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Äspö Hard Rock Laboratory

TRUE Block Scale project

Difference flow measurements in boreholes KA2563A and KA2511A at the Äspö HRL

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April 1999

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Abstract

The Difference Flowmeter (DIFF) was used in Äspö Hard Rock Laboratory in the True Block Scale boreholes KA2563A and KA2511A located at –340 m level in the tunnel. In these boreholes DIFF was used in detailed logging mode. Flow and single point resistance were logged with high depth resolution. The measurement of electric conductivity of water flowing out from chosen fractures was carried out also during the detailed flow logging. Interference tests were performed in borehole KA2563A. A packed off section P6 in borehole KI0023B, located at –450 m level in the tunnel, was used as sink. Flow and pressure responses were monitored in borehole KA2563A. Distinct flow responses were found in two fractures in borehole KA2563A.

Sammanfattning

I borrhålen KA2563A och KA2511A (True Block Scale) lokaliserade på –340 m nivå i Äspö HRL utfördes differensflödesloggning (DIFF). Mätning med hög frekvens av flöde och SP (Single Point resistance) utfördes med hög djupupplösning. Även elektriska konduktivitetsmätningar från utvalda, flödande sprickor utfördes under den högfrekventa flödesloggningen. Interferenstester genomfördes i borrhål KA2563A. En avmanschetterad sektion av borrhål KI0023B, P6, lokaliserad på –450 m nivå i tunneln, användes som sänka. Flödes- och tryckresponser mättes i borrhål KA2563A där två sprickor visade tydliga responser.

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1 Introduction

Flow logging is one step in the borehole characterisation process as input of the True Block Scale Project at the Äspö Hard Rock Laboratory. There is a need to evaluate different flowmeters in their own right in terms of accuracy, range, applicability and operational procedures. This will be followed by an intercomparison of flowmeters which will establish redundancy and complementing capabilities.

The expected results of the performed DIFF flow measurements are

- detailed flow distribution in the underground boreholes and
- degree of interconnection of fractures between the boreholes

The measurements were carried out at -340 m level in borehole KA2563A and in borehole KA2511A. Detailed flow logging using the DIFF was performed in both boreholes. Interconnection tests were done between borehole KA2563A and borehole KI0023B at -450 m level, see Figure 1-1and Figure 1-2. A packed off section P6 in borehole KI0023B was opened and closed and the flow and pressure responses were monitored in borehole KA2563A. This was done during the detailed flow logging in open borehole KA2563A. Flow and pressure response were also monitored in chosen sections when of KA2563A was closed using a rubber cone at the top of the collar.

The work is a part of the co-operation between Posiva Oy (Finland) and SKB (Sweden) within the context of the True Block Scale Project. The field work has been conducted by PRG-Tec Oy. The instrument has been used previously in Posiva's site characterisation in Finland. The earlier version of the flowmeter has been tested previously at the Zedex site at the Äspö HRL (Rouhiainen 1995, Rouhiainen 1996). The present tool was also used in borehole KI025F02 (Rouhiainen and Heikkinen, 1998).

The equipment consists of winch and cable on a trailer, downhole probe and PC computer. SKB provided rods for pushing the tool to boreholes and a rubber cone for closing holes.

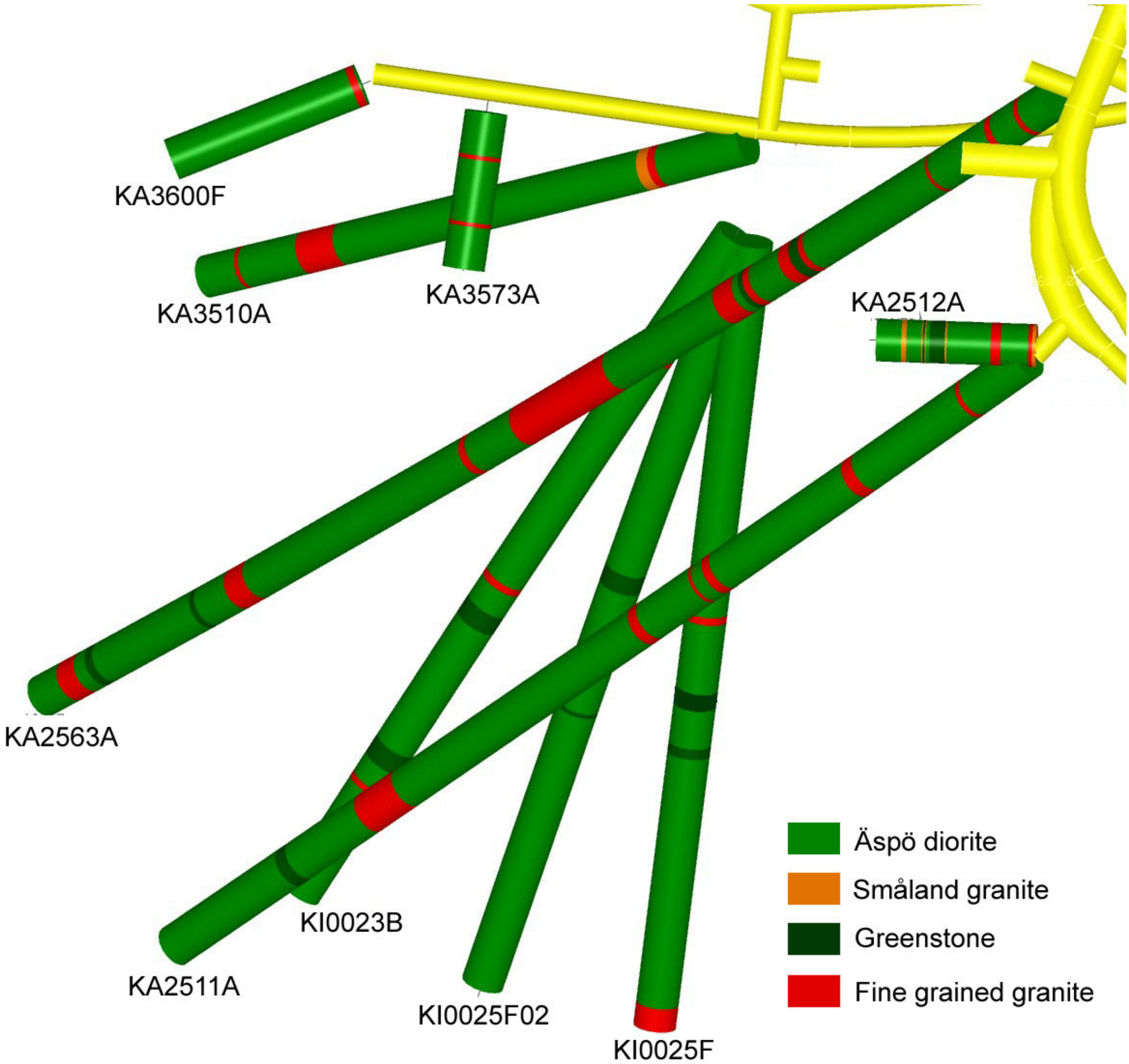

Figure 1-1 *Location of boreholes.*

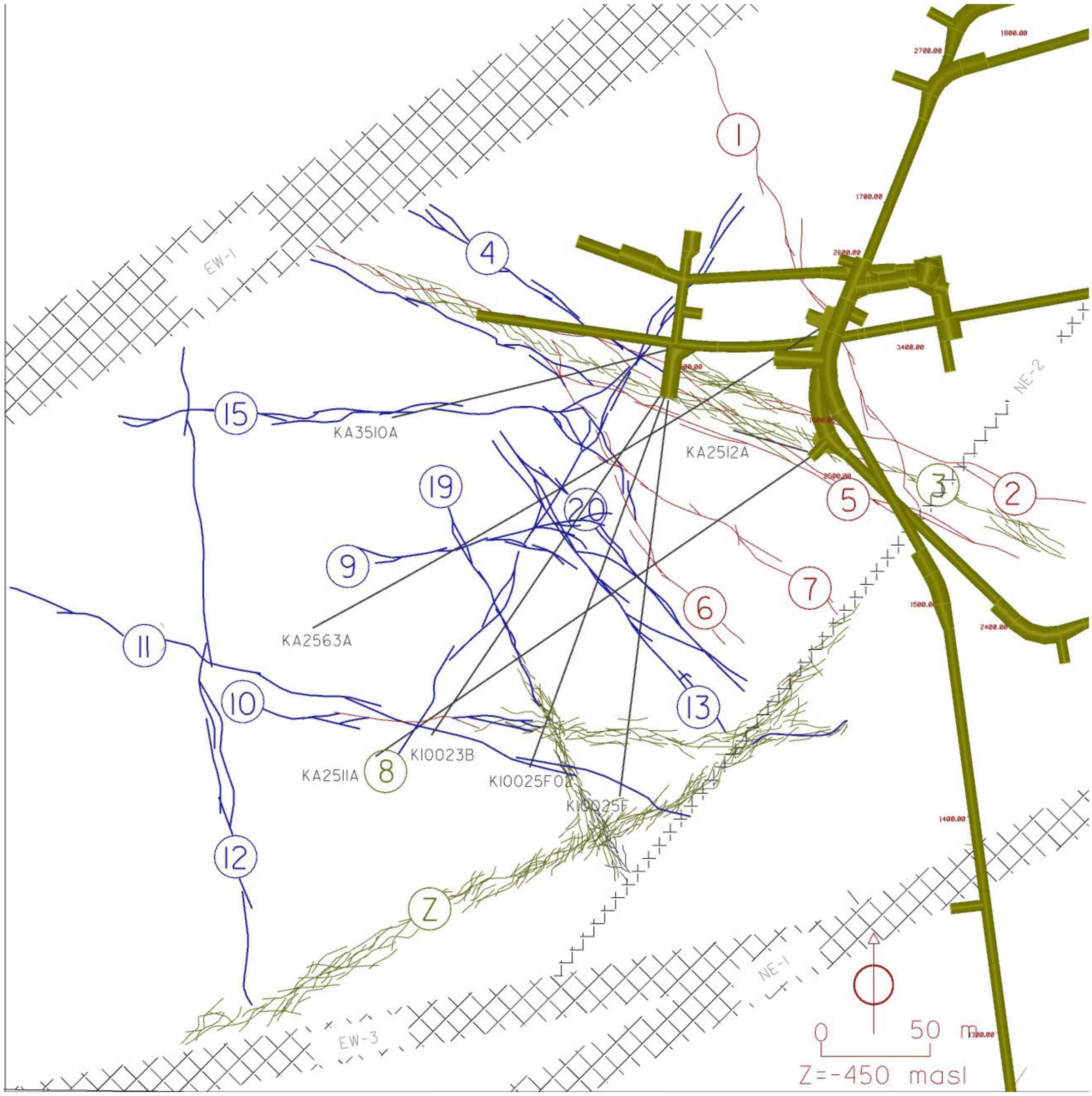

Figure 1-2 *Interpreted structures from September 1998.*

2 Principles of operation

The new method is a development of the conventional measurement of flow along a borehole. However, it is not the flow along the hole, but the changes of flow with depth that are useful when interpreting the results. Measurement of flow along a hole is problematic, especially when the flow is strong because small changes in the flow may be concealed. This problem can be avoided if the changes of flow are measured directly.

With the new flow guide, flow along the hole outside the test section is directed so that it does not come into contact with the flow sensor. The flow into or out from the borehole in the test section is the only flow that passes through the flow sensor. Instead of inflatable packers, rubber disks are used at both ends of the flow guide. These isolate the borehole section to be measured, see Figure 2.1.

The groundwater level in the borehole is kept constant by using a special pump. As a consequence, the hydraulic head in the hole is then constant, since the hydraulic conductivity of the borehole is very high compared with the conductivity of bedrock. Consequently the difference in head over the rubber disks used in the flow guide is very small. The rubber disks are designed in such a way that they are always pressed against the borehole wall. Difference flow measurements differ from the conventional double packer tests in that there is no extra hydraulic pressure in the borehole section being measured.

Constant hydraulic head in the borehole implies that the water density in the hole is constant and that there are no losses due to friction. If this is not the case, the hydraulic head at the measuring depth needs to be ascertained.

A single difference flow measurement at one depth interval normally takes 12 minutes. This time includes waiting time for temperature stabilisation, a flow measurement by the thermal pulse method, a flow measurement by the thermal dilution method and lifting of the cable to the next depth interval. The thermal dilution method is used to expand the range of measurement to include higher flow rates.

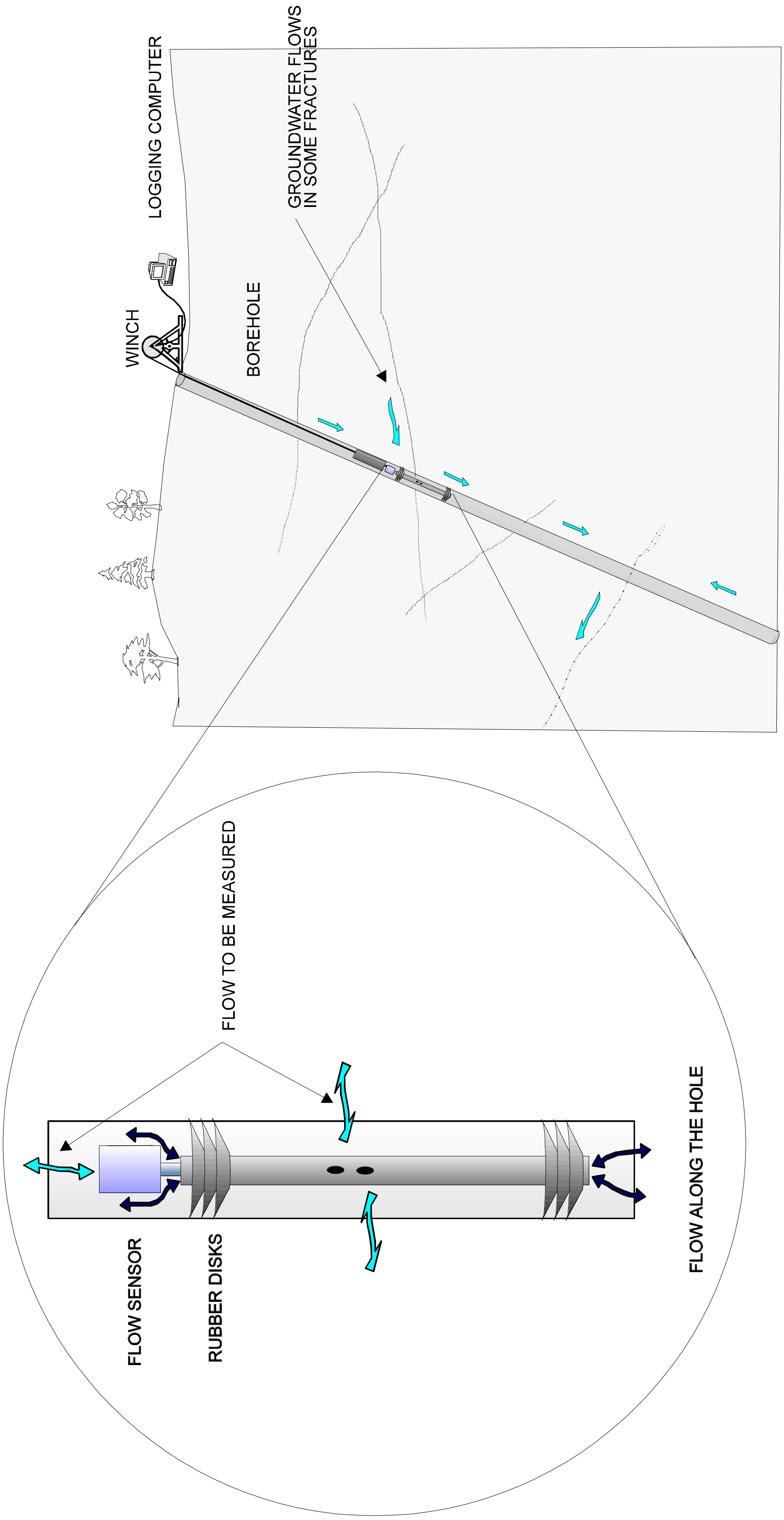

Figure 2-1 *Principles of difference flow measurement.*

3 Interpretation

If measurements are carried out using two levels of potential in the borehole test section, then the hydraulic head in the section and its conductivity can be calculated. It is assumed that a static flow condition exists.

$$Q_{n1} = K_n \cdot a \cdot (h_0 - h_1) \qquad 3\text{-}1$$

$$Q_{n2} = K_n \cdot a \cdot (h_0 - h_2), \qquad 3\text{-}2$$

where Q_{n1} and Q_{n2} are the measured flows in a section,
K_n is hydraulic conductivity of the section,
a is a constant depending on the flow geometry,
h_1 and h_2 are the hydraulic heads in the hole
h_0 is the head of the measured zone far from the hole

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

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

where L is the length of the measured section,
R is the distance to constant potential h_0 and
r_0 is the radius of the hole.

The distance to constant potential h_0 is not known and it must be chosen. Here R/r_0 is chosen to be 500.

The hydraulic head and conductivity can be deduced from the two measurements:

$$h_0 = (h_1 - b \cdot h_2)/(1-b), \qquad 3\text{-}4$$

$$K_n = (1/a) \cdot (Q_{n1} - Q_{n2}) / (h_2 - h_1) \qquad 3\text{-}5$$

where $b = Q_{n1}/Q_{n2}$

Since the actual flow geometry is not known, the calculated conductivity values should be taken as indicative of 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.

4 Equipment specifications

The flowmeter measures the flow of groundwater into or out from a borehole within a given section. A flow guide is used to separate the section to be measured. The flow guide maintains the section at the same hydraulic head as the rest of the hole. Groundwater flowing through the section is guided past the flow sensor. Flow is measured using the thermal pulse and thermal dilution methods. Measured values are transmitted in digital form to the PC computer. (Rouhiainen and Pöllänen 1998).

Type of instrument:	Difference Flow Meter.
Borehole diameters:	56 mm, 66 mm and 76 mm.
Geometry of measurement:	A variable length of test section is used.
Method of flow measurement:	Thermal pulse and thermal dilution methods.
Speed of measurement:	Depends the rate of flows to be measured.
Range of measurement:	0.1 - 5000 ml/min, both directions.
Additional measurements:	Temperature, single point resistance, conductivity of water.
Interpreted results:	Hydraulic conductivity and hydraulic head.
Winch:	Mount Sopris Wna 10, 0.55 kW, 220V/50Hz.
Logging computer:	PC, Windows 95 Software based on MS Visual Basic
Calibrated	January 1999

5 Results

5.1 Detailed flow logging

A detailed flow logging was performed with 1.0 m section length and with 0.1 m point interval in borehole KA2563A, see Appendices 1 - 16 and in borehole KA2511A, see Appendices 30 - 44. The method provides the depth and thickness of the conductive zones with a depth resolution of 10 cm. To make measurements more quickly, only the thermal dilution method was used for flow determination.

The section length determines the width of a flow anomaly of a single fracture. If the distance between leaky fractures is less than one meter the anomalies will be overlapped. The electrode of the single point resistance tool is located within the upper rubber disks. Thus the depth of the resistance anomalies of the leaky fractures fit with the lower side of the flow anomalies.

The depths of the plotted flow data are measured from the tunnel wall to the upper end of the test section. The depths of leaky fractures are marked in the appendices of the detailed flow logs.

The flow out from the open borehole KA2563A was about 44 l/min and from the open borehole KA2511A about 95 l/min. In borehole KA2511A there was a risk that this high flow could cause damage to the flow sensor. A flow limiter was therefore installed to the flow sensor to protect it. The flow limiter decreases the measured flows above about 1 l/min. The flow range measured was then 2 - 1000 ml/min. The flow limiter was not used in borehole KA2563A and the flow range in this case was 2 - 5000 ml/min.

Flow interconnection between two boreholes was tested during the detailed flow logging in borehole KA2563A. The borehole was first measured when the packed off section P6 (including the interpreted structure #9) in borehole KI0023B was closed. This corresponds to the solid line in Appendices 1 - 16. The detailed flow logging in borehole KA2563A was repeated when section P6 was opened, the dashed line in Appendices 1 - 16. There is no measurable change in flow between the depths of 278 - 189 m.

The two flow curves deviate from each other above 189 m. The flow rates were measured from the bottom of the borehole upwards. The solid line was measured first. Something evidently happened at the depth of 189 m which decreased the measured flows. The tool was lifted up after the first run. The field calibration performed proved that the flowmeter was working properly. The calibration curve was not changed. The dashed line was measured after the field calibration. Above 189 m the dashed line is correct and the solid line shows too low flow rates, possibly due to teflon tape on the flow sensor. The correct flow rate (dashed line) was later confirmed by repeated flow measurements above and below 189 m.

The conclusion of the interconnection test is that there was no measurable flow connection between borehole KA2563A at open hole conditions and borehole KI0023B section P6.

The electric conductivity of groundwater was measured during the first run of the detailed flow logging in borehole KA2563A. The conductivity sensor was attached on the top of the flow sensor. In this position it is measuring the water coming into the borehole from a fracture being tested, not the mixed water in the borehole. The tool was stopped for twelve minutes on the fractures which had a flow rate larger than 10 l/h. The temperature of flowing water from the fractures was measured as well, see Appendix 29.

Borehole KA2511A was difficult to measure because of the borehole condition and high flow rate. There are some artefact flow anomalies in borehole KA2511A, for example at the depths of 212.5 m, 185.1 m and 154.5 m, see Appendices 30 - 44. They cannot be conductive fractures because these flow anomalies are narrower than one meter, the length of the section. The artefact anomalies are induced by the borehole condition causing the rubber disks to leak.

Above 52 m in KA2511A the noise level of flow is increased. This is caused by the high flow rate, about 95 l/min, flowing along the borehole.

5.2 Flow interconnection tests in KA2563A under closed condition

Flow interconnection tests were carried out in eight sections of borehole KA2563A. One of these two meter sections was measured twice. The results of the pressure and flow transients are presented in Appendices 17 - 25.

The connection between borehole KA2563A and KI0023B section P6 was tested, the latter section including structure #9. Borehole KI0023B is equipped with a multipacker system. The sections between the packers can be opened through tubes and valves. If a valve is opened water can flow out from the corresponding section.

The measuring sequence began in borehole KA2563A under open hole conditions. The borehole was then closed with the rubber cone at the collar. Pressure and flow was measured during the pressure build up. After stabilisation time, section P6 in KI0023B was opened and the change in pressure and flow in borehole KA2563A was measured. The flow rate out of section P6 was between 2.6 - 2.8 l/min when borehole KA2563A was closed. To shorten the waiting times, section P6 was opened and closed in opposite cycles.

In the upper part of the Appendices 17 - 25 the whole sequence is presented. The lower part is a zoomed portion of the upper plot.

The hydraulic head and hydraulic conductivity is calculated first using the assumptions presented in Chapter 3. Static flow values are presented in Appendix 26 when borehole KA2563A was open and when both KA2563A and KI0023B section P6 were closed. The exception is section 188.3 - 190.3 m where the flow was measured also when borehole KA2563A was partially closed. At this section the rubber cone at the collar was loosened which caused a constant flow at the collar. This was done to decrease the flow rate at section 188.3 - 190.3 m to fit better with the flow range of the flowmeter.

Flow values in the flow rate plots are shown using a logarithmic scale. The flows are shown in both directions, the left hand side of each diagram represents flow out from the borehole within a test section and the right hand side represents flow into the borehole within a test section.

The depths of the plotted results are presented from the tunnel wall to the middle point of the test section.

Flow in borehole KA2563A under closed conditions was always positive when P6 was closed, i.e. from the fracture system into the borehole. The sum of all flows in the closed borehole must be zero. This means that the fractures which feed the water from the borehole into the fracture system were not measured.

Formation pressure (hydraulic head) and hydraulic conductivity was calculated using the equations 3-4 and 3-5, see Appendix 27.

The flow values in borehole KA2563A under closed condition when section P6 in borehole KI0023B was closed and when section P6 was open, respectively, were combined in the same plot, see Appendix 28. The last flow values at each valve position were used in Appendix 28. Two depth sections stand out from the rest, they are 188.3 - 190.3 m and 206 - 208 m.

Let us assume that KA2563A is closed and section P6 is closed. If the pressure in KA2563A is decreased, for example by removing the rubber cone at the collar, the flow into the borehole will increase.

When borehole KA2563A was closed, opening section P6 always decreased pressure in KA2563A. If there is no connection between the section under tests in KA2563A section P6, the flow rate should increase correspondingly. This happens in the most cases except in the two mentioned ones, sections 188.3 - 190.3 m and 206 - 208 m where the flow decreases, see appendix 28. This is a clear indication of flow connection in these two cases.

There may be connections which are not as clear as the two mentioned. A brief analysis of the measured data is given here. The analysis is restricted to static values, because it is easier and because it is also considered to be more important. In the geometry of difference flow measurements, flow rate is measured within the borehole section under test. In many cases there is only one fracture within the test section. Flow from the fracture into the borehole or flow from the borehole into the fracture is then measured.

The measured flow rate will change if the pressure in the borehole is changed. The measured flow rate will also change if the pressure in the fracture, outside of the borehole, is changed. The measured flow rate can change because of any combination of the two mentioned pressure changes.

Opening the valve from section P6 in borehole KI0023B always caused decrease of pressure in closed borehole KA2563A. For studying the possible connection between fractures in borehole KA2563A and section P6 in borehole KI0023B, the following hypothesis is assumed: the change in flow rate in the fracture under test originated solely from pressure change from borehole KA2563A and not from the pressure change in the fracture outside borehole KA2563A.

