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Forsmark site investigation

Difference flow logging in borehole KFM06A

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PRG-Tec Oy

January 2005

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Foreword

The performance and evaluation of the difference flow logging campaign in borehole KFM06A was made by Posiva/PRG-Tec Oy.

The evaluation of the pumping test in conjunction with the difference flow logging (Section 6.6) was performed by Jan-Erik Ludvigson, Geosigma AB.

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 KFM06A at Forsmark, Sweden, in October 2004, using the Posiva flow log. The primary aim of the measurements was to determine the position and flow rate of flow yielding fractures in borehole KFM06A prior to groundwater sampling.

The flow rate into or out of a 5 m long test sections was measured between 100.43–992.08 m borehole length 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 absolute pressure along the borehole. These measurements were carried out together with the flow measurements.

Electric conductivity (EC) and temperature of the borehole water was also measured. The EC-measurements were used to study the distrribution of saline water in the borehole during natural as well as pumped conditions. Finally, EC of fracture-specific water was measured for a selection of fractures.

The total transmissivity of the cored borehole KFM06A was estimated at 8.9×10^{-5} m^2/s from the groundwater recovery after the pumping test in conjunction with the difference flow logging. This value is in good agreement with the cumulative transmissivities of the measured 5 m sections and of the flow anomalies identified from the difference flow logging, i e 1.1×10^{-4} m^2/s. No effects of hydraulic boundaries were observed during the recovery period.

Sammanfattning

Differensflödesloggning är en snabb metod för bestämning av transmissivitet och hydraulisk tryckhöjd i borrhålssektioner och sprickor/sprickzoner i kärnborrhål. Denna rapport presenterar huvudprinciperna för metoden och resultat av mätningar utförda i borrhål KFM06A i Forsmark, Sverige, i oktober 2004 med Posiva flödesloggningsmetod. Det primära syftet med mätningarna var att bestämma läget av och flödet för vattenförande sprickor i borrhål KFM06A före grundvattenprovtagning.

Flödet till eller från en 5 m lång testsektion mättes mellan 100,43–992,08 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 längdmärkena som frästs in i borrhålsväggen vid noggrant bestämda positioner längs borrhålet. Längdmärkena detekterades med caliper och punktresistansmätningar med hjälp av sensorer anslutna på flödesloggningssonden.

En högupplösande absoluttryckgivare användes för att mäta det absoluttrycket längs borrhålet. Dessa mätningar utfördes samtidigt med flödesmätningarna.

Elektrisk konduktivitet och temperatur på borrhålsvattnet mättes också. EC-mätningarna användes för att studera saltvattenfördelningen i borrhålet under såväl naturliga som pumpade förhållanden. Slutligen mättes EC på vattnet i ett antal utvalda sprickor.

Den totala transmissiviteten för kärnborrhålet KFM06A skattades till $8,9 \times 10^{-5}$ m^2/s från tryckåterhämtningsperioden efter pumptesten i anslutning till differensflödesloggningen. Detta värde är i god överensstämmelse med den kumulativa transmissiviteten för mätta 5 m sektioner och för de identifierade flödesanomalierna från differensflödesloggningen ($1,1 \times 10^{-4}$ m^2/s). Inga effekter av hydrauliska gränser observerades under återhämtningsperioden.

Contents

1 Introduction

The difference flow logging in the core drilled borehole KFM06A at Forsmark was conducted between October 11–21, 2004. KFM06A is the sixth deep core drilled borehole in the Forsmark candidate area. The borehole is inclined c 60° from the horizontal direction. The c 1,000 m long borehole is performed with telescopic drilling technique, where the interval 0–100 m is percussion drilled with the diameter c 250 mm and the remaining interval, 100–1,000 m, is core drilled with the diameter c 77 mm. The interval 0 – c 100 m is cased with the inner diameter 200 mm. The location of borehole KFM06A at drill site DS6 within the Forsmark area is shown in Figure 1-1.

The field work and the subsequent interpretations 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/.

This document reports the results gained by the Difference flow logging in borehole KFM06A. The activity is performed within the Forsmark site investigation. The work was carried out in compliance with the SKB internal controlling document AP PF 400-04-76. Data and results were delivered to the SKB site characterization database SICADA.

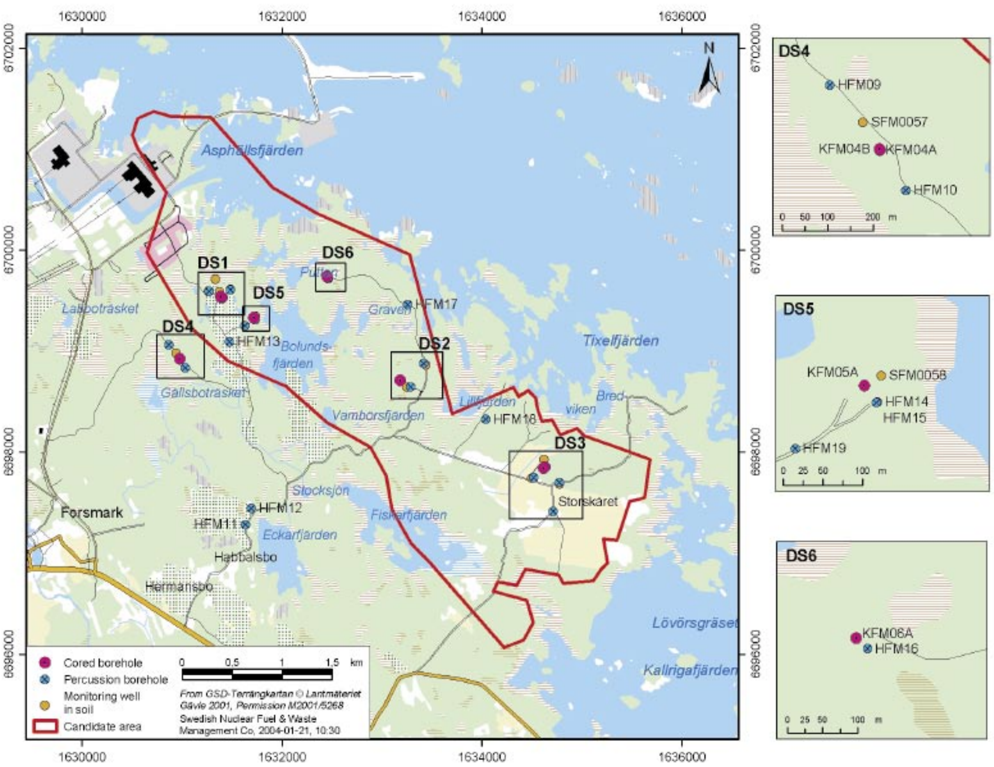

Figure 1-1. *Location of the drill sites DS1–6 at Forsmark. For the drill sites DS4–6 detailed maps of all boreholes within the sites are shown.*

2 Objective and scope

The main objective of the difference flow logging in KFM06A was to identify water-conductive sections/fractures suitable for subsequent hydro-geochemical characterisation. Secondly, the measurements aimed at a hydrogeological characterisation, including the prevailing water flow balance in the borehole and the hydraulic properties (transmissivity and undisturbed hydraulic head) of the tested sections. 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 measurement programme also included supporting measurements, performed for a better understanding of the overall hydrogeochemical conditions. These measurements included electric conductivity and temperature of the borehole fluid as well as single-point resistance of the borehole wall. The electric conductivity was also 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 pressure sensor was used to measure the absolute pressure along the borehole. These measurements were carried out simultaneously with the flow measurements. The results are used for calculation of hydraulic head along the borehole.

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

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 in the test section from that in the rest of the borehole, see Figure 3-1. The flow along the borehole outside the isolated test section is conducted 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, a sequential mode and 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. This mode is mostly used to determine the location of hydraulically conductive fractures and to classify them with regard to their flow rates.

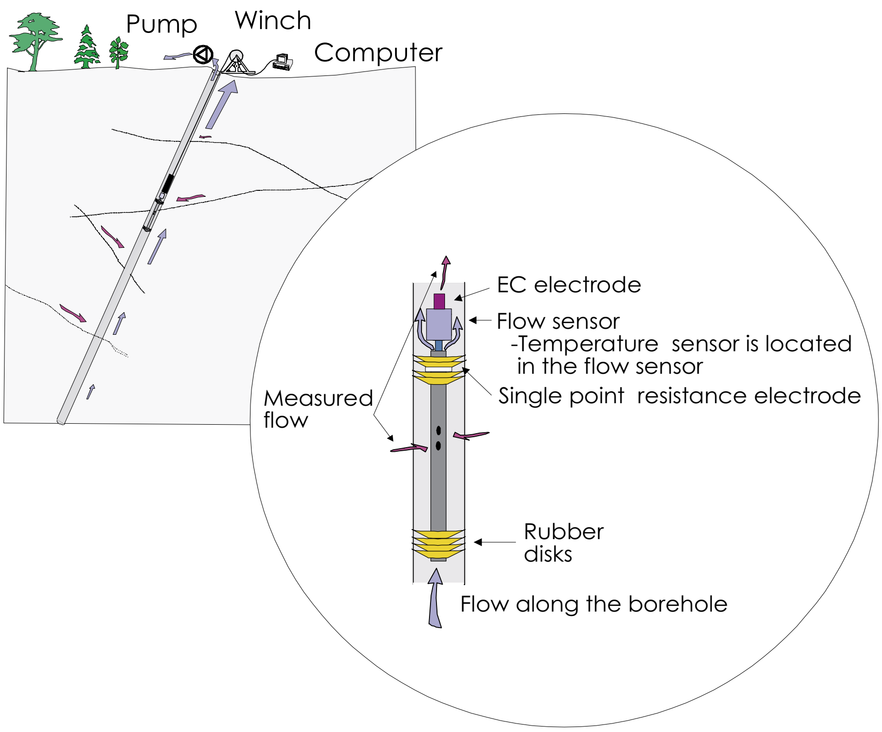

Figure 3-1. *Schematic presentation of the downhole equipment used in the Difference flowmeter.*

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 applied because it operates faster than the thermal pulse method.

Besides incremental changes of flow, the downhole tool of the Difference flowmeter can 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, see Chapter 2. 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 via another tube to the borehole water, Figure 3-2.
- Temperature of the borehole water. The temperature sensor is placed within the flow sensor, Figure 3-1.

All of the above measurements were performed in KFM06A.

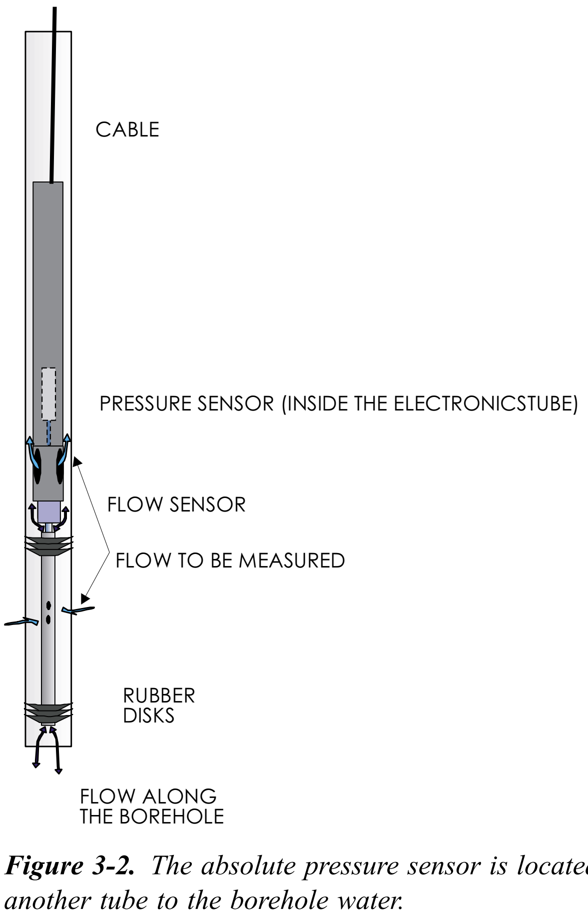

Figure 3-2. *The absolute pressure sensor is located inside the electronics tube and connected via another tube to the borehole water.*

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

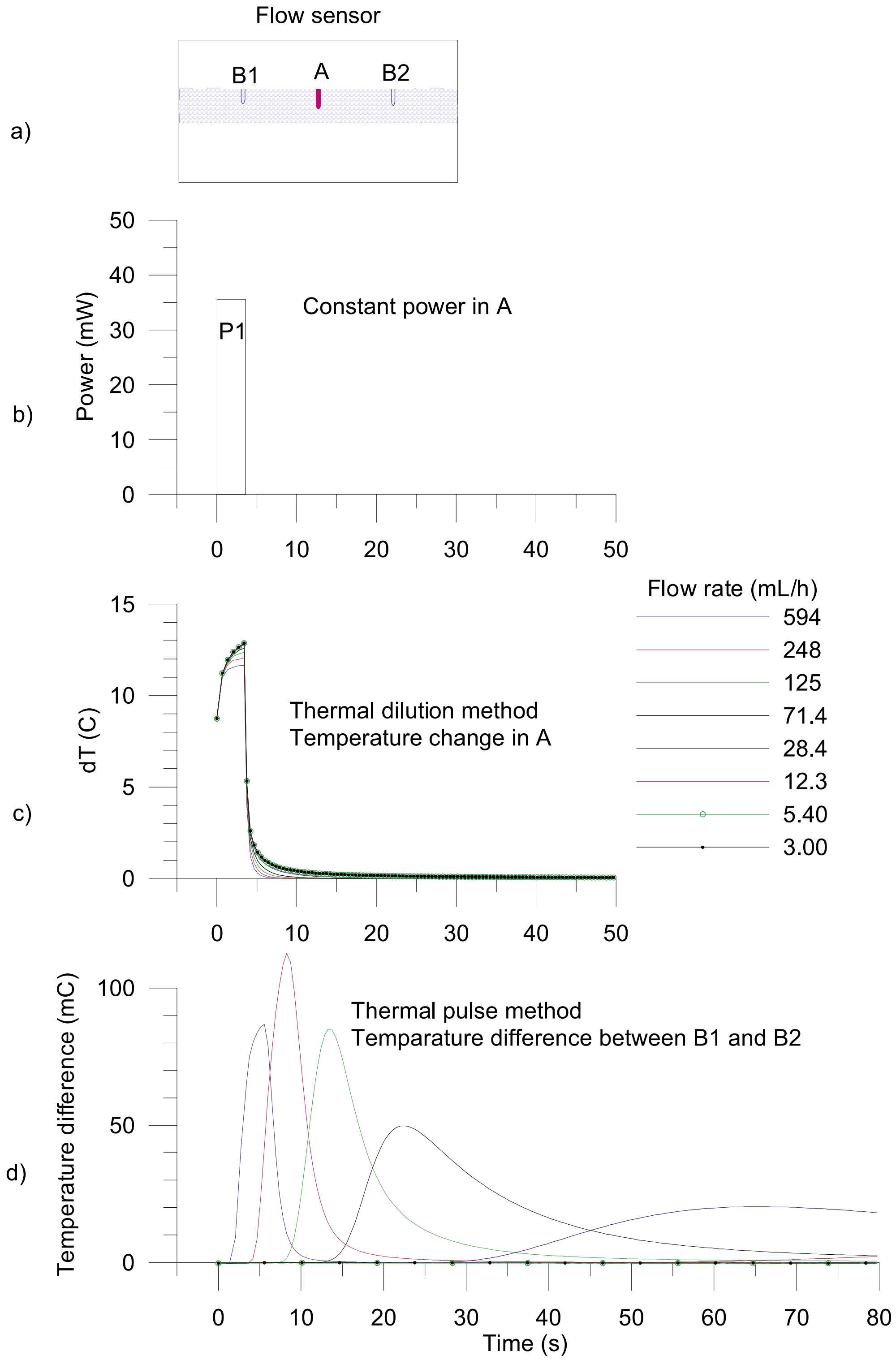

Figure 3-3. *Flow measurement, flow rate < 600 mL/h.*

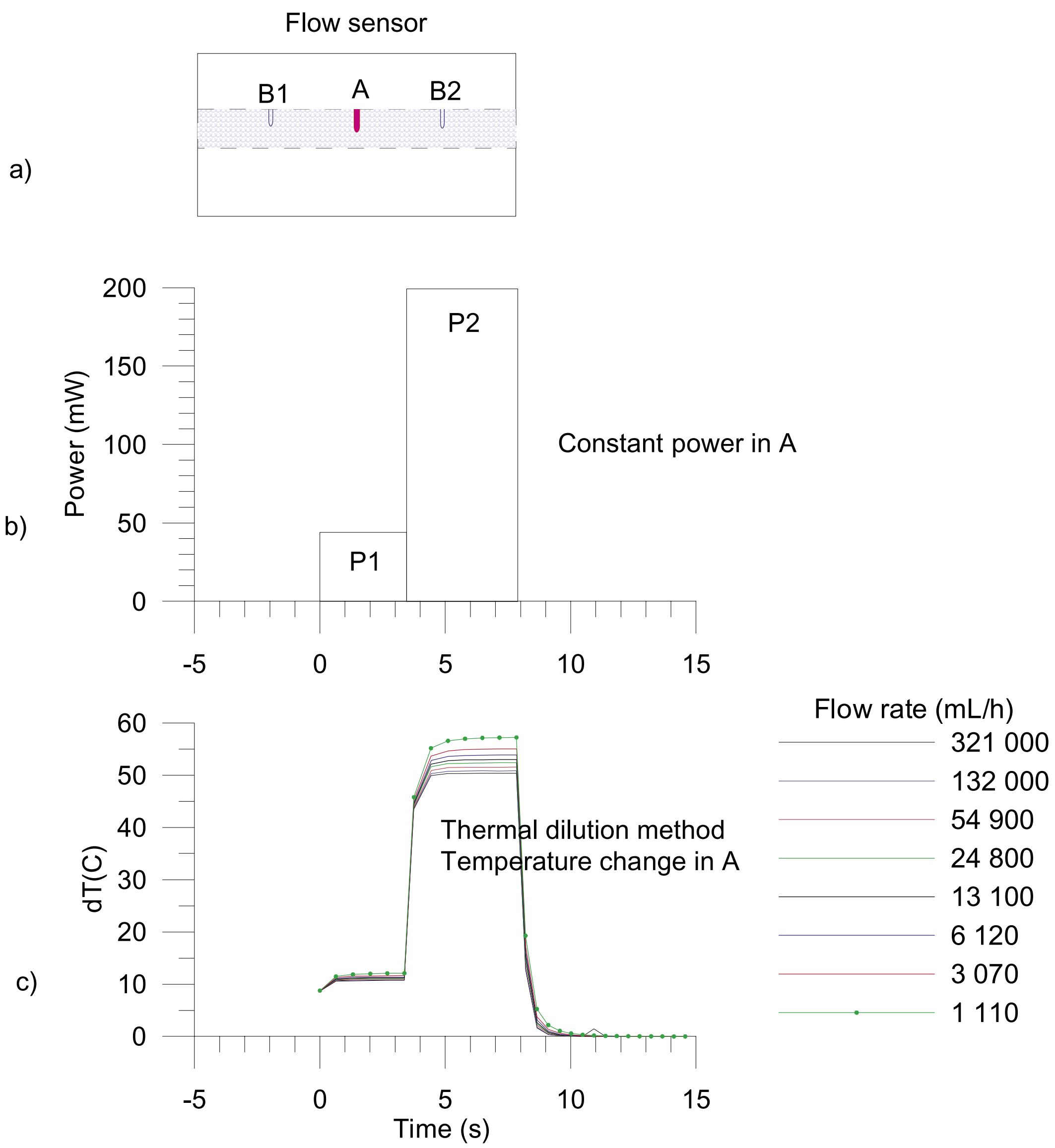

Figure 3-4. *Flow measurement, flow rate > 600 mL/h.*

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

If the flow rate during the constant power heating (Figure 3-3 b) falls below 600 mL/h, the measurement continues with monitoring of transient thermal dilution and thermal pulse response (Figure 3-3 d). When applying the thermal pulse method, also thermal dilution is always measured. The same heat pulse is used for 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 3-3 b) 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 correspond to the theoretical lowest measurable values. Depending on the borehole conditions, these limits may not always be valid. 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 measurements.

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

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/:

$$h_s - h = Q/(T \times a) \qquad 3\text{-}1$$

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

Q is the flow rate into the borehole,
T is the transmissivity of the test section,

a is a constant depending on the assumed flow geometry. For cylindrical flow, the constant a is:

$$a = 2 \times \pi / \ln(R/r_0) \qquad 3\text{-}2$$

where

r_0 is the radius of the well and
R is the radius of influence, i.e. the zone inside which the effect of the pumping is felt.

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

$$Q_{s0} = T_s \times a \times (h_s - h_0) \qquad 3\text{-}3$$
$$Q_{s1} = T_s \times a \times (h_s - h_1) \qquad 3\text{-}4$$

where

h_0 and h_1 are the hydraulic heads in the borehole at the test level,
Q_{s0} and Q_{s1} are the measured flow rates in the test section,
T_s is the transmissivity of the test section and
h_s is the undisturbed hydraulic head of the tested zone far from the borehole.

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

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

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

$h_s = (h_0 – b \times h_1)/(1–b)$ 3-5

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

where

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

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

$h_f = (h_0 – b\ h_1)/(1–b)$ 3-7

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

where

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

h_f and T_f are the hydraulic head (far away from borehole) and the transmissivity of a fracture, respectively.

Since 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/.

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 76–77 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 XP.
Software:	Based on MS Visual Basic.
Total power consumption:	1.5–2.5 kW depending on the pumps.
Calibrated:	April 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

5.1 Difference flow logging in KFM06A

The Commission was performed according to Activity Plan AP PF 400-04-76 following the SKB Method Description 322.010, Version 1.0 (Method description for difference flow logging). The Activity Plan and the Method Description are both SKB internal controlling documents. Prior to the measurements, the downhole tools and the measurement cable were disinfected. Time was synchronized with 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 KFM06A, 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.

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 flow meter 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 KFM06A (Item 6 in Table 5-1). These methods also reveal parts of the borehole widened for other reason (fracture zones, breakouts etc).

The caliper- and SPR-measurements were preceded by measurements of electric conductivity (EC) of the borehole water (Item 7) during natural (un-pumped) conditions.

The overlapping flow logging (Item 8) was carried out in the borehole interval 100.43–992.08 m. The section length was 5 m and the length increment (step length) 0.5 m. The measurements were performed during natural (un-pumped) conditions.

Pumping was started on October 15th. After c 25 hours waiting time, the overlapping flow logging (Item 9) was measured in the same interval, 100.43–992.08 m, using the same section and step lengths as before.

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 10). After that, fracture specific EC was measured on water from some selected fractures (Item 11).

Still during pumped conditions, EC of the borehole water (Item 12) was measured. After this, the pump was stopped and the recovery of the groundwater level was monitored (Item 13).

Table 5-1. Flow logging and testing in KFM06A. Activity schedule.

Item	Activity	Explanation	Date
6	Length calibration of the downhole tool.	Dummy logging (SKB Caliper and SPR). Logging without the lower rubber discs, no pumping.	2004-10-11 2004-10-13
7	EC- and temp-logging of the borehole fluid.	Logging without the lower rubber discs, no pumping.	2004-10-13
8	Overlapping flow logging.	Section length L_w = 5 m. Step length dL = 0.5 m. No pumping.	2004-10-13 2004-10-15
8 extra	Overlapping flow logging.	Section length L_w = 5 m. Step length dL = 0.5 m. No pumping. Lengths 776, 399, 398, 386, 385, 373 and 341 m were re-measured to define the flow direction.	2004-10-15
9	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).	2004-10-15 2004-10-17
10	Overlapping flow logging.	Section length L_w = 1 m. Step length dL = 0.1 m, at pumping.	2004-10-17 2004-10-19
11	Fracture-specific EC-measurements in pre-selected fractures.	Section length L_w = 1 m, at pumping (in pre-selected fractures).	2004-10-19 2004-10-20
12	EC- and temp- logging of the borehole fluid .	Logging without the lower rubber discs, at pumping.	2004-10-20
13	Recovery transient.	Measurement of water level and absolute pressure in the borehole after stop of pumping.	2004-10-20 2004-10-21
10 extra	Overlapping flow logging.	Section length L_w = 1 m. Step length dL = 0.1 m, at pumping (spots where flow exceeded the measurement limit were re-measured using a smaller drawdown).	2004-10-21

The length interval 124–276 m was selectively re-measured using a smaller drawdown, since the flow rate exceeded the measurement limit in several fractures in this interval. A section length of 1 m and a step length of 0.1 m were used here, (Item 10 extra).

5.2 Nonconformities

No deviations from were made the activity plan.

6 Results

6.1 Length calibration

6.1.1 Caliper and SPR measurement

Accurate length measurements are difficult to perform in long boreholes. The main cause of inaccuracy is stretching of the logging cable. The stretching depends on the tension of the cable, the magnitude of which in turn depends, among other things, on the inclination of the borehole and on the friction against the borehole wall. The cable tension is larger when the borehole is measured upwards. The cables, especially new cables, may also stretch out permanently. In KFM06A 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:

- The Caliper+SPR measurements (Item 6) were initially length corrected in relation to the known length marks, Appendix 1.42, black curve. Corrections between the length marks were obtained by linear interpolation.
- The SPR curve of Item 6 was then compared with the SPR curves of Items 8, 9, 10 and 11 to obtain relative length errors of these measurement sequences.
- All SPR curves could then be synchronized, as can be seen in Appendices 1.2–1.41.

The results of the caliper and single point resistance measurements from all measurements in the entire borehole are presented in Appendix 1.1. Six SPR-curves are plotted together with caliper-data. These measurements correspond to Items 6, 8, 9, 10, 11 and 10 extra in Table 5-1.

Zoomed results of caliper and SPR are presented in Appendices 1.2–1.41. The length marks were detected at 152 m, 200 m, 250 m, 301 m, 400 m (only the upper one), 500 m, 600 m, 648 m (only the upper one) and at 750 m. The length marks were not detected at 350 m, 450 m, 550 m, 700 m, 800 m, 850 m, 900 m, 950 and at 980 m. Because of many undetectable length marks, length correction values from borehole KFM05A were used for the lower end of the borehole. Boreholes KFM05A and KFM06A are very similar and the downhole tool was the same, so it can be assumed that also the length corrections are near each other. The length correction were done at 152 m, 200 m, 250 m, 301 m, 400 m, 500 m, 600 m, 648 m, 750 m and at 1,000 m. The length mark traces can be seen in the SPR results. However, the anomaly is complicated due to the four rubber disks used at the upper end of the section, two at 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 1.2–1.41 is to verify the accuracy of the length correction. The curves in these plots represent length corrected results. The same length corrections were applied to the flow- and EC measurements.

The magnitude of length correction along the borehole is presented in Appendix 1.42. 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 the following reasons:

1. The point interval in flow measurements is 0.1 m in overlapping mode. This could cause an error of +/– 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, however, 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. Flow may be detected already when a fracture is situated between the upper rubber disks. These phenomena, which can only be seen with a short step length (0.1 m), could cause an error of +/– 0.05 m.
3. Corrections between the length marks can be other than linear. This could cause an error of +/– 0.1 m in the caliper/SPR measurement (Item 6).
4. SPR curves may be imperfectly synchronized. This could cause an error of +/–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 accumulated. 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 flow logging and borehole TV. In that case, the situation may not be as severe as for the worst case above, since part of the length errors are systematic and the length error is nearly constant for 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 Electric conductivity and temperature

6.2.1 Electric conductivity and temperature of borehole water

The electric conductivity of the borehole water (EC) was initially measured when the borehole was at rest, i.e. at natural, un-pumped conditions. The measurements were performed in both directions, downwards and upwards, see Appendix 2.1.

The EC measurements were repeated during pumping (after a pumping period of about five days), see Appendix 2.1, green curve 2004-10-20. The results show clear inflow of saline water at the length of about 270 m. Clear inflow of fresh water was detected at the length of about 360 m. At these lengths there were also high calculated transmissivities, see Appendices 7.1–7.3 and 8.

Temperature of borehole water was measured simultaneously with the EC-measurements. The EC-values are temperature corrected to 25°C to make them more comparable with other EC measurements /Heikkonen et al. 2002/. The temperature results in Appendix 2.2 correspond to the EC results in Appendix 2.1. Pumping changed temperature profiles above the length of 260 m; high pumping flow rate is an apparent reason to this.

The length calibration of the borehole EC measurements is not as accurate as for the other measurements, because SPR is not registered during the borehole EC measurements. Instead the length correction of the Caliper measurement was applied to the borehole EC measurements, black curve in Appendix 1.42.

6.2.2 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 identify 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 = 1 m). The EC measurements are commenced if the flow rate exceeds 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 necessary 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 exchange the water volume within the test section about three times. The water volume in a one metre long test section is about 3.6 L. In this case, the waiting times were selected to be much longer than the calculated times.

Electric conductivity of fracture-specific water is presented on a time scale, see Appendix 11.1–11.2. The blue symbol represents the value when the tool was moved (one metre 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 Appendix 11.3.

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
125.29	126.29	126.0	1.18
127.99	128.99	128.5, 128.9	1.38
128.80	129.80	128.9, 129.4	1.46
129.60	130.60	130.3	1.46
131.00	132.00	131.7, 132.0	1.44
134.71	135.71	135.0, 135.4	1.43
176.77	177.77	177.4	1.51
180.47	181.47	181.0, 181.2	1.49
217.49	218.49	218.2	1.46
237.25	238.25	238.0	1.48
267.89	268.89	268.6	1.43
268.69	269.69	269.3	1.45
356.10	357.10	356.6	1.17
742.79	743.79	743.3	1.36

6.3 Pressure measurements

The absolute pressure was registered together with the other measurements in Items 7–13 in Table 5-1. The pressure sensor measures the sum of hydrostatic pressure in the borehole and the air pressure. Air pressure was also registered separately, see Appendix 10.2. Hydraulic head along the borehole at natural and pumped conditions respectively 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 calculated according to the following expression /Nordqvist, 2001/:

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

where

h is the hydraulic head (masl) according to the RHB 70 reference system,

p_{abs} is the absolute pressure (Pa),

p_b is the barometric (air) pressure (Pa),

ρ_{fw} is the unit density, 1,000 kg/m^3

g is the 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.

The calculated head distributions are presented in Appendix 10.1. Exact z-coordinates are important in head calculation. 10 cm error in the z-coordinate means 10 cm error in head.

6.4 Flow logging

6.4.1 General comments on results

The measuring program contains several flow logging sequences. They are presented on the same plots as the single point resistance (right hand side) and caliper plots (in the middle), see Appendices 3.1–3.45. Single point resistance usually shows a low resistance value on a fracture where flow is detected. There are also many 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 Caliper tool shows a low voltage when the borehole diameter is below 77 mm and a high voltage when the borehole diameter exceeds 77 mm.

The flow logging was firstly performed with a 5 m section length and with 0.5 m length increments, see Appendices 3.1–3.45 (red curve with pumping, dark blue curve without pumping). 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 initially for flow determination.

Under natural conditions flow direction may be into or out from the borehole. For small flow rates (< 100 ml/h) the flow direction cannot be seen in the normal overlapping mode (thermal dilution method). These small flow anomalies were separately checked using the thermal pulse method to determine flow direction. This was only done during un-pumped conditions.

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. The upper part of the borehole (above 276 m) was selectively re-measured using smaller drawdown. The flow rate exceeded the measurement limit in several spots in this interval.

Detected fractures are shown on the caliper scale together with their positions (borehole length). They are interpreted on the basis of the flow curves and therefore represent flowing fractures. A long line represents the location of a leaky fracture; a 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 are unclear because of noise.

6.4.2 Transmissivity and hydraulic head of borehole sections

The entire borehole between 100.43 m and 992.08 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 5.1–5.6. Only the results with 5 m length increments are used. All borehole sections are shown in Appendices 3.1–3.45. Secup presented in Appendices 5.1–5.6 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, whereas seclow is calculated 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 however small. Secup and seclow given in Appendices 5.1–5.6 are calculated as an average of these two values.

Pressure was measured and calculated as described in Chapter 6.3. Dh_0 and dh_1 in Appendices 5.1–5.6 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 5.1–5.6 (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 is directed from the bedrock into the borehole and vice versa. With the borehole at rest, 21 sections were detected as flow yielding, of which 7 had a flow direction from the borehole into the bedrock (negative flow). During pumping, all 46 detected flows were directed towards the borehole.

At the length 135.53 m, the flow to the section during pumped conditions was calculated as the sum of fracture-specific flow rates. The 5 m section flow result was not reliable because the ends of the section were very close to some highly flow yielding fractures, and probably some flow from those fractures leaked into the section, see Appendices 3.2 and 3.3.

The upper limit of the measurable flow range was exceeded at the lengths of 125.50 m, 215.63 m, 235.67 m and 265.72 m when the borehole was pumped. Flow rates for transmissivity calculations and corresponding borehole heads at these locations (lengths) were taken from the re-measurements with a smaller drawdown (with a section length of 1 m).

Flow data are presented as a plot, see Appendix 6.1. 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 6.1) and in the tables (Appendix 5), also the lower and upper measurement limits of flow are presented. There are both theoretical and practical lower limit for the flow rate, see Chapter 6.4.4.

The hydraulic head and the transmissivity (T_D) of the borehole sections can be calculated from flow data using the method described in Chapter 3. The hydraulic head of the section 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 6.2. The measurement limits of transmissivity are also shown in Appendix 6.2 and in Appendix 5. All the measurement limit values of transmissivity are based on the actual pressure difference in the borehole (dh_0 and dh_1 in Appendix 5).

The sum of the detected flows without pumping (Q_0) was 1.19×10^{-6} m^3/s (4,275 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 is quite far from zero. A probable reason for this is that the borehole had been pumped before the flow logging measurements started. Conditions in the borehole were still slowly changing and the water level was crawling upwards during measurements without pumping, as can be seen in Appendix 10.3.

6.4.3 Transmissivity and hydraulic head of fractures

An attempt was made to evaluate the magnitude of the 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 the fracture distance is less than one metre, it may be difficult to evaluate the flow rate. Such cases are observed for instance in Appendix 3.2. An increase or decrease of a flow anomaly at the fracture location (marked with the lines in Appendix 3) is used for determination of flow rate.

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

The total amount of detected flowing fractures is 99, but only 13 were observed without pumping. These 13 fractures could be used for head estimations and all 99 were used for transmissivity estimations. The flow rate exceeded the upper measurement limit with high-transmissivity fractures at 130.3 m, 218.2 m and 269.3 m. These fractures were re-measured with a lower drawdown and the results were used for transmissivity and head calculations. Transmissivity and hydraulic head of fractures are presented in Appendices 7.1–7.3 and 8.

Some fracture-specific results were rated to be "uncertain", see Appendix 7.1. 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 metre, or since the form of anomaly was unclear because of noise.

Fracture-specific transmissivities were compared with transmissivities of borehole sections in Appendix 9. All fracture-specific transmissivities 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.

6.4.4 Theoretical and practical measurements limits of flow and transmissivity

The theoretical minimum of measurable flow rate in the overlapping measurements (thermal dilution method only) is about 30 mL/h. The thermal pulse method can also be used when the borehole is not pumped. Its theoretical lower limit is about 6 mL/h. In this borehole the thermal pulse method was only used for flow direction, not for flow rate. The upper limit of the flow measurement is 300,000 mL/h. These limits are determined on the basis of flow calibration. It is assumed that the flow can be reliably detected between the upper and lower theoretical limits during favourable borehole conditions.

The minimum measurable flow rate may, however be much higher in practice. The borehole conditions may have an influence on the base level of flow (noise level). The noise level can be evaluated for intervals of the borehole without 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 the borehole water, such as clay or drilling debris
3) Gas bubbles in water
4) High flow rate along the borehole

A rough borehole wall always causes a high noise level, not only in flow but also in single point resistance results. The flow curve and SPR curves are typically spiky when the borehole wall is rough.

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

Pumping causes a pressure drop in the borehole water and in fracture water near the borehole. This may lead to release of gas from dissolved form to gas bubbles. Some fractures may produce more gas than other. Sometimes an 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 a decrease of the average density of the water and therefore also a decrease of the measured head in the borehole.

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

A high noise level in flow rate masks a "real" flow rate, smaller than the noise level. Real flows are totally invisible if they are about ten times smaller than the noise level. Real flows are registered correctly if they are about ten times larger than the noise level. By experience, real flow rates between 1/10 times the noise and 10 times the noise are summed up with the noise. Therefore, the 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 every case.

The noise level was not a serious problem in borehole KFM06A. The practical minimum level of flow rate is evaluated and presented in Appendices 3.1–3.45 using a grey dashed line (Lower limit of flow rate). Below this line there may be fractures or structures that remain undetected.

The noise level in KFM06A was between 5–30 ml/h. Mostly it fell below 30 mL/h, i.e. below the theoretical limit of thermal the dilution method. However, the noise line (grey dashed line) was never drawn below 30 mL/h. In many cases there are flow anomalies smaller than 30 mL/h. These fractures are marked with a short line indicating "uncertain".

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 a smaller drawdown. In KFM06A, five different locations were re-measured using a smaller drawdown.

The practical minimum of measurable flow rate is also presented in Appendix 5 (Q-lower limit P). It is taken from the plotted curve in Appendix 3 (Lower limit of flow rate). The practical minimum of measurable transmissivity can be evaluated using Q-lower limit and the actual head difference at each measurement, see Appendix 5 (T_D-measl$_{LP}$). The theoretical minimum measurable transmissivity (T_D-measl$_{LT}$) can also be evaluated using a Q value of 6 mL/h (minimum theoretical flow rate with the thermal pulse method) instead of Q-lower limit P.

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 5 (T_D-measl$_U$).

All three flow limits are also plotted with measured flow rates, see Appendix 6.1. Theoretical minimum and maximum values are 6 mL/h and 300,000 mL/h, respectively.

The three transmissivity limits are also presented graphically, see Appendix 6.2. The upper transmissivity measurement limit is constant but increases at certain positions. At these locations, a lower pumping rate (less head difference) was used, due to the high flowing fractures at these locations.

Similar flow and transmissivity limits are not given for the fracture-specific results, Appendices 7.1–7.3. Approximately the same limits would be valid also for these results. However, the exact 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 highly water yielding fracture. The situation is similar for the upper flow limit. If there are several highly flow yielding fractures closer to each other than one metre, the upper flow limit depends on the sum of the flows, which must fall below 300,000 mL/h.

6.5 Groundwater level and pumping rate

The groundwater level in the borehole during the measurement sequences is presented in Appendix 10.3. The borehole was pumped between October 15 and 20 with a drawdown of about 9.1 m. The borehole was also pumped a short time on October 21 with a smaller drawdown. Pumping rate was recorded, see Appendix 10.5.

The groundwater recovery was measured after the first pumping period, on March 20–21, Appendix 10.4. The recovery was measured with two sensors, using the water level sensor (pressure sensor for monitoring water level) and the absolute pressure sensor located at the borehole length of 984.86 m.

6.6 Evaluation of pumping test

6.6.1 General

The transmissivity of the entire cored borehole interval (c 100–1,000 m) was estimated from the pumping test in conjunction with the difference flow logging campaign in borehole KFM06A. The borehole transmissivity was estimated from the groundwater recovery period using data from both the high-resolution absolute pressure sensor at the bottom of the borehole and from the water level sensor, cf Appendix 10.4. In addition, the borehole transmissivity was estimated from the first part (c 24 h) of the flow period with nearly constant flow rate before a constant drawdown of the water level was applied, cf Appendix 10.3, and using data from both the absolute- and water level sensor. However, the flow period was disturbed due to the stop and restart of the pump in the beginning of this period. The pumping flow rate was c 65 L/min during the first part of the flow period causing a drawdown of the water level of c 9.1 m, cf Appendix 10.3.

The main purposes of the analysis of the pumping test during the difference flow logging were to estimate the total transmissivity of the cored borehole interval and to deduce information on possible hydraulic outer hydraulic boundaries during the test.

Furthermore, the results of the pumping test should be compared with the results of the difference flow logging in the borehole regarding estimated transmissivities of the measured 5 m sections and flow anomalies identified.

The registration of the water level, flow rate and pressure recovery was performed according to the Activity Plan AP PF 400-04-76 (SKB internal controlling document) and the methodology description for difference flow logging (SKB MD 322.010, Version 1.0). The evaluation of the pumping test was made in accordance with the Method Instruction SKB MD 320.004, Version 1.0 (Instruktion för analys av injektions- och enhålspumptester).

By the calculation of the pressure drawdown and -recovery from the absolute pressure sensor, the atmospheric pressure was subtracted from the measured pressure data. The variations of the atmospheric pressure during the test period are shown in Appendix 10.2. However, no such corrections were made on the measured (gauge) pressure data from the superficial transducer. By the calculation of the pressure derivatives during the flow- and recovery periods, different values were applied on the filter coefficient (step length) to study its effect on the derivative. It is desired to achieve maximum smoothing of the derivative without altering the original shape of the data curve, i.e the lowest possible step length.

Firstly, a qualitative evaluation was performed to identify the actual flow regimes during the flow- and recovery period (e.g. wellbore storage, pseudo-radial flow etc) and possible outer hydraulic boundary conditions. The qualitative analysis was made from the pressure responses together with the corresponding pressure derivatives versus time, preferably in the log-log diagrams. The pressure recovery was plotted versus real time after stop of pumping since both the pressure and flow rate were rather stable at the end of the flow period and the recovery period was rather short compared to the flow period.

The quantitative, transient interpretation of hydraulic parameters from the pumping borehole (e.g. transmissivity and skin factor) was based on the identified pseudo-radial flow regimes using the code AQTESOLV. By the analysis of the flow period, a variable flow rate was applied to account for the change in flow rate made by the stop and start of the submersible pump in the beginning of the flow period. Finally, a steady-state analysis (Moye's formula) was also made from the flow period.

6.6.2 Results

The nomenclature and symbols used for the results of the pumping test are according to SKB MD 320.004. Additional symbols used are explained in the text. The nomenclature applied in the diagrams prepared by the code AQTESOLV is shown in Appendix 12. Since no pressure responses in observation boreholes were observed, a value on the storativity must be assumed by the calculation of the skin factor. In this case, the value $S^* = 5 \cdot 10^{-5}$, obtained from interference tests in Forsmark /Ludvigson and Jönsson, 2003/, was assumed. A summary of the results of the pumping test in KFM06A is presented in Table 6-1. Selected test diagrams according to the Instruction for analysis of single-hole injection- and pumping tests together with simulated responses are presented in Appendix 12.

Interpreted flow regimes

Figures A12-1 and A12-2 in Appendix 12 show log-log- respectively lin-log graphs of the pressure recovery versus time after stop of pumping using data from the absolute pressure sensor. Figure A12-2 demonstrates that wellbore storage effects (WBS) were only seen during the first c 50 s of the pressure response in the (open) pumping borehole.

After a transition period, a nearly pseudo-radial flow regime occurred after c 1,000 s as indicated by the pressure derivative, cf Figure A12-2. No significant effects of hydraulic outer boundaries were seen during the recovery period, although a slight leakage flow is indicated by the end. Although not shown, very similar results were obtained using water level data from the superficial pressure sensor for the recovery period.

The pressure drawdown (measured by the absolute pressure sensor) during the first phase (c 24 h) of the flow period is displayed in Figures A12-3 and A12-4 in Appendix 12. As described above, the pump was stopped after c 2 500 s and re-started after c 6 500 s causing the disturbance in the graphs. As for the recovery period, wellbore storage effects occurred to c 50 s during the flow period, cf Figure A12-3. After re-starting the pump, transition to a pseudo-radial flow regime is indicated, followed by pseudo-spherical (leaky) flow by the end of the first part of the flow period. No evidences of outer hydraulic boundaries were seen during this period. The drawdown data from the absolute- and superficial pressure sensors were again very similar during the flow period.

Interpreted parameters

The transient analysis of the recovery period and the first part of the flow period was based on the identified periods with pseudo-radial flow according to theories for constant flow rate tests. The interpreted hydraulic parameters from the recovery period are considered as the most representative for the borehole. The results of the evaluation are presented in Table 6-1. The results from the flow- and recovery period are very consistent.

The calculated borehole transmissivity is similar to the cumulative transmissivity ($T = 1.1 \times 10^{-4}$ m²/s) of the measured 5 m sections and of the fractures identified during the difference flow logging, cf Appendix 5 and 7, respectively. The calculated values on the wellbore storage coefficient C are consistent with those calculated from borehole geometrical data.

Table 6-1. Summary of calculated hydraulic parameters from the pumping test in conjunction with difference flow logging in borehole KFM06A.

Test period	Q/s (m^2/s)	T_M (m^2/s)	T_T (m^2/s)	S* (–)	ζ (–)	C (m^3/Pa)
Flow period – first part	1.19×10^{-4}	1.97×10^{-4}	8.04×10^{-5}	5×10^{-5}	–5.18	4.02×10^{-6}
recovery			8.82×10^{-5}	5×10^{-5}	–4.80	3.16×10^{-6}

Q/s = specific flow,

T_M = steady-state transmissivity from Moye´s formula,

T_T = calculated transmissivity from transient evaluation of the test,

S^* = assumed value on the storativity,

ζ = skin factor,

C = wellbore storage coefficient.

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 KFM06A at Forsmark. 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.

Length calibration was made using the length marks on the borehole wall. The length marks were detected by caliper and 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 synchronizing the single point resistance logs.

The distribution of saline water along the borehole was logged by electric conductivity and temperature measurements of the borehole water. In addition, electric conductivity was measured in selected flowing fractures.

The total amount of 99 flowing fractures was detected. Transmissivity and hydraulic head were calculated for borehole sections and fractures. The highest transmissivity ($1.93 \cdot 10^{-5}$ m^2/s) was detected in a fracture at the borehole length of 130.3 m. High-transmissive fractures were also found at 181.2 m, 218.2 m, 238.0 m and 269.3 m. Below 770.8 m no flowing fractures were identified.

The total transmissivity of the cored borehole KFM06A was estimated at $8.9 \cdot 10^{-5}$ m^2/s from the groundwater recovery after the pumping during difference flow logging. This value is in good agreement with the cumulative transmissivities of the measured 5 m sections and of the flow anomalies identified, i.e. $1.1 \cdot 10^{-4}$ m^2/s. No effects hydraulic boundaries were observed during the recovery period.

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Appendices

Appendices	1.1–1.41	SPR and Caliper results after length correction
Appendix	1.42	Length correction
Appendix	2.1	Electric conductivity of borehole water
Appendix	2.2	Temperature of borehole water
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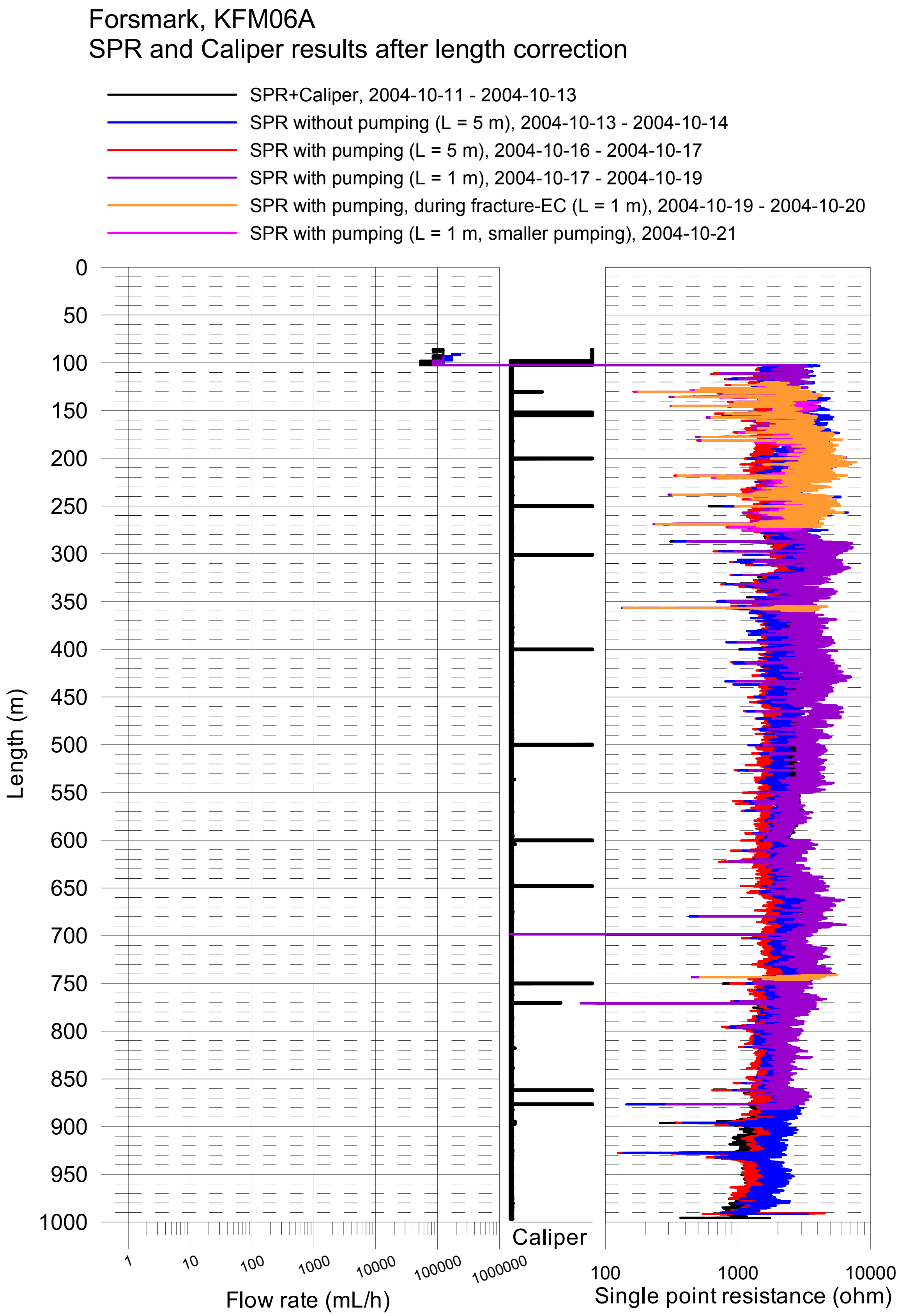
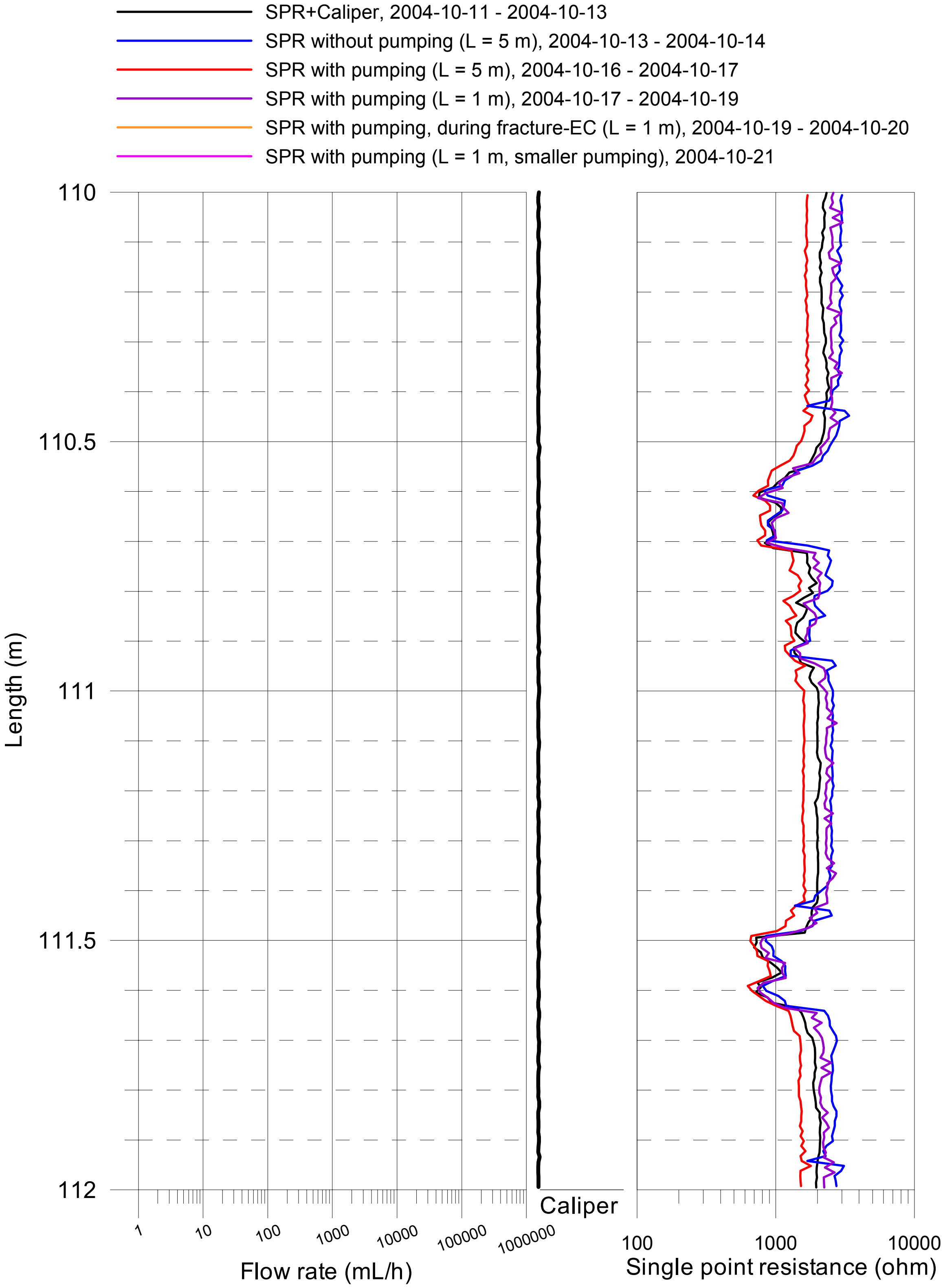
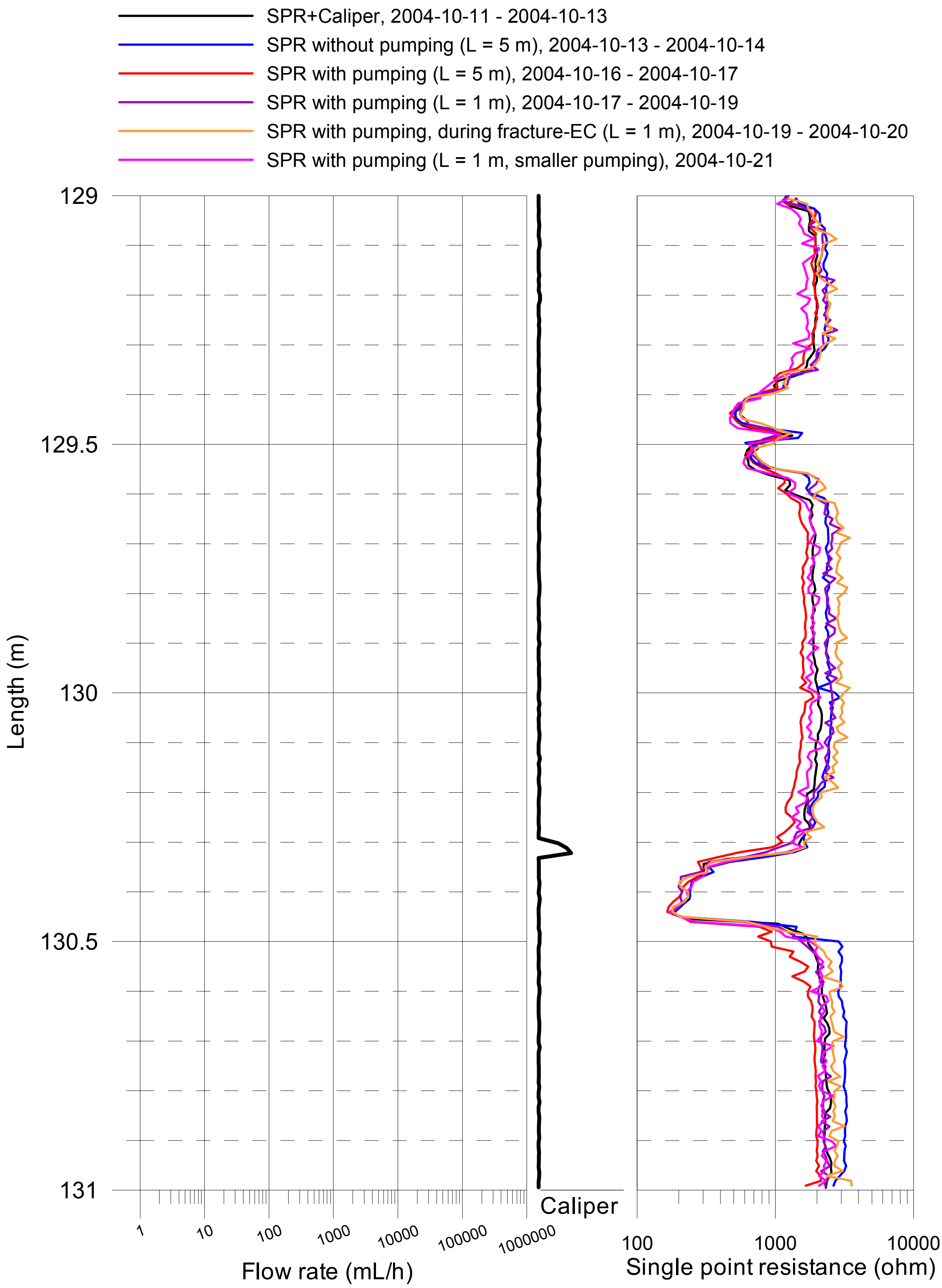
Appendix	10.5	Pumping rate
Appendices	11.1–11.3	Fracture-specific EC results
Appendices	12.1–12.3	Test diagrams from the pumping during difference flow logging


Forsmark, KFM06A
SPR and Caliper results after length correction
SPR+Caliper, 2004-10-11 - 2004-10-13
SPR without pumping (L = 5 m), 2004-10-13 - 2004-10-14
SPR with pumping (L = 5 m), 2004-10-16 - 2004-10-17
SPR with pumping (L = 1 m), 2004-10-17 - 2004-10-19
SPR with pumping, during fracture-EC (L = 1 m), 2004-10-19 - 2004-10-20
SPR with pumping (L = 1 m, smaller pumping), 2004-10-21
Length (m)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900
950
1000
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
Single point resistance (ohm)

