

Oskarshamn site investigation

Drilling of cored borehole KLX04

Henrik Ask, H Ask Geokonsult AB

Mansueto Morosini, Lars-Erik Samuelsson
Svensk Kärnbränslehantering AB

Liselotte Ekström, Studsvik RadWaste AB

Nils Håkanson, HCC- Håkanson Coring Consultants

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Svensk Kärnbränslehantering AB

Swedish Nuclear Fuel
and Waste Management Co
Box 5864

SE-102 40 Stockholm Sweden

Tel 08-459 84 00

+46 8 459 84 00

Fax 08-661 57 19

+46 8 661 57 19



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Abstract

Borehole KLX04 is located in the Laxemar subarea. Drilling was made between February and June 2004 as a part of the site investigation for a possible repository for spent nuclear fuel in Oskarshamn municipality, Sweden.

The hole was core drilled to a depth of 993.49 metres with 76 mm equipment. The uppermost section, to a depth of 100.35 metres, was constructed as a telescopic section with an inner diameter of 200 mm.

A very low water inflow of 2–4 litres per minute was estimated over the whole length of the telescopic section during percussion drilling.

Pumping tests were performed with a wireline equipment, typically with one hundred metres intervals. The resulting transmissivities (T_M) varied between 5.8×10^{-7} and 1.6×10^{-4} m²/s. The most transmissive section was between 211 and 329 metres.

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

Water sampling for chemical analysis were collected during drilling. Seven samples were collected from the core drilling phase. Only one of the seven samples had a sufficiently low drilling water content to ensure accurate results.

An airlift pumping test in the telescopic section performed when the cored hole was drilled to its full length gave a transmissivity (T_M) of 3.4×10^{-4} m²/s.

The core is dominated by Ävrö Granite with minor intercalations of granite, fine-grained diorite, fine-grained granite and fine-grained diorite-gabbro. Between 450 and 550 m rather large portions of Quartz monzodiorite occur. Another section of Quartz monzodiorite has been noted at 680 to 700 m.

Oxidation with faint to weak intensity is common from 100 to 450 m and from 870 to 970 m.

The total fracture frequency is around 10 per metre from 100 to 450 m. Between 450 and 870 m the fracture frequency is lower, ca 0–10 per metre. From 870 to 970 metres the fracture frequency is around 20 per metre. Below 970 m, however the amount of fractures is significantly lower.

One notable section of crushed rock (ie total fracture frequency > 40 per metre) was encountered at 350 m. Minor portions of crushed rock noted between 190–370 m and 890–960 m.

Sammanfattning

Borrhål KLX04 ligger inom delområde Laxemar. Borrningen utfördes mellan februari och juni 2004 som ett led i platsundersökningen för ett möjligt djupförvar för utbränt kärnbränsle i Oskarshamns kommun.

Hålet kärnborrades med 76 mm utrustning till 993,49 meters borrarad längd. Den övre delen av hålet, från markytan till 100,35 meter, utfördes som en teleskopdel med ca 200 mm inre diameter.

Ett mycket lågt vatteninflöde på 2–4 liter per minut uppskattades över hela teleskopdelen vid hammarborrningen.

Pumptester med wireline-baserad mätutrustning utfördes normalt var hundra meter. Uppmätta transmissiviteter (T_M) varierade mellan $5,8 \times 10^{-7}$ och $1,6 \times 10^{-4}$ m²/s. Den mest transmissiva sektionen var mellan 211 och 329 meter.

Kontinuerliga mätningar av borrhingsparametrar och spolvattenparametrar via DMS (drilling monitoring system) gjordes under hela kärnborrhingsfasen.

Vattenprovtagning för kemisk analysering genomfördes i samband med borrning, där sju prov togs under kärnborrhingsfasen. Endast ett prov, av de sju tagna, hade ett tillräckligt lågt spolvatteninnehåll för att ge tillförlitliga resultat.

En mammutpumpning i teleskopdelen som gjordes när kärnborrningen utförts till full längd gav en transmissivitet (T_M) på $3,4 \times 10^{-4}$ m²/s.

Borrkärnan domineras av Ävrö granit med mindre inslag av granit, finkornig dioritoid, finkornig granit och finkornig diorit-gabbro. Mellan 450 och 550 m förekommer stora partier med kvartsmonzodiorit. Ett parti med kvartsmonzodiorit har även noterats mellan 680 och 700 m.

Oxidation med mycket svag eller svag intensitet är vanlig från 100 till 450 m och från 870 till 970 m.

Den totala sprickfrekvensen är ca 10 per meter från 100 till 450 m. Mellan 450 och 870 m är sprickfrekvensen lägre, ca 0–10 per meter. Från 870 till 970 m är sprickfrekvensen omkring 20 per meter. Under 970 m minskar dock antalet sprickor betydligt.

Ett distinkt parti med krossat berg (total sprickfrekvens > 40 per meter) påträffades vid 350 m. Mindre partier med krossat berg har noterats mellan 190–370 m och 890–960 m.

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1 Introduction

SKB, the Swedish Nuclear Fuel and 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 KLX04 is located in the central part of the Laxemar subarea of the investigation area in Oskarshamn /2/.

Drilling and investigations in boreholes are fundamental activities in order to facilitate characterisation of rock and groundwater properties at depth. KLX04 was the fifth deep cored borehole within the Oskarshamn site investigation. The location of the hole in the Laxemar subarea is shown in Figure 1-1.

The drilling of KLX04 and all related on-site operations were performed according to a specific Activity Plan, which in turn refers to a number of method descriptions, see Table 1-1.

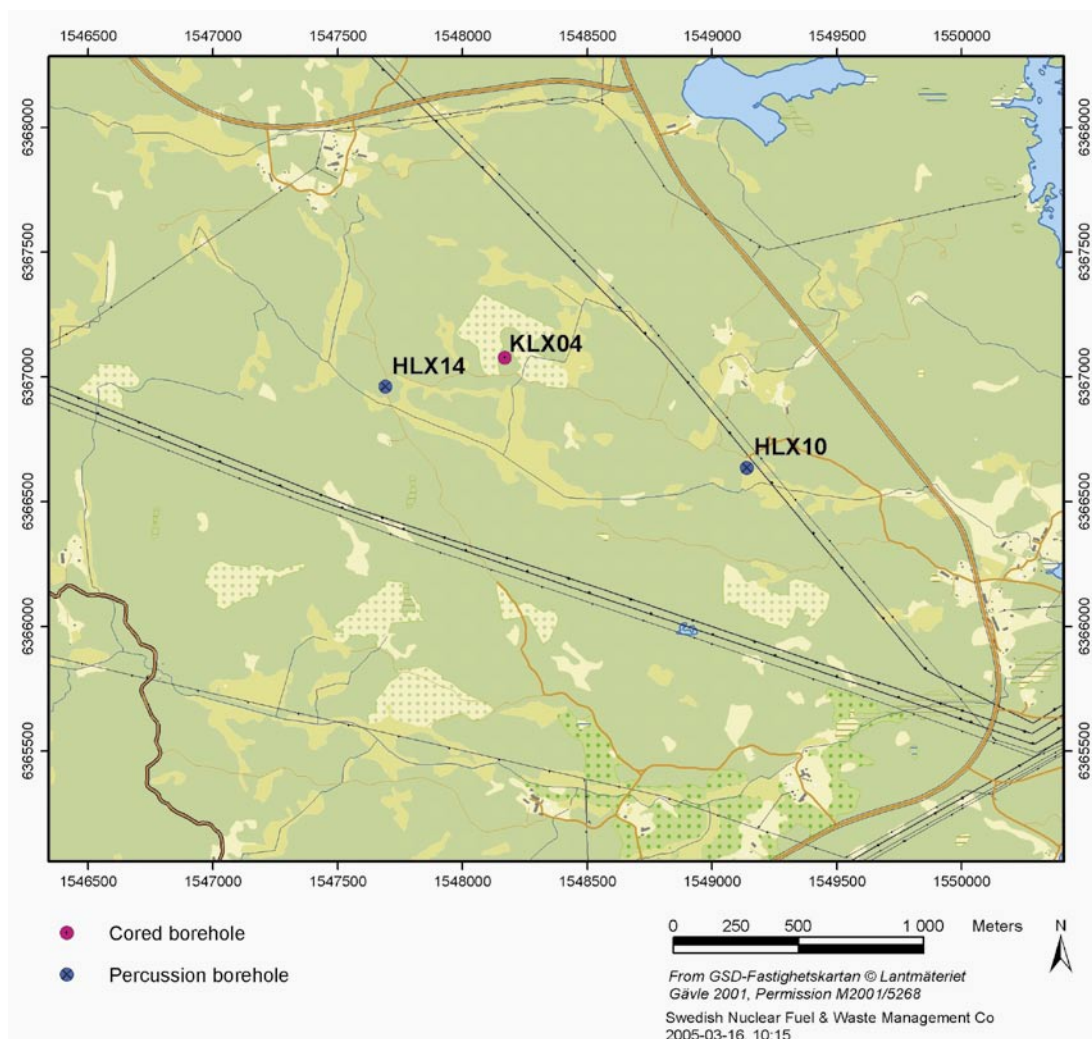


Figure 1-1. Location of the cored borehole KLX04 the Laxemar subarea and the percussion boreholes HLX10 and HLX14.

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

Activity plan	Number	Version
Kärnborring KLX04	AP PS 400-04-007	1.0
Amendment 2004-06-28	AP PS 400-04-007	SKB ID 1026797
Related activity plans	Number	Version
Karakterisering av jordlager med geotekniska metoder- jordborring, jordprovtagning och installation av grundvattenrör	AP PS 400-03-061 (includes drilling and installation of environmental monitoring wells SSM00009 and SSM00011)	1.0
Vattenkemisk och ekologisk övervakning av Ekerumsbäcken vid utsläpp av spolvatten från KLX04	AP PS 400-04-022	1.0
Method descriptions	Number	Version
Metodbeskrivning för kärnborring	SKB MD 620.003	1.0
Metodbeskrivning för hammarborring	SKB MD 610.003	1.0
Metodbeskrivning för genomförande av hydrauliska enhålstrester	SKB MD 321.003	1.0
Metodbeskrivning för registrering och provtagning av spolvattenparametrar samt borrhax under kärnborring	SKB MD 640.001	1.0
Metodbeskrivning för pumptest, tryckmätning och vattenprovtagning i samband med wireline-borring	SKB MD321.002	1.0
Mätsystembeskrivning för längdmarkering (spårfräsning)	SKB MD620.009	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 borring och undersökningar	SKB MD 600.006	1.0
Instruktion för borrhålsanläggning	SKB MD 600.005	1.0
Instruktion för spolvattenhantering	SKB MD 620.007	1.0
Instruktion för utsättning och inmätning av borrhål	SKB MD 600.002	1.0
Method description for in-situ stress measurements by means of overcoring using the Borre probe	SKB MD 181.001	1.0

The activity plans and method descriptions are SKB internal documents.

2 Objective and scope

This report will describe the methods employed and the results achieved during the drilling of KLX04. 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. Results from the overcoring measurements will only be reported here in a summary fashion as a separate report, SKB P-05-69, has been compiled /3/.

The main reasons for drilling borehole KLX04 was to gain geological information at depth of the central part of the Laxemar subarea and to facilitate further investigation at depth in the borehole. The decision to drill KLX04 is given in SKB id no 1020796.

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 issued to the regional authorities on 2003-12-19, SKB id no 1020023. A reply was received on 2004-01-26, SKB id no 1020944 (Regional Authority registration no 525-15438-03). The Regional Authorities prescribed precautionary guideline values for the emission of effluent return water from drilling, see Section 5.8.

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 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 1,000 metres, 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.

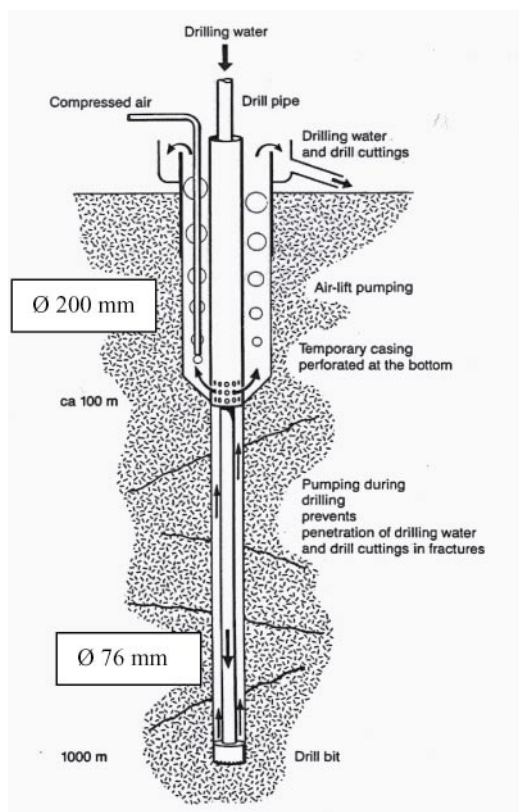


Figure 3-1. A sketch of the telescopic drilling method with air-lift pumping for retrieval of drilling water and cuttings.

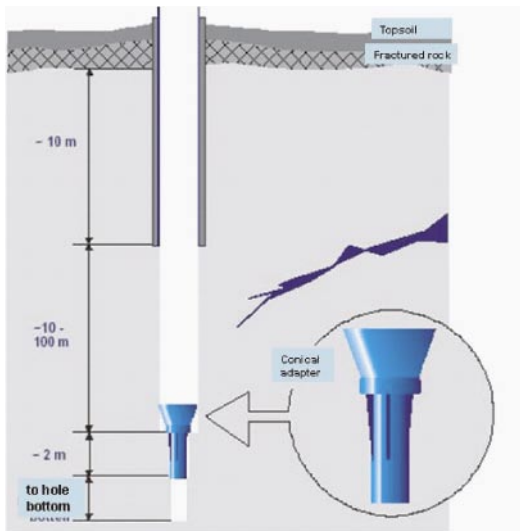


Figure 3-2. Installation of the conical guide.

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

3.1.1 The flushing water system

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

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

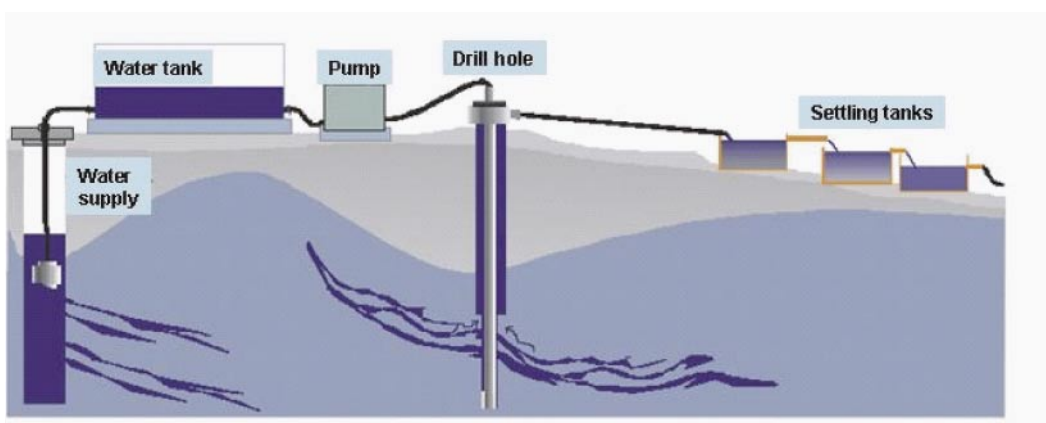


Figure 3-3. The flushing water system from source to discharge point.

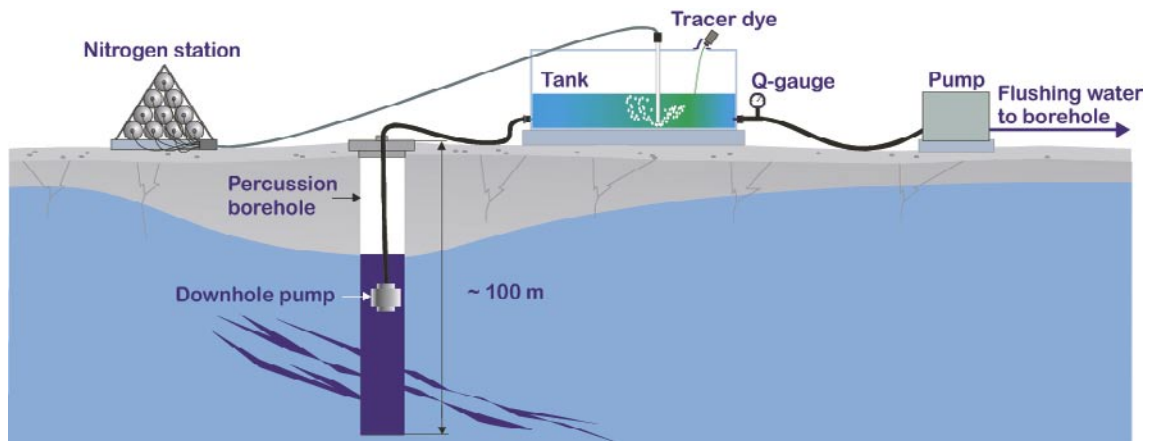


Figure 3-4. Preparation of flushing water. Uranine is added to the water in the tank as a tracer dye. Nitrogen is bubbled through the water to remove dissolved oxygen.

3.2 Measurements and sampling during drilling

3.2.1 Percussion drilling

Drill cuttings are collected manually during percussion drilling. The return water flow is measured and a sample is taken when noticeable changes in flow occur. The water colour is noted at the same time. The drill penetration rate is logged manually.

3.2.2 Core drilling

The sampling and measurements during the core drilling phase of KLX04 consisted of:

- Rock stress measurements with the overcoring method.
- Wireline measurements.
- Air lift pumping and recovery tests.
- Water sampling at the surface.
- The drilling monitoring system.

Overcoring rock stress measurements

Three-dimensional overcoring rock stress measurements are based on measuring strains when a sample of rock is released from the rock mass and the stresses acting upon it. The in situ stresses can be calculated from the measured strains and with knowledge of the elastic properties of the rock. Only a brief account of the methods employed and results obtained will be included in this report as a complete account is given in SKB report P-05-69 /3/.

Wireline measurements and water sampling

The measurements and the sampling are made in the borehole with a wire-line 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 hydrogeological measurement 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 and/or recovery

Air lift pumpings with evaluation of drawdown and/or recovery are done with 300 metres intervals, nominally at 400, 700 and 1,000 metres length. The actual levels are adapted to when changes of drill bit, or some other reason to raise the drill stem, occur. The test cycle can include both the drawdown phase and the recovery phase, however normally the recovery phase would be used for evaluation.

- 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 one hour 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, ie the water entering and returning from the borehole at the surface, are taken at 10 to 20 metres 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 parameters (logged every centimetre of bit penetration) and flushing water parameters (logged every 10 seconds). The data is compiled into a database called drilling monitoring system (DMS).

