35	18.21	
KLX03	747.15	752.15	5	–	12.99	6.00E–07	4.71	7.17E–08	–	9.95E–10	9.95E–10	9.95E–06	0.25	18.12	2.37	18.16	
KLX03	742.15	747.15	5	–1.41E–06	12.93	4.11E–05	4.58	5.04E–06	12.65	9.87E–10	9.87E–10	9.87E–06	0.22	17.98	1.56	18.07	
KLX03	737.14	742.14	5	–7.11E–07	12.91	9.81E–06	4.55	1.24E–06	12.34	9.86E–10	9.86E–10	9.86E–06	0.22	17.88	1.60	18.04	
KLX03	732.14	737.14	5	–	12.93	–	4.53	–	–	9.81E–10	9.81E–10	9.81E–06	0.22	17.79	1.40	18.02	
KLX03	727.13	732.13	5	–	12.9	–	4.51	–	–	9.82E–10	9.82E–10	9.82E–06	0.22	17.74	1.13	17.98	
KLX03	722.12	727.12	5	–	12.79	–	4.48	–	–	9.92E–10	9.92E–10	9.92E–06	0.22	17.69	1.10	17.94	
KLX03	717.11	722.11	5	–	12.84	–	4.46	–	–	9.84E–10	9.84E–10	9.84E–06	0.22	17.62	1.03	17.92	
KLX03	712.10	717.10	5	–	12.8	–	4.44	–	–	9.86E–10	9.86E–10	9.86E–06	0.22	17.52	1.00	17.85	
KLX03	707.09	712.09	5	–	12.79	–	4.38	–	–	9.80E–10	9.80E–10	9.80E–06	0.22	17.46	0.98	17.82	
KLX03	702.08	707.08	5	–	12.8	–	4.36	–	–	9.77E–10	9.77E–10	9.77E–06	0.23	17.38	0.98	17.77	

Borehole ID	Secup L(m)	Seclow L(m)	Lw (m)	Q0 (m³/s)	dh0 (m)	Q1 (m³/s)	dh1 (m)	TD (m²/s)	hi (m)	TD-measl$_{LT}$ (m²/s)	TD-measl$_{LP}$ (m²/s)	TD-measl$_{U}$ (m²/s)	EC$_{w0}$ (S/m)	Te$_{w0}$ (°C)	EC$_{w1}$ (S/m)	Te$_{w1}$ (°C)	Comments
KLX03	697.07	702.07	5	–	12.8	–	4.34	–	–	9.74E–10	9.74E–10	9.74E–06	0.22	17.32	0.97	17.71	
KLX03	692.06	697.06	5	–	12.81	–	4.26	–	–	9.64E–10	9.64E–10	9.64E–06	0.22	17.22	0.97	17.65	
KLX03	687.06	692.06	5	–	12.79	–	4.22	–	–	9.62E–10	9.62E–10	9.62E–06	0.22	17.16	0.97	17.59	
KLX03	682.05	687.05	5	–	12.7	–	4.22	–	–	9.72E–10	9.72E–10	9.72E–06	0.22	17.06	0.97	17.53	
KLX03	677.04	682.04	5	–	12.63	–	4.17	–	–	9.74E–10	9.74E–10	9.74E–06	0.23	17.00	0.96	17.49	
KLX03	672.03	677.03	5	–	12.62	–	4.15	–	–	9.73E–10	9.73E–10	9.73E–06	0.22	16.93	0.96	17.43	
KLX03	667.02	672.02	5	–	12.63	–	4.12	–	–	9.69E–10	9.69E–10	9.69E–06	0.22	16.84	0.96	17.35	
KLX03	662.01	667.01	5	5.75E–08	12.68	2.51E–06	4.11	2.83E–07	12.88	9.62E–10	9.62E–10	9.62E–06	0.20	16.75	1.45	17.23	
KLX03	657.01	662.01	5	–	12.68	1.30E–07	4.08	1.49E–08	–	9.58E–10	9.58E–10	9.58E–06	0.20	16.69	1.08	17.19	
KLX03	652.00	657.00	5	–	12.62	–	4.02	–	–	9.58E–10	9.58E–10	9.58E–06	0.19	16.62	0.98	17.14	
KLX03	646.99	651.99	5	–	12.51	–	3.95	–	–	9.63E–10	9.63E–10	9.63E–06	0.19	16.54	0.96	17.07	
KLX03	641.99	646.99	5	–	12.5	–	3.95	–	–	9.64E–10	9.64E–10	9.64E–06	0.19	16.46	0.96	17.00	
KLX03	636.98	641.98	5	–	12.49	–	3.90	–	–	9.60E–10	9.60E–10	9.60E–06	0.19	16.39	0.96	16.94	
KLX03	631.97	636.97	5	–	12.52	–	3.88	–	–	9.54E–10	9.54E–10	9.54E–06	0.19	16.31	0.96	16.87	
KLX03	626.97	631.97	5	–	12.5	–	3.83	–	–	9.51E–10	9.51E–10	9.51E–06	0.19	16.24	0.96	16.80	
KLX03	621.96	626.96	5	–	12.45	–	3.80	–	–	9.53E–10	9.53E–10	9.53E–06	0.19	16.15	0.96	16.73	
KLX03	616.95	621.95	5	–	12.37	1.03E–07	3.80	1.18E–08	–	9.62E–10	9.62E–10	9.62E–06	0.19	16.07	0.96	16.65	
KLX03	611.95	616.95	5	–	12.4	–	3.78	–	–	9.56E–10	9.56E–10	9.56E–06	0.19	15.98	0.96	16.57	
KLX03	606.94	611.94	5	–	12.39	–	3.73	–	–	9.52E–10	9.52E–10	9.52E–06	0.19	15.92	0.96	16.53	
KLX03	601.93	606.93	5	–	12.39	–	3.69	–	–	9.47E–10	9.47E–10	9.47E–06	0.19	15.83	0.97	16.46	
KLX03	596.92	601.92	5	–	12.38	–	3.65	–	–	9.44E–10	9.44E–10	9.44E–06	0.19	15.75	0.97	16.38	
KLX03	591.91	596.91	5	–	12.38	–	3.58	–	–	9.37E–10	9.37E–10	9.37E–06	0.19	15.67	0.98	16.31	
KLX03	586.90	591.90	5	–	12.34	–	3.54	–	–	9.37E–10	9.37E–10	9.37E–06	0.19	15.59	0.99	16.22	
KLX03	581.89	586.89	5	–	12.21	–	3.52	–	–	9.48E–10	9.48E–10	9.48E–06	0.19	15.52	0.99	16.16	
KLX03	576.88	581.88	5	–	12.22	–	3.50	–	–	9.45E–10	9.45E–10	9.45E–06	0.19	15.44	0.99	16.09	
KLX03	571.87	576.87	5	–	12.24	–	3.43	–	–	9.36E–10	9.36E–10	9.36E–06	0.19	15.37	1.00	16.03	
KLX03	566.87	571.87	5	–	12.23	–	3.42	–	–	9.36E–10	9.36E–10	9.36E–06	0.19	15.29	1.01	15.97	
KLX03	561.86	566.86	5	–	12.26	–	3.39	–	–	9.29E–10	9.29E–10	9.29E–06	0.19	15.22	1.01	15.83	
KLX03	556.85	561.85	5	–	12.25	–	3.36	–	–	9.27E–10	9.27E–10	9.27E–06	0.19	15.14	1.01	15.82	
KLX03	551.84	556.84	5	–	12.12	–	3.32	–	–	9.37E–10	9.37E–10	9.37E–06	0.19	15.06	1.01	15.75	

