

Forsmark site investigation

Drilling of a flushing water well, HFM06, and two groundwater monitoring wells, HFM07 and HFM08, at drillsite DS3

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February 2004

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Keywords: AP PF 400-02-36, Percussion drilling, Flushing water well, Monitoring well, Soil, Bedrock, DS3.

This report concerns a study which was conducted for SKB. The conclusions and viewpoints presented in the report are those of the authors and do not necessarily coincide with those of the client.

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1 Introduction

SKB performs site investigations to locate a deep repository for high level radioactive waste /1/. The investigations are performed in two Swedish municipalities: Östhammar and Oskarshamn. The investigation area in Östhammar is situated close to the nuclear power plant at Forsmark /2/, see Figure 1-1.

Drilling is one important activity performed within the frame of the site investigations. Three main types of boreholes are produced: core drilled boreholes, percussion drilled boreholes in solid rock and boreholes drilled through unconsolidated soil. The initial phase of the investigations includes drilling of three, c. 1000 m deep boreholes, one at each of the drillsites DS1, DS2 and DS3, see Figure 1-1. At these sites, also percussion drilled boreholes in solid rock and in soil have been produced. During the continued investigations, several drillsites for deep core drilled boreholes will be established. Some of the drillsites will serve as the starting point for two or more deep or semi-deep (500–700 m) boreholes.

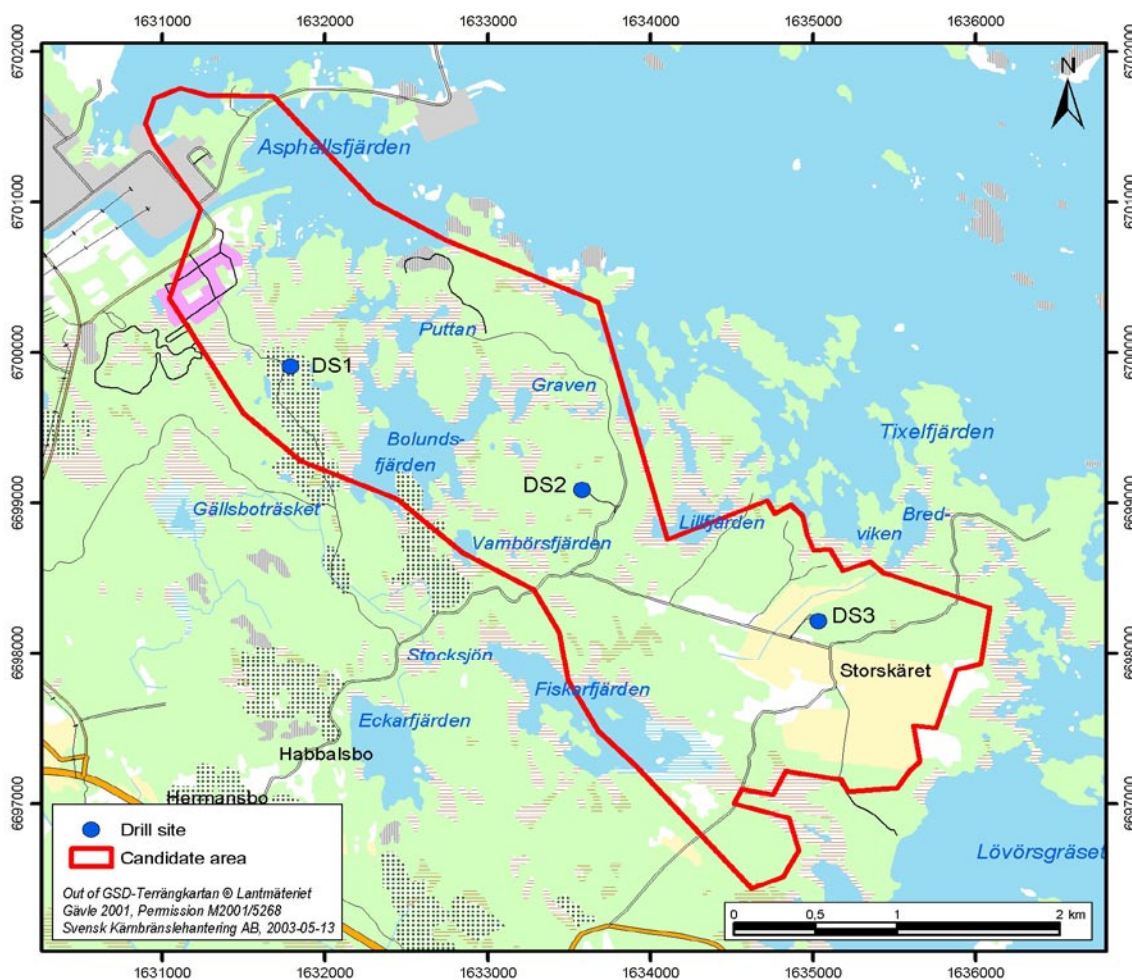


Figure 1-1. The investigation area at Forsmark including the candidate area selected for more detailed investigations. Drillsites DS1-3 are marked with blue dots.

At drillsite DS3, the deep cored borehole is named KFM03A, see Figure 1-2. The results from the drilling operations of this borehole will be presented in /3/. One extra core drilled borehole is named KFM03B, see Figure 1-2. It was drilled to 100 m depth and also the results from this borehole will be presented in /3/. Besides the core drilled boreholes, altogether three percussion boreholes in solid rock with the depths 110.70, 122.55 respectively 143.50 metres, as well as three boreholes through the soil layer were drilled at the drillsite (Figure 1-2). Results from drilling of the three monitoring wells in soil at drillsite DS3, SFM0006, SFM0007 and SFM0008 (Figure 1-2), are presented in /4/.

In the present report, performance of and results from drilling of the three percussion boreholes in solid rock, HFM06, HFM07 and HFM08, at drillsite DS3 are dealt with. The report also treats investigations made during and immediately after the drilling operations including the results obtained.

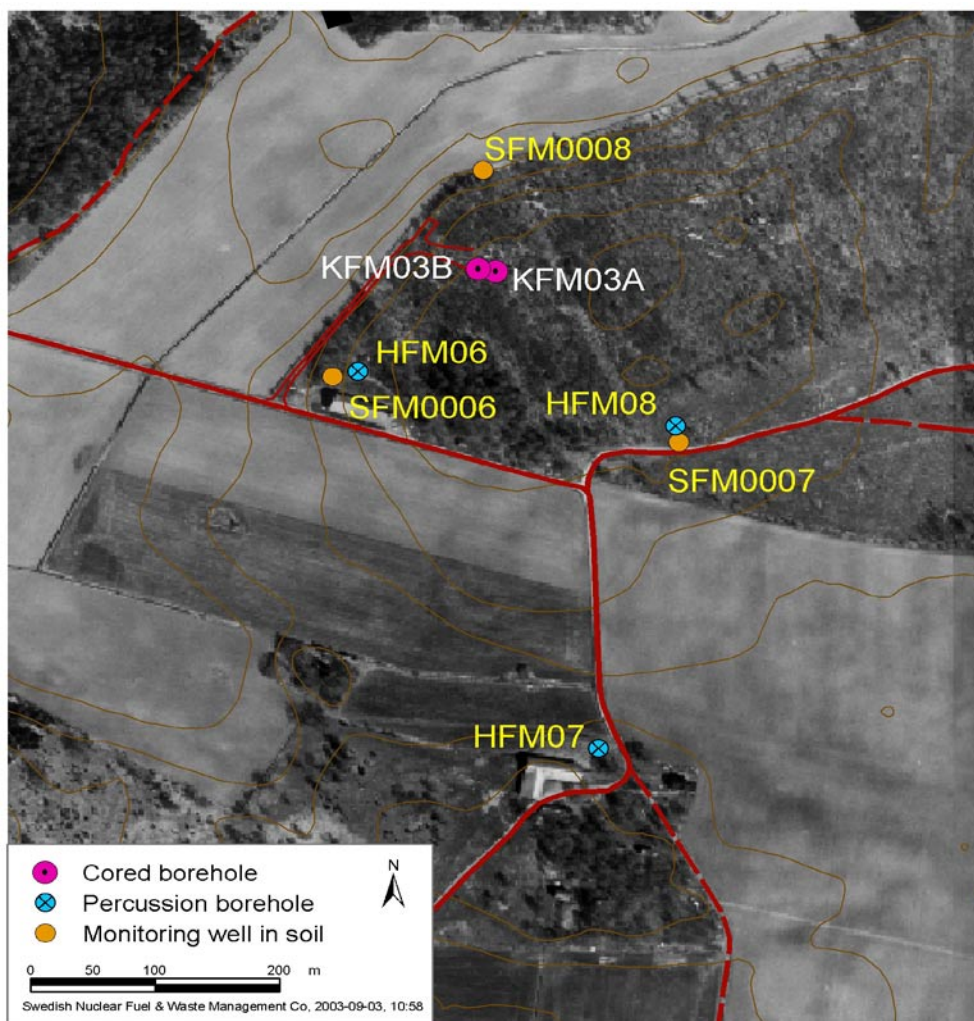


Figure 1-2. Borehole locations at drillsite DS3. Besides the flushing water well and the monitoring wells in hard rock, also three monitoring wells in unconsolidated soil were drilled.

Borehole HFM06 was produced for supply of the flushing water needed for drilling the deep cored borehole KFM03A, whereas the boreholes HFM07 and HFM08 were drilled to serve as monitoring wells, enabling long-term study of groundwater levels and ground-water-chemical composition. The drilling operations were performed by Sven Andersson in Uppsala AB, with support from SKB-personnel regarding measurements and tests during drilling. A Nemek 407 RE percussion drilling machine operated by a one-man drill crew was employed for the commission.

The drilling and measurement operations were performed according to Activity Plan AP PF 400-02-36 (SKB internal controlling document) . The Activity Plan refers to SKB MD 610.003, Version 1.0 (Method Description for Percussion Drilling).

