P-08-33

Oskarshamn site investigation

Drilling of cored borehole KLX09

Henrik Ask, H Ask Geokonsult AB

Mansueto Morosini, Svensk Kärnbränslehantering AB

Liselotte Tiberg, Studsvik Nuclear AB

August 2008

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co
Box 250, SE-101 24 Stockholm
Tel +46 8 459 84 00

ISSN 1651-4416
SKB P-08-33

Oskarshamn site investigation

Drilling of cored borehole KLX09

Henrik Ask, H Ask Geokonsult AB

Mansueto Morosini, Svensk Kärnbränslehantering AB

Liselotte Tiberg, Studsvik Nuclear AB

August 2008

Keywords: Core drilling, Bedrock, Measurement while drilling, Flushing water monitoring, Water sampling, Wireline measurements, Air-lift pumping, Telescope hole.

Data in SKB's database can be changed for different reasons. Minor changes in SKB's database will not necessarily result in a revised report. Data revisions may also be presented as supplements, available at www.skb.se.

A pdf version of this document can be downloaded from www.skb.se.

Abstract

Borehole KLX09 is located in the Laxemar subarea. Drilling was made between June and October 2005 as a part of the site investigation for a possible repository for spent nuclear fuel in Oskarshamn municipality, Sweden. KLX09 was the eleventh deep cored borehole within the site investigation in Oskarshamn.

KLX09 was core drilled to a length of 880.38 metres with N-size (76 mm) equipment. The uppermost section, to the length of 100.60 metres, was constructed as a telescopic borehole with an inner nominal diameter of 200 mm.

No water inflow could be measured over the entire length of the telescopic section after percussion drilling of the pilot borehole (nominal diameter 165 mm).

Nine successful pumping tests were performed with wireline equipment in KLX09. The resulting transmissivities (T_M) varied between 2.8×10^{-3} and 9.2×10^{-6} m^2/s. The most transmissive section was between 103 and 183 metres.

Continuous monitoring of drilling parameters and flushing water parameters with the drilling monitoring system was conducted throughout the core drilling phase in KLX09.

Eight water samples for chemical analysis were collected during the core drilling of KLX09.

The air-lift pumping test in the telescopic section performed when borehole KLX09 was core drilled to its full length gave a transmissivity (T_M) of 2.6×10^{-4} m^2/s.

Lithologically the core is dominated by Ävrö granite with intercalations of fine-grained diorite-gabbro and fine-grained dioritoid.

Rock alteration is relatively common below 260 m and consists of mostly faint to weak oxidization (red staining) and saussuritization (alteration of Ca-plagioclase to epidote).

The average fracture frequency over the entire core drilled section expressed as open fractures is 2.53 (fractures/metre).

Sammanfattning

Borrhål KLX09 ligger inom delområde Laxemar. Borrningen utfördes mellan juni och oktober 2005 som ett led i platsundersökningen för ett möjligt djupförvar för använt kärnbränsle i Oskarshamns kommun. KLX09 var det elfte djupa kärnborrhålet inom platsundersökningen i Oskarshamn.

KLX09 kärnborrades med borrstorlek N (76 mm) till 880,38 meters borrad längd. Den övre delen av hålet, från markytan till 100,60 meter, utfördes som en teleskopdel med ca 200 mm inre diameter.

Inget vatteninflöde kunde uppmätas över hela teleskopdelen vid hammarborrningen av pilotdelen (nominell diameter 165 mm).

Nio lyckade pumptester med wireline-baserad mätutrustning utfördes. De uppmätta transmissiviteterna (T_M) varierade mellan $2{,}8\times10^{-3}$ och $9{,}2\times10^{-6}$ m^2/s. Den mest transmissiva sektionen var mellan 103 och 183 meter.

Kontinuerliga mätningar av borrningsparametrar och spolvattenparametrar via DMS (drilling monitoring system) gjordes under hela kärnborrningsfasen i KLX09.

Åtta vattenprover för kemisk analysering togs i samband med borrning i KLX09.

Mammutpumpningen i teleskopdelen som gjordes när kärnborrningen i KLX09 utförts till full längd gav en transmissivitet (T_M) på $2{,}6\times10^{-4}$ m^2/s.

Litologiskt domineras kärnan av Ävrö granit med inslag av finkornig diorit-gabbro och finkornig dioritoid.

Bergartsomvandling är relativt vanlig under 260 m och består av mestadels mycket svag till svag oxidation (rödfärgning) och saussuritisering (omvandling av Ca-plagioklas till epidot).

Den genomsnittliga sprickfrekvensen över hela borrkärnan uttryckt som öppna sprickor är 2,53 (sprickor/meter).

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/. The investigations are performed in two Swedish municipalities: Östhammar and Oskarshamn. Borehole KLX09 is located in the northern 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. KLX09 was the eleventh deep cored borehole within the Oskarshamn site investigation. The location of the core drilled borehole and the water source, HLX20 in the Laxemar subarea is shown in Figure 1-1.

The drilling of KLX09 and all related on-site operations were performed according to a specific activity plan (AP PS 400-05-020), which in turn refers to a number of method descriptions, see Table 1-1.

The activity plans and method descriptions are SKB internal documents.

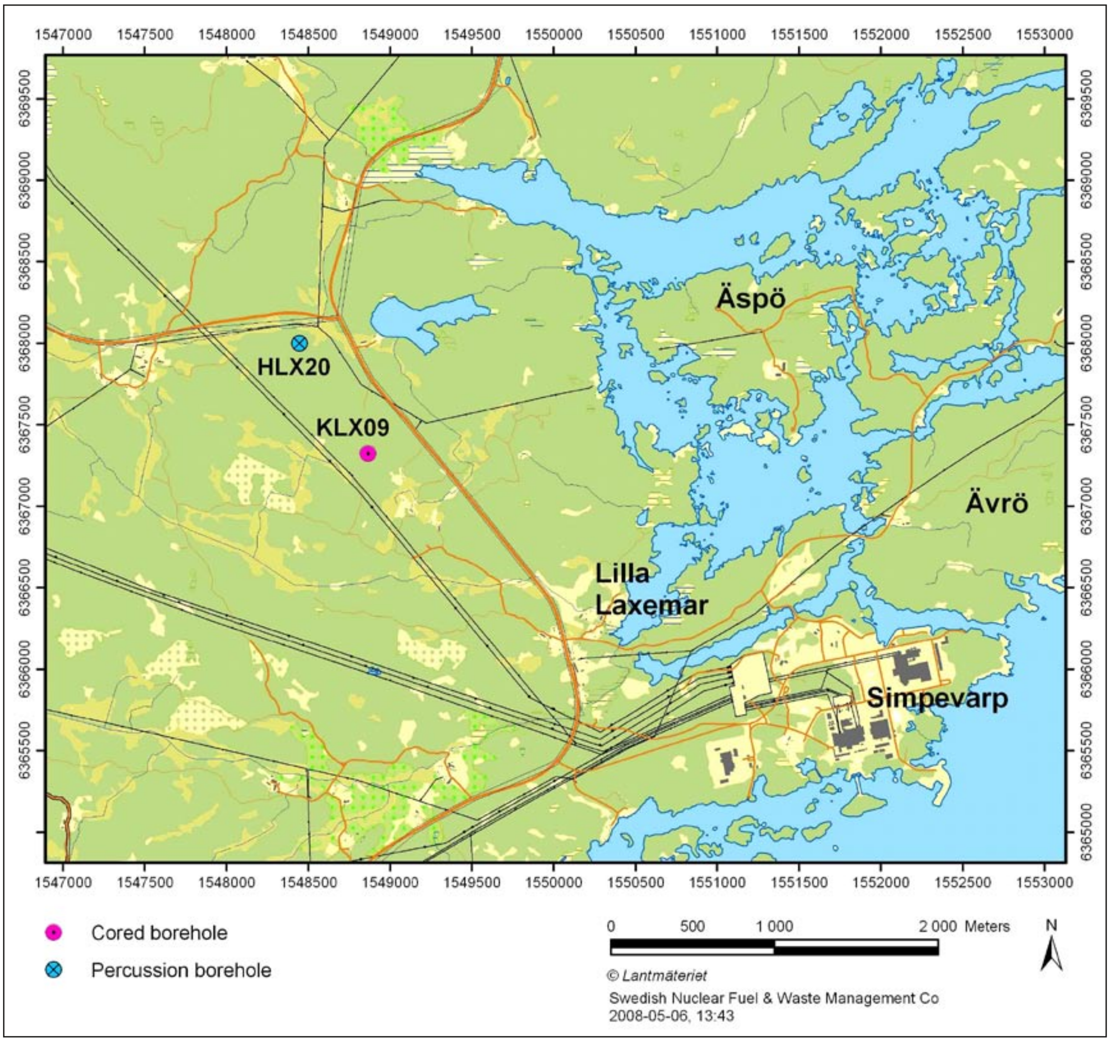


Figure 1-1. *Location of the cored borehole KLX09 and the water source, percussion borehole HLX20 in the Laxemar subarea.*

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

Activity plan	Number	Version
Kärnborrning KLX09	AP PS 400-05-020	1.0
Method descriptions	**Number**	**Version**
Metodbeskrivning för kärnborrning	SKB MD 620.003	1.0
Metodbeskrivning för hammarborrning	SKB MD 610.003	2.0
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 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 längdkalibrering vid undersökningar i kärnborrhål	SKB MD 620.010	2.0
Instruktion för hantering och provtagning av borrkärna	SKB MD 143.007	1.0
Metodbeskrivning för krökningsmätning av hammar- och kärnborrhål	SKB MD 224.001	1.0
Instruktion för miljökontroll av ytvatten, ytnära grund-vatten och mark vid borrning och pumpning i berg	SKB MD 300.003	2.0

2 Objective and scope

This report will describe the methods employed and the results achieved during the drilling of borehole KLX09. 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 main reason for drilling the borehole was to verify and characterize possible rock volumes for a deep repository as well as to gain geological information and facilitate further investigation at depth in the northwest part of the Laxemar subarea. The decision to drill KLX09 is given in SKB id no 1040726, dated 2005-06-08.

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 2005-03-03, SKB id 1036192. Information of the final coordinates and details regarding the return water handling was sent to the Regional Authorities on 2005-05-03, SKB id 1039024.

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.

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.

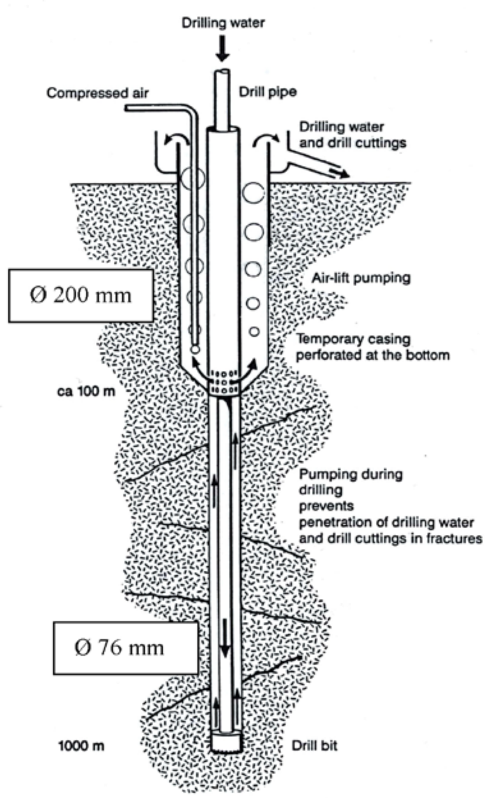


Figure 3-1. *A sketch of the telescopic drilling method with air-lift pumping for retrieval of drilling water and cuttings.*

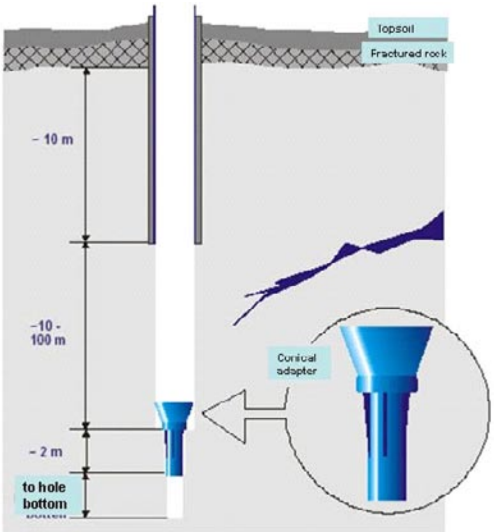


Figure 3-2. Installation of the conical guide.

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.

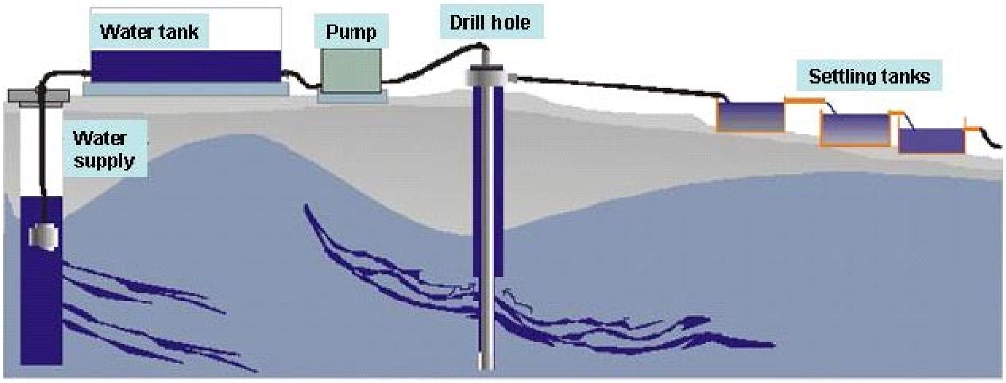


Figure 3-3. The flushing water system from source to discharge point.

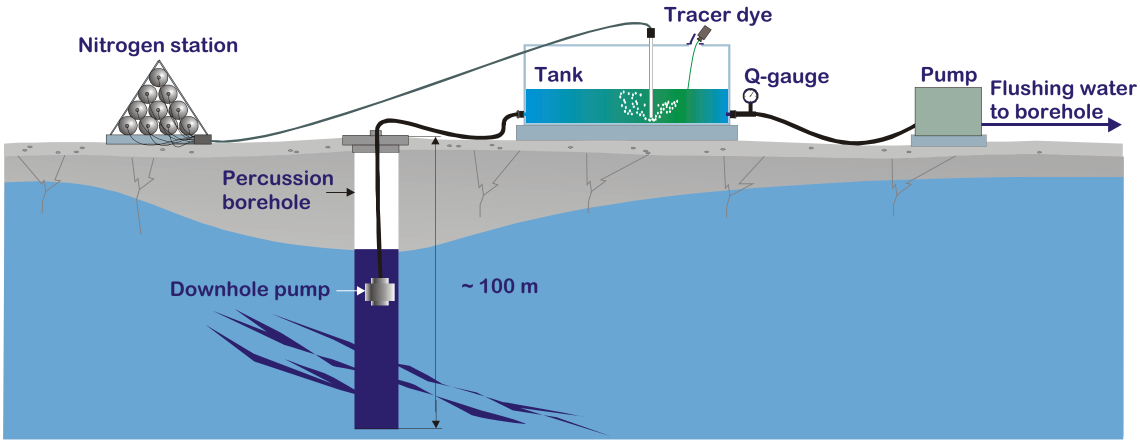


Figure 3-4. *Schematic drawing of the preparation of flushing water. Uranine is added to the water as a tracer dye and nitrogen is bubbled through the water to remove dissolved oxygen.*

3.2 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 and characteristic features of the drill cuttings. 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 (i.e. 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.

3.2.2 Core drilling

The sampling and measurements during the core drilling phase of KLX09 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. The measurements for hydrogeological purposes include pumping tests and measurements of absolute pressure 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.

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 drilling monitoring system (DMS).

4 Contractors and equipment

4.1 Contractors

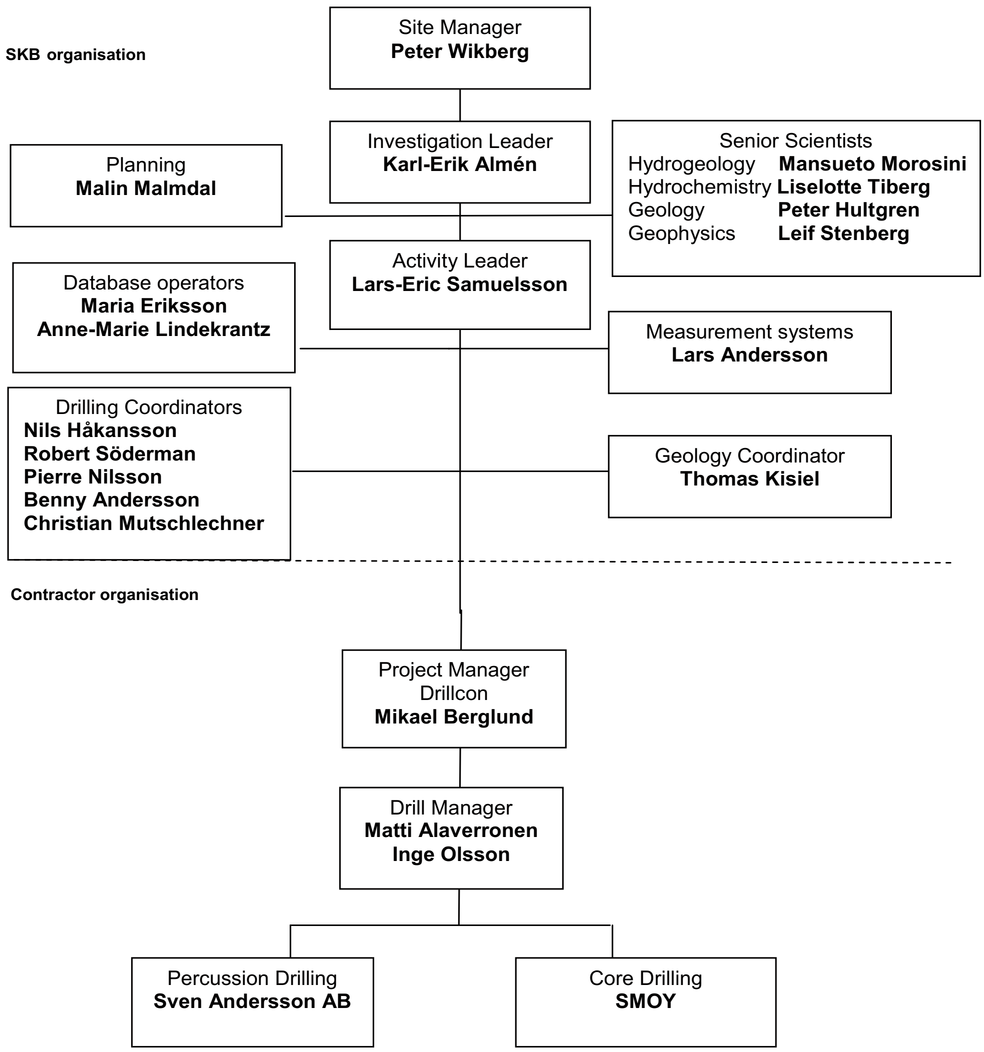
The main contractor for drilling was Drillcon Core AB, with subcontractor for core drilling Suomen Malmi OY (SMOY) and subcontractor for percussion drilling Sven Andersson AB.

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

4.2 Percussion drilling equipment

The equipment used in KLX09 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 x thickness.

Table 4-1. Drill activity organisation.



4.3 Core drilling equipment

Core drilling in KLX09 was made with a B20 APC Atlas Copco JKS Boyles 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 drilling was not made in KLX09.

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.

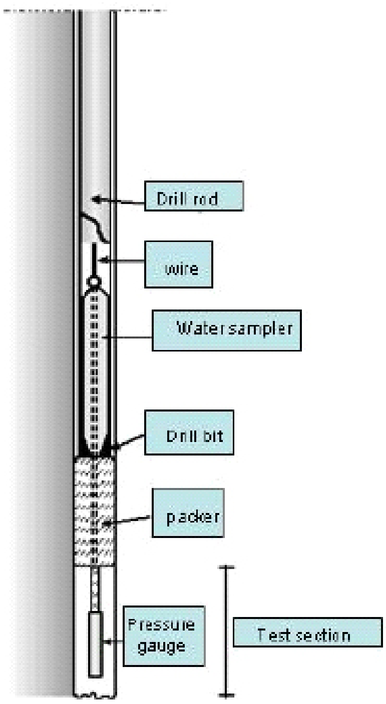


Figure 4-1. The wireline probe and its emplacement in the hole.

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 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

The wireline probe is placed in position at the drill bit. The packer is inflated and the pressure build-up in the test section is recorded for a period of at least eight hours, typically this is done overnight. The measuring range for the pressure gauge is 0–20 MPa (± 0.05% FSD). The absolute pressure measurement is conducted if the flow rate during the pumping test exceeds 1 litre per minute.

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 EZ-shot), 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.

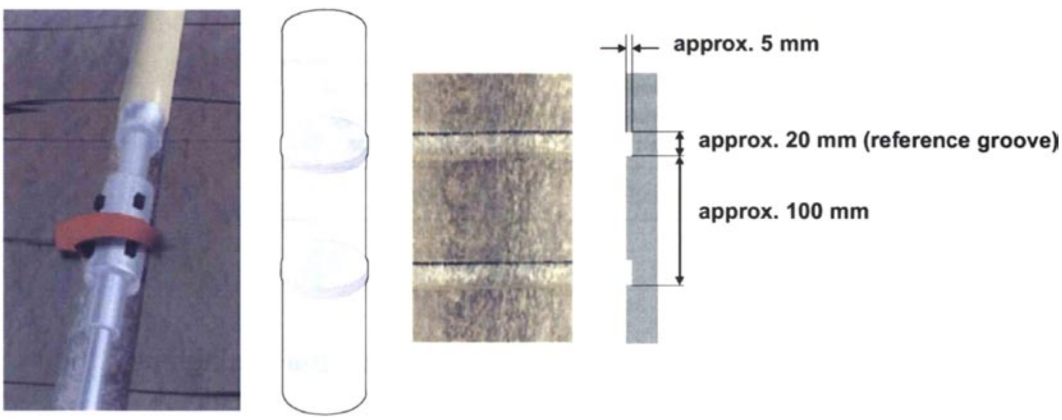


Figure 4-2. The equipment for reaming of reference slots. To the left, the reaming tool with openings for the cutters is shown. The resulting reference slots are illustrated in the three pictures to the right.

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 400-05-020.

5.1 Summary of KLX09 drilling

A technical summary of the drilling of KLX09 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.

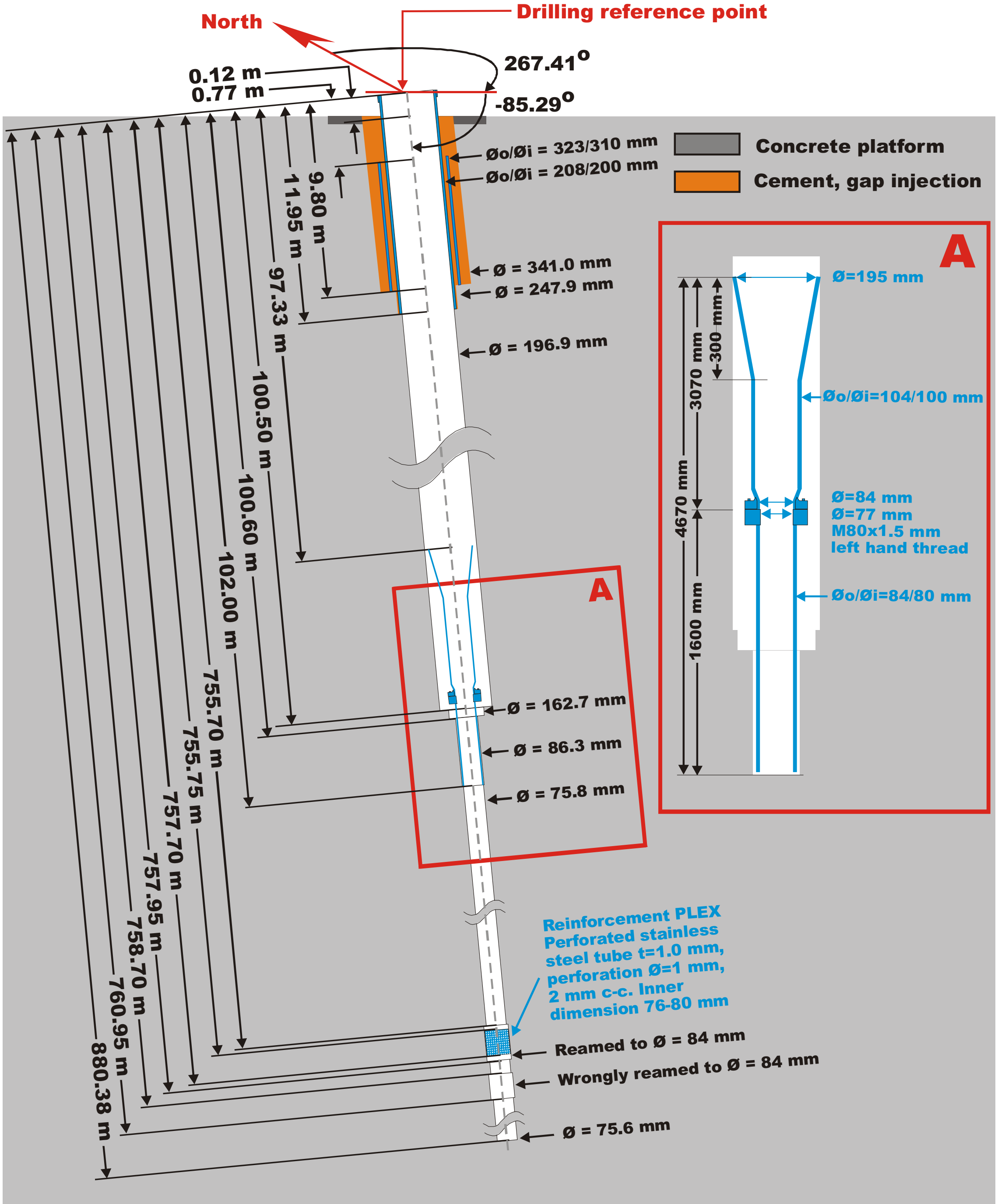
Further descriptions of the percussion drilling of the telescopic section 0–100.60 metres and the measurements performed during this phase are given in Section 5.2. The core drilling between 100.60–880.38 metres is further described in Section 5.3. Results from hydrogeological and hydrogeochemical measurements during core drilling are presented in Section 5.4. Drilling progress over time is further reported in Section 5.5 “Drilling monitoring results”.

Table 5-1. KLX09 Technical summary.

General	Technical
Name of hole: KLX09	*Percussion drill rig*: Comacchio MC1500
Location: Laxemar, Oskarshamn Municipality, Sweden	*Percussion hole length*: 100.60 m (diam 162.7 mm) 100.50 m (diam 196.9 mm)
Contractor for drilling Drillcon AB	*Core drill rig*: B20 APC Atlas Copco
	Core drill dimension: N-size (76 mm)
Subcontractor percussion drilling Sven Andersson AB	*Cored interval*: 100.60–880.38 m
Percussion drill start date June 2, 2005	*Diamond bits used*: 9
	Average bit life: 87 metres
Completion date June 13, 2005	*Position KLX09 (RT90 RH70) at top of casing:* N 6367323.45 E 15448863.18 Z 23.45 (m.a.s.l.)
Subcontractor core drilling Suomen Malmi OY (SMOY)	*Azimuth (0–360) / Dip (0–90)*: 267.41 / –85.29
Core drill start date August 26, 2005	*Position KLX09 (RT90 RH70) at 880.38 m length:* N 6367318.83 E 1548758.47 Z –850.62 (m.a.s.l.)
Completion date October15, 2005	*Azimuth (0–360) / Dip (0–90)*: 272.93 / –83.09

Technical data

Borehole KLX09



Drilling reference point

Northing: 6367323.45 (m), RT90 2,5 gon V 0:-15

Easting: 1548863.18 (m), RT90 2,5 gon V 0:-15

Elevation: 23.45 (m), RHB 70

Drilling period

Drilling start date: 2005-06-02

Drilling stop date: 2005-10-15

Ver 2008-04-14

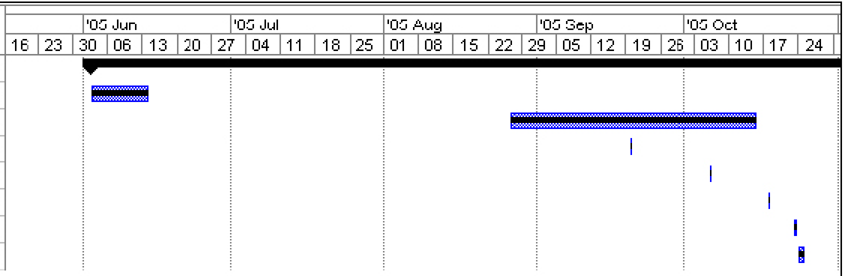
Figure 5-1. *Technical data from KLX09.*

Table 5-2. Summary of core drilling progress and borehole measurements in KLX09.

bh metres	Pumping tests and water sampling	Measurements of absolute pressure	Airlift pumping with evaluation of drawdown and/or recovery	Deviation measurement	Miscellaneous
100	050824 Pumping test without WL-probe 11.95–100.60. Flow 17 L/min at 13 m drawdown.		051109 Airlift pumping 17.92–100.50 m. 0.02 L/min at + 50 m drawdown.	050608 EZ-shot after percussion drilling 99 m Azimuth 262.6 Dip –82.8.	
200	050903 Pumping test 102.67–183.39. Flow 10 L/min at 13 m drawdown. Water sample taken.	050904 Pressure measurement 102.67–208.10 m.		050903 EZ-shot 180 m Azimuth 268.3 Dip –83.1.	
300	050909 Pumping test 182.62–292.13. Flow 8.5 L/min at 15 m drawdown. Water sample taken.	050910 Pressure measurement 205.05–297.49 m.			
400	050914 Pumping test 290.72–395.63. Flow 9.8 L/min at 12 m drawdown. Water sample taken.	050916 Pressure measurement 296.72–404.14 m.		050915 EZ-shot 395 m Azimuth 268.1 Dip –83.1.	
			050919 Airlift pumping 11.95–475.44 m. No drillstem in borehole.		
500	050921 Pumping test 393.10–505.11. Flow 11 L/min at 13 m drawdown. Water sample taken.			050924 EZ-shot 537 m Azimuth 268.3 Dip –82.9.	
		050922 Pressure measurement 402.10–523.54 m.			050924 Zone of crushed rock and core loss between 538.70 and 539.17 m.
600	050927 Pumping test 504.00–605.20. Flow was c. 9 L/min at approx. 20 m drawdown. Stable conditions could not be acheived. Water sample taken.				
		050929 Pressure measurement 522.00–619.53 m.			
700	051003 Pumping test 603.00–716.91. Flow 3.5 L/min at 12 m drawdown. Water sample taken.		051005 Airlift pumping 11.95–736.34 m. No drillstem in borehole.		
	051007 Pumping test 749.72–757.59. Flow ca 7 L/min at 14 m drawdown. Water sample taken.	051004 Pressure measurement 616.72–722.16 m.			051007 Crushed rock and core loss at 755.80 m.
800	051010 Pumping test 715.22–806.16. Flow ca 5 L/min at approx 5 m drawdown. Water sample taken.				
		051012 Pressure measurement 719.72–815.17 m.		051024 Maxibor measurement to 876 m. 051026 Flexit measurement to 876 m.	051015 Core drilling completed at 880.38 m 051028 Reaming and emplacement of PLEX-tube.
900	051015–16 Pumping test 803.72–880.38. Test failed.				