Borehole ID	Secup L(m)	Seclow L(m)	Lw (m)	Q0 (m^3/s)	dh0 (m)	Q1 (m^3/s)	dh1 (m)	TD (m^2/s)	hi (m)	TD-$measl_{LT}$ (m^2/s)	TD-$measl_{LP}$ (m^2/s)	TD-$measl_U$ (m^2/s)	EC_{w0} (S/m)	Te_{w0} (°C)	EC_{w1} (S/m)	Te_{w1} (°C)	Comments
KLX03	546.83	551.83	5	–	12.07	–	3.30	–	–	9.40E–10	9.40E–10	9.40E–06	0.18	14.99	1.02	15.69	
KLX03	541.81	546.81	5	–	12.04	–	3.19	–	–	9.31E–10	9.31E–10	9.31E–06	0.18	14.91	1.02	15.69	
KLX03	536.80	541.80	5	–	12.1	–	3.18	–	–	9.24E–10	9.24E–10	9.24E–06	0.18	14.82	1.03	15.53	
KLX03	531.79	536.79	5	–	12.1	–	3.17	–	–	9.23E–10	9.23E–10	9.23E–06	0.18	14.75	1.04	15.48	
KLX03	526.77	531.77	5	–	12.06	–	3.17	–	–	9.27E–10	9.27E–10	9.27E–06	0.18	14.67	1.04	15.41	
KLX03	521.76	526.76	5	–	12.02	–	3.16	–	–	9.30E–10	9.30E–10	9.30E–06	0.19	14.58	1.05	15.30	
KLX03	516.74	521.74	5	–	11.93	–	3.12	–	–	9.36E–10	9.36E–10	9.36E–06	0.18	14.51	1.04	15.25	
KLX03	511.73	516.73	5	–	12.03	–	3.08	–	–	9.21E–10	3.07E–09	9.21E–06	0.18	14.45	1.05	15.14	
KLX03	506.71	511.71	5	–	12	–	3.04	–	–	9.20E–10	3.07E–09	9.20E–06	0.19	14.38	1.14	15.08	
KLX03	501.70	506.70	5	–	11.96	–	2.96	–	–	9.16E–10	3.05E–09	9.16E–06	0.18	14.30	1.05	15.01	
KLX03	496.70	501.70	5	–	11.96	–	2.95	–	–	9.15E–10	3.05E–09	9.15E–06	0.22	14.21	1.11	14.93	
KLX03	491.70	496.70	5	–	11.85	–	2.87	–	–	9.18E–10	3.06E–09	9.18E–06	0.18	14.09	1.05	14.84	
KLX03	486.70	491.70	5	–	11.84	–	2.78	–	–	9.10E–10	9.10E–10	9.10E–06	0.18	14.05	1.05	14.78	
KLX03	481.70	486.70	5	–	11.86	–	2.78	–	–	9.08E–10	9.08E–10	9.08E–06	0.19	13.98	1.06	14.70	
KLX03	476.71	481.71	5	–	11.87	–	2.74	–	–	9.03E–10	9.03E–10	9.03E–06	0.18	13.91	1.05	14.63	
KLX03	471.71	476.71	5	–	11.84	–	2.70	–	–	9.02E–10	9.02E–10	9.02E–06	0.19	13.83	1.05	14.56	
KLX03	466.71	471.71	5	–	11.68	–	2.68	–	–	9.16E–10	9.16E–10	9.16E–06	0.18	13.74	1.05	14.48	
KLX03	461.72	466.72	5	–	11.7	–	2.64	–	–	9.10E–10	9.10E–10	9.10E–06	0.18	13.67	1.05	14.43	
KLX03	456.72	461.72	5	–1.64E–08	11.71	2.22E–07	2.56	2.58E–08	11.08	9.01E–10	9.01E–10	9.01E–06	0.18	13.57	1.09	14.33	
KLX03	451.72	456.72	5	–7.92E–08	11.75	9.17E–07	2.50	1.06E–07	11.01	8.91E–10	8.91E–10	8.91E–06	0.18	13.46	1.37	14.21	
KLX03	446.72	451.72	5	–	11.71	–	2.44	–	–	8.89E–10	8.89E–10	8.89E–06	0.18	13.41	1.06	14.17	
KLX03	441.71	446.71	5	–	11.63	–	2.45	–	–	8.98E–10	8.98E–10	8.98E–06	0.18	13.33	1.04	14.07	
KLX03	436.71	441.71	5	–	11.62	–	2.42	–	–	8.96E–10	8.96E–10	8.96E–06	0.18	13.26	1.04	14.00	
KLX03	431.71	436.71	5	–	11.66	–	2.43	–	–	8.93E–10	8.93E–10	8.93E–06	0.18	13.19	1.04	13.95	
KLX03	426.71	431.71	5	–	11.64	–	2.37	–	–	8.89E–10	8.89E–10	8.89E–06	0.19	13.11	1.04	13.86	
KLX03	421.71	426.71	5	–	11.53	–	2.28	–	–	8.91E–10	8.91E–10	8.91E–06	0.18	13.02	1.04	13.77	
KLX03	416.71	421.71	5	–	11.51	–	2.20	–	–	8.85E–10	8.85E–10	8.85E–06	0.18	12.95	1.04	13.69	
KLX03	411.71	416.71	5	–	11.57	–	2.20	–	–	8.80E–10	8.80E–10	8.80E–06	0.18	12.88	1.04	13.62	
KLX03	406.70	411.70	5	–1.12E–07	11.53	1.62E–06	2.20	1.83E–07	10.93	8.83E–10	8.83E–10	8.83E–06	0.18	12.75	1.34	13.48	
KLX03	401.70	406.70	5	–	11.43	5.47E–08	2.19	5.86E–09	–	8.92E–10	8.92E–10	8.92E–06	0.18	12.69	1.04	13.44	

Borehole ID	Secup L(m)	Seclow L(m)	Lw (m)	Q0 (m^3/s)	dh0 (m)	Q1 (m^3/s)	dh1 (m)	TD (m^2/s)	hi (m)	TD-$measl_{LT}$ (m^2/s)	TD-$measl_{LP}$ (m^2/s)	TD-$measl_{U}$ (m^2/s)	EC_{w0} (S/m)	Te_{w0} (°C)	EC_{w1} (S/m)	Te_{w1} (°C)	Comments
KLX03	396.69	401.69	5	–	11.41	–	2.13	–	–	8.88E–10	8.88E–10	8.88E–06	0.18	12.62	1.02	13.37	
KLX03	391.69	396.69	5	–	11.44	–	1.98	–	–	8.71E–10	8.71E–10	8.71E–06	0.18	12.54	1.02	13.29	
KLX03	386.68	391.68	5	–	11.45	–	2.02	–	–	8.74E–10	8.74E–10	8.74E–06	0.18	12.47	1.02	13.22	
KLX03	381.67	386.67	5	–	11.38	1.03E–08	2.01	1.08E–09	–	8.80E–10	8.80E–10	8.80E–06	0.18	12.39	1.02	13.15	
KLX03	376.66	381.66	5	–	11.3	–	2.01	–	–	8.87E–10	8.87E–10	8.87E–06	0.18	12.31	1.02	13.07	
KLX03	371.66	376.66	5	–	11.3	–	1.92	–	–	8.79E–10	8.79E–10	8.79E–06	0.18	12.24	1.02	12.99	
KLX03	366.65	371.65	5	–	11.33	–	1.82	–	–	8.67E–10	8.67E–10	8.67E–06	0.18	12.15	1.02	12.91	
KLX03	361.64	366.64	5	–	11.28	–	1.75	–	–	8.65E–10	8.65E–10	8.65E–06	0.18	12.07	1.02	12.84	
KLX03	356.64	361.64	5	–	11.16	–	1.77	–	–	8.78E–10	8.78E–10	8.78E–06	0.18	12.00	1.02	12.77	
KLX03	351.63	356.63	5	–	11.19	–	1.79	–	–	8.77E–10	8.77E–10	8.77E–06	0.18	11.94	1.02	12.71	
KLX03	346.62	351.62	5	–	11.22	–	1.73	–	–	8.69E–10	8.69E–10	8.69E–06	0.18	11.84	1.02	12.61	
KLX03	341.62	346.62	5	–	11.21	–	1.59	–	–	8.57E–10	8.57E–10	8.57E–06	0.18	11.76	1.02	12.53	
KLX03	336.61	341.61	5	–	11.06	–	1.60	–	–	8.71E–10	8.71E–10	8.71E–06	0.18	11.67	1.02	12.44	
KLX03	331.60	336.60	5	–	11.09	–	1.58	–	–	8.67E–10	8.67E–10	8.67E–06	0.18	11.59	1.02	12.39	
KLX03	326.60	331.60	5	–	11.11	4.33E–08	1.59	4.50E–09	–	8.66E–10	8.66E–10	8.66E–06	0.18	11.51	1.02	12.30	
KLX03	321.59	326.59	5	–	11.13	–	1.55	–	–	8.60E–10	8.60E–10	8.60E–06	0.18	11.44	1.02	12.22	
KLX03	316.59	321.59	5	–	11.07	1.94E–08	1.48	2.01E–09	–	8.59E–10	8.59E–10	8.59E–06	0.18	11.35	1.02	12.14	
KLX03	311.59	316.59	5	–	10.96	4.39E–08	1.38	4.53E–09	–	8.60E–10	8.60E–10	8.60E–06	0.18	11.29	1.02	12.07	
KLX03	306.58	311.58	5	–	11	–	1.39	–	–	8.58E–10	8.58E–10	8.58E–06	0.18	11.23	1.02	12.01	
KLX03	301.58	306.58	5	–	11.02	–	1.38	–	–	8.55E–10	8.55E–10	8.55E–06	0.20	11.15	1.02	11.93	
KLX03	296.58	301.58	5	–	11.02	–	1.38	–	–	8.55E–10	8.55E–10	8.55E–06	0.18	11.06	1.02	11.85	
KLX03	291.57	296.57	5	–	10.87	–	1.22	–	–	8.54E–10	8.54E–10	8.54E–06	0.18	10.98	1.02	11.82	
KLX03	286.56	291.56	5	–1.00E–08	10.86	1.38E–07	1.17	1.51E–08	10.21	8.51E–10	8.51E–10	8.51E–06	0.18	10.90	1.05	11.72	
KLX03	281.56	286.56	5	–	10.91	–	1.19	–	–	8.48E–10	8.48E–10	8.48E–06	0.18	10.83	1.02	11.66	
KLX03	276.55	281.55	5	–	10.91	3.61E–08	1.19	3.67E–09	–	8.48E–10	8.48E–10	8.48E–06	0.18	10.75	1.03	11.58	
KLX03	271.54	276.54	5	–	10.85	1.57E–07	1.14	1.60E–08	–	8.49E–10	8.49E–10	8.49E–06	0.18	10.68	1.08	11.46	
KLX03	266.53	271.53	5	1.28E–07	10.78	8.53E–06	1.00	8.49E–07	10.93	8.43E–10	8.43E–10	8.43E–06	0.18	10.56	1.16	11.25	
KLX03	261.52	266.52	5	–	10.77	–	1.04	–	–	8.47E–10	8.47E–10	8.47E–06	0.17	10.51	1.05	11.20	
KLX03	256.51	261.51	5	–	10.83	1.22E–07	1.06	1.23E–08	–	8.44E–10	8.44E–10	8.44E–06	0.17	10.42	0.98	11.18	
KLX03	251.49	256.49	5	–	10.81	–	1.05	–	–	8.45E–10	8.45E–10	8.45E–06	0.17	10.35	0.91	11.13	

