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Oskarshamn site investigation

Percussion drilling of boreholes HLX34 and HLX35

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December 2005

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Keywords: Percussion drilling, Lineament investigation, Hydraulic responses.

Abstract

Drilling of percussion holes is required as a supplement to the drilling of deep cored holes. In general, the percussion holes serve two principal purposes: water supply for core drilling and as investigation boreholes to shallow depth.

Drilling of percussion boreholes HLX34 and HLX35 was done to investigate interpreted lineaments in the north-western part of the Laxemar subarea.

The encountered geology in the boreholes corresponds well with expectations based on surface geological mapping.

The water yields in both holes were more than ca 185 litres per minute.

Indications of deformational zones could be seen in both boreholes HLX34 and HLX35 as high water yields, reduced magnetic susceptibility and variable penetration rates.

Sammanfattning

Hammarborrhål borras i allmänhet för två olika ändamål: dels för vattenförsörjning vid kärnborrrning och dels för att möjliggöra undersökningar i ytligare berggrund.

Borrningen av hammarborrhålen HLX34 och HLX35 utfördes för undersökning av tidigare tolkade lineament i delområdet Laxemar inom platsundersökningen i Oskarshamn.

Den geologi som påträffades i borrhålen överrensstämmer väl med det som kunde förväntas från den geologiska karteringen på ytan.

Vatteninflödet i båda borrhålen översteg ca 185 minutliter.

Borrningsresultaten från hammarborrhålen HLX34 och HLX35 gav indikationer på deformationszoner i form av hög vattenföring, reducerad magnetisk susceptibilitet och varierande borrsjunkhastighet.

Contents

1 Introduction

SKB performs site investigations in order to evaluate the feasibility of locating a deep repository for high level radioactive waste /1/ in two Swedish municipalities: Östhammar and Oskarshamn /2/.

A number of linear features, lineaments, covering the site investigation area were identified by airborne geophysical methods or by remote sensing, primarily of topography /3/.

Follow-up ground geophysics by refraction seismic and resistivity methods were done over selected lineaments /4/ and /5/, see Figure 1-1.

Percussion drilling to depths of 151.8 m was done in both holes to investigate the interpreted lineaments and related geophysical anomalies.

This report will describe the drilling of percussion boreholes HLX34 and HLX35 that were drilled to investigate interpreted lineaments. Measurements performed during the drilling phase will also be described in the report.

The holes were drilled in the north-western part of the Laxemar subarea of the Oskarshamn site investigation, see Figure 1-1.

The decision to perform the drilling of boreholes HLX34 and HLX35 is given in SKB id 1039361, date: 2005-05-10, internal document.

The drilling and all related on-site operations were performed according to a specific Activity Plan (AP PS 400-05-039). Reference is given in the activity plan to procedures in the SKB Method Description for Percussion Drilling (SKB MD 610.003, Version 1.0) and relevant method instructions for handling of chemicals, surveying and evaluation of cuttings, see Table 1-1.

The activity plans and method descriptions are SKB internal documents. All data were stored in the SICADA database for Oskarshamn.

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

Activity plan	**Number**	**Version**
Hammarborrning av HLX34 och HLX35 för lineaments-undersökningar i Laxemar	AP PS 400-05-039	1.0
Method descriptions	**Number**	**Version**
Metodbeskrivning för hammarborrning	SKB MD 610.003	1.0
Metodbeskrivning för undersökning av borrkax	SKB MD 142.001	1.0
Instruktion för rengöring av borrhålsutrustning och viss markbaserad utrustning	SKB MD 600.004	1.0
Instruktion för användning av kemiska produkter och material vid borrning och undersökningar	SKB MD 600.006	1.0
Instruktion för borrplatsanläggning	SKB MD 600.005	1.0
Instruktion för spolvattenhantering	SKB MD 620.007	1.0
Instruktion för utsättning och inmätning av borrhål	SKB MD 600.002	1.0

