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Drilling of cored borehole KLX27A

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Abstract

Borehole KLX27A is located in the Laxemar subarea. Drilling was made between August and November, 2007 as a part of the site investigation for a possible repository for spent nuclear fuel in Oskarshamn municipality, Sweden. KLX27A was the twenty-third deep cored borehole within the site investigation in Oskarshamn.

KLX27A was core drilled to a length of 650.56 metres with N-size (76 mm) equipment. The uppermost section, to the length of 75.60 metres, was constructed as a telescopic borehole with an inner nominal diameter of 200 mm.

A water inflow of 14 L/min could be measured over the entire length of the telescopic section after percussion drilling of the pilot borehole (nominal diameter 165 mm).

Nine successful tests were completed with wireline equipment in KLX27A from eleven attempts at various intervals. The resulting transmissivities (T_M) varied between 6.4×10^{-6} and 7.2×10^{-8} m^2/s. The most transmissive section was between 78 and 176 metres.

Continuous monitoring of drilling parameters and flushing water parameters with the drilling monitoring system was conducted throughout the core drilling phase in KLX27A.

Five water samples for chemical analysis were collected during the core drilling of KLX27A.

The air-lift pumping test in the telescopic section performed when borehole KLX27A was core drilled to its full length gave a transmissivity (T_M) of 1.3×10^{-4} m^2/s.

Lithologically the core is completely dominated Quartz monzodiorite with very minor intercalations of fine-grained diorite-gabbro and fine grained granite.

Rock alteration is mostly weak. A section with significant red staining and elevated fracture frequency was logged from 210 to 250 m.

The average fracture frequency over the core drilled section is 1.5 (fractures/metre) expressed as open fractures.

Sammanfattning

Borrhål KLX27A ligger inom delområde Laxemar. Borrningen utfördes mellan augusti och november 2007 som ett led i platsundersökningen för ett möjligt djupförvar för använt kärnbränsle i Oskarshamns kommun. KLX27A var det tjugotredje djupa kärnborrhålet inom platsundersökningen i Oskarshamn.

KLX27A kärnborrades med borrstorlek N (76 mm) till 650,56 meters borrad längd. Den övre delen av hålet, från markytan till 75,60 meter, utfördes som en teleskopdel med ca 200 mm inre diameter.

Ett vatteninflöde på 14 L/min kunde uppmätas över hela teleskopdelen vid hammarborrningen av pilotdelen (nominell diameter 165 mm).

Nio stycken lyckade pumptester slutfördes med wireline-baserad mätutrustning på varierande nivåer. De uppmätta transmissiviteterna (T_M) varierade mellan $6{,}4\times10^{-6}$ och $7{,}2\times10^{-8}$ m^2/s. Den mest transmissiva sektionen var mellan 78 och 177 meter.

Kontinuerliga mätningar av borrningsparametrar och spolvattenparametrar via DMS (*d*rilling *m*onitoring *s*ystem) gjordes under hela kärnborrningsfasen i KLX27A.

Fem vattenprover för kemisk analys togs i samband med borrning i KLX27A.

Mammutpumpningen i teleskopdelen som gjordes när kärnborrningen i KLX27A utförts till full längd gav en transmissivitet (T_M) på $1{,}3\times10^{-4}$ m^2/s.

Litologiskt domineras kärnan totalt av kvartsmonzodiorit med väldigt underordnade inslag av finkornig diorit-gabbro och finkornig granit.

Bergartsomvandling är oftast svag. Ett parti med betydande rödfärgning och förhöjd sprickfrekvens har karterats från 210 till 250 m.

Den genomsnittliga sprickfrekvensen i det kärnborrade partiet är 1,5 (sprickor/meter) uttryckt som öppna sprickor.

Contents

1 Introduction

SKB, the Swedish Nuclear Fuel & Waste Management Company, performs site investigations in order to evaluate the feasibility of locating a deep repository for spent nuclear fuel /1 and 2/. The investigations are performed in two Swedish municipalities: Östhammar and Oskarshamn. Borehole KLX27A was not originally within the scope of the investigation programme /2/. A management decision (id 1078517, SKB internal document) to perform additional drilling and investigation together with the suggested design criteria for KLX27A from modelling group (id 1077017, SKB internal document) gave the necessary prerequisites to proceed. Borehole KLX27A is located in the southwestern part of the Laxemar subarea of the investigation area in Oskarshamn.

Drilling and investigations in boreholes are fundamental activities in order to facilitate characterisation of rock and groundwater properties at depth. KLX27A was the twenty-third deep cored borehole within the Oskarshamn site investigation. The location of the core drilled borehole and the water source, HLX10 in the Laxemar subarea is shown in Figure 1-1.

The drilling of KLX27A and all related on-site operations were performed according to a specific activity plan (AP PS 400-07-058), which in turn refers to a number of method descriptions, see Table 1-1.

The activity plans and method descriptions are SKB internal documents.

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

Activity plan	Number	Version
Kärnborrning KLX27A	AP PS 400-07-058	1.0*
Method descriptions	**Number**	**Version**
Metodbeskrivning för kärnborrning	SKB MD 620.003	2.0
Metodbeskrivning för hammarborrning	SKB MD 610.003	3.0
Metodbeskrivning för hydrauliska enhålstrester	SKB MD 321.003	1.0
Metodbeskrivning för registrering och provtagning av spolvattenparametrar samt borrkax under kärnborrning	SKB MD 640.001	1.0
Metodbeskrivning för vattenprovtagning, pumptest och tryckmätning i samband med wireline-borrning	SKB MD 321.002	1.0
Instruktion för längdmarkering i kärnborrhål	SKB MD 620.009	2.0
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 ansättning av hammar- och kärnborrhål	SKB MD 600.002	1.0
Instruktion för hantering och provtagning av borrkärna	SKB MD 143.007	2.0
Metodbeskrivning för krökningsmätning av hammar- och kärnborrhål	SKB MD 224.001	1.0
Instruktion för miljökontroll av ytvatten, ytnära grundvatten och mark vid borrning och pumpning i berg	SKB MD 300.003	3.0
Metodbeskrivning för jordborrning	SKB MD 630.003	1.0

*One amendment to the activity plan exists.

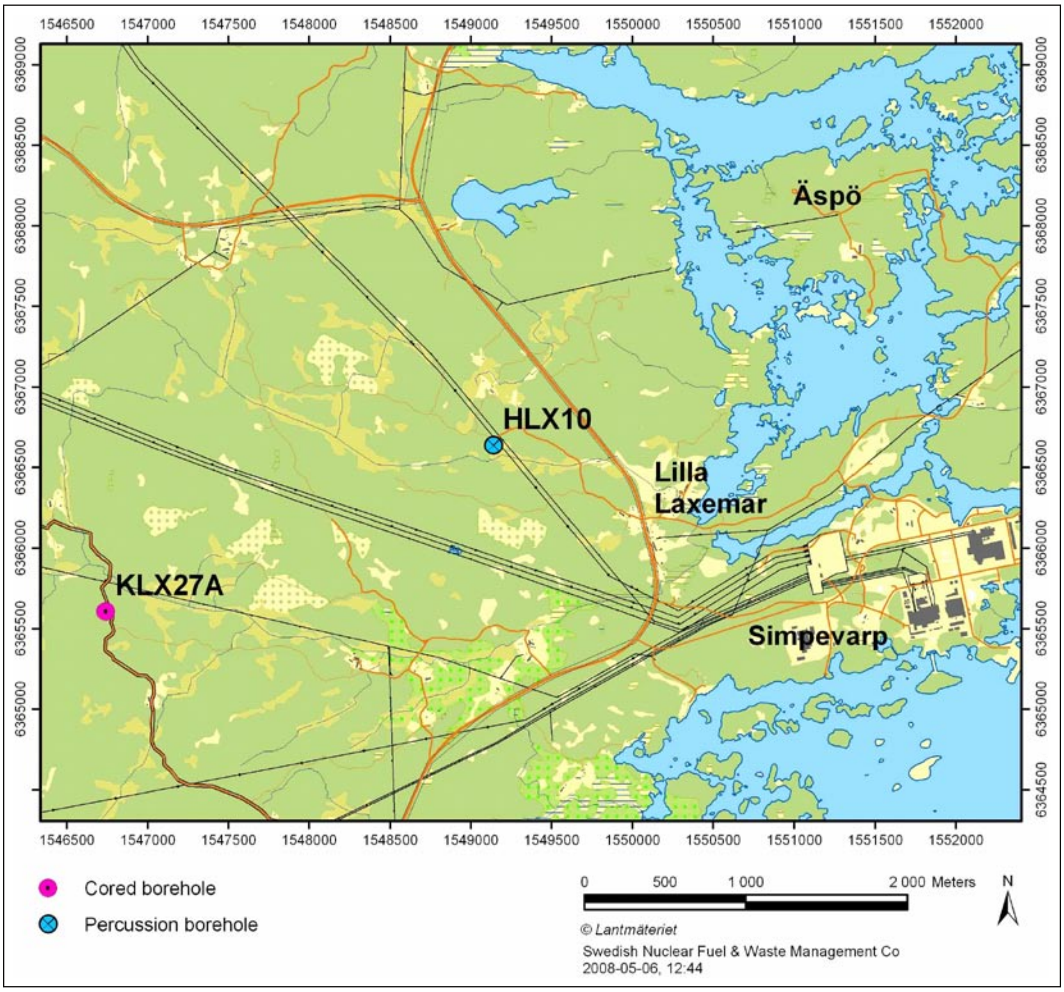


Figure 1-1. *Location of the cored borehole KLX27A and the water source, percussion borehole HLX10 in the Laxemar subarea.*

2 Objective and scope

This report will describe the methods employed and the results achieved during the drilling of borehole KLX27A. A number of related activities, such as wireline hydraulic tests, water sampling and monitoring of drilling parameters that were performed in conjunction with drilling will also be reported here.

The decision to drill KLX27A is given in SKB id 1081745, dated 2007-08-22, SKB internal document. The main purposes were to increase the knowledge of the geometry and properties of the modelled deformation zone NW042 and to obtain geological data at repository depth on the northern side of NW042.

The hole was constructed as a "telescope hole", which means that the upper, normally, 100 metre section of the hole has a wider diameter than the deeper core drilled part of the hole.

A notification in accordance with the Environmental Code was sent to the Regional Authorities 2007-07-02, SKB id 101079101, SKB internal document. Information of the final coordinates and details regarding the return water handling was sent to the Regional Authorities on 2007-07-17, SKB id 1080179, SKB internal documents.

3 Overview of the drilling method

3.1 The SKB telescope drilling method

In brief, the telescope drilling method is based on the construction of a larger diameter hole (200 mm diameter) to a length of normally 100 metres followed by a N-size (76 mm diameter) cored section to full length. The larger diameter section can either be percussion drilled or reamed with a percussion bit after core drilling of a pilot hole.

The main purpose of the upper large diameter section is to improve the removal of water from the hole by air-lift pumping in order to minimize the intrusion of foreign substances (flushing water and cuttings) to the surrounding bedrock. It also enables the use of submersible pumps for tests and to facilitate the installation of multi-packer systems for ground water pressure recordings.

After drilling 0–100 m, equipment for air-lift pumping is installed in the borehole. The air-lift pumping will create a pressure drawdown and help remove water and cuttings while core drilling between 100 metres and full planned length, see Figure 3-1. The effect of drawdown is dependent on the depth and capacity of major groundwater conductors.

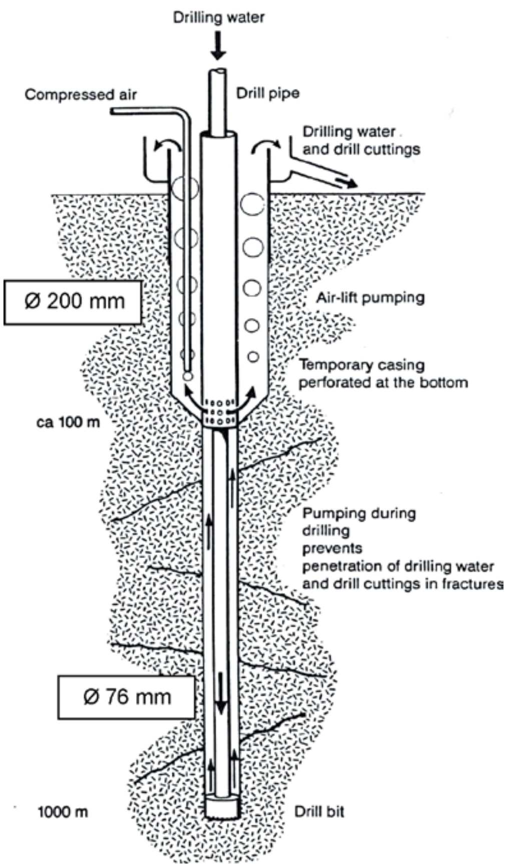


Figure 3-1. *A sketch of the telescopic drilling method with air-lift pumping for retrieval of drilling water and cuttings.*

During the core drilling phase several measurements and sampling exercises are performed through the drilling monitoring system (DMS), wireline tests for hydraulic purposes and sampling for water chemistry.

After the core drilling is completed to full length, depth reference slots are reamed in the borehole wall and a conical guide of stainless steel is installed between the telescope part and the deeper core drilled part, see Figure 3-2.

3.1.1 The flushing water system

The handling of flushing water includes a source of water with a submersible pump, tanks and air-lift pumps for raising the water from the bottom of the telescope part to surface. The return water is led to settling containers before discharge, see Figure 3-3.

Nitrogen gas is bubbled through the drilling water to remove dissolved oxygen. This is done to avoid introduction of oxygen to the formation water and thereby disturbing the pristine chemical properties.

In order to monitor possible mixing of formation and drilling water, a tracer dye (uranine) is added to the drilling water to a fixed concentration, see Figure 3-4.

3.2 Measurements and sampling during drilling

3.2.1 Percussion drilling

Drill cuttings are collected for every metre during the percussion drilling. A preliminary geological logging of the cuttings is done on site. During the preliminary logging notes are made on the dominating lithology, size and shape of the cutting or any other noticeable geological feature. The magnetic susceptibility of the cuttings samples are measured with hand held equipment. Small cups of return water are taken systematically of the return water. The water colour and intensity are noted as indications on degree of rock oxidation and clay content. The return water flow (ie the amount of water driven up by compressed air) is measured when noticeable changes in flow occur. The drill penetration rate during percussion drilling is either logged automatically (most common) or manually.

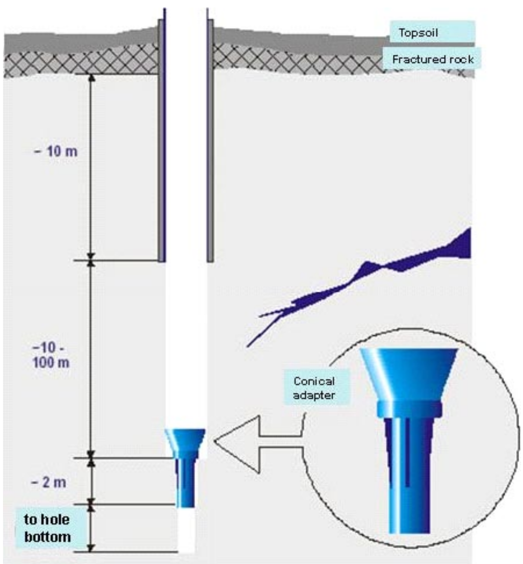


***Figure 3-2.** Installation of the conical guide.*

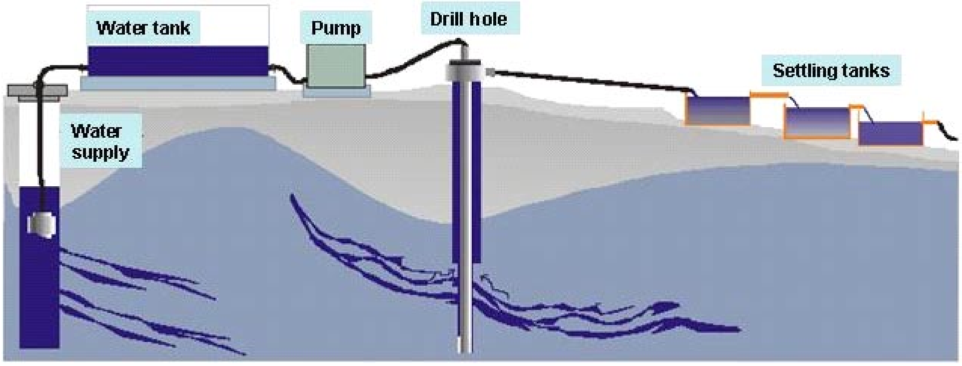


Figure 3-3. The flushing water system from source to discharge point.

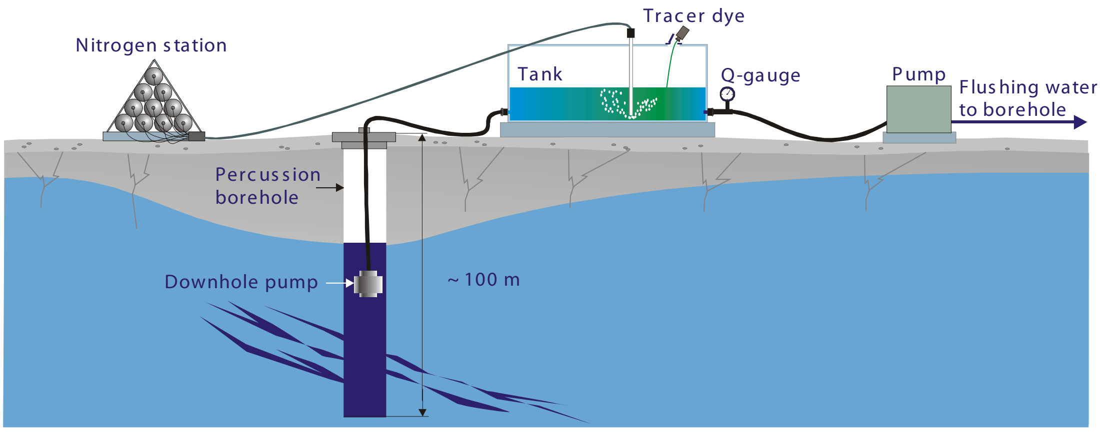


Figure 3-4. Schematic drawing of the preparation of flushing water. Uranine is added to the water as a tracer dye and nitrogen is bubbled through the water to remove dissolved oxygen.

3.2.2 Core drilling

The sampling and measurements during the core drilling phase of KLX27A consisted of:

- Wireline measurements.
- Air-lift pumping and recovery tests.
- Water sampling at the surface.
- The drilling monitoring system.

Wireline measurements and water sampling

The measurements and the sampling are made in the borehole with a wireline based equipment. Pumping tests are evaluated according to Moye /3/ and are normally performed for every 100 metres of drilled length. Sampling of water for chemical analysis is done in conjunction with the pumping tests where feasible. The wireline tests are done in accordance with SKB Method Description MB 321.002, SKB internal document.

NB Measurement of absolute pressure were not done in KLX27A following an internal decision, (Id 1044856, SKB internal document).

Air-lift pumping with evaluation of drawdown

Air-lift pumping with evaluation of drawdown is done with 300 metres intervals, nominally at 400 m and full drilled length. The actual levels are adapted to when changes of drill bit, or some other reason to raise the drill stem, occur. The test is normally based on the drawdown phase.

- The test cycle is started with air-lift pumping in the telescopic section.
- Drilling or other related activities such as rinsing of drill cuttings can occur prior to lifting the stem. This means that an inflow of water through the drill stem can occur during the initial stages of the test cycle.
- After the stem has been removed the air-lift pumping continues between 30 minutes and two hours to achieve stable conditions.
- The air-lift pumping is stopped.
- The recovery of the water table in the telescopic section is monitored.

Water sampling at the surface

Water samples of flushing and return water, i.e. the water entering and returning from the borehole at the surface, are taken at 10 to 20 metre intervals of drilled length for analysis of drilling water content (percentage of water with uranine tracer content) and electrical conductivity.

Drilling monitoring system (DMS)

Drilling is monitored on-line by continuous registration of drill rig and flushing water parameters in accordance with the method description for registration and sampling of flushing water parameters during drilling (SKB MD 640.001) and the method description for quality assurance of DMS-data (SKB MD 640.008). The method descriptions are SKB internal documents. The data is compiled into a database called *d*rilling *m*onitoring *s*ystem (DMS).

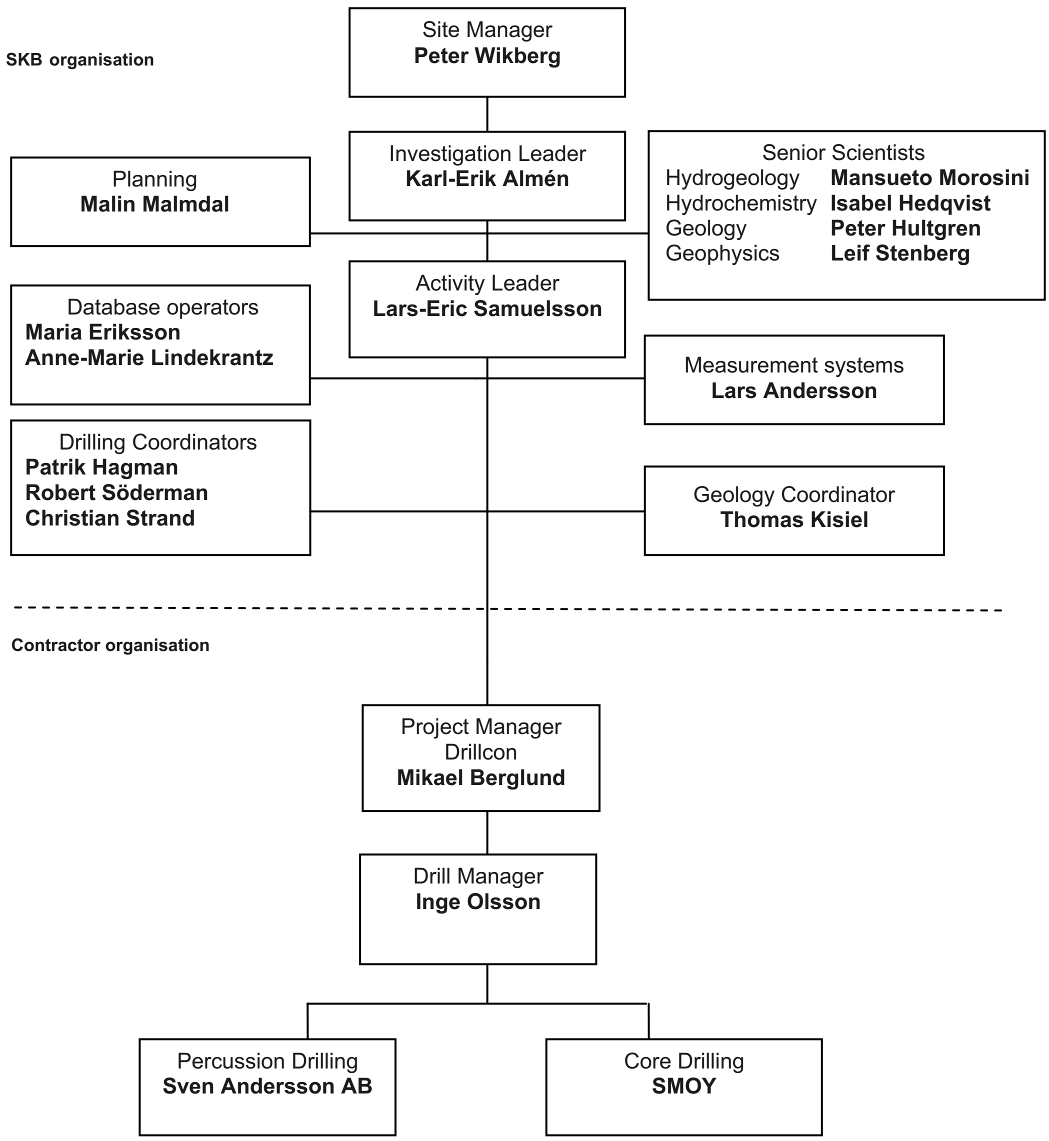
4 Contractors and equipment

4.1 Contractors

The main contractor for drilling was Drillcon Core AB, with subcontractor for core drilling Suomen Malmi OY (SMOY) and subcontractor for percussion drilling Sven Andersson AB.

An overview of the organisation for the drilling activity is given in Table 4-1.

Table 4-1. Drill activity organisation.



4.2 Percussion drilling equipment

The equipment used in KLX27A was a Comacchio MC1500 percussion drill rig with an Atlas Copco XRVS 455 Md air compressor. Overburden drilling was made with NO-X 280 mm equipment. The down-the-hole hammer was a Secoroc 165 mm for the pilot borehole and the drill rods were Driqoneq 114 mm. Reamings were done with Secoroc DTH-hammers for 200 or 250 mm diameter. The casings utilized were 208×4 mm (SS 2343, stainless) and 323×11 mm (non stainless). The casing dimensions are presented here as outer diameter by thickness.

4.3 Core drilling equipment

Core drilling in KLX27A was made with a Diamec U8 APC Atlas Copco Craelius fully hydraulic machine fitted with a modern and environmentally adapted diesel engine. The drilling was done with N-size, i.e. giving a borehole of 76 mm diameter. The core barrel was of the type AC Corac N3/50, a triple-tube wireline equipment which gives a core diameter of 50.2 mm. The rods were of type NT. Directional or guided drilling was not made in KLX27A.

The drill rig was fitted with a diesel power generator of 175 kW which would give a capacity for drilling to a depth of ca 1,500 m with N-size drilling.

4.3.1 Measurements with wireline probe

The wireline probe has been developed by SKB. With this equipment water sampling, pump tests and measurements of absolute pressure in a borehole section can be made without having to lift the drill stem.

Measurements are made as specified in method description SKB MD 321.002, SKB internal document.

The principal components are:

- an inflatable packer,
- pressure gauges for the test section and for the packer,
- a water sampler,
- a submersible pump (placed in the upper part of the drill stem),
- a flow meter (placed at the ground surface).

The probe is lowered through the drill stem into position at the drill bit. The test section is between the lower end of the packer and the bottom of the borehole, see Figure 4-1.

Before the pumping tests are made leakage tests of the drill string are done.

Hydraulic tests performed during drilling are generally affected to some degree by disturbances caused by the drilling operations. Transients from changes in pressure, temperature and salinity might affect the hydraulic response curves.

Pumping tests

The wireline probe is emplaced at the bottom of the drill stem. A submersible pump (Grundfoss MP1 or equivalent) is lowered into the upper part of the drill stem at a length of about 40 m. The test section is hydraulically connected to the drill stem by opening a valve at a predetermined pressure. This creates a passage between the test section and the water column in the drill stem. The packer remains expanded during the entire test. Water is pumped from the drill stem and the pressure in the test section and packer are recorded in a data logger. The pumped

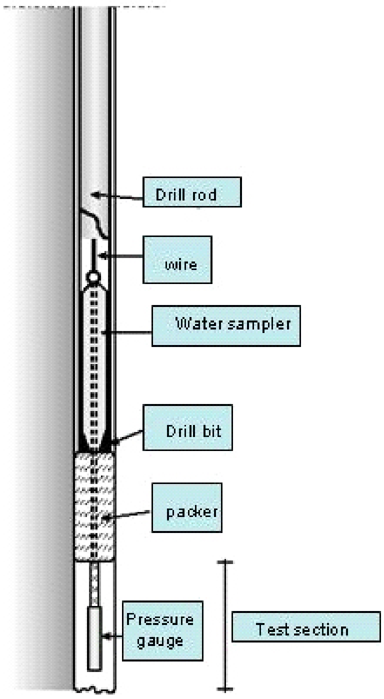


Figure 4-1. *The wireline probe and its emplacement in the hole.*

surface flow rate is recorded in a data logger on the ground surface. The pressure gauge (or pressure transducer) is situated 1.10 m below the lower end of the packer. The test consists of a pressure drawdown phase and a recovery phase. Typically the pumping time is three hours with a recovery phase of the same duration. However, the duration is sometimes adapted to the hydraulic situation of the tested section. The tests are normally carried out in sections of about 100 m length.

Water sampling

The equipment for water sampling is the same as for the pumping tests. The water volume in the section is removed at least three times by pumping water out of the drill stem. The water in the test section is then replaced by formation water and a sample is collected. The wireline probe, with the sampling unit containing a maximum volume of 5 litres, is subsequently brought to the surface.

Pumping tests and water sampling are normally performed as an integrated activity. The aim is to characterize the hydrochemistry as well as the hydrology in the bedrock when the conditions are least affected by hydraulic short circuiting in the borehole.

Absolute pressure measurement

No measurements of absolute pressure were done in KLX27A.

4.3.2 Drilling monitoring system

During the core drilling phase continuous monitoring was made of several measurement-while-drilling (MWD) parameters and flushing water parameters. The data is compiled into the DMS database. The procedure for data handling and quality assurance is given in method description SKB MD 640.008 (SKB internal document).

The drill rig (MWD) parameters include:

- Rotational pressure (bar).
- Bit force (kN).
- Flush water flow in (L/min).
- Water pressure at bit (kPa).
- Rotation (rpm).
- Penetration rate (cm/min).

The flushing water parameters include:

- Water level in the telescope part of the borehole (kPa).
- Oxygen level of flushing water (mg/L).
- Flow of flushing (ingoing) and return (outgoing) water (L/min).
- Electrical conductivity of flushing and return water (mS/m).
- Barometric pressure (kPa).

Data from on-line monitoring of flushing water parameters were stored on two different logging units (CR10 and CR23). A separate logging unit was used for the measurement-while-drilling (MWD) dataset. The data from the loggers was downloaded either continuously (CR10 and CR23) or by disk to the DMS database.

4.3.3 Deviation measurements

Two types of deviation measurements were made:

- Measurements to keep track on the borehole orientation were made with the magnetometer/accelerometer method Reflex EZ-AQ/EMS (or Easy-Shot) and Flexit, see also Table 5-2 and section 5.3.3.
- Final measurements, along the entire length of the borehole after the drilling was completed, were made with two methods, Flexit and Maxibor. The Maxibor (Reflex MAXIBOR™) is a non-magnetic, optical method. The Flexit instrument (Flexit SmartTool) is based on magnetometer/accelerometer measurements.

4.3.4 Equipment for reaming reference slots

In order to establish accurate and similar depth references for the various measurements that will be performed in the borehole, reference slots are reamed in the borehole wall.

The equipment has been developed by SKB and consists of a reaming tool that can be fitted to conventional drilling rods for 56 and 76 mm drilling equipment. The reaming tool is operated hydraulically from the surface, so that the cutters expand when the water pressure is increased.

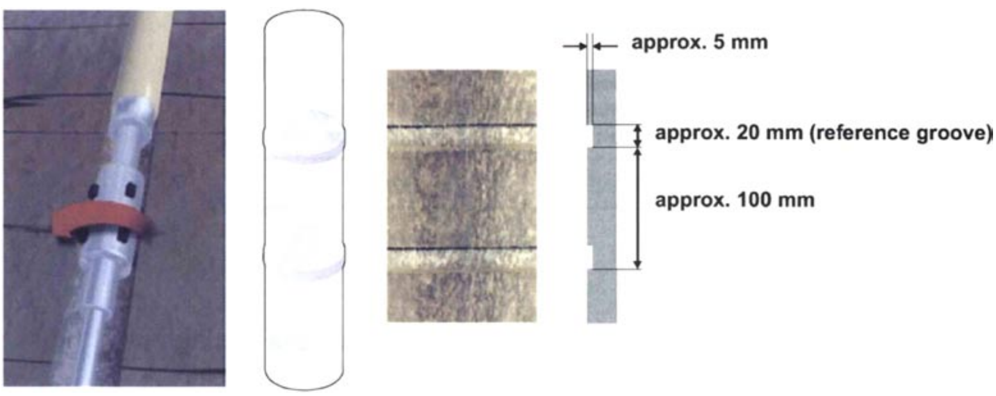


Figure 4-2. The equipment for reaming of reference slots. To the left, the reaming tool with openings for the cutters is shown. The resulting reference slots are illustrated in the three pictures to the right.