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KLX03	246.48	251.48	5	–	10.67	1.18E–07	0.96	1.20E–08	–	8.49E–10	8.49E–10	8.49E–06	0.17	10.28	0.94	11.06	
KLX03	241.48	246.48	5	–	10.71	–	0.86	–	–	8.37E–10	8.37E–10	8.37E–06	0.17	10.20	0.92	10.99	
KLX03	236.48	241.48	5	–	10.75	–	0.89	–	–	8.36E–10	8.36E–10	8.36E–06	0.16	10.14	0.92	10.97	
KLX03	231.48	236.48	5	–	10.73	–	0.90	–	–	8.38E–10	8.38E–10	8.38E–06	0.16	10.04	0.92	10.89	
KLX03	226.48	231.48	5	–	10.59	–	0.88	–	–	8.49E–10	8.49E–10	8.49E–06	0.16	9.97	0.92	10.84	
KLX03	221.47	226.47	5	–	10.64	–	0.70	–	–	8.29E–10	8.29E–10	8.29E–06	0.16	9.89	0.92	10.75	
KLX03	216.47	221.47	5	–	10.68	–	0.73	–	–	8.28E–10	8.28E–10	8.28E–06	0.16	9.82	0.92	10.69	
KLX03	211.45	216.45	5	–	10.68	–	0.76	–	–	8.31E–10	8.31E–10	8.31E–06	0.16	9.75	0.92	10.63	
KLX03	206.44	211.44	5	–	10.65	–	0.76	–	–	8.33E–10	2.22E–09	8.33E–06	0.16	9.66	0.92	10.57	
KLX03	201.43	206.43	5	–2.42E–07	10.56	1.34E–05	0.72	1.37E–06	10.38	8.38E–10	2.23E–09	8.38E–06	0.16	9.53	0.90	10.23	
KLX03	196.43	201.43	5	–	10.6	5.72E–07	0.57	5.64E–08	–	8.22E–10	2.19E–09	8.22E–06	0.16	9.51	0.49	10.14	
KLX03	191.42	196.42	5	1.17E–06	10.62	7.56E–05	0.59	7.34E–06	10.78	8.22E–10	2.19E–09	8.22E–06	1.57	9.42	0.23	9.71	
KLX03	186.42	191.42	5	–	10.54	–	0.58	–	–	8.28E–10	2.21E–09	8.28E–06	0.17	9.37	0.35	9.73	
KLX03	181.42	186.42	5	–	10.49	–	0.59	–	–	8.33E–10	2.22E–09	8.33E–06	0.18	9.30	0.35	9.73	
KLX03	176.42	181.42	5	–	10.53	–	0.57	–	–	8.28E–10	2.21E–09	8.28E–06	0.18	9.23	0.41	9.72	
KLX03	171.42	176.42	5	–	10.57	–	0.52	–	–	8.20E–10	2.19E–09	8.20E–06	0.19	9.17	0.41	9.70	
KLX03	166.42	171.42	5	–	10.54	1.97E–07	0.49	1.94E–08	–	8.20E–10	2.19E–09	8.20E–06	0.20	9.09	0.32	9.69	
KLX03	161.41	166.41	5	–	10.4	–	0.50	–	–	8.33E–10	2.22E–09	8.33E–06	0.21	9.02	0.41	9.66	
KLX03	156.41	161.41	5	–	10.44	–	0.46	–	–	8.26E–10	2.20E–09	8.26E–06	0.22	8.96	0.42	9.64	
KLX03	151.41	156.41	5	–	10.48	3.78E–08	0.46	3.73E–09	–	8.23E–10	2.19E–09	8.23E–06	0.22	8.89	0.42	9.62	
KLX03	146.39	151.39	5	–	10.5	3.75E–07	0.45	3.69E–08	–	8.20E–10	2.19E–09	8.20E–06	0.24	8.81	0.30	9.59	
KLX03	141.38	146.38	5	–	10.36	–	0.44	–	–	8.31E–10	2.22E–09	8.31E–06	0.28	8.74	0.42	9.58	
KLX03	136.37	141.37	5	–	10.34	2.50E–08	0.45	2.50E–09	–	8.33E–10	2.22E–09	8.33E–06	0.26	8.68	0.42	9.55	
KLX03	131.36	136.36	5	–	10.4	2.42E–08	0.45	2.40E–09	–	8.28E–10	2.21E–09	8.28E–06	0.27	8.61	0.42	9.53	
KLX03	126.35	131.35	5	–	10.43	–	0.30	–	–	8.14E–10	8.14E–10	8.14E–06	0.29	8.53	0.42	9.50	
KLX03	121.34	126.34	5	–8.33E–08	10.41	2.41E–06	0.37	2.46E–07	10.07	8.21E–10	8.21E–10	8.21E–06	0.31	8.41	0.20	9.39	
KLX03	116.33	121.33	5	–8.06E–08	10.29	1.64E–06	0.38	1.72E–07	9.83	8.32E–10	8.32E–10	8.32E–06	0.38	8.35	0.22	9.33	
KLX03	111.32	116.32	5	–	10.32	–	0.40	–	–	8.31E–10	8.31E–10	8.31E–06	0.42	8.32	0.41	9.39	
KLX03	106.31	111.31	5	–	10.37	4.08E–08	0.36	4.03E–09	–	8.23E–10	8.23E–10	8.23E–06	0.35	8.25	0.41	9.35	
KLX03	101.30	106.30	5	–	10.35	–	0.22	–	–	8.14E–10	8.14E–10	8.14E–06	0.48	8.19	0.41	9.31	

PFL – DIFFERENCE FLOW LOGGING – Inferred flow anomalies from overlapping flow logging

Borehole ID	Length to flow anom. L (m)	L_w (m)	dL (m)	Q_0 (m^3/s)	dh_0 (m)	Q_1 (m^3/s)	dh_1 (m)	T_D (m^2/s)	h_i (m)	Comments
KLX03	110.2	1.0	0.1	–	10.36	5.44E–08	0.41	5.41E–09	–	
KLX03	116.9	1.0	0.1	–8.56E–08	10.30	1.50E–06	0.35	1.58E–07	9.76	
KLX03	124.2	1.0	0.1	–8.39E–08	10.42	2.28E–06	0.30	2.31E–07	10.06	
KLX03	133.4	1.0	0.1	–	10.40	2.42E–08	0.47	2.41E–09	–	uncertain
KLX03	137.3	1.0	0.1	–	10.37	2.50E–08	0.44	2.49E–09	–	uncertain
KLX03	151.1	1.0	0.1	–	10.50	3.33E–07	0.41	3.27E–08	–	
KLX03	156.4	1.0	0.1	–	10.47	3.78E–08	0.41	3.71E–09	–	uncertain
KLX03	167.8	1.0	0.1	–	10.53	1.41E–07	0.49	1.38E–08	–	
KLX03	193.2	1.0	0.1	–	10.62	4.25E–08	0.56	4.18E–09	–	uncertain
KLX03	195.3	1.0	0.1	1.17E–06	10.62	1.27E–04	0.59	1.24E–05	10.71	
KLX03	195.8	1.0	0.1	–	10.63	2.08E–07	0.60	2.05E–08	–	uncertain
KLX03	197.7	1.0	0.1	–	10.62	5.00E–07	0.58	4.93E–08	–	
KLX03	201.3	1.0	0.1	–	10.58	1.25E–08	0.66	1.25E–09	–	uncertain
KLX03	204.3	1.0	0.1	–	10.56	1.17E–05	0.75	1.18E–06	–	
KLX03	248.2	1.0	0.1	–	10.70	8.61E–08	0.98	8.76E–09	–	
KLX03	248.6	1.0	0.1	–	10.68	1.78E–08	0.99	1.81E–09	–	uncertain
KLX03	258.4	1.0	0.1	–	10.83	1.04E–07	1.01	1.05E–08	–	
KLX03	266.8	1.0	0.1	–	10.79	7.64E–06	1.17	7.85E–07	–	
KLX03	274.7	1.0	0.1	–	10.86	1.34E–07	1.23	1.37E–08	–	
KLX03	280.6	1.0	0.1	–	10.89	3.61E–08	1.26	3.71E–09	–	uncertain
KLX03	288.3	1.0	0.1	–	10.86	1.15E–07	1.36	1.20E–08	–	
KLX03	315.9	1.0	0.1	–	11.00	3.92E–08	1.66	4.15E–09	–	
KLX03	316.7	1.0	0.1	–	11.03	3.89E–09	1.64	4.10E–10	–	uncertain
KLX03	319.6	1.0	0.1	–	11.09	1.44E–08	1.59	1.50E–09	–	
KLX03	327.0	1.0	0.1	–	11.13	1.84E–07	1.72	1.94E–08	–	
KLX03	385.0	1.0	0.1	–	11.40	6.67E–09	2.28	7.23E–10	–	uncertain
KLX03	404.4	1.0	0.1	–	11.44	2.69E–08	2.27	2.91E–09	–	
KLX03	405.4	1.0	0.1	–	11.48	2.06E–08	2.29	2.21E–09	–	
KLX03	409.9	1.0	0.1	–	11.55	1.49E–06	2.46	1.62E–07	–	
KLX03	453.4	1.0	0.1	–	11.73	4.83E–07	2.82	5.37E–08	–	
KLX03	454.4	1.0	0.1	–	11.75	3.22E–07	2.84	3.58E–08	–	
KLX03	456.7	1.0	0.1	–	11.72	1.40E–07	2.82	1.56E–08	–	
KLX03	457.4	1.0	0.1	–1.31E–08	11.72	1.85E–07	2.83	2.21E–08	11.13	
KLX03	619.4	1.0	0.1	–	12.37	6.11E–08	4.18	7.38E–09	–	uncertain
KLX03	620.1	1.0	0.1	–	12.36	1.94E–08	4.18	2.35E–09	–	uncertain
KLX03	660.2	1.0	0.1	–	12.66	4.44E–08	4.57	5.43E–09	–	uncertain
KLX03	661.2	1.0	0.1	–	12.67	6.11E–08	4.55	7.44E–09	–	uncertain
KLX03	662.4	1.0	0.1	–	12.68	1.28E–06	4.54	1.55E–07	–	
KLX03	663.0	1.0	0.1	–	12.68	4.19E–07	4.55	5.10E–08	–	uncertain
KLX03	666.7	1.0	0.1	–	12.63	2.64E–07	4.54	3.23E–08	–	

Borehole ID	Length to flow anom. L (m)	L_w (m)	dL (m)	Q_0 (m³/s)	dh_0 (m)	Q_1 (m³/s)	dh_1 (m)	T_D (m²/s)	h_i (m)	Comments
KLX03	740.8	1.0	0.1	–3.28E–07	12.92	3.44E–06	5.12	4.78E–07	12.24	
KLX03	741.8	1.0	0.1	–	12.90	2.78E–06	5.12	3.53E–07	–	uncertain
KLX03	742.3	1.0	0.1	–	12.91	8.64E–06	5.13	1.10E–06	–	
KLX03	744.1	1.0	0.1	–	12.90	2.00E–05	5.13	2.55E–06	–	
KLX03	746.4	1.0	0.1	–	12.93	8.33E–07	5.19	1.06E–07	–	
KLX03	747.7	1.0	0.1	–	12.96	5.06E–07	5.24	6.48E–08	–	
KLX03	754.3	1.0	0.1	–	12.97	3.03E–07	5.40	3.96E–08	–	
KLX03	755.1	1.0	0.1	–	12.97	1.59E–07	5.41	2.08E–08	–	uncertain
KLX03	771.0	1.0	0.1	–	13.13	2.45E–07	5.52	3.18E–08	–	
KLX03	771.1	1.0	0.1	–	13.14	1.01E–06	5.51	1.31E–07	–	uncertain
KLX03	772.3	1.0	0.1	–	13.15	1.65E–06	5.54	2.15E–07	–	
KLX03	772.6	1.0	0.1	–	13.15	1.17E–06	5.55	1.52E–07	–	uncertain
KLX03	811.0	1.0	0.1	–	13.65	6.00E–08	6.12	7.88E–09	–	uncertain
KLX03	970.1	1.0	0.1	–	16.16	3.33E–06	8.63	4.38E–07	–	
KLX03	970.5	1.0	0.1	–	16.16	1.08E–07	8.62	1.42E–08	–	uncertain