2 Objective and scope

Drilling of a 1000 m deep cored borehole according to SKB procedures is associated with extensive operations regarding e.g. water handling. A so called telescopic drilling technique is applied, which involves that the upper 100 m of the borehole is percussion drilled with a large diameter (≥ 200 mm), whereas the borehole section 100–1000 m is core drilled with a diameter of approximately 76–77 mm.

Core drilling demands injection of relatively large amounts of flushing water through the drill string and drill bit for cooling the drill bit and transportation of drill cuttings from the borehole bottom to the ground surface. At the SKB site investigations, an air-lift pump is installed in the upper, large-diameter part of the telescopic drilled borehole in order to enhance the recovery of flushing water and drill cuttings. During the entire drilling period (comprising c. three months when drilling a 1000 m borehole) the air-lift pumping and, to a lesser extent, the injection of flushing water, affects the groundwater levels and, possibly, the groundwater-chemical composition in the near-surrounding of the deep borehole. To enable observation of groundwater level fluctuations due to the operations in connection with drilling of a deep cored borehole, monitoring wells have to be drilled.

However, borehole HFM06 was drilled with the primary aim to, at a convenient distance (c. 140 m) from the core drilled boreholes KFM03A and KFM03B, account for the supply of relatively large amounts (c. 400 L/min) of clean flushing water, whereas the boreholes HFM07 and HFM08 were drilled to serve primarily as a monitoring wells. Such wells may be used for the study of groundwater levels and groundwater-chemical conditions under undisturbed as well as disturbed conditions.

Boreholes HFM06-08 are of so called SKB chemical type. This means that the boreholes are prioritized for hydro-geochemical investigations (also including study of microorganisms, primarily bacteria, occurring in the groundwater). The practical consequence is that all DTH (Down The Hole)-equipment used during and/or after drilling must undergo severe cleaning procedures, see Section 4.1.

The strategy for locating the monitoring wells HFM07 and HFM08 was to set them within the expected radius of influence of groundwater-level draw-down (approximately 300–400 m from borehole KFM03A) due to air-lift pumping during drilling. The location was also selected between geophysical anomalies in what was estimated to be homogeneous, low-fractured bedrock /5/. Another purpose with the monitoring wells HFM07 and HFM08 was to investigate a couple of the by reflection seismics indicated geological structures in the area (Figure 2-1).

Data gained during monitoring of undisturbed conditions will be part of the characterization of the groundwater conditions of the shallow part of the bedrock. Monitoring during the percussion and core drilling operations in KFM03A and KFM03B is primarily part of the environmental control program for these drilling operations. However, also these data may be used for basic characterization purposes. After completion of drilling and borehole investigations at DS3, boreholes HFM06, HFM07 and HFM08 will be used for long-term groundwater level monitoring and groundwater sampling.

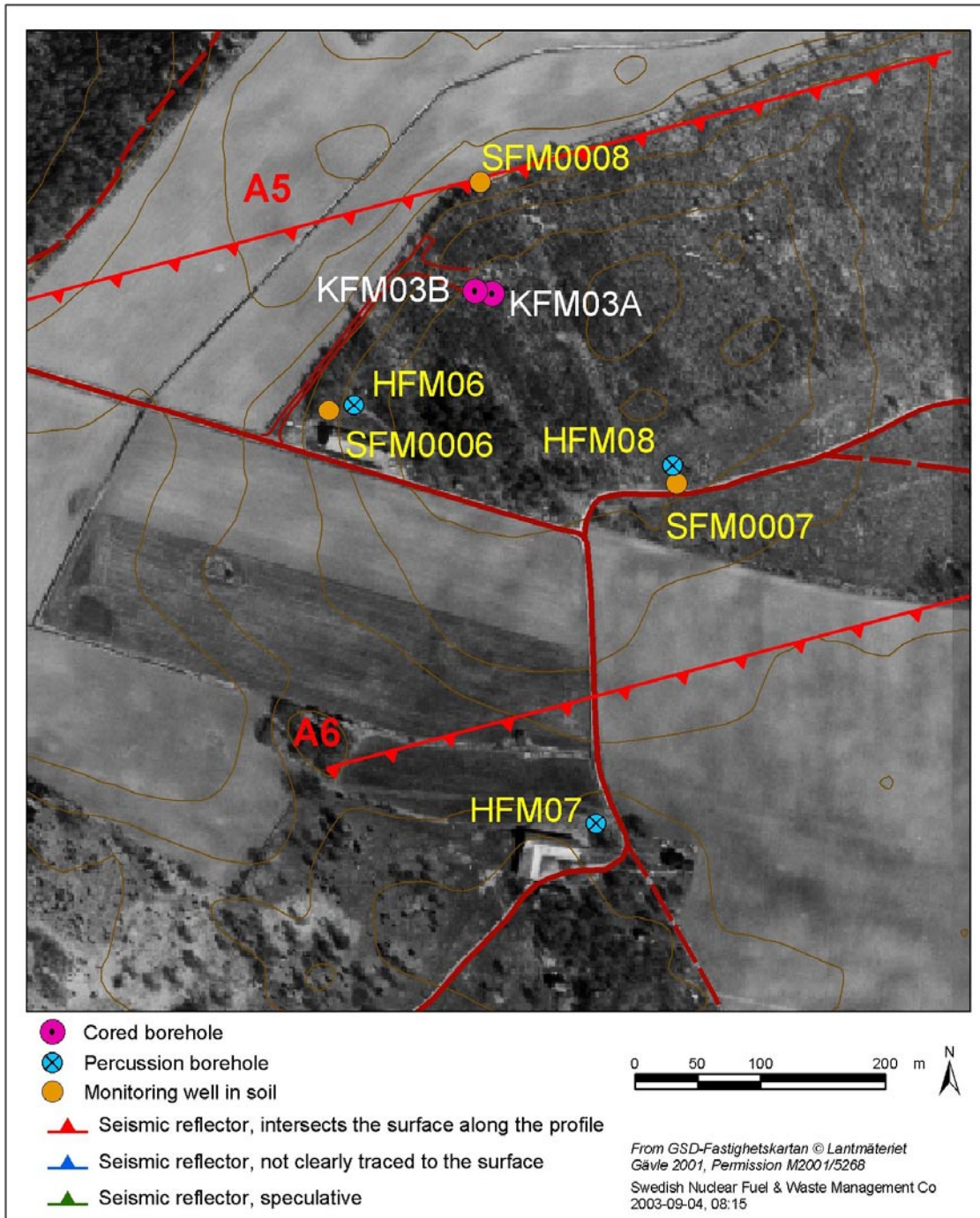


Figure 2-1. Borehole and seismic reflector locations at drillsite DS3.

3 Equipment

Drilling of the three percussion boreholes in solid rock at drillsite DS3 was performed with a Nemek 407 RE DTH percussion drilling machine (Figure 3-1) supplied with various accessory equipment. In this chapter short descriptions are given of the drilling equipment, the technique and equipment for gap injection of the borehole casing and of the instrumentation used for deviation measurements performed after completion of drilling. Also the equipment used for measurements and sampling during drilling is briefly described.



Figure 3-1. The Nemek 407 percussion drilling machine engaged for drilling the three percussion boreholes in solid rock at drillsite DS3. Water and drilling debris is discharged to the container. Photo Alf Sevastik.

3.1 Drilling equipment

The drilling machine was equipped with separate engines for transportation and power supplies. For discharge of water and drill cuttings from the borehole, a 27 bar diesel air-compressor, type Atlas-Copco XRVS 455 Md was used. The DTH drillhammer was of type Secoroc 5", lowered into the borehole by a Driconeq 76 mm pipe string.

A 254 mm (external diameter) temporary steel casing was driven through the soil layer and further through fractured rock and a certain distance into solid rock, see detailed description in Section 4.3. The gap between the borehole wall and the casing was grouted with cement, see Section 3.2.

Cleaning of all DTH-equipment was performed with a high-capacity steam cleaner of type Kärcher HDS 1195.

Recovered drill cuttings and groundwater were, for environmental reasons, not allowed to spread out on the ground surface, but was conducted to and collected in a steel container. After completion of drilling, the container was removed from the site and emptied at an approved deposit.

3.2 Gap injection technics and equipment

Grouting the gap between the borehole wall and the casing pipe with cement is performed in order to prevent surface water and shallow groundwater to infiltrate into deeper parts of the borehole. The cement application may be performed using different techniques and equipment. Two variants of gap injection with cement are illustrated in Figure 3-2. In boreholes HFM06, HFM07 and HFM08 only the hose technique was applied.

3.3 Equipment for deviation measurements

Deviation measurements were performed in all three boreholes using a Reflex EZ-shot (magnetic) equipment. Azimuth and dip were measured every third metre. The coordinates for the starting point and the measured values were used for calculating the coordinates for every measured point.

3.4 Equipment for measurements and sampling during drilling

Flow measurements during drilling were performed using measuring vessels of different sizes and a stop watch. Measurements of drilling penetration rate were accomplished with a carpenter's rule and a stop watch.

Samples of soil and drill cuttings were collected in sampling pots and groundwater in small bottles. A field measuring devise was used for measurements of electrical conductivity of the groundwater.