Following the notations presented in Chapter 3, the equations can be written

$Q_{open} = K_n \cdot a \cdot (h_0 - h_{open})$, 5-1

$Q_{p6c} = K_n \cdot a \cdot (h_0 - h_{p6c})$, 5-2

$Q_{p6o} = K_n \cdot a \cdot (h_0 - h_{p6o})$, 5-3

where

Q_{open} is the measured flow when borehole KA2563A was open,
Q_{p6c} is the measured flow when borehole KA2563A and section P6 were closed
Q_{p6o} is the measured flow when borehole KA2563A was closed and section P6 was open
K_n is hydraulic conductivity,
a is a constant depending on the flow geometry,
h_0 is the head of the measured zone far from the hole,
h_{open} is the hydraulic head when in borehole when KA2563A was open,
h_{p6c} is the hydraulic head in borehole when KA2563A and section P6 were closed,
h_{p6o} is the hydraulic head in borehole when KA2563A was closed and section P6 was open.

K_n and h_0 can be solved from equations (5-1) and (5-2):

$h_0 = (Q_{open} \cdot h_{p6c} - Q_{p6c} \cdot h_{open})/(Q_{open} - Q_{p6c})$ 5-4

$K_n = (1/a)\cdot(Q_{p6c} - Q_{open})/(h_{p6c} - h_{open})$ 5-5

Q_{p6o} can be solved if equations (5-4) and (5-5) are entered into equation (5-3):

$Q_{p6o} = (Q_{open} (h_{p6o} - h_{p6c}) + Q_{p6c} (h_{open} - h_{p6o}))/(h_{p6c} - h_{open})$ 5-5

The data used calculation are presented in Table 5-1. The first column is the depth to the middle point of the respective two meter section. The next three columns are the file numbers of the flow measurements. The heads and flow rates are presented under the same notations as above.

Table 5-1: Steady state data of borehole KA2563A during the interconnection test.

Depth (m)	$File_{p6o}$	$File_{p6c}$	$File_{open}$	h_{p6o} (m)	h_{p6c} (m)	h_{open} (m)	Q_{p6o} (ml/h)	Q_{p6c} (ml/h)	Q_{open} (ml/h)
266.2	7737	7755	7702	274.98	280.10	0.00	14346	11359	96313
253	7853	7789	7756	279.32	280.54	0.00	5123	4302	53947
230.5	7886	7901	7854	277.91	282.28	0.00	1626	1124	35283
207	7949	7933	7903	278.96	281.82	0.00	165	307	51873
189.3	7982	8003	8012	279.68	283.36	240.04	-38527	74774	222977
272.36	8091	8082	8017	280.30	283.42	0.00	6917	5197	80142
245.45	8114	8129	8092	279.73	283.57	0.00	34582	28720	351068
237.5	8166	8147	8130	279.82	282.76	0.00	19805	17565	159050
189.3	8308	8288	8167	280.75	283.57	0.00	-31849	50683	393987

The calculated flow rates from equation (5-5) are presented in Table 5-2. The deviation between measured and calculated flow rate is presented as well as the deviation percentage to the calculated flow rate (dQ).

Table 5-2: Comparison of measured and predicted flow rates during the interconnection test.

Depth (m)	Q_{p6o} (ml/h)	Qp6ocalc (ml/h)	Qp6o -Qp6ocalc (ml/h)	dQ (%)
266.2	14346	12912	1434	11
253	5123	4518	605	13
230.5	1626	1653	-27	-2
207	165	830	-665	-80
189.3	-38527	87364	-125891	-144
272.36	6917	6022	894	15
245.45	34582	33085	1497	5
237.5	19805	19036	769	4
189.3	-31849	54097	-85946	-159

Equation (5-4) does not contain any geometrical constants. However, it is assumed that the system is linear; when pressure in the borehole is changed the flow rate should change with a constant proportion at a given location. This is not fully guaranteed because of the high gradients and flow rates (turbulent flow), especially when borehole KA2563A was open.

It is also assumed that static flow conditions exists. This is was never exactly the case because the waiting time might have been too short and because background pressure may change when operations are going on in the tunnel, see for example Appendix 19.

Finally, there are always errors in pressure and flow measurement. On the basis of calibrations, the error of flow measurement is assumed to be less than 10% of the current reading. The total error of flow measurement including non-linearity and stability is assumed to be much larger, in the range of 20-30 %.

There are two depth sections in Table 5-2 where the deviation percentage (dQ) is considerably larger than the evaluated error percentage. They are sections 206 - 208 m and 188.3 - 190.3 m. In the other sections the deviation percentage (dQ) is much smaller than the error percentage. The conclusion of this is that in this measurement set up there is a flow connection between these two section and section P6 while there is no measurable flow connection between the rest of the measured sections in KA2563A and P6.

6 Discussion and conclusion

The high flow rate along the borehole did not noticeably increase the noise level in the measured flow in borehole KA2563A where the flow out from the borehole was 44 l/min. The measured flow range in this borehole was 2 - 5000 ml/min. The noise level was increased in borehole KA2511A where the flow rate out from the borehole was 95 l/min. A flow limiter was used in KA2511A to protect the flow sensor. The measured flow range in KA2511A was about 30- 1000 ml/min above the depth of 52 m and 2 - 1000 ml/min below 52 m. Both of these boreholes have a diameter of 56 mm.

The interconnection tests were carried out between two boreholes KA2563A and KI0023B. When borehole KA2563A was open no measurable interconnection was found between borehole KA2563A and section P6 of borehole KI0023B. In closed borehole KA2563A two of the measured sections had clear flow connection to section P6. These are sections 206 - 208 m and 188.3 - 190.3 m. The other six sections in KA2563A did not have measurable connection to section P6.

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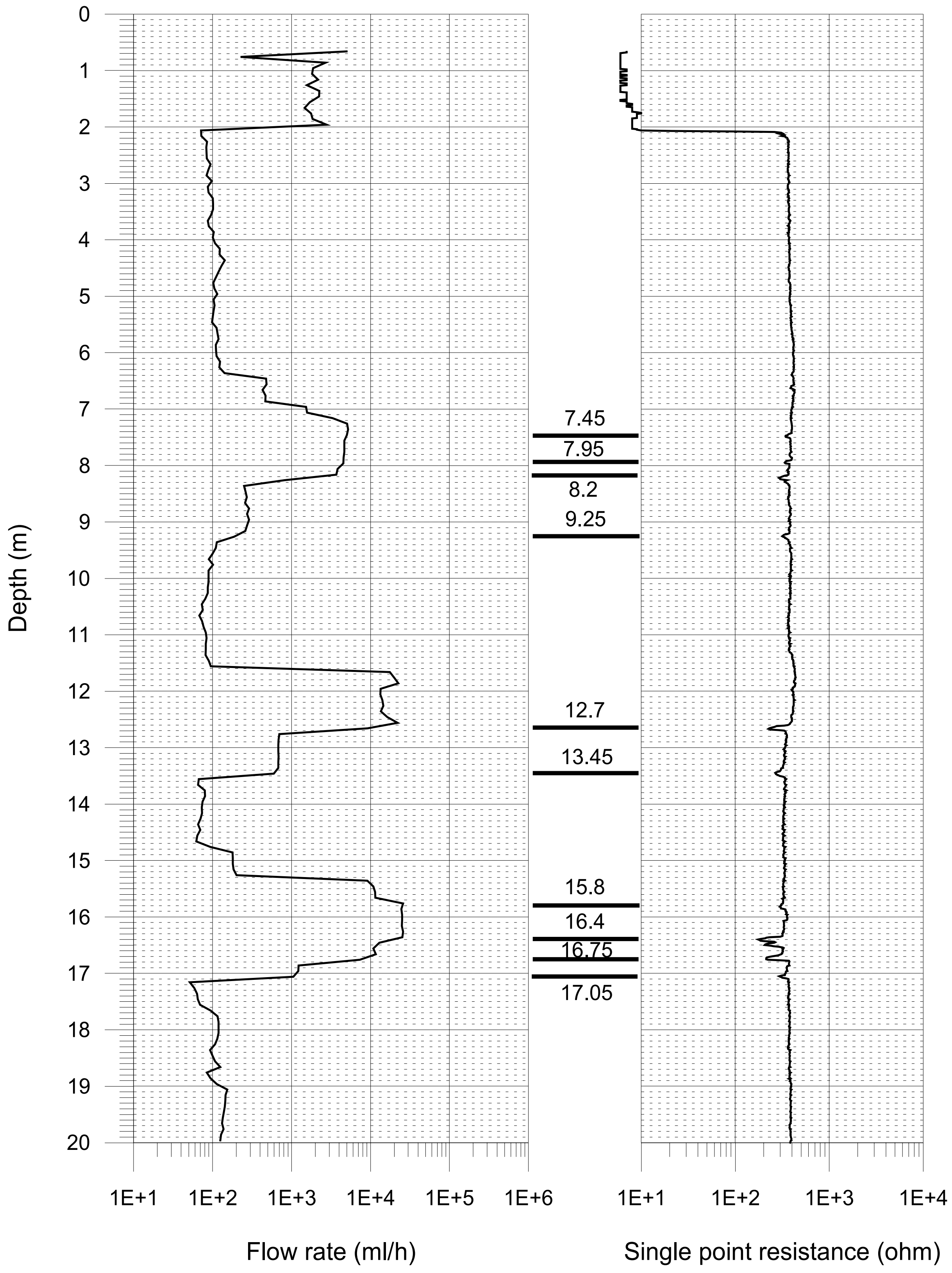
Appendices

Appendices 1 - 16	DIFF results in detailed logging mode, borehole KA2563A
Appendices 17 - 25	Pressure and flow transients during the interconnection test, borehole KA2563A
Appendix 26	Flow rates in the measured sections, borehole KA2563A
Appendix 27	Calculated formation pressure and hydraulic conductivity, borehole KA2563A
Appendix 28	Flow rates when section P6 in borehole KI0023B was open and when it was closed, borehole KA2563A
Appendix 29	Electric conductivity of water and temperature of water from large fractures during the detailed flow logging, borehole KA2563A
Appendices 30 - 44	DIFF results in detailed logging mode, borehole KA2511A

FLOW RATE AND SINGLE POINT RESISTANCE LOGS
DEPTHS OF LEAKY FRACTURES
ÄSPÖ, KA2563A



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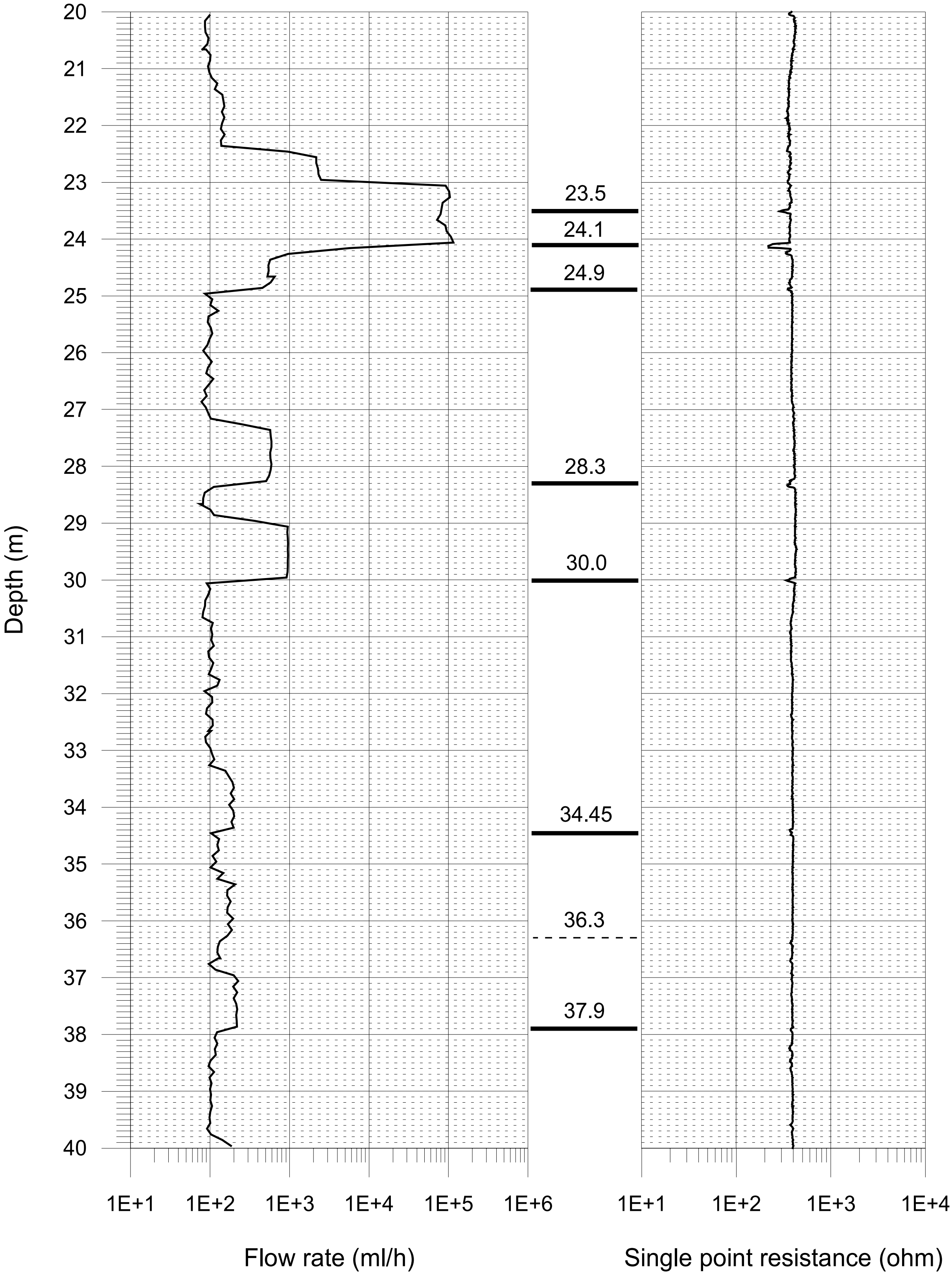

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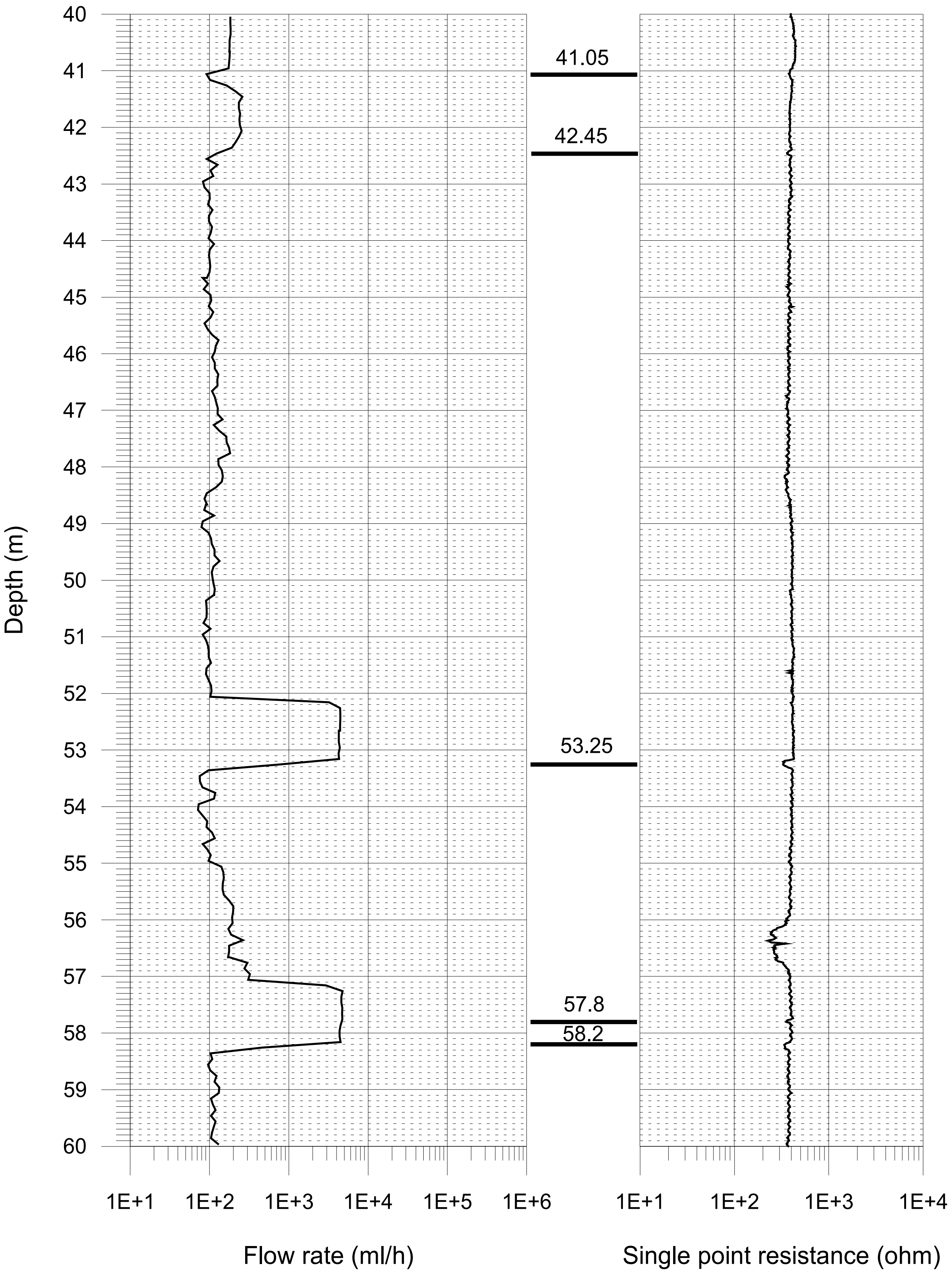

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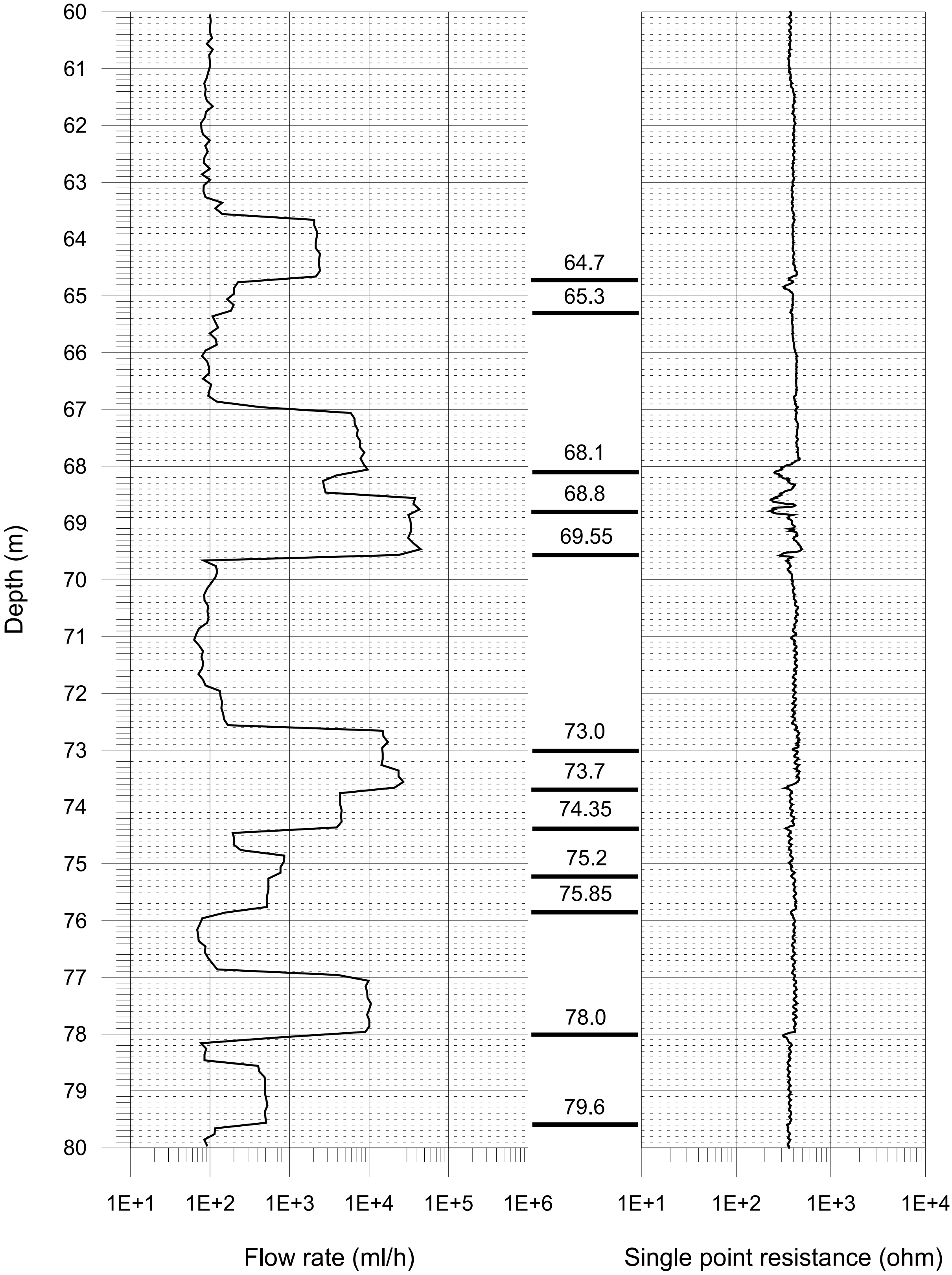

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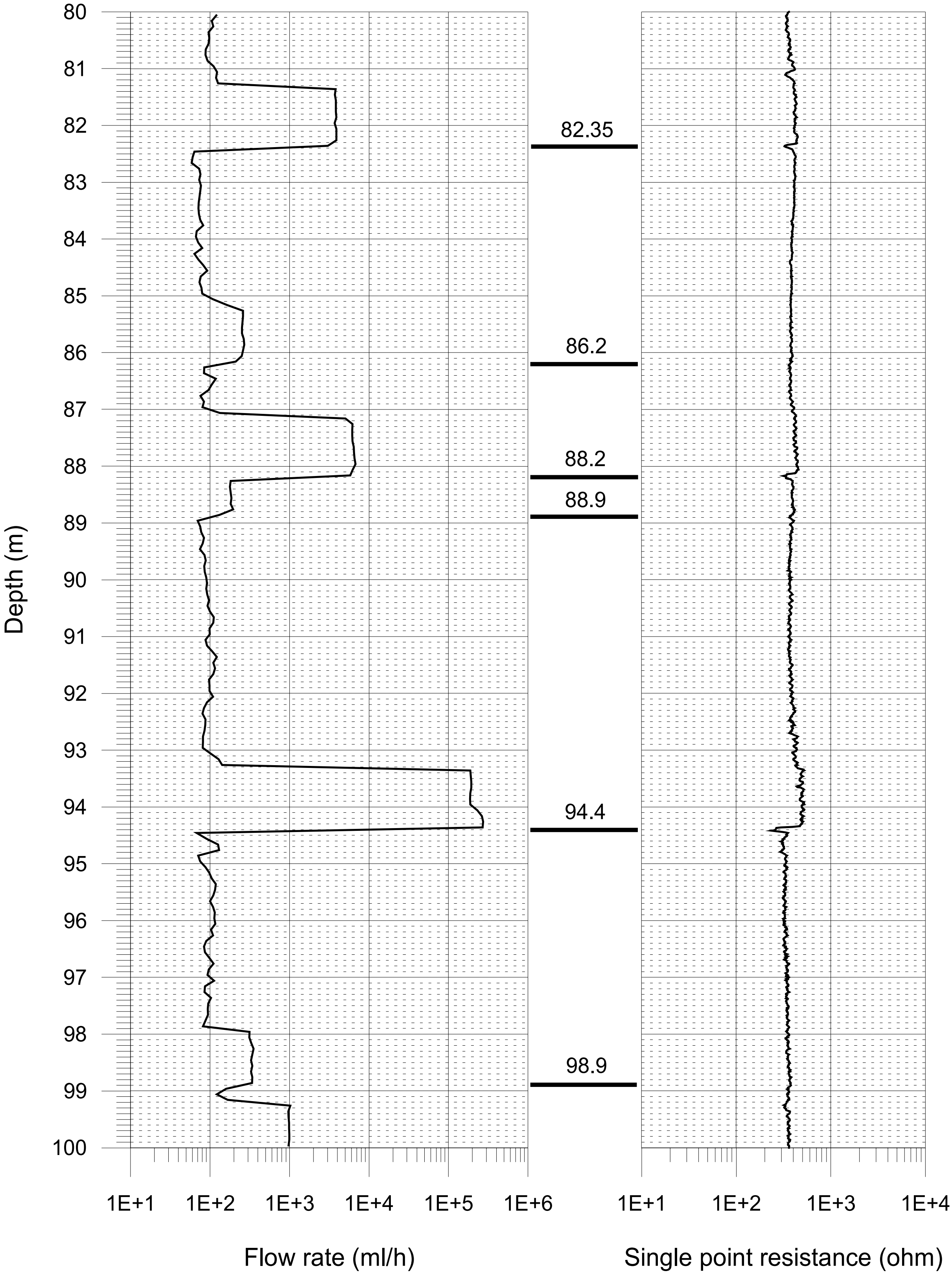