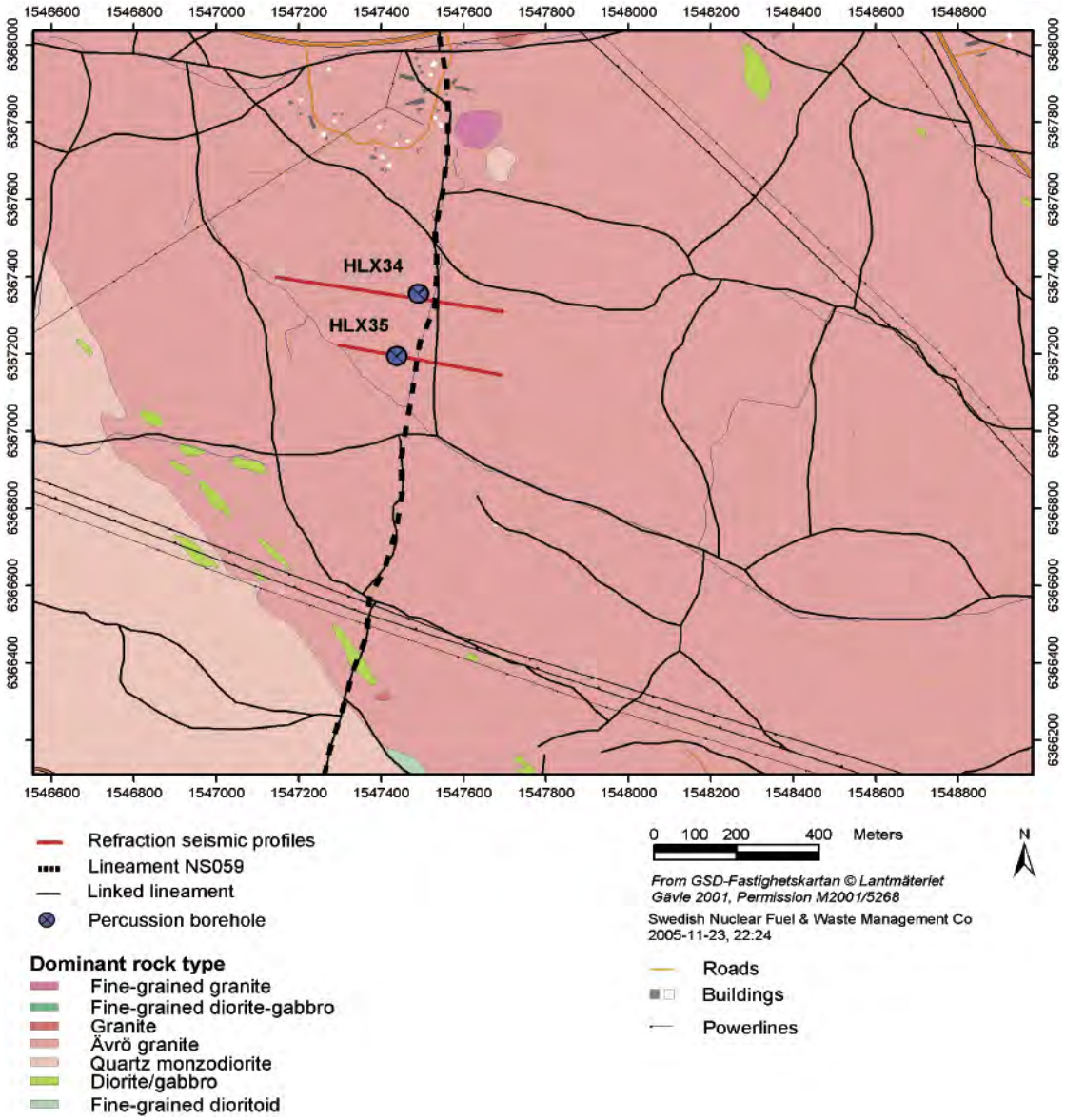

Figure 1-1. *Location of boreholes HLX34 and HLX35 in the north-western part of the Laxemar subarea. The map shows the bedrock geology, lineaments, as well as houses, roads and power lines. Borehole HLX34 is drilled parallel to the geophysical profile LSM000278 and HLX35 parallel to geophysical profile LSM000537. The geophysical profiles are shown here as red lines.*

2 Objective and scope

This report will describe the drilling of the two percussion holes HLX34 and HLX35 as well as the measurements performed during drilling i.e. logging of preliminary geology and measurements of water inflow.

The objectives for the boreholes, prior to drilling, are summarised in Table 2-1.

Borehole HLX35 was drilled parallel to a seismic profile /4/ and a resistivity profile /5/ to test anomalies and interpreted lineaments. Borehole HLX34 was drilled along a seismic refraction profile to further test the interpreted lineament.

Table 2-1. Borehole objectives before drilling.

Borehole	Drilling objective
HLX35	HLX35 was drilled first with the aim of cross-cutting a deformation zone related to the lineament at the surface and geophysical anomalies at ca 80–120 m for a steeply west dipping or vertical structure.
HLX34	Two alternative locations were planed initially, which alternative was used depended on the results from HLX35. The aim of the chosen location was to verify the same deformation zone as in HLX35 and to establish if there was a hydraulic connection between the two boreholes.

3 Equipment

In this chapter the drilling equipment and the equipment used for measurements and sampling is briefly described.

Drilling and completion were made by contractor Sven Andersson, Uppsala AB.

3.1 Drilling equipment

The drilling of boreholes HLX34 and HLX35 was made with a Nemek 710 drilling rig supplied with accessories. For the raising of water and drill cuttings from the borehole, a 27 bar diesel air-compressor, type Atlas-Copco XRVS 466 Md was used. The DTH drillhammer was of type Secoroc 5” (140 mm), lowered into the borehole by a Driconeq 114 mm pipe string.

3.2 Equipment for measurements and sampling during drilling

Flow measurements during drilling were performed using a graded vessel and a stop watch.

Measurement of the drilling penetration time was done automatically with MWD (Measurement While Drilling) equipment. The lengths recorded by manual observations (flow measurements and preliminary geology) can differ a few centimeters from the lengths recorded automatically with the MWD equipment (drilling penetration time). This should, however, not be regarded as an inconsistency but as a reflection of the inherent uncertainty in length measurements.

Samples of soil and drill cuttings were collected in sampling pots and a preliminary geological logging was done. Magnetic susceptibility in the samples was measured with a hand-held meter, a JH-8 from Geoinstruments, Finland. In borehole HLX35 from 40.2 m till the end of hole the electric conductivity of return water was measured with a hand-held Waterproof TDScan WP4 Pocket Conductivity Tester from EUTECH instruments, see also Section 4.5.

Hydraulic responses in surrounding boreholes were normally measured with Mini-Troll pressure loggers.

4 Execution

The work was performed in accordance with SKB MD 610.003, Version 1.0 (Method Description for Percussion Drilling, SKB internal document) and consisted of:

- preparations,
- drilling through overburden,
- gap injection techniques and equipment,
- percussion drilling in hard rock,
- sampling and measurements,
- borehole completion,
- data handling,
- environmental control.

4.1 Preparations

The preparation stage included the Contractor's functional control of his equipment. The machinery and chemicals used have to comply with SKB MD 600.006, Version 1.0 (Method Instruction for Chemical Products and Materials, SKB internal document).

The equipment was cleaned in accordance with SKB MD 600.004, Version 1.0 (Method Instruction for Cleaning Borehole Equipment and certain Ground-based Equipment, SKB internal document).

4.2 Drilling through overburden

For boreholes HLX34 and HLX35 excentric percussion drilling with 190 mm diameter (TUBEX 140) was made through the unconsolidated soil and fractured near-surface bedrock installing a casing with diameter 168 mm to a depth of 9 and 6 m respectively.

4.3 Gap injection techniques and equipment

In order to prevent surface water and shallow groundwater to infiltrate into deeper parts of the borehole, the gap between the borehole wall and the casings was grouted with cement, see Figure 4-1.

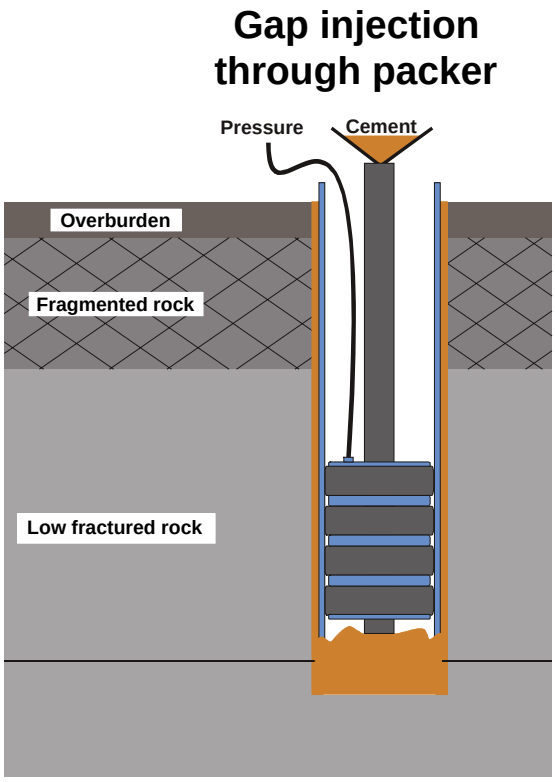

Figure 4-1. *Gap injection technique.*

A packer was installed at the bottom of the cased section. The concrete was introduced through the packer and allowed to flow up between the casing and the bedrock wall. A reference sample of the cement paste was kept cool and dark on the surface to ensure that drilling was not resumed until the mixture had hardened.