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

Explanations

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
Test type (1–6)	(–)	1A: Pumping test – wire-line eq., 1B:Pumping test – submersible pump, 1C: Pumping test – airlift pumping, 2: Interference test, 3: Injection test, 4: Slug test, 5A: Difference flow logging – PFL-DIFF-Sequential, 5B: Difference flow logging – PFL-DIFF-Overlapping, 6: Flow logging-Impeller.
Date of test, start	YY-MM-DD	Date for start of pumping.
Time of test, start	hh:mm	Time for start of pumping.
Date of flowl., start .	YY-MM-DD	Date for start of the flow logging.
Time of flowl., start	hh:mm	Time for start of the flow logging.
Date of test, stop	YY-MM-DD	Date for stop of the test.
Time of test, stop	hh:mm	Time for stop of the test.
L_w	m	Section length used in the difference flow logging.
dL	m	Step length (increment) used in the difference flow logging.
Q_{p1}	m^3/s	Flow rate at surface by the end of the first pumping period of the flow logging.
Q_{p2}	m^3/s	Flow rate at surface by the end of the second pumping period of the flow logging.
t_{p1}	s	Duration of the first pumping period.
t_{p2}	s	Duration of the second pumping period.
t_{F1}	s	Duration of the first recovery period.
t_{F2}	s	Duration of the second recovery period.
h_0	masl	Initial hydraulic head before pumping. Elevation of water level in open borehole in the local co-ordinates system with z=0 m.
h_1	masl	Stabilised hydraulic head during the first pumping period. Elevation of water level in open borehole in the local co-ordinates system with z=0 m.

Header	Unit	Explanations
h_2	masl	Stabilised hydraulic head during the second pumping period. Elevation of water level in open borehole in the local co-ordinates system with z=0 m.
s_1	m	Drawdown of the water level in the borehole during first pumping period. Difference between the actual hydraulic head and the initial head ($s_1 = h_1 – h_0$).
s_2	m	Drawdown of the water level in the borehole during second pumping period. Difference between the actual hydraulic head and the initial head ($s_2 = h_2 – h_0$).
T	m^2/s	Transmissivity of the entire borehole.
Q_0	m^3/s	Measured flow rate through the test section or flow anomaly under natural conditions (no pumping) with $h=h_0$ in the open borehole.
Q_1	m^3/s	Measured flow rate through the test section or flow anomaly during the first pumping period.
Q_2	m^3/s	Measured flow rate through the test section or flow anomaly during the second pumping period.
dh_0	m	Corrected initial hydraulic head difference along the hole due to e.g. varying salinity conditions of the borehole fluid before pumping.
dh_1	m	Corrected hydraulic head difference along the hole due to e.g. varying salinity conditions of the borehole fluid during the first pumping period.
dh_2	m	Corrected hydraulic head difference along the hole due to e.g. varying salinity conditions of the borehole fluid during the second pumping period.
EC_w	S/m	Measured electric conductivity of the borehole fluid in the test section during difference flow logging.
Te_w	°C	Measured borehole fluid temperature in the test section during difference flow logging.
EC_f	S/m	Measured fracture-specific electric conductivity of the fluid in flow anomaly during difference flow logging.
Te_f	°C	Measured fracture-specific fluid temperature in flow anomaly during difference flow logging.
T_D	m^2/s	Transmissivity of section or flow anomaly based on 2D model for evaluation of formation properties of the test section based on PFL-DIFF.
T-measl$_{LT}$	m^2/s	Estimated theoretical lower measurement limit for evaluated T_D. If the estimated T_D equals T_D-measlim, the actual T_D is considered to be equal or less than T_D-measlim.
T-measl$_{LP}$	m^2/s	Estimated practical lower measurement limit for evaluated T_D. If the estimated T_D equals T_D-measlim, the actual T_D is considered to be equal or less than T_D-measlim.
T-measl$_U$	m^2/s	Estimated upper measurement limit for evaluated T_D. If the estimated T_D equals T_D-measlim, the actual T_D is considered to be equal or less than T_D-measlim.
h_i	m	Calculated relative, natural freshwater head for test section or flow anomaly (undisturbed conditions).

Calculation of conductive fracture frequency

SecUp (m)	SecLow (m)	Number of fractures, total	Number of fractures 10–100 (mL/h)	Number of fractures 100–1,000 (mL/h)	Number of fractures 1,000–10,000 (mL/h)	Number of fractures 10,000–100,000 (mL/h)	Number of fractures 100,000–1,000,000 (mL/h)
987.42	992.42	0	0	0	0	0	0
982.42	987.42	0	0	0	0	0	0
977.41	982.41	0	0	0	0	0	0
972.41	977.41	0	0	0	0	0	0
967.39	972.39	2	0	1	0	1	0
962.38	967.38	0	0	0	0	0	0
957.36	962.36	0	0	0	0	0	0
952.34	957.34	0	0	0	0	0	0
947.34	952.34	0	0	0	0	0	0
942.34	947.34	0	0	0	0	0	0
937.34	942.34	0	0	0	0	0	0
932.33	937.33	0	0	0	0	0	0
927.33	932.33	0	0	0	0	0	0
922.33	927.33	0	0	0	0	0	0
917.33	922.33	0	0	0	0	0	0
912.33	917.33	0	0	0	0	0	0
907.33	912.33	0	0	0	0	0	0
902.33	907.33	0	0	0	0	0	0
897.32	902.32	0	0	0	0	0	0
892.31	897.31	0	0	0	0	0	0
887.31	892.31	0	0	0	0	0	0
882.30	887.30	0	0	0	0	0	0
877.29	882.29	0	0	0	0	0	0
872.29	877.29	0	0	0	0	0	0
867.28	872.28	0	0	0	0	0	0
862.27	867.27	0	0	0	0	0	0
857.27	862.27	0	0	0	0	0	0
852.26	857.26	0	0	0	0	0	0
847.26	852.26	0	0	0	0	0	0
842.25	847.25	0	0	0	0	0	0
837.25	842.25	0	0	0	0	0	0
832.24	837.24	0	0	0	0	0	0
827.24	832.24	0	0	0	0	0	0
822.23	827.23	0	0	0	0	0	0
817.23	822.23	0	0	0	0	0	0
812.22	817.22	0	0	0	0	0	0
807.21	812.21	1	0	1	0	0	0
802.21	807.21	0	0	0	0	0	0
797.20	802.20	0	0	0	0	0	0

