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Oskarshamn site investigation

Percussion drilling of boreholes HLX38, HLX39, HLX40, HLX41, HLX42 and HLX43 for lineament investigation

Henrik Ask, H Ask Geokonsult AB

January 2007

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co
Box 5864
SE-102 40 Stockholm Sweden
Tel 08-459 84 00
+46 8 459 84 00
Fax 08-661 57 19
+46 8 661 57 19

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Keywords: Percussion drilling, Lineament investigation, Hydraulic responses.

Abstract

In general, the percussion holes serve two principal purposes: water supply for core drilling and as investigation boreholes to shallow depth, typically 150 to 200 metres.

Borehole HLX38 was drilled for investigation of lineament NS059. The boreholes HLX39, HLX40 and HLX41 were drilled for investigation of lineament EW900. HLX42 was drilled for a dual purpose; as a potential flushing water supply for future core drilling in the area and for investigation of lineament NE107. HLX43 was drilled for investigation of lineament NS001.

The results from drilling of HLX38 indicate a water-bearing deformation zone (NS059) with vertical or steep westerly dip. Elevated levels of electrical conductivity were encountered in the return water from HLX38 beneath 67 m drilled length.

The drilling results from HLX39, HLX40 and HLX41 indicate a deformation zone (EW900) dipping south with about 60 degrees. The main indicator of the deformation zone from drilling is intervals with reduced magnetic susceptibility. No water inflow was noted in the interpreted position of the deformation zone.

No clear indication of the geometry of the modelled zone NE107 could be established from the drilling of HLX42. The poor quality of the water in borehole HLX42, probably due to unsuccessful casing grouting, led to a decision not to use the borehole as a water supply for core drilling.

HLX43 was drilled through a dolerite dike that was coupled with a massive inflow of water. The borehole features correspond very well to the modelled deformation zone NS001.

Sammanfattning

Hammarborrhål borras i allmänhet för två olika ändamål: dels vattenförsörjning inför kärnborrning dels för att möjliggöra undersökningar i ytligare berggrund, oftast 150 till 200 meter.

Borrhål HLX38 borrades för undersökning av lineament NS059. HLX39, HLX40 och HLX41 borrades för undersökning av lineament EW900. HLX42 borrades med ett tvådelat syfte; dels som en möjlig spolvattenbrunn för kommande kärnborrning i området och dels för undersökning av lineament NE107. HLX43 borrades för undersökning av lineament NS001.

Resultaten från borrning av HLX38 indikerar en vattenförande deformationszon (NS059) med vertikal till brant västlig stupning.

Borrningsresultaten från HLX39, HLX40 och HLX41 indikerar en deformationszon (EW900) som stupar mot syd med omkring 60 grader. Den främsta indikationen på deformationszonen från borrning är intervall med sänkt magnetisk susceptibilitet. Inget inflöde av vatten kunde ses i det tolkade läget för deformationszonen.

Ingen tydlig indikation på geometrin på modellobjekt NE107 kunde fastställas från borrning av HLX42. Den dåliga vattenkvaliteten i borrhål HLX42, som troligen beror på misslyckad spaltinjektering av foderröret, ledde till ett beslut att inte använda borrhålet som spolvattenkälla.

HLX43 borrades igenom en diabasgång som sammanföll med ett rejält vatteninflöde. De företeelser som påträffats i borrhålet sammanfaller mycket väl med den modellerade deformationszonen NS001.

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.

This report will describe the drilling of the six percussion holes, HLX38–43 and the measurements performed during the drilling phase. The holes were drilled on deformation zones NS059, EW900, NS001 and NE107 in the southern and western parts of the Laxemar subarea of the Oskarshamn site investigation, see Figure 1-1.

Drilling of the deformation zones NS059 (HLX38), EW900 (HLX39, 40 and 41) and NS001 (HLX43) was done in accordance with the programme for further investigations in Laxemar /2/.

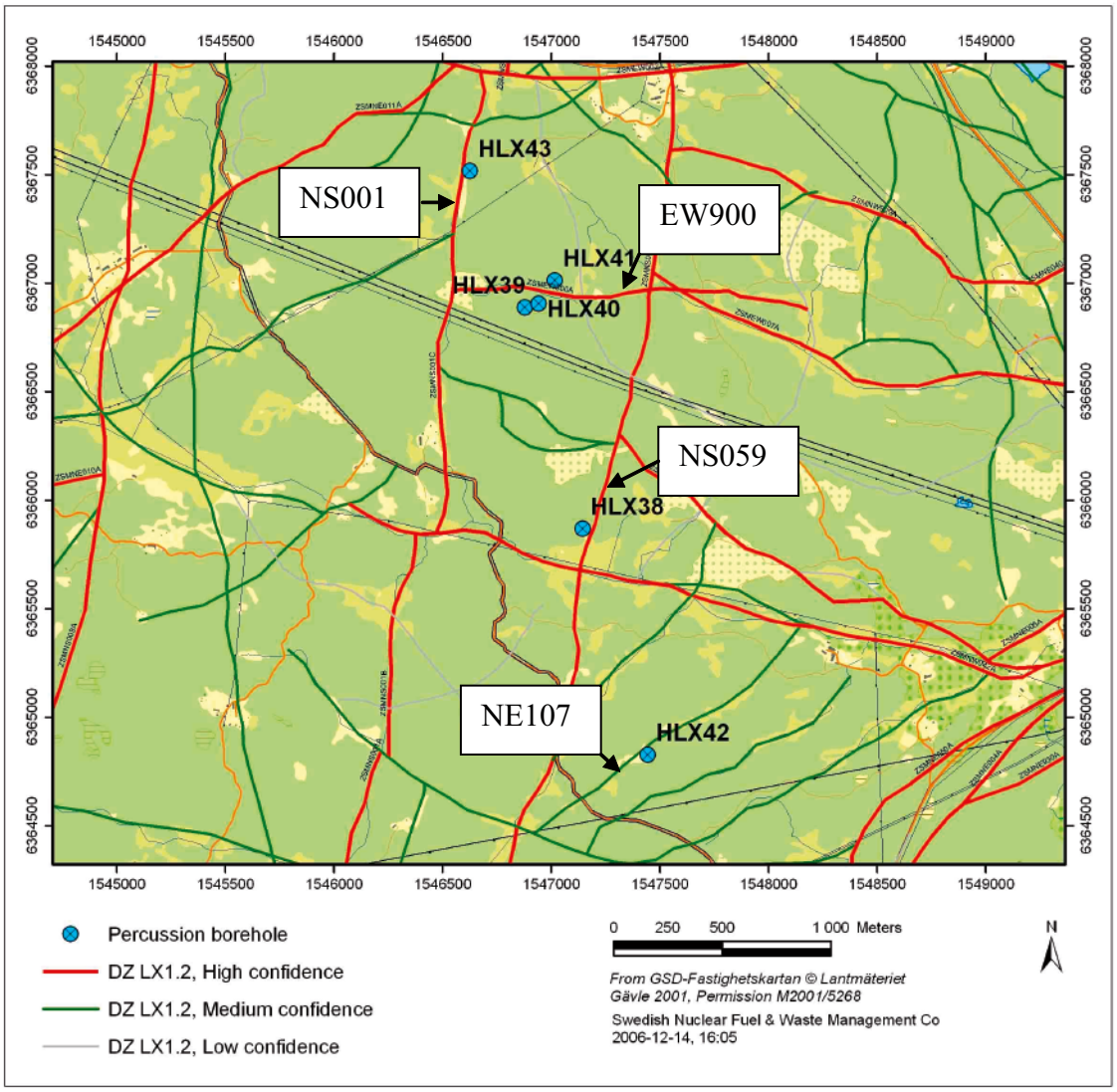


Figure 1-1. *Location of boreholes HLX38, HLX39, HLX40, HLX41, HLX42 and HLX43 in the western and southern parts of Laxemar. The positions of the investigated lineaments NS001, NS059, EW900 and NE107 are shown in the figure.*

The drilling of HLX42 towards deformation zone NE107 was done as a consequence of the increased attention within the site investigation to the southern parts of the Laxemar subarea during 2006.

The decision to drill boreholes:

- HLX38–HLX41 is given in SKB id 1051479 (2006-03-07), internal document.
- HLX42 is given in SKB id 1062413 (2006-10-25), internal document.
- HLX43 is given in SKB id 1061100 (2006-10-03), internal document.

The regional authorities were informed by letters on:

- 2006-03-07, SKB id 1051468, (HLX38–41).
- 2006-10-25, SKB id 1062400, (HLX42).
- 2006-09-29, SKB id 1060852, (HLX43).

The drilling and all related on-site operations were performed according to specific activity plans, see Table 1-1. 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.

Method descriptions and activity plans 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 HLX38–41	AP PS 400-06-037	1.0*
Hammarborring HLX42	AP PS 400-06-109	1.0
Hammarborring HLX43	AP PS 400-06-114	1.0
Method descriptions	**Number**	**Version**
Metodbeskrivning för hammarborrning	SKB MD 610.003	2.0
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 utsättning och inmätning av borrhål	SKB MD 600.002	1.0

*One amendment exists.

2 Objective and scope

This report will describe the drilling of six percussion boreholes, HLX38, HLX39, HLX40, HLX41, HLX42 and HLX43, and the measurements performed during drilling ie the preliminary geological logging and monitoring of hydraulic responses.

The objectives for the boreholes, prior to drilling, are summarised in Table 2-1. The positioning of boreholes HLX38, 39, 40, 41 and 43 was based on knowledge given in the Preliminary site description /3/ for deformation zones NS059, EW900 and NS001. The drilling of borehole HLX43 was, as already mentioned in Chapter 1, a result of the increased attention within the site investigation to the southern parts of the Laxemar subarea during 2006.

The locations of the boreholes HLX38–43 and related geophysical profiles are given in Figure 2-1 together with closely located boreholes that have been used for monitoring of hydraulic responses.

Table 2-1. Borehole objectives before drilling.

Borehole	Deformation zone	Drilling objective
HLX38	NS059	The borehole would intercept a possible subvertical deformation zone related to lineament NS059 (mainly identified as a magnetic anomaly) at 100 m drilled length if the underlying structure is vertical. Refraction seismic measurement in profile LSM000539, done in 2005, however showed that no low-velocity zone could be found at the position for lineament NS059 /4/.
HLX39	EW900	The purpose was of HLX39–41 was verify the existence and geometry of deformation zone EW900 before deciding on subsequent core drilling towards the deformation zone. Measurements with the seismic refraction method had confirmed a low-velocity zone that could be correlated with lineament EW900 (LSM000567) /5/.
HLX40	EW900	The borehole would intercept a possible brittle deformation zone at 100 m drilled length if the zone dips 70 degrees south.
HLX41	EW900	The borehole would intercept deformation zone EW900 if the zone is vertical or dipping north.
HLX42	NE107	The percussion borehole HLX42 was planned as a potential flushing water well for core drilling. The additional motive for the HLX42 was to penetrate NE107 if the structure was vertical or dipping southeast.
HLX43	NS001	The borehole was designed to penetrate the deformation zone NS001 and thereby add to the characterisation of the zone. Results from simplified Boremap mapping of HLX36 and HLX37, also drilled in deformation zone NS001 during 2005, had shown that a dolerite was present in a position that could explain the modelled deformation zone NS001 /6/. The aim of HLX43 was therefore also to test the lateral continuity of the dolerite. Surface information of the lineament was also available from earlier performed geophysical measurements along profile LSM000302 /7/.

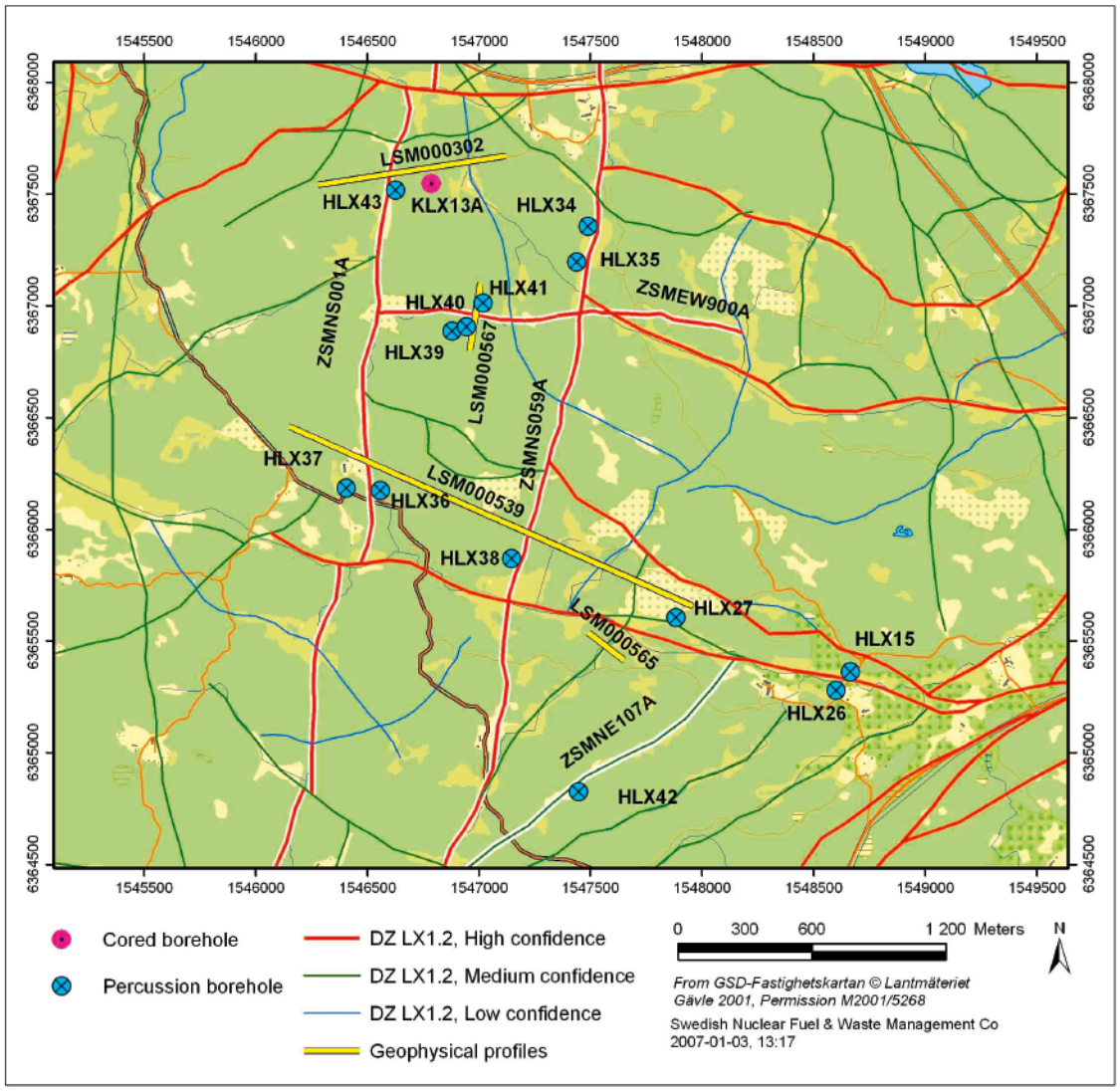


Figure 2-1. *The location of the boreholes HLX38–43 and related geophysical profiles. Boreholes that have been used for monitoring of hydraulic responses are also shown, see section 5.3.*

3 Equipment

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

3.1 Drilling equipment

The percussion drilling was performed by contractor Sven Andersson AB. The drill rig used was Enteco E14G for boreholes HLX38–41 and a Nemek 407 for boreholes HLX42–43.