5 Execution and results

The original data and results are stored in the SICADA database. Only the datasets in the database will be used for further interpretation and modelling. The data is traceable in SICADA by the Activity Plan number, AP PS 400-07-058.

5.1 Summary of KLX27A drilling

A technical summary of the drilling of KLX27A is given in Table 5-1. A graphical presentation of the borehole after completion is given in Figure 5-1. A summary of drilling progress and borehole measurements is given in Table 5-2 and chronological summary is presented in Table 5-3.

Further descriptions of the percussion drilling of the telescopic section 0–75.60 metres and the measurements performed during this phase are given in section 5.2. The core drilling between 75.60–650.56 metres is further described in section 5.3. Results from hydrogeological and hydrogeochemical measurements during core drilling are presented in section 5.4. Drilling progress over time is further reported in section 5.5 "Drilling monitoring results".

5.2 Drilling, measurements and results in the telescopic section 0–75.60 m

Drilling, reaming and grouting (gap injection) were made from August 15 to 27, 2007.

5.2.1 Preparations

A cement pad for emplacement of drill rig, fuel container and compressor was built. A suitable area was cleared and levelled for establishing of a drill site. Cleaning of all DTH (down-the-hole) equipment was done with a high-capacity steam cleaner.

Table 5-1. KLX27A Technical summary.

General	Technical
Name of hole KLX27A	**Percussion drill rig** Comacchio MC1500
Location Laxemar, Oskarshamn Municipality, Sweden	**Percussion hole length** 75.50 m (diam 197.0 mm) 75.60 m (diam 157.0 mm)
Contractor for drilling Drillcon AB	**Core drill rig** B20 APC Atlas Copco
Subcontractor percussion drilling Sven Andersson AB	**Core drill dimension** N-size (76 mm)
Percussion drill start date August 15, 2007	**Cored interval** 75.60–650.56 m
Completion date August 27, 2007	**Diamond bits used** 7
Subcontractor core drilling Suomen Malmi OY (SMOY)	**Average bit life** 82 metres
Core drill start date October 8, 2007	**Position KLX27A (RT90 RH70) at top of casing** N 6365608.29 E 1546742.63 Z 16.98 (m.a.s.l.)
Completion date November 21, 2007	**Azimuth (0–360)/ Dip (0–90)** 0.73/–65.37
	Position KLX27A (RT90 RH70) at 650.56 m length N 6365894.88 E 1546745.30 Z –566.94 (m.a.s.l.)
	Azimuth (0–360)/ Dip (0–90) 0.97/–61.44

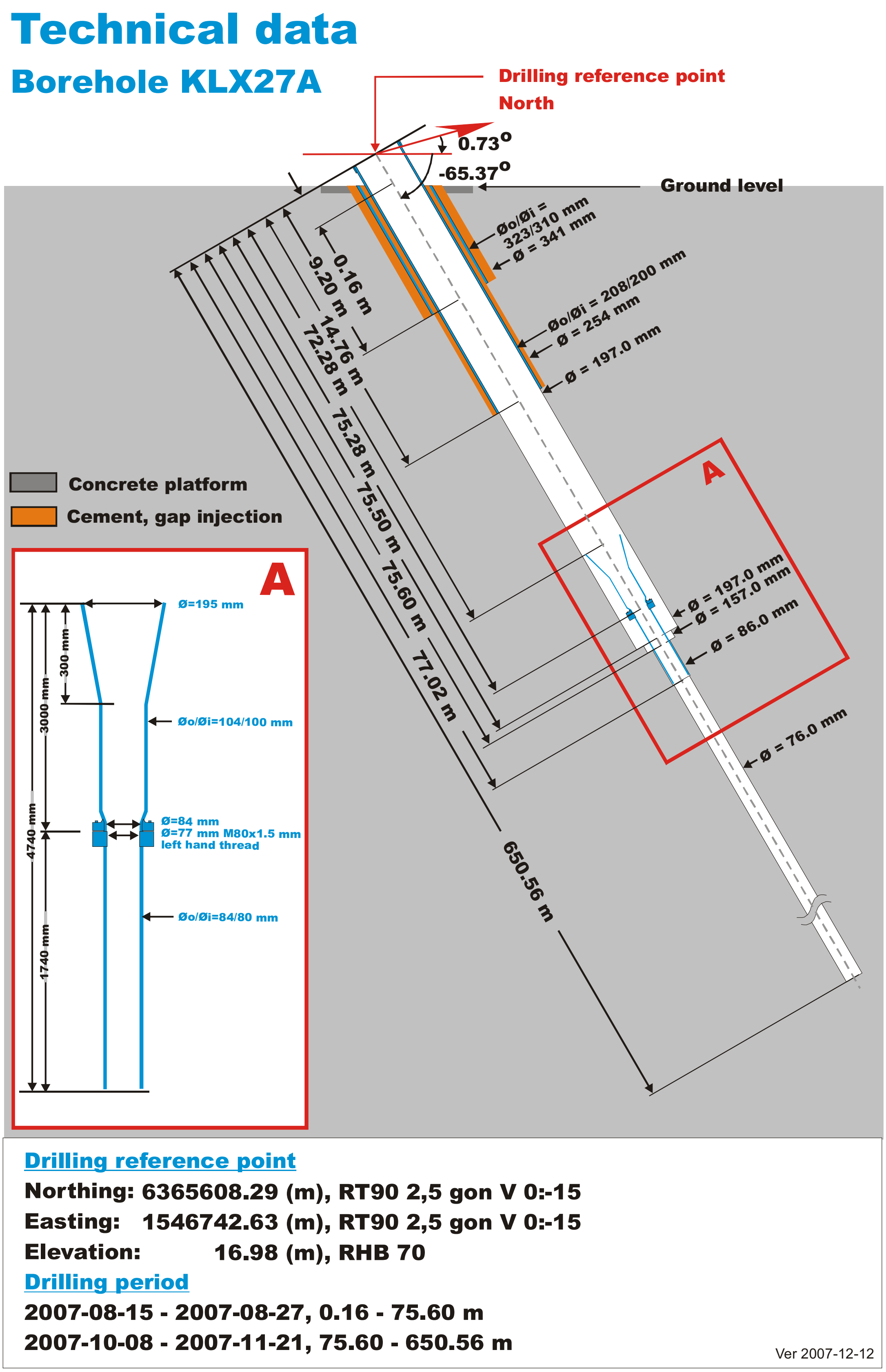


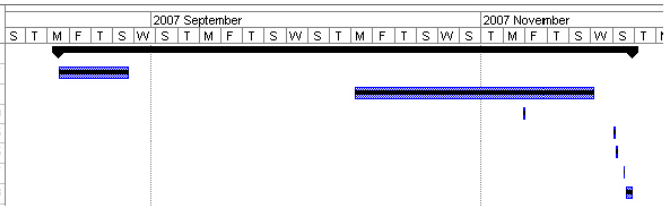
Figure 5-1. *Technical data from KLX27A.*

Table 5-2. Summary of core drilling progress and borehole measurements in KLX27A.

bh metres	Pumping tests and water sampling	Airlift pumping with evaluation of drawdown and/or recovery	Deviation measurement	Miscellaneous
			070907 Collar survey Azimuth 0.73 Dip -65.37	
100	070822 Pumping test without WL-probe in telescopic section 14.76-75.60 m Flow 8 L/min at 20 m drawdown.		070822 EZ-shot 62 m Azimuth 358.0 Dip -65.1.	071018-071021 Longer pumping test 210.20-247.20 m. Water flow 4 L/min at 43 m drawdown.
200	071012 Pumping test 77.50-176.50 Flow 6 L/min at 17 m drawdown. Water sample taken.		071012 EZ-shot 175 m Azimuth 357.6 Dip -64.4.	
	071018 Pumping test 174.50-245.40 Flow 3.5 L/min at 21 m drawdown. Water sample taken.			
300	071025 Pumping test 174.20-278.14 Flow 1 L/min at 47 m drawdown. No water sample.		071025 EZ-shot 275 m Azimuth 357.6 Dip -64.1.	
400	071031 Pumping test 276.00-368.46 Flow 0.1 L/min at 30 m drawdown. No water sample.			
500	071108 Pumping test 366.00-464.56 Flow 0.07 L/min at 21 m drawdown. No water sample.	071109 Airlift pumping 14.76-479.56 m. No drillstem in borehole.	071107 EZ-shot 460 m Azimuth 357.0 Dip -63.4.	
	071116 Pumping test 462.20-569.56 Flow 0.18 L/min at 20 m drawdown. No water sample.			
600	071122 Pumping test 567.20-650.56 Flow 5.3 L/min at 20 m drawdown. No water sample.		071124 EZ-shot 640 m Azimuth 357.8 Dip -61.6.	
	071123 Pumping test 639.20-650.56 Flow 4.8 L/min at 26 m drawdown. Water sample taken.	071127 Airlift pumping 14.76-650.56 m. No drillstem in borehole.	071125 Maxibor measurement	071121 Core drilling completed at 650.56 m

Table 5-3. Chronological summary of main drilling events in KLX27A.

Aktivitet	Start	Finish
First activity starts	**Wed 07-08-15**	**Wed 07-11-28**
Percussion drilling	Wed 07-08-15	Mon 07-08-27
Core drilling	Mon 07-10-08	Wed 07-11-21
Recovery test	Thu 07-11-08	Fri 07-11-09
Maxibor measurement	Sun 07-11-25	Sun 07-11-25
Maxibor measurement	Sun 07-11-25	Sun 07-11-25
Recovery test	Mon 07-11-26	Tue 07-11-27
Length calibration marks	Tue 07-11-27	Wed 07-11-28



5.2.2 Drilling and casing installation

The construction of the upper telescope section (0–65.42 metres) of KLX17A was made in steps as shown in Figure 5-2 and described below:

Drilling was done by Sven Andersson AB and consisted of the following items:

- Drilling was made to 9.2 metres length with NO-X 280 mm equipment. This gave a hole diameter of 341 mm and left a casing (323/310 mm diameter) to a length of 9.2 m.
- Inner supportive casing for guidance for the drill string was mounted.
- A pilot percussion hole was drilled to a depth of 75.60 metres with 5” DTH-hammer. (nominal diameter 165 mm).
- Deviation measurements with the Easy-Shot equipment was done in the pilot borehole to 62 m length.
- Reaming to diameter 254 mm was done to 14.76 m.
- Stainless casing of 208×4 mm was installed from 0 to 14.76 metres.
- Casing grouting (gap injection) with low alkali cement based concrete (536 kg or 525 litres) was made for both sets of casing. The outer casing was cut along the ground surface.
- After the concrete had hardened the borehole was rinsed and flushed to remove loose concrete and water. The tightness of the concrete casing grouting is normally made by emplacing a packer below the casing, filling the steel casing with water and then monitor the reduction in the water table over time. No record of measuring the tightness of the casing grouting and the casing is however found for KLX27A.

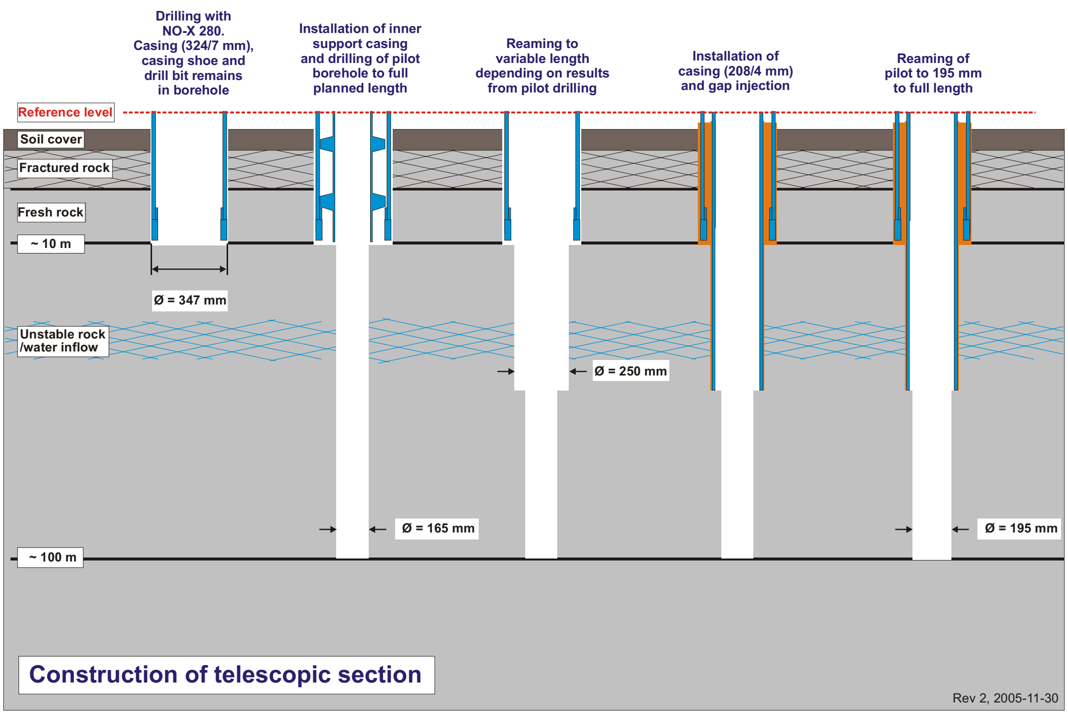


Figure 5-2. Construction of the telescopic section. The cement for casing grouting is introduced between the casing and the rock wall. The drill bit acts as a barrier so that cement does not enter the pilot hole.

5.2.3 Measurements and sampling during drilling of the telescopic section

Sampling and measurements done during drilling of the telescopic section included:

- The percussion drilling progress was monitored by a contracted geologist. Drill cuttings samples were collected every metre and a preliminary geological logging including measurement of magnetic susceptibility was made.
- Penetration rate (expressed as seconds per 20 cm) was recorded automatically and observation of changes in water flow was noted.

The preliminary geological results with penetration rate and magnetic susceptibility as measured on the cuttings are presented in Figure 5-3.

The depth to bedrock from top of casing (TOC) was 0.7 m. The depth of overburden (ground surface to rock) was ca 0.5 metres. The drilling reference level (TOC) was located 16 cm above the concrete slab. The overburden from 0.16 to 0.7 m consisted of concrete and gravel fill.

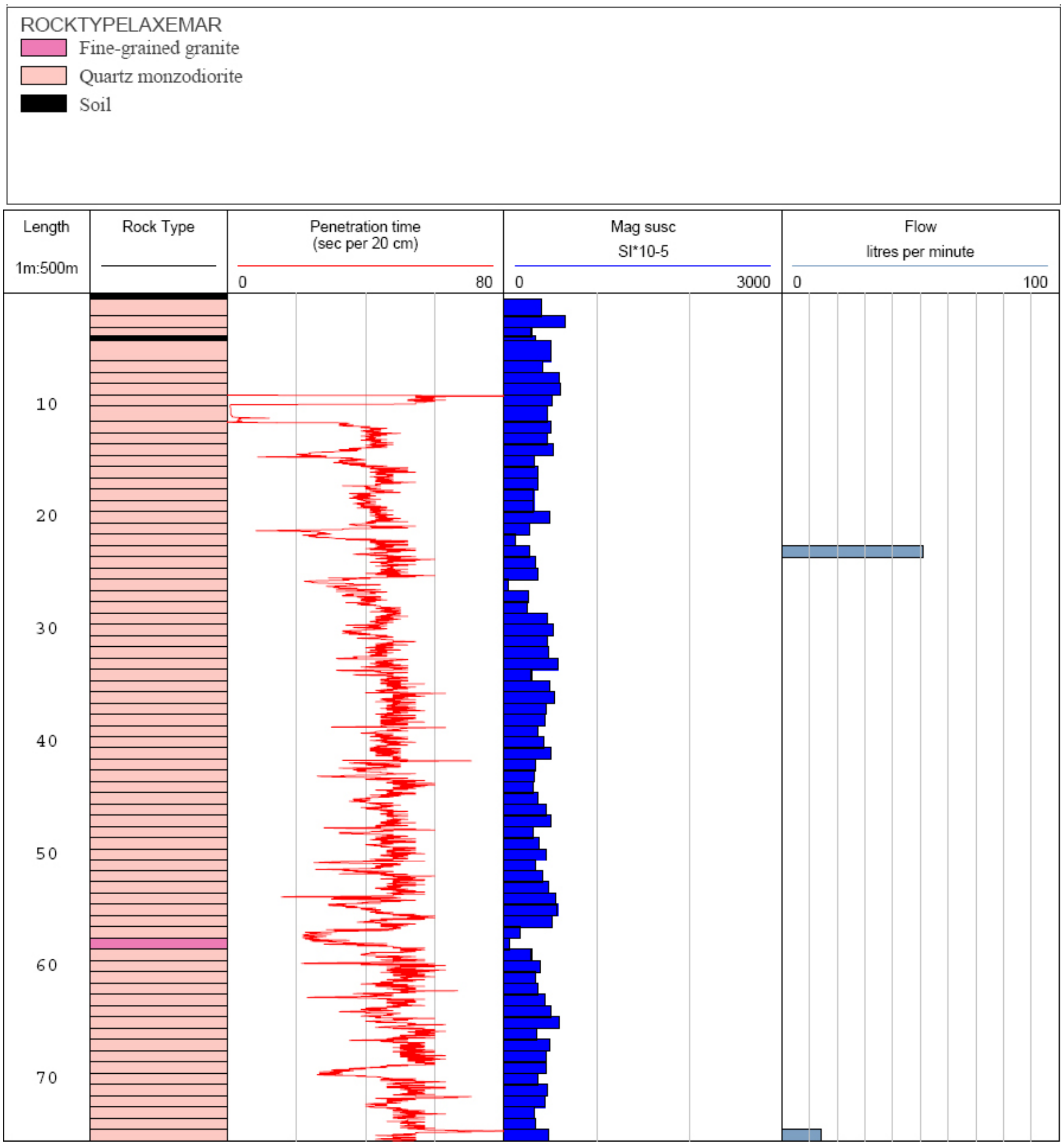


Figure 5-3. Preliminary geological results based on logging of drill cuttings and penetration rate from percussion drilling of KLX27A.

Unconsolidated gravel was logged between 4 and 4.4 m. The interval from 0.7 to 4.0 m was interpreted as a boulder. The start of the bedrock surface could therefore be said to be at 4.4 m.

A water inflow of 13.8 L/min could be measured over the entire length of the telescopic section after percussion drilling of the pilot borehole (nominal diameter 165 mm).

The results from the preliminary geological logging, measurements of magnetic susceptibility in the drill cuttings and water flow during drilling are given in Figure 5-3.

No water samples were collected in the telescopic section in KLX27A.

5.2.4 Hydrogeological measurements and results during percussion drilling 9.20–75.60 m.

In the percussion drilled part of KLX27A, 9.20–75.60 m, one single-hole pumping test was performed in the open borehole between August 22 and 23. The test comprised a pumping phase of 23 h and 55 min. The pump test was performed in the pilot borehole i.e. with a borehole diameter of ca 160 mm, before reaming to final width and also before grouting of the diameter 200 mm casing. The result is shown in Table 5-4.

5.3 Core drilling KLX27A 75.60–650.56 m

Core drilling in KLX27A was conducted between October 8 and November 21, 2007.

The main work in KLX27A after drilling the telescopic section consisted of the following steps:

- preparations for core drilling,
- flushing and return water handling,
- core drilling and deviation measurements,
- borehole completion including risk assessment of the borehole wall stability.

Measurements and results from wireline tests and drilling monitoring are given in sections 5.4 and 5.5.

5.3.1 Preparations

The preparations for core drilling started on October 1, 2007 and consisted of mounting the drill rig, installation of air-lift pumping equipment and supportive casing for alignment of the core drill rods, see Figure 5-4.

Table 5-4. Results from single-hole pumping test in open borehole KLX27A, 9.20–75.60 m.

Tested section [m]	Q/s [m²/s]	T_M [m²/s]	Comments
9.20–75.60	$4.7 \cdot 10^{-6}$	$5.3 \cdot 10^{-6}$	Pumping test without wire line probe. An initial fast drawdown to the intake level of the pump was followed by a fairly constant flow and a water level above the pump.

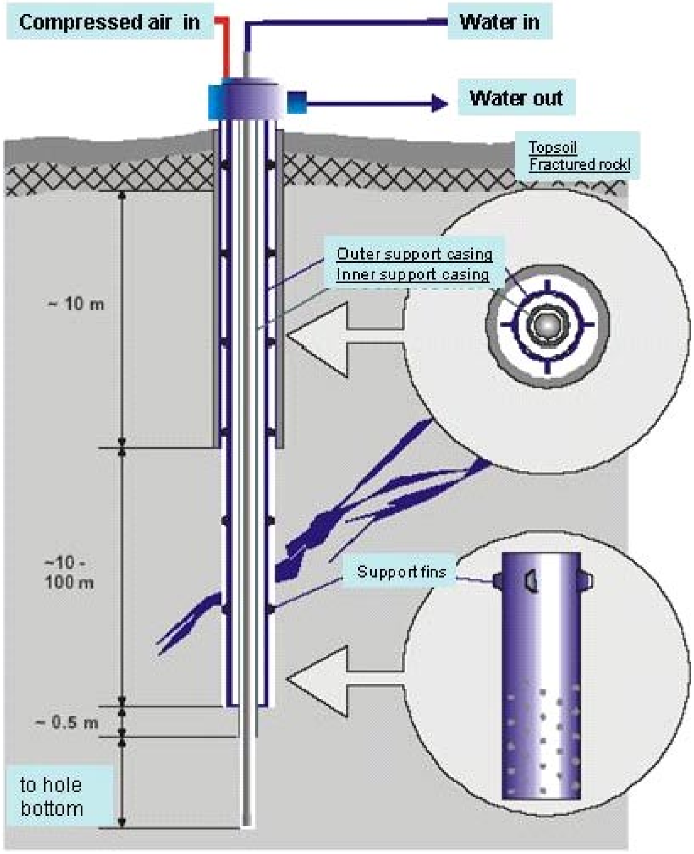


Figure 5-4. In the telescopic part of the drill hole a temporary installation is made with casing tubes for support and alignment and equipment for air-lift pumping. In the uppermost part the return water discharge header is mounted. The water discharge is led to the settling containers.

The installation of supportive casing was done in steps:

- An outer casing with a diameter of 98/89 mm, fitted with fins to align with the diameter of the percussion drilled borehole was installed to 75.50 m.
- Equipment for air-lift pumping was installed and a discharge header was fitted to collect the return water.
- Drilling was made between 75.60 and 76.12 m with T-86 equipment. An inner supportive casing with diameter 84/77 mm was installed to the borehole bottom.

The supportive casings have a perforated section below 65 metres length so that water from the borehole can be lead to the air-lift pumping system outside the supportive casings. A pressure meter for monitoring of the water level was emplaced at a length of 65 metres.

5.3.2 Flushing and return water handling

The flushing water source was percussion borehole HLX10, see also sections 5.4.2 and 5.5. The location of the water source, borehole HLX10 is shown in Figure 1-1.

The water from HLX10 was transported by truck to the KLX27A drillsite. Treatment of the flushing water before introduction into the boreholes consisted of stripping (removal) of oxygen with nitrogen gas and addition of the fluorescent tracer uranine. The water is also treated with ultraviolet light in order to reduce the microbial content. The flushing and return water handling and the emplacement of related monitoring equipment in KLX27A is shown in Figure 5-5.

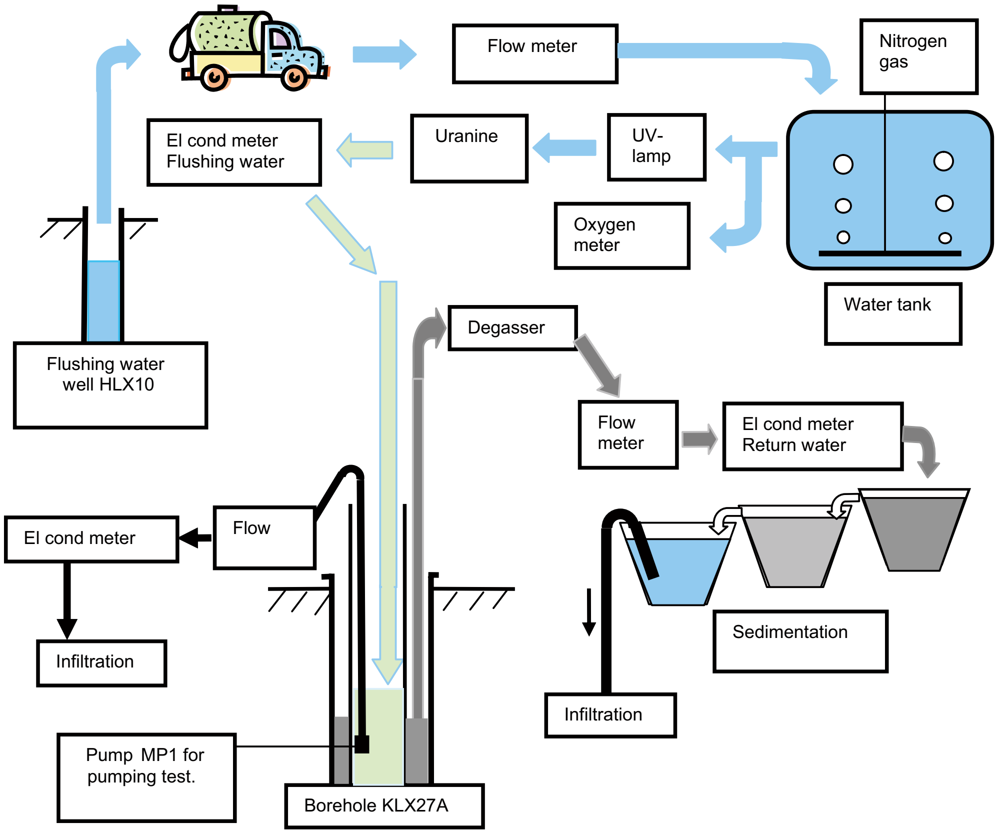


***Figure 5-5.** The flushing and return water handling and the emplacement of related monitoring equipment in KLX27A.*

The targeted content for uranine in the flushing water was 0.20 mg/L and the actual average uranine content was 0.230 mg/L, see also Figure 5-9 and section 5.4.2.

The return water from drilling was led to a series of sedimentation containers in order to collect cuttings before infiltration to the ground, see also section 5.8.

5.3.3 Drilling and deviation measurements KLX27A

Core drilling with T-86 equipment giving an 86 mm diameter hole was done from 75.60 to 76.12 m in KLX27A. The part from 76.16 to 77.02 m was first drilled with N-size and subsequently reamed to T-86 as part of the borehole completion, see section 5.3.4.

Core drilling with N-size (76 mm) triple-tube, wireline equipment was conducted from 76.12 m to the final length of 650.56 m in KLX27A.

The core diameters and intervals for drilling dimensions are given in Table 5-5. Directional drilling, i.e. intentional change of direction or dip of the borehole was not made in KLX27A.

Table 5-5. Core diameters, borehole diameters and drilling dimensions during core drilling in KLX27A.

Core diameter [mm]	Borehole diameter [mm]	Interval [m drilled length]	Drilling dimension	Comment
72.0	86	75.60–76.12	T-86	
50.2	86	76.12–77.02	N and T-86	Reamed to 86 mm diameter
50.2	76	76.12–650.56	N	

Measurements of borehole deviation are made for two purposes:

- Monitoring of drilling progress.
- Measurements at full drilled length for final calculation of borehole deviation.

The drilling progress was followed by deviation measurements five times with the EZ-shot method; one time after the percussion drilling of the telescopic section and four times in the core drilled section. The results from these measurements are not stored in the Sicada database but are given in a summary fashion in Table 5-2.

Measurements were done with Maxibor equipment and magnetometer/accelerometer (Flexit equipment) for the final evaluation of the borehole deviation in KLX27A. The Maxibor measurement was done as part of the drilling activity whereas the Flexit measurement was done as part of a separate activity (AP PS 400-07-064). Measurements for borehole deviation were performed both up and down the hole between 0 and 645 metres.

The final deviation file in KLX27A is calculated based on the measurements given in Table 5-6 together with the surveyed bearing and inclination of the top-of-casing. The inclination data from the Maxibor measurement have not been used for calculation of borehole deviation in KLX27A as readings oscillated to an extent that was deemed unsatisfactory.

The calculation of the final deviation file is made according to routines specified in the SICADA database and general expert judgement. Further comment on the method for calculation of final borehole deviation is given in /4/.

Horizontal and vertical plots of the results of the calculated deviation covering the entire length of borehole KLX27A are given in Appendix 4. Information about which deviation measurement, or parts thereof, that are used for calculation of the borehole deviation are stored in the Sicada database under activity ID 13177762 (activity type code EG154).

Three sections with core losses were noted in KLX27A during the Boremap (geological) mapping, see Table 5-7.

A total of seven drill bits were used for KLX27A, see Figure 5-6.

Further results from drill monitoring i.e. drill penetration rate and various measurements will be presented in section 5.5 "Drilling monitoring results" and in Appendix 1.

Table 5-6. Measurements used for borehole deviation calculation in KLX27A.

Deviation measurement method	Used for calculation of bearing/ inclination	Interval From [m]	Interval To [m]	Measuring direction	Date	Sicada database activity ID
Maxibor	BEARING	21	645	down/in	2007-11-25	13177335
Maxibor	BEARING	21	645	up/out	2007-12-14	13177336
Flexit	BEARING	21	645	down/in	2007-12-14	13177474
Flexit	INCLINATION	3	645	down/in	2007-12-14	13177474
Flexit	BEARING	21	645	up/out	2007-12-14	13177475
Flexit	INCLINATION	3	645	up/out	2007-12-14	13177475

Table 5-7 Core losses in KLX27A

From [m]	To [m]	Missing length [m]	Comment
95.507	95.559	0.052	Missing Core Piece
253.807	253.867	0.060	Crushed Zone
503.597	503.612	0.015	Missing Core Piece

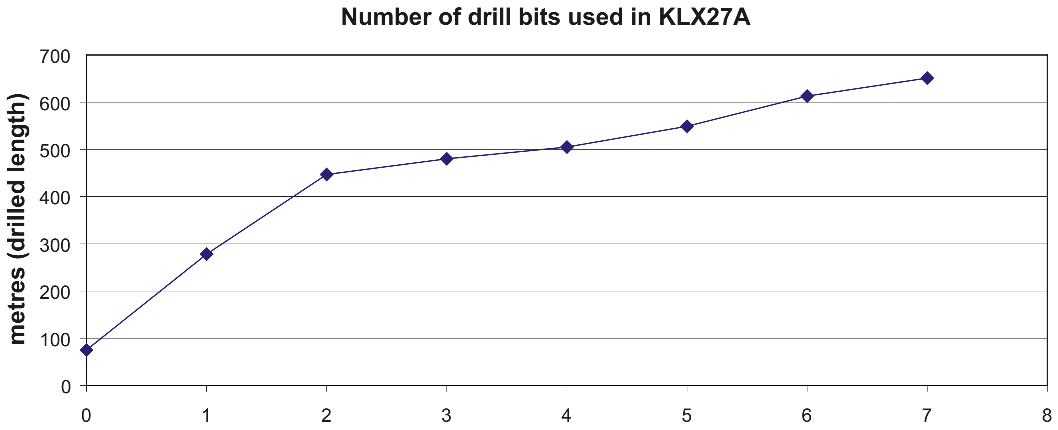


Figure 5-6. *Drill bit changes during core drilling in KLX27A.*

5.3.4 Borehole wall risk assessment, stabilisation and completion

Borehole wall risk assessment and stabilisation

A final borehole wall assessment was prepared on December 11, 2007, SKB id 1091604, SKB internal document.