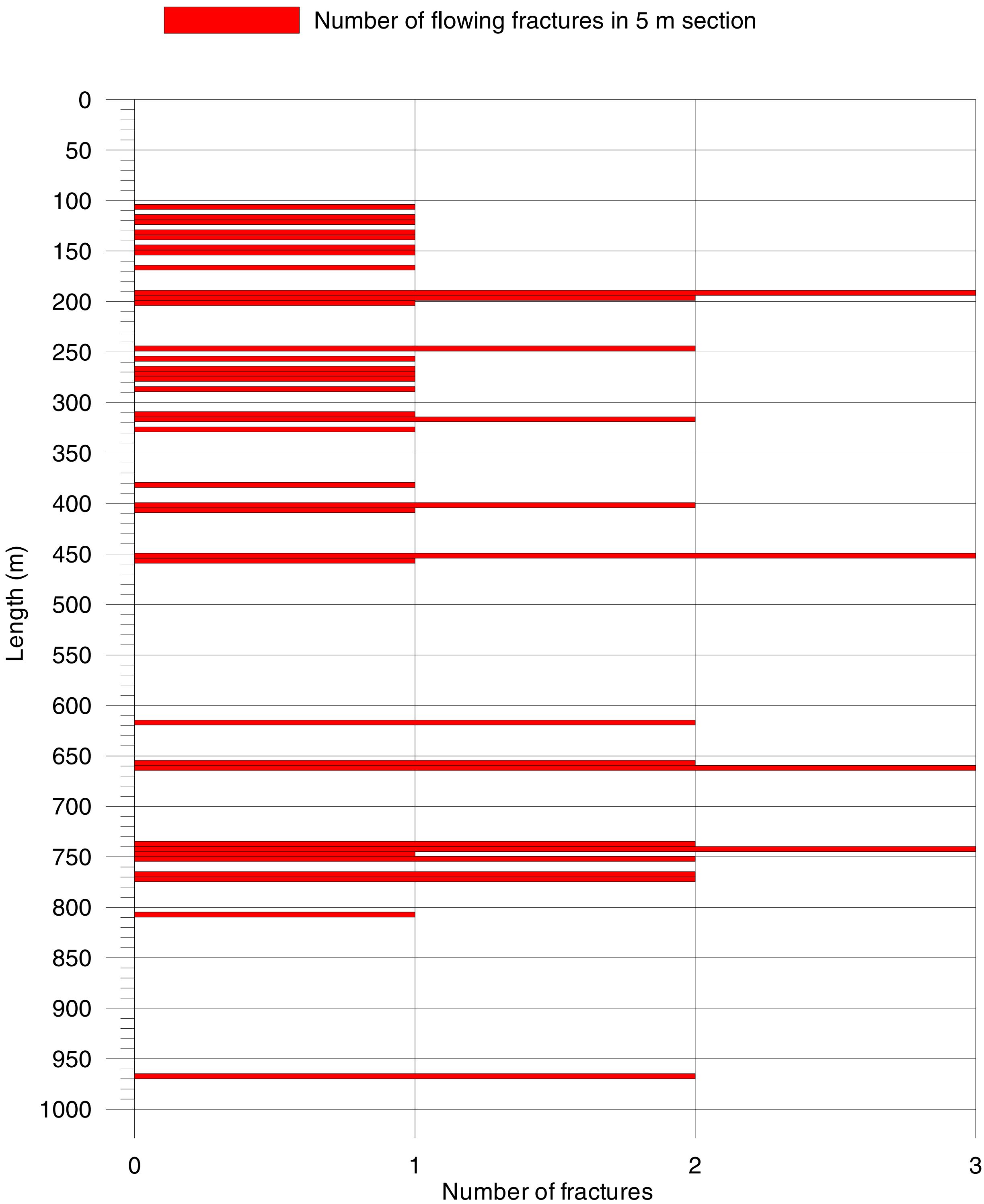
SecUp (m)	SecLow (m)	Number of fractures, total	Number of fractures 10–100 (mL/h)	Number of fractures 100–1,000 (mL/h)	Number of fractures 1,000–10,000 (mL/h)	Number of fractures 10,000–100,000 (mL/h)	Number of fractures 100,000–1,000,000 (mL/h)
792.19	797.19	0	0	0	0	0	0
787.19	792.19	0	0	0	0	0	0
782.18	787.18	0	0	0	0	0	0
777.17	782.17	0	0	0	0	0	0
772.17	777.17	2	0	0	2	0	0
767.17	772.17	2	0	1	1	0	0
762.16	767.16	0	0	0	0	0	0
757.16	762.16	0	0	0	0	0	0
752.16	757.16	2	0	1	1	0	0
747.15	752.15	1	0	0	1	0	0
742.15	747.15	3	0	0	1	2	0
737.14	742.14	2	0	0	0	1	0
732.14	737.14	0	0	0	0	0	0
727.13	732.13	0	0	0	0	0	0
722.12	727.12	0	0	0	0	0	0
717.11	722.11	0	0	0	0	0	0
712.10	717.10	0	0	0	0	0	0
707.09	712.09	0	0	0	0	0	0
702.08	707.08	0	0	0	0	0	0
697.07	702.07	0	0	0	0	0	0
692.06	697.06	0	0	0	0	0	0
687.06	692.06	0	0	0	0	0	0
682.05	687.05	0	0	0	0	0	0
677.04	682.04	0	0	0	0	0	0
672.03	677.03	0	0	0	0	0	0
667.02	672.02	0	0	0	0	0	0
662.01	667.01	3	0	1	2	0	0
657.01	662.01	2	0	2	0	0	0
652.00	657.00	0	0	0	0	0	0
646.99	651.99	0	0	0	0	0	0
641.99	646.99	0	0	0	0	0	0
636.98	641.98	0	0	0	0	0	0
631.97	636.97	0	0	0	0	0	0
626.97	631.97	0	0	0	0	0	0
621.96	626.96	0	0	0	0	0	0
616.95	621.95	2	1	1	0	0	0
611.95	616.95	0	0	0	0	0	0
606.94	611.94	0	0	0	0	0	0
601.93	606.93	0	0	0	0	0	0
596.92	601.92	0	0	0	0	0	0
591.91	596.91	0	0	0	0	0	0
586.90	591.90	0	0	0	0	0	0
581.89	586.89	0	0	0	0	0	0

SecUp (m)	SecLow (m)	Number of fractures, total	Number of fractures 10–100 (mL/h)	Number of fractures 100–1,000 (mL/h)	Number of fractures 1,000–10,000 (mL/h)	Number of fractures 10,000–100,000 (mL/h)	Number of fractures 100,000–1,000,000 (mL/h)
576.88	581.88	0	0	0	0	0	0
571.87	576.87	0	0	0	0	0	0
566.87	571.87	0	0	0	0	0	0
561.86	566.86	0	0	0	0	0	0
556.85	561.85	0	0	0	0	0	0
551.84	556.84	0	0	0	0	0	0
546.83	551.83	0	0	0	0	0	0
541.81	546.81	0	0	0	0	0	0
536.80	541.80	0	0	0	0	0	0
531.79	536.79	0	0	0	0	0	0
526.77	531.77	0	0	0	0	0	0
521.76	526.76	0	0	0	0	0	0
516.74	521.74	0	0	0	0	0	0
511.73	516.73	0	0	0	0	0	0
506.71	511.71	0	0	0	0	0	0
501.70	506.70	0	0	0	0	0	0
496.70	501.70	0	0	0	0	0	0
491.70	496.70	0	0	0	0	0	0
486.70	491.70	0	0	0	0	0	0
481.70	486.70	0	0	0	0	0	0
476.71	481.71	0	0	0	0	0	0
471.71	476.71	0	0	0	0	0	0
466.71	471.71	0	0	0	0	0	0
461.72	466.72	0	0	0	0	0	0
456.72	461.72	1	0	1	0	0	0
451.72	456.72	3	0	1	2	0	0
446.72	451.72	0	0	0	0	0	0
441.71	446.71	0	0	0	0	0	0
436.71	441.71	0	0	0	0	0	0
431.71	436.71	0	0	0	0	0	0
426.71	431.71	0	0	0	0	0	0
421.71	426.71	0	0	0	0	0	0
416.71	421.71	0	0	0	0	0	0
411.71	416.71	0	0	0	0	0	0
406.70	411.70	1	0	0	1	0	0
401.70	406.70	2	2	0	0	0	0
396.69	401.69	0	0	0	0	0	0
391.69	396.69	0	0	0	0	0	0
386.68	391.68	0	0	0	0	0	0
381.67	386.67	1	1	0	0	0	0
376.66	381.66	0	0	0	0	0	0
371.66	376.66	0	0	0	0	0	0
366.65	371.65	0	0	0	0	0	0

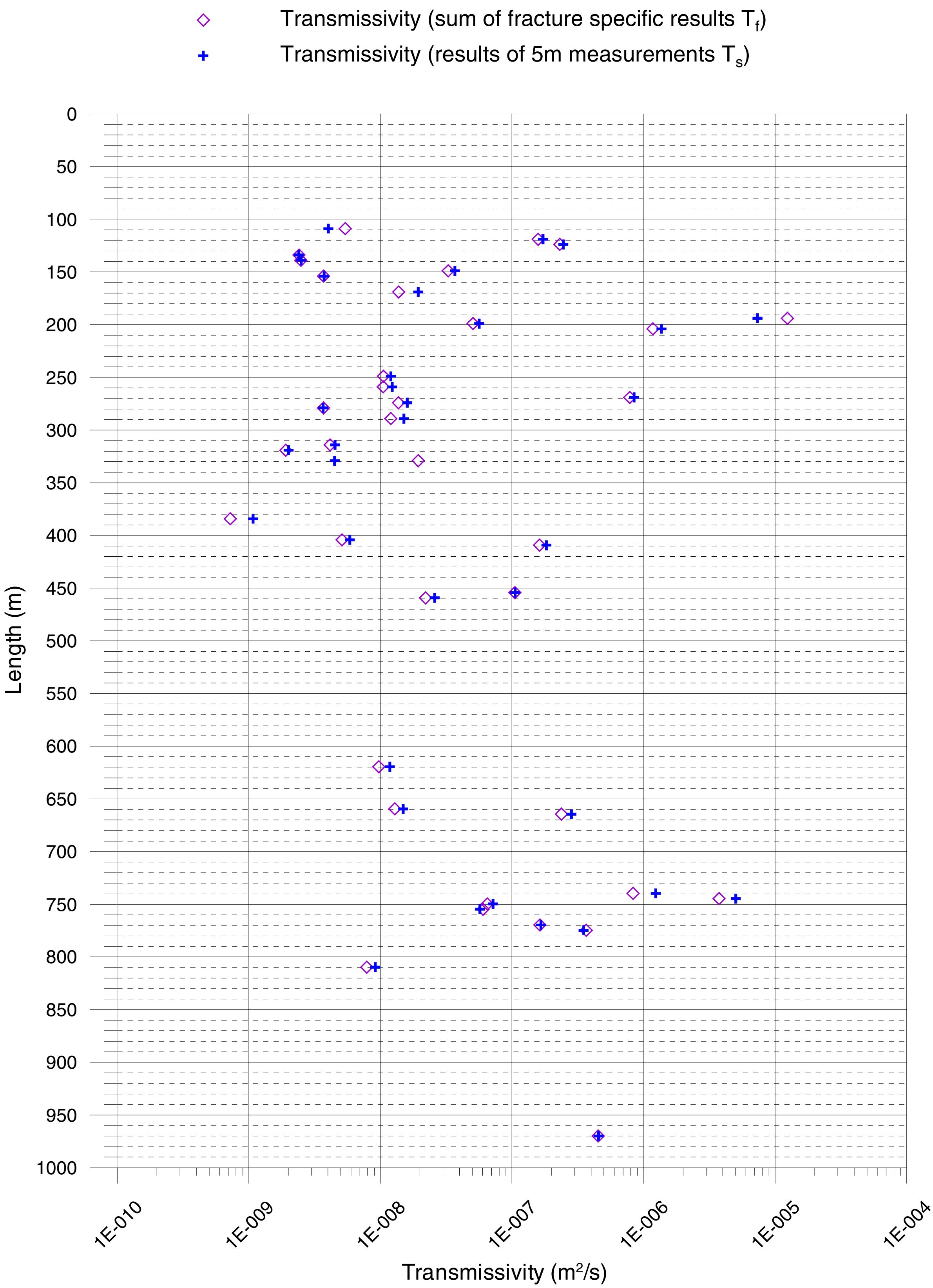
SecUp (m)	SecLow (m)	Number of fractures, total	Number of fractures 10–100 (mL/h)	Number of fractures 100–1,000 (mL/h)	Number of fractures 1,000–10,000 (mL/h)	Number of fractures 10,000–100,000 (mL/h)	Number of fractures 100,000–1,000,000 (mL/h)
361.64	366.64	0	0	0	0	0	0
356.64	361.64	0	0	0	0	0	0
351.63	356.63	0	0	0	0	0	0
346.62	351.62	0	0	0	0	0	0
341.62	346.62	0	0	0	0	0	0
336.61	341.61	0	0	0	0	0	0
331.60	336.60	0	0	0	0	0	0
326.60	331.60	1	0	1	0	0	0
321.59	326.59	0	0	0	0	0	0
316.59	321.59	2	2	0	0	0	0
311.59	316.59	1	0	1	0	0	0
306.58	311.58	0	0	0	0	0	0
301.58	306.58	0	0	0	0	0	0
296.58	301.58	0	0	0	0	0	0
291.57	296.57	0	0	0	0	0	0
286.56	291.56	1	0	1	0	0	0
281.56	286.56	0	0	0	0	0	0
276.55	281.55	1	0	1	0	0	0
271.54	276.54	1	0	1	0	0	0
266.53	271.53	1	0	0	0	1	0
261.52	266.52	0	0	0	0	0	0
256.51	261.51	1	0	1	0	0	0
251.49	256.49	0	0	0	0	0	0
246.48	251.48	2	1	1	0	0	0
241.48	246.48	0	0	0	0	0	0
236.48	241.48	0	0	0	0	0	0
231.48	236.48	0	0	0	0	0	0
226.48	231.48	0	0	0	0	0	0
221.47	226.47	0	0	0	0	0	0
216.47	221.47	0	0	0	0	0	0
211.45	216.45	0	0	0	0	0	0
206.44	211.44	0	0	0	0	0	0
201.43	206.43	1	0	0	0	1	0
196.43	201.43	2	1	0	1	0	0
191.42	196.42	3	0	2	0	0	1
186.42	191.42	0	0	0	0	0	0
181.42	186.42	0	0	0	0	0	0
176.42	181.42	0	0	0	0	0	0
171.42	176.42	0	0	0	0	0	0
166.42	171.42	1	0	1	0	0	0
161.41	166.41	0	0	0	0	0	0
156.41	161.41	0	0	0	0	0	0
151.41	156.41	1	0	1	0	0	0