The concrete seal was tested by blowing compressed air in the hole and measuring the amount of in-flowing water. As no water could be measured in the hole, the tightness of the gap injection was considered to be sufficient.

4.4 Percussion drilling in hard rock

After allowing the cement to harden, drilling could continue and was performed to the full borehole length with conventional percussion drilling with a nominal diameter of 140 mm.

Figure 4-2. *Drilling rig and crew drilling percussion borehole HLX34 in the north-western part of the Laxemar subarea.*

4.5 Sampling and measurements

Sampling and measurements done by the drill site geologist, and the drilling crew during drilling included:

- Samples of rock chip drill cuttings were taken along the hole. One sample was taken per metre drilled. The samples were stored for subsequent logging of preliminary geology (lithology, dominant mineralogy, grain-size, roundness and, if possible, structural or textural information) and measurement of magnetic susceptibility with hand held equipment.
- Small cups of return water were collected during drilling, one for every metre, for determination of water colour and intensity which in turn gives an indication of clay content and level of oxidation, see Figure 4-3. Electric conductivity was measured with hand held equipment in each cup, in borehole HLX35 from 40.2 m to the end of the hole.
- Penetration time was logged automatically.
- The water yield from the hole was estimated when noticeable changes in water flow occurred and after the drilling phase was completed. The method employed is blowing compressed air through the drill stem and measuring the amount of return water during steady state conditions. The method gives an indication of the actual yield in litres per minute.

When the drilling was completed the hole was rinsed from drill cuttings by blowing air with the compressor at maximum capacity for 30 minutes.

Figure 4-3. *Geologist sampling during drilling, drill cuttings are collected in a sieve sitting within the green sieve below the cyclone and return water into small plastic cups, at the drilling site of HLX34 in the north-western part of the Laxemar subarea.*

4.6 Borehole completion

The boreholes were secured by mounting of lockable steel caps on the casing.

Removal of all equipment, cleaning of the drill sites and joint inspections were made by representatives from SKB and the Contractor to ensure that the sites had been restored to a satisfactory level.

4.7 Data handling

Data collected by the drillers and drill site personnel were reported in daily logs and other protocols and delivered to the Activity Leader. The information was entered to SICADA (SKB database) by database operators.

Figure 4-4. *The drilling site of HLX35 in the north-western part of the Laxemar subarea after removal of drilling equipment, but before mounting the lockable steel cap on the casing (covered with blue cover).*

4.8 Environmental control

The SKB routine for environmental control (SDP-301, SKB internal document) was followed throughout the activity. A checklist was filled in and signed by the Activity Leader and filed in the SKB archive.

All waste generated during the establishment, drilling and completion phases have been removed and disposed of properly. Water effluent from drilling was allowed to infiltrate to the ground, in accordance with an agreement with the environmental authorities.

Recovered drill cuttings were collected in a steel container. After completion of drilling, the container was removed from the site and emptied at an approved site.

5 Results

Technical data from drilling are presented in Section 5.1.

Hydrogeological results from drilling are given in Section 5.2.

The results from the preliminary geological mapping are commented in Section 5.3.

5.1 Borehole design

A summary of data from the boreholes are presented in Tables 5-1.

Technical drawings of the boreholes are given in Appendix 1.

Table 5-1. Geometric and technical data for boreholes HLX34 and HLX35.

Parameter	HLX34		HLX35	
Drilling period	From 2005-06-09 to 2005-06-14		From 2005-05-28 to 2005-06-02	
Borehole inclination (starting point) (0 to –90)	–59.727°		–59.877°	
Borehole azimuth (0–360)	101.068°		102.216°	
Borehole length	151.800 m		151.800 m	
Soil depth	1.3 m		3.0 m	
Drill bit diameter (m)	0.137		0.140	
Starting point coordinates (system RT90/RHB70)	Northing: 6367355.125 m Easting: 1547489.558 m Elevation: 14.290 masl		Northing: 6367194.788 m Easting: 1547437.792 m Elevation: 14.444 masl	
Water yield	198 l/min		185 l/min	
Borehole diameter	0–9.10 m	190.0	0–6.10 m	190.0
(interval) (diameter mm)	9.10–151.8 m	137.7	6.10–151.8 m	139.5
Casing diameter (interval) (diameter mm)	0–8.94 m	$Ø_o$ = 168 $Ø_i$ = 160	0–5.94 m	$Ø_o$ = 168 $Ø_i$ = 160
	8.94–9.03 m	$Ø_o$ = 168 $Ø_i$ = 147	5.94–6.03 m	$Ø_o$ = 168 $Ø_i$ = 147

5.2 Hydrogeological results

The water yields obtained from blowing of compressed air during drilling are given in Table 5-2 and are also shown in Appendix 2. Yields below ca 1–2 litres per minute should be regarded as very approximative estimates only, as well as flows exceeding ca 100–150 litres per minute.

The measured water yields during drilling is usually not the same as the observed level of inflow, normally the measurement takes place when the drilling seems to have passed the water yielding fractures and the water inflow is not increasing. The observed levels of water inflow during drilling are summarised in Table 5-3, and shown graphically in Figure 6-1.

The amount of effluent water that was released to the ground from the drilling activities is estimated in Table 5-4. The release of water was made within 30 m from the collar location.

Measurements of electrical conductivity in the return water were measured in HLX34 from 40.2 m length and show generally low values; approximately 40 mS/m until ca 66 m length where it starts to increase until about 82–91 m length, up to 70 mS/m, where it is stable until the end of the borehole.

Table 5-2. Measured water yields during drilling (date_time_depth taken from MWD).