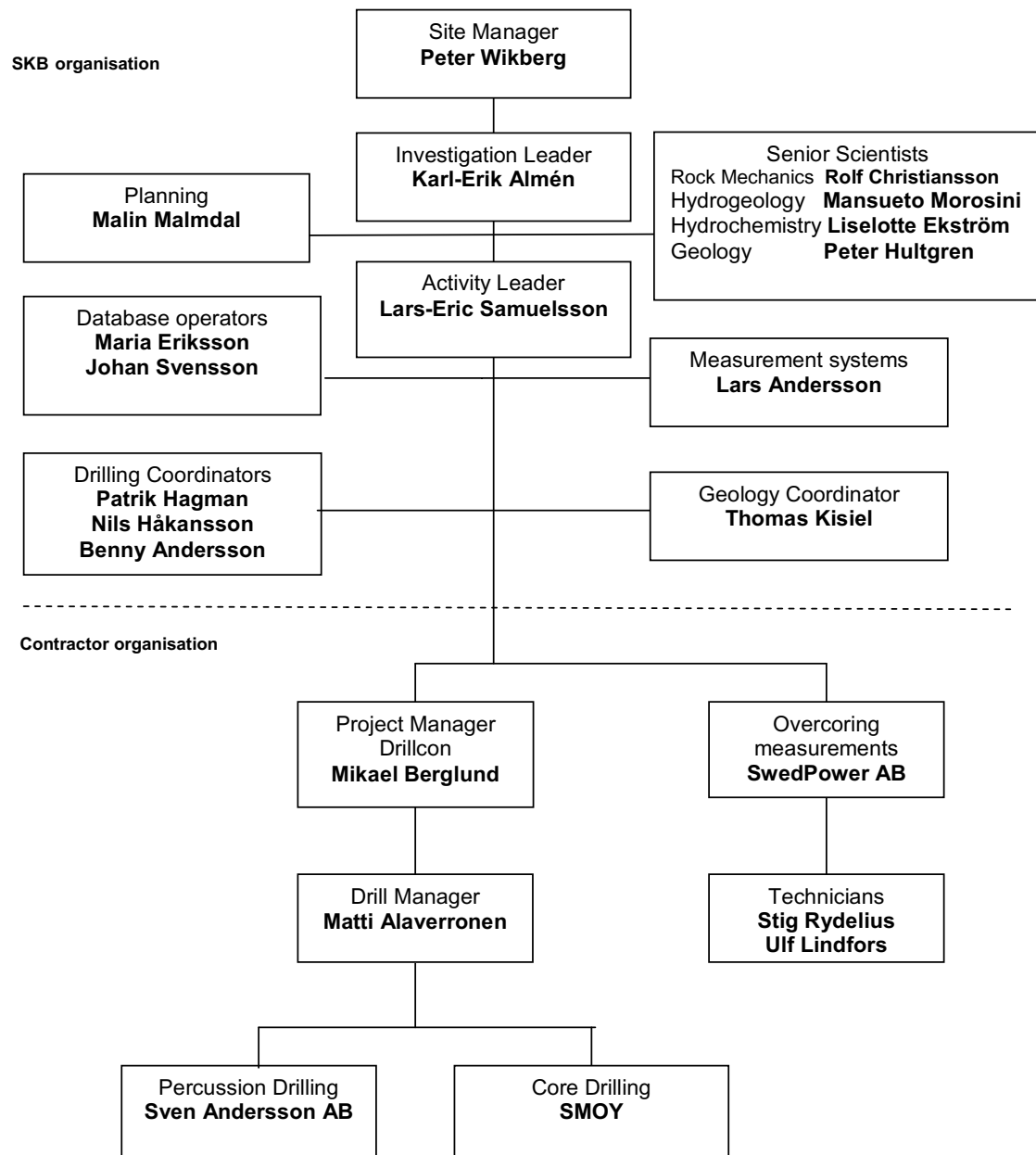
4 Contractors and equipment

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.

Table 4-1. Drill activity organisation.



4.2 Percussion drilling equipment

The equipment used was a Puntel MX1000 percussion drill rig with an Atlas Copco XRVS 455 Md air compressor. The down-the-hole hammer was a Secoroc 8" or 6" and the drill rods were Driqoneq 114 mm. The casing utilized was SS 2343 208×4 mm and 324×7 mm. The casing dimensions are presented as outer diameter and thickness.

4.3 Core drilling equipment

Core drilling in KLX04 was made with a B 20 P Atlas Copco fully hydraulic machine fitted with a modern and environmentally adapted diesel engine. The rods were of the type Corac N3/50 NT with a 76 mm wireline triple tube core barrel system which gives a core diameter of 50.2 mm.

4.3.1 Equipment for overcoring measurements

The *Borre* probe is owned and used by Swedpower AB for stress measurements in deep, water-filled boreholes. The equipment for overcoring rock stress measurements using the *Borre* probe comprises:

- pilot hole drilling equipment for wireline core drilling, including planing tool,
- inspection tool (test probe) with built-in borehole cleaning brush,
- *Borre* probe with built-in data logger,
- set of strain gauges (to be mounted on the *Borre* probe),



Figure 4-1. The KLX04 drill site prior to establishing the drill rig.

- glue (for bonding strain gauges to the borehole wall),
- cell adapter (installation tool),
- biaxial test equipment including load cell, pressure gauge, hydraulic pump and strain indicator; and
- portable computer.

Execution of measurements

Overcoring stress measurement using the *Borre* probe involves:

1. Pilot hole drilling and examination.
2. Preparation and installation of the *Borre* probe.
3. Overcoring and recovery of the probe.
4. Biaxial testing of the overcore sample.

The procedure for stress measurement using the *Borre* probe is briefly summarized in Figure 4-2. Further description of equipment and procedure is given in /3/.

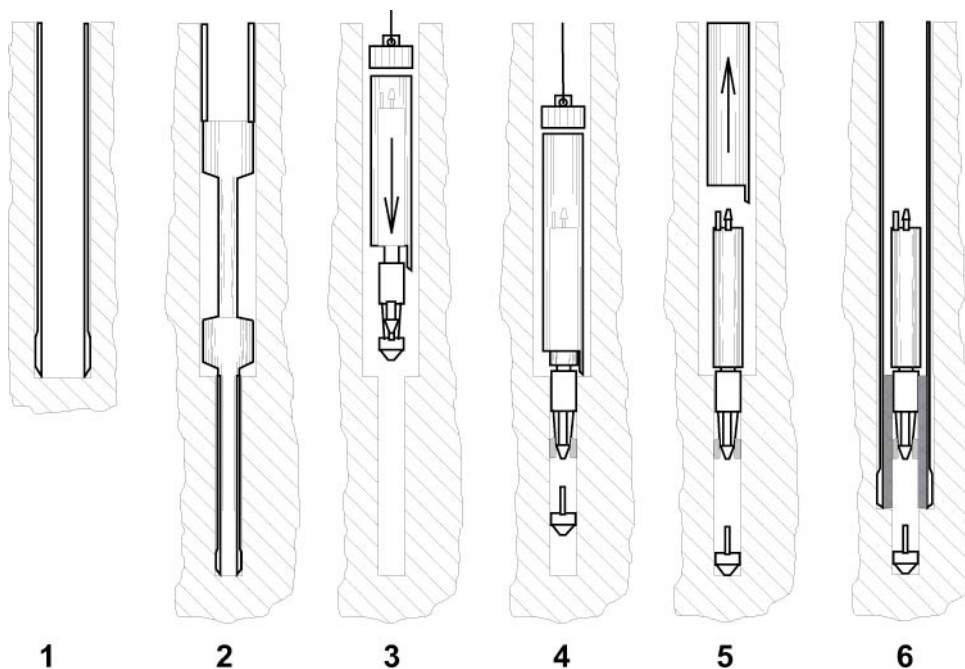


Figure 4-2. Installation and measurement procedure with the *Borre* probe:

1. Advance 76 mm-diameter main borehole to measurement depth. Grind the hole bottom using the planing tool.
2. Drill 36 mm-diameter pilot hole and recover core for appraisal. Flush the borehole to remove drill cuttings.
3. Prepare the *Borre* probe for measurement and apply glue to strain gauges. Insert the probe in installation tool into hole.
4. Tip of probe with strain gauges enters the pilot hole. Probe releases from installation tool through a latch, which also fixes the compass, thus recording the installed probe orientation. Gauges bonded to pilot hole wall under pressure from the nose cone.
5. Allow glue to harden (usually overnight). Pull out installation tool and retrieve to surface. The probe is bonded in place.
6. Overcore the *Borre* probe and record strain data using the built-in data logger. Break the core after completed overcoring and recover in core barrel to surface.

4.3.2 Wireline measurements equipment

The wireline probe equipment 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 with a wireline probe as specified in method description SKB MD 321.002, SKB internal document.

The principal components are:

- an inflatable packer,
- a probe fitted with 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 and packer are 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 4-3.

Before the pumping tests are made, measurements for absolute pressure and a leakage test of the drill string is done.

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

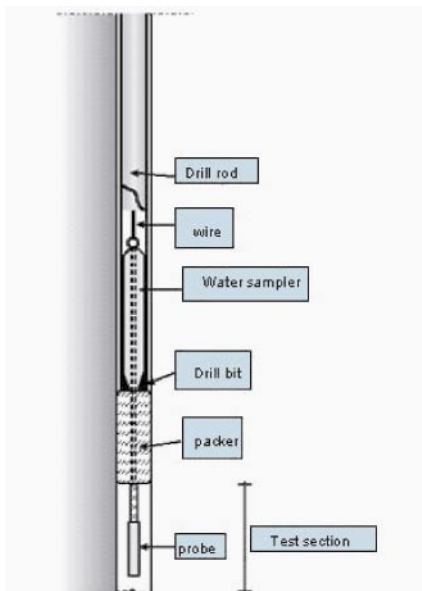


Figure 4-3. The wireline probe and its emplacement in the hole.

Pumping tests

The wireline probe is emplaced at the bottom of the drill stem. A submersible pump 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 in the probe at a pre-determined 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 in the probe. The pumped surface flow rate is recorded to a data logger on the ground surface. The 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 a maximum sample 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 ($\pm 0.05\%$ FSD).

4.3.3 Drilling monitoring system

During the core drilling phase continual monitoring was made of several measurement while-drilling (MWD) parameters and flushing water parameters. The data is compiled into the DMS database.

The results presented in this report have been checked in accordance with a working routines for quality assurance of DMS data that have been in use since October 2003.

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).
- Air 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 diskette or CD-ROM to the DMS database.

4.3.4 Equipment for deviation measurements

Deviation measurements were performed in the boreholes using a Reflex MAXIBOR™ (non-magnetic) optical equipment.



Figure 4-4. The CR23 logging unit for parameters “air-pressure” and “electrical conductivity”.

4.3.5 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 when the water pressure is increased the cutters expand.

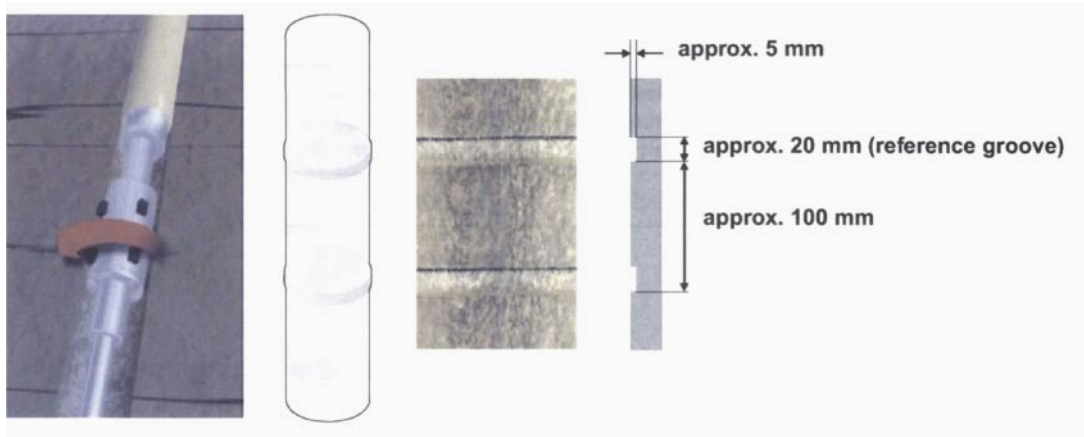


Figure 4-5. The equipment for reaming of reference slots. To the left, the reaming tool with openings for the cutters is shown. The resulting reference slots are illustrated in the three pictures to the right.

5 Execution and results

5.1 Summary of KLX04 drilling

A technical summary of the drilling of KLX04 and the borehole design after completion is given in Table 5-1 and Figure 5-1. A summary of drilling progress and borehole measurements is given in Table 5-2. Drilling progress over time is given in Section 5.5 “Drilling monitoring results”, see Figure 5-14.

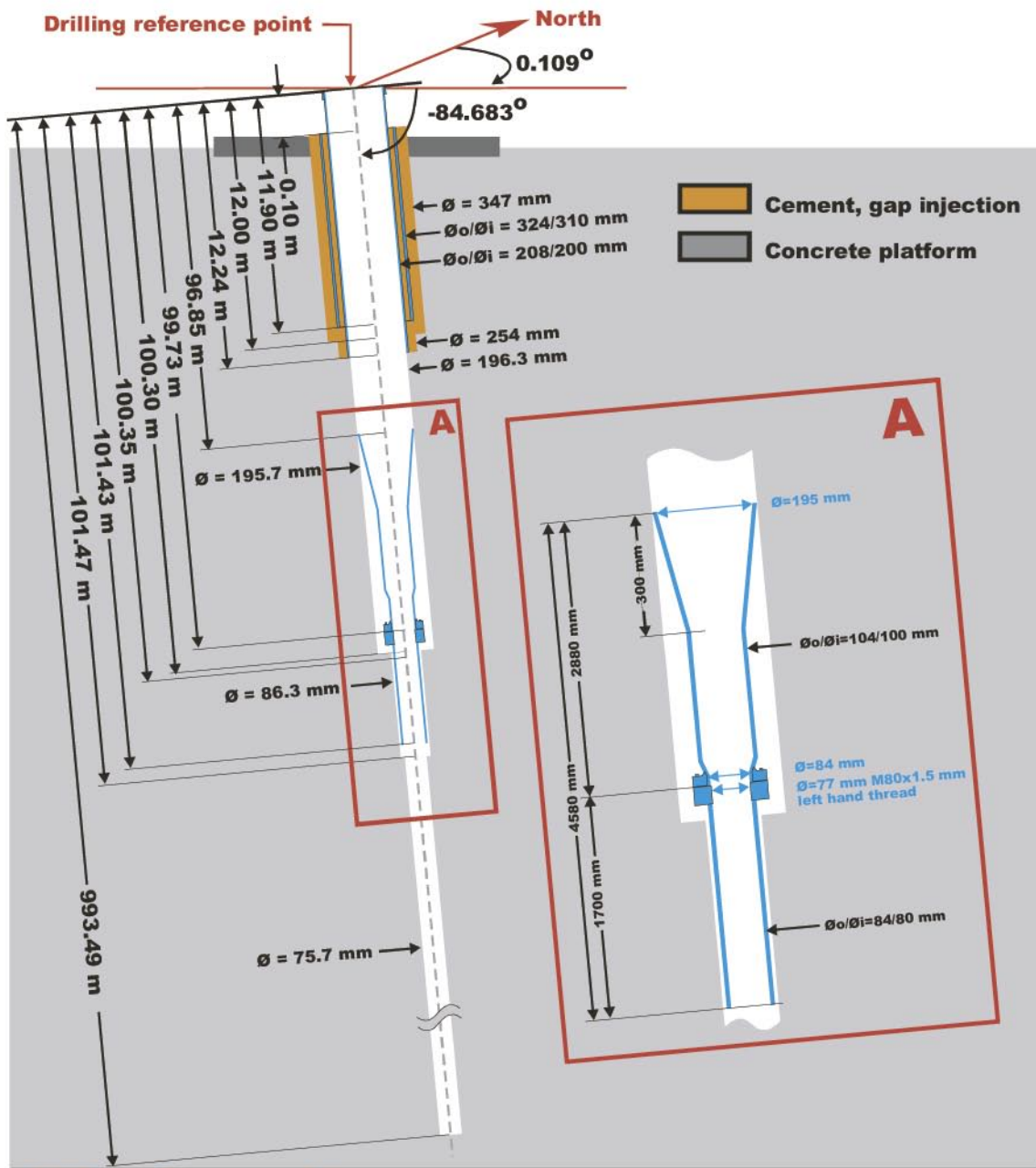
Further descriptions of the two main drilling steps, the telescope section 0–100.35 metres and the core drilling section 100.35–993.49 metres are given in Sections 5.2 and 5.3 respectively.

Table 5-1. KLX04 Technical summary.

General	Technical
Name of hole: KLX04	Percussion drill rig Puntel MX 1000
Location: Simpevarp, Oskarshamn Municipality, Sweden	Percussion hole length 100.35 m (160 mm) 100.30 m (196 mm)
Contractor for drilling: Drillcon AB	Core drill rig B 20 P Atlas Copco Core drill dimension 76 mm
Subcontractor percussion drilling: Sven Andersson AB	Cored interval 100.35–993.49 m Average core length retrieved in one run 2.06 m
Subcontractor core drilling: Suomen Malmi OY (SMOY)	Number of runs 434
Drill start date February 11, 2004	Diamond bits used 14
Completion date June 28, 2004	Average bit life 64 metres
	Position KLX04 (RT90 RH70) at top of casing: N 6367077.19 E 1548171.94 Z 24.09 (masl) Azimuth (0–360)/ Dip (0–90) 0.1 / –84.7
	Position KLX04 (RT90 RH70) at 987 m length: N 6367158.83 E 1548222.75 Z –957.57 (masl) Azimuth (0–360)/ Dip (0–90) 63.3 / –82.6

Technical data

Borehole KLX04



Drilling reference point

Northing: 6367077.19 (m), RT90 2,5 gon V 0:-15

Easting: 1548171.94 (m), RT90 2,5 gon V 0:-15

Elevation: 24.09 (m), RHB 70

Drilling period

Drilling start date: 2004-02-11

Drilling stop date: 2004-06-28

Figure 5-1. Technical data from KLX04.

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

KLX04 Core drilling history and summary of measurements					
		Measurements of absolute pressure	Air lift pumping with evaluation of drawdown and/or recovery	Deviation measurement	Miscellaneous
0	Pumping tests, water sampling			22/3-04 Maxibor measurement 0-183 m. 1.26 m right 1.46 m above.	
100	25/3-04. Drilled length 213 m. Three attempts to do pump tests. The third test worked. Test section 103.00-213.14m with water sampler. Ca 2.4 L/min, 14 m drawdown. Water sample taken.	Measurement of pressure was not done because the rock stress measurements were done instead.			
200	18/4-04. Drilled length 329m. Pumping test in section 211.00-329.15 m, without water sampler. Flow 7 L/min with 9 m drawdown. Water sample collected on the surface (ie not with downhole sampler)	18/4-04. Measurement of absolute pressure, section 210.00-344.17 m.		16/4-04 Maxibor measurement 0-306 m. 3.80 m right 2.27 m above.	Possible cave-in at levels 256, 263, 295 and 350 m. These levels were flushed before rock stress measurements were made.
300	7/5-04. Drilled length 403.82 m. Pumping test in section 329.00-403.82 m, without water sampler. Flow 5.9 L/min with 7.5 m drawdown. Water sample taken on the surface	9/5-04. Measurement of absolute pressure, section 329.00 - 418.95 m.	Recovery measurement 12.24 - 403.82 m. No pipes in borehole.	27/5-04 Maxibor measurement 300-534 m. 4.75 m right. 0.13 m above.	
400	24/5-04. Drilled length 515.10 m. Pumping test in section 402.00 - 515.10 m, without water sampler. Flow 3.2 L/min with 8.0 m drawdown. Water sample taken on the surface.	25/5-04. Measurement of absolute pressure, section 402.00 - 522.65 m.			
500	3 and 4/6-04. Drilled length 617.00 m. Two pumping tests done, problems with pump MP1. Tested section 513.15-617.00 m, without water sampler. Flow 2.9 l/min with 7.5 m drawdown. No water sample taken	6/6-04. Measurement of absolute pressure, section 513.15 - 639.26 m.			
600	10/6-04. Drilled length 701 m. Pumping test in section 615.00-701.16m, without water sampler. Flow 2.0 L/min with 18 m drawdown. Water sample at surface	12/6-04. Measurement of absolute pressure, section 615.00 - 701.16 m.	Recovery measurement 12.24 - 757.00 m. No pipes in borehole.		
700	19/6-04. Drilled length 850 m. Pumping test in section 698.20-850.40 m, with water sampler. Flow 0.85 L/min with 21 m drawdown. Water sample taken with downhole sampler.	No measurement of absolute pressure as the flow was below 1 L/min.		15/6-04 Maxibor measurement 0-744 m. 25.08 m right. 2.13 m below.	
800					
900	28/6-04. Drilled length 993.49 m. Pumping test in section 849.00-993.49 m, with water sampler. Flow 0.65 L/min with 30 m drawdown. Water sample taken with downhole sampler.	No measurement of absolute pressure as the flow was below 1 L/min.	Recovery measurement 12.24 - 993.49 m. No pipes in borehole.	28/6-04. Maxibor measurement 0-987 m. 48.48 m right. 7.65 m below.	
1000					

5.2 Drilling, measurements and results in the telescopic section 0–100.35 m

Drilling, reaming and gap injection were made from February 11 to 18, 2004.