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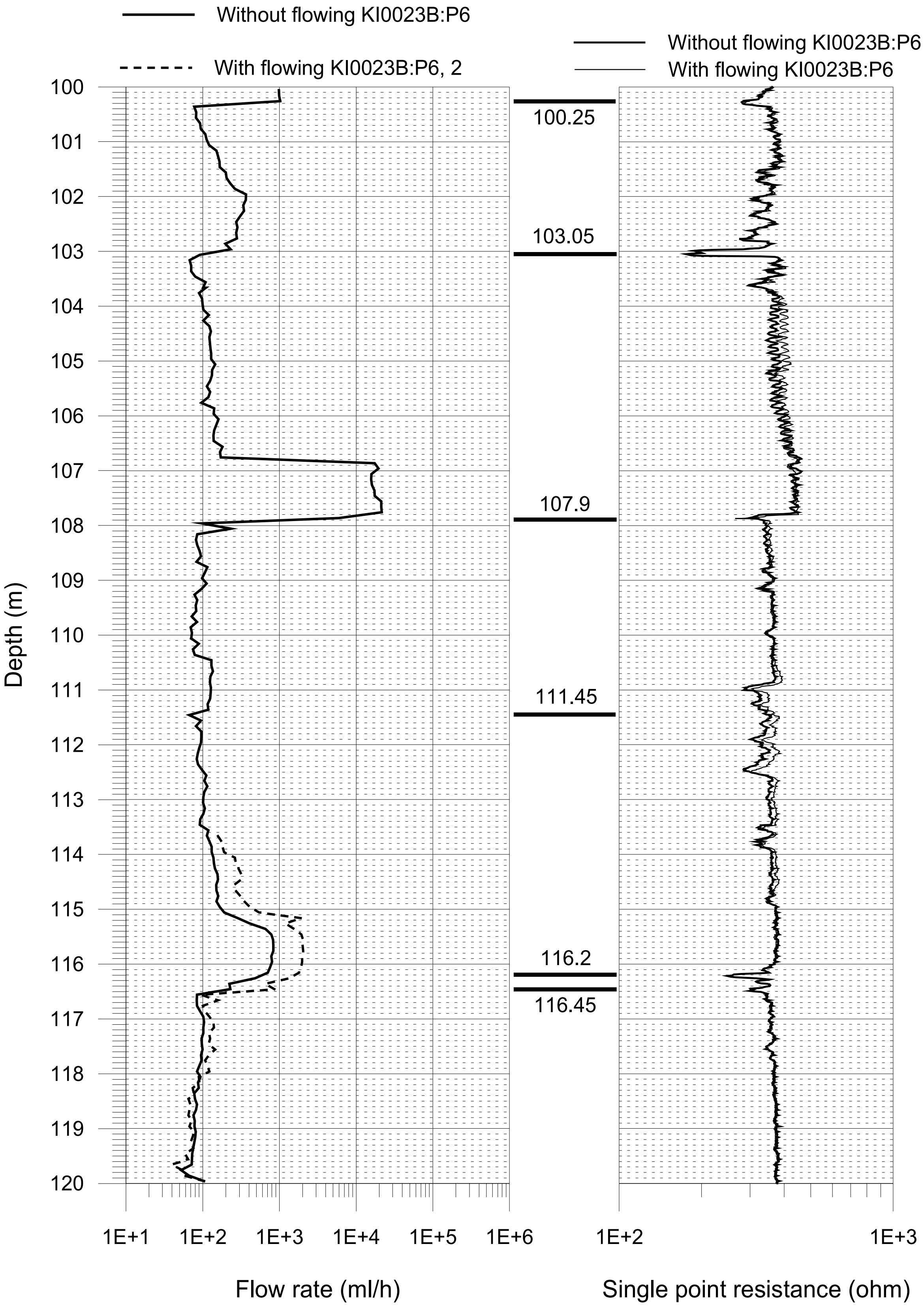

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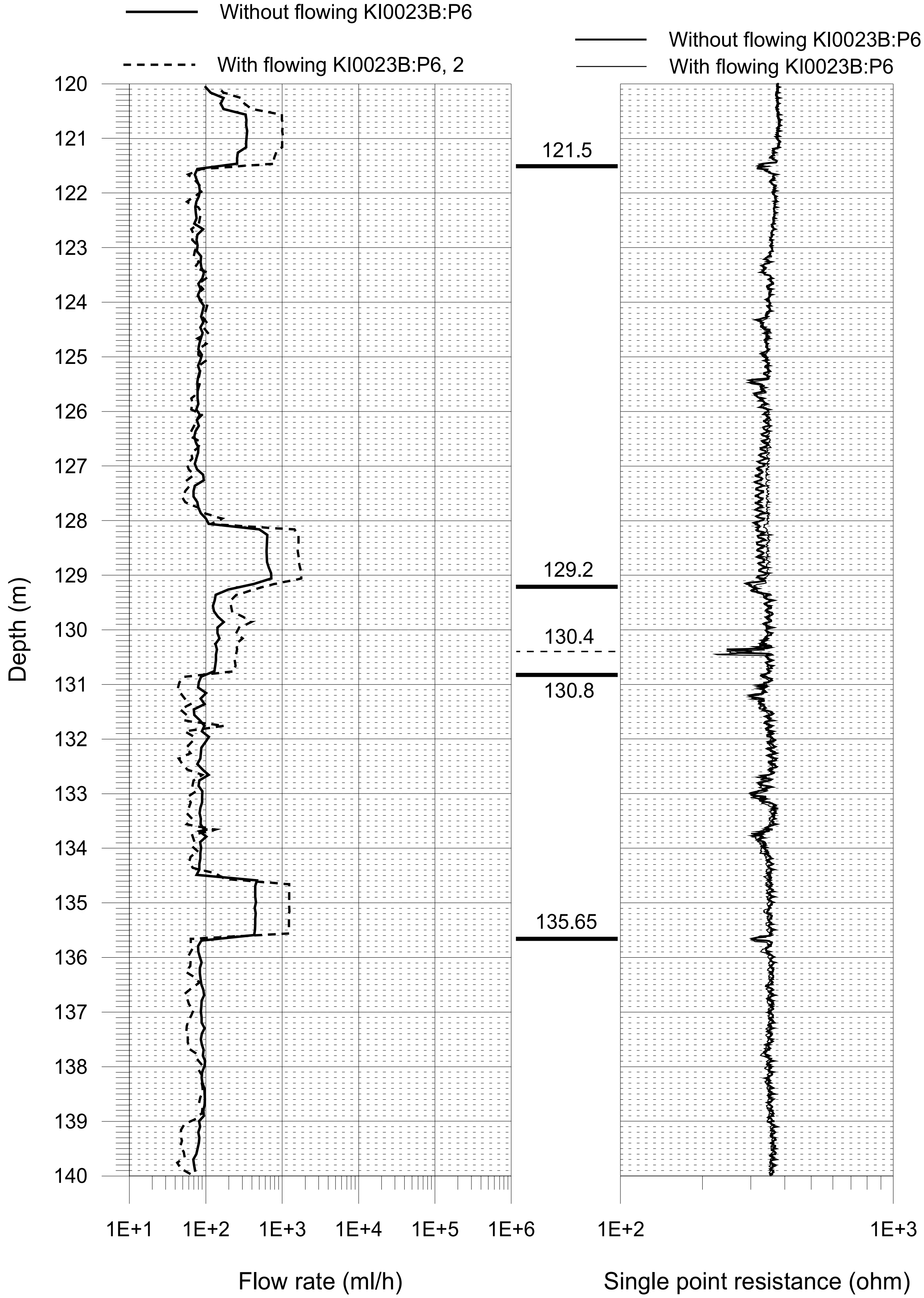

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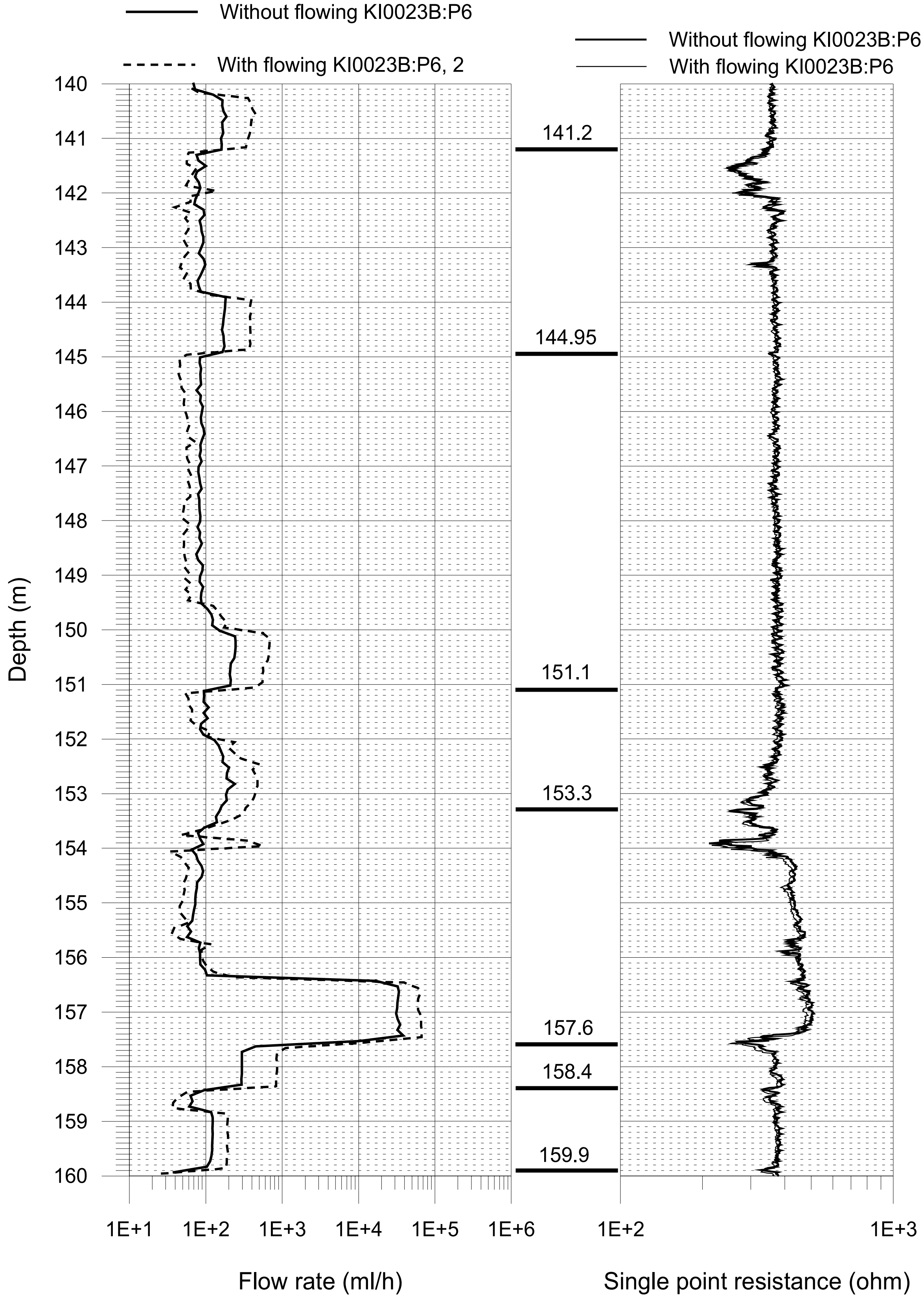
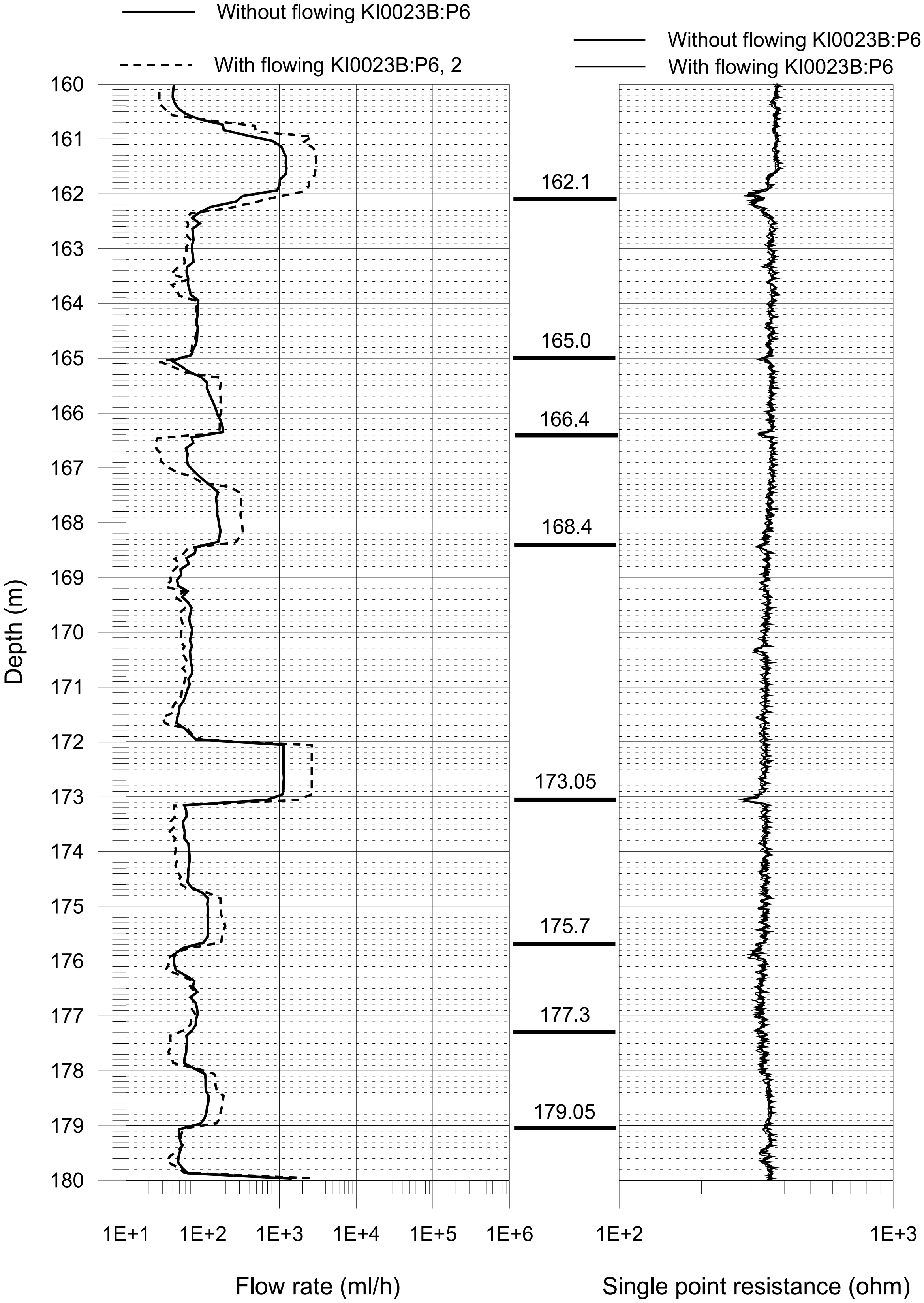
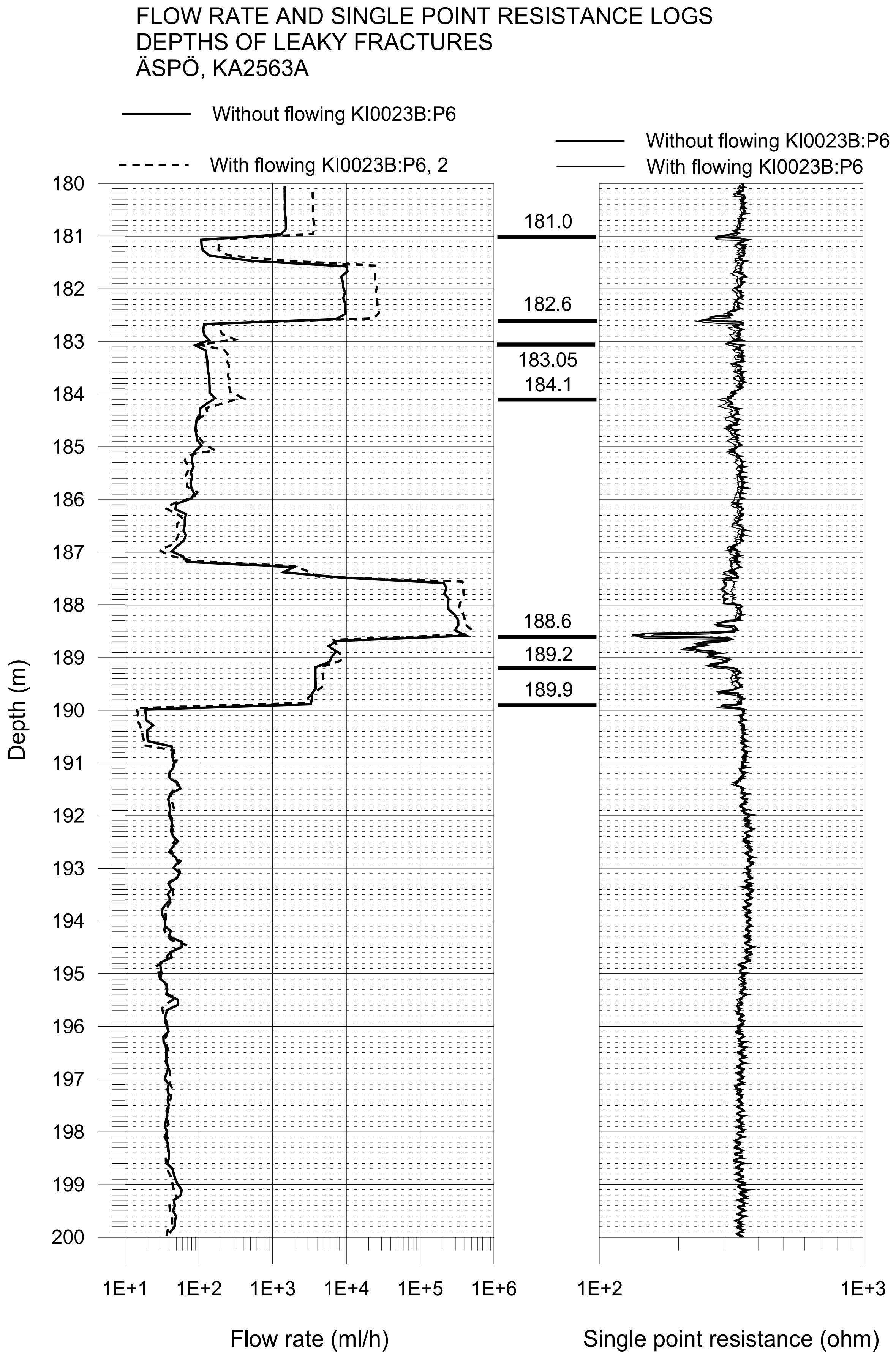
DEPTHS OF LEAKY FRACTURES
ÄSPÖ, KA2563A

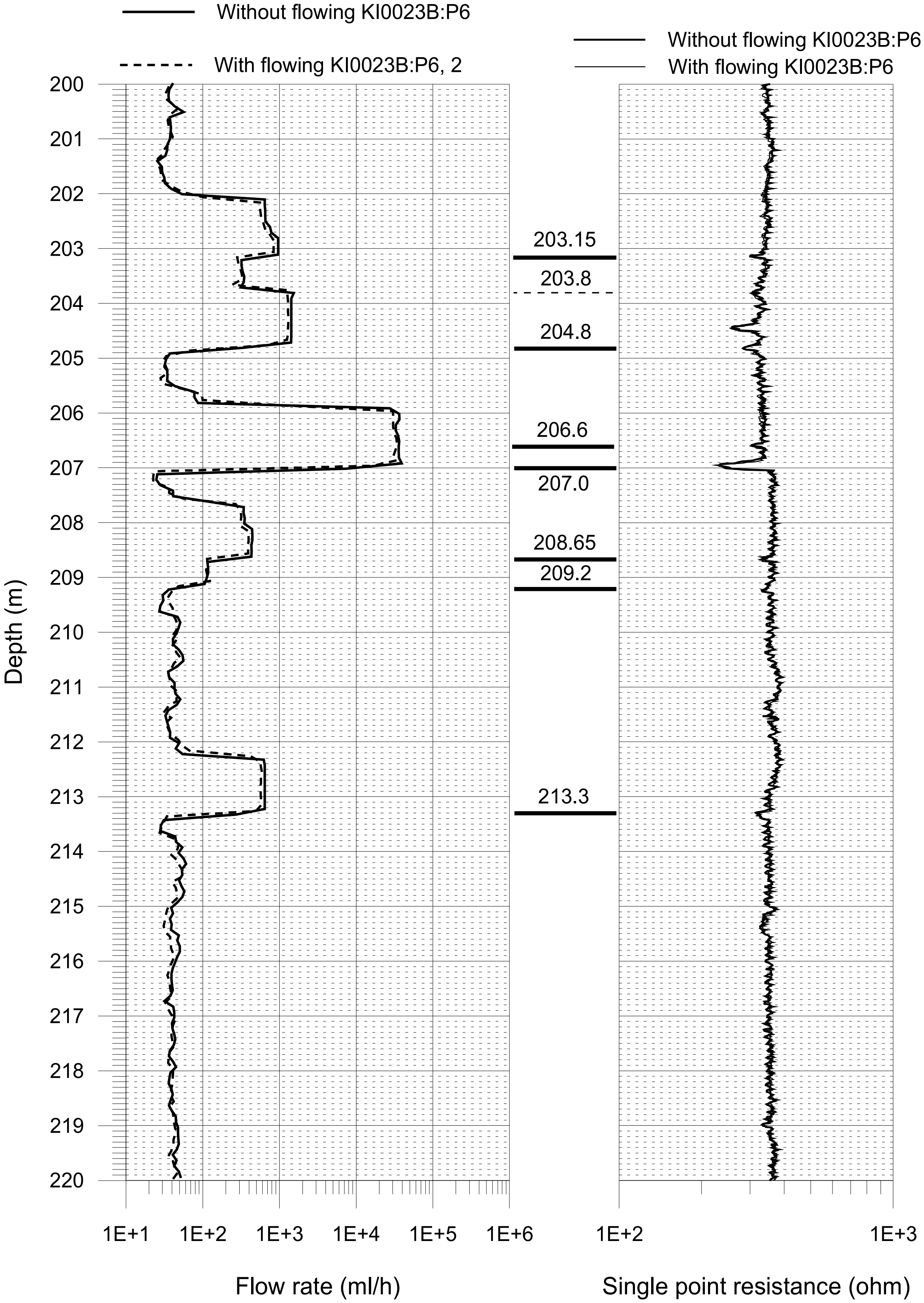


FLOW RATE AND SINGLE POINT RESISTANCE LOGS
DEPTHS OF LEAKY FRACTURES
ÄSPÖ, KA2563A

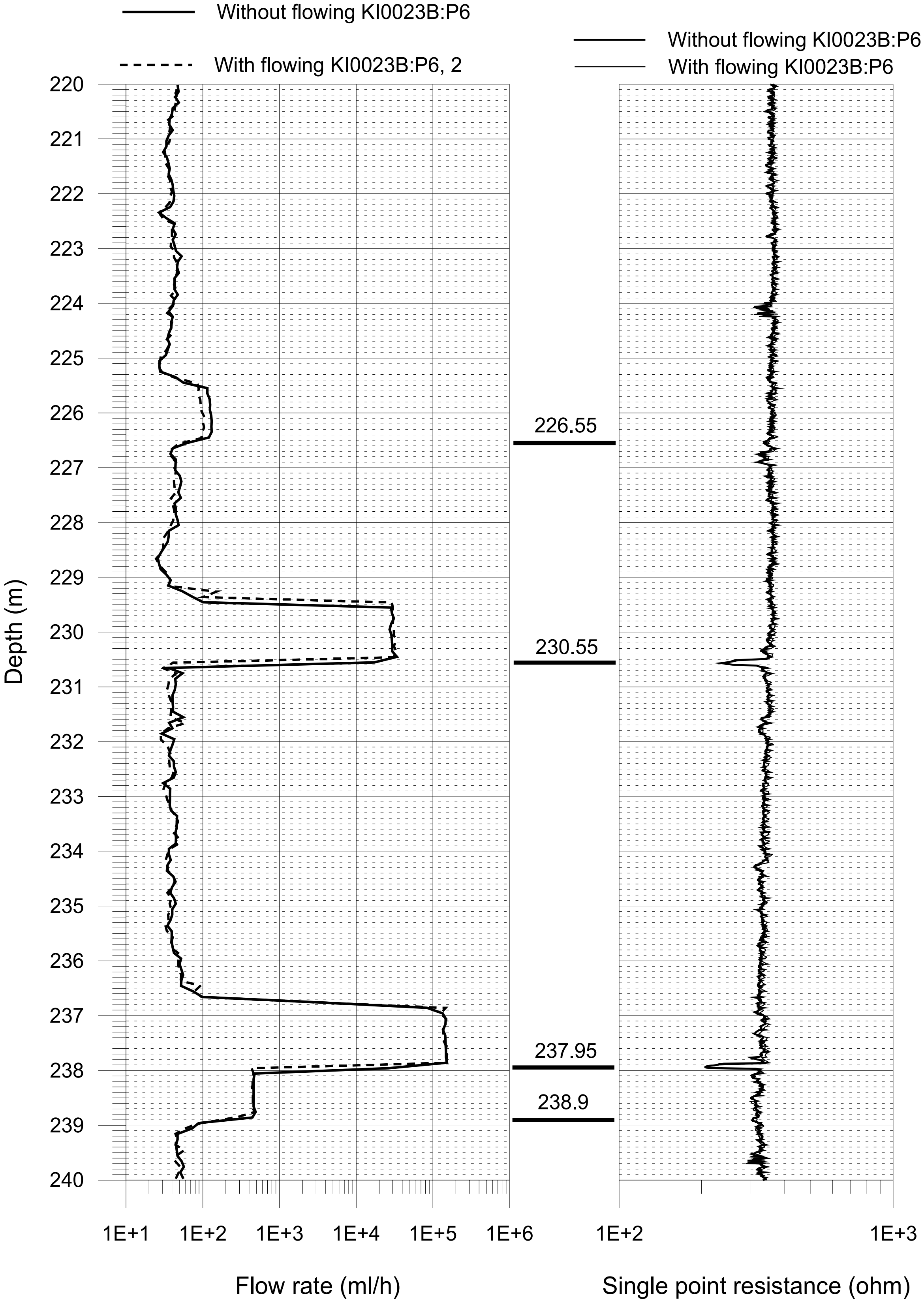



FLOW RATE AND SINGLE POINT RESISTANCE LOGS
DEPTHS OF LEAKY FRACTURES
ÄSPÖ, KA2563A
Without flowing KI0023B:P6
With flowing KI0023B:P6, 2
Without flowing KI0023B:P6
With flowing KI0023B:P6
181.0
182.6
183.05
184.1
188.6
189.2
189.9
Depth (m)
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
1E+1
1E+2
1E+3
1E+4
1E+5
1E+6
Flow rate (ml/h)
1E+2
1E+3
Single point resistance (ohm)