SecUp (m)	SecLow (m)	Number of fractures, total	Number of fractures 10–100 (mL/h)	Number of fractures 100–1,000 (mL/h)	Number of fractures 1,000–10,000 (mL/h)	Number of fractures 10,000–100,000 (mL/h)	Number of fractures 100,000–1,000,000 (mL/h)
146.39	151.39	1	0	0	1	0	0
141.38	146.38	0	0	0	0	0	0
136.37	141.37	1	1	0	0	0	0
131.36	136.36	1	1	0	0	0	0
126.35	131.35	0	0	0	0	0	0
121.34	126.34	1	0	0	1	0	0
116.33	121.33	1	0	0	1	0	0
111.32	116.32	0	0	0	0	0	0
106.31	111.31	1	0	1	0	0	0
101.30	106.30	0	0	0	0	0	0

Laxemar, borehole KLX03
Calculation of conductive fracture frequency

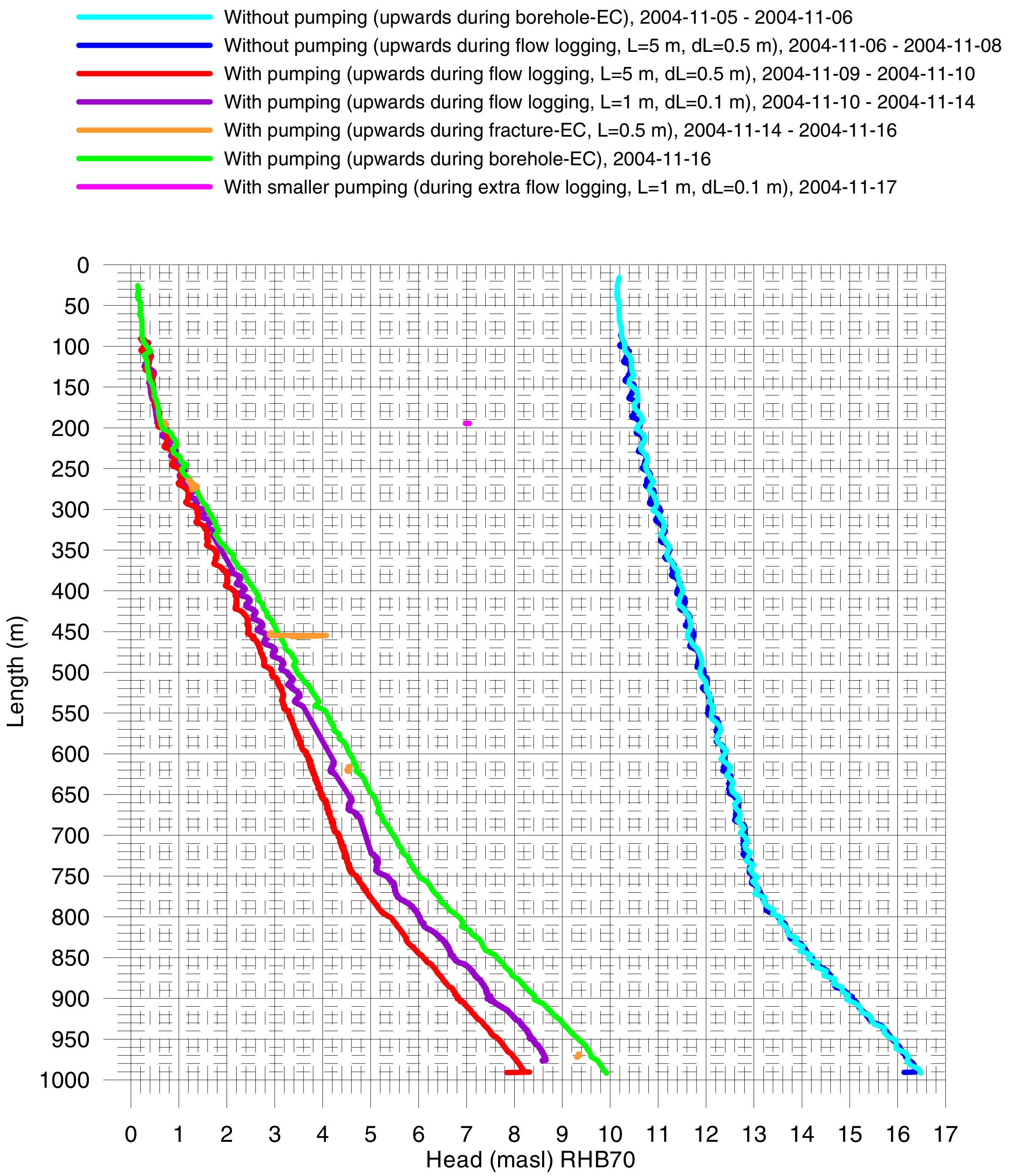


Laxemar, borehole KLX03
Comparison between section transmissivity and fracture transmissivity