5.2.1 Preparations

A cement pad for emplacement of drill rig, fuel container and compressor was built.

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

5.2.2 Drilling and casing installation

The construction of the upper telescope section (0–100.35 metres) of KLX04 was made in steps as described below:

Drilling was done by Sven Andersson AB from February 10 to 18 and consisted of the following items:

- Drilling was made to 12.00 metres length with NO-X 280 mm equipment. This gave a hole diameter of 347 mm and left a casing (324×7 mm diameter) to a depth of 11.90 m. The soil depth was 1.9 metres.
- Inner supportive casing for guidance for the drill string was mounted and a cement plug was emplaced at 12.00 metres.
- A pilot percussion hole of 162.7 mm was drilled to a depth of 100.35 metres.
- The hole was reamed to diameter 254 mm between 12.00–12.24 m.
- Stainless casing of 208×4 mm was installed from 0 to 12.24 m and gap injection with low alkali cement based concrete (500 kg or 560 litres) was made as described in Figure 5-2.
- After hardening the hole was rinsed and flushed to remove concrete and water. The tightness of the concrete gap filling was tested by manual groundwater measurements which confirmed that the water inflow was less than the required 0.5 litres per minute.
- The borehole was reamed to a diameter of 195.7 mm (lower end) between 12.24 and 100.3 metres.

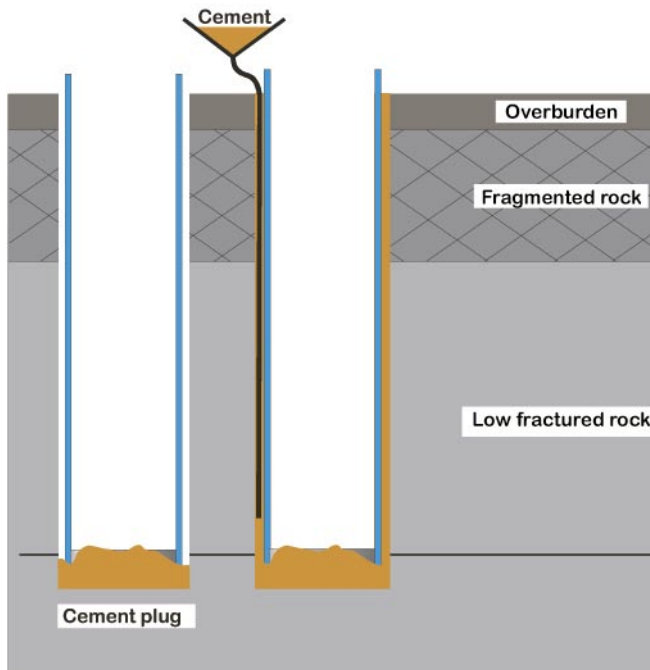


Figure 5-2. Gap injection technique I A cement plug is emplaced at the bottom and allowed to harden. The gap filling cement is introduced between the casing and the rock wall.

5.2.3 Measurements and sampling in the telescopic section

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

- Drill cuttings were collected by taking three grab samples over a length of three metres resulting in one composite sample per three metres. The samples were stored for preliminary logging.
- Penetration rate (expressed as seconds per 20 cm) was recorded manually and observation of changes in water flow was noted.

The preliminary geological results and penetration rate is presented in Figure 5-3.

Hydrogeology

The total water yield at full length was 2–4 L/min. No distinct zones of water inflow could be noted during percussion drilling.

Hydrochemistry

No water samples were collected from the telescopic section in KLX04.

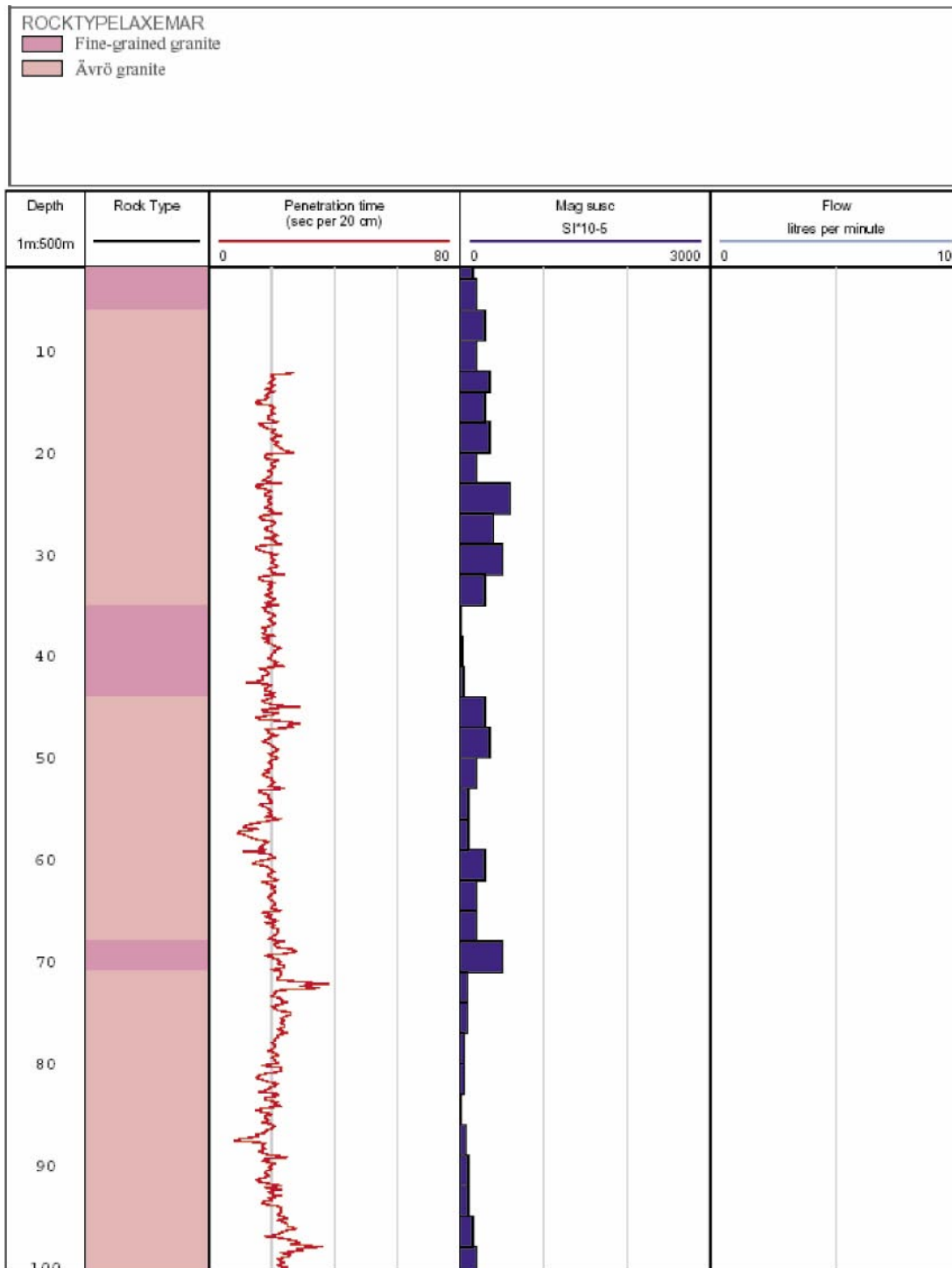


Figure 5-3. Preliminary geological results based on logging of drill cuttings and penetration rate from percussion drilling of KLX04.

5.3 Core drilling 100.35–993.49 m

Core drilling in KLX04 was conducted between March 13, 2004 and June 28, 2004.

The main work in KLX04 after drilling the telescopic section consisted of the following

steps:

- preparations for core drilling,
- core drilling,
- overcoring rock stress measurements,
- deviation measurements,
- borehole completion.

Measurements and results from wireline tests and drill monitoring are given in Sections 5.4 and 5.5.

5.3.1 Preparations

The preparations for the core drilling consisted of installation of air-lift pumping equipment and supportive casing for alignment of the core drill rods, see Figure 5-4.

The installation of supportive casing was done in two 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 100.35 and 101.47 m with T-86 equipment. An inner supportive casing with diameter 84/77 mm was installed to 101.47 m.

The supportive casings have a perforated section between 99.67 and 99.97 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 89.57 metres.

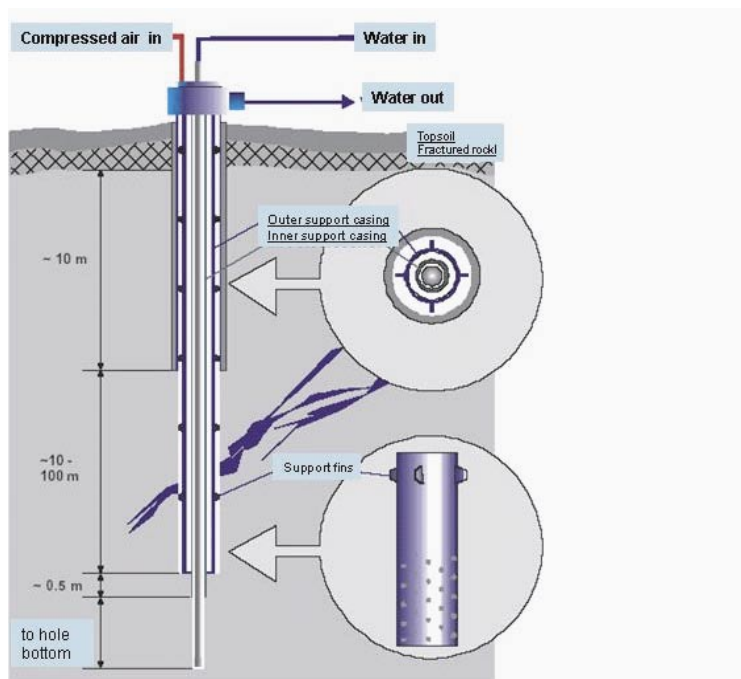


Figure 5-4. In the telescopic part of the drill hole a temporary installation is made with casing tubes for support and alignment and equipment for air-lift pumping. In the uppermost part the return water discharge header is mounted. The water discharge is led to the settling containers.



Figure 5-5. Fitting the air-lift pumping equipment before installation in the borehole.

The flushing water source was percussion borehole HLX10, see Figure 1-1. Treatment of the flushing water before introduction into borehole KLX04 consisted of removal of oxygen by nitrogen flushing and addition of the fluorescent tracer uranine. The average uranine content was 0.21 mg/L, see also Figure 5-9 and Section 5.5.2.

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

5.3.2 Drilling

Core drilling with 76 mm triple-tube, wireline equipment was conducted from 101.47 m to the final length of 993.49 m which gave a core of 50.2 mm diameter.

A total of fourteen drill bits were used for KLX04, see Figure 5-6.

The elasticity of the drill stem was not measured during the drilling of KLX04.

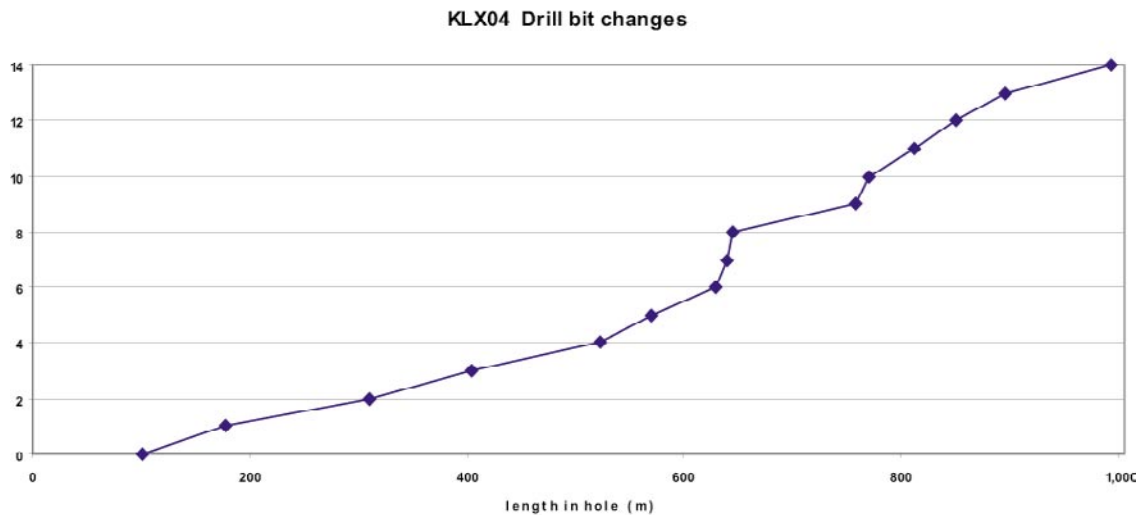


Figure 5-6. Changes of drill bit during core drilling in KLX04.

Further results from drill monitoring ie drill penetration rate and various measurements will be presented in Chapter 5.5 “Drilling monitoring results” and in Appendix 1. The drilling progress over time is shown in Section 5.5, see Figure 5-14.

5.3.3 Overcoring measurements

Measurements were made in two length intervals, 233–245 metres and at 374–451 metres.

The stress state in borehole KLX04 was characterized by low stress in the upper interval and relatively high stress in the lower interval. The direction of the major principal stress varied between the two measured levels.

The overcoring rock stress measurements are reported separately /3/ and will not be commented further here.

5.3.4 Deviation measurements

Two plots of the results of the final run with the Maxibor method covering the entire length of borehole KLX04 are given in Appendix 4.

5.3.5 Borehole completion

Reaming of depth reference slots was done at intervals as shown in Table 5-3. 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.

After core drilling was concluded, the air lift pumping equipment and the inner supportive casing in the telescopic section was removed.

A steel conical guide was installed between 96.85 m and 99.73 m depth together with a 86/80 mm casing between 99.73 and 101.47 m. The conical guide tapers from an inner diameter of 195 mm to 77 mm.

Table 5-3. Depth reference slots (m).

110.00 m	550.00 m
150.00 m	600.00 m
200.00 m	650.00 m
250.00 m	700.00 m
300.00 m	750.00 m
349.00 m	800.00 m
400.00 m	849.00 m
450.00 m	899.00 m
500.00 m	950.00 m

The length of the hole was rinsed by flushing nitrogen gas four times. A total of 30 m³ of water was flushed out of the hole. A dummy probe was run through the length of the hole to ensure that the hole was unobstructed.

The borehole was secured by mounting a lockable steel cap 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 100.35–993.49 m

The performed measurements, as already outlined in Table 5-2, can be summarised as follows:

Wireline measurements:

- Nine pumping tests, all successful, were conducted, see Section 5.4.1.
- Five measurements of absolute pressure, see Section 5.4.1.
- Water samples were successfully collected from seven of the nine pumping tests, see Section 5.4.2.

Analytical results from sampling of flushing and return water at the surface are given in Section 5.4.2.

Three air lift pumping tests with evaluation of drawdown and/or recovery were made, see Section 5.4.3.

Hydraulic responses were observed in conjunction with flushing with nitrogen gas, see Section 5.4.3.

5.4.1 Hydrogeological results from wireline measurements

Results from the pumping tests in KLX04 are presented in Table 5-4 and Figure 5-7.

The pumping tests were evaluated with steady-state assumption in accordance with /4/. The flow rate at the end of the drawdown phase was used for calculating the specific capacity (Q/s) and transmissivity (T_M), where “Q” is the flow rate in L/min, “s” is the drawdown in kPa and “T_M” is the transmissivity.

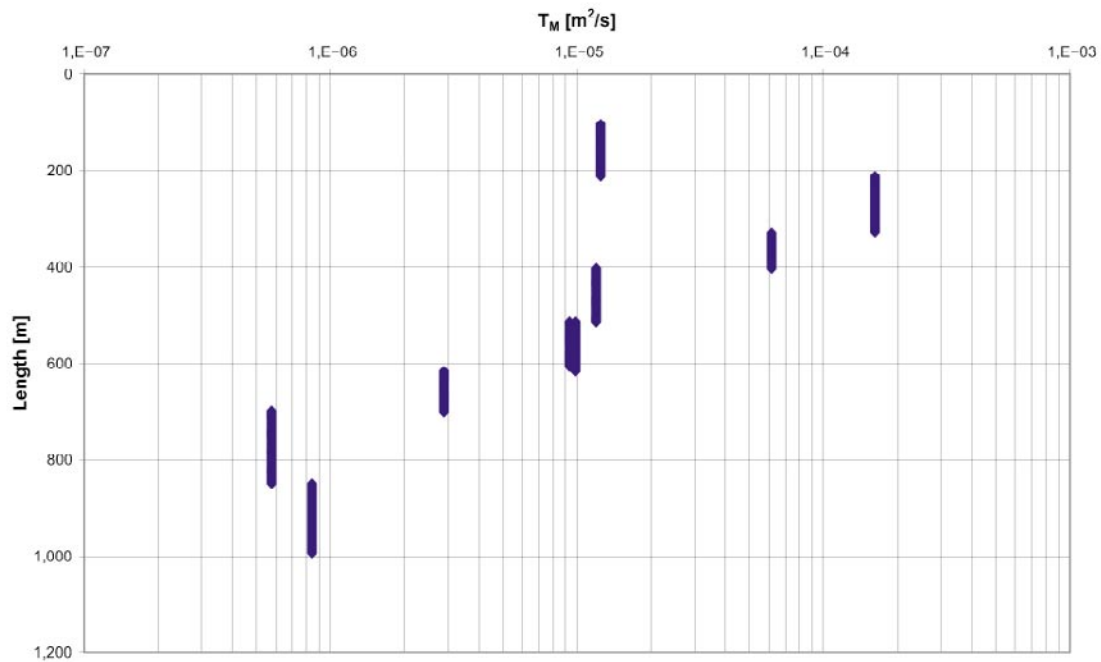


Figure 5-7. Transmissivity from wireline pumping tests in KLX04 versus borehole length.

Table 5-4. Pumping tests with the wireline probe in KLX04.