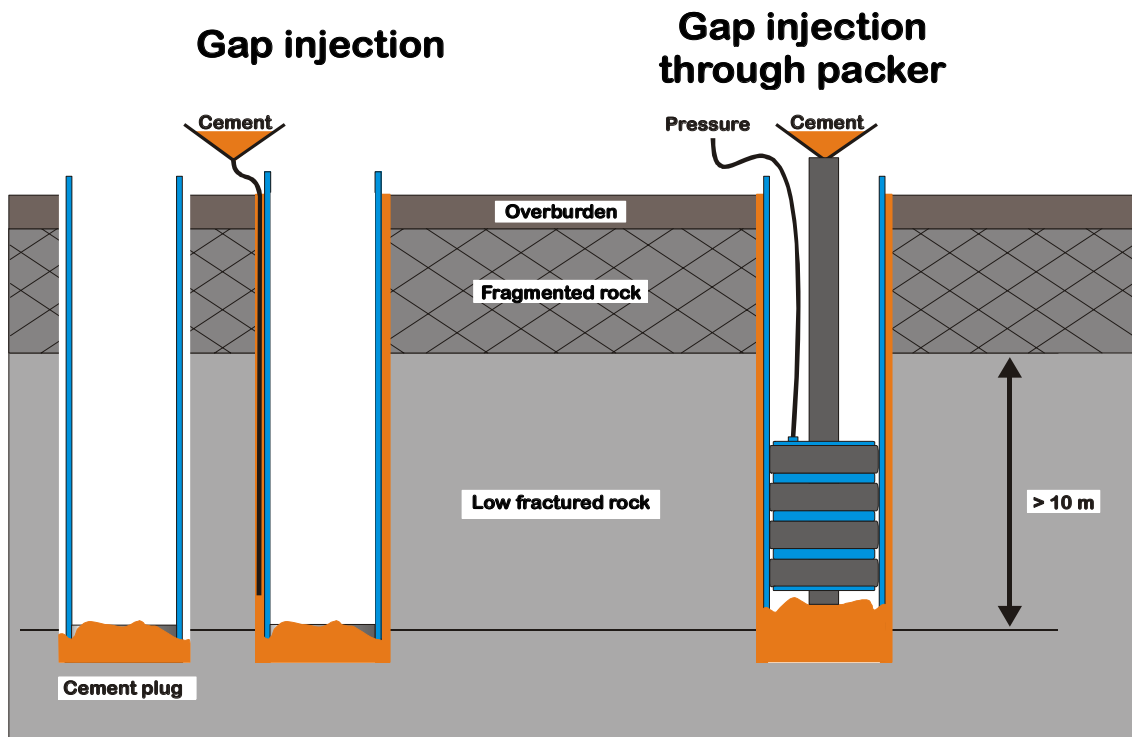


Figure 3-2. Gap injection technique. In order to grout the gap between the borehole wall and the casing, two different systems may be used. To the left, filling up a cement-water mixture with a flexible hose is shown. To the right, injection is performed through a borehole packer.

4 Execution

The performance of the work followed SKB MD 610.003, Version 1.0 (Method Description for Percussion Drilling) and included the following items:

- preparations,
- mobilisation, including lining up the machine and measuring the position,
- drilling, measurements, and sampling during drilling,
- finishing off work,
- deviation measurements,
- data handling,
- environmental control.

4.1 Preparations

The preparation stage included the Contractor's service and function control of his equipment. The machinery was obliged to be supplied with fuel, oil and grease exclusively of the types stated in SKB MD 600.006, Version 1.0 (Method Instruction for Chemical Products and Materials). Finally, the equipment was cleaned (Figure 4-1) in accordance with SKB MD 600.004, Version 1.0 (Method Instruction for Cleaning Borehole Equipment and certain Ground-based Equipment) at level two, used for SKB boreholes of chemical type.

4.2 Mobilisation

Mobilisation onto and at the site started with transport of drilling and accessory equipment to the drill site. The mobilisation also comprised preparation of the drill site, cleaning of all DTH-equipment at level two according to SKB MD 600.004, Version 1.0, lining up the machine and final control of function.

4.3 Drilling, measurements, and sampling during drilling

4.3.1 Drilling through the overburden

In normal Swedish terrain, the rock surface is often covered with a more or less thick stratum of unconsolidated rock material, e.g. till. The procedure of drilling a percussion borehole is in this case divided into two drill phases: 1) drilling through the overburden and 2) drilling in fractured and/or solid rock. The bedrock where boreholes HFM06, HFM07 and HFM08 are situated is till covered, and hence drilling was performed according to these two phases. Figure 4-2 schematically illustrates the different steps carried out.



Figure 4-1. A high temperature steam cleaner is used for cleaning the drill pipes at level two according to SKB MD 600.004, Version 1.0, before start of Ejector-NO-X drilling. Photo Alf Sevastik.

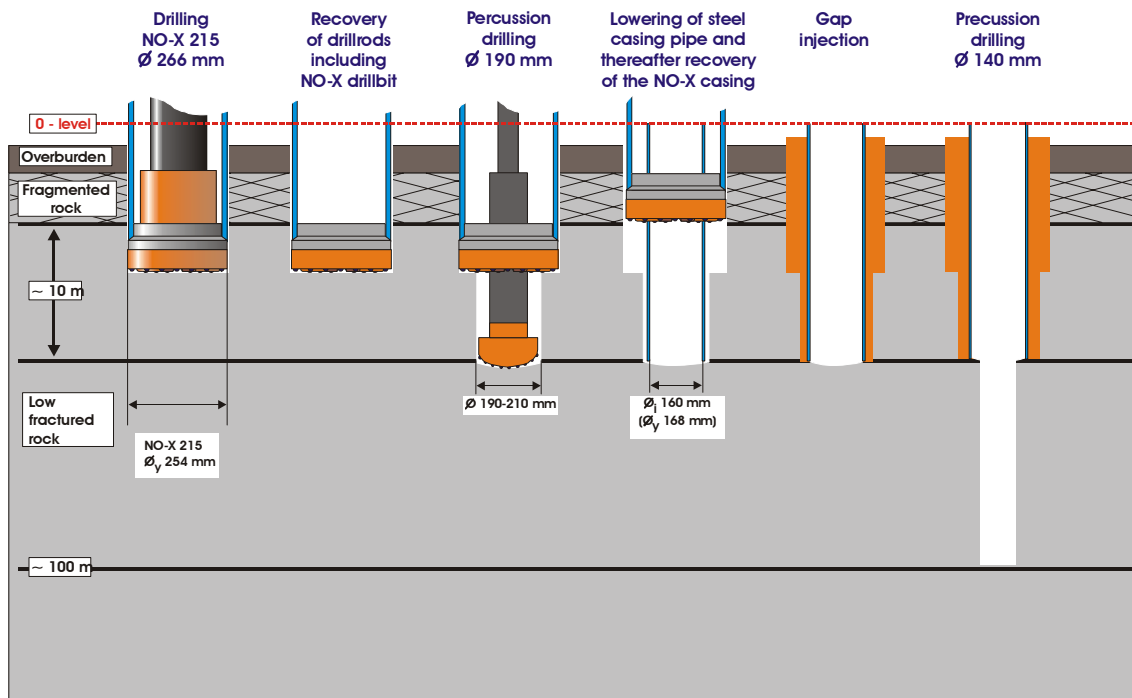


Figure 4-2. The different steps included in the performance of the percussion drilled boreholes HFM06-08.

Drilling through the overburden may be accomplished by using different technical approaches. In the present commission, so called Ejector-NO-X was applied. The prefix “ejector” indicates that the discharge channels for the flushing medium, in this case compressed air, are constructed in such a way that the oxygen and oil contamination of the penetrated soil layers is reduced compared to conventional systems. The NO-X system represents a method for concentric drilling and simultaneous casing driving through the overburden. A circular pilot bit, attached to a DTH-hammer shank, and with large internal flushing holes and external flushing grooves, is connected to a symmetrical ring bit (reamer) with an internal bayonet coupling. The pilot bit and the ring bit are both rotating clockwise, thereby drilling a borehole with a diameter large enough to let the casing easily slip down into the reamed borehole. The ring bit is rotating freely against the casing shoe, which is welded to the lower end of the casing. The casing is non-rotating during drilling.

Drilling through the overburden of boreholes HFM06-08 basically followed the principles for the Ejector-NO-X system. However, the method was to some extent applied in a non-conventional manner. During drilling of a borehole with the diameter 266 mm, a temporary steel casing with an outer diameter of 254 mm was driven through the till overburden and through fragmented rock a short distance into fresh, low-fractured rock, see Figure 4-2. The drillrods with the drillhammer and pilot bit were then retrieved from the borehole. A percussion drill bit was lowered into the borehole inside the temporary casing, and a borehole with a diameter of 190 mm were drilled 12 m in HFM06, 18 m in HFM07 respectively 18 m in HFM08 into high-quality, low-fractured rock.

Again the drillrods, drillhammer and drill bit were retrieved, whereafter a stainless steel casing with the external/internal diameter 168/160 mm was lowered into the borehole in 3 m-lengths, which were successively welded together.

4.3.2 Gap injection

When the casing string had been firmly installed in the borehole, the narrow gap between the borehole wall and the outer wall of the casing was grouted with a cement/water-mixture according to the hose technique illustrated in Figure 3-2.

4.3.3 Percussion drilling in hard rock

After stiffening of the grout, drilling could continue and was now performed to the full borehole length with conventional percussion drilling. Before start of drilling, the diameter of the drill bit was measured. In this last drill step, the initial borehole diameter (approximately the same as the drill bit diameter) is normally 140 mm, see Figure 4-2. However, a diameter decrease of about 1 mm/100 m drill length is to be expected when drilling in the rock types prevailing in the Forsmark area. For boreholes deeper than 100 metres the drill bit has to be grinded.

4.3.4 Sampling and measurements during drilling

During drilling, a sampling and measurement program was performed, which included:

- Collecting of one soil sample per metre drill length. Analysis and results are reported in /6/.
- Collecting of one sample per 3 metre drill length of drill cuttings from the bedrock (Figure 4-3). Each sample consists of three individual samples taken at every metre borehole length, collected in one plastic box marked with a sample number. Effort is devoted to avoid mixing of the three individual samples. A first description of the material was made on-site including the mineral content and rock structure, which gave a preliminary classification of the rock type. These samples were examined and interpreted together with a BIPS-log (so called Boremap-mapping) and reported in /7/.
- Measurements of the penetration rate (one measurement per 20 cm drill length). The time needed for the drill bit to sink 20 cm was recorded manually in a paper record.
- Performing one observation of groundwater flow (if any) and water colour per 20 cm drill length and a measurement of the flow rate at each major flow change observed. The measured values were noted in a paper record.
- Measurements of the electrical conductivity of the groundwater (if any) at each 3 metre drill length (noted in a paper record).