Borehole	From (m)	To (m)	Measured water yield (L/min)	Measurement date (yymmdd)_local time (hh:mm:ss)	Local time for final rinsing by air blow (hh:mm)
HLX34	9.1	40.2	5.2	050613_15:43:36	
HLX34	9.1	70.5	5.2	050613_17:39:04	
HLX34	9.1	73.5	47	050613_18:08:27	
HLX34	9.1	73.5	84	050614_11:50:55	
HLX34	9.1	112.5	106	050614_13:33:17	
HLX34	9.1	151.8	198	050614_17:16:08	17:50
HLX35	6.1	100.5	57	050601_14:32:23	
HLX35	6.1	121.5	57	050601_15:53:37	
HLX35	6.1	121.5	69	050602_11:21:54	
HLX35	6.1	127.5	170	050602_11:49:31	
HLX35	6.1	145.5	205	050602_14:27:43	
HLX35	6.1	151.8	185	050602_15:52:00	16:25

Table 5-3. Observed levels of water inflow during drilling.

Borehole	Noticeable inflow of water during drilling (metres drilled length)
HLX34	35, 72.5, 112, 144
HLX35	98.5, 125, 142

Table 5-4. Amount of released water from drilling.

Borehole	Estimated amount of water released (m^3)
HLX34	77
HLX35	76

5.2.1 Hydraulic responses

Selected results from the monitoring of hydraulic responses in surrounding boreholes during drilling are presented in Figures 5-1 and 5-2. The monitored surrounding boreholes were HLX13, HLX14, HLX20, HLX25, HLX27, HLX28, HLX30, HLX31, HLX33 and KLX04, as well as in HLX35 while drilling of borehole HLX34 took place, see Figure 5-3 for locations. Hydraulic responses during drilling of HLX34 could only be established in borehole HLX35, see Figure 5-1. During drilling of HLX35 responses were only observed in boreholes HLX13 and HLX14, see Figure 5-2. None of the other monitored boreholes showed any response during drilling of boreholes HLX34 and HLX35.

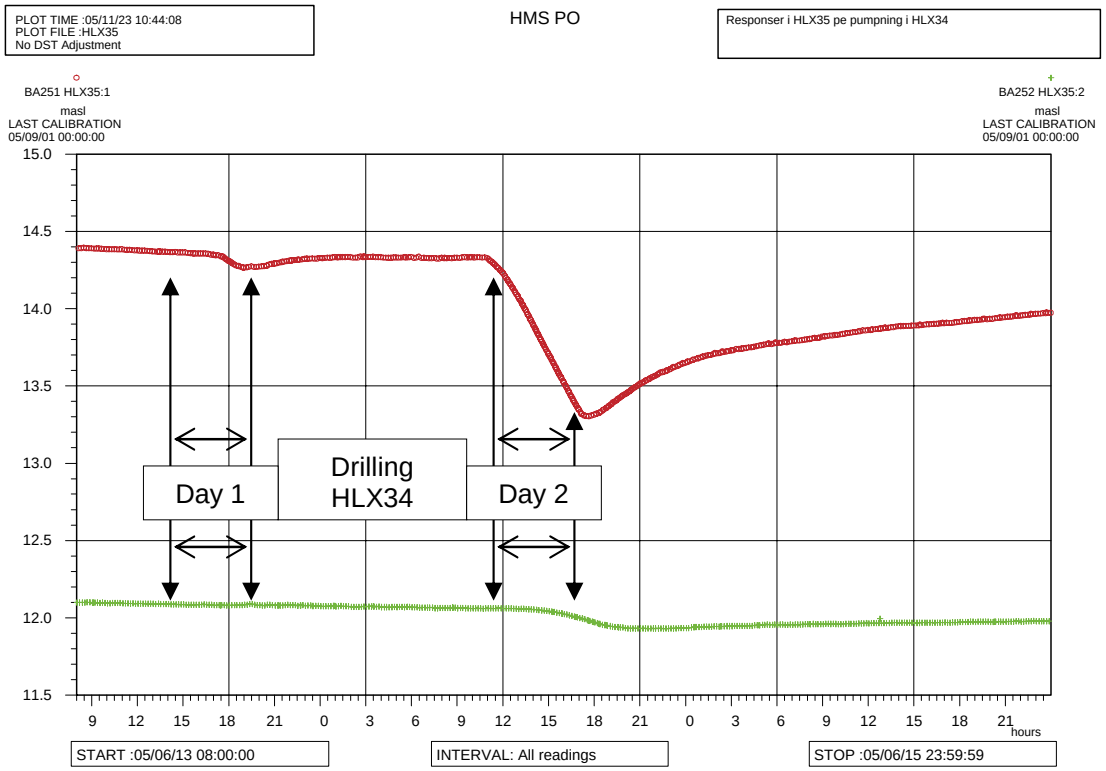

Figure 5-1. *Hydraulic responses in HLX35 shown as masl (metres above sea level) on the vertical axis, during the period 050613 (08:00:00) to 050615 (23:59:59), shown on the horizontal axis. The arrows mark the start and finish of drilling in HLX34, first day 050613 from ca 14:08 at 9.14 m until ca 18:08 at 73.52 m, and the second day 050614 from ca 11:51 at 73.54 m until ca 17:16 at 151.78 m. Two loggers were installed in borehole HLX35 with a packer at 64.00 m. Logger 1, in red, shows changes below the packer and logger 2, in green, shows the changes in water level above the packer. There is a very distinct response during drilling of HLX34, especially during the second day of drilling.*