Table 5-3. Chronological summary of main core drilling events in KLX09.

ID	Aktivitet	Start
1	**First activity starts**	**Thu 05-06-02**
2	Percussion drilling	Thu 05-06-02
3	Core drilling	Fri 05-08-26
4	Recovery test	Mon 05-09-19
5	Recovery test	Wed 05-10-05
6	Recovery test	Mon 05-10-17
7	Length calibration marks	Sun 05-10-23
8	Maxibor measurement	Mon 05-10-24



5.2 Drilling, measurements and results in the telescopic section 0–100.60 m

Drilling, reaming and casing grouting (gap injection) were made from June 2 to 13, 2005.

5.2.1 Preparations

The drill site was prepared for percussion drilling by clearing of the site and removing the top soil and overburden. Percussion drilling was started directly on the bedrock surface and gravel fill was emplaced after the percussion drilling. This explains why the outer casing is 0.77 m below the borehole reference level (top-of-casing), see Figure 5-1. Two pictures of the drill site, pre- and post-drilling, are given in Figures 5-2 and 5-3.

Cleaning of all DTH (down-the-hole) equipment was done with a high-capacity steam cleaner.

Figure 5-2. *Site Investigation personnel, including Public Relations Manager, Activity Leader Geology and Site Ecologist reconnoitring the future site for KLX09, April 2005.*

Figure 5-3. The drill site KLX09 in September 2005, i.e. during core drilling.

5.2.2 Drilling and casing installation

The construction of the upper telescope section (0–100.60 metres) of KLX09 was made in steps as shown in Figure 5-4 and described below:

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

- Drilling was made to 9.8 metres length with NO-X 280 mm equipment. This gave a hole diameter of 339 mm and left a casing (323/310 mm diameter) to a length of 9.8 m.
- Inner supportive casing for guidance for the drill string was mounted.
- A pilot percussion hole was drilled to a depth of 100.60 metres with 5" DTH-hammer. The starting diameter was 162.7 mm. The diameter of the pilot drill bit at 100.60 m was 162.4 mm.
- Deviation measurement with EZ-shot equipment was done in the pilot borehole to 99 m length.
- Reaming to diameter 247.9 mm was done to 11.95 m. Stainless casing of 208×4 mm was installed from 0 to 11.95 metres.
- Casing grouting (gap injection) with low alkali cement based concrete (428 kg or 360 litres) was made for both sets of casing. The outer casing (diam 323 mm) was cut at the bedrock surface, 0.77 m below the future reference level.
- After the concrete had hardened the borehole was rinsed and flushed to remove loose concrete and water. The tightness of the concrete seal (casing grouting) was made by measuring the water table recovery.
- The borehole was reamed from 11.95 to 100.50. The initial bit diameter was 197.3 mm and the final bit diameter at 100.50 m was 196.9 mm.

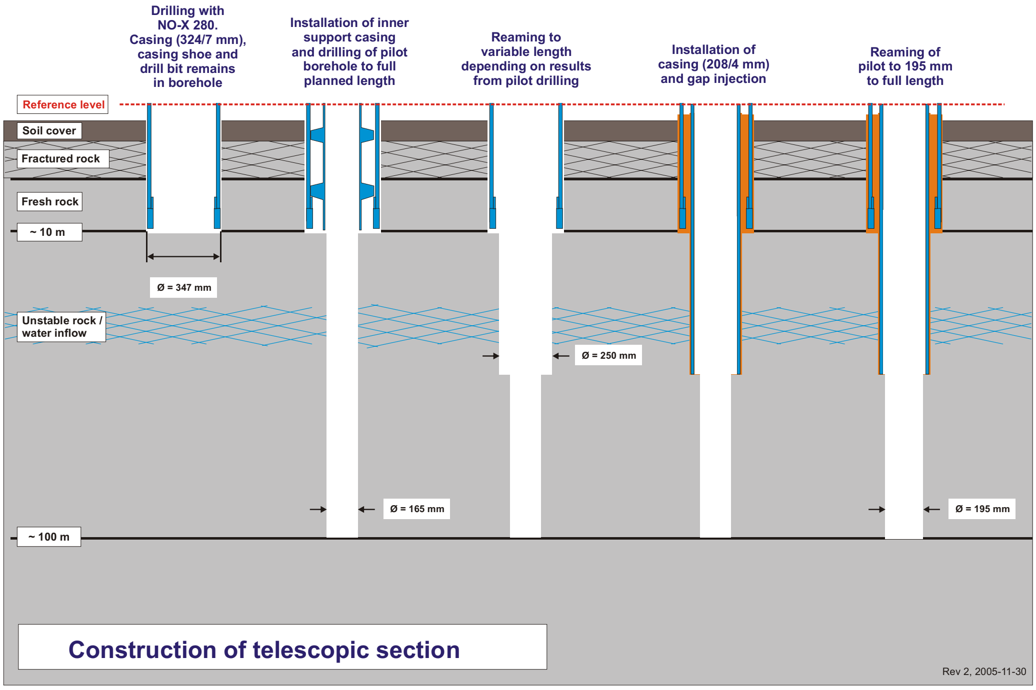


Figure 5-4. *Construction of the telescopic section. The cement for casing grouting is introduced between the casing and the rock wall. The drill bit acts as a barrier so that cement does not enter the pilot hole.*

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 5-5.

Percussion drilling was started on the bedrock surface after the overburden had been removed. No record of the thickness or composition of the natural soil was kept as part of the drilling activity. A geological fracture mapping activity (AP PS 400-05-049) was made over the drill site just after the percussion drilling.

No inflow of water was noted during the percussion drilling.

5.2.4 Hydrogeological measurements and results during percussion drilling

In section 11.95–100.60 m a single-hole pumping test was conducted, for results see Table 5-4 and Figure 5-6. The pumping test was made in the telescopic section on August 24 i.e just before the core drilling started. The test was evaluated according to Moye /2/. Pumping was made during four hours with a flow of 16.9 L/min and caused 14 m drawdown.

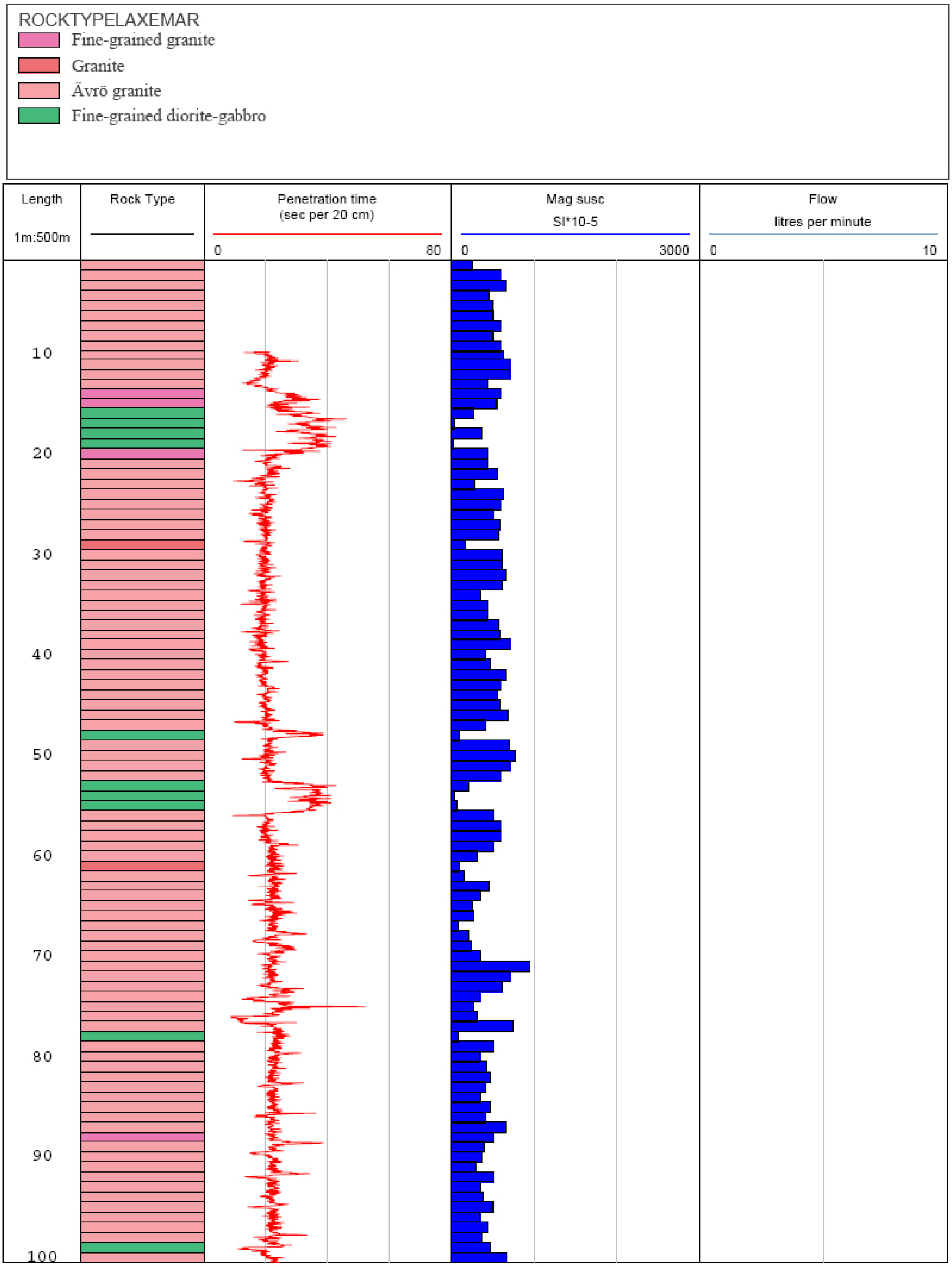


Figure 5-5. *Preliminary geological results based on logging of drill cuttings and penetration rate from percussion drilling of KLX09.*

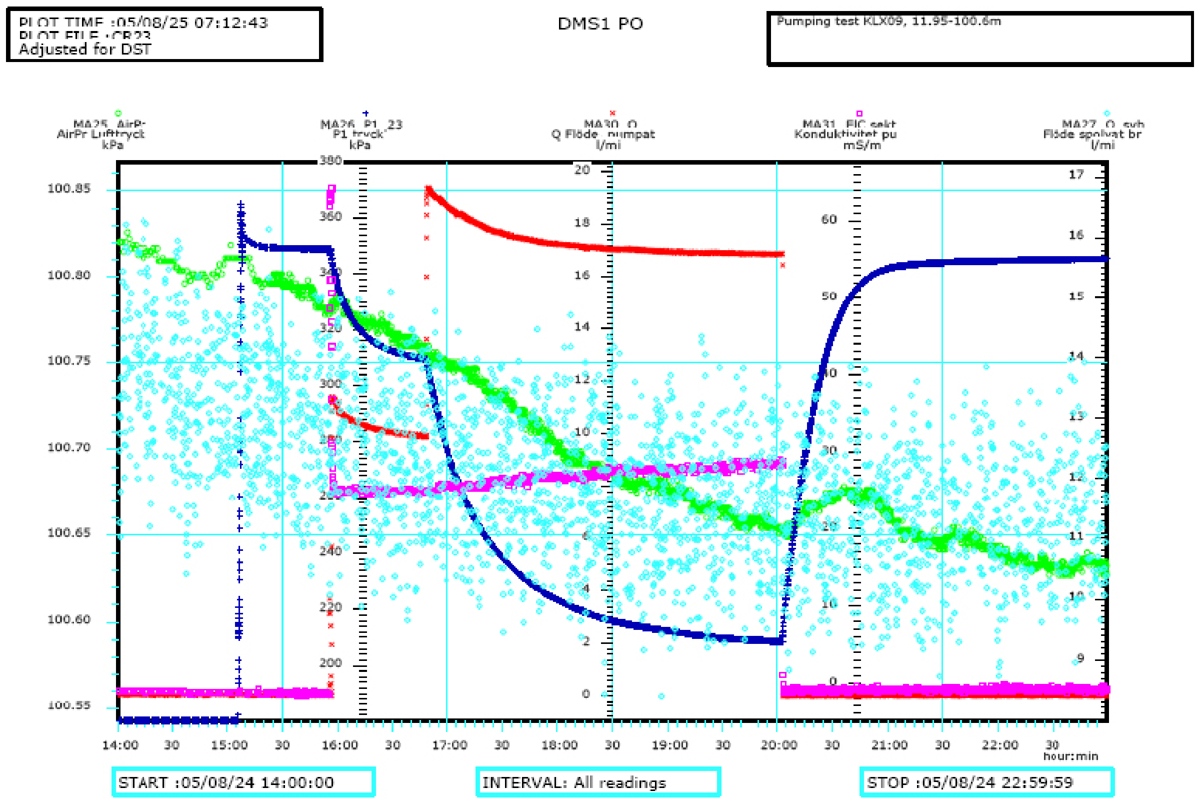


Figure 5-6. *Pumping test in the telescopic section 11.95–100.60 m on August 24.*

Table 5-4. Results from single-hole pumping test in open borehole 11.95–100.60 m in KLX09.

Tested section [m]	Flow rate [L/min]	Drawdown [m]	Q/s [m²/s]	T_M [m²/s]	Comments
11.95–100.60	16.9	14	$2.0 \cdot 10^{-5}$	$2.2 \cdot 10^{-5}$	

5.3 Core drilling KLX09 100.60–880.38 m

Core drilling in KLX09 was conducted between August 26 and October 15, 2005.

The main work in KLX09 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 consisted of levelling the drill site with gravel, casting of a cement pad, mounting the drill rig, installation of air-lift pumping equipment and supportive casing for alignment of the core drill rods. The installations in the telescopic section can be seen in Figure 5-7.

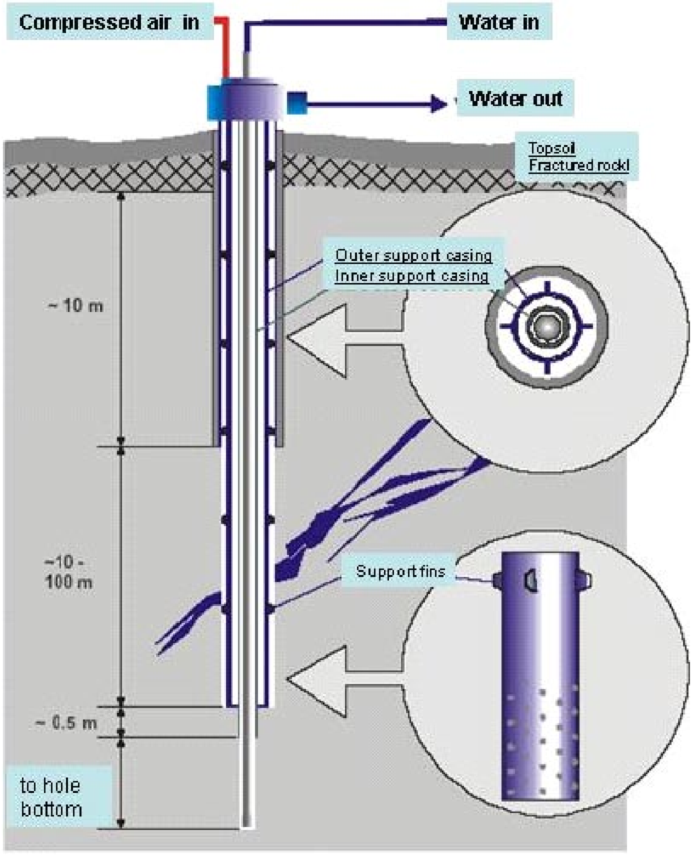


Figure 5-7. In the telescopic part of the drill hole a temporary installation is made with casing tubes for support, alignment and equipment for air-lift pumping. In the uppermost part the return water discharge header is mounted. The water discharge is led to the settling containers.

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.
- Equipment for air-lift pumping was installed and a discharge header was fitted to collect the return water.
- Drilling was made between 100.60 and 101.05 m with T-86 equipment. An inner supportive casing with diameter 84/77 mm was installed to 101.05 m.

The supportive casings have a perforated section below 90 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 90 metres.

5.3.2 Flushing and return water handling

The flushing water source was percussion borehole HLX20, see also Sections 5.4.2 and 5.5. The location of the water source, borehole HLX20 is shown in Figure 1-1.

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 KLX09 is shown in Figure 5-8.

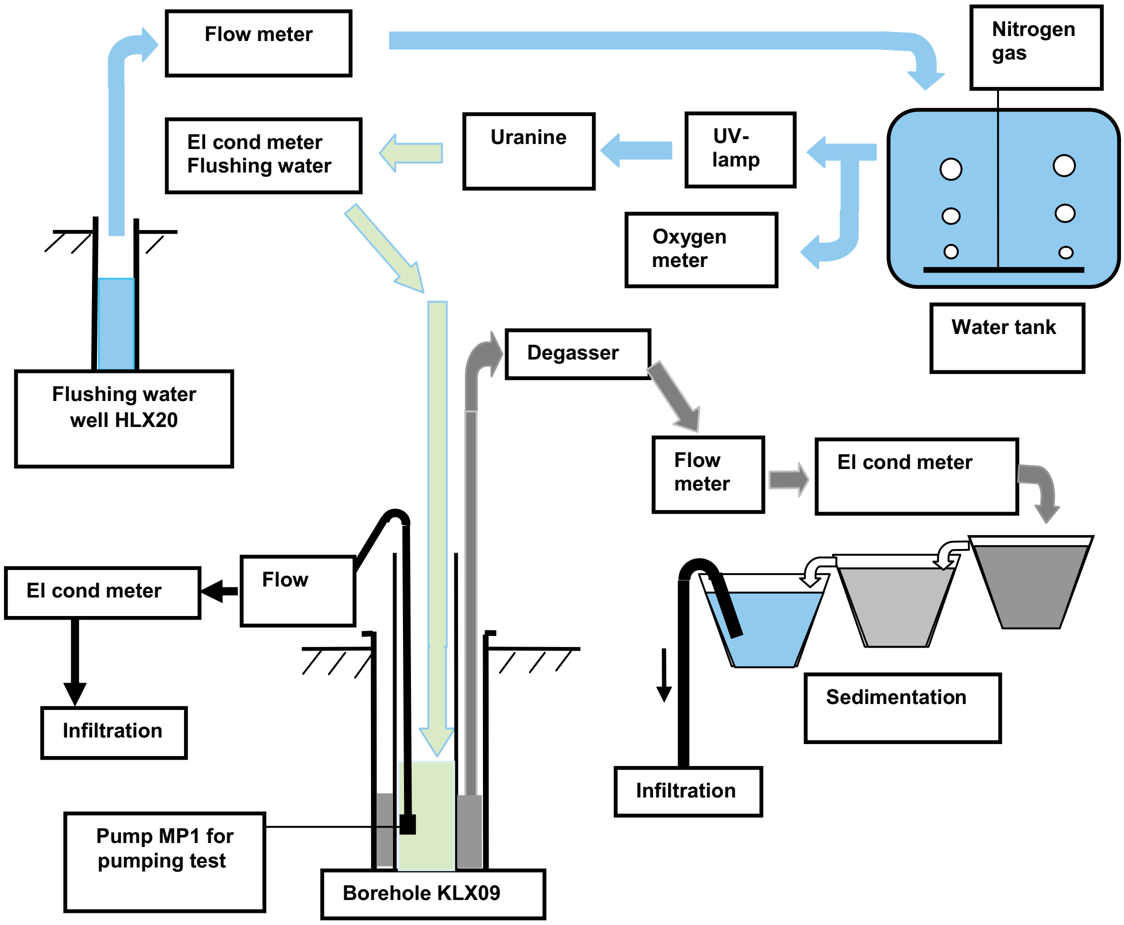


Figure 5-8. The flushing and return water handling and the emplacement of related monitoring equipment in KLX09

The targeted content for uranine in the flushing water was 0.20 mg/L and the actual average uranine content was 0.193 mg/L, see also Figure 5-12 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 KLX09

Core drilling with T-86 equipment giving an 86 mm diameter hole was done from 100.60 to 101.05 m in KLX09. The part from 101.05 to 102.00 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 101.05 m to the final length of 880.38 m in KLX09. After core drilling was completed, reaming and borehole wall stabilization was done with the PLEX method around 755 to 760 m.

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 KLX09.

Table 5-5. Core diameters, borehole diameters and drilling dimensions during core drilling in KLX09.

Core diameter (mm)	Borehole diameter* (mm)	Interval (m drilled length)	Drilling dimension	Comment
72.0	86	100.33–101.05	T-86	
50.2	86	101.05–102.00	N and T-86	Reamed to 86 mm diameter
50.2	76	102.00–755.75	N	
50.2	82	755.75–757.95	N	PLEX-tube installed between 755.75 and 757.95 m
50.2	76	757.95–758.70	N	
50.2	82	758.70–760.95	N	Reamed between 758.70 m and 760.95 m
50.2	76	760.95–880.38	N	

* reaming of depth reference slots also increases the borehole diameter, see Section 5.3.4.

The PLEX method is schematically described in Figure 5-9 and consists of:

- Lowering of the PLEX tool to the section to be stabilised.
- Extruding the reaming cutters with water pressure and gently reaming the problematic section.
- Expanding the rubber packer with water pressure and thereby forcing the perforated roll of steel plate into contact with the borehole wall.
- When the water pressure is removed the PLEX tool can be retracted.

The borehole wall is stabilised but retains permeability for water flow and hence it is possible to do hydrogeological tests.

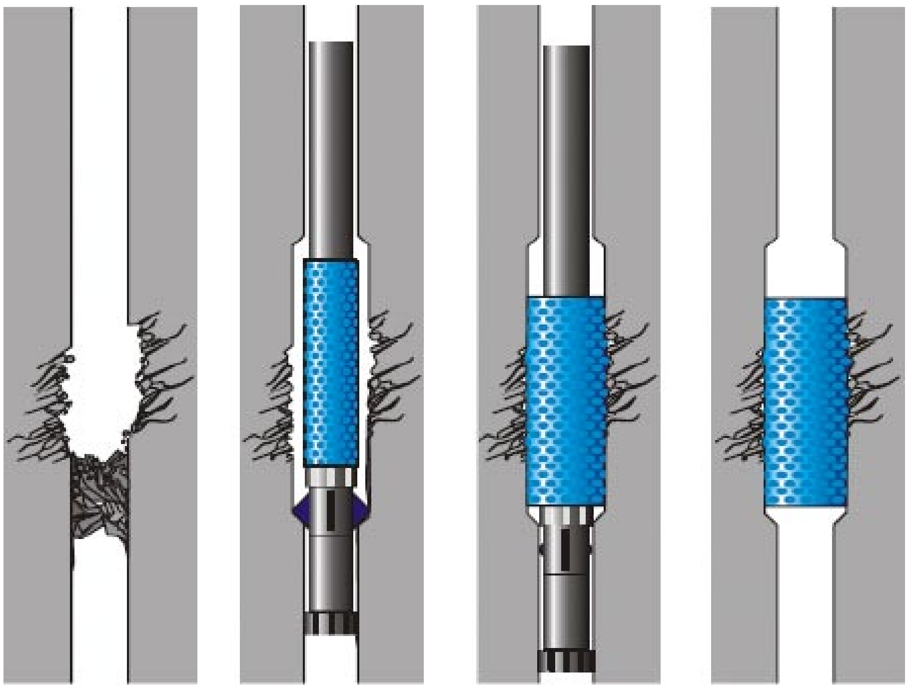


Figure 5-9. *Schematic description of the PLEX method.*

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 core drilling progress was followed by deviation measurements with the EZ-shot method four times along the core drilled section of the borehole. 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 the Flexit and Maxibor methods for the final evaluation of the borehole deviation in KLX09. The Maxibor and the Flexit measurements were done as part of the drilling activity. The Flexit tool was run both up and down the borehole from 0 to 876 metres. The Flexit readings for bearing were only used in intervals where the magnetic disturbances from installations in the borehole (casings, steel conical guide etc) were deemed to be minimal. Flexit data was used to calculate dip from 3 to 876 m. In addition, measurements with the Maxibor instrument were performed both up and down the hole between 0 and 876 metres, however only measurements from 117 m and down were used for calculation of borehole bearing due to disturbances in the supportive casing.

The final deviation file in KLX09 is calculated based on the measurements given in Table 5-6 together with the surveyed bearing and inclination of the top-of-casing. The calculations are 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 /3/. 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 13144267 (activity type code EG154).

Horizontal and vertical plots of the results of the calculated deviation covering the entire length of borehole KLX09 are given in Appendix 4.

Core losses were noted during the Boremap mapping, see Section 5.6, at the intervals given in Table 5-7.

A total of nine drill bits were used for KLX09, see Figure 5-10.

Table 5-6. Measurements used for borehole deviation calculation in KLX09.

Deviation measurement method	Used for calculation of bearing/ inclination	Interval From (m)	Interval To (m)	Measuring direction	Date	Sicada database activity ID
Maxibor	BEARING	117.00	876.00	down/in	2005-10-24	13094370
Maxibor	BEARING	117.00	876.00	up/out	2005-10-24	13139118
Flexit	BEARING	117.00	876.00	down/in	2005-10-26	13139120
Flexit	INCLINATION	3.00	876.00	down/in	2005-10-26	13139120
Flexit	BEARING	117.00	876.00	up/out	2005-10-26	13116290
Flexit	INCLINATION	3.00	876.00	up/out	2005-10-26	13116290

Table 5-7. Core losses noted in KLX09.

From (m)	To (m)	Core loss length (m)	Comment
291.77	292.24	0.47	Missing Core Piece
538.59	539.14	0.55	Missing Core Piece
540.69	540.78	0.09	Missing Core Piece
756.00	756.20	0.20	Missing Core Piece

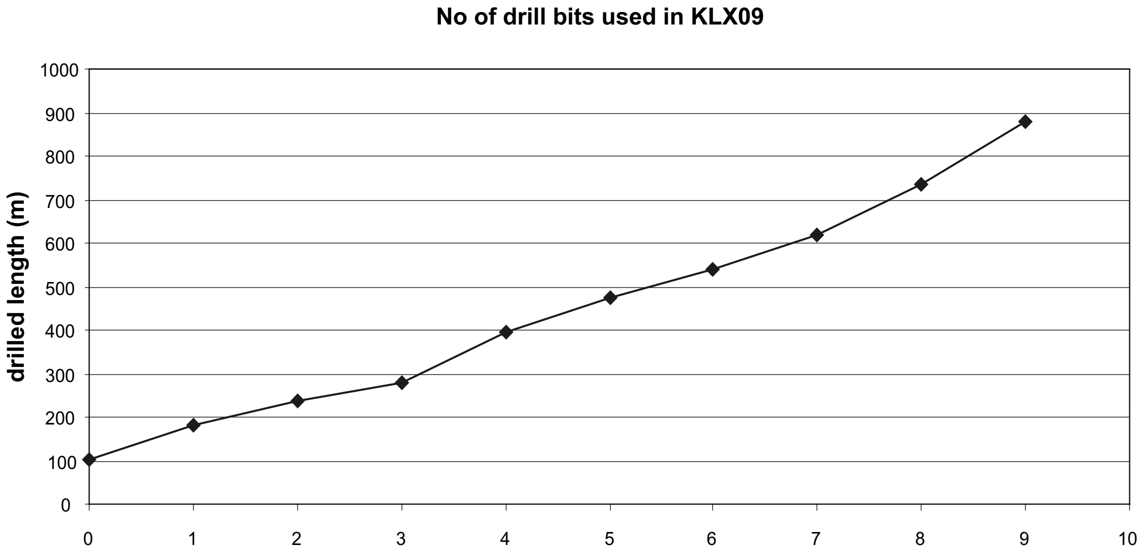


Figure 5-10. *Drill bit changes during core drilling in KLX09.*

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.

5.3.4 Borehole wall risk assessment, stabilisation and completion

Borehole wall risk assessment and stabilisation

A borehole wall assessment was prepared on November 15, 2005, SKB id no 1046547, SKB internal document.

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

- Core losses were noted during drilling at 538.7 and 755.8 m length. Core drilling ended at length 880.38 m.
- The steel dummy got stuck at borehole length 755 m. A section between 754 and 758 was steel brushed and flushed with water. The brush was subsequently lowered to the bottom of the borehole.
- Logging with the BIPS instrument was done from 101.5 to 880 m.
- 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. The flush and brush tool is shown in Figure 5-11.
- Milling and verifying indications for reference grooves between 110 and 850 m.
- Relogging with BIPS from 650 m to 800 m.
- Deviation measurements with the Maxibor and Flexit methods.
- Reaming of two sections 755.70–757.95 and 758.70–760.95 m length for planned PLEX tubing. The lower of the two sections was reamed in the wrong section.
- Emplacement of PLEX tube between 755.75 and 757.70 m length.
- The steel dummy was lowered to 880 m.
- Nitrogen gas lifting for clearing the borehole of cuttings and water was done. Approximately 24 m^3 of water was removed.