The drilling machine was equipped with separate engines for transportation and power supplies. For the raising of water and drill cuttings from the borehole, a 27 bar diesel air-compressor, type Atlas-Copco XRVS 455 Md was used. The DTH (down-the-hole) drillhammer was a Secoroc 5” (140 mm) fitted with a guide sleeve. The hammer was lowered into boreholes HLX38–41 by a Driconeq 114 mm pipe string. In the boreholes HLX42 and HLX43 a 76 mm pipe string was used.

3.2 Equipment for measurements and sampling during drilling

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

Measurement of the drilling penetration was done automatically with MWD equipment in boreholes HLX38, HLX40 and HLX41. The drill penetration was measured manually in boreholes HLX39, HLX42 and HLX43, see also section 4.5.

Samples of soil and drill cuttings were collected and a preliminary geological logging was done. The magnetic susceptibility in the samples was measured with a hand-held meter, SM-20 from GF Instruments. The electrical conductivity of the return water was measured with a hand-held Waterproof TDScan WP Pocket Conductivity tester from Eutech Instruments.

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

Figure 3-1. *Drill site HLX40 with the Enteco E14G drill rig.*

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,
- casing grouting technique and equipment,
- percussion drilling in hard rock,
- sampling and measurements,
- borehole completion,
- hydraulic responses,
- 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

Excentric percussion drilling with 190 mm diameter ("TUBEX 140") was made through the unconsolidated soil and near-surface bedrock to a depth of between 6 and 12 metres.

4.3 Casing grouting technique and equipment

In order to prevent surface water and shallow groundwater to infiltrate into deeper parts of the borehole, the annular space between the borehole wall and the casing was grouted with low-alkali cement, see Figure 4-3.

A packer was installed at the bottom of the cased section. The concrete was pumped via a tremie pipe through the packer and allowed to flow up between the casing and the bedrock wall, see Figures 4-4 and 4-5. 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 holes and measuring the amount of in-flowing water. No water could be measured in all but one of the holes, the tightness of the casing grouting was considered to be sufficient.

Figure 4-1. *Starting up the casing drilling with TUBEX 140 in HLX40. The stainless steel casing rests on the excentric drill bit.*

Figure 4-2. *Welding of casing in HLX38. The sections of casing are welded together in order to provide a watertight seal to the surrounding soil and water.*

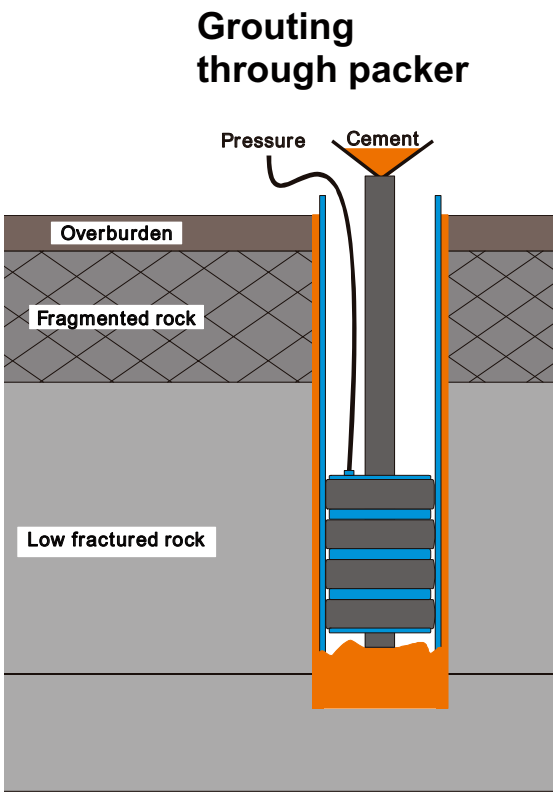


Figure 4-3. *Casing grouting technique.*

Figure 4-4. *Tremie pipe and packer for casing grouting.*

Figure 4-5. *Mixing station for the concrete slurry. The slurry is pumped from the mixing station through the tremie pipe and packer into the borehole.*

In HLX42 a water inflow of ca 50 L/min was encountered while casing drilling through the overburden ie prior to casing grouting. The grouting was done first once and then a second time on the same day. The inflow of water after casing grouting was reduced to ca 10 L/minute.

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.

4.5 Sampling and measurements

Sampling and measurements done by the drillsite geologist and the drilling crew included the following items:

- 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 estimation of water colour and intensity which in turn gives an indication of clay content and level of oxidation. The electrical conductivity was measured every three metres.
- Penetration time (expressed as seconds per 20 cm) was logged automatically in HLX38, HLX40 and HLX41. However, in HLX39, HLX42 and HLX43 the penetration rate was logged manually.
- 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 was to blow compressed air through the drill stem and to measure the amount of return water during steady state conditions. The method employed gives an indication of the actual yield. The lower detection limit is estimated at 1–2 litres/minute. At higher flow rates (over 100 litres/minute) the uncertainty of the method increases.

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

Borehole deviation measurements were not made in conjunction with drilling but will be made as part of separate geophysical activities.

4.6 Borehole completion

All equipment was removed, the sites cleaned and joint inspections were made by representatives from SKB and the Contractor to ensure that the sites had been restored to a satisfactory level. Lockable steel caps on the casing have been fitted on all six percussion boreholes.

4.7 Hydraulic responses

The water levels in selected neighbouring boreholes were monitored for hydraulic responses with MiniTroll pressure loggers. The logger settings were:

- Scan time: 1 s
- Log time: 10 s
- Event: 0.1 kPa

The scan time is the interval for the pressure readings. With an event function of 0.1 kPa, the logger saves any data that has changed more than 0.1 kPa since the previous scanning. The log time is the interval between data savings regardless of pressure changes.

Figure 4-6. *Return water from drilling (HLX38) is led to a settling container. The cyclone for directing the cuttings to the collecting sieve can be seen fastened on top of the container.*

Figure 4-7. *Steel cap fitted on casing in HLX42.*

4.8 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.

4.9 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. The water amounted to very small quantities.

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

HLX38 was drilled towards deformation zone NS059 between April 10 and 24, 2006.

Boreholes HLX39, 40 and 41 were drilled towards deformation zone EW900 between May 2 and June 14, 2006.

HLX42 was drilled with the dual purpose of providing information on the modelled deformation zone NE107 and being a possible water supply for subsequent core drilling. Percussion drilling was performed between November13 and 16, 2006. As borehole HLX42 was initially planned as a water supply well, an environmental monitoring well, SSM000270 was drilled in the vicinity of the percussion hole, see section 5.5.

HLX43 was drilled towards deformation zone NS001 between October 19 and 26, 2006.

Technical data for the boreholes are given in section 5.1

Notes on electrical conductivity and water quality in return water while drilling are given in section 5.2

Hydrogeological results and observations are given in section 5.3.

5.1 Borehole design

A summary of data from the boreholes are presented in Tables 5-1, 5-2 and 5-3. Technical drawings of the boreholes are given in Appendix 1.

Table 5-1. Geometric and technical data for borehole HLX38 and HLX39.

Parameter	HLX38		HLX39	
Drilling period	From 2006-04-10 to 2006-04-24		From 2006-06-07 to 2006-06-14	
Borehole inclination (starting point) (0 to –90)	–59.39°		–59.35°	
Borehole azimuth (0–360)	110.0°		14.3°	
Borehole length	199.50 m		199.30 m	
Soil depth	0.3–6.2 m below TOC		0 m	
Starting point coordinates (system RT90/RHB70)	Northing: 6365868.86 m Easting: 1547146.08 m Elevation: 11.53 m.a.s.l.		Northing: 6366887.87 m Easting: 1546880.48 m Elevation: 27.044 m.a.s.l.	
Water yield (interval)	99 L/min (0–199.5 m)		11 L/min (0–199.3 m)	
Borehole diameter	0–15.10 m	190 mm	0–6.10 m	190 mm
(interval) (diameter)	15.10–103.2 m	140.1 mm	6.10–121.0 m	138.4 mm
	103.2–199.5 m	139.0 mm	121.0–199.3 m	137.9 mm
Casing diameter (interval) (diameter)	0–14.93 m	$Ø_o$ = 168 $Ø_i$ = 160	0–5.93 m	$Ø_o$ = 168 $Ø_i$ = 160
	14.93–15.02 m	$Ø_o$ = 168 $Ø_i$ = 143	5.93–6.02 m	$Ø_o$ = 168 $Ø_i$ = 143

Table 5-2. Geometric and technical data for borehole HLX40 and HLX41.

Parameter	HLX40		HLX41	
Drilling period	From 2006-05-02 to 2006-05-09		From 2006-05-22 to 2006-06-01	
Borehole inclination (starting point) (0 to –90)	–59.57°		–59.09°	
Borehole azimuth (0–360)	11.0°		208.3°	
Borehole length	199.50 m		199.50 m	
Soil depth	0 m		0 m	
Starting point coordinates (system RT90/RHB70)	Northing: 6366906.76 m Easting: 1546943.95 m Elevation: 25.737 m.a.s.l.		Northing: 6367013.20 m Easting: 1547017.61 m Elevation: 21.797 m.a.s.l.	
Water yield (interval)	3 L/min (0–199.5 m)		0 L/min (0–199.5 m)	
Borehole diameter	0–6.10 m	190 mm	0–6.10 m	190 mm
(interval) (diameter)	6.10–121.2 m	138.4 mm	6.10–121.2 m	140.4 mm
	121.2–199.5 m	137.7 mm	121.2–199.5 m	139.4 mm
Casing diameter (interval) (diameter)	0–5.93 m	$Ø_o$ = 168 $Ø_i$ = 160	0–5.93 m	$Ø_o$ = 168 $Ø_i$ = 160
	5.93–6.02 m	$Ø_o$ = 168 $Ø_i$ = 143	5.93–6.02 m	$Ø_o$ = 168 $Ø_i$ = 143

Table 5-3. Geometric and technical data for borehole HLX42 and HLX43.

Parameter	HLX42		HLX43	
Drilling period	From 2006-11-13 to 2006-11-16		From 2006-10-19 to 2006-10-26	
Borehole inclination (starting point) (0 to –90)	–57.11°		–50.74°	
Borehole azimuth (0–360)	321.51.6°		268.55°	
Borehole length	152.60 m		170.60 m	
Soil depth	0.3–1.80 m below TOC		0 m	
Starting point coordinates (system RT90/RHB70)	Northing: 6364827.04 m Easting: 1547446.73 m Elevation: 12.88 m.a.s.l.		Northing: 6367517.45 m Easting: 1546626.60 m Elevation: 24.20 m.a.s.l.	
Water yield (interval)	44 L/min* (0–152.6 m)		290 L/min (0–170.5 m)	
Borehole diameter	0–9.10 m	190 mm	0–6.00 m	190 mm
(interval) (diameter)	9.10–152.9 m	139.0 mm	6.00–101.20 m	140.0 mm
			101.2–170.6 m	139.7 mm
Casing diameter (interval) (diameter)	0–9.01 m	$Ø_o$ = 168 $Ø_i$ = 160	0–5.91 m	$Ø_o$ = 168 $Ø_i$ = 160
	9.01–9.10 m	$Ø_o$ = 168 $Ø_i$ = 143	5.91–6.00 m	$Ø_o$ = 168 $Ø_i$ = 143

* The value of 44 L/min in HLX42 includes the near-surface water originating from inflow following the unsuccessful casing grouting in HLX42. The inflow of water after casing grouting was ca 10 L/minute. A more correct estimate of the water yield over the non-cased section would be 30–35 L/min.

No deviation measurements were done in conjunction with drilling. This does not consitute a formal nonconformity, however, as deviation measurements with the Flexit method has or will be done as part of separate geophysical Borehole Imaging loggings (BIPS).

5.2 Notes on electrical conductivity and water quality in return water while drilling

Elevated levels of electrical conductivity were encountered in HLX38 beneath 67 m drilled length. The conductivity increased stepwise with increasing water flow, see Table 5-4.

Measurements of the electrical conductivity in the return water of HLX39, 40, 41 and 42 show that the values are low and stable around 30–60 mS/m.

A slight increase in the electrical conductivity was noted while drilling through the dolerite in HLX43, see Table 5-4.

The observed quality of the return water from HLX42 was such that a decision was taken NOT to utilise HLX42 as a water supply for core drilling. The return water in HLX42 was brownish with a probable high content of organic matter, see Table 5-4. The likely cause of the poor water quality is the unsuccessful grouting of the annular space between casing and rock, see also section 4.3 and section 5.3. One water sample (SKB ID 11529) was taken in HLX42 at full drilled length,152.60 m. The sample had an electrical conductivity of 36 mS/m and was not analysed for any other parametres.

A slight increase in conductivity during the initial metre of drilling beneath the casing is common. This is however related to drilling through the bottom plug of concrete and is not commented in Table 5-4.

Table 5-4. Electrical conductivity in return water while drilling in HLX38–43.

Borehole	Interval drilled length (m)	Electrical conductivity measurements (mS/m)	Comments
HLX38	0–67 m	40 mS/m	The increase of electrical conductivity is correlated to the increased water inflow in the borehole at ca 67 m drilled length (flow 17 L/min) and at ca 100 m drilled length (flow 60 L/min)
	67–100 m	200 mS/m	
	100–199.50 m	300–400 mS/m	
HLX39	7–199.3 m	30–60 mS/m	
HLX40	0–122 m	no data	
	122–190.50 m	40–50 mS/m	
HLX41	6–199.5 m	30–40 mS/m	
HLX42	2–152 m	30–40 mS/m	Sample (SKB ID 11529) taken at full drilled length 152.60 m had a electrical conductivity of 36 mS/m.
			The return water in HLX42 was brownish with a probable high content of organic matter.
HLX43	0–44 m	no data	The reduction in conductivity occurred shortly after the dolerite was drilled through.
	44–78 m	100 mS/m	
	78–170.30	60 mS/m	

5.3 Hydrogeological observations and results

The water yields obtained from blowing of compressed air during drilling (air-lifting) are given in Table 5-5.