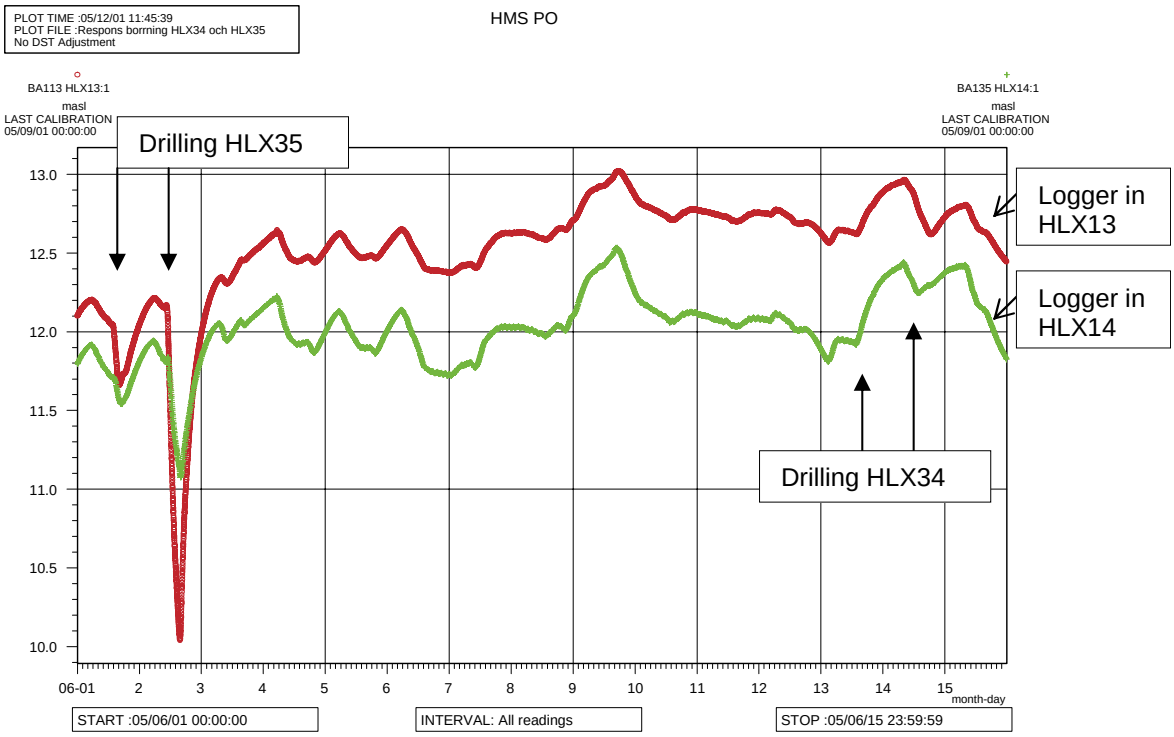

Figure 5-2. *Hydraulic responses in HLX13 (red line) and HLX14 (green line) during the drilling of HLX34 and HLX35, in the period 050601 (00:00:00) to 050615 (23:59:59), the arrows indicate the approximate start of drilling for each day. The response is very distinct during drilling of HLX35, in both HLX13 and HLX14, while there is no response during the drilling of HLX34. For location of boreholes HLX13 and HLX14 see Figure 5-3.*

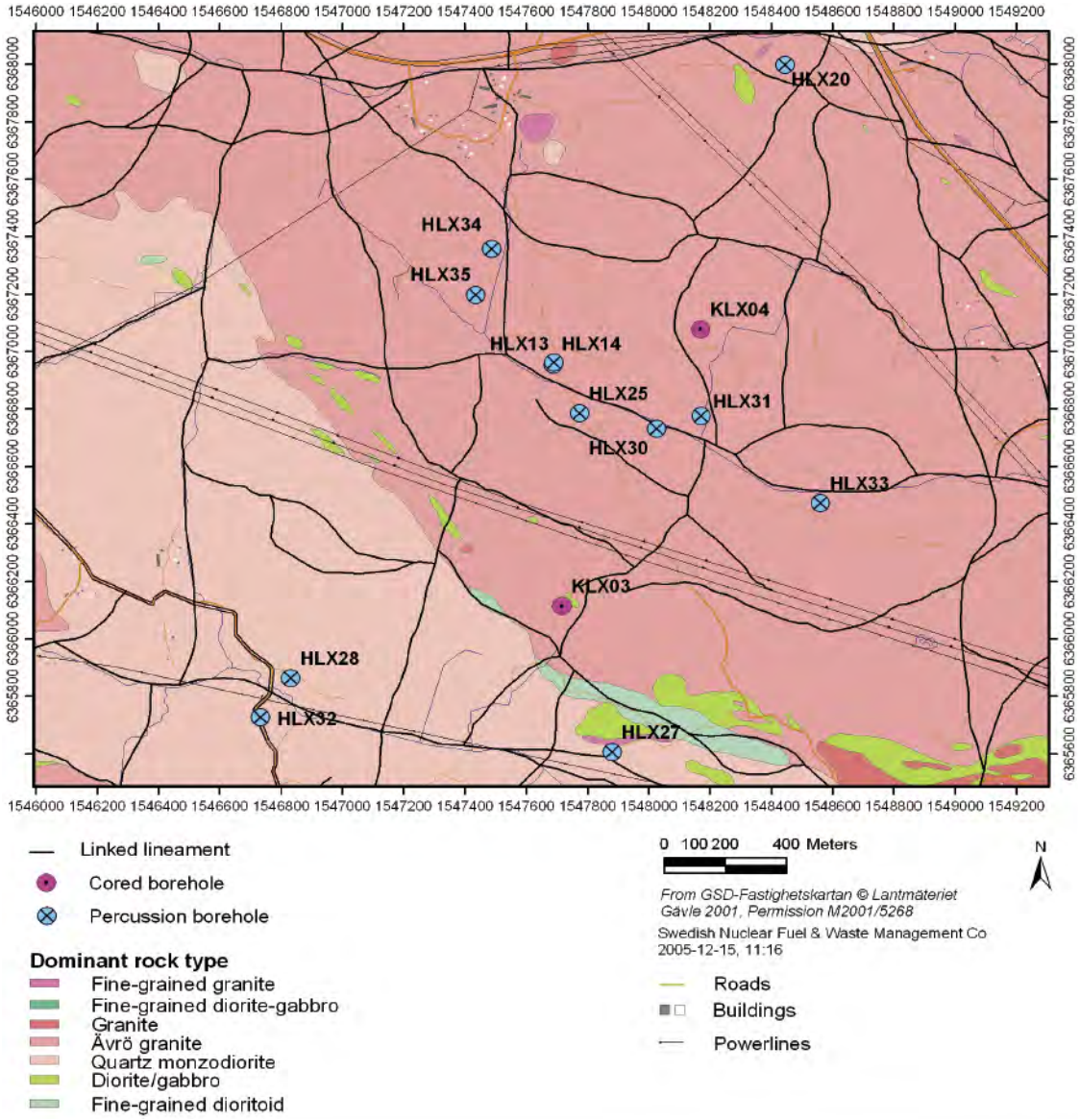

Figure 5-3. *Location of boreholes HLX13, HLX14, HLX20, HLX25, HLX27, HLX28, HLX30, HLX31, HLX32, HLX33, HLX34 and HLX35, as well as KLX03 and KLX04 in the Laxemar subarea. The map shows the bedrock geology, lineaments, as well as houses, roads and power lines.*

5.3 Geological results

Lithologically boreholes HLX34 and HLX35 are dominated by Ävrö granite, with minor occurrences of fine-grained diorite-gabbro. The rock is cut by occasional dikes of granite (medium to coarse grained) and fine-grained granite in HLX34 and by pegmatite in HLX35, see Table 5-6.