The overall assessment was that the probability for rock fallout was low 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)
105	107
116	118
119	120
148	149
161	163
280	281
290	293
297	298
322	323
399	401
494	496
527	529
533	534
536	544
689	696
711	713
716	717
720	721
754	758

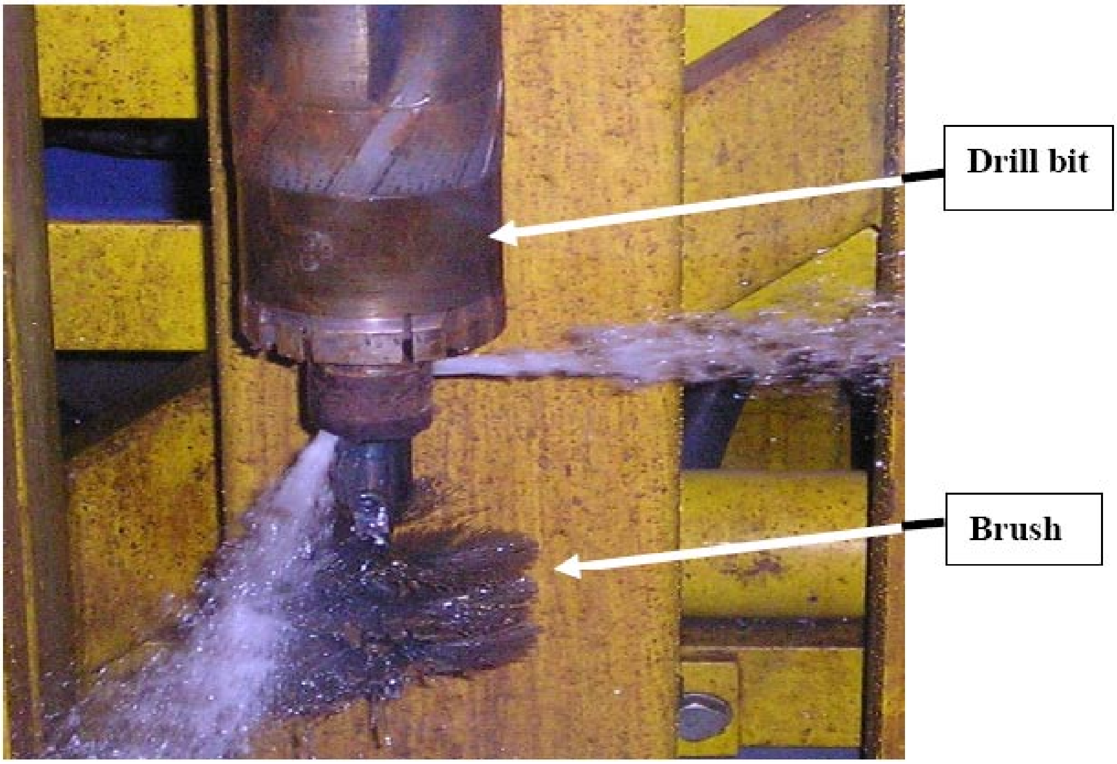


Figure 5-11. *The water flushing and rotating steel brush tool. The tool is lowered into the drill stem and can be seen in place just below the drill bit. During operating the drill string is moved up and down to remove loose rock fragments from the borehole wall.*

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 101.05 to 102.00 with T-86 equipment. A steel conical guide was installed in KLX09 between 97.33 m and 102.00 m. The conical guide tapers from an inner diameter of 195 mm to 77 mm.

The length of the holes was rinsed by flushing (lifting) with nitrogen gas at times given in Table 5-10.

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.

5.4 Hydrogeological and hydrochemical measurements and results 100.6–880.38 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 pumping tests were conducted at various intervals in the core drilled section, see Section 5.4.1.
- Seven measurements for absolute pressure, see Section 5.4.1.
- Eight water samples were taken, see Section 5.4.2.

Table 5-9. Depth reference slots (m) in KLX09.

110.00	500.00
150.00	550.00
200.00	600.00
250.00	650.00
300.00	700.00
350.00	750.00
400.00	800.00
450.00	850

Table 5-10. Nitrogen gas lifting in KLX09 (the time is given in Swedish Normal time, GMT+1).

Date	Time	Interval (m)	Volume removed (m^3)	Comment
051102	18.05	11.95–880.38	10	No data on duration of nitrogen lifting
051103	6.00	11.95–880.38	7	No data on duration of nitrogen lifting
051103	9.00	11.95–880.38	7	No data on duration of nitrogen lifting

Three 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 KLX09 are commented in Section 5.4.4.

5.4.1 Hydrogeological results from wireline measurements

Results from the wireline tests in KLX09 are presented in Table 5-11 and Figure 5-12. The most transmissive section was the uppermost (102.67–183.39 m) and the least transmissive section was the deepest (803.72–880.38 m).

The pumping tests were evaluated with steady-state assumption in accordance with Moye /2/. 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.

A total of nine tests were performed in KLX09 that achieved sufficiently stable conditions for calculating pseudo steady-state transmissivity and hydraulic conductivity.

The plots from all nine 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.

Measurements of the absolute pressure were conducted in seven sections, as specified in Table 5-13 and Figure 5-13. The plots from the pressure measurements are given in Appendix 6.

Table 5-11. Pumping tests with wireline probe in KLX09.

Tested section [m]	Q/s [m²/s]	T_M [m²/s]	Comments
102.67–183.39	$2.2 \cdot 10^{-3}$	$2.8 \cdot 10^{-3}$	Pressure in casing in transient recovery phase prior to pump start, value of h_i is taken from end of recovery phase. Pseudo steady, good data.
182.62–292.13	$2.4 \cdot 10^{-5}$	$3.2 \cdot 10^{-5}$	Test functionally ok, steady state, good data.
			Pressure in casing in transient recovery phase, unaffected of pumping test.
290.72–395.63	$7.7 \cdot 10^{-5}$	$1.0 \cdot 10^{-4}$	Test functionally ok, steady state, good data.
			Pressure in casing in transient recovery phase, unaffected of pumping test.
393.10–505.11	$5.9 \cdot 10^{-5}$	$7.8 \cdot 10^{-5}$	Varying flow during first three hours of test, but test functionally ok, good data, steady state.
504.00–605.20	$8.9 \cdot 10^{-6}$	$1.2 \cdot 10^{-5}$	Stable flow conditions and pseudo steady state are not yet completely reached. Still, the test is considered to be possible to evaluate according to Moye.
			Pressure in casing in transient recovery phase, unaffected of pumping test.
603.00–716.91	$7.1 \cdot 10^{-6}$	$9.4 \cdot 10^{-6}$	Test functionally ok, good data, steady state.
			Pressure in casing in transient recovery phase, unaffected of pumping test.
749.72–757.59	$9.9 \cdot 10^{-6}$	$8.9 \cdot 10^{-6}$	Test functionally ok, pseudo steady state.
			Pressure in casing in transient recovery phase, unaffected of pumping test.
715.22–806.16	$7.1 \cdot 10^{-6}$	$9.2 \cdot 10^{-6}$	Unplanned pump stop after approximately five hours. Pseudo steady state.
803.72–880.38	$1.6 \cdot 10^{-7}$	$2.0 \cdot 10^{-7}$	Pseudo steady state conditions seem to have been achieved. Very noisy flow-rate signal due to operating at or below the lower measurement limit

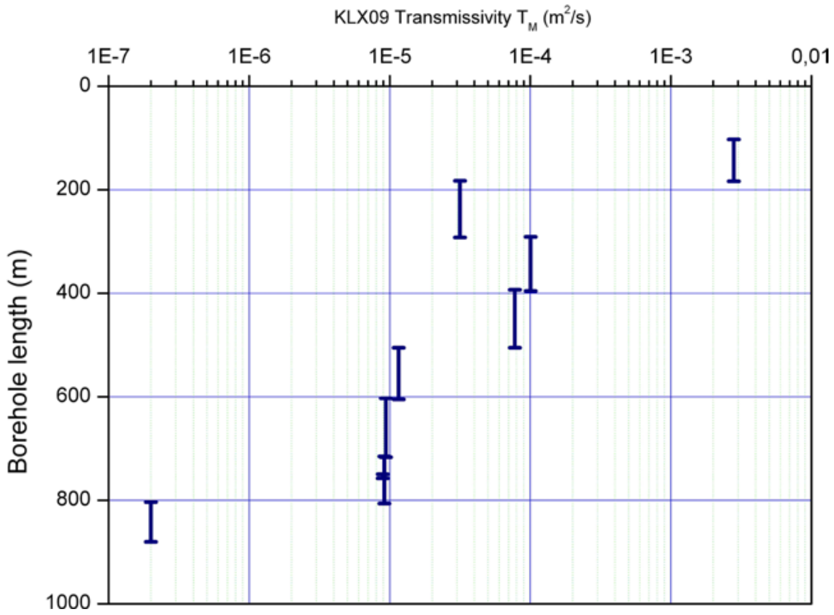


Figure 5-12. *Transmissivity from wireline pumping tests in KLX09 versus borehole length.*

Table 5-12. Evaluated test periods.

Tested section	Start (YYYY-MM-DD HH:MM)*	Stop (YYYY-MM-DD HH:MM)*
102.67–183.39	2005-09-03 17:10	2005-09-04 02:25
182.62–292.13	2005-09-09 17:30	2005-09-10 02:30
290.72–395.63	2005-09-14 17:14	2005-09-15 02:41
393.10–505.11	2005-09-21 17:00	2005-09-22 02:53
504.00–605.20	2005-09-27 16:48	2005-09-28 03:14
603.00–716.91	2005-10-03 16:48	2005-10-04 02:43
749.72–757.59	2005-10-07 16:00	2005-10-08 02:16
715.22–806.16	2005-10-10 17:56	2005-10-10 22:47
803.72–880.38	2005-10-16 10:58	2005-10-16 15:00

* times are given with daylight saving time (GMT+2).

Table 5-13. Absolute pressure measurements in KLX09.

Tested section (m)	Last pressure reading during build-up [kPa]	Duration of pressure build-up [hours]	Borehole length to pressure gauge [m]
102.67–208.10	1,021	12.6	103.77
205.05–297.49	1,987	12.6	206.15
296.72–404.14	2,905	12.5	297.82
402.10–523.54	3,936	12.6	403.20
522.00–619.53	5,103	12.0	523.10
616.72–722.16	6,091	12.9	617.82
719.72–815.17	6,987	13.2	720.82

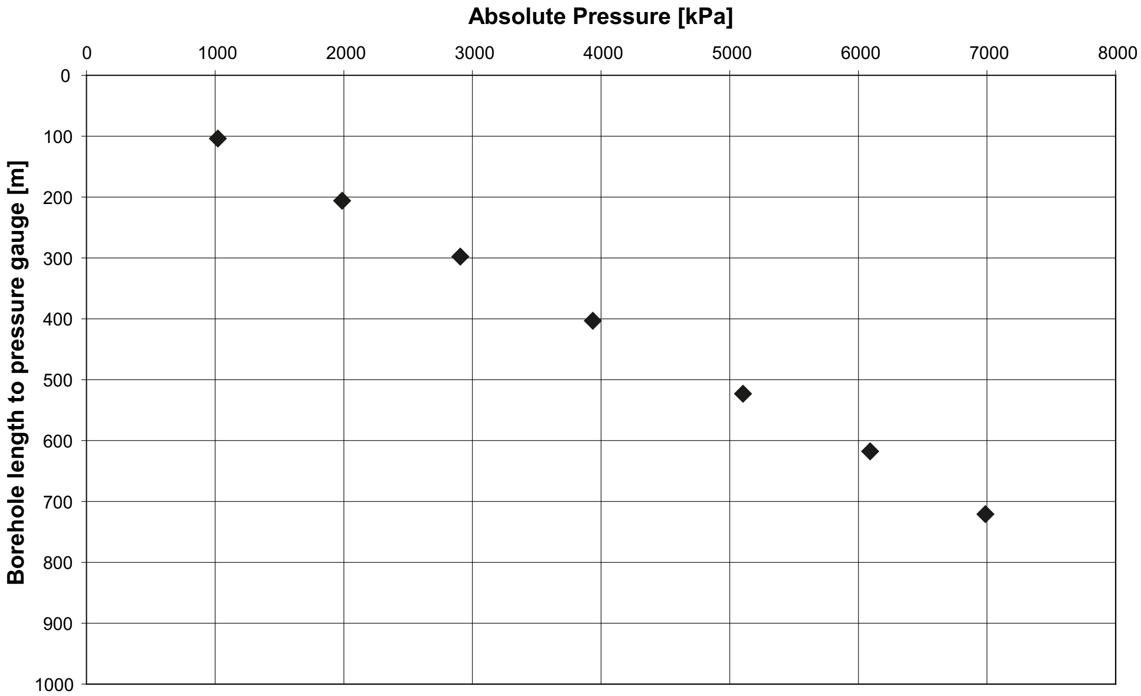


Figure 5-13. Absolute pressure measurements from wireline tests in KLX09 versus borehole length.

After packer inflation the pressure stabilization phase often displays different types of transient effects, both of increasing and decreasing pressure. The reason for these transients is not known, though they might be attributable to previous disturbances in the borehole caused by the drilling operations, such as pressure, salinity, and temperature.

5.4.2 Hydrochemistry

Eight water samples were collected in connection with core drilling in KLX09. Times and lengths for the samples are given in Table 5-14.

Sampling and analysis were performed according to the SKB classes specified in Table 5-14. All samples were collected at the drill site as soon as possible after the sampling occasion and prepared and conserved at the Äspö laboratory. The samples were stored in refrigerator until the drilling of the borehole was completed. At that time it was decided which samples should be sent external laboratories for analyses.

The six samples 10483 through 10536 in Table 5-14 were intended for analysis according to SKB chemistry class 3. Based on the analysis of drill water content a selection of the samples suited for further analysis was made. 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. Sample 10536 was not used for further analysis due to high drill water content in the sample.

Samples 10483 and 10531 were not analysed for isotopes due to high drill water content (10531) and a low prioritised section (10483). Sufficient amounts of water from these samples are stored, frozen or refrigerated, at the Äspö laboratory for possible future isotope analysis.

Samples 10540 and 10541 were collected as class 1 samples and only analysed for uranine i.e. drilling water content.

Archive samples have been collected for all class 3 samples in Table 5-14 except for sample 10536.

Selected analytical results from KLX09 are given in Table 5-15. A complete record of analytical results is given in Appendix 2.

The percussion drilled borehole HLX20 was used as water source during the drilling of KLX09. Samples of total organic content, TOC, have been collected from HLX20 at an earlier occasion and the results are reported in a previous report /4/.

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

Table 5-14. Sample dates and length during core drilling in KLX09.

Sample number	Borehole	Date	Test section length (m)	SKB chemistry class
10483	KLX09	2005-09-04	102.67–183.39	3 (not analysed for isotopes)
10496*	KLX09	2005-09-10	182.62–292.13	3 (and all option isotopes)
10505	KLX09	2005-09-15	290.72–395.63	3 (and all option isotopes)
10526	KLX09	2005-09-22	393.10–505.11	3 (and all option isotopes)
10531*	KLX09	2005-09-28	504.00–605.20	3 (not analysed for isotopes)
10536	KLX09	2005-10-04	603.00–716.91	3 (only analysed for uranine i.e. drill water content)
10540	KLX09	2005-10-08	749.72–757.59	1
10541	KLX09	2005-10-11	715.22–806.16	1

* Br not analysed at the Äspö laboratory due to analytical problems. This only affects samples with <0.2 mg/l Br and <100 mg/l Cl (like samples 10496 and 10531).

Table 5-15. Analytical results from water chemistry sampling.

Borehole	Sample no	Date	From m	To m	Drill water %	pH	Conductivity mS/m	Cl
KLX09	10483	2005-09-04	102.67	183.39	0.62	8.18	48.8	11.4
KLX09	10496	2005-09-10	182.62	292.13	1.06	8.39	113.0	101.0
KLX09	10505	2005-09-15	290.72	395.63	26.10	8.92	50.0	23.9
KLX09	10526	2005-09-22	393.10	505.11	15.40	8.77	74.8	68.3
KLX09	10531	2005-09-28	504.00	605.20	36.30	8.96	102.0	185.0
KLX09	10536	2005-10-04	603.00	716.91	61.20	NA*	NA	NA
KLX09	10540	2005-10-08	749.72	757.59	59.50	NA	NA	NA
KLX09	10541	2005-10-11	715.22	806.16	97.90	NA	NA	NA

*NA - no assay.

Sampling for uranine tracer content and electrical conductivity

From KLX09, a total of 86 samples for uranine content and electrical conductivity in flushing and returning water were taken along the borehole.

The results are shown graphically in Figure 5-14. All the samples were analysed at the Äspö laboratory.

The calculated average uranine content for the whole borehole is 0.193 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.

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

Three air-lift pumping tests were conducted. Two were done during drilling and one was made 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, was calculated according to Moye /2/, as well as the specific capacity, Q / s. The results are shown in Table 5-16 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 5-15, 5-16 and 5-17.

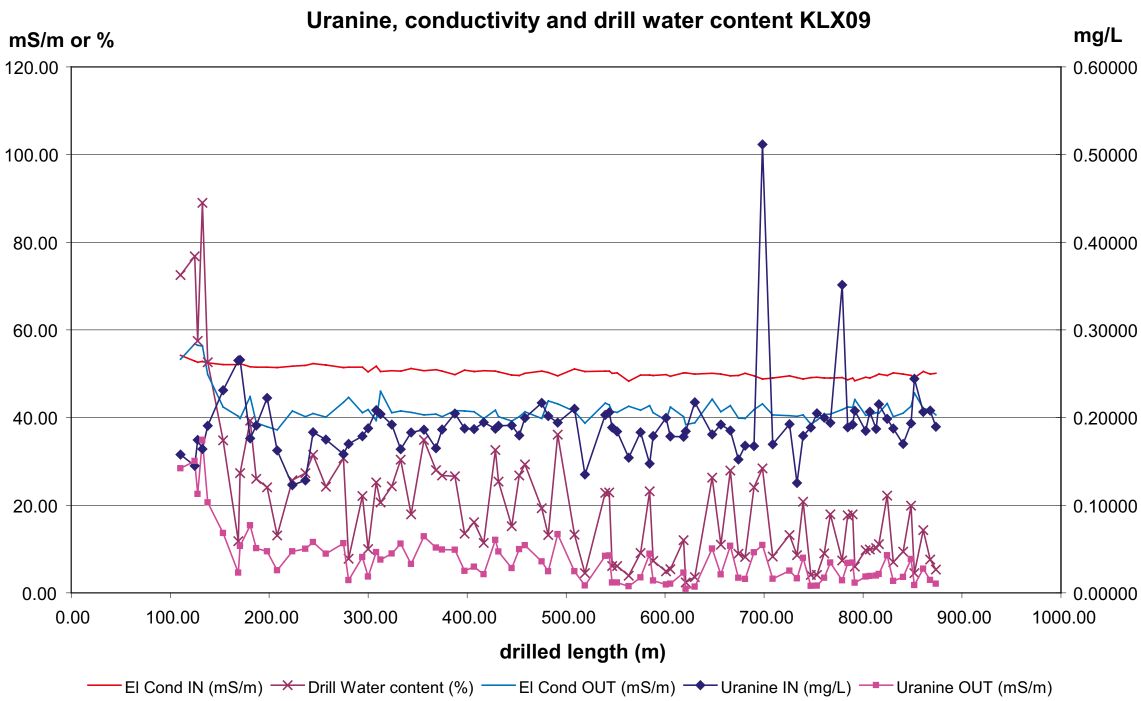


Figure 5-14. *The uranine concentration and electrical conductivity of the flushing water (IN) and the return water (OUT) in KLX09. The drill water content in the returning water is also shown.*

Table 5-16. Results from airlift pumping in KLX09.

Tested section [m]	Flow rate [L/min]	Drawdown [m]	Q/s [m²/s]	T_M [m²/s]	Comments
11.95–475.44	42.8	6.5	$1.1 \cdot 10^{-4}$	$1.7 \cdot 10^{-4}$	Q derives from accumulated volumes of water in and out. Q = ΣV/dt
11.95–736.34	43.9	5.2	$1.4 \cdot 10^{-4}$	$2.3 \cdot 10^{-4}$	Q derives from accumulated volumes of water in and out. Q = ΣV/dt
11.95–880.38	44	4.7	$1.6 \cdot 10^{-4}$	$2.6 \cdot 10^{-4}$	Q derives from accumulated volumes of water in and out. Q = ΣV/dt

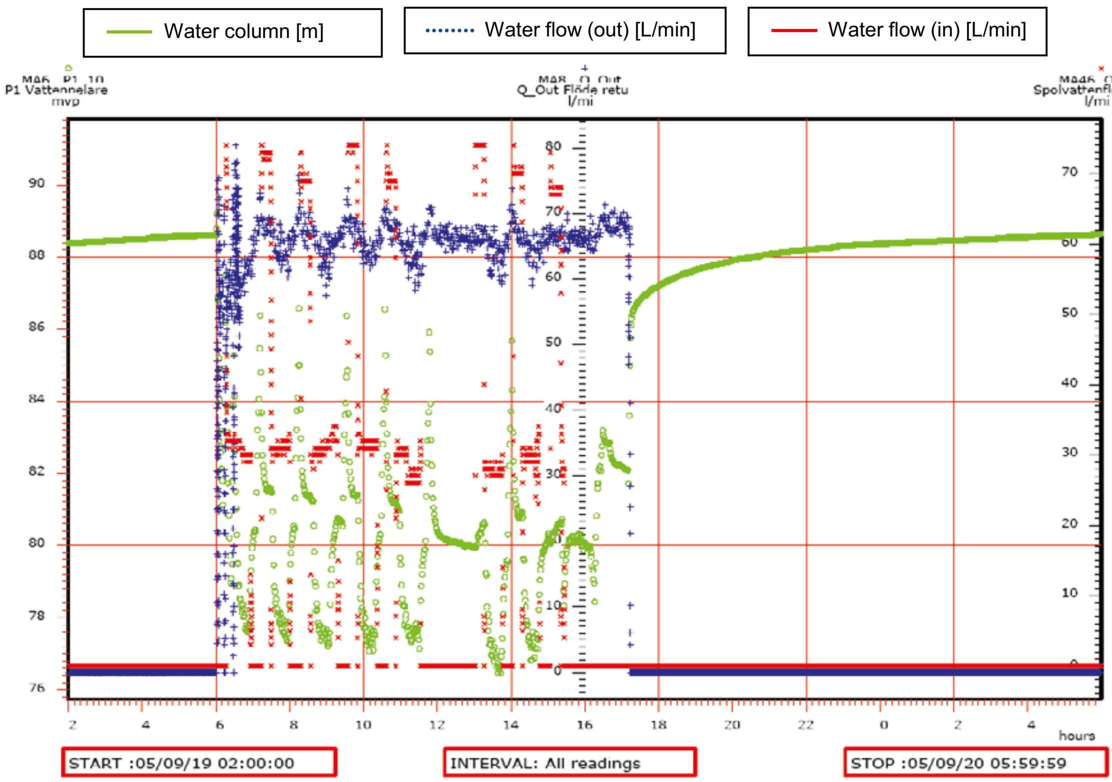


Figure 5-15. *Airlift pumping in KLX09 11.95–475.44 m. The green line represents the height of the water column in the borehole, the out flow is shown as the blue dotted line and the inflow rate as the red line. Times are given in Swedish Normal Time (GMT+1).*

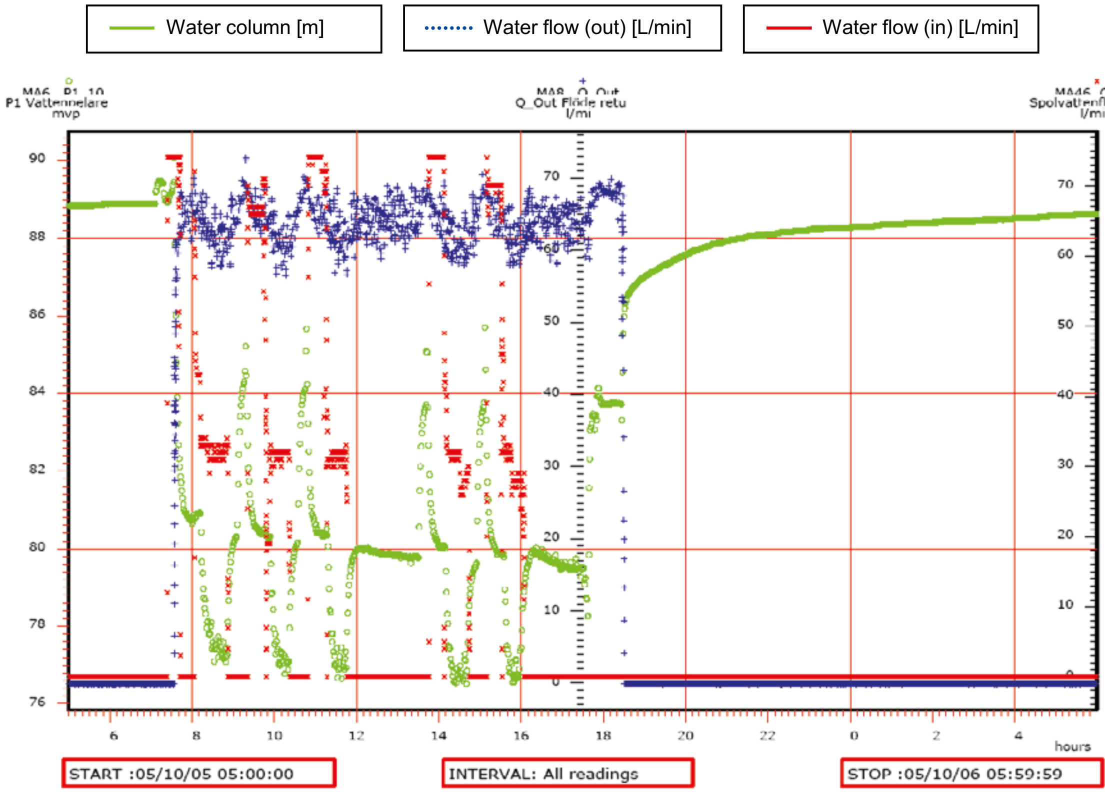


Figure 5-16. *Airlift pumping in KLX09 11.95–736.34 m. The green line represents the height of the water column in the borehole, the out flow is shown as the blue dotted line and the inflow rate as the red line. Times are given in Swedish Normal Time (GMT+1).*

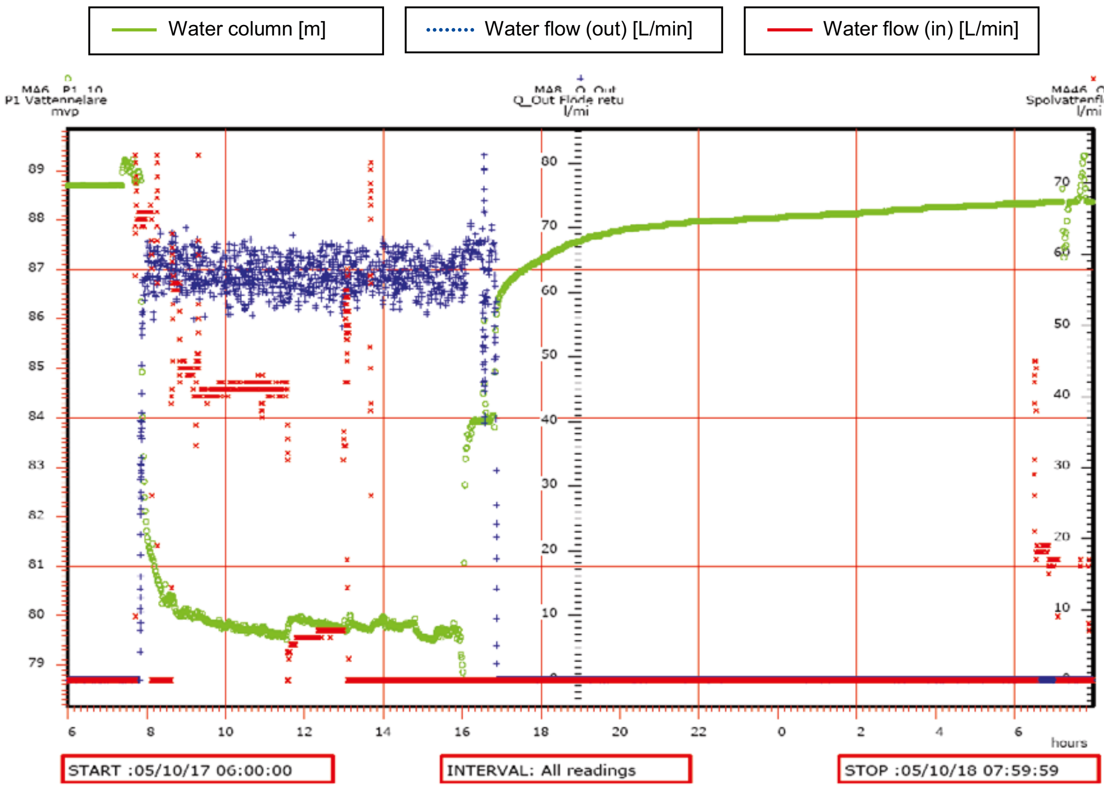


Figure 5-17. *Airlift pumping in KLX09 11.95–880.38 m. The green line represents the height of the water column in the borehole, the out flow is shown as the blue dotted line Times are given in Swedish Normal Time (GMT+1).*

5.4.4 Hydraulic responses in near-by boreholes

Hydraulic responses from drilling activities in a borehole can be created by the drawdown from air-lift pumping during core drilling and from flushing or rinsing the borehole with nitrogen gas (i.e. lifting the water with nitrogen gas). Percussion drilling of the telescopic section also constitutes an air-lift pumping from a hydrogeological point of view.

No correlation between groundwater levels in any of the observation boreholes HLX01, HLX02, HLX06, HLX07, HLX13, HLX14, HLX20, HLX21, HLX22, HLX23, HLX24, HLX25, KLX01, KLX02, KLX04 or KLX06 and the drilling activities (percussion drilling, core drilling or nitrogen gas lifting) in borehole KLX09 could be found. The locations of the boreholes are shown in Figure 5-22.

No data was available from observation borehole HLX04 during the drilling in KLX09. Limitations in the availability of water level data in the observation boreholes are listed in Table 5-17.

Plots showing the water levels in selected observation boreholes together with water levels in the borehole KLX09 and the flushing water well HLX20 are given in Figures 5-18 through 5-21. All times in plots or text in Section 5.4.4 are given in Swedish Normal Time (GMT+1).

Additional comments on hydraulic responses are also given in Section 5.8 under "Monitoring of soil ground water levels".

Table 5-17. Limitations in the availability of water level data in the observation boreholes during drilling of KLX09.