Tested section (m)	Q/s (m ² /s)	T _M (m ² /s)	Comments
103.00–213.14	9.5×10 ⁻⁶	1.2×10 ⁻⁵	Test functionally OK.
211.00–329.15	1.2×10 ⁻⁴	1.6×10 ⁻⁴	Water sample from ground surface. The test was OK despite some missing values of flow, conductivity, and pressure due to technical problems.
329.00–403.82	4.9×10 ⁻⁵	6.2×10 ⁻⁵	Water sample from ground surface. Test functionally OK.
402.00–515.10	9.1×10 ⁻⁶	1.2×10 ⁻⁵	Water sample from ground surface. Test functionally OK.
513.15–608.15	7.2×10 ⁻⁶	9.3×10 ⁻⁶	Test functionally OK, but short pumping time (97 min).
513.15–617.00	7.5×10 ⁻⁶	9.9×10 ⁻⁶	Highly variable flow at the end of the pumping period.
615.00–701.16	2.3×10 ⁻⁶	2.9×10 ⁻⁶	Water sample from ground surface. Test functionally OK.
698.20–850.40	4.2×10 ⁻⁷	5.8×10 ⁻⁷	Highly variable flow in the first hour of pumping. Stable flow and pressure at the end of pump phase.
849.00–993.49	6.2×10 ⁻⁷	8.4×10 ⁻⁷	Test functionally OK.

A total of nine pumping tests were performed, and all of them achieved sufficiently stable conditions for calculating pseudo steady-state transmissivity. The individual plots from the 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 5-5.

Table 5-5. Start and stop times for the interval used for evaluation of the pumping tests.

Tested section (m)	Start (YY-MM-DD HH:MM)	Stop (YY-MM-DD HH:MM)
103.00–213.14	2004-03-24 18:02	2004-03-25 06:31
211.00–329.15	2004-04-17 17:25	2004-04-18 04:30
329.00–403.82	2004-05-07 04:50	2004-05-07 15:22
402.00–515.10	2004-05-24 16:45	2004-05-25 00:20
513.15–608.15	2004-06-03 02:35	2004-06-03 04:12
513.15–617.00	2004-06-04 03:28	2004-06-04 05:04
615.00–701.16	2004-06-10 19:48	2004-06-10 22:20
698.20–850.40	2004-06-19 18:45	2004-06-19 21:45
849.00–993.49	2004-06-28 19:42	2004-06-28 22:44

Measurements of the absolute pressure were conducted in five sections, see Table 5-6. Graphical results from the tests are shown in Figure 5-8 and in full in Appendix 6.

Table 5-6. Absolute pressure measurements in KLX04.

Tested section	Last pressure reading during build-up (kPa)	Duration of pressure build-up (hours)	Borehole length to pressure gauge (m)
210.00–344.17	2,056	13.5	212.10
329.00–418.95	3,194	13.5	330.10
402.00–522.65	3,928	18	403.10
513.15–639.26	5,009	9	514.25
615.00–701.16	6,005	12.5	616.10

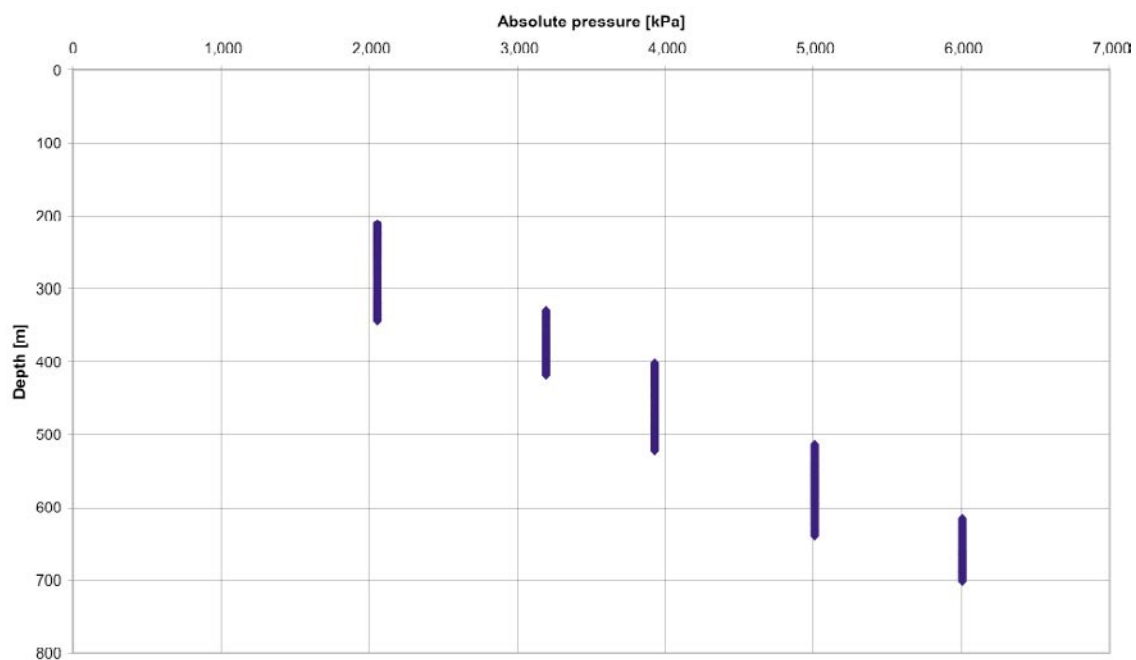


Figure 5-8. Absolute pressure measurements from wireline tests in KLX04 versus borehole length.

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.

5.4.2 Hydrochemistry

In total, seven water samples were collected in connection with core drilling in KLX04. The times and lengths, together with information on SKB chemistry class for the samples are given in Table 5-7.

Selected analytical results from KLX04 are given in Table 5-8. A complete record of analytical results is given in Appendix 2.

Of the two samples intended for analysis in SKB class 3, only sample 7253 had sufficiently low drilling water content to warrant a complete analysis. Cations and isotopes were not analysed in sample 7300 due to high concentration of drilling water.

Five samples were sampled for analysis according to SKB class 1. Due to high drilling water percentage no other parameters were analysed in these samples.

Table 5-7. Sample dates and length during core drilling in KLX04.

SKB number	Date	Test section, length (m)	SKB chemistry class
7253	2004-03-25	103.00–213.14	3 and all option isotopes except Cl-37 and S-34
7300	2004-04-18	210.00–329.14	3 (not analysed for main components and isotopes)
7347	2004-05-07	329.00–403.82	1
7386	2004-05-24	401.00–515.10	1
7498	2004-06-11	614.00–701.16	1
7505	2004-06-20	698.20–850.40	1
7563	2004-06-29	849.00–993.49	1

Table 5-8. Analytical results from water chemistry sampling.

Borehole	Sample no	Date	From m	To m	Drilling water %	pH	Conductivity mS/m	Cl mg/l
KLX04	7253	2004-03-25	103.00	213.14	7.76	8.12	59.2	28.6
KLX04	7300	2004-04-18	210.00	329.14	40.70	8.63	62.8	42.4
KLX04	7347	2004-05-07	329.00	403.82	66.70			
KLX04	7386	2004-05-24	401.00	515.10	96.60			
KLX04	7498	2004-06-11	614.00	701.16	97.60			
KLX04	7505	2004-06-20	698.20	850.40	91.10			
KLX04	7563	2004-06-29	849.00	993.49	100.00*			

*In the Sicada database the drilling water percentage is given at 105%. This value is not realistic and it is here reported as 100%.

The percussion drilled borehole HLX10 was used as water source. There were no samples taken from HLX10 in connection with the drilling of KLX04 but samples have been collected from HLX10 at earlier occasions and results from those analyses are reported in /5/.

A total of 146 samples for laboratory testing of uranine content in flushing and returning water were taken along the borehole. The results are shown in Figure 5-9.

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

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

Two airlift pumping tests were conducted during drilling, and one additional test was conducted after the borehole was drilled to full length. The execution of the tests can vary in detail as drilling or other related activities such as cleaning and flushing of drill cuttings can occur prior to lifting the stem. The inflow of water in the initial stage of the test made between 12.24–403.82 m is related to rinsing of cuttings after drilling.

Transmissivities were calculated on the drawdown phase according to /4/. The results are given in Table 5-9 and in Figures 5-10, 5-11 and 5-12 and stored in the Sicada database as “recovery tests” (code HY050). The tested section is defined here as being between the lower end of the grouted casing and the borehole bottom.

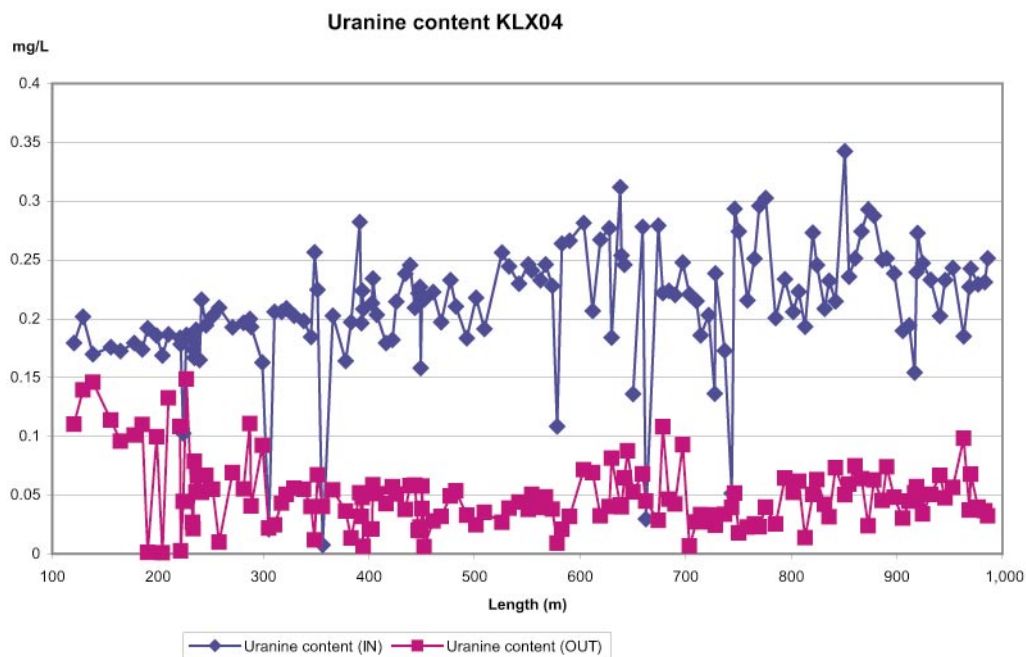


Figure 5-9. The uranine concentration of flushing water (IN) and returning water (OUT) in KLX04 during drilling.

Table 5-9. Specific capacity and transmissivity derived from air lift pumping tests conducted in borehole KLX04.

Tested section (m)	Flow rate (L/min)	Drawdown (m)	Q/s (m ² /s)	TM (m ² /s)	Comments
12.24–403.82	88	23.5	6.2×10^{-5}	9.5×10^{-5}	Recovery preceded by a too short pumping period. Drawdown from everyday airlift pumping evaluated instead.
12.24–757.00	110	7.5	2.4×10^{-4}	4.0×10^{-4}	No connection with DMS close before pumping phase. Initial head of groundwater taken at 9.24 in plot.
12.24–993.49	92	7.5	2.0×10^{-4}	3.4×10^{-4}	Groundwater level has not yet reached stable conditions.

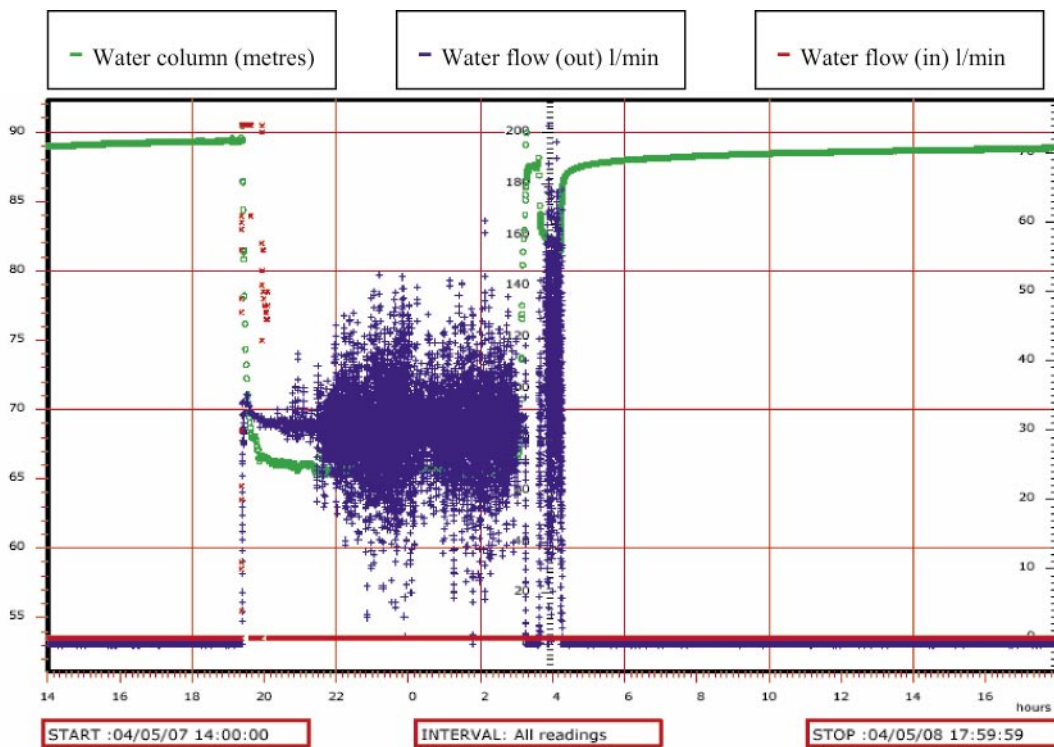


Figure 5-10. Air lift pumping test in KLX04 12.24–403.82 m (KLX04) showing the inflow rate (red), the net outflow rate (blue) and the height of the water column (green) in the telescopic part of the borehole. The pressure transducer was positioned 89.57 metres below top of casing and the flow rate was measured at the ground surface. The water flow into the borehole during the evening of May 7 is due to rinsing of the borehole prior to the lifting of the drill stem.

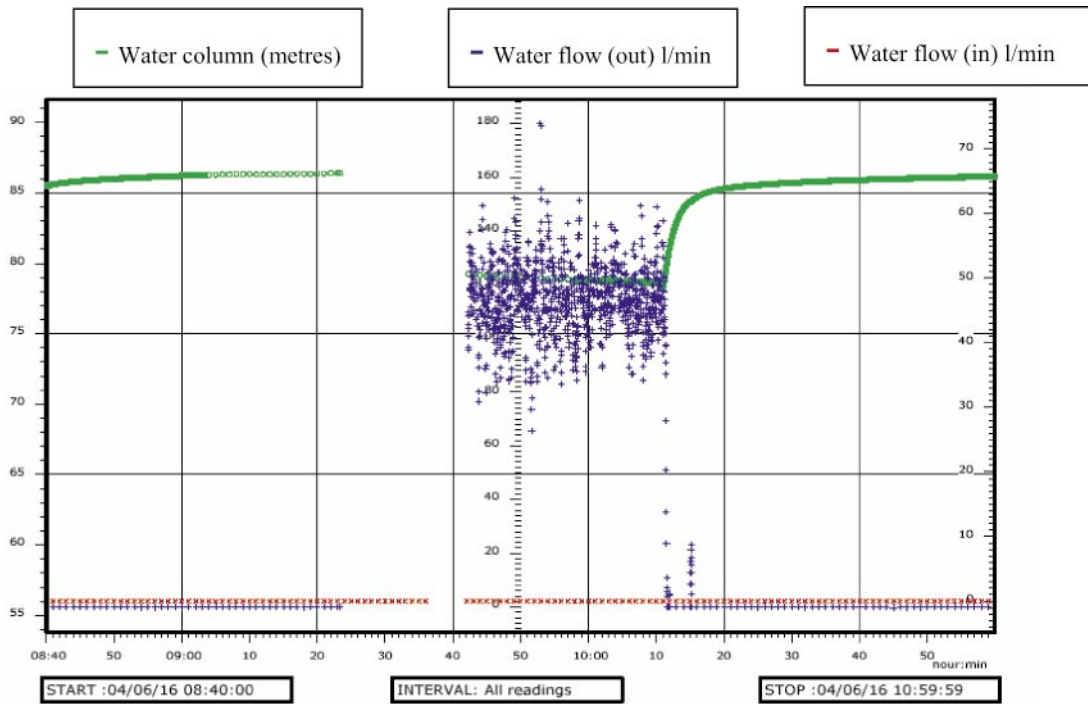


Figure 5-11. Air lift pumping in KLX04 12.24 m–757.00 m showing the inflow rate (red), the net outflow rate (blue) and the height of the water column (green) in the telescopic part of the borehole. The pressure transducer was positioned 89.57 metres below top of casing and the flow rate was measured at the ground surface.

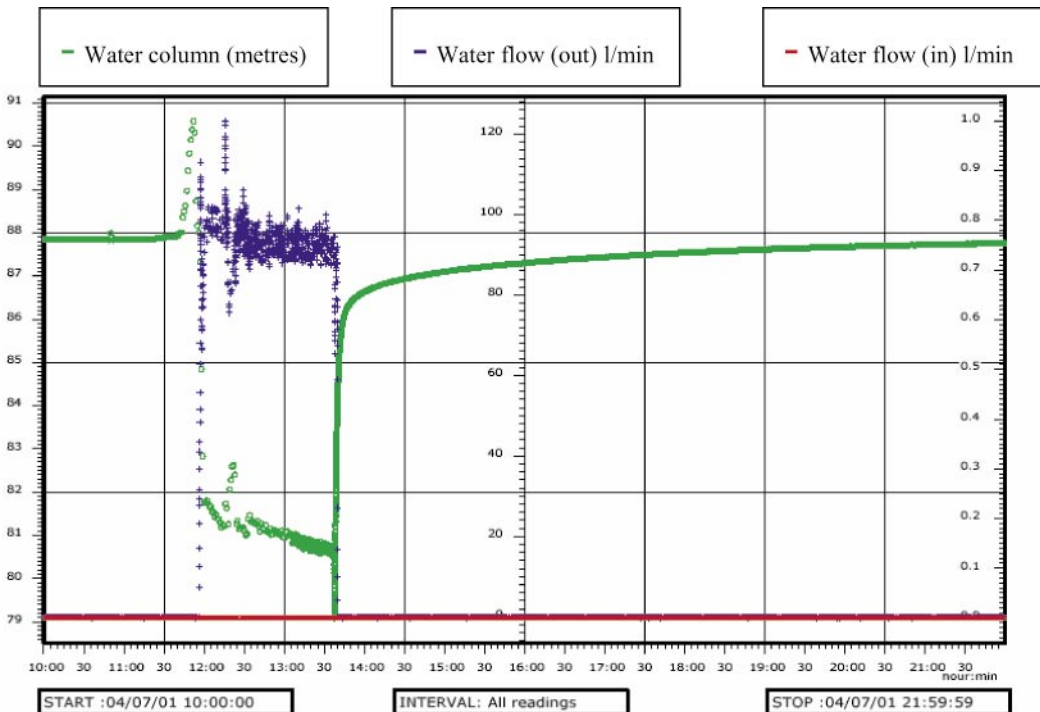


Figure 5-12. Air lift pumping in KLX04 12.24 m–993.49 m showing the outflow rate (blue) and the height of the water column (green) in the telescopic part of the borehole. There was no inflowing water during the test, as shown by the red line. The pressure transducer was positioned 89.57 metres below top of casing and the flow rate was measured at the ground surface.