Logging results of preliminary geology together with magnetic susceptibility, penetration time and measured water flow are presented in Appendix 2.

Table 5-6. Lithology of drilled boreholes.

Borehole	Dominating rock type	Subordinate rock type
HLX34	Ävrö granite	Fine-grained diorite-gabbro, granite and fine-grained granite
HLX35	Ävrö granite	Fine-grained diorite-gabbro and pegmatite

5.4 Consumption of oil and chemicals

Small amounts of hammer oil and compressor oil enter the holes during drilling but are continuously retrieved by air flushing during drilling. After the drilling is completed, only minor remainders of the products are left in the borehole.

The consumption of cement paste (low alkali cement) and oils is given in Table 5-7.

Table 5-7. Consumption of cement paste and oils.

Borehole	Cement paste used (kg)	Hammer oil Preem Hydra 46 (L)	Compressor oil Schuman 46 (L)
HLX34	35.5	15	None noted
HLX35	35.5	15	None noted

5.5 Nonconformities

No logger was present in boreholes HLX32 and KLX03, see Figure 5-3 for location, during the time HLX34 and HLX35 were drilled.

6 Interpretation

The results from the drilling of percussion boreholes HLX34 and HLX35 indicates the following:

1. The existence of a deformation zone is verified, based mainly on the occurrence of high water yielding fracture zones, see Tables 5-2 and 5-3 as well as Figure 6-1.
2. The zone is probably vertical or steeply dipping to the west, based on both the geophysical profiles as well as the drilling, see Figure 6-1.
3. The hydraulic responses in surrounding boreholes show that the structure is at least partly connected to the south, see Figure 5-1, and with fracture zones to the south, see Figure 5-2.

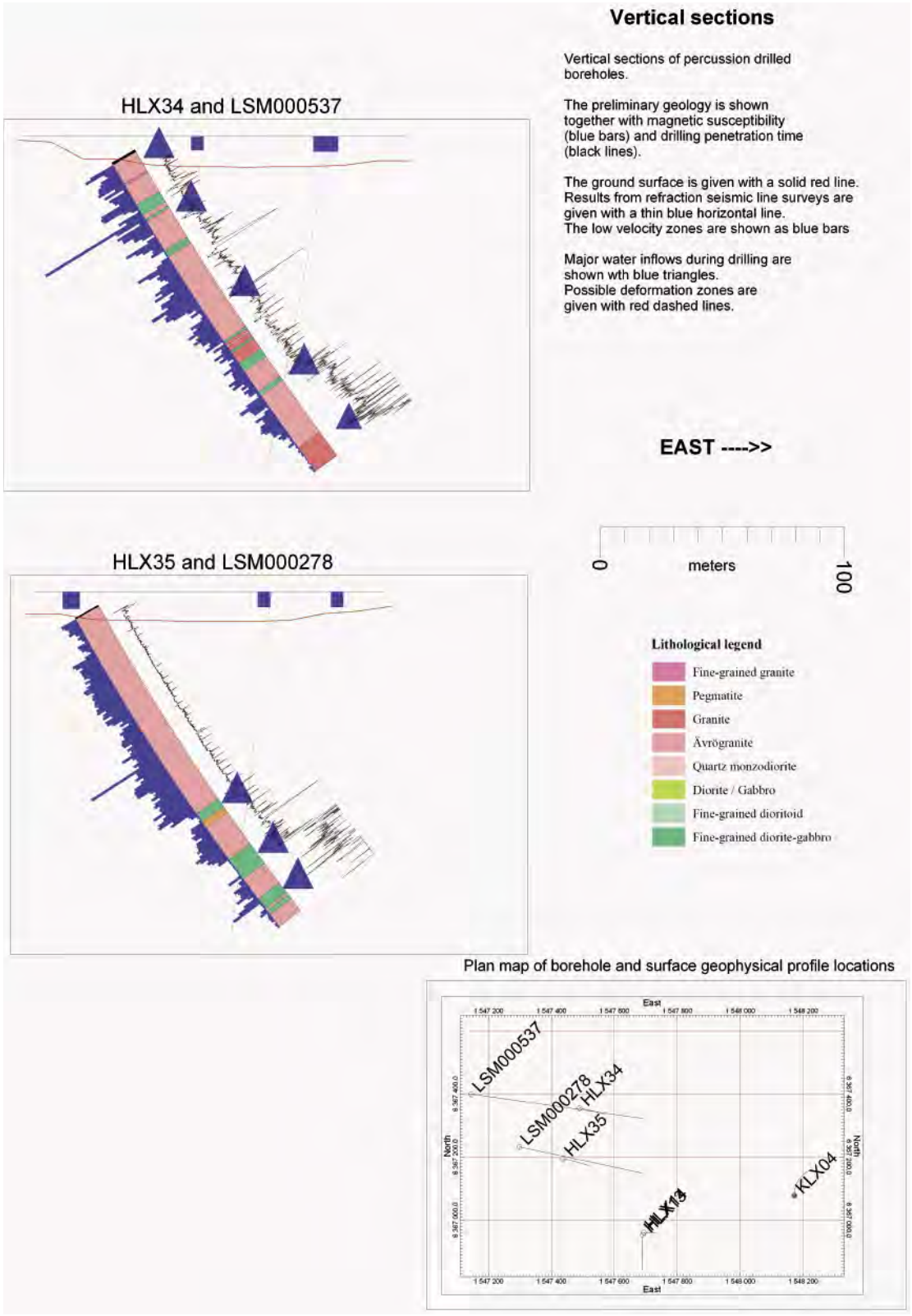

Figure 6-1. *Profile of boreholes HLX34 and HLX35 in the western part of the Laxemar subarea. Shown with preliminary geological results (soil is shown in black), magnetic susceptibility (blue bars), drilling penetration time (black line) and major water inflows (blue triangles). Plan map shows the Swedish grid coordinates (system RT90/RHB70), the positions of boreholes HLX34, HLX35, HLX13 and HLX14 as well as borehole KLX04. Positions of the geophysical profiles LSM000278 and LSM000537 are also shown.*

7 References

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/2/ **SKB, 2001.** Geovetenskapligt program för platsundersökning vid Simpevarp. SKB R-01-44. Svensk Kärnbränslehantering AB.

/3/ **SKB, 2004.** Oskarshamn site investigation. Joint interpretation of lineaments. SKB P-04-49. Svensk Kärnbränslehantering AB.

/4/ **Lindqvist G, 2004.** Oskarshamn site investigation. Refraction seismic measurements in Laxemar. SKB P-04-134. Svensk Kärnbränslehantering AB.