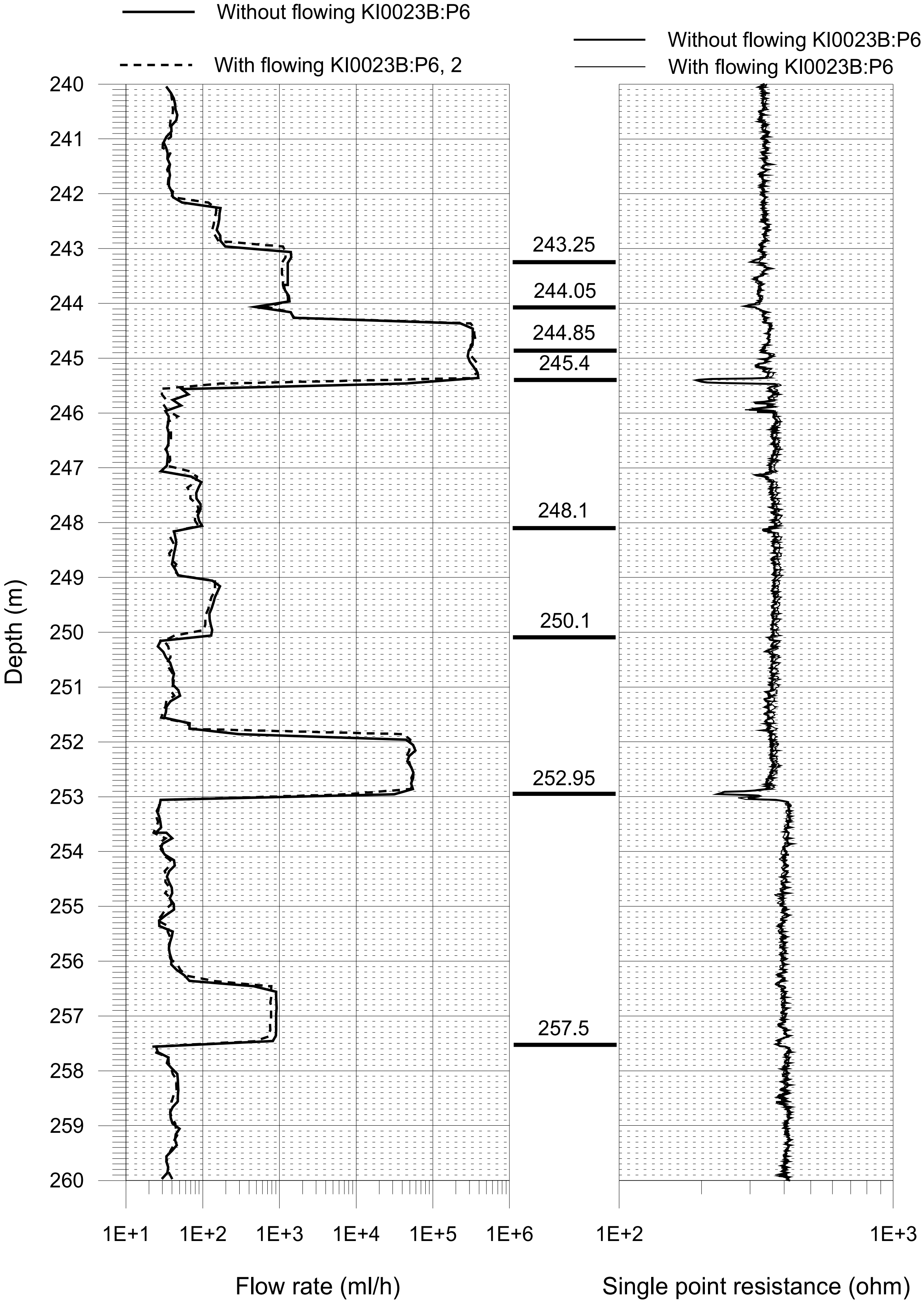
FLOW RATE AND SINGLE POINT RESISTANCE LOGS
DEPTHS OF LEAKY FRACTURES
ÄSPÖ, KA2563A



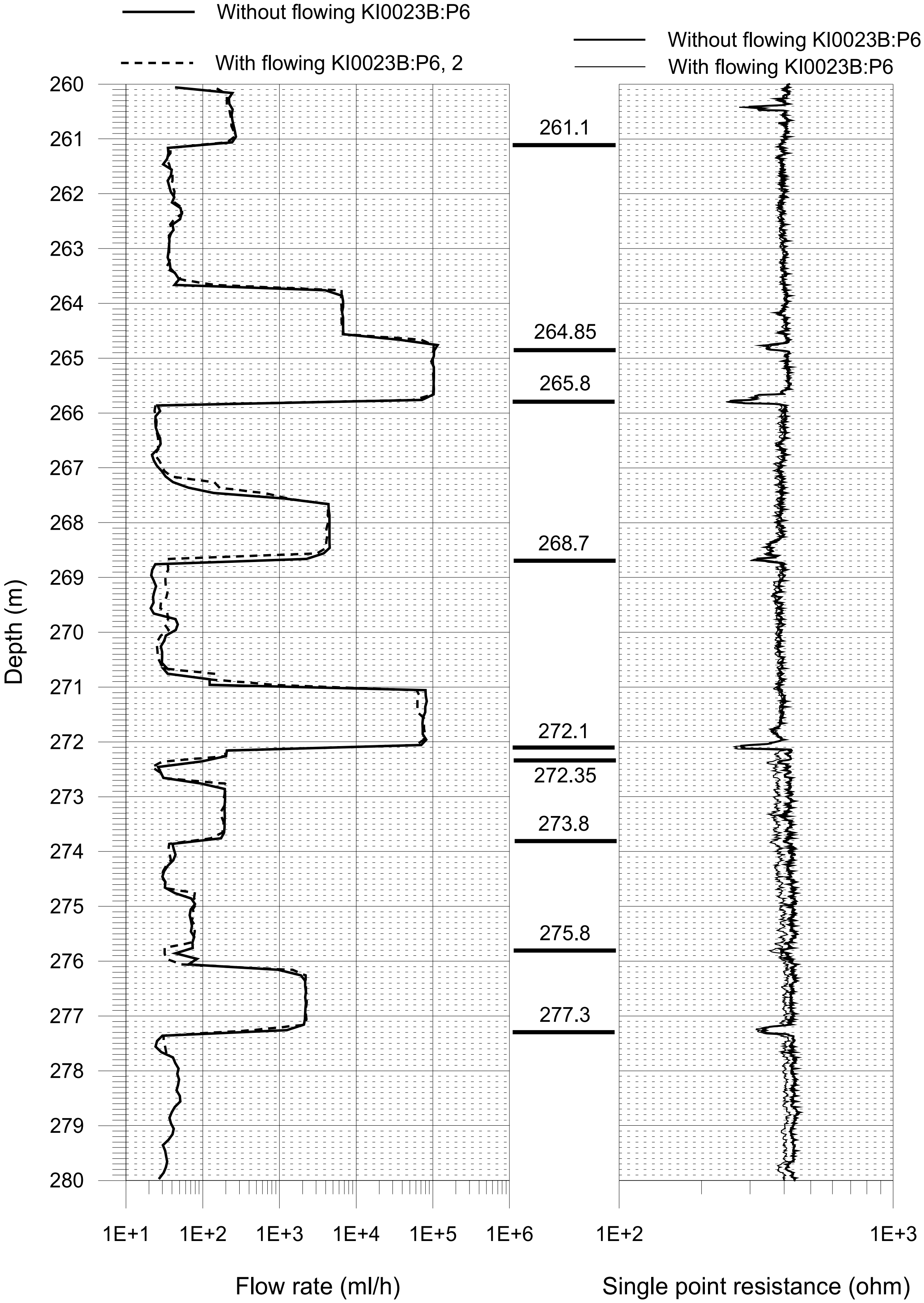
FLOW RATE AND SINGLE POINT RESISTANCE LOGS
DEPTHS OF LEAKY FRACTURES
ÄSPÖ, KA2563A



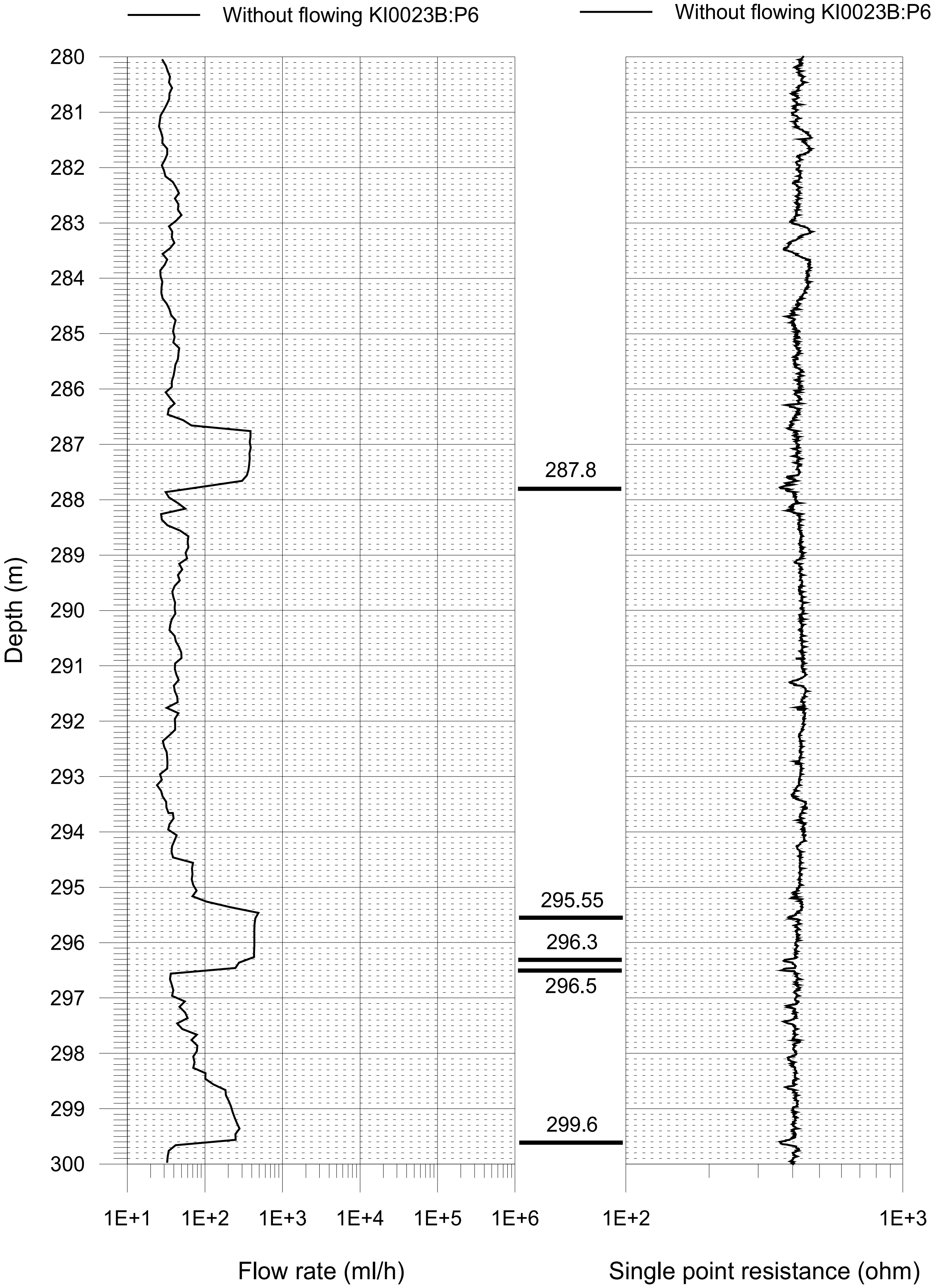
FLOW RATE AND SINGLE POINT RESISTANCE LOGS
DEPTHS OF LEAKY FRACTURES
ÄSPÖ, KA2563A



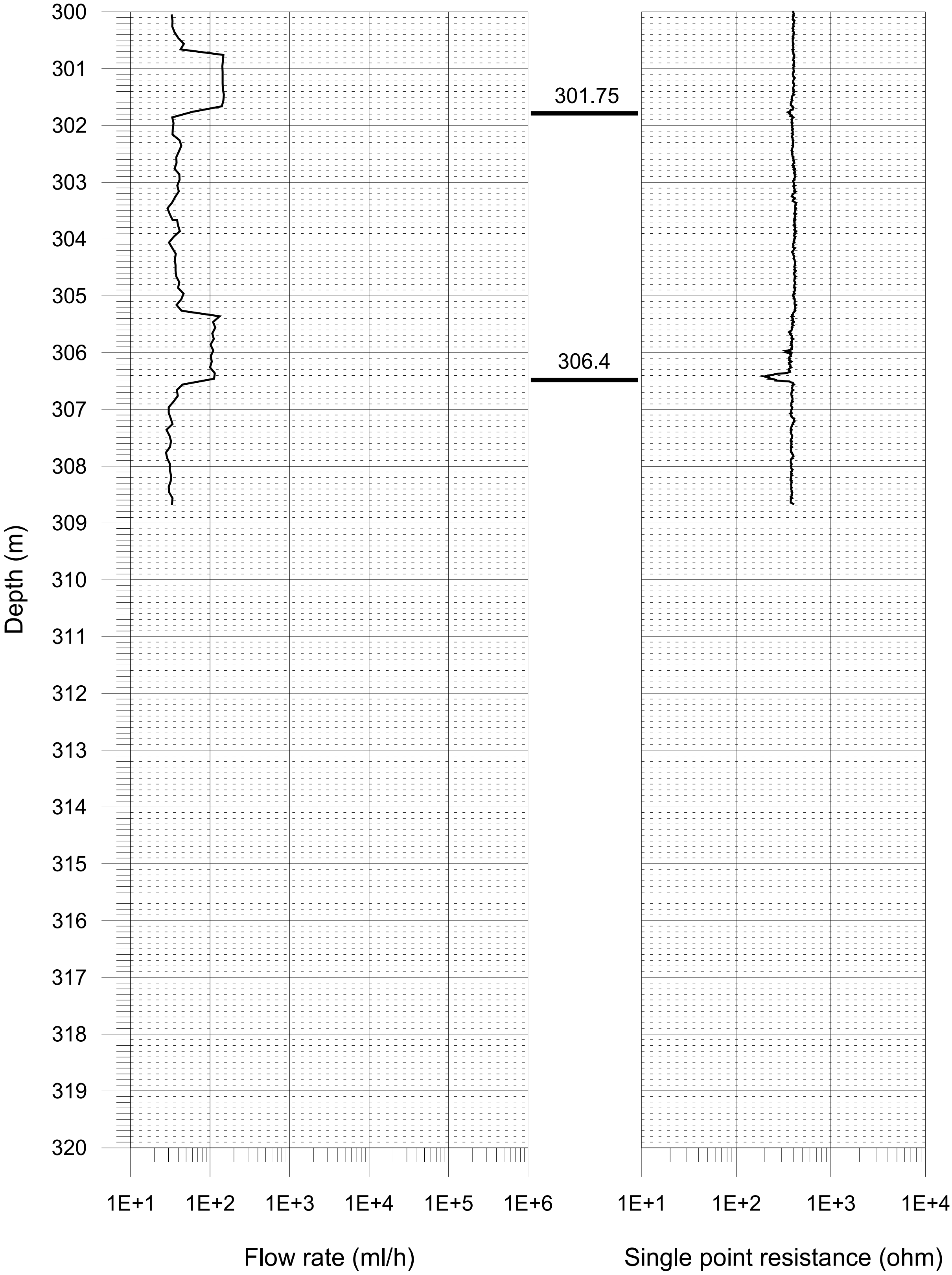
FLOW RATE AND SINGLE POINT RESISTANCE LOGS
DEPTHS OF LEAKY FRACTURES
ÄSPÖ, KA2563A



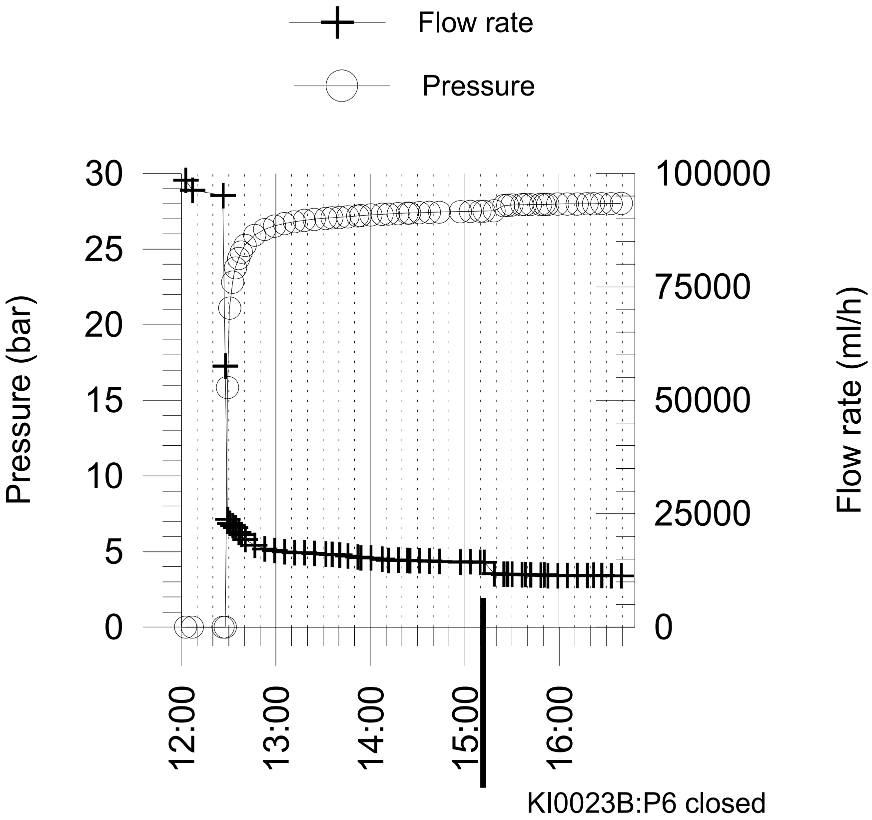
FLOW RATE AND SINGLE POINT RESISTANCE LOGS
DEPTHS OF LEAKY FRACTURES
ÄSPÖ, KA2563A

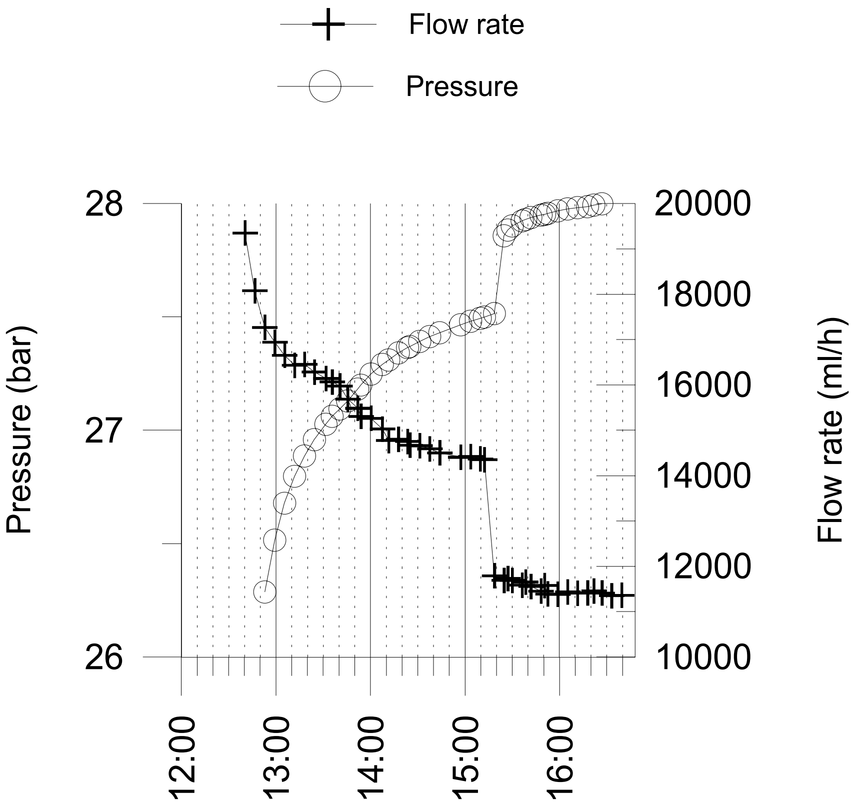


FLOW RATE AND SINGLE POINT RESISTANCE LOGS
DEPTHS OF LEAKY FRACTURES
ÄSPÖ, KA2563A

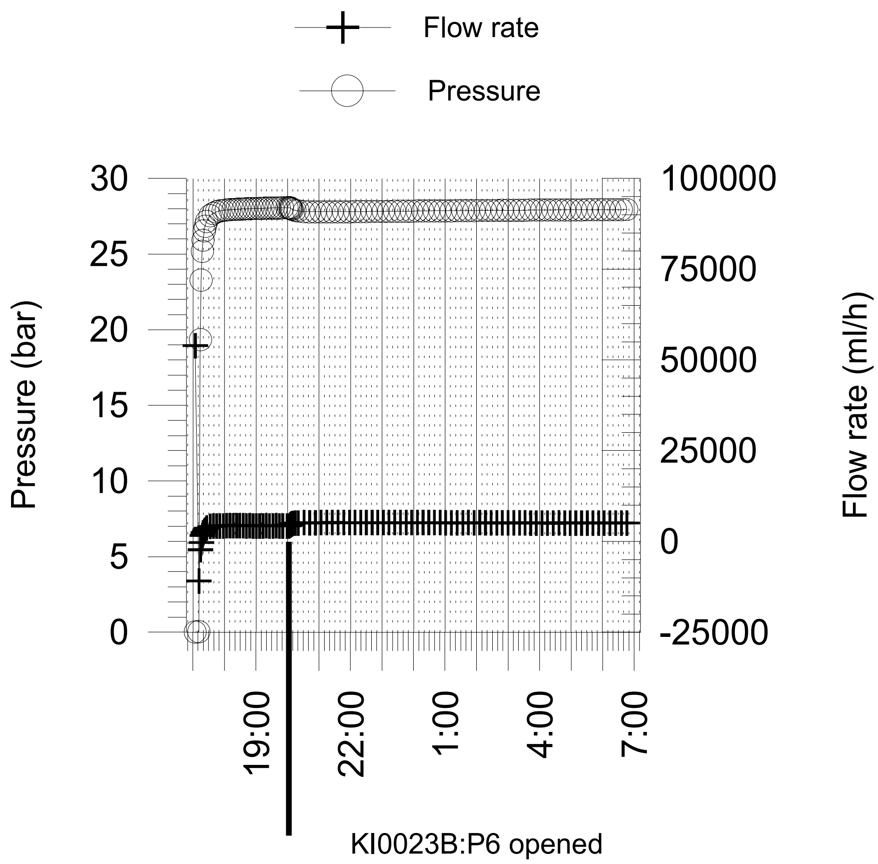


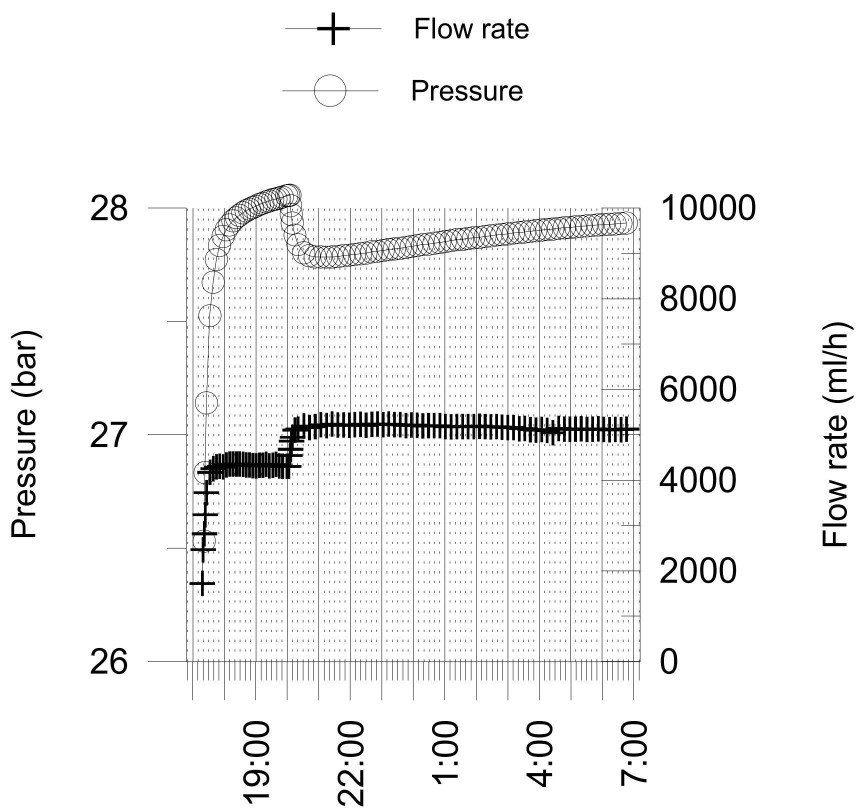
Äspö, 28.01.99 borehole KA2563A, 265.2 - 267.2 m