The main drilling events that have influence on the risk assessment are summarized as follows:

- BIPS logging of the interval 209 to 250 m was done on November 7. Fallout of rock pieces had occurred in conjunction with lifting of the drill stem, drill bit changes etc.
- Diamond drilling was completed at 650.56 m on November 21.
- The steel dummy was lowered without any problems along the entire length of the borehole. The probe is designed so that it will run smoothly along the borehole if the curvature does not exceed 0.1 degree/metre.
- Flushing and brushing with high water pressure on the borehole wall was done along intervals as given in Table 5-8. The selection of the intervals to rinse was based on study of the drill core and BIPS images from the interval 209 to 250 m. The flush and brush tool is shown in Figure 5-7.
- Downhole operations consisting of deviation measurements, milling of reference grooves and flushing of the borehole with nitrogen gas were made without stability problems.
- BIPS logging for final risk assessment was done to full drilled length.

The overall assessment was that the probability for rock fallout was low to medium in the borehole.

Table 5-8 Borehole sections that were mechanically rinsed by water flushing and rotating steel brush.

From [bh length m]	To [bh length m]
106	108
150.5	151.5
220	223
226	230
233	234
242	243
644	645

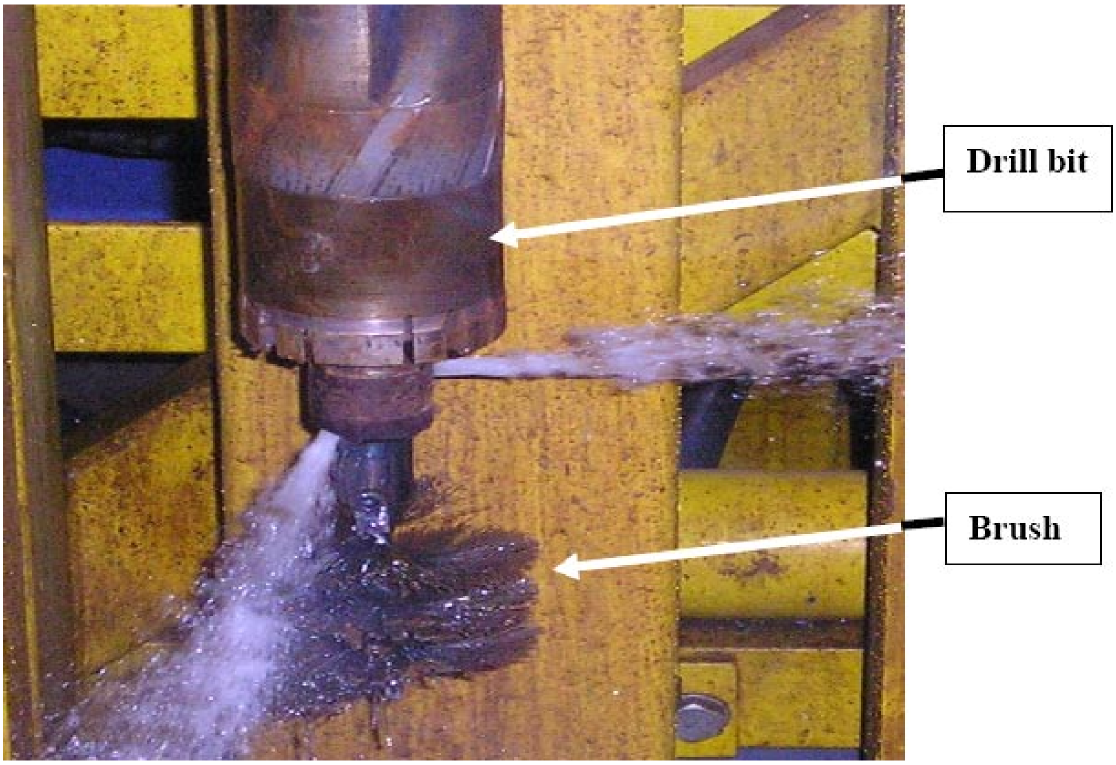


Figure 5-7. *The water flushing and rotating steel brush tool. The tool is lowered into the drill stem and can be seen in place just below the drill bit. During operating the drill string is moved up and down to rwemove loose rock fragments from the borehole wall.*

Borehole completion

Reaming of depth reference slots was done at the drilled lengths shown in Table 5-9. The depth reference slots are used for depth calibration of down-hole equipment for subsequent investigations in the hole. The presence of the depth reference slots have been confirmed by caliper log measurements.

The air lift pumping equipment and the inner supportive casing in the telescopic section were removed.

The borehole was reamed from 76.12 to 77.02 with T-86 equipment. A steel conical guide was installed in KLX27A between 72.28 m and 77.02 m. The conical guide tapers from an inner diameter of 195 mm to 77 mm.

The borehole was rinsed by flushing (lifting) with nitrogen gas at times given in Table 5-10. The nitrogen lifting on November 6 was done as a preparation for the BIPS logging on November 7. There is no record of the amount of water removed.

The final nitrogen lifting was done on December 1 and 2 and flushed out a total of 8,000 litres of water.

The boreholes were secured by mounting of lockable steel caps fastened to the concrete pad. All equipment was removed, the site cleaned and inspected by representatives from SKB and the contractor to ensure that the site had been satisfactorily restored.

Table 5-9. Depth reference slots [m] in KLX27A.

100.00	400.00
150.00	450.00
200.00	500.00
250.00	550.00
300.00	600.00
350.00	630.00

Table 5-10. Nitrogen gas lifting in KLX27A (time is in Swedish Normal Time i.e. GMT+1).

Date	Time	Interval [m]
071106	17.00–17.15	14.76–464.65
071106	17.40–18.10	14.76–464.65
071106	18.40–18.55	14.76–464.65
071106	19.04–19.44	14.76–464.65
071201	16.22–16.39	14.76–650.56
071202	06.28–06.47	14.76–650.56
071202	07.18–07.43	14.76–650.56
071202	08.18–08.39	14.76–650.56
071202	09.14–09.31	14.76–650.56
071202	10.13–10.31	14.76–650.56
071202	12.40–13.01	14.76–650.56
071202	13.14–13.32	14.76–650.56
071202	13.58–14.27	14.76–650.56

5.4 Hydrogeological and hydrochemical measurements and results 75.60–650.56 m.

The performed measurements, as already outlined in Tables 5-2 and 5-3, can be summarized as follows.

Measurements and sampling with wireline equipment:

- Nine successful tests were conducted at various intervals, see Section 5.4.1.
- Five water samples were taken, see Section 5.4.2.

Two air-lift pumping tests with evaluation of drawdown and/or recovery phase were made, for results see Section 5.4.3.

Hydraulic responses in near-by boreholes from drilling in KLX27A are commented in Section 5.4.4.

5.4.1 Hydrogeological results from wireline measurements

Results from the wire line tests in KLX27A are presented in Table 5-11 and Figure 5-8.

The pumping tests were evaluated with steady-state assumption in accordance with Moye /3/. The flow rate at the end of the drawdown phase was used for calculating the transmissivity (T_M) and the specific capacity (Q/s), where Q is the flow rate and s is the drawdown.

Table 5-11. Pumping tests with wire line probe in KLX27A.

Tested section [m]	Q/s [m²/s]	T_M [m²/s]	Comments
77.50–176.50	4.9×10^{-6}	6.4×10^{-6}	Fairly stabilised flow and drawdown. Good test!
174.5–245.40	2.9×10^{-6}	3.6×10^{-6}	Fairly stabilised flow and drawdown. Good test!
210.20–247.20	1.5×10^{-6}	1.7×10^{-6}	Fairly stabilised flow and drawdown. Good test! The pumping test was performed as an interference test and lasted three days from Oct 18 to 21. The main objective was to test connectivity with deformation zone NW042.
174.20–278.14	6.8×10^{-7}	8.9×10^{-7}	Fairly stabilised flow and drawdown. Good test!
276.00–368.46	5.6×10^{-8}	7.2×10^{-8}	The magnitude of the drawdown is uncertain due to lack of rest water level prior to test. Calculated parameters are regarded as an upper bound, i.e. T is less than given figure.
366.00–464.56	6.7×10^{-8}	8.7×10^{-8}	Large sudden drawdown at pump start then head is recovering throughout the pumping phase. Average drawdown was used for calculation of transmissivity; T. T may be regarded as a minimum because of this.
462.20–569.56	6.4×10^{-8}	8.4×10^{-8}	Large sudden drawdown at pump start then head is recovering throughout the pumping phase. Average drawdown was used for calculation of transmissivity; T. T may be regarded as a minimum because of this.
567.20–650.56	4.8×10^{-6}	6.1×10^{-6}	The pumping period was only 83 minutes and the recovery was interrupted shortly after pump stop. Fairly stabilised flow and drawdown. Good test!
639.20–650.56	3.6×10^{-6}	3.4×10^{-6}	Fairly stabilised flow and drawdown. EC seem to start stabilising at the end of the pumping. Good test! The pumping phase lasted 14 hours. The test was evaluated as an interference test.

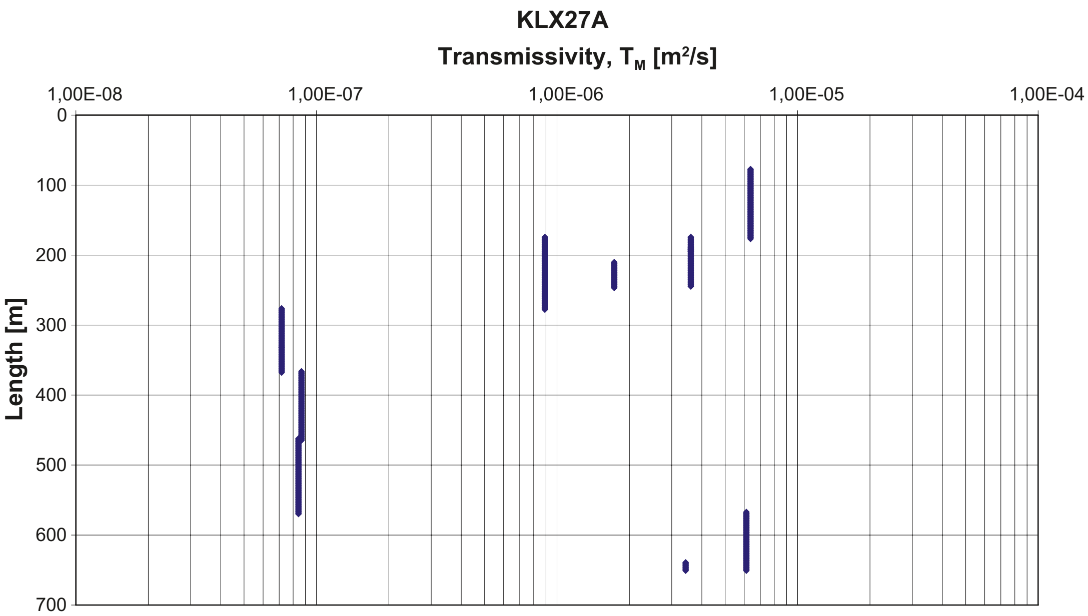


Figure 5-8. Transmissivity from wireline pumping tests in KLX27A versus borehole length.

A total of ten tests were performed in KLX27A, and nine achieved sufficiently stable conditions for calculating pseudo steady-state transmissivity and hydraulic conductivity. One test was interrupted because of malfunction wireline probe. The wireline tests normally have a pumping time of between 2 and 12 hours.

Two of the wireline tests were conducted as interference tests with longer pumping times, dedicated monitoring and evaluation of hydraulic responses. The test between 210.20 and 247.20 m however was pumped over three days (October 18 to 21) with the expressed objective to confirm any hydraulic interference or connection along the modelled deformation zone NW042. The deepest wireline test between 639.20 and 650.56 m was conducted as a combined interference test and hydrochemical sampling effort. The pumping in this section lasted 14 hours. A separate evaluation report of the two hydraulic interference tests is presented in /5/.

The plots from all wireline pumping tests are given in Appendix 5.

The start and stop times for the interval used for evaluation of the pumping tests are given in Table 5-12.

5.4.2 Hydrochemistry

Five water samples were collected in connection with core drilling in KLX27A. Times and lengths for the samples are given in Table 5-13.

Sampling and analysis were performed according to the SKB classes specified in Table 5-13. The samples were collected at the drill site as soon as possible after the sampling occasion and prepared and conserved at the Äspö laboratory. The class 3 samples were stored in refrigerator until the drilling of the borehole was completed.

Sample 15214 was taken at the lowermost level (639.20–650.56 m) as a class 5 sample following a separate decision (SKB id 1178413, SKB internal document). Class 5 samples have to be taken and prepared with extra care, see Appendix 3 for further detail. Water in the section was pumped for several hours and afterwards the section had two hours of recovery before sampling. This was needed to ensure good water quality and low flushing water content.

No analyses of main components or isotopes were taken in samples 15149 and 15213 due to high content of flush water (26–73%).

The drilling water content is a measure of the amount of uranine tracer in the return water. A low percentage of drilling water implies that the amount of pristine formation water is high in the sample i.e. low amount of the uranine-spiked flushing water.

Archive samples have been collected for all five samples. The samples are stored in a freezer at the Äspö laboratory.

Selected analytical results from KLX27A are given in Table 5-14. A complete record of analytical results is given in Appendix 2.

The percussion drilled borehole HLX10 was used as water source during the drilling of KLX27A.

No water samples were collected from HLX10 in connection with the drilling of KLX27A. However, water samples have been collected from HLX10 at earlier occasions and results from those analyses are reported in the drilling report for borehole KLX12A /6/ and references therein.

Table 5-12. Evaluated test periods (GMT+1).

Tested section	Start (YYYY-MM-DD HH:MM)	Stop (YYYY-MM-DD HH:MM)
77.50–176.50	2007-10-12 14:59	2007-10-13 02:03
174.5–245.40	2007-10-17 17:20	2007-10-18 01:50
210.20–247.20*	2007-10-18 19:03*	2007-10-21 11:01*
174.20–278.14	2007-10-24 15:05	2007-10-24 18:06
276.00–368.46	2007-10-31 16:10	2007-10-31 19:10
366.00–464.56	2007-11-07 17:32	2007-11-07 20:40
462.20–569.56	2007-11-15 16.09	2007-11-15 19.03
567.20–650.56	2007-11-22 09.05	2007-11-22 10.28
639.20–650.56	2007-11-22 14.30	2007-11-23 05.22

* the pumping in this test lasted for three days i.e. considerably longer than the other tests

Table 5-13 Sample dates and length during core drilling in KLX27A.

Sample number	Date	Test section, length (m)	SKB chemistry class
15131	2007-10-13	77.50–176.50	3
15148	2007-10-17	174.60–245.40	3
15149	2007-10-22	210.20–247.20	3 (main components and isotopes not included)
15213	2007-11-22	639.20–650.56	3 (main components and isotopes not included)
15214	2007-11-23	639.20–650.56	5 (Ra/Rn not included)

Table 5-14. Analytical results from water chemistry sampling in KLX27A.

Sample no	Date	Section [m]	Drill water [%]	pH	Conductivity [mS/m]	Cl [mg/l]
15131	2007-10-13	77.50–176.50	4.10	8.15	140.0	255.0
15148	2007-10-17	174.60–245.40	12.00	8.22	166.0	311.0
15149	2007-10-22	210.20–247.20	26.40	8.78	87.9	130.0
15213	2007-11-22	639.20–650.56	72.70	8.60	53.6	28.8
15214	2007-11-23	639.20–650.56	6.69	7.40	491.0	1,500.0

Monitoring of uranine tracer content

From KLX27A, a total of 90 samples for uranine content and electrical conductivity in flushing and returning water were taken along the borehole.

The results are shown graphically in Figure 5-9. All the samples were analysed at the Äspö laboratory.

The calculated average uranine content for the whole borehole is 0.230 mg/l. This value has also been used for further calculations of the drill water content in the samples collected after drilling. However, for the samples collected during drilling (i.e the samples in this report), the drill water content for each sample is based on the average uranine content in the flushing water samples up to the time of sampling.

A further account on analytical method, chemistry class 3 and 5 and quality is given in Appendix 3.

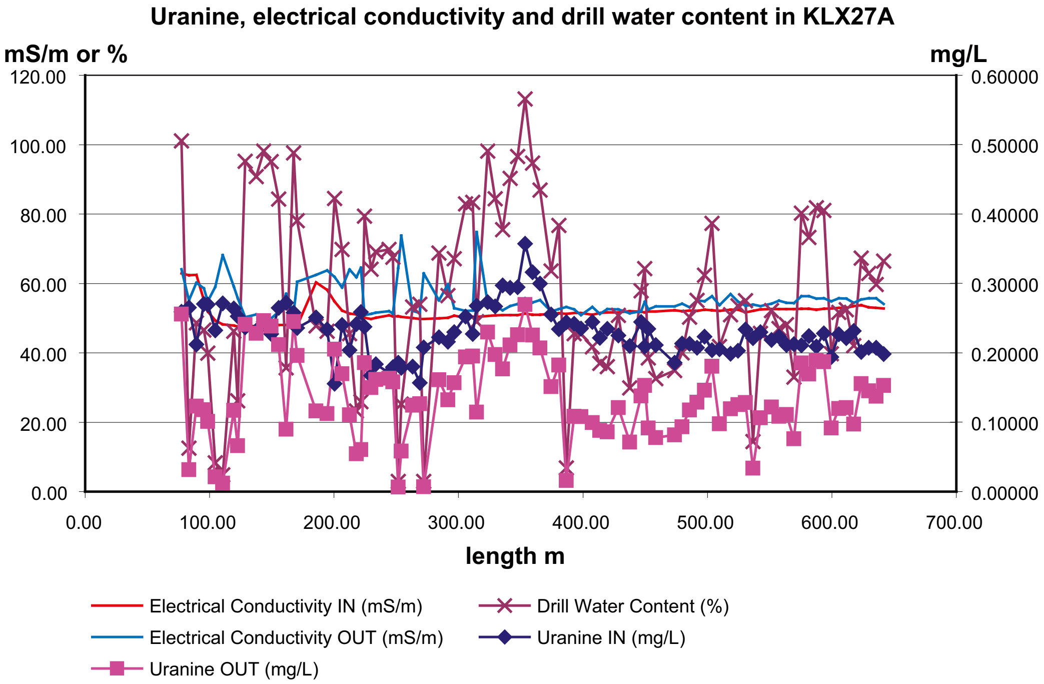


Figure 5-9. The uranine concentration and electrical conductivity of the flushing water (IN) and the return water (OUT) in KLX27A. The drill water content in the returning water is also shown.

5.4.3 Results from air-lift pumping with evaluation of drawdown and/or recovery

Two airlift pumping test were made, one was conducted during drilling and another was conducted after the borehole was drilled to full depth. The execution of the tests varies in detail as drilling or other related activities such as cleaning and flushing of drill cuttings may occur prior to lifting the stem.

The steady state transmissivity, T_M, as well as the specific capacity, Q/s, was calculated according to Moye /3/. The results are shown in Table 5-15, and stored in the SICADA database as "recovery tests" (code HY050). The tested section is here defined as the section between the lower end of the grouted casing and the borehole bottom.

The plots from the drawdown and recovery tests are given in Figures 5-10 and 5-11.

Table 5-15. Results from airlift pumping in KLX27A.

Tested section [m]	Flow rate [L/min]	Drawdown [m]	Q/s [m²/s]	T_M [m²/s]	Comments
75.60–479.56	59	6.0	1.6×10^{-4}	2.5×10^{-4}	The recovery measurement was preceded by 7 hours of air lift pumping and core drilling, followed by 100 minutes of air-lift pumping only.
75.60–650.56	51.5	12	7.1×10^{-5}	1.3×10^{-4}	The recovery measurement was preceded by 11.5 hours of air lift pumping including cleaning (brushing) of borehole intervals

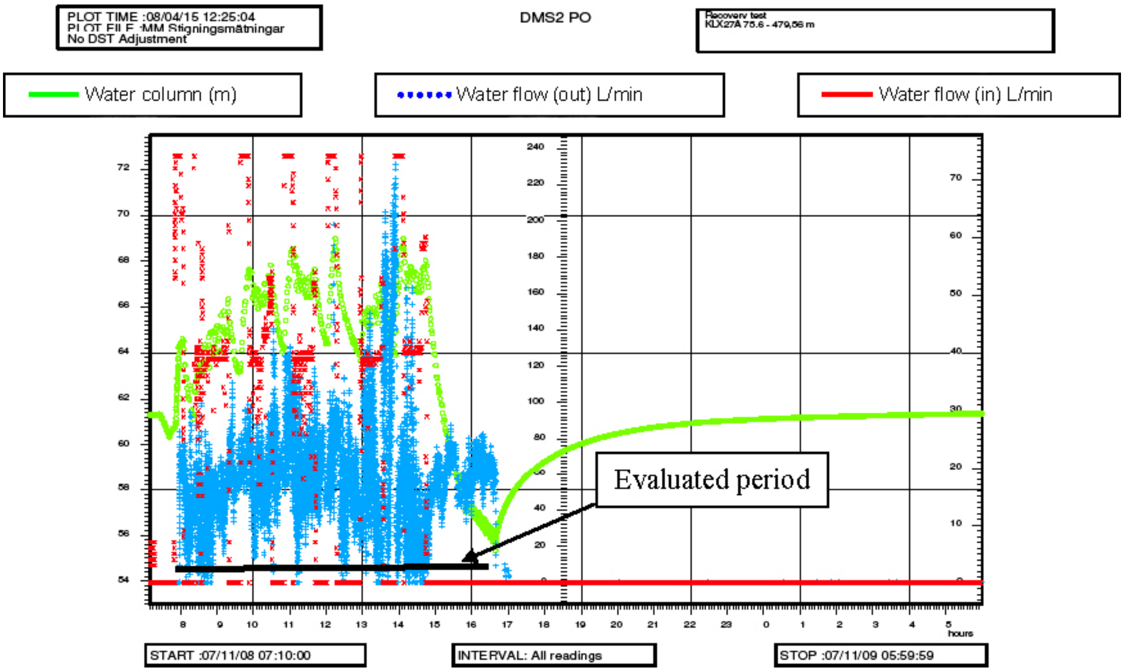


Figure 5-10. *Airlift pumping in KLX27A 75.60–479.56 m. The green line represents the height of the water column in the borehole; the out flow is shown as the blue dotted line and the inflow rate as the red line.*

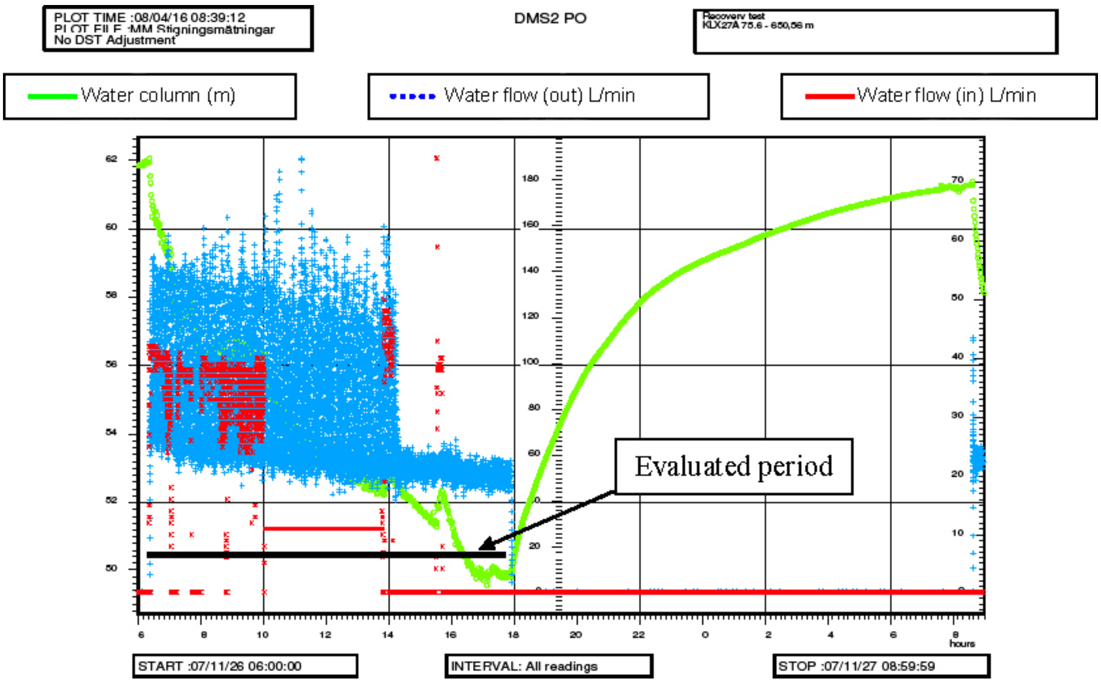


Figure 5-11. *Airlift pumping in KLX27A 75.60–650.56 m. The green line represents the height of the water column in the borehole; the out flow is shown as the blue dotted line and the inflow rate as the red line.*

5.4.4 Hydraulic responses in near-by boreholes.

Hydraulic responses from drilling activities in a borehole are created by the drawdown from air-lift pumping during core drilling and from flushing or rinsing the borehole with nitrogen gas (ie lifting the water with nitrogen gas). Percussion drilling of the telescopic section also constitutes an air-lift pumping from a hydrogeological point of view. All times in plots in this section (section 5.4.4) are given in Swedish Normal Time (GMT+1).

Summary conclusions are listed below.

- Hydraulic responses could be seen in observation boreholes HLX32, KLX11A and KLX19A from drilling activities in KLX27A. Further comment and graphical examples are given Figures 5-12 to 5-17 and the related text. Boreholes HLX32, KLX11A and KLX19A were divided by packers into sections that are pressure monitored individually. The downhole section lengths are given in Table 5-16.
- No clear hydraulic responses could be seen in observation boreholes KLX03, KLX14A, KLX15A, KLX16A, KLX20A, HLX15, HLX26, HLX27, HLX28, HLX36, HLX37, HLX38 or HLX42 from drilling related activities in KLX27A. Very weak responses could be inferred in HLX28, HLX37 and KLX20A.
- Two interference tests were made with the wireline equipment in KLX27A between 210.20–247.20 m and 639.20–650.56 m. A full evaluation report from the interference tests is given in /5/.
- In the three day test on October 18 to 21 between 210.20 and 247.20 m, a clear response could only be seen in KLX19A and possible weak responses in several other observation boreholes.
- No hydraulic responses could be seen in any observation borehole from the test between 639.20–650.56 m.
- The flushing water well HLX10 was located quite far away from the drill site for KLX27A and also from the observation boreholes. No influence could be seen from the pumping of HLX10 in the observation boreholes or in KLX27A.

The location of the observation boreholes, flushing water supply well and KLX27A is shown in Figure 5-18.

Hydraulic responses in observation borehole HLX32

Section 1 and 2, i.e. the lowermost sections are clearly affected by the air-lift pumping as can be seen in Figure 5-12. Section 3 is however not affected by the air-lift pumping in KLX27A.

KLX27A was not affected by nitrogen lifting, see Figure 5-13. No data is available before September 9, 2007 due to installation of monitoring equipment, hence no data from the time when percussion drilling was performed.

Hydraulic responses in observation borehole KLX11A

The lower sections (2, 3, 4 and 5) in KLX11A clearly respond to nitrogen lifting in KLX11A whereas section does not respond at all, see Figure 5-14. Only weak and dampened responses could be seen in sections 6, 7 and 8. However the responses only occur during the final nitrogen lifting on December 1 and 2 i.e. no response occurred from nitrogen lifting on November 6, see Figure 5-15. The reason for this could be that the nitrogen lifting on November 6 did not remove as much water as the final nitrogen lifting in December *or* that the hydraulic connection is located below the level at which the nitrogen lifting in November was performed i.e. between 464 and 650 m.

No responses could be noted in any section of KLX11A from air-lift pumping or wireline pumping during core drilling.

No data is available before October 16, 2007 due to installation of monitoring equipment, hence no data from the time when percussion drilling was performed.