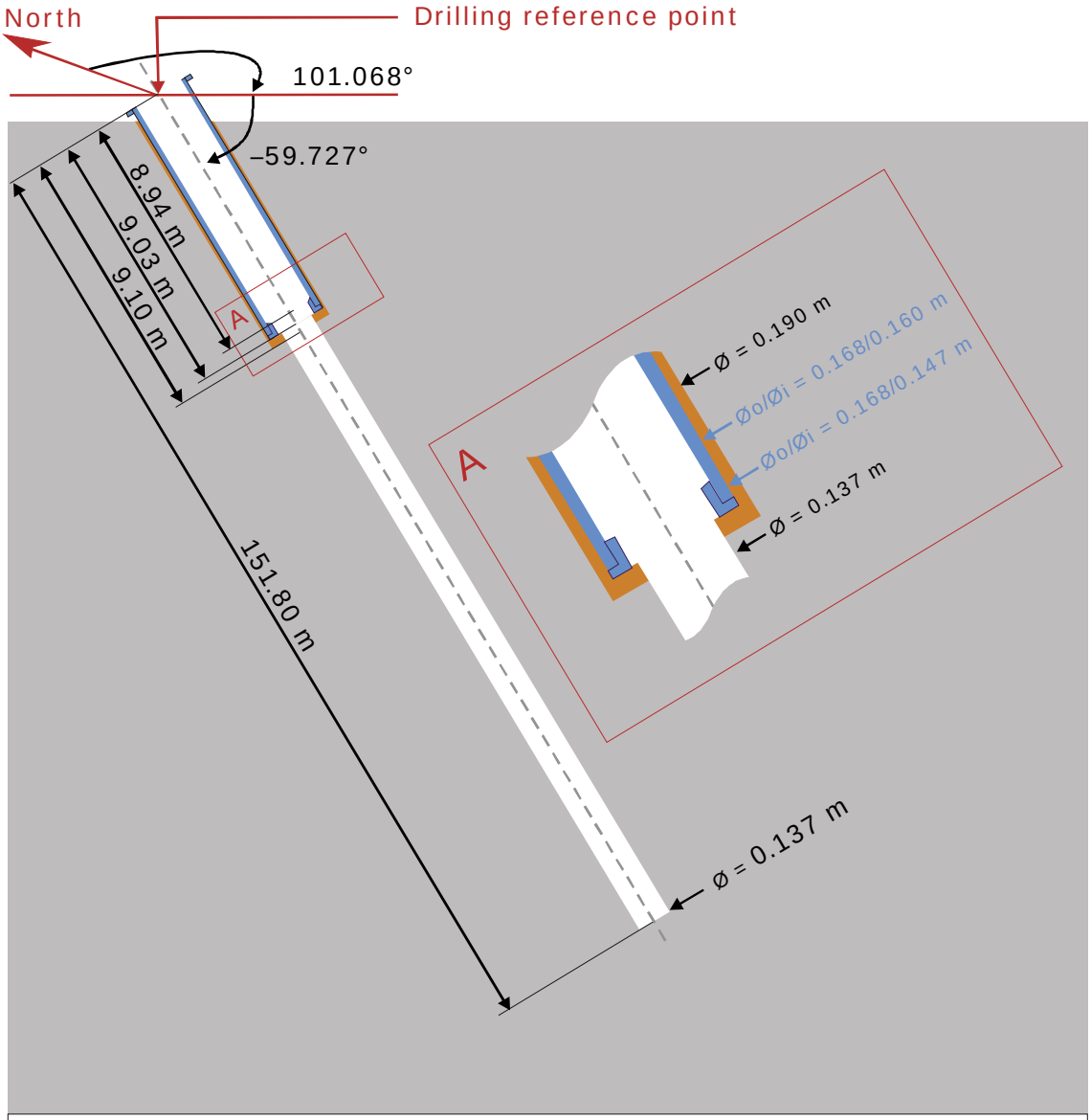
/5/ **Thunehed H, Triumf C-A, Pitkänen T, 2004.** Oskarshamn site investigation. Geophysical profile measurements over interpreted lineaments in the Laxemar area. SKB P-04-211. Svensk Kärnbränslehantering AB.

Appendix 1

Technical data for boreholes HLX34 and HLX35

Technical data

Borehole HLX34



Drilling reference point

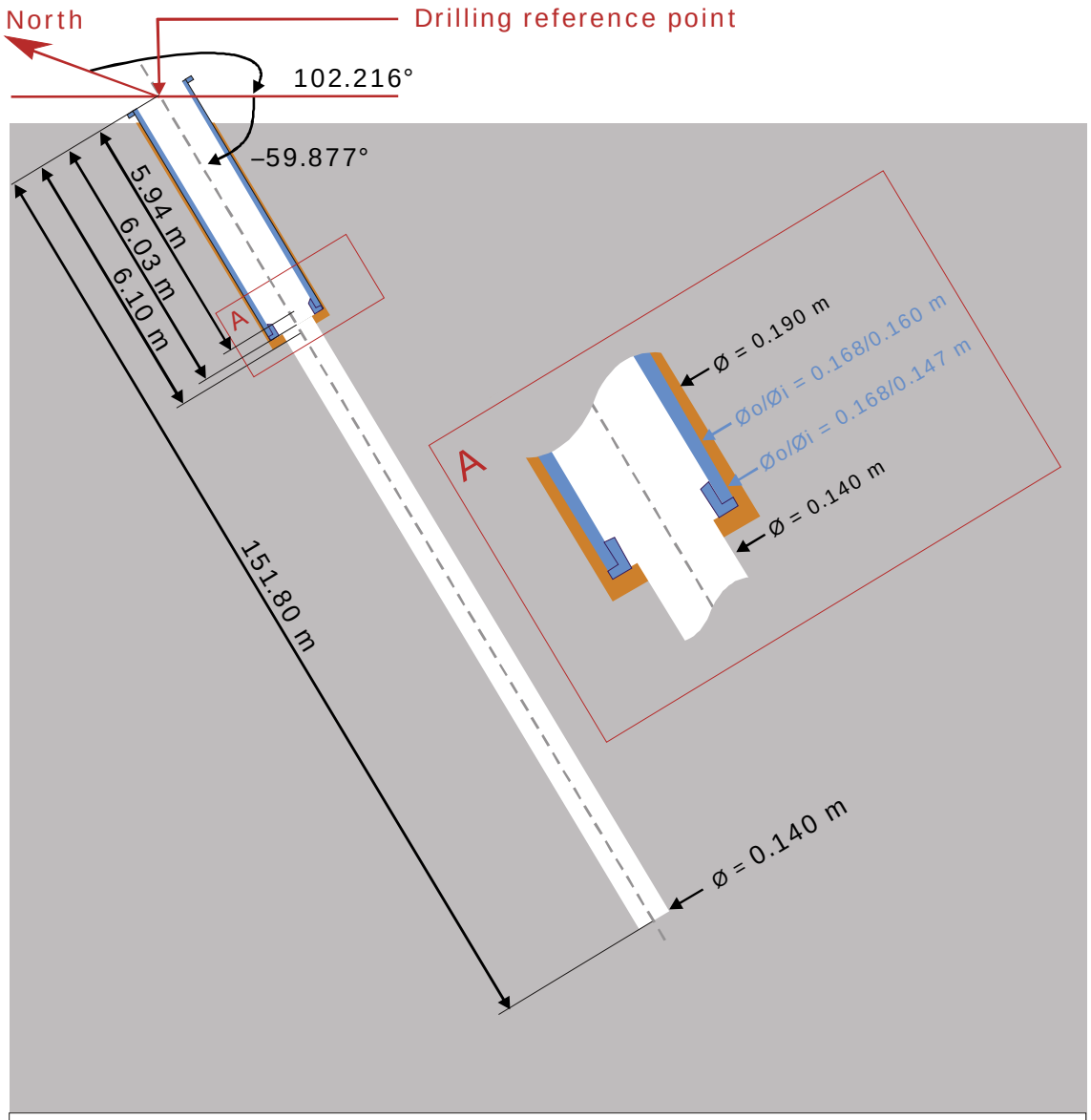
Northing:	6367355.125 (m), RT90 2,5 gon V 0:-15
Easting:	1547489.558 (m), RT90 2,5 gon V 0:-15
Elevation:	14.290 (m), RHB 70