The amount of effluent water released to the ground from the drilling activities is estimated in Table 5-6. The release of water was made within 30 metres from the collar location.

Manual measurements of the ground water level were normally done after the drilling was completed and the drill stem removed from the borehole. The results are shown in Table 5-7. Removing the drill stem takes about one hour which means that in boreholes with a lot of water, the water table will often be recovered at the time of measurement.

Table 5-5. Water yields from drilling.

Drilled length (m)	Time (local)	Time (SNT*)	Date	Flow (L/min)	Borehole	Comment
2.00	14:30	13:30	2006-04-11	0	HLX38	
15.10	18:15	17:15	2006-04-11	0	HLX38	
67.20	16:45	15:45	2006-04-18	17	HLX38	
103.20	19:00	18:00	2006-04-18	60	HLX38	
104.20	13:15	12:15	2006-04-19	60	HLX38	
184.50	20:35	19:35	2006-04-19	90	HLX38	
185.50	08:15	07:15	2006-04-20	108	HLX38	
199.50	11:40	10:40	2006-04-20	99	HLX38	
199.50	14:00	13:00	2006-04-20	No measurement – no change noted	HLX38	Final air-lift pumping
1.00	11:45	10:45	2006-06-07	0	HLX39	
7.20	10:35	09:35	2006-06-08	0	HLX39	
34.20	12:00	11:00	2006-06-08	0	HLX39	
35.00	12:55	11:55	2006-06-12	2	HLX39	
121.00	17:50	16:50	2006-06-12	2	HLX39	
122.00	12:45	11:45	2006-06-13	0	HLX39	
196.30	17:45	16:45	2006-06-13	14	HLX39	
199.30	19:10	18:10	2006-06-13	11	HLX39	
199.30	8:00	7:00	2006-06-14	No measurement – no change noted	HLX39	Final air-lift pumping
1.00	16:10	15:10	2006-05-02	0	HLX40	
6.10	17:55	16:55	2006-05-02	0	HLX40	
7.20	08:30	07:30	2006-05-04	0	HLX40	
121.20	14:40	13:40	2006-05-04	0	HLX40	
122.20	14:30	13:30	2006-05-08	0	HLX40	
199.50	17:55	16:55	2006-05-08	3	HLX40	
199.50	8:00	7:00	2006-05-09	No measurement – no change noted	HLX40	Final air-lift pumping

Drilled length (m)	Time (local)	Time (SNT*)	Date	Flow (L/min)	Borehole	Comment
1.00	13:30	12:30	2006-05-23	0	HLX41	
7.20	14:35	13:35	2006-05-29	0	HLX41	
91.20	20:40	19:40	2006-05-29	0	HLX41	
92.20	09:10	08:10	2006-05-31	0	HLX41	
199.50	17:45	16:45	2006-05-31	0	HLX41	
199.50	18:45	17:45	2006-05-31	No measurement – no change noted	HLX41	Final air-lift pumping
1.00	13:30	13:30	2006-11-13	0	HLX42	
9.10	17:00	17:00	2006-11-13	50	HLX42	
10.10	10:00	10:00	2006-11-15	10**	HLX42	
54.20	13:50	13:50	2006-11-15	14**	HLX42	
101.60	16:20	16:20	2006-11-15	18**	HLX42	
102.60	09:00	09:00	2006-11-16	28**	HLX42	
152.60	14:15	14:15	2006-11-16	44**	HLX42	
152.60	15:00	15:00	2006-11-16	No measurement – no change noted	HLX42	Final air-lift pumping
1.00	15:15	14:15	2006-10-19	0	HLX43	
6.20	17:15	16:15	2006-10-19	0	HLX43	
7.20	13:50	12:50	2006-10-23	0	HLX43	
62.20	17:35	16:35	2006-10-23	0	HLX43	
63.20	09:30	08:30	2006-10-24	0	HLX43	
80.20	10:35	09:35	2006-10-24	126	HLX43	
83.20	10:55	09:55	2006-10-24	240	HLX43	
101.20	12:00	11:00	2006-10-24	280	HLX43	
102.20	09:05	08:05	2006-10-25	210	HLX43	
170.50	16:15	15:15	2006-10-25	290	HLX43	
170.50	17:30	16:30	2006-10-25	No measurement – no change noted	HLX43	Final air-lift pumping

NB Measurements at similar lengths in a hole can occur because one measurement is done at the end of the working day and second is done the following morning. The latter measurement sometimes gives a significantly higher value due to recovery and storage.

*SNT – Swedish Normal Time ie not adjusted for daylight saving time

** The water flow measured in HLX42 below the casing includes the near-surface water originating from inflow following the unsuccessful casing grouting in HLX42. The inflow of water after casing grouting was ca 10 L/minute. A more correct estimate of the water yield over the non-cased section at full drilled length would be 30–35 L/min.

Table 5-6. Amount of released water from drilling.

Borehole	Amount of water released (m^3)
HLX38	58
HLX39	6
HLX40	0
HLX41	0
HLX42	38
HLX43	156

Table 5-7. Manual measurements of ground water levels in HLX38–43.

Borehole	Date	Time*	Drilled length (m)	Water level (m below toc along the borehole)
HLX38	2006-04-24	15:00	199.5	7.1
HLX39	2006-06-14	10:10	170.3	61.3
HLX39	2006-06-14	10:20	170.3	56.7
HLX39	2006-06-14	10:30	170.3	52.6
HLX39	2006-06-14	10:40	170.3	49.0
HLX39	2006-06-14	10:50	170.3	44.0
HLX39	2006-06-14	11:00	170.3	40.4
HLX39	2006-06-14	11:10	170.3	36.6
HLX39	2006-06-14	11:20	170.3	32.3
HLX39	2006-06-14	11:30	170.3	29.5
HLX39	2006-06-14	11:40	170.3	26.1
HLX40	2006-05-09	11:00	199.5	10.5
HLX40	2006-05-09	12:00	199.5	10.5
HLX41	2006-05-31	21:00	199.5	> 100 metres**
HLX42	N/A	N/A	N/A	No measurements made in HLX42
HLX43	N/A	N/A	N/A	No measurements made in HLX43

* Local time ie with daylight saving time.

** No water encountered with a 100 metre long tape.

Hydraulic responses

Monitoring of hydraulic responses ie changes in water column in an observation borehole related to drilling or pumping in another borehole, was done routinely during the drilling activities in HLX38–43.

The hydraulic responses are summarised in Tables 5-8 through 5-11. Data from selected observation boreholes are also shown graphically in Figures 5-1 to 5-3. The location of boreholes previously not mentioned in this report are shown in Figure 2-1. A legend explaining the symbols used in Tables 5-8 to 5-11 is given in Table 5-12.

One, rather questionnable, response can be seen in HLX35 during drilling activities in HLX38, see Table 5-8 and Figure 5-1. The data in observation borehole HLX28 was obscured by on-going pumping in that hole.

Table 5-8. Hydraulic responses from the drilling of HLX38.

Event	Observation borehole			
	HLX27	HLX28*	HLX34	HLX35
Drilling HLX38 18/4	No	?	No	No
Drilling HLX38 19/4	No	?	No	No
Drilling HLX38 20/4	No	?	No	?

*HLX28 is dominated by pumping.

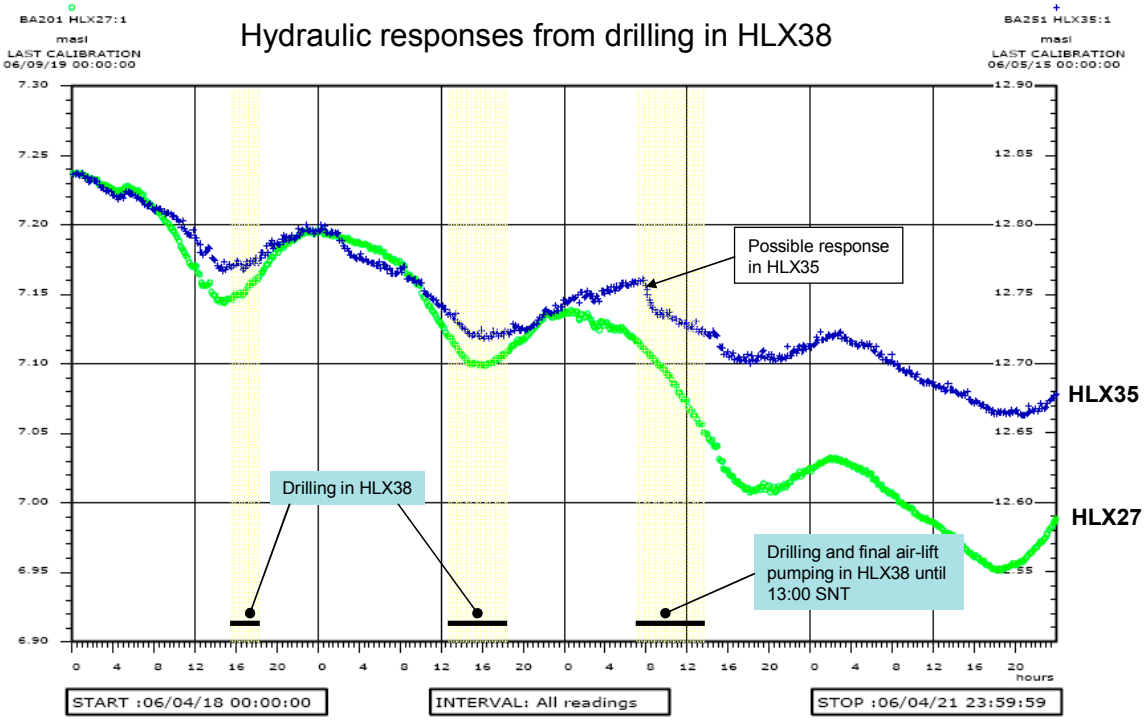


Figure 5-1. *The variations of the water column for boreholes HLX27 (green) and HLX35 (blue) are shown for the period April 18 to April 21, 2006. The times for active drilling and air-lift pumping of borehole HLX38 are given with black horizontal bars and yellow raster. A possible response, seen mainly as a drawdown curve, can be interpreted in HLX35 on April 20 that could be related to the final day of drilling in HLX38. It should be stressed that this interpretation is preliminary and a more detailed study is warranted in order to fully evaluate the hydraulic response. The time scale is in Swedish Normal Time.*

A possible response from air-lift pumping in HLX40 can be seen in HLX25 and HLX34. Two rather distinct responses can be seen in HLX40 from the last two days of drilling and air-lift pumping in HLX39, see Table 5-9 and Figure 5-2. No monitoring was done in HLX41 during the drilling of HLX39 (June 7–14, 2006).

Table 5-9. Hydraulic responses from the drilling of HLX39, HLX40 and HLX41.

Event	Observation borehole				
	HLX25	HLX34	HLX35	HLX40	HLX41*
Drilling HLX40 2/5	No	No	No	ND	ND
Drilling HLX40 4/5	No	No	No	ND	ND
Drilling HLX40 8/5	No	No	No	ND	ND
Air-lift pumping HLX40 9/5	?	?	N/A	ND	ND
Drilling HLX41 23/5	No	No	N/A	No	ND
Drilling HLX41 29/5	No	No	N/A	No	ND
Drilling HLX41 31/5	No	No	N/A	No	ND
Drilling HLX39 7/6	No	No	N/A	No	N/A
Drilling HLX39 8/6	No	No	N/A	No	N/A
Drilling HLX39 12/6	No	No	N/A	No	N/A
Drilling HLX39 13/6	No	No	N/A	Yes	N/A
Air-lift pumping HLX39 14/6	No	No	N/A	Yes	N/A

*HLX41 was not monitored.

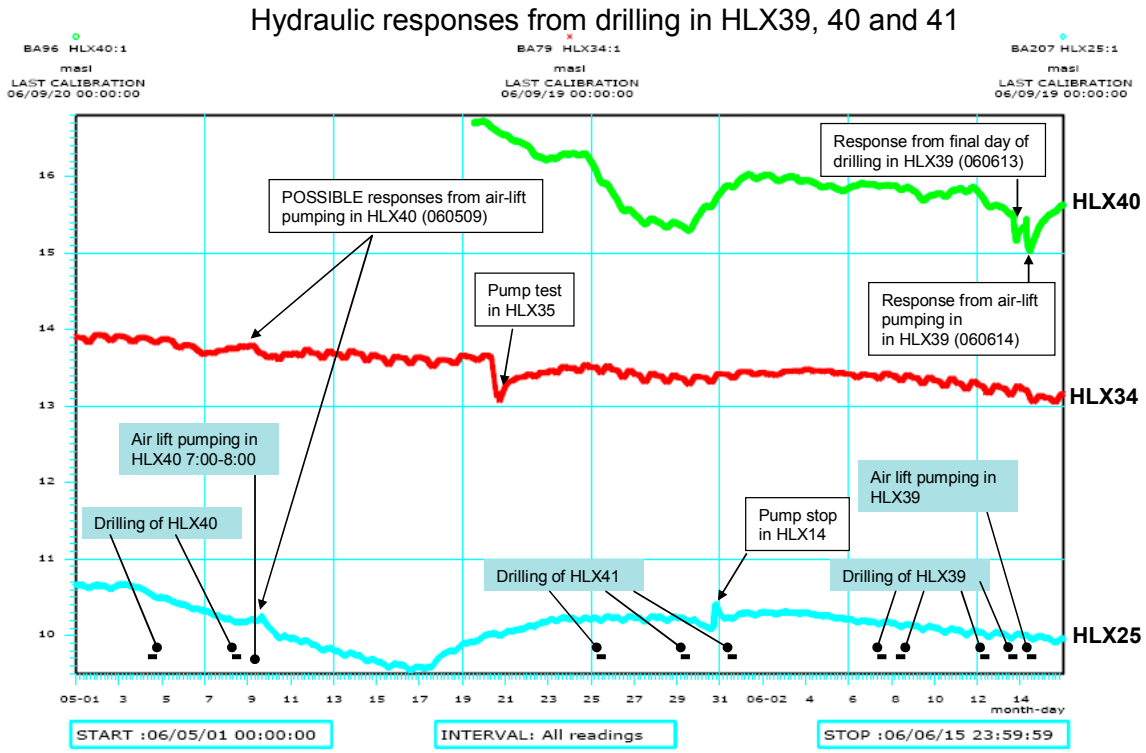


Figure 5-2. *The variations of the water column for boreholes HLX40 (green), HLX34 (red) and HLX25 (light blue) are shown for the period May 1 to May 15, 2006. The times for active drilling and air-lift pumping of boreholes HLX40, HLX41 and HLX39 respectively are given with black horizontal bars and yellow raster. Possible responses, seen as a drawdown curve, can be interpreted in HLX25 and HLX34 on May 9 that could be related to the final air-lift pumpng in HLX40. Rather clear reponses from drilling and air-lift pumping in HLX39 can be seen in HLX40 on June 13 and June 14. It should be stressed that this interpretation is preliminary and a more detailed study is warranted in order to fully evaluate the hydraulic responses. The time scale is in Swedish Normal Time.*

No hydraulic response from drilling and air-lift pumping in HLX42 could be seen in HLX27, see Table 5-10. No monitoring was done in HLX28 during drilling of HLX42. (November 15–16, 2006).