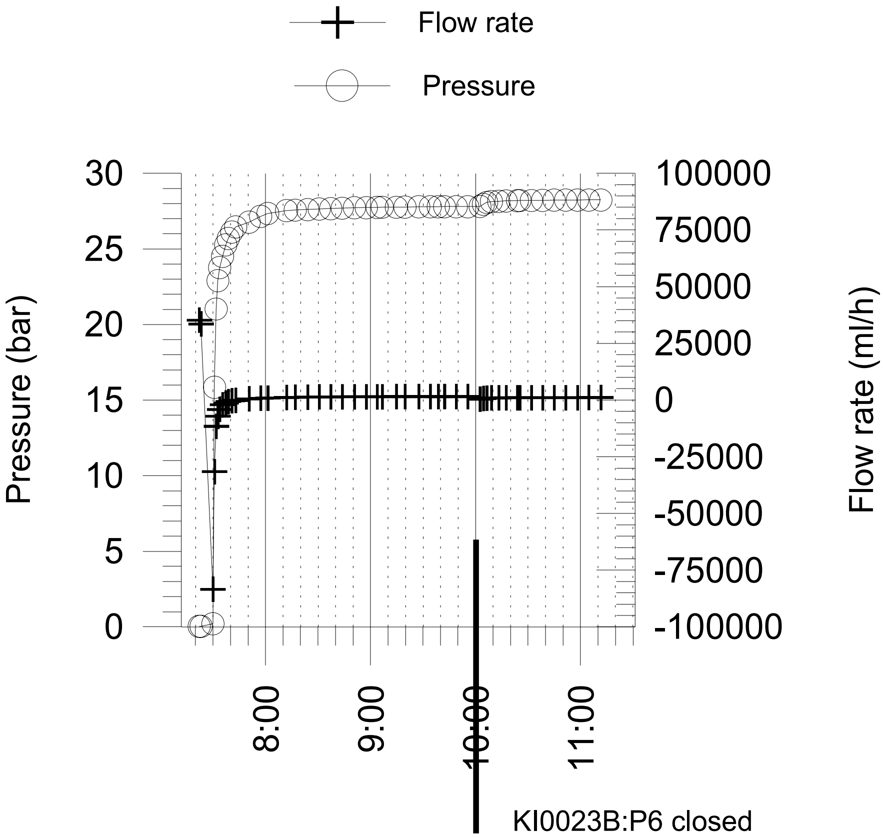


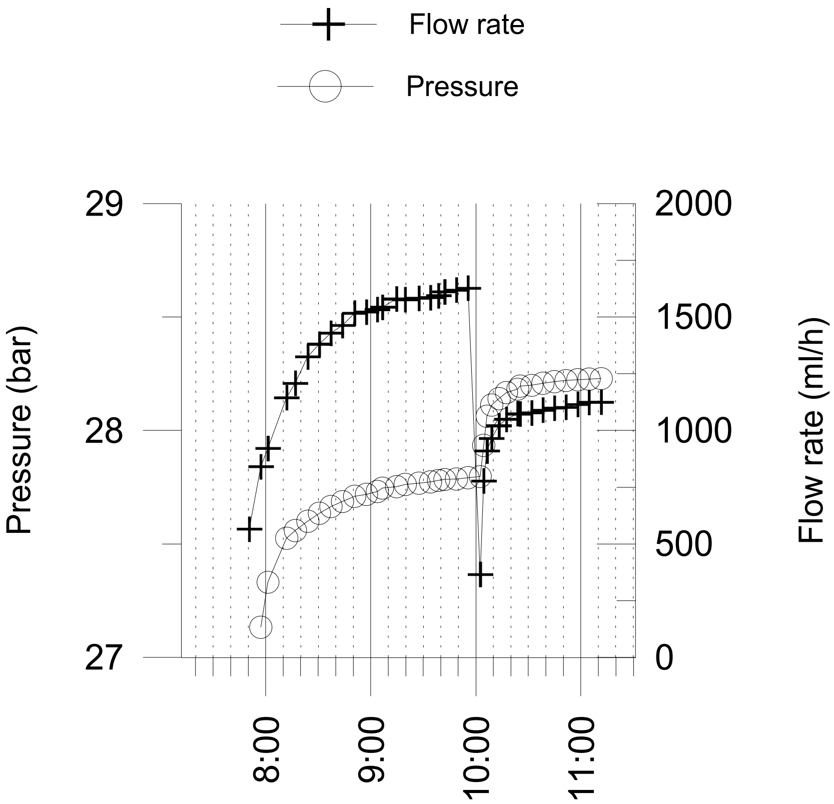
Äspö, 28.01.99 borehole KA2563A, 252.0 - 254.0 m



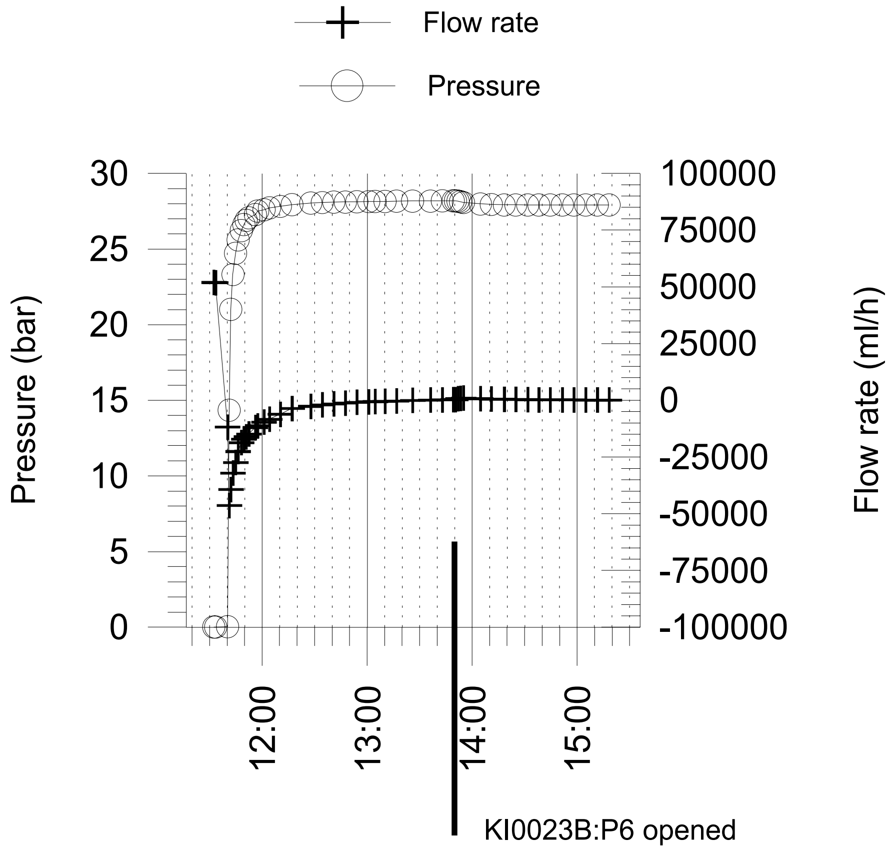


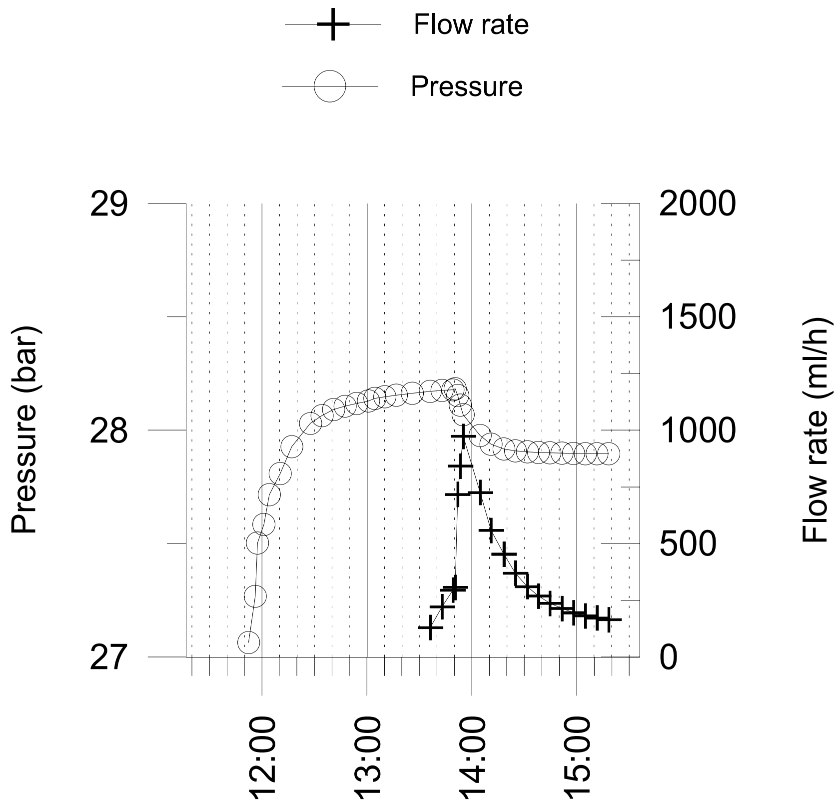
Äspö, 29.01.99 borehole KA2563A, 229.5 - 231.5 m



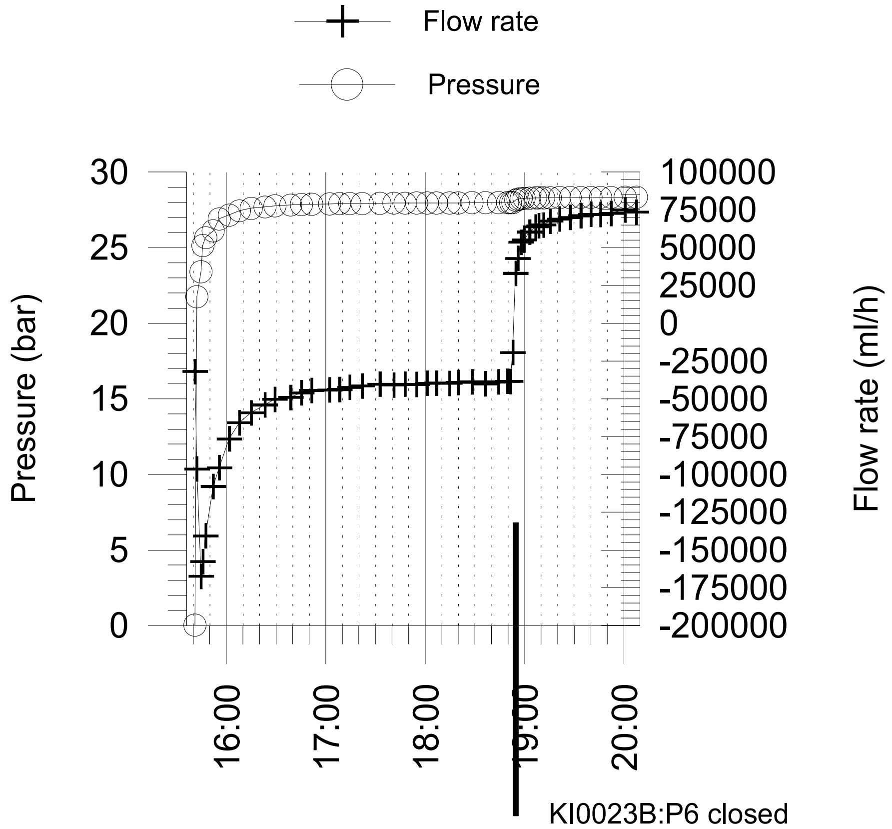


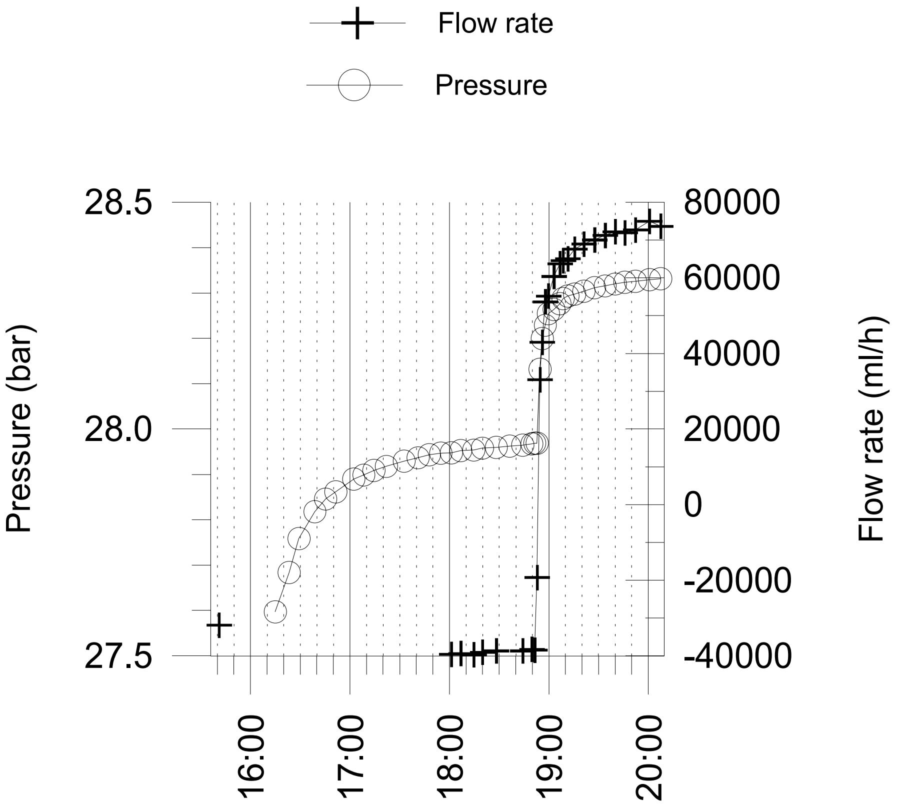
Äspö, 29.01.99 borehole KA2563A, 206.0 - 208.0 m



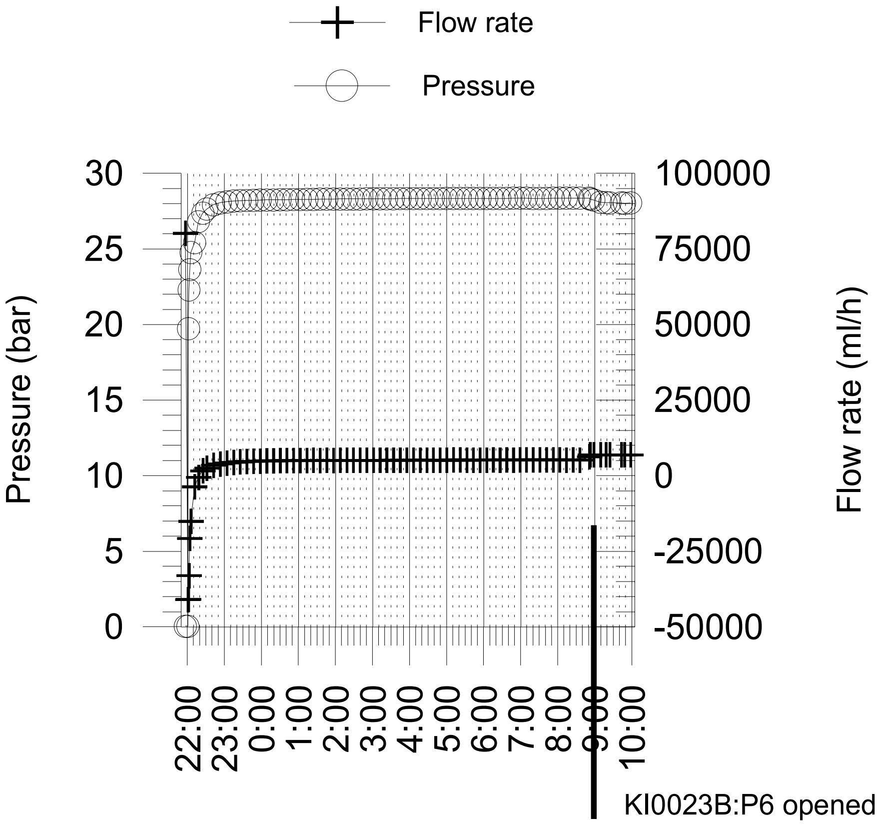


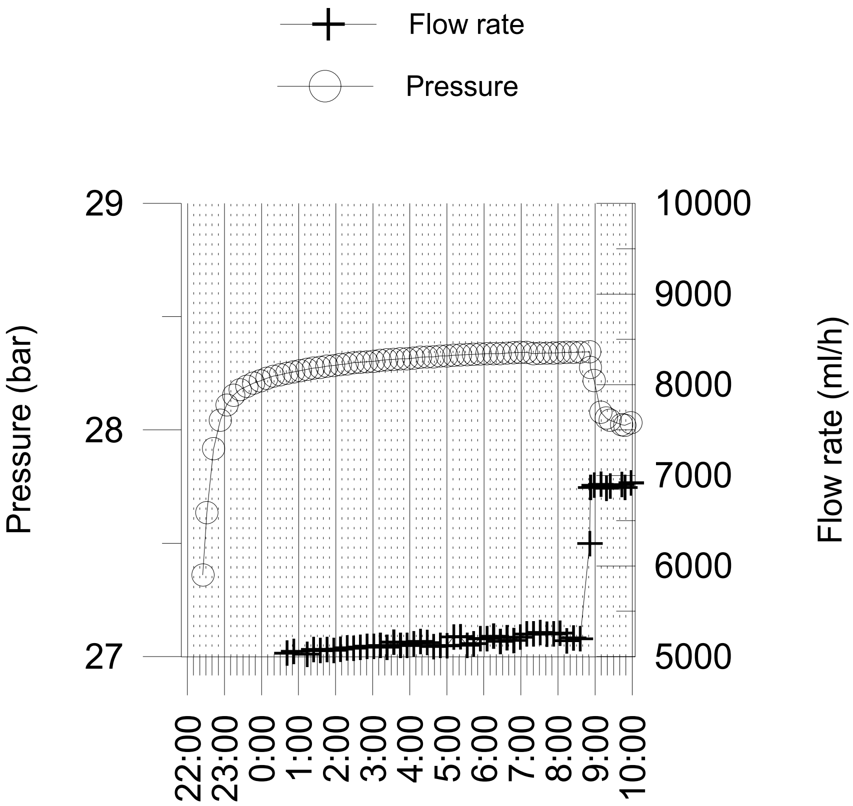
Äspö, 29.01.99 borehole KA2563A, 188.3 - 190.3 m



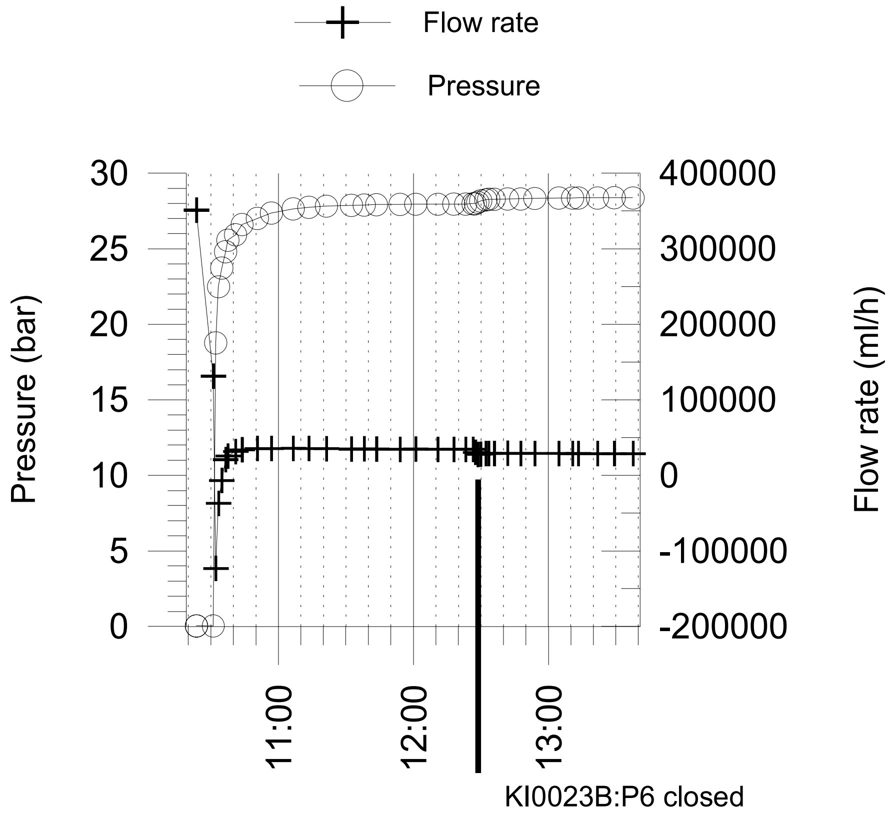


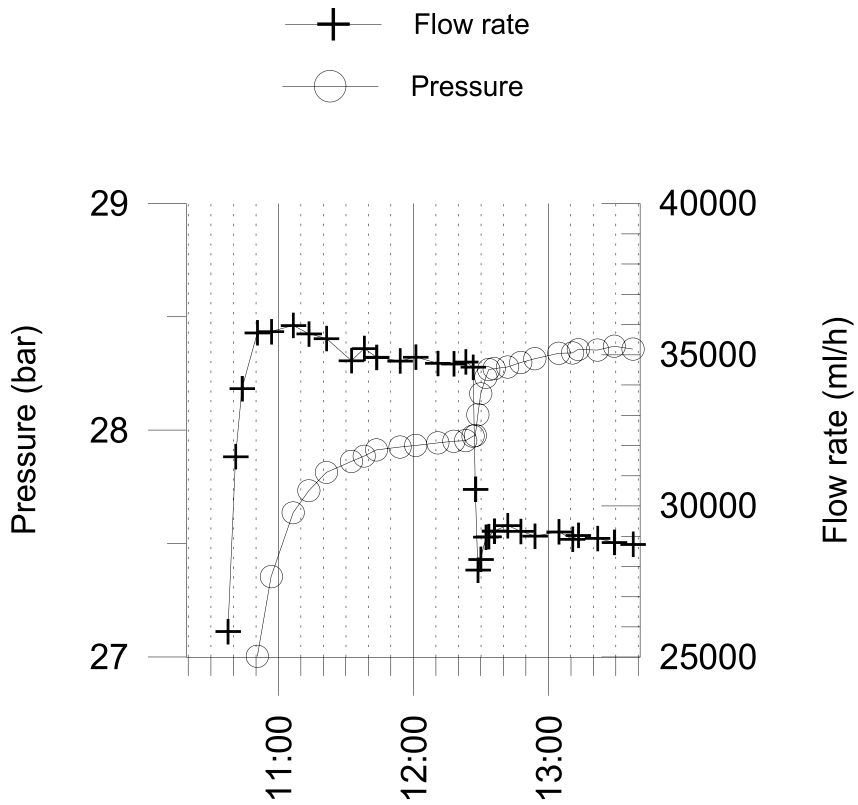
Äspö, 30.01.99 borehole KA2563A, 271.3 - 273.3 m



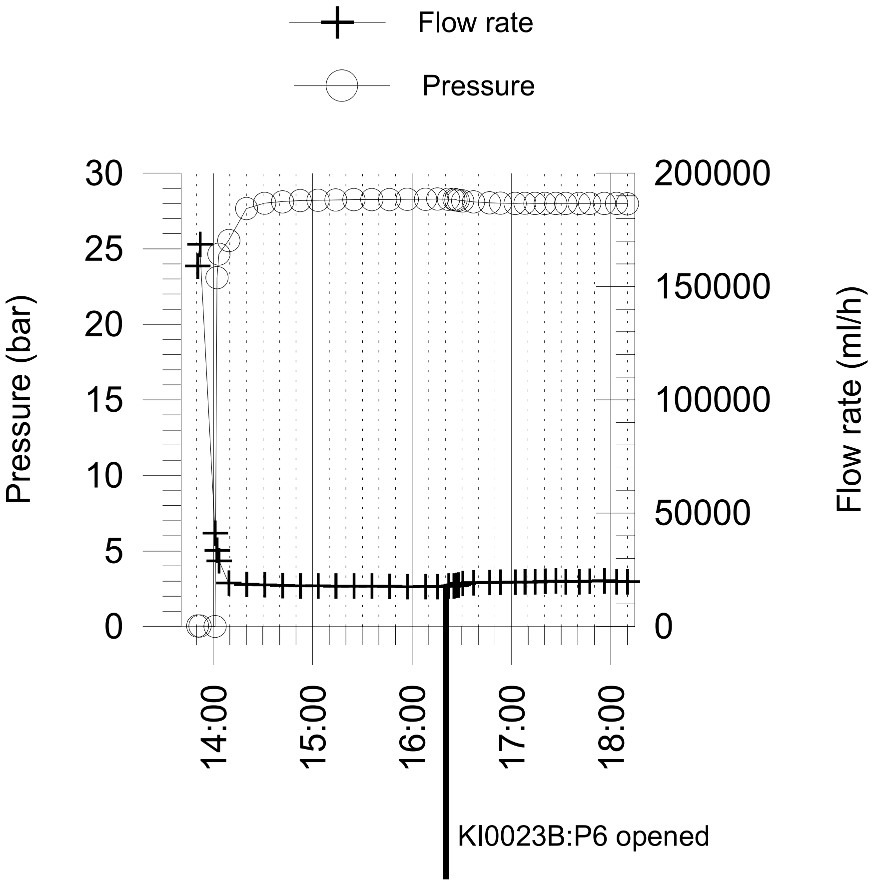


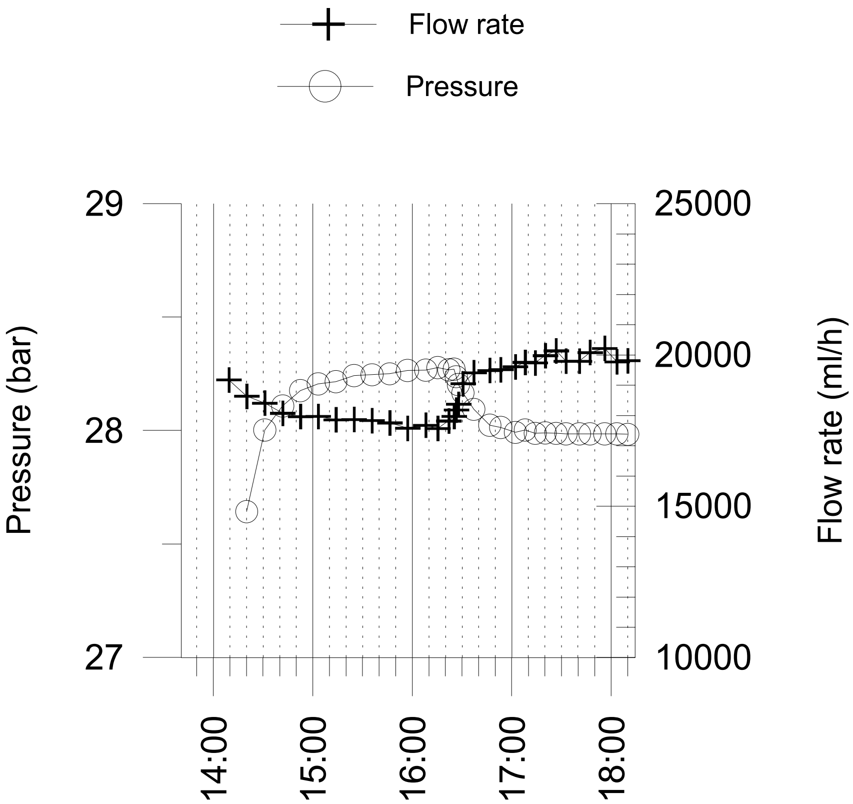
Äspö, 30.01.99 borehole KA2563A, 244.45 - 246.45 m