The results from the third and fourth items were used as supporting data for the Boremap-mapping mentioned above. The last item gave on-site information about hydraulic and hydro-geochemical characteristics of the penetrated aquifers at the respective drillsites.



*Figure 4-3. Sampling of one sample per 3 metre drill length of drill cuttings from the bedrock.
Photo Alf Sevastik.*

4.4 Finishing off work

Finishing off work included rinsing of the borehole from drill cuttings by a “blow out” with the compressor at maximum capacity during 30 minutes. The recovery of the ground-water table after rinsing was recorded, enabling a preliminary evaluation of the hydraulic conditions. The drillrods were then removed from the hole, and the diameter of the drill bit was measured as well as the deviation of the borehole. The borehole was secured by a stainless steel lockable cap, mounted on the casing. Finally, the equipment was removed, the site cleaned and a joint inspection made by representatives from SKB and the Contractor, to ensure that the site had been satisfactorily restored.

4.5 Data handling

Minutes for the following items: Activities, Cleaning of equipment, Drilling, Borehole, Percussion drilling penetration rate, Deliverance of field material and Discrepancy report were collected by the Activity Leader, who made a control of the information, and had it stored in the SKB database SICADA /8/.

4.6 Environmental control

A programme according to SKB’s routine for environmental control was followed throughout the activity. A checklist was filled in and signed by the Activity Leader and finally filed in the SKB archive.

5 Results

All data were stored in the SICADA database for Forsmark. Field Note numbers are 77, 78, 79 and 86 /8/.

Below, a summary of the data achieved is presented.

5.1 Borehole design

Administrative, geometric, and technical data for the percussion drilled boreholes HFM06–08 are presented in Table 5-1. The technical design of each borehole is illustrated in drawings in Figures 5-1, 5-2 and 5-3.

Table 5-1. Administrative, geometric and technical data for boreholes HFM06–08.

Parameter	HFM06	HFM07	HFM08
Drilling period	From 2002-12-18 to 2003-01-14	From 2003-01-16 to 2003-01-28	From 2003-01-29 to 2003-02-12
Borehole inclination (starting point)	–84.60° (– = downwards)	–84.52° (– = downwards)	–84.44° (– = downwards)
Borehole bearing	2.44°	342.32°	348.69°
Borehole length	110.70 m	122.55 m	143.50 m
Borehole diameter	From 0.00 m to 2.50 m: 0.254 m From 2.50 m to 12.00 m: 0.215 m From 12.00 m to 110.70 m: 0.134 m	From 0.00 m to 7.40 m: 0.254 m From 7.60 m to 18.00 m: 0.214 m From 18.00 m to 122.50 m: 0.140 m	From 0.00 m to 6.10 m: 0.254 m From 6.1 m to 18.00 m: 0.213 m From 18.00 m to 125.50 m: decreasing from 0.139 m to 0.137 m
Casing length	12.00 m	18.00 m	18.00 m
Casing diameter	$\varnothing_o/\varnothing_i = 168 \text{ mm}/160 \text{ mm}$ to 12.00 m $\varnothing_o/\varnothing_i = 168 \text{ mm}/146 \text{ mm}$ between 11.98 and 12.00 m	$\varnothing_o/\varnothing_i = 168 \text{ mm}/160 \text{ mm}$ to 18.00 m $\varnothing_o/\varnothing_i = 168 \text{ mm}/146 \text{ mm}$ between 17.98 and 18.00 m	$\varnothing_o/\varnothing_i = 168 \text{ mm}/160 \text{ mm}$ to 18.00 m $\varnothing_o/\varnothing_i = 168 \text{ mm}/146 \text{ mm}$ between 17.98 and 18.00 m
Drill bit diameter	Start of drilling: 0.134 m End of drilling: 0.134 m	Start of drilling: 0.140 m End of drilling: 0.140 m	Start of drilling: 0.139 m End of drilling: 0.137 m
Starting point coordinates (system RT90/RHB70)	Northing: 6697752.01 m Easting: 1634522.19 m Elevation: 6.64 m.a.s.l.	Northing: 6697416.25 m Easting: 1634715.69 m Elevation: 5.78 m.a.s.l.	Northing: 6697703.28 m Easting: 1634777.50 m Elevation: 7.13 m.a.s.l.

Technical data

Borehole HFM06

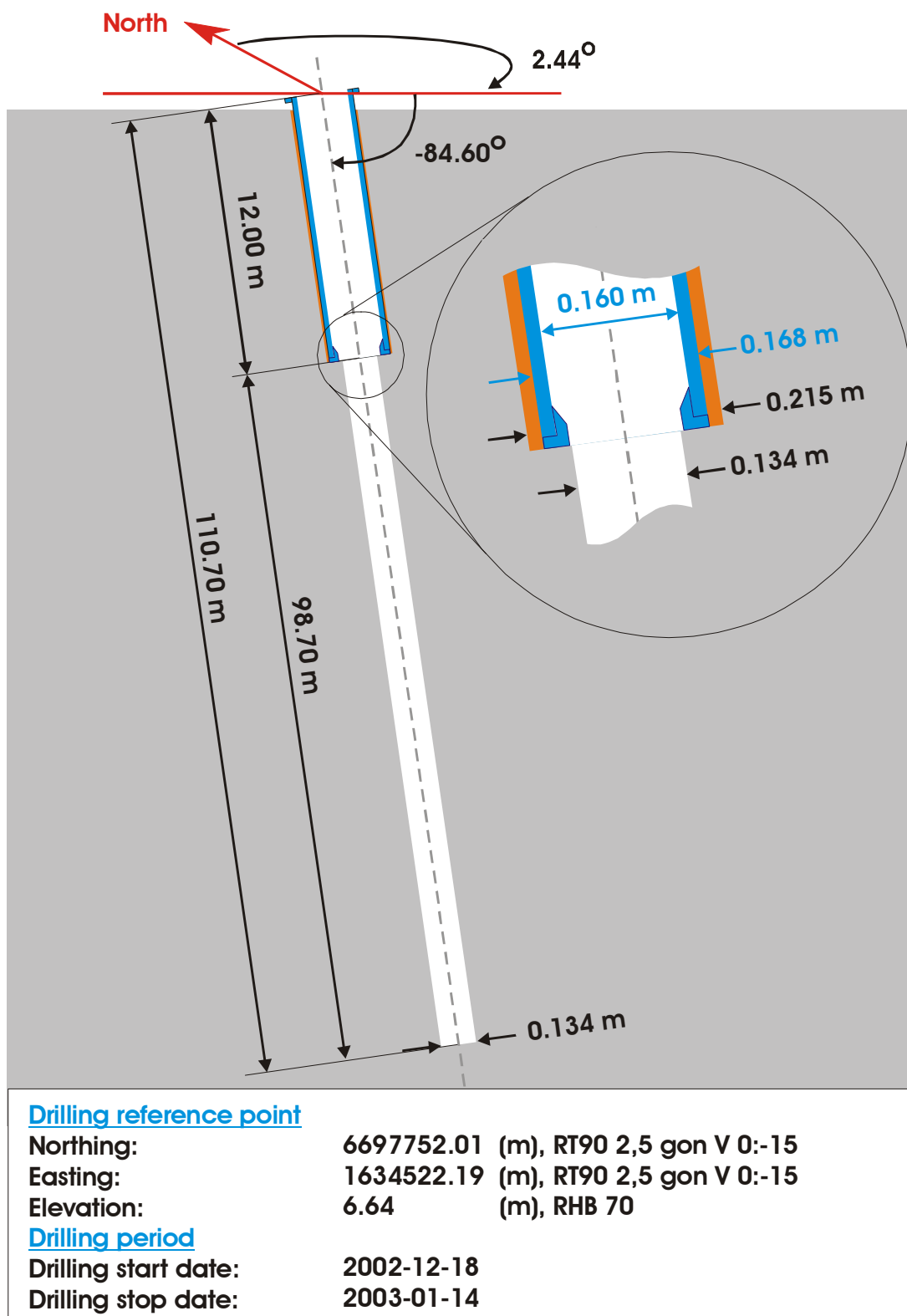
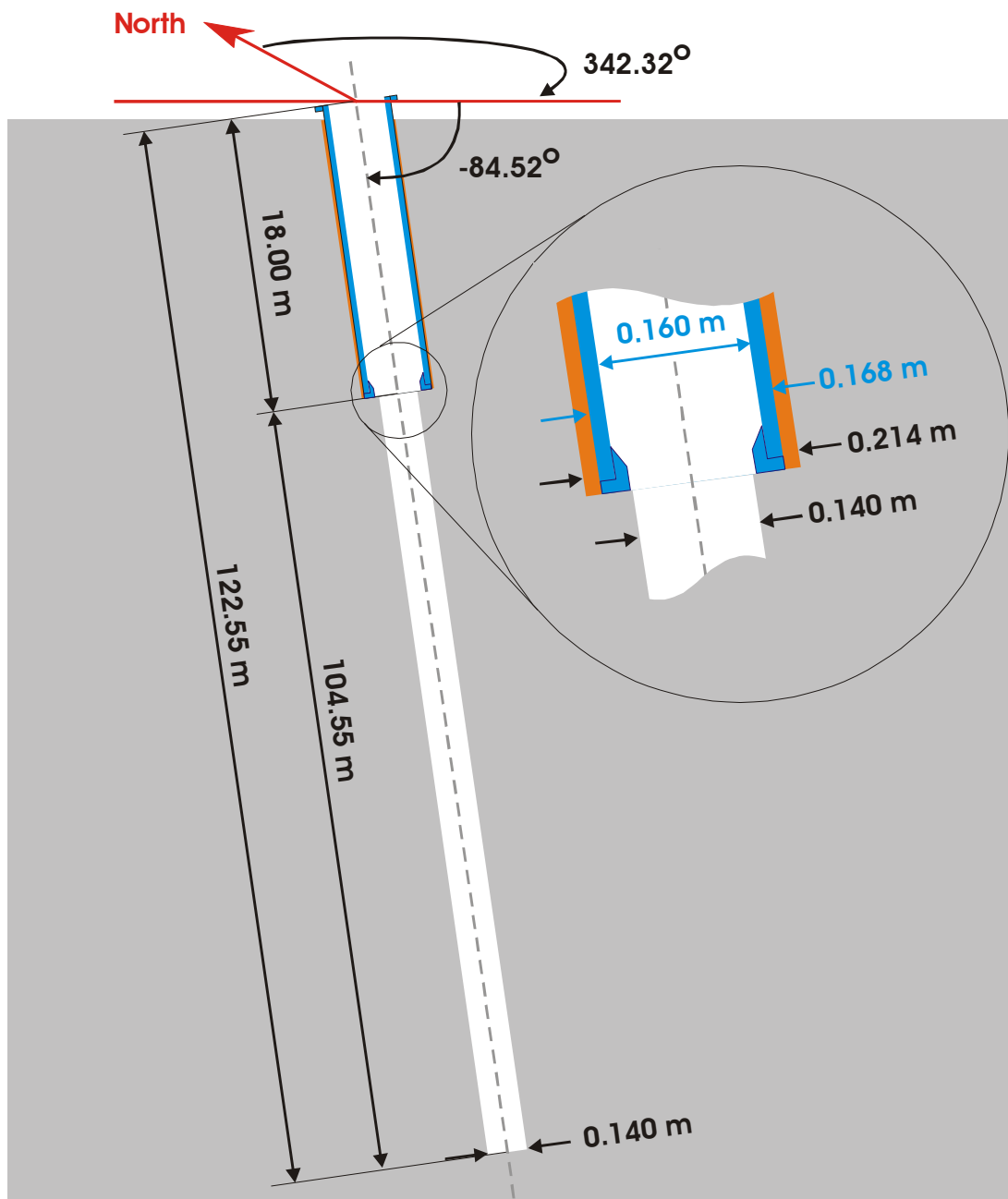