Borehole	Comment on data availability
HLX01	No data before 2005-09-22
HLX02	No data before 2005-10-25
HLX04	No data
HLX06	No data before 2005-09-22
HLX07	No data before 2005-09-24
HLX20	No data after 2005-08-24

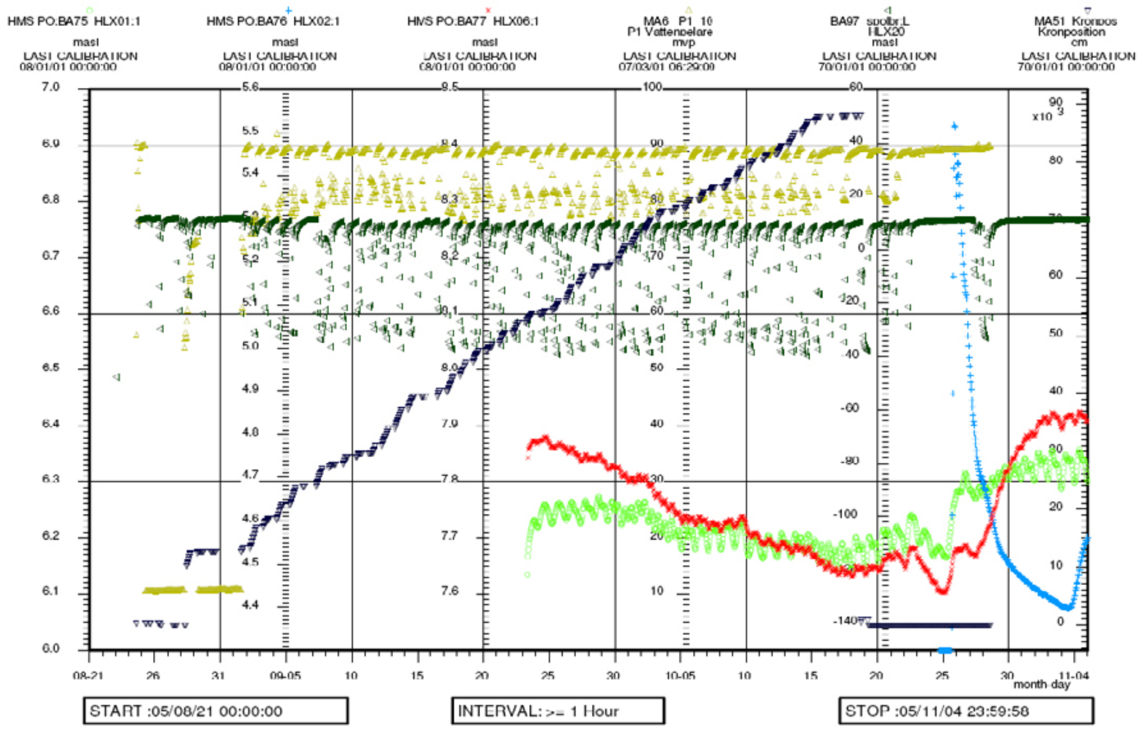


***Figure 5-18.** Groundwater levels in boreholes HLX01, HLX02 and HLX06 together with drilling parameters (pressure in the drilling borehole, position of drill bit and water level in the flushing water well) during the drilling in borehole KLX09 during the period 2005-08-2–2005-11-04. No response from core drilling or nitrogen gas lifting in KLX09 can be seen in HLX01 (light green) or HLX06 (red). No response from nitrogen gas lifting can be seen in HLX02 (blue).*

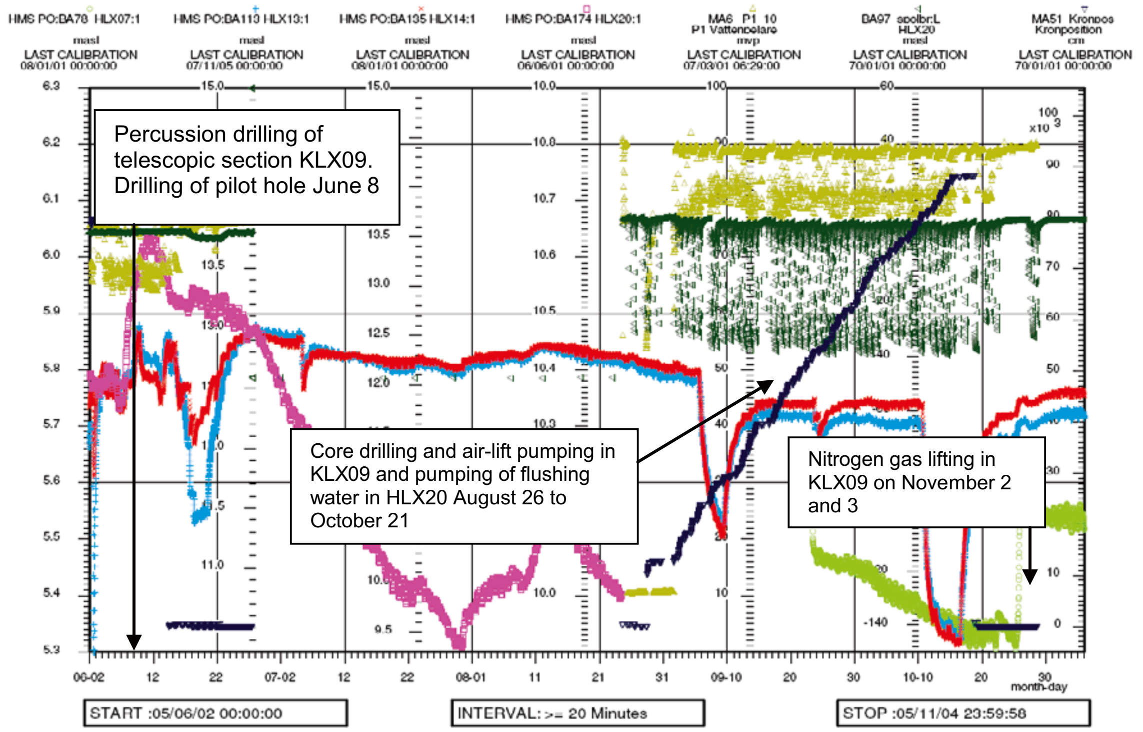


***Figure 5-19.** Groundwater levels in boreholes HLX07, HLX13, HLX14 and HLX20 together with drilling parameters (pressure in the drilling borehole, position of drill bit and water level in the flushing water well) during the drilling in borehole KLX09 during the entire drilling period from 2005-06-02 to 2005-11-04. No response can be seen in HLX07 (light green), HLX13 (blue) or HLX14 (red) from percussion drilling, core drilling or nitrogen gas lifting in KLX09.*

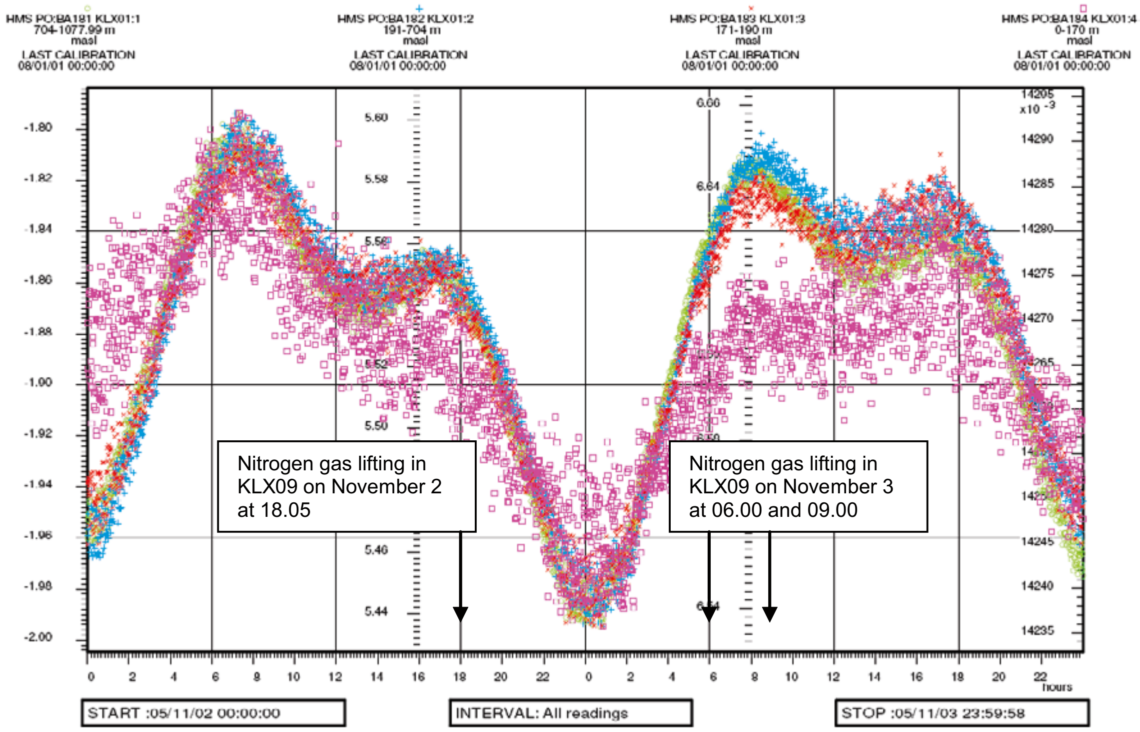


Figure 5-20. *Groundwater levels in borehole KLX01 during the nitrogen lifting in borehole KLX09, 2005-11-02–2005-11-03. No response from the nitrogen gas lifting in KLX09 can be seen in any section of KLX01.*

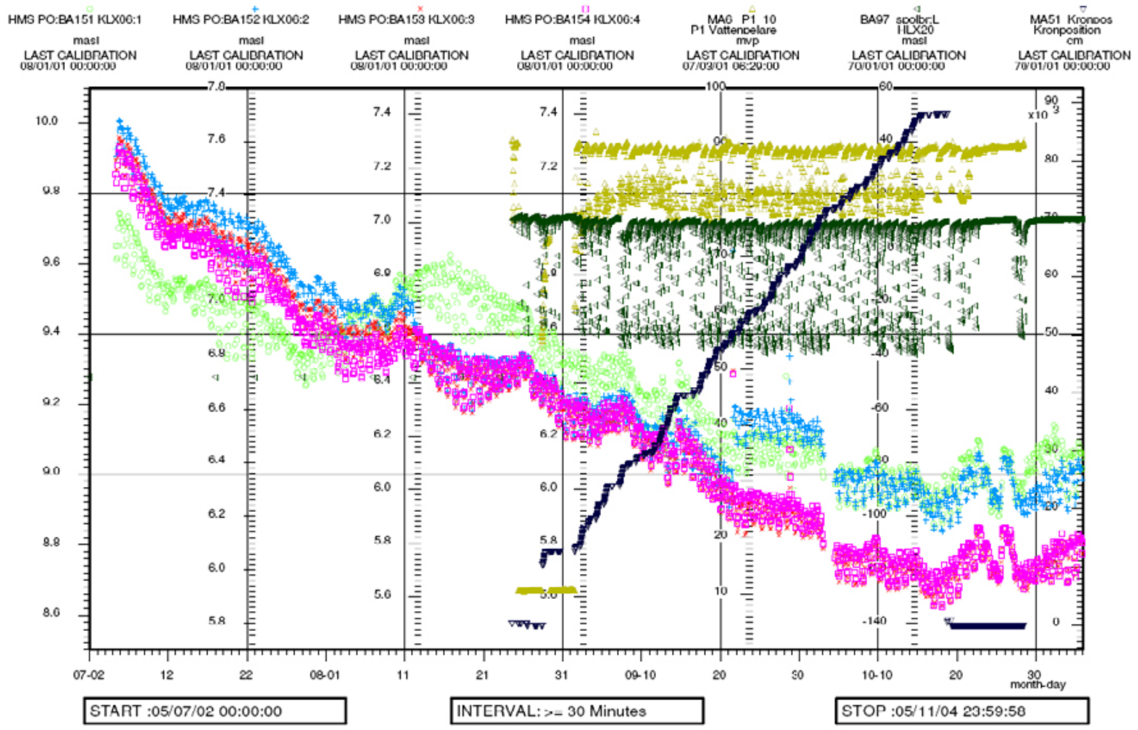


Figure 5-21. *Groundwater levels in borehole KLX06, sections 1–4, together with drilling parameters (pressure in the drilling borehole, position of drill bit and water level in the flushing water well) during the drilling in borehole KLX09 during the period 2005-07-02 to 2005-11-04. No response from core drilling of nitrogen gas lifting in KLX09 can be seen in KLX06.*

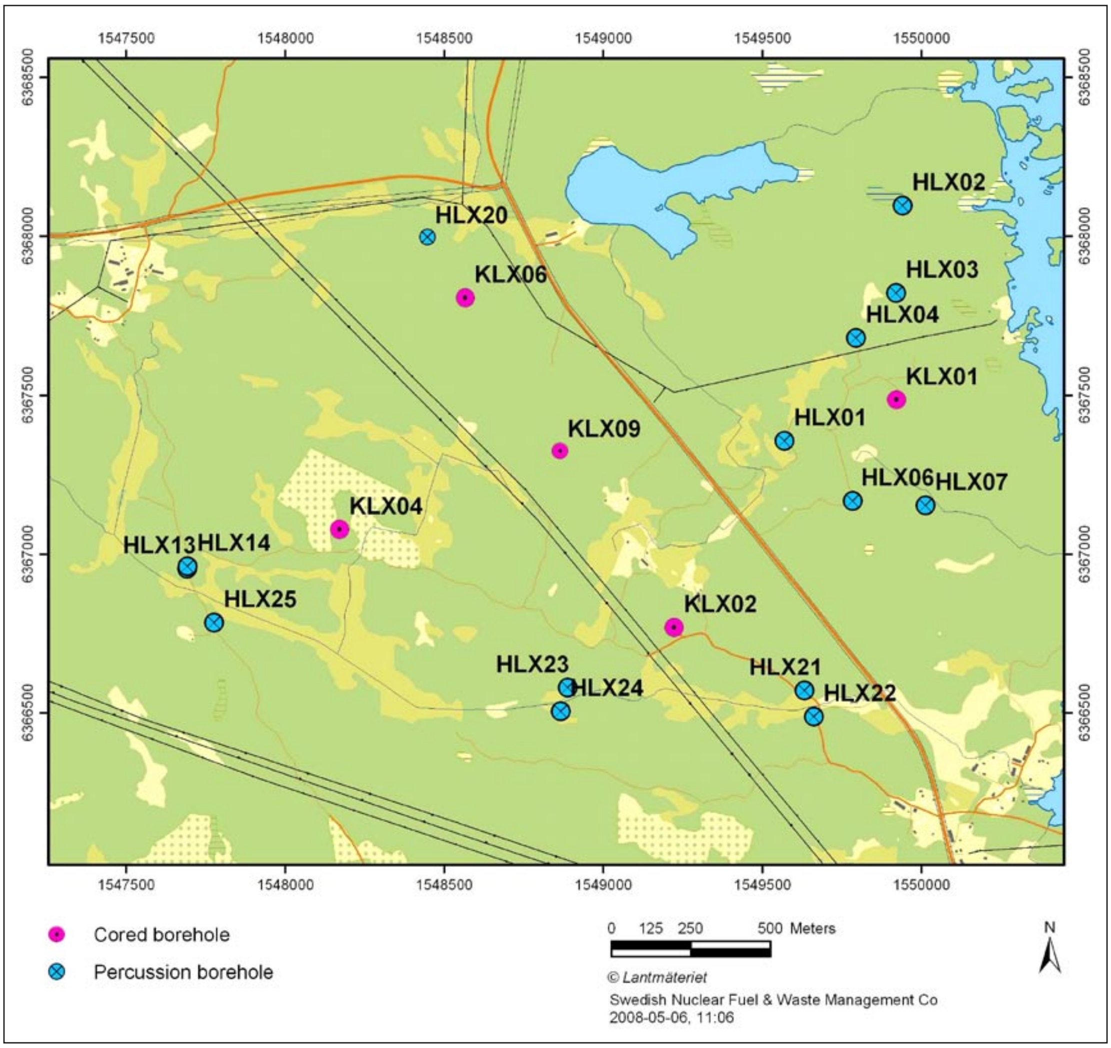


Figure 5-22. *Map showing the location of cored boreholes KLX01, KLX02, KLX04 KLX06 and KLX09 and the percussion boreholes HLX01, HLX02, HLX04, HLX06, HLX07, HLX13, HLX14, HLX20, HLX21, HLX22, HLX23, HLX24 and HLX25.*

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. The two main drilling steps, the telescope section 0–100.60 metres and the core drilling section 100.60–880.38 metres are described in Sections 5.2 and 5.3 respectively.

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 5-23 through 5-25 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.

In order to maintain reasonable size data files, a reduction in the number of points incorporated in the pictures has been done in Figures 5-16 through 5-18. Since DMS data are related to time (i.e. not strictly to borehole length) periods where drilling is not performed are also registered.

Figure 5-23 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 5-24 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 litres/minute corresponding to pumped flow during drilling.
- A flow of ca 70 litres/minute corresponding to the flow while pumping down the core barrel.
- No flow (zero litres/minute) when no drilling is performed.

Figure 5-25 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 (<5 mg/L).

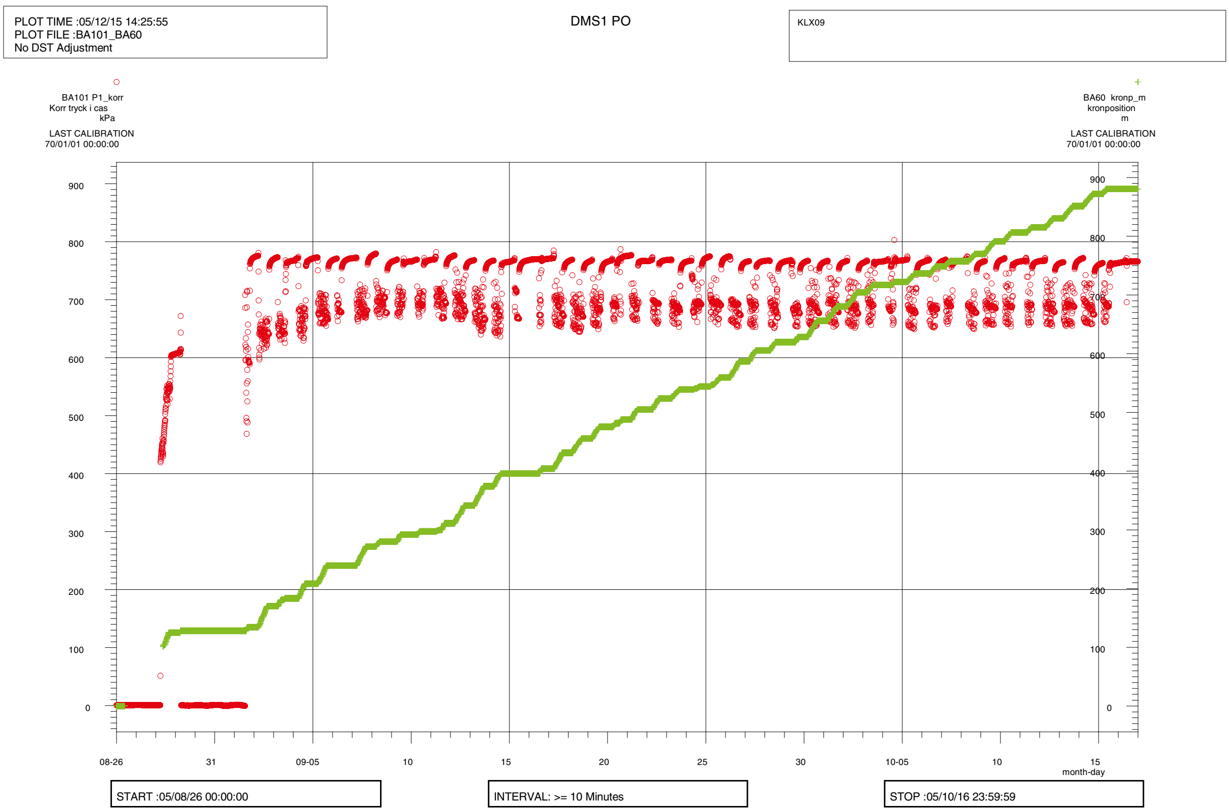


Figure 5-23. *Drill bit position (green) and water level from air-lift pumping (red). The water level is expressed as the pressure in kPa of the water column overlying the pressure gauge i.e. the ambient air-pressure has been subtracted. The pressure gauge is emplaced at 90 metres borehole length.*

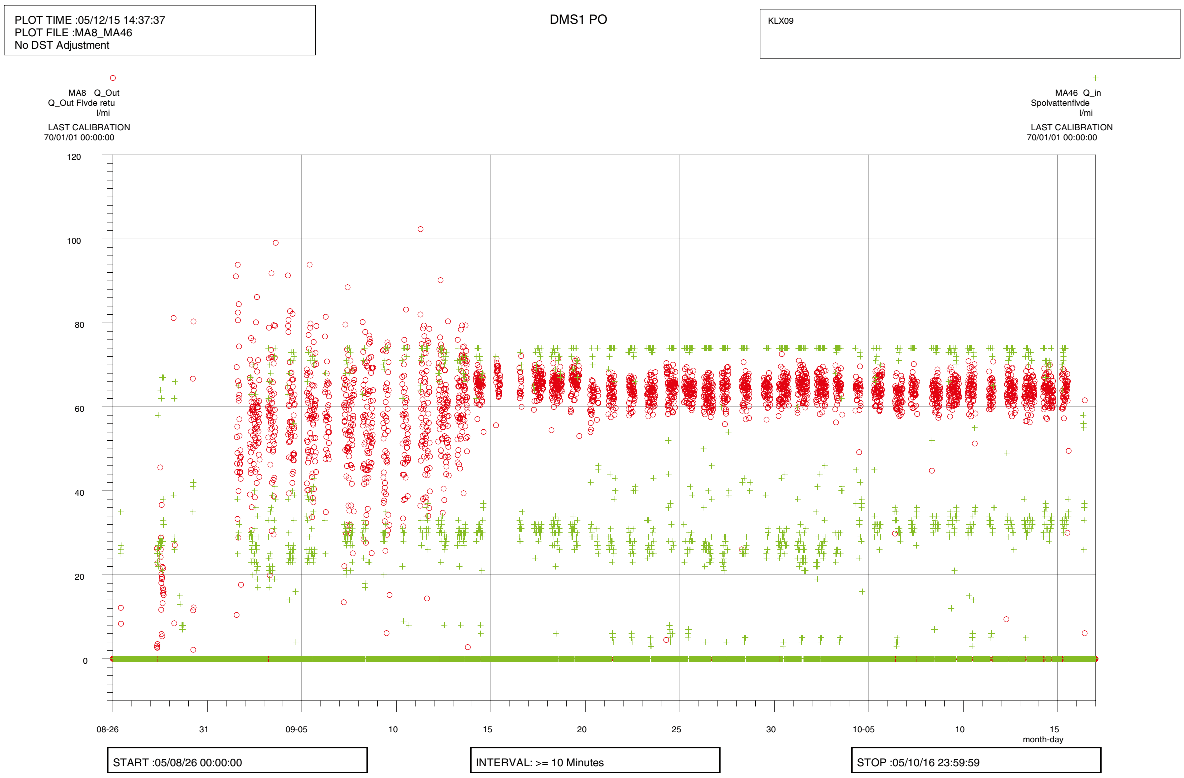


Figure 5-24. *Flushing water flow (green) and return water flow (red) in litres per minute.*

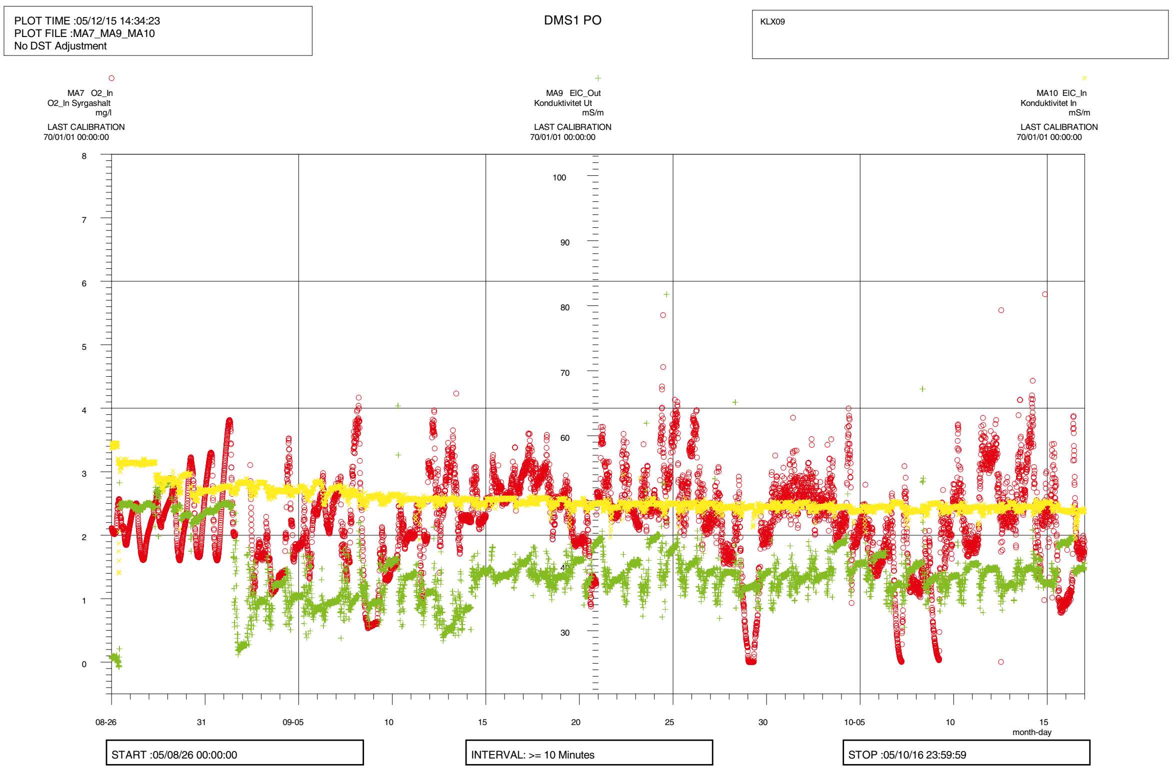


Figure 5-25. *Conductivity of flushing water (yellow) and return water (green). The oxygen content in mg/L of the flushing water (red) is also shown. The oxygen content of the flushing water is low (<5 mg/L). The conductivity of the return water (green) is also low at below 100 mS/m.*

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 5-26.

The amount of flushing water consumed during drilling was 640 m^3, giving an average consumption of ca 0.8 m^3 per metre core drilled. The amount of effluent return water from drilling in KLX09 was measured by the DMS system to 1,720 m^3, giving an average of ca 2.2 m^3 per metre core drilled.

Drill cutting balance

The weight of cuttings in the settling containers amounted to 1,517 kg. The content of suspended material in the return water was not analysed in borehole KLX09, however previous sampling has shown the content to be 400 mg/L /5/. The amount of material in suspension carried with the return water would then amount to 690 kg (based on 1,720 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 780 metres is 5,265 kg assuming a density of 2.7 kg/dm^3.

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 5-18. The results show that almost 53% of the introduced amount uranine was retrieved during drilling of KLX09.

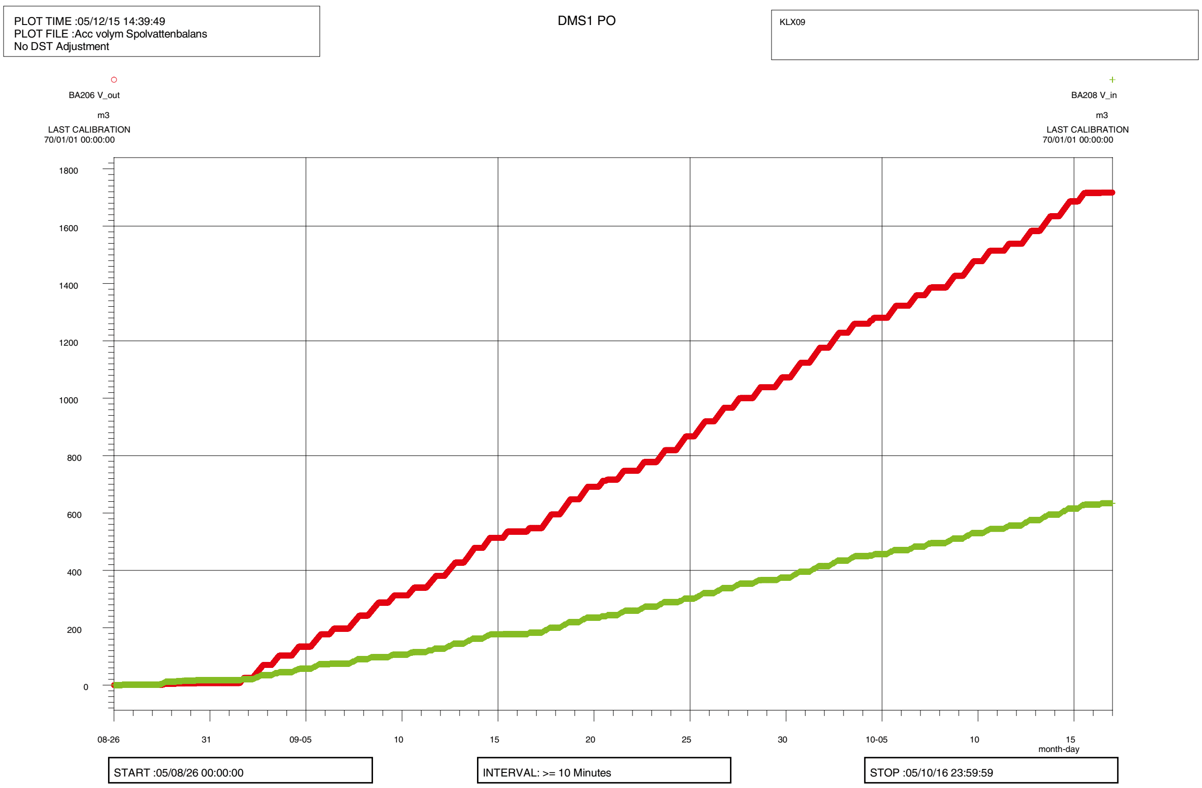


Figure 5-26. *The flushing water balance in KLX09 as recorded by the DMS system. The accumulated volume of the ingoing flushing water is shown in green and the outgoing return water is shown in red.*

Table 5-18. Balance calculation of uranine tracer in KLX09.

Average uranine content IN (mg/L)	0.193
Flushing water volume IN (m^3)	640
Amount uranine introduced (g)	124
Average uranine content OUT (mg/L)	0.038
Return water volume OUT (m^3)	1,720
Amount uranine recovered (g)	65

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 /6/.

Lithologically the core is dominated by Ävrö granite with intercalations of fine-grained diorite-gabbro and fine-grained dioritoid. Very minor portions of pegmatite, diorite-gabbro and fine grained granite were noted in the borehole.

Rock alteration is relatively common below 260 m and consists of mostly faint to weak oxidization (red staining) and saussuritization (alteration of Ca-plagioclase to epidote). Sections with red staining are indicated as "oxidized" in Appendix 1.