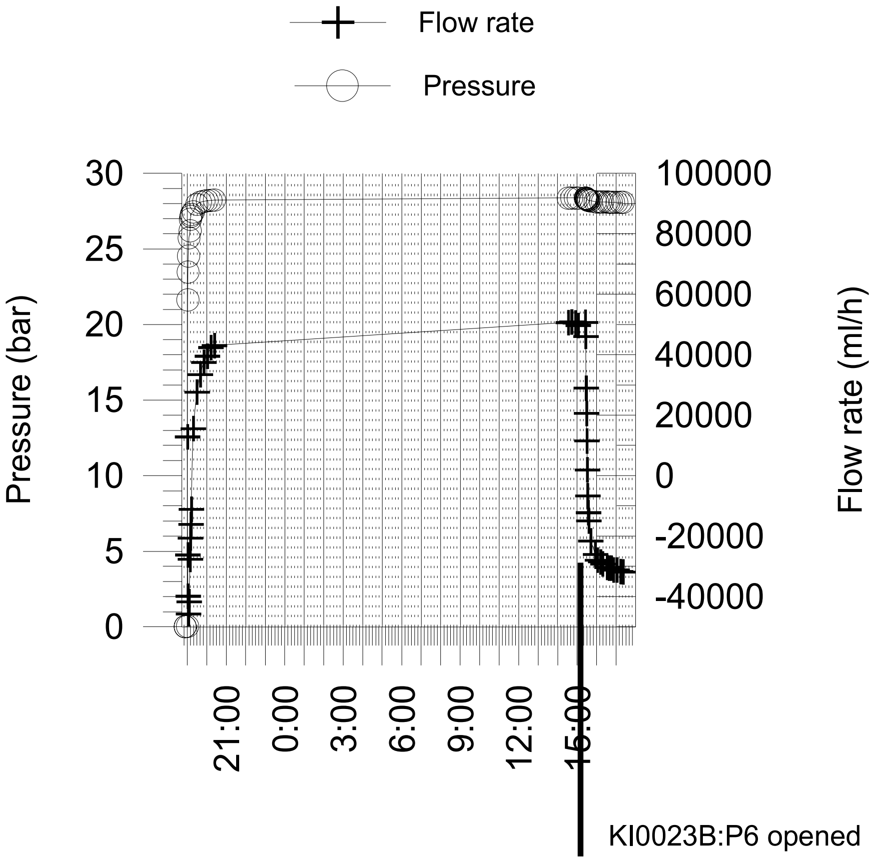


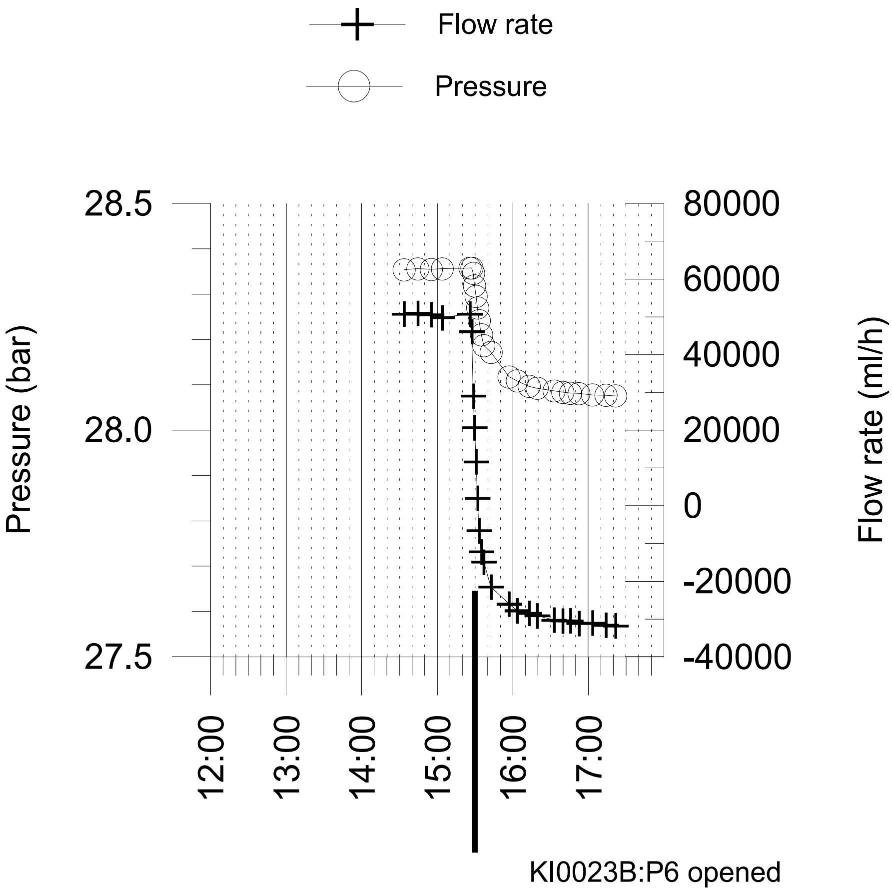
Äspö, 30.01.99 borehole KA2563A, 236.5 - 238.5 m



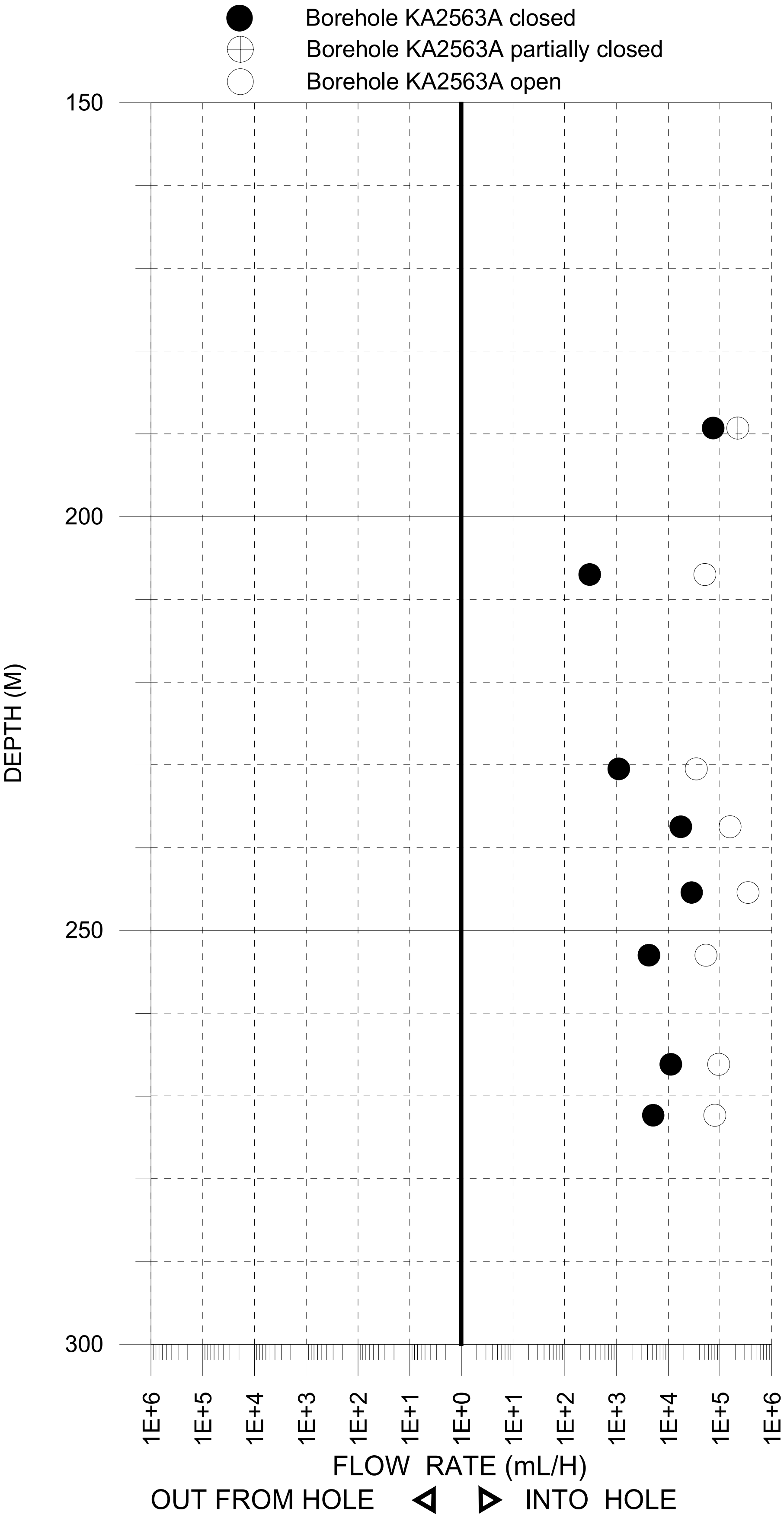


Äspö, 31.01.99 borehole KA2563A, 188.3 - 190.3 m

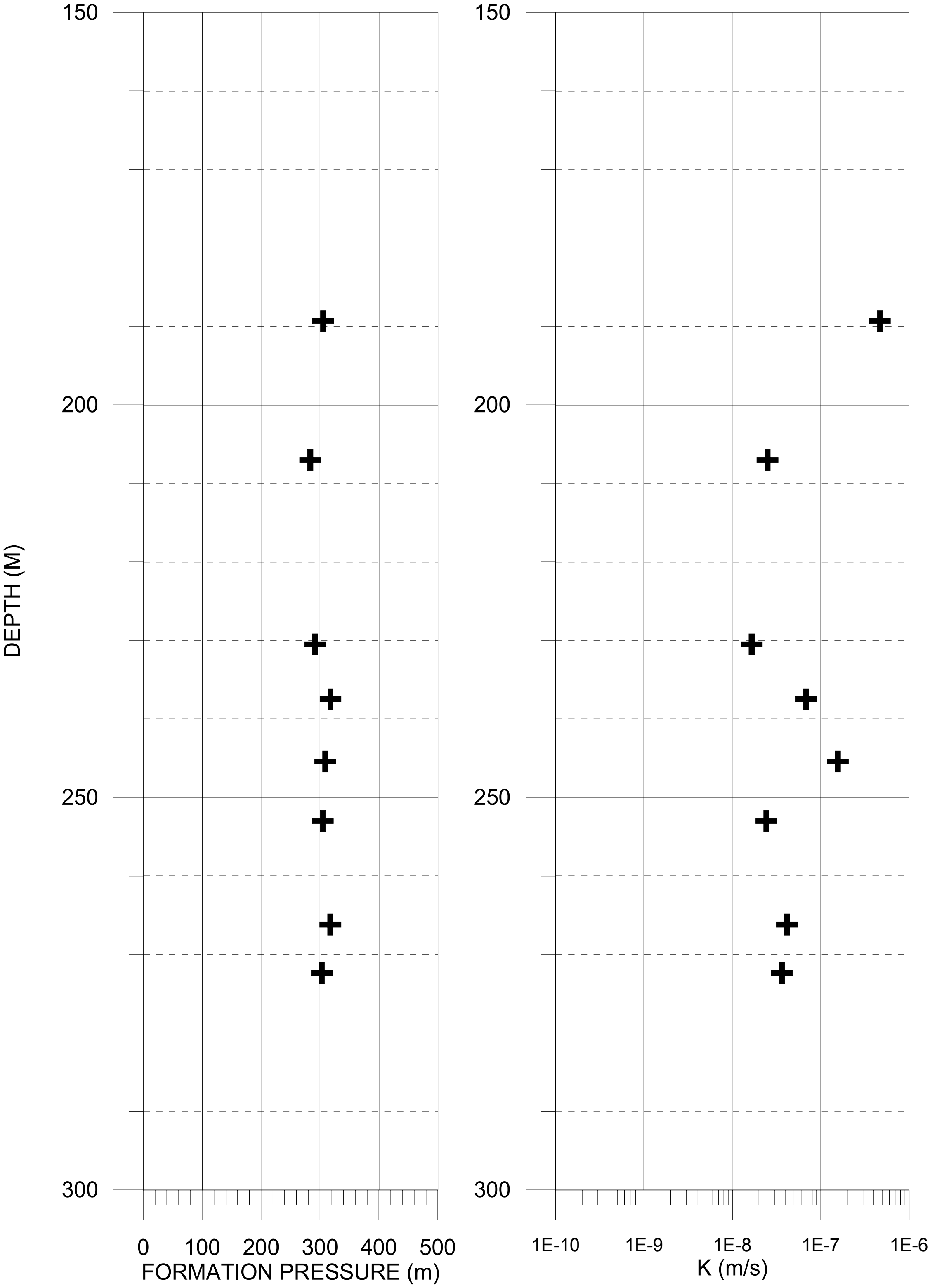




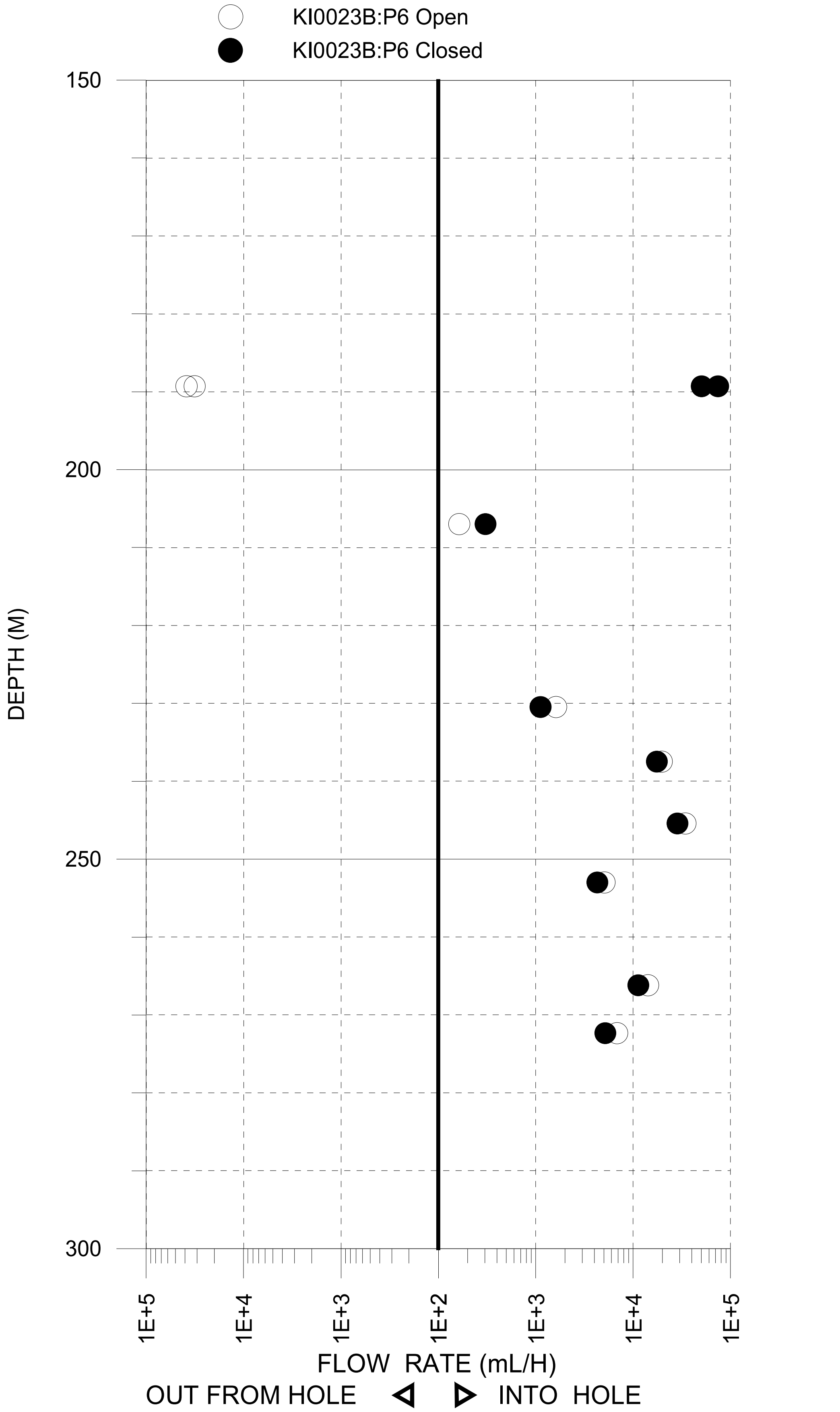
DIFFERENCE FLOW MEASUREMENT, ÄSPÖ, BOREHOLE KA2563A
FLOW RATES, LENGTH OF SECTION 2 M
KI0023B:P6 CLOSED



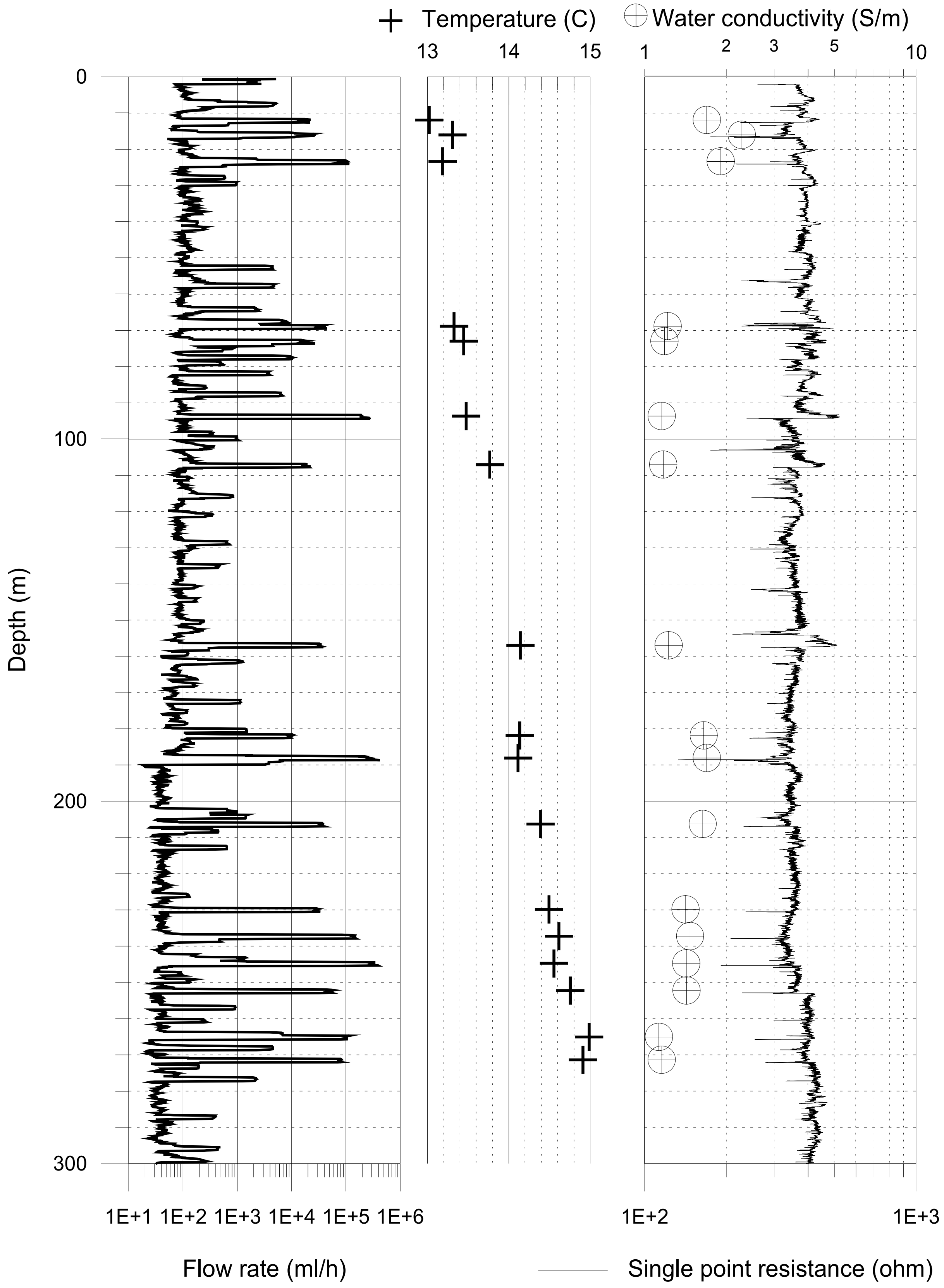
DIFFERENCE FLOW MEASUREMENT, ÄSPÖ, BOREHOLE KA2563A
FORMATION PRESSURE AND HYDRAULIC CONDUCTIVITY, LENGTH OF SECTION 2 M
KI0023B:P6 CLOSED



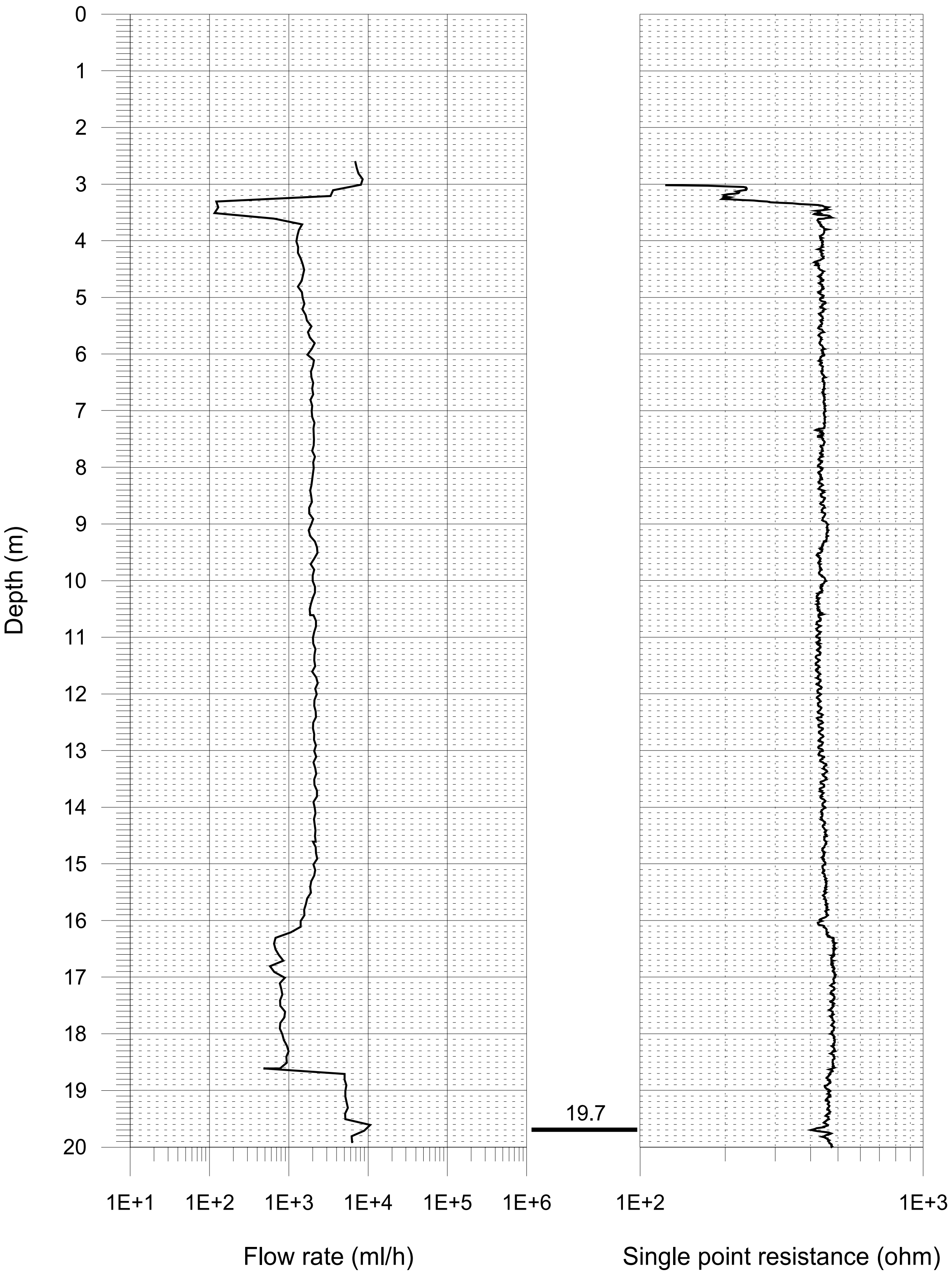
DIFFERENCE FLOW MEASUREMENT, ÄSPÖ, BOREHOLE KA2563A
FLOW RATES, LENGTH OF SECTION 2 M
BOREHOLE KA2563A CLOSED