Figure 5-1. Technical data for borehole HFM06.

Technical data

Borehole HFM07



Drilling reference point

Northing: 6697416.25 (m), RT90 2,5 gon V 0:-15
Easting: 1634715.69 (m), RT90 2,5 gon V 0:-15
Elevation: 5.78 (m), RHB 70

Drilling period

Drilling start date: 2003-01-16
Drilling stop date: 2003-01-28

Figure 5-2. Technical data for borehole HFM07.

Technical data

Borehole HFM08

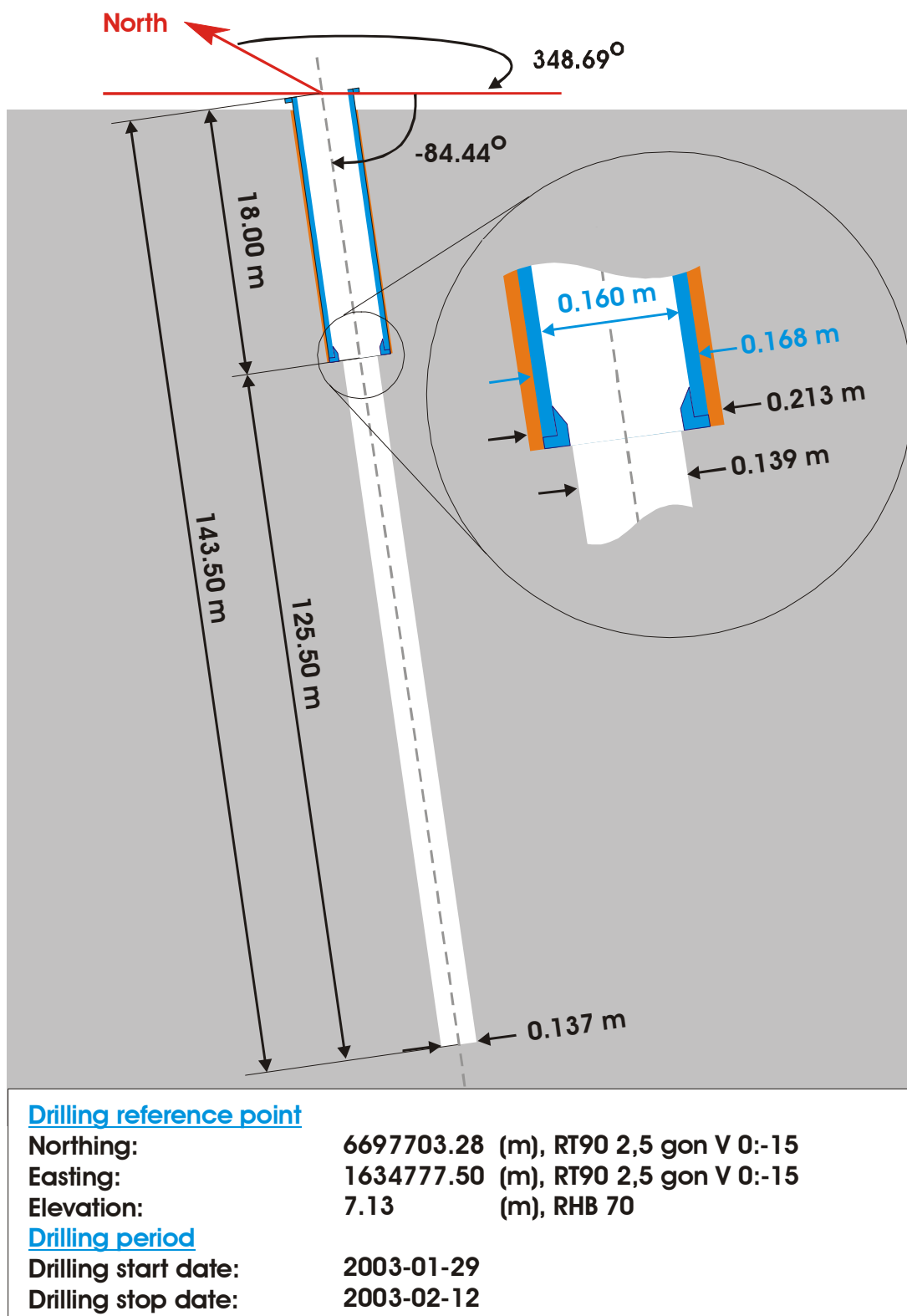


Figure 5-3. Technical data for borehole HFM08.

5.2 Consumables

The amount of oil products consumed in each borehole during drilling and grout used for gap injection of the respective casings is reported in Tables 5-2 and 5-3. Regarding hammer oil and compressor oil, these products are indeed entering the borehole but are, on the other hand, continuously retrieved from the borehole due to the permanent air flushing during drilling. After completion of drilling, only minor remainders of the products are left in the borehole.

5.3 Well Cad presentations

Technical as well as geoscientific results achieved during drilling are also presented in Figures 5-4, 5-5 and 5-6.

The deviation measurements made in boreholes HFM06, HFM07 and HFM08 (Figure 5-4, 5-5 and 5-6) indicate that the deviation is quite normal, i.e. it follows the drill rotation (clockwise) and moves slightly upwards.

The end (bottom) point of HFM06 deviates approximately 0.3 m upwards and 2 m to the left compared to an imagined straight line following the dip and strike of the borehole start point (inclination -84.8° and bearing 4.2°). The corresponding values for borehole HFM07 are 0.3 m upwards and 6.6 m to the right, compared to a straight line with the inclination -84.5° and bearing 342.3° and for borehole HFM08 0.8 m upwards and 13.5 m to the right, compared to a straight line with the inclination -84.4° and bearing 348.7° .

Especially notable results are associated with a written comment in the Well Cad diagram. In borehole HFM06 (Figure 5-4), decreasing penetration rate in combination with a water inflow of 200 L/min (see the Deltaqi column) is interpreted as a moderately dipping fracture zone at approximately 60–72 m, and is commented as such in the diagram. The interpretation of the zone being moderately dipping, is however, not based on specific measurements during or after drilling of this first borehole at drillsite DS3 but is rather an overall assessment, based on results from all boreholes at the site.

Table 5-2. Oil consumption.

Borehole ID	Hammer oil Preem Hydra 46	Compressor oil Schuman 46
HFM06	4 L	Not detected
HFM07	4 L	Not detected
HFM08	5 L	Not detected

Table 5-3. Consumption of cement grouting.