The average fracture frequency over the entire core drilled section expressed as open fractures is 2.53 (fractures/metre). The fracture frequency is unevenly distributed with elevated frequencies at 260–320 m, around 440 m, 480–560 m and often below 680 m NB The fracture frequency given in Appendix 1 shows the total fracture frequency (i.e. 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. Water effluent from drilling was 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 SSM000218 and SSM000219 is shown in Figure 5-27. 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

Monitoring of effluent water

The electrical conductivity, as measured by the DMS system, of the return water from the core drilling of KLX09 was typically below 100 mS/m. Samples of the return water that were analysed for electrical conductivity were also all below 100 mS/m, see Figure 5-14.

The uranine content was well below 0.3 mg/L, see Figure 5-14.

The concentration of suspended material was not analysed in the boreholes, however previous sampling had shown that the concentration was well below 600 mg/L /5/.

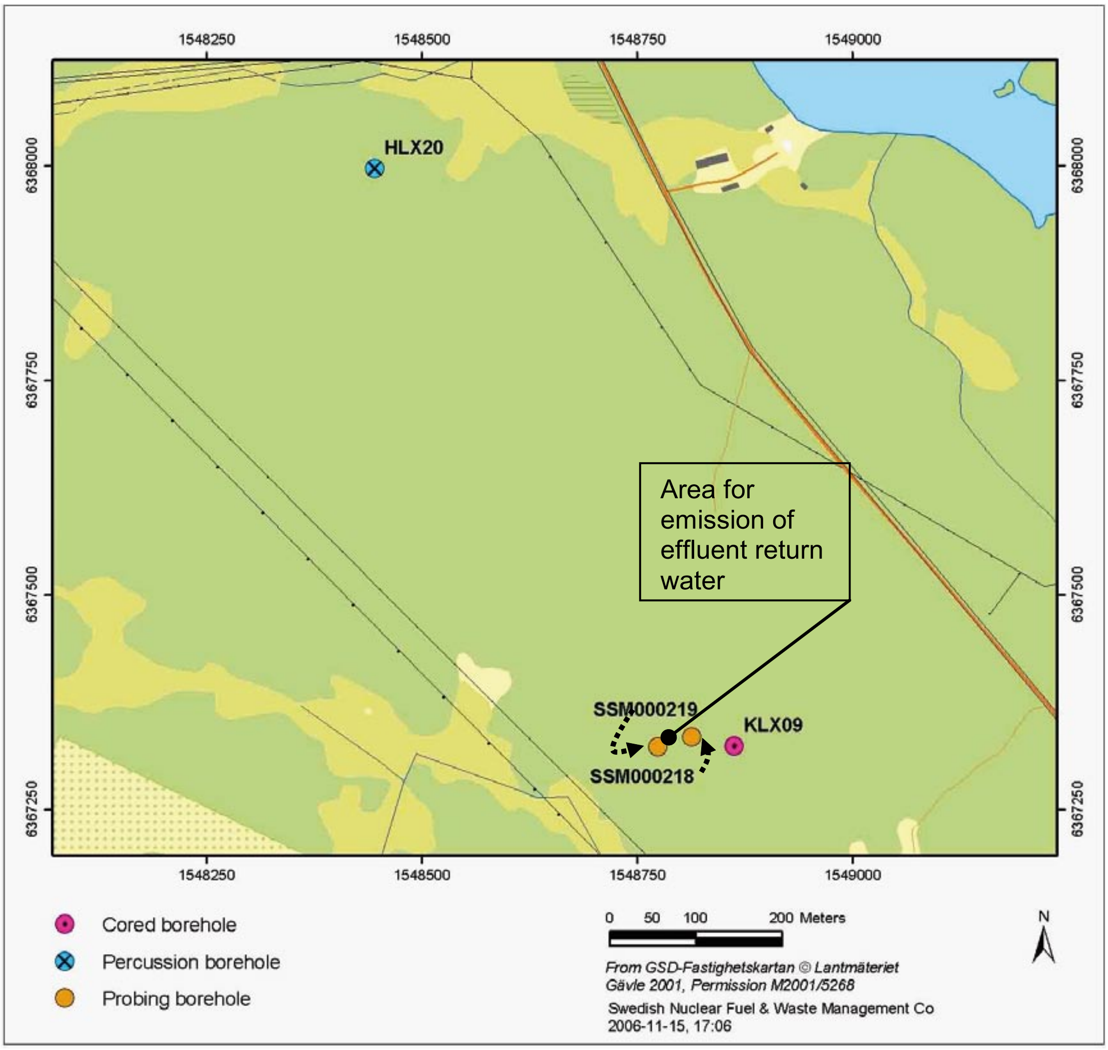


Figure 5-27. *The location of the site for return water emission and the environmental monitoring wells SSM000218 and SSM000219 in relation to the core drill site for KLX09 and the water supply well HLX20.*

To sum up the monitored parameters in the emitted water complied with the prescribed guideline values.

Environmental monitoring wells and reference sampling

Two environmental monitoring wells, SSM000218 and SSM000219, were drilled as part of the core drilling activity for KLX09. The technical specifications including soil classifications are given in Appendix 6. It should be noted that the slotted filter screens are located in sandy till, i.e. permeable soil in both monitoring wells.

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

Pressure loggers (transducers) for measuring the ground water table were installed in SSM000218 and SSM000219 during the core drilling of KLX09. The water tables are given graphically in Figures 5-28 and 5-29. The water table in SSM000219 is probably affected by the emission of return water as a stable increase in the water level can be seen shortly after the core drilling and related water emission started. No influence from the emission of return water from drilling is noted in the water table in SSM000218. This would indicate that the water flow is directed towards the west, which is supportive of the original assumptions for the design of the return water handling and emplacement of environmental monitoring wells.

Table 5-19. Reference samples for environmental monitoring.

Date	Sample No	Comment
2005-05-18	SKB PO 9007	Undisturbed soil sample
2005-06-16	10359	Reference water sample in SSM000218
2005-06-16	10358	Reference water sample in SSM000219

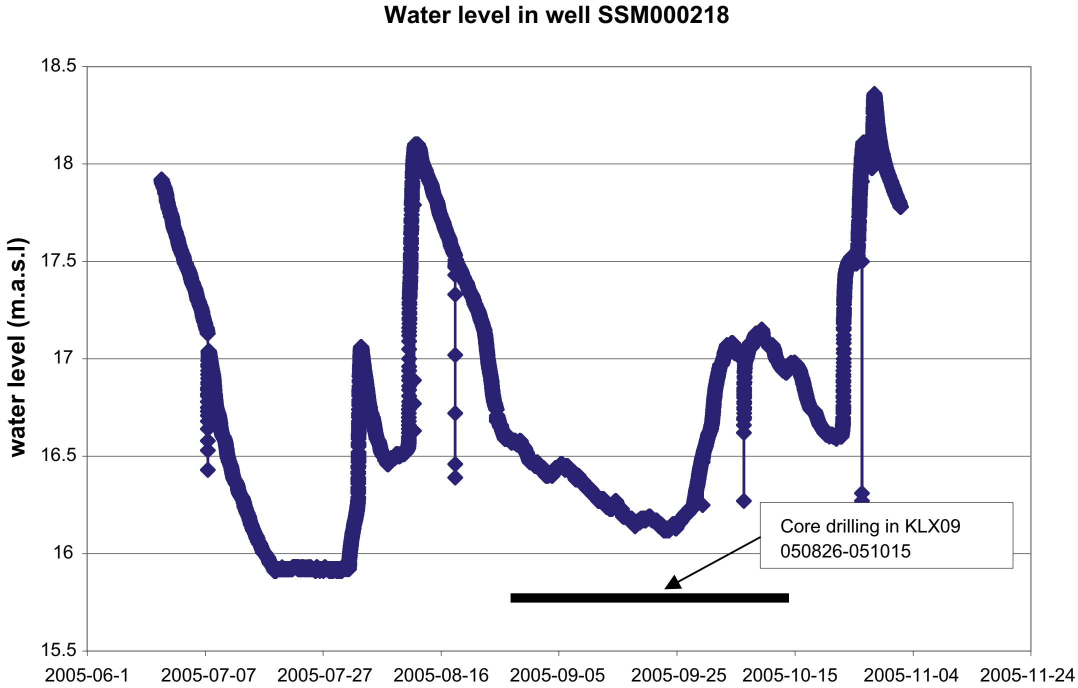


Figure 5-28. The ground water level in well SSM000218. The momentary dips in water levels are related to water sampling. The water level is not affected by emission of drilling return water from KLX09.

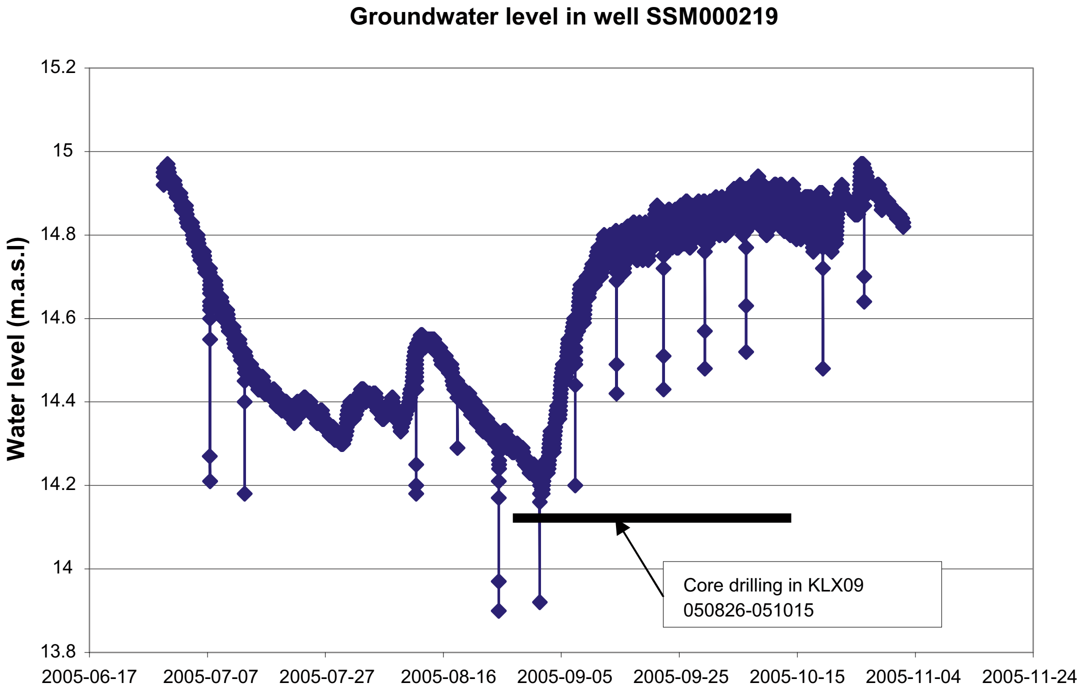


Figure 5-29. *The ground water level in well SSM000219. The momentary dips in water levels are related to water sampling. A steady increase in the water table can be seen from September 1. This is likely a result of infiltration of return water from core drilling in KLX09.*

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 SSM000218 and SSM000219, see Figures 5-30 and 5-31.

No significant change can be seen in the chemistry of the shallow ground water in well SSM000219 from the drilling activity in KLX09. The water chemistry in SSM000218 however seems to be completely untouched by infiltration of drilling return water from KLX09. The increase in electrical conductivity and the low pH coincides with the removal of soil and filling of gravel on the drill site. The changes in water chemistry are not straightforward to explain but could be related to for instance remnants of road salt in the fill material (conductivity) and absence of buffering soil (low pH that is more or less the same as rain water). It is nevertheless clear that the increase in conductivity and decrease in pH is very local as no effect can be seen in the monitoring well SSM000219.

5.8.1 Consumption of oil and chemicals

The consumption of hammer oil (Hydra 46) was 15 litres for the percussion drilling of the telescopic section. No other significant amounts of oils or lubricants were consumed during the drilling.

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

5.9 Nonconformities

One nonconformity report was written by the drilling contractor, Drillcon, for borehole KLX09 concerning malfunction in the air-lift pumping system at the start of core drilling.

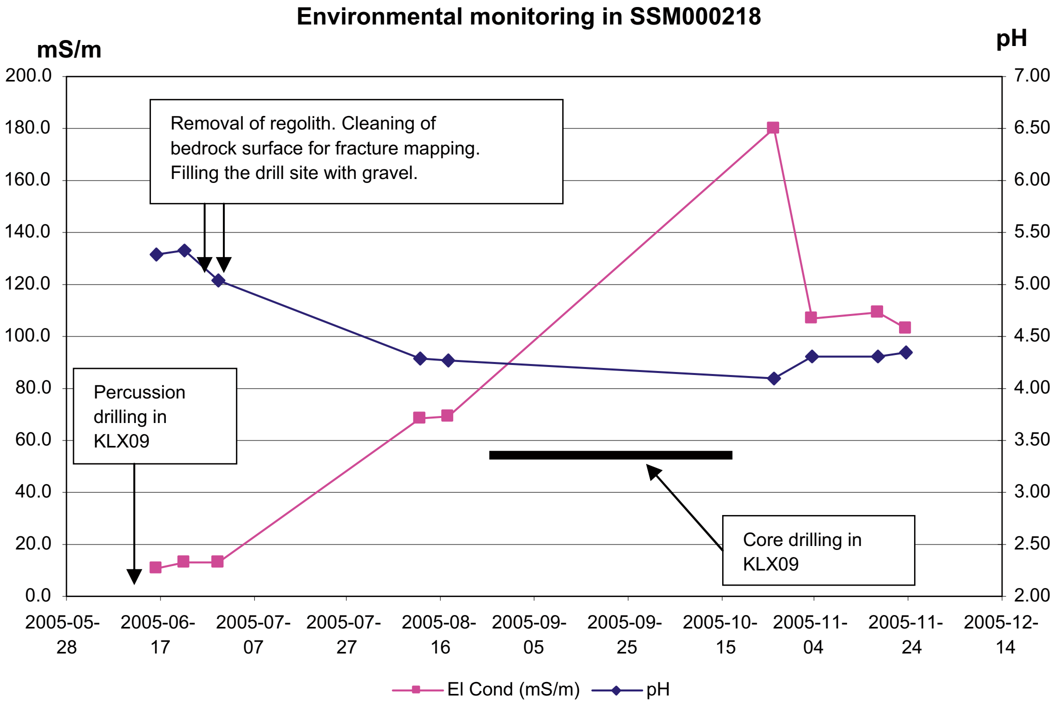


Figure 5-30. Electrical conductivity and pH in ground water samples from SSM000218. The sampling events are shown with blue or purple symbols. The increase in conductivity and coeval reduction in pH are related to the removal of regolith and/or filling up with gravel for the drill site.

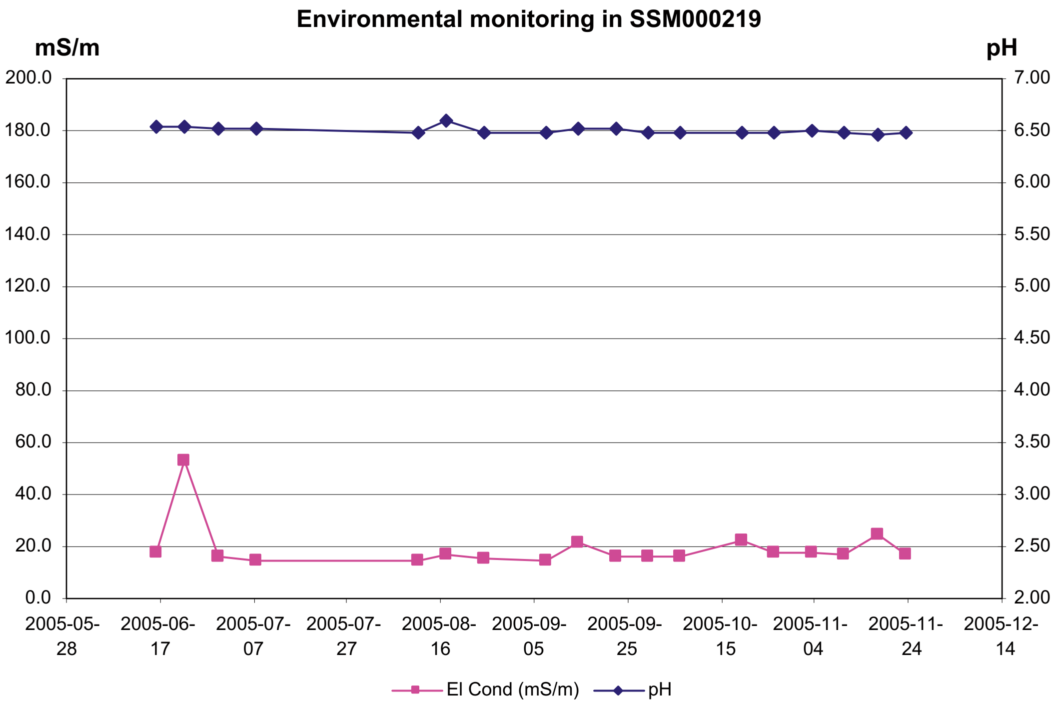


Figure 5-31. Electrical conductivity and pH in ground water samples from SSM000219. The sampling events are shown with blue or purple symbols.

6 References

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

/2/ **Moye D G, 1967.** Diamond drilling for foundation exploration, Civil Eng. Trans. Inst. Eng, Australia.

/3/ **Stenberg L, Håkanson N, 2007.** Revision of borehole deviation measurements in Oskarshamn. SKB P-07-55, Svensk Kärnbränslehantering AB.

/4/ **Ask H, Morosini M, Samuelsson L-E, Ekström L, Håkanson N, 2005.** Drilling of cored borehole KLX06. SKB P-05-234, Svensk Kärnbränslehantering AB.

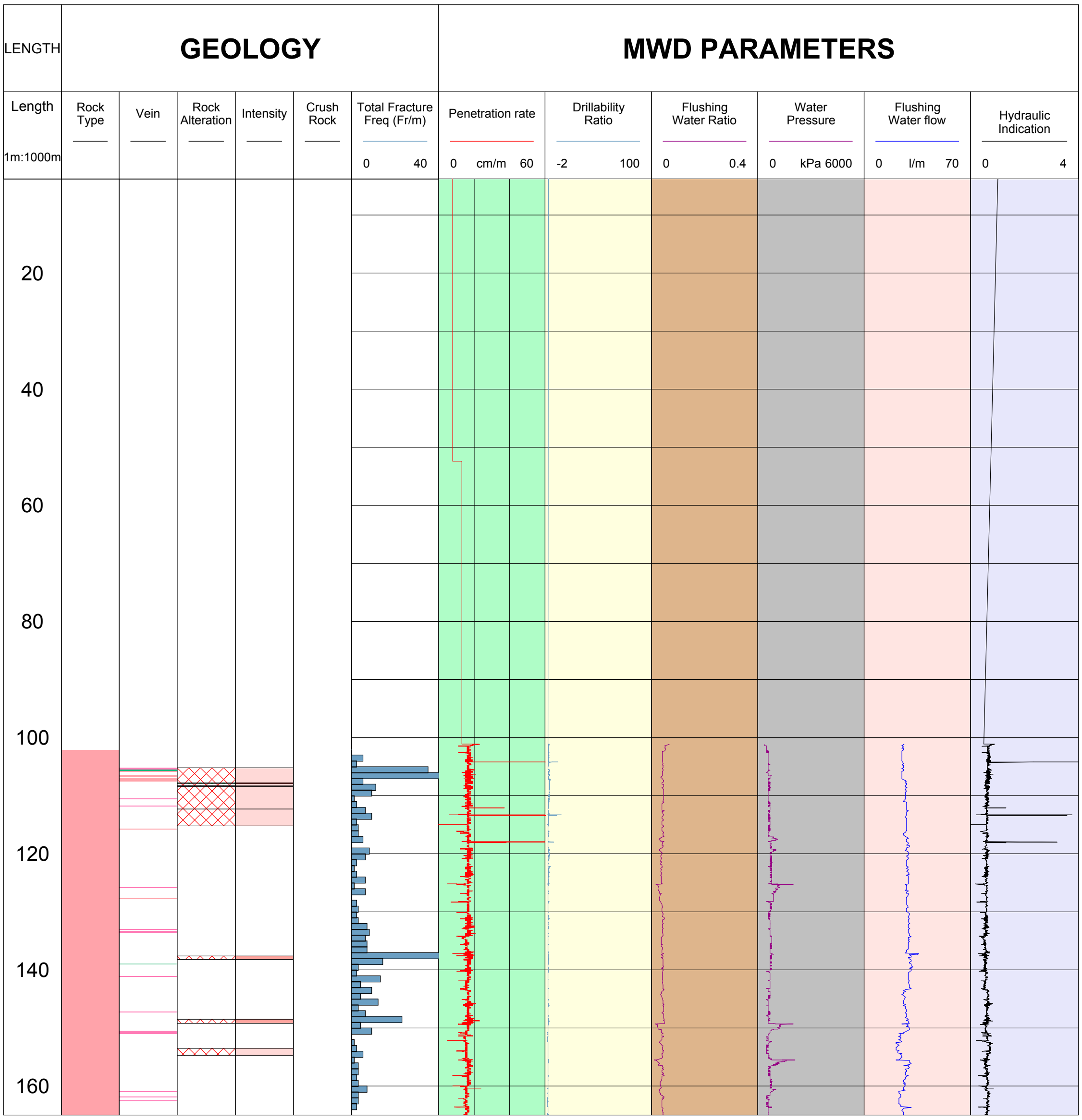
/5/ **Ask H, Morosini M, Samuelsson L-E, Ekström L, Håkanson N, 2004.** Core drilling of KSH03. SKB P-04-233, Svensk Kärnbränslehantering AB.

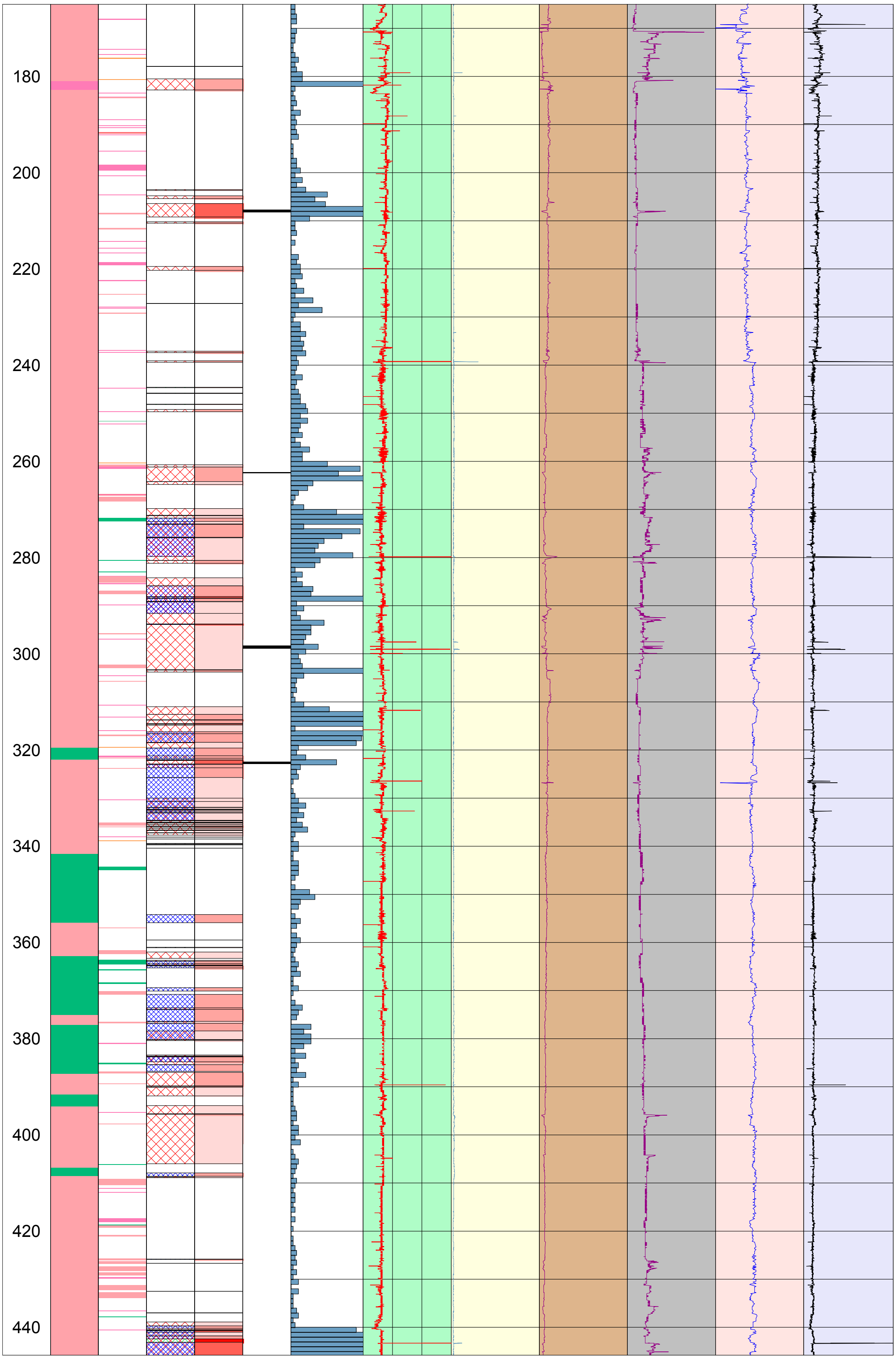
/6/ **Rauséus G, Mattsson K-J**, **Dahlin P, Ehrenborg J, 2007.** Boremap mapping of core drilled borehole KLX09. SKB P-06-240, Svensk Kärnbränslehantering AB.

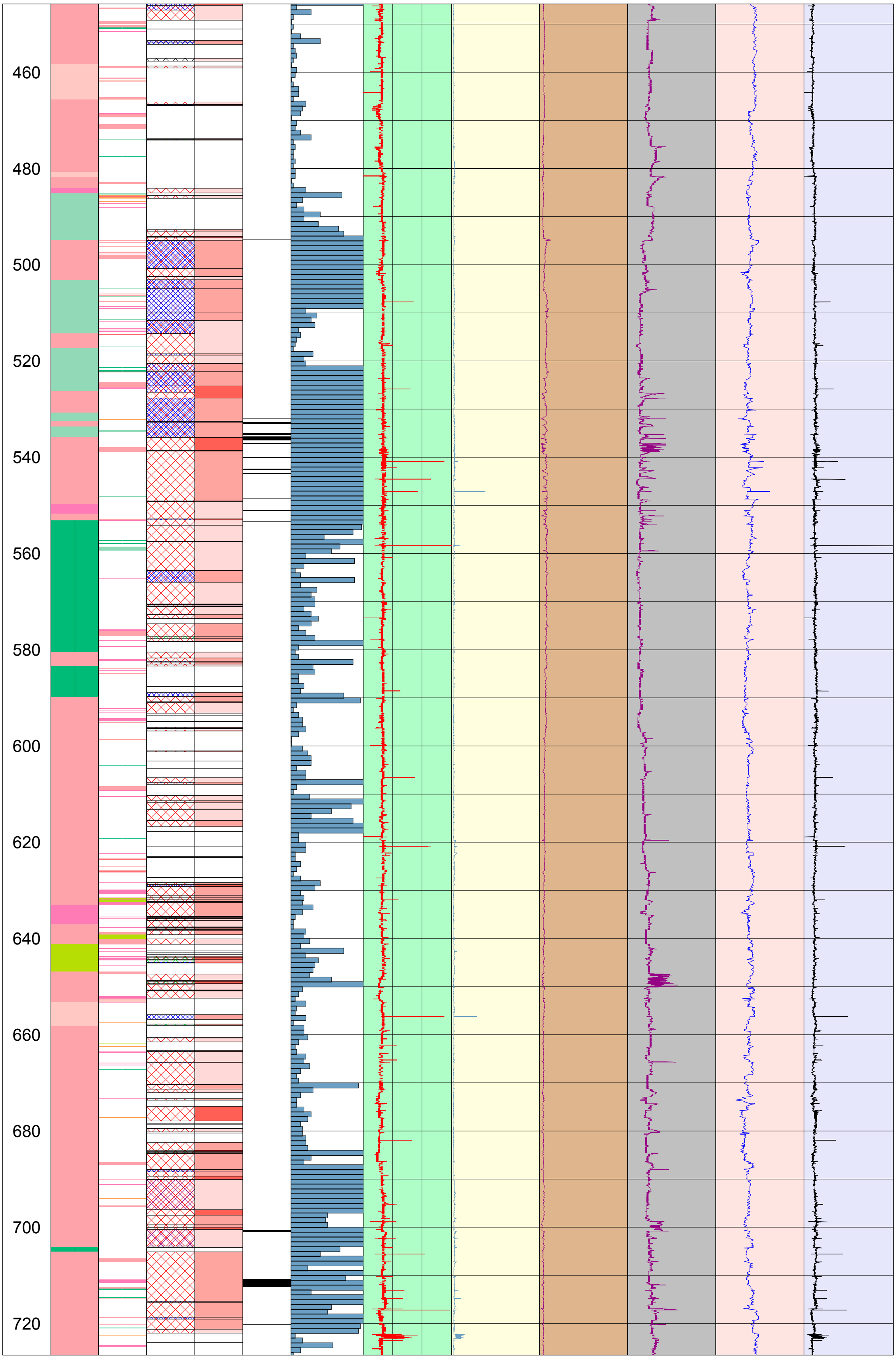
Geology and MWD parameters KLX09

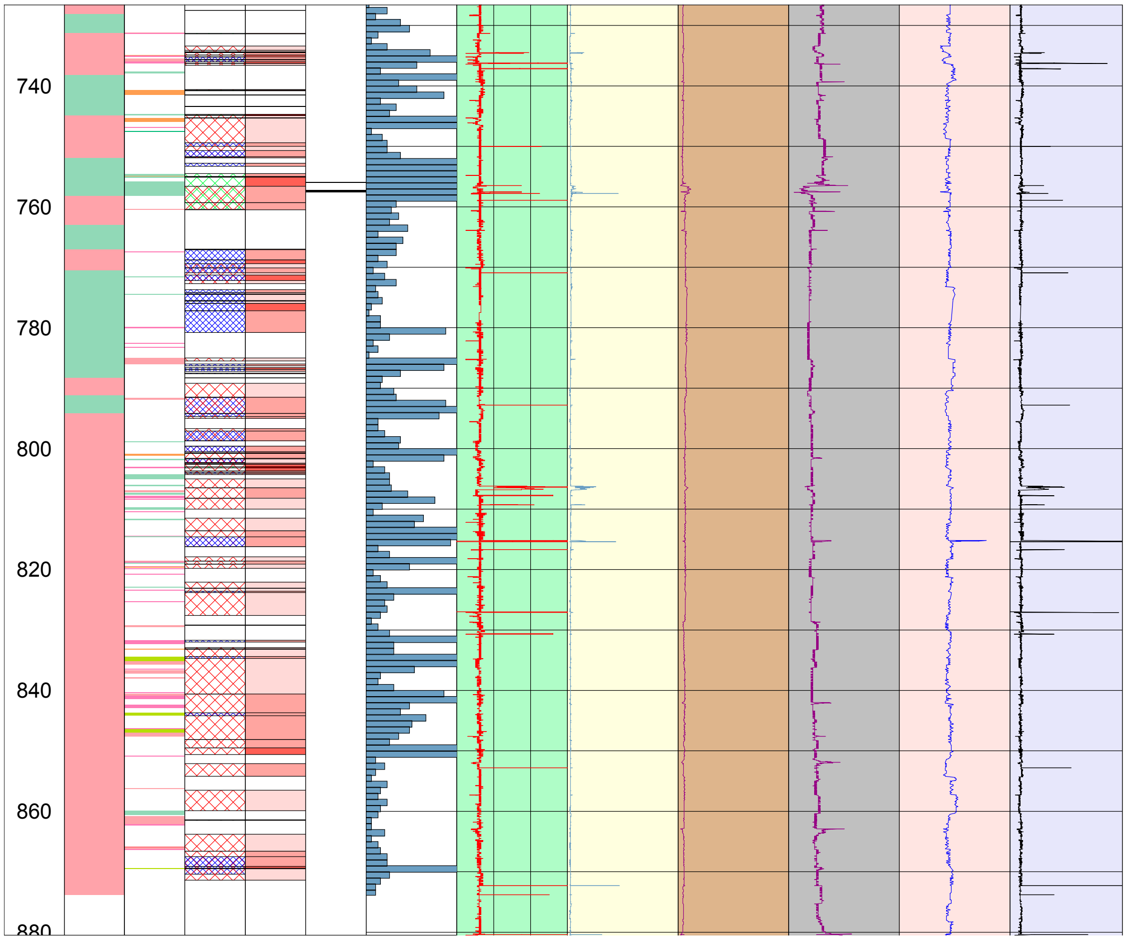
Title	GEOLOGY & MWD PARAMETERS KLX09		Appendix 1
Site	LAXEMAR	Coordinate System	RT90-RHB70
Borehole	KLX09	Northing [m]	6367322.63
Diameter [mm]	76	Easting [m]	1548863.23
Length [m]	880.380	Elevation [m.a.s.l.]	23.38
Bearing [°]	267.40	Drilling Start Date	2005-06-02 13:00:00
Inclination [°]	-85.29	Drilling Stop Date	2005-06-13 17:30:00
Date of mapping	2006-02-02 14:40:00	Plot Date	2006-10-18 21:10:07