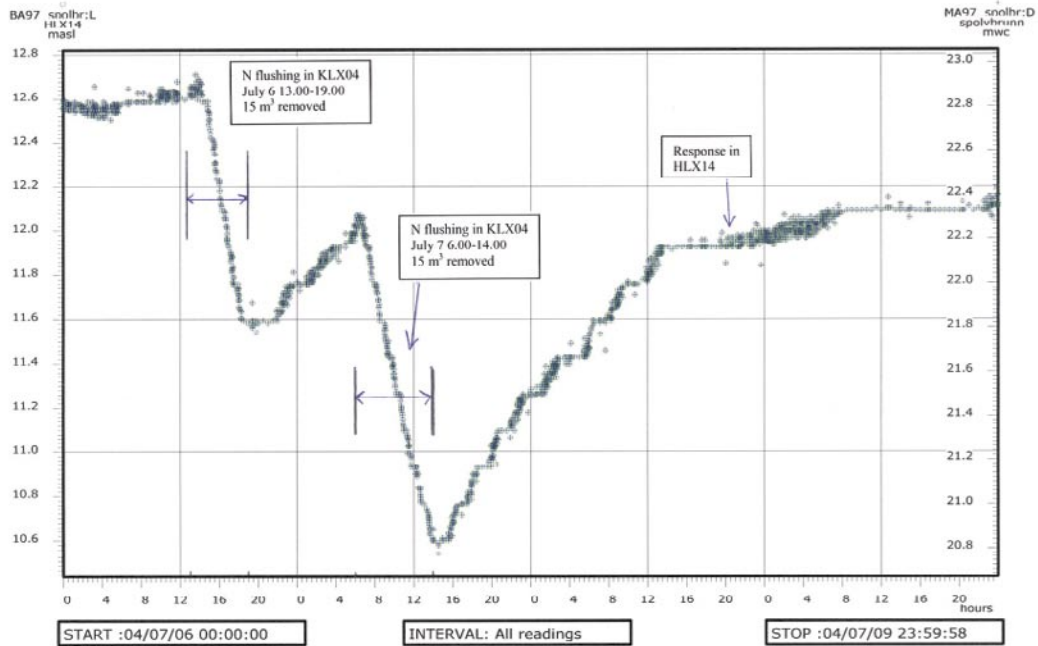


Figure 5-13. Hydraulic response in percussion borehole HLX14 during nitrogen flushing of KLX04.

5.4.4 Hydraulic responses

Hydraulic responses were observed in percussion borehole HLX14 during flushing with nitrogen gas in KLX04, see Figure 5-13. The locations of the boreholes are given in Figure 1-1.

5.5 Drilling monitoring results

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 5-14 through 5-16 below.

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

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

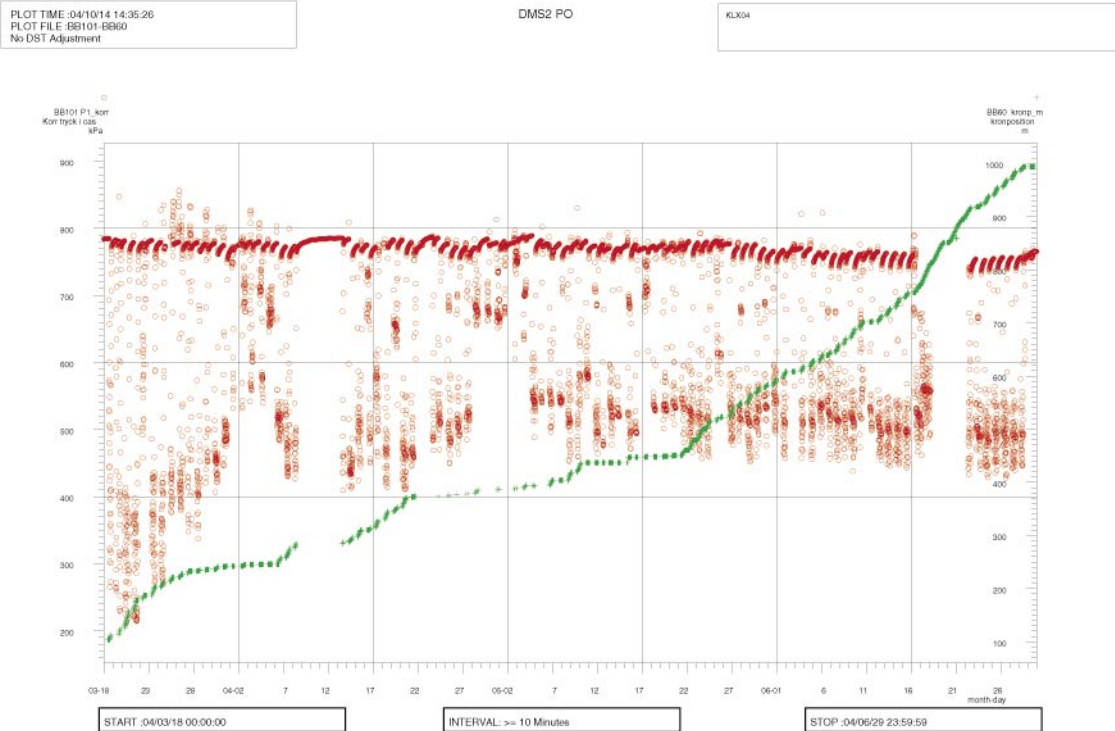


Figure 5-14. Drill bit position (green) and water level from air-lift pumping (red). The water level is expressed as the pressure in kPa of the water column overlying the pressure gauge ie the ambient air-pressure has been subtracted. The pressure gauge is emplaced at 89.57 metres borehole length. The drill bit position is given in $\text{cm} \times 10^3$.

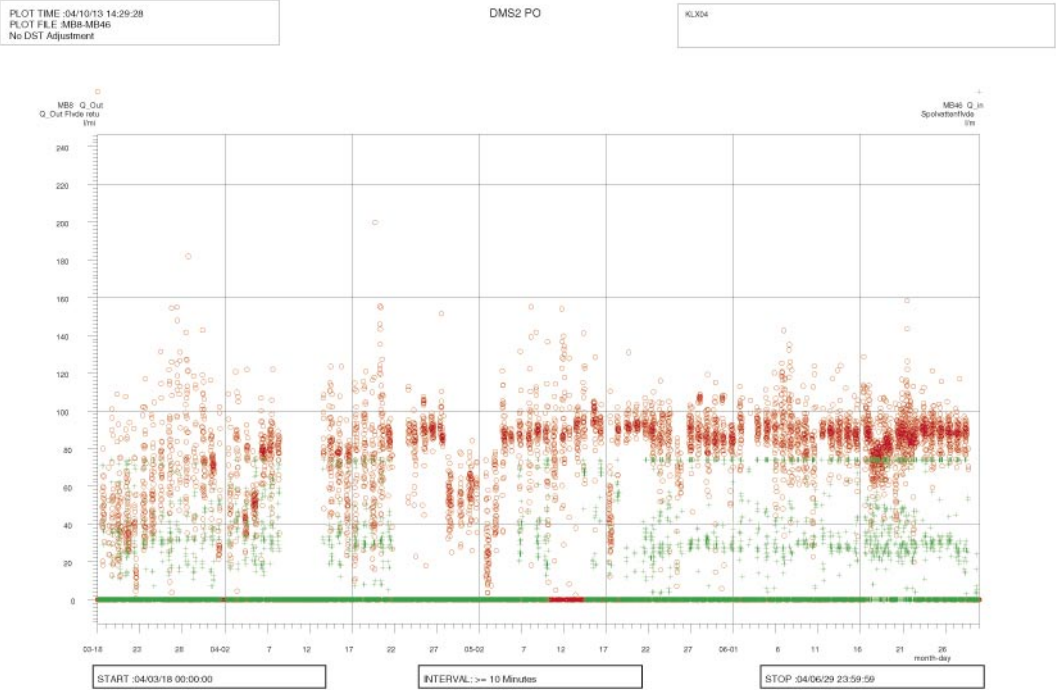


Figure 5-15. Flushing water flow (green) and return water flow (red) in litres per minute.

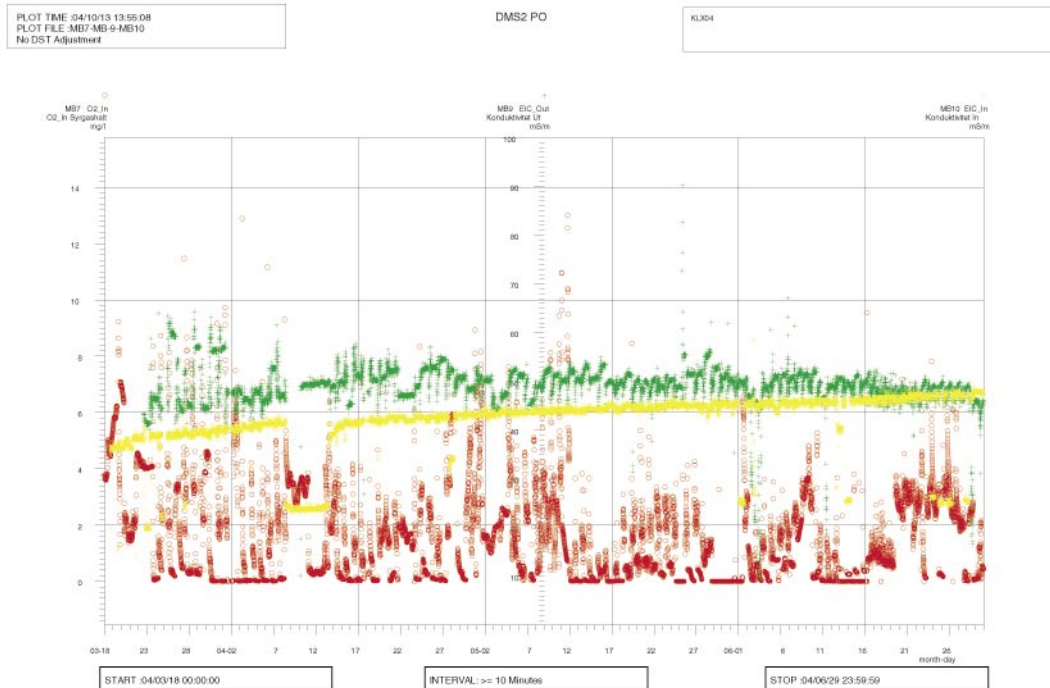


Figure 5-16. Conductivity of flushing water (yellow) and return water (green). The oxygen content in mg/l of the flushing water (red) is also shown. The oxygen content of the flushing water is normally below 4 mg/l. Short periods of higher values (5–10 mg/l) were registered due to technical problems with the oxygen metre. Typically the higher values are noted at the beginning of each day. The drop in flushing water conductivity between March 9 and 13 is due to a break in drilling over Easter.

In order to maintain reasonable size data files, a reduction in the number of points incorporated in the pictures has been done in Figures 5-14 through 5-16. Since DMS data are related to time (ie not strictly to borehole length) periods where drilling is not performed are also registered.

Figure 5-14 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 5-15 shows the flushing water flow (green) entering the hole and the return water flow (red).

Figure 5-16 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 is normally below 4 mg/l. Short periods of higher values are registered due to technical problems with the oxygen metre. Typically the higher values were often noted at the beginning of each day. The drop in flushing water conductivity between March 9 and 13 is due to a break in drilling over Easter.

5.5.2 Measurements of flushing water and drill cuttings

A calculation of accumulated water flow based on water flow measurements from the DMS system (continuous readings) is given in Figure 5-17.

The amount of flushing water consumed during drilling was 2,000 m³, giving an average consumption of ca 2.2 m³ per metre drilled.

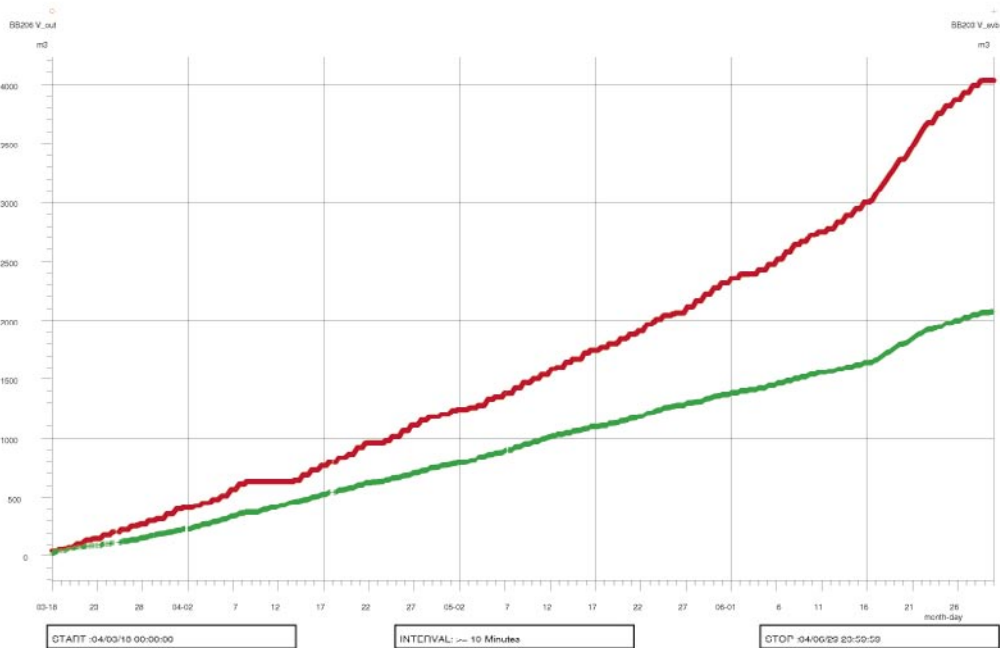


Figure 5-17. Flushing water balance from KLX04 as recorded by the DMS system. The accumulated volume of the incoming flushing water is shown in green and the outgoing return water is shown in red.

The amount of return water from drilling in KLX04 was 4,000 m³ with an average of ca 4.4 m³ per metre drilled.

The weight of cuttings in the settling containers amounted to 1,195 kg. The content of suspended material in the return water was not analysed in borehole KLX04, however samples in previous boreholes have shown the content to be 400 mg/L /9/. The amount of material in suspension carried with the return water would amount to 1,600 kg. The theoretical amount that should be produced from drilling with 76 mm triple tubing over a length of 900 metres is 6,000 kg assuming a density of 2.65 kg/dm³. This means that slightly less than half the amount of material liberated by drilling is removed from the formation. The recovered drill cuttings were collected in steel containers. After completion of drilling, the containers were removed from the site and emptied at an approved site.

The amount of introduced and recovered uranine is presented in Table 5-10. The results show that just under 50% of the introduced uranine is retrieved from the formation during drilling.

Table 5-10. Balance calculation of uranine tracer in KLX04.

Average uranine content IN (mg/L)	0.21
Volume IN (m ³)	2,000
Amount uranine introduced (g)	420
Average uranine content OUT (mg/L)	0.05
Volume OUT (m ³)	4,000
Amount uranine recovered (g)	200

5.6 Geology

The geological results based on the Boremap logging, /6/, are shown in Appendix 1.

The core is dominated by Ävrö Granite with minor intercalations of granite, fine-grained diorite, fine-grained granite and fine-grained diorite-gabbro. Between 450 and 550 m rather large portions of Quartz monzodiorite occur. Another section of Quartz monzodiorite has been noted at 680 to 700 m.

Oxidation with faint to weak intensity is common from 100 to 450 m and from 870 to 970 m.

The total fracture frequency is around 10 per metre from 100 to 450 m. Between 450 and 870 m the fracture frequency is lower, ca 0–10 per metre. From 870 to 970 m the fracture frequency is around 20 per metre. Below 970 m, however, the amount of fractures is significantly lower.

One notable section of crushed rock (ie total fracture frequency > 40 per metre) was encountered at 350 m. Minor portions of crushed rock noted between 190–370 m and 890–960 m.

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 for the infiltration was between KLX04 and SSM000009, see Figure 5-18.

Precautionary guidelines 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.

Drilling of environmental monitoring wells and reference sampling

Drilling of environmental monitoring wells SSM000009 and SSM000011 was done according to /7/. The locations of the wells are given in Figure 5-18.

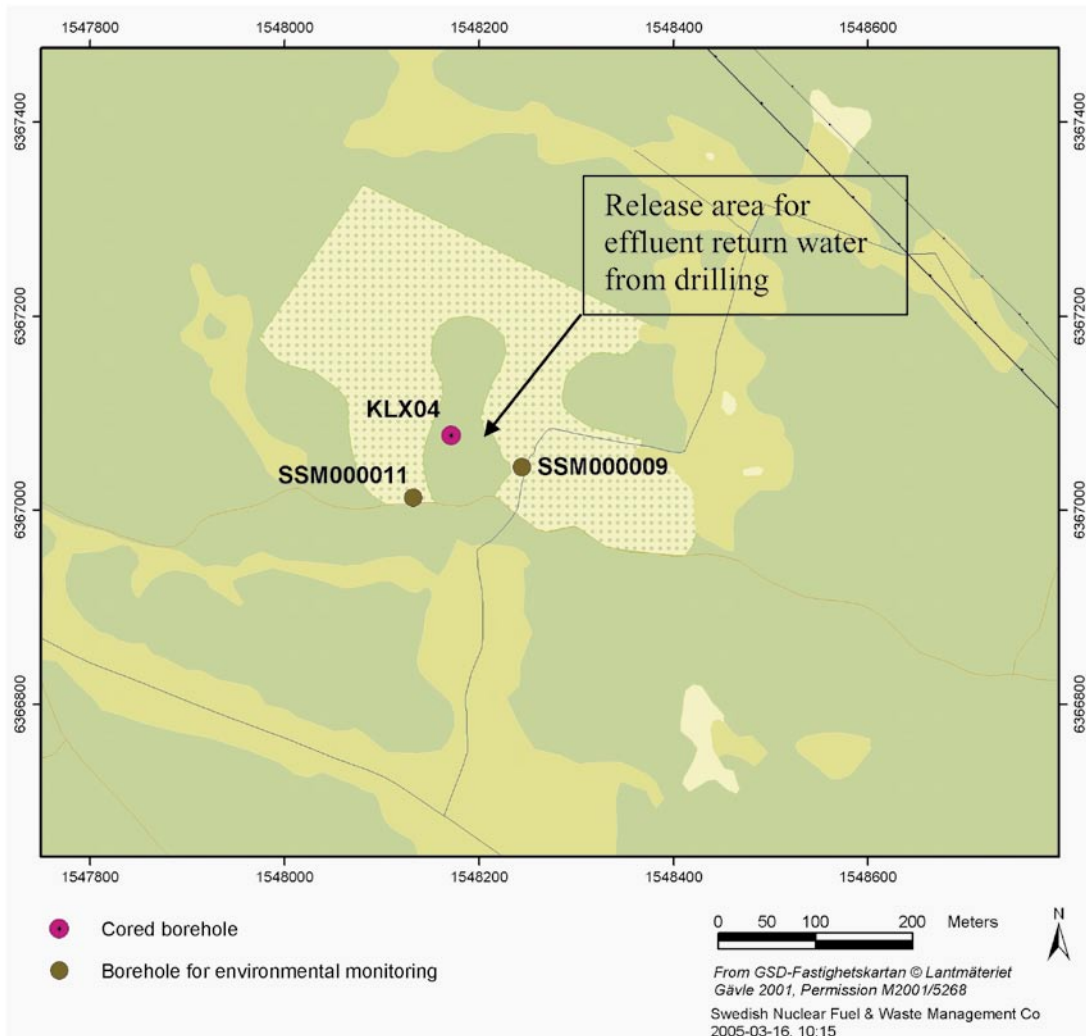


Figure 5-18. Location of environmental monitoring wells SSM000009 and SSM000011 in relation to the core drill site for KLX04. The effluent return water from drilling was released to the ground between KLX04 and SSM000009.