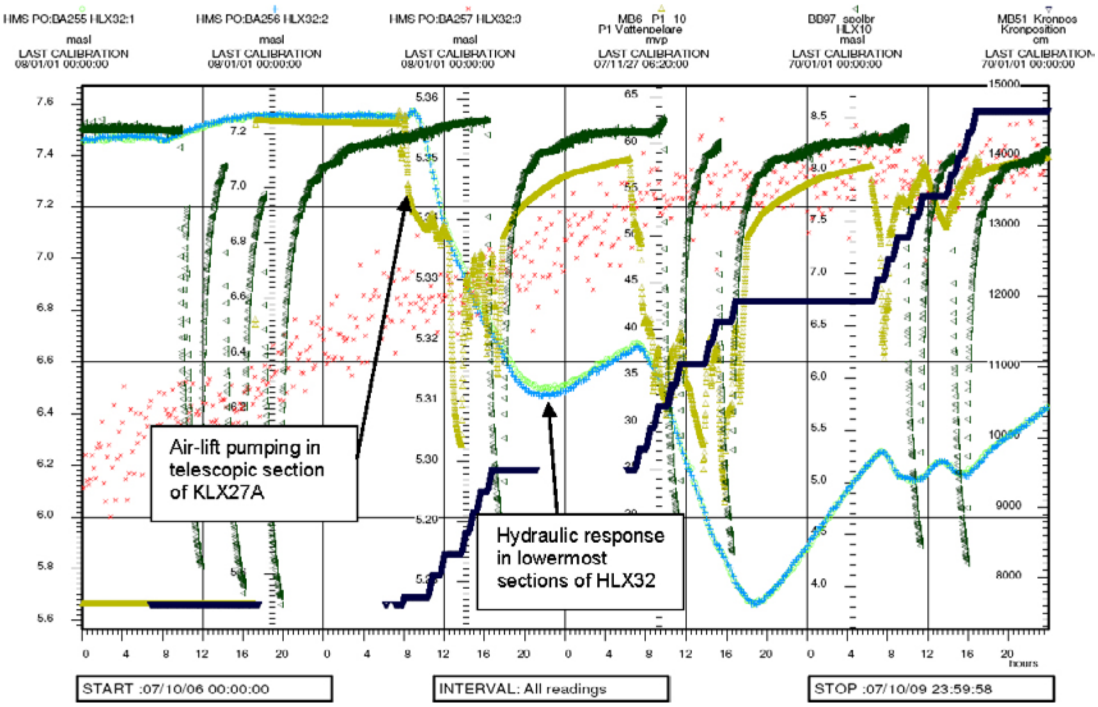


Figure 5-12. *Groundwater levels in borehole HLX32 together with drilling parameters (pressure in the drilling borehole, position of drill bit and water level in the flushing water well) during the drilling in borehole KLX27A, October 6 through 9, 2007. The water level in the two lowermost sections in HLX32, shown in the figure with light blue and light green, clearly follow the air-lift pumping in KLX27A (olive green).*

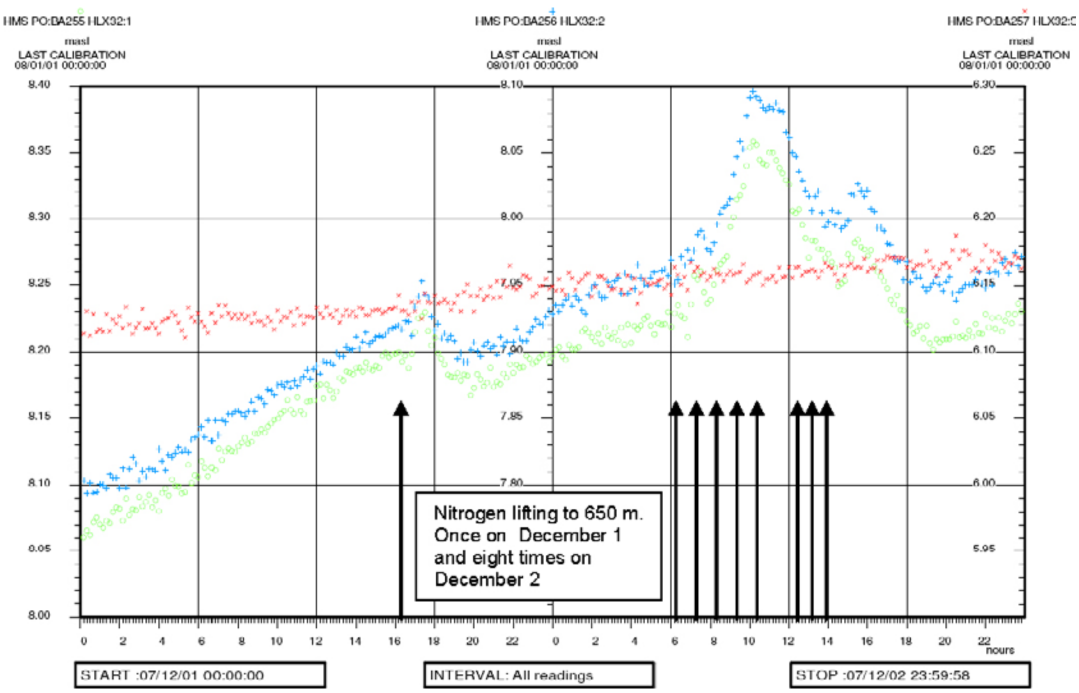


Figure 5-13. *Groundwater levels in borehole HLX32 during the nitrogen lifting in borehole KLX27A, December 1 and 2, 2007. No hydraulic responses can be seen from the nitrogen lifting.*

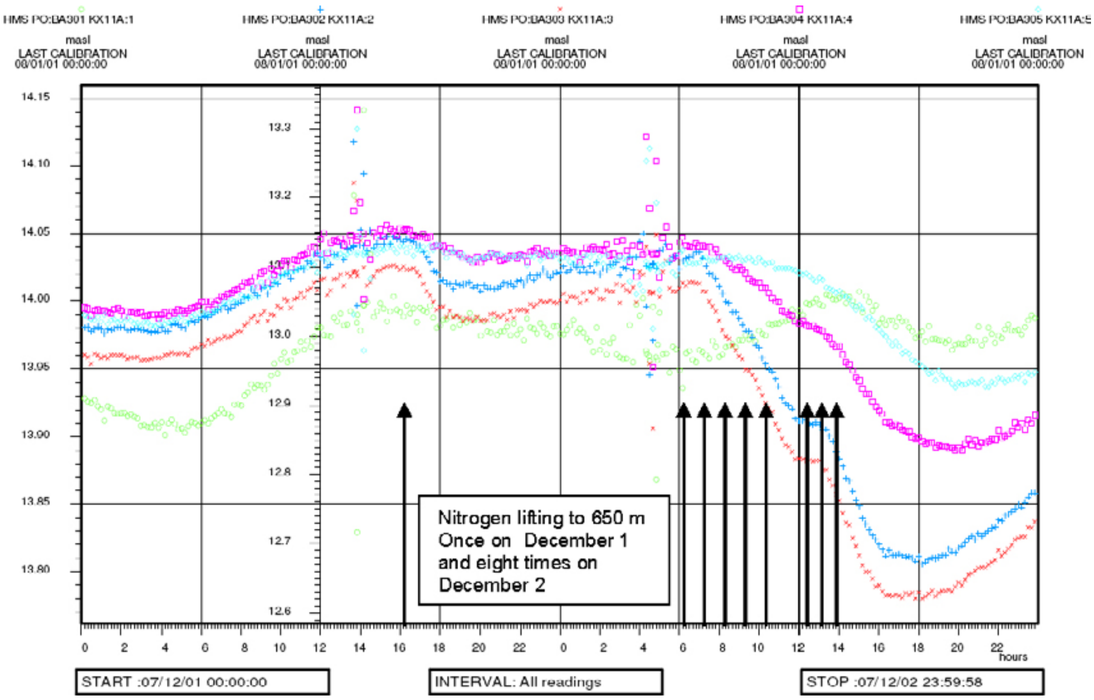


Figure 5-14. *Groundwater levels in borehole KLX11A, sections 1–5, the nitrogen lifting in borehole KLX27A during December 1 and 2, 2007. Responses can be seen in sections 2, 3, 4 and 5. Section 1 (light green) does not respond at all.*

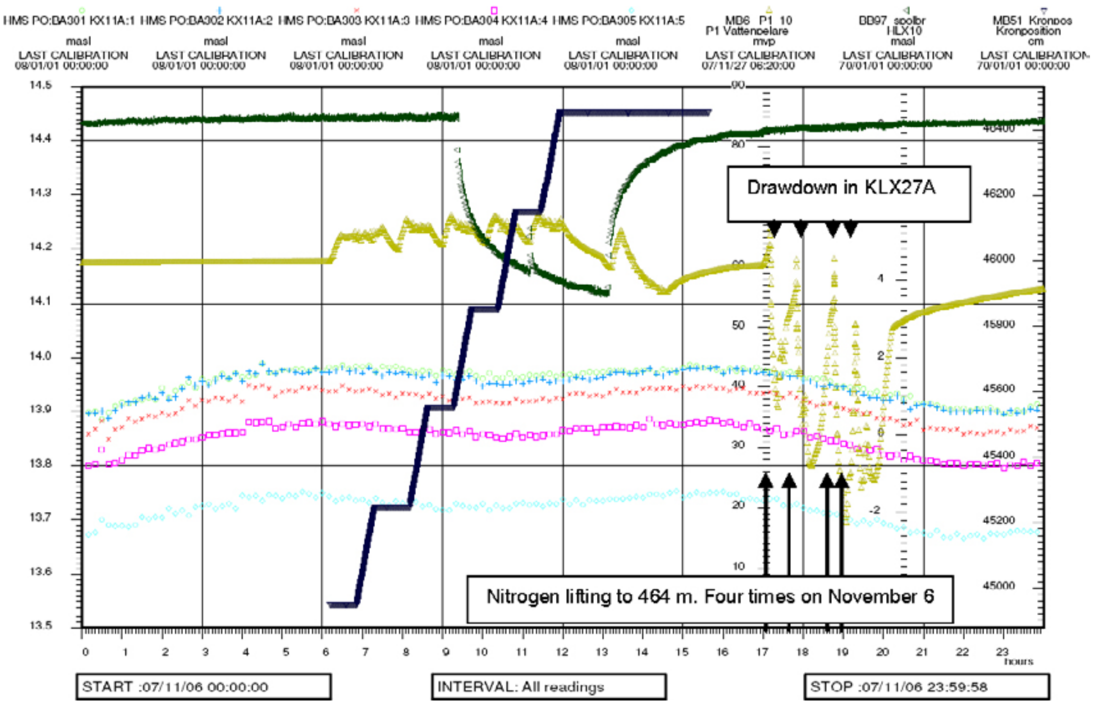


Figure 5-15. *Groundwater levels in borehole KLX11A, sections 1–5, together with drilling parameters (pressure in the drilling borehole, position of drill bit and water level in the flushing water well) during the drilling in borehole KLX27A during November 6, 2007. No response was noted in KLX11A, sections 1 to 5.*

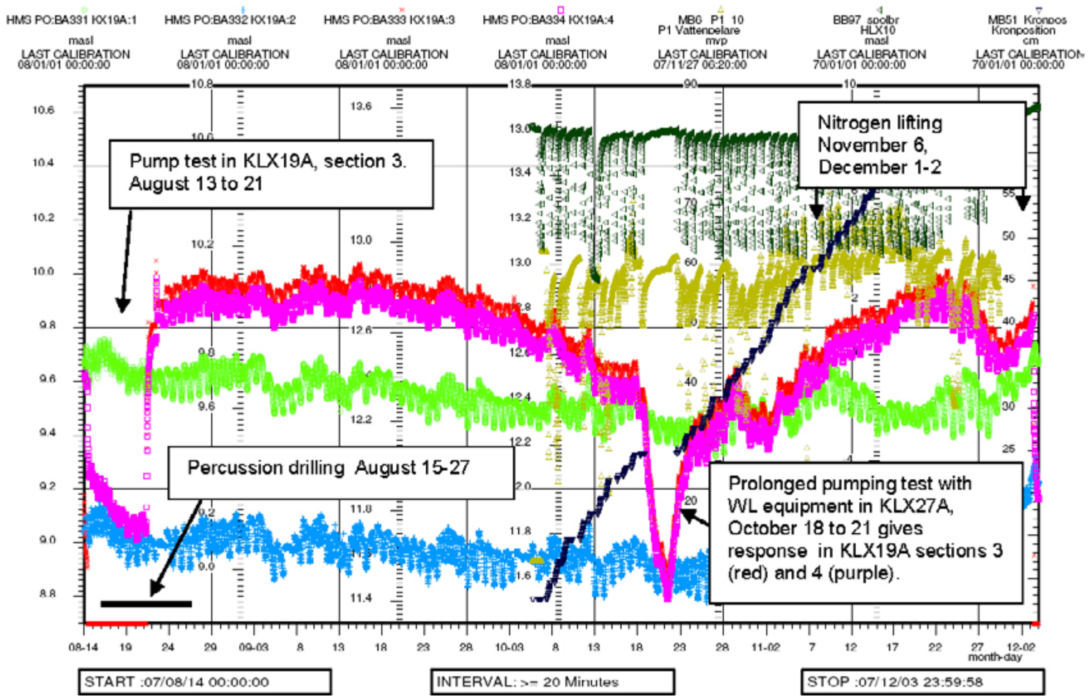


Figure 5-16. *Groundwater levels in borehole KLX19A, section 1–4, together with drilling parameters (pressure in the drilling borehole, position of drill bit and water level in the flushing water well) during the drilling in borehole KLX27A. Overview of entire drilling period, August 14 to December 3, 2007. Drawdown from the three day pumping in KLX27A in October is very clearly seen in KLX19A, sections 3 (red) and 4 (purple).*

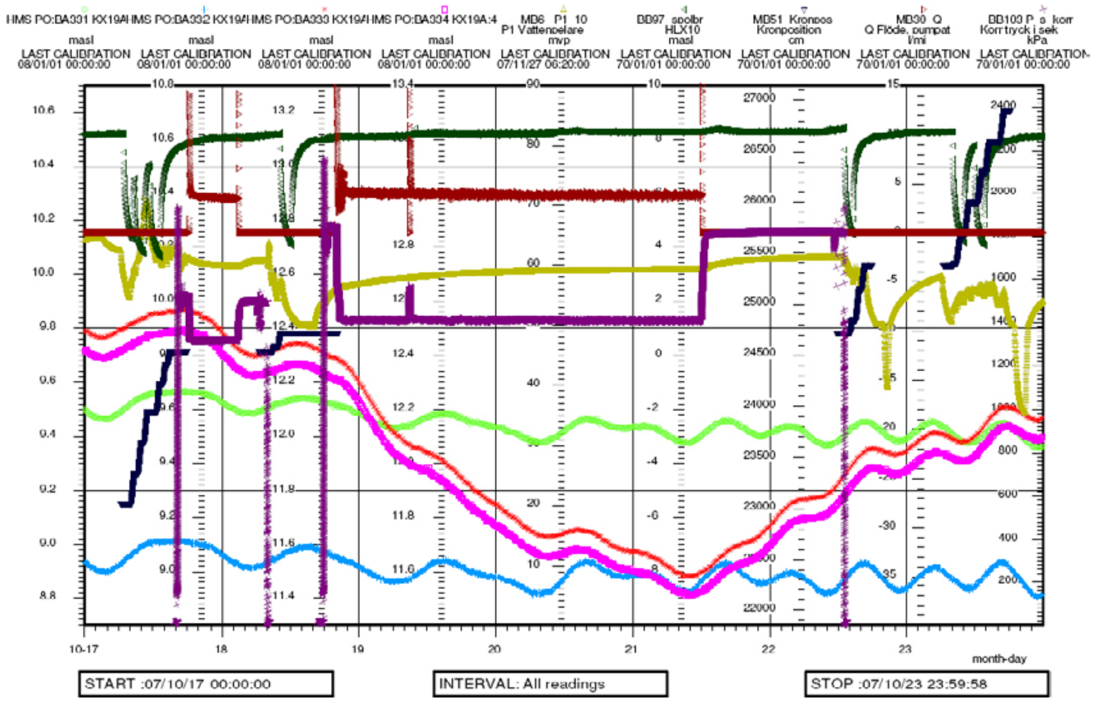


Figure 5-17. *Groundwater levels in borehole KLX19A, section 1–4, together with drilling parameters (pressure in the drilling borehole, position of drill bit, water level in the flushing water well, pressure in an isolated section in the drilling borehole and flow in an isolated section in the drilling borehole) during the drilling in borehole KLX27A, October 17 to 23, 2007. A distinct drawdown is seen in KLX19A, sections 3 (red) and 4 (purple) from when the pumping in KLX27A starts on October 18. No response can be seen in sections 1 (light green) or 2 (blue).*

Table 5-16. Section lengths for pressure monitoring in boreholes HLX32, KLX11A and KLX19A.

Section	HLX32*	KLX11A**	KLX19A
10	N/A	12.05–102.00	N/A
9	N/A	103.00–179.00	N/A
8	N/A	180.00–255.00	98.75–135.00
7	N/A	256.00–272.00	136.00–290.00
6	N/A	273.00–314.00	291.00–310.000
5	N/A	315.00–494.00	311.00–480.50
4	N/A	495.00–572.00	481.50–508.00
3	12.30–19.00	573.00–586.00	509.00–517.00
2	20.00–30.00	587.00–702.00	518.00–660.00
1	31.00–162.60	703.00–992.29	661.00–800.07

*installed September 9, 2007

**installed October 16, 2007

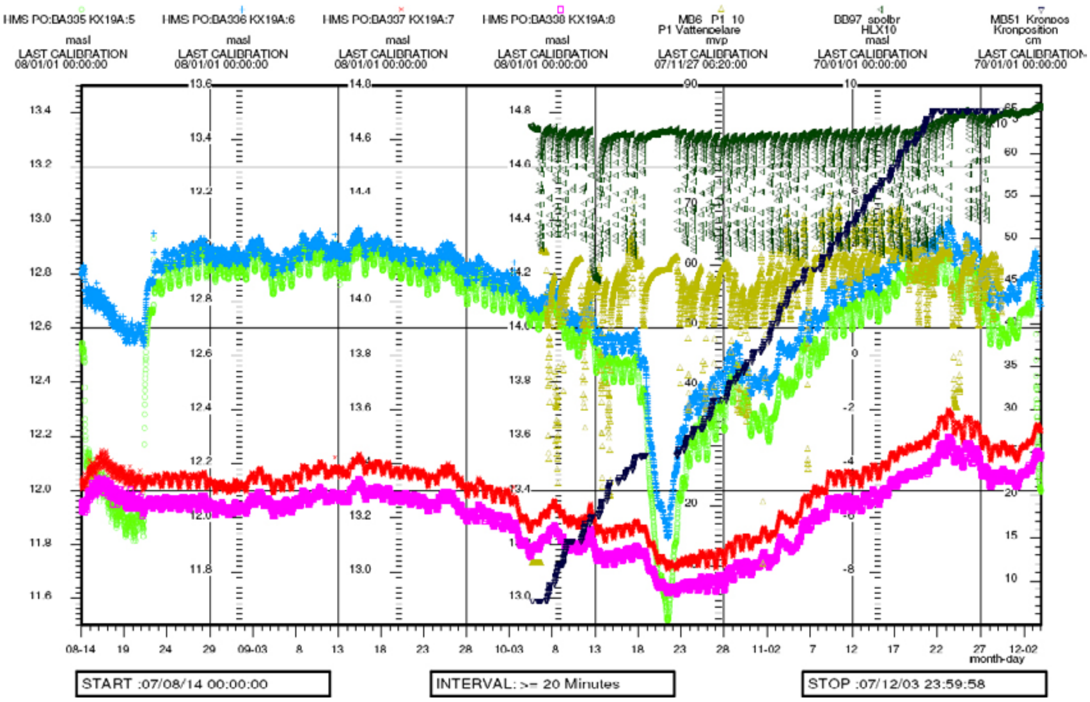


Figure 5-18. Groundwater levels in borehole KLX19A, section 5–8, together with drilling parameters (pressure in the drilling borehole, position of drill bit and water level in the flushing water well) during the drilling in borehole KLX27A from August 14 to December 3, 2007. A distinct drawdown from the interference test with wireline pumping in October 18–21 between 210.20 and 247.20 m in KLX27A can be seen in section 5 (green) and 6 (blue)of KLX19A. A less obvious but still visible response can be seen in sections 7 (red) and 8 (purple) in KLX19A during the same time.

Hydraulic responses in observation borehole KLX19A

Drawdown in the water table from the three day interference test pumping during October 18 to 21 in KLX27A can be seen in sections 3, 4, 5, 6, 7 and 8 in KLX19A, see Figure 5-16 through 5-18. No response from the same test can however be seen in sections 1 or 2, as is evident from Figure 5-17.

No hydraulic responses in KLX19A could be seen from nitrogen lifting or percussion drilling in KLX27A as exemplified in Figure 5-16.

Hydraulic monitoring during three day interference test with wireline pumping in section 210.20 to 247.20 m in KLX27A.

The prolonged wireline pumping was aimed at establishing any hydraulic connection to the modelled deformation zone NW042. The drawdown in KLX27A during the interference wireline pumping tests was 40 m. The pumping lasted for three days from October 18 to 21, 2007.

In the observation borehole KLX19A are sections 3, 4, 5 and 6 clearly affected by the wireline pumping in section 210.20–247.20 m in KLX27A, see Figures 5-16 to 5-18.

With the exception of KLX19A there are no clear hydraulic responses with drawdown and recovery in any of the observation boreholes. In boreholes HLX15, HLX28, HLX37, HLX38, HLX42, KLX03, KLX11A and KLX20A a weak drawdown can be seen that coincides with the start of pumping on October 18. Graphical plots of water levels in most observation boreholes are given in Figures 5-19 through 5-29.

The location of the observation boreholes, water supply well and KLX27A is given in Figure 5-30.

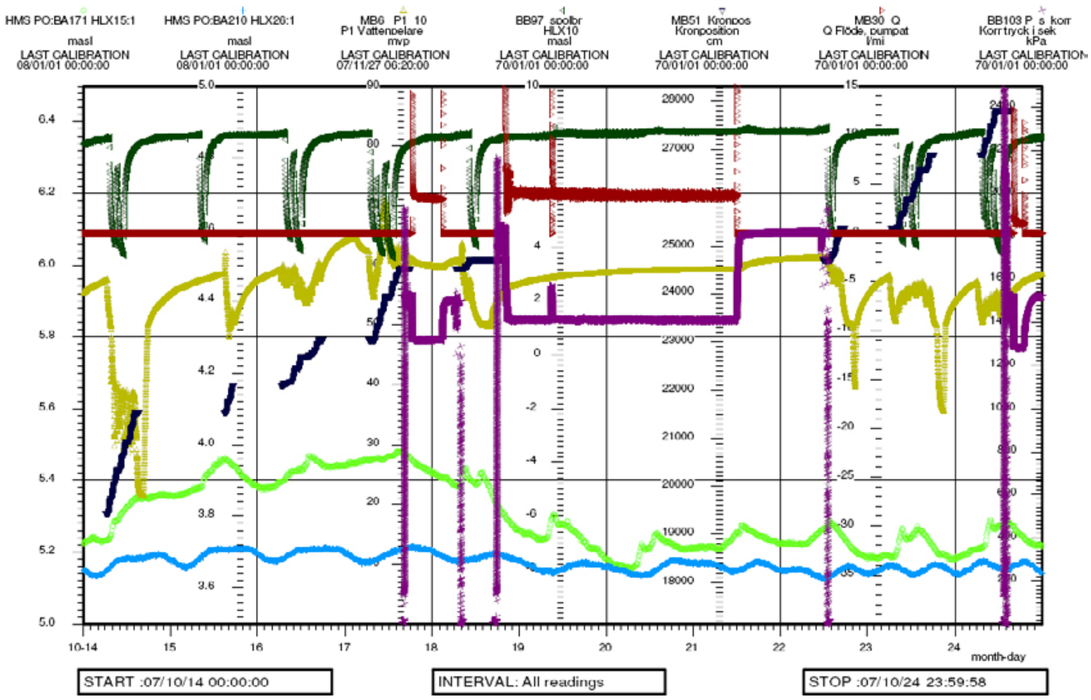


Figure 5-19. Groundwater levels in boreholes HLX15 and HLX26 together with drilling parameters (pressure in the drilling borehole, position of drill bit, water level in the flushing water well, pressure in an isolated section of the drilling borehole and flow in an isolated section of the drilling borehole) during the drilling in borehole KLX27A. Detail October 14 to 24. The water level variations in the drilling borehole and in the flushing water well do not cause any noticeable level variations in the observation boreholes HLX15 and HLX26. The typical variations related to earth tide are not affected by the drilling activities. The pumping in KLX27A (210.2–247.2 m) on October 18 to 21 does not provide any clear responses in the observation boreholes HLX15 or HLX26. In HLX15, a slightly decreasing head can be discerned in connection to the start of the pumping, but no recovery can be seen.

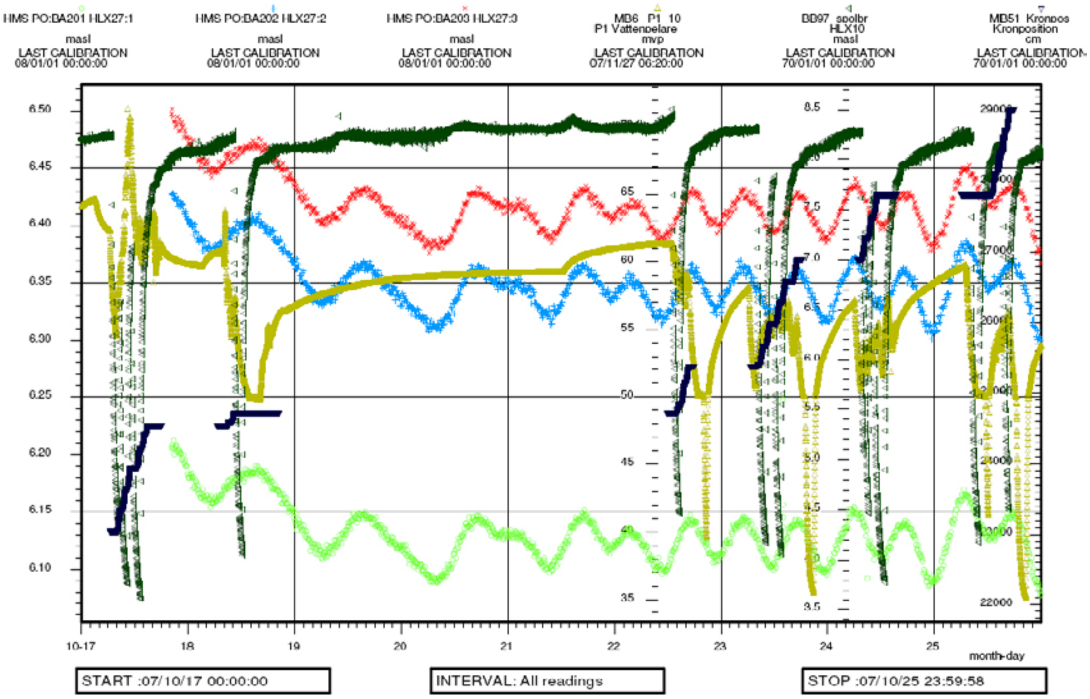


***Figure 5-20.** Groundwater levels in borehole HLX27 together with drilling parameters (pressure in the drilling borehole, position of drill bit and water level in the flushing water well) during the drilling in borehole KLX27A. Detail October 17 to 25, 2007. The water level variations in the drilling borehole and in the flushing water well do not cause any noticeable level variations in the observation borehole HLX27. The typical variations related to earth tide are not affected by the drilling activities.*

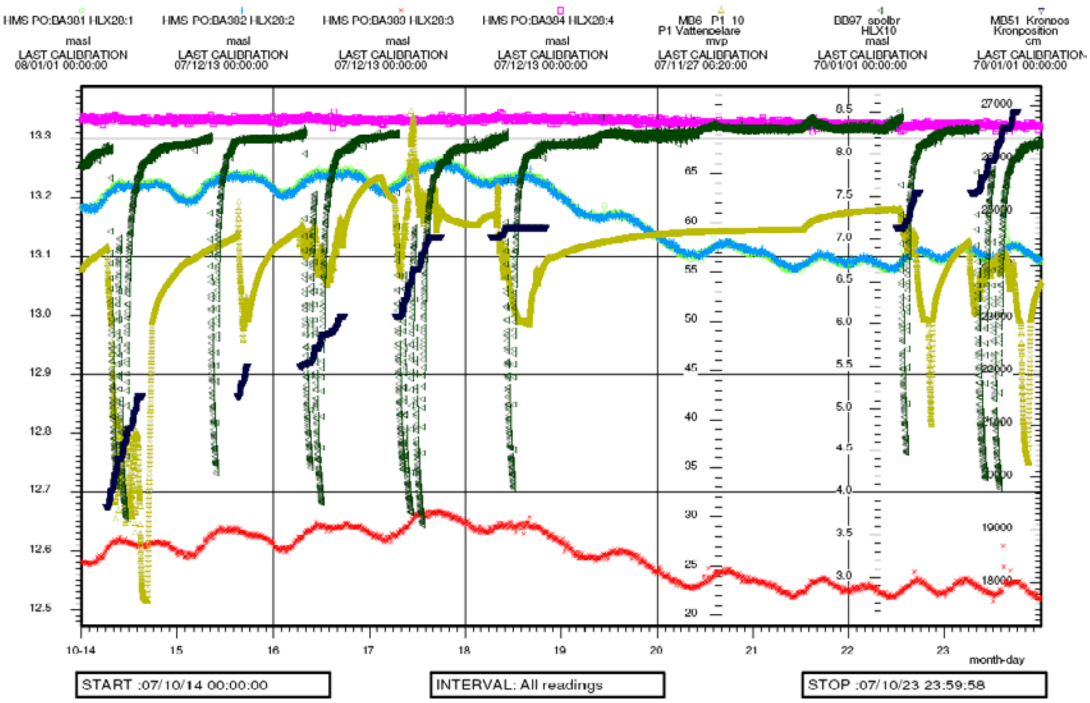


***Figure 5-21.** Groundwater levels in borehole HLX28 together with drilling parameters (pressure in the drilling borehole, position of drill bit and water level in the flushing water well) during the drilling in borehole KLX27A. Detail October 14 to 23. The water level variations in the drilling borehole and in the flushing water well do not cause any noticeable level variations in the observation borehole HLX28. The typical variations related to earth tide are not affected by the drilling activities. In HLX28, a slightly decreasing head can be seen in connection to the start of the pumping in KLX27A (210.2–247.2 m) on October 18, but no recovery can be seen.*

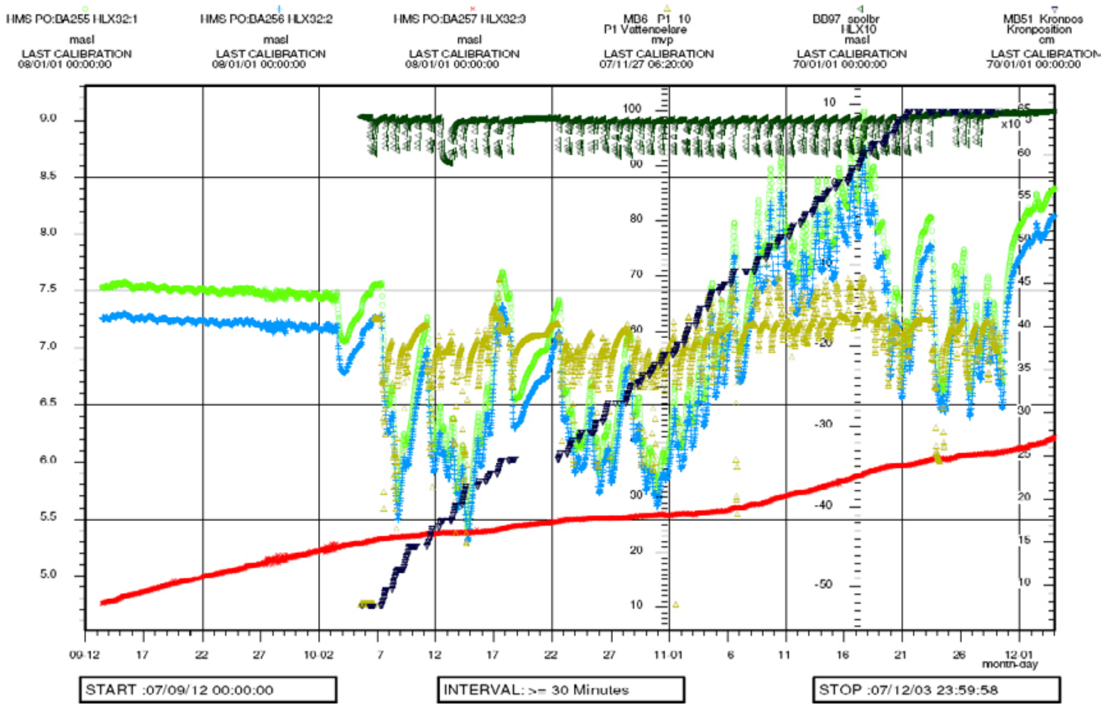


Figure 5-22. *Groundwater levels in borehole HLX32 together with drilling parameters (pressure in the drilling borehole, position of drill bit and water level in the flushing water well) during the drilling period from September to December in borehole KLX27A. The water levels in sections 1 and 2 in HLX32 follow the pressure variations in the drilling borehole; KLX27A. However, section 3 in HLX32 does not seem to be affected by the water level variations in the drilling borehole. No reaction can be seen from the pumping in KLX27A (210.2–247.2 m) between October 18 and 21.*

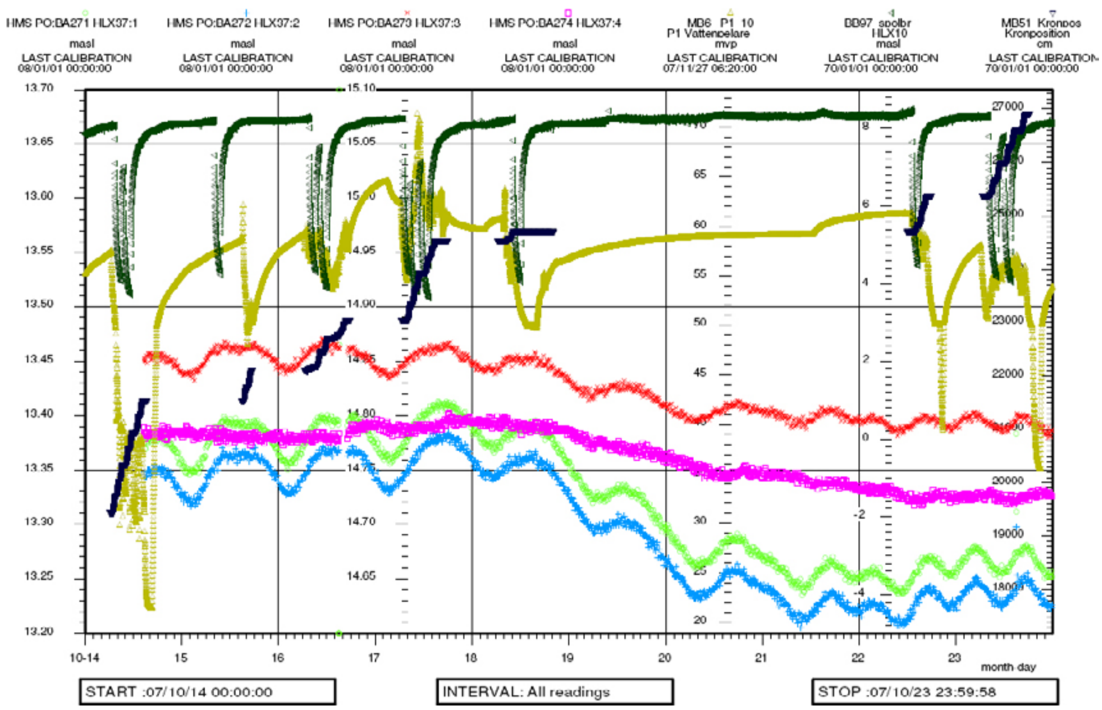


Figure 5-23. *Groundwater levels in borehole HLX37 together with drilling parameters (pressure in the drilling borehole, position of drill bit and water level in the flushing water well) during the drilling in borehole KLX27A. Detail October 14 to 23, 2007. The water level variations in the drilling borehole and in the flushing water well do not cause any noticeable level variations in the observation borehole HLX37. The typical variations related to earth tide and are not affected by the drilling activities. In HLX37, a slightly decreasing head can be seen on the start of the pumping in KLX27A (210.2–247.2 m) on the October 18. The decrease in the water table of sections 1 (green) and 2 (blue) are more noticeable than in sections 3 (red) or 4 (purple). No recovery can be seen.*