Borehole ID	Casing length	Cement volume (Portland Standard Cement)	Grouting method
HFM06	12.00 m	300 kg	Hose
HFM07	18.00 m	200 kg	Hose
HFM08	18.00 m	250 kg	Hose

Title PERCUSSION DRILLED BOREHOLE HFM06

Svensk Kärnbränslehantering AB

Site	FORSMARK	Coordinate System	RT90-RHB70
Borehole	HFM06	Northing [m]	6697752.01
Diameter [mm]	134	Easting [m]	1634522.19
Length [m]	110.70	Elevation [m.a.s.l.]	6.64
Bearing [°]	2.44	Drilling Start Date	2002-12-18 07:00:00
Inclination [°]	-84.60	Drilling Stop Date	2003-01-14 12:00:00
Remark		Plot Date	2004-02-10 21:03:31

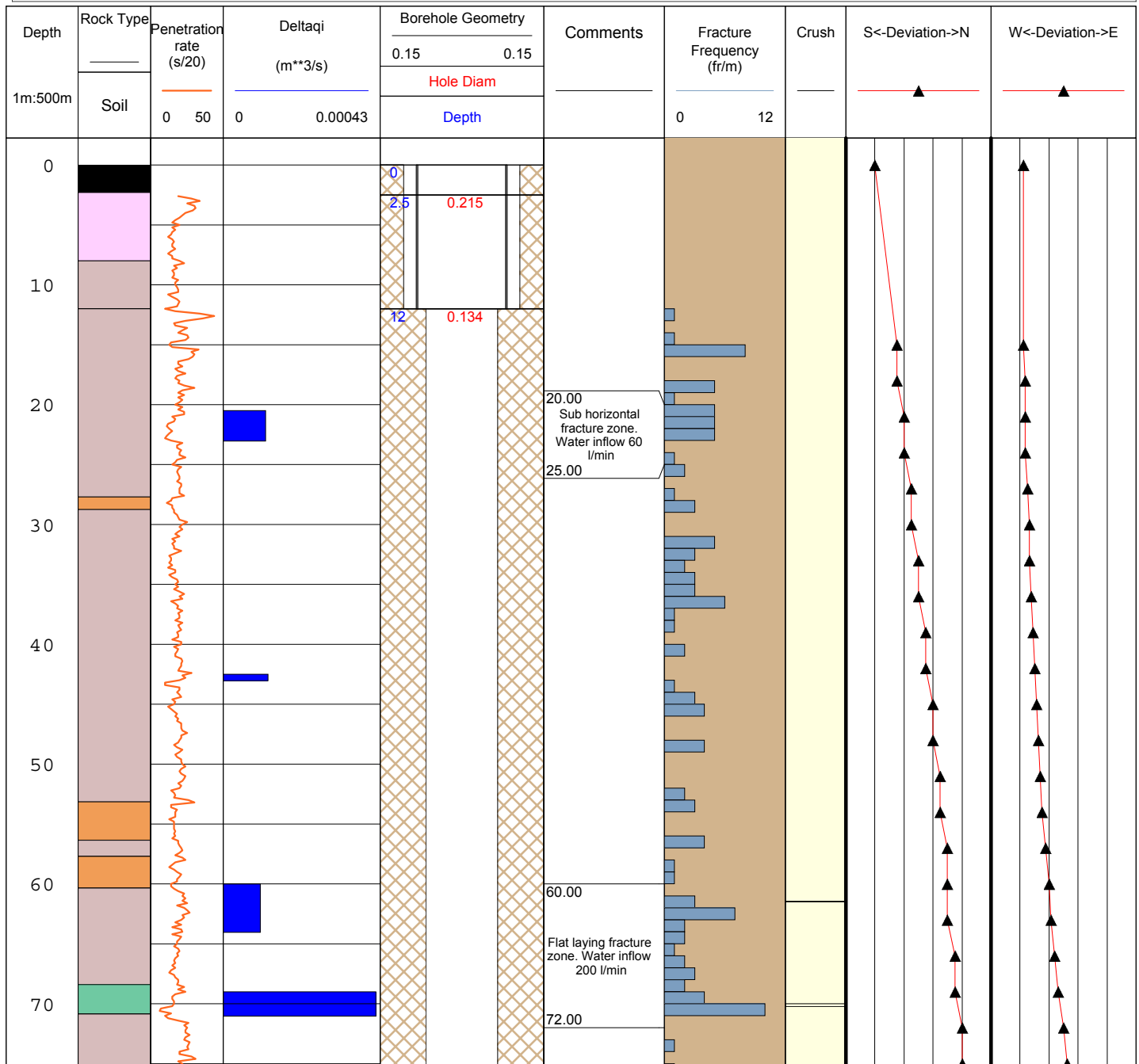
ROCKTYPE FORSMARK

- Pegmatite, pegmatitic granite
- Granite, granodiorite and tonalite, metamorphic, fine- to medium-grained
- Granite to granodiorite, metamorphic, medium-grained
- Amphibolite

SOIL

- Soil

Script Name



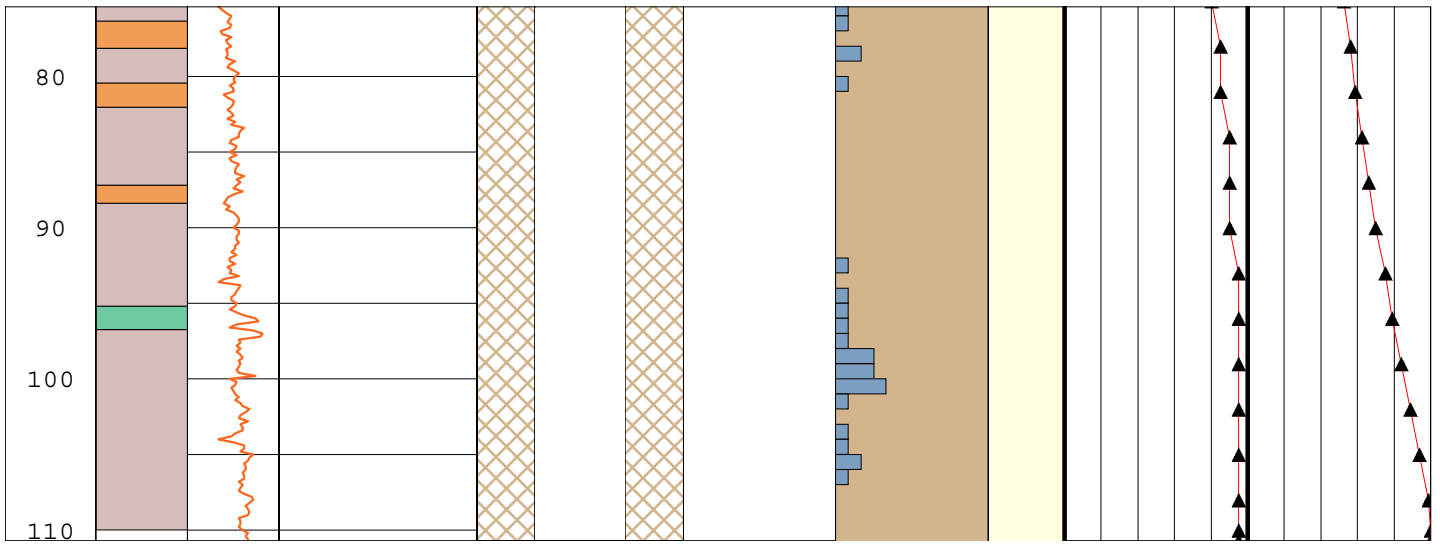


Figure 5-4. Results achieved during drilling of borehole HFM06.

Title PERCUSSION DRILLED BOREHOLE HFM07

Svensk Kärnbränslehantering AB

Site	FORSMARK	Coordinate System	RT90-RHB70
Borehole	HFM07	Northing [m]	6697416.25
Diameter [mm]	140	Easting [m]	1634715.69
Length [m]	122.55	Elevation [m.a.s.l.]	5.78
Bearing [°]	342.32	Drilling Start Date	2003-01-16 13:00:00
Inclination [°]	-84.52	Drilling Stop Date	2003-01-28 13:00:00
Remark		Plot Date	2004-02-10 21:03:31

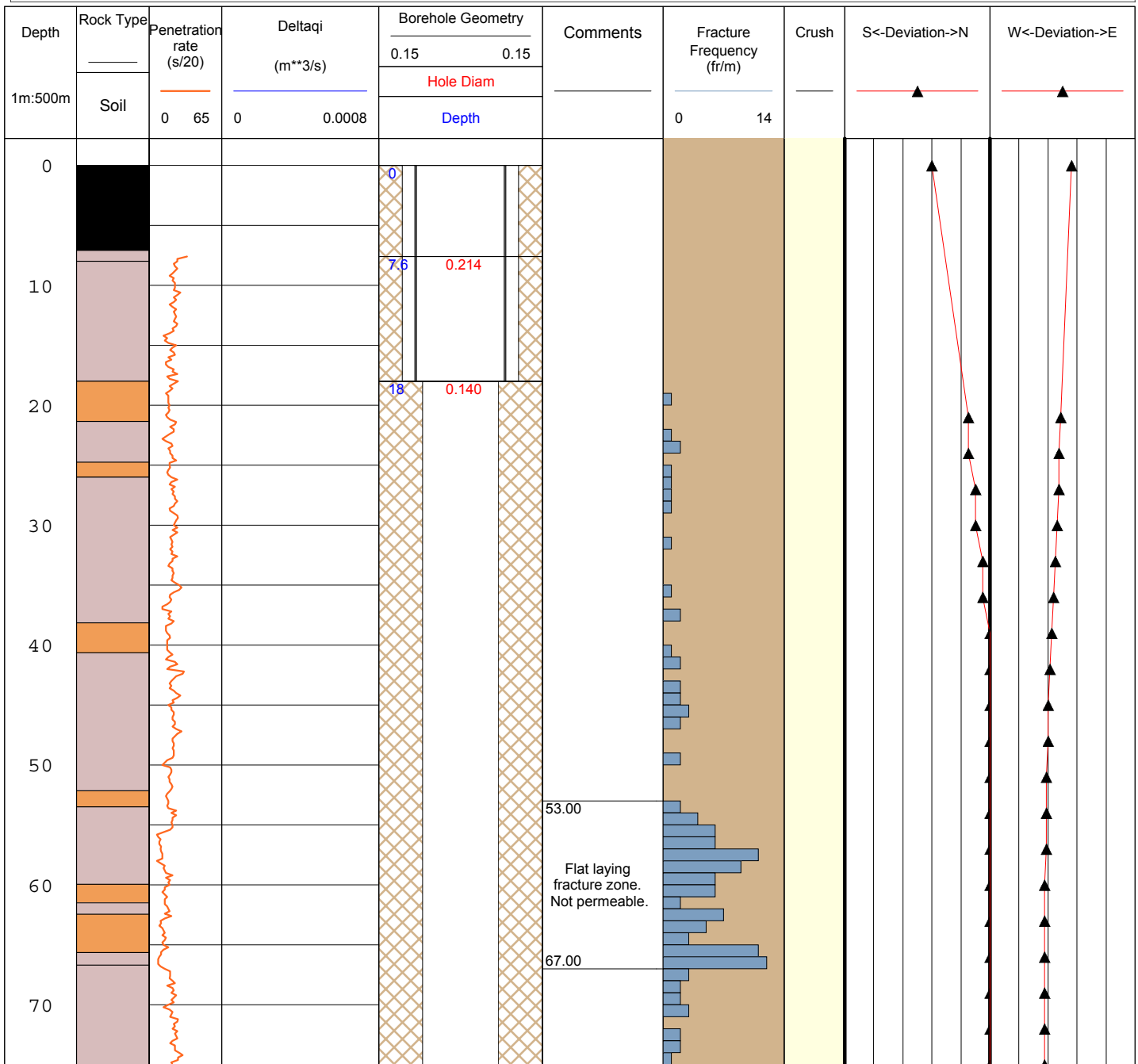
ROCKTYPE FORSMARK

- Pegmatite, pegmatitic granite
- Granite, granodiorite and tonalite, metamorphic, fine- to medium-grained
- Granite to granodiorite, metamorphic, medium-grained