Forsmark, KFM06A
SPR and Caliper results after length correction



Forsmark, KFM06A
SPR and Caliper results after length correction



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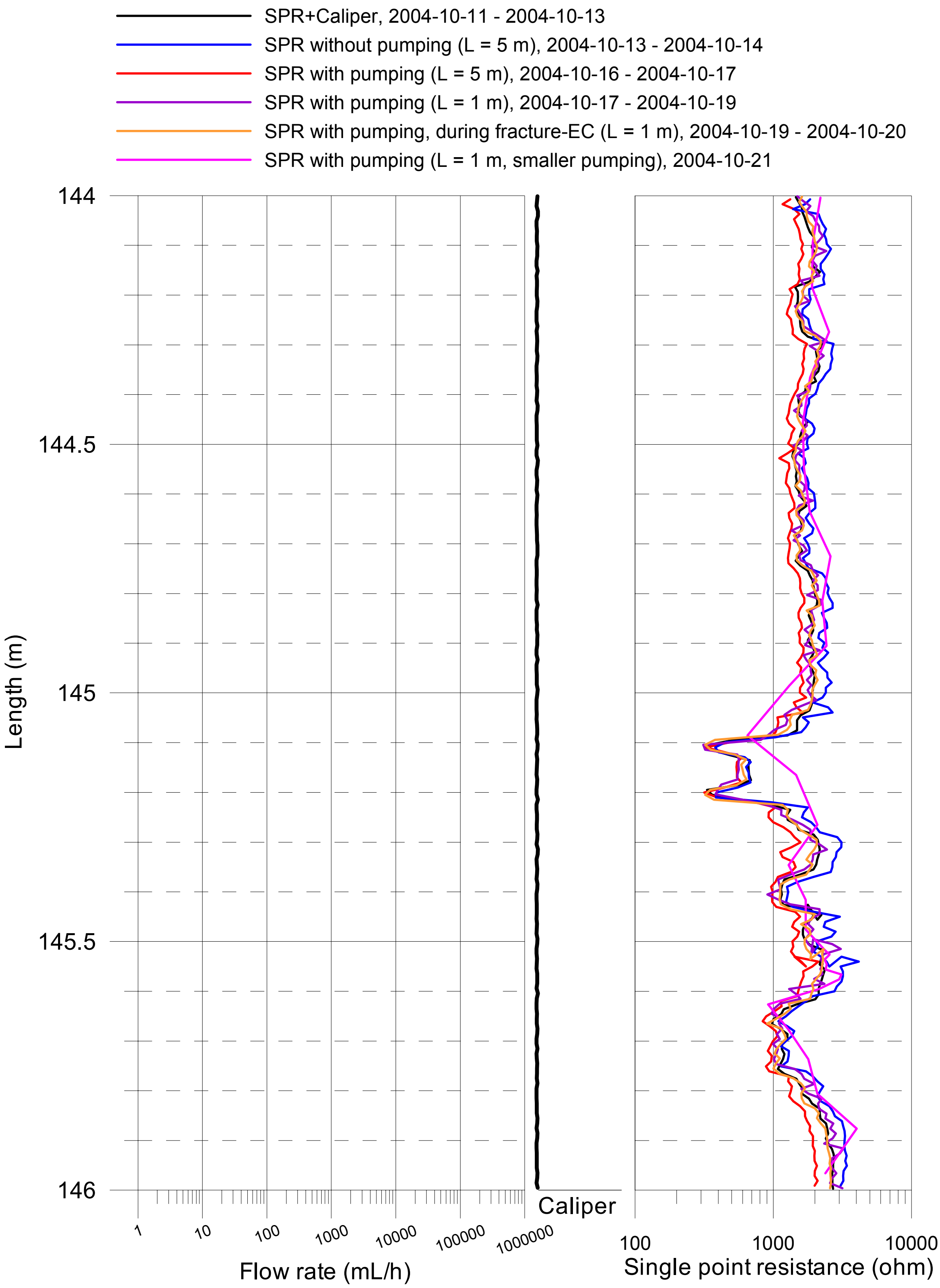
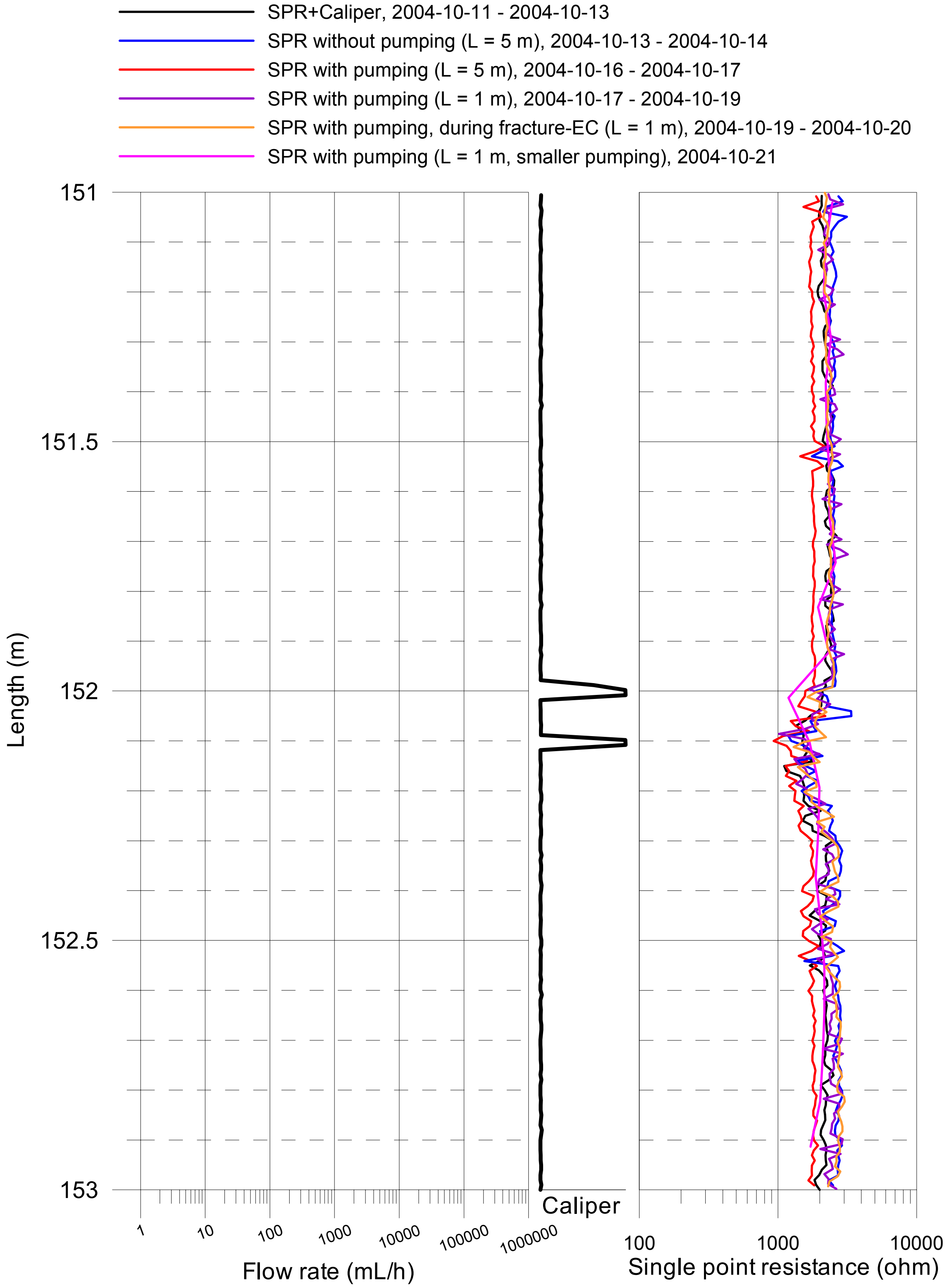
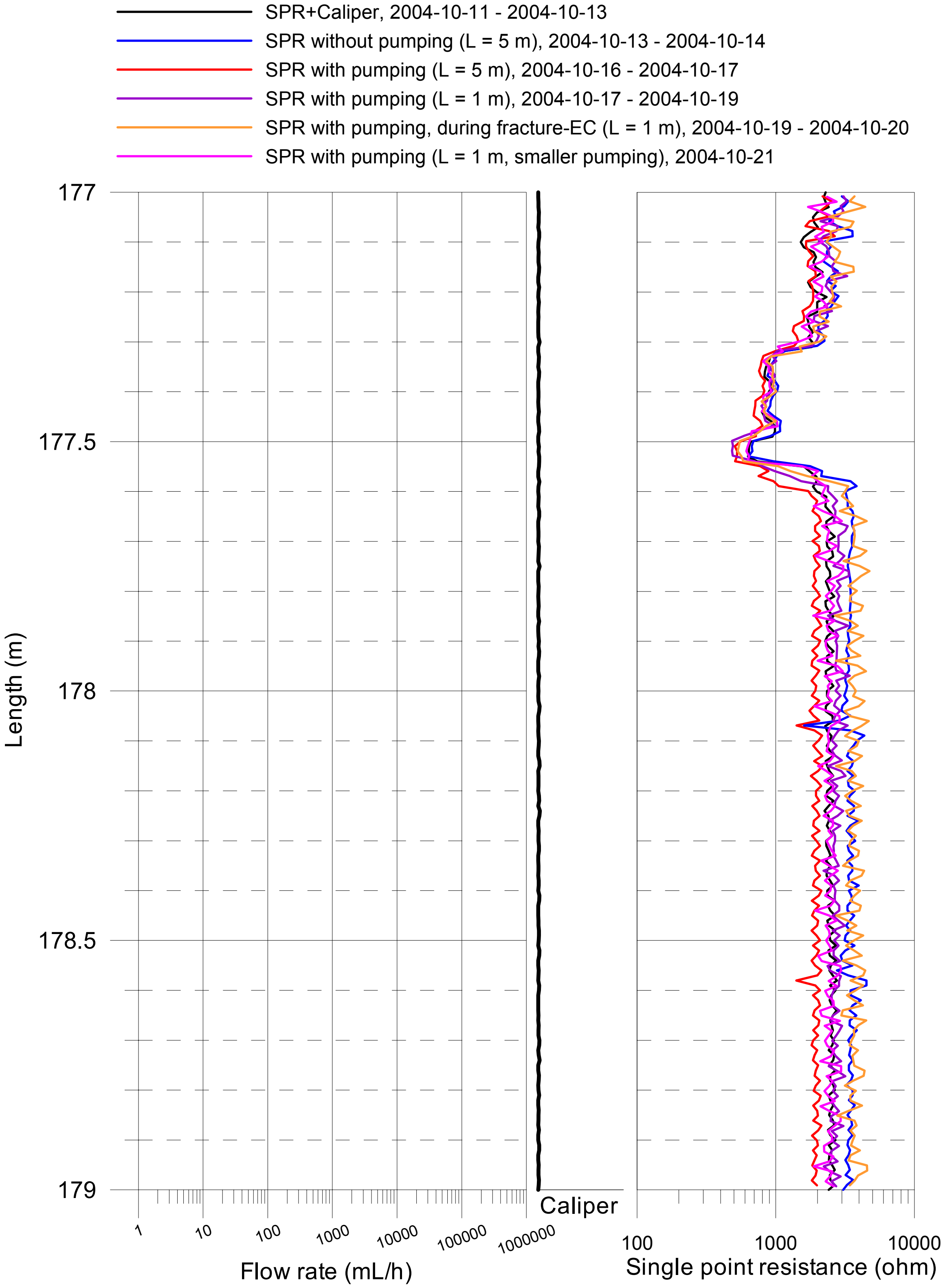
SPR and Caliper results after length correction



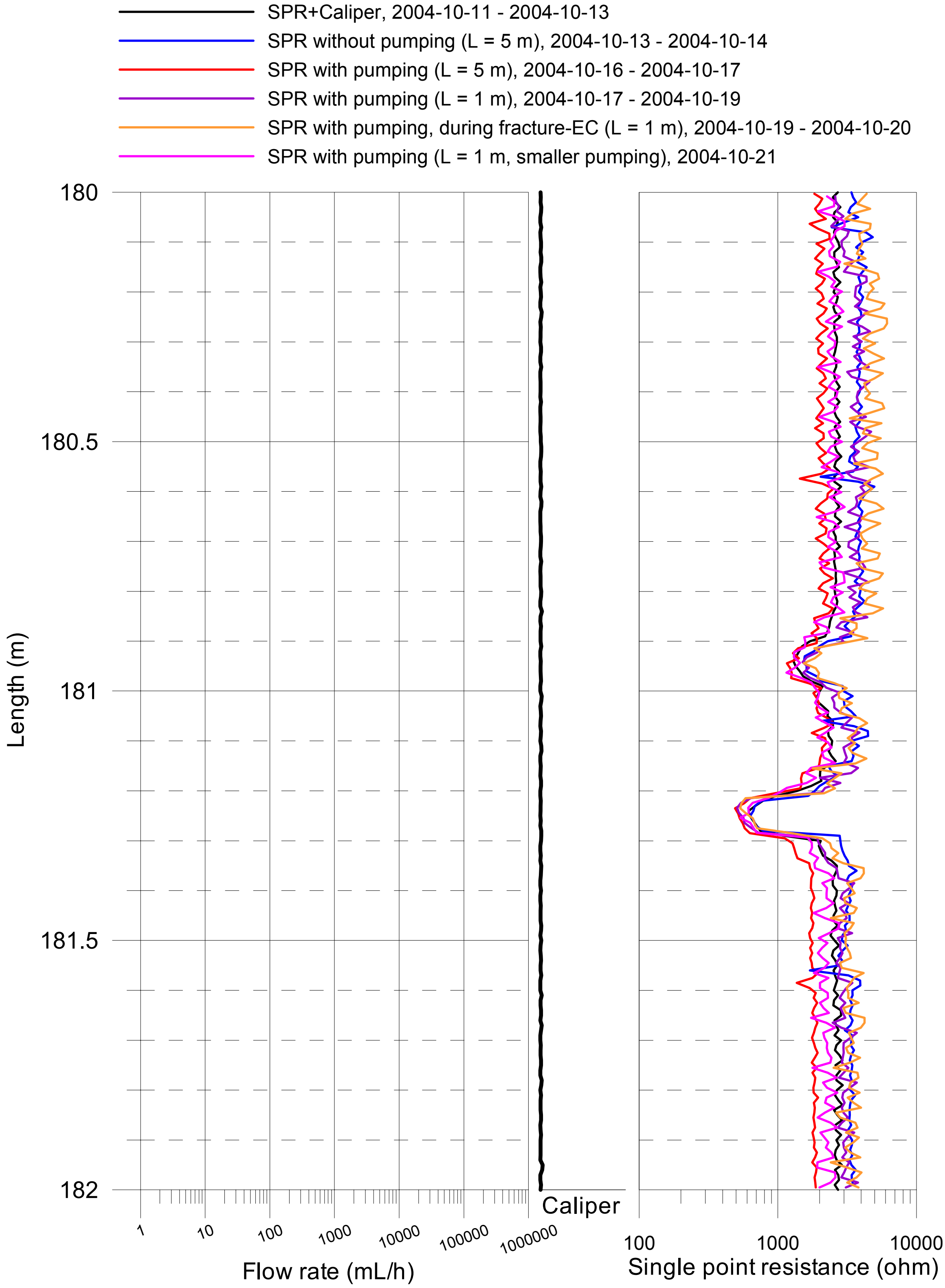
Forsmark, KFM06A
SPR and Caliper results after length correction



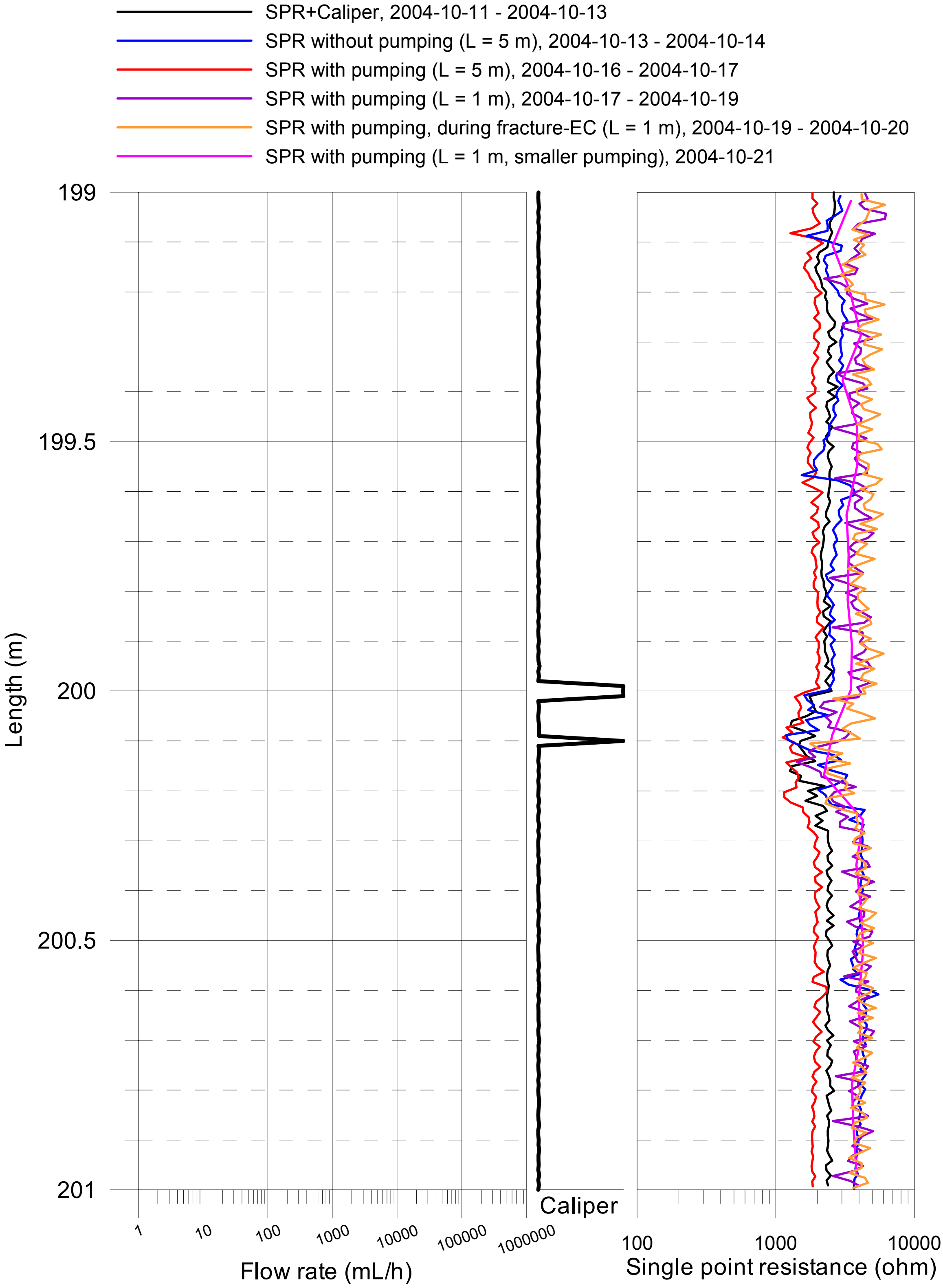
Forsmark, KFM06A
SPR and Caliper results after length correction

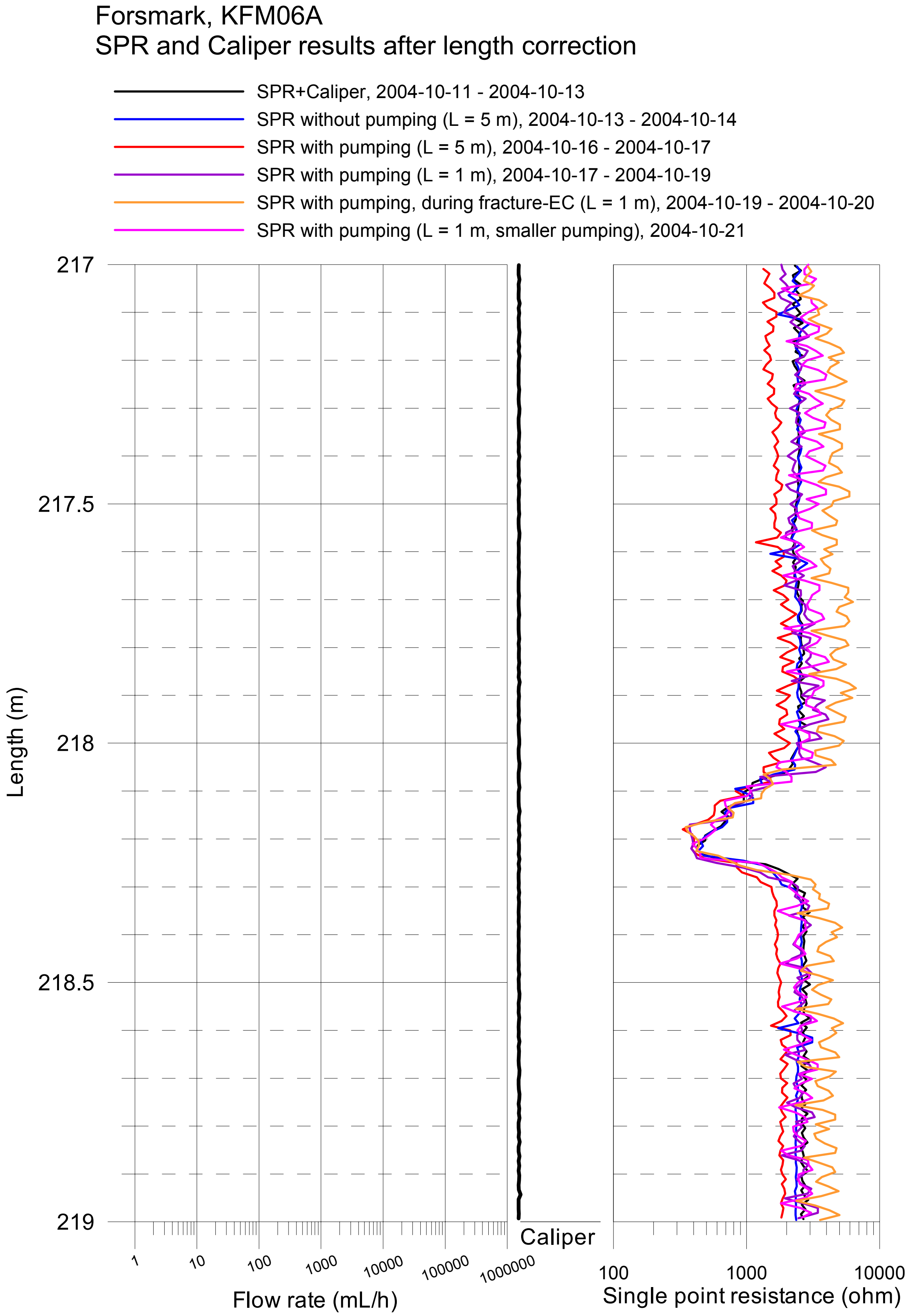


Forsmark, KFM06A
SPR and Caliper results after length correction

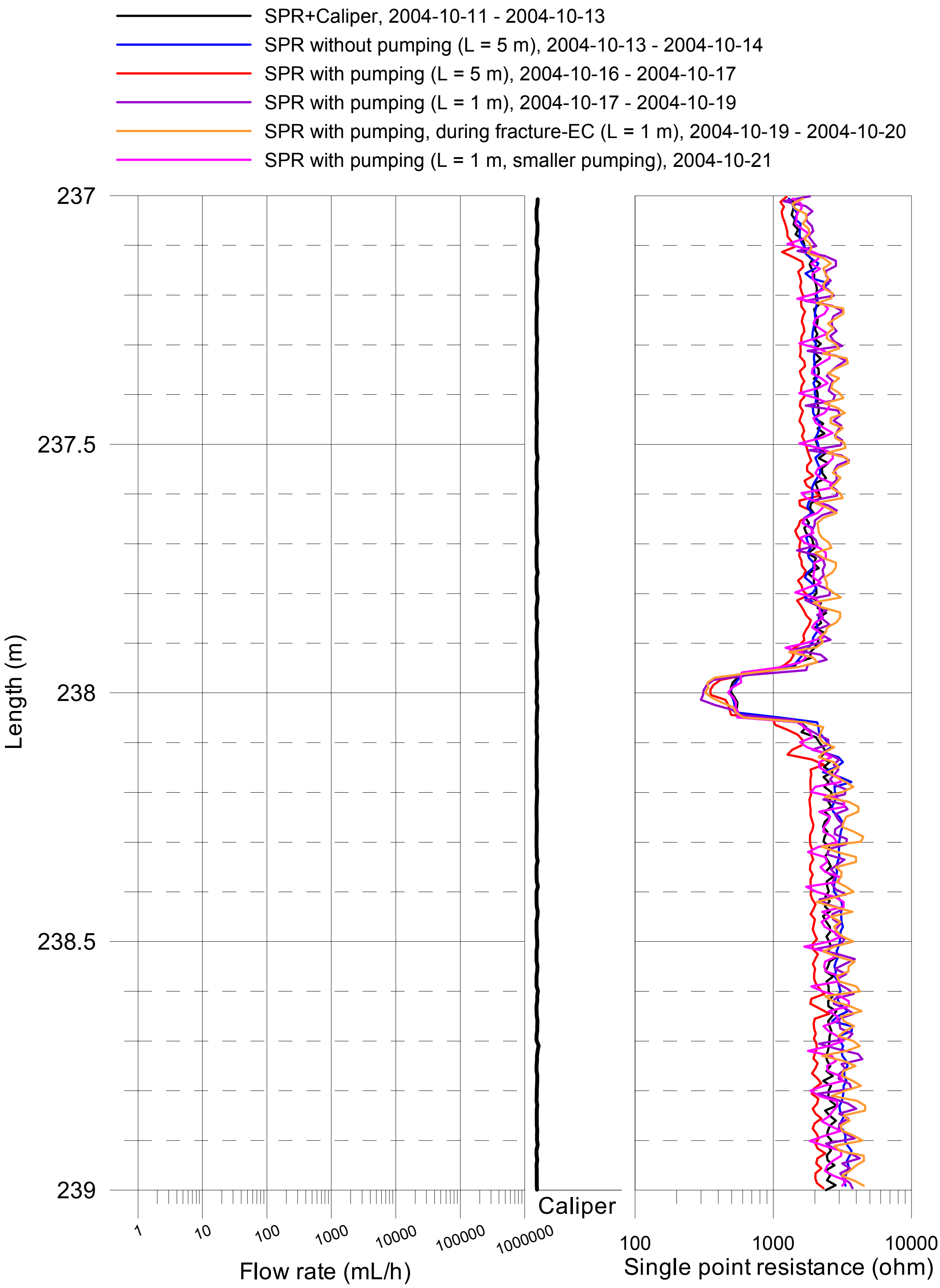


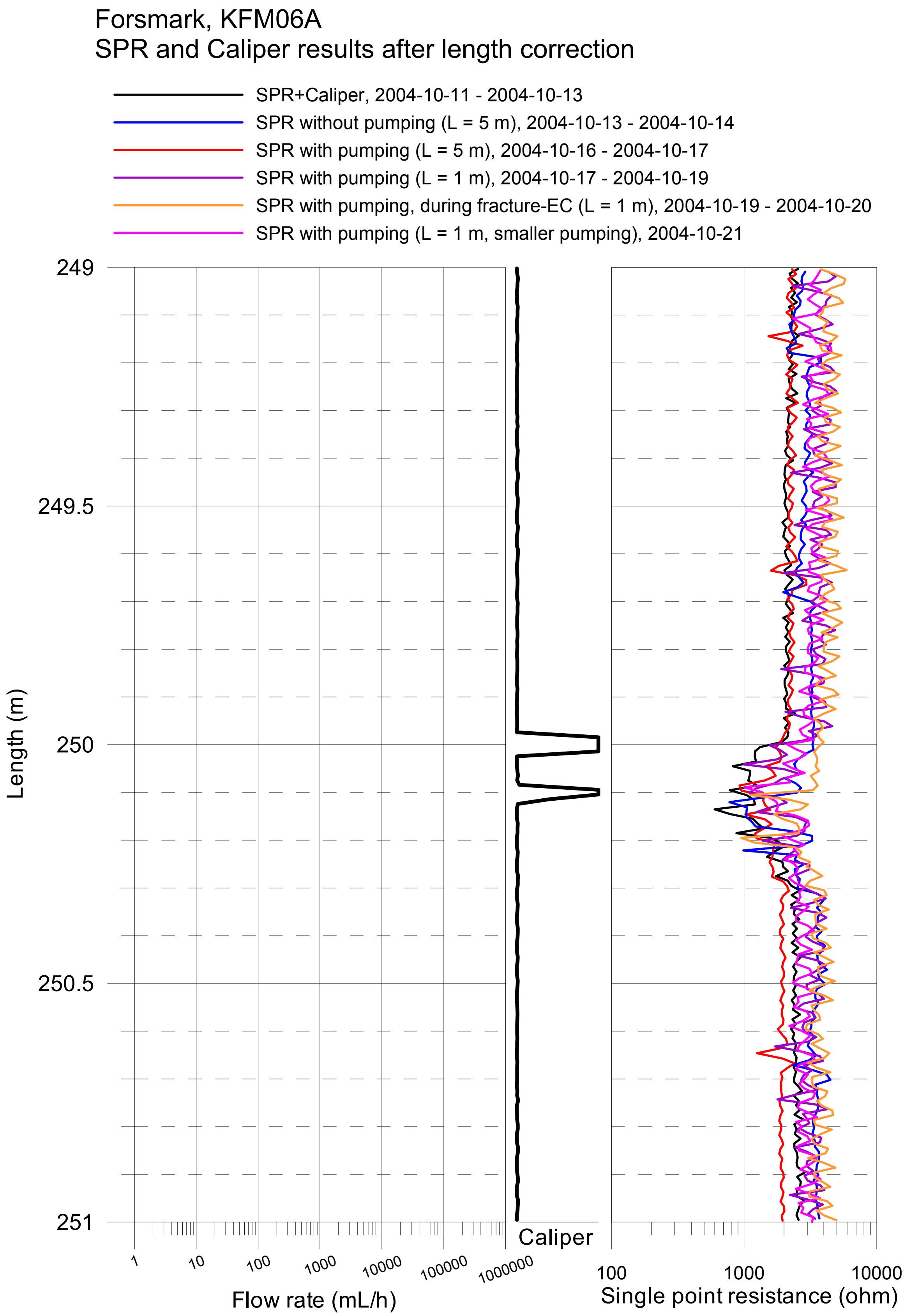
Forsmark, KFM06A
SPR and Caliper results after length correction



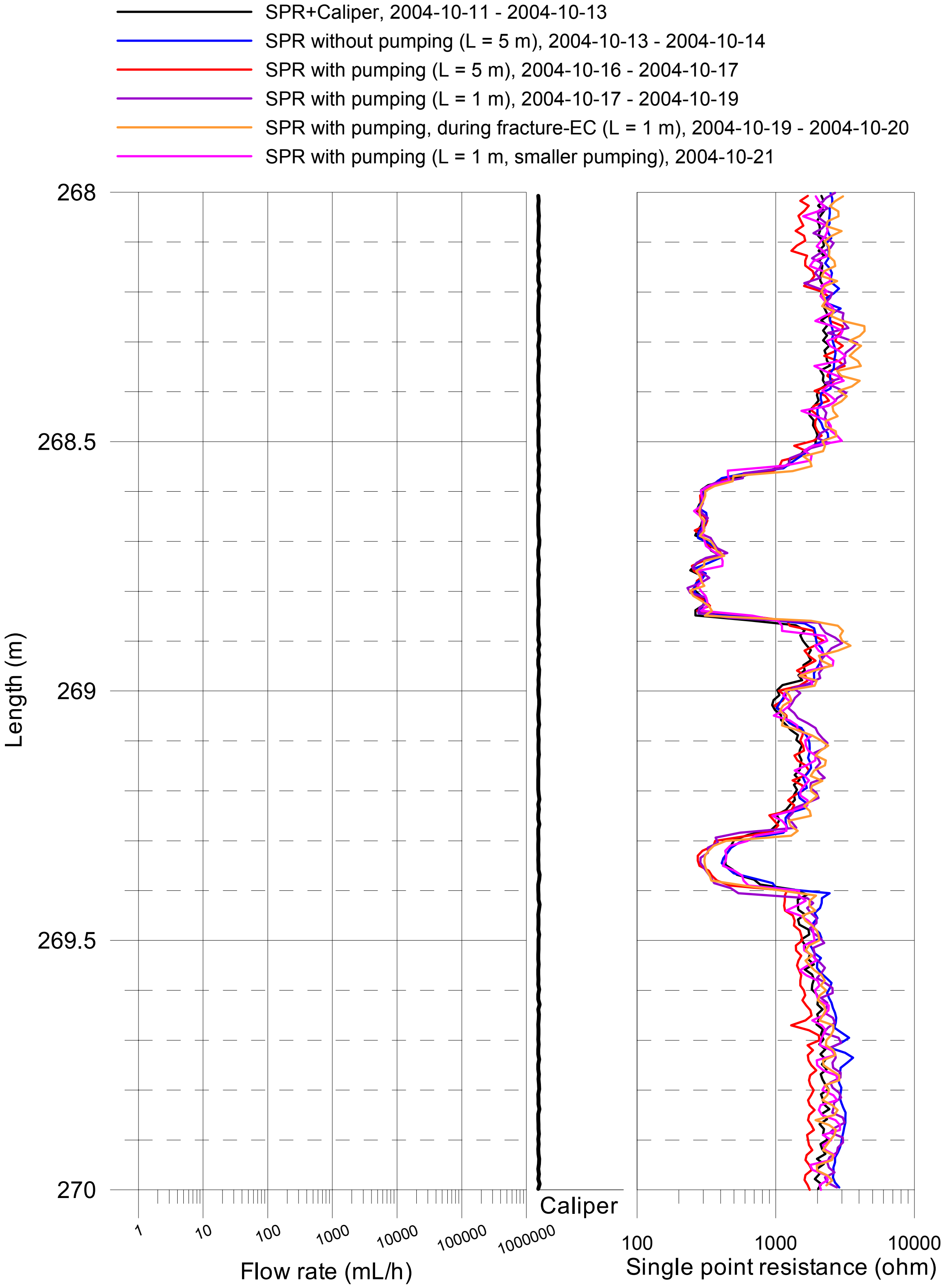

Forsmark, KFM06A
SPR and Caliper results after length correction
SPR+Caliper, 2004-10-11 - 2004-10-13
SPR without pumping (L = 5 m), 2004-10-13 - 2004-10-14
SPR with pumping (L = 5 m), 2004-10-16 - 2004-10-17
SPR with pumping (L = 1 m), 2004-10-17 - 2004-10-19
SPR with pumping, during fracture-EC (L = 1 m), 2004-10-19 - 2004-10-20
SPR with pumping (L = 1 m, smaller pumping), 2004-10-21
Length (m)
217
217.5
218
218.5
219
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
Single point resistance (ohm)

Forsmark, KFM06A
SPR and Caliper results after length correction

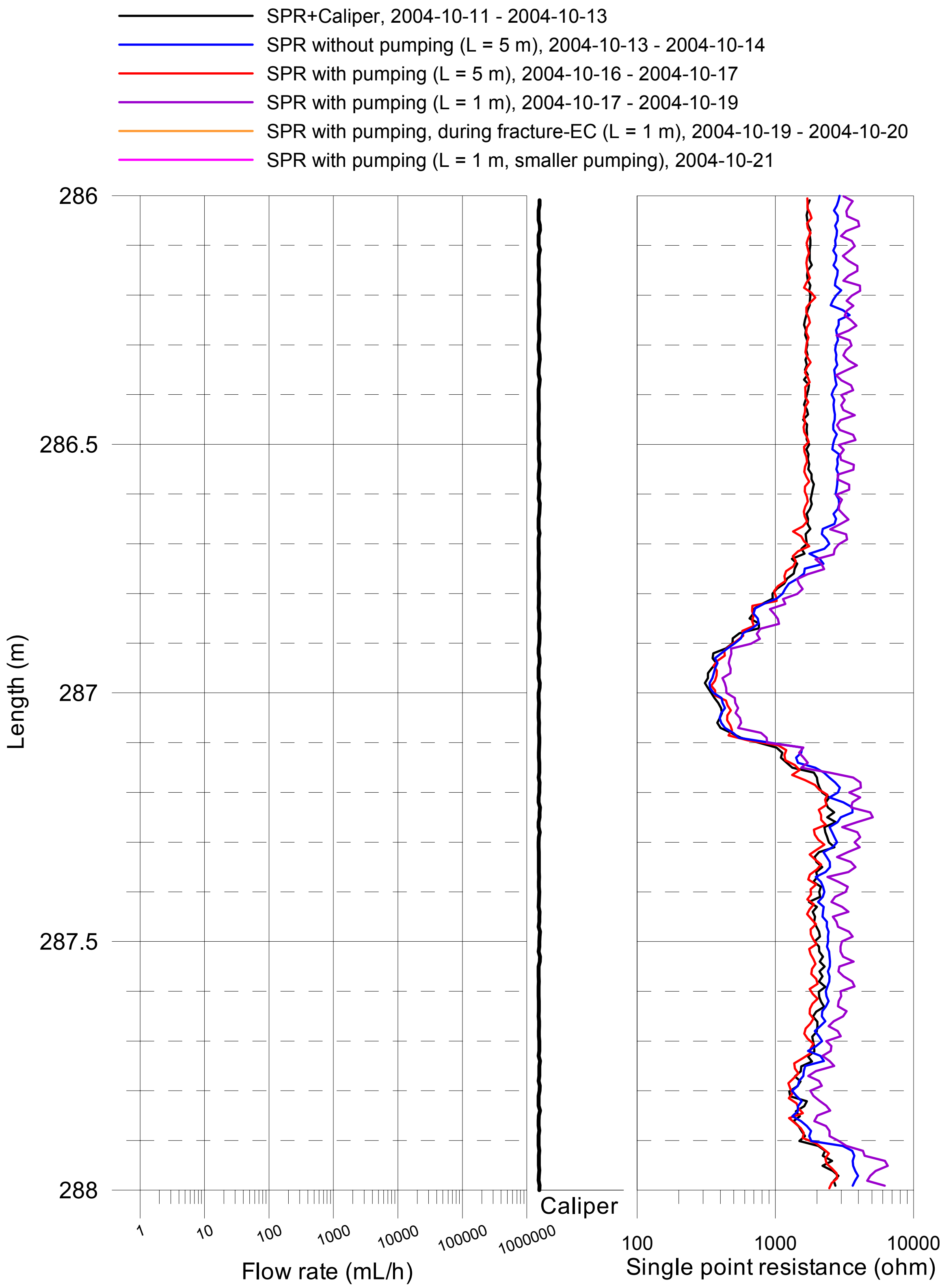


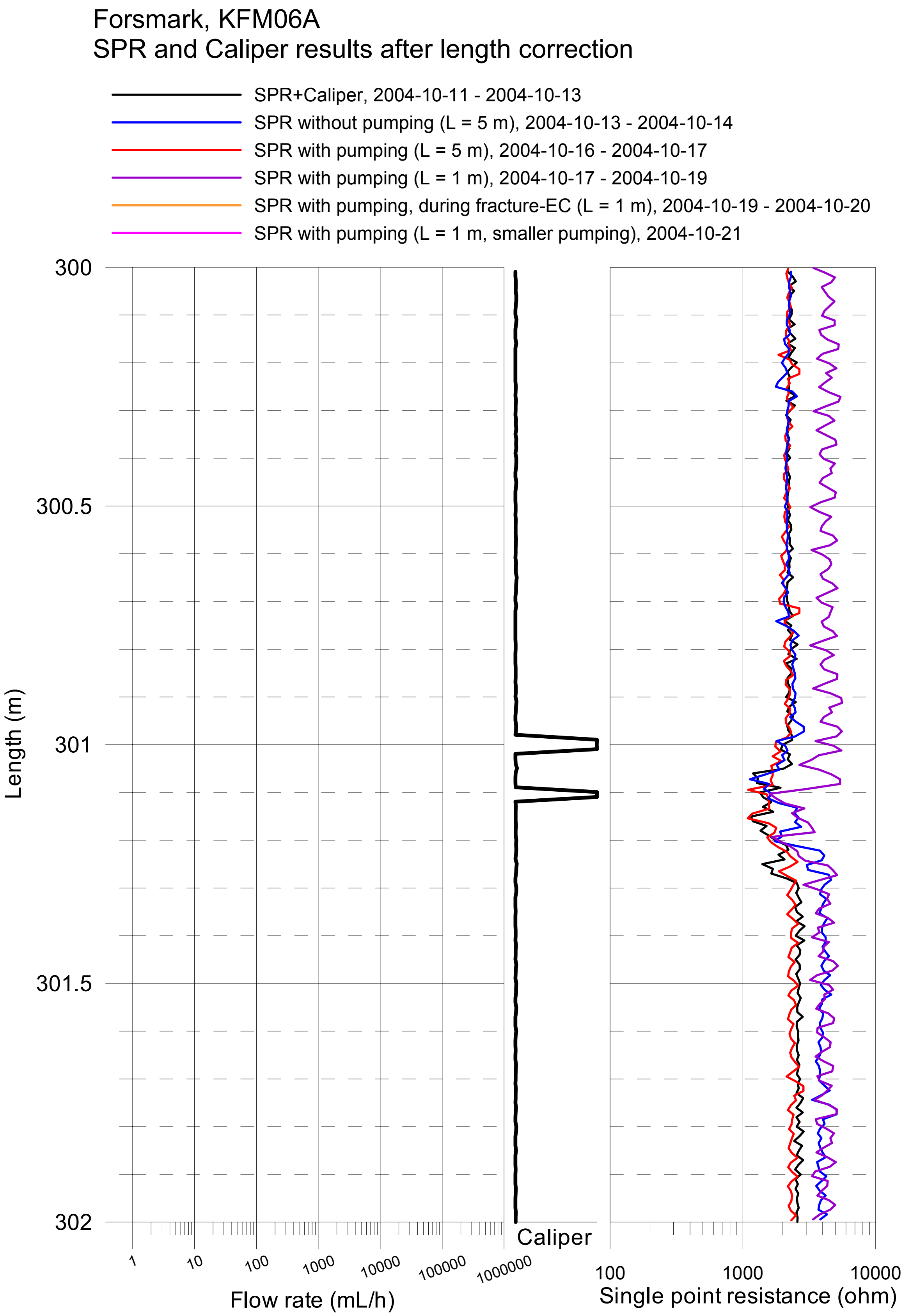

Forsmark, KFM06A
SPR and Caliper results after length correction
SPR+Caliper, 2004-10-11 - 2004-10-13
SPR without pumping (L = 5 m), 2004-10-13 - 2004-10-14
SPR with pumping (L = 5 m), 2004-10-16 - 2004-10-17
SPR with pumping (L = 1 m), 2004-10-17 - 2004-10-19
SPR with pumping, during fracture-EC (L = 1 m), 2004-10-19 - 2004-10-20
SPR with pumping (L = 1 m, smaller pumping), 2004-10-21
249
249.5
250
250.5
251
Length (m)
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
Single point resistance (ohm)

Forsmark, KFM06A
SPR and Caliper results after length correction

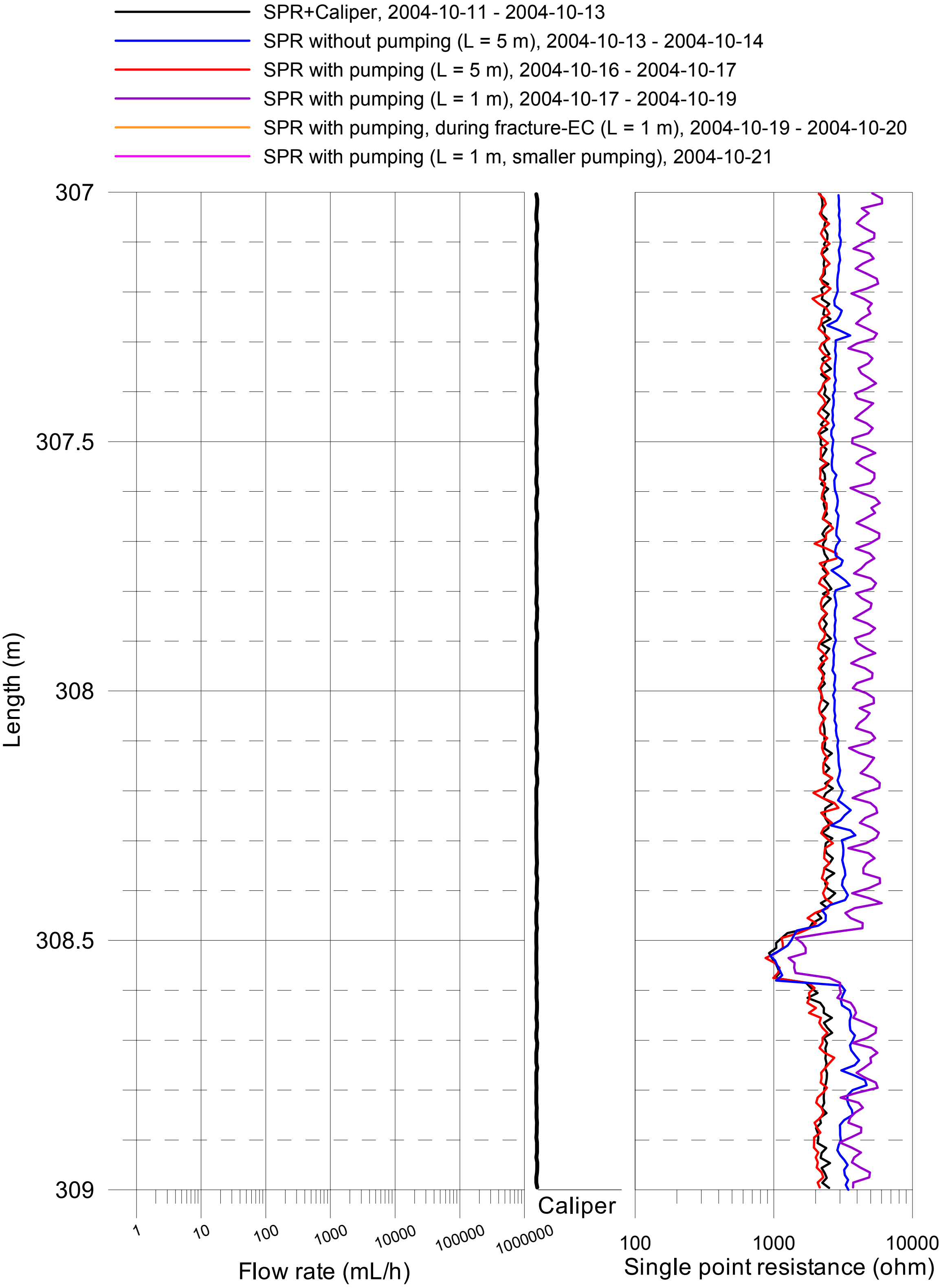


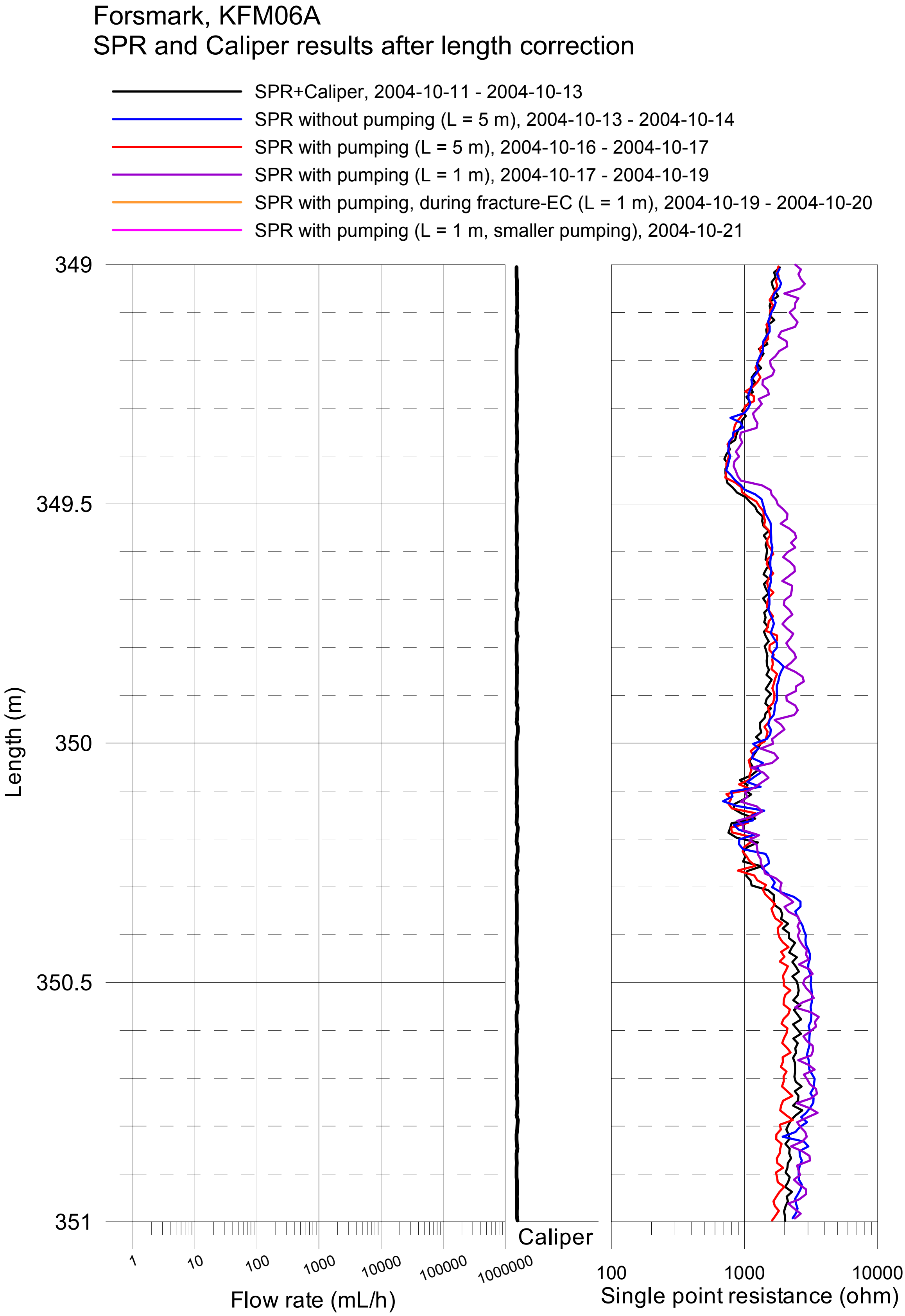
Forsmark, KFM06A
SPR and Caliper results after length correction

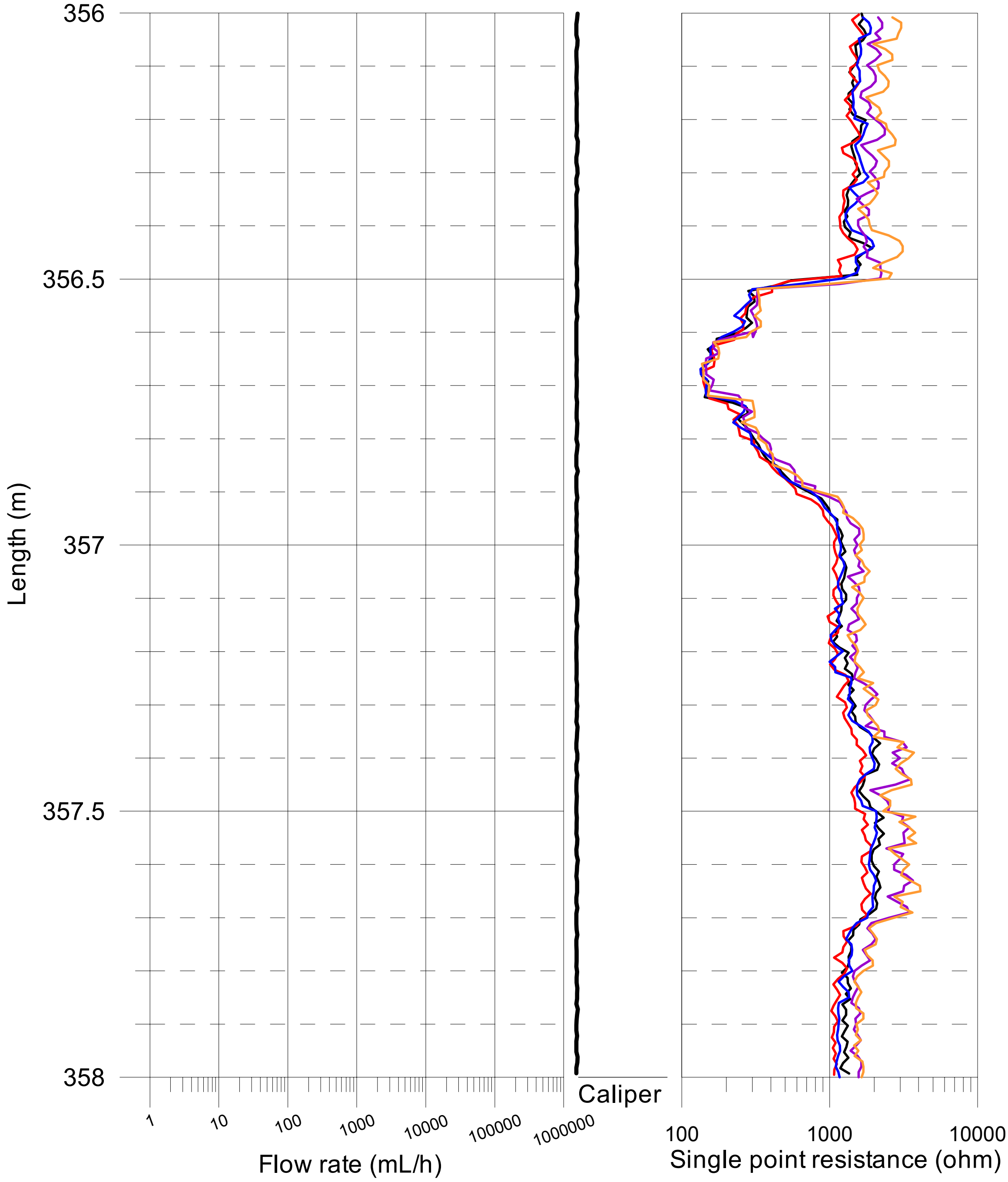



Forsmark, KFM06A
SPR and Caliper results after length correction
SPR+Caliper, 2004-10-11 - 2004-10-13
SPR without pumping (L = 5 m), 2004-10-13 - 2004-10-14
SPR with pumping (L = 5 m), 2004-10-16 - 2004-10-17
SPR with pumping (L = 1 m), 2004-10-17 - 2004-10-19
SPR with pumping, during fracture-EC (L = 1 m), 2004-10-19 - 2004-10-20
SPR with pumping (L = 1 m, smaller pumping), 2004-10-21
Length (m)
300
300.5
301
301.5
302
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
Single point resistance (ohm)

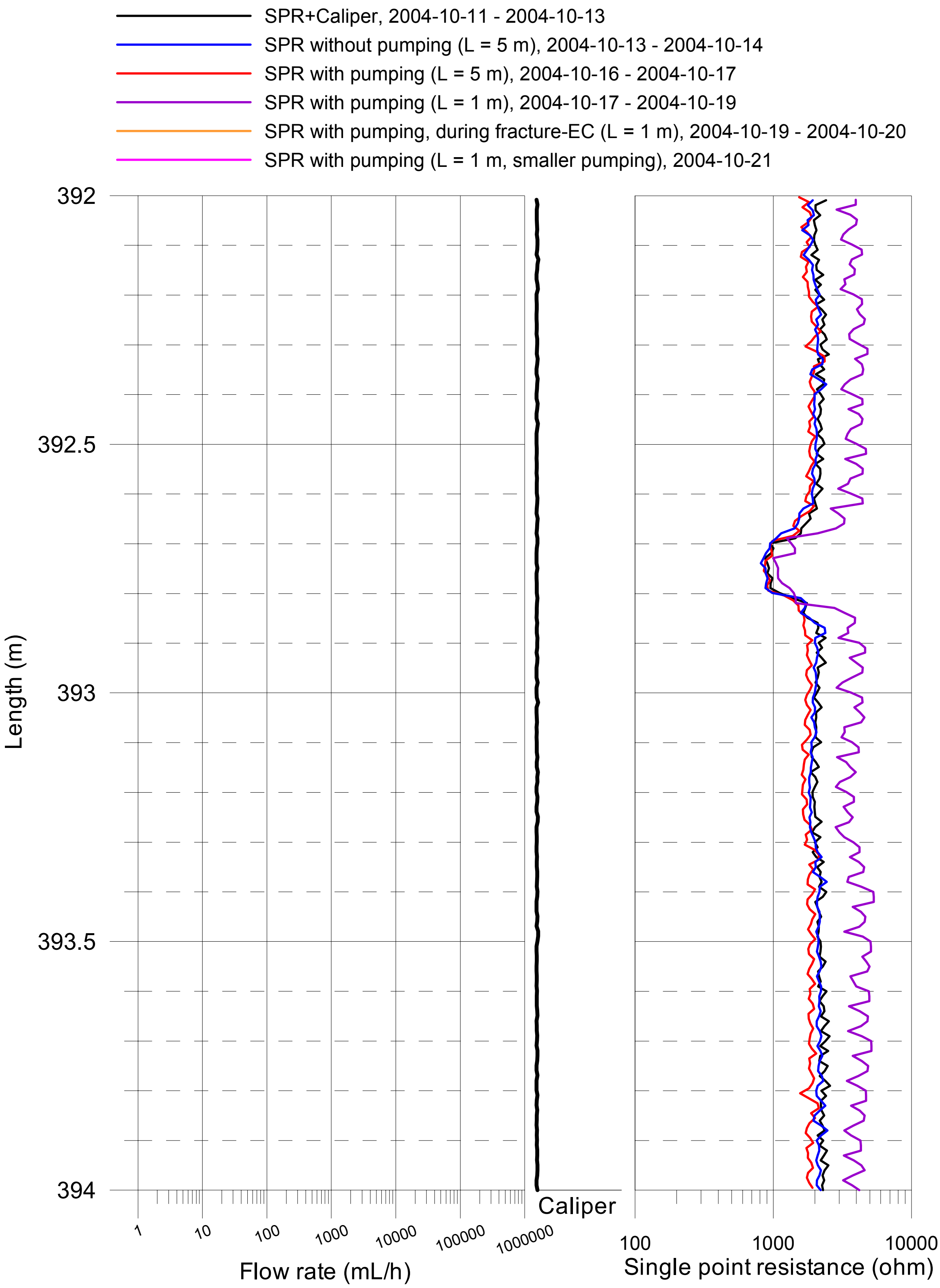
Forsmark, KFM06A
SPR and Caliper results after length correction



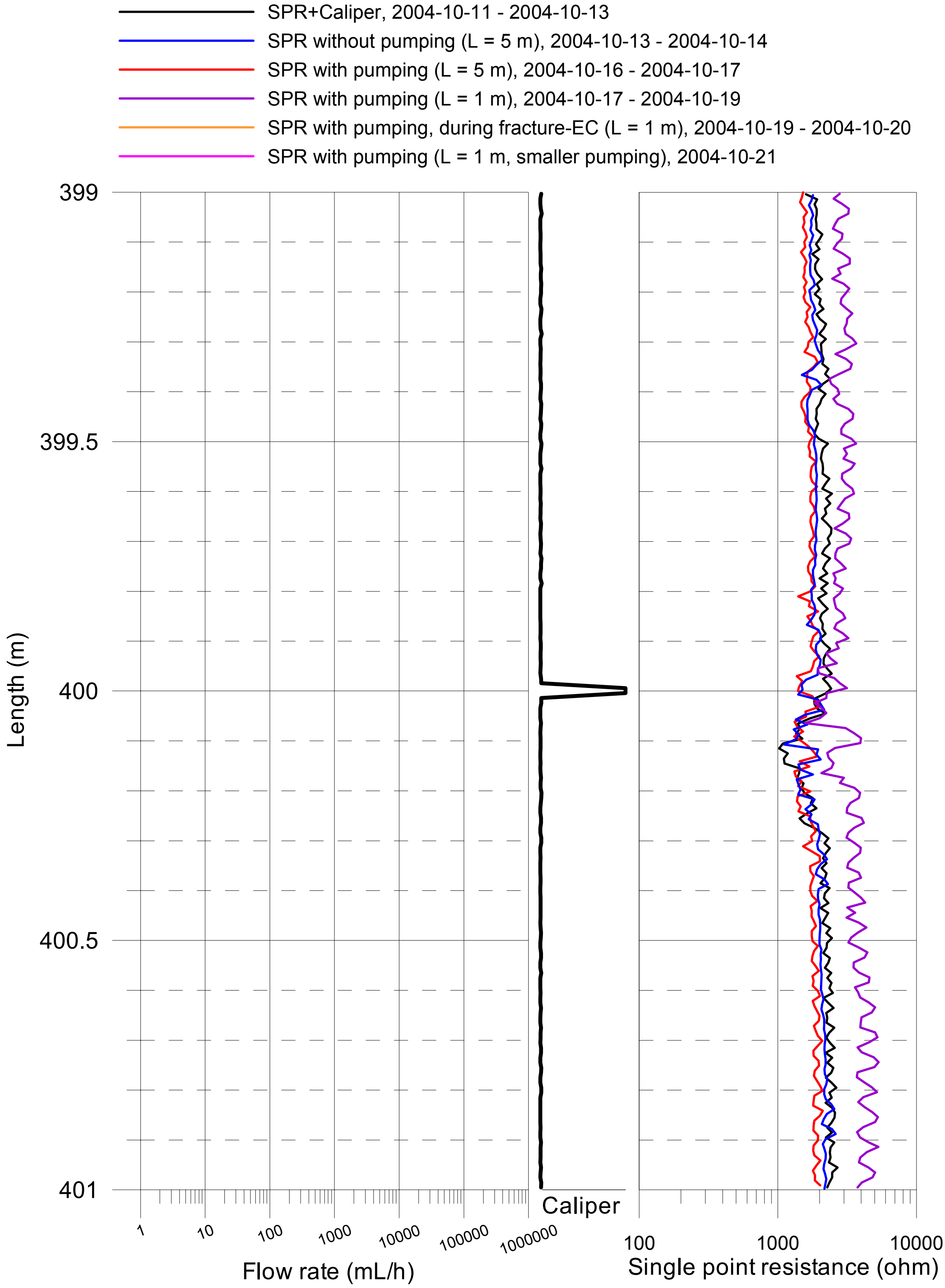

Forsmark, KFM06A
SPR and Caliper results after length correction
SPR+Caliper, 2004-10-11 - 2004-10-13
SPR without pumping (L = 5 m), 2004-10-13 - 2004-10-14
SPR with pumping (L = 5 m), 2004-10-16 - 2004-10-17
SPR with pumping (L = 1 m), 2004-10-17 - 2004-10-19
SPR with pumping, during fracture-EC (L = 1 m), 2004-10-19 - 2004-10-20
SPR with pumping (L = 1 m, smaller pumping), 2004-10-21
Length (m)
349
349.5
350
350.5
351
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
Single point resistance (ohm)

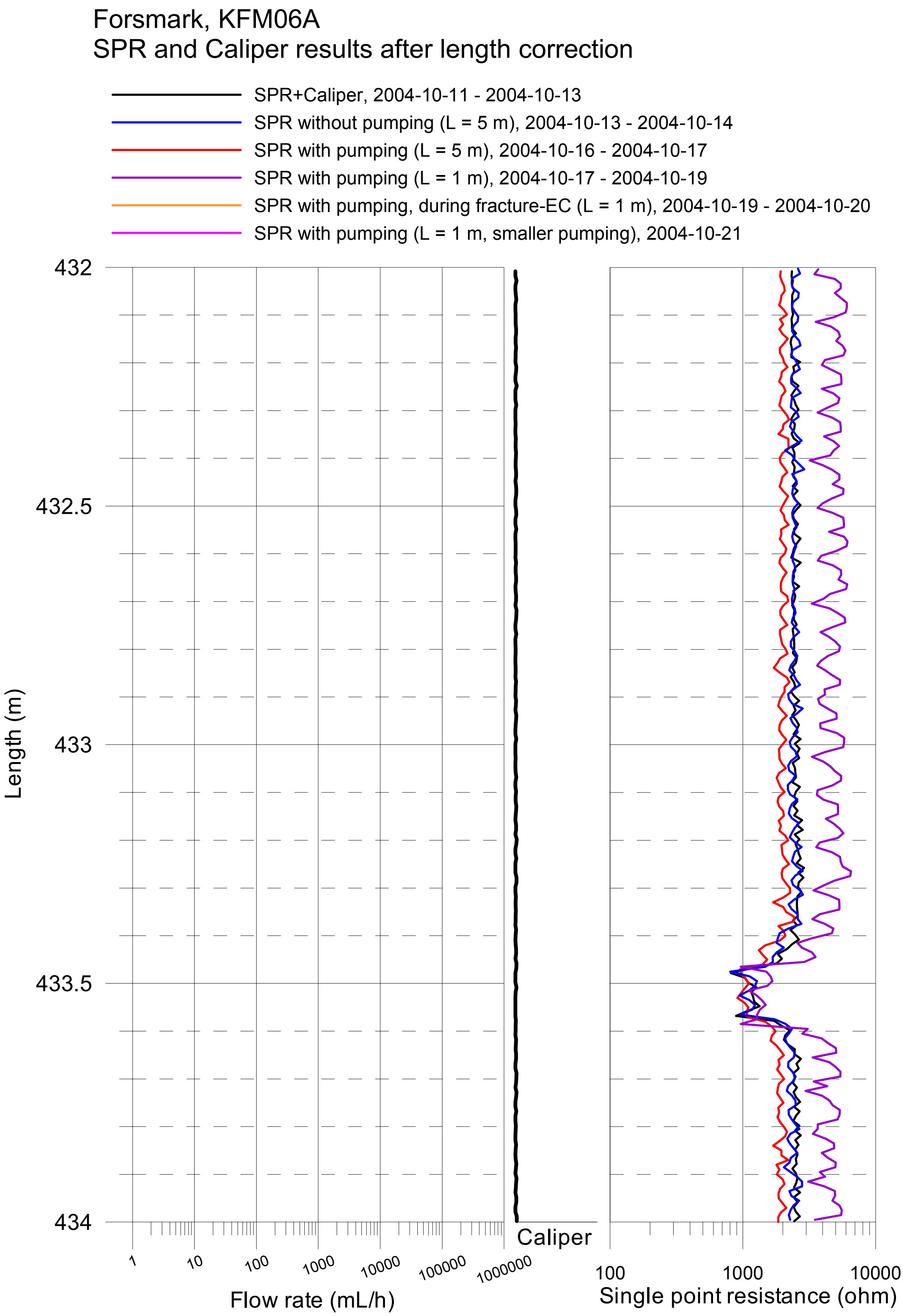

Forsmark, KFM06A
SPR and Caliper results after length correction
SPR+Caliper, 2004-10-11 - 2004-10-13
SPR without pumping (L = 5 m), 2004-10-13 - 2004-10-14
SPR with pumping (L = 5 m), 2004-10-16 - 2004-10-17
SPR with pumping (L = 1 m), 2004-10-17 - 2004-10-19
SPR with pumping, during fracture-EC (L = 1 m), 2004-10-19 - 2004-10-20
SPR with pumping (L = 1 m, smaller pumping), 2004-10-21
Length (m)
356
356.5
357
357.5
358
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
Single point resistance (ohm)