Drilling period

Drilling start date:	2005-06-09
Drilling stop date:	2005-06-14

Technical data

Borehole HLX35



Drilling reference point

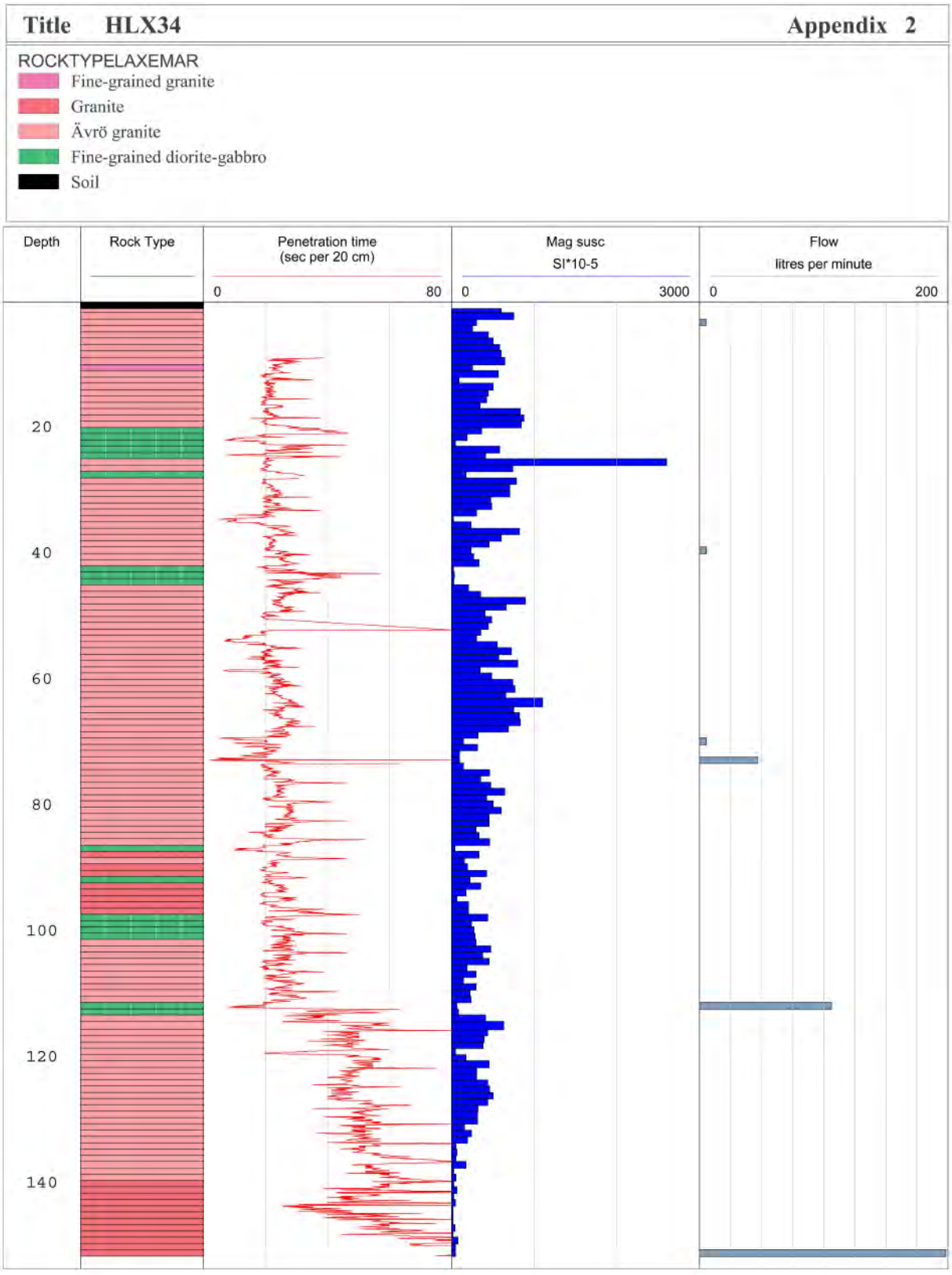
Northing:	6367194.788 (m), RT90 2,5 gon V 0:-15
Easting:	1547437.792 (m), RT90 2,5 gon V 0:-15
Elevation:	14.444 (m), RHB 70

Drilling period

Drilling start date:	2005-05-28
Drilling stop date:	2005-06-02

Geological summary for boreholes HLX34 and HLX35

Preliminary geological mapping, drilling penetration time, magnetic susceptibility and measured water flow during drilling.



Title HLX35 **Appendix 2**