SOIL

- Soil

Script Name



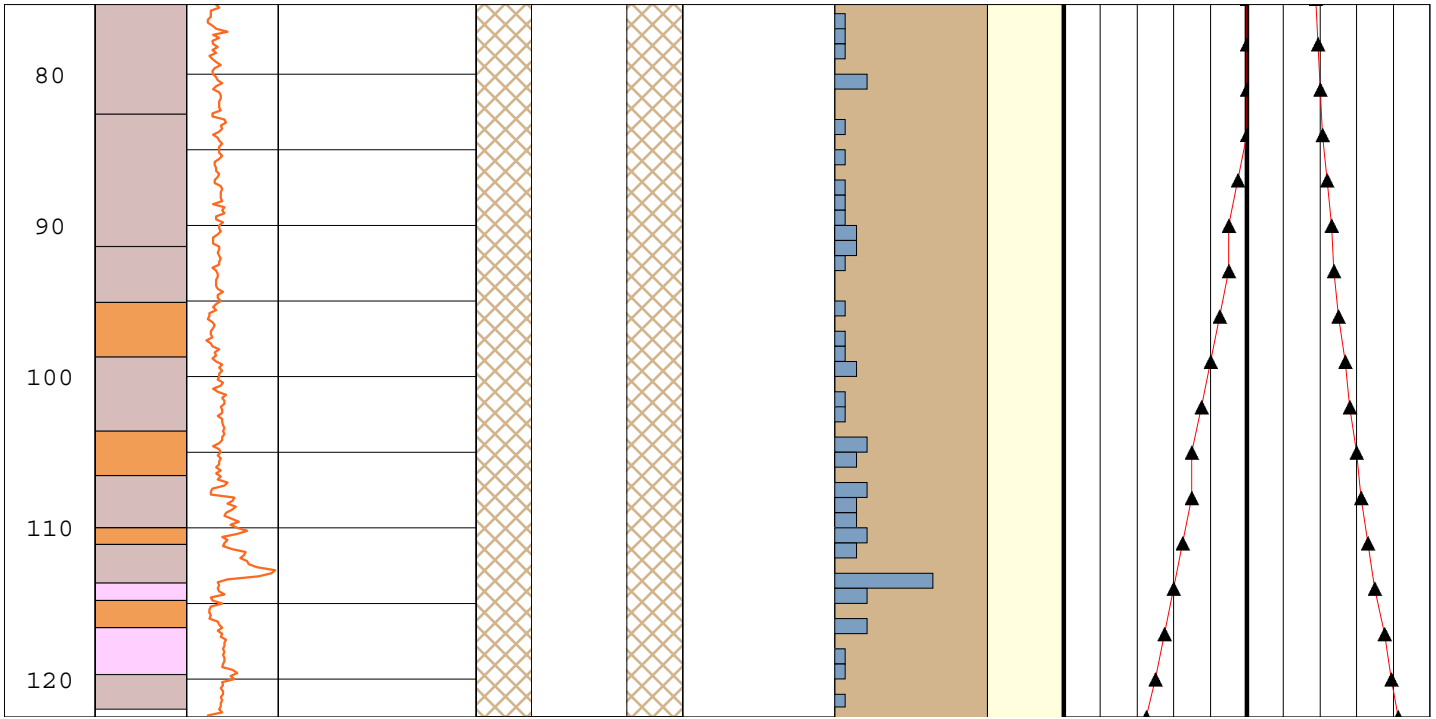


Figure 5-5. Results achieved during drilling of borehole HFM07.

Title PERCUSSION DRILLED BOREHOLE HFM08

Svensk Kärnbränslehantering AB

Site FORSMARK
 Borehole HFM08
 Diameter [mm] 137
 Length [m] 143.50
 Bearing [°] 348.69
 Inclination [°] -84.44
 Remark

Coordinate System RT90-RHB70
 Northing [m] 6697703.28
 Easting [m] 1634777.50
 Elevation [m.a.s.l.] 7.13
 Drilling Start Date 2003-01-29 09:00:00
 Drilling Stop Date 2003-02-12 12:00:00
 Plot Date 2004-02-10 21:03:31

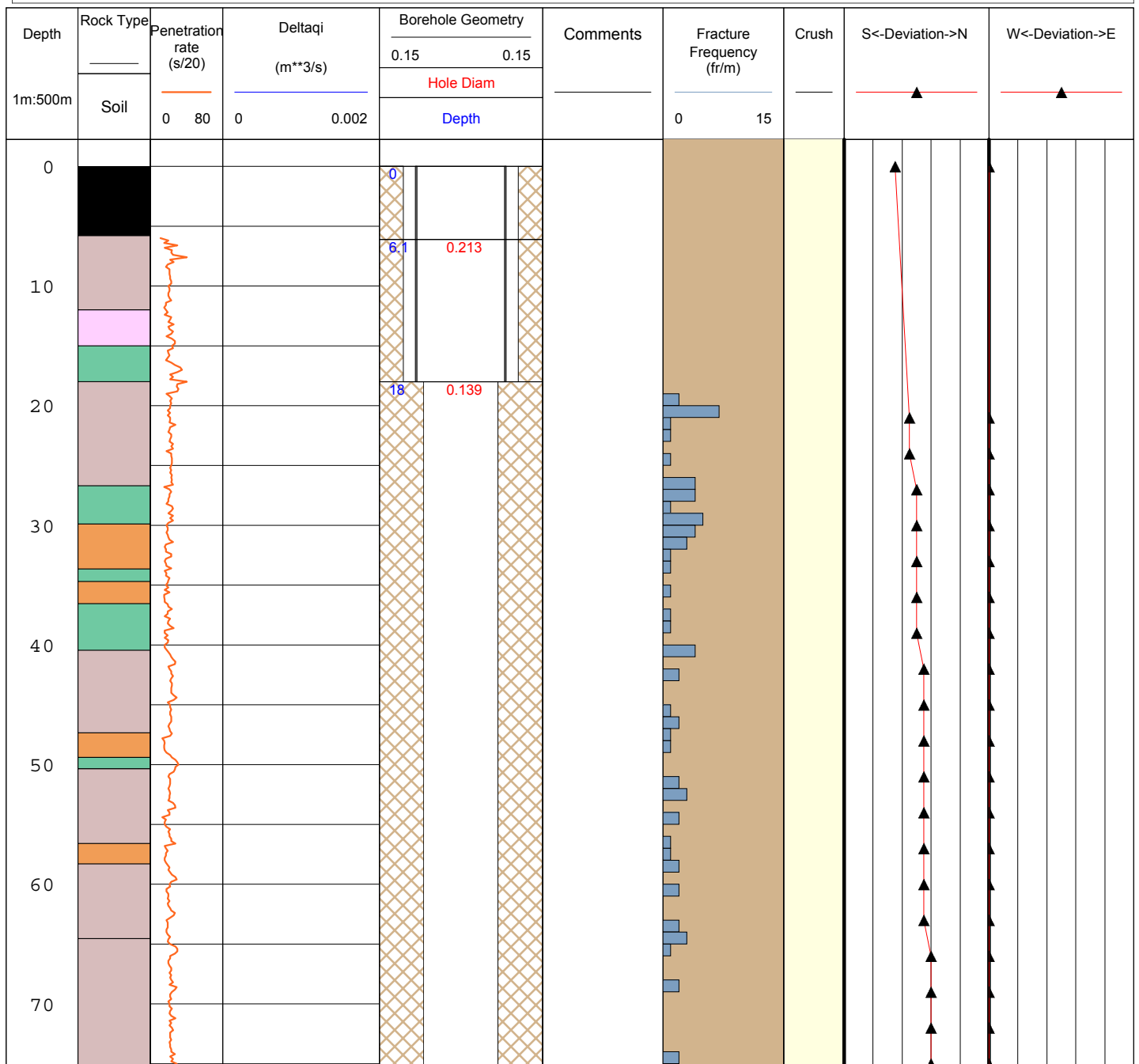
ROCKTYPE FORSMARK

- Pegmatite, pegmatitic granite
- Granite, granodiorite and tonalite, metamorphic, fine- to medium-grained
- Granite to granodiorite, metamorphic, medium-grained
- Amphibolite