Only one possible hydraulic response from drilling in HLX43 could be seen in HLX39, see Table 5-11 and Figure 5-3. Borehole KLX13A was divided into sections with packers before the drilling of HLX43 commenced. KLX13A:1, section 1, is the deepest (between 469 and 595.85 m drilled length) and section 3 is the most shallow (0–339 m drilled length).

Table 5-10. Hydraulic responses from the drilling of HLX42.

Event	Observation borehole			
	HLX15*	HLX26*	HLX27	HLX28**
Drilling HLX42 15/11	N/A	N/A	No	N/A
Drilling HLX42 16/11	N/A	N/A	No	N/A

*HLX15 and HLX26 – no data has been retrieved from loggers at time of writing.

**No data available from HLX28.

Table 5-11. Hydraulic responses from the drilling of HLX43.

Event	Observation borehole						
	KLX13A:1	KLX13A:3	HLX36	HLX37	HLX39	HLX40*	HLX41*
Drilling HLX43 23/10	No	No	No	No	No	N/A	N/A
Drilling HLX43 24/10	No	No	No	No	No	N/A	N/A
Drilling HLX43 25/10	No	No	No	No	?	N/A	N/A

*HLX40 and HLX41 – the data has not been retrieved from loggers at time of writing.

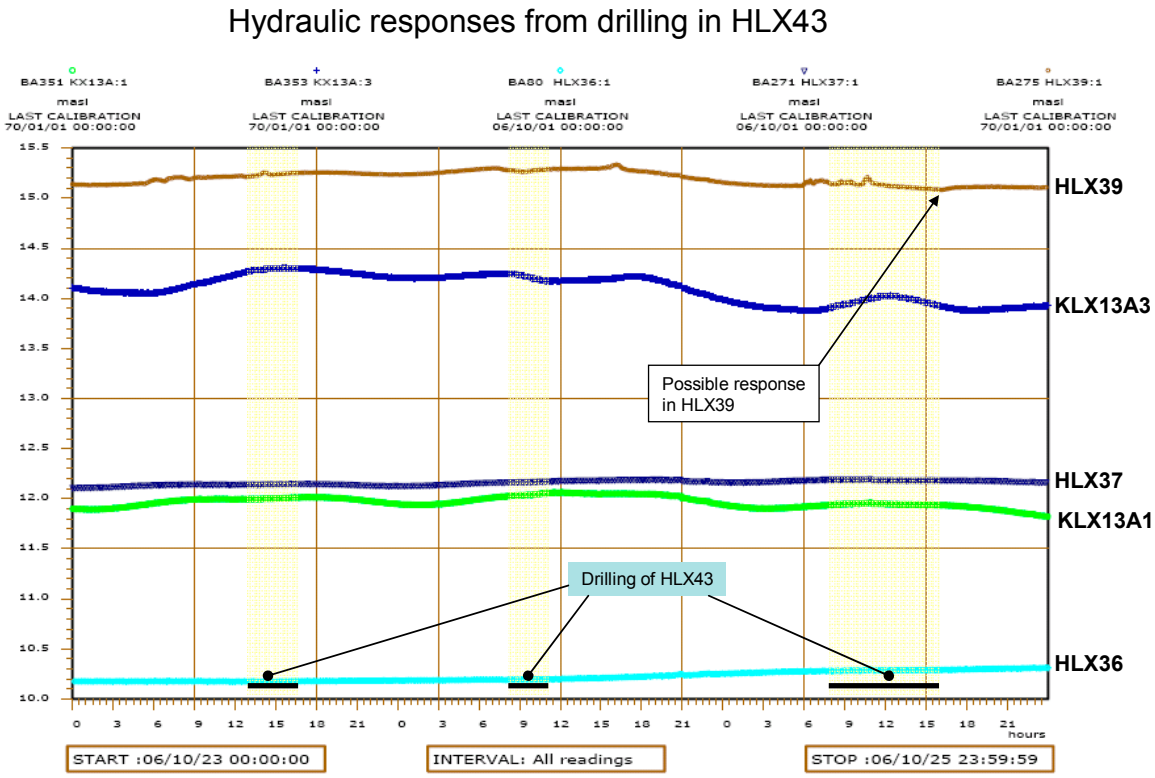


Figure 5-3. *The variations of the water column for boreholes KLX13A:1 (green), KLX13A:3 (medium blue), HLX36 (light blue), HLX37 (dark blue) and HLX39 (brown are shown for the period October 23 to October 25. The times for active drilling and air-lift pumping is given with black horizontal bars and yellow raster. A possible response, seen as a faint recovery curve, can be interpreted in HLX39 (brown) on October 25 at 16:00. It should be stressed that this interpretation is preliminary and a more detailed study is warranted in order to fully evaluate the hydraulic response. The time scale is in Swedish Normal Time.*

Table 5-12. Legend – Hydraulic responses.

Possible response	?
Data is too disturbed to be interpreted	?
No data available	N/A
Not drilled	ND
No response	No
Response	Yes

5.4 Geological results

The geological results based on the preliminary mapping are presented in Appendix 2.

Further comment on the geometrical interpretations of the deformation zones is given in section 6.

5.5 Drilling of environmental monitoring well SSM000270

As borehole HLX42 was drilled with the original motive of supplying water for core drilling, an environmental monitoring well was drilled in the immediate vicinity of the percussion borehole. The location of the monitoring well, SSM000270 is given in Figure 5-4 together with HLX42 and the planned cored borehole KLX16A.

Drilling was made with a HAFO 1500 drilling rig fitted with a Furukawa top-hammer.

Rock probing was done on November 15, 2006 with 54 mm diameter rods to four metres below ground surface. The probing was done according to Swedish geotechnical class 1 "Jb1" and is also called soil-rock-sounding /8/. The boundary between the overburden and bedrock was noted at 1.8 metres below ground surface, see Figure 5-5.

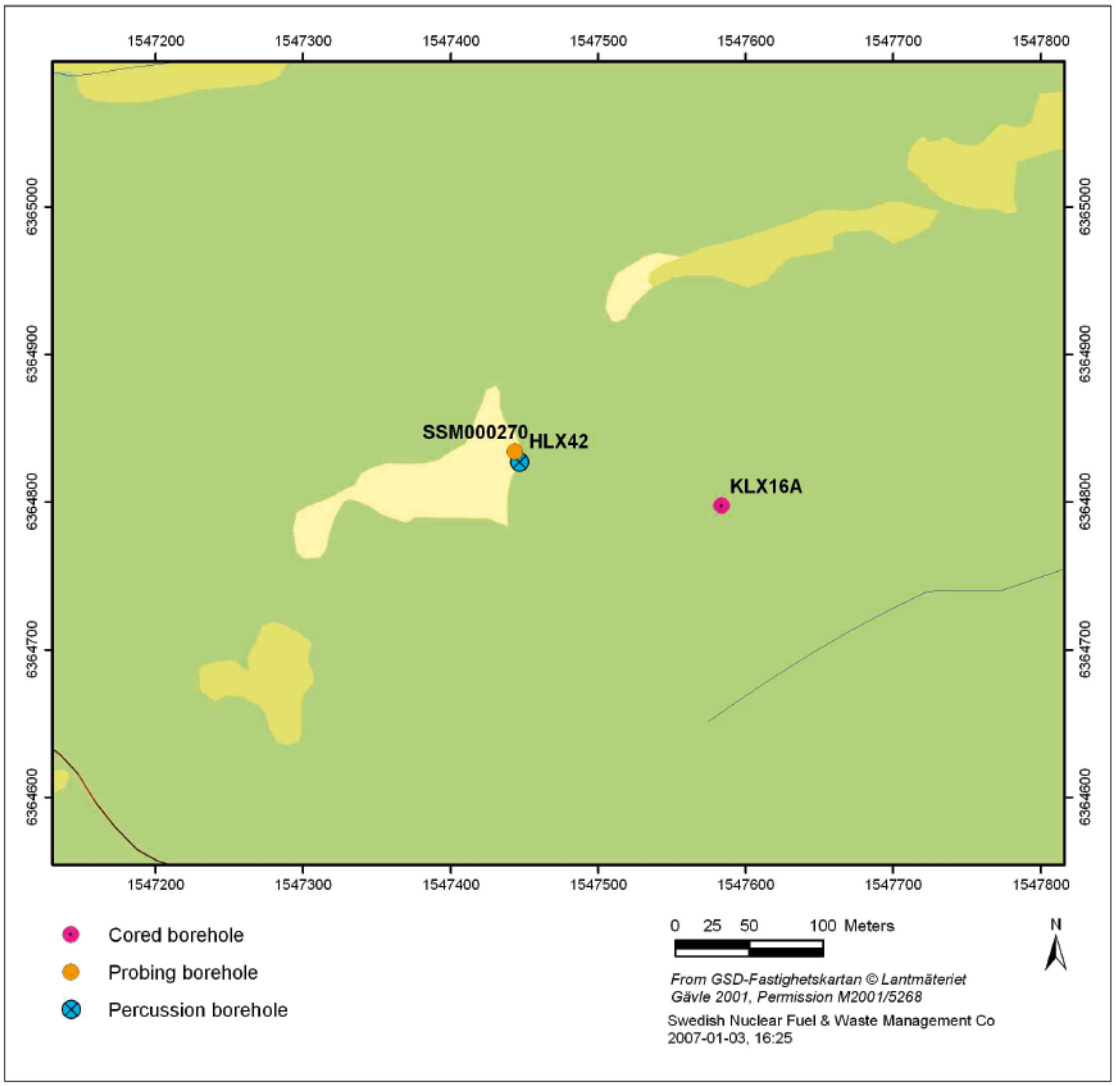


Figure 5-4. *The location of SSM000270 in relation to HLX42 and planned cored borehole KLX16A.*

Drilling with NO-X equipment (continuous casing drilling with retractable pilot drill bit) was also done on November 15, 2006. Drilling through the overburden was done to a depth of 1.9 metres below ground surface. The drilling dimension was NO-X 90 which gives a borehole diameter of 125 mm. An inner tube of inert polyethylene plastic with the dimension 63/50 mm was installed from 1.32 metres above ground level to 1.9 metres below surface. The lowermost section of the inner tube is slotted to allow water infiltration in the well. The top of the inner tube is used as reference level for future measurements in the borehole.

The steel drill casing was removed in conjunction with filter sand filling of the annular space. A bentonite seal was emplaced to prevent influx of surface water into the sand filter.

The technical data together with geological information from drilling of SSM000270 is given in Table 5-13 and shown graphically in Figure 5-5.

A environmental reference water sample (SKB id 11554) was taken on November 23, 2006.

No further sampling or logging was done for environmental purposes as borehole HLX42 was not to be used as a water supply for core drilling,

5.6 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 low alkali cement paste and oils are given in Table 5-14.

Probing	
Drill rig:	HAFO 1500
Hammer:	Furukawa
Stem:	44 mm
Bit:	57 mm Star (four-cutter)
Flushing media :	Air

Drilling	
Drill rig:	HAFO 1500
Drill dimension:	NO-X 90
Borehole diameter:	125 mm
Inner tube	63/50 mm

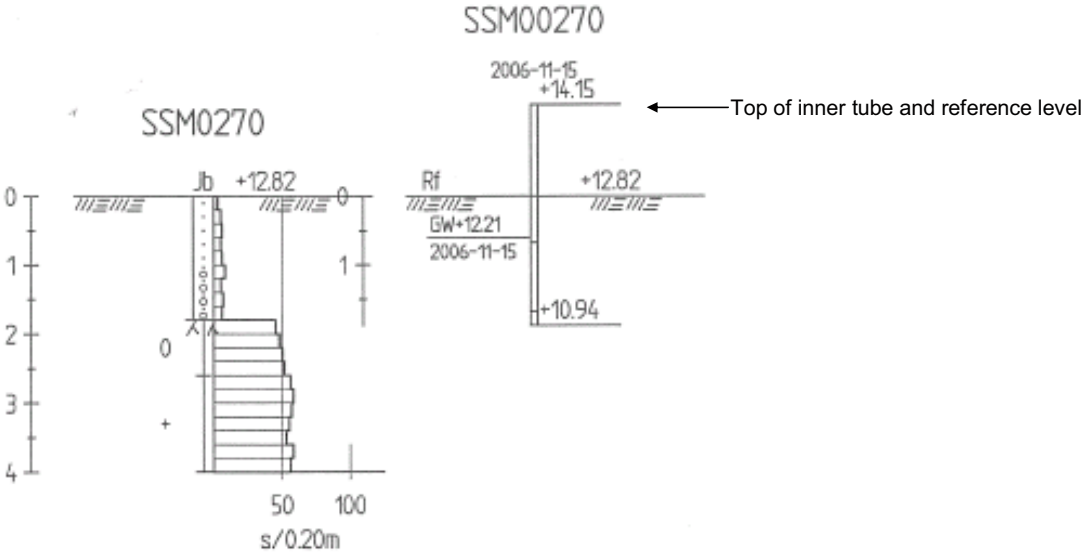


Figure 5-5. *Probing and drilling of environmental monitoring well SSM000270.*

Table 5-13. Geometric and technical data for environmental monitoring well SSM000270.

Parameter	SSM000270	
Drilling date (probing and NO-X)	2006-11-15	
Borehole inclination (starting point) (0 to –90)	–88.45°	
Borehole azimuth (0–360)	62.0° (NB close to vertical hole)	
Borehole length	3.20 m (below reference)	
Soil depth	1.32–3.1 m (below reference)	
Reference point coordinates (system RT90/RHB70)	Northing: 634834.14 m Easting: 1547444.01 m Elevation: 14.15 m.a.s.l.	
Ground water level	12.21 m.a.s.l.	
(observation after drilling 2006-11-15	1.94 m (below reference)	
Borehole diameter	0–1.32 m	N/A
(interval) (diameter)	1.32–3.20 m	125 mm
Inner tube	0–3.20 m	$Ø_o$ = 63
(interval) (diameter)		$Ø_i$ = 50

Table 5-14. Consumption of cement paste and oils.