Forsmark, KFM06A
SPR and Caliper results after length correction

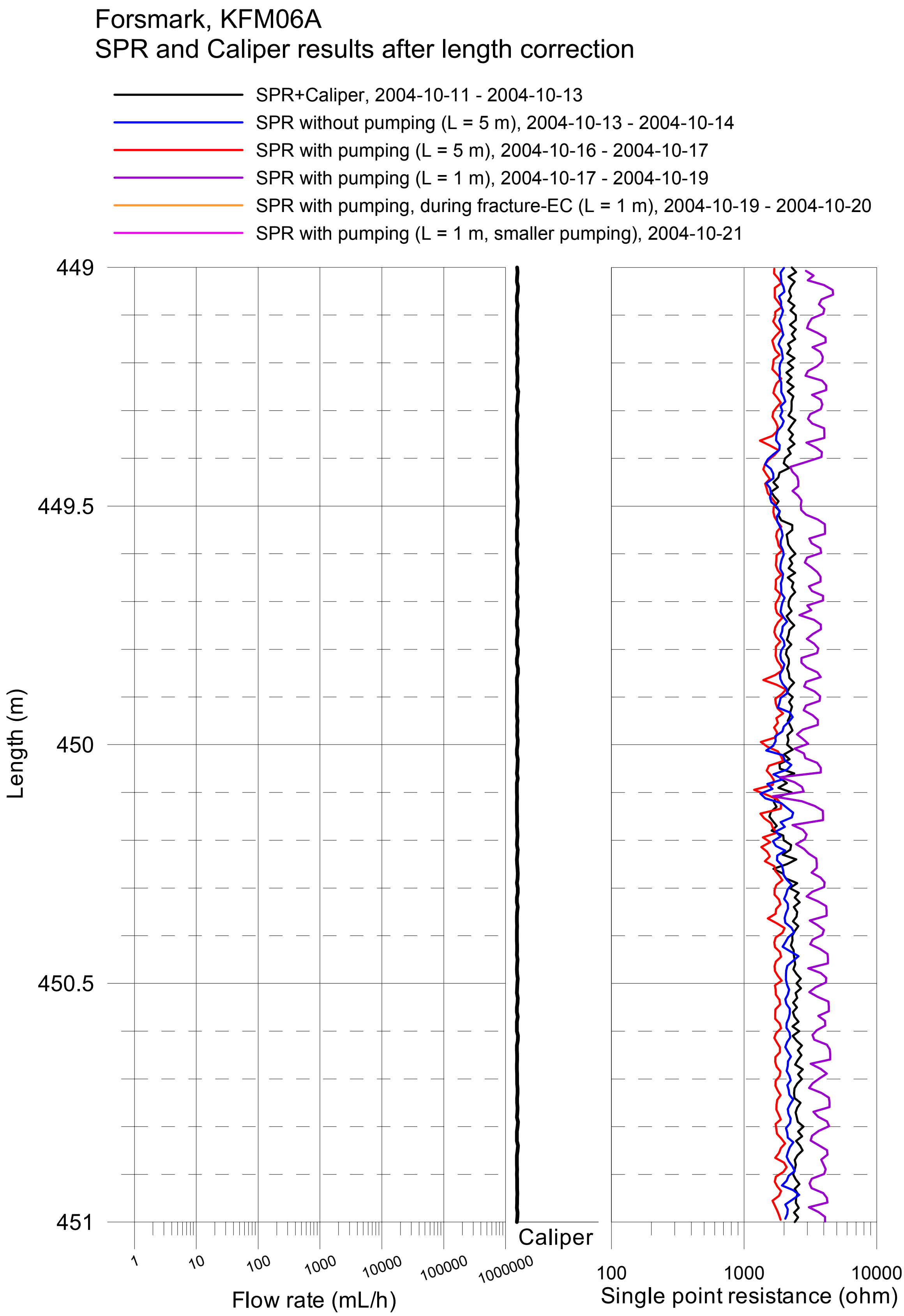


Forsmark, KFM06A
SPR and Caliper results after length correction

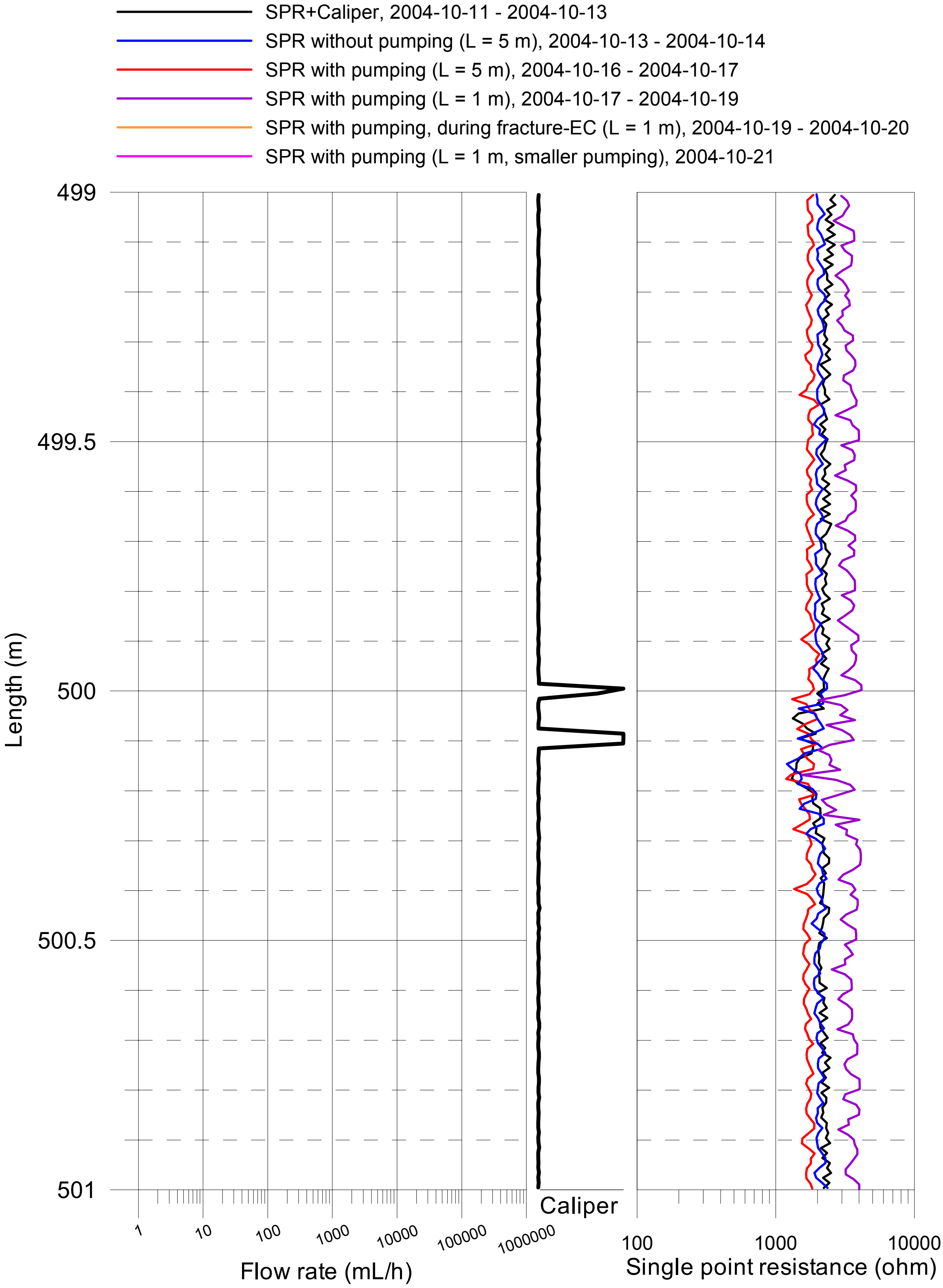


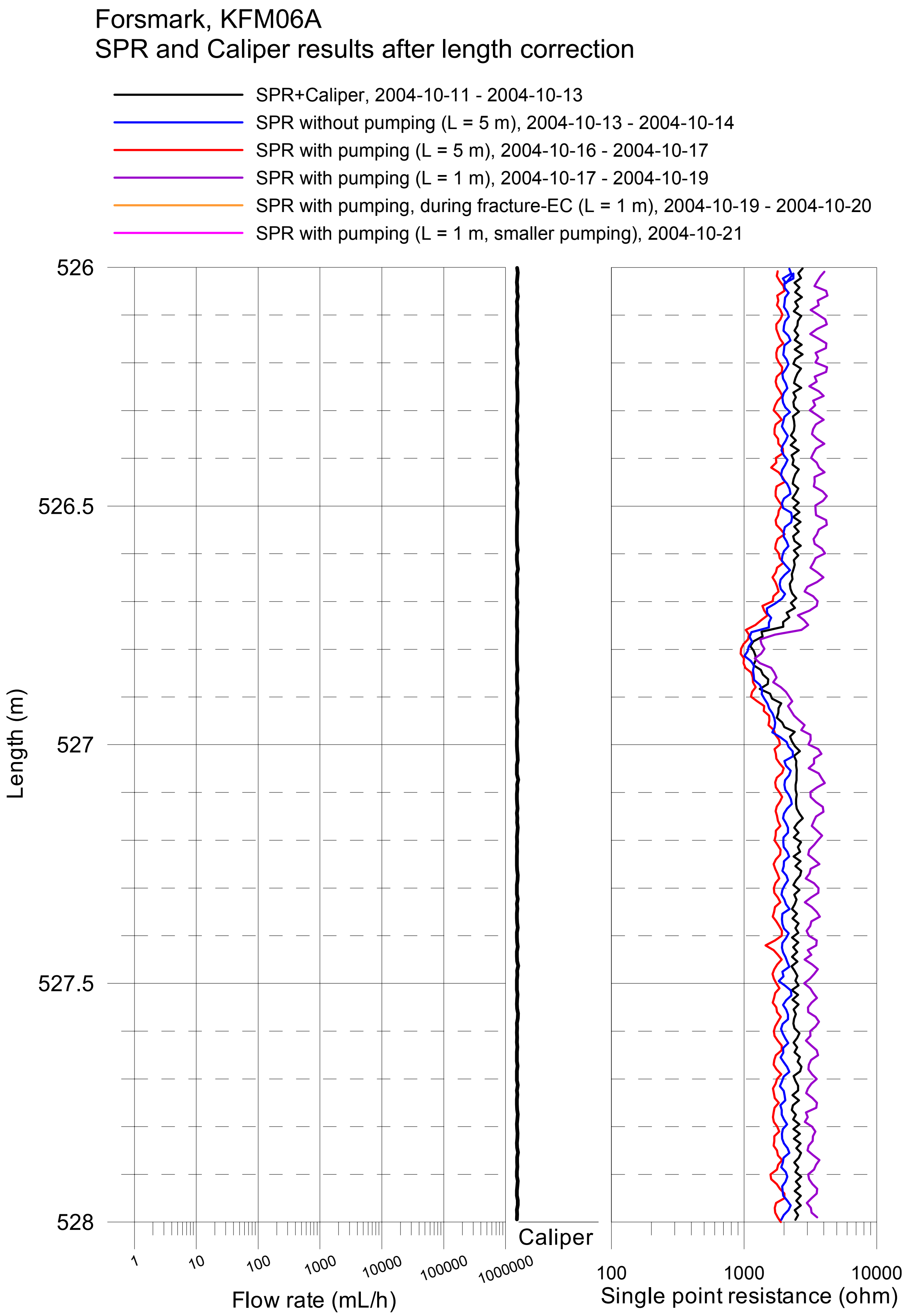


Forsmark, KFM06A
SPR and Caliper results after length correction
SPR+Caliper, 2004-10-11 - 2004-10-13
SPR without pumping (L = 5 m), 2004-10-13 - 2004-10-14
SPR with pumping (L = 5 m), 2004-10-16 - 2004-10-17
SPR with pumping (L = 1 m), 2004-10-17 - 2004-10-19
SPR with pumping, during fracture-EC (L = 1 m), 2004-10-19 - 2004-10-20
SPR with pumping (L = 1 m, smaller pumping), 2004-10-21
432
432.5
433
433.5
434
Length (m)
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
Single point resistance (ohm)

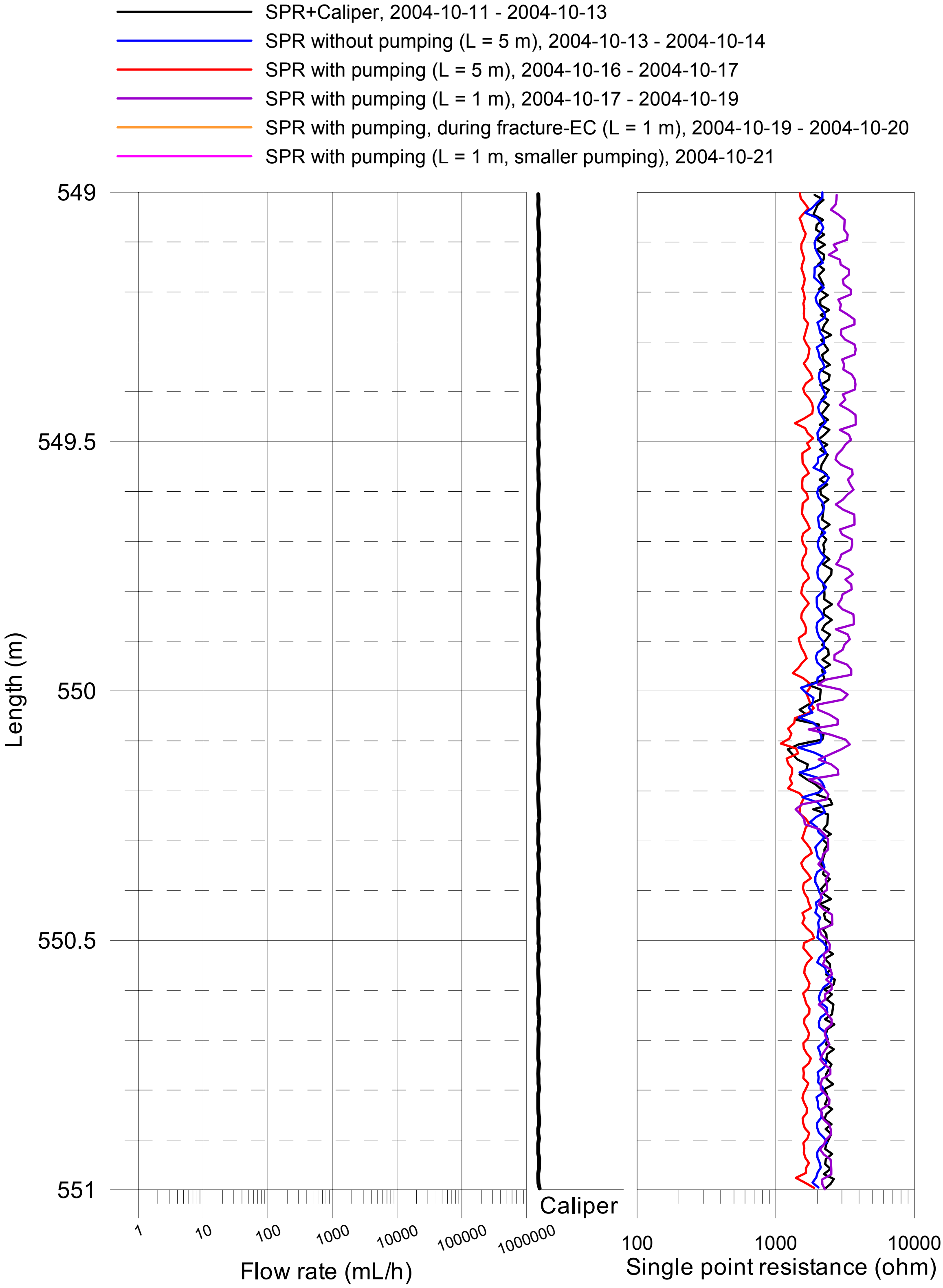

Forsmark, KFM06A
SPR and Caliper results after length correction
SPR+Caliper, 2004-10-11 - 2004-10-13
SPR without pumping (L = 5 m), 2004-10-13 - 2004-10-14
SPR with pumping (L = 5 m), 2004-10-16 - 2004-10-17
SPR with pumping (L = 1 m), 2004-10-17 - 2004-10-19
SPR with pumping, during fracture-EC (L = 1 m), 2004-10-19 - 2004-10-20
SPR with pumping (L = 1 m, smaller pumping), 2004-10-21
449
449.5
450
450.5
451
Length (m)
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
Single point resistance (ohm)

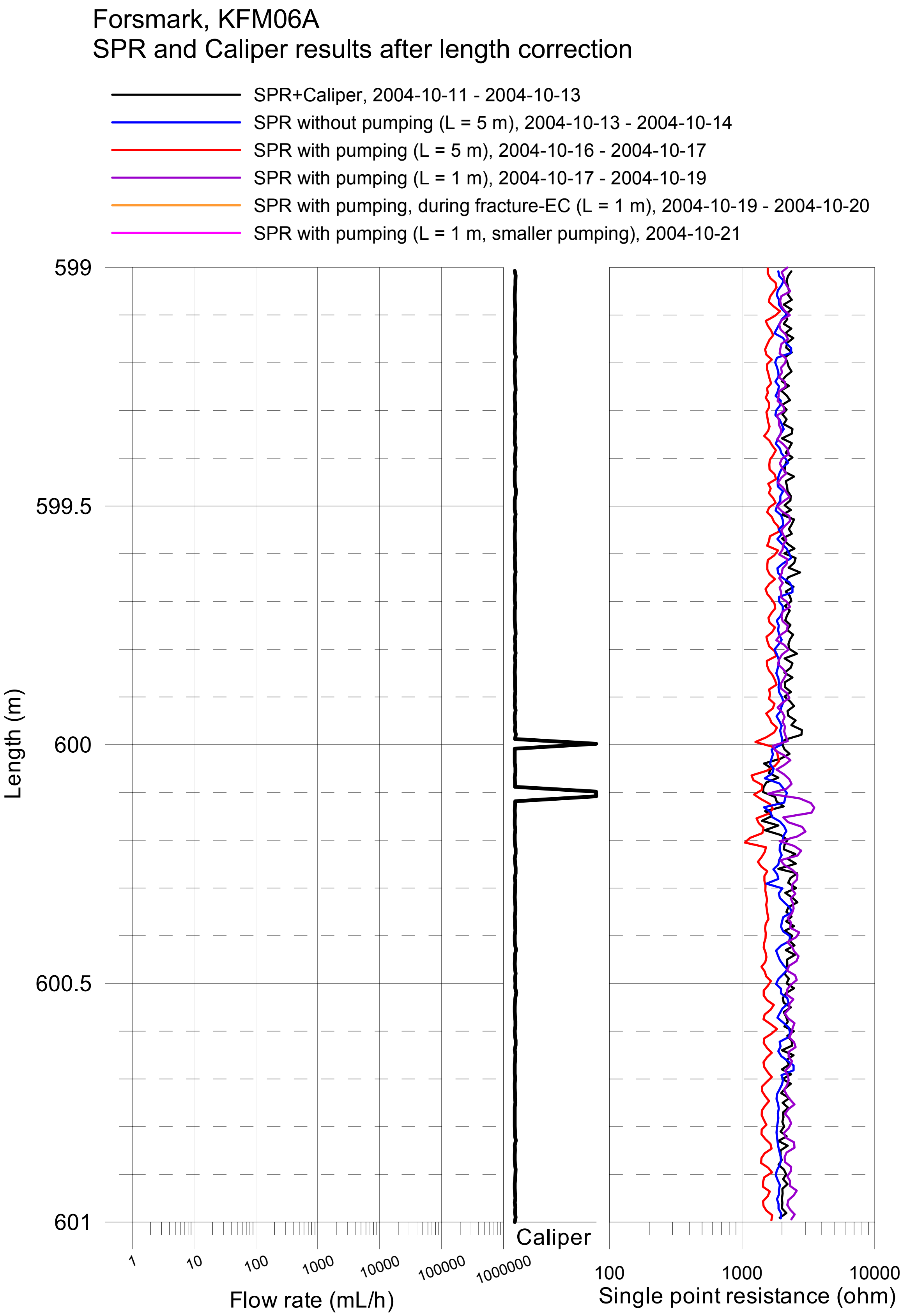
Forsmark, KFM06A
SPR and Caliper results after length correction

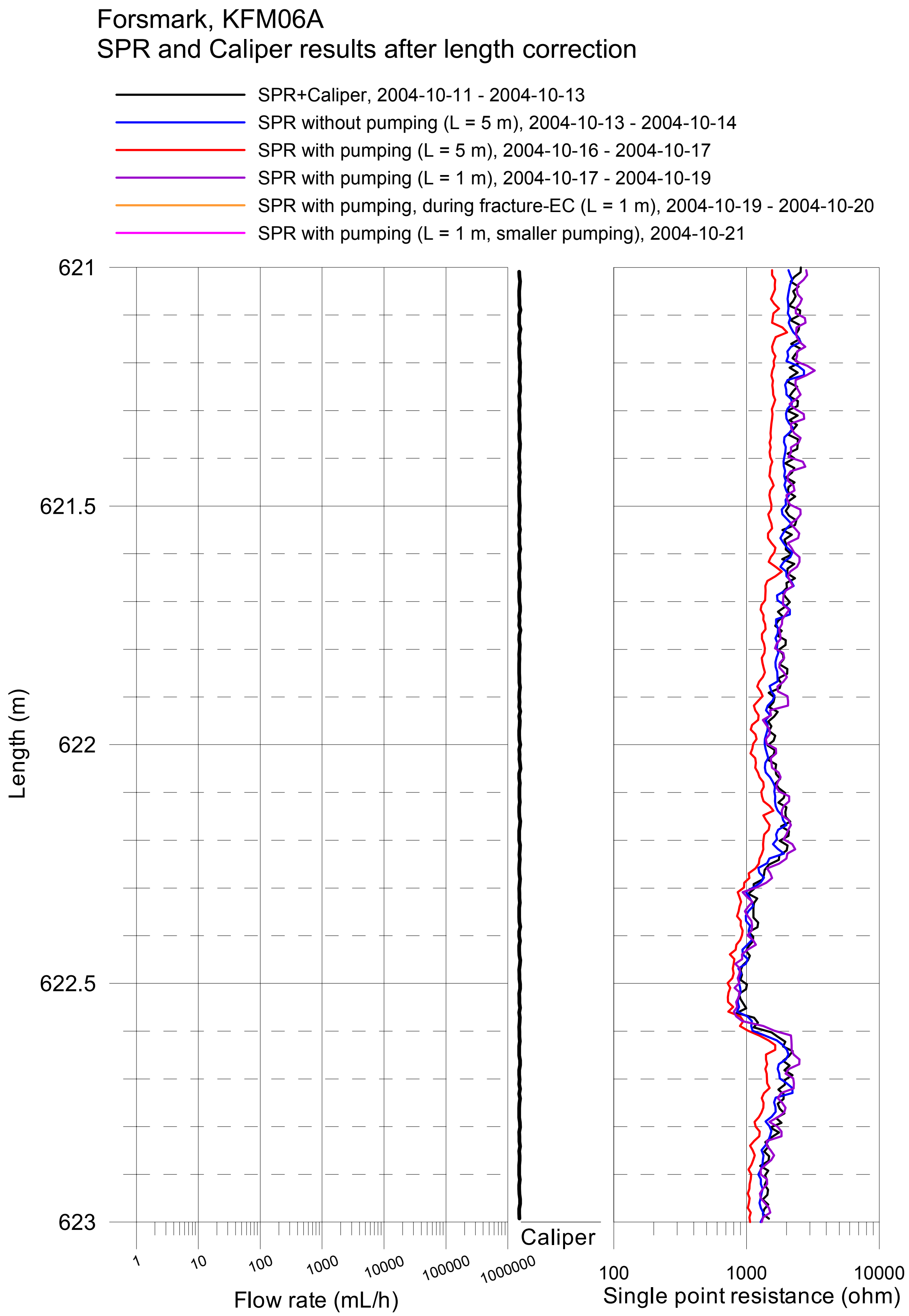


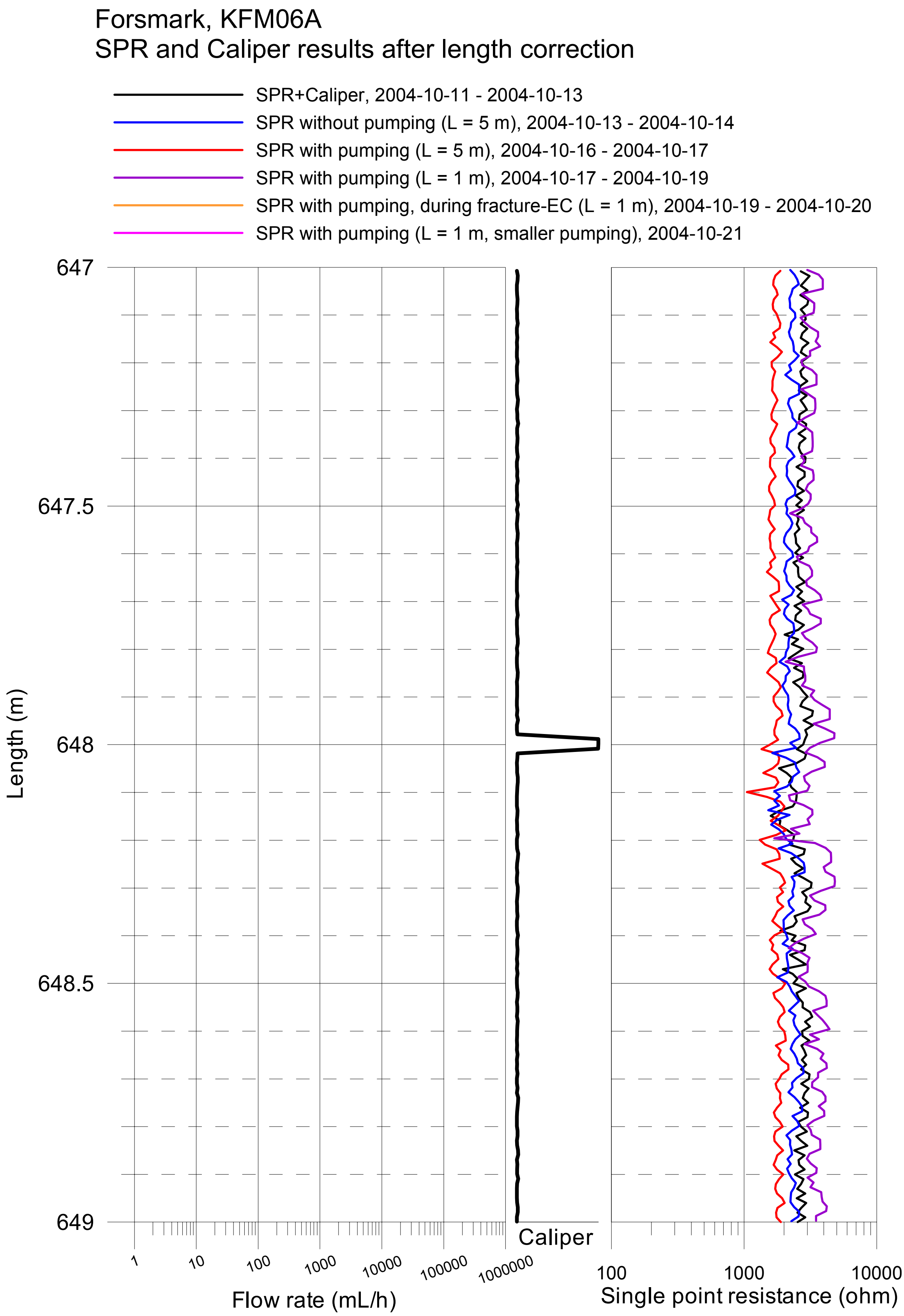

Forsmark, KFM06A
SPR and Caliper results after length correction
SPR+Caliper, 2004-10-11 - 2004-10-13
SPR without pumping (L = 5 m), 2004-10-13 - 2004-10-14
SPR with pumping (L = 5 m), 2004-10-16 - 2004-10-17
SPR with pumping (L = 1 m), 2004-10-17 - 2004-10-19
SPR with pumping, during fracture-EC (L = 1 m), 2004-10-19 - 2004-10-20
SPR with pumping (L = 1 m, smaller pumping), 2004-10-21
Length (m)
526
526.5
527
527.5
528
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
Single point resistance (ohm)

Forsmark, KFM06A
SPR and Caliper results after length correction

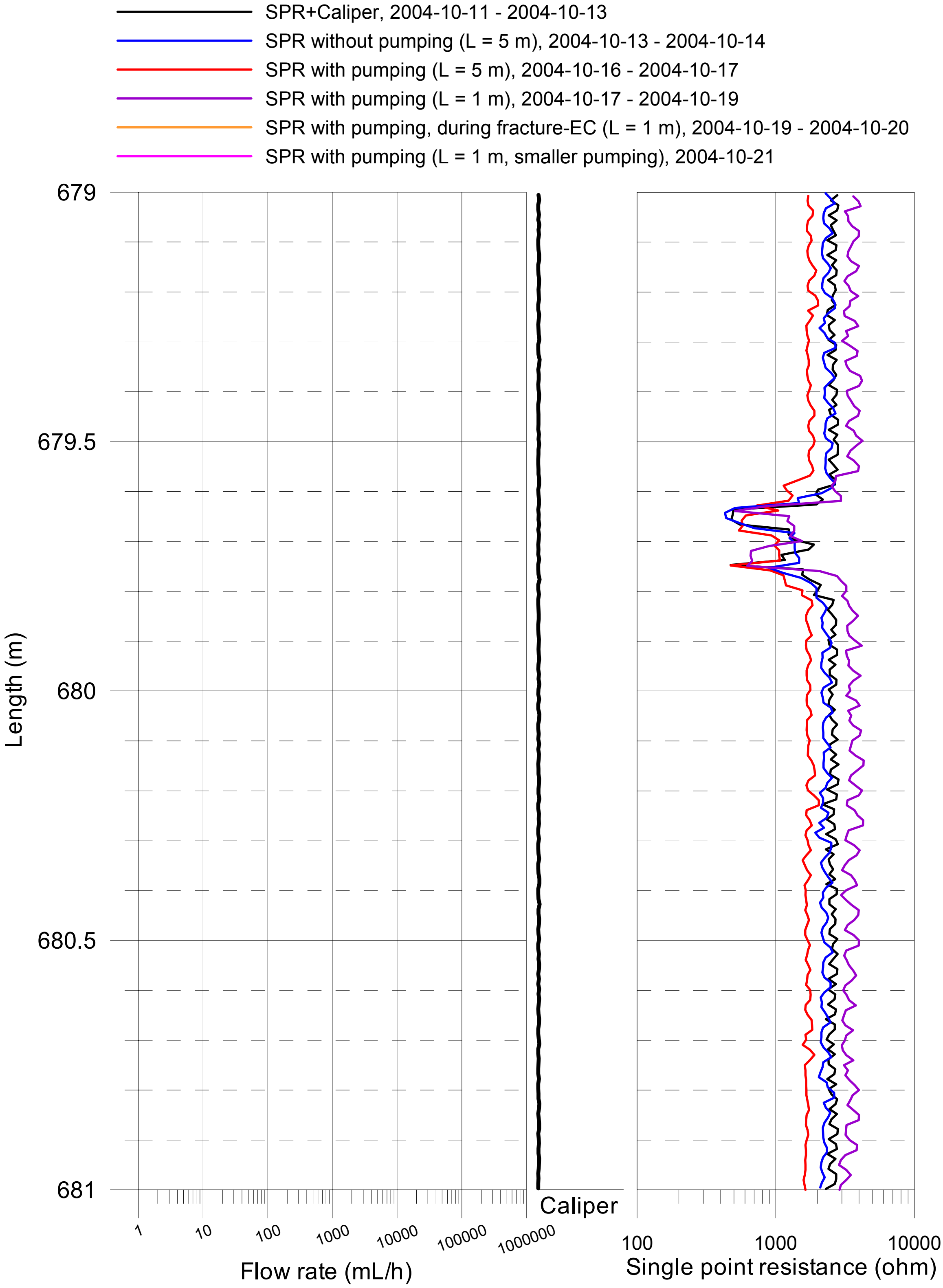



Forsmark, KFM06A
SPR and Caliper results after length correction
SPR+Caliper, 2004-10-11 - 2004-10-13
SPR without pumping (L = 5 m), 2004-10-13 - 2004-10-14
SPR with pumping (L = 5 m), 2004-10-16 - 2004-10-17
SPR with pumping (L = 1 m), 2004-10-17 - 2004-10-19
SPR with pumping, during fracture-EC (L = 1 m), 2004-10-19 - 2004-10-20
SPR with pumping (L = 1 m, smaller pumping), 2004-10-21
Length (m)
599
599.5
600
600.5
601
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
Single point resistance (ohm)

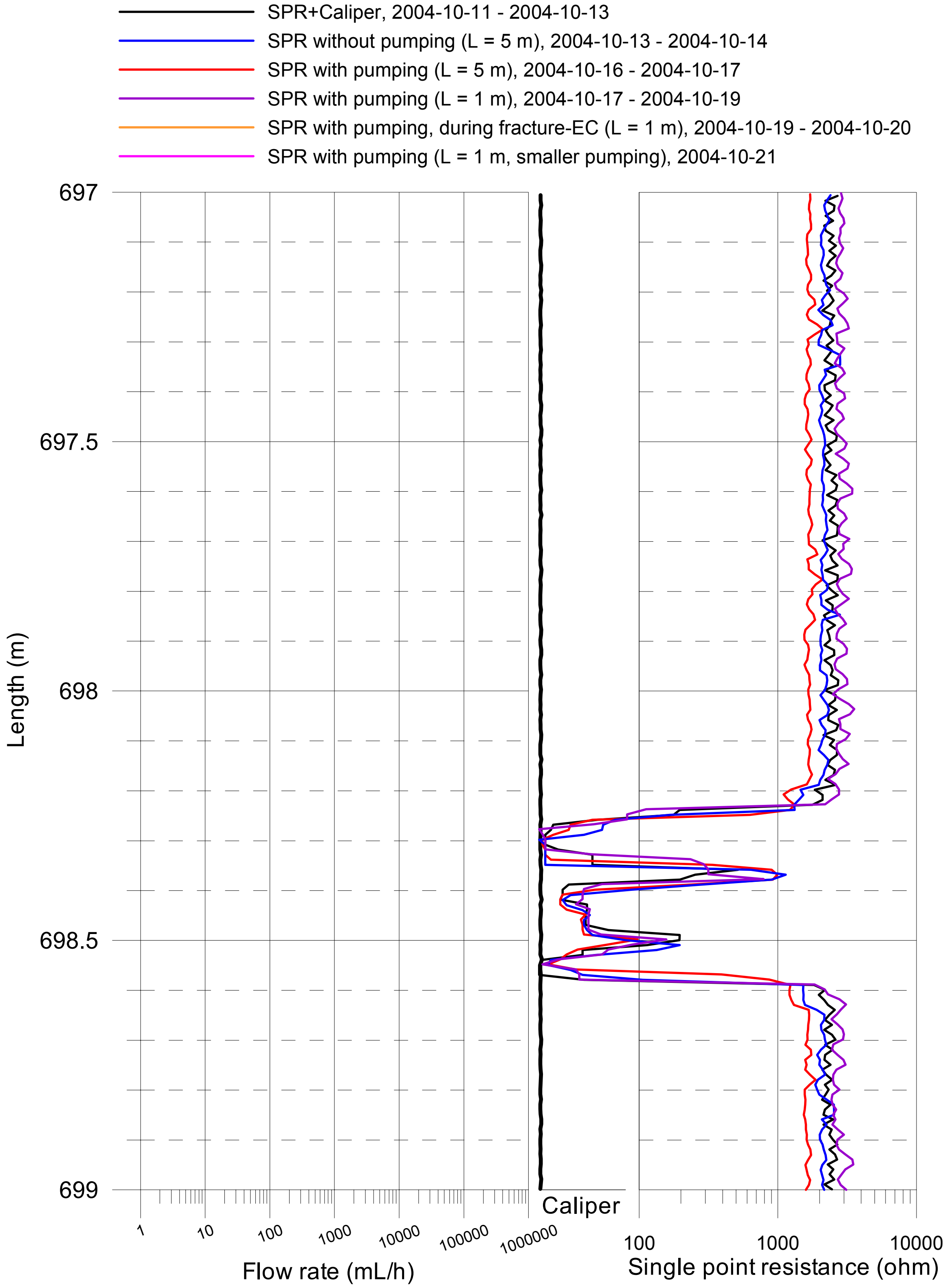

Forsmark, KFM06A
SPR and Caliper results after length correction
SPR+Caliper, 2004-10-11 - 2004-10-13
SPR without pumping (L = 5 m), 2004-10-13 - 2004-10-14
SPR with pumping (L = 5 m), 2004-10-16 - 2004-10-17
SPR with pumping (L = 1 m), 2004-10-17 - 2004-10-19
SPR with pumping, during fracture-EC (L = 1 m), 2004-10-19 - 2004-10-20
SPR with pumping (L = 1 m, smaller pumping), 2004-10-21
621
621.5
622
622.5
623
Length (m)
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
Single point resistance (ohm)


Forsmark, KFM06A
SPR and Caliper results after length correction
SPR+Caliper, 2004-10-11 - 2004-10-13
SPR without pumping (L = 5 m), 2004-10-13 - 2004-10-14
SPR with pumping (L = 5 m), 2004-10-16 - 2004-10-17
SPR with pumping (L = 1 m), 2004-10-17 - 2004-10-19
SPR with pumping, during fracture-EC (L = 1 m), 2004-10-19 - 2004-10-20
SPR with pumping (L = 1 m, smaller pumping), 2004-10-21
Length (m)
647
647.5
648
648.5
649
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
Single point resistance (ohm)

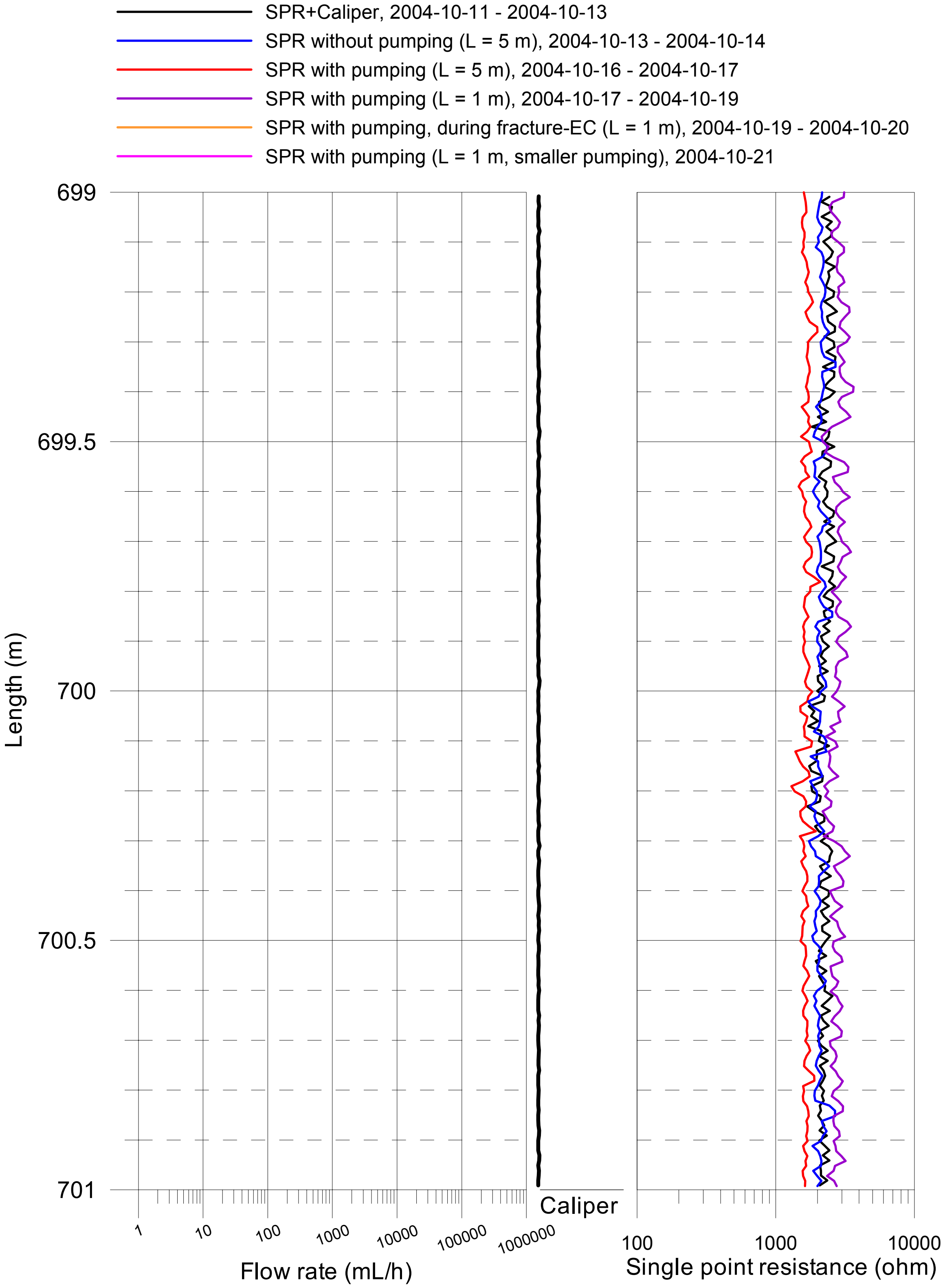
Forsmark, KFM06A
SPR and Caliper results after length correction



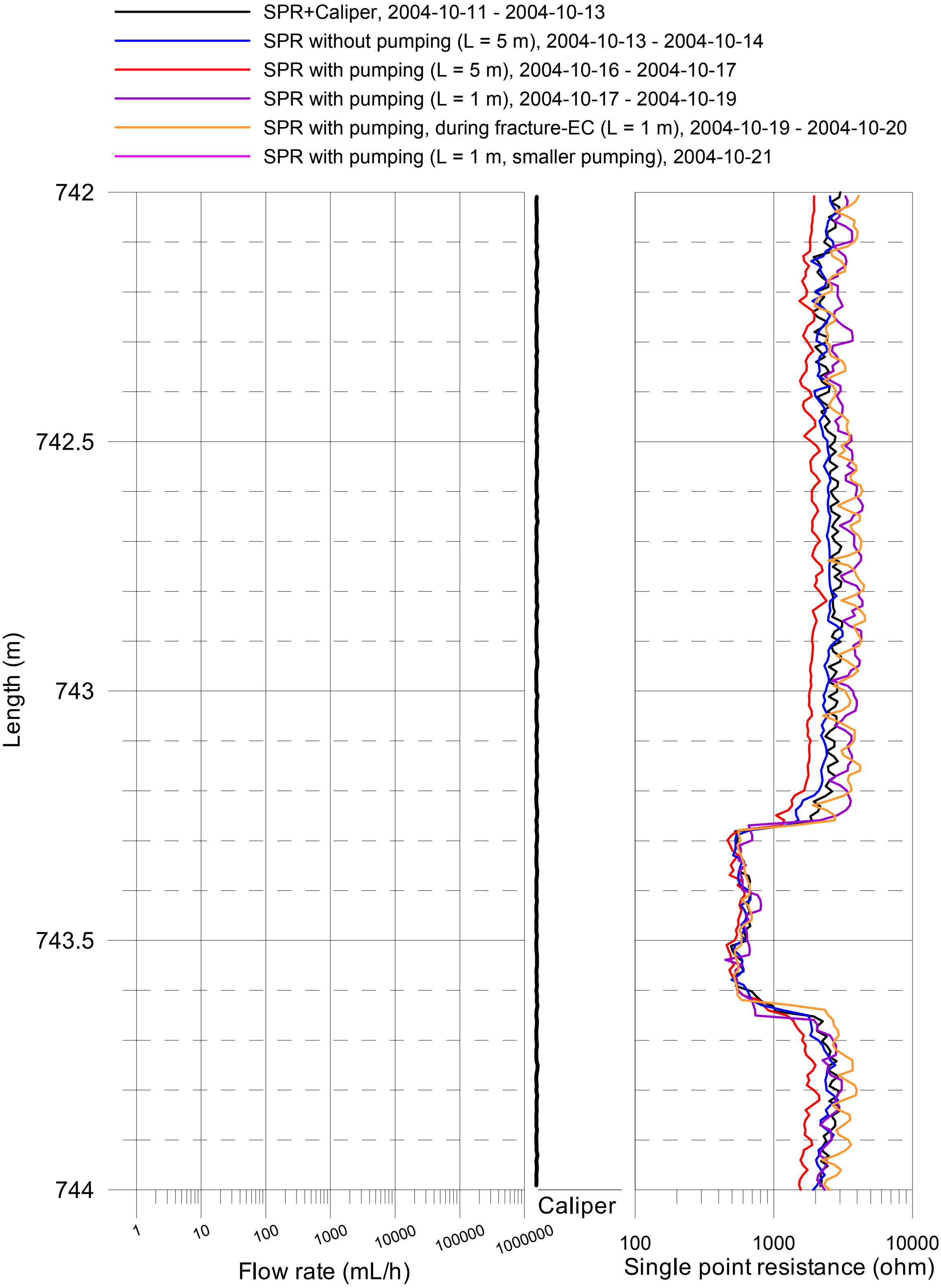
Forsmark, KFM06A
SPR and Caliper results after length correction



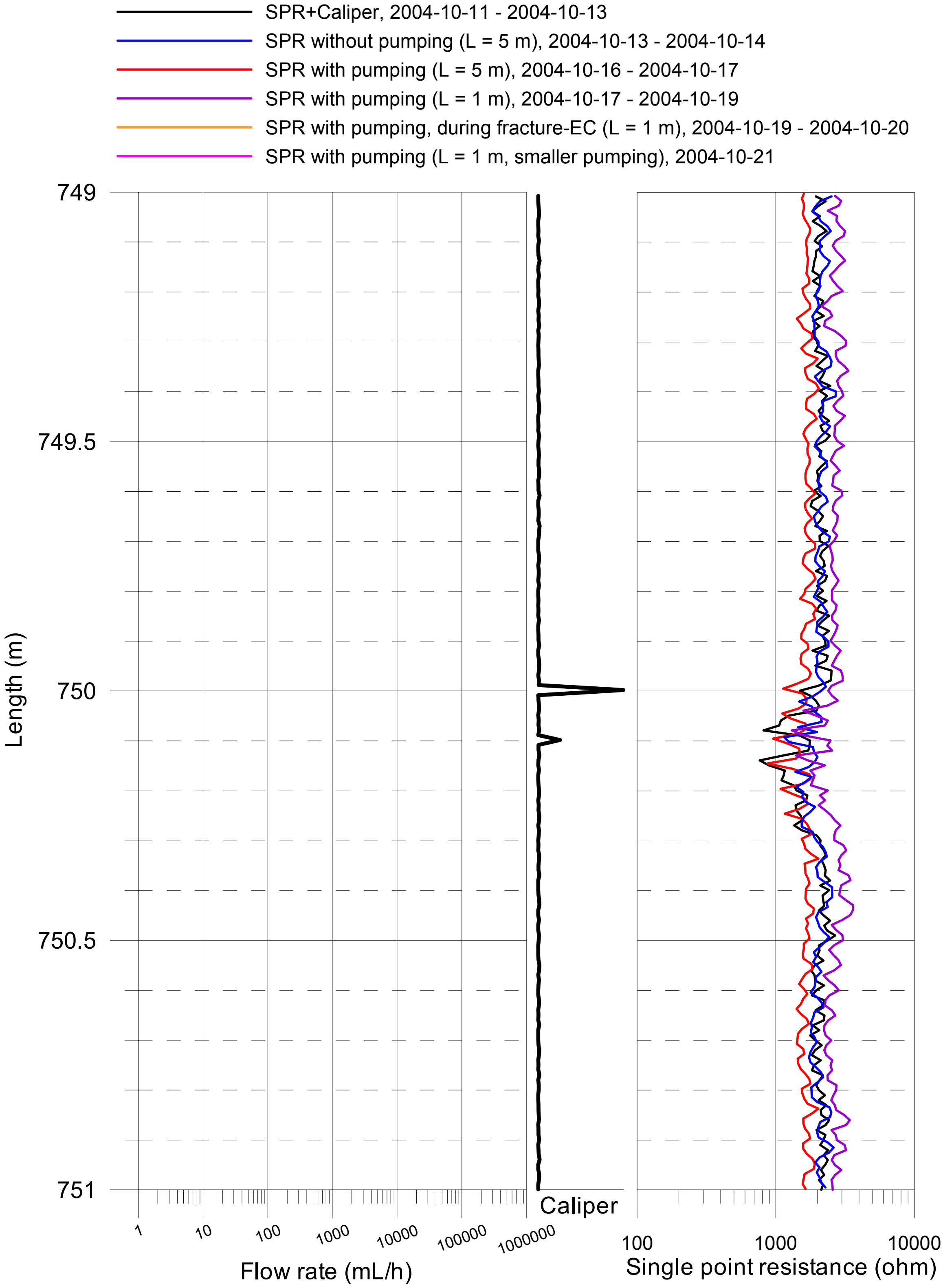
Forsmark, KFM06A
SPR and Caliper results after length correction



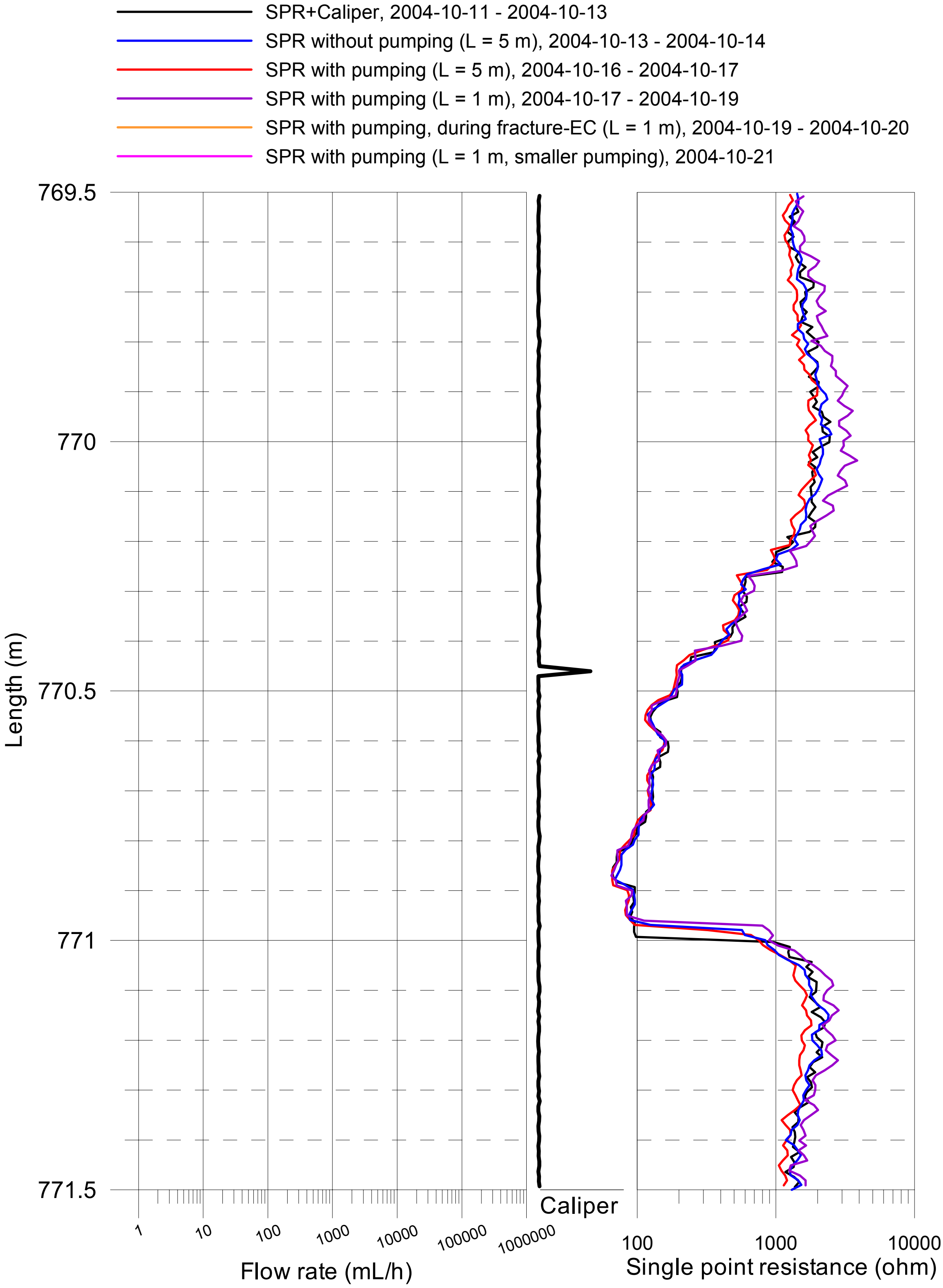
Forsmark, KFM06A
SPR and Caliper results after length correction



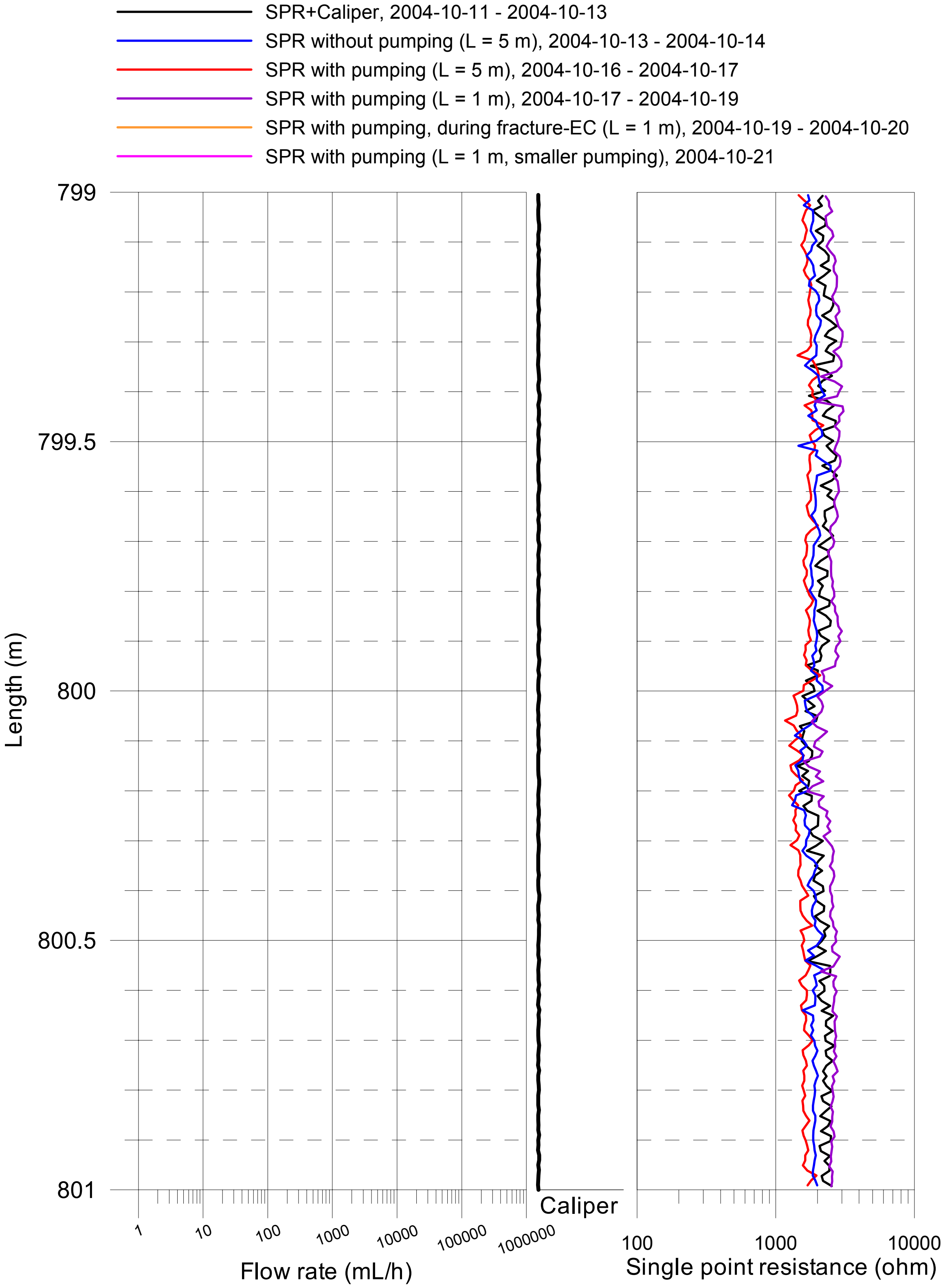
Forsmark, KFM06A
SPR and Caliper results after length correction



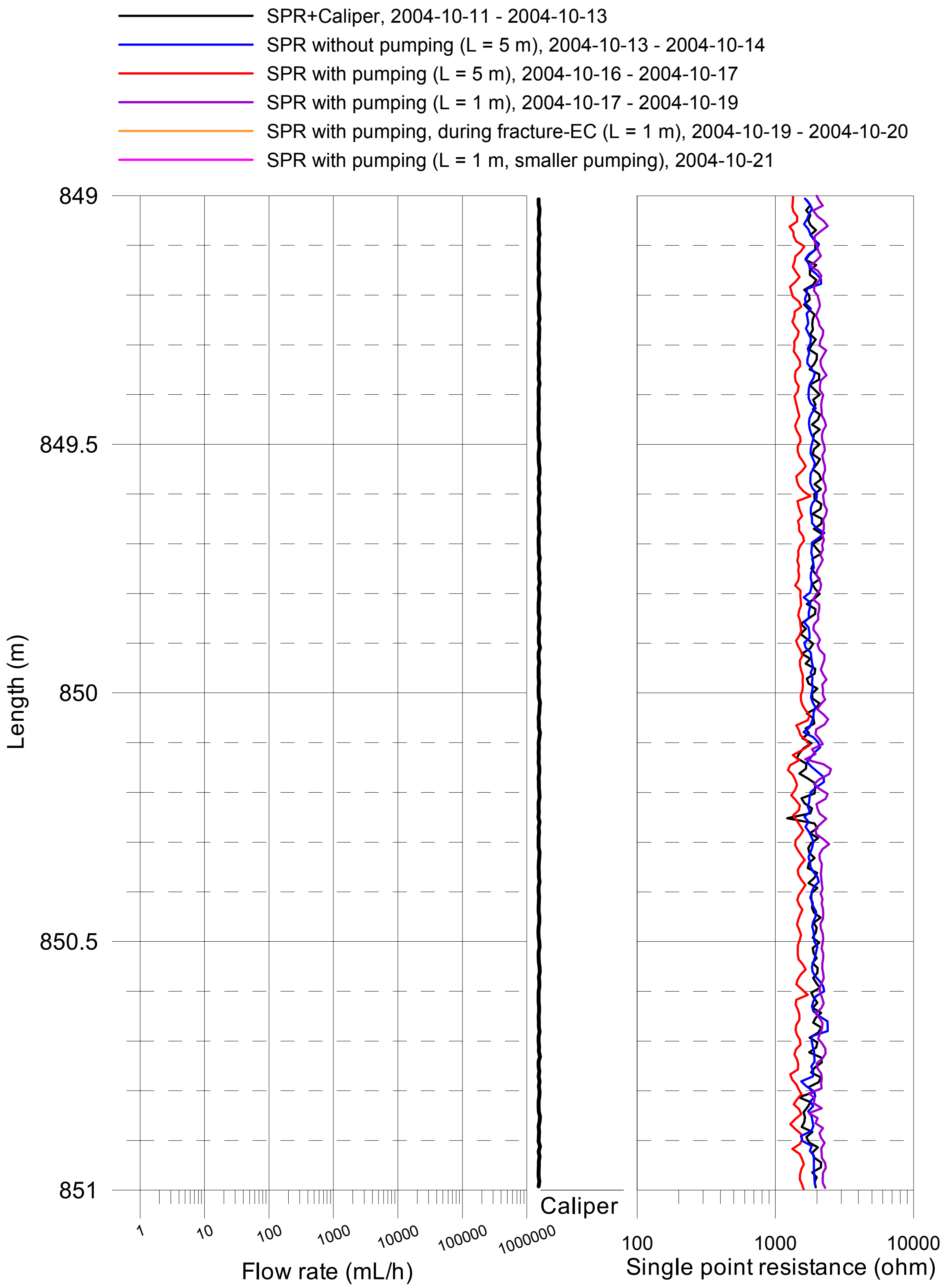
Forsmark, KFM06A
SPR and Caliper results after length correction



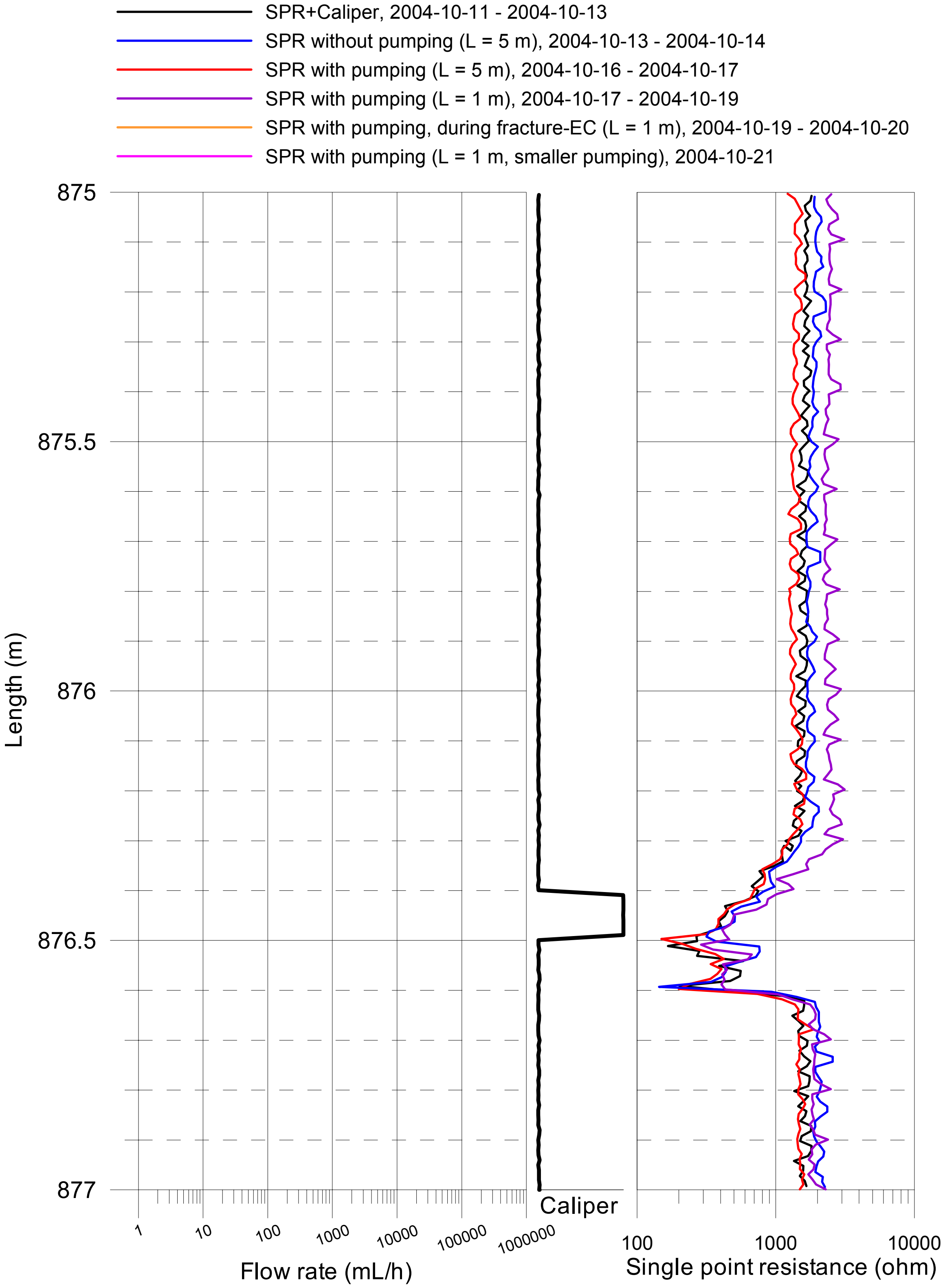
Forsmark, KFM06A
SPR and Caliper results after length correction