Reference sampling of soil and water together with pressure logger installation was done in accordance with SKB routine for environmental control (SDP-301, SKB internal document).

Reference samples of ground water from the environmental wells SSM000009 and SSM000011 were taken on 2004-04-05. The sample IDs are 7258 and 7259.

A reference sample of surface soil from the core drill site was taken on 2004-02-09. The sample ID is SKB PO 09003.

Pressure loggers for measuring the ground water table were installed on 2004-04-05. The loggers were in place for the duration of the drilling.

Monitoring of effluent water

Monitoring of the return water showed that the conductivity of emitted water varied, as a daily average, between 40 and 60 mS/m /8/.

The uranine content varied between 0.15 and 0.3 mg/l, see Figure 5-9.

The concentration of suspended material was not analysed in this borehole, however analyses in previous drilled boreholes has shown that the concentration was well below the prescribed guideline value /9/.

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

Monitoring of ground and surface water recipients

To monitor the possible effects in the ground and surface water a monitoring programme was set up with focus on salinity and the effects of salinity. No indication of an increase in salinity in the surface water could be seen during the period of core drilling /8/.

5.8.1 Consumption of oil and chemicals

15 litres of hammer oil, Preem Hydra 46, was consumed during percussion drilling.

No significant amounts of other oils lubricants were consumed during the drilling.

The concrete consumption was 500 kg in total. The concrete was based on white silica, low alkali cement.

5.9 Nonconformities


Date	Reported by	Nonconformity
2004-04-01	Jonny Sjöberg, SwedPower	Several unsuccessful installations of the Borre cell resulted in following suggestions: <ol style="list-style-type: none">1. The winch for the drill rig needs adjustments.2. The amounts of cuttings in the borehole needs to be reduced by longer time of flushing.

A difference in length intervals between different wireline tests has been noted, see for instance in Tables 5-4 and 5-6 for comparison. The intervals for pumping tests and water sampling should be the same but are not. Length intervals as given in the Sicada database are reported here.

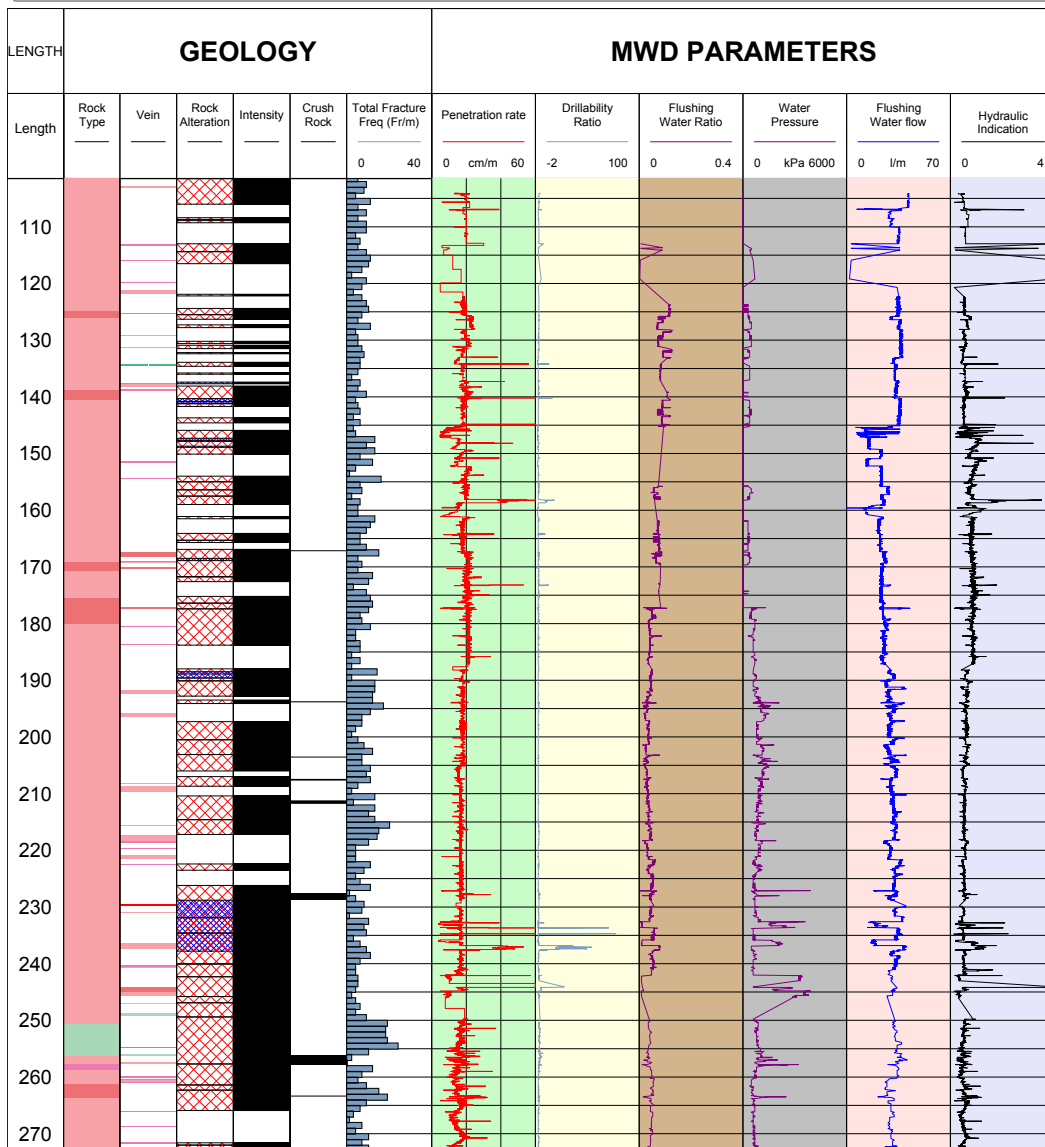
6 References

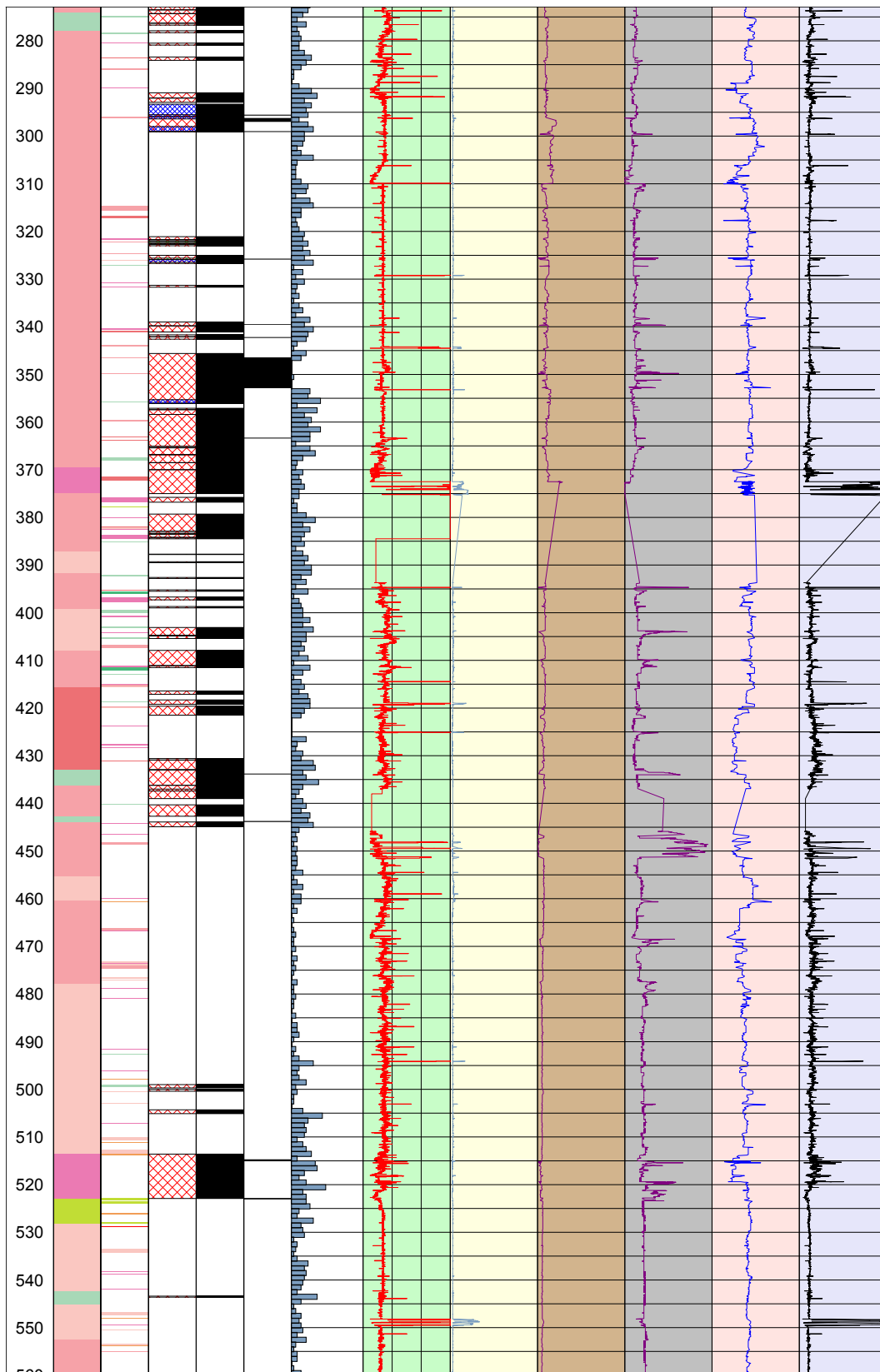
- /1/ **SKB, 2001.** Platsundersökningar, Undersökningsmetoder och generellt genomförandeprogram SKB R-01-10, Svensk Kärnbränslehantering AB.
- /2/ **SKB, 2001.** Geovetenskapligt program för platsundersökning vid Simpevarp, SKB R-01-44, Svensk Kärnbränslehantering AB.
- /3/ **SKB, 2004.** Overcoring rock stress measurements in borehole KLX04, SKB P-05-69 (in prep), Svensk Kärnbränslehantering AB.
- /4/ **Moye D G, 1967.** Diamond drilling for foundation exploration, Civil Eng. Trans. Inst. Eng, Australia.
- /5/ **Ask, Morosini, Samuelsson and Ekström, 2004.** Drilling of cored borehole KSH02, SKB P-04-151, Svensk Kärnbränslehantering AB.
- /6/ **SKB, 2005.** Boremap mapping of core drilled boreholes KLX04, SKB P-05-23 (in prep), Svensk Kärnbränslehantering AB.
- /7/ **Johansson and Adestam, 2004.** Drilling and sampling in soil. Installation of groundwater monitoring wells, SKB P-04-121, Svensk Kärnbränslehantering AB.
- /8/ **Aquilonius and Wijnblad, 2005.** Compilation and evaluation of data from monitoring of flushing water from KLX03 and KLX04, SKB P-05-41, Svensk Kärnbränslehantering AB.
- /9/ **Ask et al. 2004.** Drilling of cored borehole KSH03, SKB P-04-233, Svensk Kärnbränslehantering AB.

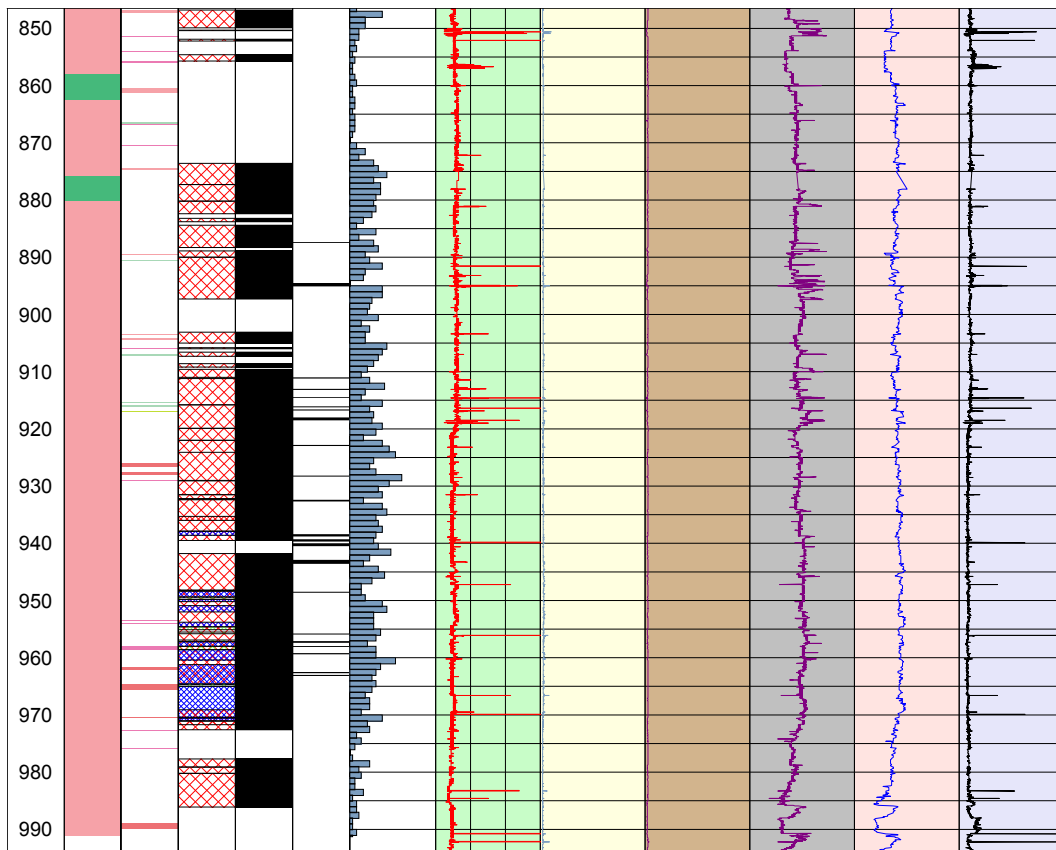
Geology and MWD parameters KLX04

	Site	LAXEMAR	Coordinate System	RT90-RHB70
	Borehole	KLX04	Northing [m]	6367076.37
	Diameter [mm]	76	Easting [m]	1548171.99
	Length [m]	993.490	Elevation [m.a.s.l.]	24.02
	Bearing [°]	1.62	Drilling Start Date	2004-02-11 11:30:00
	Inclination [°]	-84.71	Drilling Stop Date	2004-06-28 10:12:00
	Date of mapping	2004-07-22 10:00:00	Plot Date	2005-05-23 23:18:24

ROCKTYPE LAXEMAR		ROCK ALTERATION		INTENSITY	
	Fine-grained granite		Oxidized		Faint
	Granite		Chloritized		Weak
	Ävrö granite		Epidotized		Medium
	Quartz monzodiorite		Quartz dissolution		Strong
	Diorite / Gabbro		Saussuritization		
	Fine-grained dioritoid				
	Fine-grained diorite-gabbro				







Chemical results

Borehole	KLX04	KLX04	KLX04	KLX04	KLX04	KLX04	KLX04
Date of measurement	2004-03-25	2004-04-18	2004-05-07	2004-05-24	2004-06-11	2004-06-20	2004-06-29
Upper section limit (m)	103.00	210.00	329.00	401.00	614.00	698.20	849.00
Lower section limit (m)	213.14	329.14	403.82	515.10	701.16	850.40	993.49
Sample No	7,253	7,300	7,347	7,386	7,498	7,505	7,563
Groundwater Chemistry Class	3	3	1	1	1	1	1
pH	8.12	8.63					
Conductivity mS/m	59.2	62.8					
Drill water %	7.76	40.7	66.7	96.6	97.6	91.1	105
Na mg/l	118						
K mg/l	2.44						
Ca mg/l	17.2						
Mg mg/l	4.1						
HCO ₃ mg/l Alkalinity	318	277					
Cl mg/l	28.6	42.4					
SO ₄ mg/l	17.4	27.1					
SO ₄ _S mg/l Total Sulphur	5.88						
Br mg/l	<0.2	<0.2					
F mg/l	2.92						
Si mg/l	6.83						
Fe mg/l Total Iron	3.79						
Mn mg/l	0.123						
Li mg/l	0.016						
Sr mg/l	0.255						
PMC % Modern Carbon	61.3						
C-13 dev PDB	-18.1						
AGE_BP Groundwater age	3,875						
AGE_BP_CORR	45						
D dev SMOW	-76.8						
Tritium TU	4.1						
O-18 dev SMOW	-10.8						
B-10 B-10/B-11	0.238						
Sr-87 Sr-87/Sr86	0.715408						

Chemistry – analytical method

Analysis	Sample bottle	Preparation	SKB label	Laboratory
pH, conductivity, alkalinity	250 ml	Filtering Pallfilter	green	Äspö/field
Anions (F ⁻ , Br ⁻ , Cl ⁻ , SO ₄ ²⁻)	250 ml	Filtering Pallfilter	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	1000 ml dried	Flooded at least once	green	Waterloo
Sr-87	100 ml square		green	IFE
Cl-37	Same as for Tritium		green	Waterloo
B-10	Same as for main components	Filtering membrane filter	red	Analytica
C-13, PMC	2*2 st 100 ml brown glass		green	Waterloo och Uppsala
S-34	1,000 ml		green	IFE

Quality of the analyses

The charge balance errors give an indication of the quality and uncertainty of the analyses of the major components. The relative charge balance error is calculated for sample 7253. The error is -1.05% which is fully satisfactory.

The charge balance errors are not calculated for the other samples collected in KLX04 due to the high drilling water percentage (and therefore the lack of analyses) in those samples.


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

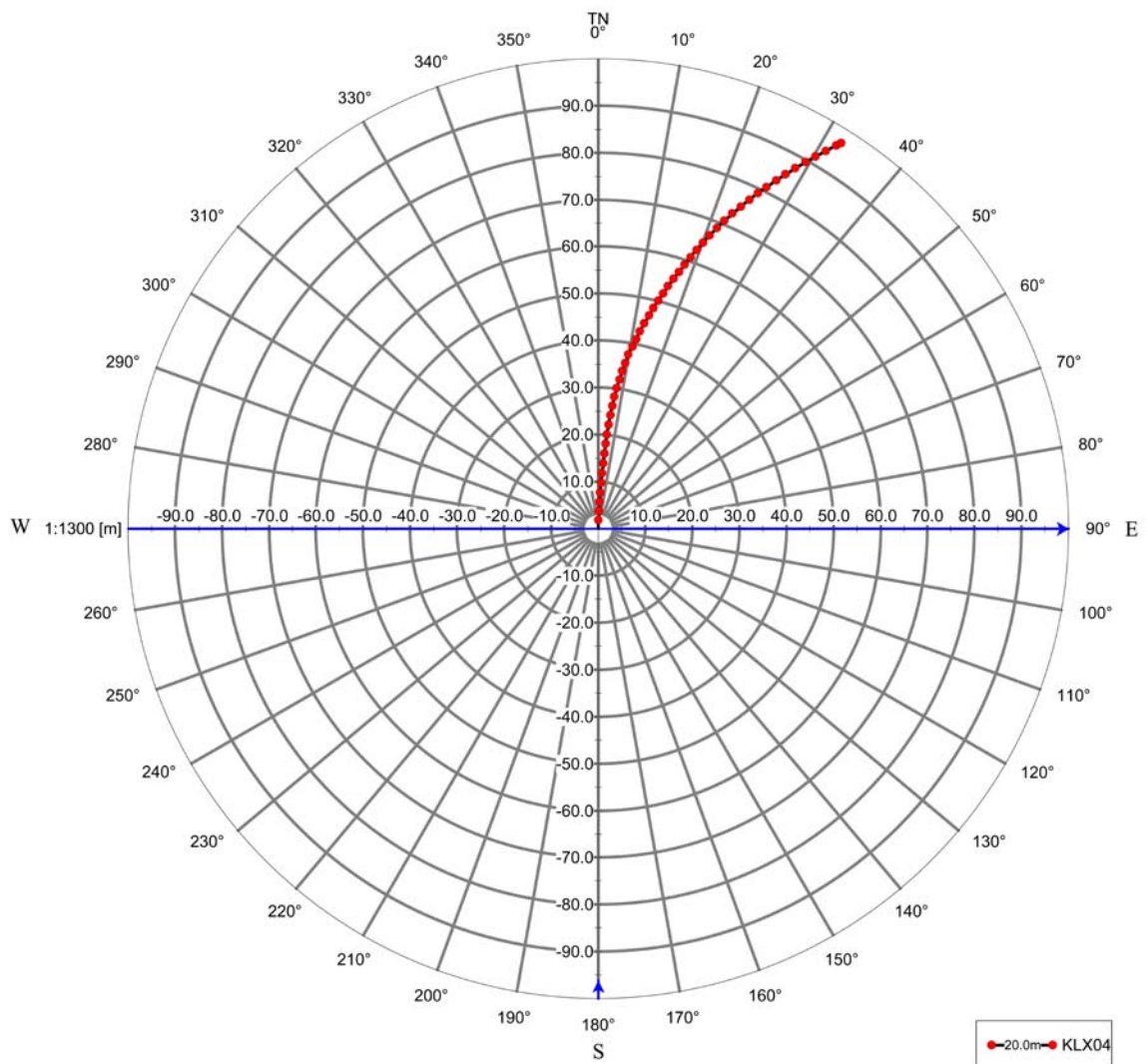
- Several components are determined by more than one method and/or laboratory. Control analyses by an independent laboratory are normally performed as a standard procedure on every five or ten collected samples. Control analyses were not done in this case because of the small number of samples taken.
- 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 $\pm 5\%$ are considered acceptable. For surface waters errors of $\pm 10\%$.