Borehole	Cement paste used (low-alkali White Cement based) litres/kg	Hammer oil (Preem Hydra 46) litres	Compressor oil (Schuman 46) litres
HLX38	72/70	20	None noted
HLX39	36/35	10	None noted
HLX40	36/35	No data	None noted
HLX41	36/40	20	None noted
HLX42	50/72	10	None noted
HLX43	25/35	8	None noted

5.7 Nonconformities

In HLX42 the inflow of water after casing grouting was ca 10 L/minute ie complete tightness was not achieved.

No monitoring was done in HLX41 during the drilling of HLX39 (June 7–14, 2006).

No monitoring was done in HLX28 during drilling of HLX42. (November 15–16, 2006)

Borehole deviation measurements were not made in conjunction with drilling but will be made as part of separate geophysical activities.

6 Interpretation

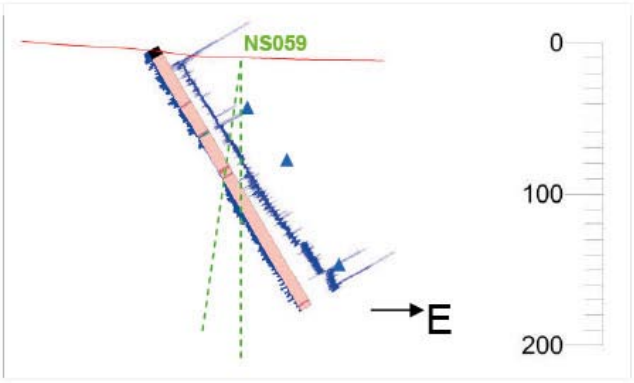
The results from drilling of HLX38–43 are summarised in Figure 6-1. The figure consists of four different parts, 6-1a through 6-1d, each showing the drilling results related to one deformation zone.

In HLX38 a section with reduced magnetic susceptibility coupled with water flows of 17–60 litres/minute was encountered between 67 and 100 metres. This section is a likely candidate for a deformation zone underlying lineament NS059 and could explain the magnetic anomaly along NS059 /3/. The dip of the deformation zone would then be vertical or steeply to the west if the borehole section between 67 and 100 metres is connected to the surface lineament, see Figure 6-1a. A significant water inflow occurred at ca 185 metres drilled length where the return water flow increased from 60 to ca 100 litres/minute.

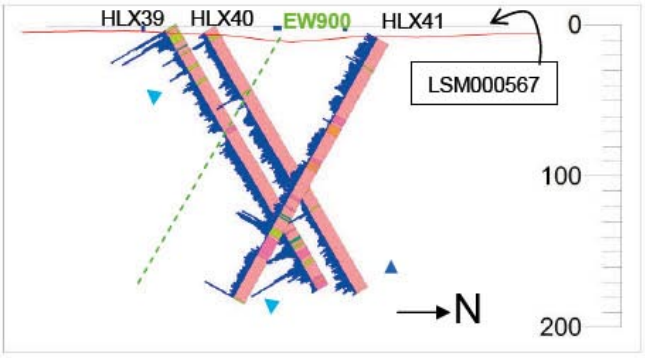
A potential deformation zone underlying lineament EW900 was drilled with three boreholes: HLX39, HLX40 and HLX41. The lineament EW900 is recognised on the surface as a topographic depression and a magnetic anomaly /3/. A low-velocity zone from refraction seismics in profile LSM000567 also coincides with the position of the lineament /5/. A plausible continuation at depth of the magnetic anomaly on the surface can be seen in HLX40 and HLX39 as distinct lows in magnetic susceptibility. The interpreted dip of the deformation zone is 60 degrees to the south, see Figure 6-1b. There was however no water inflow at the position of the possible deformation zone. It should be added that there was very little water inflow from any of the three boreholes. No clear indication of any deformation zone could be seen in HLX41.

HLX42 was drilled towards lineament NE107. The magnetic susceptibility of the rocks beneath 30 metres drilled length was very low. It is however not clear from the drilling data if this is a primary feature of the rocks or if they are altered. A modest water inflow was noted at ca 50 m drilled length. A significantly higher water flow was measured at the bottom of the borehole. It was nevertheless difficult to pinpoint the exact position where the increased water inflow occurred. The geometry and characteristics of deformation zone NE107 is not fully clarified from the drilling results in HLX42. Possible dips of deformation zone NE107 are tentatively indicated by three stippled lines, see Figure 6-1c.

Lineament NS001 is characterised on the surface as a topographic depression and a magnetic anomaly (magnetic low) /3/. Geophysical measurements along profile LSM000302, in the vicinity of the borehole, has indicated a VLF-anomaly that is centrally located in the topographic depression /7/. Borehole HLX43 penetrated a dolerite dyke that could explain the magnetic low. On the western side of the dolerite a massive inflow of water (> 200 L/min) was measured. It is plausible that the water bearing zone could be linked with the surface VLF-anomaly. The deformation zone NS001 could therefore be interpreted as a dolerite dike with a water bearing zone on the western contact zone. The structure is here interpreted as being steeply dipping to the west, see Figure 6-1d.

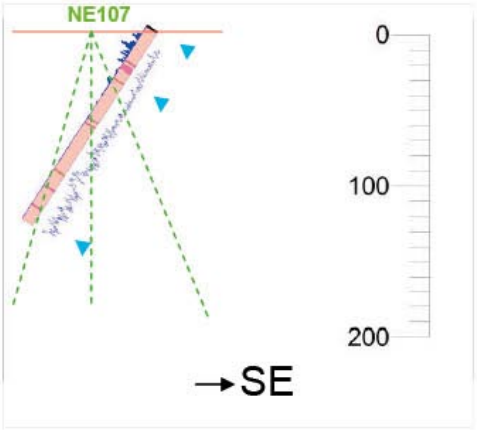


A NS059 and HLX38



B EW900, HLX39, HLX40, HLX41 and LSM000567

C NE107 and HLX42



D NS001, HLX43 and LSM000302

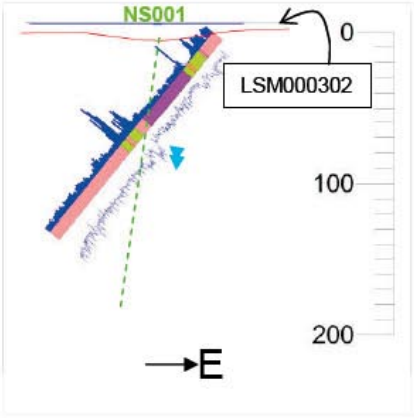


Figure 6-1. *Boreholes HLX38, HLX39, HLX40, HLX41, HLX42 and HLX43 shown with preliminary geological results, magnetic susceptibility (blue bars) and drilling penetration time (blue line) in Figures 6-1a through 6-1d. Positions for water inflow are indicated by blue triangles. Triangles in different shades of blue has been used in Figure 6-1a in order to discriminate which borehole the triangle is pointing at. The different colours of the triangles do not have any geoscientific meaning. Soil is shown with black colour in the boreholes. The lithological colour legend is shown for each borehole in Appendix 2. The topography is given with a red line. The drill penetration data is not shown in Figure 6-1b in order to keep the figure readable.*

7 References

/1/ **SKB, 2001**. Platsundersökningar. Undersökningsmetoder och generellt genomförandeprogram SKB R-01-10, Svensk Kärnbränslehantering AB.

/2/ **SKB, 2005.** Program för fortsatta undersökningar av berggrund, mark, vatten och miljö inom delområde Laxemar. SKB R-05-37, Svensk Kärnbränslehantering AB.

/3/ **SKB, 2006.** Preliminary site description. Laxemar subarea – version 1.2. SKB R-06-10, Svensk Kärnbränslehantering AB.

/4/ **Lindqvist G, 2005.** Oskarshamn site investigation. Refraction seismic measurements in Laxemar spring 2005. SKB P-05-155, Svensk Kärnbränslehantering AB.

/5/ **Lindqvist G, 2006.** Oskarshamn site investigation. Refraction seismic measurements in Laxemar spring 2006. SKB P-06-49, Svensk Kärnbränslehantering AB.

/6/ **Sigurdsson O, 2006.** Oskarshamn site investigation. Simplified Boremap mapping of percussion boreholes HLX34 and HLX35 on lineament NS059 and of percussion boreholes HLX36 and HLX37 on lineament NS001, P-05-279, (revised September 2006). Svensk Kärnbränslehantering AB.

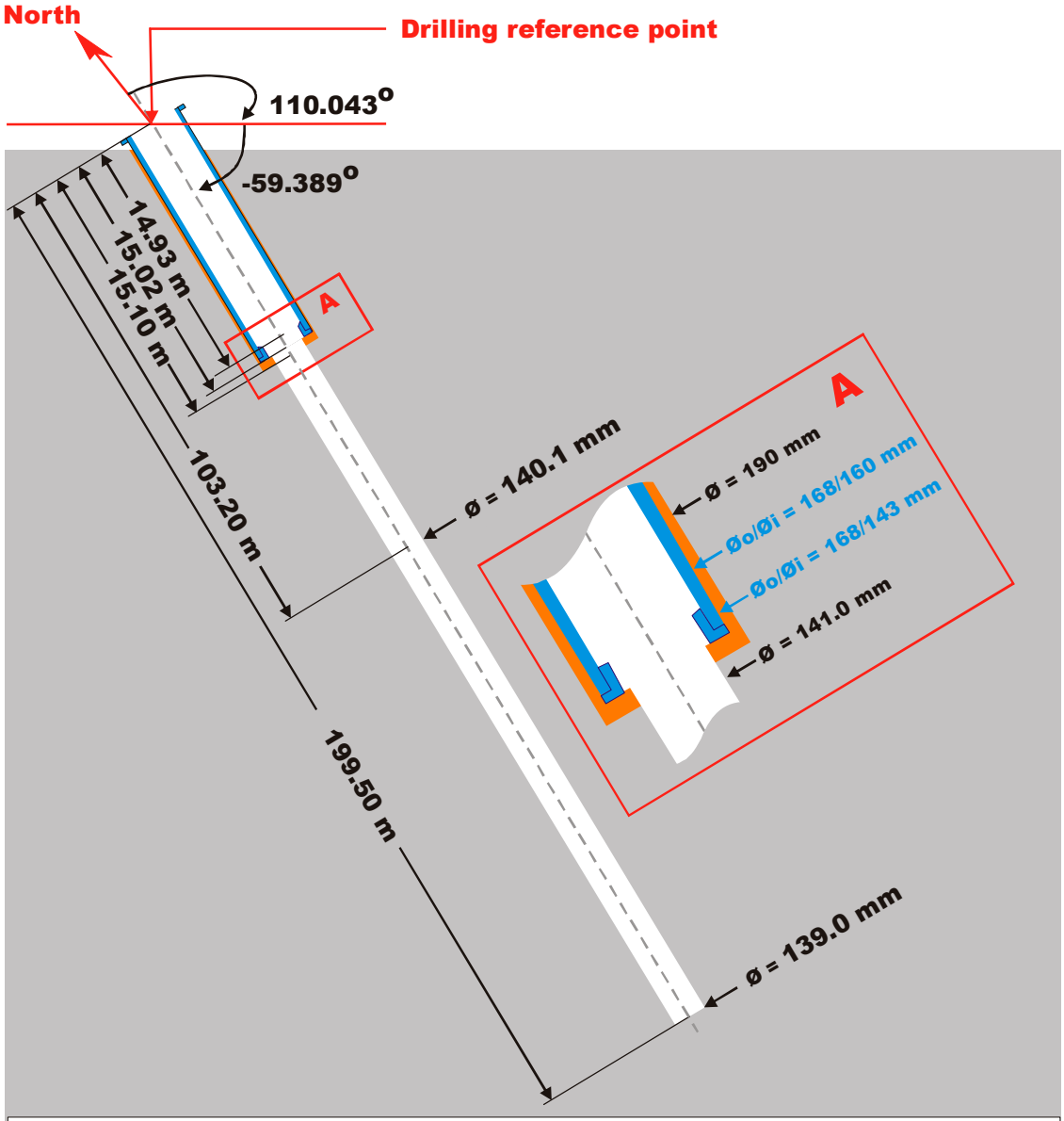
/7/ **Stenberg L, Sehlstedt S, 1989.** Swedish Hard Rock Laboratory. Geophysical profile measurements on interpreted regional aeromagnetic lineaments in the Simpevarp area. Progress Report 25-89-13. Svensk Kärnbränslehantering AB.

/8/ **Svenska Geotekniska Föreningen, 1999**. Metodbeskrivning för Jord-bergsondering (Jb-sondering), Svenska Geotekniska Föreningen (Swedish Geotechnical Society), SGF Rapport 2:99.