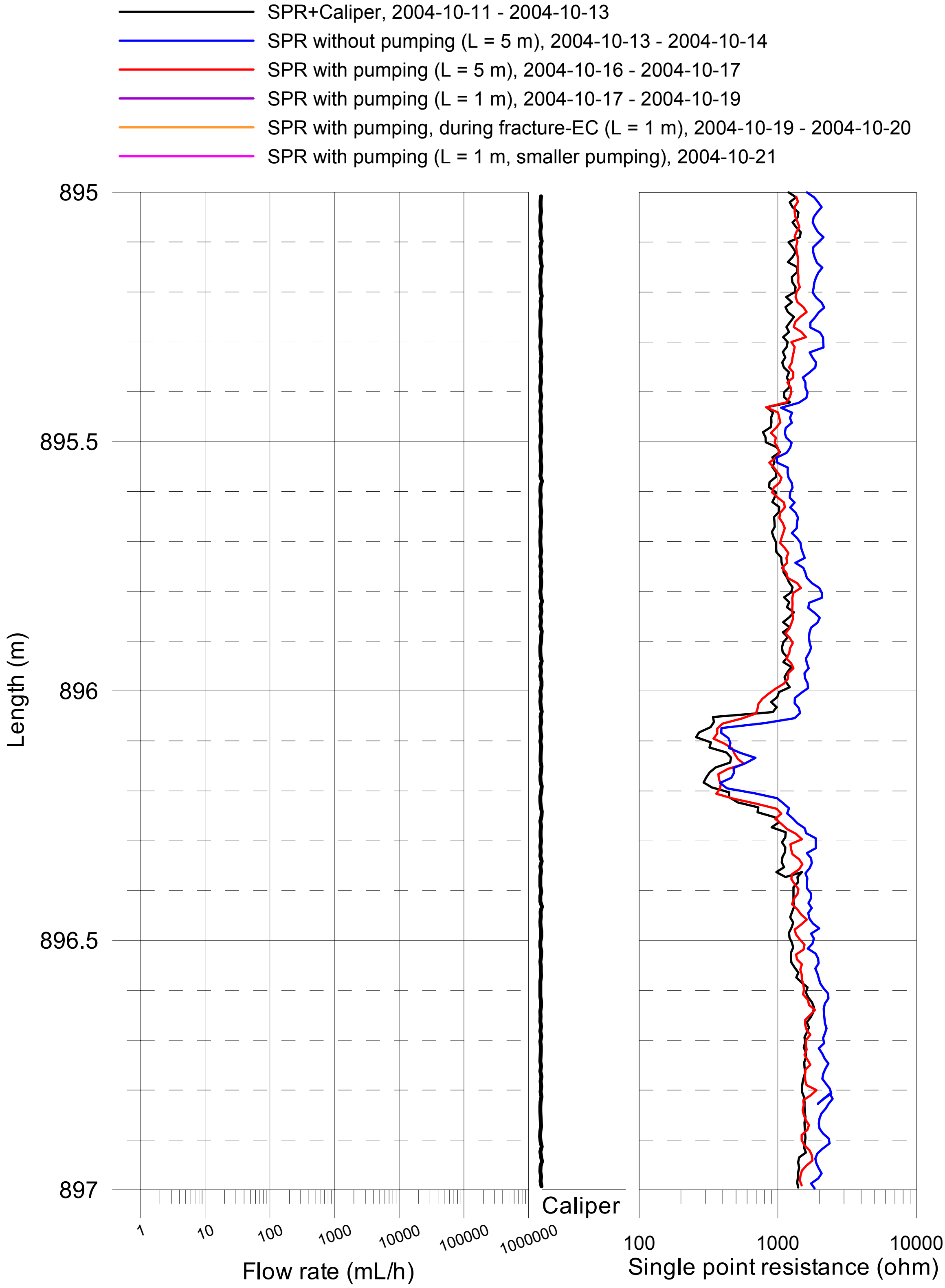
Forsmark, KFM06A
SPR and Caliper results after length correction



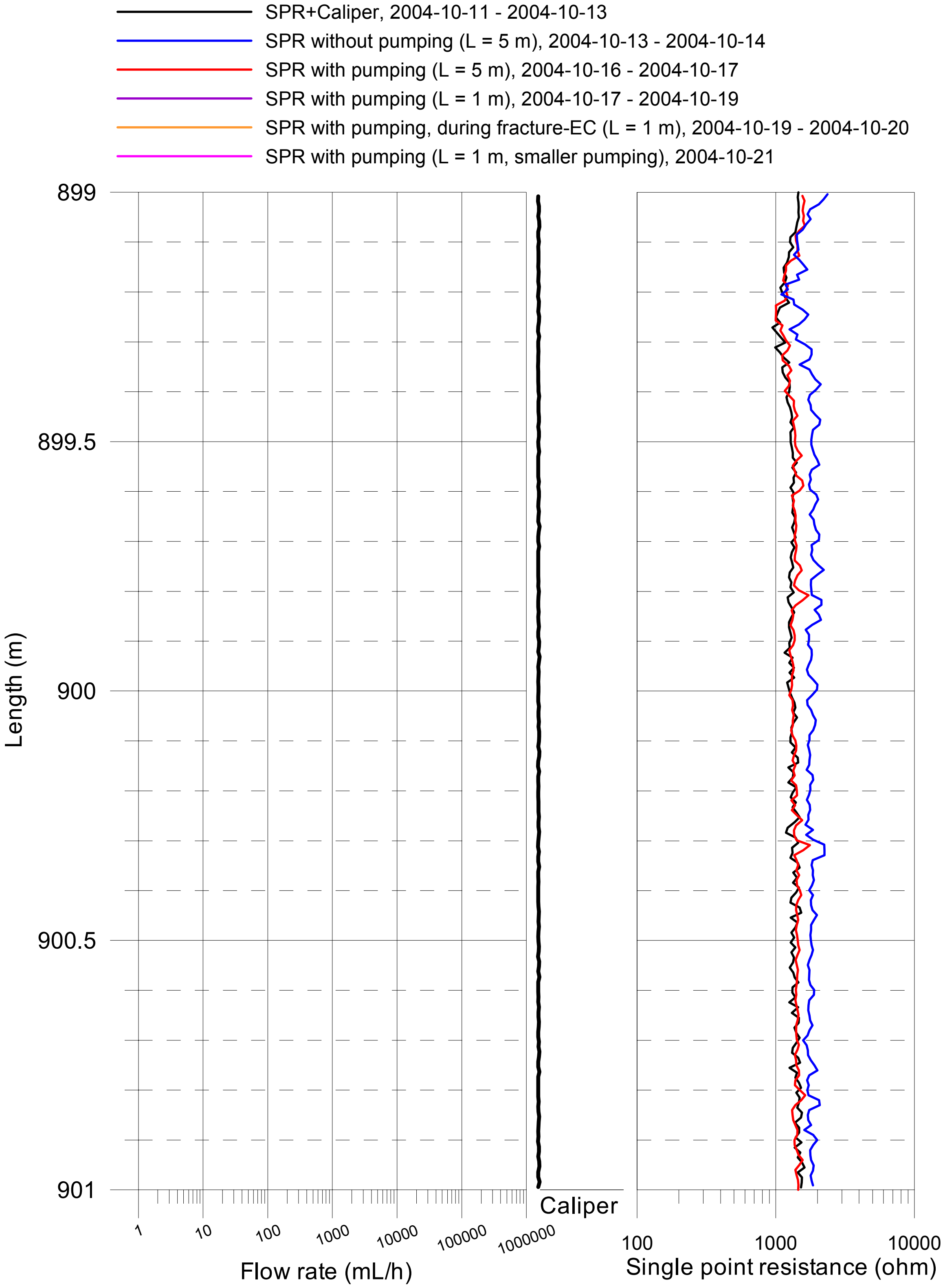
Forsmark, KFM06A
SPR and Caliper results after length correction



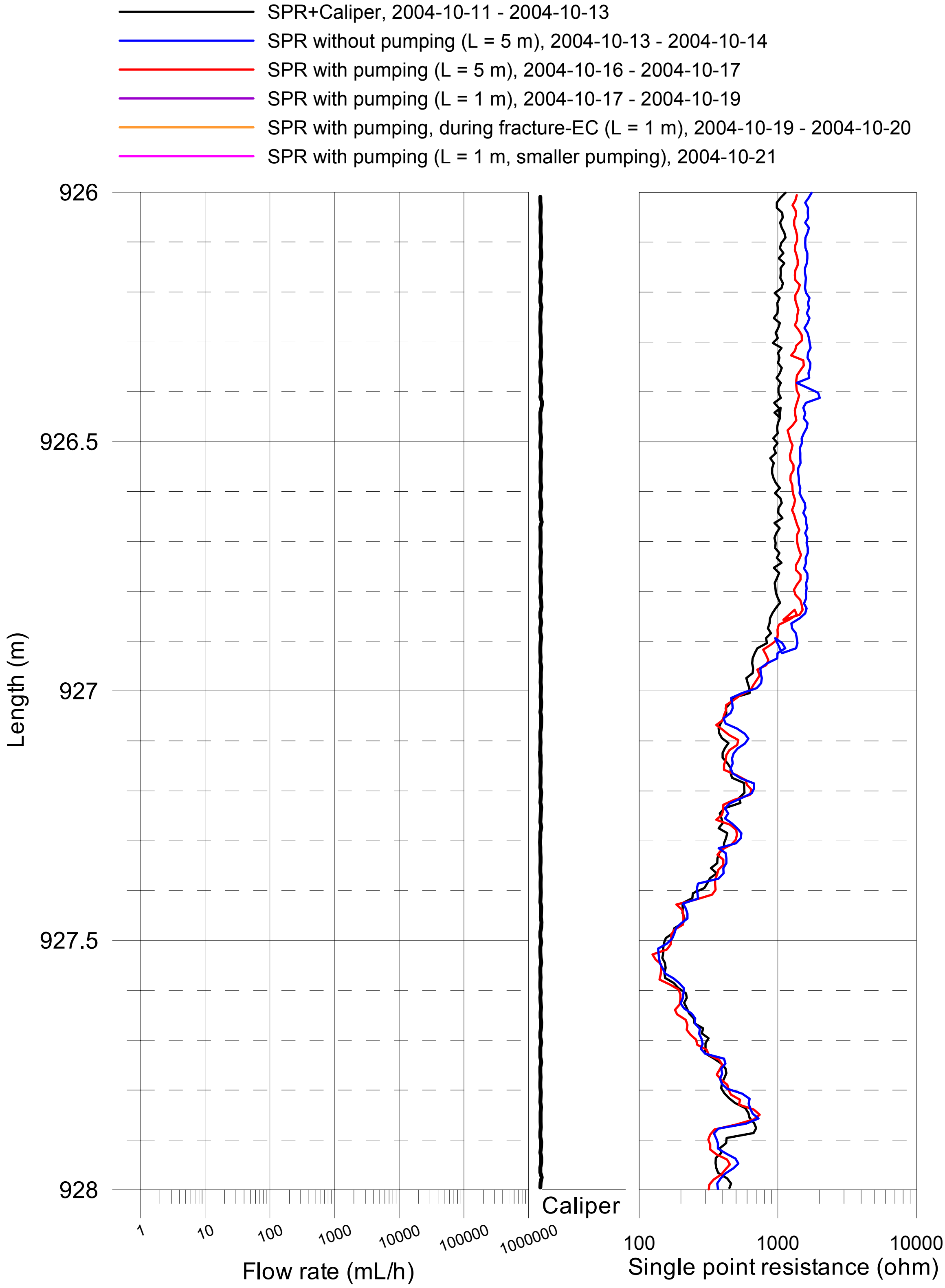
Forsmark, KFM06A
SPR and Caliper results after length correction



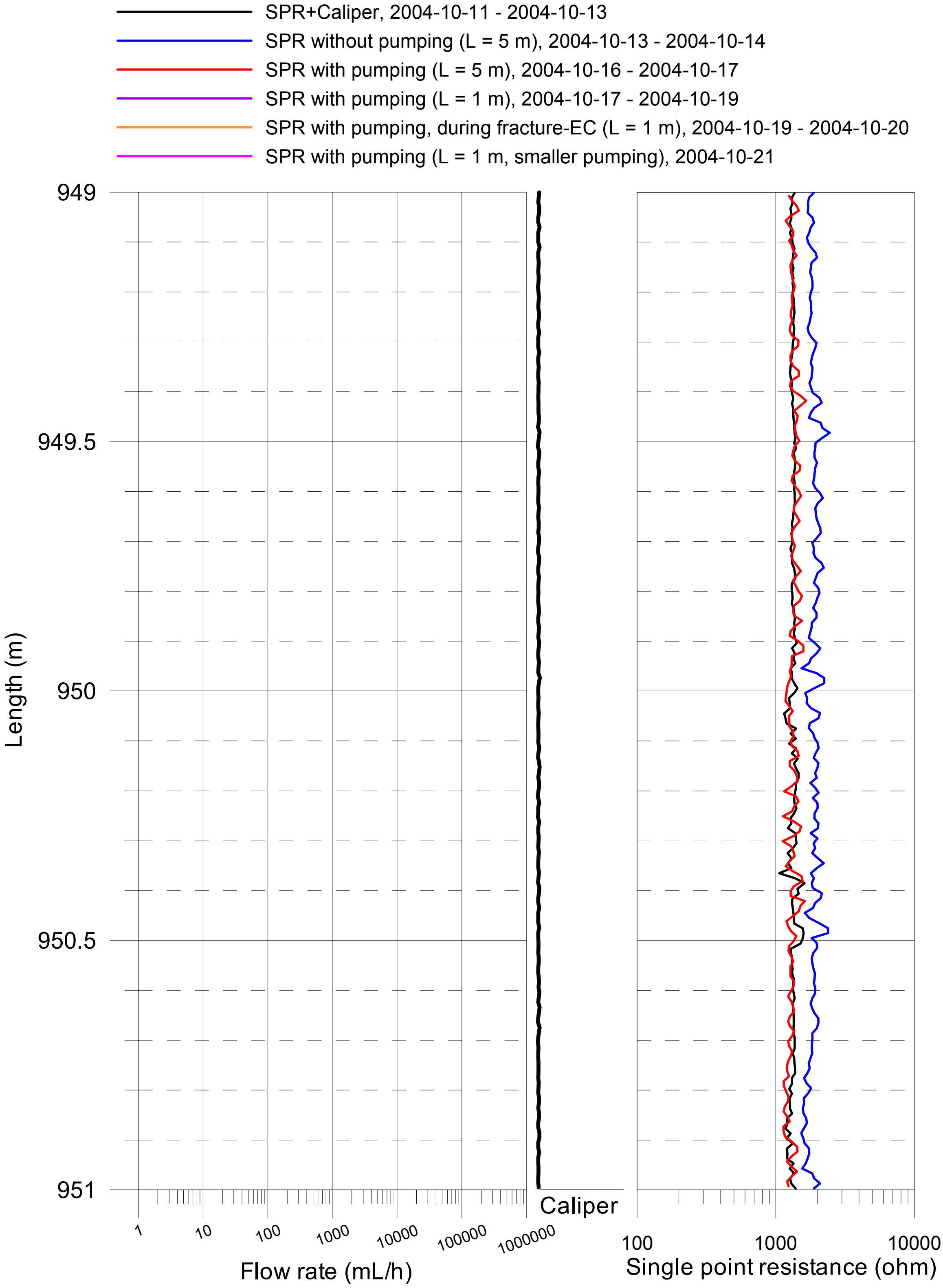
Forsmark, KFM06A
SPR and Caliper results after length correction



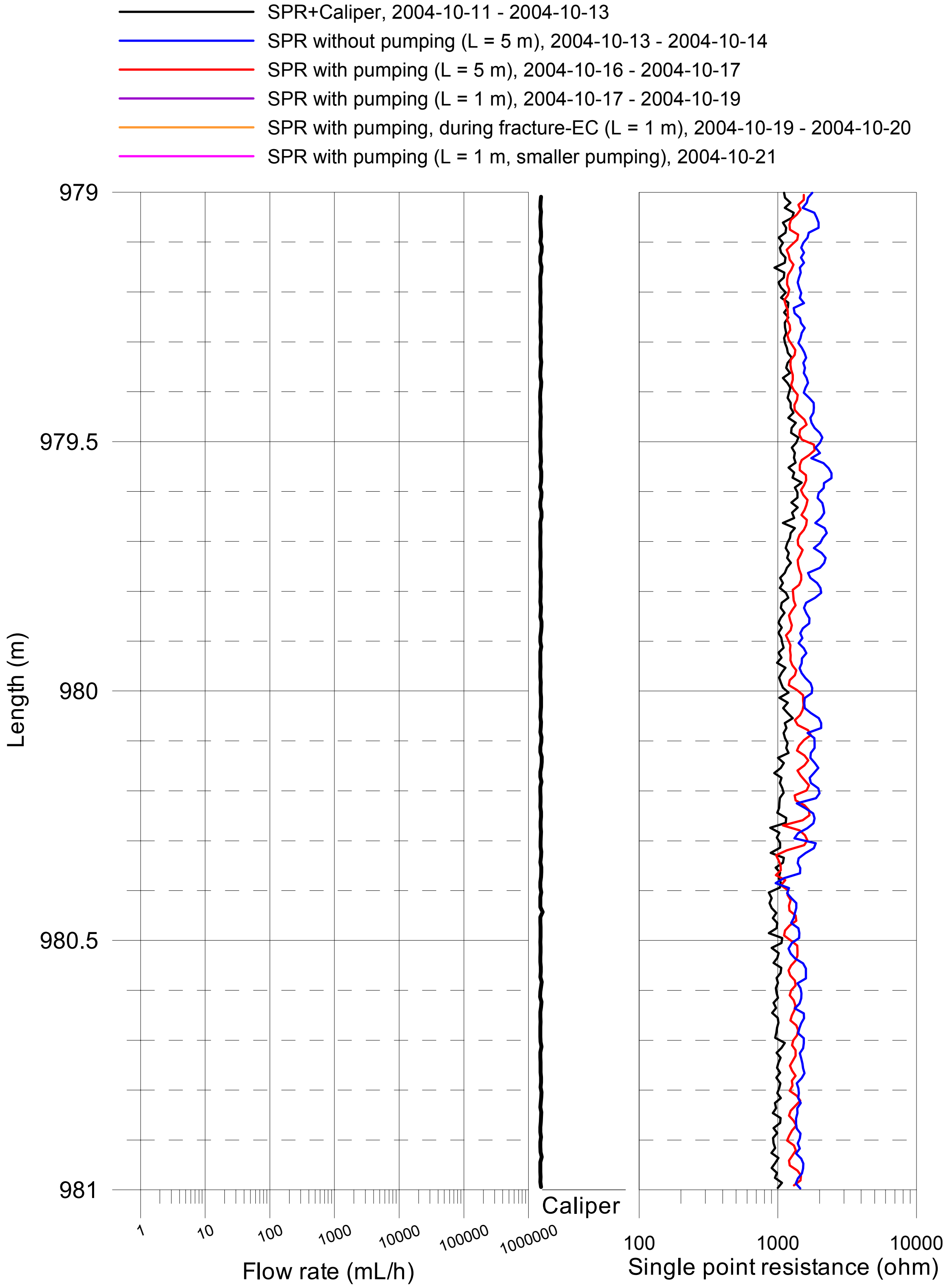
Forsmark, KFM06A
SPR and Caliper results after length correction



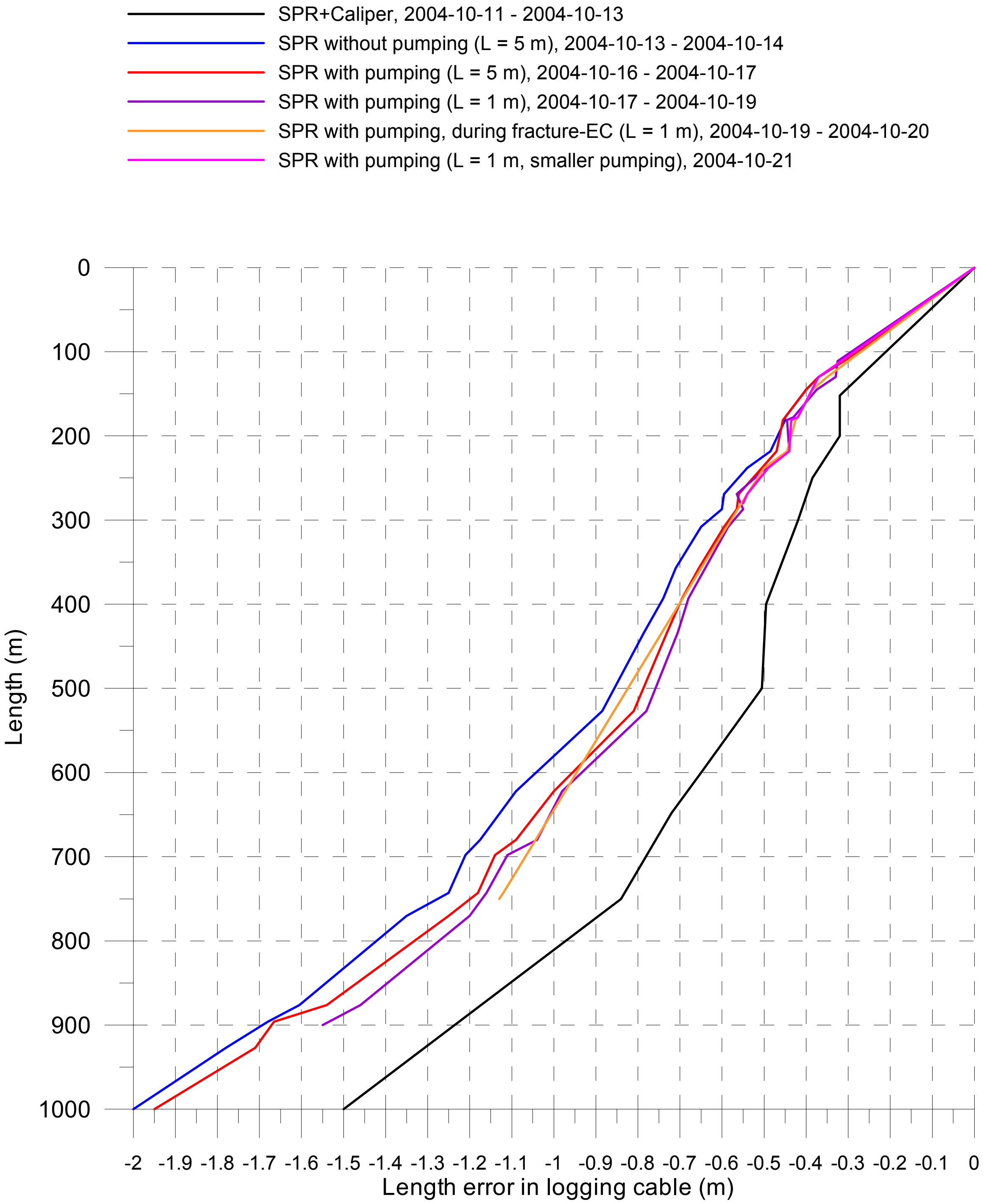
Forsmark, KFM06A
SPR and Caliper results after length correction



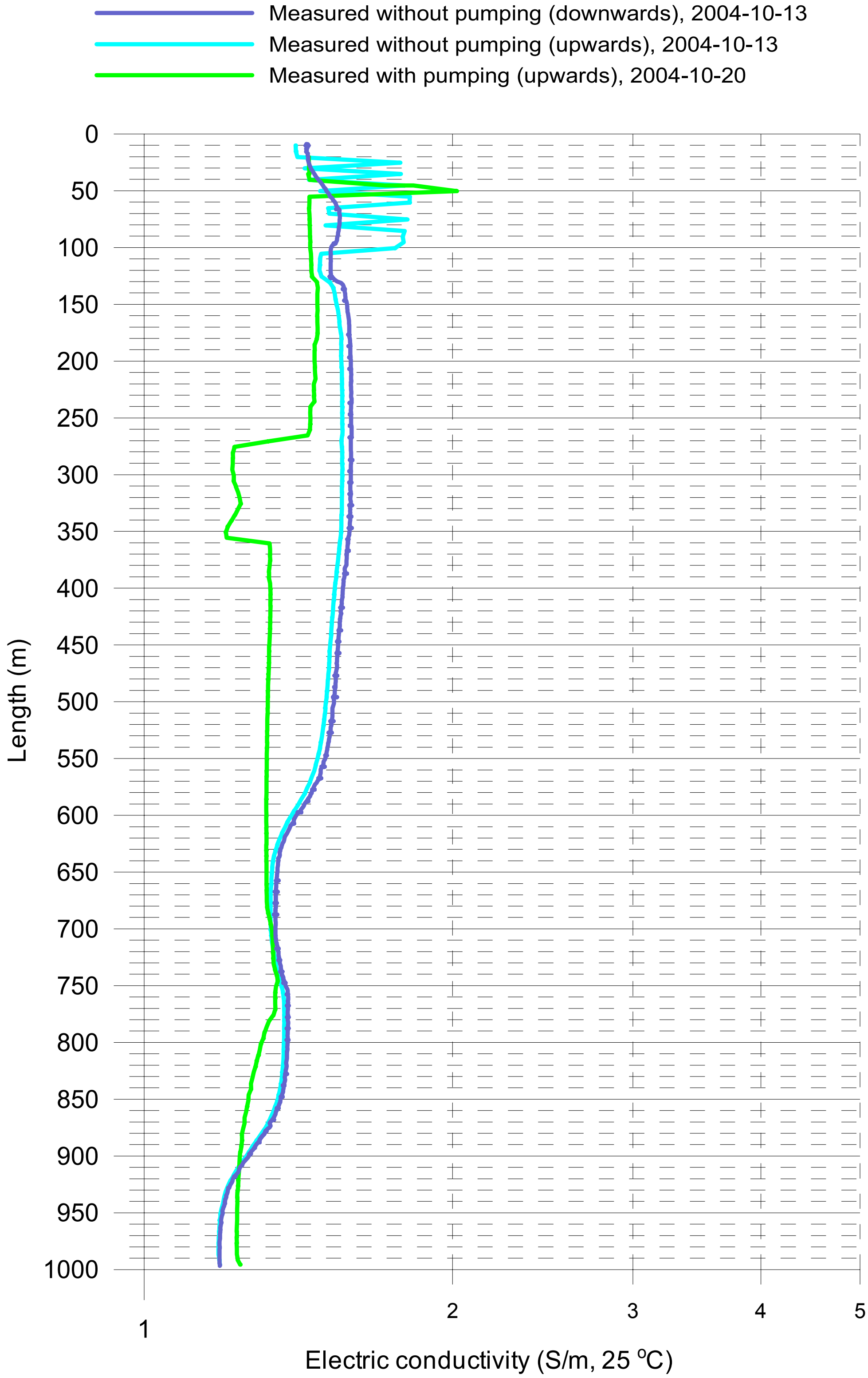
Forsmark, KFM06A
SPR and Caliper results after length correction



Forsmark, KFM06A
Length correction

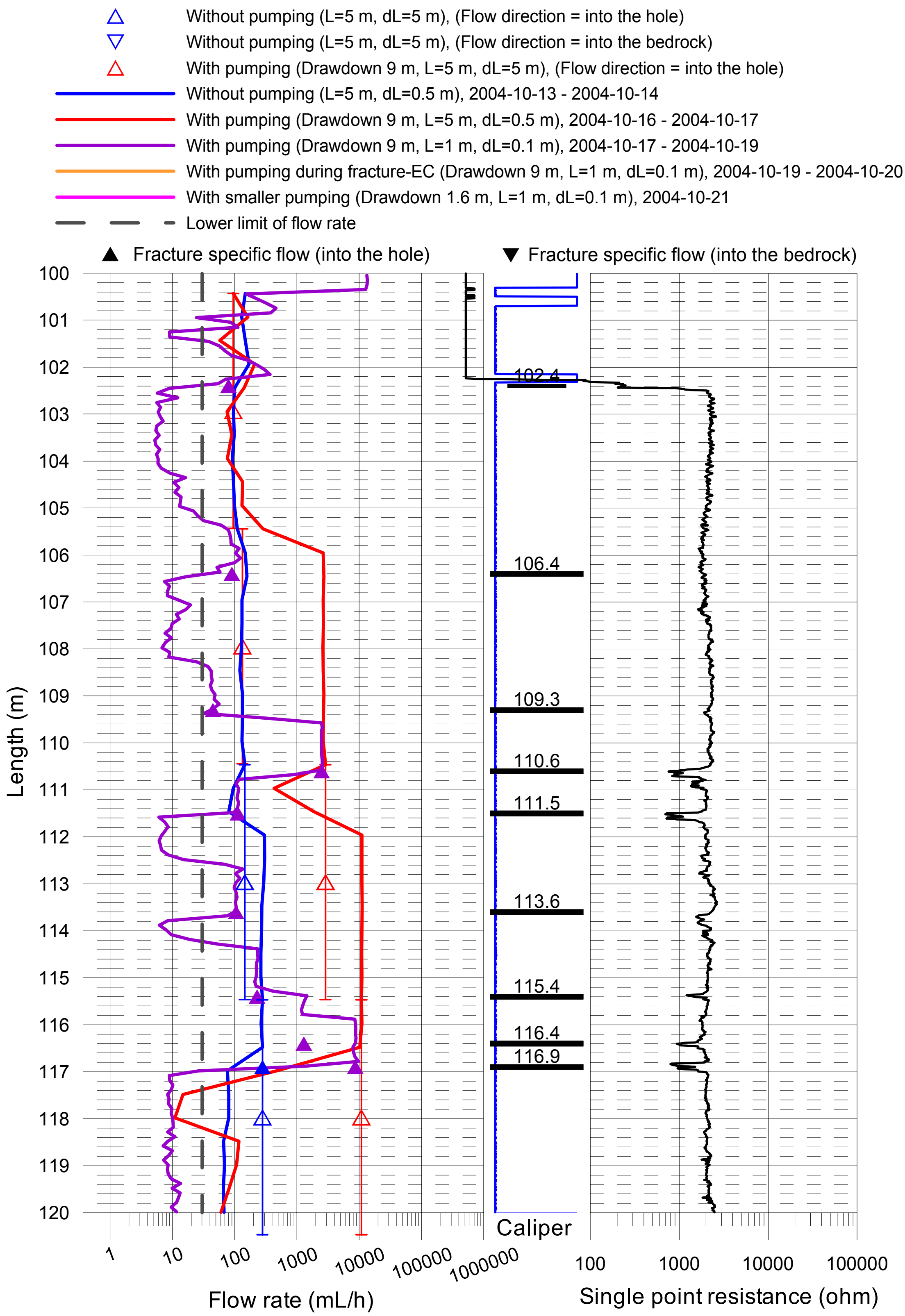


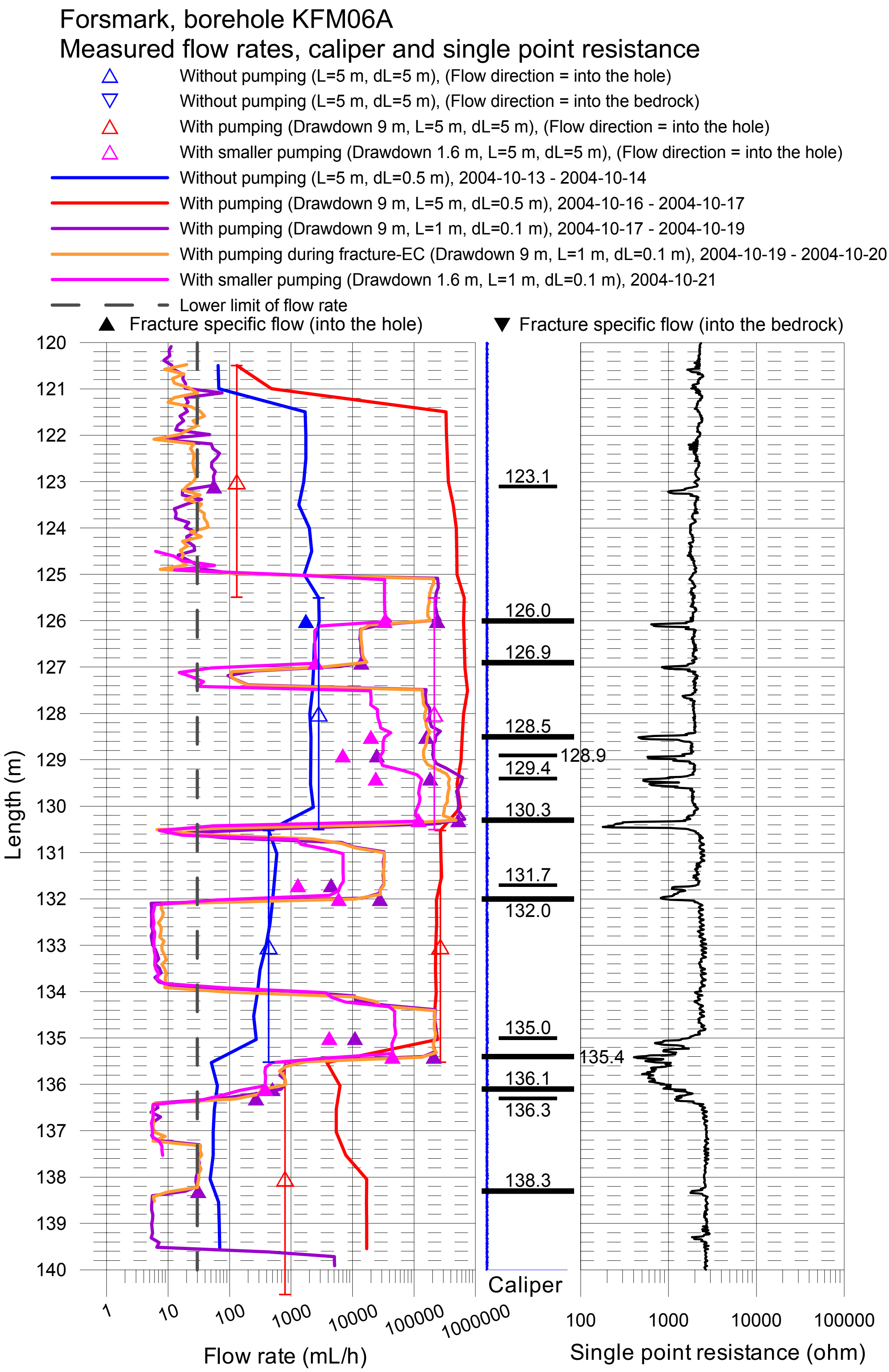
Forsmark, borehole KFM06A
Electric conductivity of borehole water

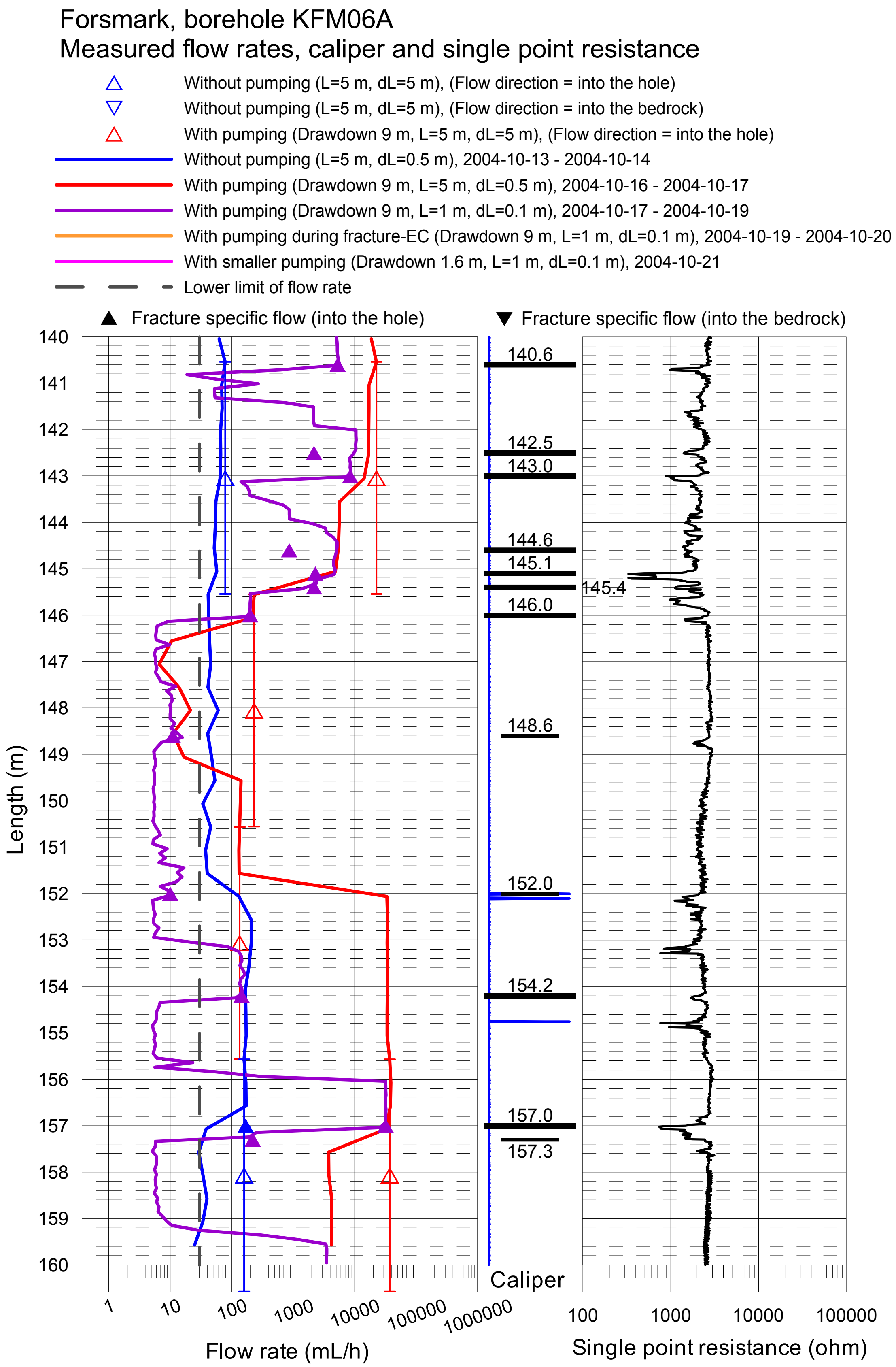


Forsmark, borehole KFM06A
Temperature of borehole water

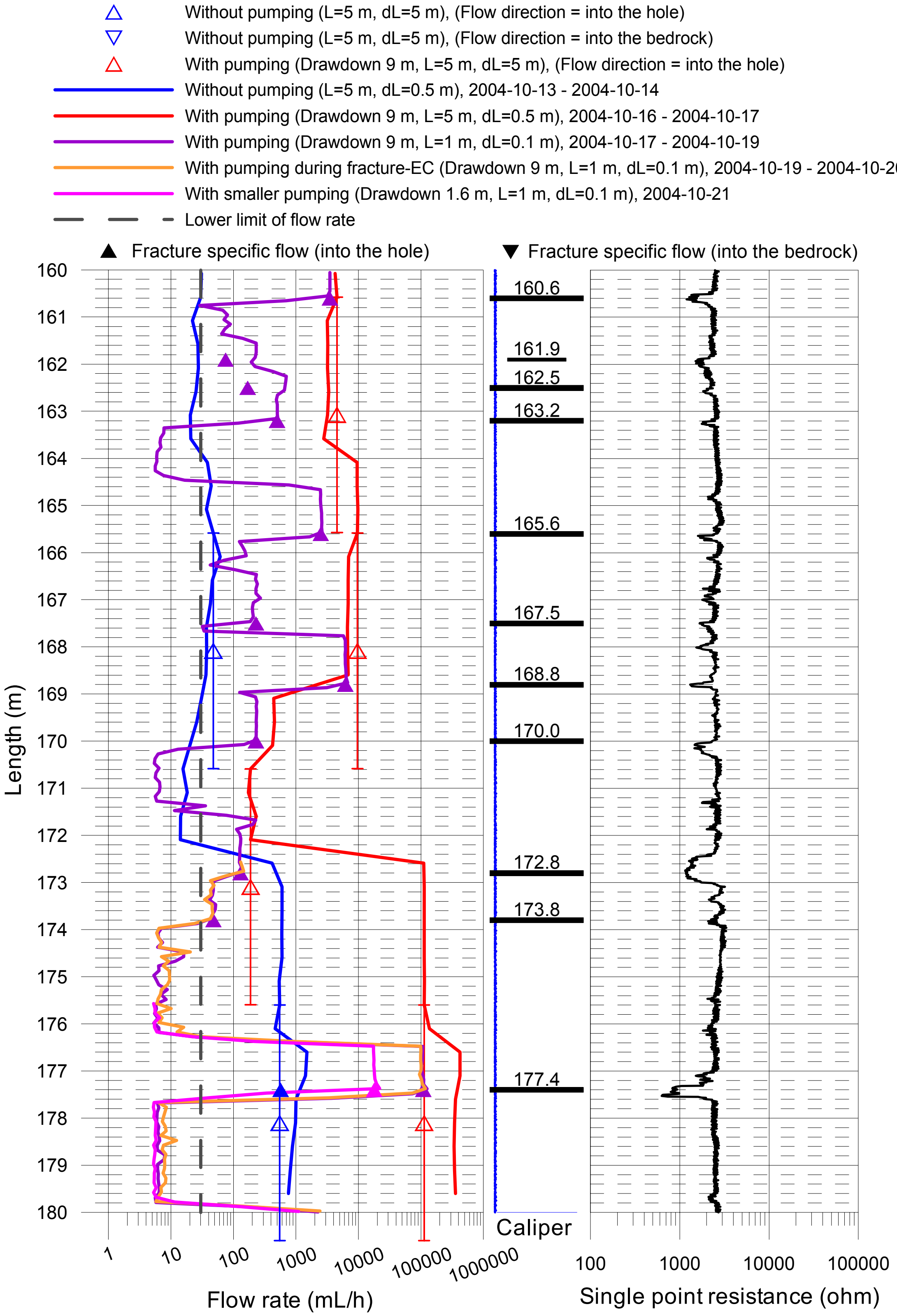
Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance

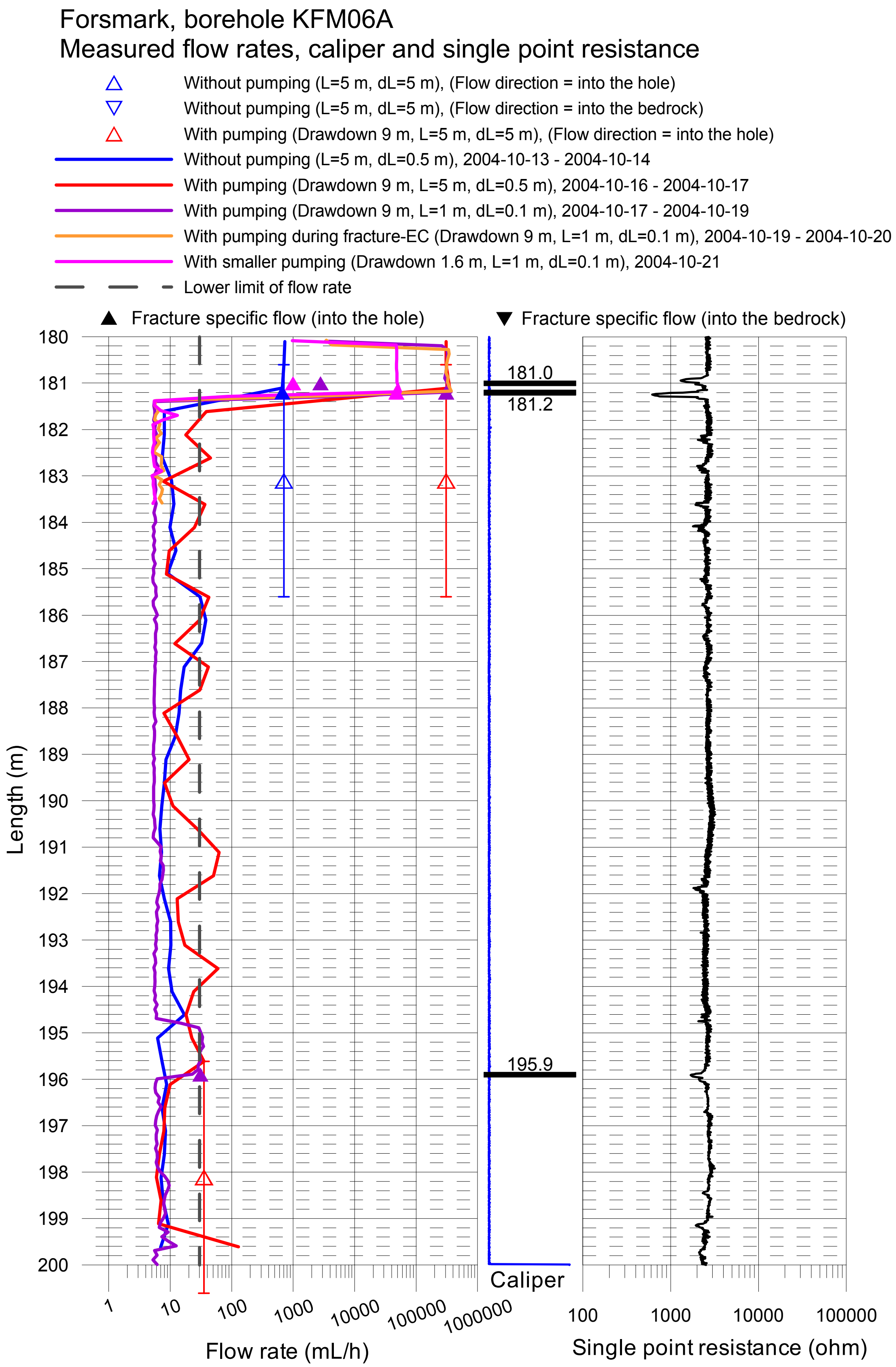



Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (Drawdown 9 m, L=5 m, dL=5 m), (Flow direction = into the hole)
With smaller pumping (Drawdown 1.6 m, L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=0.5 m), 2004-10-13 - 2004-10-14
With pumping (Drawdown 9 m, L=5 m, dL=0.5 m), 2004-10-16 - 2004-10-17
With pumping (Drawdown 9 m, L=1 m, dL=0.1 m), 2004-10-17 - 2004-10-19
With pumping during fracture-EC (Drawdown 9 m, L=1 m, dL=0.1 m), 2004-10-19 - 2004-10-20
With smaller pumping (Drawdown 1.6 m, L=1 m, dL=0.1 m), 2004-10-21
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
123.1
126.0
126.9
128.5
128.9
129.4
130.3
131.7
132.0
135.0
135.4
136.1
136.3
138.3
Caliper
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
100
1000
10000
100000
Single point resistance (ohm)

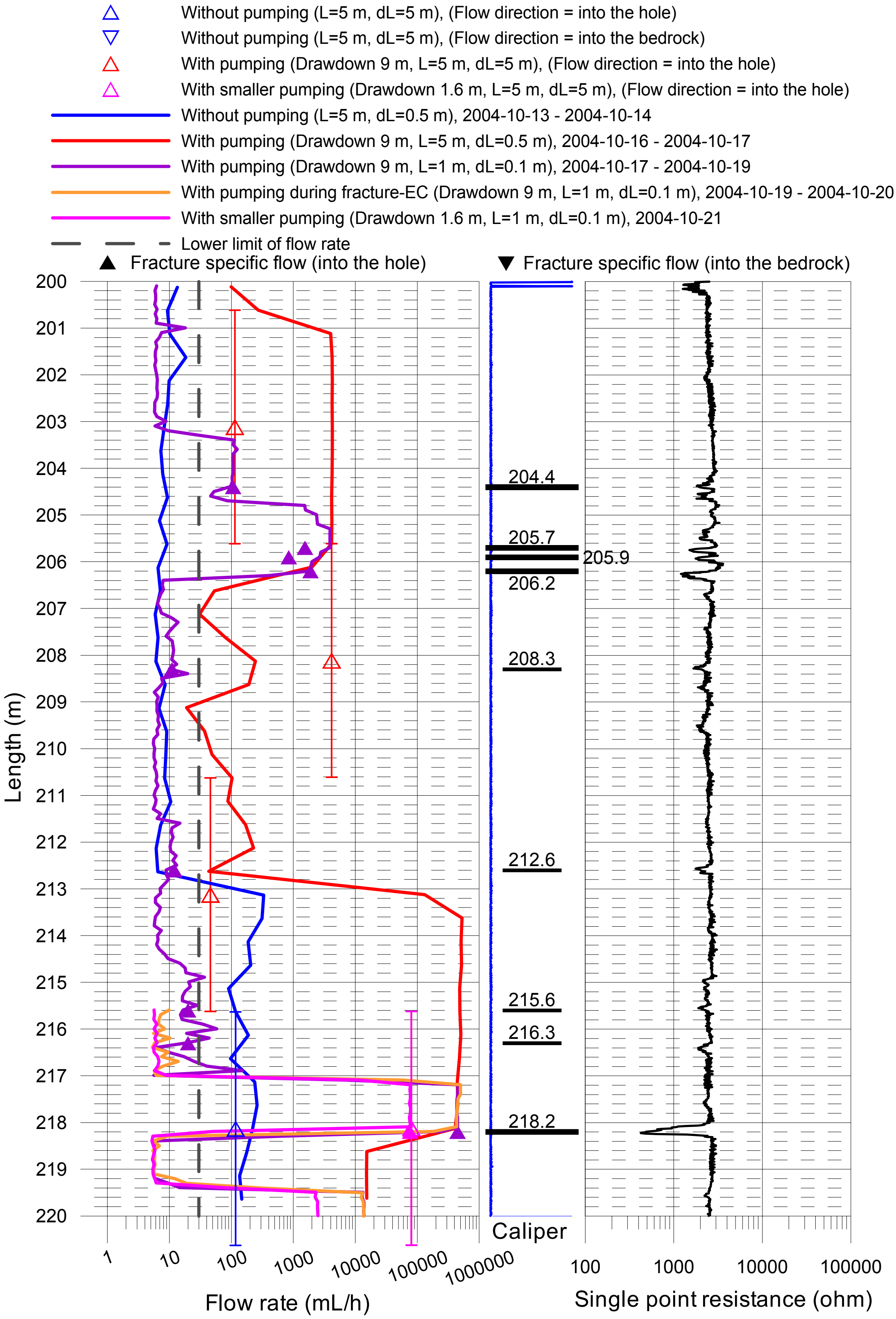

Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (Drawdown 9 m, L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=0.5 m), 2004-10-13 - 2004-10-14
With pumping (Drawdown 9 m, L=5 m, dL=0.5 m), 2004-10-16 - 2004-10-17
With pumping (Drawdown 9 m, L=1 m, dL=0.1 m), 2004-10-17 - 2004-10-19
With pumping during fracture-EC (Drawdown 9 m, L=1 m, dL=0.1 m), 2004-10-19 - 2004-10-20
With smaller pumping (Drawdown 1.6 m, L=1 m, dL=0.1 m), 2004-10-21
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
140.6
142.5
143.0
144.6
145.1
145.4
146.0
148.6
152.0
154.2
157.0
157.3
Caliper
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
100
1000
10000
100000
Single point resistance (ohm)

Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance

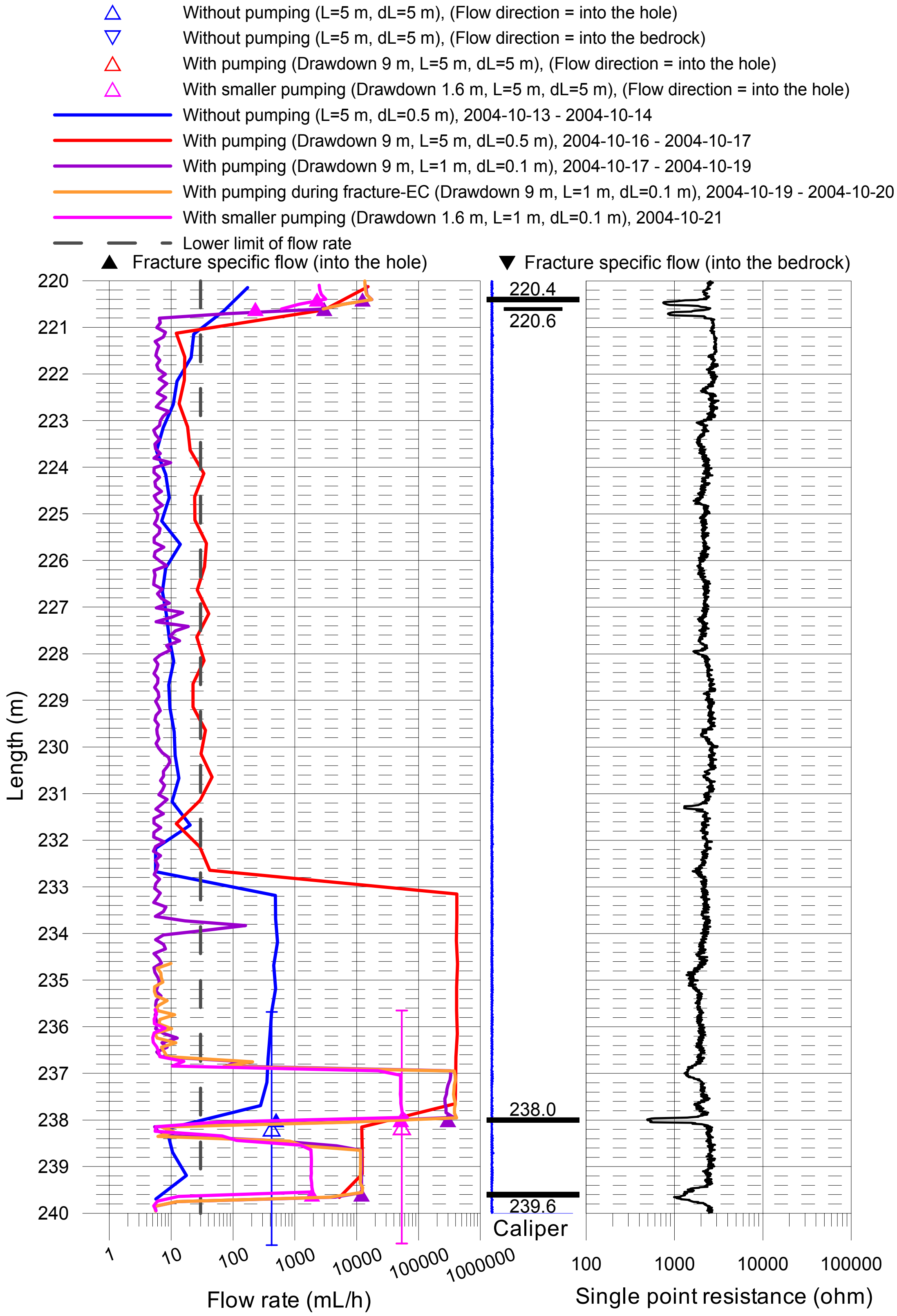



Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (Drawdown 9 m, L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=0.5 m), 2004-10-13 - 2004-10-14
With pumping (Drawdown 9 m, L=5 m, dL=0.5 m), 2004-10-16 - 2004-10-17
With pumping (Drawdown 9 m, L=1 m, dL=0.1 m), 2004-10-17 - 2004-10-19
With pumping during fracture-EC (Drawdown 9 m, L=1 m, dL=0.1 m), 2004-10-19 - 2004-10-20
With smaller pumping (Drawdown 1.6 m, L=1 m, dL=0.1 m), 2004-10-21
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
181.0
181.2
195.9
Caliper
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
100
1000
10000
100000
Single point resistance (ohm)

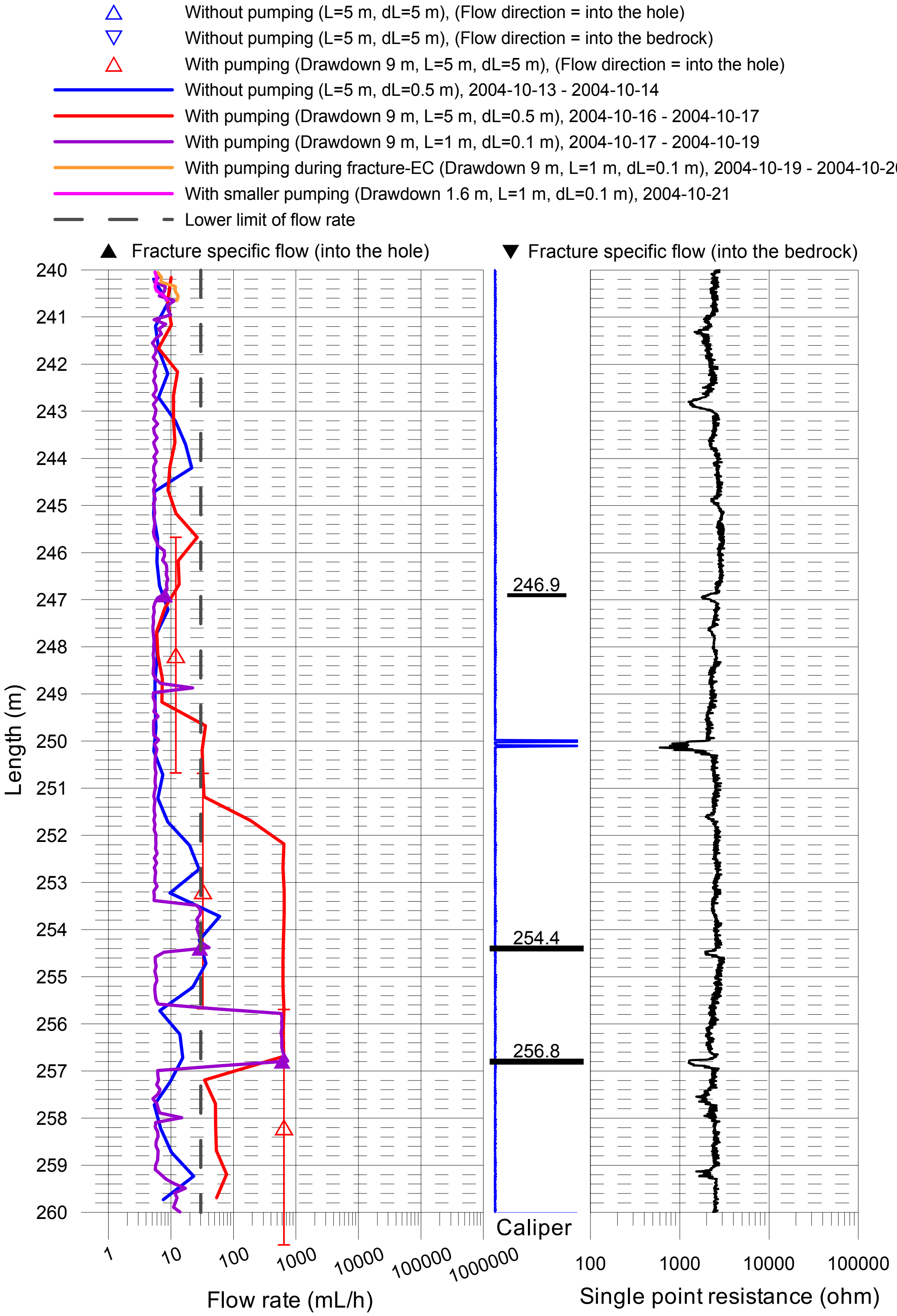
Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance

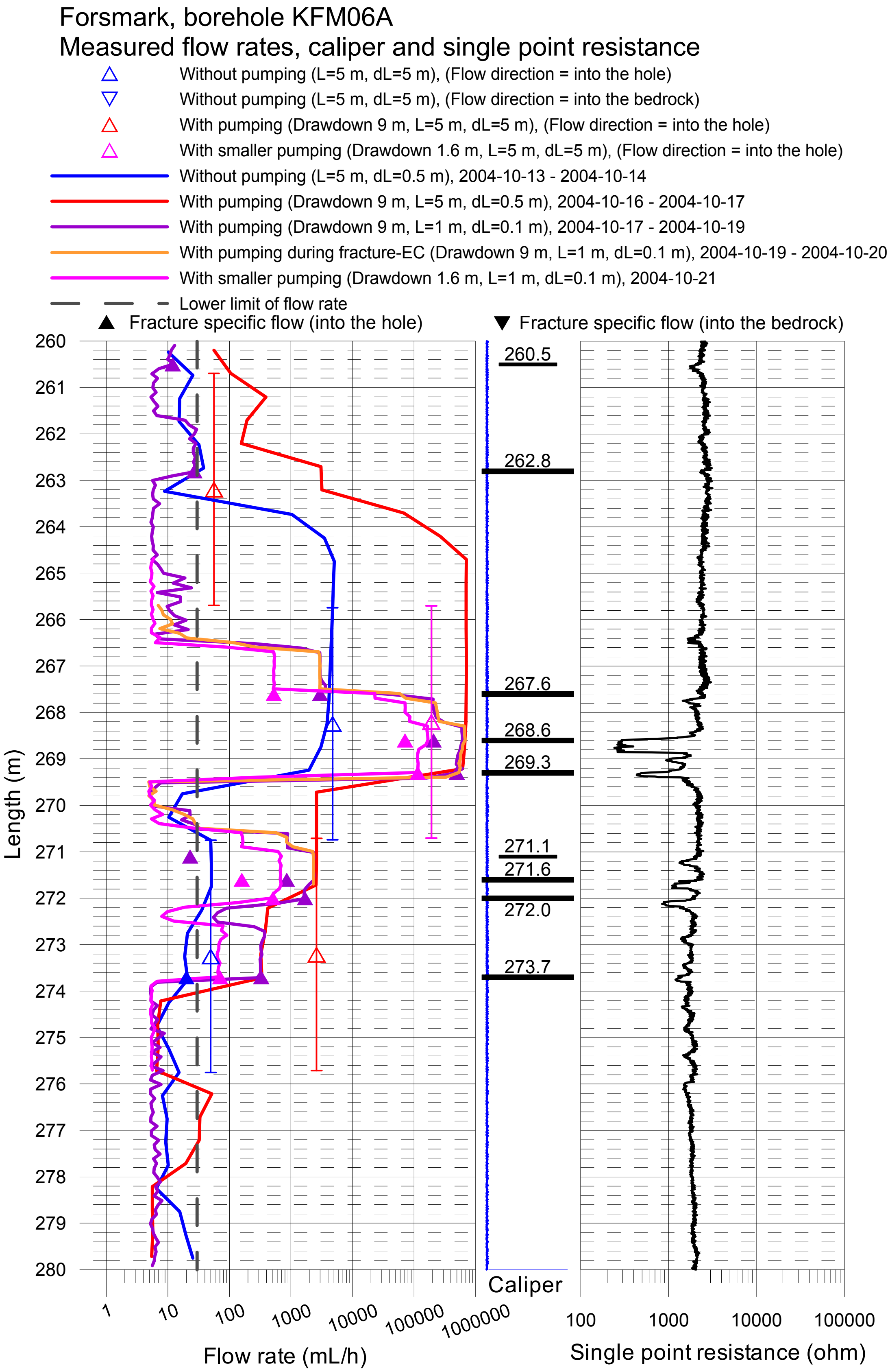


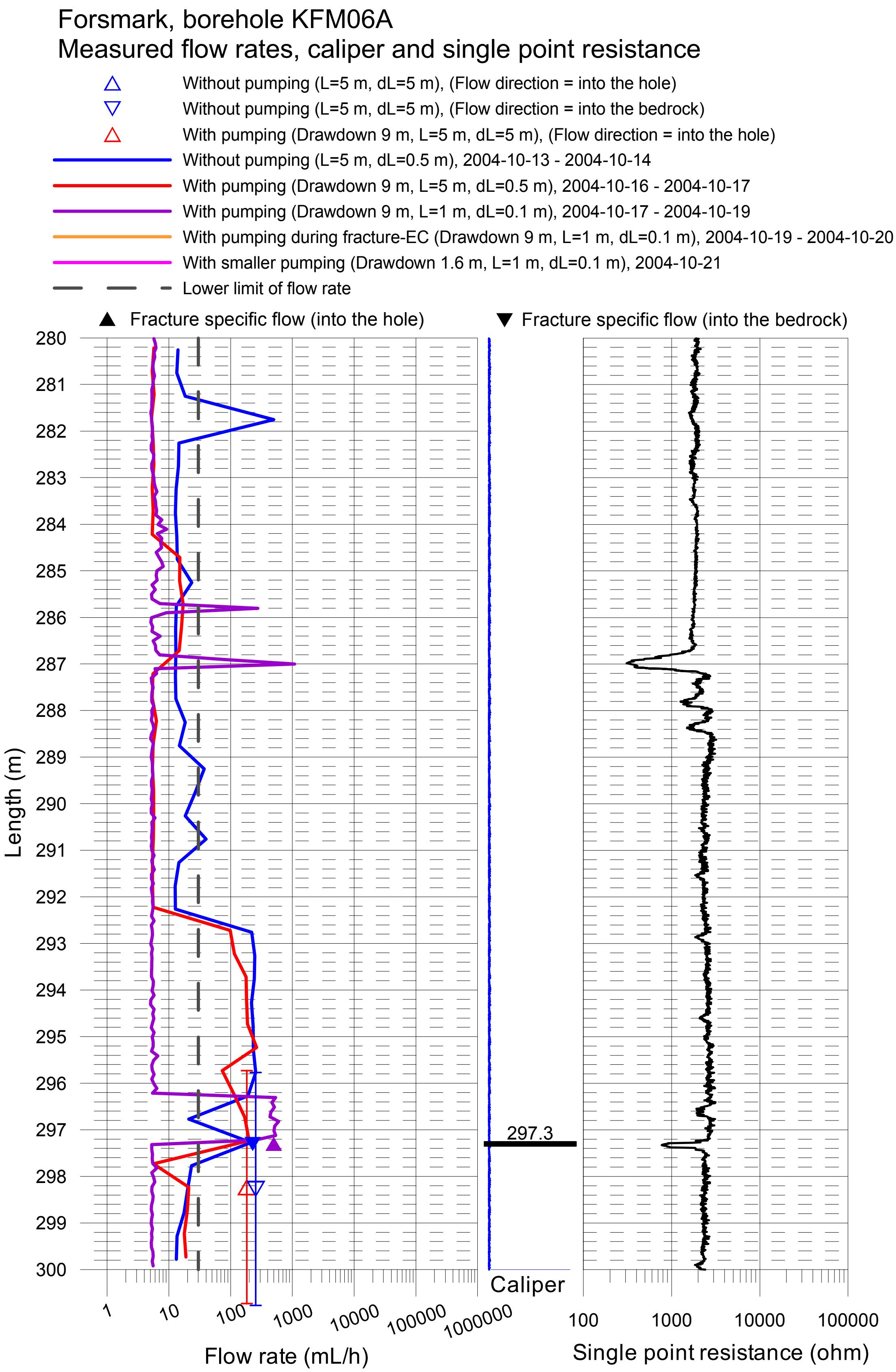
Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance

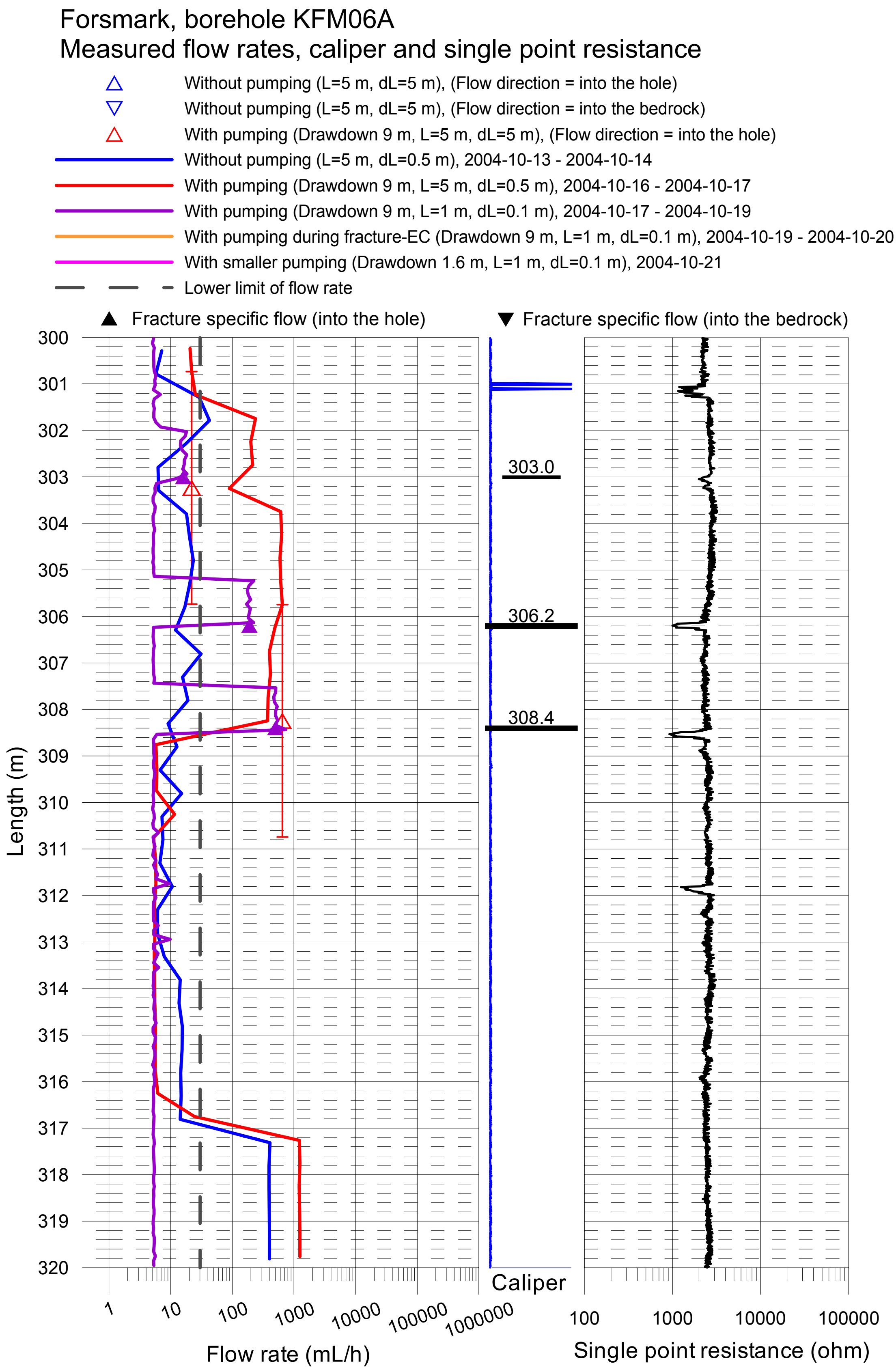


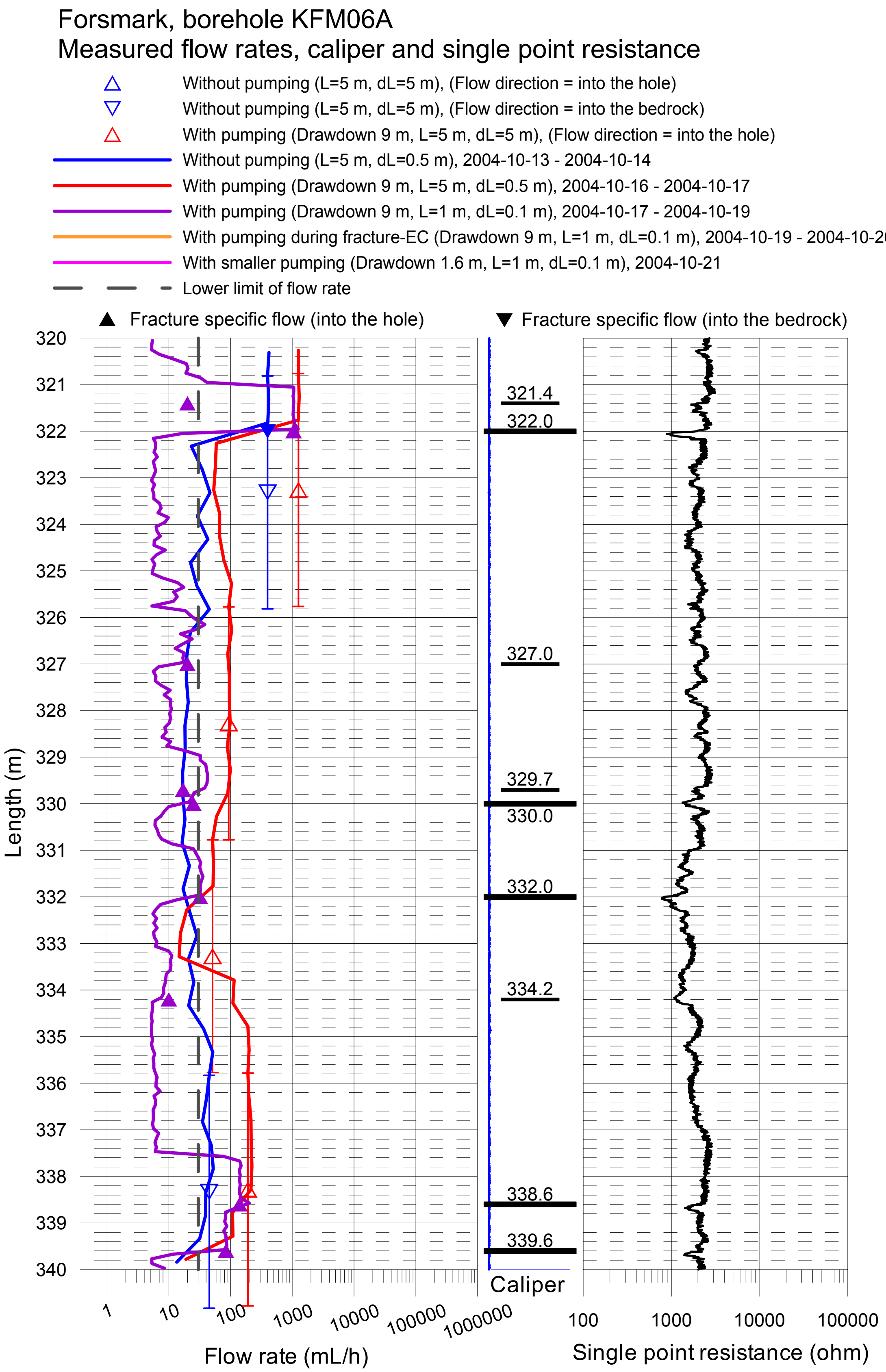
Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance



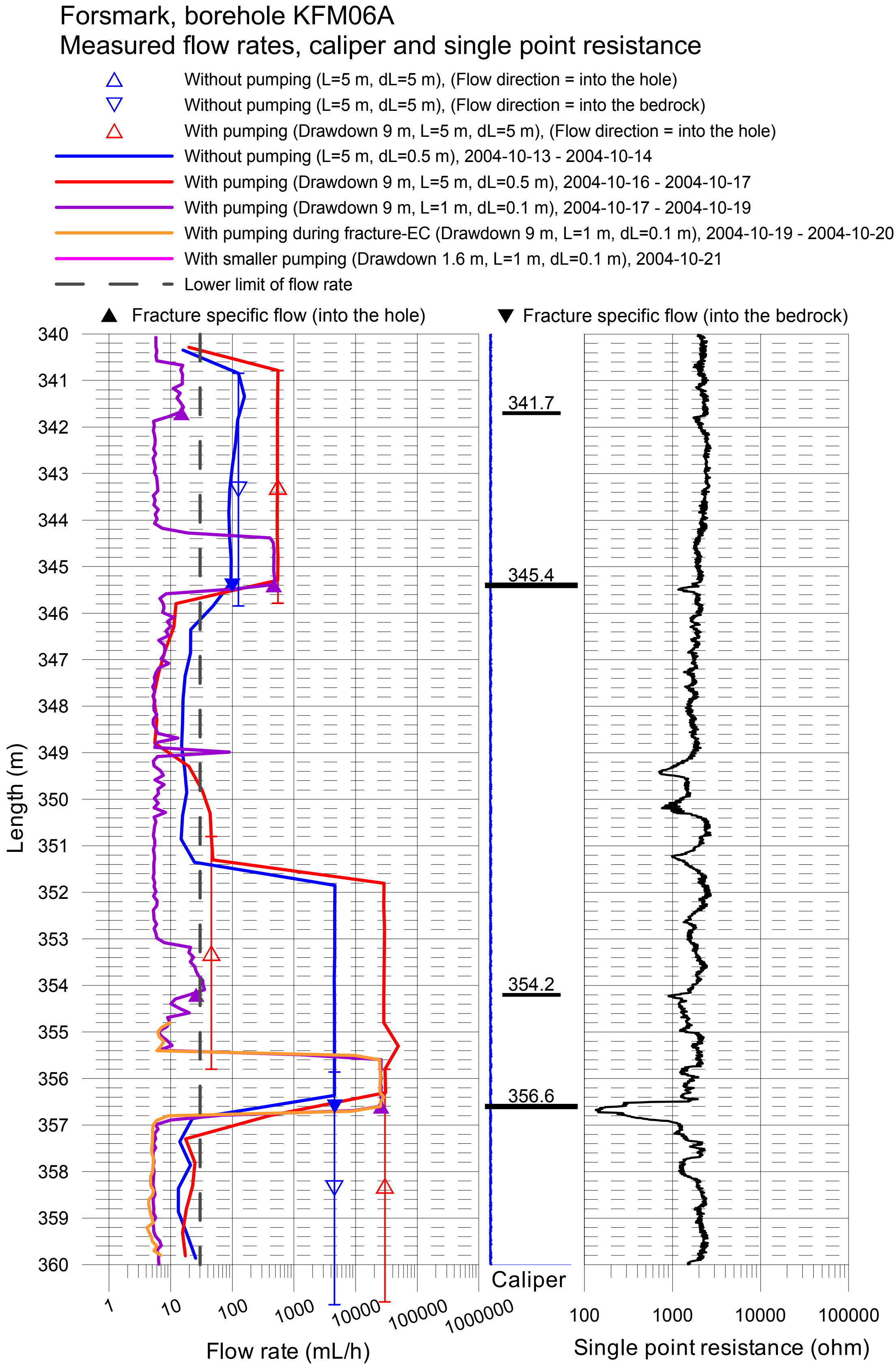

Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (Drawdown 9 m, L=5 m, dL=5 m), (Flow direction = into the hole)
With smaller pumping (Drawdown 1.6 m, L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=0.5 m), 2004-10-13 - 2004-10-14
With pumping (Drawdown 9 m, L=5 m, dL=0.5 m), 2004-10-16 - 2004-10-17
With pumping (Drawdown 9 m, L=1 m, dL=0.1 m), 2004-10-17 - 2004-10-19
With pumping during fracture-EC (Drawdown 9 m, L=1 m, dL=0.1 m), 2004-10-19 - 2004-10-20
With smaller pumping (Drawdown 1.6 m, L=1 m, dL=0.1 m), 2004-10-21
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
260
261
262
263
264
265
266
267
268
269
270
271
272
273
274
275
276
277
278
279
280
260.5
262.8
267.6
268.6
269.3
271.1
271.6
272.0
273.7
Caliper
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
100
1000
10000
100000
Single point resistance (ohm)

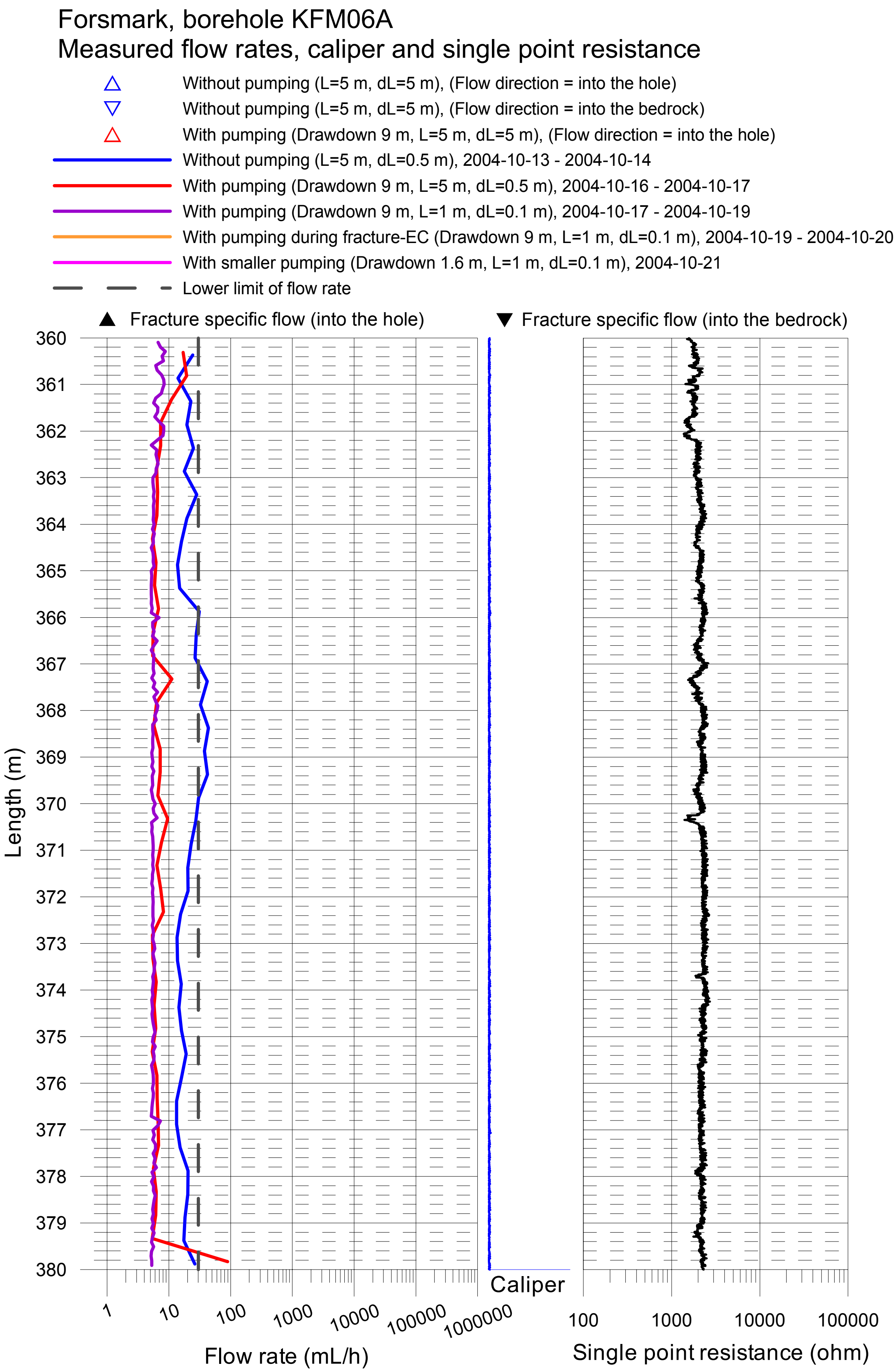

Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (Drawdown 9 m, L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=0.5 m), 2004-10-13 - 2004-10-14
With pumping (Drawdown 9 m, L=5 m, dL=0.5 m), 2004-10-16 - 2004-10-17
With pumping (Drawdown 9 m, L=1 m, dL=0.1 m), 2004-10-17 - 2004-10-19
With pumping during fracture-EC (Drawdown 9 m, L=1 m, dL=0.1 m), 2004-10-19 - 2004-10-20
With smaller pumping (Drawdown 1.6 m, L=1 m, dL=0.1 m), 2004-10-21
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
300
297.3
Caliper
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
100
1000
10000
100000
Single point resistance (ohm)


Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (Drawdown 9 m, L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=0.5 m), 2004-10-13 - 2004-10-14
With pumping (Drawdown 9 m, L=5 m, dL=0.5 m), 2004-10-16 - 2004-10-17
With pumping (Drawdown 9 m, L=1 m, dL=0.1 m), 2004-10-17 - 2004-10-19
With pumping during fracture-EC (Drawdown 9 m, L=1 m, dL=0.1 m), 2004-10-19 - 2004-10-20
With smaller pumping (Drawdown 1.6 m, L=1 m, dL=0.1 m), 2004-10-21
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
300
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
303.0
306.2
308.4
Caliper
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
100
1000
10000
100000
Single point resistance (ohm)

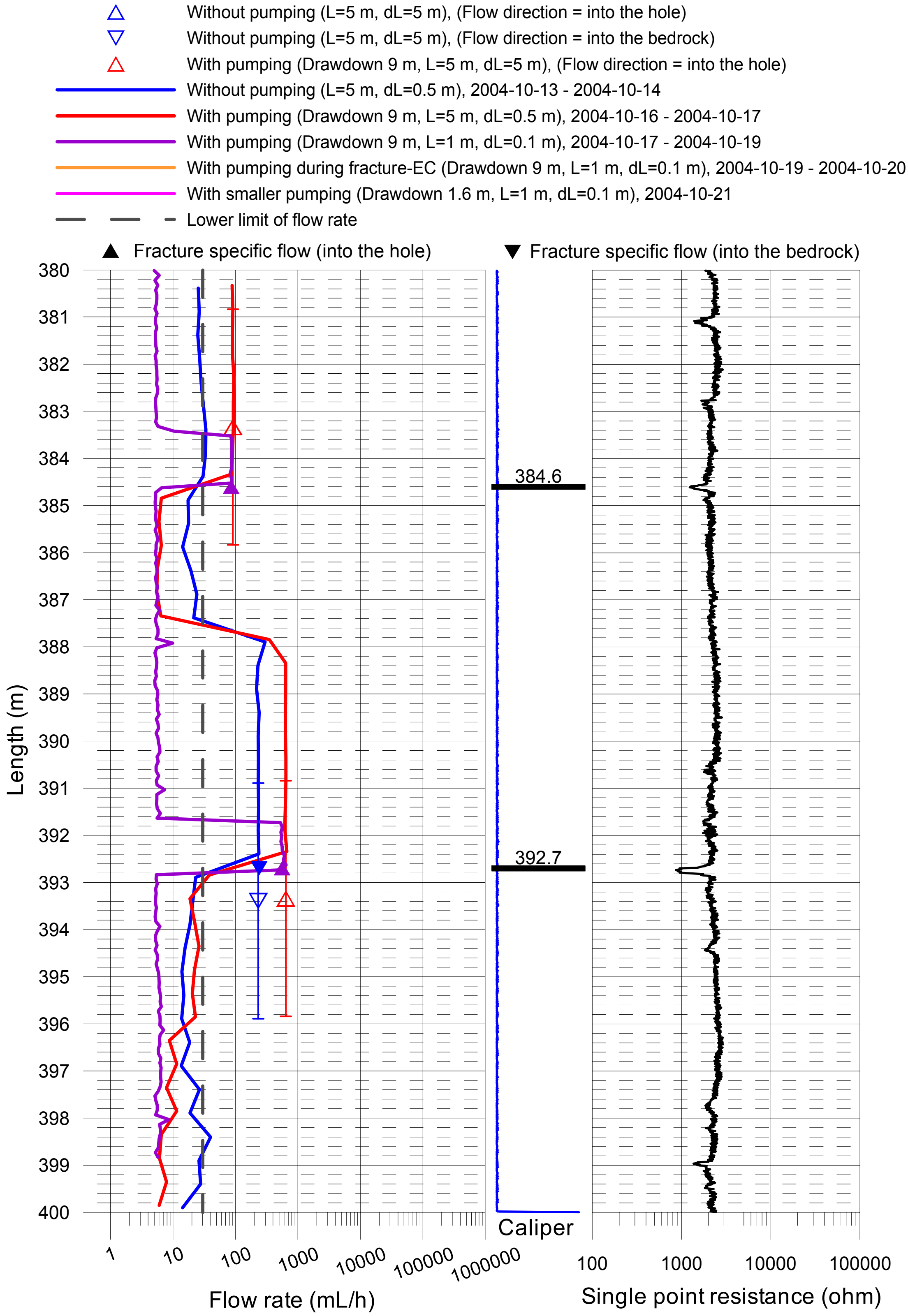


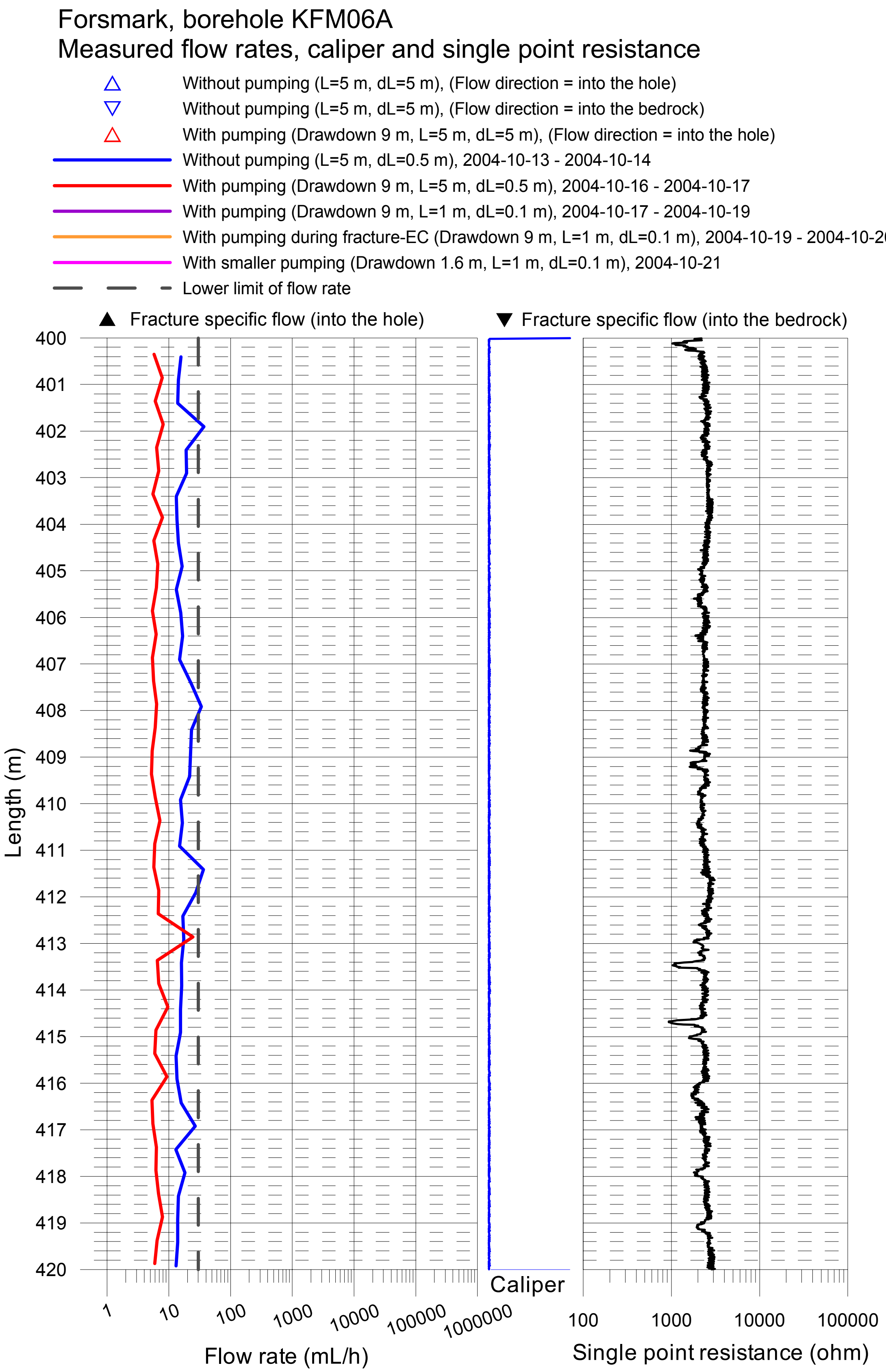
Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (Drawdown 9 m, L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=0.5 m), 2004-10-13 - 2004-10-14
With pumping (Drawdown 9 m, L=5 m, dL=0.5 m), 2004-10-16 - 2004-10-17
With pumping (Drawdown 9 m, L=1 m, dL=0.1 m), 2004-10-17 - 2004-10-19
With pumping during fracture-EC (Drawdown 9 m, L=1 m, dL=0.1 m), 2004-10-19 - 2004-10-20
With smaller pumping (Drawdown 1.6 m, L=1 m, dL=0.1 m), 2004-10-21
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
320
321
322
323
324
325
326
327
328
329
330
331
332
333
334
335
336
337
338
339
340
321.4
322.0
327.0
329.7
330.0
332.0
334.2
338.6
339.6
Caliper
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
100
1000
10000
100000
Single point resistance (ohm)


Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (Drawdown 9 m, L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=0.5 m), 2004-10-13 - 2004-10-14
With pumping (Drawdown 9 m, L=5 m, dL=0.5 m), 2004-10-16 - 2004-10-17
With pumping (Drawdown 9 m, L=1 m, dL=0.1 m), 2004-10-17 - 2004-10-19
With pumping during fracture-EC (Drawdown 9 m, L=1 m, dL=0.1 m), 2004-10-19 - 2004-10-20
With smaller pumping (Drawdown 1.6 m, L=1 m, dL=0.1 m), 2004-10-21
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
341.7
345.4
354.2
356.6
Caliper
Flow rate (mL/h)
Single point resistance (ohm)

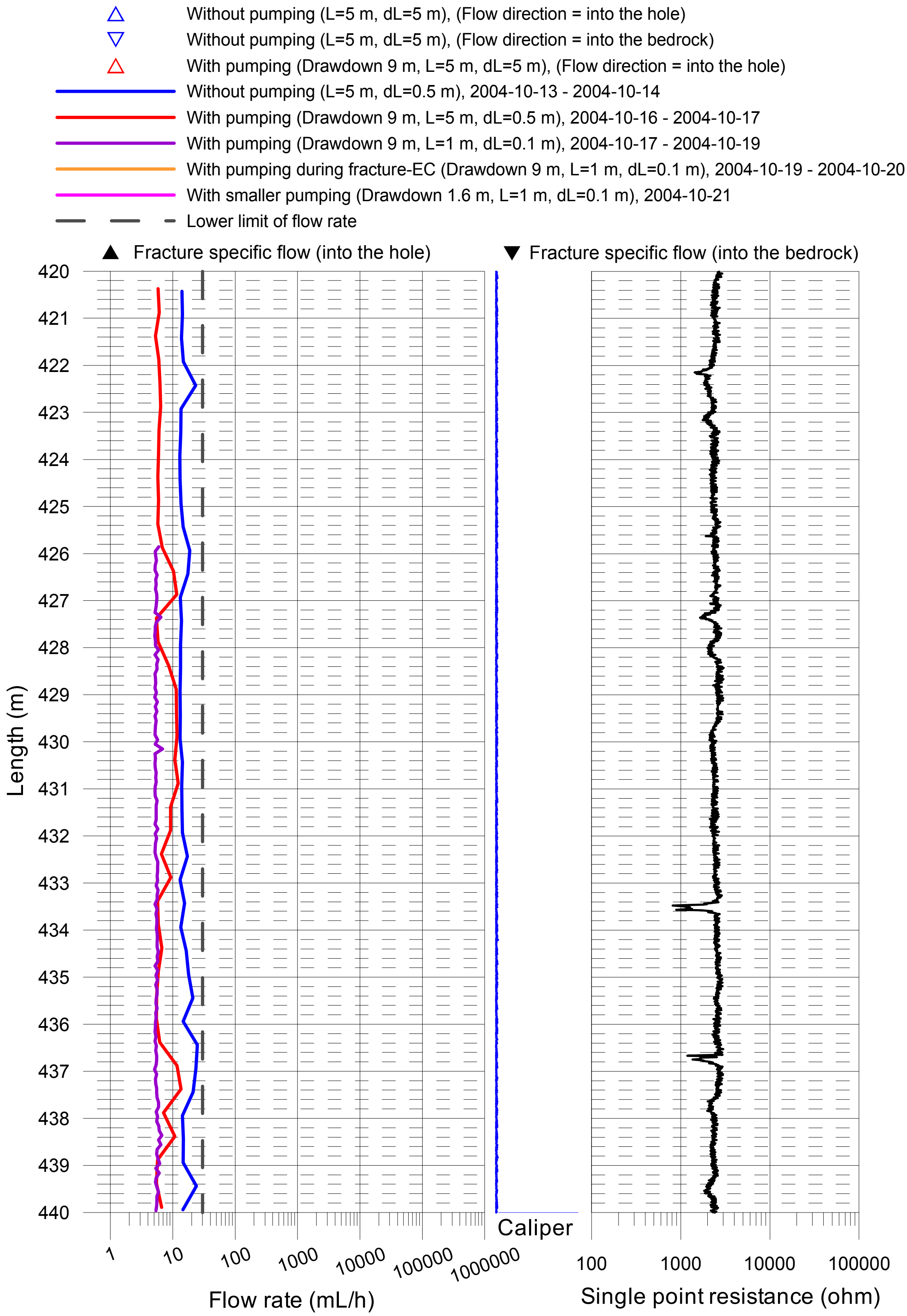

Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (Drawdown 9 m, L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=0.5 m), 2004-10-13 - 2004-10-14
With pumping (Drawdown 9 m, L=5 m, dL=0.5 m), 2004-10-16 - 2004-10-17
With pumping (Drawdown 9 m, L=1 m, dL=0.1 m), 2004-10-17 - 2004-10-19
With pumping during fracture-EC (Drawdown 9 m, L=1 m, dL=0.1 m), 2004-10-19 - 2004-10-20
With smaller pumping (Drawdown 1.6 m, L=1 m, dL=0.1 m), 2004-10-21
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
360
361
362
363
364
365
366
367
368
369
370
371
372
373
374
375
376
377
378
379
380
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)

Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance

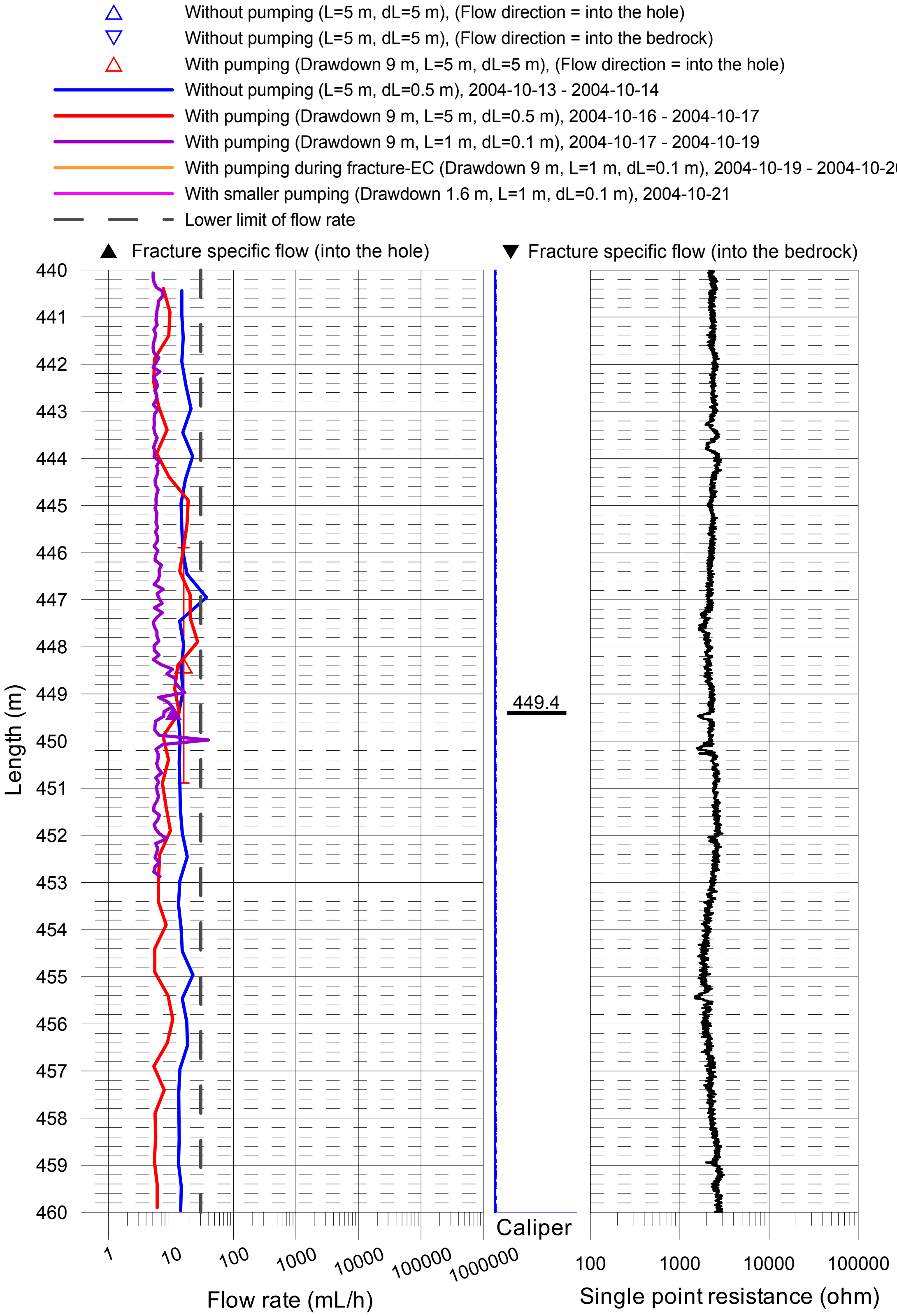


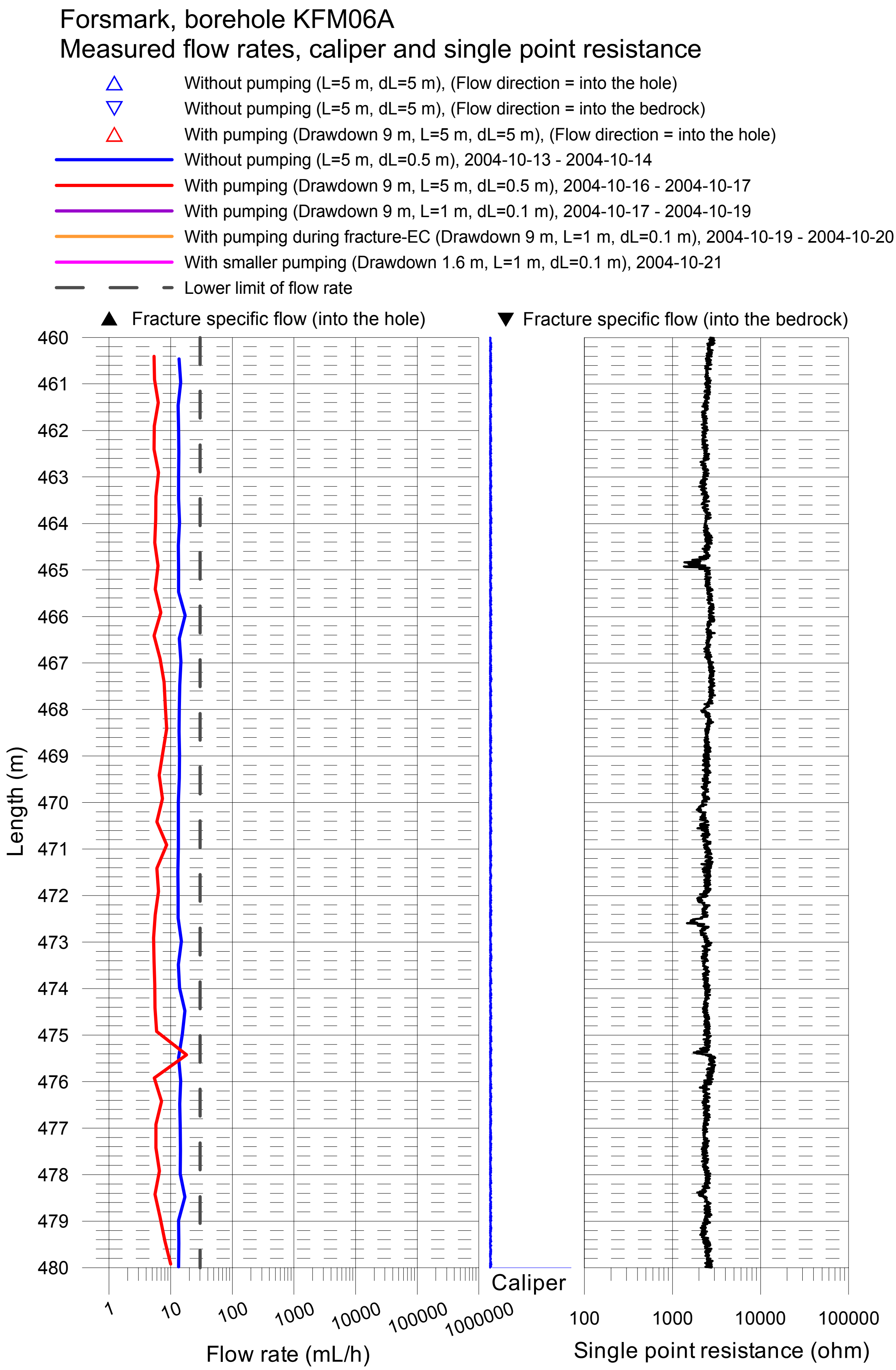

Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (Drawdown 9 m, L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=0.5 m), 2004-10-13 - 2004-10-14
With pumping (Drawdown 9 m, L=5 m, dL=0.5 m), 2004-10-16 - 2004-10-17
With pumping (Drawdown 9 m, L=1 m, dL=0.1 m), 2004-10-17 - 2004-10-19
With pumping during fracture-EC (Drawdown 9 m, L=1 m, dL=0.1 m), 2004-10-19 - 2004-10-20
With smaller pumping (Drawdown 1.6 m, L=1 m, dL=0.1 m), 2004-10-21
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
400
401
402
403
404
405
406
407
408
409
410
411
412
413
414
415
416
417
418
419
420
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)

Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance

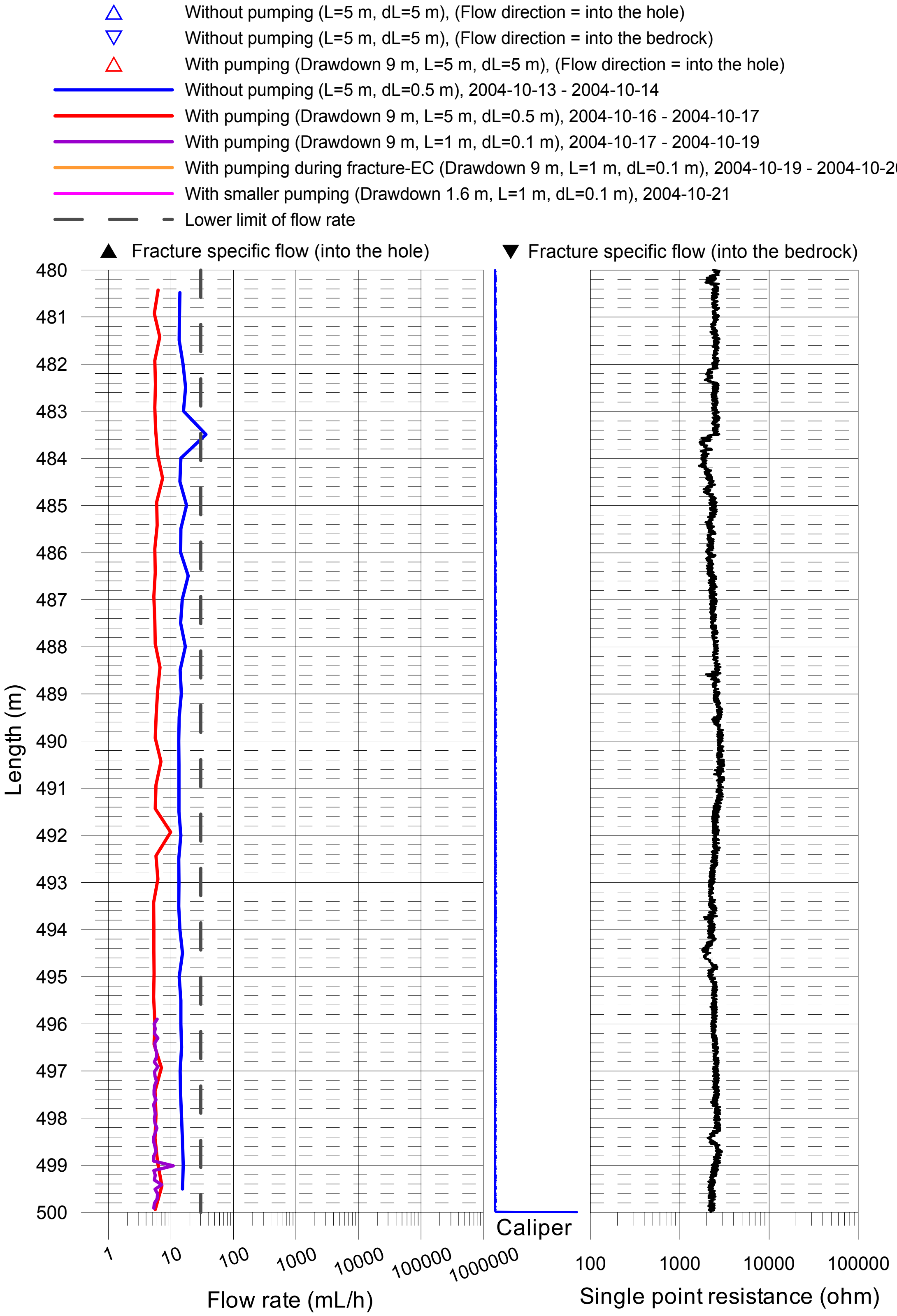


Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance

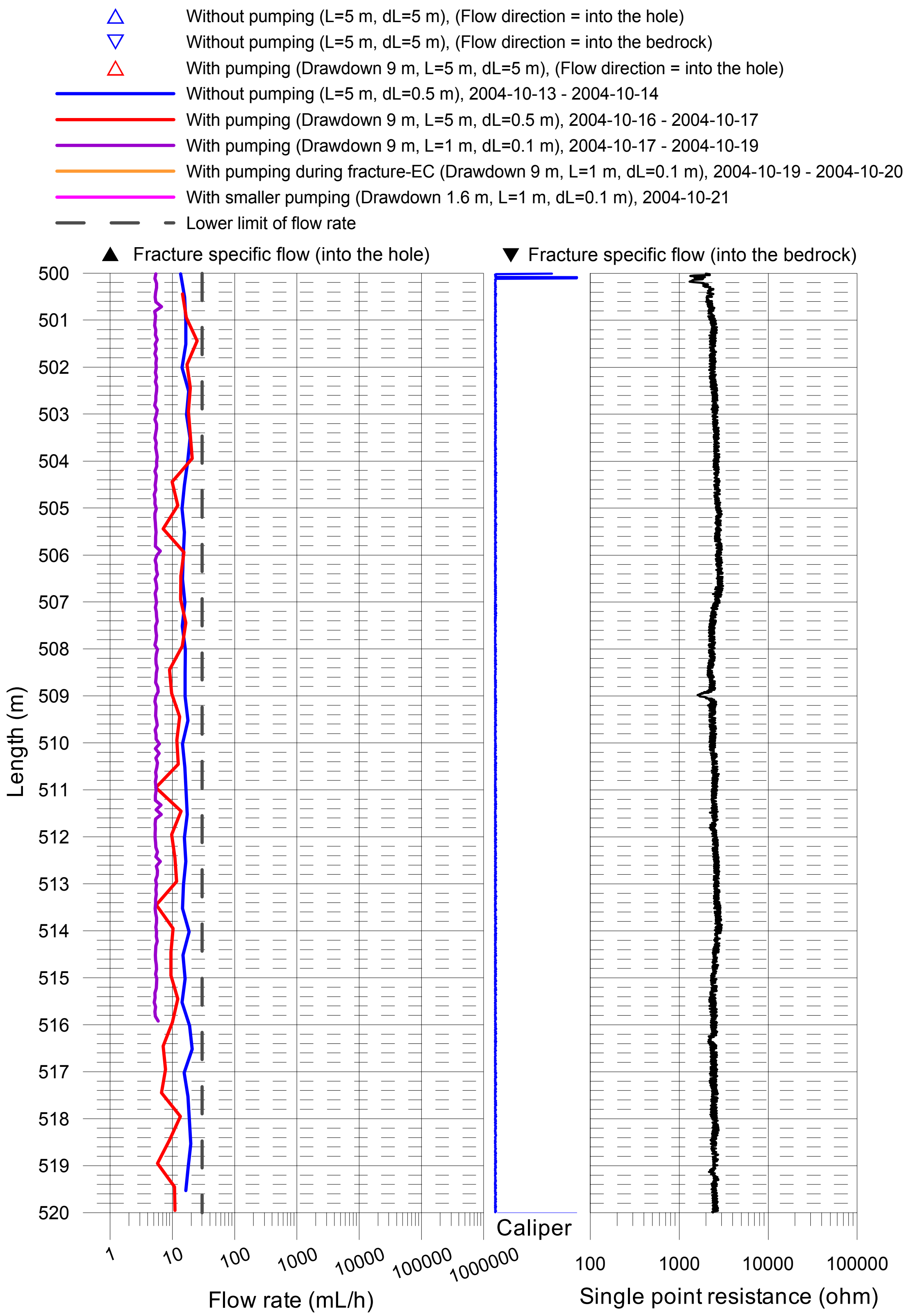



Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (Drawdown 9 m, L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=0.5 m), 2004-10-13 - 2004-10-14
With pumping (Drawdown 9 m, L=5 m, dL=0.5 m), 2004-10-16 - 2004-10-17
With pumping (Drawdown 9 m, L=1 m, dL=0.1 m), 2004-10-17 - 2004-10-19
With pumping during fracture-EC (Drawdown 9 m, L=1 m, dL=0.1 m), 2004-10-19 - 2004-10-20
With smaller pumping (Drawdown 1.6 m, L=1 m, dL=0.1 m), 2004-10-21
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
Caliper
Flow rate (mL/h)
Single point resistance (ohm)

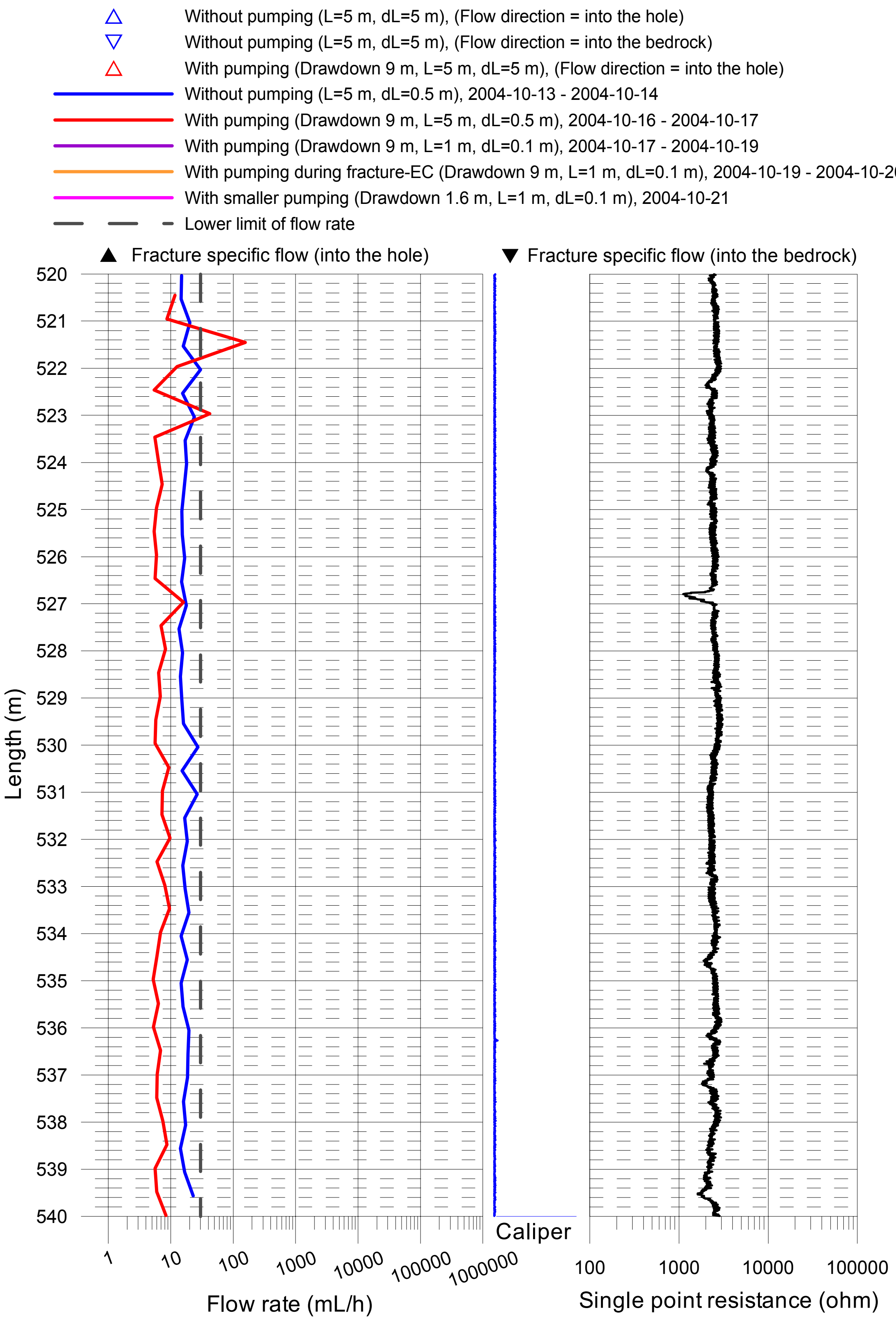
Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance

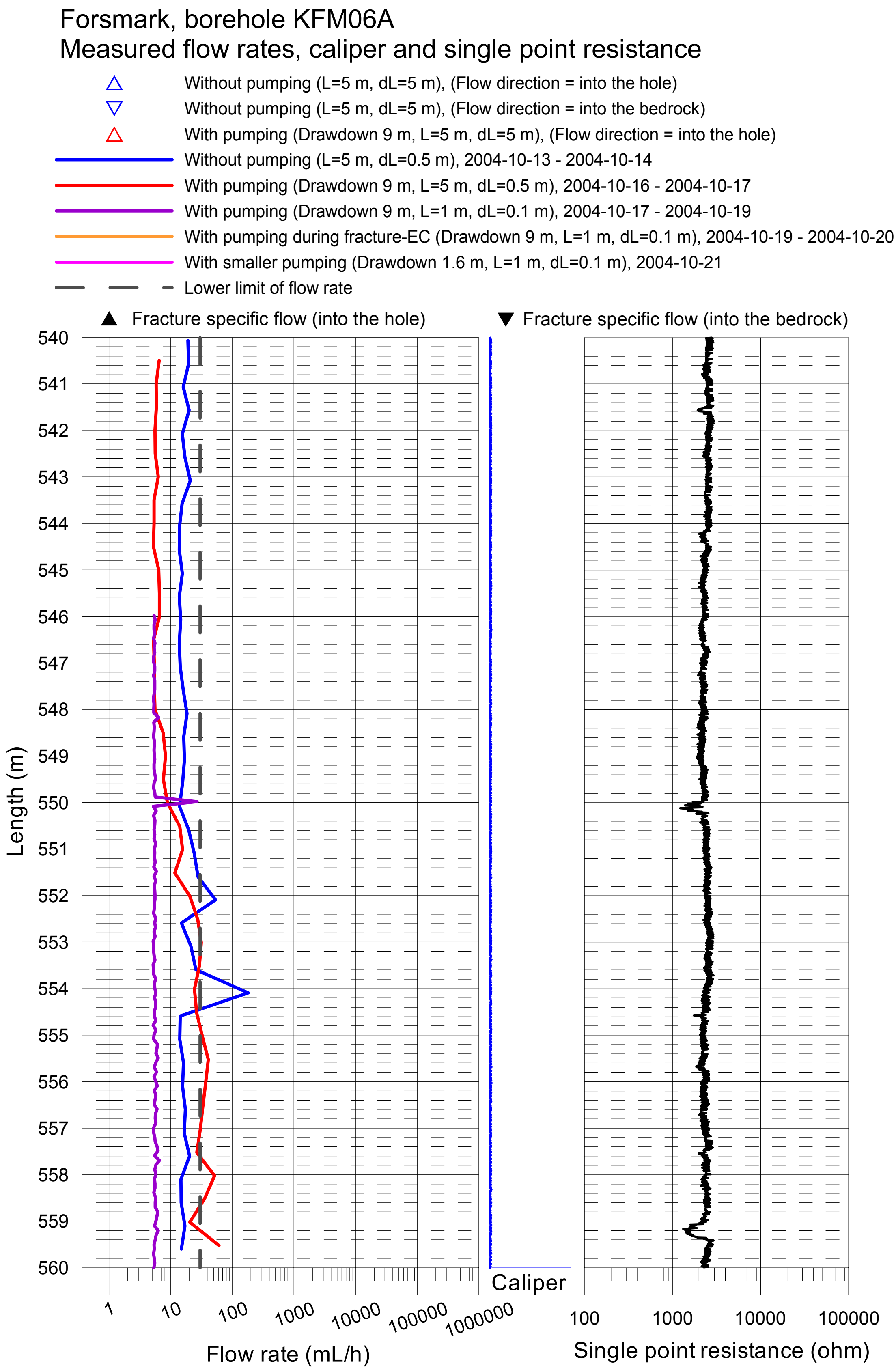


Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance

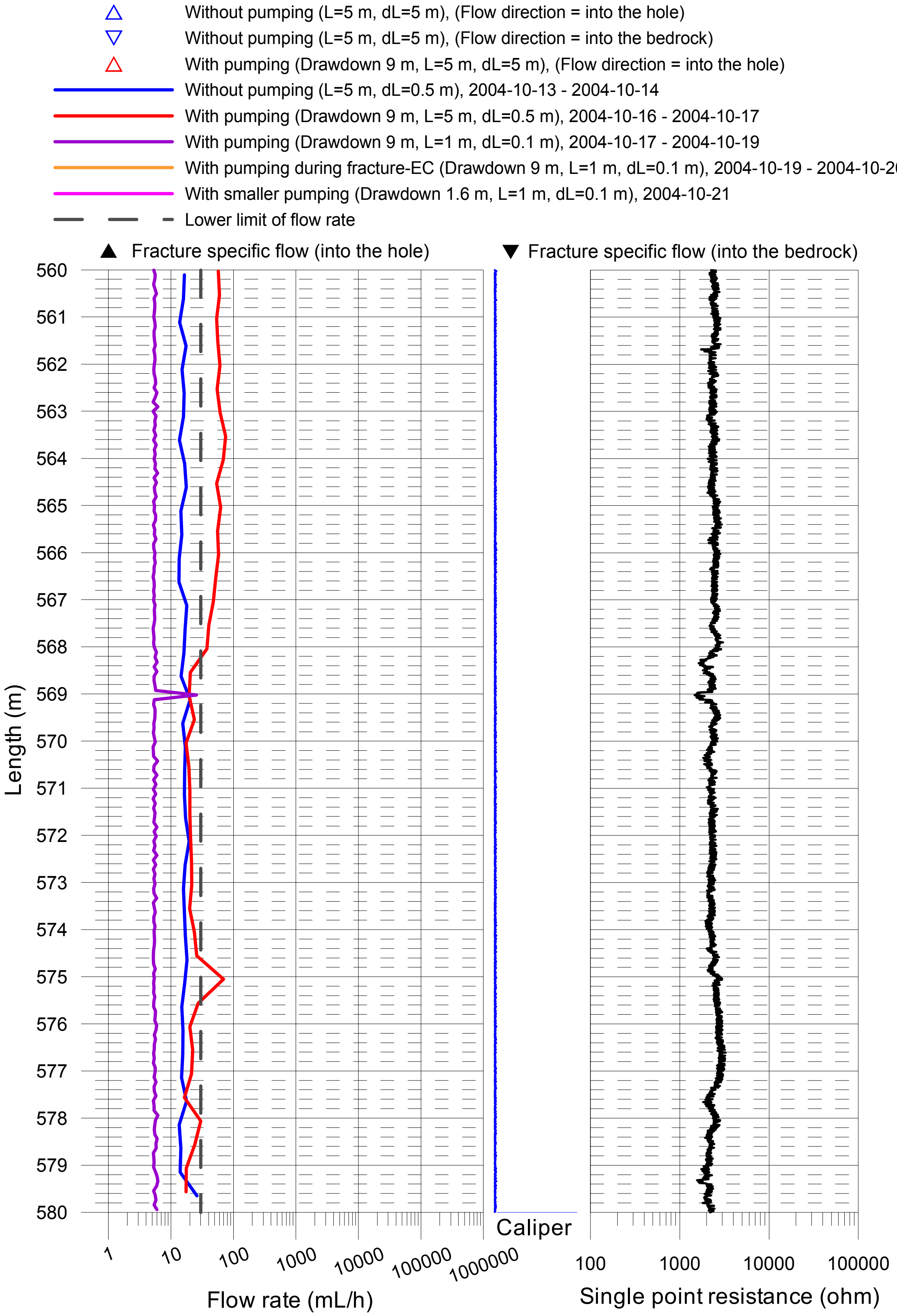


Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance

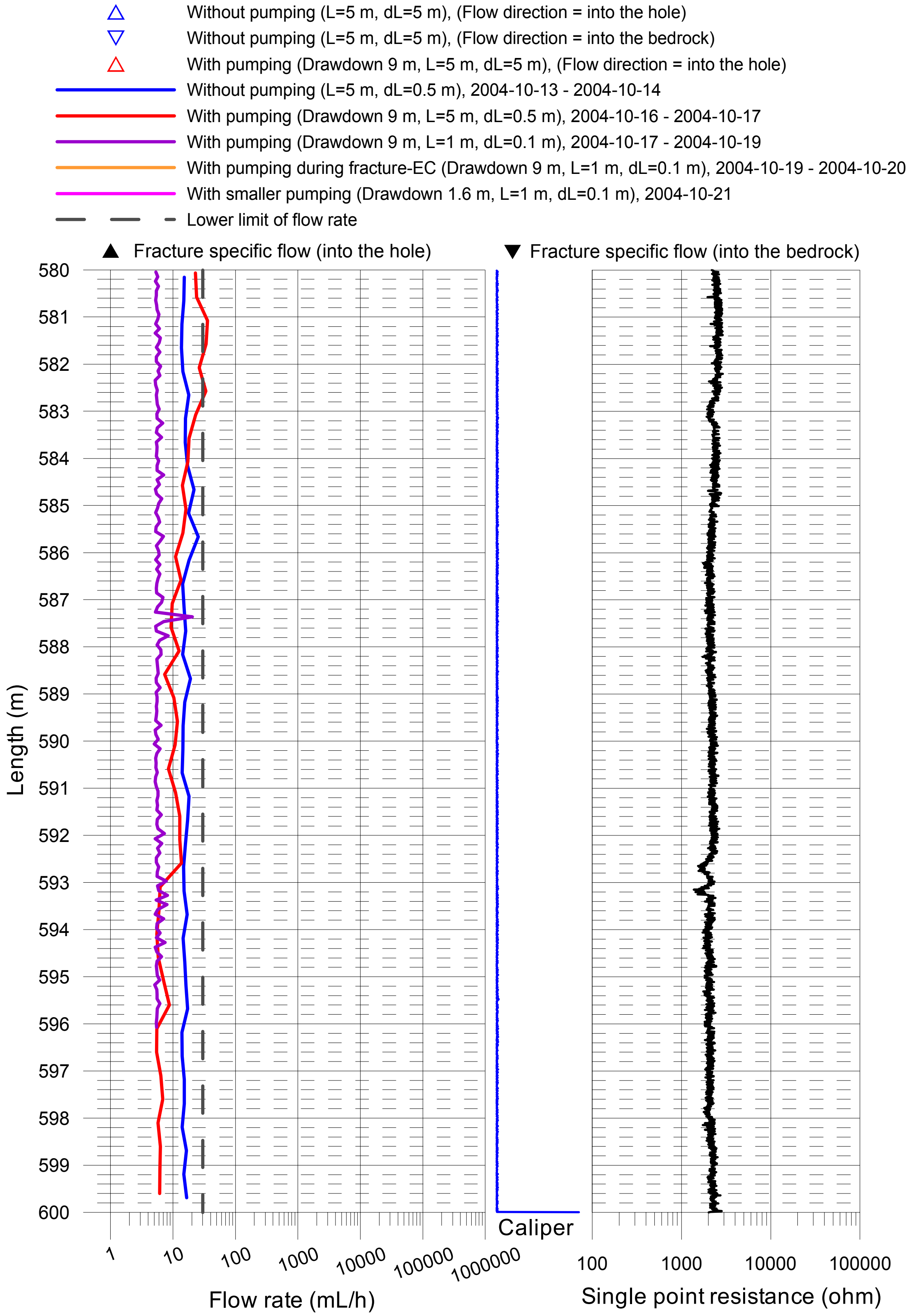



Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (Drawdown 9 m, L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=0.5 m), 2004-10-13 - 2004-10-14
With pumping (Drawdown 9 m, L=5 m, dL=0.5 m), 2004-10-16 - 2004-10-17
With pumping (Drawdown 9 m, L=1 m, dL=0.1 m), 2004-10-17 - 2004-10-19
With pumping during fracture-EC (Drawdown 9 m, L=1 m, dL=0.1 m), 2004-10-19 - 2004-10-20
With smaller pumping (Drawdown 1.6 m, L=1 m, dL=0.1 m), 2004-10-21
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
540
541
542
543
544
545
546
547
548
549
550
551
552
553
554
555
556
557
558
559
560
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)