ROCKTYPE LAXEMAR	ROCK ALTERATION	INTENSITY
Fine-grained granite	Oxidized	Faint
Ävrö granite	Chloritisized	Weak
Quartz monzodiorite	Epidotisized	Medium
Diorite / Gabbro	Quartz dissolution	Strong
Fine-grained dioritoid	Silicification	
Fine-grained diorite-gabbro	Argillization	
	Saussuritization	




180
200
220
240
260
280
300
320
340
360
380
400
420
440


460
480
500
520
540
560
580
600
620
640
660
680
700
720


740
760
780
800
820
840
860
880

Appendix 2

Chemical results

Borehole	KLX09	KLX09	KLX09	KLX09	KLX09	KLX09	KLX09	KLX09
Date of measurement	2005-09-04	2005-09-10	2005-09-15	2005-09-22	2005-09-28	2005-10-04	2005-10-08	2005-10-11
Upper section limit (m)	102.67	182.62	290.72	393.10	504.00	603.00	749.72	715.22
Lower section limit (m)	183.39	292.13	395.63	505.11	605.20	716.91	757.59	806.16
Sample_no	10483	10496	10505	10526	10531	10536	10540	10541
Groundwater Chemistry Class	3	3	3	3	3	3	1	1
pH	8.18	8.39	8.92	8.77	8.96			
Conductivity mS/m	48.8	113.0	50.0	74.8	102.0			
Drill water %	0.62	1.06	26.10	15.40	36.30	61.20	59.50	97.90
Density g/ml	0.9961	0.9965	0.9964		0.9964			
Charge balance %	2.43	5.39	10.40	0.70	0.28			
Na mg/l	83.7	229.0	103.0	155.0	182.0			
K mg/l	2.43	5.25	9.55	3.68	3.98			
Ca mg/l	8.8	18.9	17.6	12.9	23.9			
Mg mg/l	1.8	5.6	11.2	4.3	4.5			
HCO3 mg/l Alkalinity	195	267	223	261	190			
Cl mg/l	11.4	101.0	23.9	68.3	185.0			
SO4 mg/l	16.4	115.0	32.8	54.8	44.9			
SO4_S mg/l Total Sulphur	6.03	45.30	11.90	19.30	15.70			
Br mg/l	<0.200		<0.200	0.520				
F mg/l	3.84	5.39	4.58	6.02	4.33			
Si mg/l	8.33	14.70	40.90	19.30	7.66			
Fe mg/l Total Iron	1.6600	4.7100	26.9000	10.6000	2.5800			
Mn mg/l	0.0515	0.1270	0.3940	0.1400	0.0829			
Li mg/l	0.013	0.029	0.030	0.024	0.031			
Sr mg/l	0.159	0.310	0.233	0.185	0.388			
PMC % Modern Carbon		37.15	53.46	43.96				
C-13 dev PDB		–14.06	–15.71	–16.57				
AGE_BP Groundwater age		7900	4976	6549				
AGE_BP_CORR		35	30	40				
D dev SMOW		–78.4	–80.5	–78.7				
Tr TU		–0.80	2.30	–0.80				
O-18 dev SMOW		–11.00	–11.10	–10.80				
B-10 B-10/B-11		0.2383	0.2391	0.2391				
S-34 dev SMOW		30.3	28.8	23.6				
Cl-37 dev SMOC		–0.13	0.19	–0.03				
Sr-87 Sr-87/Sr86		0.716254	0.719378	0.716507				

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		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	Analytica
Archive samples	2 ea 250 ml	Filtering Pallfilter	green	
Option				
Deuterium, O-18	100 ml square		green	IFE
Tritium	500 ml dried	Flooded at least once	green	Waterloo
Sr-87	100 ml square		green	IFE
Cl-37	500 ml		green	Waterloo
B-10	*Same as for main components*	1 ml HNO_3 suprapur, filtering membrane filter	red	Analytica
C-13, PMC	2 st 100 ml brown glass		green	Waterloo
S-34	1000 ml		green	IFE

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 errors are calculated for the selected set of data from the borehole KLX09. The errors do not exceed ± 5% in any of the samples except for 10496 and 10505 (which have charge balance errors of 5.39% and 10.40% respectively).

The charge balance errors are not calculated for the samples 10536, 10540 and 10541 collected in KLX09.

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 KLX09.
- 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%.

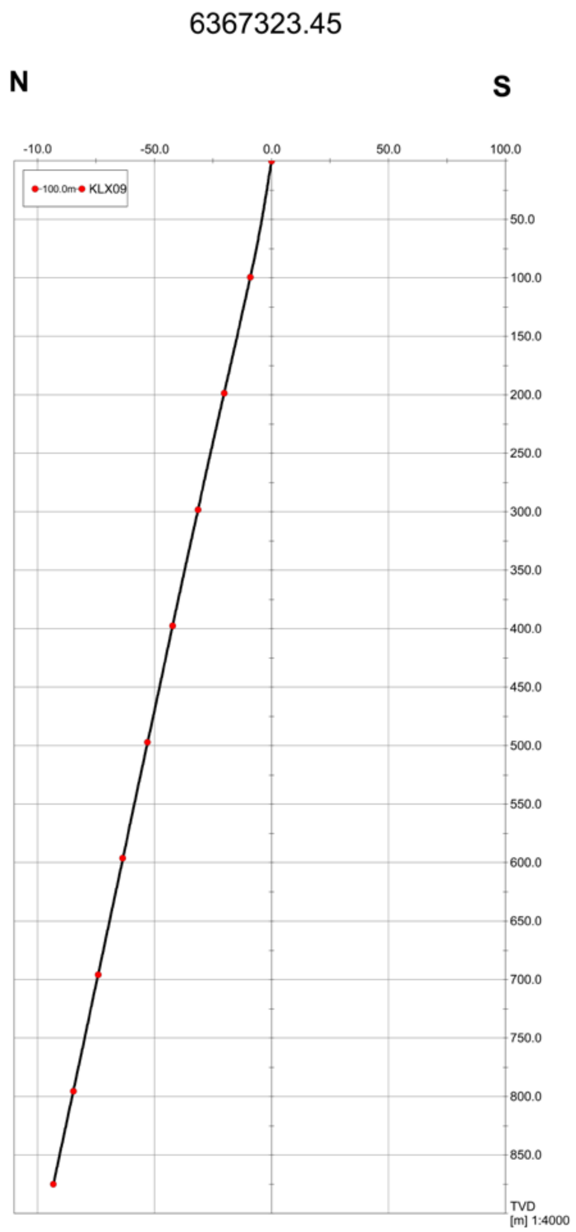
– Rel. Error (%) = $100\times \frac{(\sum \text{cations(equivalents)} - \sum \text{anions(equivalents)})}{(\sum \text{cations(equivalents)} + \sum \text{anions(equivalents)})}$

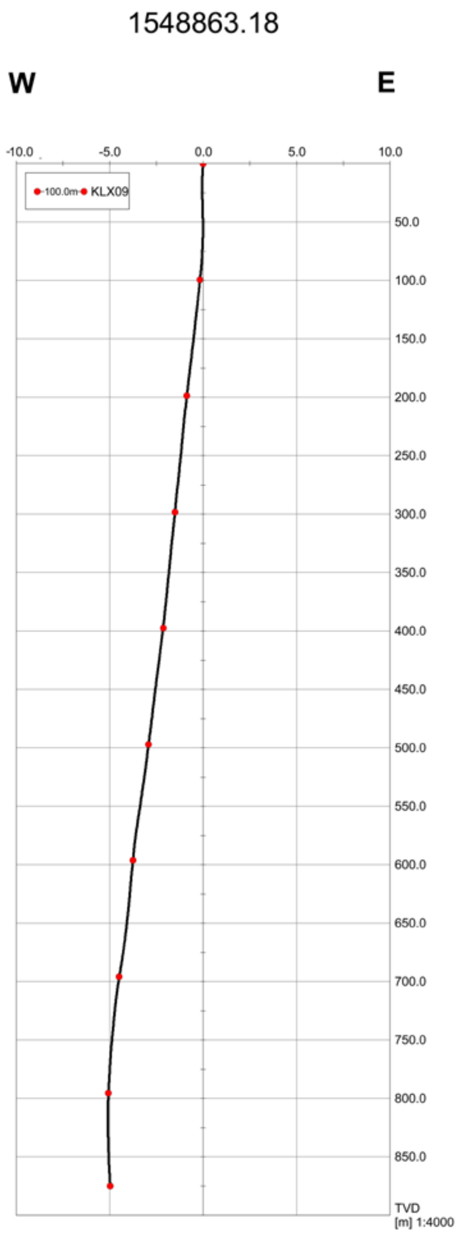
– General expert judgement of plausibility based on earlier results and experiences.

All results from "biochemical" components and special analyses of trace metals 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.

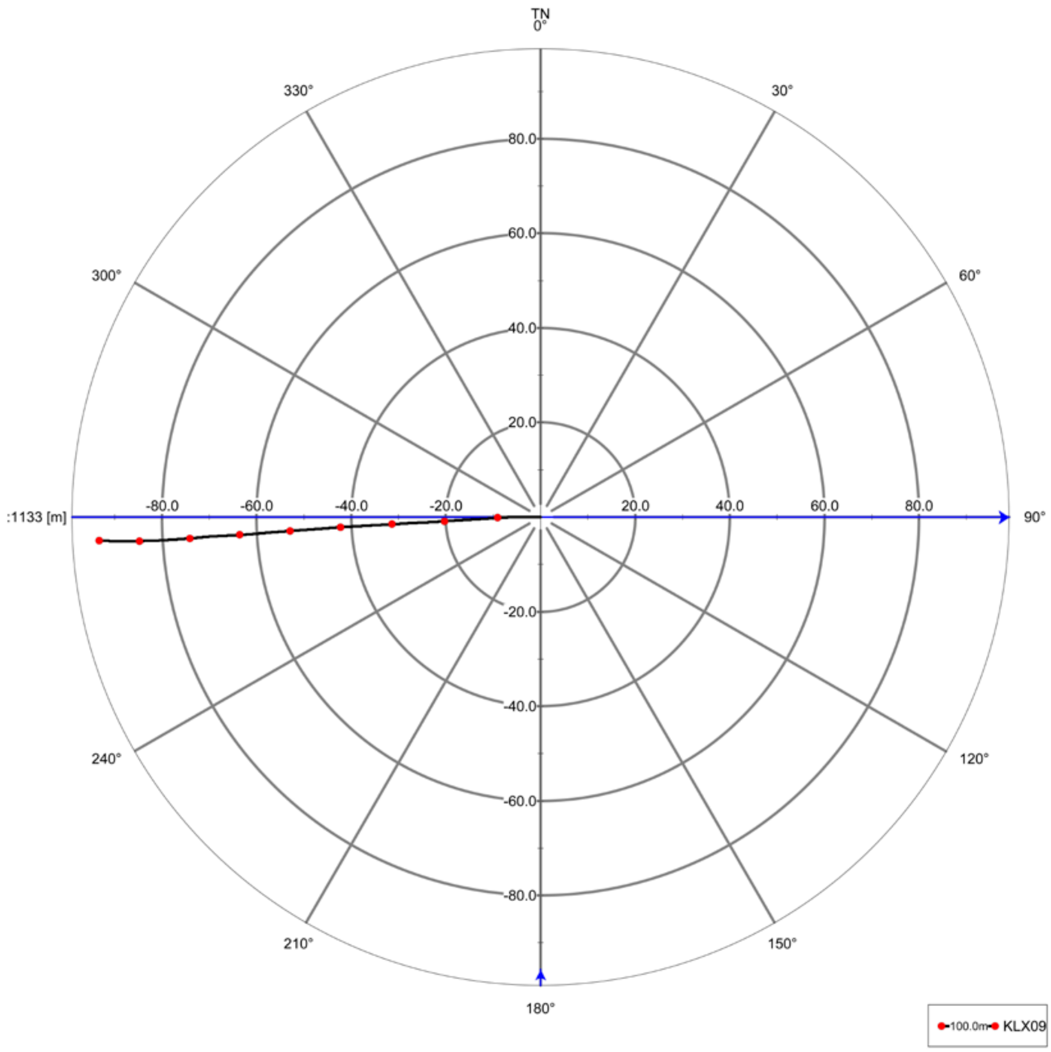
Deviation measurements

Vertical section / Orthogonal projection		Appendix: 4
Borehole	KLX09	
Site	Laxemar	
Coordinate system	RT90-RHB70	
Length	880.380	
Bearing	267.40	
Inclination	-85.29	
● Interval		





Deviation measurement		Appendix: 4
Site	Laxemar	
Borehole	KLX09	
View from above		

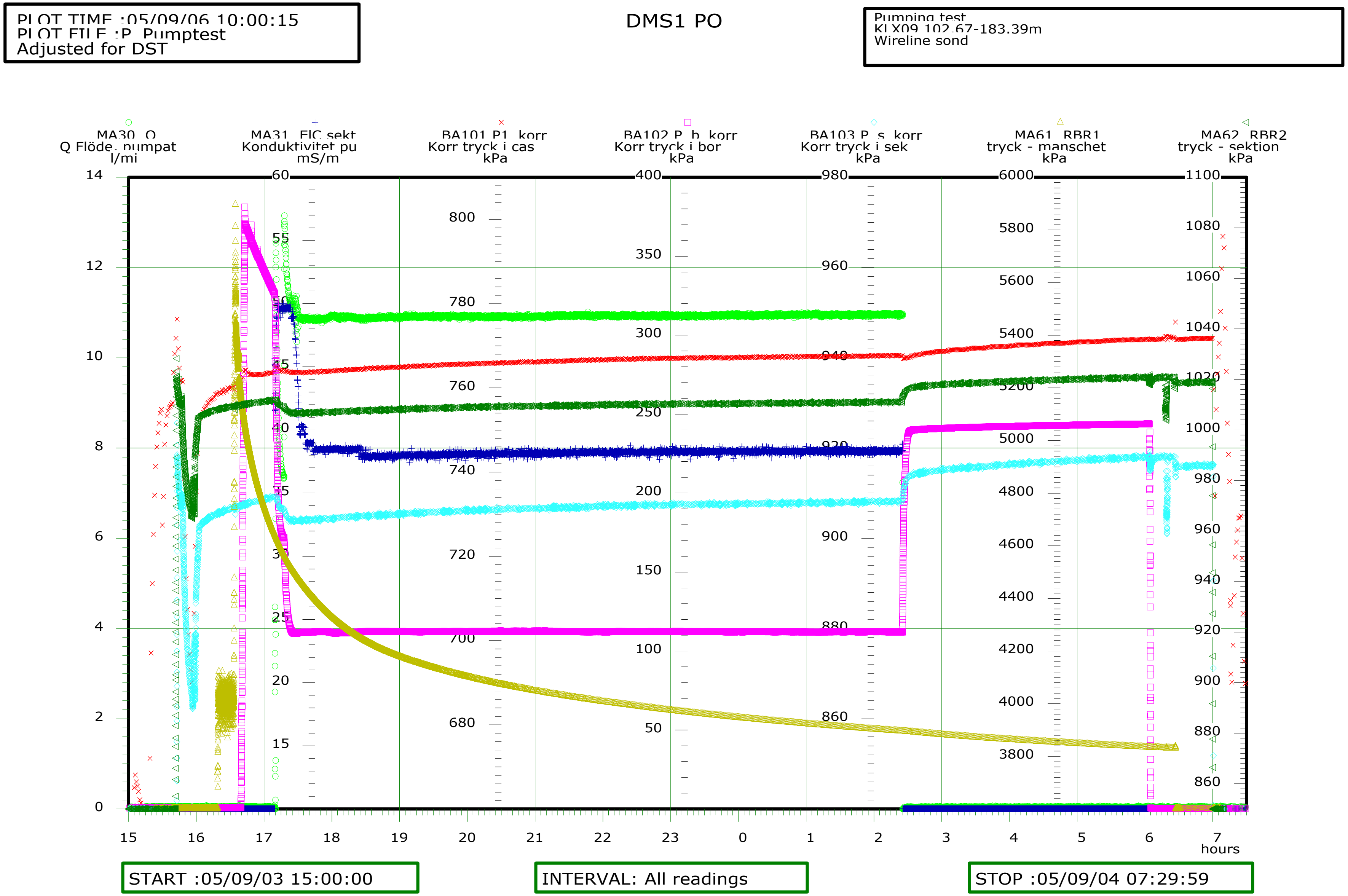


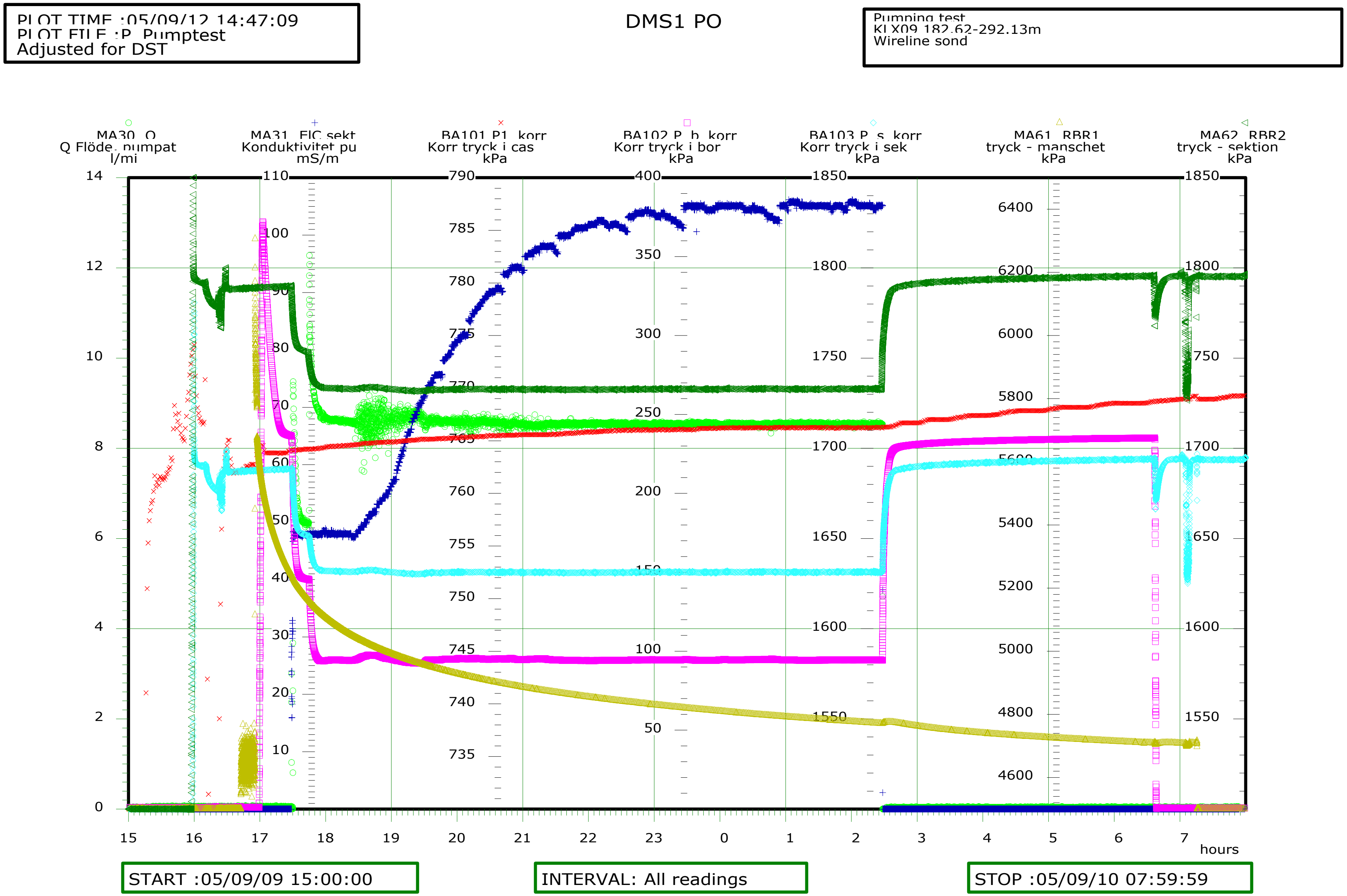
Appendix 5

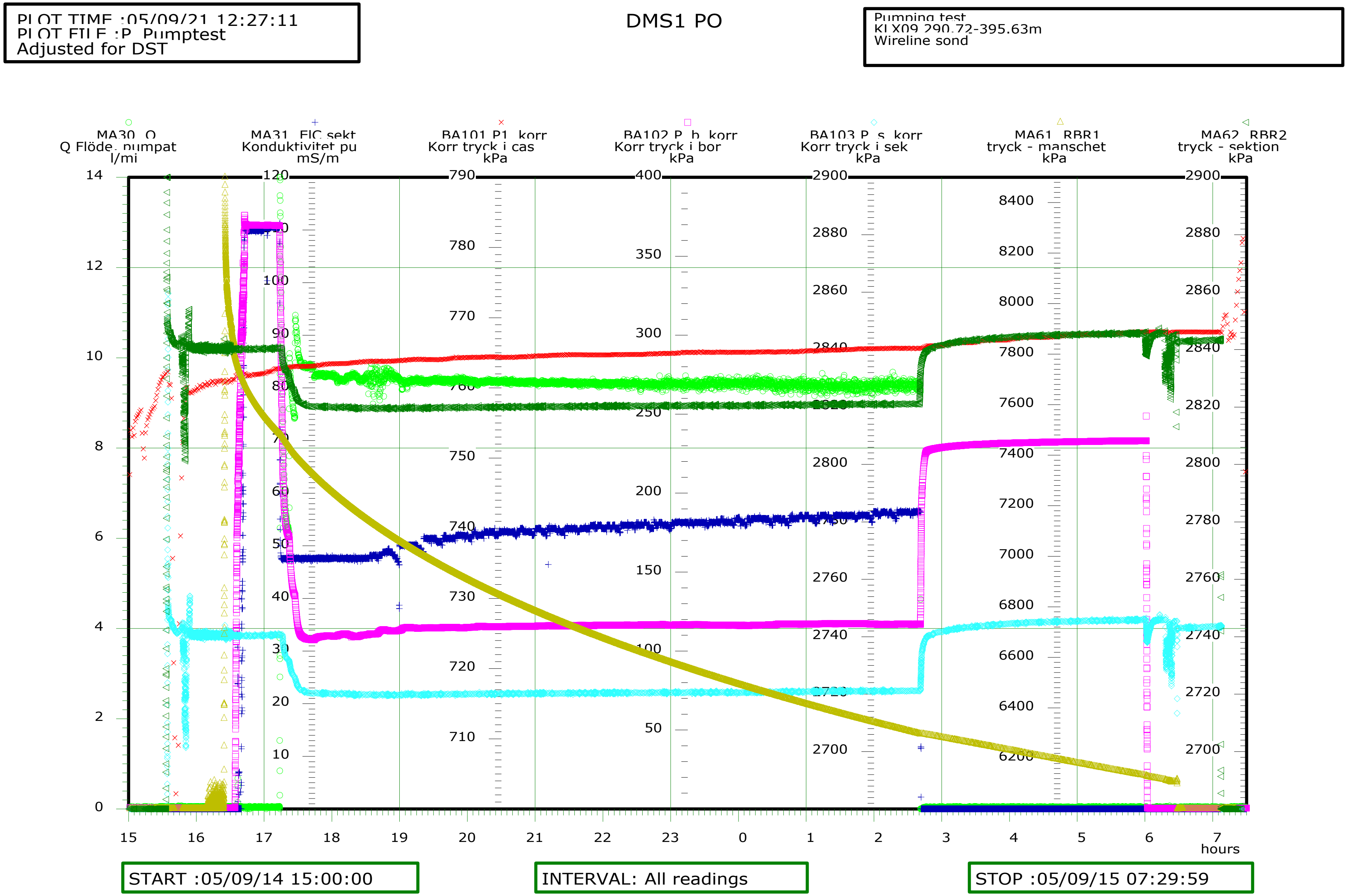
Wireline pumping tests in KLX09

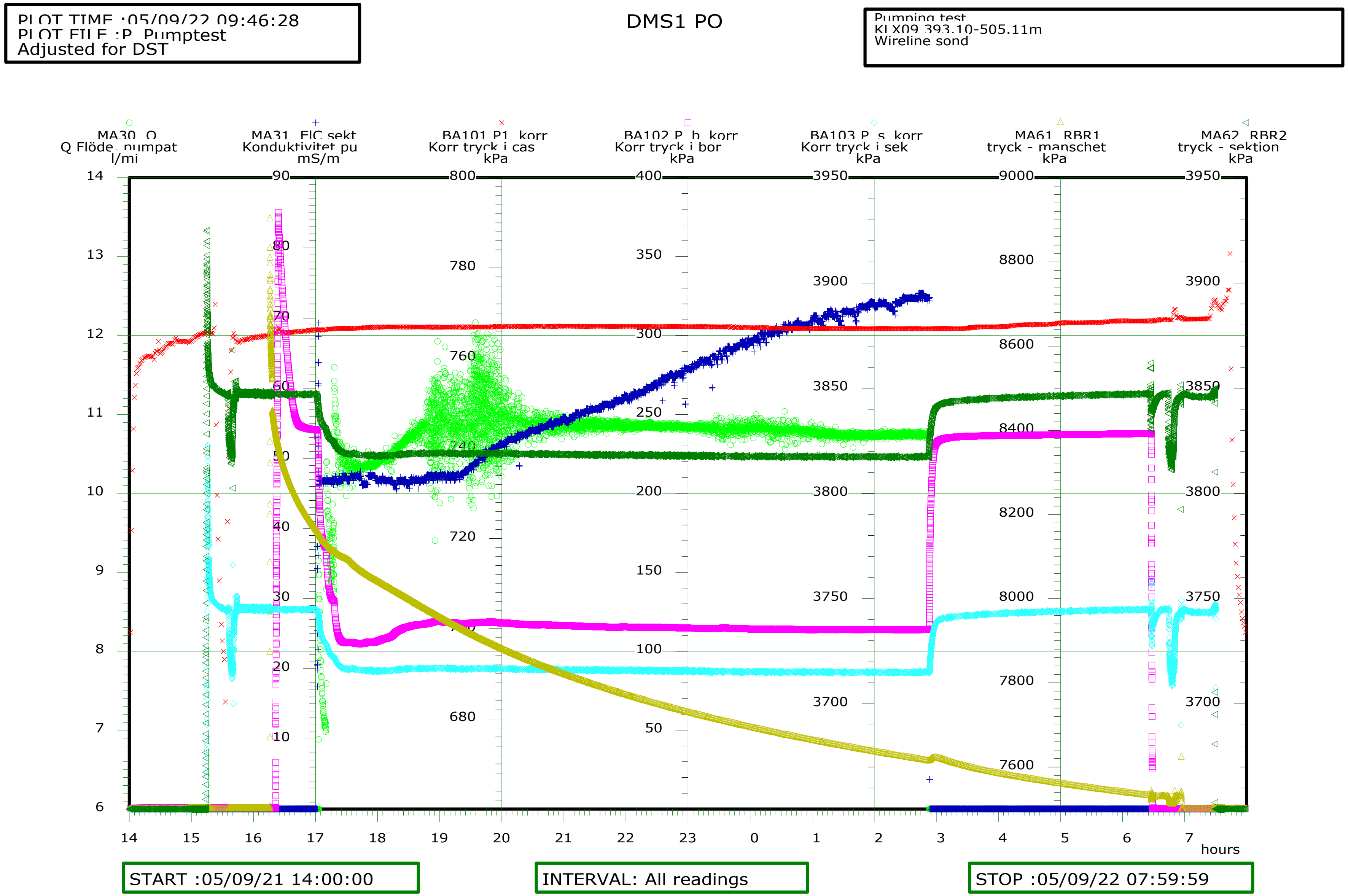
Description of the parameters in the enclosed plots