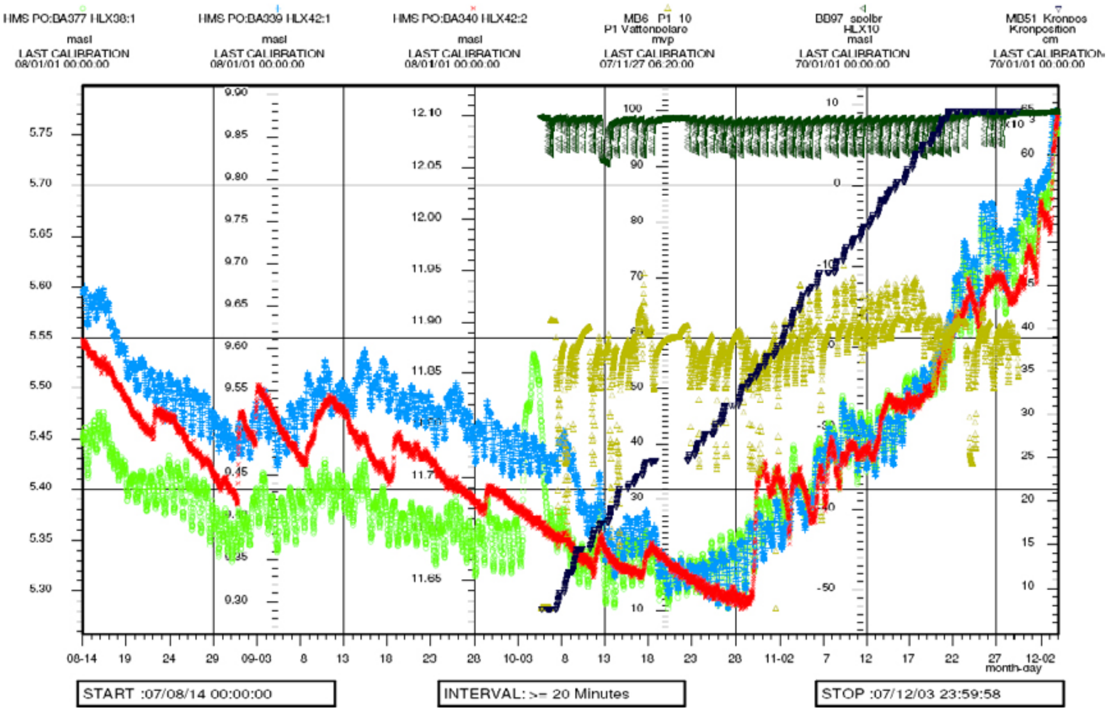


Figure 5-24. *Groundwater levels in boreholes HLX38 and HLX42 together with drilling parameters (pressure in the drilling borehole, position of drill bit and water level in the flushing water well) during the entire drilling period, August to December, in borehole KLX27A. No response from the drilling activities can be observed. In HLX38 and HLX42, a slightly decreasing head can be inferred in connection to the start of the pumping in KLX27A (210.2–247.2 m) on October 18 but since these sections not shows any recovery, the decreasing is probably part of a trend and not related to the pumping in KLX27A. The increasing head after October 28 is probably related to precipitation.*

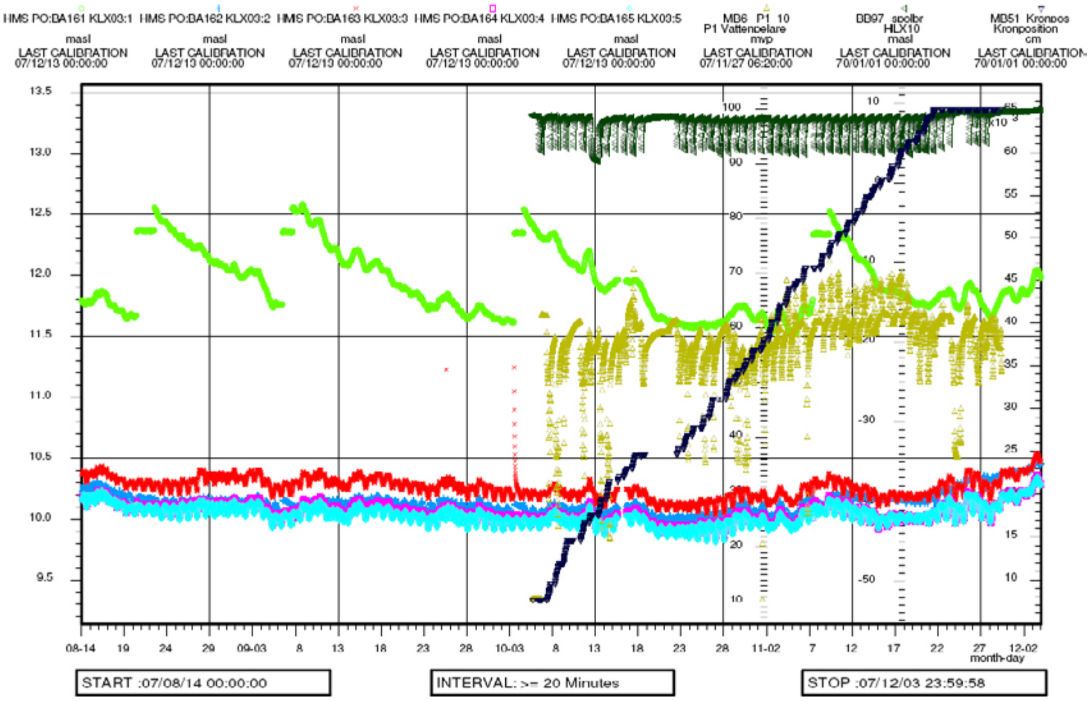


Figure 5-25. *Groundwater levels in borehole KLX03, sections 1–5, together with drilling parameters (pressure in the drilling borehole, position of drill bit and water level in the flushing water well) during the entire drilling period from August to December in borehole KLX27A. No response from the drilling activities can be observed in KLX03, sections 1–5. A slightly decreasing head can be seen in connection to the start of the pumping in KLX27A (210.2–247.2 m) on October 18.*

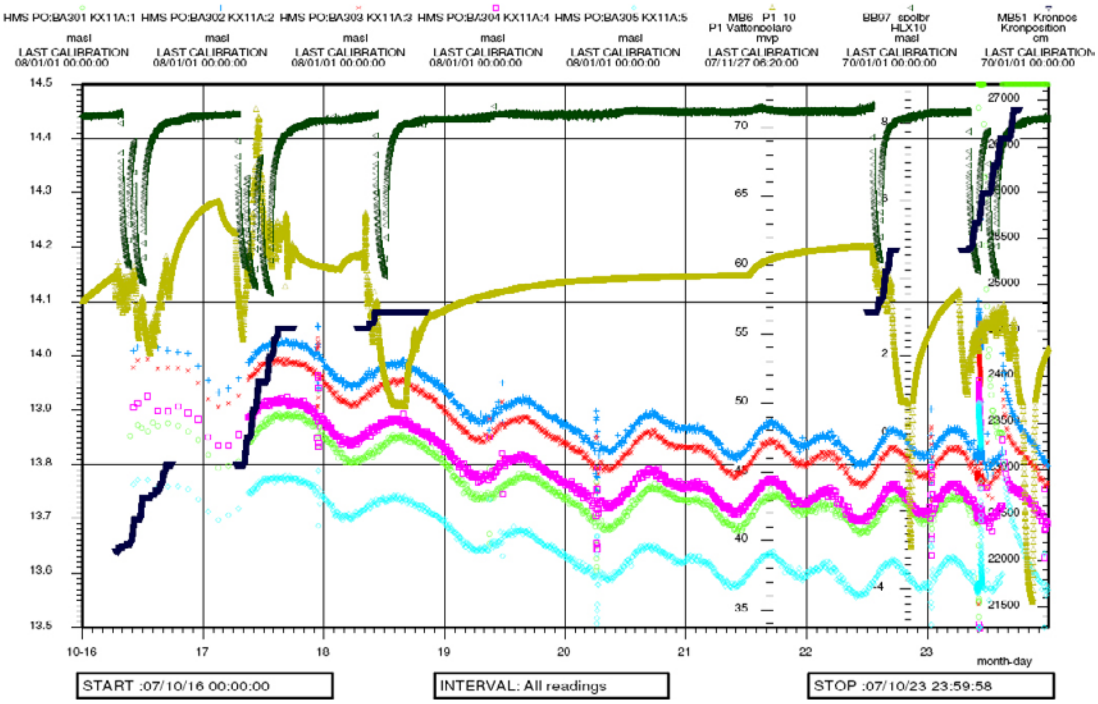


Figure 5-26. *Groundwater levels in borehole KLX11A, sections 1–5, together with drilling parameters (pressure in the drilling borehole, position of drill bit and water level in the flushing water well) during the drilling in borehole KLX27A. Detail October 16 to 23. The water level variations in the drilling borehole and in the flushing water well do not cause any noticeable level variations in the observation borehole KLX11A, sections 1–5. The typical variations related to earth tide are not affected by the drilling activities. In KLX11A, sections 1–5, a slightly decreasing head can be discerned in connection to the start of the pumping in KLX27A (210.2–247.2 m) on October 18.*

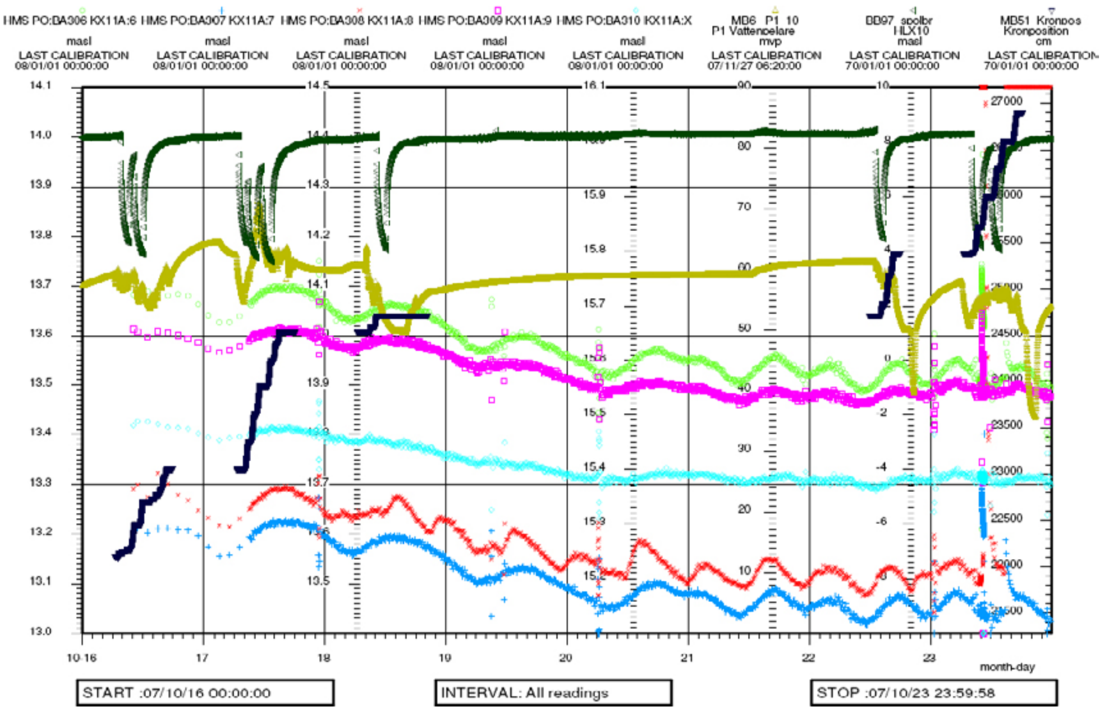


Figure 5-27. *Groundwater levels in borehole KLX11A, sections 6–10, together with drilling parameters (pressure in the drilling borehole, position of drill bit and water level in the flushing water well) during the drilling in borehole KLX27A. Detail October 16 to 23. The water level variations in the drilling borehole and in the flushing water well do not cause any noticeable level variations in the observation borehole KLX11A, sections 6–10. The typical variations related to earth tide are not affected by the drilling activities. In KLX11A, sections 6–10, a slightly decreasing head can be discerned in connection to the start of the pumping in KLX27A (210.2–247.2 m) on October 18. this decreasing head may to some part be related to the pumping in KLX27A since the nitrogen lifting, see Figures 5-14 and 5-15, did give a response in some of these sections.*

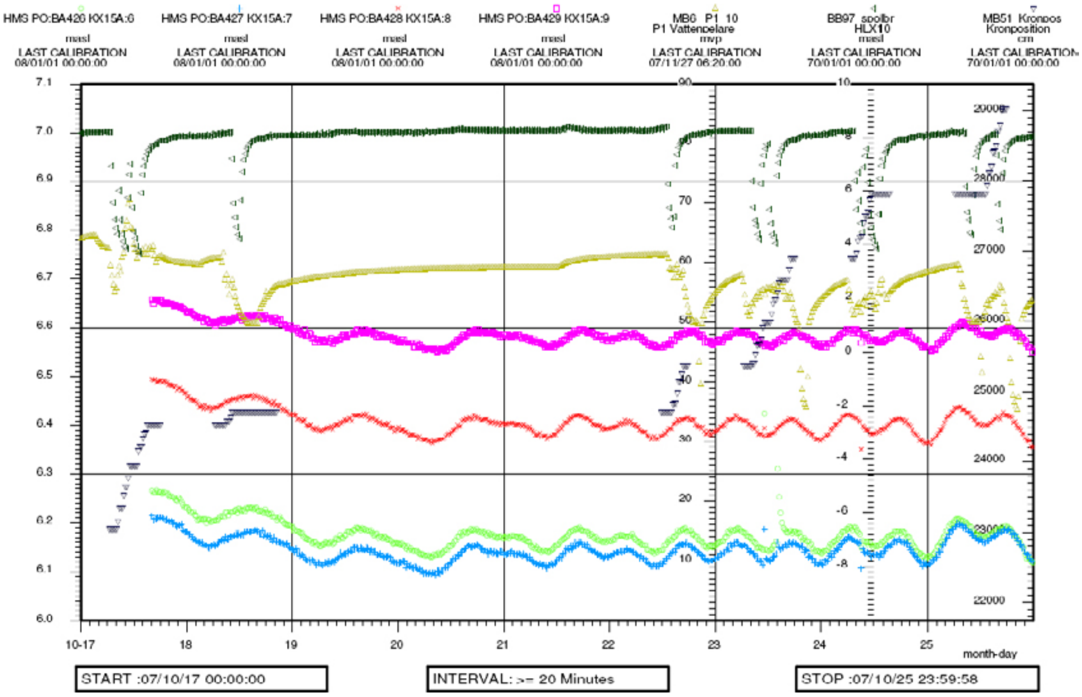


Figure 5-28. *Groundwater levels in borehole KLX15A, section 6–9, together with drilling parameters (pressure in the drilling borehole, position of drill bit and water level in the flushing water well) during the drilling in borehole KLX27A. Detail October 17 to 25. No response from the pumping test starting on October 18 can be seen in KLX15A, section 6–9.*

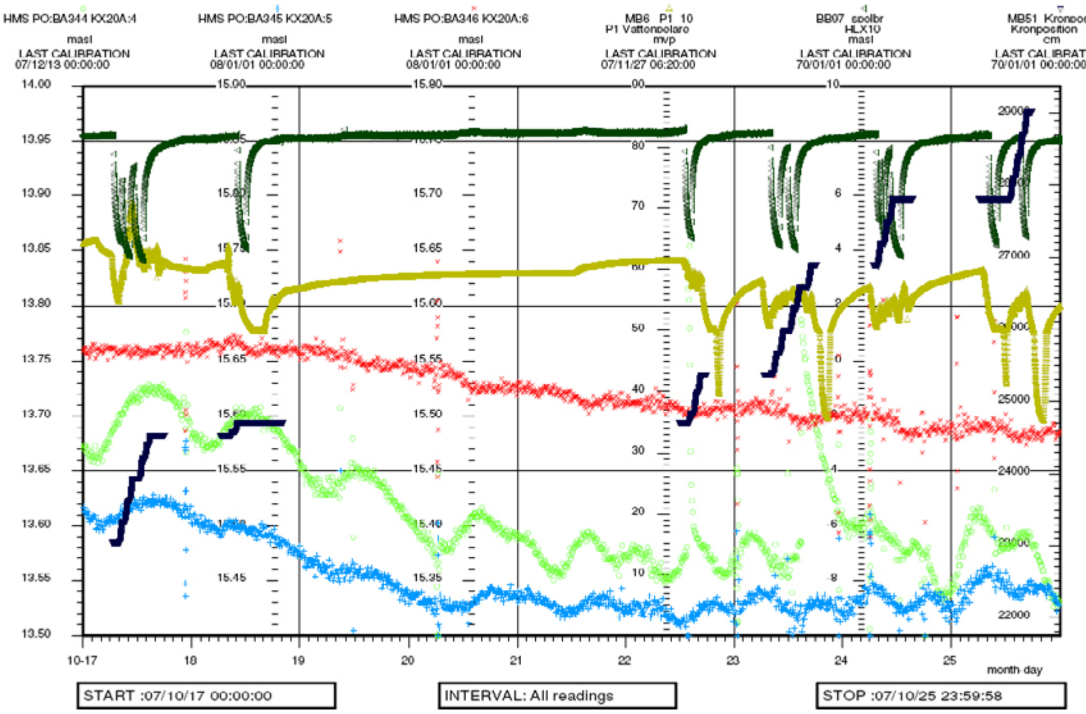


Figure 5-29. *Groundwater levels in borehole KLX20A, section 4–6, together with drilling parameters (pressure in the drilling borehole, position of drill bit and water level in the flushing water well) during the drilling in borehole KLX27A. Detail October 17 to 25. The water level variations in the drilling borehole and in the flushing water well do not cause any noticeable level variations in the observation borehole KLX20A sections 4–6. The typical variations related to earth tide are not affected by the drilling activities. In KLX20A, sections 4–6, a slightly decreasing head can be inferred at the start of the pumping in KLX27A (210.2–247.2 m) on October 18.*

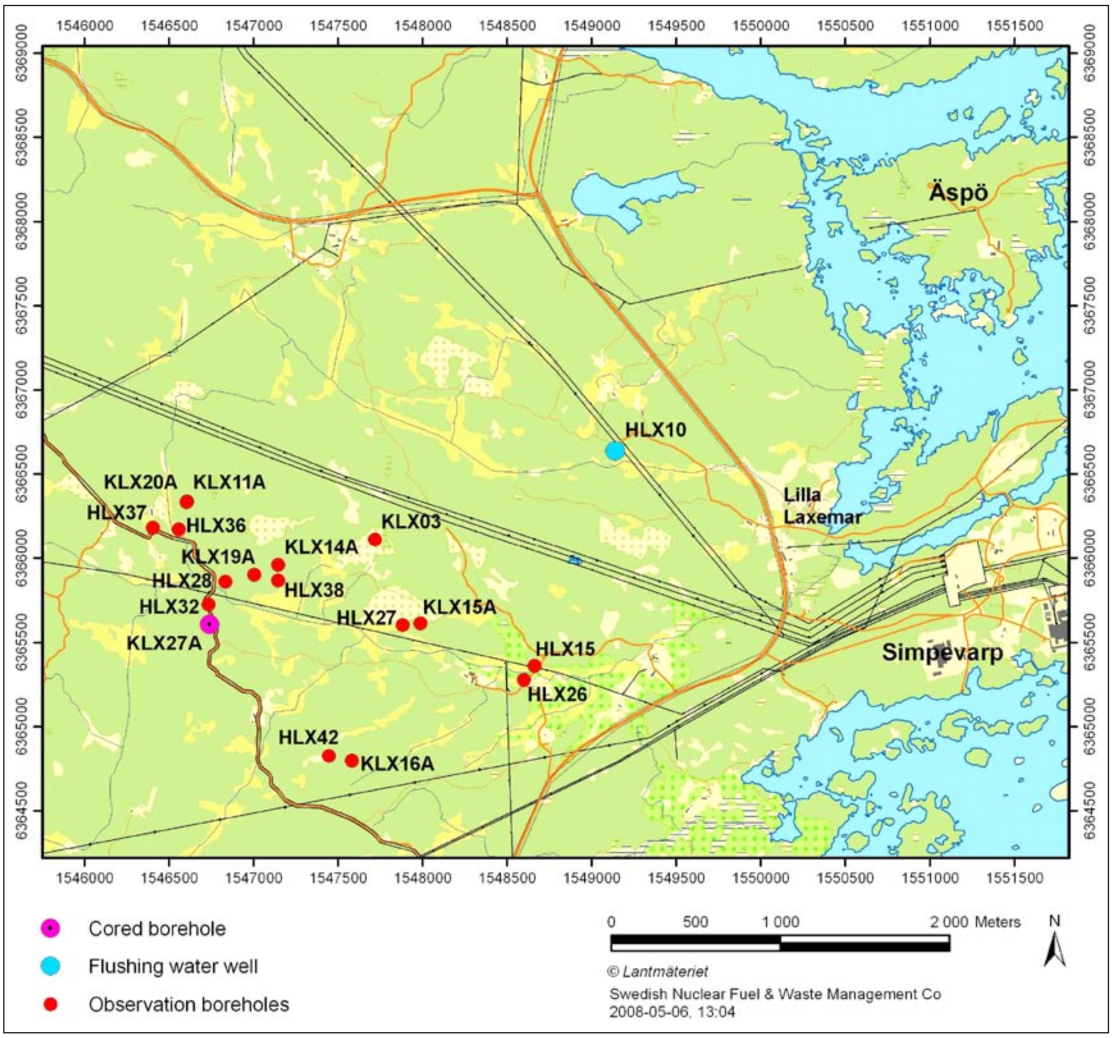


Figure 5-30. *Map showing the location of KLX27A together with observation boreholes and the flushing water well HLX10. The observation boreholes consist of cored boreholes KLX03, KLX11A, KLX14A, KLX15A, KLX16A, KLX19A and KLX20A and the percussion boreholes HLX15, HLX26, HLX27, HLX28, HLX32, HLX36, HLX37, HLX38 and HLX42.*

5.5 Drilling monitoring results

This section presents the results from drill monitoring i.e. continuous data series of water parameters or technical drilling parameters.

5.5.1 Drill monitoring system – DMS

The DMS database contains substantial amounts of drilling monitoring data. A selection of results primarily from the monitoring of the flushing water parameters are presented in Figures 5-31 through 5-33 below.

Selected parameters from the drill rig (MWD parameters) are presented in Appendix 1. The MWD parameters require some explanation:

- Drillability ratio – this parameter is defined as penetration rate divided by feed force.
- Flushing water ratio – this is defined as flushing water flow divided by flushing water pressure.
- Water pressure (of the water entering the drill stem).
- Flushing water flow (flow of ingoing water).
- Penetration rate (rate of drill bit penetration as measured on the surface on the drill stem).
- Hydraulic indication – this parameter is defined as penetration rate divided by flushing water flow.

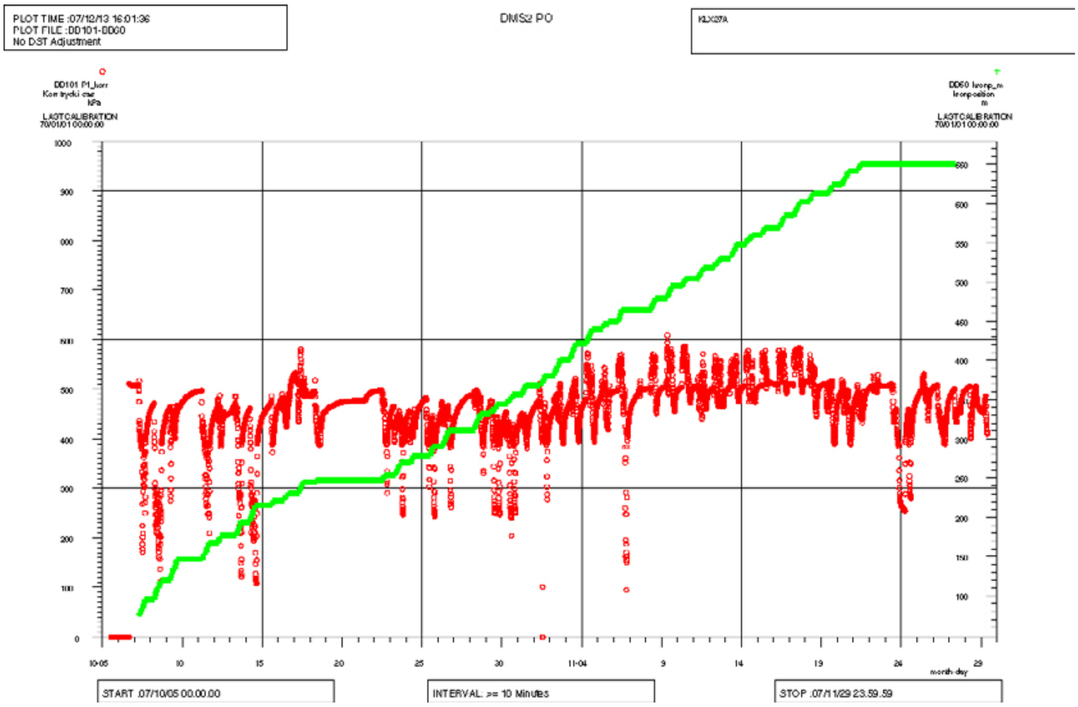


Figure 5-31. *Drill bit position (green) and water level from air-lift pumping (red). The water level is expressed as the pressure in kPa of the water column overlying the pressure gauge i.e. the ambient air-pressure has been subtracted. The pressure gauge is emplaced at 65 metres borehole length.*

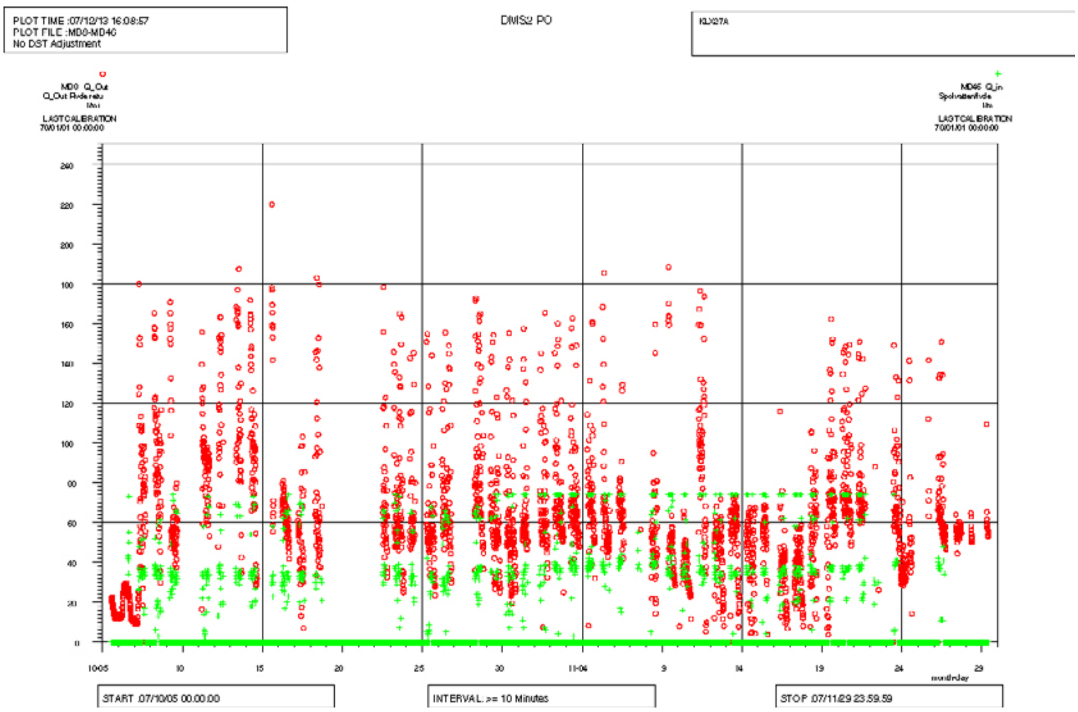


Figure 5-32. *Flushing water flow (green) and return water flow (red) in litres per minute.*

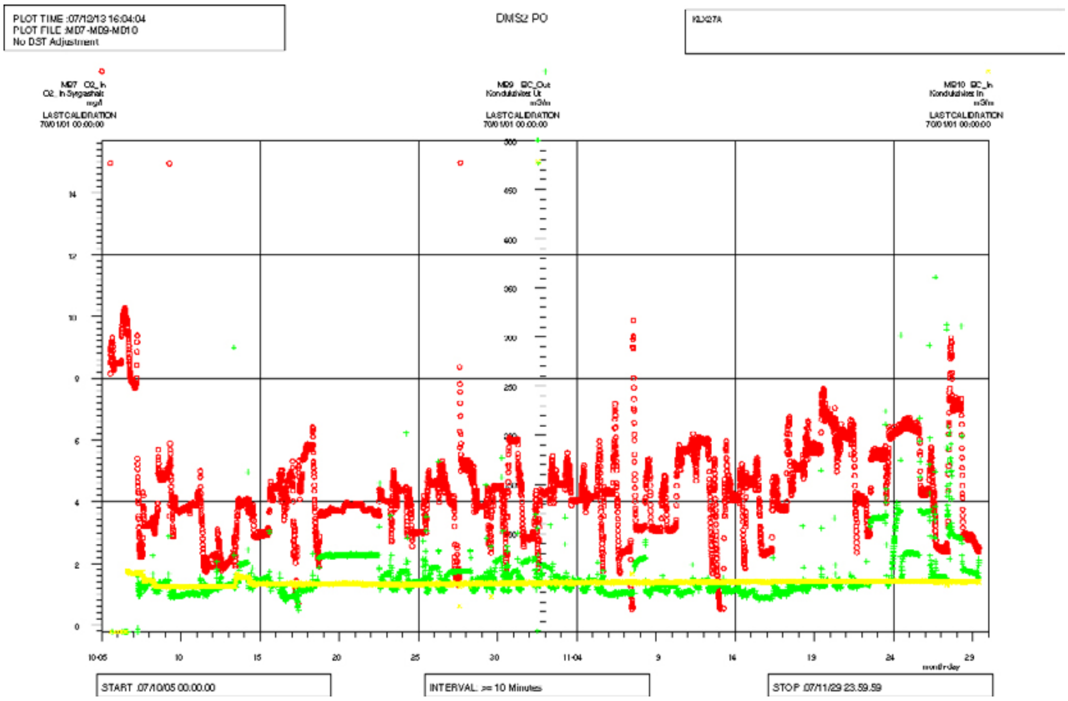


Figure 5-33. *Conductivity of flushing water (yellow) and return water (green). The oxygen content in mg/L of the flushing water (red) is also shown. The oxygen content of the flushing water is low with erratic peak values at 8–10 mg/L. The conductivity of the return water (green) is also generally low, typically between 50 and 100 mS/m. However sparse occurrences with peak values at between 300 and 350 mS/m were recorded during the end of November i.e. during the borehole completion stage.*

In order to maintain reasonable size data files, a reduction in the number of points incorporated in the pictures has been done in Figures 5-19 through 5-21. Since DMS data are related to time (ie not strictly to borehole length) periods where drilling is not performed are also registered.