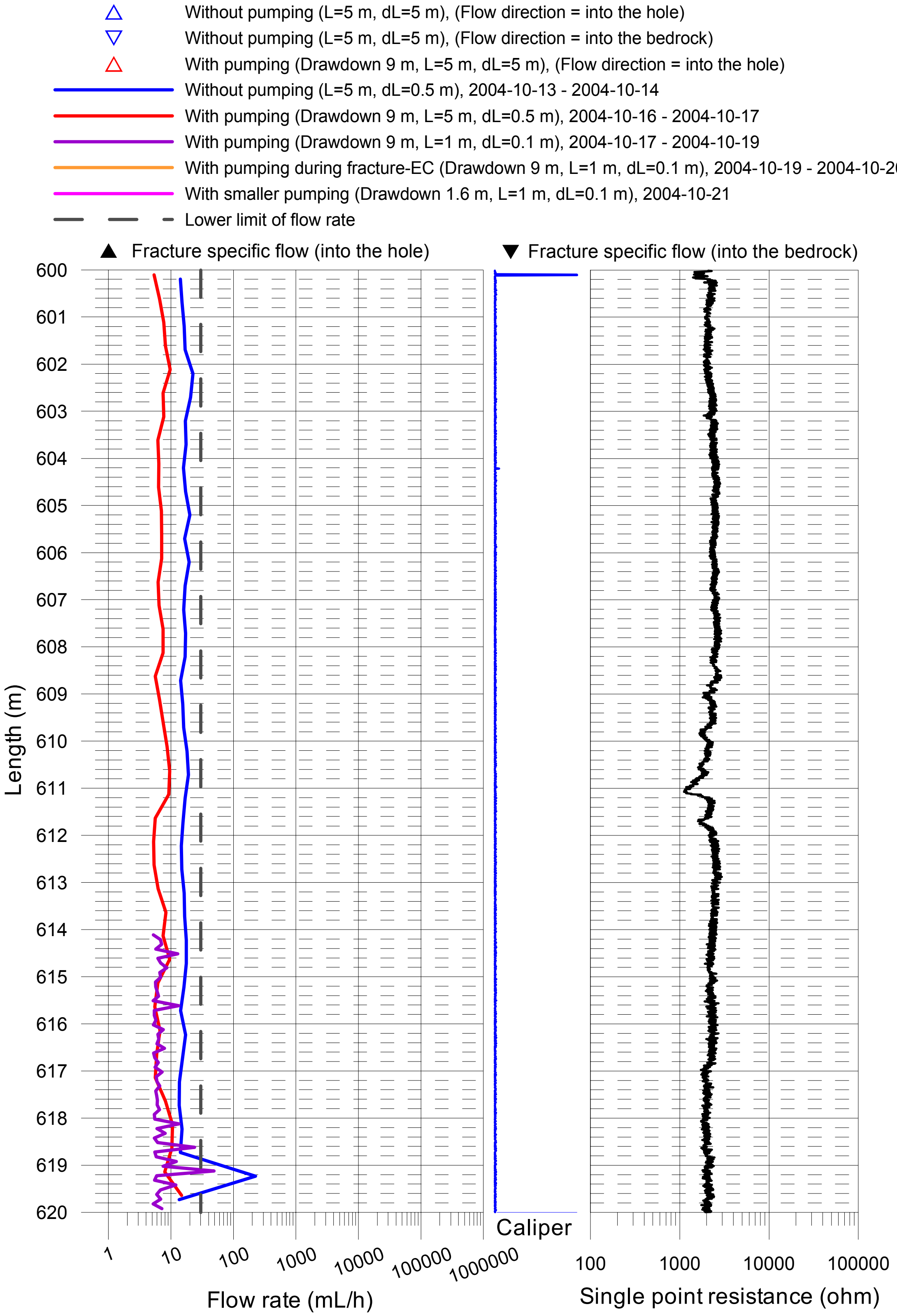
Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance



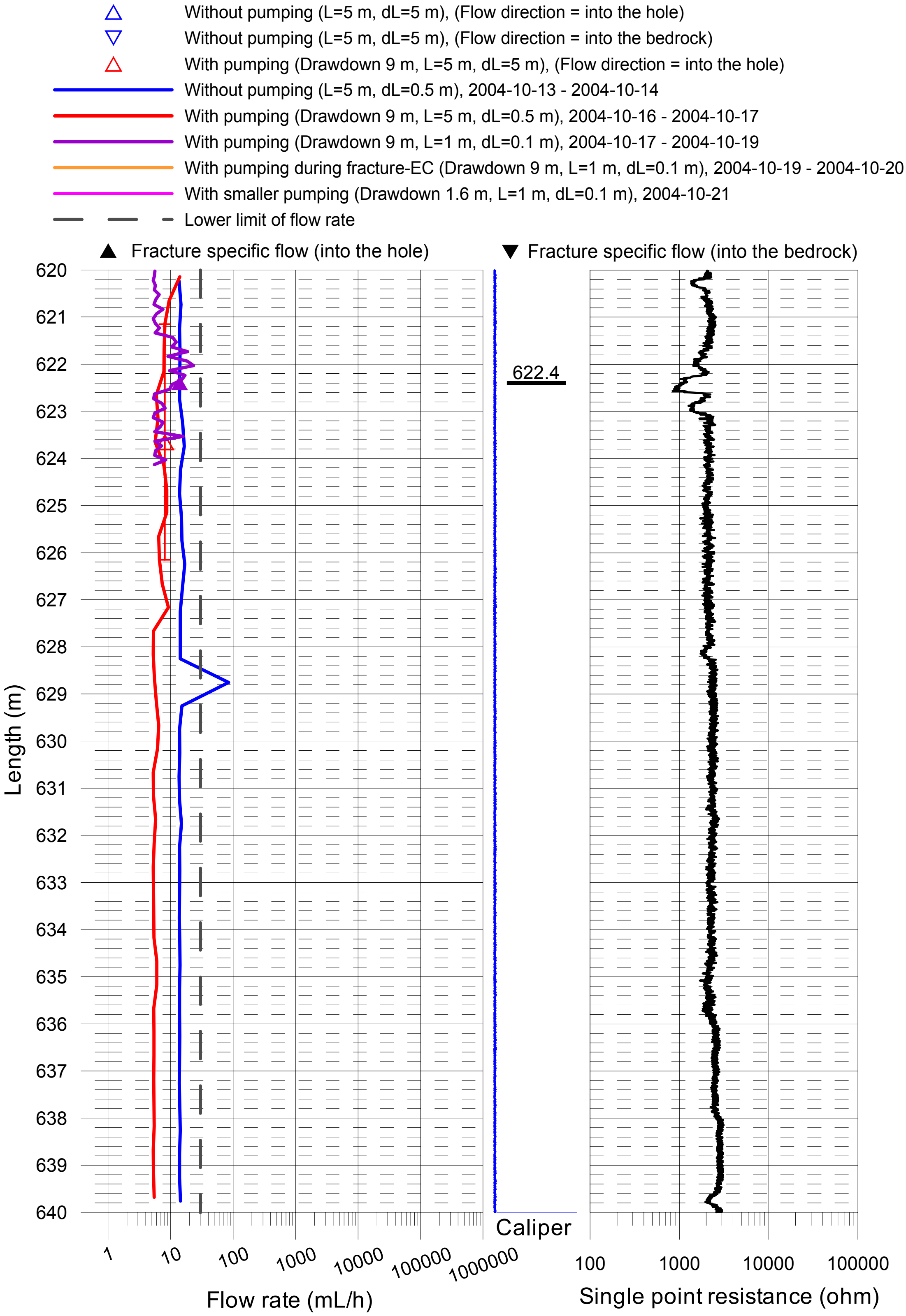
Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance

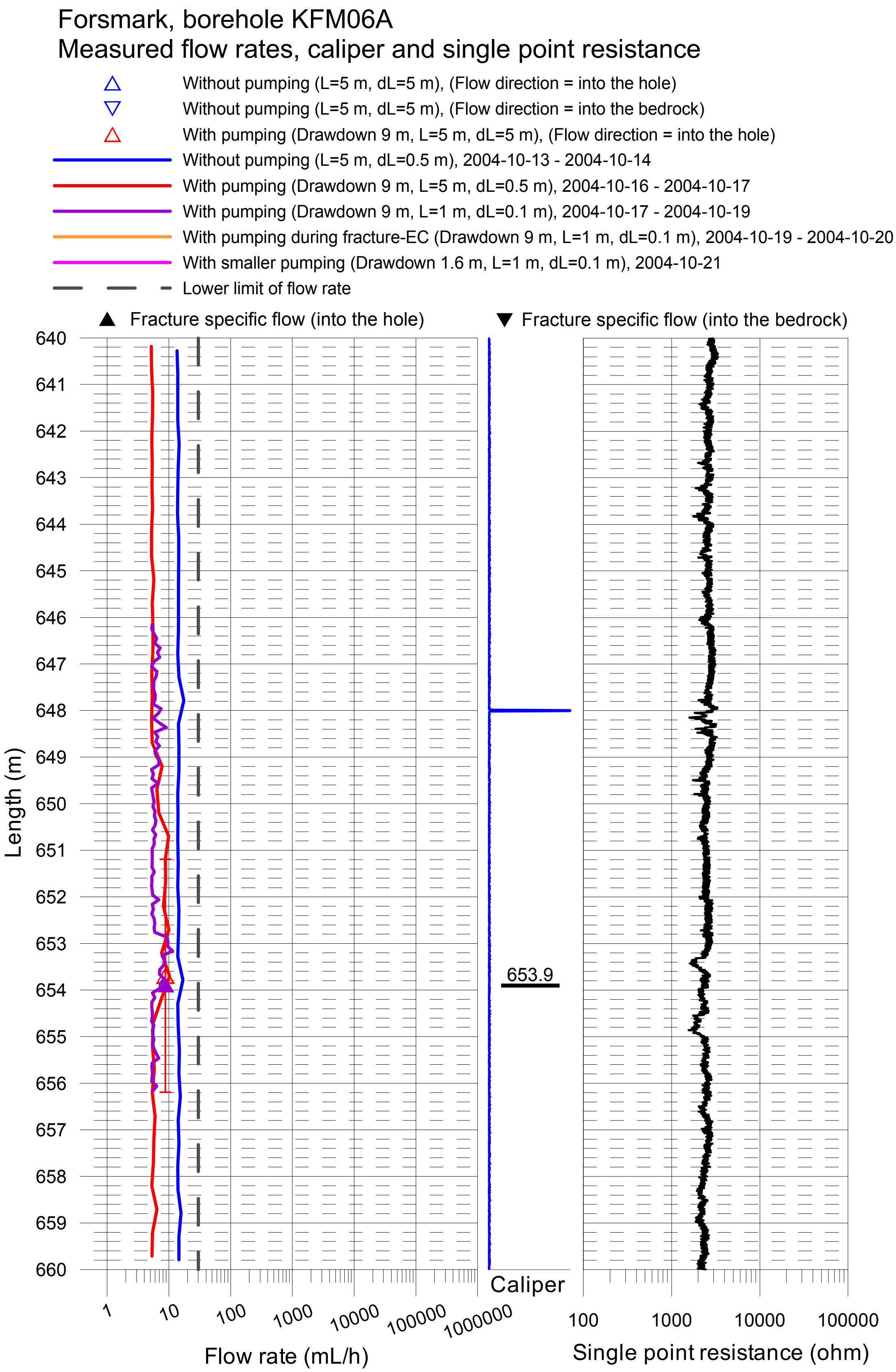


Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance

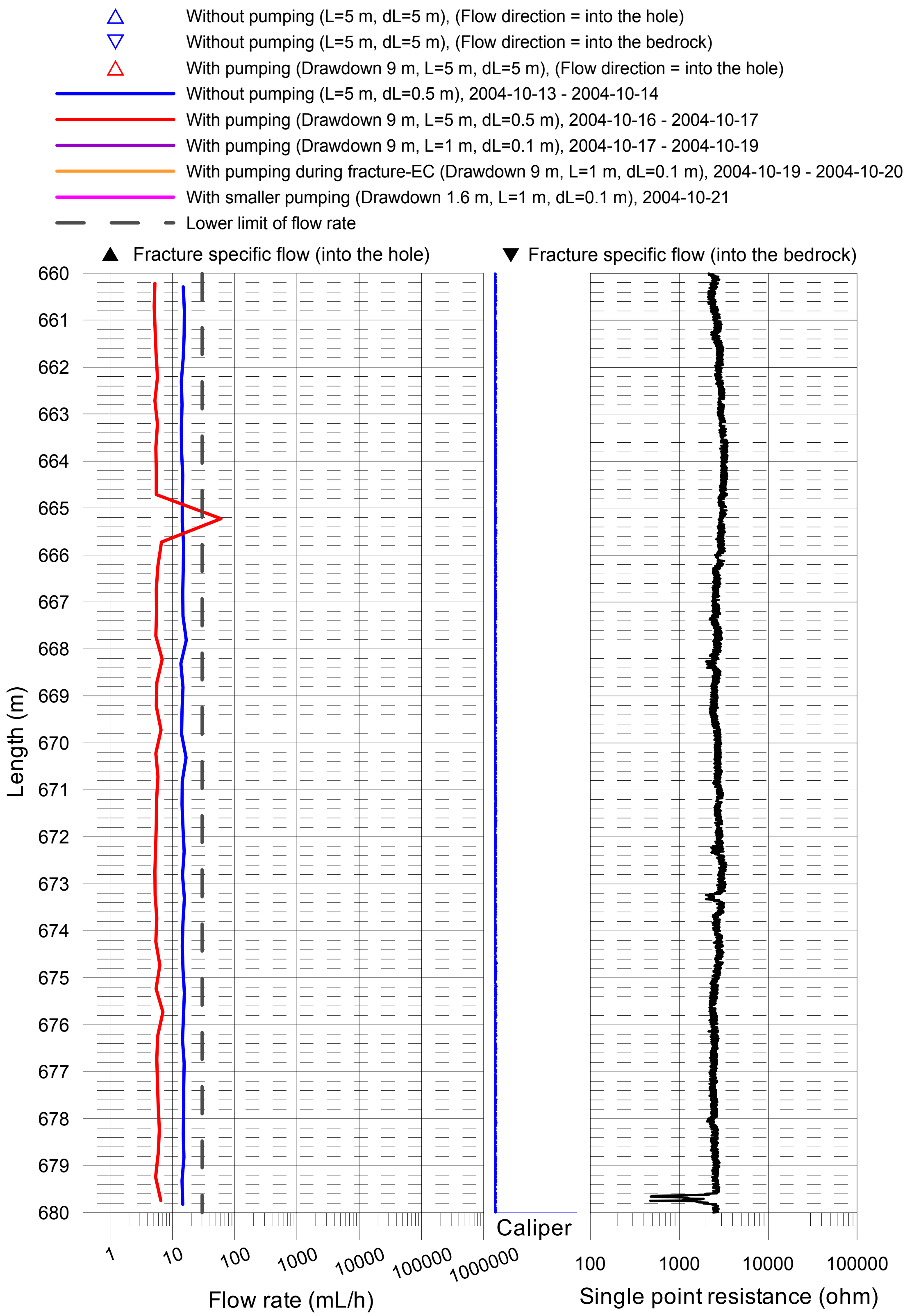


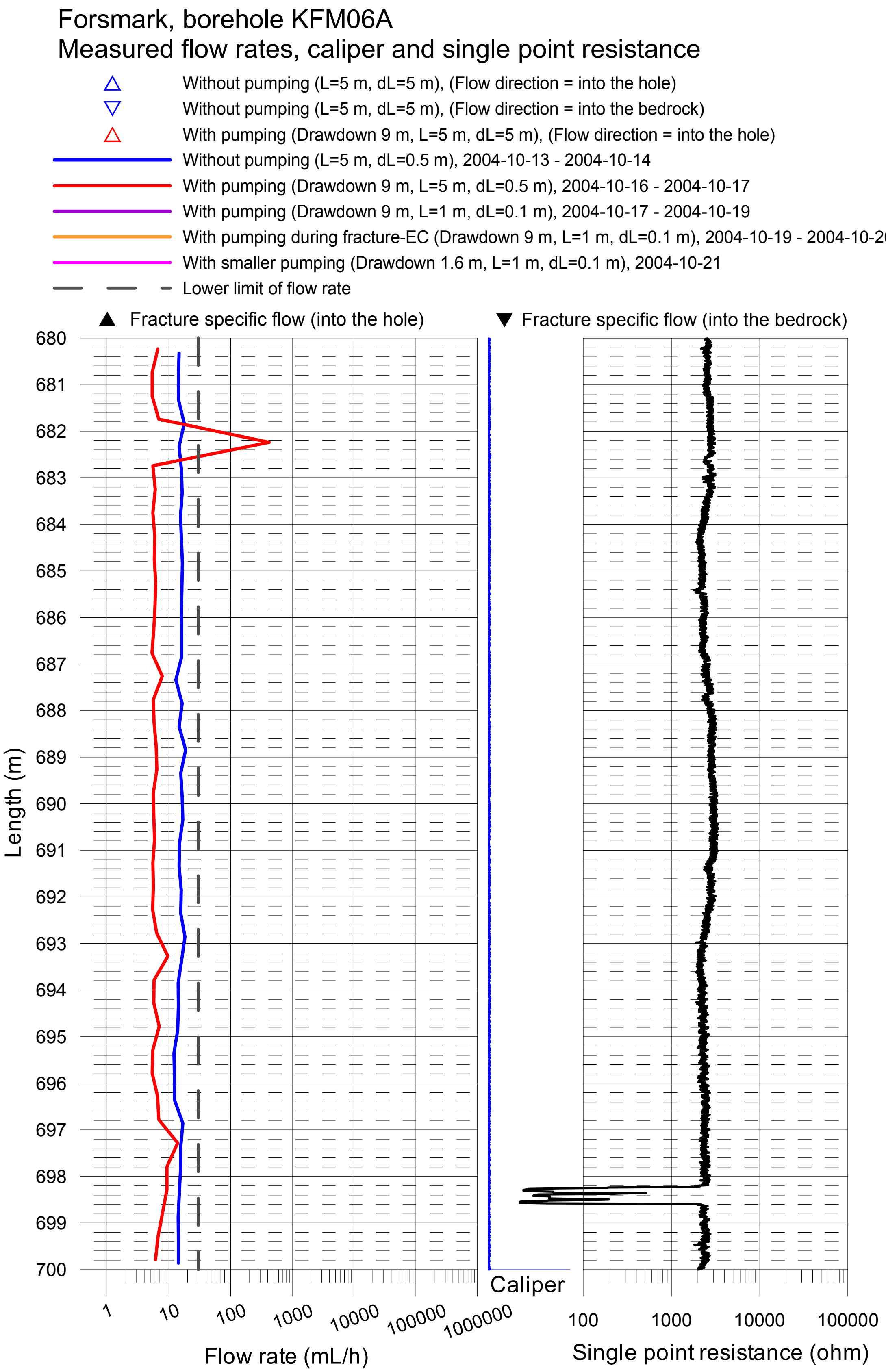
Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance




Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (Drawdown 9 m, L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=0.5 m), 2004-10-13 - 2004-10-14
With pumping (Drawdown 9 m, L=5 m, dL=0.5 m), 2004-10-16 - 2004-10-17
With pumping (Drawdown 9 m, L=1 m, dL=0.1 m), 2004-10-17 - 2004-10-19
With pumping during fracture-EC (Drawdown 9 m, L=1 m, dL=0.1 m), 2004-10-19 - 2004-10-20
With smaller pumping (Drawdown 1.6 m, L=1 m, dL=0.1 m), 2004-10-21
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
640
641
642
643
644
645
646
647
648
649
650
651
652
653
654
655
656
657
658
659
660
653.9
Caliper
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
100
1000
10000
100000
Single point resistance (ohm)

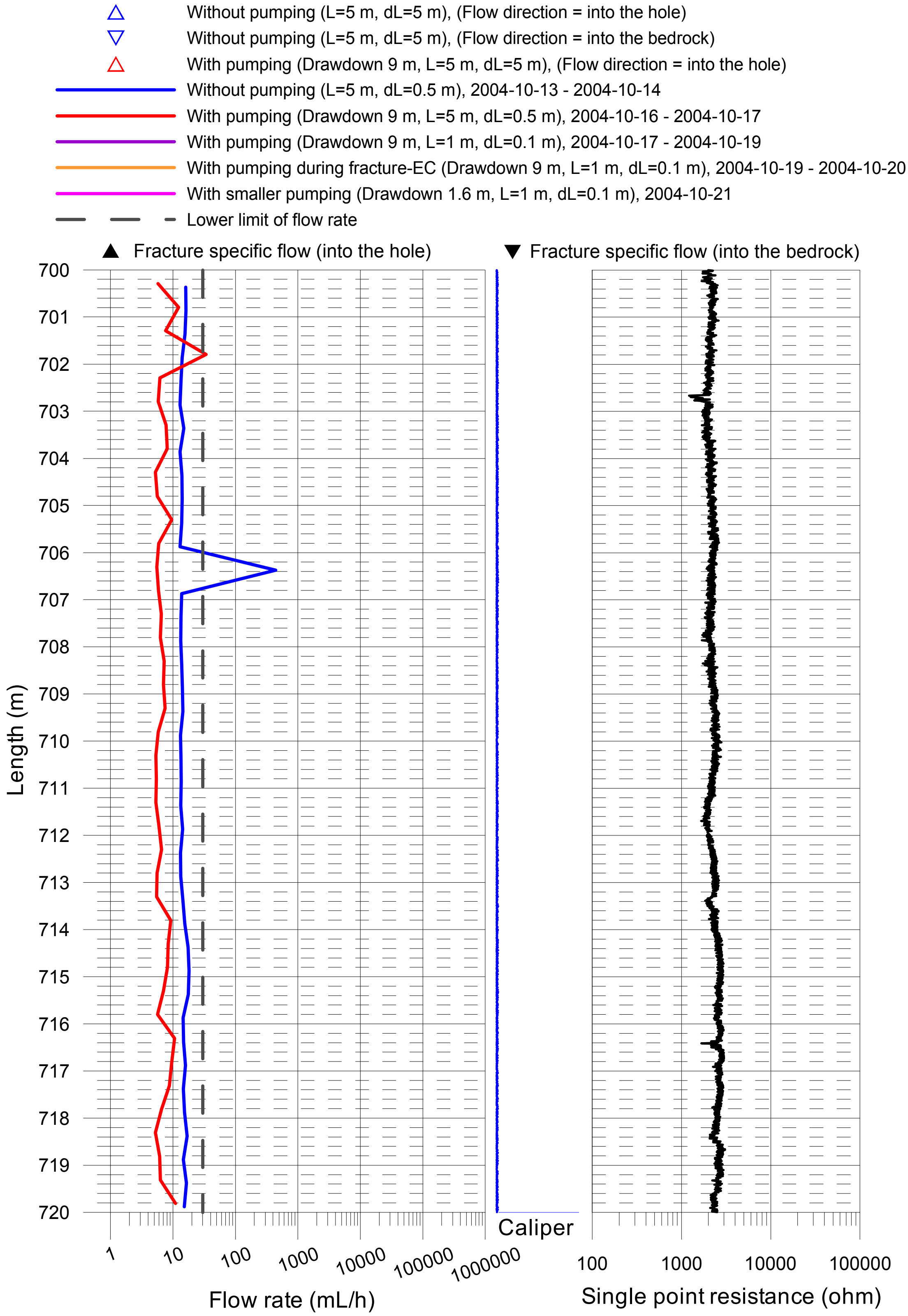
Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance



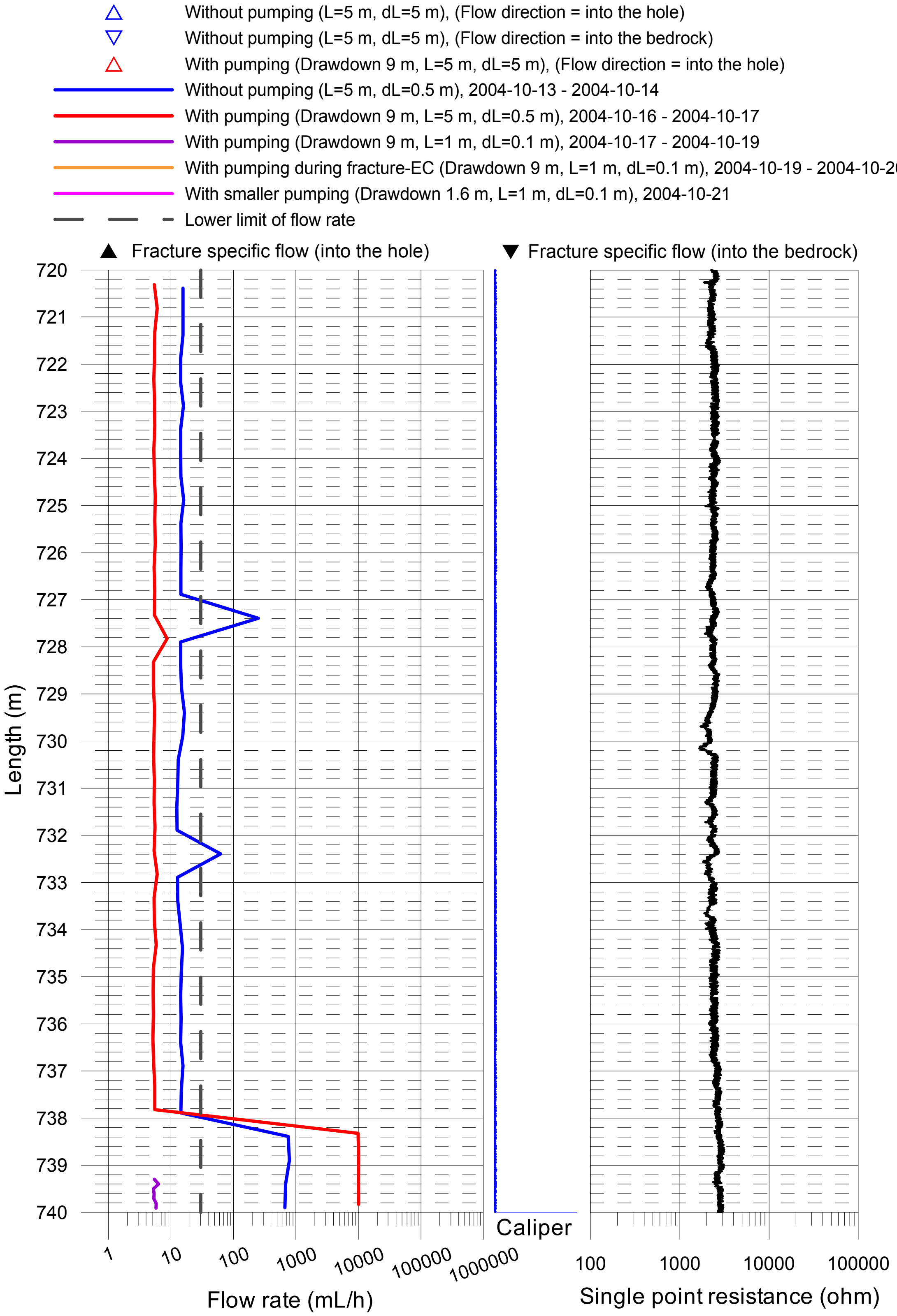


Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (Drawdown 9 m, L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=0.5 m), 2004-10-13 - 2004-10-14
With pumping (Drawdown 9 m, L=5 m, dL=0.5 m), 2004-10-16 - 2004-10-17
With pumping (Drawdown 9 m, L=1 m, dL=0.1 m), 2004-10-17 - 2004-10-19
With pumping during fracture-EC (Drawdown 9 m, L=1 m, dL=0.1 m), 2004-10-19 - 2004-10-20
With smaller pumping (Drawdown 1.6 m, L=1 m, dL=0.1 m), 2004-10-21
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
680
681
682
683
684
685
686
687
688
689
690
691
692
693
694
695
696
697
698
699
700
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)

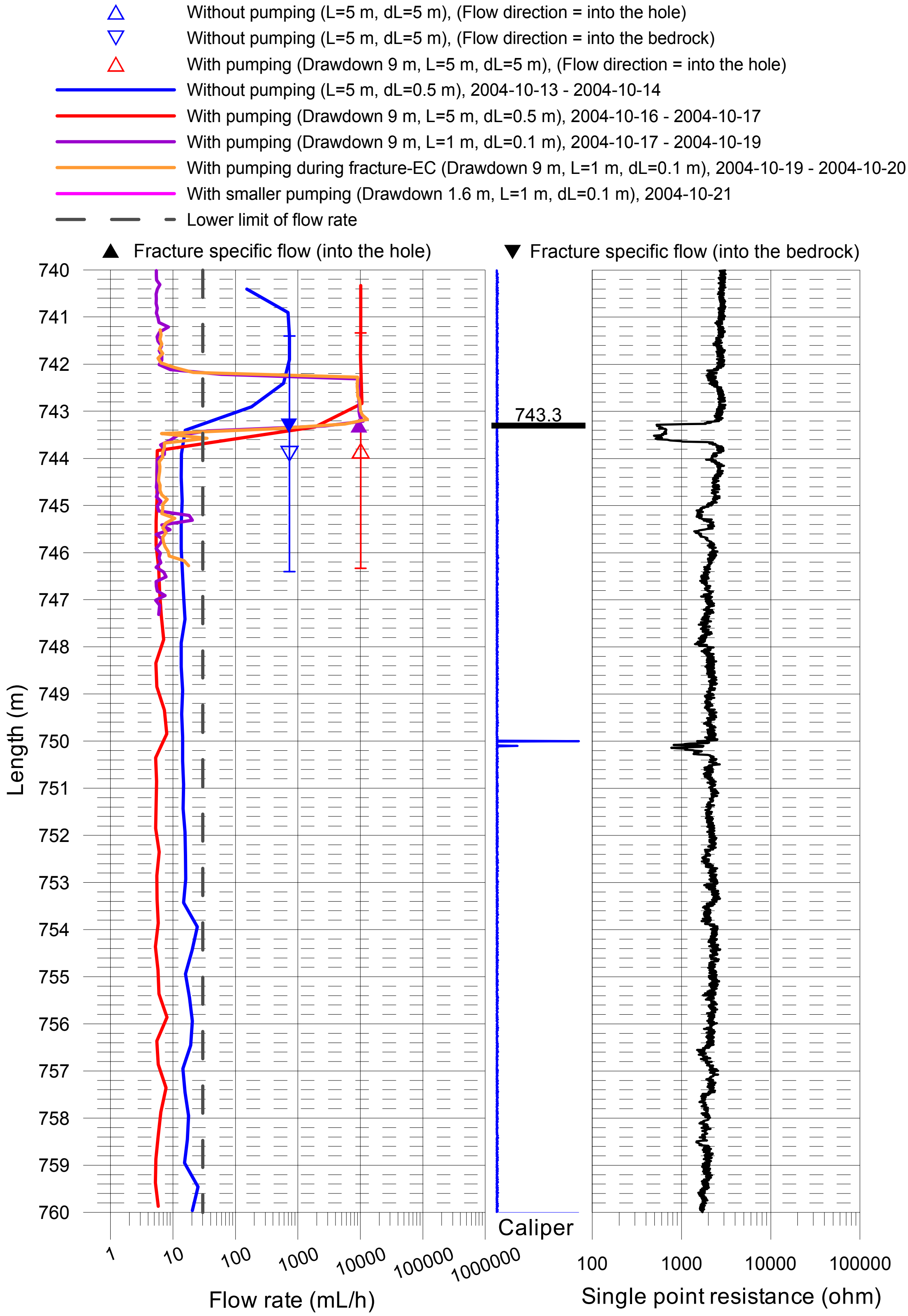
Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance



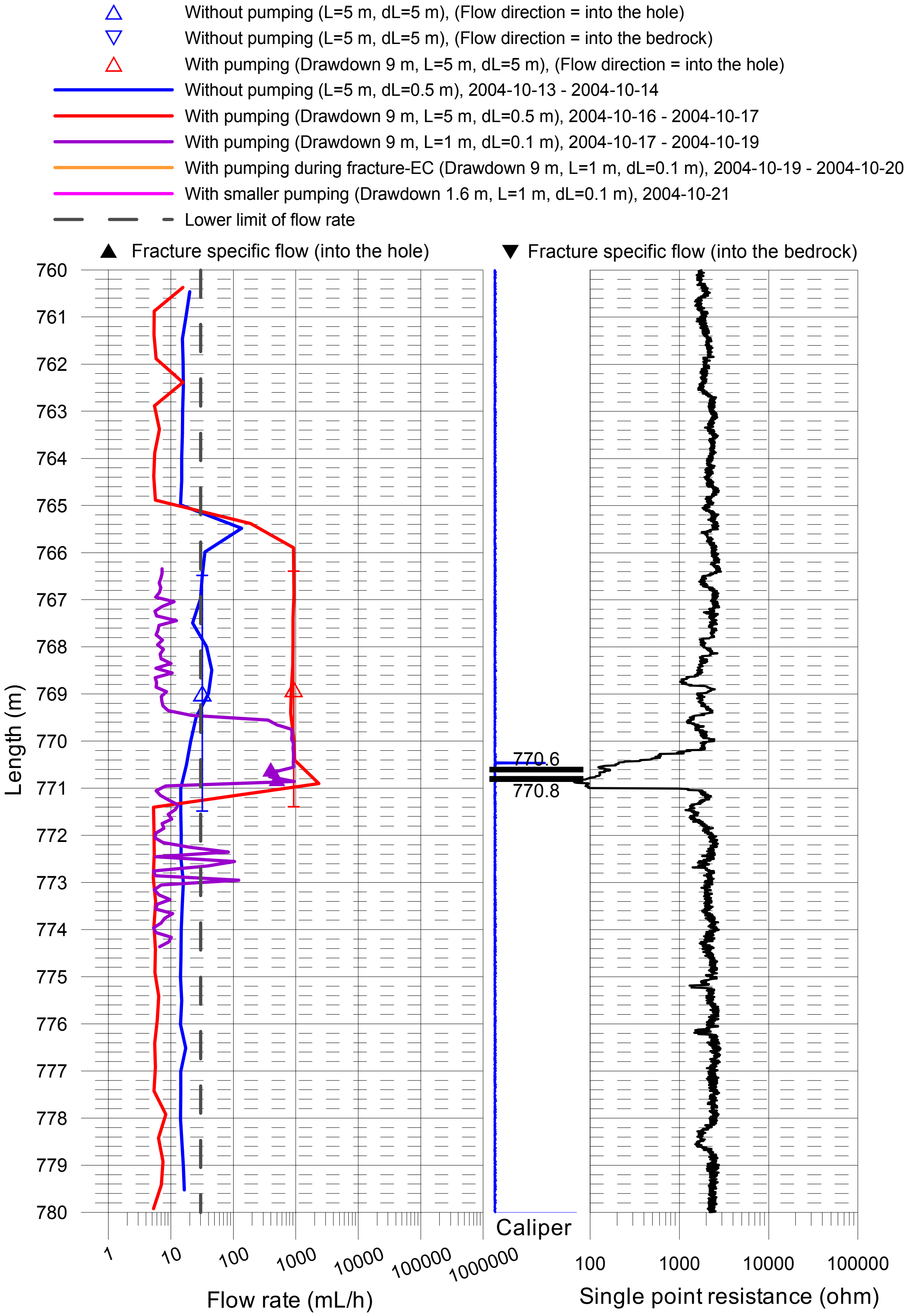
Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance



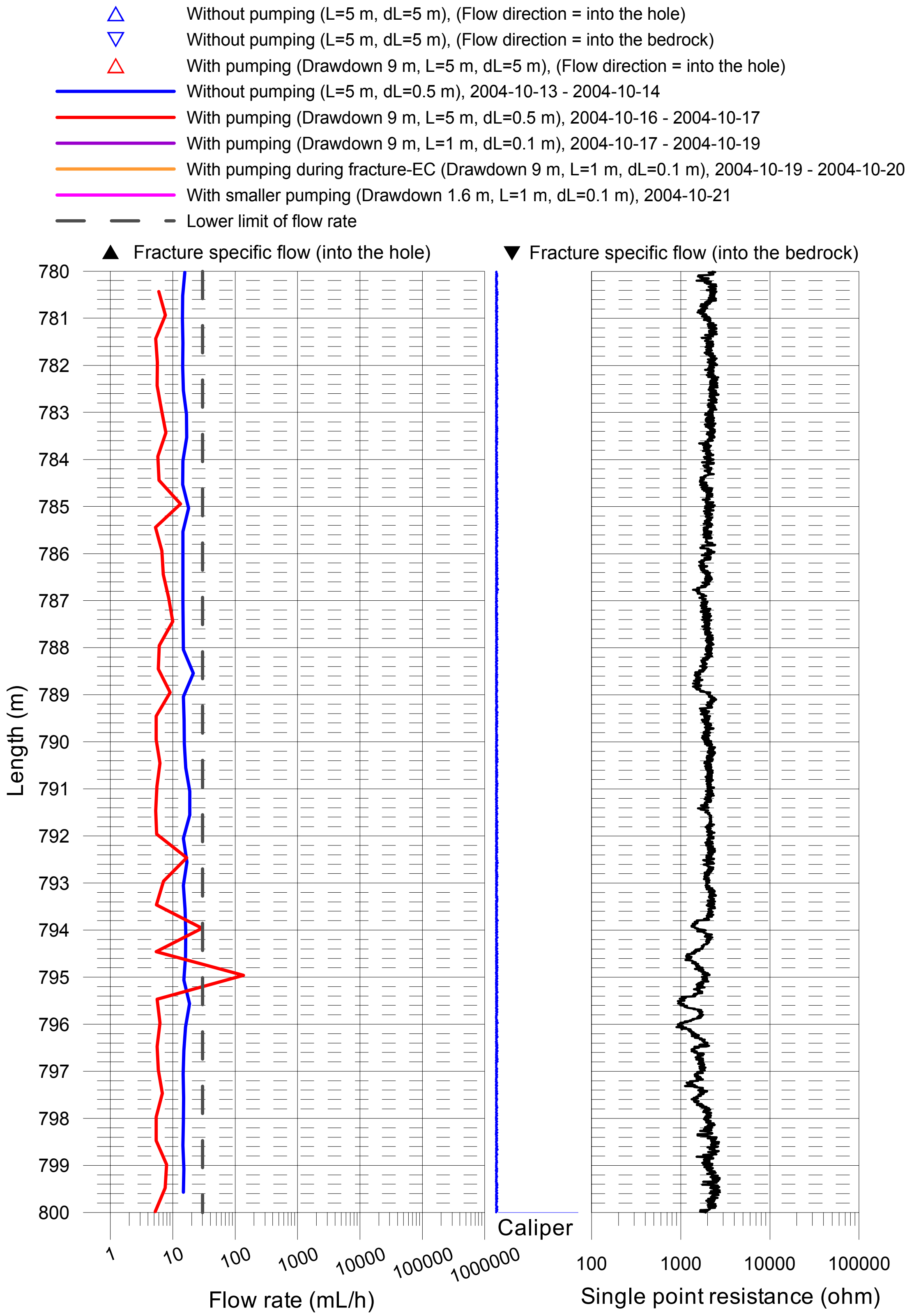
Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance



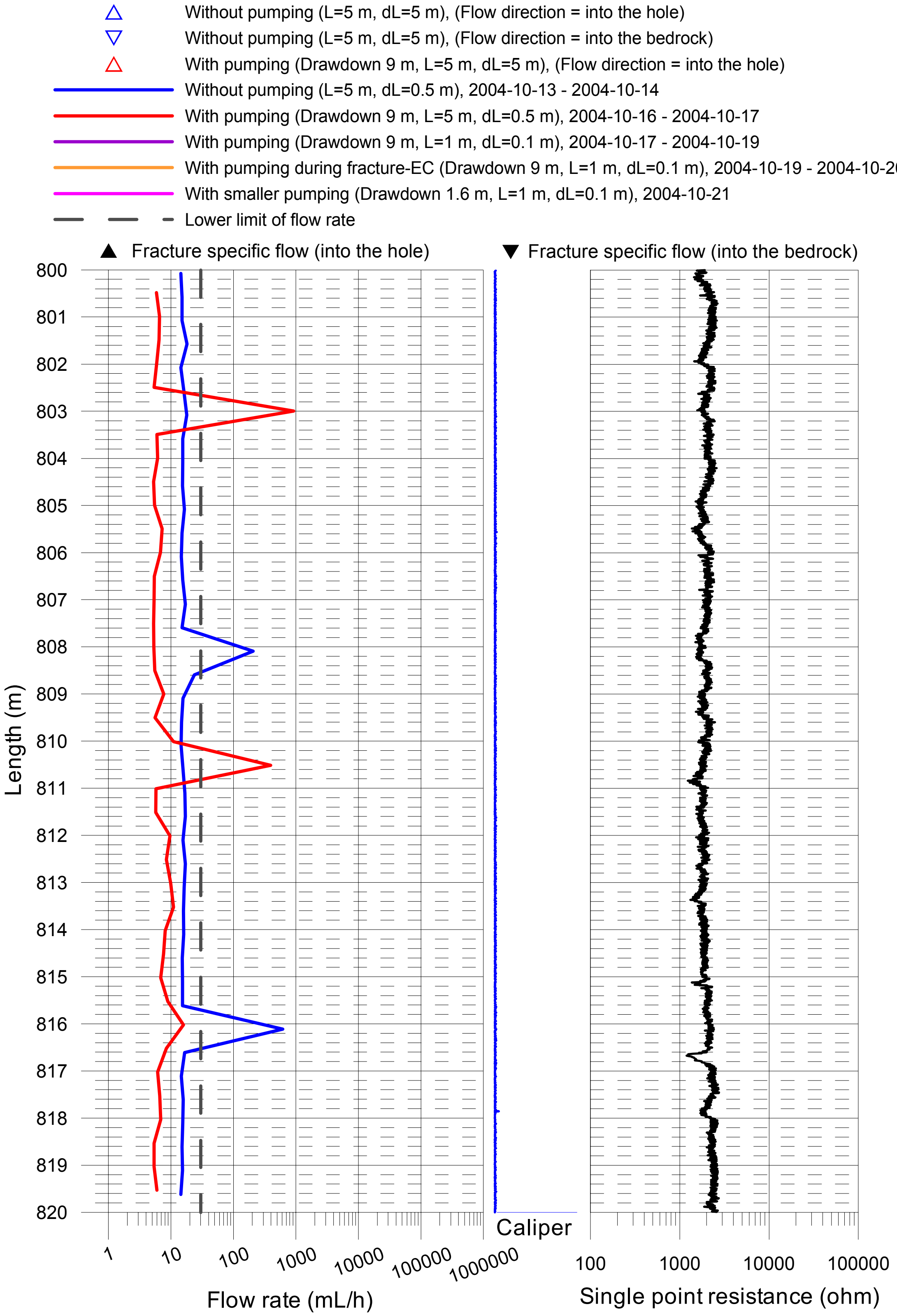
Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance

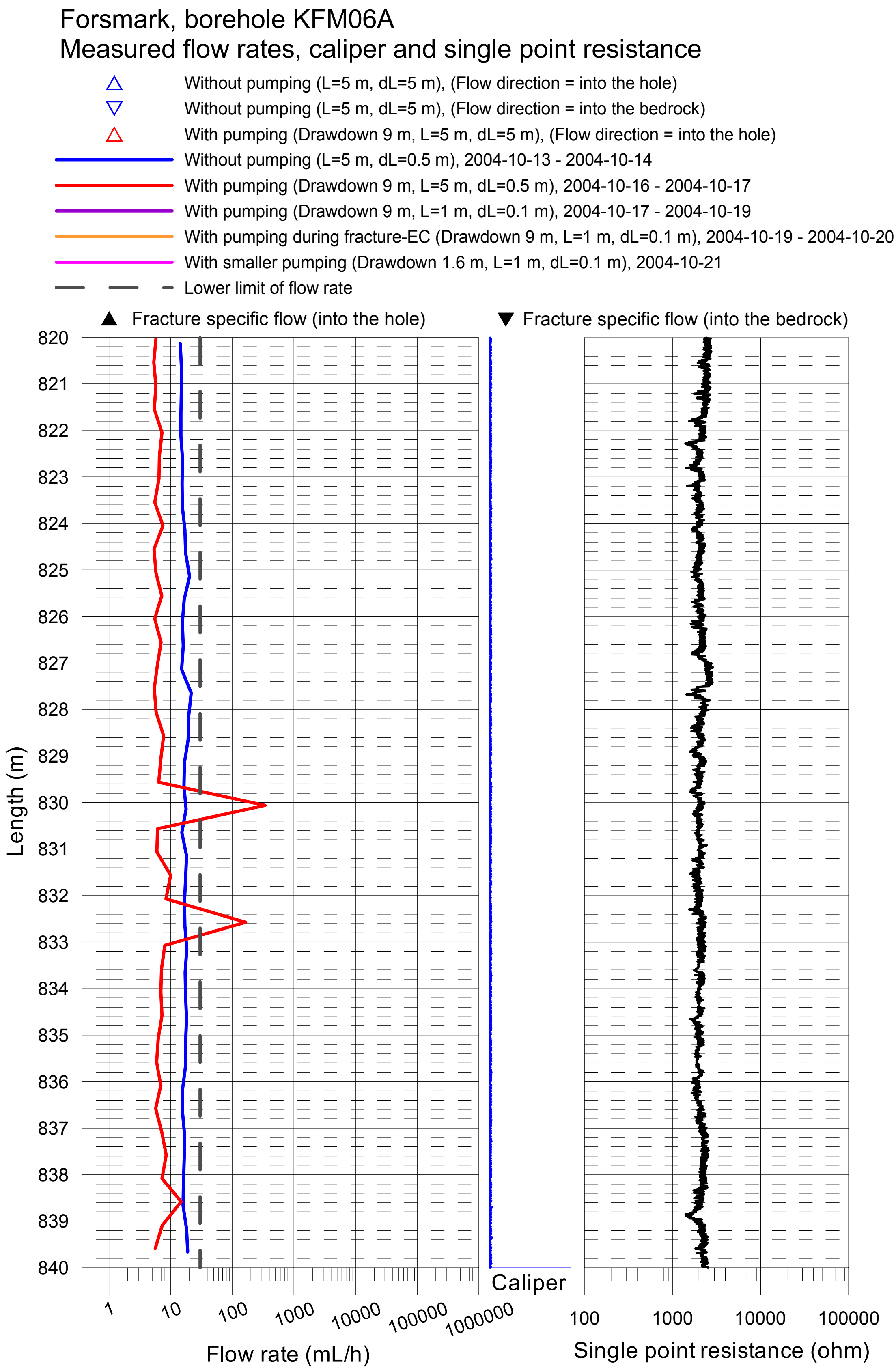


Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance

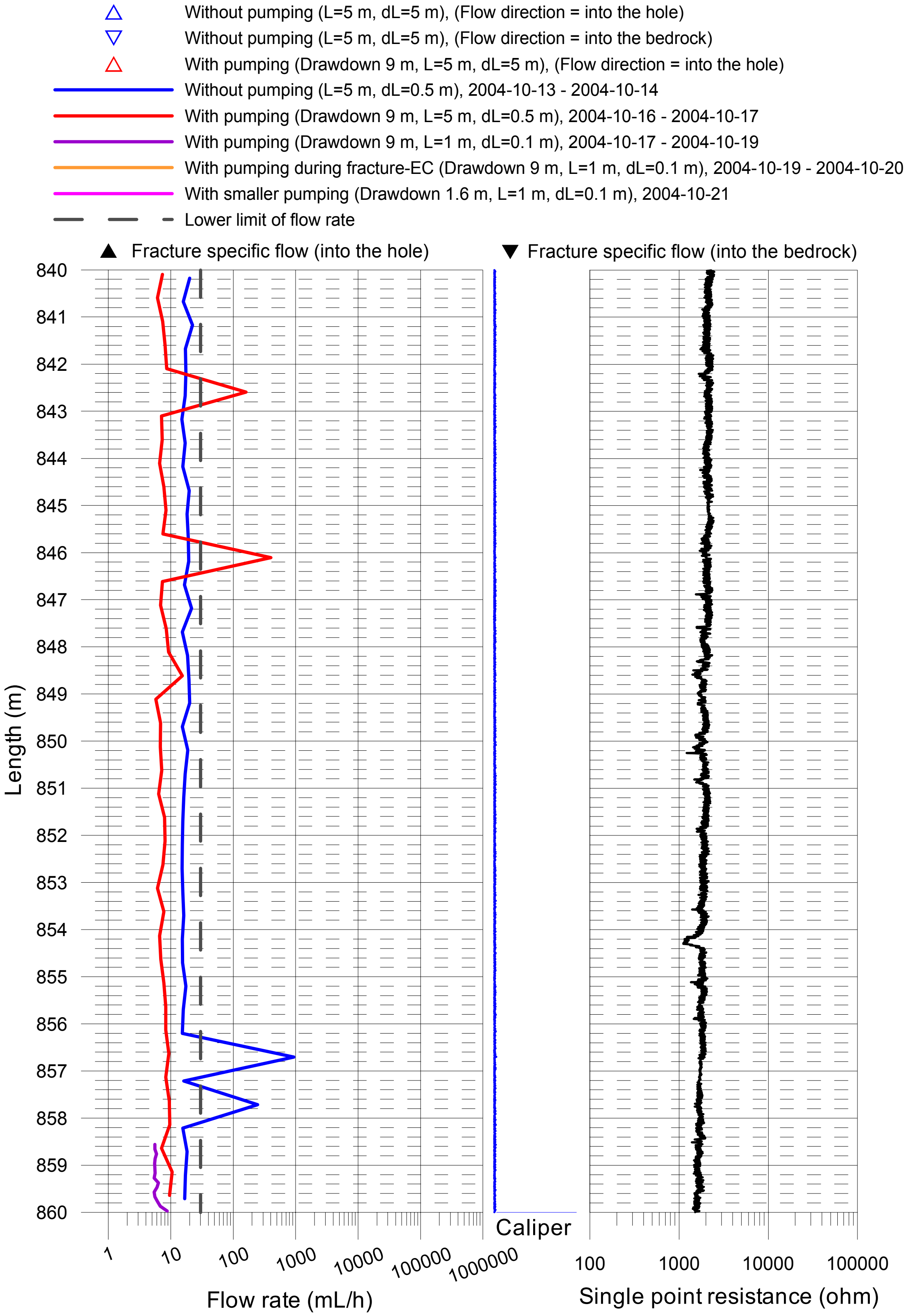


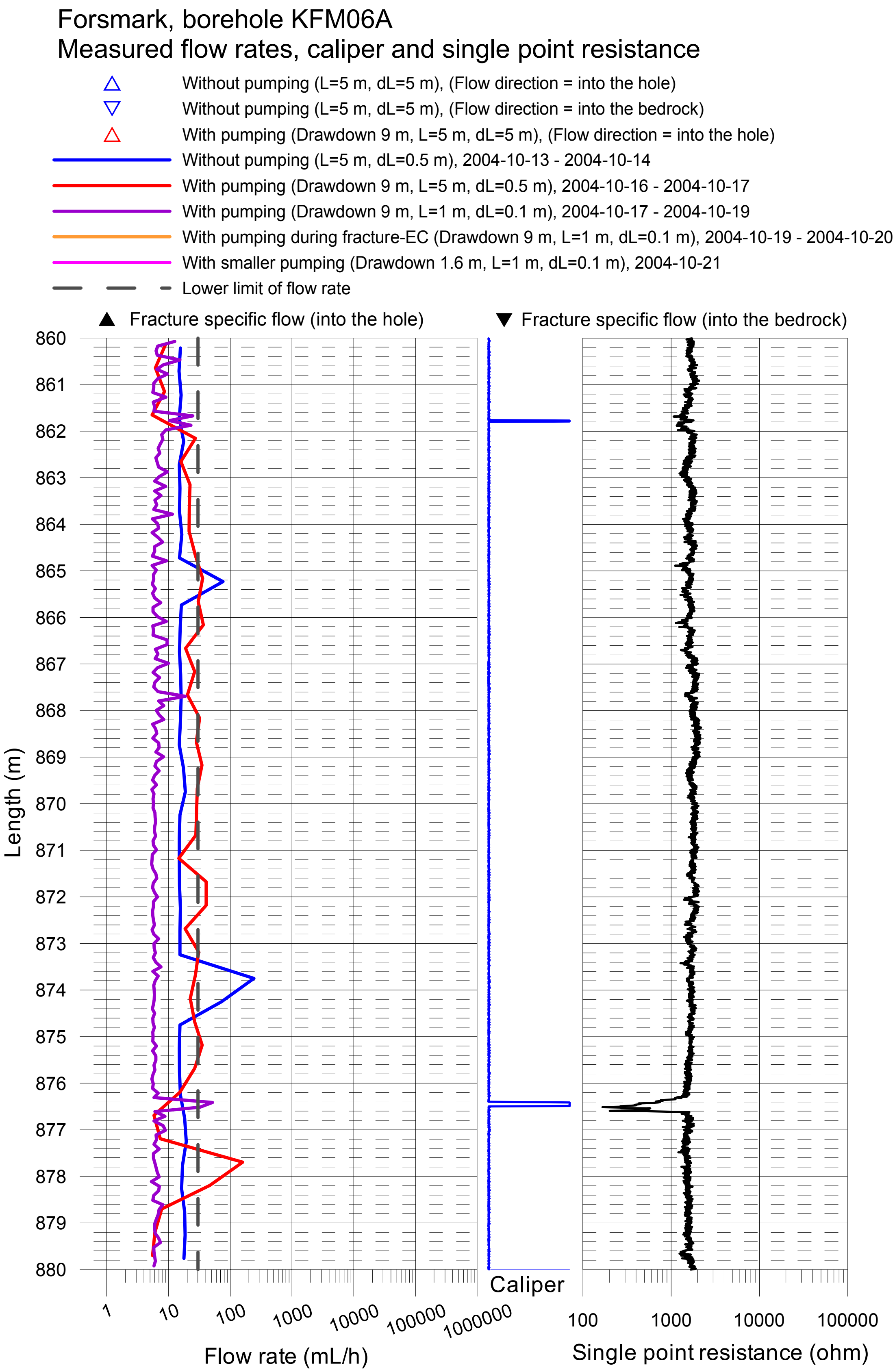
Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance



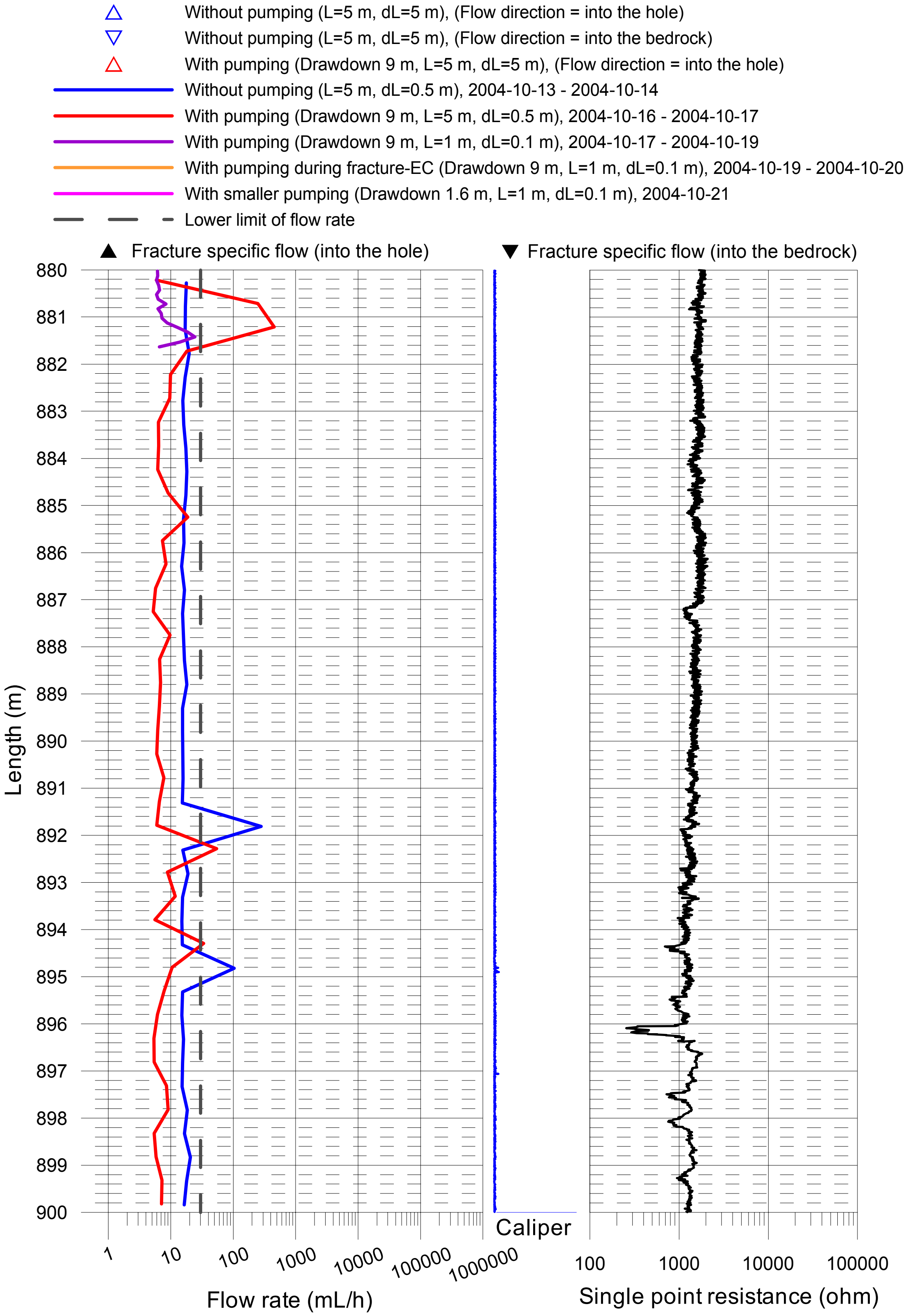

Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (Drawdown 9 m, L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=0.5 m), 2004-10-13 - 2004-10-14
With pumping (Drawdown 9 m, L=5 m, dL=0.5 m), 2004-10-16 - 2004-10-17
With pumping (Drawdown 9 m, L=1 m, dL=0.1 m), 2004-10-17 - 2004-10-19
With pumping during fracture-EC (Drawdown 9 m, L=1 m, dL=0.1 m), 2004-10-19 - 2004-10-20
With smaller pumping (Drawdown 1.6 m, L=1 m, dL=0.1 m), 2004-10-21
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
820
821
822
823
824
825
826
827
828
829
830
831
832
833
834
835
836
837
838
839
840
Caliper
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
100
1000
10000
100000
Single point resistance (ohm)

Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance

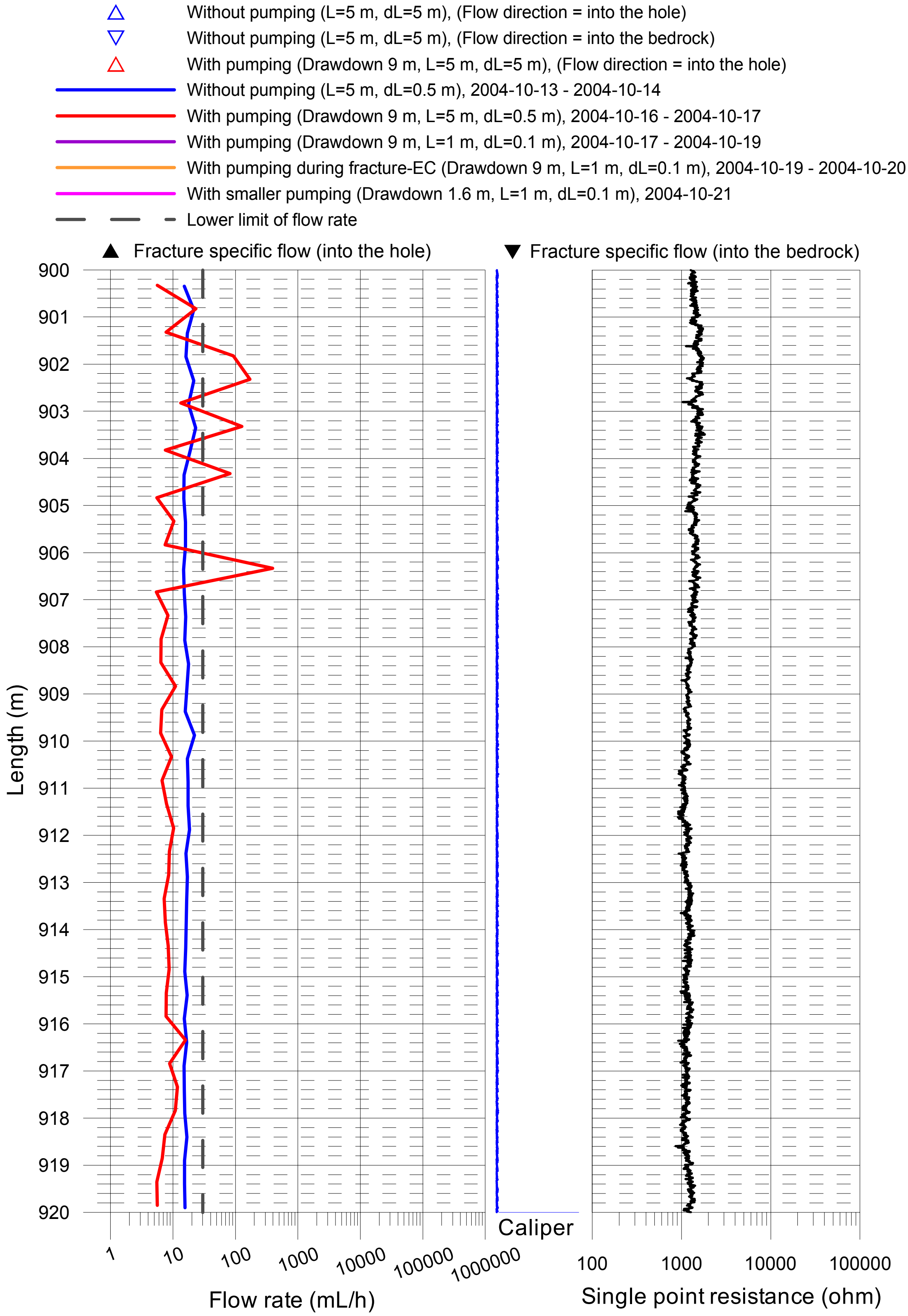



Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (Drawdown 9 m, L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=0.5 m), 2004-10-13 - 2004-10-14
With pumping (Drawdown 9 m, L=5 m, dL=0.5 m), 2004-10-16 - 2004-10-17
With pumping (Drawdown 9 m, L=1 m, dL=0.1 m), 2004-10-17 - 2004-10-19
With pumping during fracture-EC (Drawdown 9 m, L=1 m, dL=0.1 m), 2004-10-19 - 2004-10-20
With smaller pumping (Drawdown 1.6 m, L=1 m, dL=0.1 m), 2004-10-21
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
860
861
862
863
864
865
866
867
868
869
870
871
872
873
874
875
876
877
878
879
880
Length (m)
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)

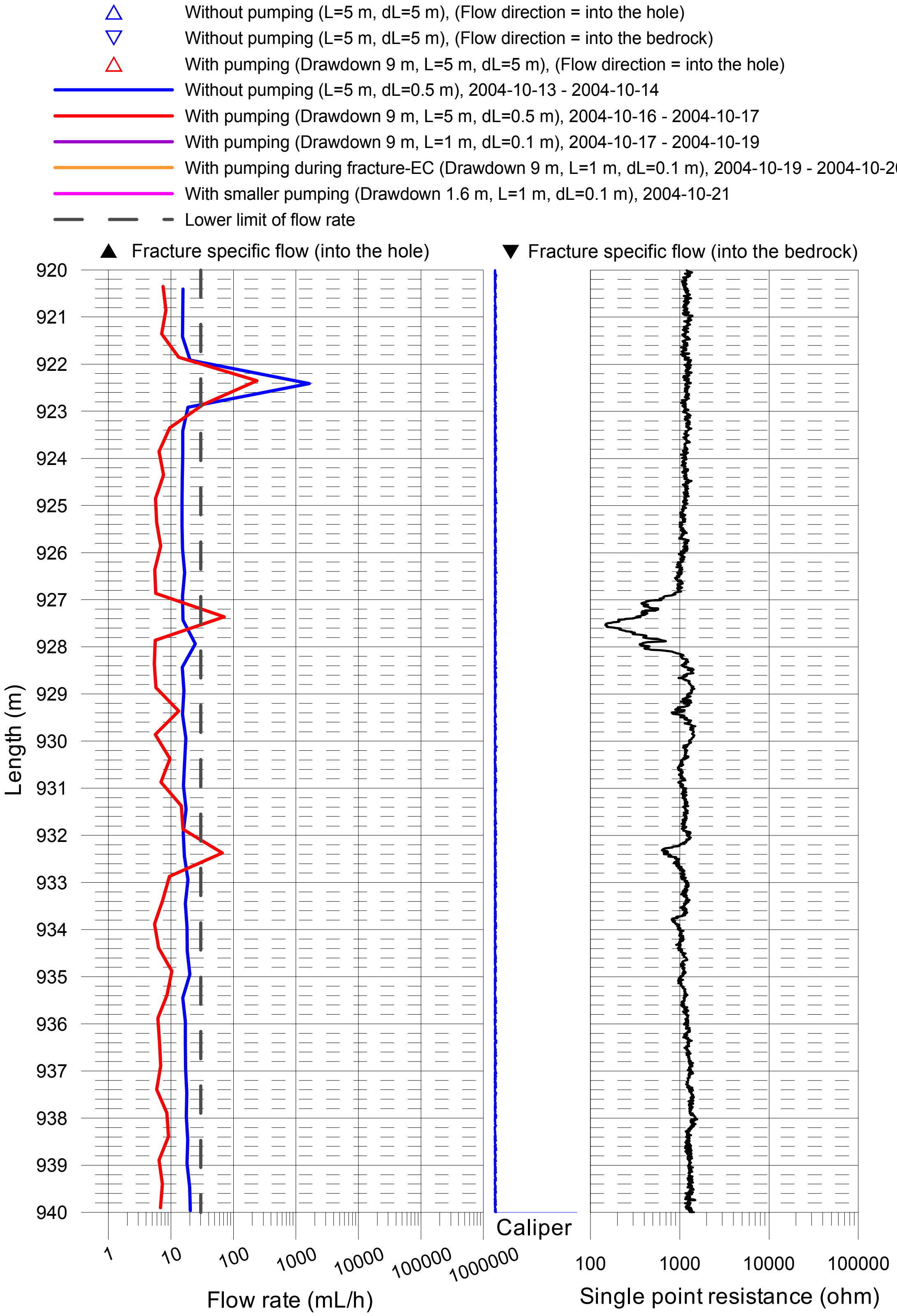
Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance



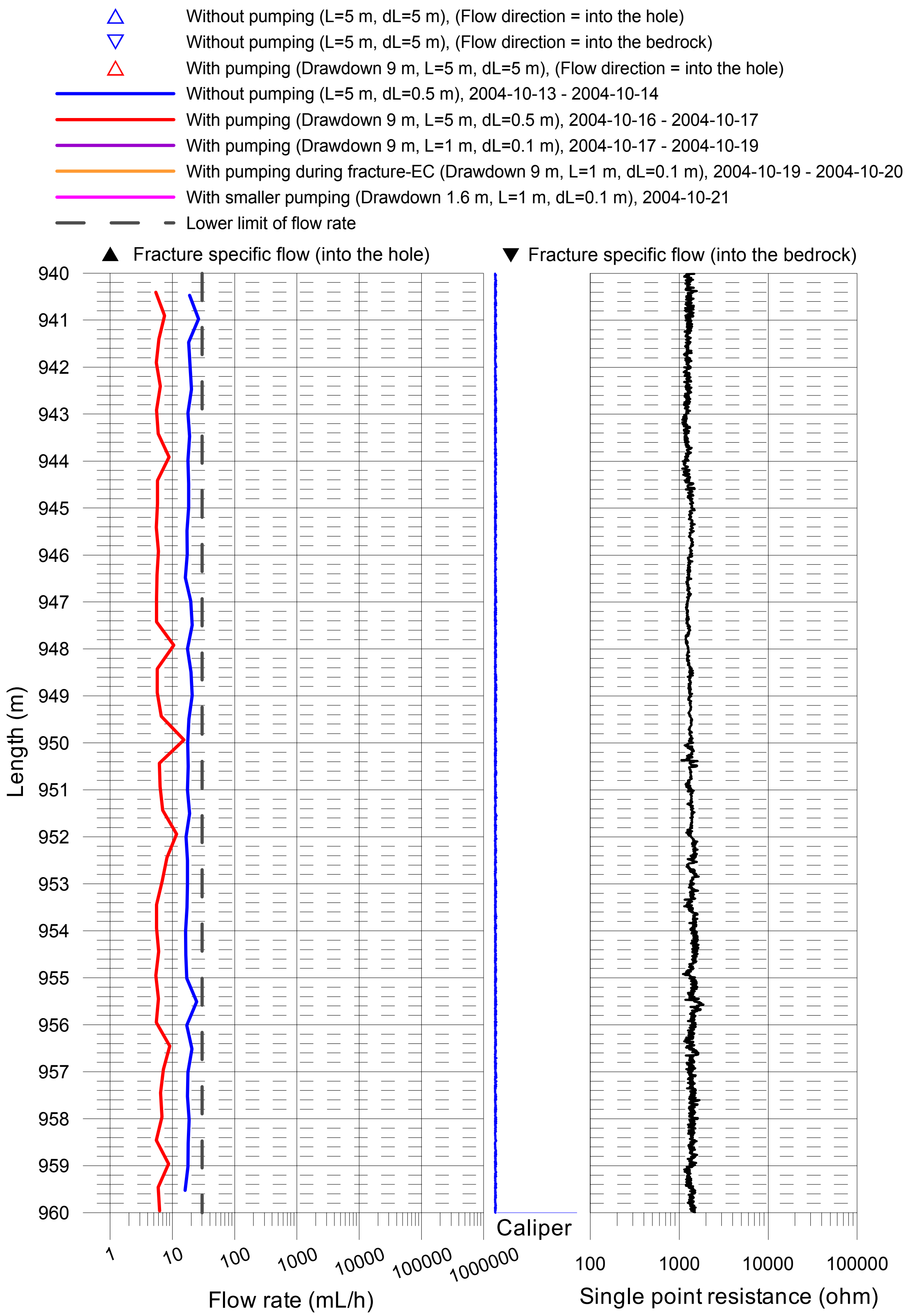
Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance



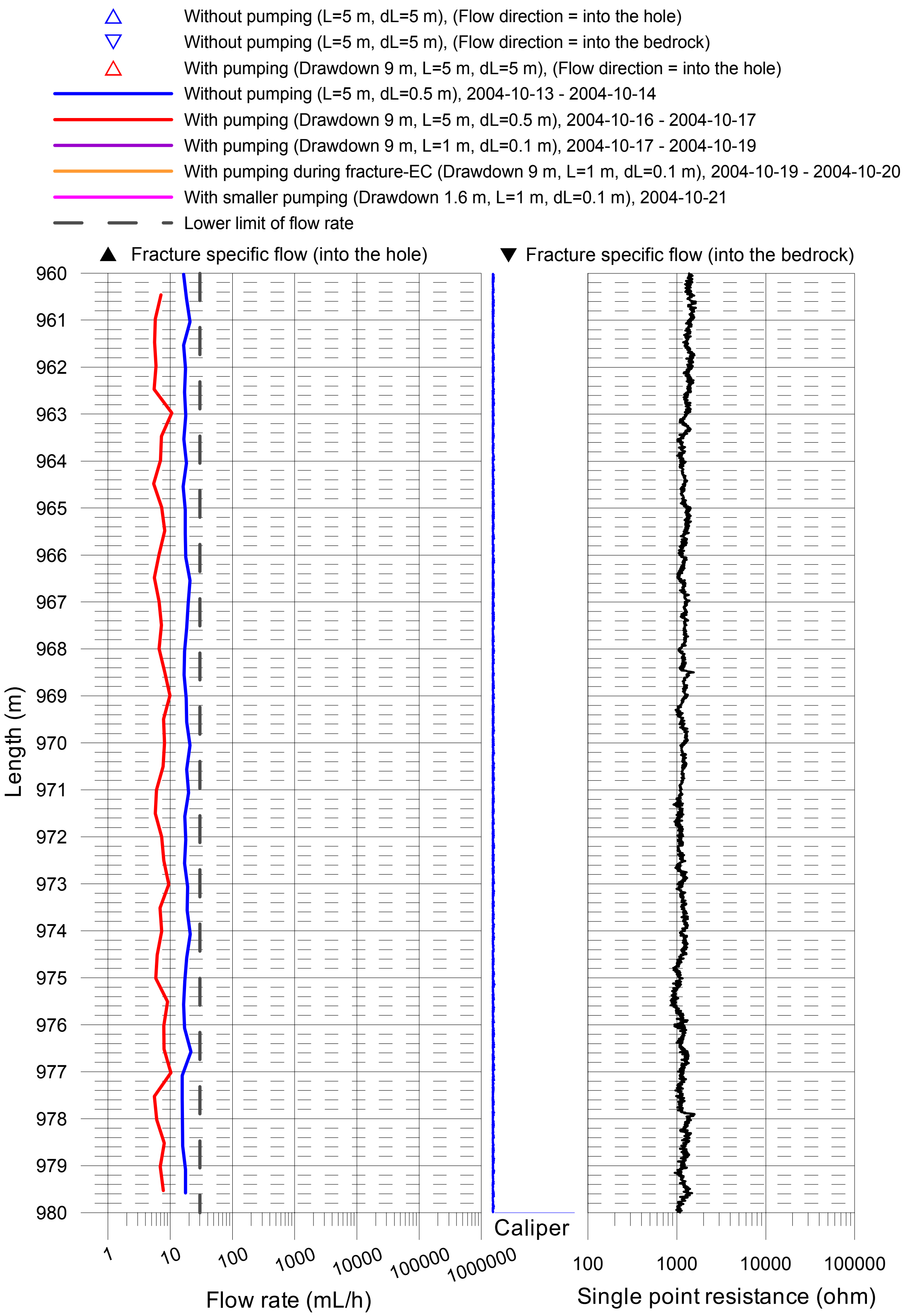
Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance



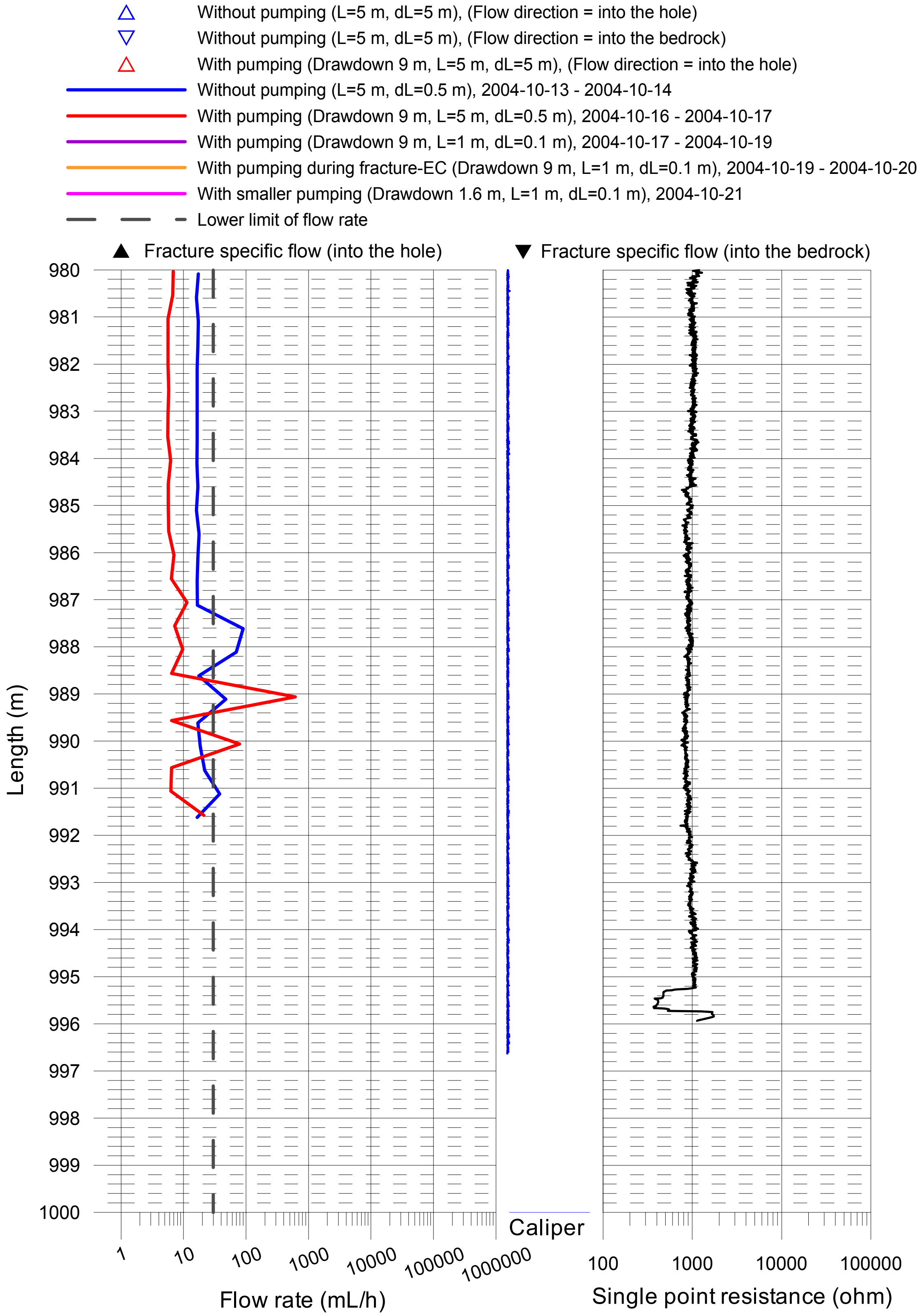
Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance



Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance



Forsmark, borehole KFM06A
Measured flow rates, caliper and single point resistance



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	m a.s l.	Initial hydraulic head before pumping. Elevation of water level in open borehole in the local co-ordinates system with z = 0 m.
h_1	m a s l.	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.
h_2	m.a.s l.	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 ($s_2 = h_2-h_0$)

Header	Unit	Explanations
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-meas$_{lLP}$	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-meas$_{lU}$	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)

Table of transmissivity and head of 5 m sections

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)	Q-lower limit P (mL/h)	TD-measlLT (m²/s)	TD-measlLP (m²/s)	TD-measlU (m²/s)	ECw0 (S/m)	Tew0 (°C)	ECw1 (S/m)	Tew1 (°C)	Com-ments
KFM06A	987.08	992.08	5	–	5.78	–	–3.22	–	–	30	9.16E–10	9.16E–10	9.16E–06	1.16	15.57	1.20	15.58	
KFM06A	982.06	987.06	5	–	5.81	–	–3.20	–	–	30	9.15E–10	9.15E–10	9.15E–06	1.16	15.54	1.20	15.54	
KFM06A	977.05	982.05	5	–	5.82	–	–3.19	–	–	30	9.15E–10	9.15E–10	9.15E–06	1.17	15.49	1.20	15.49	
KFM06A	972.03	977.03	5	–	5.85	–	–3.17	–	–	30	9.14E–10	9.14E–10	9.14E–06	1.17	15.45	1.19	15.45	
KFM06A	967.02	972.02	5	–	5.88	–	–3.15	–	–	30	9.13E–10	9.13E–10	9.13E–06	1.17	15.43	1.19	15.43	
KFM06A	962.00	967.00	5	–	5.87	–	–3.12	–	–	30	9.17E–10	9.17E–10	9.17E–06	1.17	15.35	1.20	15.34	
KFM06A	956.98	961.98	5	–	5.89	–	–3.10	–	–	30	9.17E–10	9.17E–10	9.17E–06	1.17	15.29	1.20	15.29	
KFM06A	951.97	956.97	5	–	5.89	–	–3.12	–	–	30	9.15E–10	9.15E–10	9.15E–06	1.18	15.24	1.20	15.23	
KFM06A	946.95	951.95	5	–	5.92	–	–3.10	–	–	30	9.14E–10	9.14E–10	9.14E–06	1.17	15.19	1.20	15.19	
KFM06A	941.94	946.94	5	–	5.92	–	–3.08	–	–	30	9.16E–10	9.16E–10	9.16E–06	1.17	15.15	1.20	15.15	
KFM06A	936.92	941.92	5	–	5.93	–	–3.06	–	–	30	9.17E–10	9.17E–10	9.17E–06	1.18	15.10	1.20	15.09	
KFM06A	931.91	936.91	5	–	5.95	–	–3.07	–	–	30	9.14E–10	9.14E–10	9.14E–06	1.18	15.02	1.20	15.02	
KFM06A	926.89	931.89	5	–	5.97	–	–3.07	–	–	30	9.12E–10	9.12E–10	9.12E–06	1.19	14.98	1.21	14.98	
KFM06A	921.88	926.88	5	–	5.94	–	–3.07	–	–	30	9.15E–10	9.15E–10	9.15E–06	1.19	14.92	1.21	14.90	
KFM06A	916.87	921.87	5	–	5.97	–	–3.05	–	–	30	9.14E–10	9.14E–10	9.14E–06	1.20	14.87	1.21	14.85	
KFM06A	911.86	916.86	5	–	6.00	–	–3.02	–	–	30	9.14E–10	9.14E–10	9.14E–06	1.21	14.82	1.21	14.81	
KFM06A	906.85	911.85	5	–	6.02	–	–3.03	–	–	30	9.11E–10	9.11E–10	9.11E–06	1.22	14.76	1.22	14.75	
KFM06A	901.83	906.83	5	–	6.02	–	–3.03	–	–	30	9.11E–10	9.11E–10	9.11E–06	1.22	14.74	1.22	14.72	
KFM06A	896.82	901.82	5	–	6.04	–	–3.03	–	–	30	9.09E–10	9.09E–10	9.09E–06	1.23	14.67	1.23	14.64	
KFM06A	891.80	896.80	5	–	6.03	–	–3.00	–	–	30	9.13E–10	9.13E–10	9.13E–06	1.24	14.60	1.23	14.61	
KFM06A	886.77	891.77	5	–	6.03	–	–2.99	–	–	30	9.14E–10	9.14E–10	9.14E–06	1.26	14.54	1.24	14.52	
KFM06A	881.75	886.75	5	–	6.06	–	–2.97	–	–	30	9.13E–10	9.13E–10	9.13E–06	1.26	14.51	1.24	14.49	

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)	Q-lower limit P (mL/h)	TD-measlLT (m²/s)	TD-measlLP (m²/s)	TD-measlU (m²/s)	ECw0 (S/m)	Tew0 (°C)	ECw1 (S/m)	Tew1 (°C)	Com-ments
KFM06A	876.72	881.72	5	–	6.10	–	–2.94	–	–	30	9.12E–10	9.12E–10	9.12E–06	1.27	14.45	1.25	14.43	
KFM06A	871.71	876.71	5	–	6.10	–	–2.92	–	–	30	9.14E–10	9.14E–10	9.14E–06	1.28	14.39	1.25	14.37	
KFM06A	866.70	871.70	5	–	6.10	–	–2.91	–	–	30	9.15E–10	9.15E–10	9.15E–06	1.29	14.33	1.25	14.31	
KFM06A	861.69	866.69	5	–	6.08	–	–2.92	–	–	30	9.16E–10	9.16E–10	9.16E–06	1.30	14.27	1.26	14.26	
KFM06A	856.67	861.67	5	–	6.10	–	–2.92	–	–	30	9.14E–10	9.14E–10	9.14E–06	1.31	14.24	1.26	14.21	
KFM06A	851.66	856.66	5	–	6.11	–	–2.92	–	–	30	9.13E–10	9.13E–10	9.13E–06	1.31	14.18	1.26	14.18	
KFM06A	846.65	851.65	5	–	6.13	–	–2.89	–	–	30	9.14E–10	9.14E–10	9.14E–06	1.32	14.14	1.27	14.12	
KFM06A	841.63	846.63	5	–	6.10	–	–2.93	–	–	30	9.13E–10	9.13E–10	9.13E–06	1.32	14.09	1.27	14.06	
KFM06A	836.62	841.62	5	–	6.11	–	–2.91	–	–	30	9.14E–10	9.14E–10	9.14E–06	1.33	13.99	1.27	13.98	
KFM06A	831.60	836.60	5	–	6.09	–	–2.92	–	–	30	9.15E–10	9.15E–10	9.15E–06	1.32	13.95	1.28	13.93	
KFM06A	826.59	831.59	5	–	6.10	–	–2.93	–	–	30	9.13E–10	9.13E–10	9.13E–06	1.33	13.89	1.28	13.88	
KFM06A	821.58	826.58	5	–	6.11	–	–2.93	–	–	30	9.12E–10	9.12E–10	9.12E–06	1.32	13.84	1.28	13.82	
KFM06A	816.57	821.57	5	–	6.10	–	–2.91	–	–	30	9.15E–10	9.15E–10	9.15E–06	1.34	13.78	1.28	13.76	
KFM06A	811.56	816.56	5	–	6.08	–	–2.93	–	–	30	9.15E–10	9.15E–10	9.15E–06	1.32	13.73	1.29	13.71	
KFM06A	806.54	811.54	5	–	6.09	–	–2.94	–	–	30	9.13E–10	9.13E–10	9.13E–06	1.32	13.73	1.29	13.66	
KFM06A	801.53	806.53	5	–	6.08	–	–2.93	–	–	30	9.15E–10	9.15E–10	9.15E–06	1.34	13.64	1.29	13.64	
KFM06A	796.52	801.52	5	–	6.08	–	–2.92	–	–	30	9.16E–10	9.16E–10	9.16E–06	1.33	13.59	1.30	13.58	
KFM06A	791.51	796.51	5	–	6.05	–	–2.96	–	–	30	9.15E–10	9.15E–10	9.15E–06	1.34	13.51	1.30	13.49	
KFM06A	786.49	791.49	5	–	6.05	–	–2.97	–	–	30	9.14E–10	9.14E–10	9.14E–06	1.33	13.46	1.29	13.45	
KFM06A	781.48	786.48	5	–	6.05	–	–2.96	–	–	30	9.15E–10	9.15E–10	9.15E–06	1.34	13.40	1.31	13.40	
KFM06A	776.46	781.46	5	–	6.05	–	–2.96	–	–	30	9.15E–10	9.15E–10	9.15E–06	1.34	13.35	1.31	13.34	
KFM06A	771.45	776.45	5	–	6.06	–	–3.00	–	–	30	9.10E–10	9.10E–10	9.10E–06	1.31	13.31	1.30	13.28	
KFM06A	766.44	771.44	5	8.86E–09	6.05	2.57E–07	–3.00	2.71E–08	6.37	30	9.11E–10	9.11E–10	9.11E–06	1.34	13.27	1.26	13.21	
KFM06A	761.42	766.42	5	–	6.01	–	–3.00	–	–	30	9.15E–10	9.15E–10	9.15E–06	1.34	13.22	1.31	13.18	
KFM06A	756.41	761.41	5	–	6.02	–	–3.01	–	–	30	9.13E–10	9.13E–10	9.13E–06	1.34	13.17	1.31	13.15	
KFM06A	751.39	756.39	5	–	6.04	–	–3.00	–	–	30	9.12E–10	9.12E–10	9.12E–06	1.32	13.12	1.31	13.12	

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)	Q-lower limit P (mL/h)	TD-measlLT (m²/s)	TD-measlLP (m²/s)	TD-measlU (m²/s)	ECw0 (S/m)	Tew0 (°C)	ECw1 (S/m)	Tew1 (°C)	Com-ments
KFM06A	746.38	751.38	5	–	6.05	–	–3.01	–	–	30	9.10E–10	9.10E–10	9.10E–06	1.33	13.09	1.31	13.09	
KFM06A	741.37	746.37	5	–2.05E–07	6.02	2.82E–06	–3.04	3.30E–07	5.41	30	9.10E–10	9.10E–10	9.10E–06	1.33	13.00	1.27	13.03	
KFM06A	736.36	741.36	5	–	6.02	–	–3.06	–	–	30	9.08E–10	9.08E–10	9.08E–06	1.32	12.93	1.31	12.91	
KFM06A	731.36	736.36	5	–	5.99	–	–3.09	–	–	30	9.08E–10	9.08E–10	9.08E–06	1.32	12.88	1.31	12.86	
KFM06A	726.35	731.35	5	–	6.00	–	–3.09	–	–	30	9.07E–10	9.07E–10	9.07E–06	1.31	12.85	1.30	12.84	
KFM06A	721.35	726.35	5	–	5.95	–	–3.10	–	–	30	9.11E–10	9.11E–10	9.11E–06	1.31	12.78	1.30	12.80	
KFM06A	716.35	721.35	5	–	5.94	–	–3.13	–	–	30	9.09E–10	9.09E–10	9.09E–06	1.31	12.71	1.30	12.73	
KFM06A	711.34	716.34	5	–	5.93	–	–3.14	–	–	30	9.09E–10	9.09E–10	9.09E–06	1.31	12.64	1.31	12.67	
KFM06A	706.34	711.34	5	–	5.93	–	–3.15	–	–	30	9.08E–10	9.08E–10	9.08E–06	1.30	12.60	1.31	12.63	
KFM06A	701.33	706.33	5	–	5.90	–	–3.16	–	–	30	9.10E–10	9.10E–10	9.10E–06	1.31	12.57	1.31	12.60	
KFM06A	696.32	701.32	5	–	5.90	–	–3.18	–	–	30	9.08E–10	9.08E–10	9.08E–06	1.31	12.54	1.31	12.55	
KFM06A	691.31	696.31	5	–	5.85	–	–3.23	–	–	30	9.08E–10	9.08E–10	9.08E–06	1.31	12.45	1.31	12.47	
KFM06A	686.30	691.30	5	–	5.83	–	–3.23	–	–	30	9.10E–10	9.10E–10	9.10E–06	1.31	12.41	1.31	12.43	
KFM06A	681.29	686.29	5	–	5.82	–	–3.25	–	–	30	9.09E–10	9.09E–10	9.09E–06	1.30	12.34	1.30	12.36	
KFM06A	676.28	681.28	5	–	5.80	–	–3.27	–	–	30	9.09E–10	9.09E–10	9.09E–06	1.31	12.33	1.31	12.35	
KFM06A	671.27	676.27	5	–	5.76	–	–3.29	–	–	30	9.11E–10	9.11E–10	9.11E–06	1.31	12.28	1.31	12.30	
KFM06A	666.26	671.26	5	–	5.76	–	–3.31	–	–	30	9.09E–10	9.09E–10	9.09E–06	1.31	12.21	1.31	12.23	
KFM06A	661.26	666.26	5	–	5.73	–	–3.32	–	–	30	9.11E–10	9.11E–10	9.11E–06	1.31	12.15	1.31	12.15	
KFM06A	656.25	661.25	5	–	5.73	–	–3.35	–	–	30	9.08E–10	9.08E–10	9.08E–06	1.30	12.11	1.30	12.11	
KFM06A	651.24	656.24	5	–	5.72	2.44E–09	–3.35	2.66E–10	–	30	9.09E–10	9.09E–10	9.09E–06	1.32	12.06	1.31	12.07	
KFM06A	646.23	651.23	5	–	5.71	–	–3.37	–	–	30	9.08E–10	9.08E–10	9.08E–06	1.31	12.01	1.31	12.03	
KFM06A	641.23	646.23	5	–	5.65	–	–3.44	–	–	30	9.07E–10	9.07E–10	9.07E–06	1.32	11.96	1.31	11.96	
KFM06A	636.22	641.22	5	–	5.63	–	–3.45	–	–	30	9.08E–10	9.08E–10	9.08E–06	1.32	11.91	1.31	11.93	
KFM06A	631.21	636.21	5	–	5.60	–	–3.47	–	–	30	9.09E–10	9.09E–10	9.09E–06	1.33	11.85	1.31	11.86	
KFM06A	626.20	631.20	5	–	5.61	–	–3.49	–	–	30	9.06E–10	9.06E–10	9.06E–06	1.33	11.85	1.32	11.84	
KFM06A	621.20	626.20	5	–	5.59	2.26E–09	–3.52	2.45E–10	–	30	9.05E–10	9.05E–10	9.05E–06	1.34	11.78	1.32	11.84	

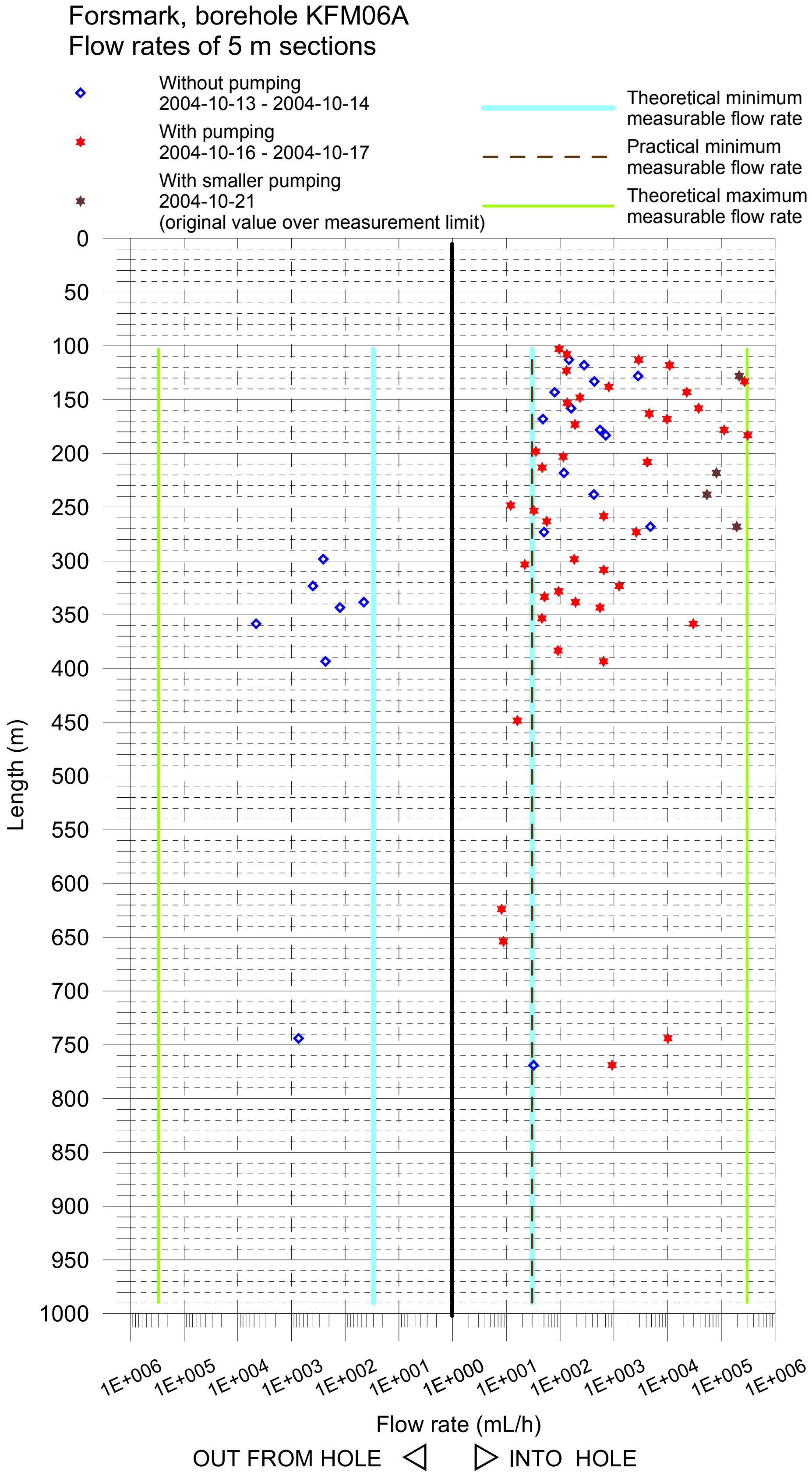
Borehole ID	Secup L(m)	Seclow L(m)	Lw (m)	Q0 (m³/s)	dh0 (m)	Q1 (m³/s)	dh1 (m)	TD (m²/s)	hi (m)	Q-lower limit P (mL/h)	TD-measlLT (m²/s)	TD-measlLP (m²/s)	TD-measlU (m²/s)	ECw0 (S/m)	Tew0 (°C)	ECw1 (S/m)	Tew1 (°C)	Com-ments
KFM06A	616.19	621.19	5	–	5.56	–	–3.53	–	–	30	9.07E–10	9.07E–10	9.07E–06	1.35	11.74	1.32	11.84	
KFM06A	611.17	616.17	5	–	5.54	–	–3.55	–	–	30	9.07E–10	9.07E–10	9.07E–06	1.34	11.67	1.31	11.67	
KFM06A	606.16	611.16	5	–	5.50	–	–3.58	–	–	30	9.08E–10	9.08E–10	9.08E–06	1.33	11.62	1.32	11.63	
KFM06A	601.15	606.15	5	–	5.48	–	–3.60	–	–	30	9.08E–10	9.08E–10	9.08E–06	1.36	11.58	1.32	11.59	
KFM06A	596.14	601.14	5	–	5.47	–	–3.61	–	–	30	9.08E–10	9.08E–10	9.08E–06	1.37	11.51	1.32	11.53	
KFM06A	591.13	596.13	5	–	5.43	–	–3.67	–	–	30	9.06E–10	9.06E–10	9.06E–06	1.37	11.49	1.32	11.49	
KFM06A	586.12	591.12	5	–	5.41	–	–3.70	–	–	30	9.05E–10	9.05E–10	9.05E–06	1.39	11.43	1.33	11.45	
KFM06A	581.11	586.11	5	–	5.38	–	–3.70	–	–	30	9.08E–10	9.08E–10	9.08E–06	1.38	11.36	1.31	11.36	
KFM06A	576.10	581.10	5	–	5.37	–	–3.72	–	–	30	9.07E–10	9.07E–10	9.07E–06	1.41	11.31	1.32	11.33	
KFM06A	571.09	576.09	5	–	5.35	–	–3.76	–	–	30	9.05E–10	9.05E–10	9.05E–06	1.41	11.27	1.32	11.28	
KFM06A	566.08	571.08	5	–	5.33	–	–3.77	–	–	30	9.06E–10	9.06E–10	9.06E–06	1.42	11.21	1.33	11.23	
KFM06A	561.07	566.07	5	–	5.28	–	–3.83	–	–	30	9.05E–10	9.05E–10	9.05E–06	1.41	11.17	1.32	11.18	
KFM06A	556.06	561.06	5	–	5.23	–	–3.85	–	–	30	9.08E–10	9.08E–10	9.08E–06	1.41	11.13	1.32	11.13	
KFM06A	551.05	556.05	5	–	5.21	–	–3.89	–	–	30	9.06E–10	9.06E–10	9.06E–06	1.41	11.08	1.33	11.09	
KFM06A	546.04	551.04	5	–	5.20	–	–3.92	–	–	30	9.04E–10	9.04E–10	9.04E–06	1.44	11.01	1.35	11.03	
KFM06A	541.03	546.03	5	–	5.15	–	–3.97	–	–	30	9.04E–10	9.04E–10	9.04E–06	1.45	10.99	1.35	11.01	
KFM06A	536.02	541.02	5	–	5.11	–	–4.01	–	–	30	9.04E–10	9.04E–10	9.04E–06	1.43	10.93	1.35	10.94	
KFM06A	531.01	536.01	5	–	5.10	–	–4.01	–	–	30	9.05E–10	9.05E–10	9.05E–06	1.44	10.88	1.34	10.90	
KFM06A	526.00	531.00	5	–	5.08	–	–4.06	–	–	30	9.02E–10	9.02E–10	9.02E–06	1.45	10.84	1.36	10.85	
KFM06A	520.99	525.99	5	–	5.02	–	–4.08	–	–	30	9.06E–10	9.06E–10	9.06E–06	1.45	10.79	1.35	10.81	
KFM06A	515.99	520.99	5	–	5.00	–	–4.11	–	–	30	9.05E–10	9.05E–10	9.05E–06	1.44	10.75	1.35	10.76	
KFM06A	510.99	515.99	5	–	4.98	–	–4.17	–	–	30	9.01E–10	9.01E–10	9.01E–06	1.46	10.71	1.37	10.71	
KFM06A	505.98	510.98	5	–	4.95	–	–4.19	–	–	30	9.02E–10	9.02E–10	9.02E–06	1.46	10.66	1.36	10.67	
KFM06A	500.98	505.98	5	–	4.91	–	–4.23	–	–	30	9.02E–10	9.02E–10	9.02E–06	1.46	10.62	1.37	10.62	
KFM06A	495.97	500.97	5	–	4.86	–	–4.27	–	–	30	9.03E–10	9.03E–10	9.03E–06	1.45	10.56	1.37	10.57	
KFM06A	490.97	495.97	5	–	4.84	–	–4.34	–	–	30	8.98E–10	8.98E–10	8.98E–06	1.47	10.50	1.39	10.52	

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)	Q-lower limit P (mL/h)	TD-measlLT (m²/s)	TD-measlLP (m²/s)	TD-measlU (m²/s)	ECw0 (S/m)	Tew0 (°C)	ECw1 (S/m)	Tew1 (°C)	Com-ments
KFM06A	485.96	490.96	5	–	4.81	–	–4.37	–	–	30	8.98E–10	8.98E–10	8.98E–06	1.47	10.47	1.39	10.48	
KFM06A	480.96	485.96	5	–	4.78	–	–4.41	–	–	30	8.97E–10	8.97E–10	8.97E–06	1.48	10.42	1.39	10.44	
KFM06A	475.95	480.95	5	–	4.74	–	–4.45	–	–	30	8.97E–10	8.97E–10	8.97E–06	1.46	10.38	1.38	10.39	
KFM06A	470.94	475.94	5	–	4.71	–	–4.45	–	–	30	9.00E–10	9.00E–10	9.00E–06	1.48	10.33	1.40	10.34	
KFM06A	465.94	470.94	5	–	4.66	–	–4.48	–	–	30	9.02E–10	9.02E–10	9.02E–06	1.48	10.29	1.40	10.29	
KFM06A	460.93	465.93	5	–	4.60	–	–4.57	–	–	30	8.99E–10	8.99E–10	8.99E–06	1.48	10.25	1.41	10.26	
KFM06A	455.93	460.93	5	–	4.55	–	–4.60	–	–	30	9.01E–10	9.01E–10	9.01E–06	1.47	10.20	1.39	10.21	
KFM06A	450.92	455.92	5	–	4.55	–	–4.59	–	–	30	9.02E–10	9.02E–10	9.02E–06	1.47	10.15	1.39	10.16	
KFM06A	445.92	450.92	5	–	4.52	4.44E–09	–4.63	4.80E–10	–	30	9.01E–10	9.01E–10	9.01E–06	1.49	10.10	1.41	10.13	
KFM06A	440.92	445.92	5	–	4.48	–	–4.68	–	–	30	9.00E–10	9.00E–10	9.00E–06	1.48	10.06	1.40	10.08	
KFM06A	435.91	440.91	5	–	4.45	–	–4.72	–	–	30	8.99E–10	8.99E–10	8.99E–06	1.49	10.03	1.42	10.03	
KFM06A	430.91	435.91	5	–	4.42	–	–4.75	–	–	30	8.99E–10	8.99E–10	8.99E–06	1.49	10.00	1.42	10.00	
KFM06A	425.90	430.90	5	–	4.41	–	–4.81	–	–	30	8.94E–10	8.94E–10	8.94E–06	1.49	9.97	1.42	9.96	
KFM06A	420.90	425.90	5	–	4.37	–	–4.84	–	–	30	8.95E–10	8.95E–10	8.95E–06	1.49	9.91	1.43	9.89	
KFM06A	415.89	420.89	5	–	4.34	–	–4.87	–	–	30	8.95E–10	8.95E–10	8.95E–06	1.49	9.86	1.38	9.87	
KFM06A	410.89	415.89	5	–	4.27	–	–4.93	–	–	30	8.96E–10	8.96E–10	8.96E–06	1.50	9.81	1.43	9.81	
KFM06A	405.88	410.88	5	–	4.23	–	–4.97	–	–	30	8.96E–10	8.96E–10	8.96E–06	1.49	9.79	1.41	9.79	
KFM06A	400.88	405.88	5	–	4.20	–	–5.00	–	–	30	8.96E–10	8.96E–10	8.96E–06	1.49	9.75	1.41	9.75	
KFM06A	395.87	400.87	5	–	4.14	–	–5.05	–	–	30	8.97E–10	8.97E–10	8.97E–06	1.50	9.73	1.42	9.73	
KFM06A	390.87	395.87	5	–6.47E–08	4.08	1.79E–07	–5.13	2.61E–08	1.63	30	8.95E–10	8.95E–10	8.95E–06	1.50	9.68	1.36	9.68	
KFM06A	385.86	390.86	5	–	4.03	–	–5.17	–	–	30	8.96E–10	8.96E–10	8.96E–06	1.50	9.63	1.41	9.63	
KFM06A	380.86	385.86	5	–	4.00	2.54E–08	–5.21	2.72E–09	–	30	8.95E–10	8.95E–10	8.95E–06	1.50	9.58	1.43	9.59	
KFM06A	375.86	380.86	5	–	3.96	–	–5.26	–	–	30	8.94E–10	8.94E–10	8.94E–06	1.51	9.53	1.40	9.55	
KFM06A	370.85	375.85	5	–	3.88	–	–5.31	–	–	30	8.97E–10	8.97E–10	8.97E–06	1.50	9.52	1.42	9.53	
KFM06A	365.84	370.84	5	–	3.84	–	–5.34	–	–	30	8.98E–10	8.98E–10	8.98E–06	1.51	9.49	1.43	9.50	
KFM06A	360.84	365.84	5	–	3.82	–	–5.42	–	–	30	8.92E–10	8.92E–10	8.92E–06	1.51	9.46	1.41	9.47	

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)	Q-lower limit P (mL/h)	TD-measlLT (m²/s)	TD-measlLP (m²/s)	TD-measlU (m²/s)	ECw0 (S/m)	Tew0 (°C)	ECw1 (S/m)	Tew1 (°C)	Com-ments
KFM06A	355.83	360.83	5	–1.26E–06	3.83	8.34E–06	–5.46	1.02E–06	2.61	30	8.87E–10	8.87E–10	8.87E–06	1.51	9.37	1.25	9.44	
KFM06A	350.83	355.83	5	–	3.52	1.27E–08	–5.51	1.39E–09	–	30	9.13E–10	9.13E–10	9.13E–06	1.51	9.35	1.27	9.40	
KFM06A	345.82	350.82	5	–	3.61	–	–5.54	–	–	30	9.01E–10	9.01E–10	9.01E–06	1.51	9.28	1.27	9.34	
KFM06A	340.81	345.81	5	–3.49E–08	3.57	1.53E–07	–5.60	2.02E–08	1.87	30	8.99E–10	8.99E–10	8.99E–06	1.51	9.25	1.26	9.30	
KFM06A	335.81	340.81	5	–1.25E–08	3.49	5.33E–08	–5.63	7.14E–09	1.76	30	9.04E–10	9.04E–10	9.04E–06	1.52	9.21	1.26	9.26	
KFM06A	330.80	335.80	5	–	3.48	1.42E–08	–5.69	1.53E–09	–	30	8.99E–10	8.99E–10	8.99E–06	1.51	9.17	1.27	9.24	
KFM06A	325.80	330.80	5	–	3.36	2.61E–08	–5.73	2.84E–09	–	30	9.07E–10	9.07E–10	9.07E–06	1.51	9.14	1.27	9.19	
KFM06A	320.79	325.79	5	–1.11E–07	3.41	3.50E–07	–5.76	4.97E–08	1.20	30	8.99E–10	8.99E–10	8.99E–06	1.51	9.10	1.25	9.15	
KFM06A	315.78	320.78	5	–	3.27	–	–5.81	–	–	30	9.08E–10	9.08E–10	9.08E–06	1.51	9.08	1.27	9.14	
KFM06A	310.78	315.78	5	–	3.30	–	–5.88	–	–	30	8.98E–10	8.98E–10	8.98E–06	1.51	9.05	1.27	9.10	
KFM06A	305.77	310.77	5	–	3.18	1.80E–07	–5.92	1.96E–08	–	30	9.06E–10	9.06E–10	9.06E–06	1.51	8.98	1.27	9.04	
KFM06A	300.76	305.76	5	–	3.13	6.09E–09	–5.96	6.63E–10	–	30	9.07E–10	9.07E–10	9.07E–06	1.51	8.96	1.27	9.01	
KFM06A	295.75	300.75	5	–7.08E–08	3.19	5.08E–08	–6.01	1.31E–08	–2.17	30	8.96E–10	8.96E–10	8.96E–06	1.51	8.91	1.28	8.95	
KFM06A	290.74	295.74	5	–	2.87	–	–6.10	–	–	30	9.19E–10	9.19E–10	9.19E–06	1.50	8.91	1.28	8.93	
KFM06A	285.73	290.73	5	–	3.09	–	–6.15	–	–	30	8.92E–10	8.92E–10	8.92E–06	1.51	8.86	1.28	8.90	
KFM06A	280.73	285.73	5	–	2.79	–	–6.19	–	–	30	9.18E–10	9.18E–10	9.18E–06	1.51	8.85	1.28	8.88	
KFM06A	275.73	280.73	5	–	2.96	–	–6.23	–	–	30	8.97E–10	8.97E–10	8.97E–06	1.50	8.82	1.28	8.86	
KFM06A	270.73	275.73	5	1.39E–08	2.79	7.27E–07	–6.29	7.77E–08	2.97	30	9.08E–10	9.08E–10	9.08E–06	1.51	8.82	1.27	8.84	
KFM06A	265.72	270.72	5	1.33E–06	2.71	5.36E–05	0.98	2.99E–05	2.75	30	4.76E–09	4.76E–09	4.76E–05	1.32	8.75	1.39	8.75	**
KFM06A	260.71	265.71	5	–	2.77	1.56E–08	–6.39	1.69E–09	–	30	9.00E–10	9.00E–10	9.00E–06	1.51	8.71	1.44	8.73	
KFM06A	255.71	260.71	5	–	2.50	1.80E–07	–6.44	1.99E–08	–	30	9.22E–10	9.22E–10	9.22E–06	1.51	8.67	1.44	8.72	
KFM06A	250.70	255.70	5	–	2.70	9.02E–09	–6.48	9.72E–10	–	30	8.98E–10	8.98E–10	8.98E–06	1.51	8.62	1.44	8.72	
KFM06A	245.69	250.69	5	–	2.44	3.33E–09	–6.53	3.68E–10	–	30	9.19E–10	9.19E–10	9.19E–06	1.52	8.57	1.44	8.71	
KFM06A	240.68	245.68	5	–	2.46	–	–6.61	–	–	30	9.09E–10	9.09E–10	9.09E–06	1.48	8.57	1.44	8.71	
KFM06A	235.67	240.67	5	1.18E–07	2.48	1.50E–05	0.65	8.03E–06	2.49	30	4.50E–09	4.50E–09	4.50E–05	1.48	8.47	1.46	8.57	**
KFM06A	230.66	235.66	5	–	2.22	–	–6.71	–	–	30	9.23E–10	9.23E–10	9.23E–06	1.51	8.45	1.46	8.61	
KFM06A	225.64	230.64	5	–	2.45	–	–6.77	–	–	30	8.94E–10	8.94E–10	8.94E–06	1.51	8.43	1.46	8.61	

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)	Q-lower limit P (mL/h)	TD-measlLT (m²/s)	TD-measlLP (m²/s)	TD-measlU (m²/s)	ECw0 (S/m)	Tew0 (°C)	ECw1 (S/m)	Tew1 (°C)	Com-ments
KFM06A	220.63	225.63	5	–	2.17	–	–6.81	–	–	30	9.18E–10	9.18E–10	9.18E–06	1.51	8.39	1.47	8.60	
KFM06A	215.63	220.63	5	3.27E–08	2.22	2.25E–05	0.43	1.24E–05	2.22	30	4.60E–09	4.60E–09	4.60E–05	1.51	8.30	1.48	8.43	**
KFM06A	210.63	215.63	5	–	2.16	1.28E–08	–6.93	1.39E–09	–	30	9.07E–10	9.07E–10	9.07E–06	1.50	8.30	1.47	8.48	
KFM06A	205.62	210.62	5	–	1.94	1.16E–06	–7.01	1.28E–07	–	30	9.21E–10	9.21E–10	9.21E–06	1.51	8.25	1.48	8.47	
KFM06A	200.62	205.62	5	–	2.13	3.17E–08	–7.06	3.41E–09	–	30	8.97E–10	8.97E–10	8.97E–06	1.50	8.22	1.47	8.46	
KFM06A	195.61	200.61	5	–	1.83	9.84E–09	–7.12	1.09E–09	–	30	9.21E–10	9.21E–10	9.21E–06	1.51	8.19	1.47	8.47	
KFM06A	190.61	195.61	5	–	1.96	–	–7.21	–	–	30	8.99E–10	8.99E–10	8.99E–06	1.49	8.14	1.47	8.46	
KFM06A	185.61	190.61	5	–	1.78	–	–7.27	–	–	30	9.11E–10	9.11E–10	9.11E–06	1.51	8.13	1.47	8.46	
KFM06A	180.60	185.60	5	1.96E–07	1.71	8.59E–05	–7.32	9.38E–06	1.73	30	9.13E–10	9.13E–10	9.13E–06	1.41	8.02	1.50	8.24	
KFM06A	175.60	180.60	5	1.53E–07	1.74	3.13E–05	–7.37	3.38E–06	1.78	30	9.05E–10	9.05E–10	9.05E–06	1.44	8.01	1.51	8.23	
KFM06A	170.59	175.59	5	–	1.49	5.25E–08	–7.44	5.81E–09	–	30	9.23E–10	9.23E–10	9.23E–06	1.51	7.98	1.48	8.33	
KFM06A	165.58	170.58	5	1.33E–08	1.69	2.70E–06	–7.49	2.89E–07	1.74	30	8.98E–10	8.98E–10	8.98E–06	1.50	7.93	1.52	8.30	
KFM06A	160.57	165.57	5	–	1.37	1.26E–06	–7.59	1.39E–07	–	30	9.20E–10	9.20E–10	9.20E–06	1.50	7.91	1.49	8.31	
KFM06A	155.57	160.57	5	4.45E–08	1.52	1.04E–05	–7.64	1.12E–06	1.56	30	9.00E–10	9.00E–10	9.00E–06	1.48	7.86	1.53	8.22	
KFM06A	150.56	155.56	5	–	1.36	3.75E–08	–7.69	4.10E–09	–	30	9.11E–10	9.11E–10	9.11E–06	1.48	7.86	1.48	8.29	
KFM06A	145.55	150.55	5	–	1.27	6.47E–08	–7.75	7.10E–09	–	30	9.14E–10	9.14E–10	9.14E–06	1.44	7.77	1.48	8.29	
KFM06A	140.54	145.54	5	2.19E–08	1.30	6.32E–06	–7.83	6.82E–07	1.33	30	9.03E–10	9.03E–10	9.03E–06	1.48	7.72	1.52	8.24	
KFM06A	135.53	140.53	5	–	1.05	2.23E–07	–7.88	2.46E–08	–	30	9.23E–10	9.23E–10	9.23E–06	1.47	7.66	1.49	8.25	
KFM06A	130.52	135.52	5	1.20E–07	1.25	7.49E–05	–7.93	8.05E–06	1.26	30	8.98E–10	8.98E–10	8.98E–06	1.41	7.52	1.50	8.01	
KFM06A	125.50	130.50	5	7.82E–07	0.96	5.97E–05	–0.69	3.53E–05	0.98	30	5.00E–09	5.00E–09	5.00E–05	1.45	7.46	1.51	7.69	**
KFM06A	120.49	125.49	5	–	1.14	3.64E–08	–8.06	3.92E–09	–	30	8.96E–10	8.96E–10	8.96E–06	1.46	7.45	1.47	7.79	
KFM06A	115.47	120.47	5	7.78E–08	0.88	3.03E–06	–8.11	3.25E–07	1.12	30	9.17E–10	9.17E–10	9.17E–06	1.45	7.42	1.36	7.78	
KFM06A	110.46	115.46	5	4.04E–08	1.04	8.03E–07	–8.13	8.22E–08	1.53	30	8.99E–10	8.99E–10	8.99E–06	1.45	7.39	1.44	7.84	
KFM06A	105.44	110.44	5	–	0.81	3.69E–08	–8.17	4.07E–09	–	30	9.18E–10	9.18E–10	9.18E–06	1.46	7.37	1.46	7.83	
KFM06A	100.43	105.43	5	–	0.88	2.65E–08	–8.26	2.87E–09	–	30	9.02E–10	9.02E–10	9.02E–06	1.46	7.31	1.47	7.84	

** Values from the measurement with smaller pumping (original pumped flow over measurement limit)



Forsmark, borehole KFM06A
Flow rates of 5 m sections
Without pumping
2004-10-13 - 2004-10-14
With pumping
2004-10-16 - 2004-10-17
With smaller pumping
2004-10-21
(original value over measurement limit)
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

Forsmark, borehole KFM06A
Transmissivity and head of 5 m sections

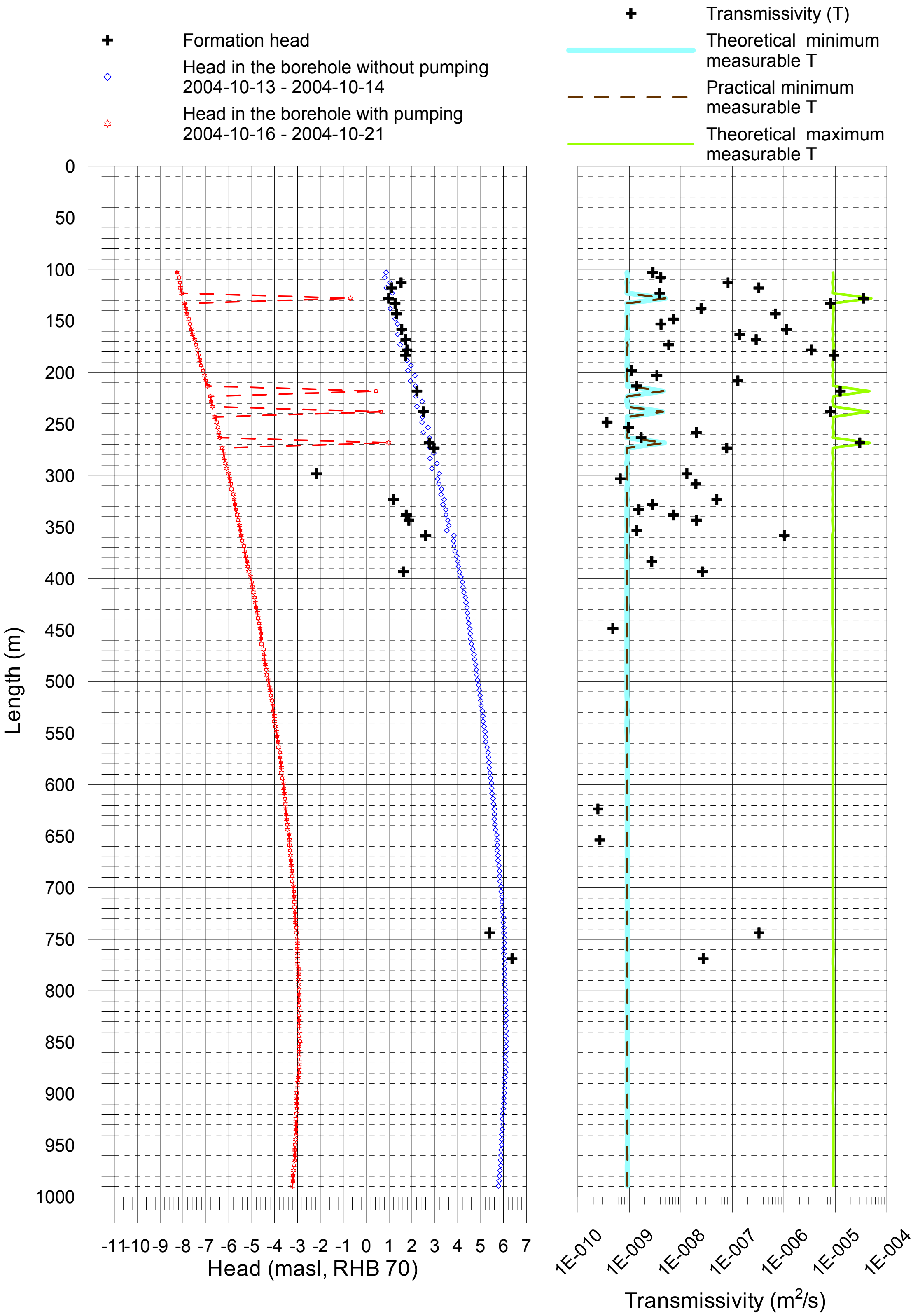


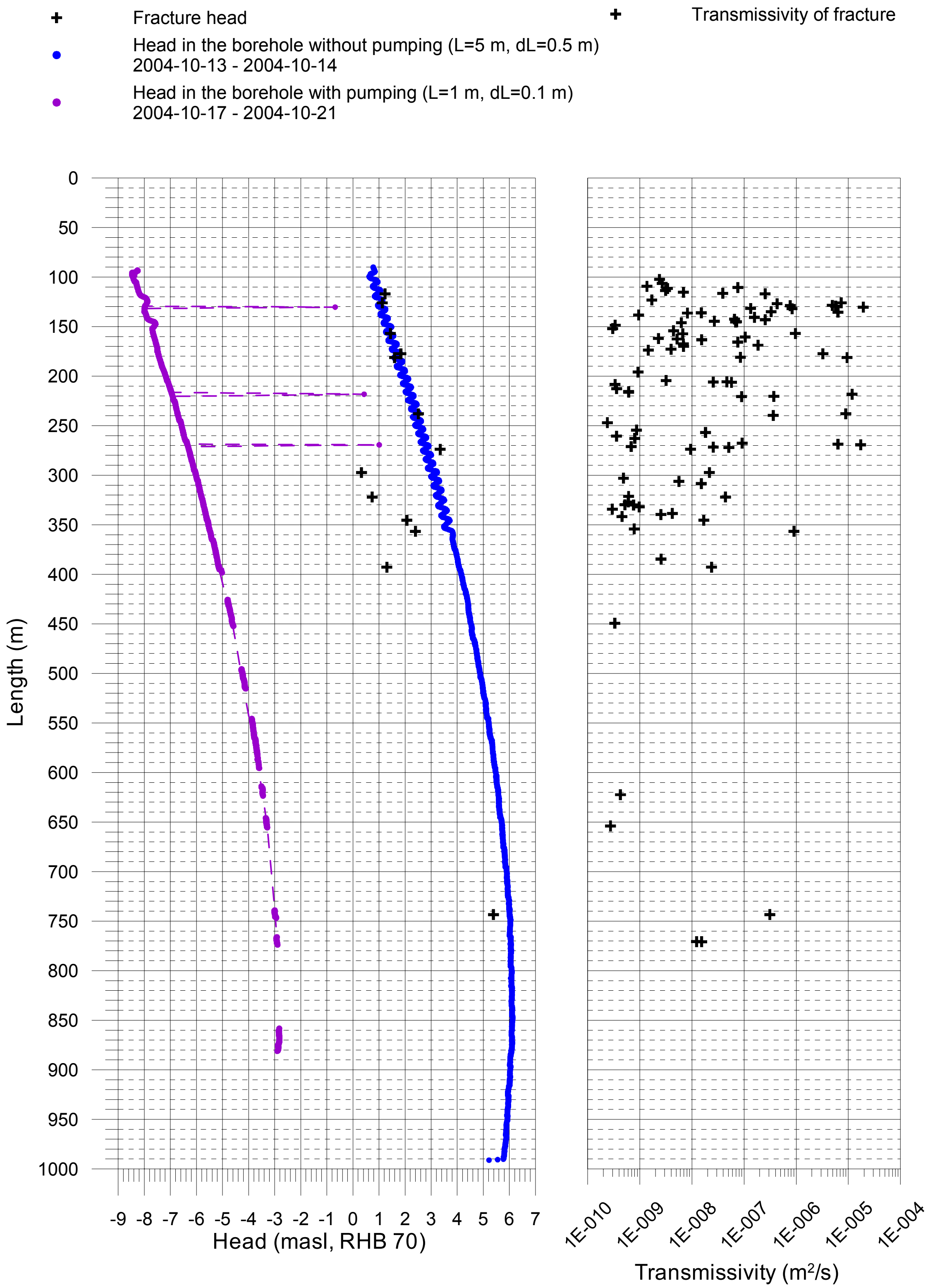
Table of transmissivity and head of detected fractures.