- 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.

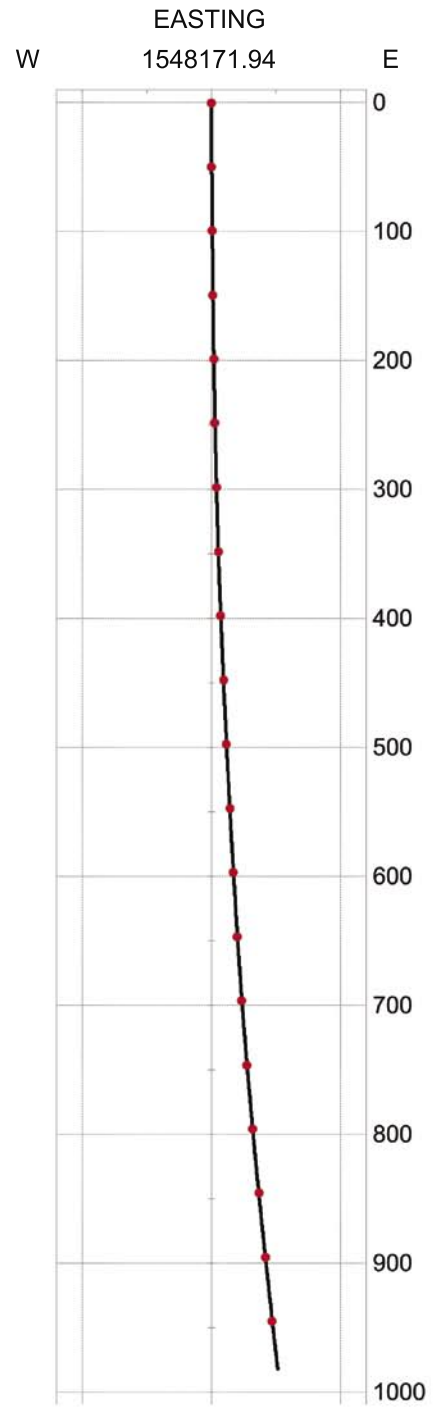
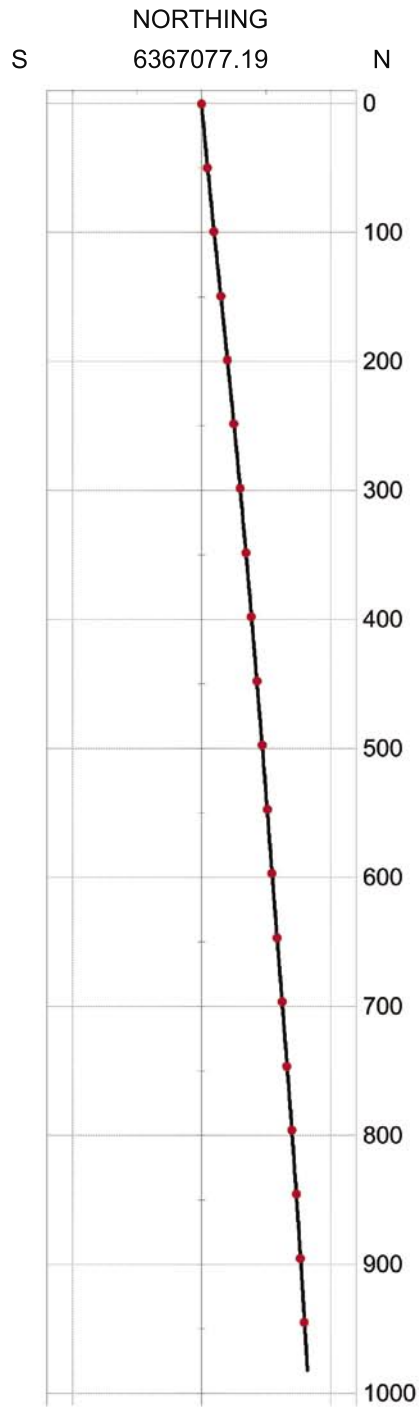
All results from “biochemical” components and special analyses of trace metals and isotopes are inserted directly into primary data tables. In those cases where the analyses are repeated or performed by more than one laboratory, a “best choice” notation will indicate those results which are considered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

Deviation measurement

	Site	LAXEMAR
	Borehole	KLX04
	View from above	



Borehole KLX04
Site Laxemar
Coordinate system RT90-RHB70
Length 993.49m
Bearing 1.62
Inclination -84.71
● Interval 50m



Wireline pumping tests

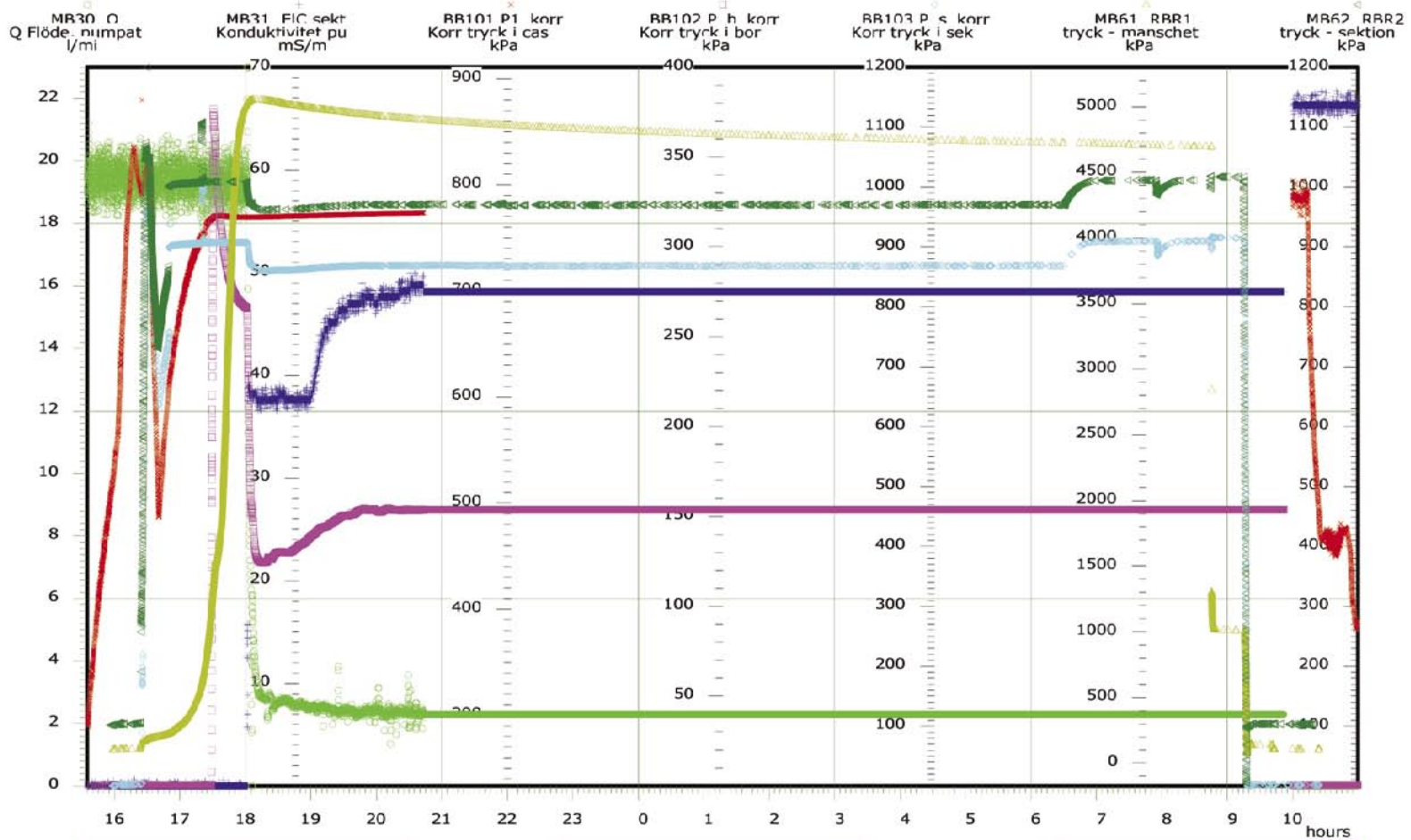
Description of the parameters in the enclosed plots.

Channel	Parameter	Unit	Description
MB30	Water flow	Litre/minute	Flow of water pumped up from the borehole during the test.
MB31	Electrical conductivity	mS/m	Electrical conductivity in the pumped out water.
BB101	Pressure	kPa	Pressure of the water column in the telescopic section subtracted with the ambient air pressure.
BB102	Pressure	kPa	Pressure of the water column in the test section ie at depth in the borehole, subtracted with the ambient air pressure.
BB103	Pressure–section	kPa	Pressure of the water column in the test section ie at depth in the borehole, subtracted with the ambient air pressure.
MB61	Pressure–packer	kPa	Inflation pressure in packer.
MM62	Pressure–section	kPa	Pressure of the water column in the test section ie at depth in the borehole. Not corrected for ambient air pressure.

PLOT TIME : 04/09/24 11:12:44
 PLOT FILE : P_numpstest
 Adjusted for DST

DMS2 PO

Pumping test
 KI X04 103 00-213.14m
 Wireline probe



START : 04/03/24 15:35:00

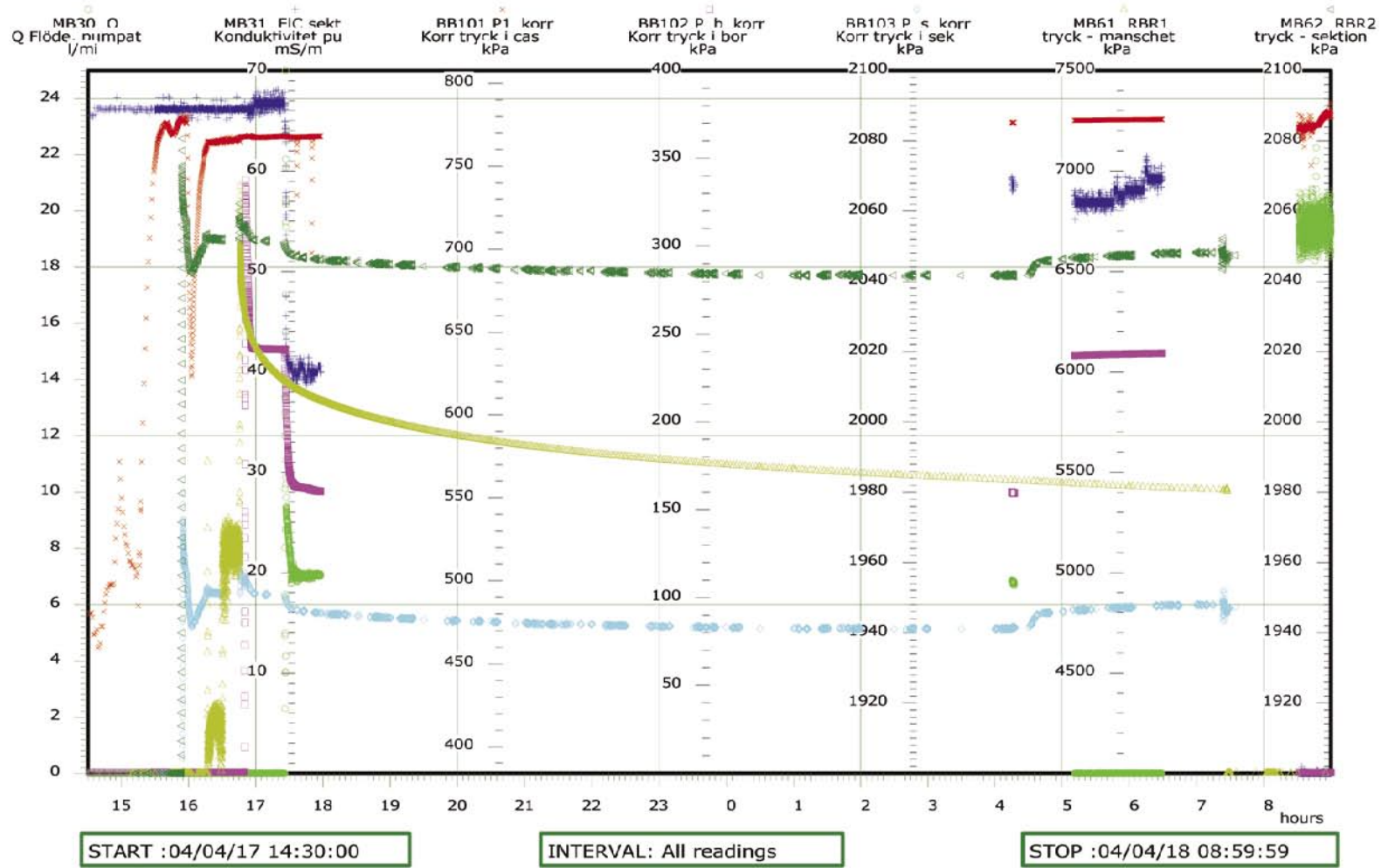
INTERVAL: All readings

STOP : 04/03/25 10:59:59

PLOT TIME : 04/09/24 12:19:19
 PLOT FILE : P_pumptest
 Adjusted for DST

DMS2 PO

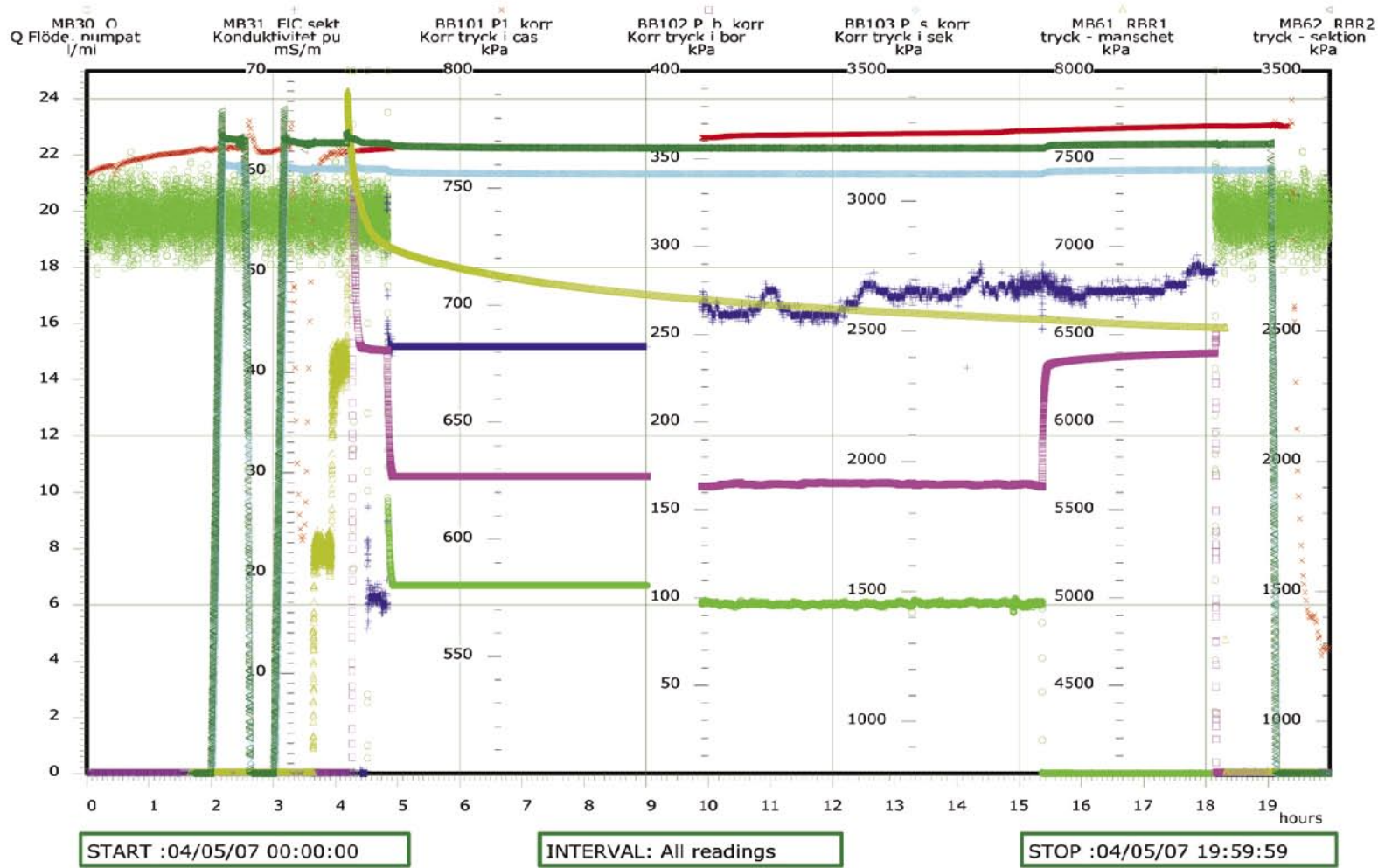
Pumping test
 K1 X04 211.00-329.15m
 Wireline probe