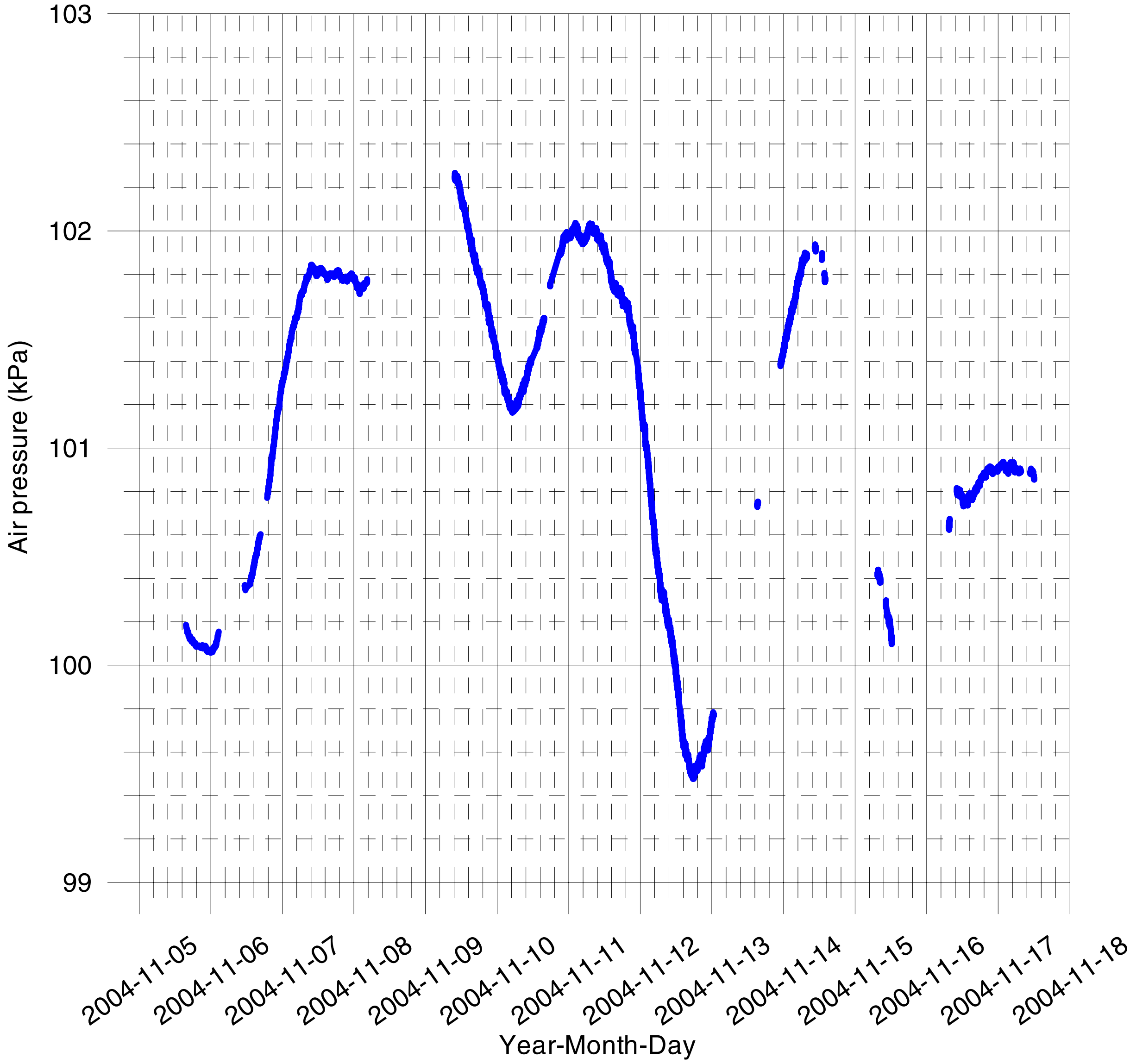


Laxemar, borehole KLX03
Head in the borehole during flow logging

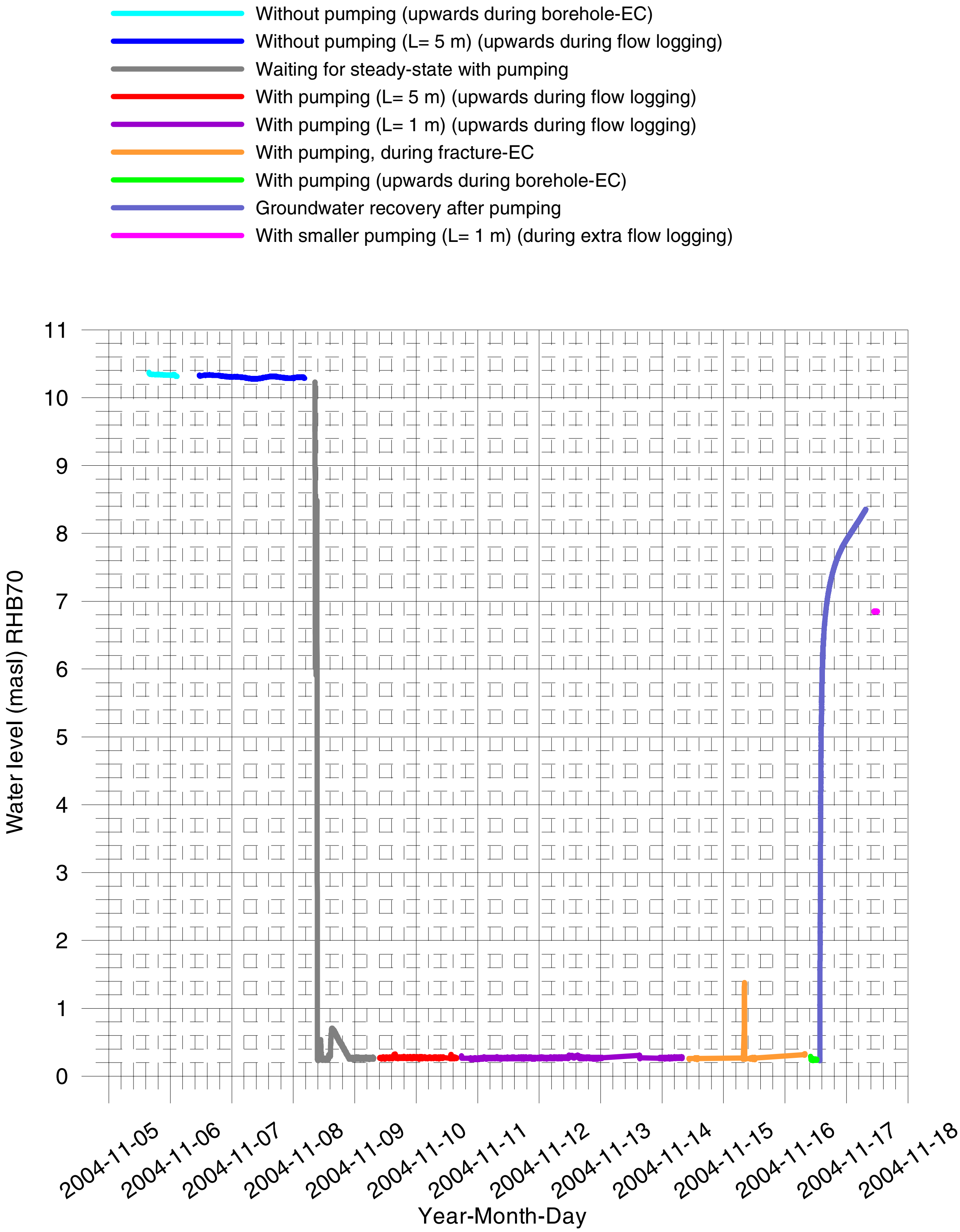
Head(masl)= (Absolute pressure (Pa) - Airpressure (Pa) + Offset) /(1000 kg/m^3 * 9.80665 m/s^2) + Elevation (m)
Offset = 2460 Pa (Correction for absolut pressure sensor)