Borehole ID	Length to flow anom L (m)	Lw (m)	dL (m)	Q0 (m³/s)	dh0 (m)	Q1 (m³/s)	dh1 (m)	TD (m²/s)	hi (m)	Com-ments
KFM06A	102.4	1.0	0.1	0	0.82	2.22E–08	–8.41	2.38E–09	–	*
KFM06A	106.4	1.0	0.1	0	0.89	2.5E–08	–8.30	2.69E–09	–	
KFM06A	109.3	1.0	0.1	0	0.76	1.25E–08	–8.28	1.37E–09	–	
KFM06A	110.6	1.0	0.1	0	0.78	6.94E–07	–8.26	7.60E–08	–	
KFM06A	111.5	1.0	0.1	0	0.88	3.14E–08	–8.26	3.40E–09	–	
KFM06A	113.6	1.0	0.1	0	1.06	2.94E–08	–8.23	3.13E–09	–	
KFM06A	115.4	1.0	0.1	0	1.01	6.39E–08	–8.21	6.85E–09	–	
KFM06A	116.4	1.0	0.1	0	0.96	3.61E–07	–8.19	3.90E–08	–	
KFM06A	116.9	1.0	0.1	7.78E–08	0.93	2.41E–06	–8.19	2.53E–07	1.23	
KFM06A	123.1	1.0	0.1	0	1.14	1.56E–08	–7.89	1.70E–09	–	*
KFM06A	126.0	1.0	0.1	4.86E–07	1.06	6.67E–05	–7.90	7.31E–06	1.13	
KFM06A	126.9	1.0	0.1	0	1.03	3.89E–06	–7.91	4.30E–07	–	
KFM06A	128.5	1.0	0.1	0	0.95	4.44E–05	–7.95	4.94E–06	–	
KFM06A	128.9	1.0	0.1	0	0.96	6.94E–06	–7.97	7.69E–07	–	*
KFM06A	129.4	1.0	0.1	0	0.97	5.14E–05	–7.97	5.69E–06	–	*
KFM06A	130.3	1.0	0.1	0	1.03	3.33E–05	–0.68	1.93E–05	–	**
KFM06A	131.7	1.0	0.1	0	1.22	1.25E–06	–7.99	1.34E–07	–	*
KFM06A	132.0	1.0	0.1	0	1.24	7.78E–06	–8.00	8.33E–07	–	
KFM06A	135.0	1.0	0.1	0	1.16	3.06E–06	–7.99	3.30E–07	–	*
KFM06A	135.4	1.0	0.1	0	1.14	5.83E–05	–7.97	6.33E–06	–	
KFM06A	136.1	1.0	0.1	0	1.11	1.39E–07	–7.96	1.51E–08	–	
KFM06A	136.3	1.0	0.1	0	1.09	7.5E–08	–7.96	8.20E–09	–	*
KFM06A	138.3	1.0	0.1	0	1.05	8.61E–09	–7.93	9.48E–10	–	
KFM06A	140.6	1.0	0.1	0	1.31	1.47E–06	–7.91	1.58E–07	–	
KFM06A	142.5	1.0	0.1	0	1.33	6.11E–07	–7.87	6.57E–08	–	
KFM06A	143.0	1.0	0.1	0	1.31	2.36E–06	–7.84	2.55E–07	–	
KFM06A	144.6	1.0	0.1	0	1.22	2.42E–07	–7.68	2.69E–08	–	
KFM06A	145.1	1.0	0.1	0	1.21	6.39E–07	–7.62	7.16E–08	–	
KFM06A	145.4	1.0	0.1	0	1.19	6.11E–07	–7.61	6.87E–08	–	
KFM06A	146.0	1.0	0.1	0	1.17	5.56E–08	–7.59	6.27E–09	–	
KFM06A	148.6	1.0	0.1	0	1.35	3.06E–09	–7.60	3.38E–10	–	*
KFM06A	152.0	1.0	0.1	0	1.41	2.78E–09	–7.70	3.02E–10	–	*
KFM06A	154.2	1.0	0.1	0	1.29	4.03E–08	–7.68	4.44E–09	–	
KFM06A	157.0	1.0	0.1	4.72E–08	1.39	8.89E–06	–7.66	9.66E–07	1.44	
KFM06A	157.3	1.0	0.1	0	1.43	6.11E–08	–7.66	6.65E–09	–	*
KFM06A	160.6	1.0	0.1	0	1.50	9.72E–07	–7.62	1.05E–07	–	
KFM06A	161.9	1.0	0.1	0	1.43	2.08E–08	–7.61	2.28E–09	–	*
KFM06A	162.5	1.0	0.1	0	1.40	4.72E–08	–7.60	5.19E–09	–	
KFM06A	163.2	1.0	0.1	0	1.37	1.39E–07	–7.60	1.53E–08	–	
KFM06A	165.6	1.0	0.1	0	1.50	6.94E–07	–7.57	7.57E–08	–	
KFM06A	167.5	1.0	0.1	0	1.69	6.39E–08	–7.55	6.84E–09	–	
KFM06A	168.8	1.0	0.1	0	1.67	1.72E–06	–7.53	1.85E–07	–	
KFM06A	170.0	1.0	0.1	0	1.61	6.39E–08	–7.52	6.92E–09	–	
KFM06A	172.8	1.0	0.1	0	1.48	3.61E–08	–7.50	3.98E–09	–	
KFM06A	173.8	1.0	0.1	0	1.51	1.33E–08	–7.51	1.46E–09	–	
KFM06A	177.4	1.0	0.1	1.58E–07	1.79	3.06E–05	–7.47	3.25E–06	1.84	
KFM06A	181.0	1.0	0.1	0	1.58	7.78E–07	–7.43	8.54E–08	–	
KFM06A	181.2	1.0	0.1	1.86E–07	1.58	8.61E–05	–7.43	9.43E–06	1.60	
KFM06A	195.9	1.0	0.1	0	1.96	8.61E–09	–7.23	9.27E–10	–	
KFM06A	204.4	1.0	0.1	0	2.06	2.97E–08	–7.13	3.20E–09	–	
KFM06A	205.7	1.0	0.1	0	2.00	4.31E–07	–7.09	4.68E–08	–	
KFM06A	205.9	1.0	0.1	0	1.99	2.36E–07	–7.10	2.57E–08	–	
KFM06A	206.2	1.0	0.1	0	1.97	5.28E–07	–7.09	5.76E–08	–	
KFM06A	208.3	1.0	0.1	0	1.95	3.06E–09	–7.06	3.35E–10	–	*

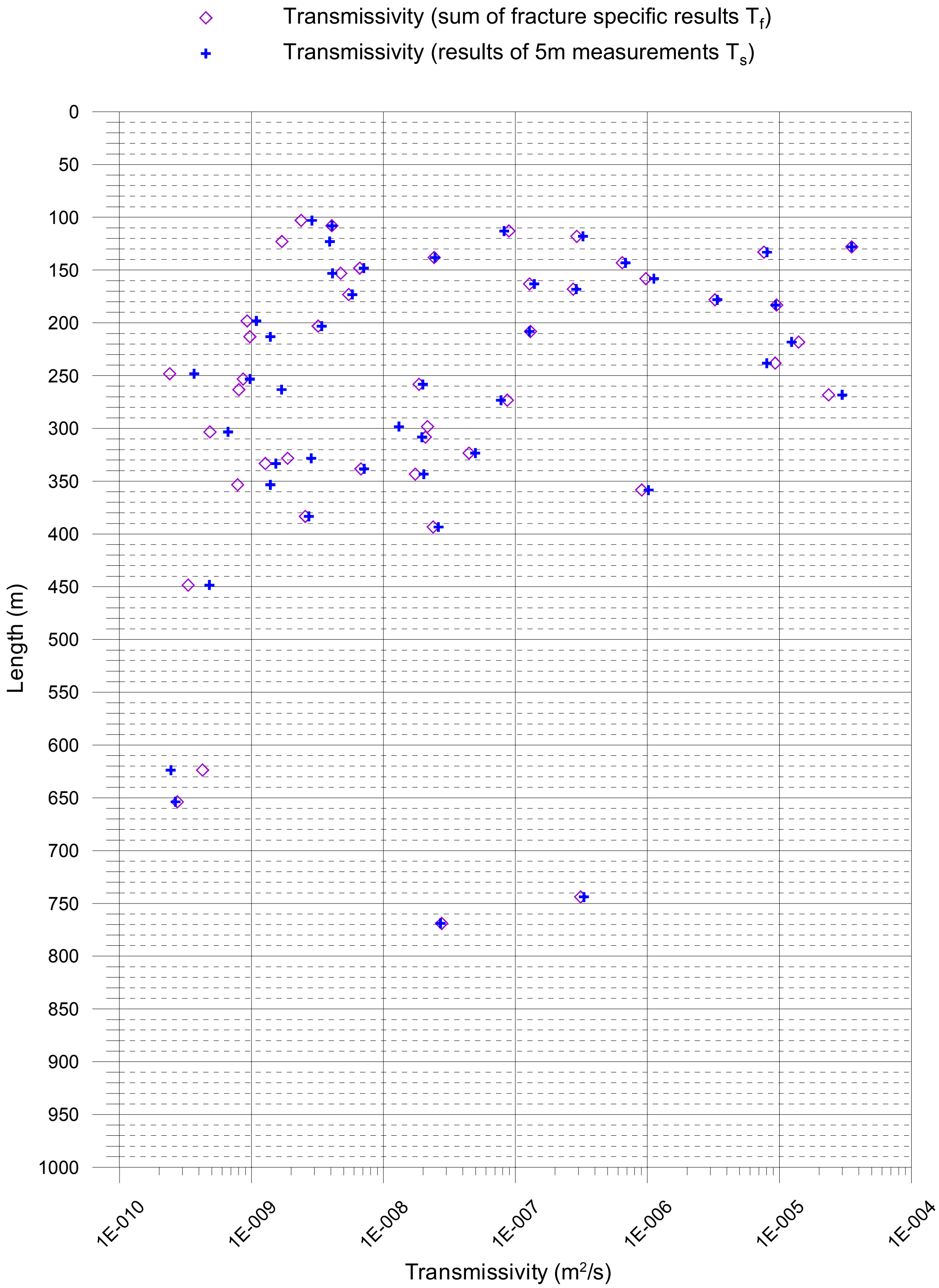
Borehole ID	Length to flow anom L (m)	Lw (m)	dL (m)	Q0 (m³/s)	dh0 (m)	Q1 (m³/s)	dh1 (m)	TD (m²/s)	hi (m)	Com-ments
KFM06A	212.6	1.0	0.1	0	2.20	3.33E–09	–7.01	3.58E–10	–	*
KFM06A	215.6	1.0	0.1	0	2.01	5.56E–09	–6.96	6.13E–10	–	*
KFM06A	216.3	1.0	0.1	0	2.02	5.56E–09	–6.95	6.13E–10	–	*
KFM06A	218.2	1.0	0.1	0	2.23	2.14E–05	0.43	1.18E–05	–	**
KFM06A	220.4	1.0	0.1	0	2.33	3.47E–06	–6.91	3.72E–07	–	
KFM06A	220.6	1.0	0.1	0	2.33	8.33E–07	–6.90	8.93E–08	–	*
KFM06A	238.0	1.0	0.1	1.39E–07	2.49	8.33E–05	–6.71	8.94E–06	2.51	
KFM06A	239.6	1.0	0.1	0	2.38	3.33E–06	–6.71	3.63E–07	–	
KFM06A	246.9	1.0	0.1	0	2.55	2.22E–09	–6.59	2.40E–10	–	*
KFM06A	254.4	1.0	0.1	0	2.69	8.06E–09	–6.53	8.64E–10	–	
KFM06A	256.8	1.0	0.1	0	2.54	1.67E–07	–6.51	1.82E–08	–	
KFM06A	260.5	1.0	0.1	0	2.75	3.33E–09	–6.48	3.57E–10	–	*
KFM06A	262.8	1.0	0.1	0	2.80	7.5E–09	–6.46	8.01E–10	–	
KFM06A	267.6	1.0	0.1	0	2.63	8.33E–07	–6.36	9.17E–08	–	
KFM06A	268.6	1.0	0.1	0	2.76	5.83E–05	–6.36	6.33E–06	–	
KFM06A	269.3	1.0	0.1	0	2.86	3.22E–05	1.01	1.74E–05	–	**
KFM06A	271.1	1.0	0.1	0	2.90	6.39E–09	–6.33	6.85E–10	–	*
KFM06A	271.6	1.0	0.1	0	2.88	2.39E–07	–6.31	2.57E–08	–	
KFM06A	272.0	1.0	0.1	0	2.86	4.72E–07	–6.31	5.09E–08	–	
KFM06A	273.7	1.0	0.1	5.56E–09	2.77	9.17E–08	–6.29	9.40E–09	3.35	
KFM06A	297.3	1.0	0.1	–6.3E–08	3.23	1.39E–07	–6.04	2.16E–08	0.33	
KFM06A	303.0	1.0	0.1	0	3.08	4.44E–09	–5.99	4.85E–10	–	*
KFM06A	306.2	1.0	0.1	0	3.31	5.28E–08	–5.93	5.65E–09	–	
KFM06A	308.4	1.0	0.1	0	3.18	1.39E–07	–5.92	1.51E–08	–	
KFM06A	321.4	1.0	0.1	0	3.20	5.56E–09	–5.80	6.11E–10	–	*
KFM06A	322.0	1.0	0.1	–1.1E–07	3.24	2.92E–07	–5.81	4.40E–08	0.74	
KFM06A	327.0	1.0	0.1	0	3.41	5.56E–09	–5.74	6.01E–10	–	*
KFM06A	329.7	1.0	0.1	0	3.28	4.72E–09	–5.73	5.18E–10	–	*
KFM06A	330.0	1.0	0.1	0	3.27	6.94E–09	–5.74	7.62E–10	–	
KFM06A	332.0	1.0	0.1	0	3.31	8.89E–09	–5.71	9.75E–10	–	
KFM06A	334.2	1.0	0.1	0	3.56	2.78E–09	–5.70	2.97E–10	–	*
KFM06A	338.6	1.0	0.1	0	3.48	3.89E–08	–5.66	4.21E–09	–	
KFM06A	339.6	1.0	0.1	0	3.43	2.33E–08	–5.64	2.54E–09	–	
KFM06A	341.7	1.0	0.1	0	3.42	4.17E–09	–5.61	4.56E–10	–	*
KFM06A	345.4	1.0	0.1	–2.8E–08	3.70	1.31E–07	–5.58	1.69E–08	2.07	
KFM06A	354.2	1.0	0.1	0	3.60	7.22E–09	–5.50	7.85E–10	–	*
KFM06A	356.6	1.0	0.1	–1.3E–06	3.80	7.22E–06	–5.48	9.06E–07	2.4	
KFM06A	384.6	1.0	0.1	0	4.01	2.39E–08	–5.21	2.56E–09	–	
KFM06A	392.7	1.0	0.1	–6.7E–08	4.07	1.56E–07	–5.15	2.38E–08	1.3	
KFM06A	449.4	1.0	0.1	0	4.52	3.06E–09	–4.62	3.31E–10	–	*
KFM06A	622.4	1.0	0.1	0	5.57	3.89E–09	–3.46	4.26E–10	–	*
KFM06A	653.9	1.0	0.1	0	5.72	2.5E–09	–3.29	2.74E–10	–	*
KFM06A	743.3	1.0	0.1	–2E–07	6.02	2.64E–06	–2.98	3.12E–07	5.39	
KFM06A	770.6	1.0	0.1	0	6.05	1.11E–07	–2.91	1.23E–08	–	
KFM06A	770.8	1.0	0.1	0	6.05	1.39E–07	–2.91	1.53E–08	–	

* Uncertain = The flow rate is less than 30 mL/h or the flow anomalies are overlapping or they are unclear because of noise.
** Values from the measurement with smaller pumping (original pumped flow over measurement limit)

Forsmark, borehole KFM06A
Transmissivity and head of detected fractures

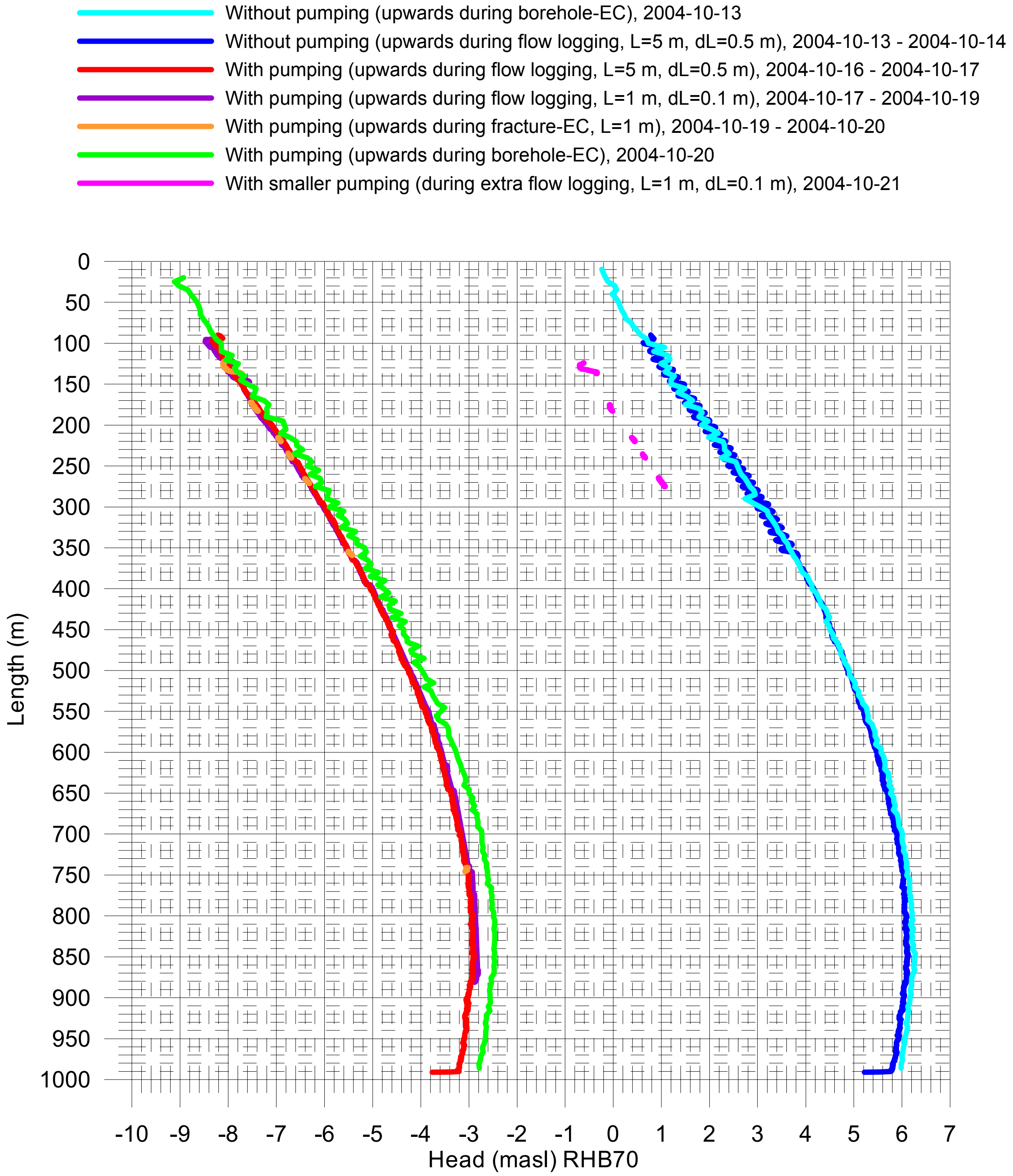


Forsmark, borehole KFM06A
Comparison between section transmissivity and fracture transmissivity

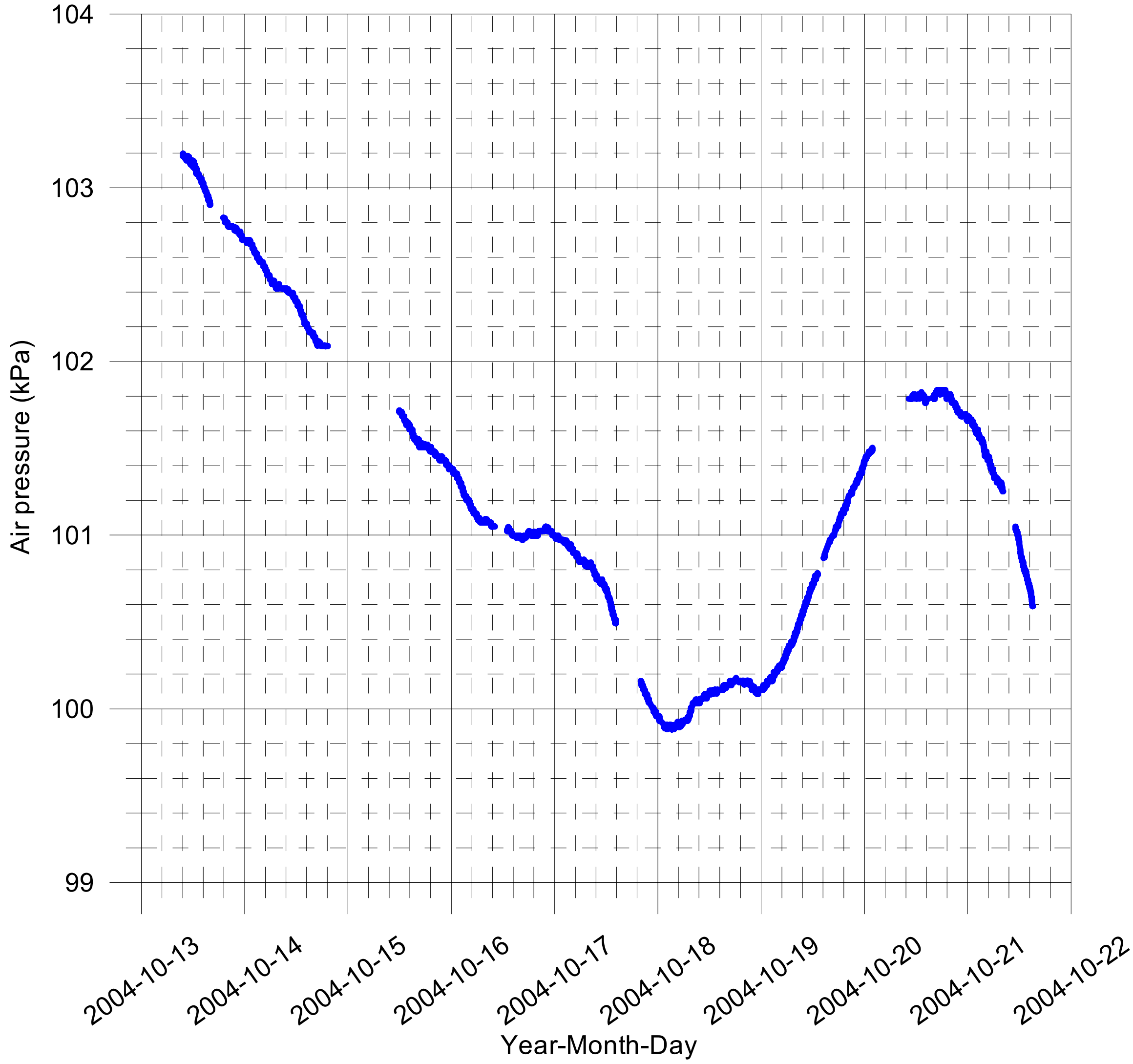


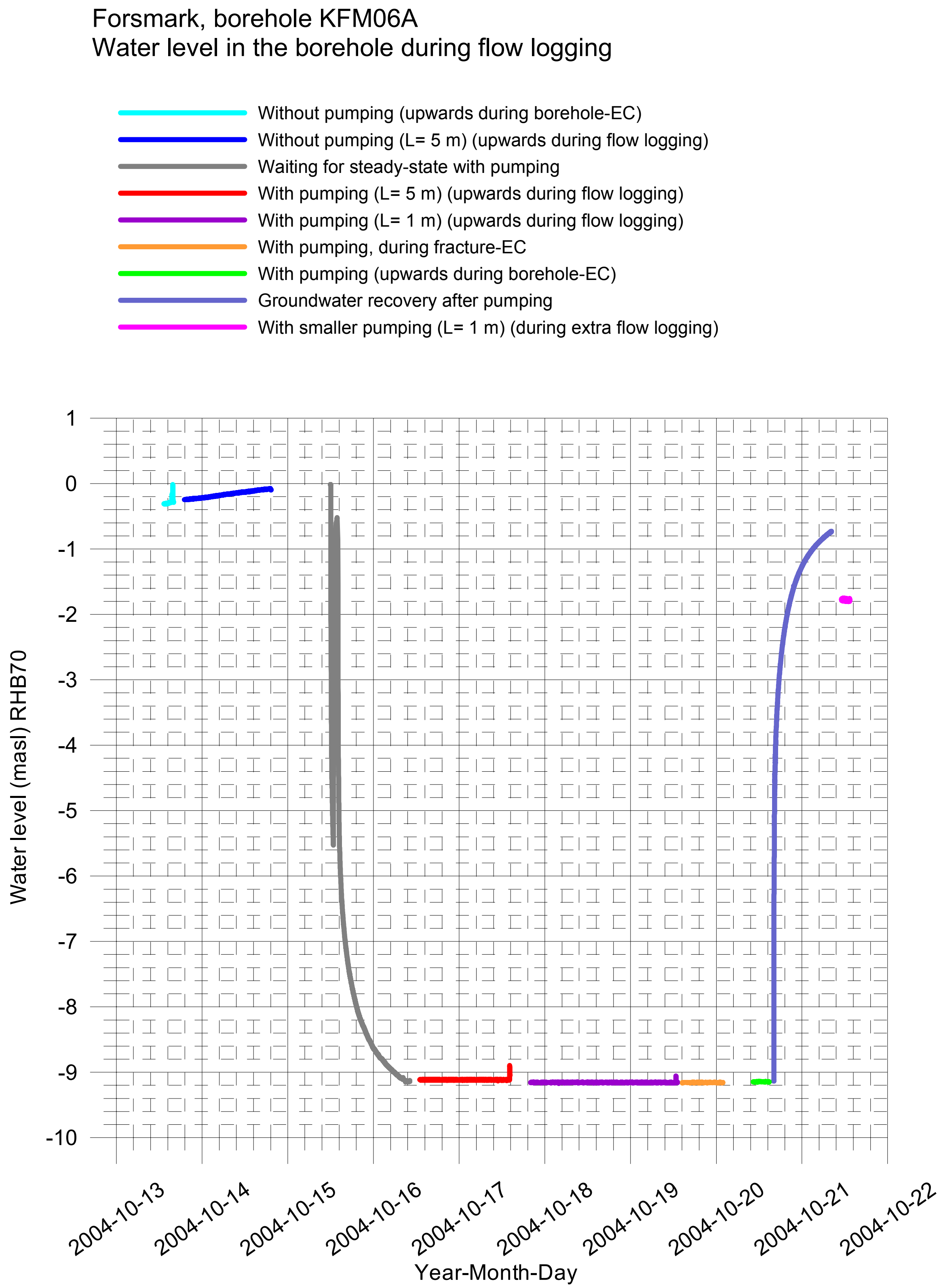
Forsmark, borehole KFM06A
Head in the borehole during flow logging

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)



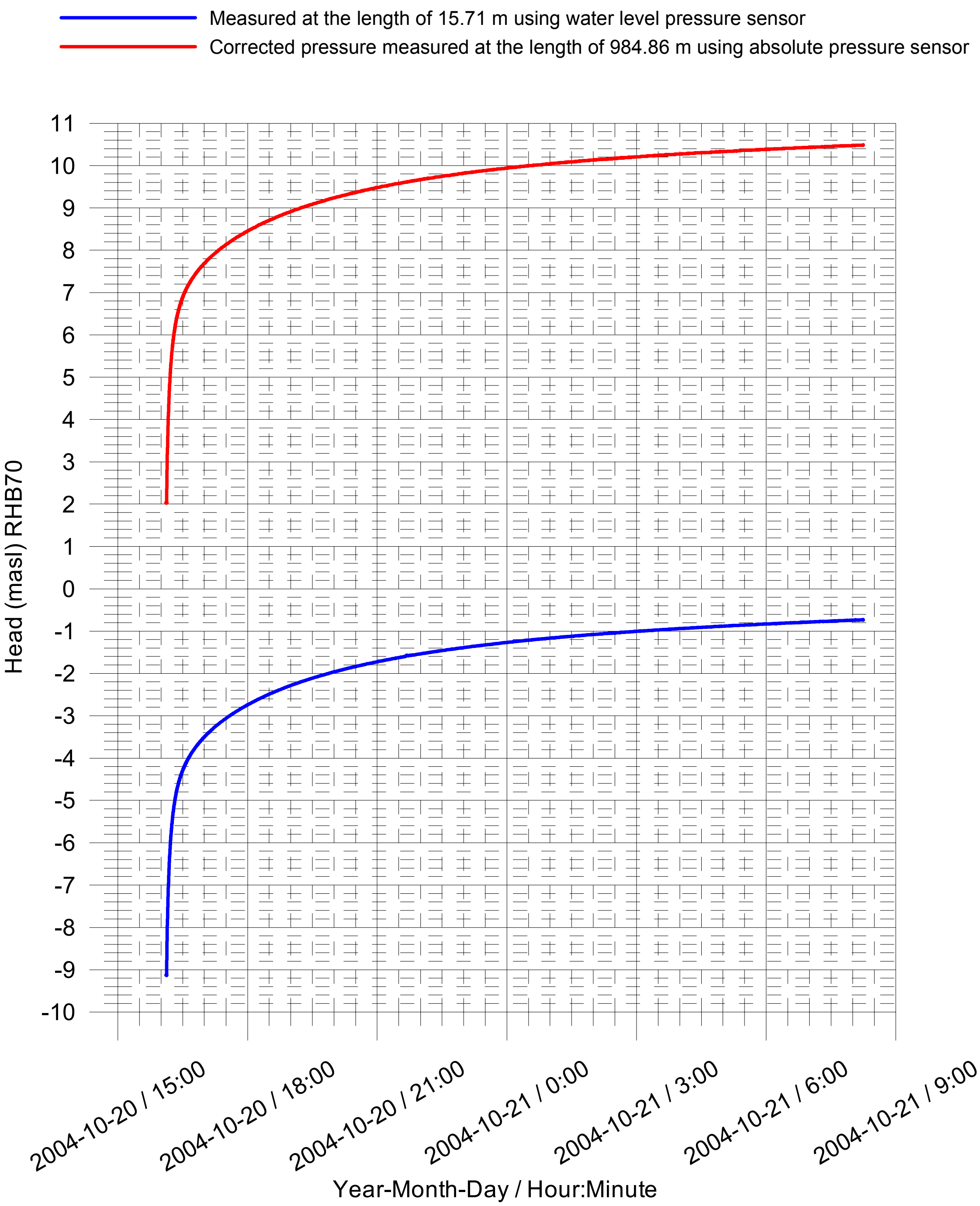
Forsmark, borehole KFM06A
Air pressure during flow logging
2004-10-13 - 2004-10-21



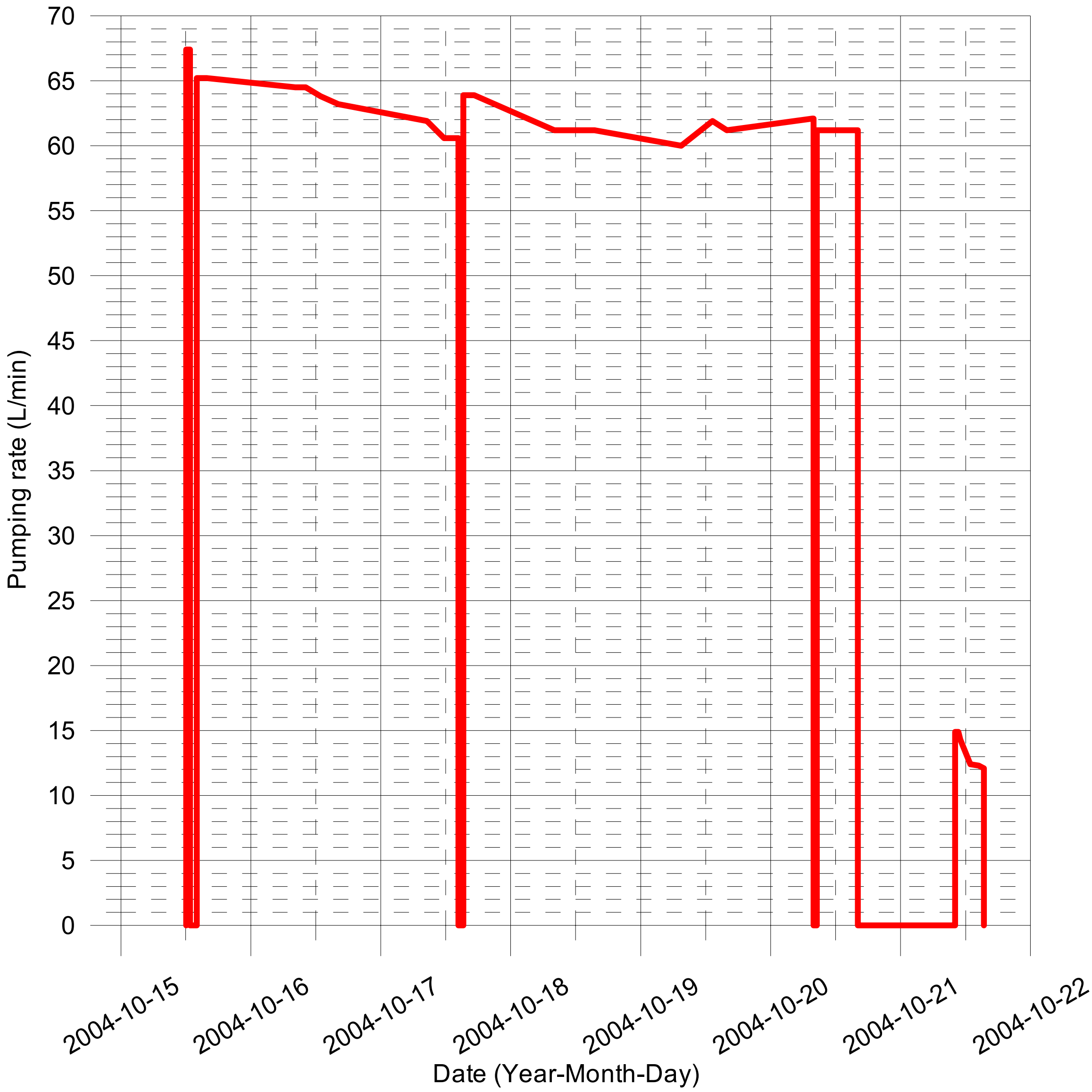

Forsmark, borehole KFM06A
Water level in the borehole during flow logging
Without pumping (upwards during borehole-EC)
Without pumping (L= 5 m) (upwards during flow logging)
Waiting for steady-state with pumping
With pumping (L= 5 m) (upwards during flow logging)
With pumping (L= 1 m) (upwards during flow logging)
With pumping, during fracture-EC
With pumping (upwards during borehole-EC)
Groundwater recovery after pumping
With smaller pumping (L= 1 m) (during extra flow logging)
Water level (masl) RHB70
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
2004-10-13
2004-10-14
2004-10-15
2004-10-16
2004-10-17
2004-10-18
2004-10-19
2004-10-20
2004-10-21
2004-10-22
Year-Month-Day

Forsmark, borehole KFM06A
Groundwater recovery after pumping

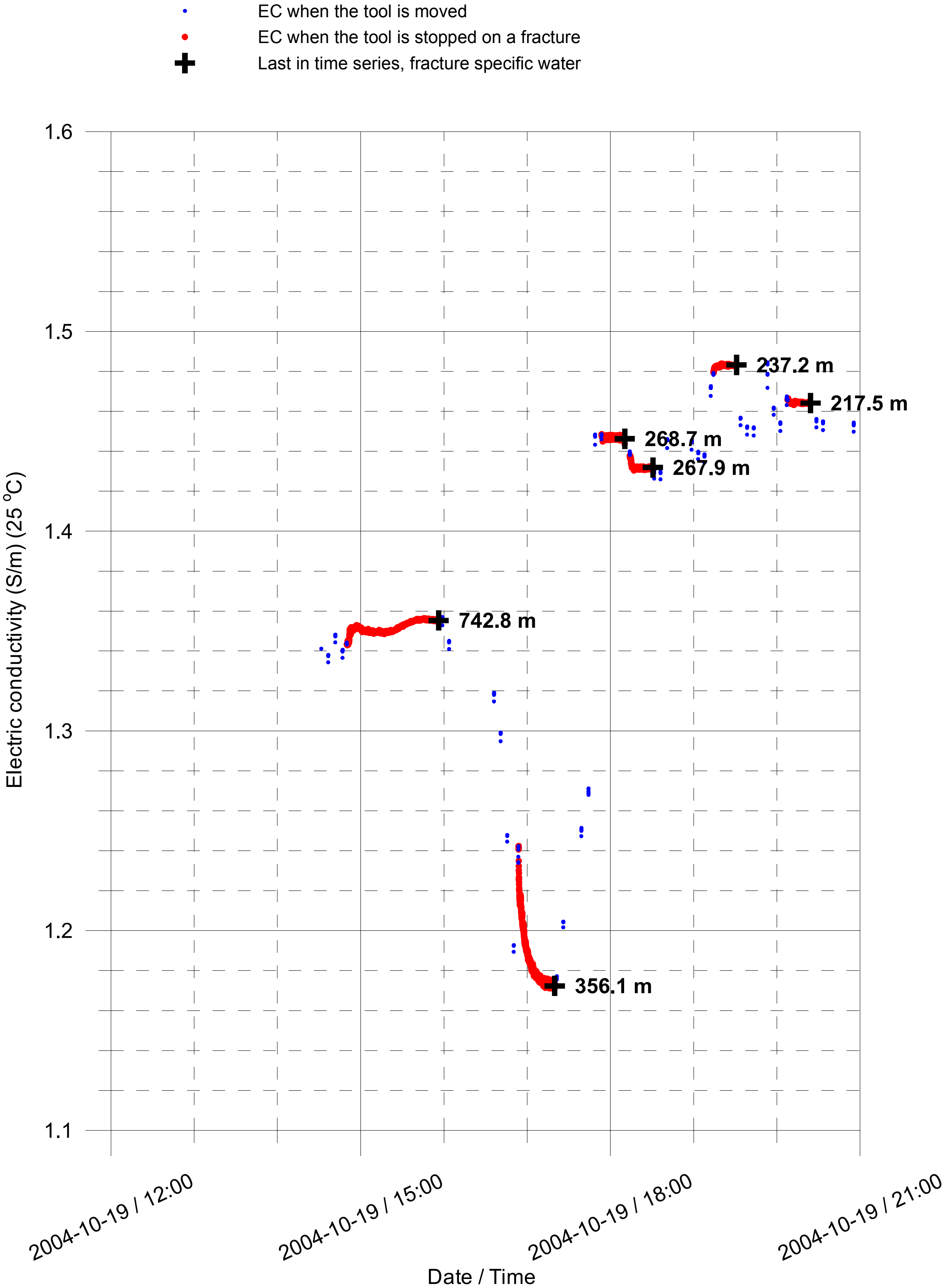
Head(masl)= (Absolute pressure (Pa) - Airpressure (Pa) + Offset) /(1000 kg/m^3 * 9.80665 m/s^2) + Elevation (m)
Offset = 2460 Pa (Correction for absolut pressure sensor)



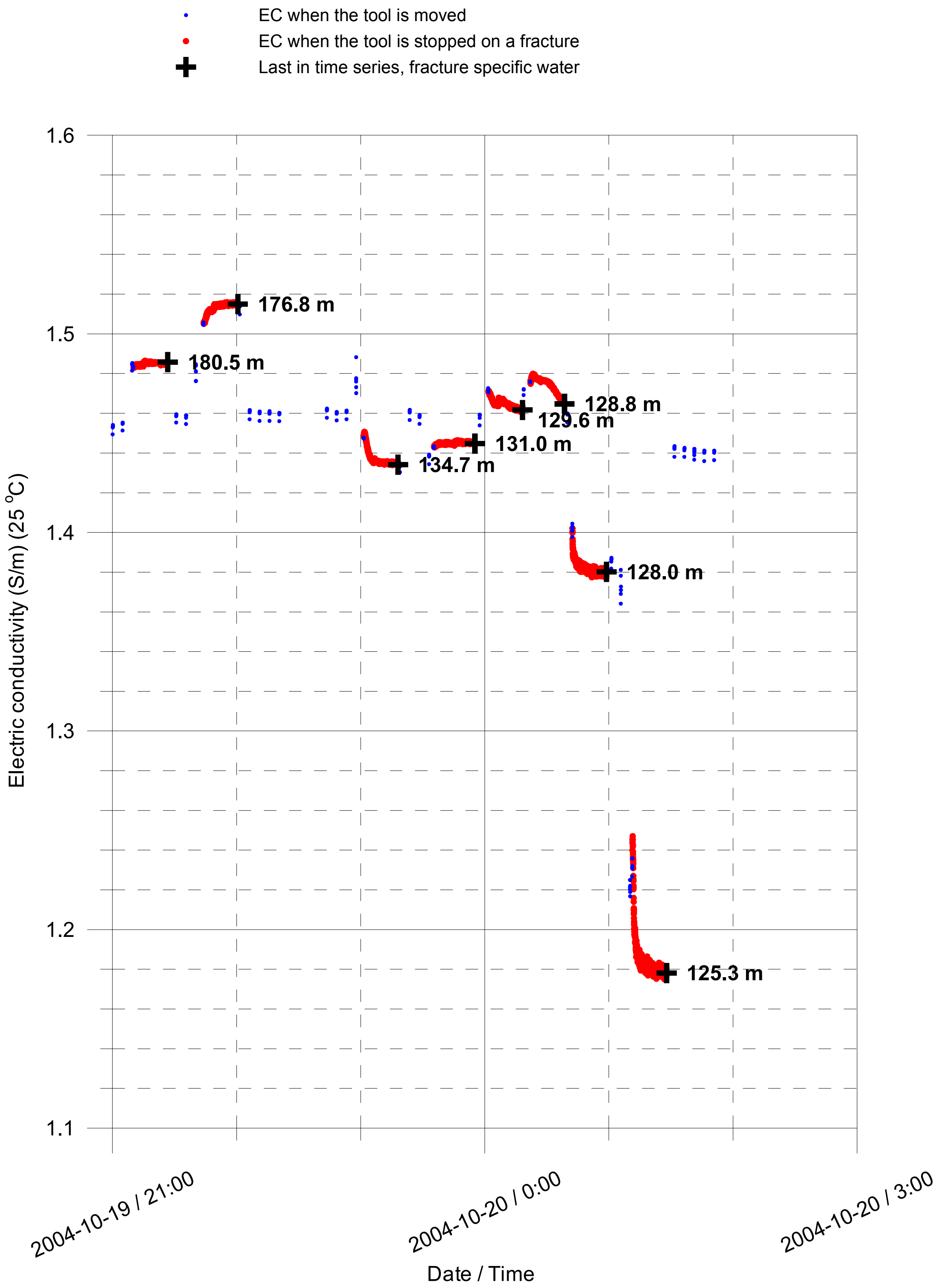
Forsmark, borehole KFM06A
Pumping rate during flow logging



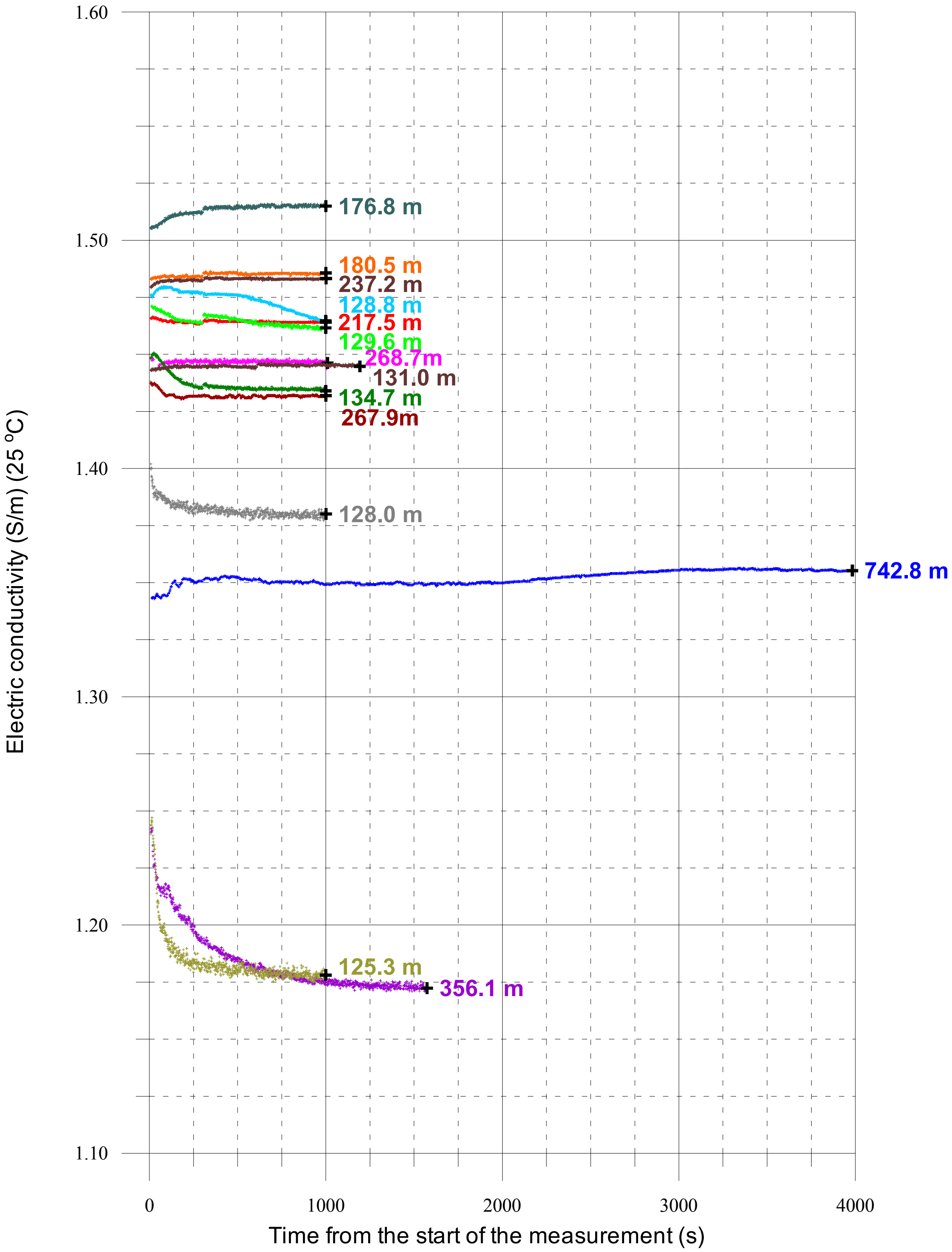
Forsmark, KFM06A
Fracture-specific EC results by date



Forsmark, KFM06A
Fracture-specific EC results by date



Forsmark, borehole KFM06A
Time series of fracture-specific EC
2004-10-19 - 2004-10-20



Forsmark, borehole KFM06A

Test data diagrams from pumping test during difference flow logging

Nomenclature used in the test data diagrams from Aqtesolv:

T = transmissivity (m^2/s),
S = storativity (–),
K_Z/K_r = ratio of hydraulic conductivities in the vertical and radial direction (set to 1),
S_w = skin factor,
r(w) = borehole radius (m),
r(c) = effective casing radius (m),
C = well loss constant (set to 0).

Diagrams presented

Flow period (log-log and lin-log)	Figures A12-1 and A12-2
Recovery period (log-log and lin-log)	Figures A12-3 and A12-4

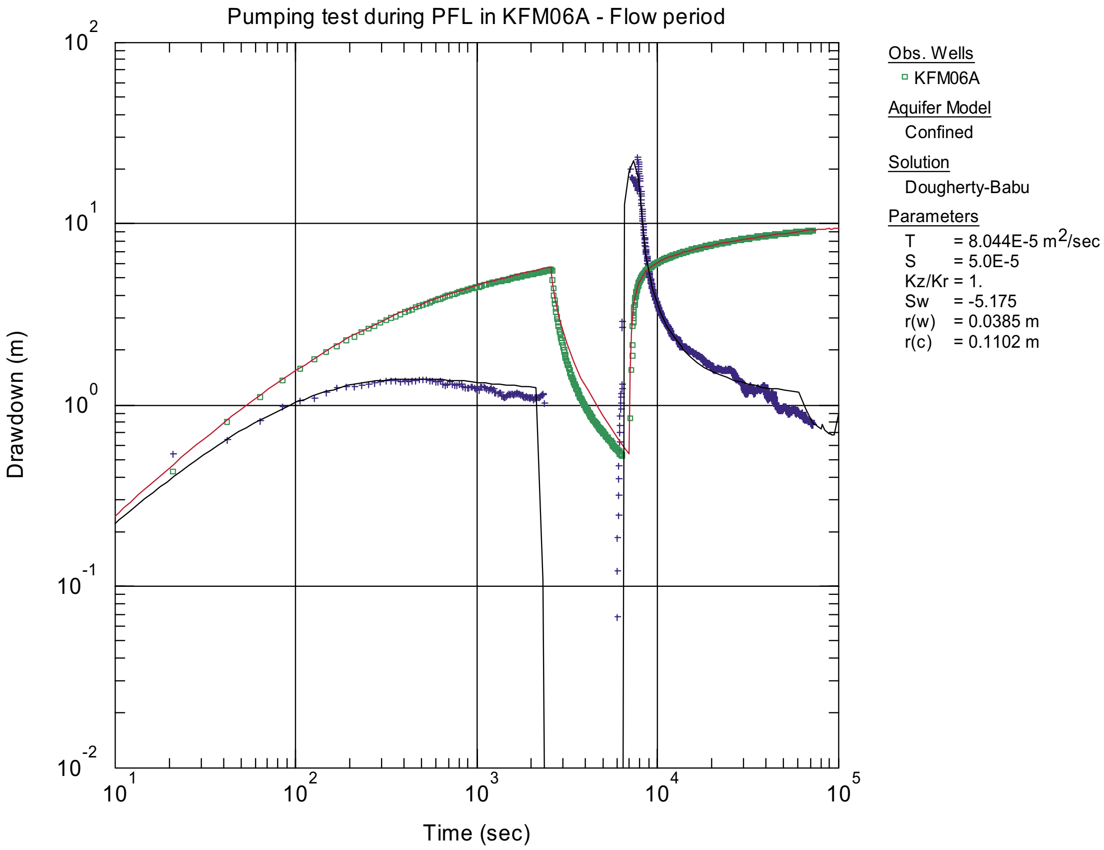


Figure A12-1. *Log-log plot of measured (green) and simulated (red) pressure drawdown and – derivative (blue) versus time during the first phase of the flow period of the pumping test in KFM06A.*

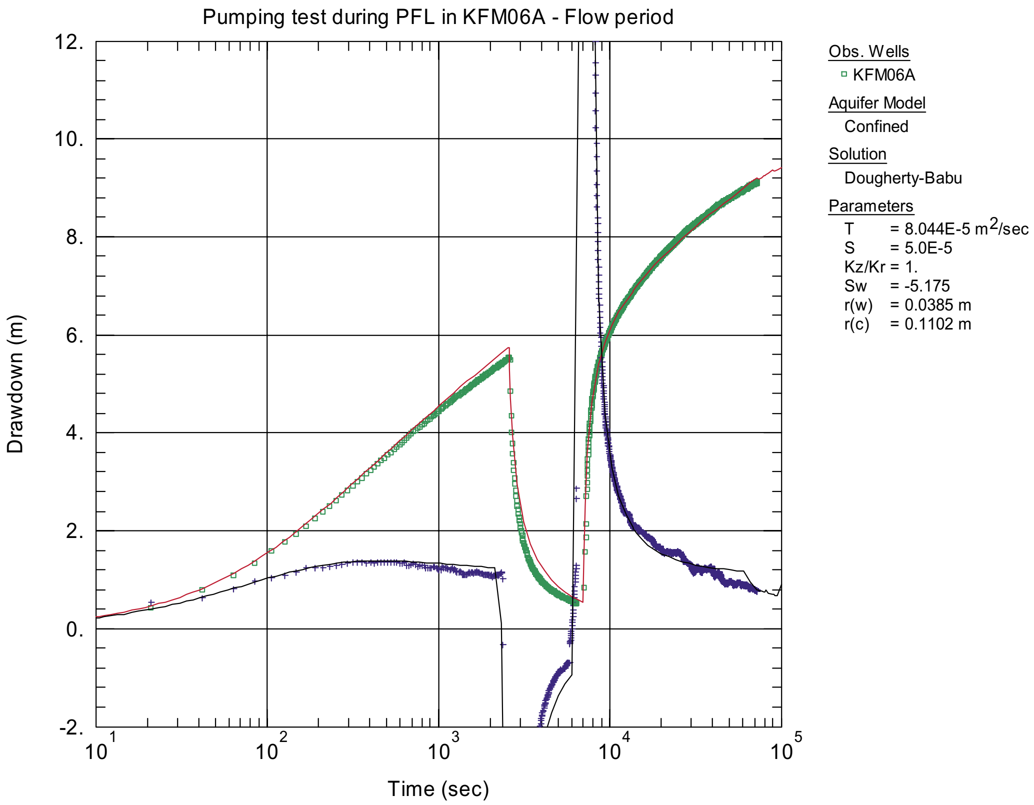


Figure A12-2. *Lin-log plot of measured (green) and simulated (red) pressure drawdown and – derivative (blue) versus time during the first phase of the flow period of the pumping test in KFM06A.*

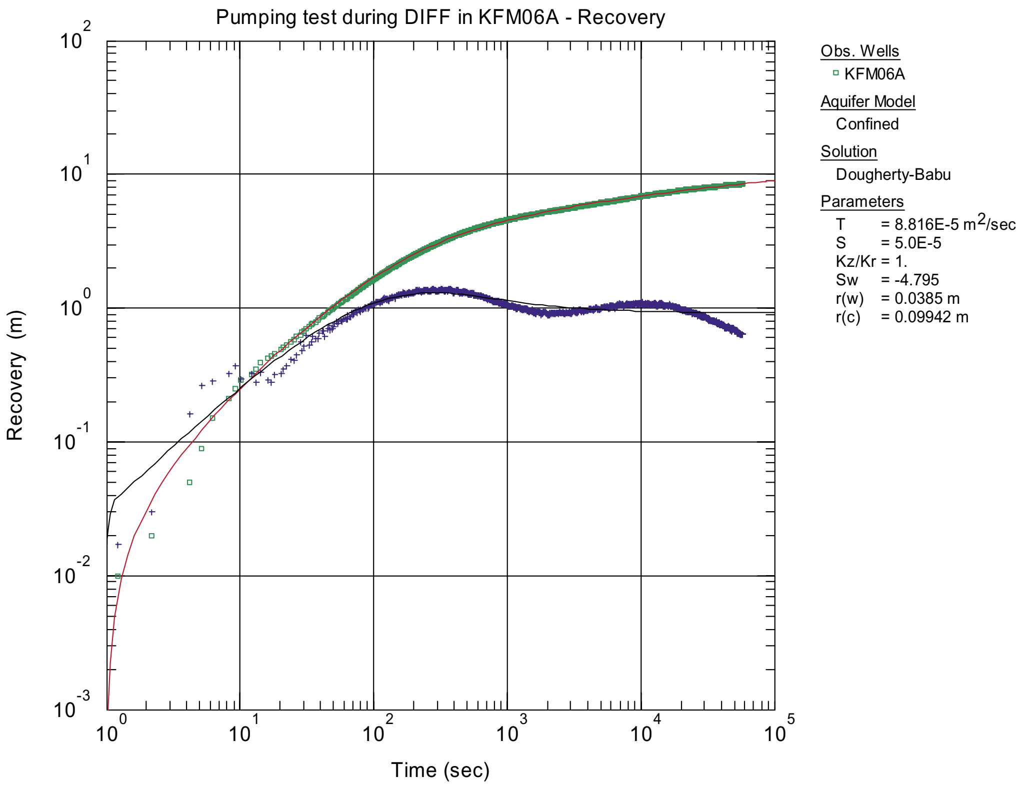


Figure A12-3. *Log-log plot of measured (green) and simulated (red) pressure recovery and –derivative (blue) versus time during the pumping test in borehole KFM06A.*

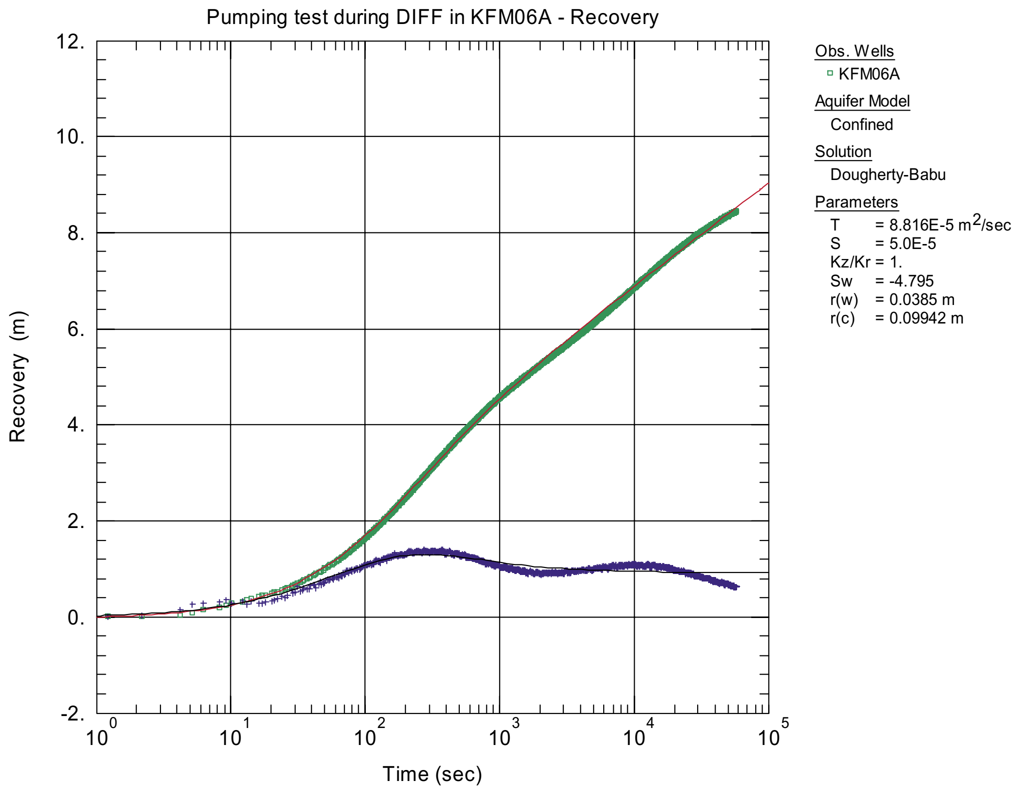


Figure A12-4. *Lin-log plot of measured (green) and simulated (red) pressure recovery and –derivative (blue) versus time during the pumping test in borehole KFM06A.*