Technical data boreholes HLX38, HLX39, HLX40, HLX41, HLX42 and HLX43

Technical data

Borehole HLX38



Drilling reference point

Northing:	**6365868.861 (m), RT90 2,5 gon V**
Easting:	**1547146.084 (m), RT90 2,5 gon V**
Elevation:	**11.530 (m), RHB 70**

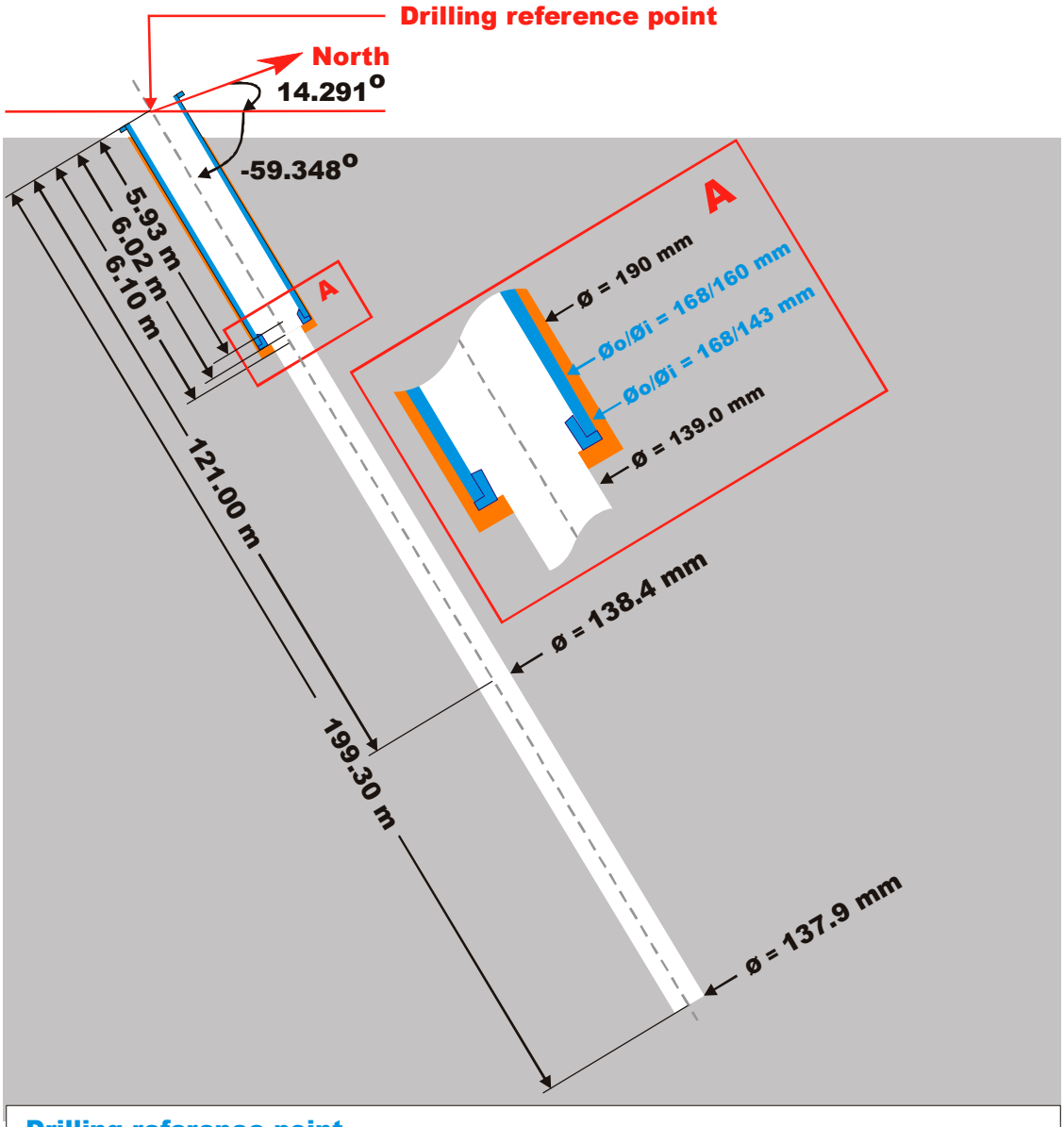
Drilling period

Drilling start date:	**2006-04-10**
Drilling stop date:	**2006-04-24**

Rev 2006-12-21

Technical data

Borehole HLX39



Drilling reference point

Northing: 6366887.869 (m), RT90 2,5 gon V
Easting: 1546880.479 (m), RT90 2,5 gon V
Elevation: 27.044 (m), RHB 70

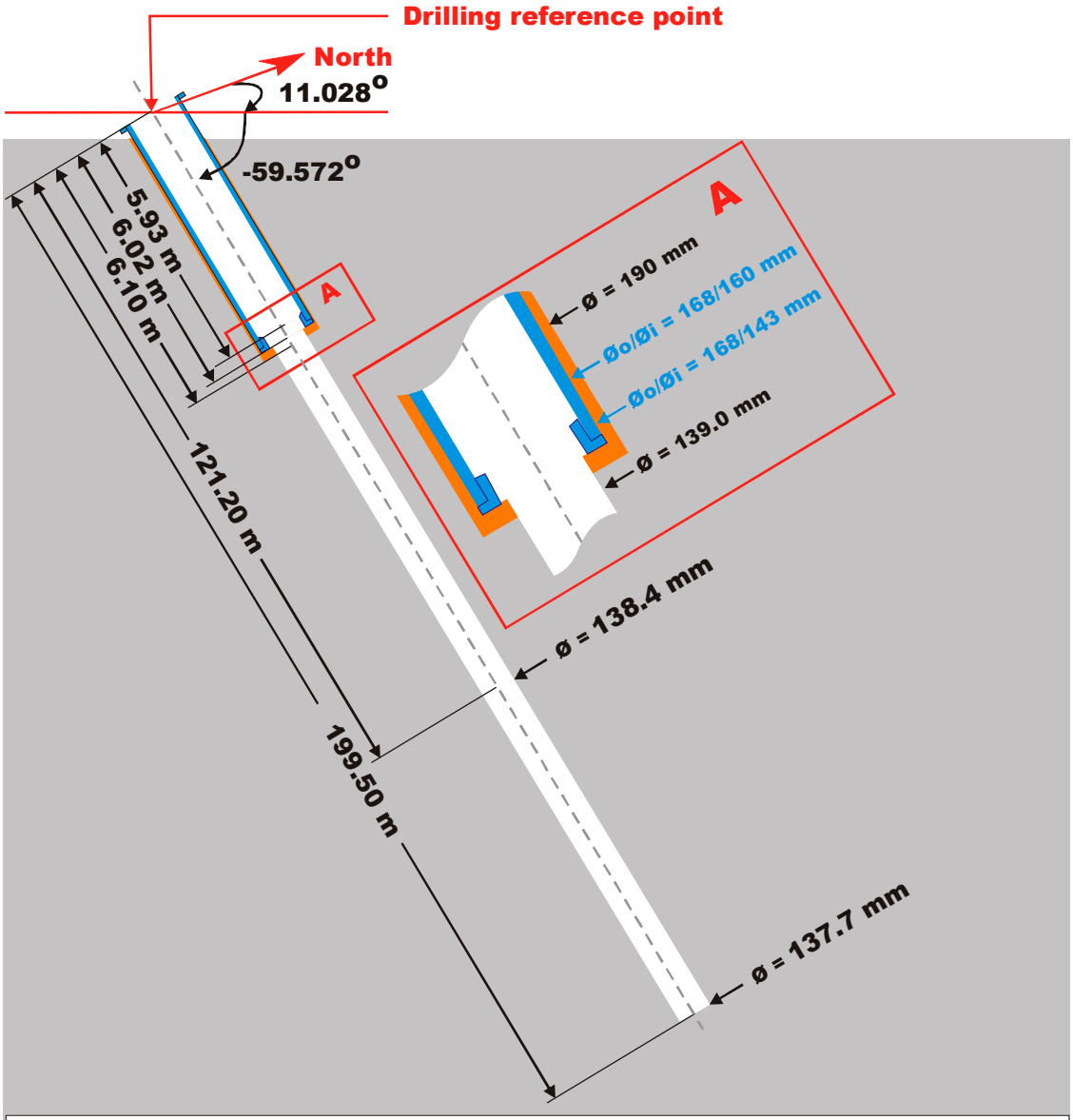
Drilling period

Drilling start date: 2006-06-07
Drilling stop date: 2006-06-14

Rev 2006-12-21

Technical data

Borehole HLX40



Drilling reference point

Northing: 6366906.756 (m), RT90 2,5 gon V

Easting: 1546943.948 (m), RT90 2,5 gon V

Elevation: 25.737 (m), RHB 70

Drilling period

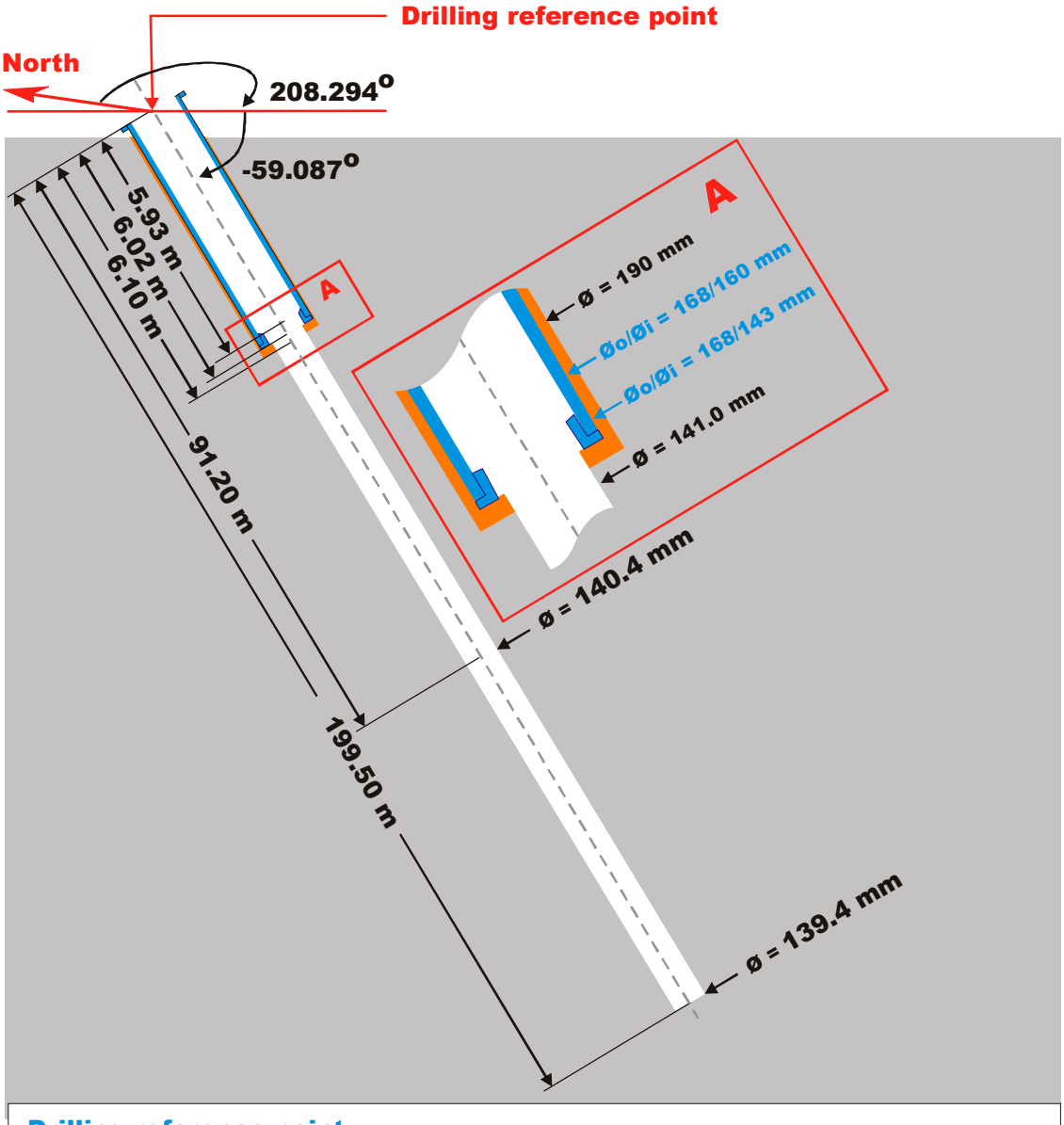
Drilling start date: 2006-05-02

Drilling stop date: 2006-05-09

Rev 2006-12-21

Technical data

Borehole HLX41



Drilling reference point

Northing: 6367013.201 (m), RT90 2,5 gon V
Easting: 1547017.609 (m), RT90 2,5 gon V
Elevation: 21.797 (m), RHB 70

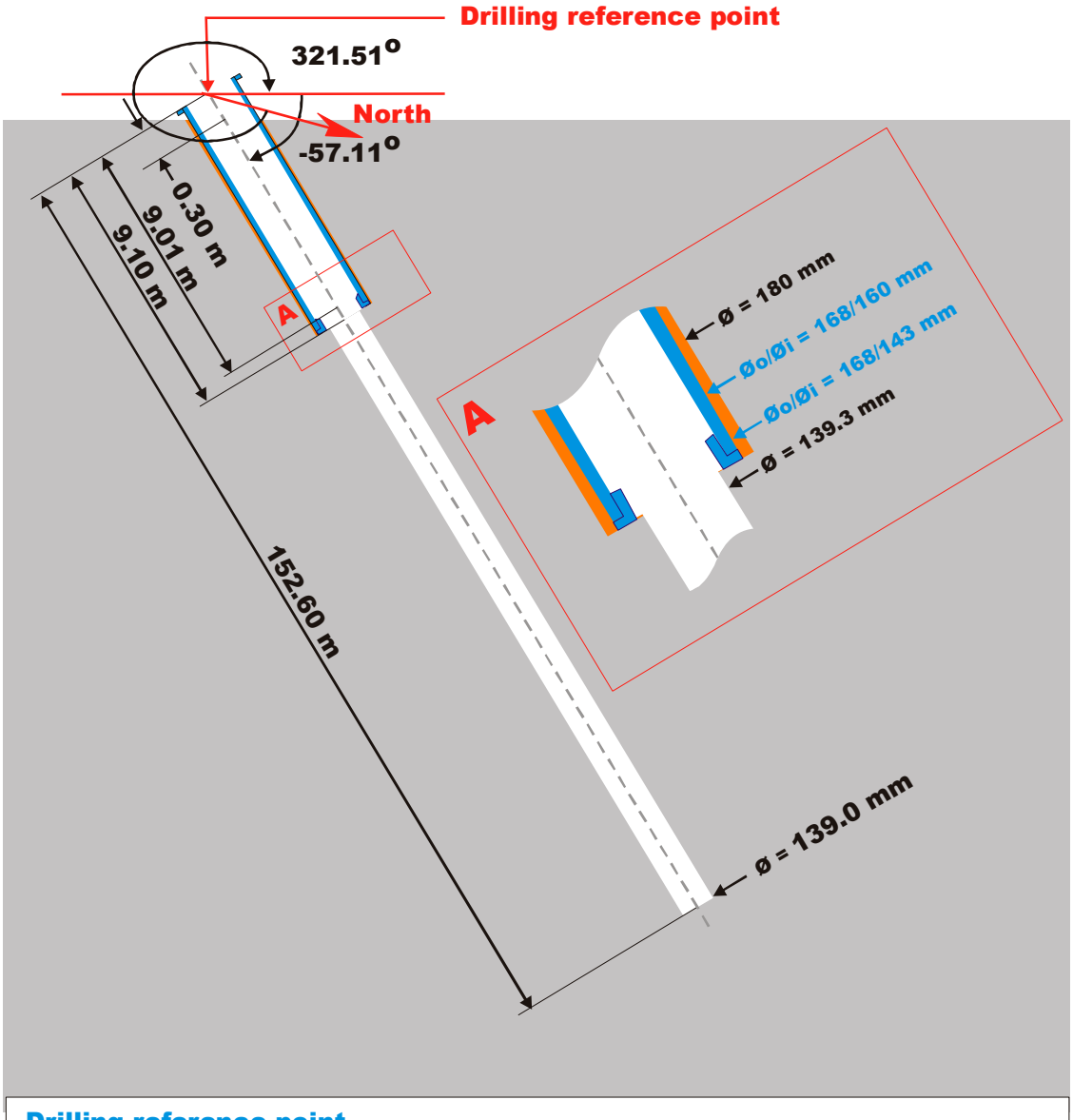
Drilling period

Drilling start date: 2006-05-22
Drilling stop date: 2006-06-01

Rev 2006-12-21

Technical data

Borehole HLX42



Drilling reference point

Northing:	**6364827.04 (m), RT90 2,5 gon V 0:-15**
Easting:	**1547446.73 (m), RT90 2,5 gon V 0:-15**
Elevation:	**12.88 (m), RHB 70**