Figure 5-31 depicts the drill bit position (green) over time and the water level (red) in the telescope part of the drill hole. The water level, given as pressure of the overlying water column reflects the air-lift pumping activity in the hole.

Figure 5-32 shows the flushing water flow (green) entering the hole and the return water flow (red). The flushing water flows (green) show three distinct levels of flow:

- A flow of ca 30–40 litres/minute corresponding to pumped flow during drilling.
- A flow of 60–80 litres/minute corresponding to the flow while pumping down the core barrel.
- No flow (zero litres/minute) when no drilling is performed.

Figure 5-33 shows the conductivity of the ingoing flushing water, conductivity of the return water and the oxygen content of the flushing water. The oxygen content of the flushing water was low with erratic peak values at 8–10 mg/L.

5.5.2 Measurements of flushing water and drill cuttings

A calculation of accumulated amounts of water flowing in and out of the borehole based on water flow measurements from the DMS system (continuous readings) is given in Figure 5-34.

The amount of flushing water consumed during drilling was 560 m^3, giving an average consumption of 0.9 m^3 per metre core drilled. The amount of effluent return water from drilling in KLX27A was measured by the DMS system to 1,900 m^3, giving an average of ca 3.9 m^3 per metre core drilled.

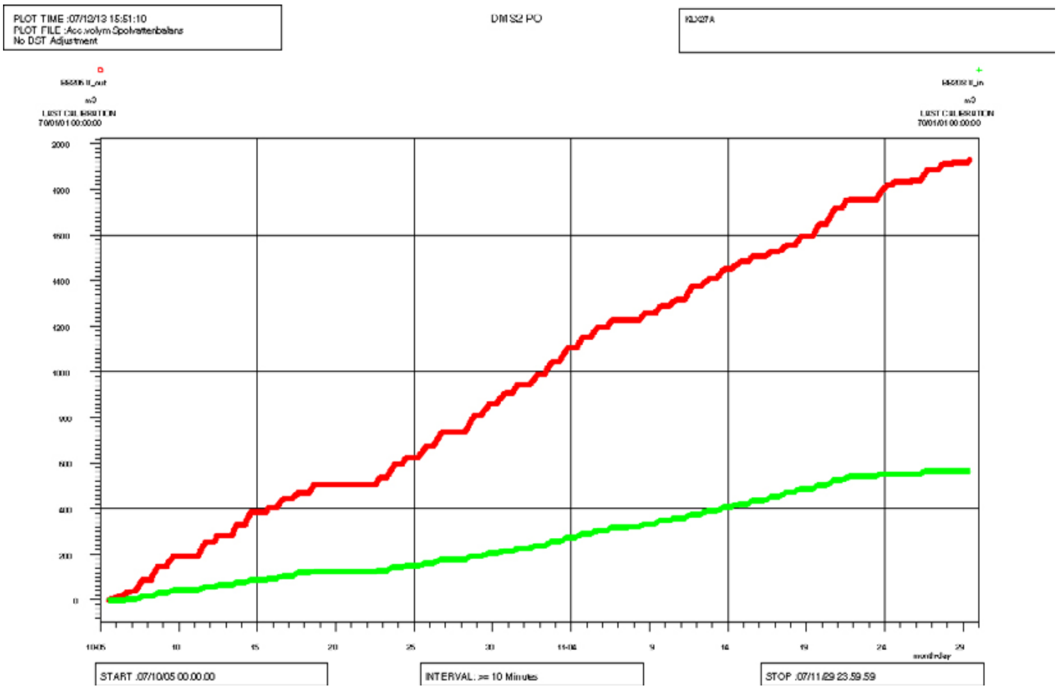


Figure 5-34. *The flushing water balance in KLX27A as recorded by the DMS system. The accumulated volume of the ingoing flushing water is shown in green and the outgoing return water is shown in red.*

Drill cutting balance

The weight of cuttings in the settling containers amounted to 822 kg. The content of suspended material in the return water is estimated to be 600 mg/L, see section 5.8 "Environmental control, monitoring of effluent water". The amount of material in suspension carried with the return water would amount to 1,140 kg (based on 1,900 m^3 of return water). The theoretical amount that should be produced from drilling with 76 mm triple tubing, with core barrel N3/50, over a length of 485 metres is 3,270 kg assuming a density of 2.7 kg/dm^3. This means that 60% of the material liberated by drilling is accountable as removed from the borehole or the formation.

The recovered drill cuttings were collected in steel containers. After completion of drilling, the containers were removed from the site and emptied at an approved site.

Uranine tracer balance

The amount of introduced and recovered uranine is presented in Table 5-17. The results show that all (actually a lot more than 100%!) of the introduced amount of uranine is estimated to be retrieved during drilling of KLX27A.

Table 5-17. Balance calculation of uranine tracer in KLX27A.

Average uranine content IN (mg/L)	0.230
Flushing water volume IN (m^3)	560
Amount uranine introduced (g)	129
Average uranine content OUT (mg/L)	0.136
Return water volume OUT (m^3)	1,900
Amount uranine recovered (g)	258

5.6 Geology

A preliminary geological mapping of the core is done as drilling progresses as part of the drilling activity. This mapping phase includes a first pass mapping of major geological features as well as RQD-logging and photodocumentation of the core.

A more detailed mapping with the Boremap method is made after measurements have been made in the borehole that can provide orientation of geological features. Boremap mapping and the related measurements are not part of the drilling activity. The results from the Boremap logging are included in this report as it represents a more complete geological record than the preliminary geological mapping.

The geological results based on the Boremap logging are shown in Appendix 1. It should be stressed that the geological description given in this report is a brief summary only. A more complete account is given in /7/.

Lithologically the core is completely dominated Quartz monzodiorite with very minor intercalations of fine-grained diorite-gabbro and fine grained granite.

Rock alteration is mostly weak. A section with significant red staining, indicated as oxidized in Appendix 1, was logged from 210 to 250 m. This section also coincides with an elevated frequency of fractures as can be seen in Appendix 1.

Three minor sections with core losses were noted in KLX27A during the Boremap mapping, see also Table 5-7. The core losses were labelled as "crushed zone".

The average fracture frequency over the core drilled section is 1.5 (fractures/metre) expressed as open fractures. NB The fracture frequency given in Appendix 1 shows the total fracture frequency (ie open fractures, sealed fractures, sealed network and fractures in crushed sections).

5.7 Data handling

Data collected by the drilling contractor and the SKB drill coordinators 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.

5.8 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. The return water from drilling was pumped from the drill site to an emission point and there allowed to infiltrate to the ground in accordance with an agreement with the environmental authorities. The location of the water emission area and the environmental monitoring wells SSM000254, SSM000255 and SSM000277 is shown in Figure 5-35. Precautionary guideline values for effluent return water emission to the ground were prescribed by the Regional Authorities for the following parameters:

- Salinity, 2,000 mg/l (monitored as electrical conductivity, with the limit 300 mS/m).
- Uranine content, 0.3 mg/l.
- Suspended material, 600 mg/l.

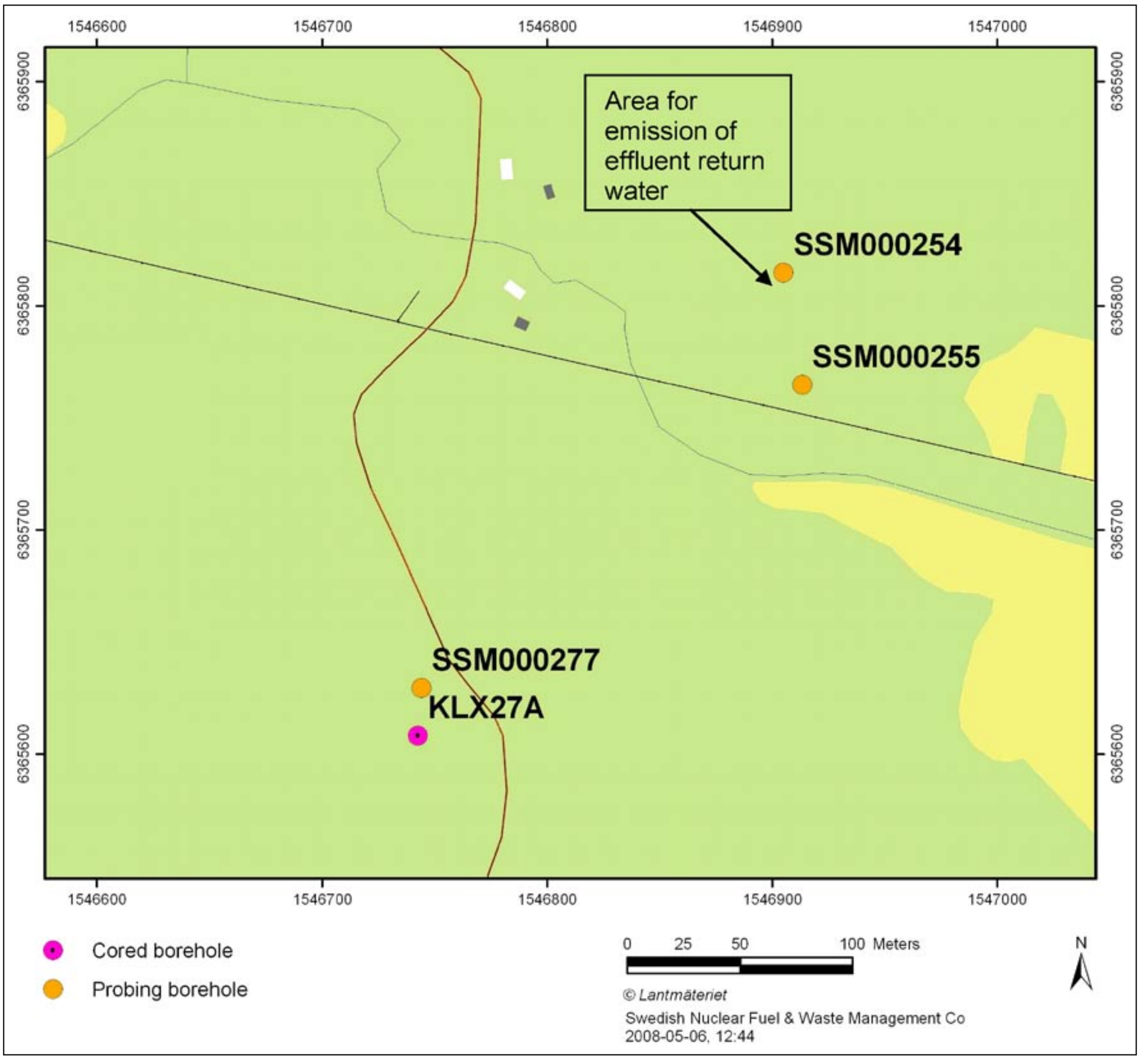


Figure 5-35. *The location of the site for return water emission and the environmental monitoring wells SSM000254, SSM000255 and SSM000277 in relation to the core drill site for KLX27A.*

Monitoring of effluent water

The electrical conductivity, as measured by the DMS system, of the return water from the core drilling of KLX27A was normally between 50 and 100 mS/m throughout the core drilling phase. Samples of the return water that were analysed for electrical conductivity were also all around 50 to 60 mS/m, see Figure 5-9. Sparse occurrences with peak values at between 300 and 350 mS/m were recorded by the DMS system during the end of November i.e. after the core drilling during the borehole completion stage.

The uranine content was well below 0.3 mg/L, see Figure 5-9.

The concentration of suspended material in the return water from drilling was not analysed in the borehole KLX27A but has been analysed in previous drillings in boreholes KSH03 and KLX17A. Changes in the handling of the return water with the purpose of reducing the amount of suspended material in the return water were initiated in borehole KLX15A /8/ and also used in KLX27A. It is therefore reasonable to assume that the content of suspended material in the return water from KLX27A should be the same as in KLX15A and a figure of 600 mg/L has therefore been used for mass-balance calculations of borehole cuttings, see section 5.5.2.

Environmental monitoring wells and reference sampling

One environmental well, SSM000277, was constructed by the KLX27A drill site. The technical specifications for SSM000277 are given in Appendix 6. Two other wells, SSM000254 and SSM000255, were also used for environmental monitoring during the drilling in KLX27A. The two wells were however drilled as part of a previous drilling activity and the technical specifications are given in /9/.

Reference samples of the surface soil and ground water, before drill start and establishment of the drill site were taken as given in Table 5-19.

Monitoring of soil ground water levels

A pressure logger (transducer) for measuring the ground water table was installed in SSM000255 during the core drilling of KLX27A. A plot from SSM000255 is given graphically in Figure 5-36. The water table is not strongly affected by external activities, such as emission of return water or drilling.

Table 5-19. Reference samples for environmental monitoring.

Date	Sample No	Comment
2007-07-26	SKB PO 9017	Undisturbed soil sample
2006-05-18	11071	Reference water sample in SSM000254
2006-05-18	11070	Reference water sample in SSM000255
2007-09-26	15123	Reference water sample in SSM000277

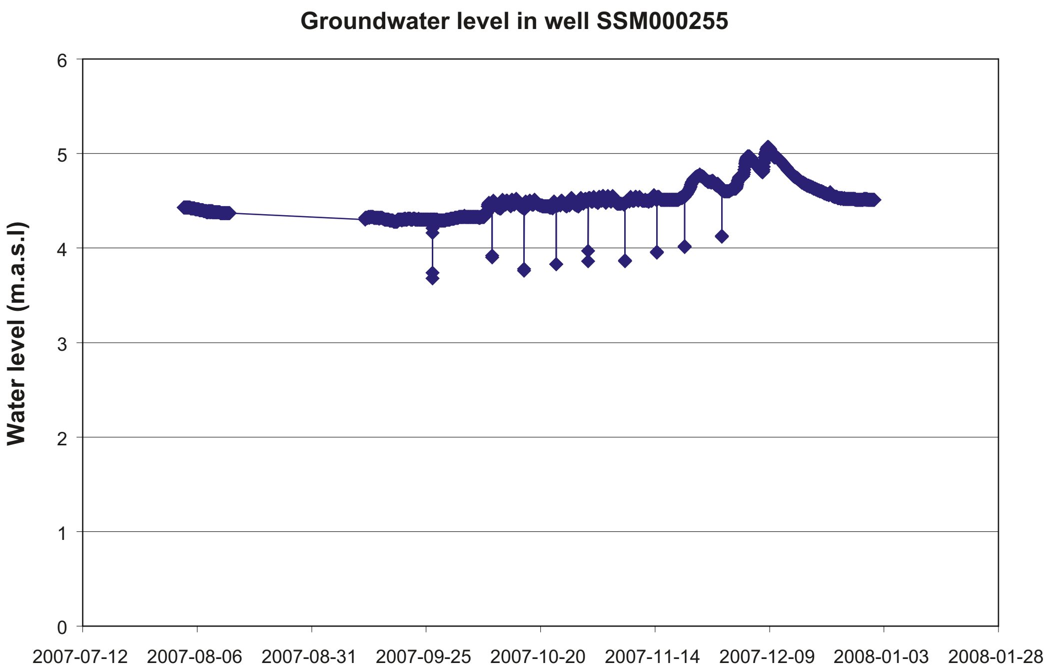


***Figure 5-36.** The ground water level in well SSM000255. The momentary dips in water levels are related to water sampling.*

Monitoring of electrical conductivity and pH in ground water samples

Water samples were collected with a one to two week interval for monitoring of the electrical conductivity and pH in the ground water in the environmental monitoring wells SSM000255 and SSM000277, see Figures 5-37 and 5-38.

No significant influence can be seen on the shallow ground water in the monitoring wells SSM000255 or SSM000277 from the drilling activity in KLX27A.

5.8.1 Consumption of oil and chemicals

The consumption of hammer oil (Hydra 46) is typically around 20 litres for the percussion drilling of the telescopic section, no exact record of the oil consummation was kept. No other significant amounts of oils or lubricants were consumed during the drilling.

The concrete consumption was 360 litres (324 kg) in total. The concrete was based on white silica, low alkali cement.

5.9 Nonconformities

One formal nonconformity was noted for borehole KLX27A:

- The use of non stainless material in water tanks together with an unknown source of soil and grass gave an accumulation of rust flakes, soil particles and grass in the drill rig water pump. This led to an unscheduled stop in drilling.

No record of measuring the tightness of the casing grouting and the casing was kept for KLX27A.

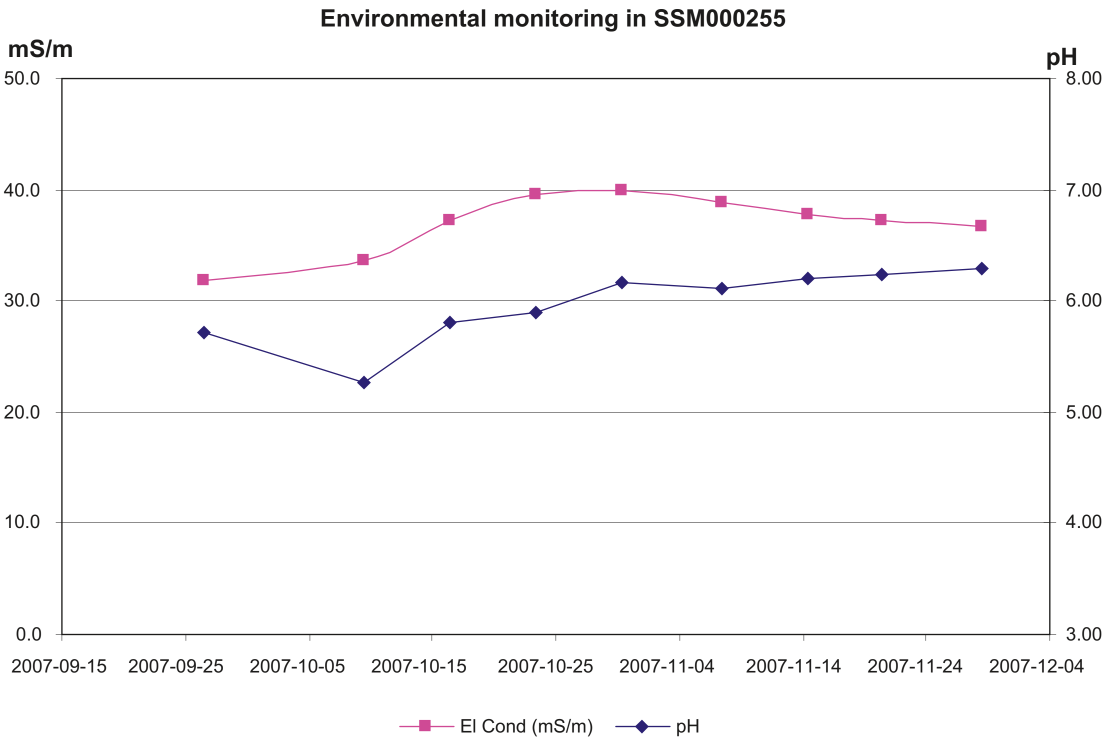


Figure 5-37. *Electrical conductivity and pH in ground water samples from SSM000255. The sampling events are shown with blue or purple symbols.*

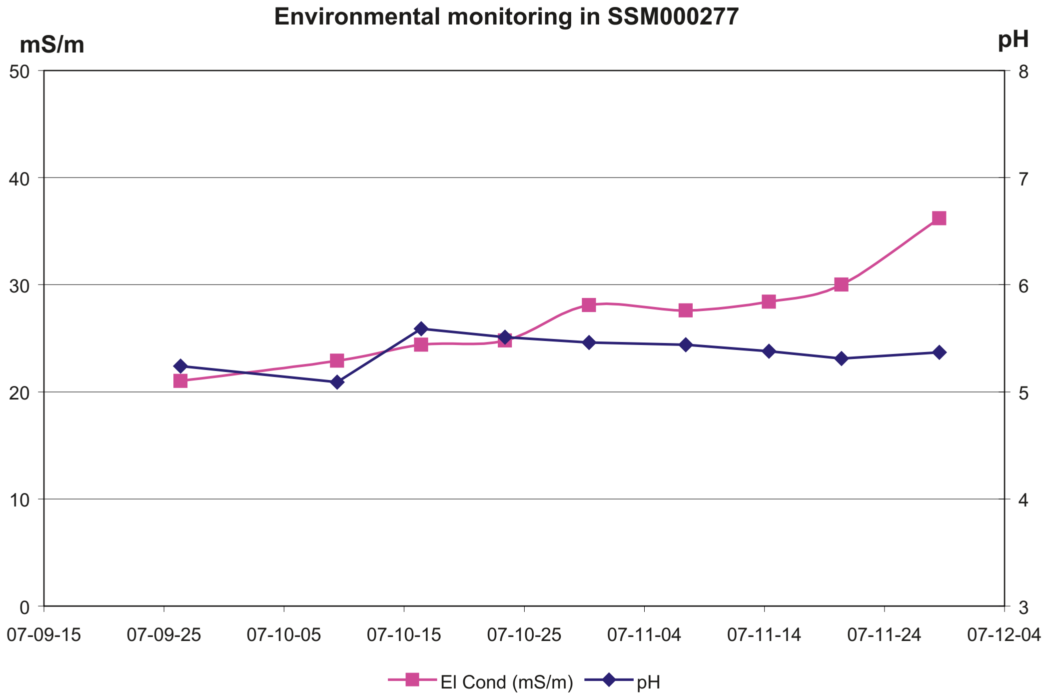


Figure 5-38. *Electrical conductivity and pH in ground water samples from SSM000277. The sampling events are shown with blue or purple symbols.*

6 References

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

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

/3/ **Moye D G, 1967.** Diamond drilling for foundation exploration, Civil Eng. Trans. Inst. Eng, Australia.

/4/ **Stenberg L, Håkanson N, 2007.** Revision of borehole deviation measurements in Oskarshamn, SKB P-07-55, Svensk Kärnbränslehantering AB.

/5/ **Enachescu C, Rohs S, van der Wall R, Wolf Ph, Morosini M, 2008.** Evaluation of hydraulic interference tests, pumping borehole KLX27A, SKB P-08-16, Svensk Kärnbränslehantering AB.

/6/ **Ask H, Morosini M, Samuelsson L-E, Ekström L, Håkanson N, 2007.** Drilling of cored borehole KLX12A, SKB P-06-305, Svensk Kärnbränslehantering AB.

/7/ **Mattsson K-J, Eklund S, 2008.** Boremap mapping of telescopic drilled borehole KLX27A. SKB P-08-39, Svensk Kärnbränslehantering AB.

/8/ **Ask H, Morosini M, Hedqvist I, 2008.** Drilling of cored borehole KLX15A, SKB P-08-58 Svensk Kärnbränslehantering AB.

/9/ **Ask H, Morosini M, Samuelsson L-E, Tiberg L, 2007.** Drilling of cored borehole of KLX19A, SKB P-07-202, Svensk Kärnbränslehantering AB.Chemistry – analytical method.

Geology and MWD parameters KLX27A

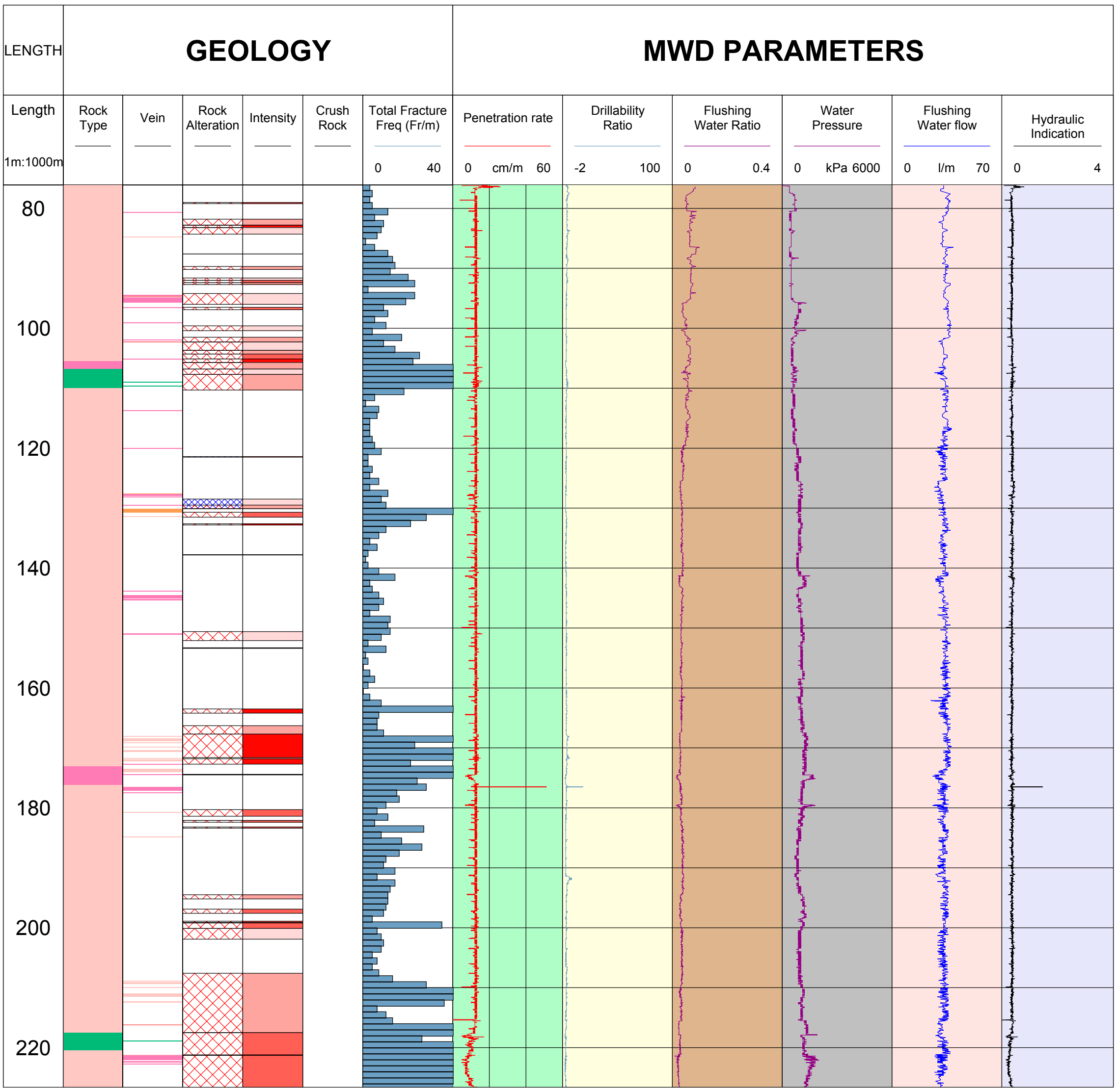
Title GEOLOGY & MWD PARAMETERS KLX27A **Appendix 1**

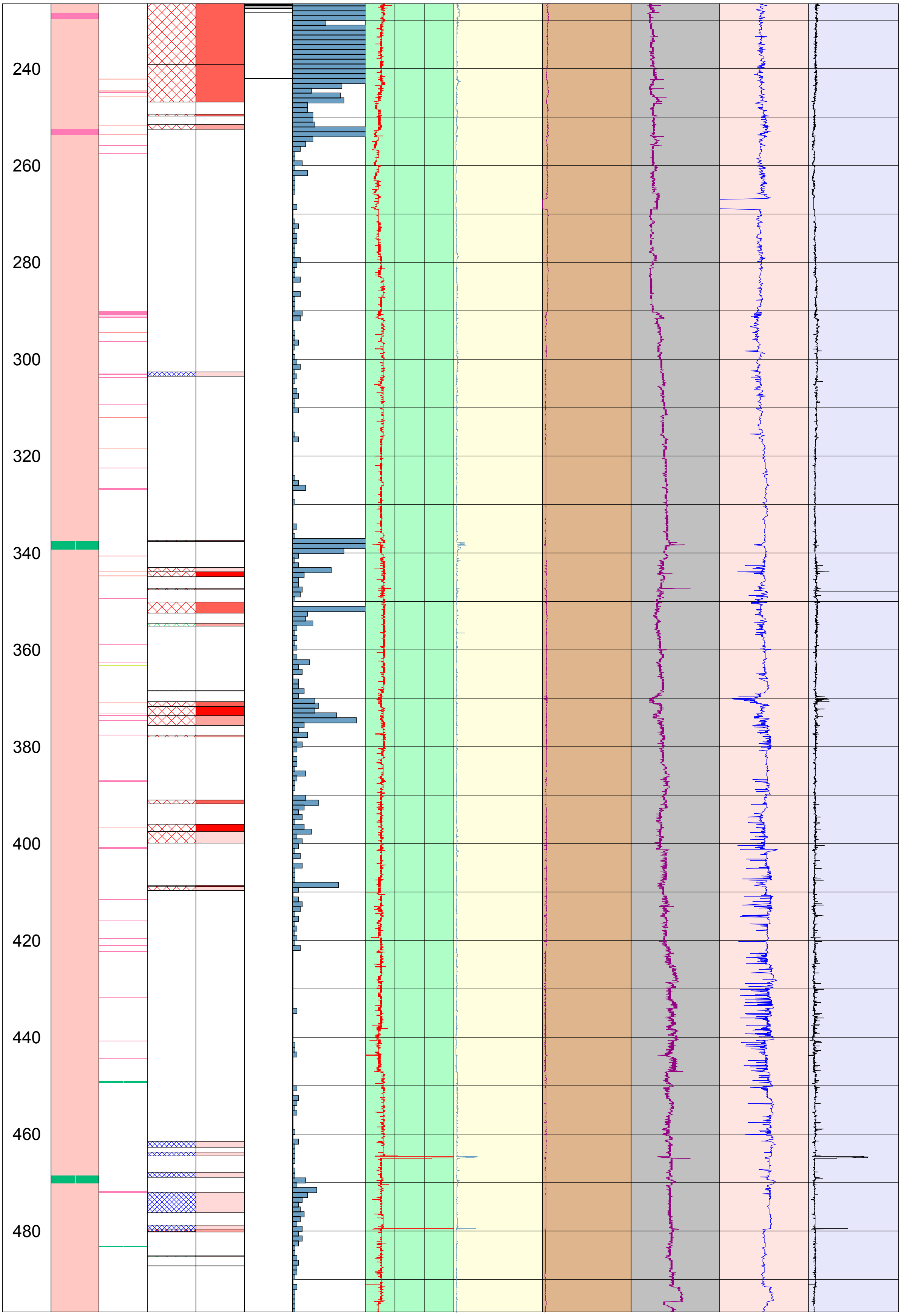
Site	LAXEMAR	**Coordinate System**	RT90-RHB70
Borehole	KLX27A	**Northing [m]**	6365608.29
Diameter [mm]	76	**Easting [m]**	1546742.63
Length [m]	650.560	**Elevation [m.a.s.l.]**	16.98
Bearing [°]	0.73	**Drilling Start Date**	2007-08-15 07:00:00
Inclination [°]	-65.36	**Drilling Stop Date**	2007-11-21 11:30:00
Date of mapping	2007-12-12 09:03:00	**Plot Date**	2008-02-05 22:03:18

ROCKTYPE LAXEMAR
- Fine-grained granite
- Quartz monzodiorite
- Fine-grained diorite-gabbro

ROCK ALTERATION
- Oxidized
- Chloritisized
- Epidotisized
- Argillization
- Saussuritization