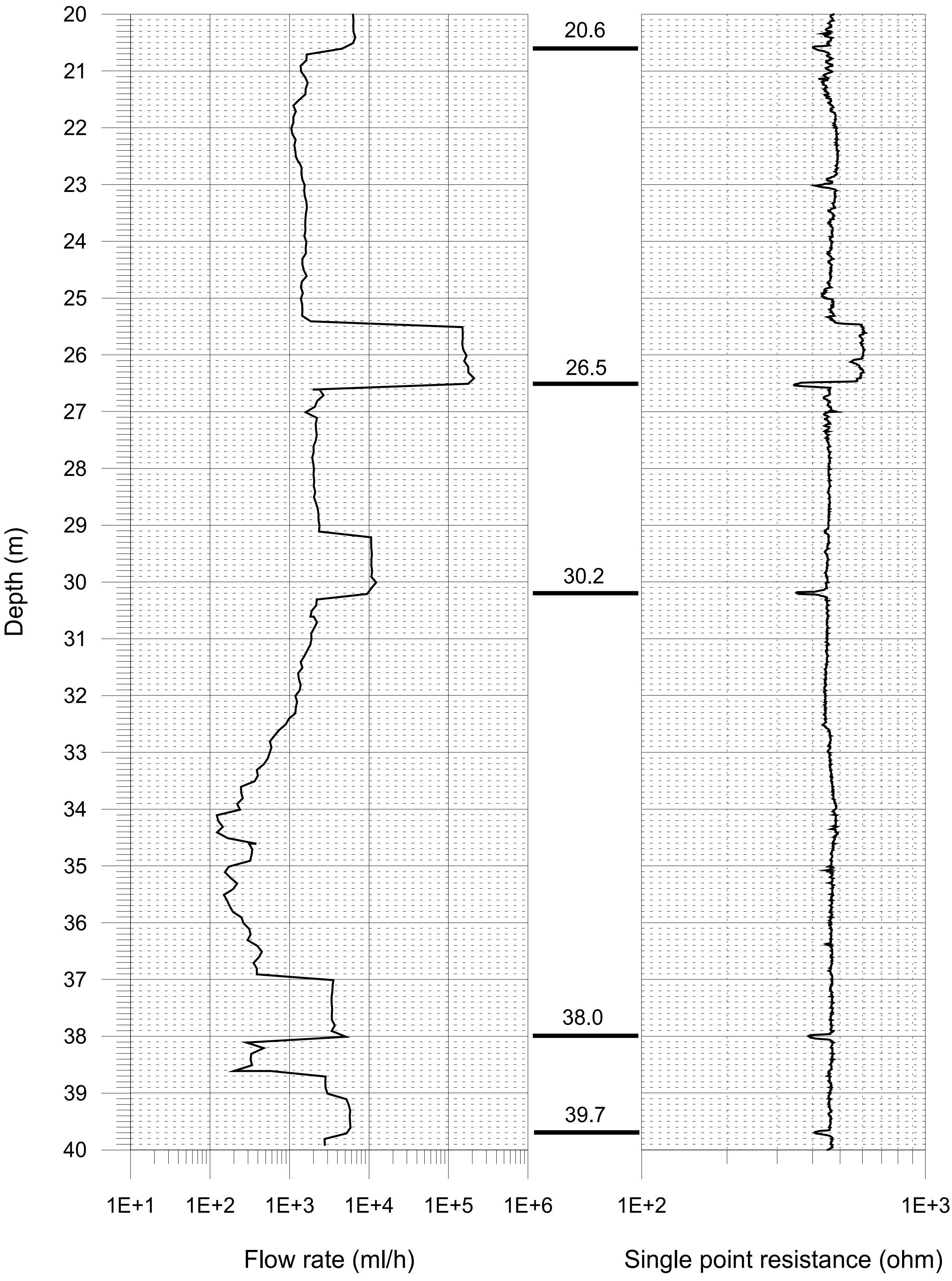
TEMPERATURE AND CONDUCTIVITY OF GROUNDWATER
FROM LARGE FRACTURES
ÄSPÖ, KA2563A



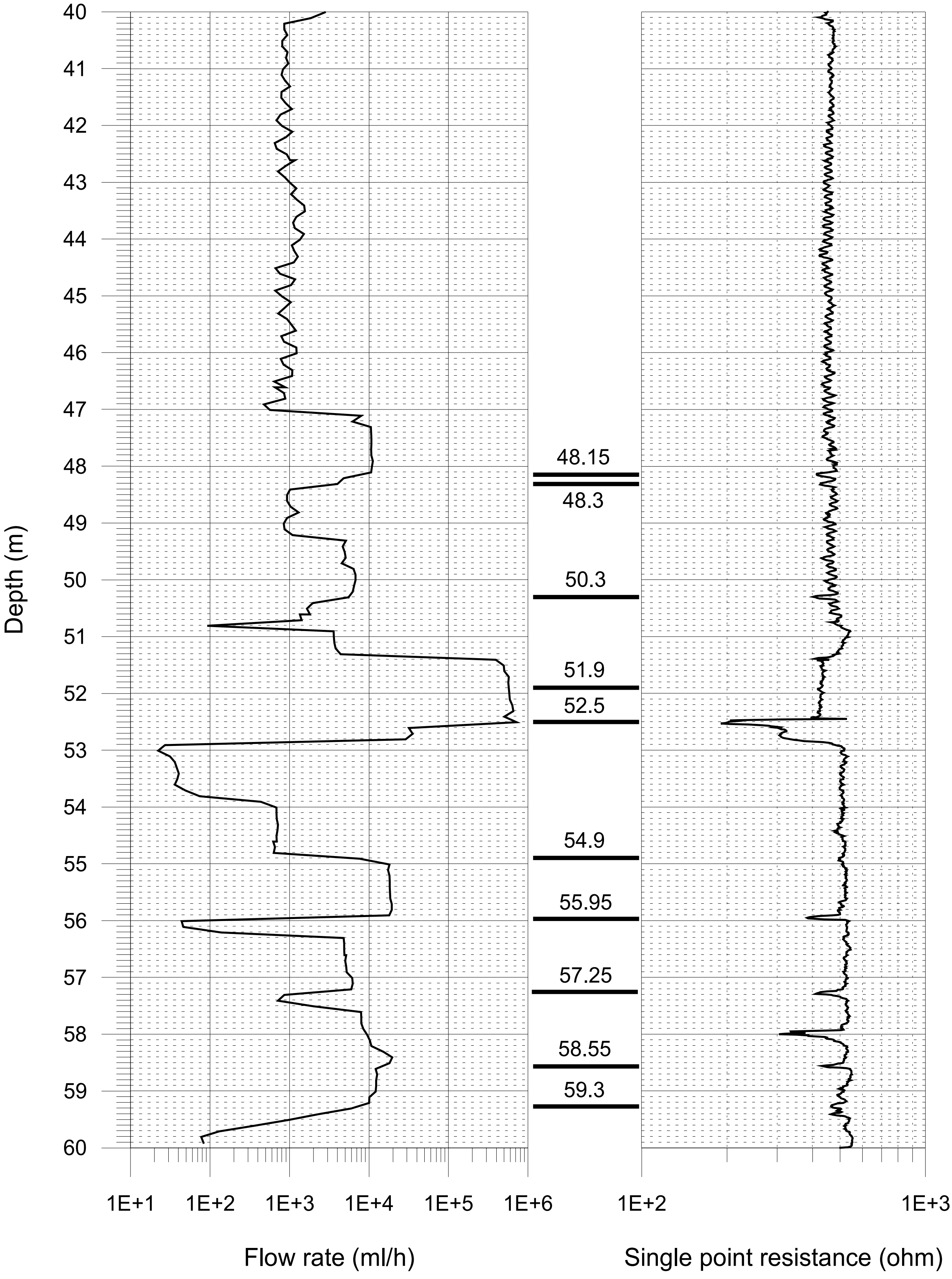
FLOW RATE AND SINGLE POINT RESISTANCE LOGS
DEPTHS OF LEAKY FRACTURES
ÄSPÖ, KA2511A



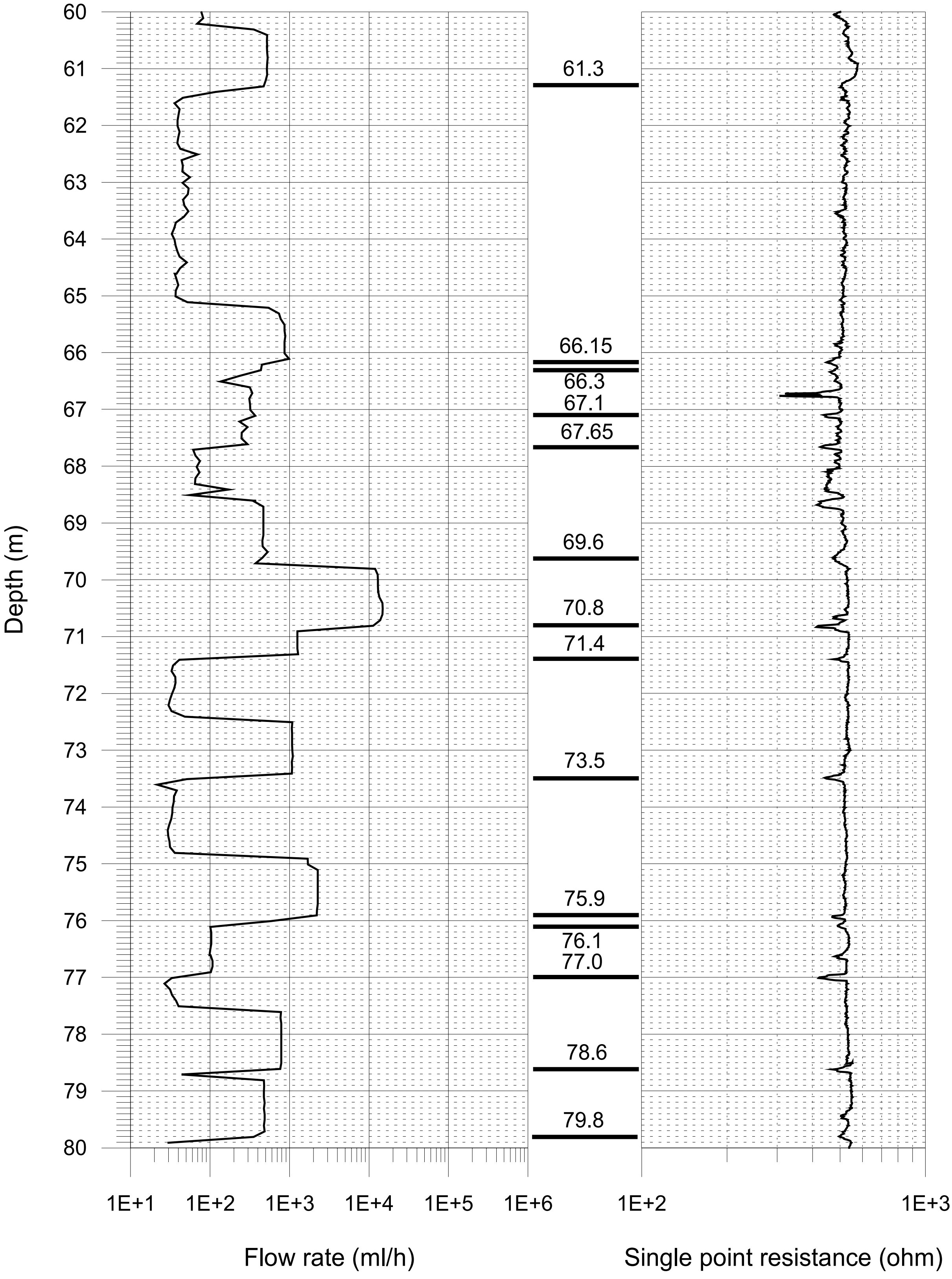
FLOW RATE AND SINGLE POINT RESISTANCE LOGS
DEPTHS OF LEAKY FRACTURES
ÄSPÖ, KA2511A



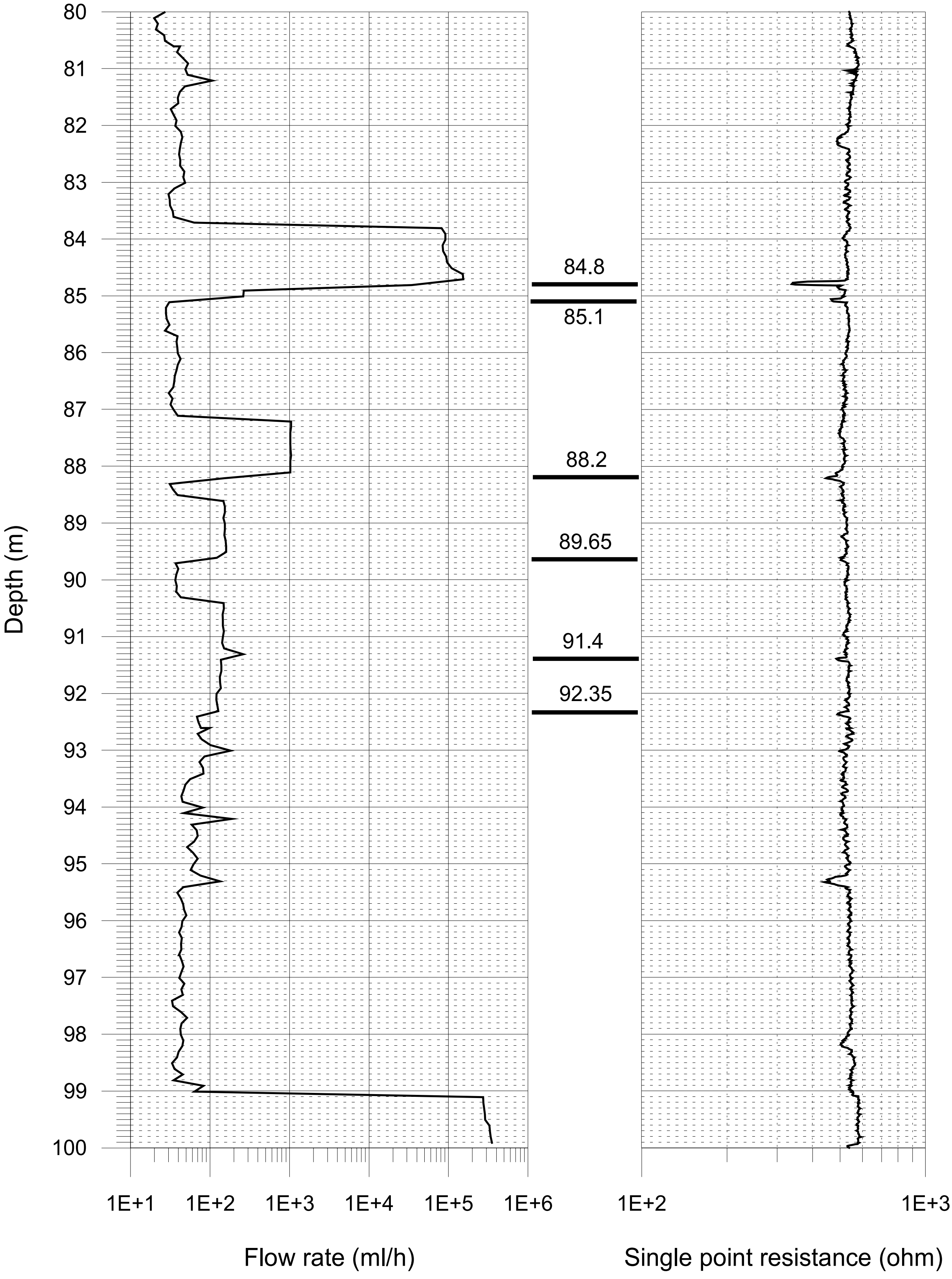
FLOW RATE AND SINGLE POINT RESISTANCE LOGS
DEPTHS OF LEAKY FRACTURES
ÄSPÖ, KA2511A



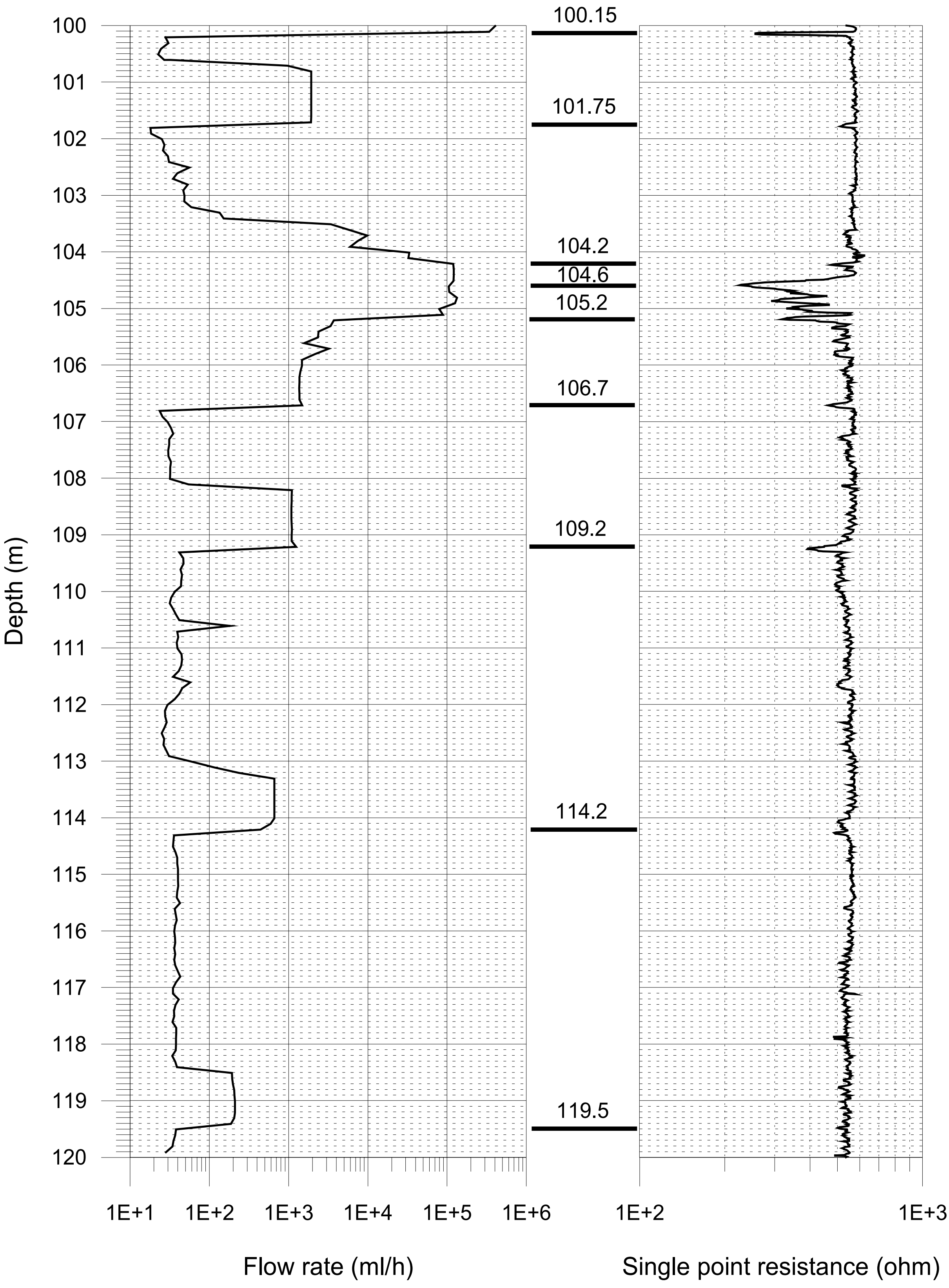
FLOW RATE AND SINGLE POINT RESISTANCE LOGS
DEPTHS OF LEAKY FRACTURES
ÄSPÖ, KA2511A



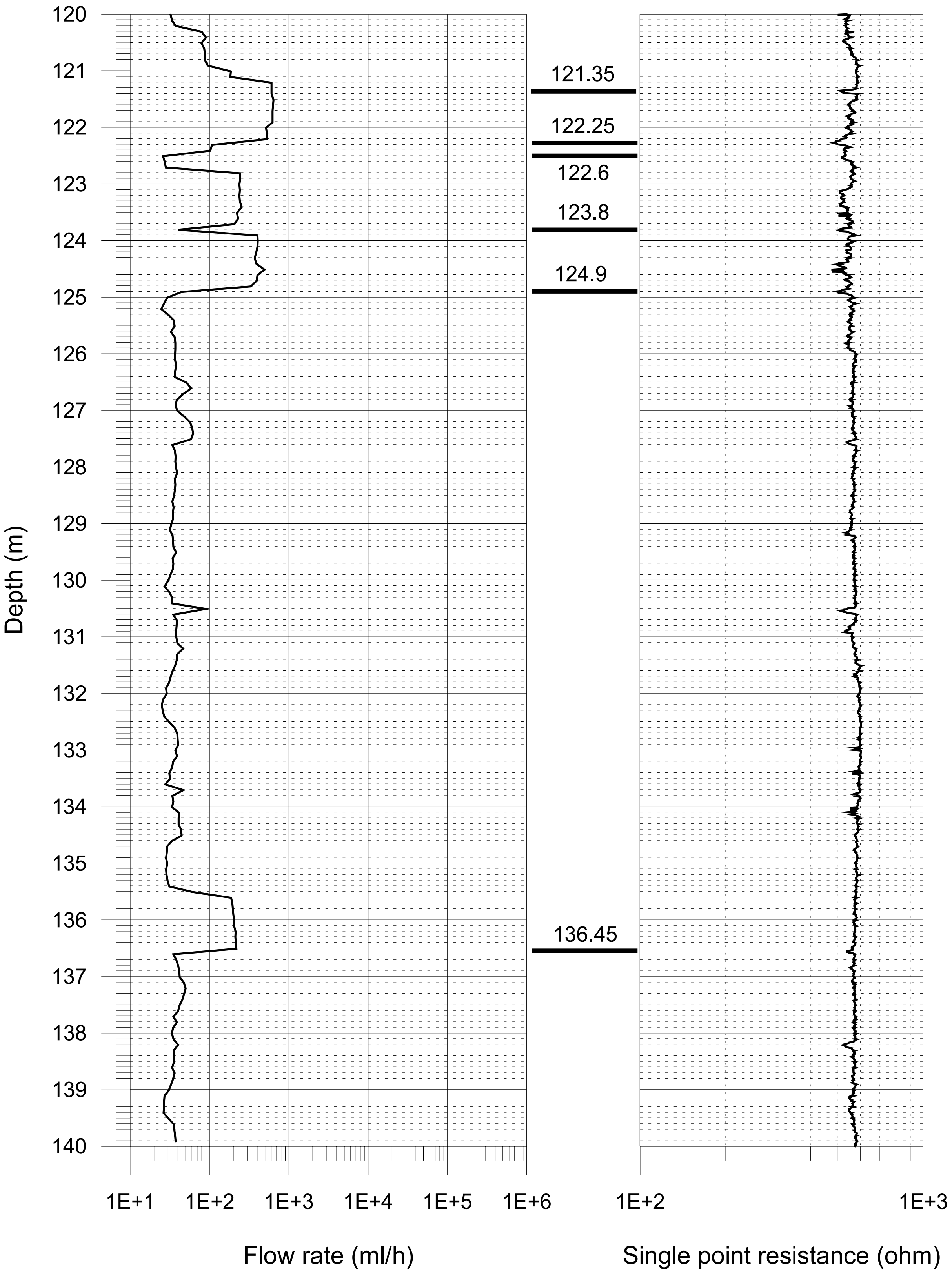
FLOW RATE AND SINGLE POINT RESISTANCE LOGS
DEPTHS OF LEAKY FRACTURES
ÄSPÖ, KA2511A



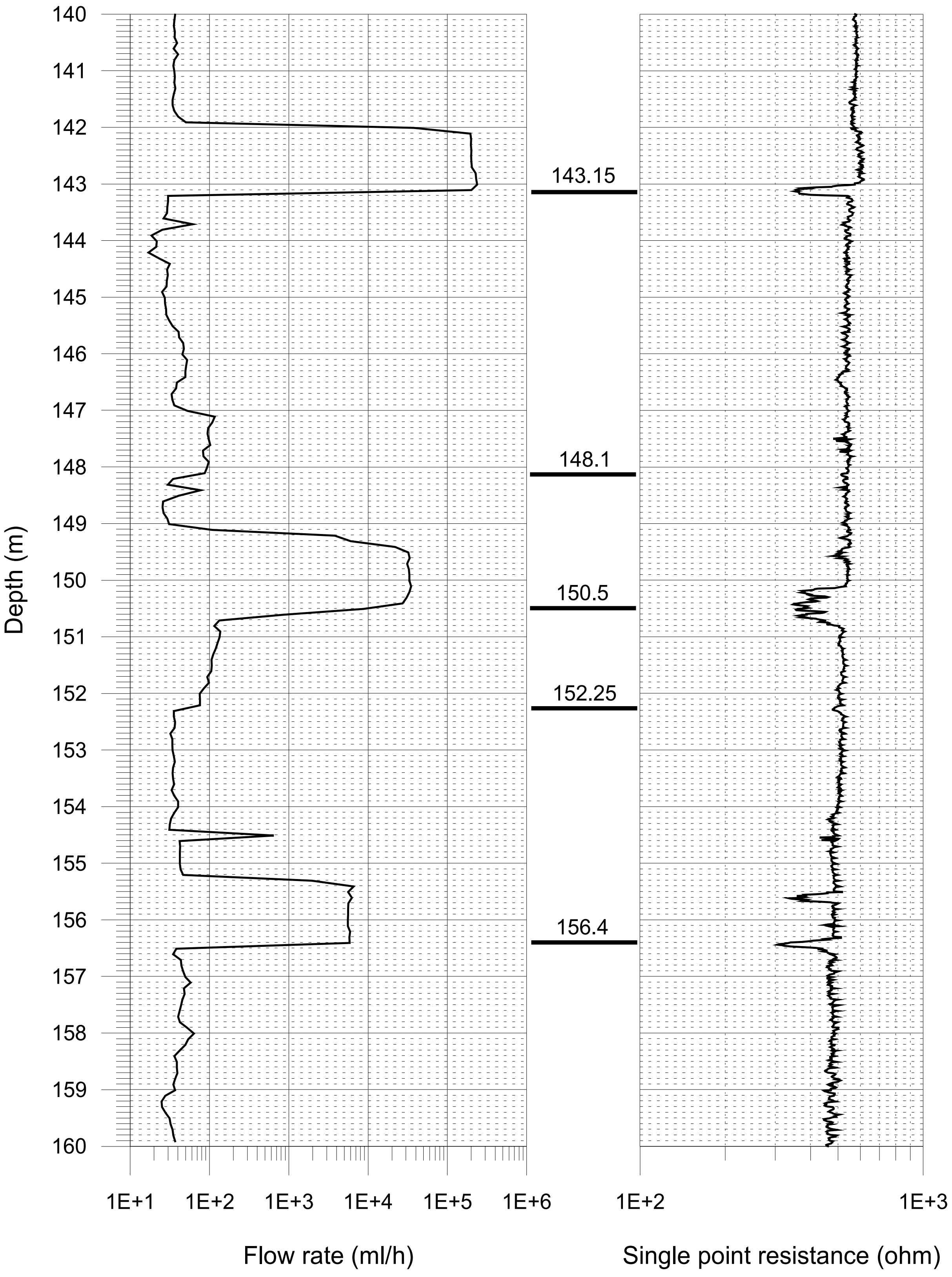
FLOW RATE AND SINGLE POINT RESISTANCE LOGS
DEPTHS OF LEAKY FRACTURES
ÄSPÖ, KA2511A