SOIL

Soil

Script Name



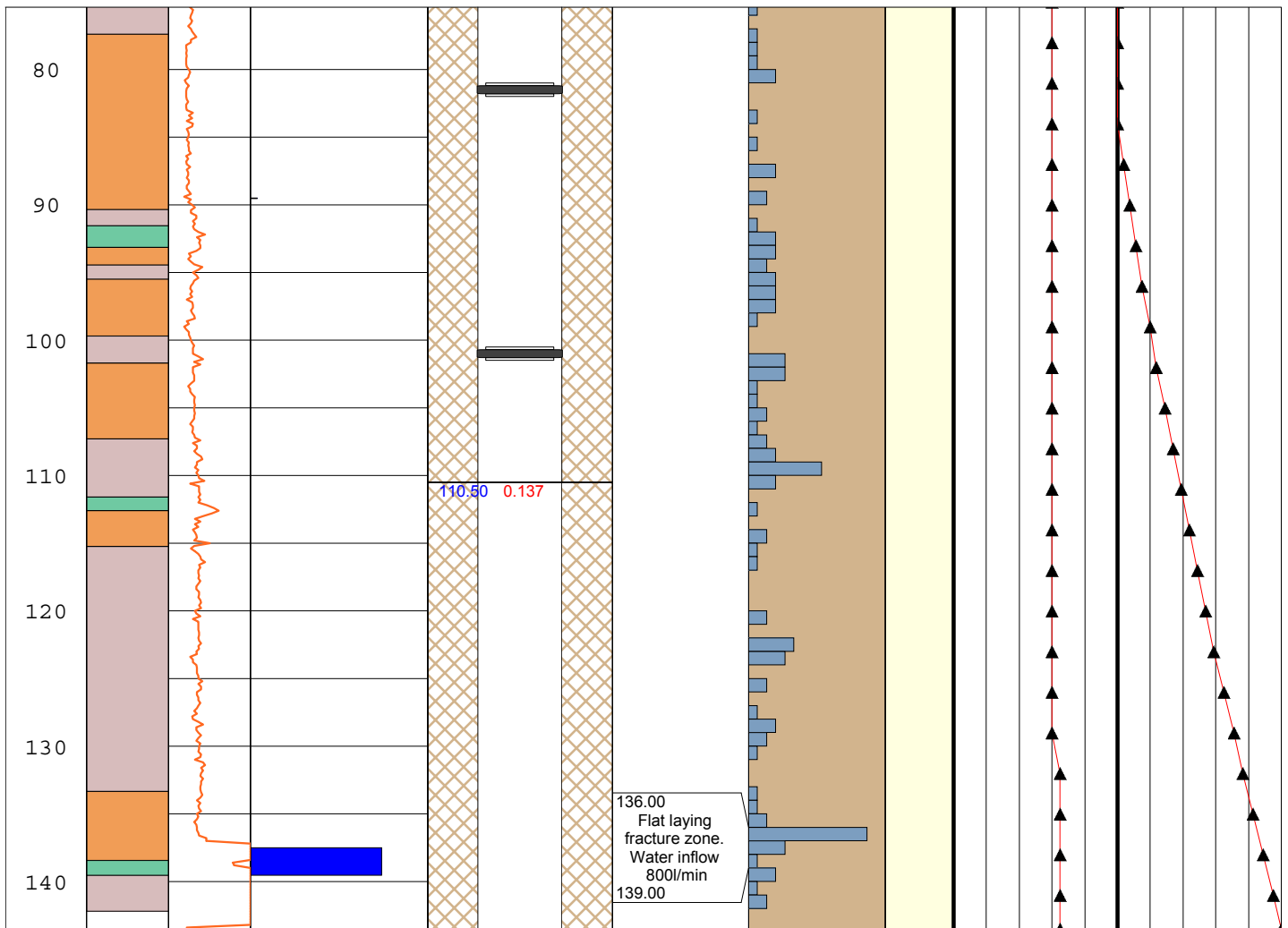


Figure 5-6. Results achieved during drilling of borehole HFM08.

Also in borehole HFM08 a fracture zone was revealed. This zone, which is situated at a deeper level, 136–139 m (Figure 5-6), is associated with an increased fracture frequency and a very large inflow of groundwater, c. 700 L/min.

In borehole HFM07 (Figure 5-5) a fracture zone at 53–67 m was indicated by decreasing penetration rate. No water inflow was however detected. This zone might correspond to reflector A6 illustrated in Figure 2-1.

5.4 Hydrogeology

Prior to the start of the percussion drilling of HFM08, a logger with a pressure transducer was installed in HFM06, situated c. 260 m west of HFM08, see Figure 1-2. In HFM08 a highly water yielding zone was penetrated around 130 metres. When drilling through this zone, a significant hydraulic response in HFM06 (Figure 5-7) was observed. Later, during drilling of KFM03A, hydraulic responses were observed in HFM06 as well as in HFM08. This indicates that the fracture zones observed in HFM06 and HFM08 (Figure 5-8) may be one and the same and is probably coinciding with reflector A5 shown in Figure 2-1. If so, this fracture zone has a dip of 30–40°.

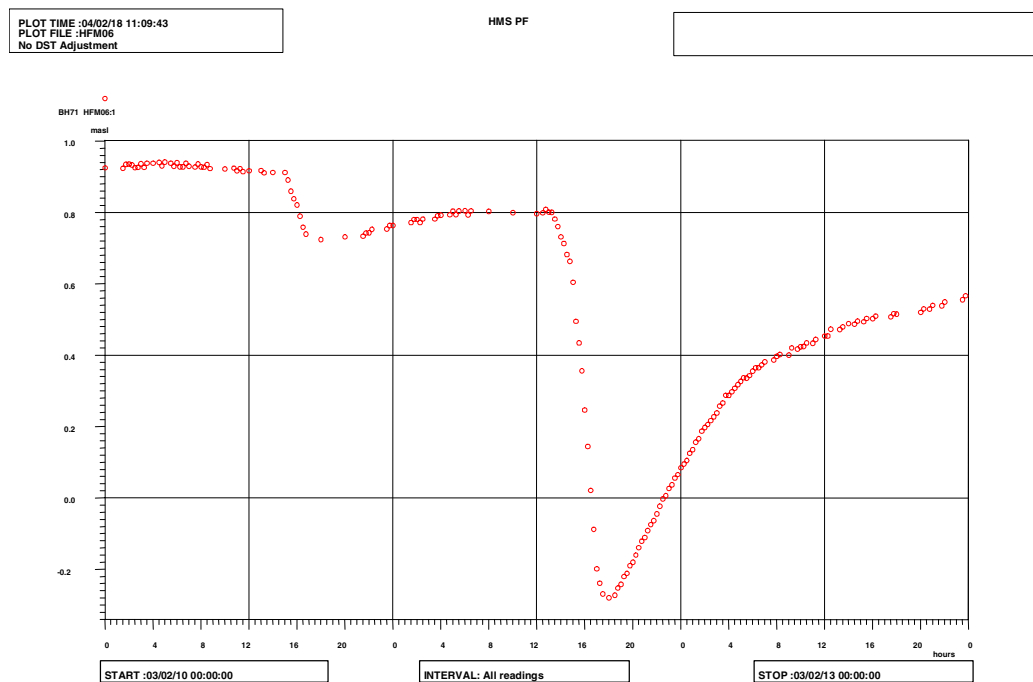


Figure 5-7. Hydraulic response in HFM06 when pumping in HFM08.

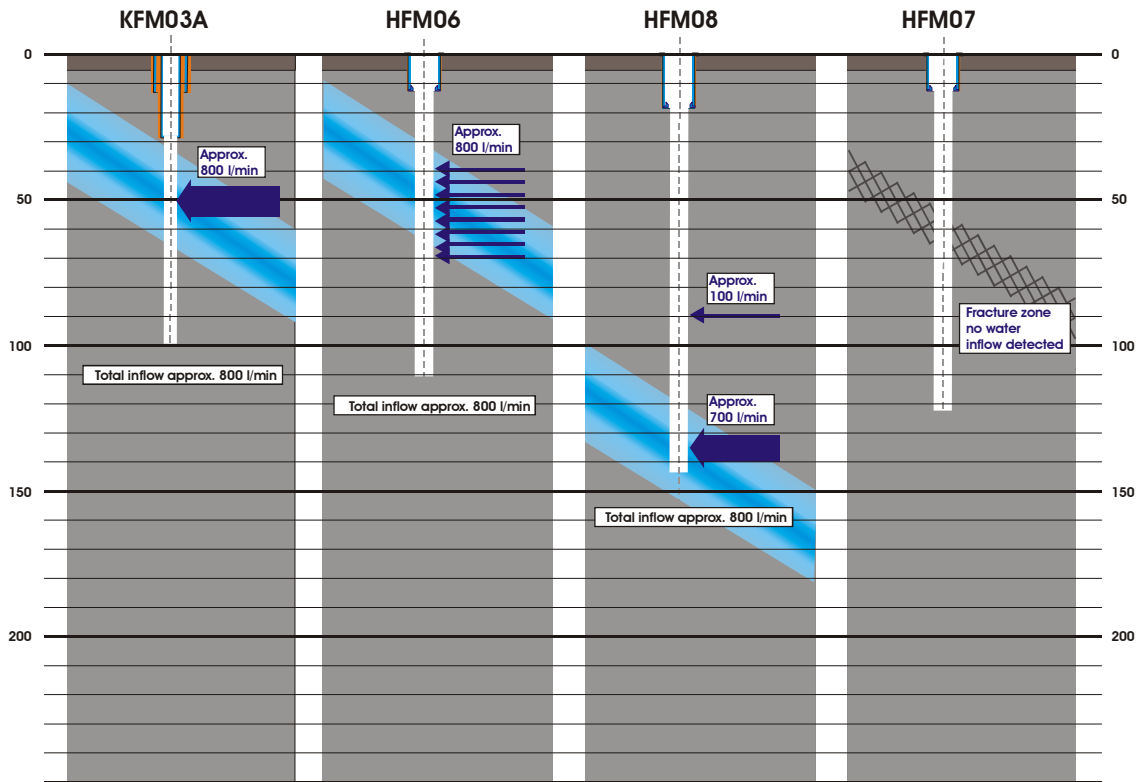


Figure 5-8. *Tentative, simplified interpretation of the structural conditions in the shallow part of the bedrock at drillsite DS3. Drilling and measured hydraulic responses strongly indicate that the fracture zone penetrated by both HFM06 and HFM08 may also be intersected by borehole KFM03A.*

6 References

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