INTENSITY
- Faint
- Weak
- Medium
- Strong

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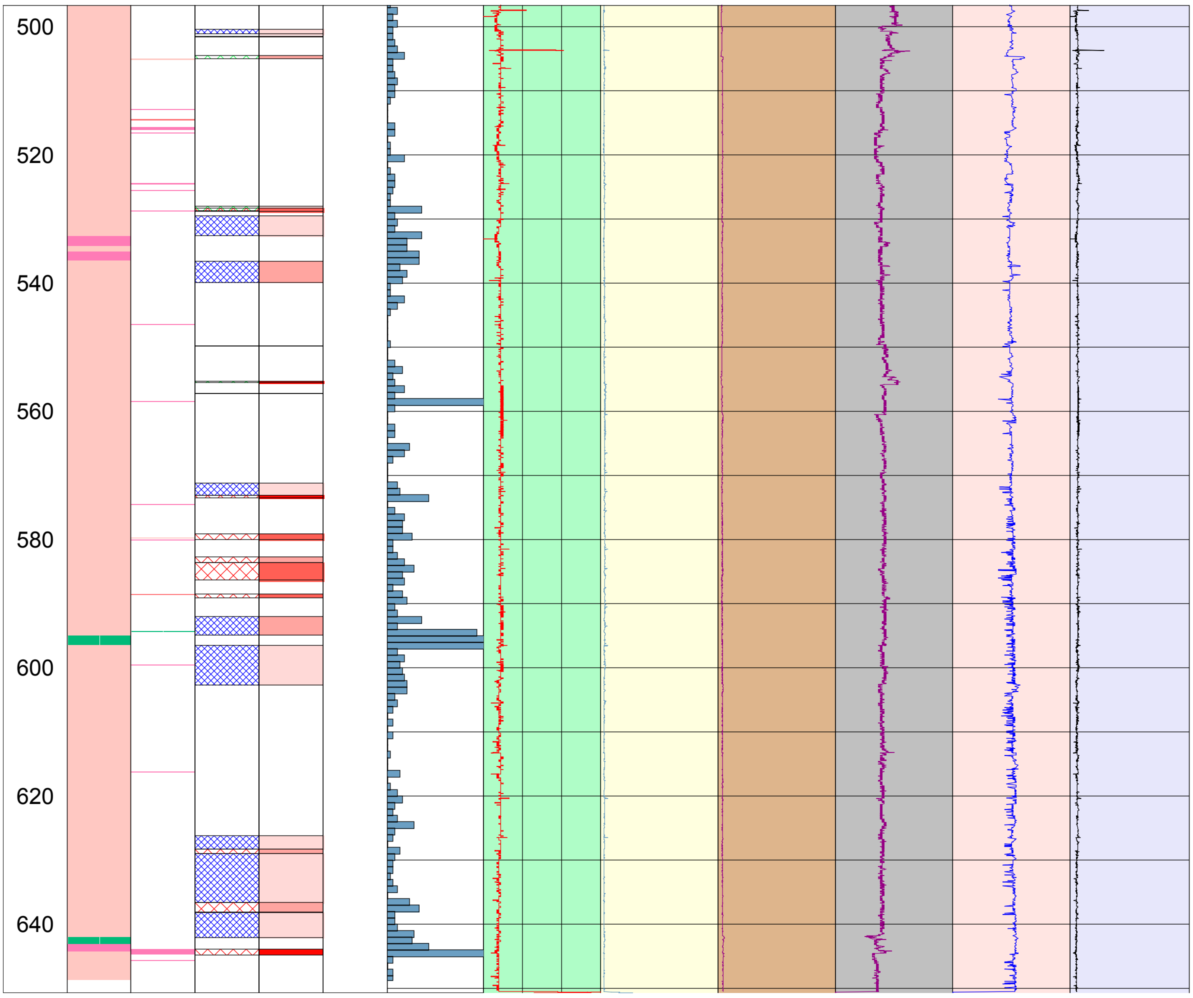
260
280
300
320
340
360
380
400
420
440
460
480


500
520
540
560
580
600
620
640

Appendix 2

Chemical results

Borehole	KLX27A	KLX27A	KLX27A	KLX27A	KLX27A
Date of measurement	**2007-10-13**	**2007-10-17**	**2007-10-22**	**2007-11-22**	**2007-11-23**
Upper section limit (m)	**77.5**	**174.60**	**210.20**	**639.20**	**639.20**
Lower section limit (m)	**176.50**	**245.40**	**247.20**	**650.56**	**650.56**
Sample_no	**15131**	**15148**	**15149**	**15213**	**15214**
Groundwater Chemistry Class	**3**	**3**	**3**	**3**	**5**
pH	8.15	8.22	8.78	8.60	7.40
Conductivity mS/m	141.0	166.0	87.9	53.6	491.0
Drill water %	4.10	12.00	26.40	72.70	6.69
Density g/ml	0.9977	0.9979	0.9974	0.9974	0.9991
Charge balance %	–1.02	–1.21	x	x	–0.48
Na mg/l	251.0	308.0	x	x	886.0
K mg/l	3.28	4.37	x	x	5.13
Ca mg/l	28.8	24.6	x	x	101.0
Mg mg/l	5.6	6.1	x	x	2.6
HCO3 mg/l Alkalinity	224.00	167.00	189.00	209.00	24.00
Cl mg/l	255.0	311.0	130.0	28.8	1,500.0
SO4 mg/l	92.40	176.00	70.80	47.80	86.50
SO4_S mg/l Total Sulphur	33.40	62.80	x	x	32.00
Br mg/l	0.790	0.930	0.415	< 0.200	7.100
F mg/l	4.23	3.49	2.99	3.26	3.42
I mg/l	x	x	x	x	0.028
Si mg/l	6.07	3.77	x	x	10.50
Fe mg/l Total Iron (mg/l)	9.6100	0.0317	x	x	39.3000
Fe^{2+} (mg/l)	x	x	x	x	15.800
Fe_{total} (mg/l)	x	x	x	x	17.900
Mn mg/l	0.17800	0.10800	x	x	0.28800
Li mg/l	0.026	0.028	x	x	0.077
Sr mg/l	0.481	0.318	x	x	1.660
As µg/l	x	x	x	x	2.8100
Ba µg/l	x	x	x	x	157.0000
Cd µg/l	x	x	x	x	< 0.0200
Hg µg/l	x	x	x	x	0.0029
V µg/l	x	x	x	x	4.3000
U µg/l	x	x	x	x	0.4530
Th µg/l	x	x	x	x	0.2190
Sc µg/l	x	x	x	x	0.2080
Rb µg/l	x	x	x	x	18.5000
Y µg/l	x	x	x	x	0.4330
Zr ug/l	x	x	x	x	0.5230
In µg/l	x	x	x	x	< 0.500
Cs µg/l	x	x	x	x	0.8430
La µg/l	x	x	x	x	1.6100
Hf µg/l	x	x	x	x	< 0.0500

Borehole	KLX27A	KLX27A	KLX27A	KLX27A	KLX27A
Date of measurement	**2007-10-13**	**2007-10-17**	**2007-10-22**	**2007-11-22**	**2007-11-23**
Upper section limit (m)	**77.5**	**174.60**	**210.20**	**639.20**	**639.20**
Lower section limit (m)	**176.50**	**245.40**	**247.20**	**650.56**	**650.56**
Sample_no	**15131**	**15148**	**15149**	**15213**	**15214**
Groundwater Chemistry Class	**3**	**3**	**3**	**3**	**5**
Tl µg/l	x	x	x	x	0.0432
Ce µg/l	x	x	x	x	2,2800
Pr µg/l	x	x	x	x	0,2240
Nd µg/l	x	x	x	x	0,7820
Sm µg/l	x	x	x	x	0,1200
Eu µg/l	x	x	x	x	< 0,0500
Gd µg/l	x	x	x	x	0,1040
Tb µg/l	x	x	x	x	< 0,0500
Dy µg/l	x	x	x	x	0,0721
Ho µg/l	x	x	x	x	< 0,0500
Er µg/l	x	x	x	x	< 0,0500
Tm µg/l	x	x	x	x	< 0,0500
Yb µg/l	x	x	x	x	< 0,0500
Lu µg/L	x	x	x	x	< 0,0500
H_2S mg/l	x	x	x	x	0,119
TOC mg/l	x	x	x	x	2,1
DOC mg/l	x	x	x	x	< 1,0
NO_2-N mg/l	x	x	x	x	< 0,0002
NO_3-N mg/l	x	x	x	x	0,0007
NO_2/NO_3-N	x	x	x	x	0,0008
NH_4-N mg/l	x	x	x	x	0,0111
PO_4-P mg/l	x	x	x	x	0,0050
P mg/l	x	x	x	x	0,11400
PMC % Modern Carbon	46,70	37,60	x	x	42,90
C-13 dev PDB	–16,30	–14,20	x	x	–19,30
D dev SMOW	–83,8	–83,9	x	x	–106,7
Tr TU	1,10	1,20	x	x	1,40
O-18 dev SMOW	–11,50	11,70	x	x	–14,40
B-10 B-10/B-11	0,2354	0,2355	x	x	0,2353
S-34 dev CDT	22,6	25,3	x	x	21,1
Cl-37 dev SMOC	0,02	0,21	x	x	0,69
Sr-87 Sr-87/Sr-86	0,715464	0,716510	x	x	0,715812
U-238 mBq/kg	x	x	x	x	7,10
U-235 mBq/kg	x	x	x	x	0,20
U-234 mBq/kg	x	x	x	x	26,70
Th-232 mBq/kg	x	x	x	x	1,25
Th-230 mBq/kg	x	x	x	x	1,35

x=not analysed

Appendix 3

Chemistry – analytical method and quality

SKB Chemistry class 3

Analysis	Sample bottle	Preparation	SKB label	Laboratory
pH, conductivity, alkalinity	250 ml		green	Äspö/field
Anions (F^-, Br^-, Cl^-, SO_4^{2-})	250 ml	Filtered in connection with analyse	green	Äspö/field
Uranine	100 ml brown glass		green	Äspö/field
Main components (except Fe, Mn)	Analytica's 100 ml acid washed	1 ml HNO_3 suprapur, filtering membrane filter	red	ALS
Archive samples	2 ea 250 ml	Filtering Pallfilter	green	
Option				
Deuterium, O-18	100 ml square		green	IFE, Norway
Tritium	500 ml dried	Flooded at least once	green	Waterloo, Canada
Sr-87	100 ml square		green	IFE, Norway
Cl-37	500 ml		green	Waterloo, Canada
B-10	Same as for main components	1 ml HNO_3 suprapur, filtering membrane filter	red	ALS
C-13, PMC	2 st 100 ml plastic		green	Ångström
S-34	1,000 ml		green	IFE, Norway

SKB Chemistry class 5

Analysis	Sample bottle	Preparation	SKB label	Laboratory
pH, conduktivity, alkalinity	250 ml		green	Äspö/field
Anions (F^-, Br^-, Cl^-, SO_4^{2-})	250 ml	Filtered in connection with analyse	green	Äspö/field
Uranine	100 ml brown glass		green	Äspö/field
Fe II + Fe tot	500 ml acid washed PEH-bottle	5 ml HCl suprapur, filtering membrane filter	Red	Äspö/field
NH_4^+	25 ml in 2 reagent washed 50 ml graduated flasks			Äspö/field
HS^-	2 Winlker bottles	Filtering Pall filter, overflowed, concervation 0.5 ml 1 M ZnAc and 1 M NaOH		Äspö/field
Main components B-10 As, In Environmental metals Lantanoides Trace elements	Analytica's 100 ml acid washed	1 ml HNO_3 suprapur, filtering membrane filter	red	ALS
I^-	100 ml bottle	Filtering Pall filter		
NO_3 NO_2 NO_2 + NO_3 PO_4^{3-}	250 ml	Filtering Pall filter directly to bottle, freezed samples before delivery	green	Stockholm University, Institute of System Ecology
DOC	250 ml	Filtering Pall filter, freezed samples before delivery	green	Ramböll, Finland
Deuterium, O-18	100 ml square		green	IFE, Norway
Tritium	500 ml dried	Flowed at least once	green	Waterloo, Canada
Archive samples	2 ea. 250 ml	Filtering membran filter	green	
Option				
TOC	250 ml	Freezed samples before delivery	green	Ramböll, Finland
Sr-87	100 ml square		green	IFE, Norway
Cl-37	500 ml		green	Waterloo, Canada
B-10	*Same as for main components*	1 ml HNO_3 suprapur, filtering membrane filter	red	ALS
C-13, PMC	2 st 100 ml plastic		green	Ångström
S-34	1,000 ml		green	IFE, Norway
U/Th	1,000 ml HDPE bottle	Express delivery	green	SUERC, Scotland

Quality of the analyses

The charge balance errors (see Appendix 2) give an indication of the quality and uncertainty of the analyses of the major components. The relative charge balance error is calculated for the set of data from borehole KLX27A, i.e. samples with SKB-nr 15131, 15148 and 15214. The error does not exceed ± 1%.

The following routines for quality control and data management are generally applied for hydrogeochemical analysis data, independent of sampling method or sampling object.

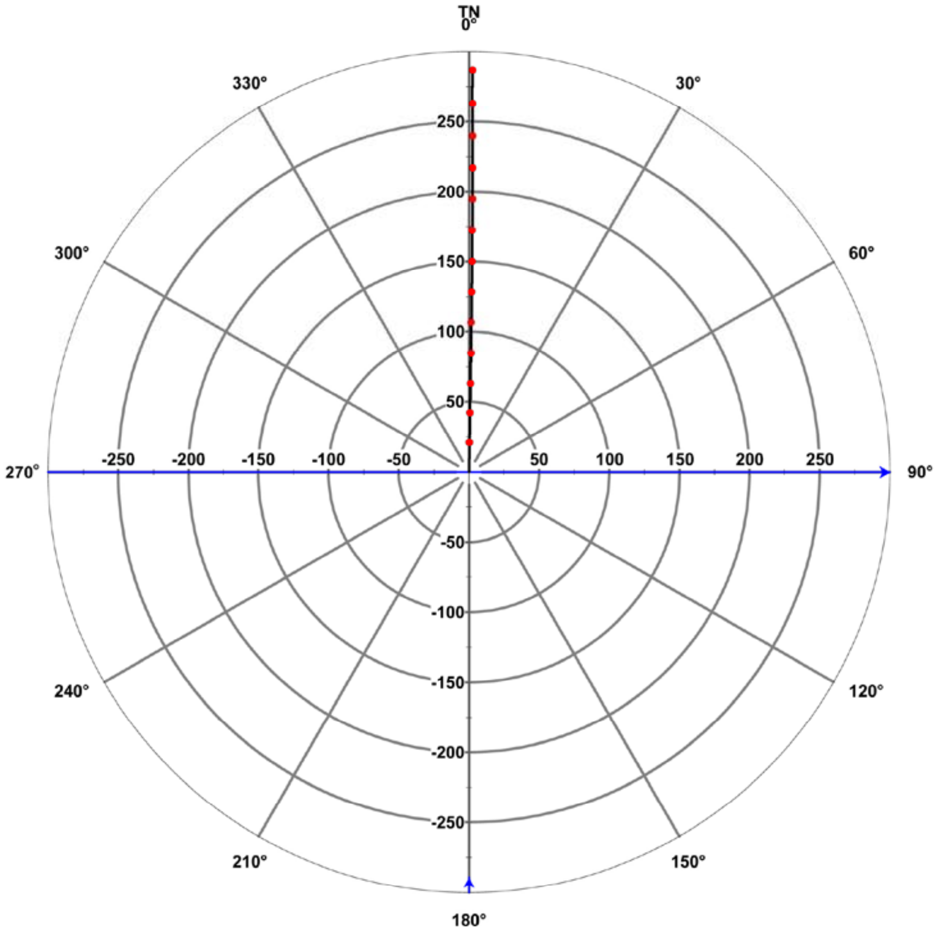
- Several components are determined by more than one method and/or laboratory. Control analyses by an independent laboratory are normally performed as a standard procedure on every five or ten collected samples. No control analyses were performed on the water samples from KLX27A.
- All analytical results were stored in the SICADA database. The chemistry part of the database contains two types of tables, raw data tables and primary data tables (final data tables).
- Data on basic water analyses are inserted into raw data tables for further evaluation. The evaluation results in a final reduced data set for each sample. These data sets are compiled in a primary data table named "water composition". The evaluation is based on:
  – Comparison of the results from different laboratories and/or methods. The analyses are repeated if a large disparity is noted (generally more than 10%).
  – Calculation of charge balance errors. Relative errors within ± 5% are considered acceptable. For surface waters errors of ± 10%.
  – $\text{Rel. Error (\%)} = 100 \times \frac{(\sum \text{cations(equivalents)} - \sum \text{anions(equivalents)})}{(\sum \text{cations(equivalents)} + \sum \text{anions(equivalents)})}$
  – General expert judgement of plausibility based on earlier results and experiences.

All results from "biochemical" components and special analyses of trace elements and isotopes are inserted directly into primary data tables. In those cases where the analyses are repeated or performed by more than one laboratory, a "best choice" notation will indicate those results which are considered most reliable.

Appendix 4

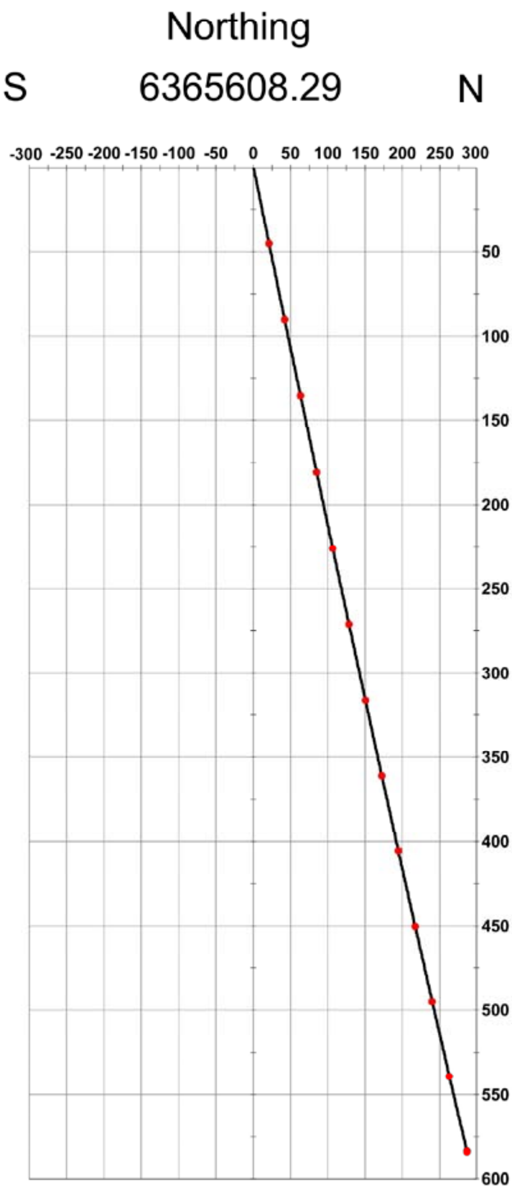
Deviation measurements

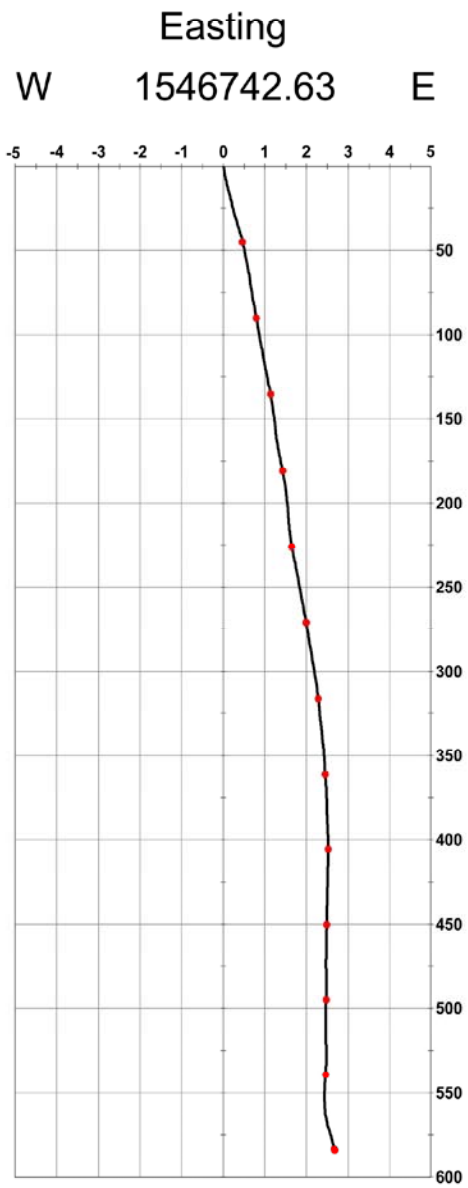
Deviation measurement		Appendix: 4
	Site LAXEMAR Borehole KLX27A View from above	



Deviation measurement	Appendix: 4

Site LAXEMAR
Borehole KLX27A
Vertical Section



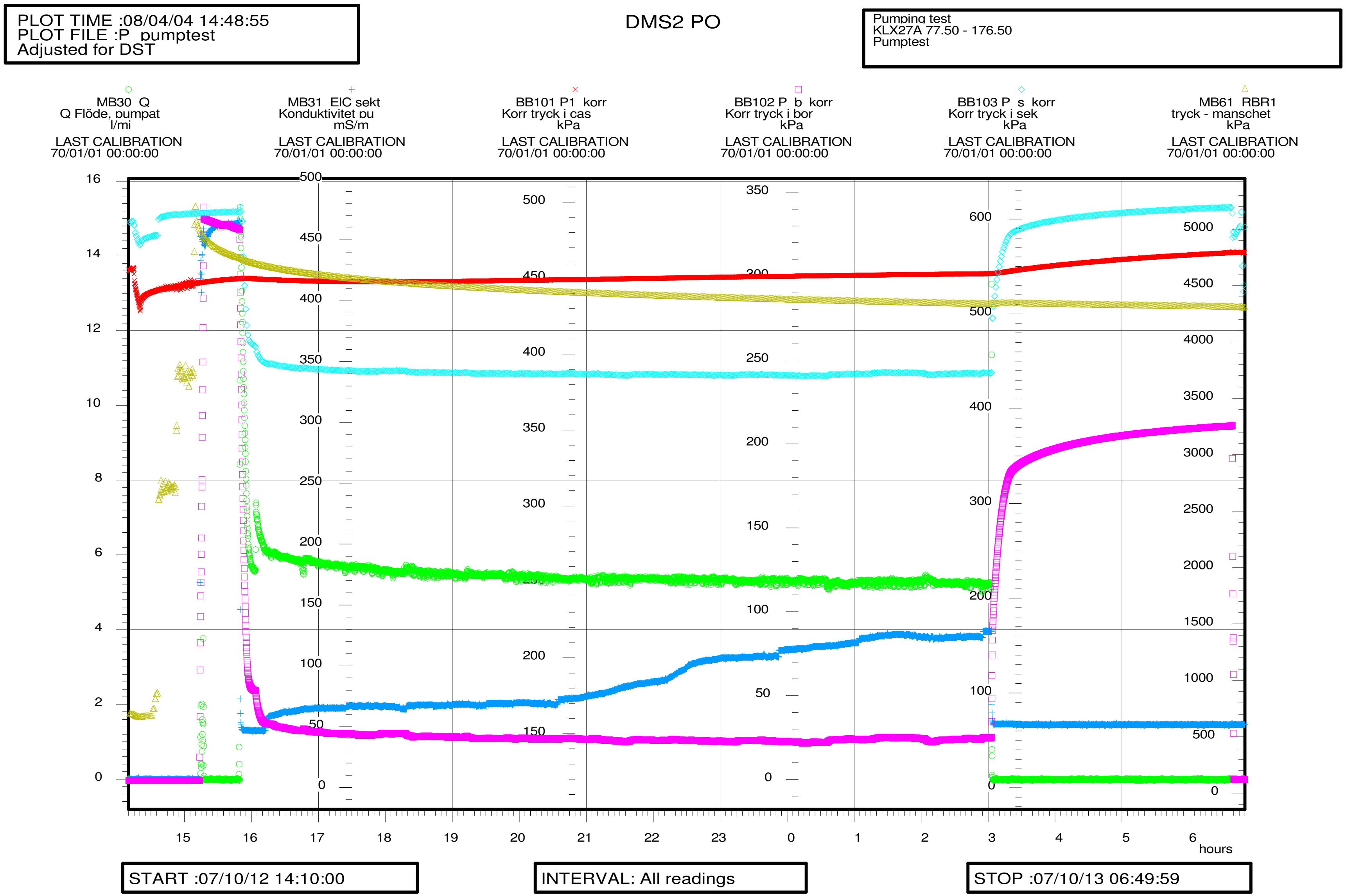


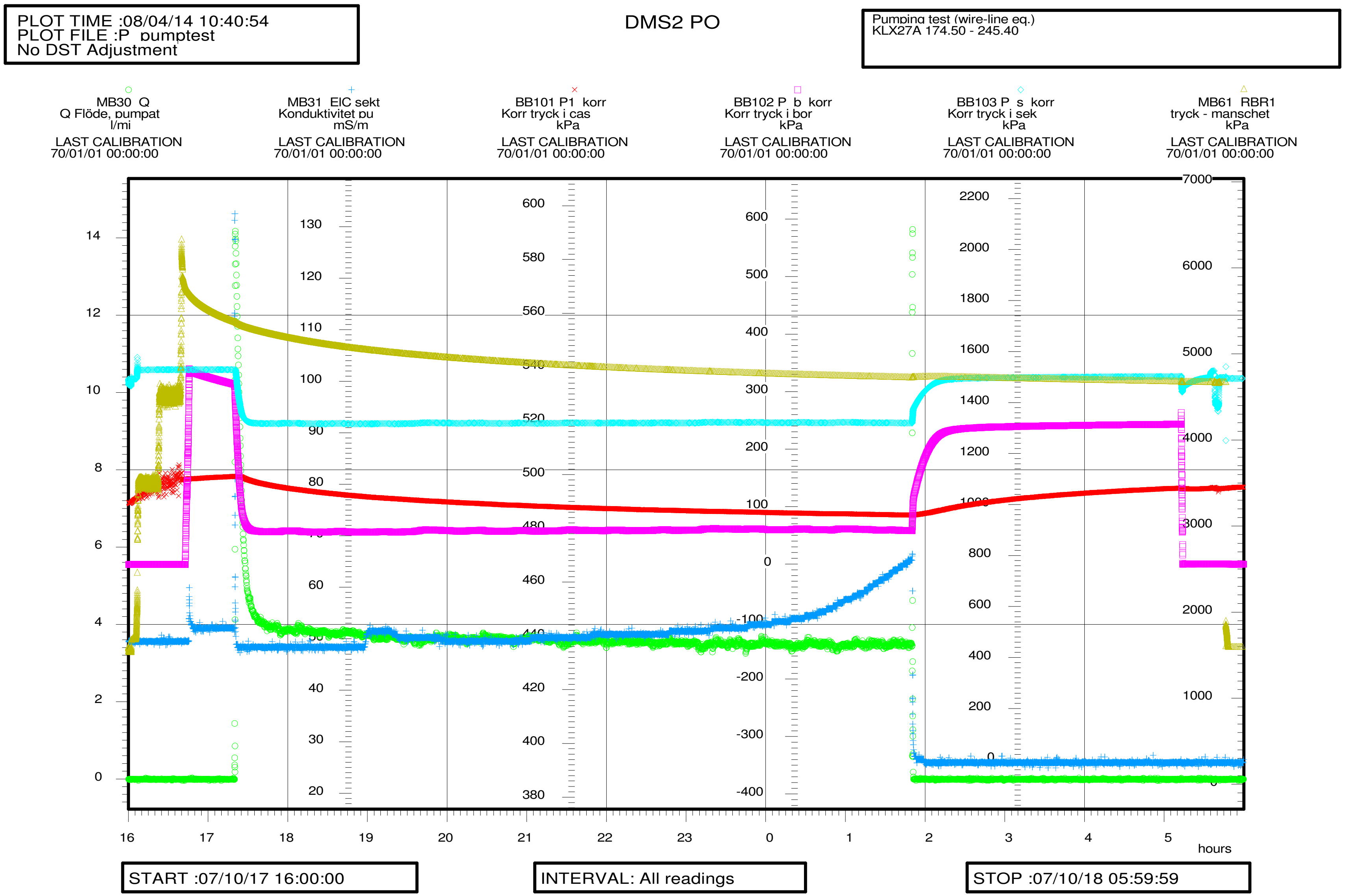
Appendix 5

Wireline pumping tests in KLX27A

Description of the parameters in the enclosed plots

Channel	Parameter	Unit	Description
MB30	Water flow	Litre/minute	Flow of water pumped up from the borehole during the test.
MB31	Electrical conductivity	mS/m	Electrical conductivity in the pumped out water.
BB101	Pressure	kPa	Pressure of the water column in the telescopic section subtracted with the ambient air pressure.
BB102	Pressure	kPa	Pressure of the water column in the test section i.e. at depth in the borehole, subtracted with the ambient air pressure.
BB103	Pressure – section	kPa	Pressure of the water column in the test section i.e. at depth in the borehole, subtracted with the ambient air pressure.
MB61	Pressure – packer	kPa	Inflation pressure in packer.
MB62	Pressure – section	kPa	Pressure of the water column in the test section i.e. at depth in the borehole. Not corrected for ambient air pressure.