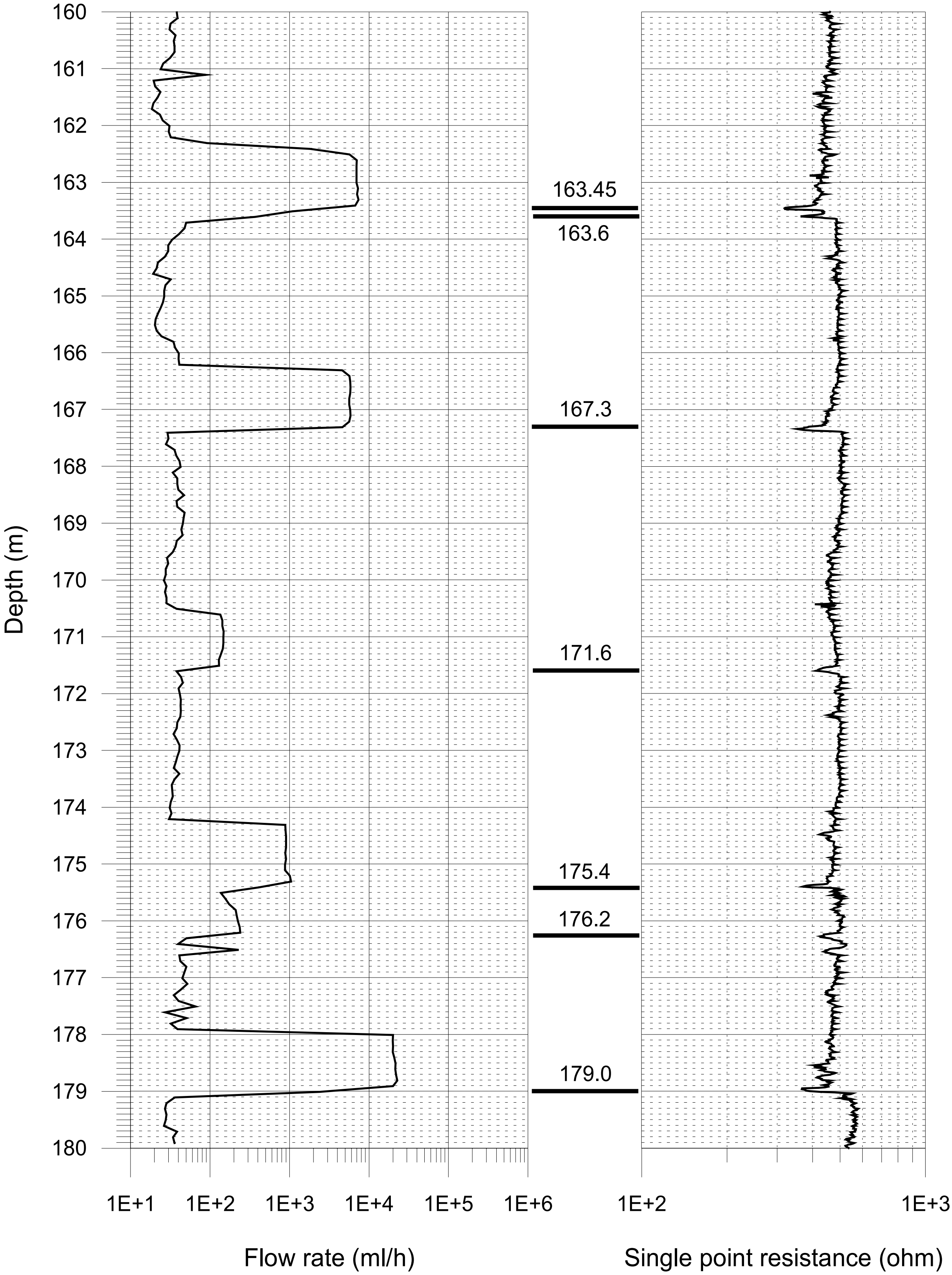
FLOW RATE AND SINGLE POINT RESISTANCE LOGS
DEPTHS OF LEAKY FRACTURES
ÄSPÖ, KA2511A



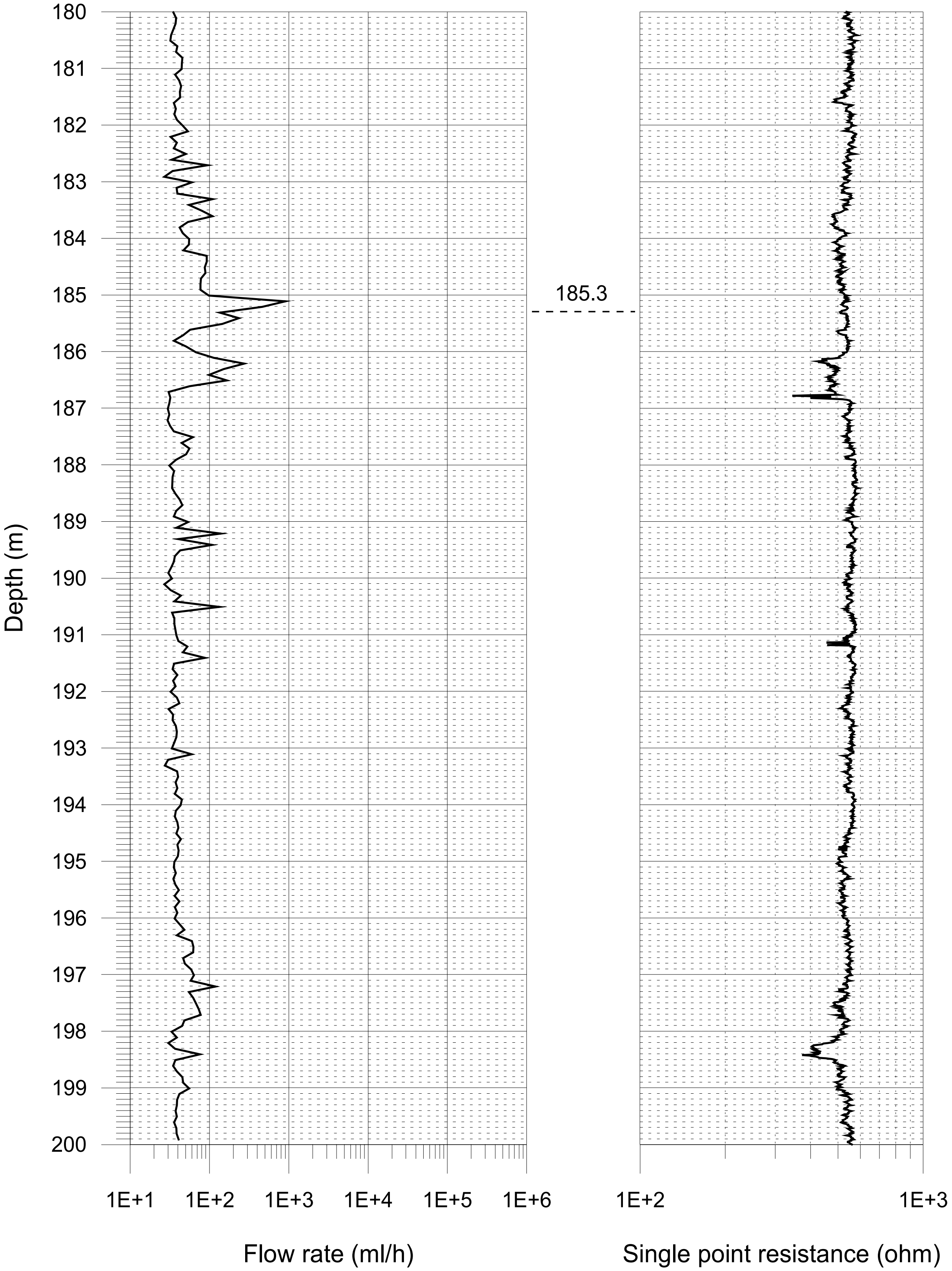
FLOW RATE AND SINGLE POINT RESISTANCE LOGS
DEPTHS OF LEAKY FRACTURES
ÄSPÖ, KA2511A



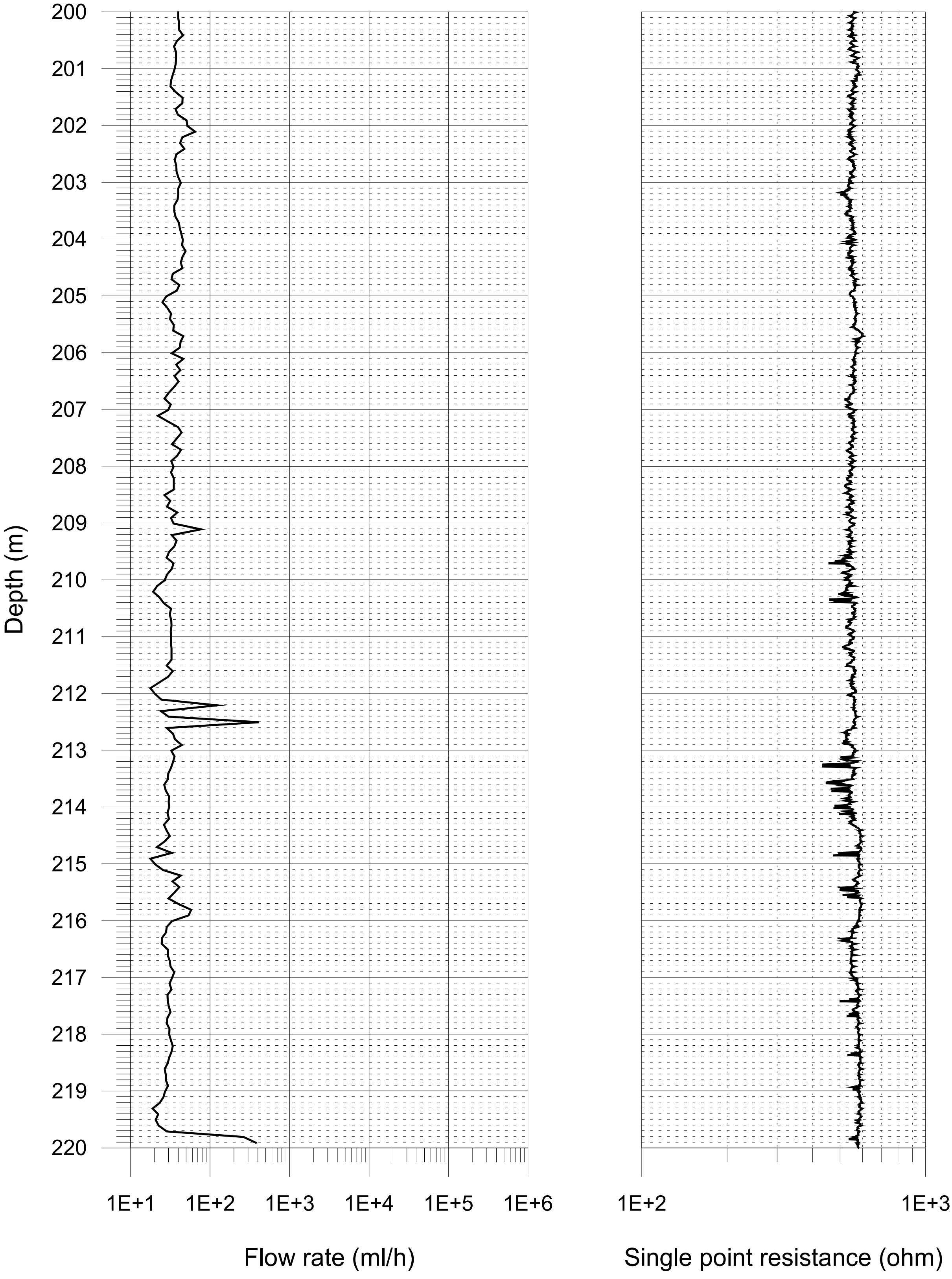
FLOW RATE AND SINGLE POINT RESISTANCE LOGS
DEPTHS OF LEAKY FRACTURES
ÄSPÖ, KA2511A



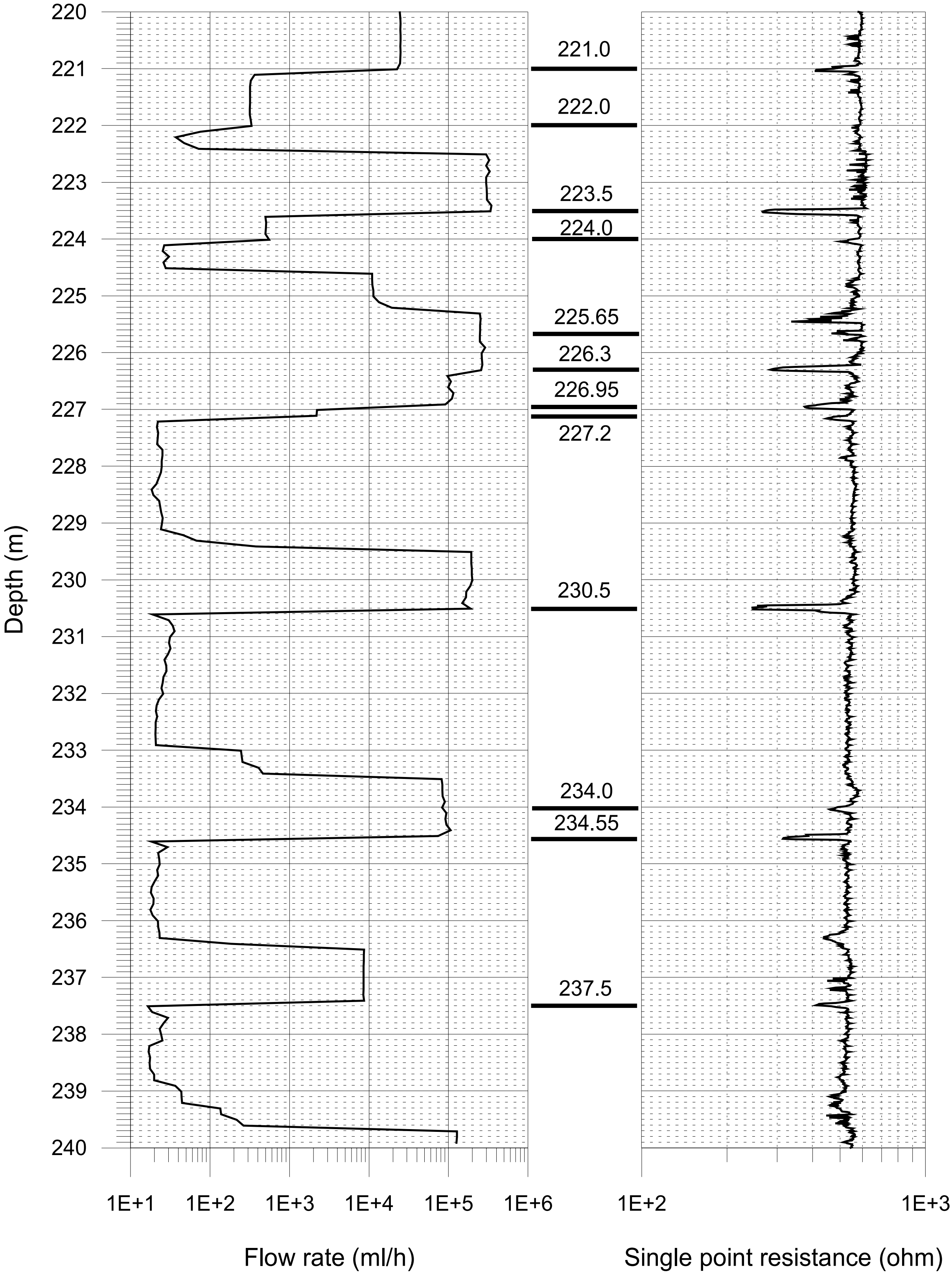
FLOW RATE AND SINGLE POINT RESISTANCE LOGS
DEPTHS OF LEAKY FRACTURES
ÄSPÖ, KA2511A



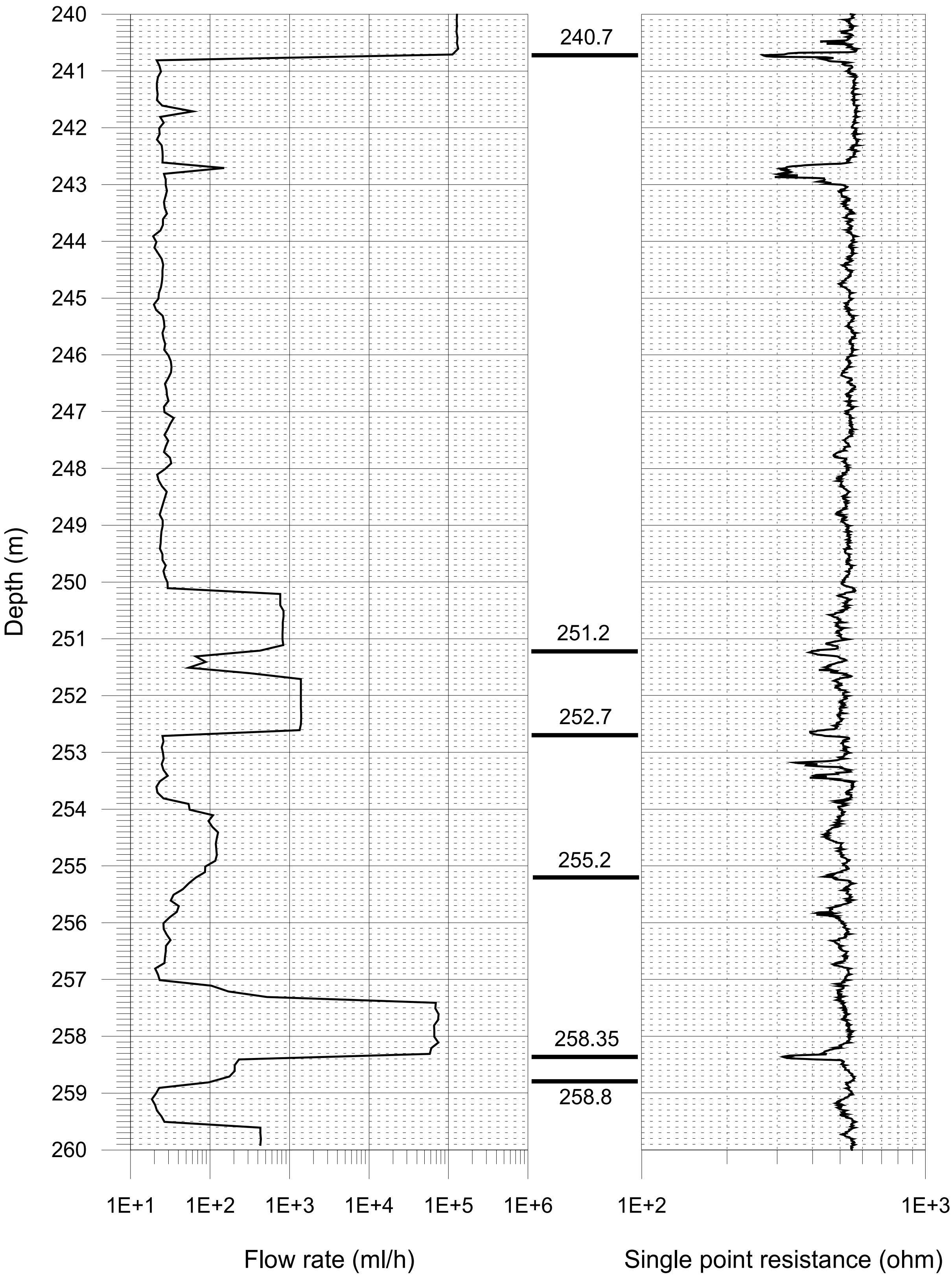
FLOW RATE AND SINGLE POINT RESISTANCE LOGS
DEPTHS OF LEAKY FRACTURES
ÄSPÖ, KA2511A



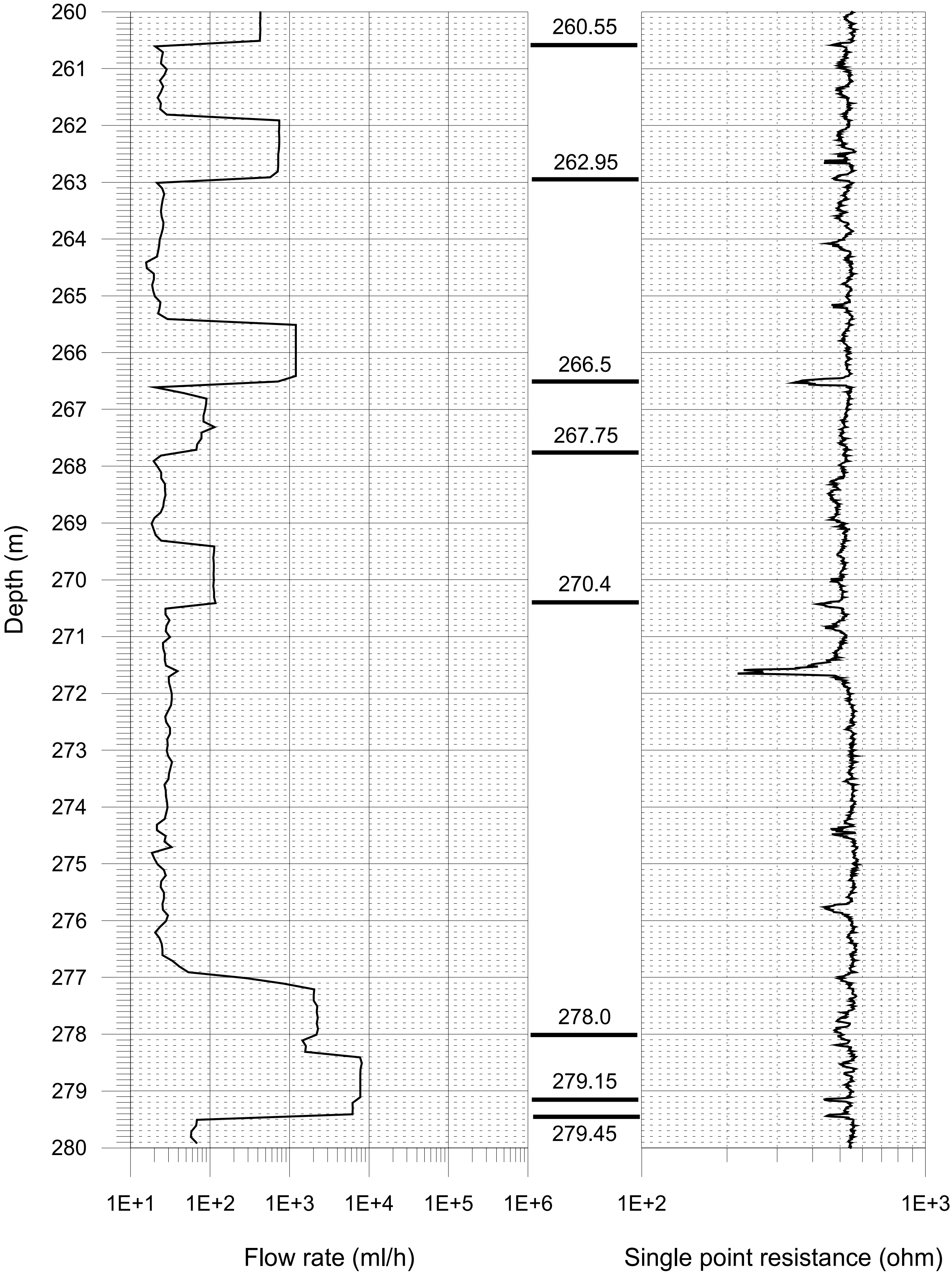
FLOW RATE AND SINGLE POINT RESISTANCE LOGS
DEPTHS OF LEAKY FRACTURES
ÄSPÖ, KA2511A



FLOW RATE AND SINGLE POINT RESISTANCE LOGS
DEPTHS OF LEAKY FRACTURES
ÄSPÖ, KA2511A



FLOW RATE AND SINGLE POINT RESISTANCE LOGS
DEPTHS OF LEAKY FRACTURES
ÄSPÖ, KA2511A



FLOW RATE AND SINGLE POINT RESISTANCE LOGS
DEPTHS OF LEAKY FRACTURES
ÄSPÖ, KA2511A