Laxemar, borehole KLX03
Air pressure during flow logging
2004-11-05 - 2004-11-17

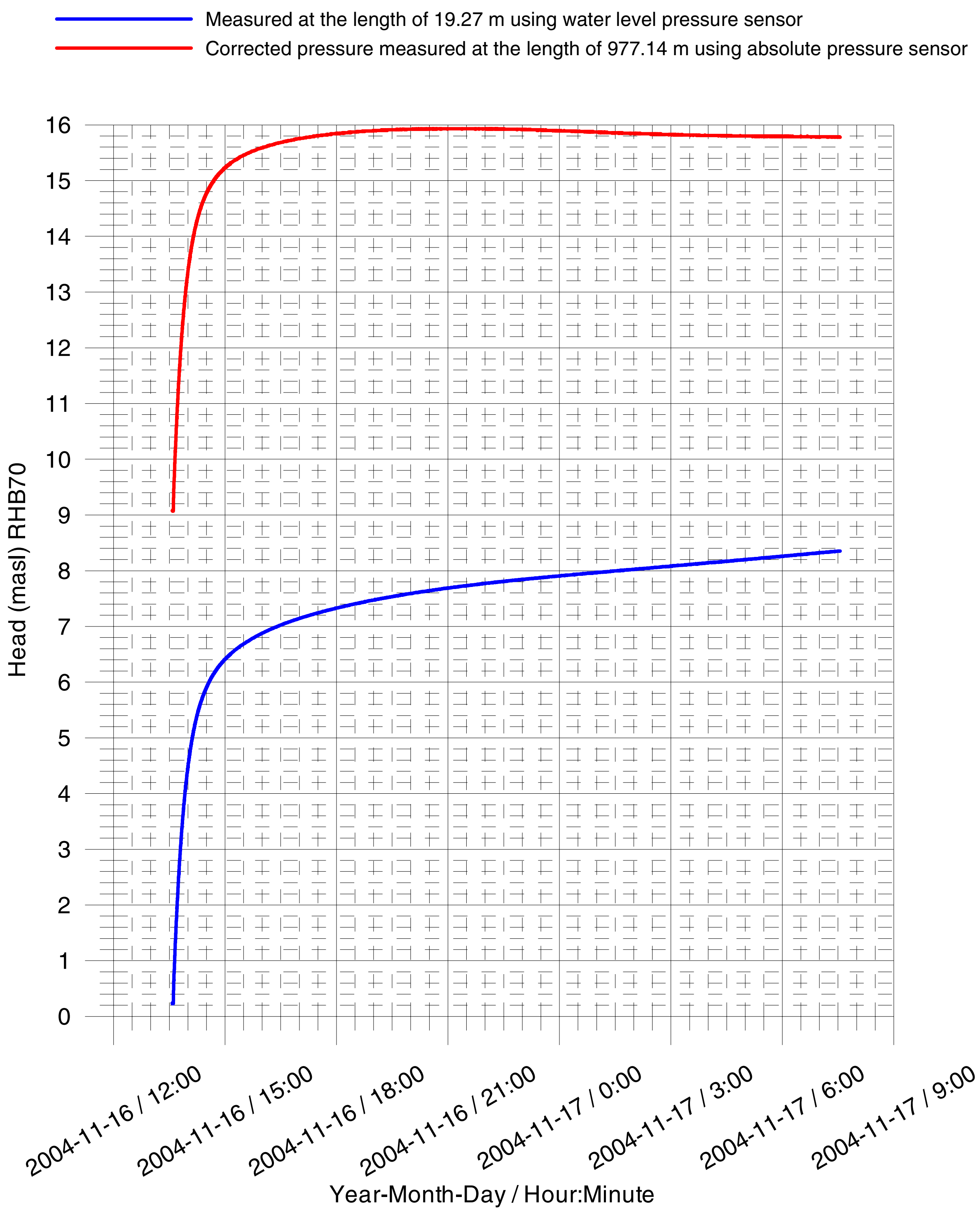


Laxemar, borehole KLX03
Water level in the borehole during flow logging

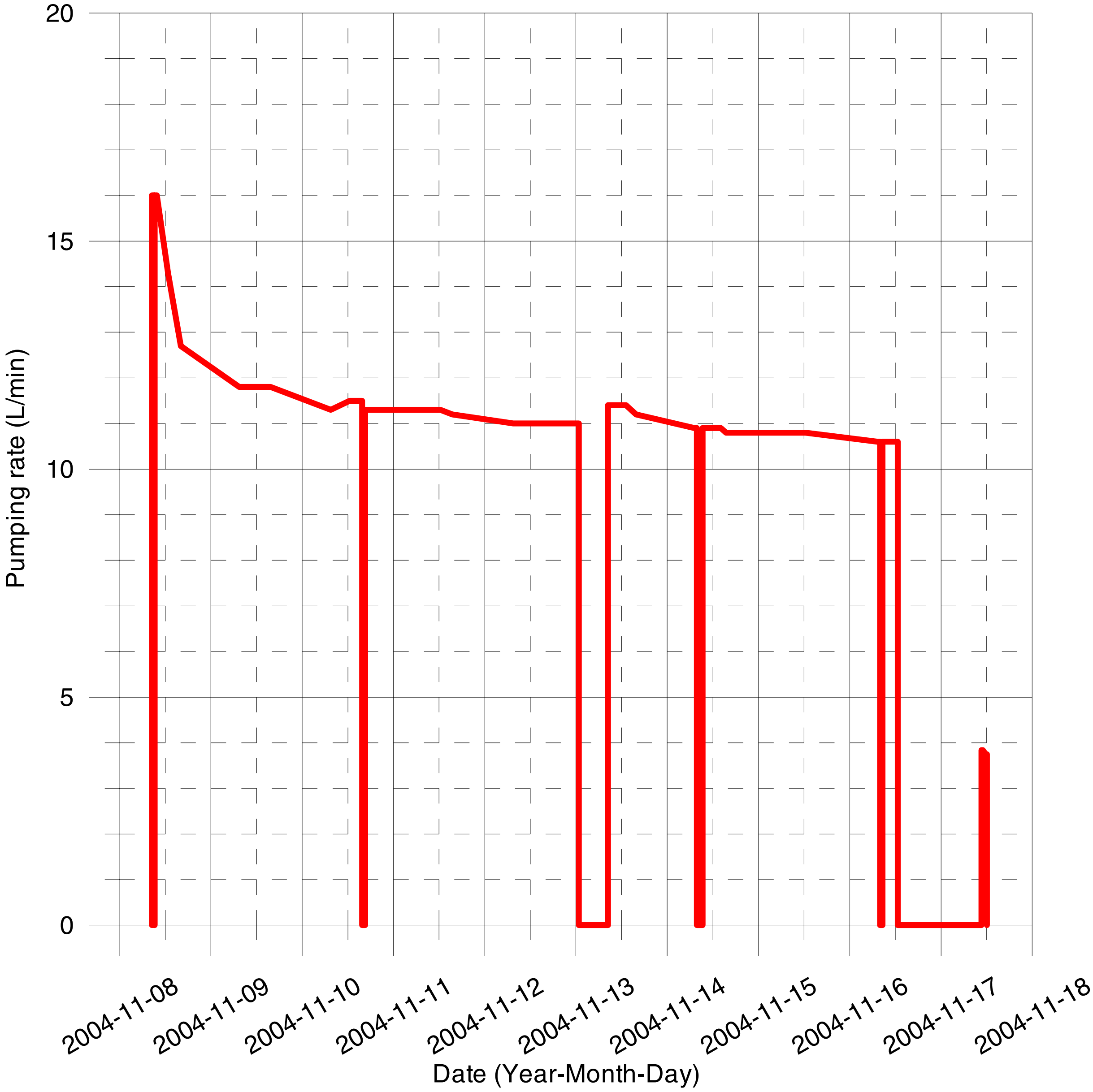


Laxemar, borehole KLX03
Groundwater recovery after pumping

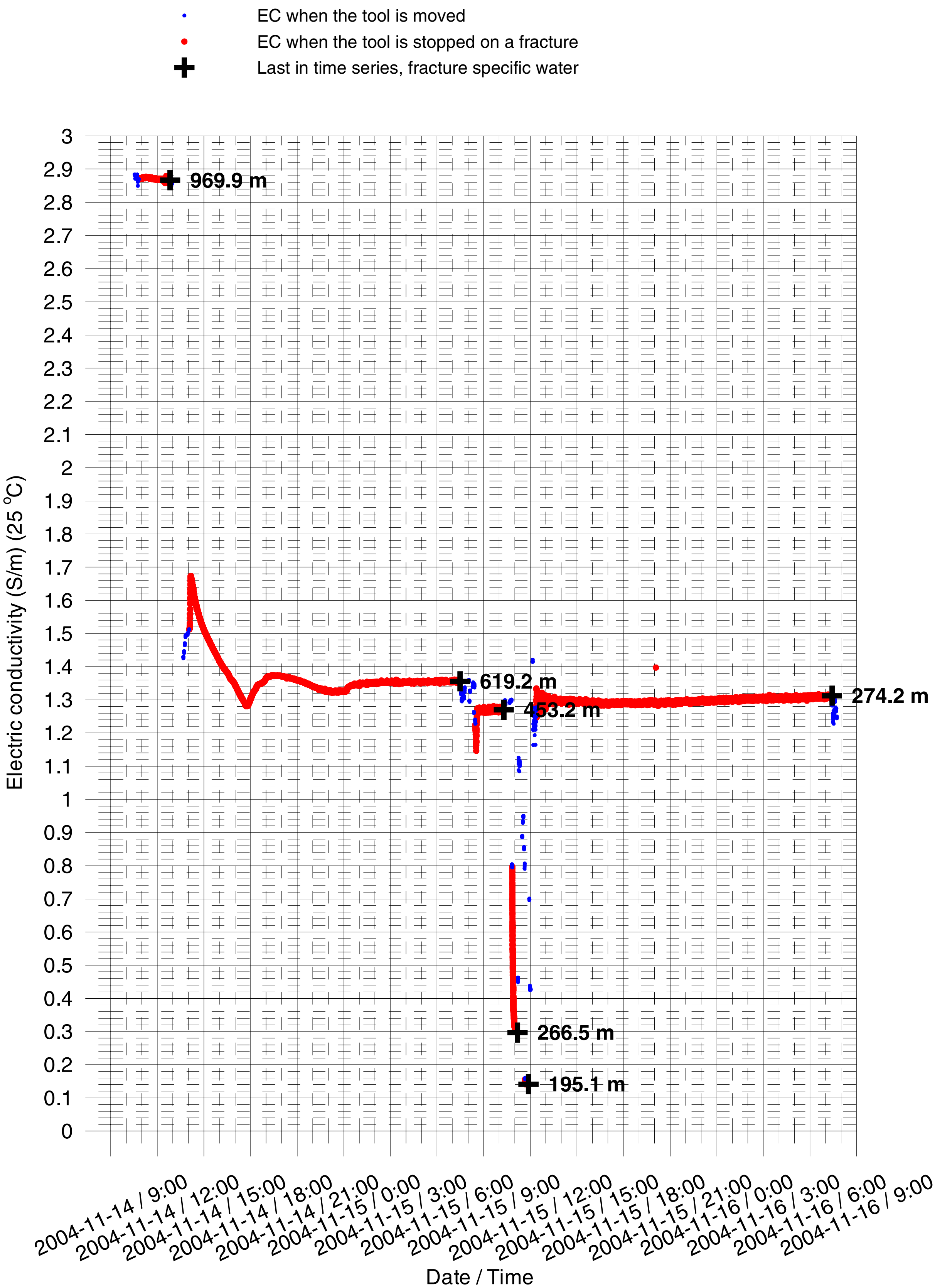
Head(masl)= (Absolute pressure (Pa) - Airpressure (Pa) + Offset) /(1000 kg/m^3 * 9.80665 m/s^2) + Elevation (m)
Offset = 2460 Pa (Correction for absolut pressure sensor)



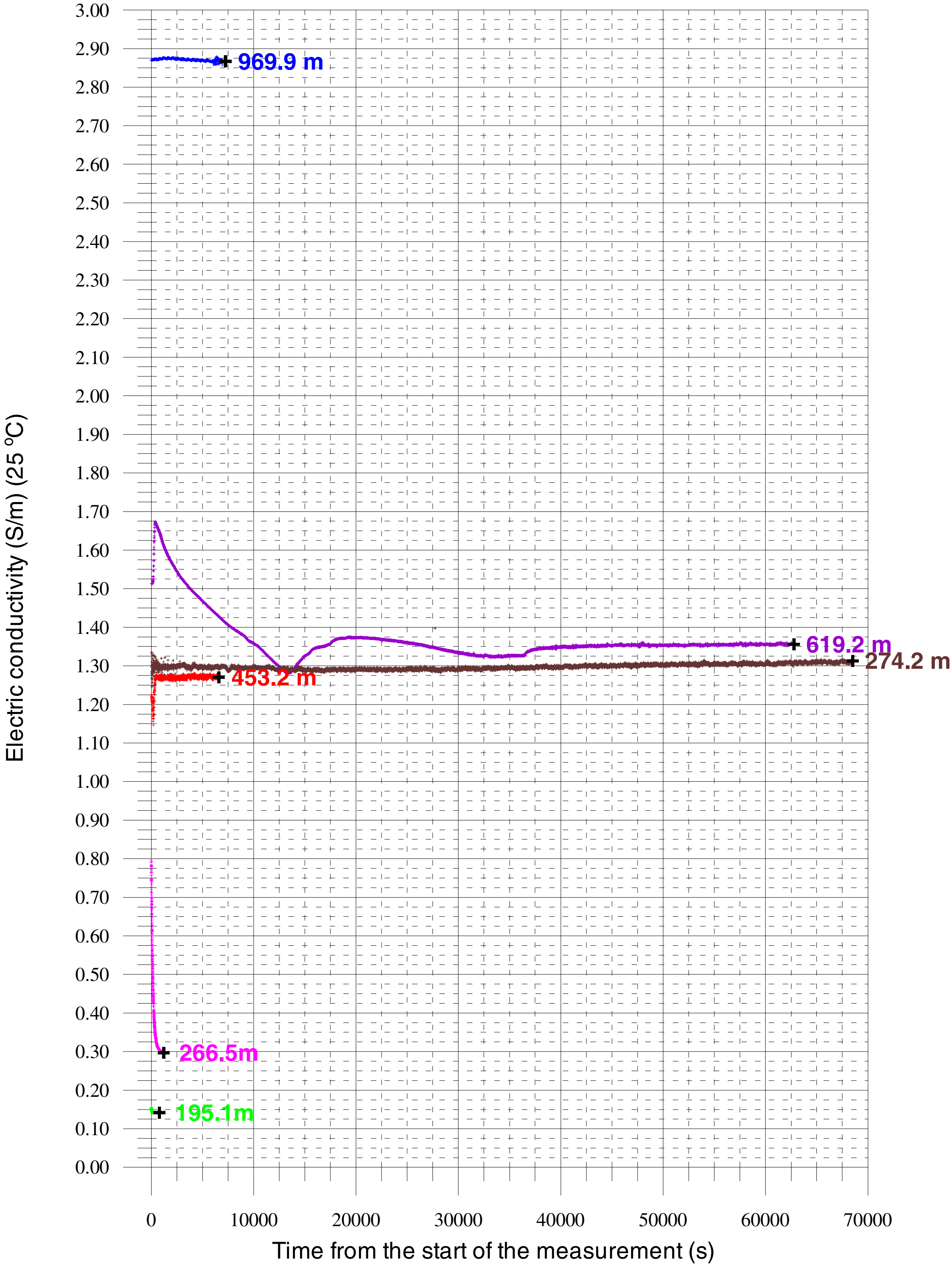
Laxemar, borehole KLX03
Pumping rate during flow logging



Laxemar, KLX03
Fracture-specific EC results by date



Laxemar, borehole KLX03
Time series of fracture-specific EC
2004-11-14 - 2004-11-16



Laxemar, borehole KLX03
Time series of fracture-specific EC
2004-11-14 - 2004-11-16