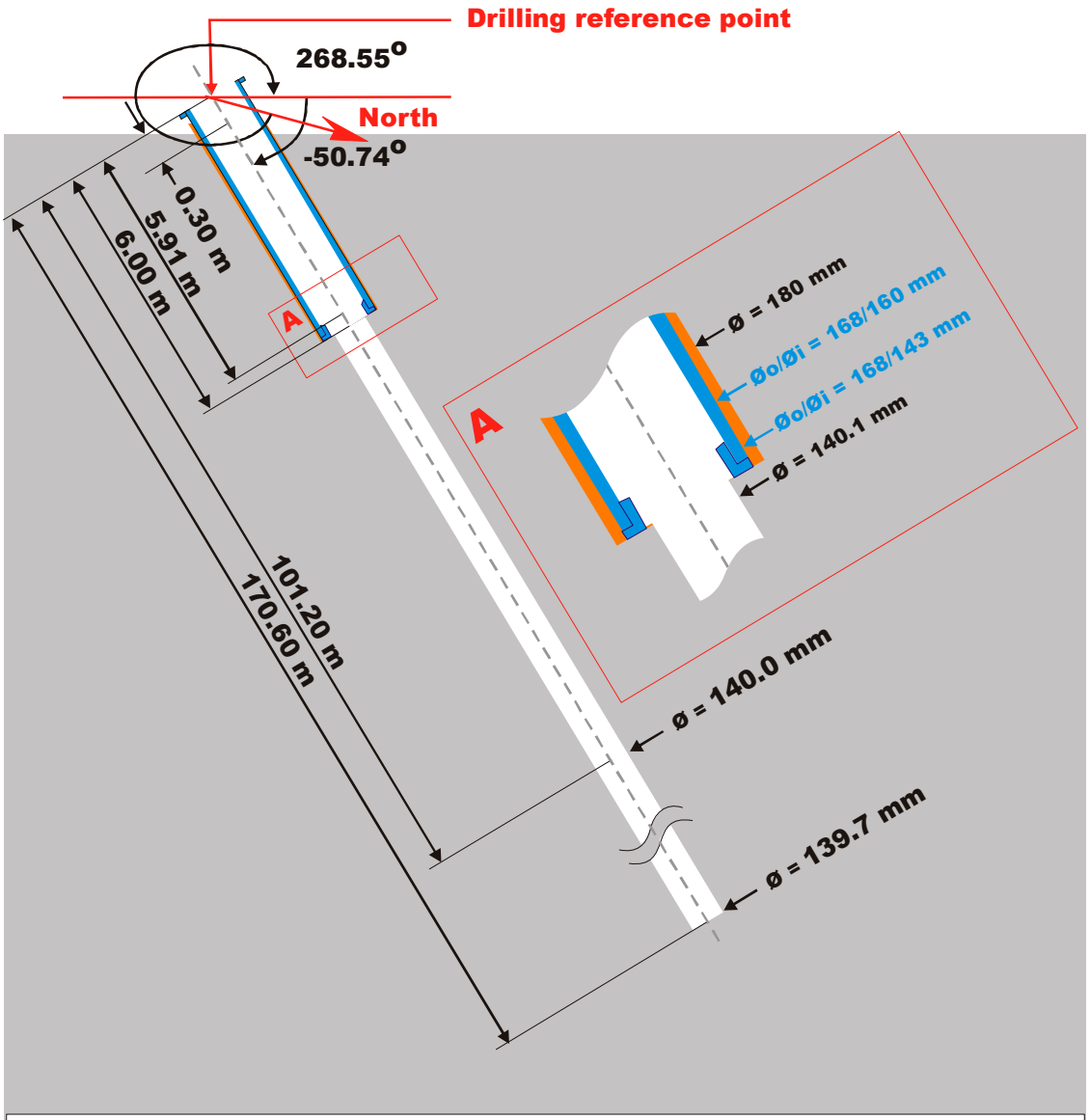
Drilling period

Drilling start date:	**2006-11-13**
Drilling stop date:	**2006-11-16**

Rev 2006-12-19

Technical data

Borehole HLX43



Drilling reference point

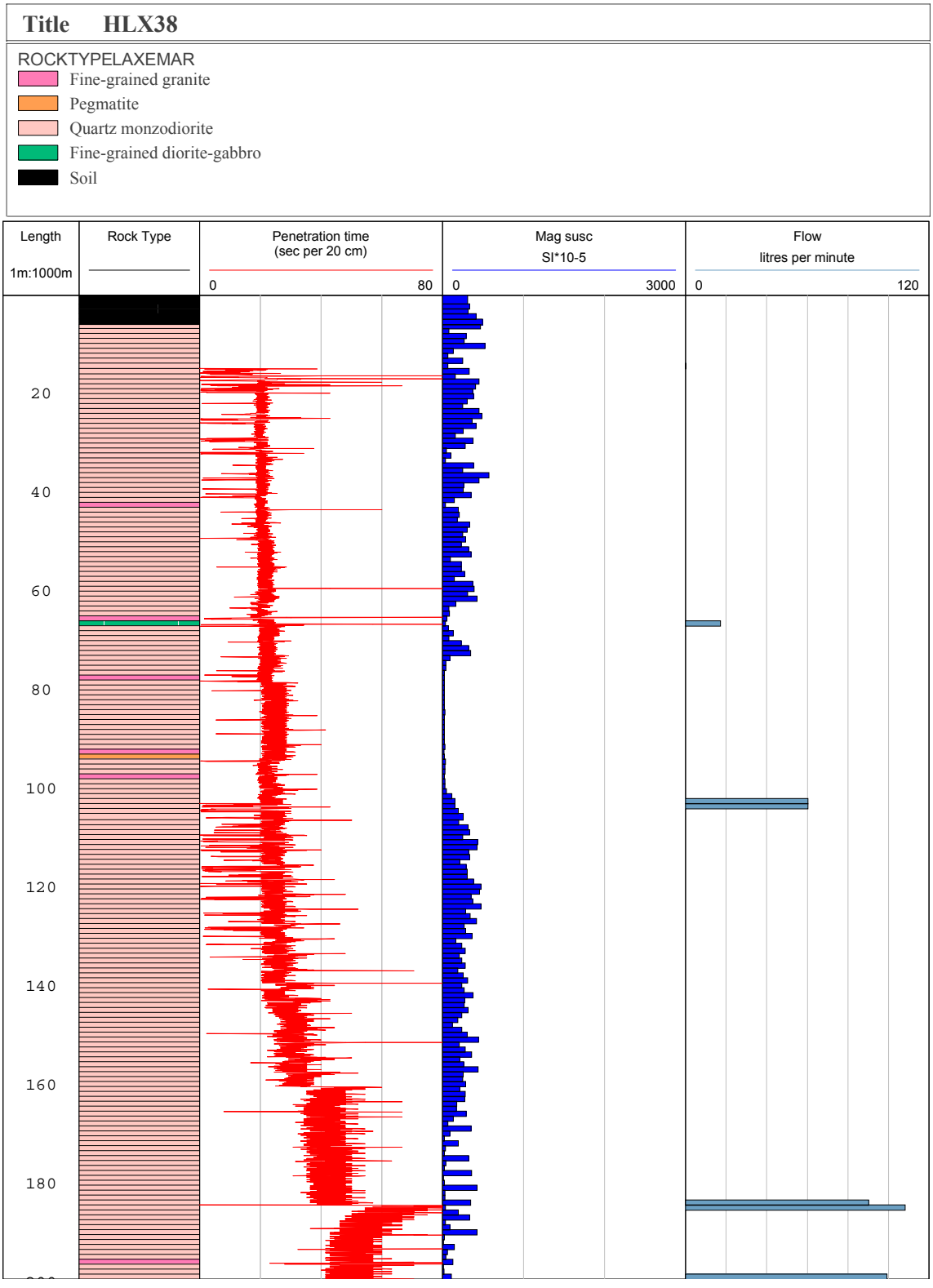
Northing:	**6367517.45 (m), RT90 2,5 gon V 0:-15**
Easting:	**1546626.60 (m), RT90 2,5 gon V 0:-15**
Elevation:	**24.20 (m), RHB 70**

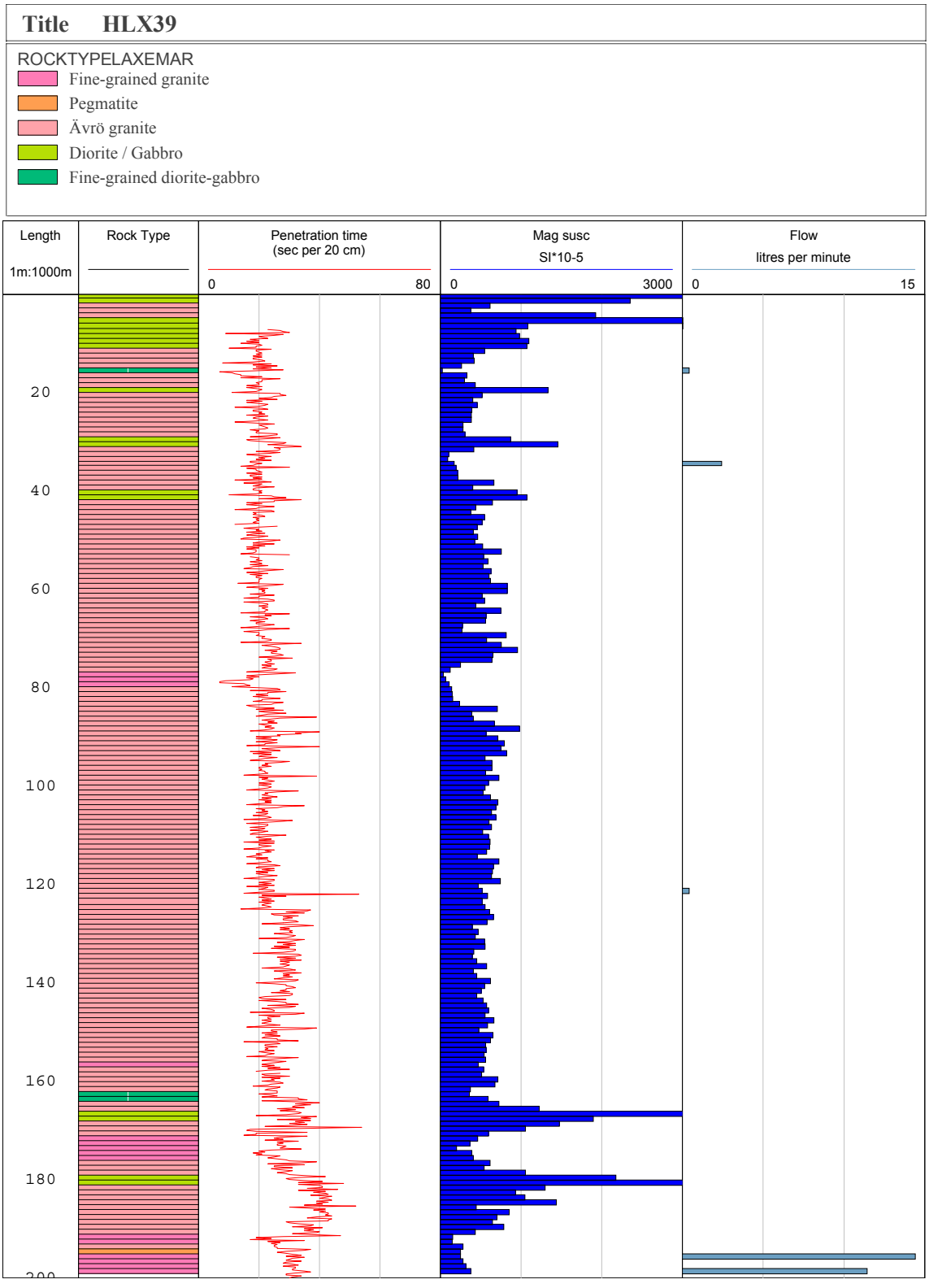
Drilling period

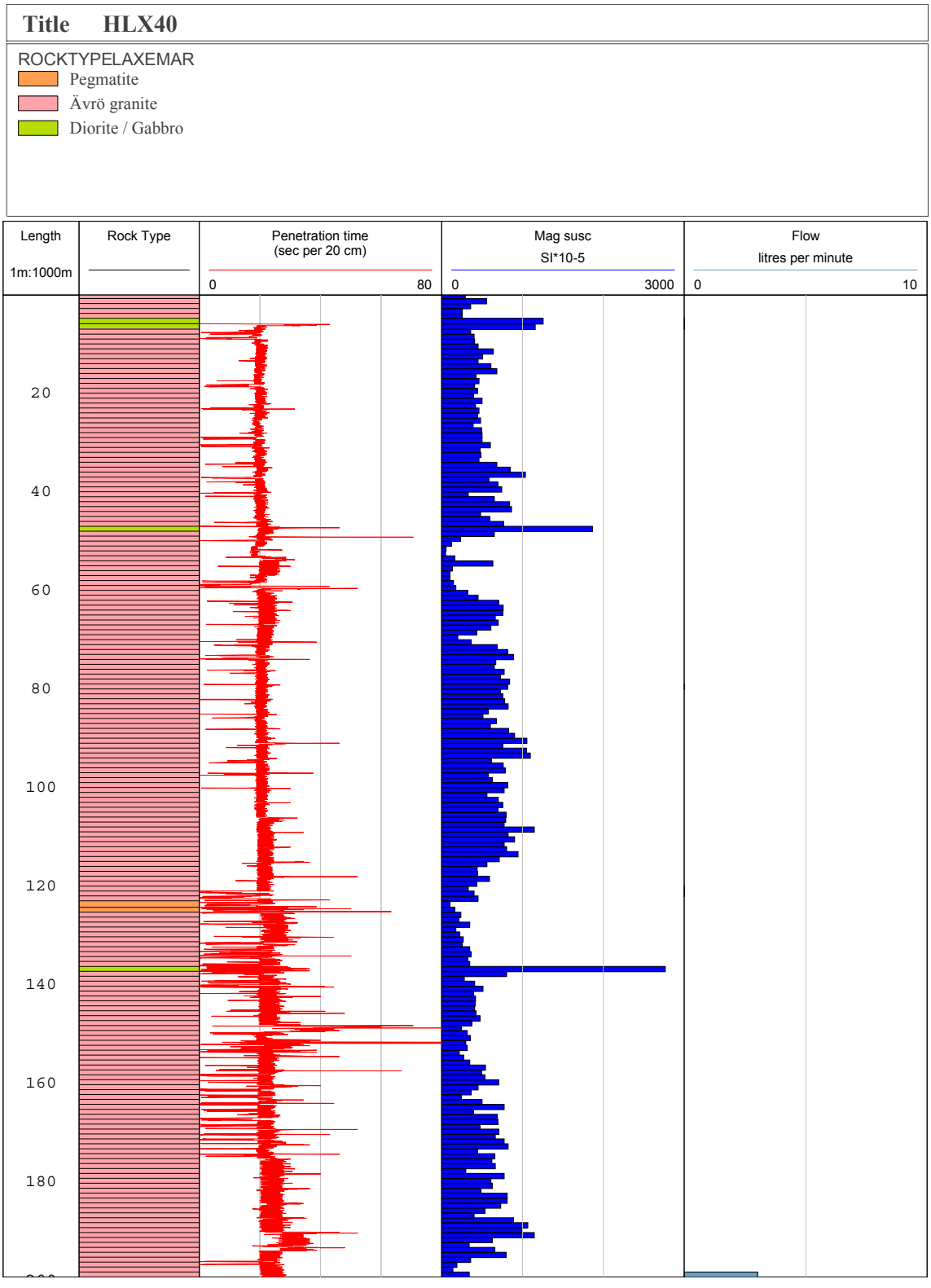
Drilling start date:	**2006-10-19**
Drilling stop date:	**2006-10-26**