Channel	Parameter	Unit	Description
MA30	Water flow	Litre/minute	Flow of water pumped up from the borehole during the test.
MA31	Electrical conductivity	mS/m	Electrical conductivity in the pumped out water.
BA101	Pressure	kPa	Pressure of the water column in the telescopic section subtracted with the ambient air pressure.
BA102	Pressure	kPa	Pressure of the water column in the test section i.e. at depth in the borehole, subtracted with the ambient air pressure.
BA103	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.
MA61	Pressure – packer	kPa	Inflation pressure in packer.
MA62	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 :05/09/06 10:00:15
PLOT FILE :P_Pumptest
Adjusted for DST
DMS1 PO
Pumping test
KLX09 102.67-183.39m
Wireline sond
MA30 Q
Q Flöde, pumpat
l/mi
MA31 FIC sekt
Konduktivitet pu
mS/m
BA101 P1 korr
Korr tryck i cas
kPa
BA102 P b korr
Korr tryck i bor
kPa
BA103 P s korr
Korr tryck i sek
kPa
MA61 RBR1
tryck - manschet
kPa
MA62 RBR2
tryck - sektion
kPa
hours
START :05/09/03 15:00:00
INTERVAL: All readings
STOP :05/09/04 07:29:59


PLOT TIME :05/09/12 14:47:09
PLOT FILE :P_Pumptest
Adjusted for DST
DMS1 PO
Pumping test
KLX09 182.62-292.13m
Wireline sond
MA30 Q
Q Flöde, pumpat
l/mi
MA31 FIC sekt
Konduktivitet pu
mS/m
BA101 P1 korr
Korr tryck i cas
kPa
BA102 P b korr
Korr tryck i bor
kPa
BA103 P s korr
Korr tryck i sek
kPa
MA61 RBR1
tryck - manschet
kPa
MA62 RBR2
tryck - sektion
kPa
hours
START :05/09/09 15:00:00
INTERVAL: All readings
STOP :05/09/10 07:59:59

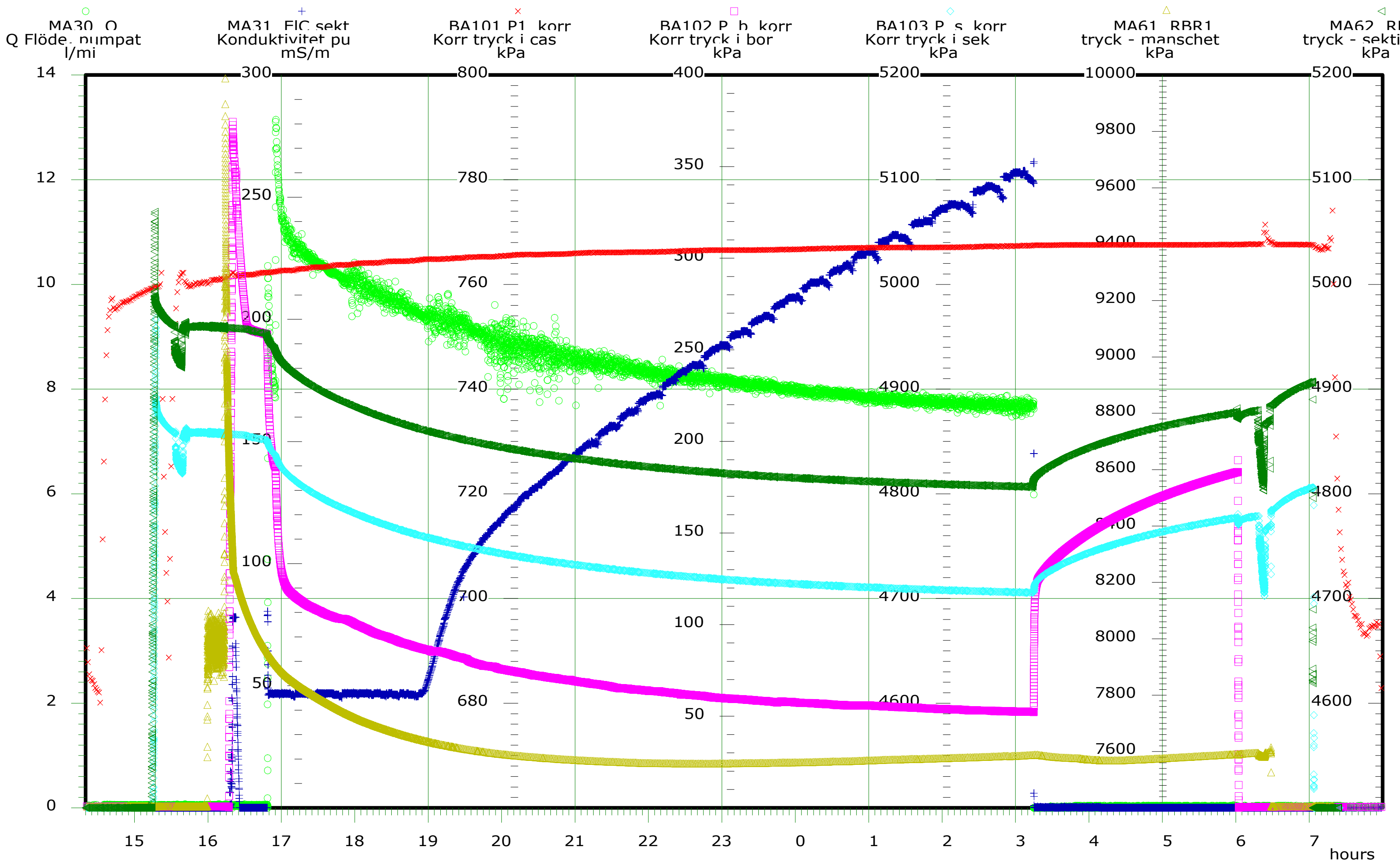

PLOT TIME :05/09/21 12:27:11
PLOT FILE :P_Pumptest
Adjusted for DST
DMS1 PO
Pumping test
KLX09 290.72-395.63m
Wireline sond
MA30 Q
Q Flöde, pumpat
l/mi
MA31 EC sekt
Konduktivitet pu
mS/m
BA101 P1 korr
Korr tryck i cas
kPa
BA102 P b korr
Korr tryck i bor
kPa
BA103 P s korr
Korr tryck i sek
kPa
MA61 RBR1
tryck - manschet
kPa
MA62 RBR2
tryck - sektion
kPa
hours
START :05/09/14 15:00:00
INTERVAL: All readings
STOP :05/09/15 07:29:59


PLOT TIME :05/09/22 09:46:28
PLOT FILE :P_Pumptest
Adjusted for DST
DMS1 PO
Pumping test
KLX09 393.10-505.11m
Wireline sond
MA30 Q
Q Flöde, pumpat
l/mi
MA31 FIC sekt
Konduktivitet pu
mS/m
BA101 P1 korr
Korr tryck i cas
kPa
BA102 P b korr
Korr tryck i bor
kPa
BA103 P s korr
Korr tryck i sek
kPa
MA61 RBR1
tryck - manschet
kPa
MA62 RBR2
tryck - sektion
kPa
hours
START :05/09/21 14:00:00
INTERVAL: All readings
STOP :05/09/22 07:59:59

PLOT TIME :05/09/28 10:17:37
PLOT FILE :P_Pumptest
Adjusted for DST

DMS1 PO

Pumping test
KLX09 504.00-605.20m
Wireline sond



START :05/09/27 14:20:00

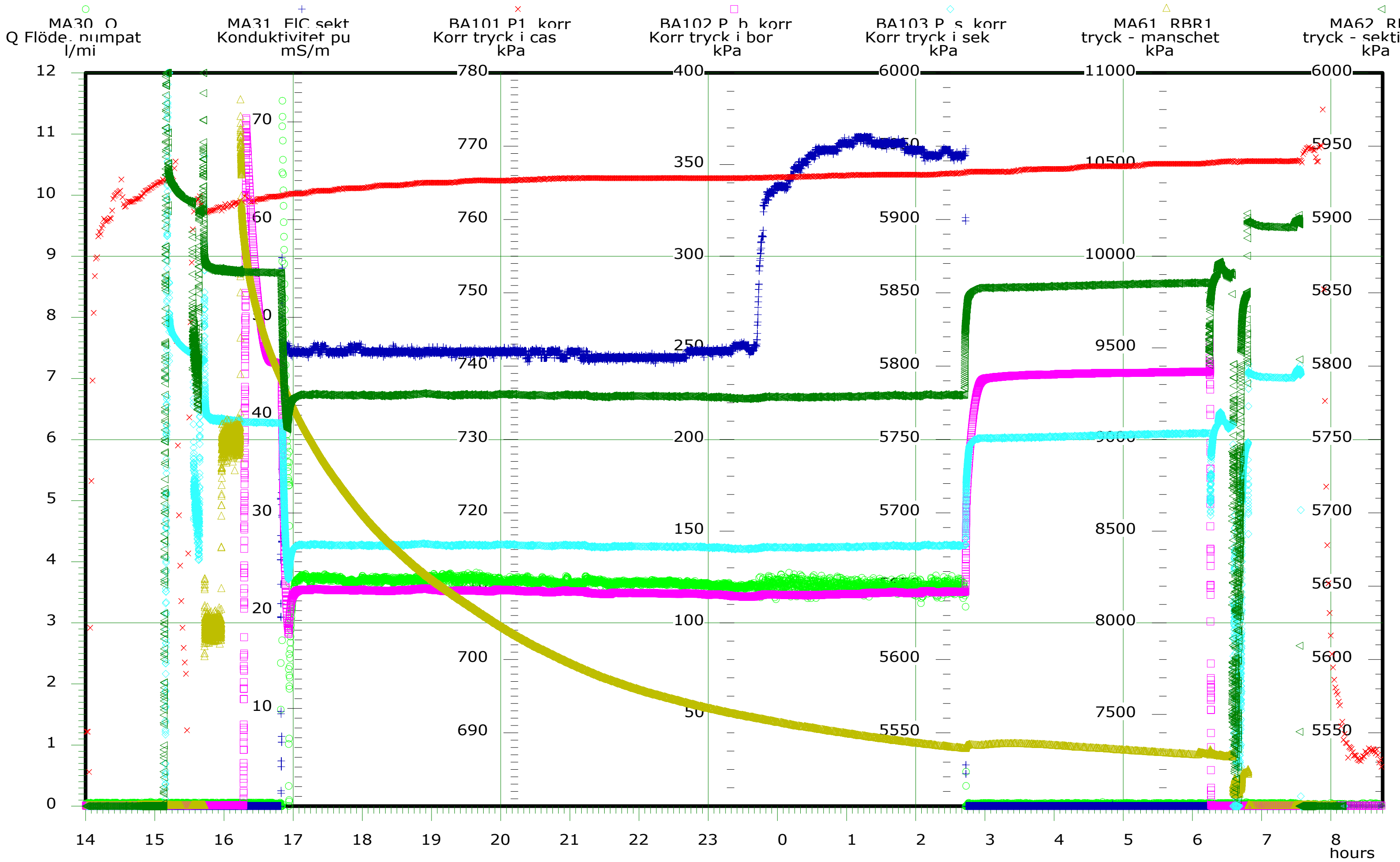
INTERVAL: All readings

STOP :05/09/28 07:59:59

PLOT TIME :05/10/04 09:56:40
PLOT FILE :P_Pumptest
Adjusted for DST

DMS1 PO

Pumping test
KLX09 603.00-716.91m
Wireline sond

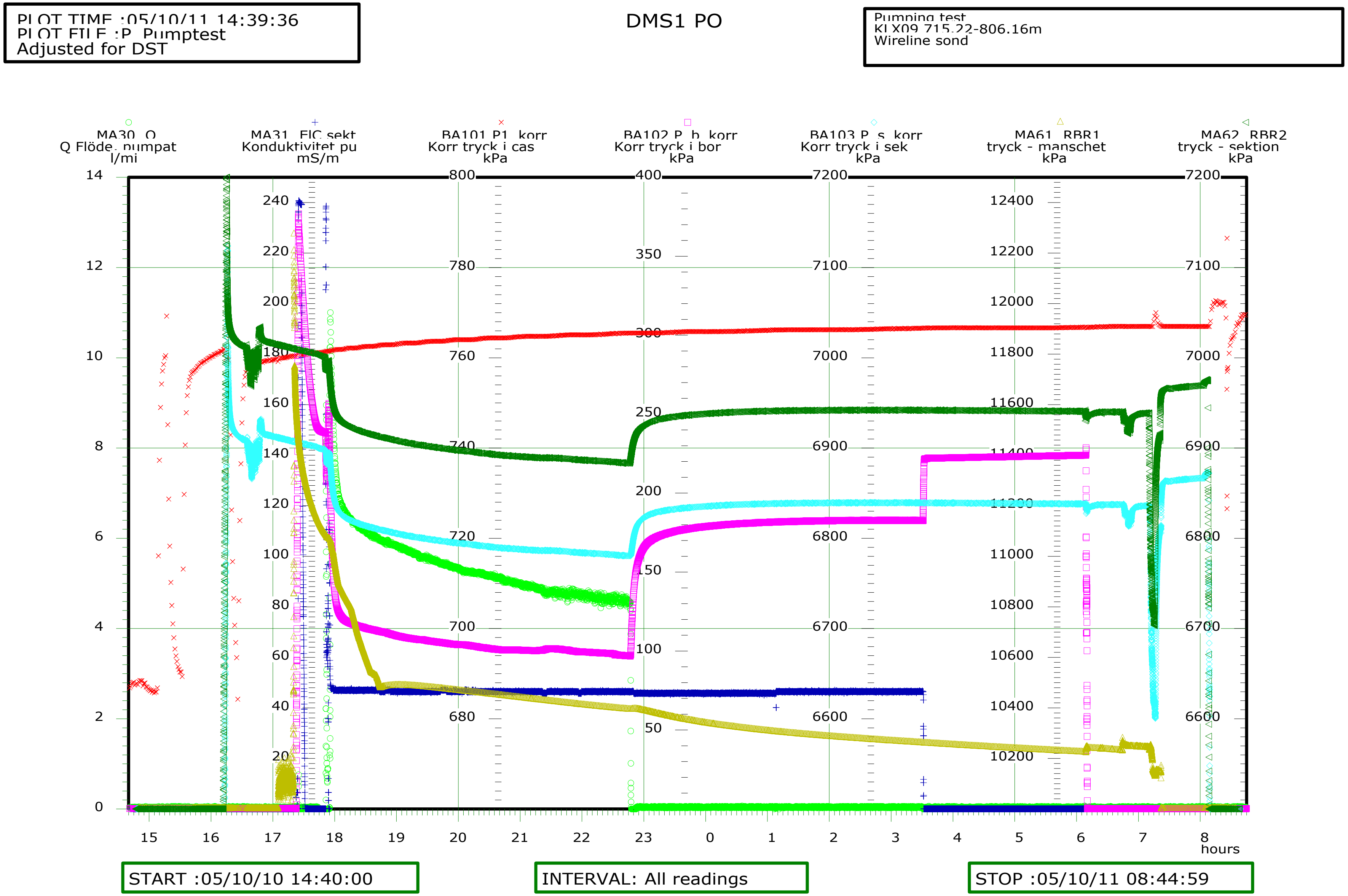


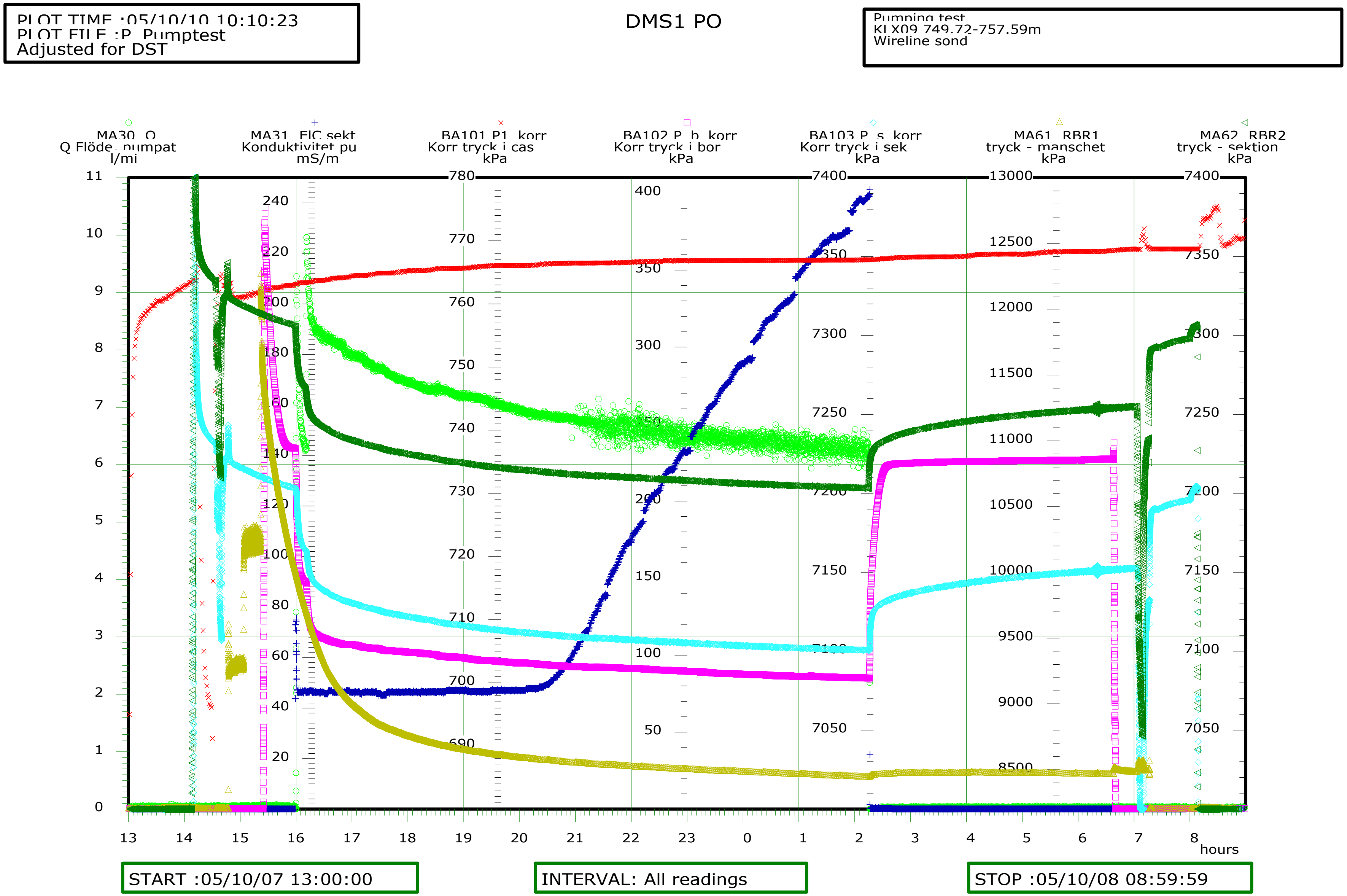
START :05/10/03 14:00:00

INTERVAL: All readings

STOP :05/10/04 08:44:59

71


PLOT TIME :05/10/11 14:39:36
PLOT FILE :P_Pumptest
Adjusted for DST
DMS1 PO
Pumping test
KLX09 715.22-806.16m
Wireline sond
MA30_Q
Q Flöde, pumpat
l/mi
MA31_EIC sekt
Konduktivitet pu
mS/m
BA101_P1_korr
Korr tryck i cas
kPa
BA102_P_b_korr
Korr tryck i bor
kPa
BA103_P_s_korr
Korr tryck i sek
kPa
MA61_RBR1
tryck - manschet
kPa
MA62_RBR2
tryck - sektion
kPa
15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6 7 8
hours
START :05/10/10 14:40:00
INTERVAL: All readings
STOP :05/10/11 08:44:59



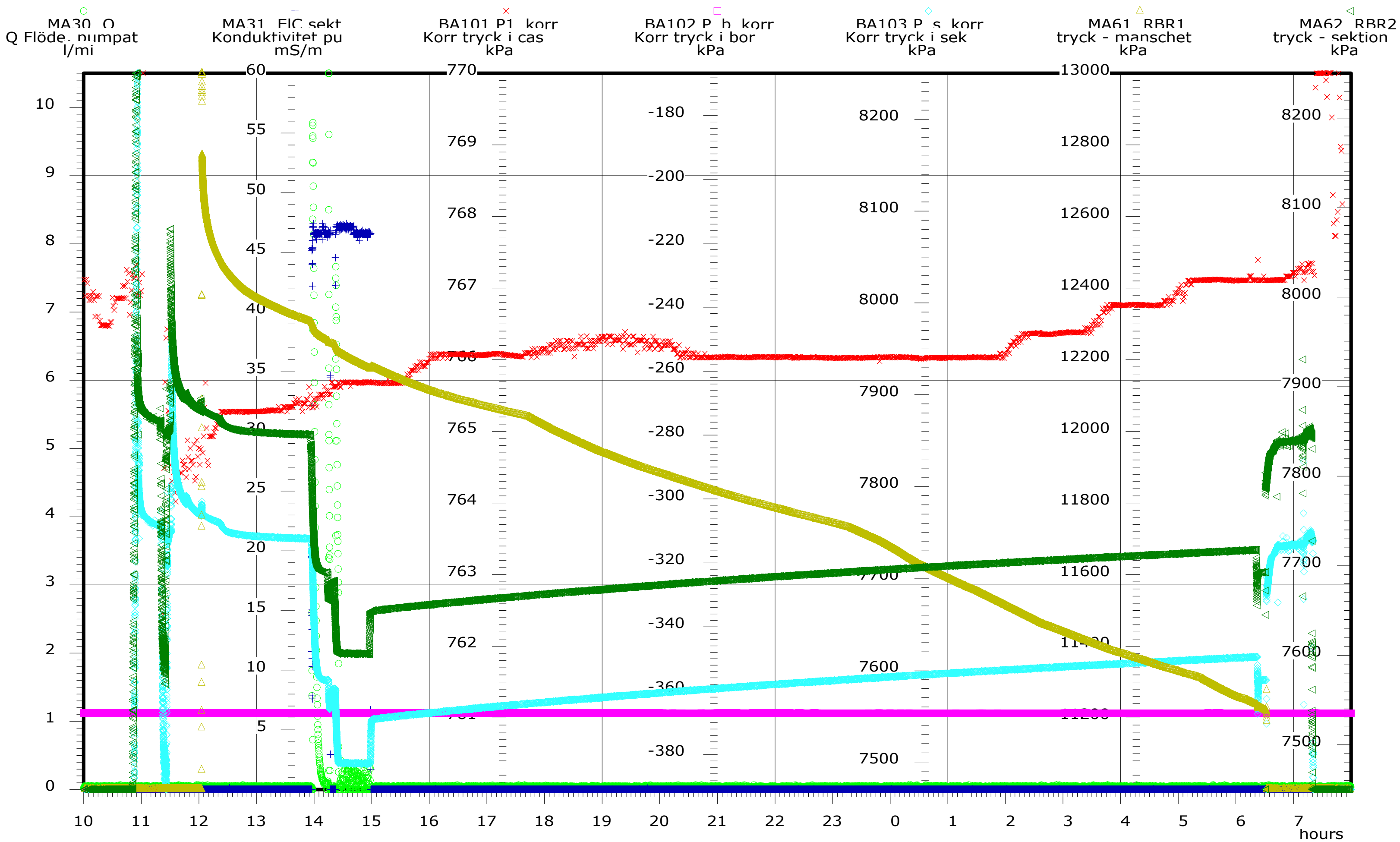
PLOT TIME :05/10/10 10:10:23
PLOT FILE :P_Pumptest
Adjusted for DST
DMS1 PO
Pumping test
KLX09 749.72-757.59m
Wireline sond
MA30 Q
Q Flöde, pumpat
l/mi
MA31 EIC sekt
Konduktivitet pu
mS/m
BA101 P1 korr
Korr tryck i cas
kPa
BA102 P_b korr
Korr tryck i bor
kPa
BA103 P_s korr
Korr tryck i sek
kPa
MA61 RBR1
tryck - manschet
kPa
MA62 RBR2
tryck - sektion
kPa
hours
START :05/10/07 13:00:00
INTERVAL: All readings
STOP :05/10/08 08:59:59

73

PLOT TIME :05/10/17 12:43:45
PLOT FILE :P_Pumptest
Adjusted for DST

DMS1 PO

Pumping test
KLX09 803.72-880.38m
Wireline sond



START :05/10/16 10:00:00

INTERVAL: All readings

STOP :05/10/17 07:59:59

Measurements of absolute pressure in KLX09

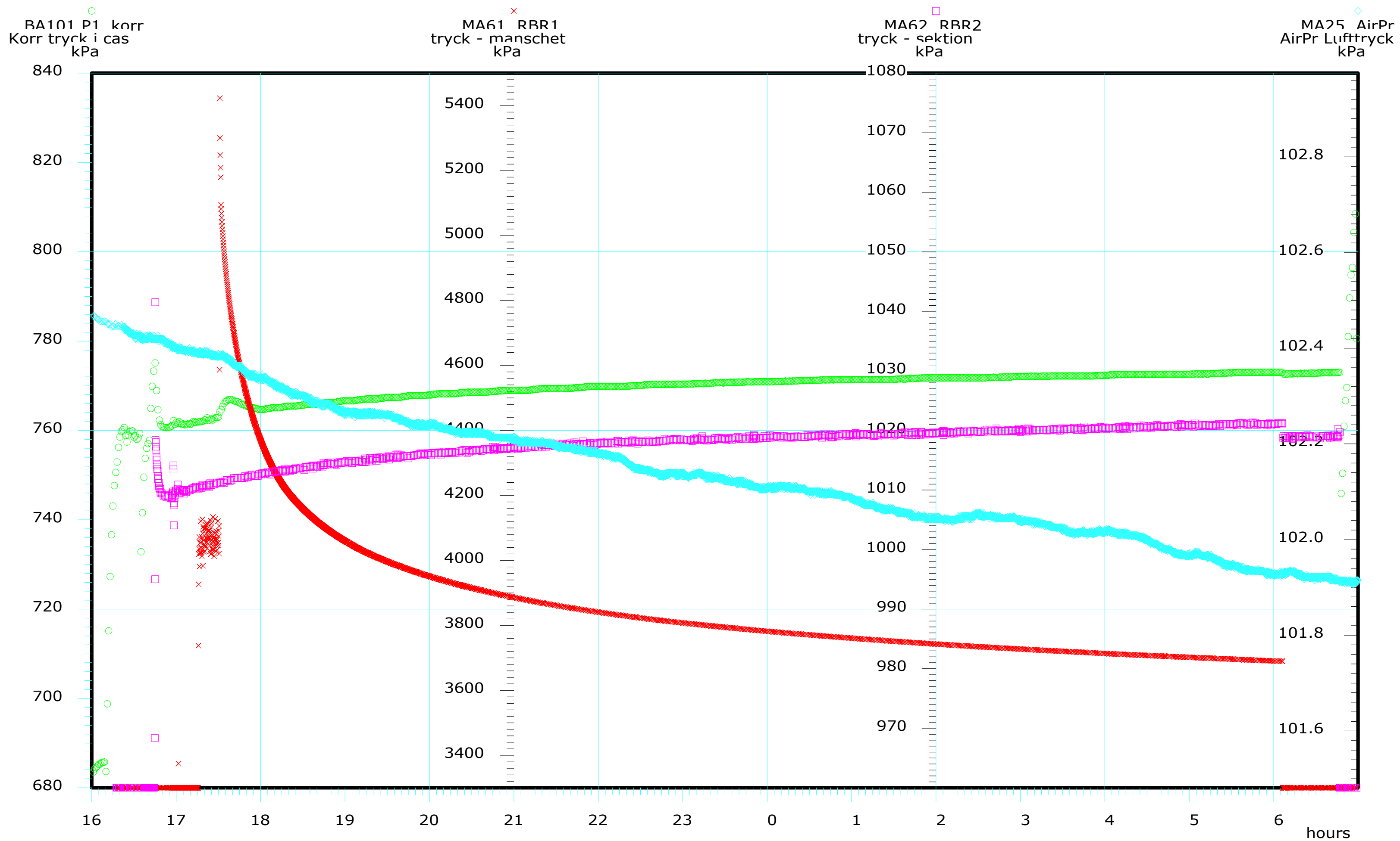
Description of the parameters in the enclosed plots

Channel	Parameter	Unit	Description
BA101	Pressure	kPa	Pressure of the water column in the telescopic section subtracted with the ambient air pressure.
MA61	Pressure - packer	kPa	Inflation pressure in packer
MA62	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
MA25	Air pressure	kPa	