PLOT TIME :08/04/04 14:48:55
PLOT FILE :P_pumptest
Adjusted for DST
DMS2 PO
Pumping test
KLX27A 77.50 - 176.50
Pumptest
MB30 Q
Q Flöde, pumpat
l/mi
LAST CALIBRATION
70/01/01 00:00:00
MB31 EIC sekt
Konduktivitet pu
mS/m
LAST CALIBRATION
70/01/01 00:00:00
BB101 P1 korr
Korr tryck i cas
kPa
LAST CALIBRATION
70/01/01 00:00:00
BB102 P b korr
Korr tryck i bor
kPa
LAST CALIBRATION
70/01/01 00:00:00
BB103 P s korr
Korr tryck i sek
kPa
LAST CALIBRATION
70/01/01 00:00:00
MB61 RBR1
tryck - manschet
kPa
LAST CALIBRATION
70/01/01 00:00:00
15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6
hours
START :07/10/12 14:10:00
INTERVAL: All readings
STOP :07/10/13 06:49:59

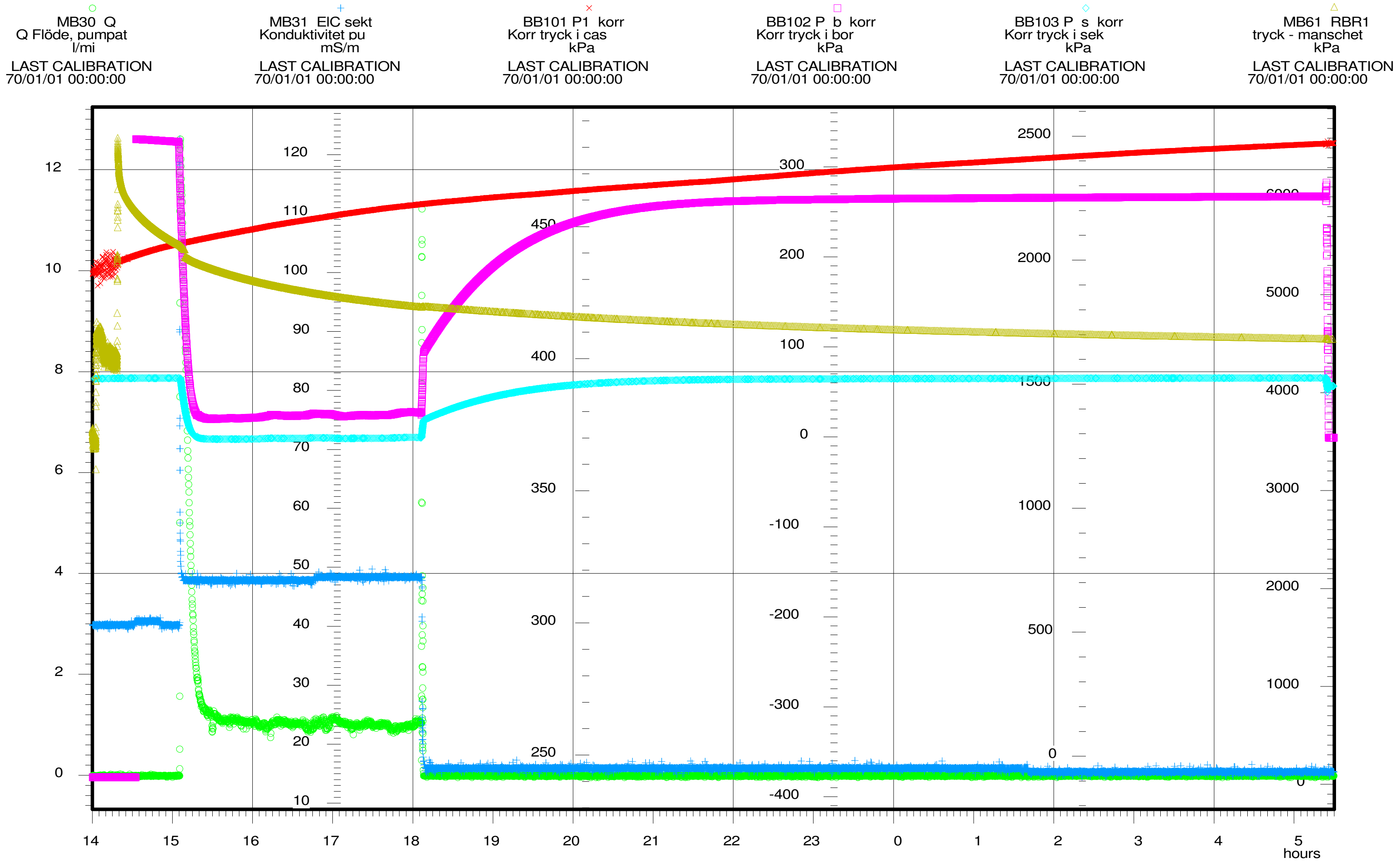


PLOT TIME :08/04/14 10:40:54
PLOT FILE :P pumptest
No DST Adjustment
DMS2 PO
Pumping test (wire-line eq.)
KLX27A 174.50 - 245.40
MB30 Q
Q Flöde, pumpat
l/mi
LAST CALIBRATION
70/01/01 00:00:00
MB31 EIC sekt
Konduktivitet pu
mS/m
LAST CALIBRATION
70/01/01 00:00:00
BB101 P1 korr
Korr tryck i cas
kPa
LAST CALIBRATION
70/01/01 00:00:00
BB102 P b korr
Korr tryck i bor
kPa
LAST CALIBRATION
70/01/01 00:00:00
BB103 P s korr
Korr tryck i sek
kPa
LAST CALIBRATION
70/01/01 00:00:00
MB61 RBR1
tryck - manschet
kPa
LAST CALIBRATION
70/01/01 00:00:00
hours
START :07/10/17 16:00:00
INTERVAL: All readings
STOP :07/10/18 05:59:59

PLOT TIME :08/04/14 12:48:04
PLOT FILE :P pumptest
No DST Adjustment

DMS2 PO

Pumping test (wire-line eq.)
KLX27A 174.20 - 278.14



START :07/10/24 14:00:00

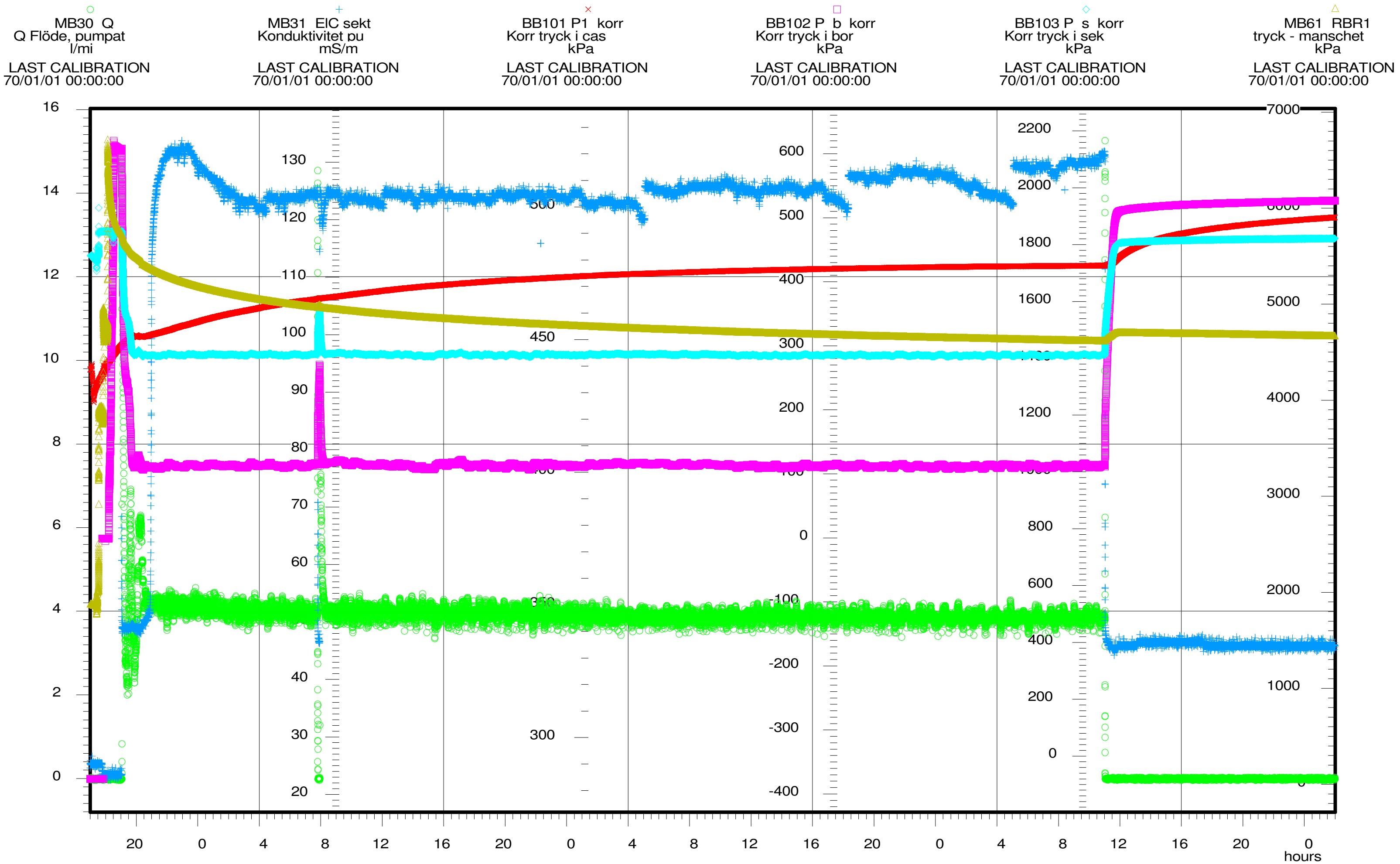
INTERVAL: All readings

STOP :07/10/25 05:29:59

PLOT TIME :08/04/14 12:25:53
PLOT FILE :P pumptest
No DST Adjustment

DMS2 PO

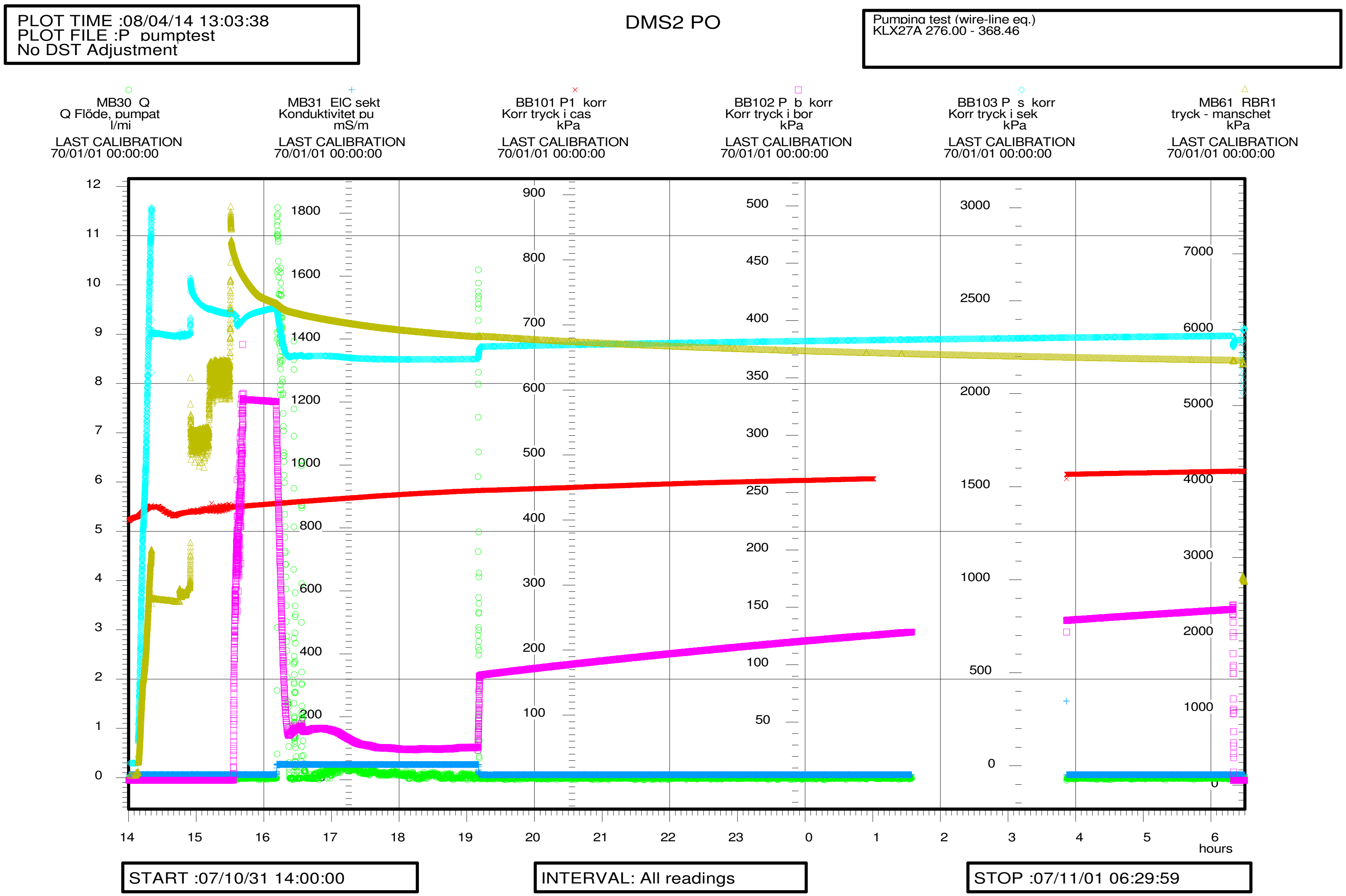
Pumping test (wire-line eq.)
KLX27A 210.20 - 247.20



START :07/10/18 17:00:00

INTERVAL: All readings

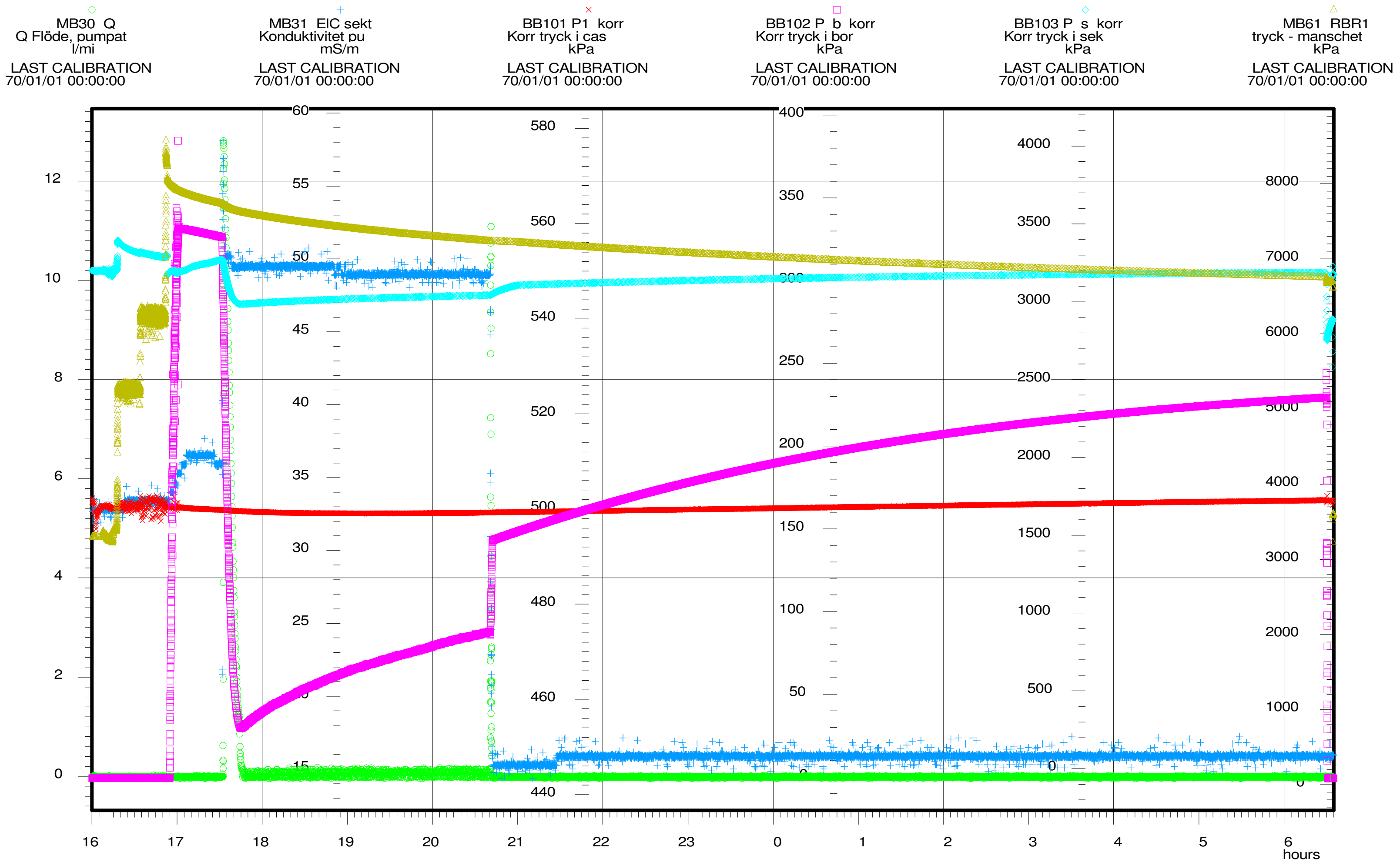
STOP :07/10/22 01:59:59


PLOT TIME :08/04/14 13:03:38
PLOT FILE :P pumptest
No DST Adjustment
DMS2 PO
Pumping test (wire-line eq.)
KLX27A 276.00 - 368.46
MB30 Q
Q Flöde, pumpat
l/mi
LAST CALIBRATION
70/01/01 00:00:00
MB31 ElC sekt
Konduktivitet pu
mS/m
LAST CALIBRATION
70/01/01 00:00:00
BB101 P1 korr
Korr tryck i cas
kPa
LAST CALIBRATION
70/01/01 00:00:00
BB102 P b korr
Korr tryck i bor
kPa
LAST CALIBRATION
70/01/01 00:00:00
BB103 P s korr
Korr tryck i sek
kPa
LAST CALIBRATION
70/01/01 00:00:00
MB61 RBR1
tryck - manschet
kPa
LAST CALIBRATION
70/01/01 00:00:00
hours
START :07/10/31 14:00:00
INTERVAL: All readings
STOP :07/11/01 06:29:59

PLOT TIME :08/04/14 13:20:40
PLOT FILE :P_pumptest
No DST Adjustment

DMS2 PO

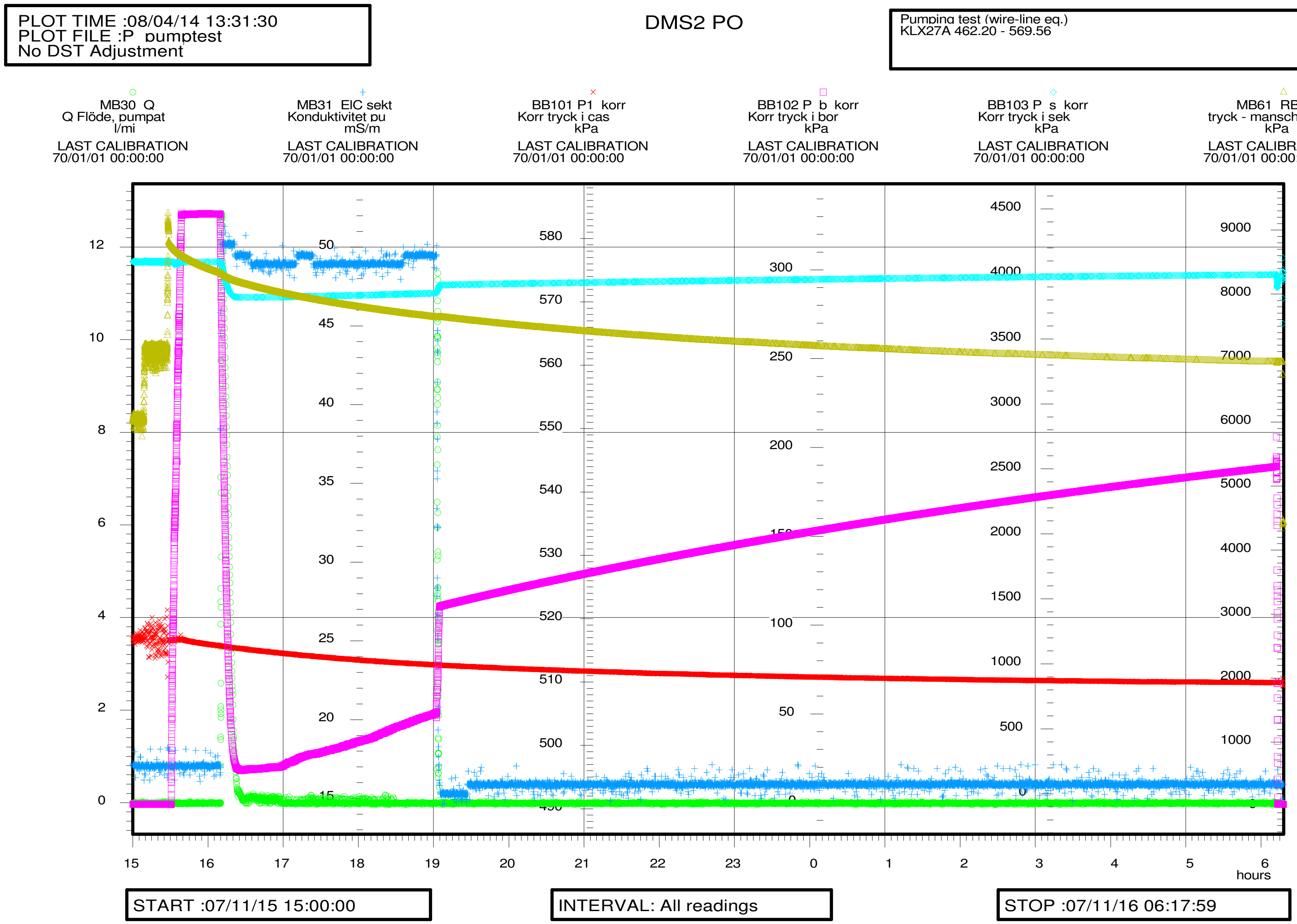
Pumping test (wire-line eq.)
KLX27A 366.00 - 464.56



START :07/11/07 16:00:00

INTERVAL: All readings

STOP :07/11/08 06:34:59

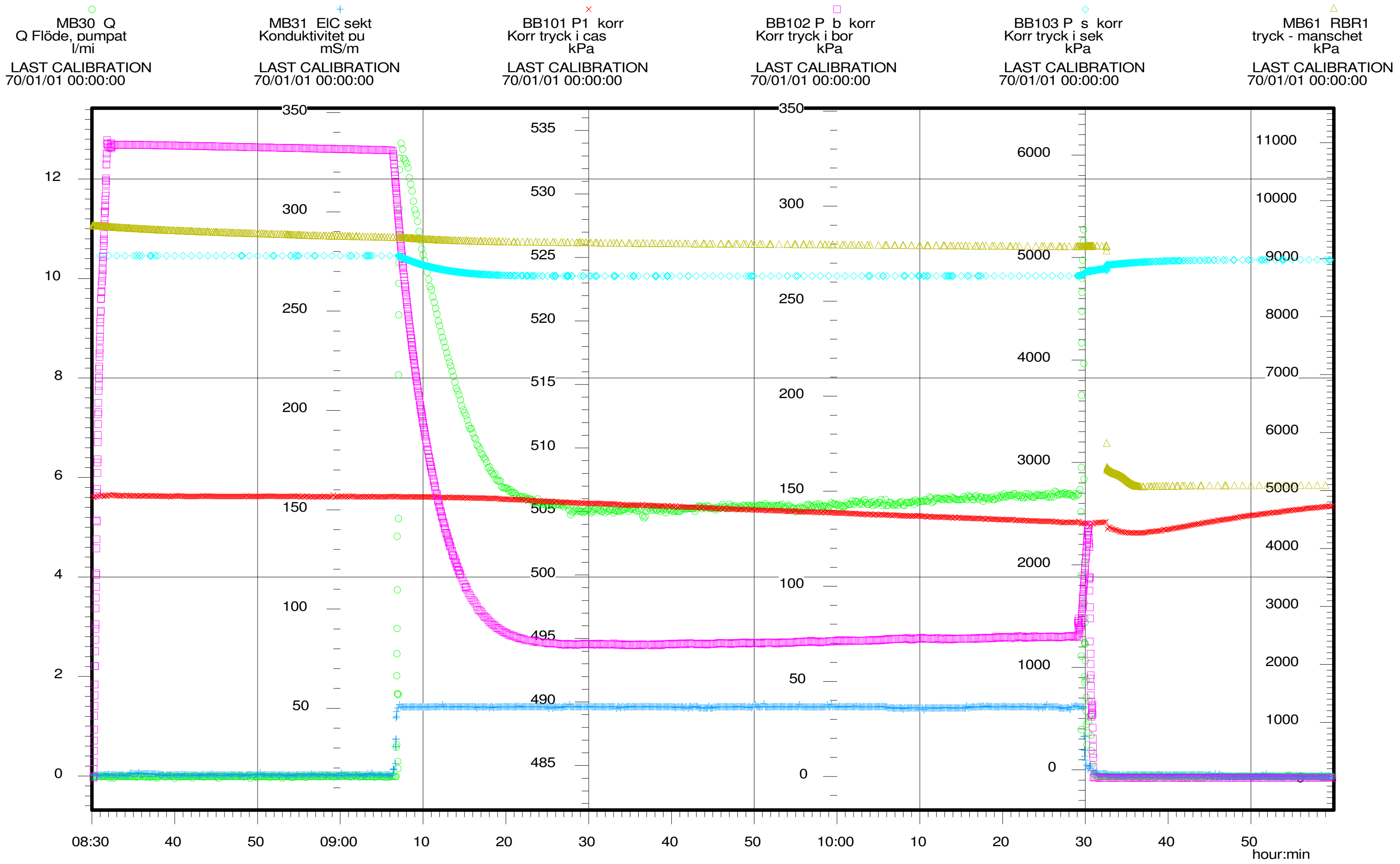


PLOT TIME :08/04/14 13:31:30
PLOT FILE :P pumptest
No DST Adjustment
DMS2 PO
Pumping test (wire-line eq.)
KLX27A 462.20 - 569.56
MB30 Q
Q Flöde, pumpat
l/mi
LAST CALIBRATION
70/01/01 00:00:00
MB31 EIC sekt
Konduktivitet pu
mS/m
LAST CALIBRATION
70/01/01 00:00:00
BB101 P1 korr
Korr tryck i cas
kPa
LAST CALIBRATION
70/01/01 00:00:00
BB102 P b korr
Korr tryck i bor
kPa
LAST CALIBRATION
70/01/01 00:00:00
BB103 P s korr
Korr tryck i sek
kPa
LAST CALIBRATION
70/01/01 00:00:00
MB61 RBR1
tryck - manschet
kPa
LAST CALIBRATION
70/01/01 00:00:00
hours
START :07/11/15 15:00:00
INTERVAL: All readings
STOP :07/11/16 06:17:59

PLOT TIME :08/04/14 13:45:39
PLOT FILE :P pumptest
No DST Adjustment

DMS2 PO

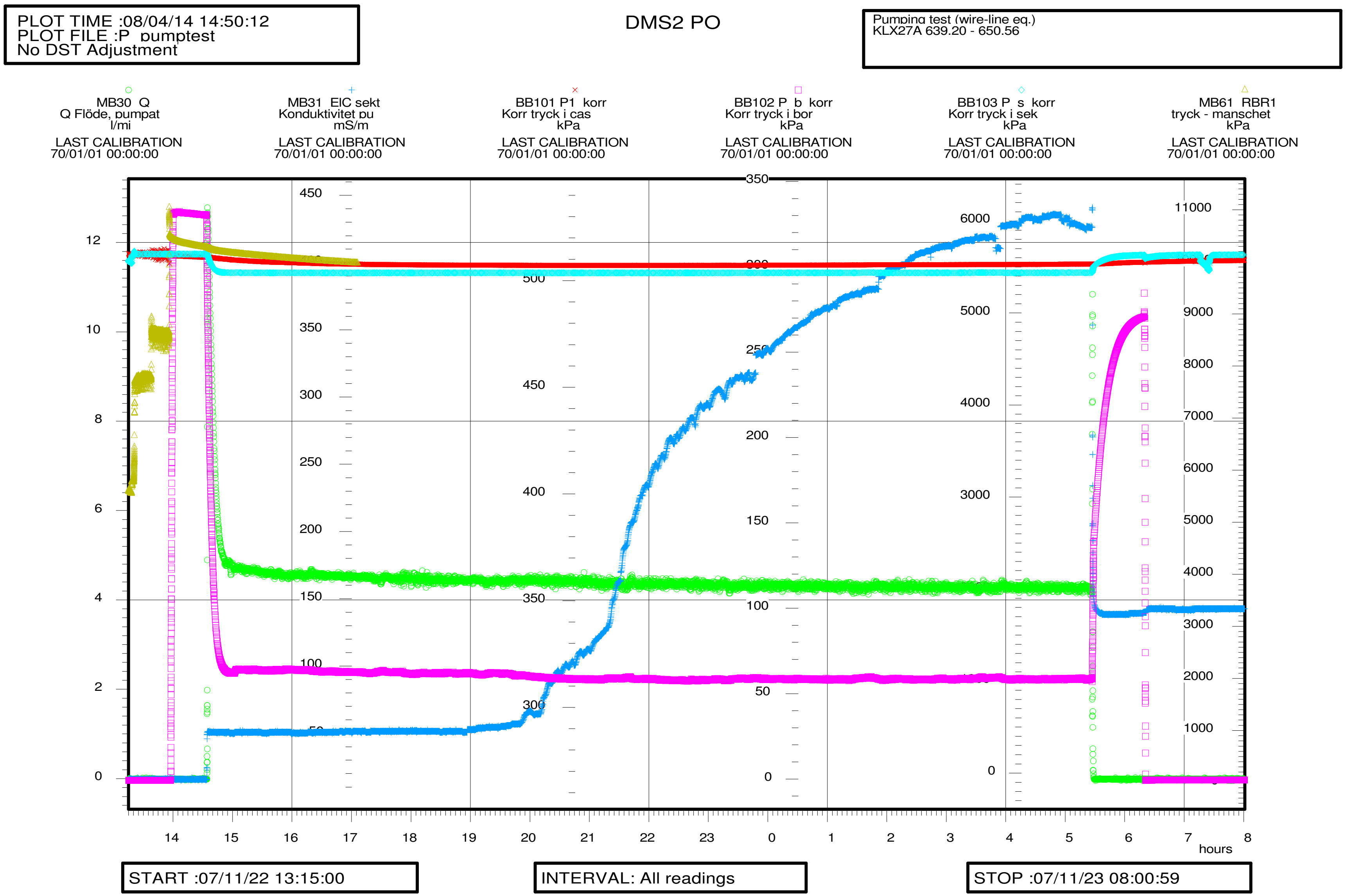
Pumping test (wire-line eq.)
KLX27A 567.20 - 650.56



START :07/11/22 08:30:00

INTERVAL: All readings

STOP :07/11/22 10:59:59


PLOT TIME :08/04/14 14:50:12
PLOT FILE :P_pumptest
No DST Adjustment
DMS2 PO
Pumping test (wire-line eq.)
KLX27A 639.20 - 650.56
MB30 Q
Q Flöde, pumpat
l/mi
LAST CALIBRATION
70/01/01 00:00:00
MB31 EIC sekt
Konduktivitet pu
mS/m
LAST CALIBRATION
70/01/01 00:00:00
BB101 P1 korr
Korr tryck i cas
kPa
LAST CALIBRATION
70/01/01 00:00:00
BB102 P b korr
Korr tryck i bor
kPa
LAST CALIBRATION
70/01/01 00:00:00
BB103 P s korr
Korr tryck i sek
kPa
LAST CALIBRATION
70/01/01 00:00:00
MB61 RBR1
tryck - manschet
kPa
LAST CALIBRATION
70/01/01 00:00:00
hours
START :07/11/22 13:15:00
INTERVAL: All readings
STOP :07/11/23 08:00:59

Appendix 6

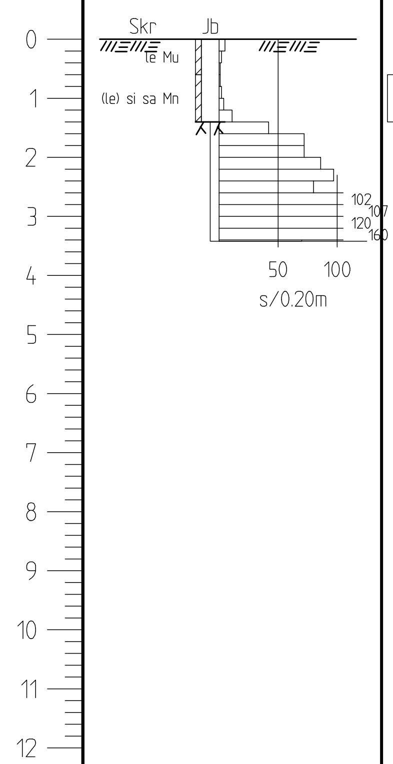
Technical data from environmental monitoring well SSM000277

WSP

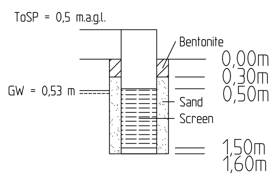
BOREHOLE SSM000277

Company rep.		Top of stand pipe
Company rep. Torbjörn Johansson Magnus Göransson Client: Svensk Kärnbränslehantering AB	Northing :6365630 Easting :1546744 ToSP +14,72 Coordinate system : RT90-RHB70	Top of stand pipe : 0.5 m.a.g.l. Total pipe length : 2,10 m Groundwater level : 0,53 m.b.g.l. Date of completion : 2007-09-04

Depth (m)	Description	Samples	Groundwater monitoring well description	Borehole Construction Information



Samples: 1



Drilling method : NOEK
Borehole diameter : 120 mm
sampling method : Auger

CASING
Material : PEH
Outer diameter : 63 mm
Inner diameter : 50 mm
Total length : 1,00 m

SCREEN
Material : PEH
Outer diameter : 63 mm
Inner diameter : 50 mm
Total length : 1,00 m
Slot : 0,3 mm

ANNULUS SEAL
Material : Bentonite clay
Total length : 0,30 m

SAND PACK
Grain size : 0,4-0,8 mm
Total length : 1,30 m

DRILLING EQUIPMENT
Drilling rig : GM 65 GTT
Drill hammer : Furukawa HB2G
Drill rod : Geostång Φ44
Drill bit : Stift Φ54

GEOLOGICAL LOG
0-0,6m clayey topsoil
0,6-1,4m somewhat clayey silty sandy till
1,4m rock surface

ToSP : Top of Stand Pipe
m.a.g.l. : meters above ground level
m.b.g.l. : meters below ground level

Nomenclature see SGF homepage: www.sgf.net