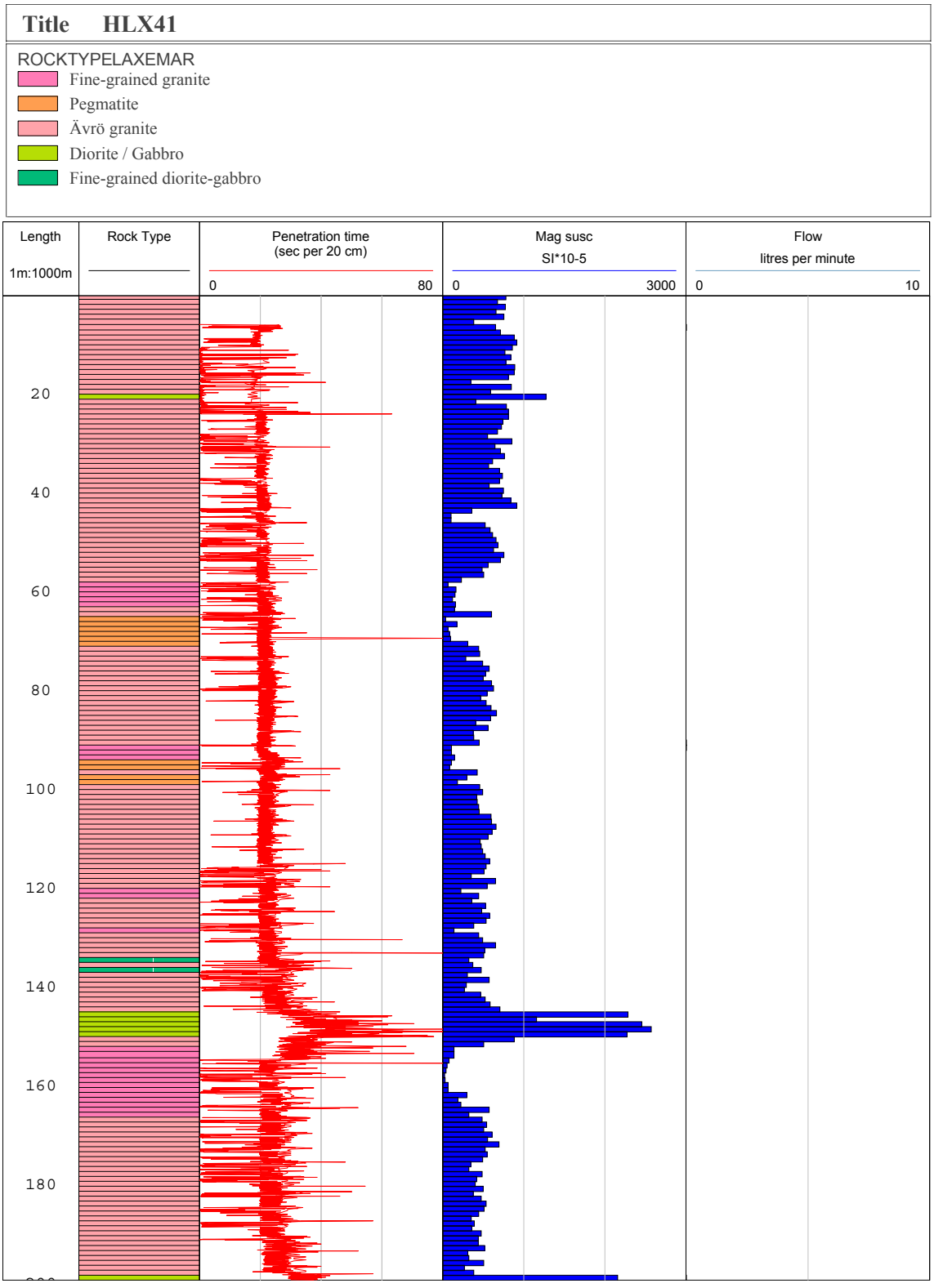
Rev 2006-12-19

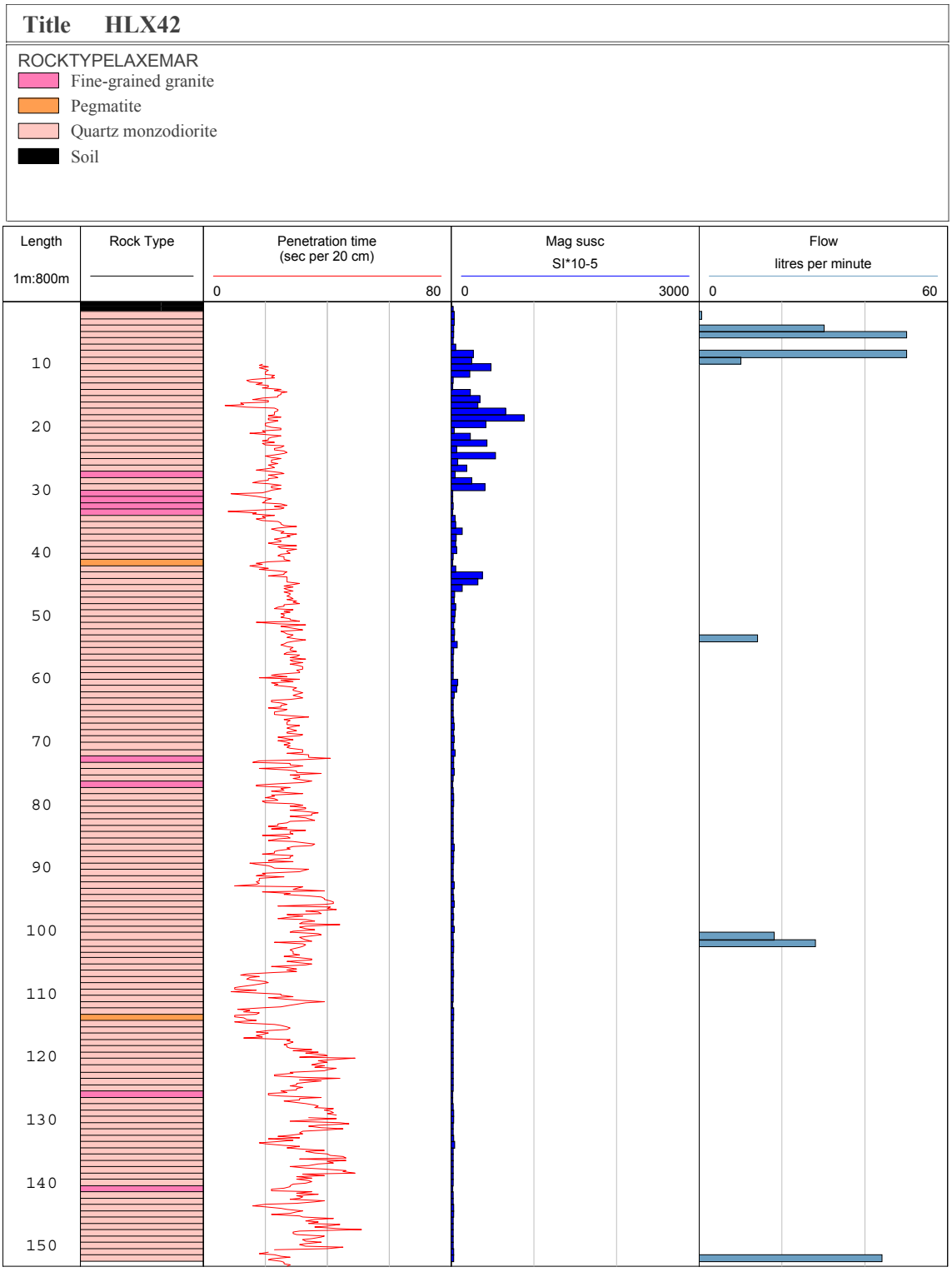
Geoscientific summary for boreholes HLX38, HLX39, HLX40, HLX41, HLX42 and HLX43

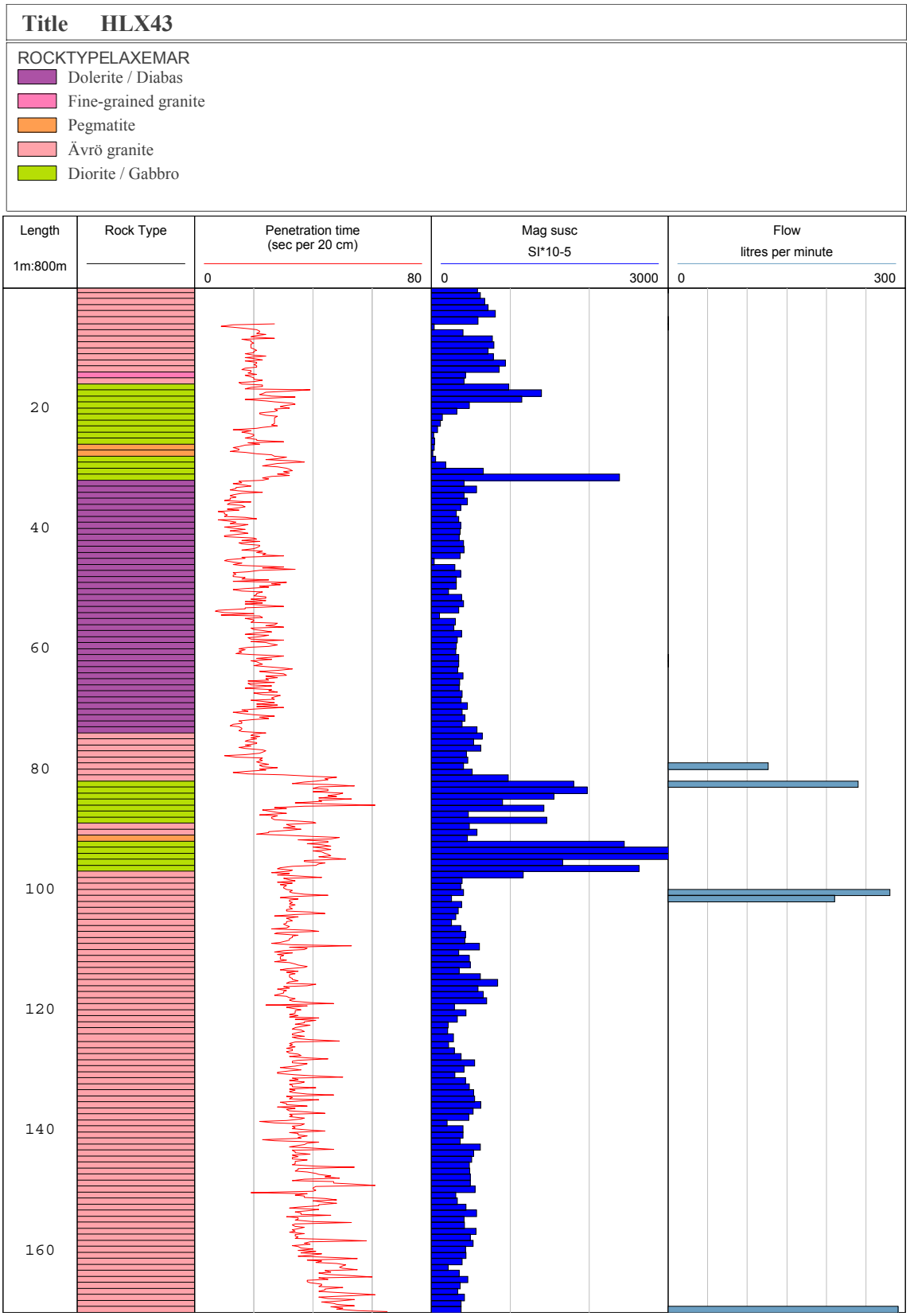



Title HLX39
ROCKTYPELAXEMAR
Fine-grained granite
Pegmatite
Ävrö granite
Diorite / Gabbro
Fine-grained diorite-gabbro
Length
1m:1000m
Rock Type
Penetration time
(sec per 20 cm)
0
80
Mag susc
SI*10-5
0
3000
Flow
litres per minute
0
15
20
40
60
80
100
120
140
160
180


Title HLX40
ROCKTYPELAXEMAR
Pegmatite
Ävrö granite
Diorite / Gabbro
Length
1m:1000m
Rock Type
Penetration time
(sec per 20 cm)
0
80
Mag susc
SI*10-5
0
3000
Flow
litres per minute
0
10
20
40
60
80
100
120
140
160
180


Title HLX41
ROCKTYPELAXEMAR
Fine-grained granite
Pegmatite
Ävrö granite
Diorite / Gabbro
Fine-grained diorite-gabbro
Length
1m:1000m
Rock Type
Penetration time
(sec per 20 cm)
0
80
Mag susc
SI*10-5
0
3000
Flow
litres per minute
0
10
20
40
60
80
100
120
140
160
180


Title HLX42
ROCKTYPELAXEMAR
Fine-grained granite
Pegmatite
Quartz monzodiorite
Soil
Length
1m:800m
Rock Type
Penetration time
(sec per 20 cm)
0
80
Mag susc
SI*10-5
0
3000
Flow
litres per minute
0
60
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150


Title HLX43
ROCKTYPELAXEMAR
Dolerite / Diabas
Fine-grained granite
Pegmatite
Ävrö granite
Diorite / Gabbro
Length
1m:800m
Rock Type
Penetration time
(sec per 20 cm)
0
80
Mag susc
SI*10-5
0
3000
Flow
litres per minute
0
300
20
40
60
80
100
120
140
160