PLOT TIME :05/09/06 10:40:35
PLOT FILE :P_tryck_i _sektion
Adjusted for DST

DMS1 PO

Absolute pressure measurement
KLX09 102.67-208.10m
Wireline sond



START :05/09/04 16:00:00

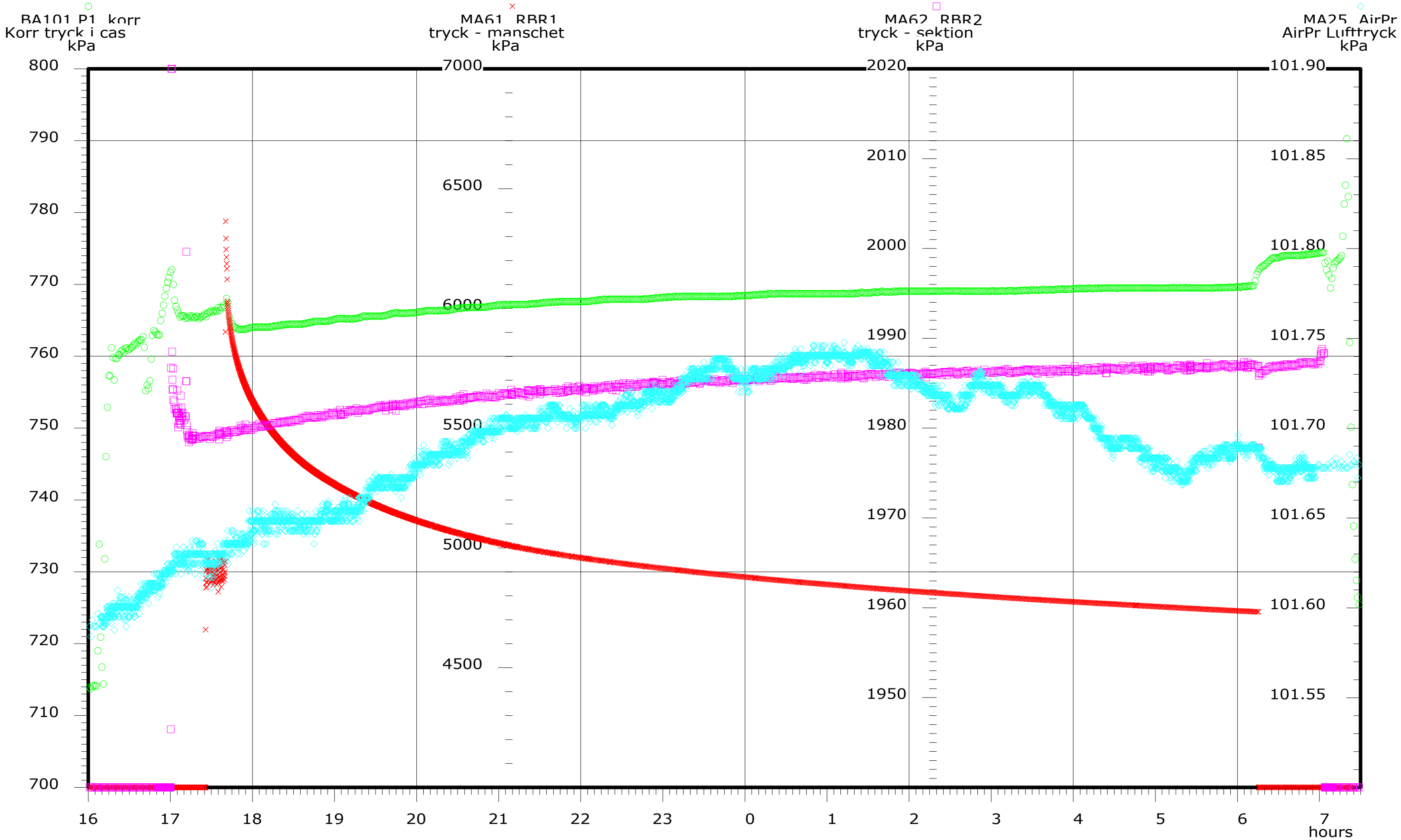
INTERVAL: All readings

STOP :05/09/05 06:59:59

PLOT TIME :05/09/12 15:11:27
PLOT FILE :P_tryck_i _sektion
Adjusted for DST

DMS1 PO

Absolute pressure measurement
KLX09 205.05-297.49m
Wireline sond



START :05/09/10 16:00:00

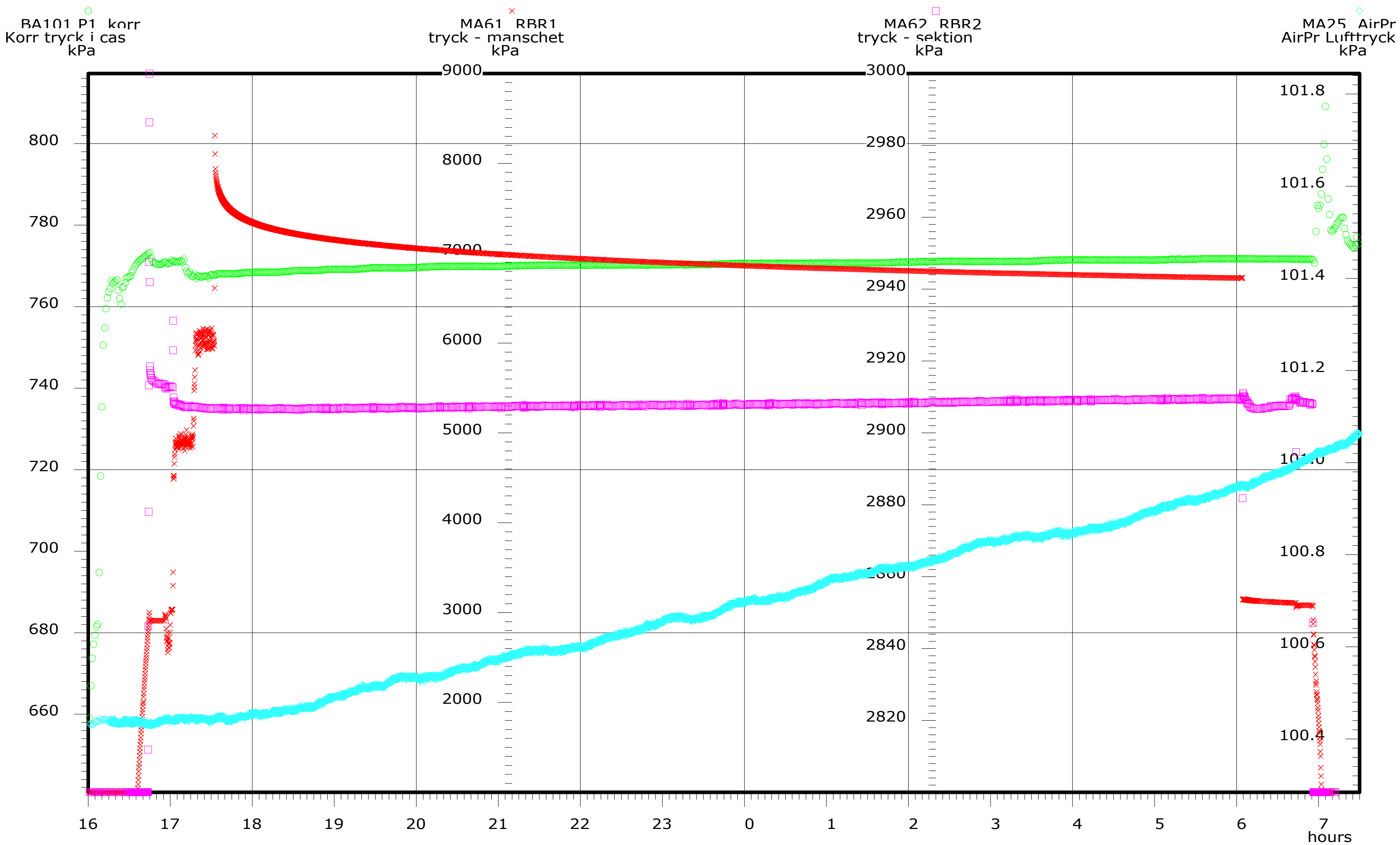
INTERVAL: All readings

STOP :05/09/11 07:29:59

PLOT TIME :05/09/21 12:52:06
PLOT FILE :P_tryck_i _sektion
Adjusted for DST

DMS1 PO

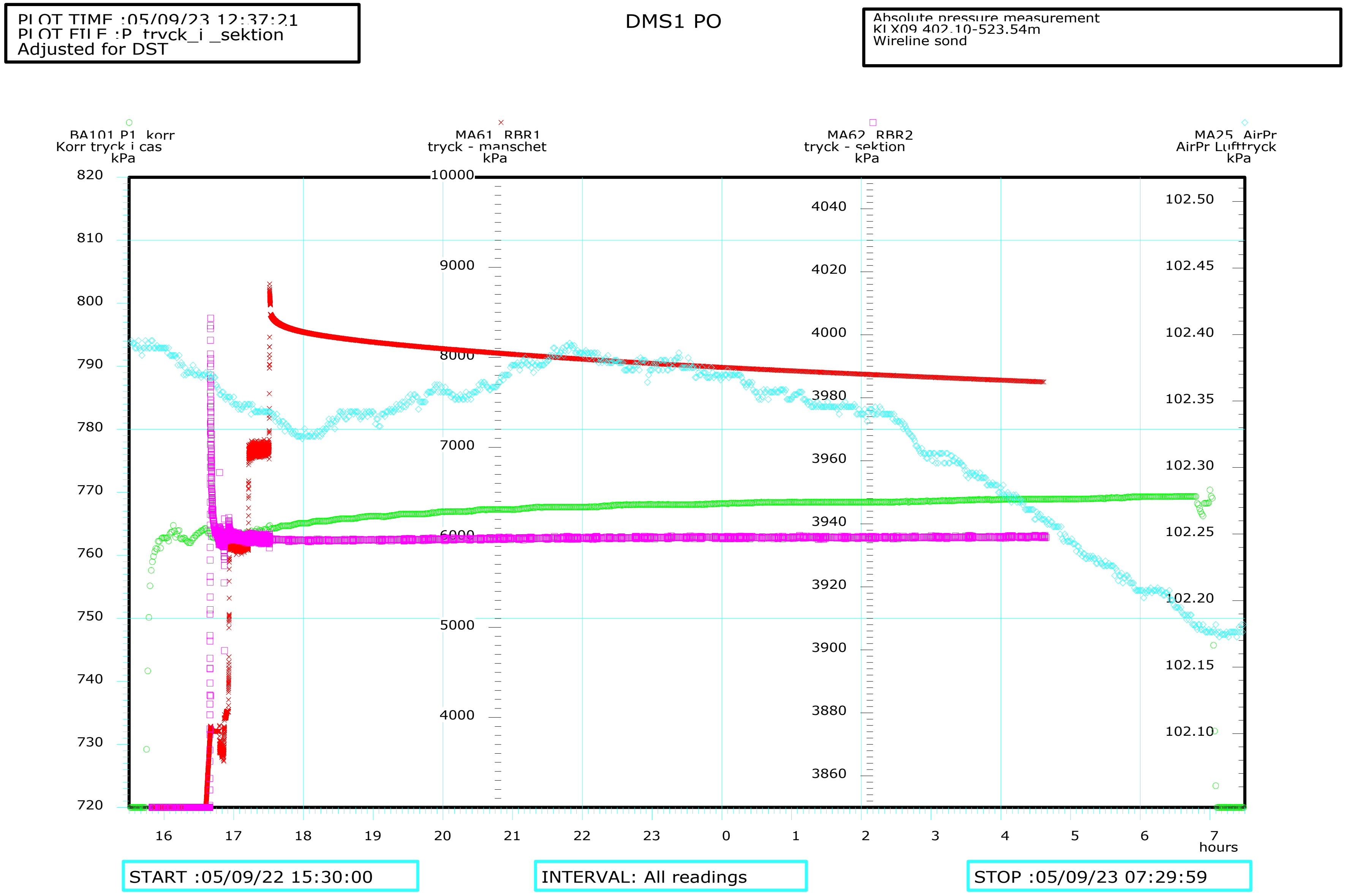
Absolute pressure measurement
KLX09 296.72-404.14m
Wireline sond



START :05/09/16 16:00:00

INTERVAL: All readings

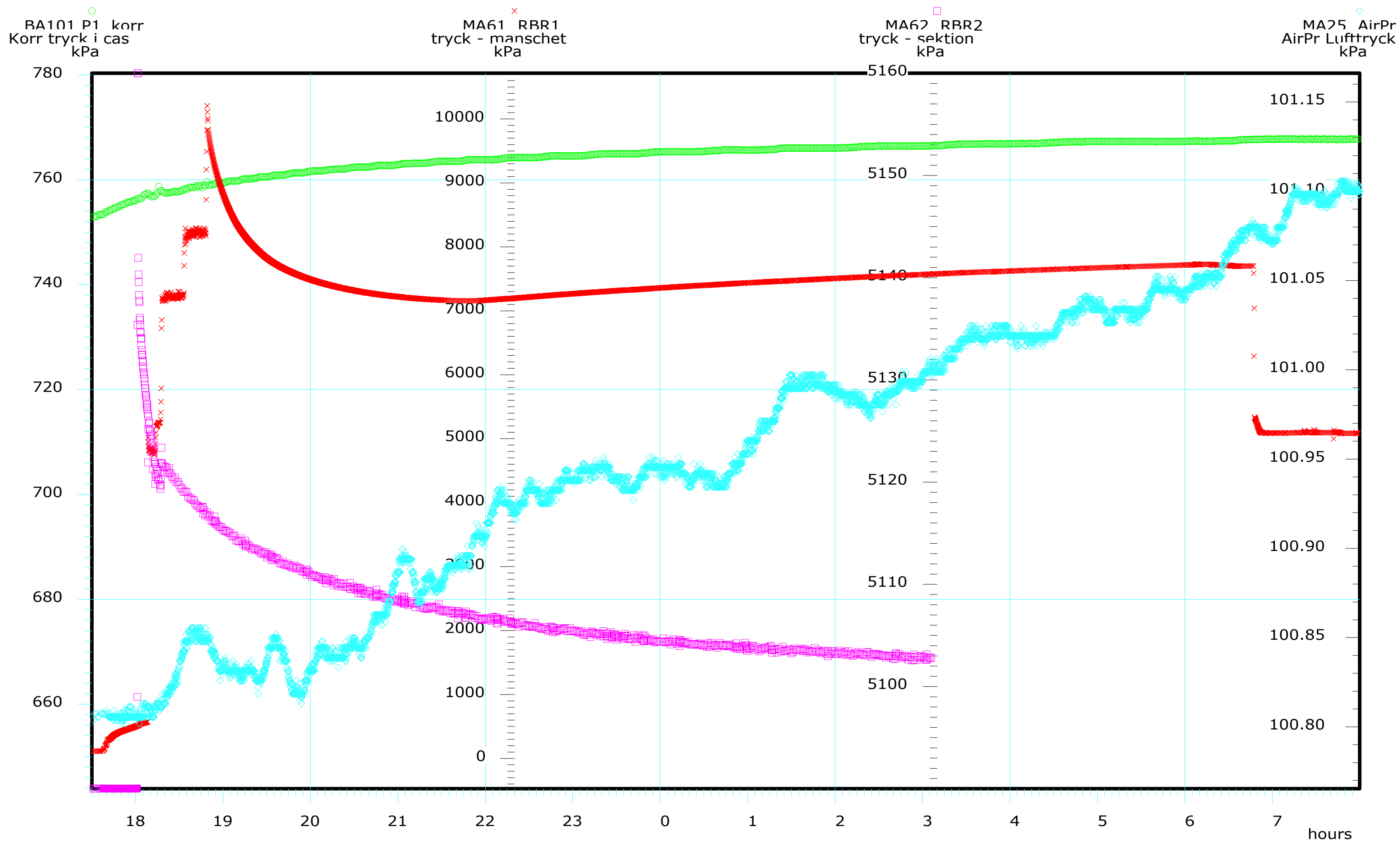
STOP :05/09/17 07:29:59


PLOT TIME :05/09/23 12:37:21
PLOT FILE :P_tryck_i _sektion
Adjusted for DST
DMS1 PO
Absolute pressure measurement
KLX09 402.10-523.54m
Wireline sond
BA101_P1_korr
Korr tryck i cas
kPa
MA61_RBR1
tryck - manschet
kPa
MA62_RBR2
tryck - sektion
kPa
MA25_AirPr
AirPr Lufttryck
kPa
hours
START :05/09/22 15:30:00
INTERVAL: All readings
STOP :05/09/23 07:29:59

PLOT TIME :05/09/29 11:50:33
PLOT FILE :P_tryck_i _sektion
Adjusted for DST

DMS1 PO

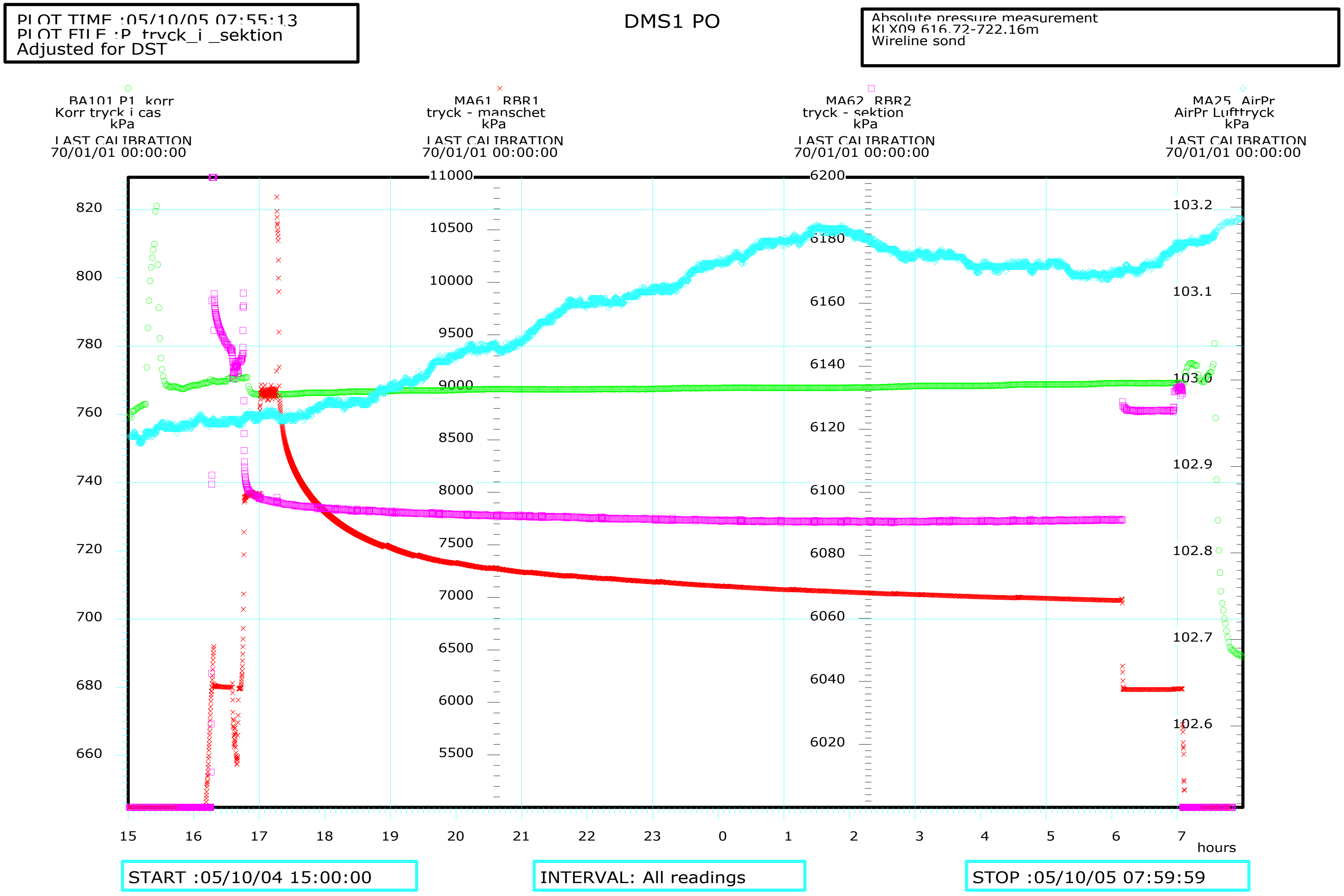
Absolute pressure measurement
KLX09 522.10-619.53m
Wireline sond



START :05/09/28 17:30:00

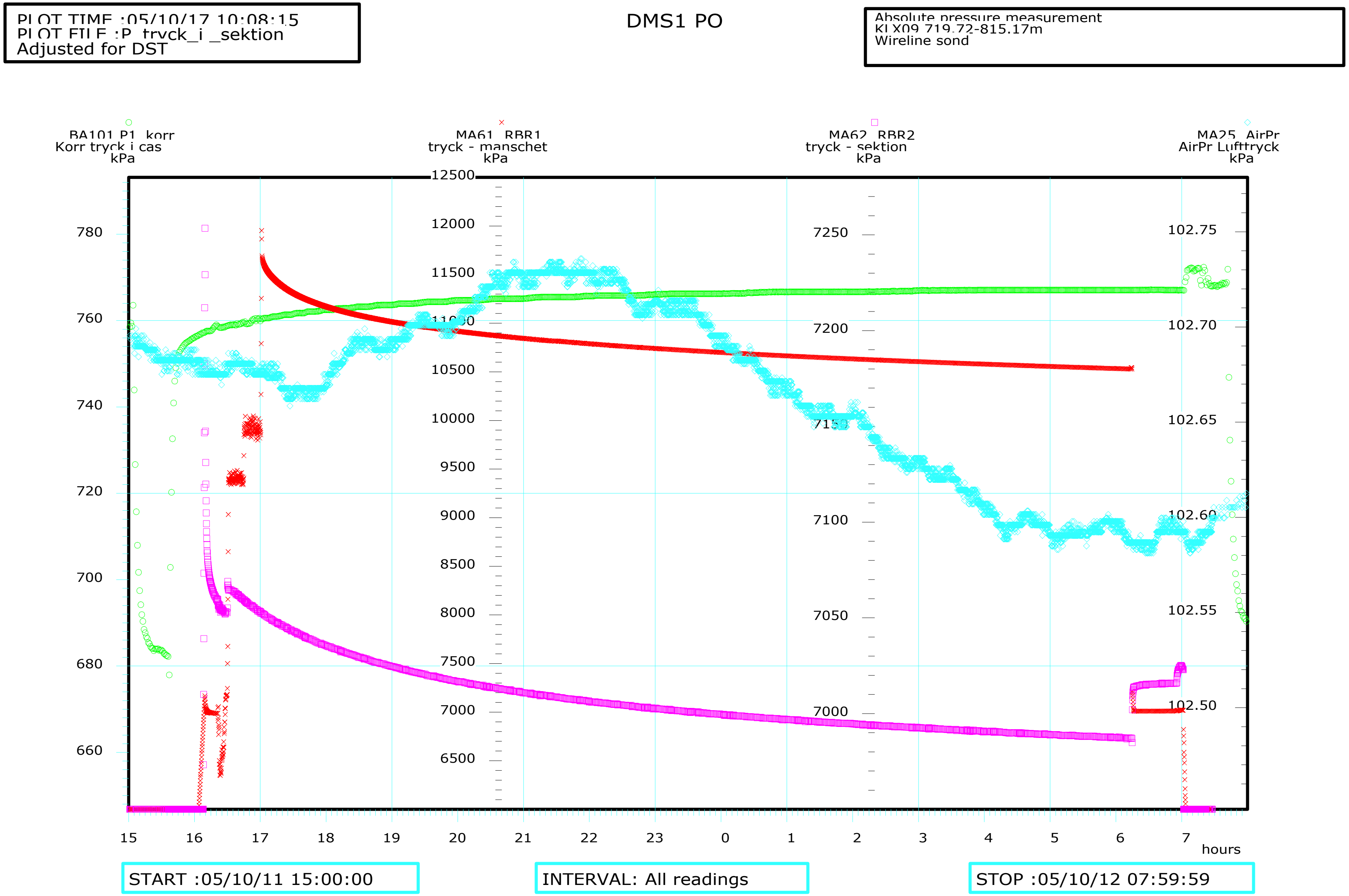
INTERVAL: All readings

STOP :05/09/29 07:59:59



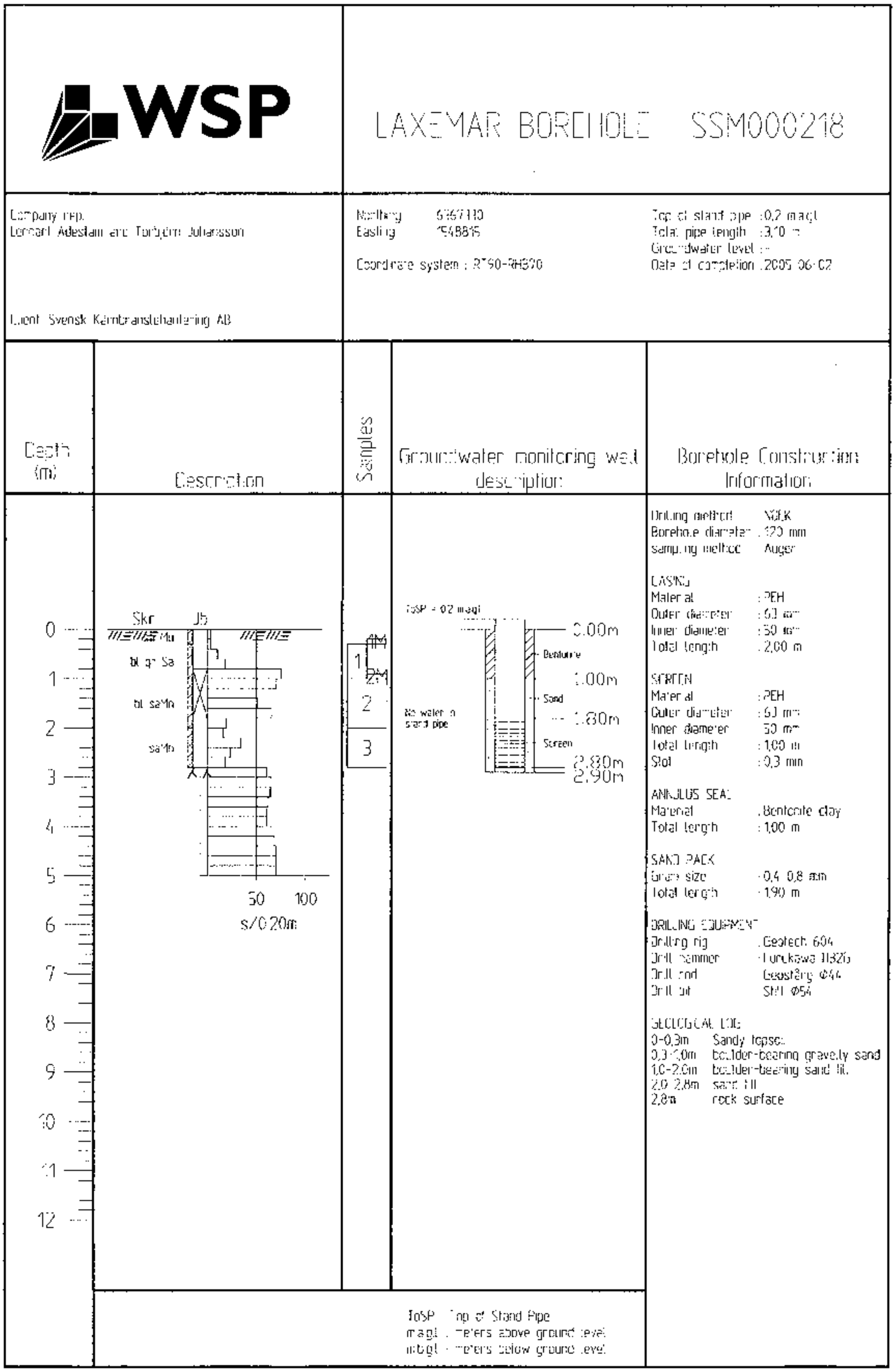
PLOT TIME :05/10/05 07:55:13
PLOT FILE :P_tryck_i _sektion
Adjusted for DST
DMS1 PO
Absolute pressure measurement
KLX09 616.72-722.16m
Wireline sond
BA101 P1 korr
Korr tryck i cas
kPa
LAST CALIBRATION
70/01/01 00:00:00
MA61 RBR1
tryck - manschet
kPa
LAST CALIBRATION
70/01/01 00:00:00
MA62 RBR2
tryck - sektion
kPa
LAST CALIBRATION
70/01/01 00:00:00
MA25 AirPr
AirPr Lufttryck
kPa
LAST CALIBRATION
70/01/01 00:00:00
hours
START :05/10/04 15:00:00
INTERVAL: All readings
STOP :05/10/05 07:59:59

81


PLOT TIME :05/10/17 10:08:15
PLOT FILE :P_tryck_i _sektion
Adjusted for DST
DMS1 PO
Absolute pressure measurement
KLX09 719.72-815.17m
Wireline sond
BA101 P1 korr
Korr tryck i cas
kPa
MA61 RBR1
tryck - manschet
kPa
MA62 RBR2
tryck - sektion
kPa
MA25 AirPr
AirPr Lufttryck
kPa
780
760
740
720
700
680
660
12500
12000
11500
11000
10500
10000
9500
9000
8500
8000
7500
7000
6500
7250
7200
7150
7100
7050
7000
102.75
102.70
102.65
102.60
102.55
102.50
15
16
17
18
19
20
21
22
23
0
1
2
3
4
5
6
7
hours
START :05/10/11 15:00:00
INTERVAL: All readings
STOP :05/10/12 07:59:59

Appendix 7

Technical data from environmental monitoring wells SSM000218 and SSM000219



LAXEMAR BOREHOLE SSM000219

Company rep
Lennart Adestam and Torbjörn Johansson

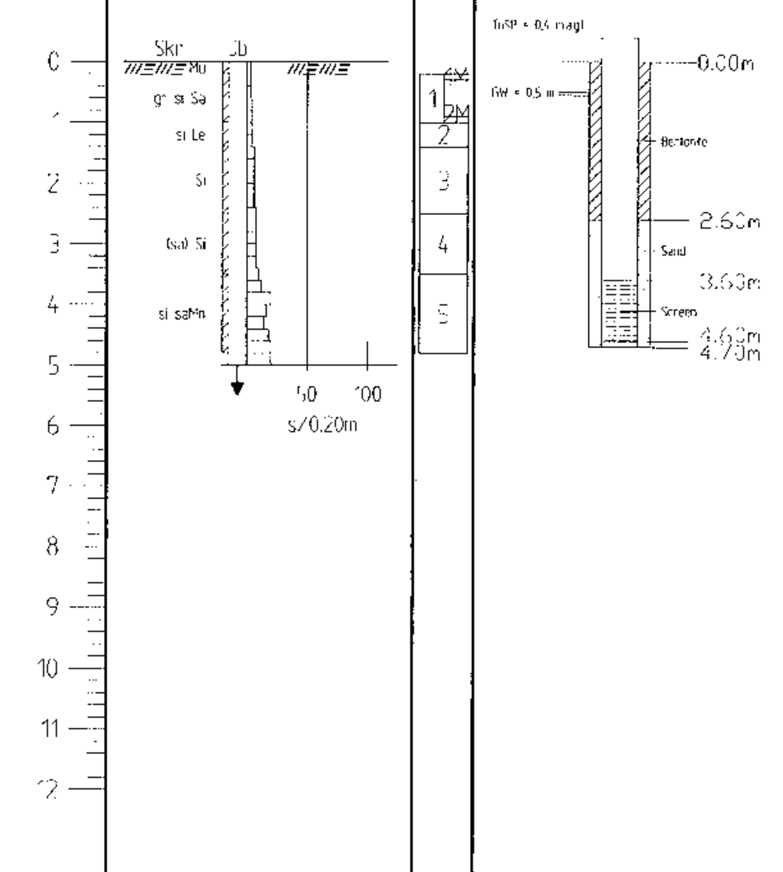
Client: Svensk Kärnbränslehantering AB

Northing: 6367322
Easting: 1548773

Coordinate system: RT90-RH870

Top of stand pipe: 0.4 m.a.g.
Total pipe length: 5,10 m
Groundwater level: 0,5 m.b.g.l.
Date of completion: 2005-06-01

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



Drilling method: ROCK
Borehole diameter: 120 mm
Sampling method: Auger

CASING
Material: PEH
Outer diameter: 63 mm
Inner diameter: 50 mm
Total length: 4,00 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: 2,60 m

SAND PACK
Grain size: 0,4–0,8 mm
Total length: 2,10 m

DRILLING EQUIPMENT
Drilling rig: Geotech 604
Drill hammer: Furukawa HB2G
Drill rod: Geoslång Φ44
Drill bit: Shit Φ54

GEOLOGICAL LOG
0–0,2 m Topsoil
0,2–1,0m gravelly silty sand
1,0–1,4m silty clay
1,4–2,5m silt
2,5–3,5m somewhat sandy silt
3,5–4,8m silty sand fill

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