PILOT TIME : 04/09/29 07:44:18
PILOT FILE : P_numpptest
Adjusted for DST

DMS2 PO

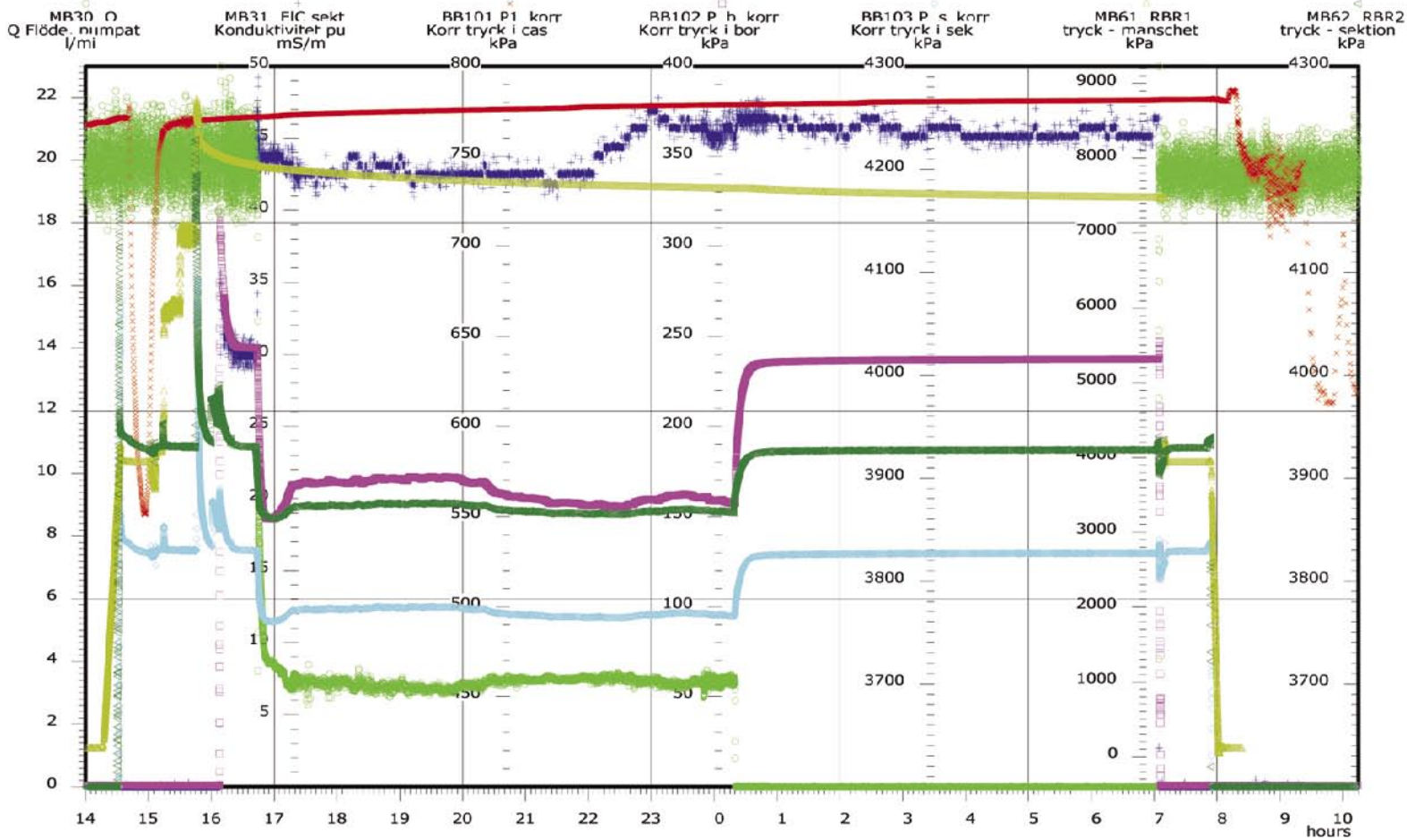
Pumping test
KI X04 329.00-403.82m
Wireline probe



PI OT TIME : 04/09/79 08:21:28
 PI OT FILE : P_pumpstest
 Adjusted for DST

DMS2 PO

Pumping test
 K1 X04 402.00-515.10m
 Wireline probe



START : 04/05/24 14:00:00

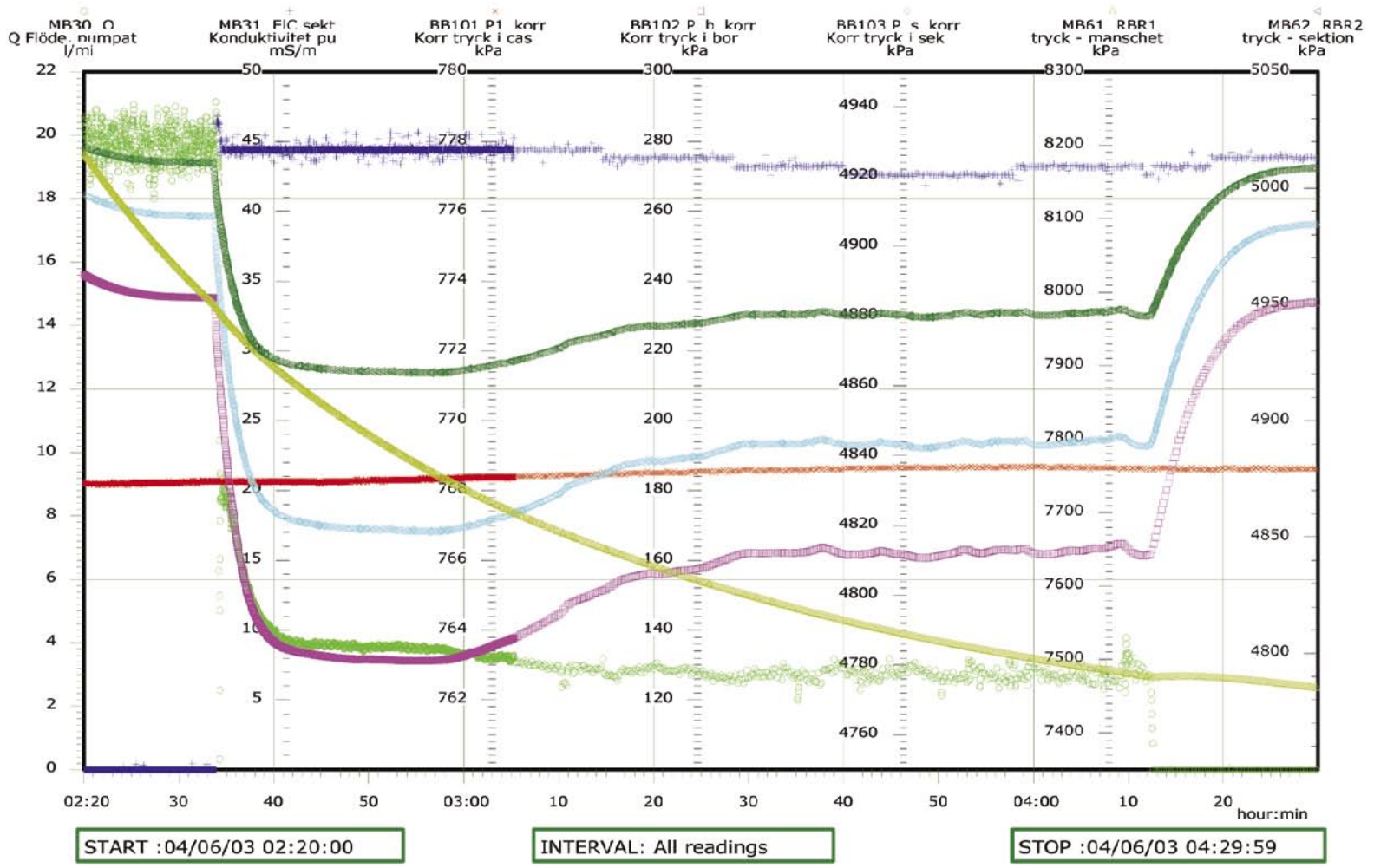
INTERVAL: All readings

STOP : 04/05/25 10:14:59

PLOT TIME : 04/10/07 14:36:54
 PLOT FILE : P_numpstest
 Adjusted for DST

DMS2 PO

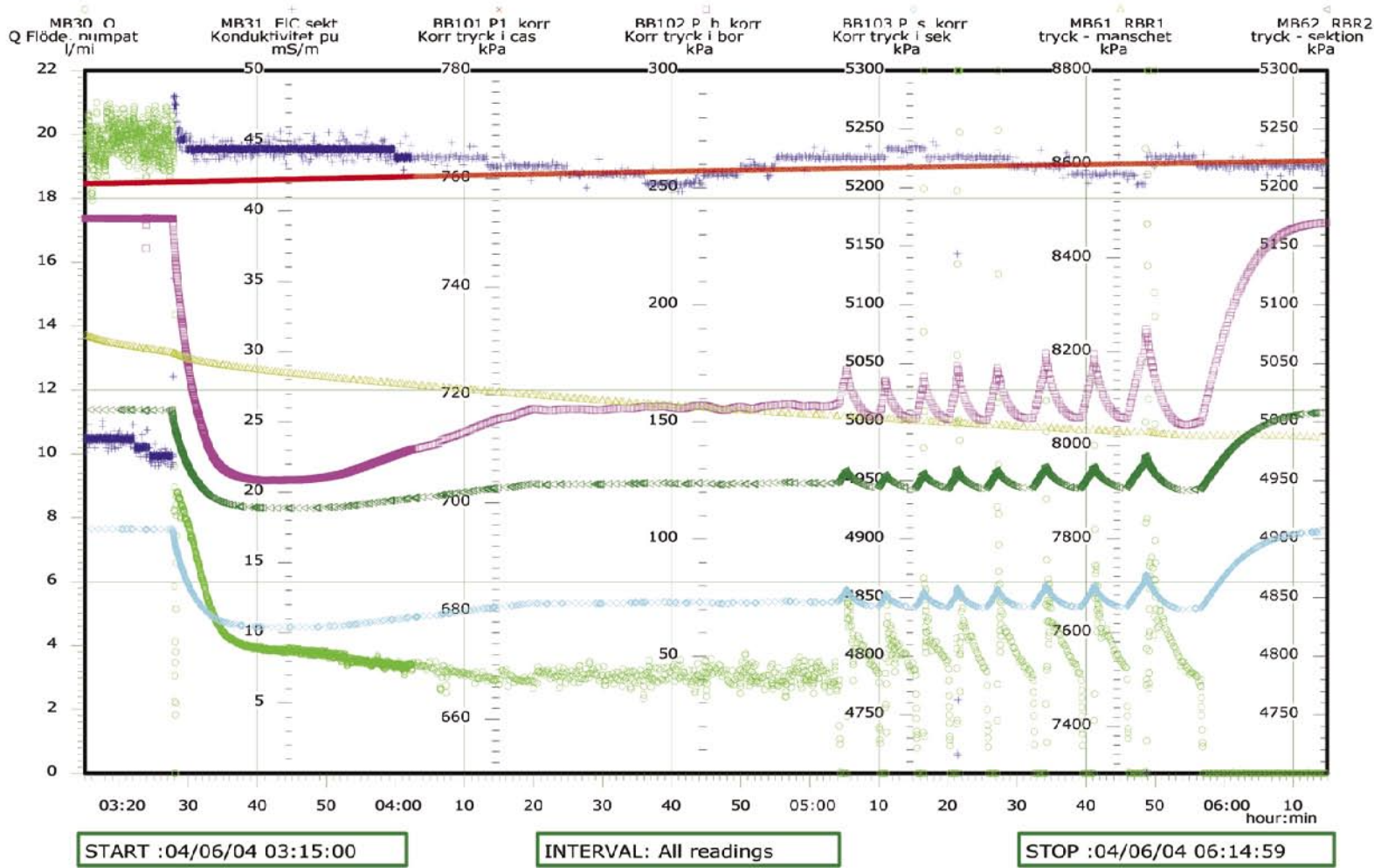
Pumping test
 K1 X04 513 15-608.15m
 Wireline probe



PLOT TIME : 04/10/08 10:47:24
 PLOT FILE : P_pumpstest
 Adjusted for DST

DMS2 PO

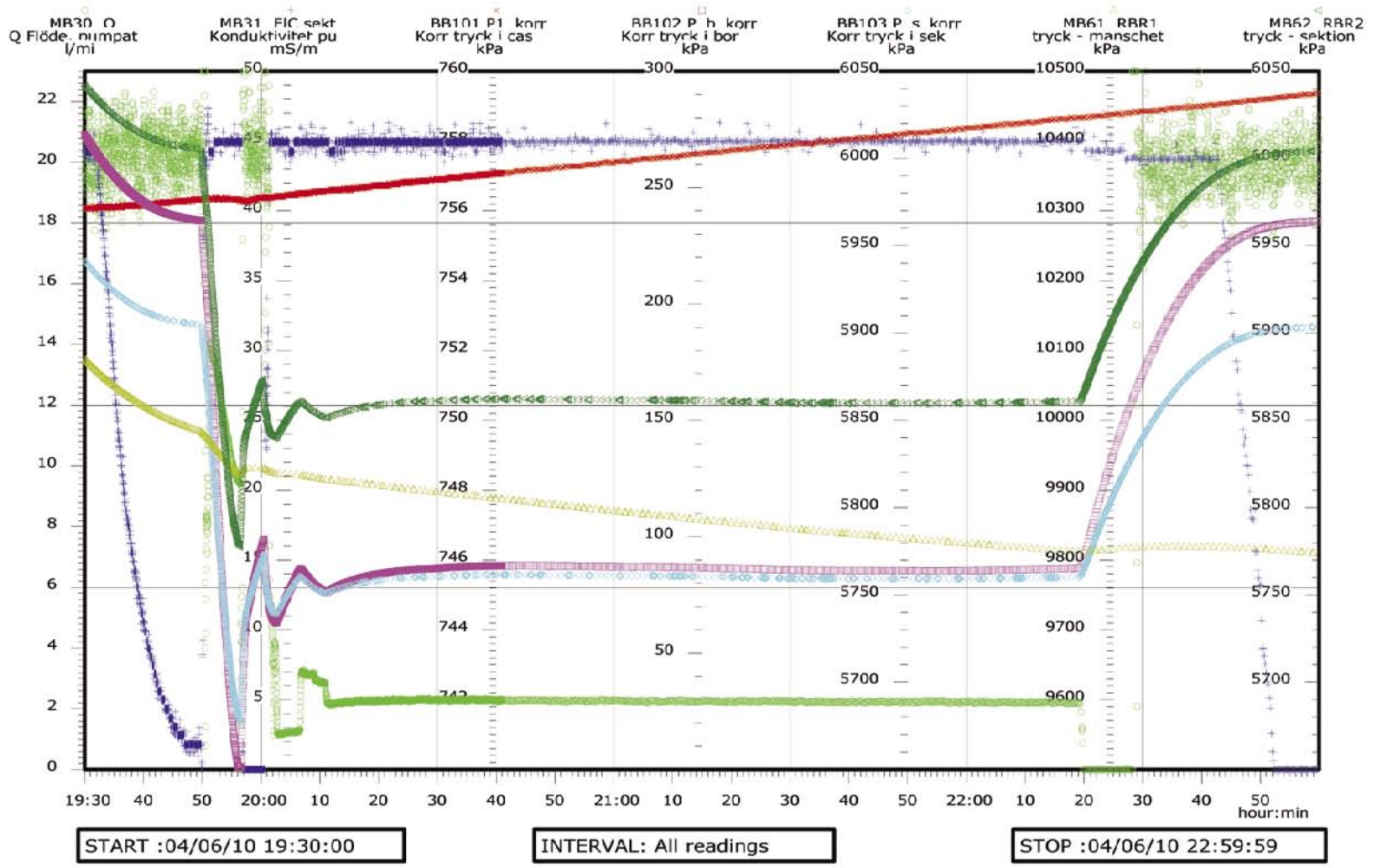
Pumping test
 K1 X04 513 15-617.00m
 Wireline probe



PLOT TIME : 04/09/29 10:44:05
 PLOT FILE : P_numpstest
 Adjusted for DST

DMS2 PO

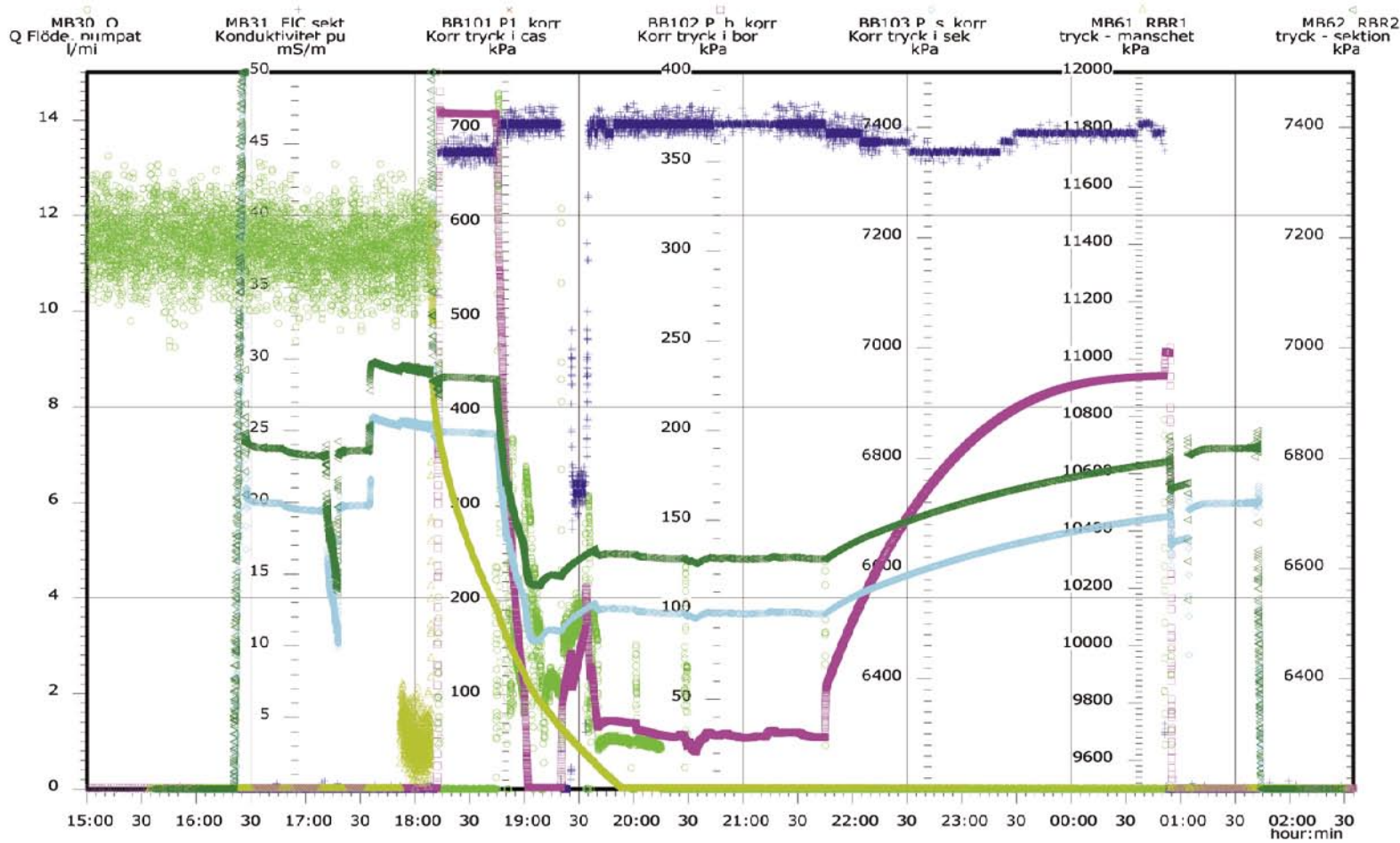
Pumping test
 K1 X04 615.00-701.16m
 Wireline probe



PLOT TIME : 04/09/29 12:25:30
 PLOT FILE : P_numpstest
 Adjusted for DST

DMS2 PO

Pumping test
 KI X04 698.20-850.40m
 Wireline probe



START : 04/06/19 15:00:00

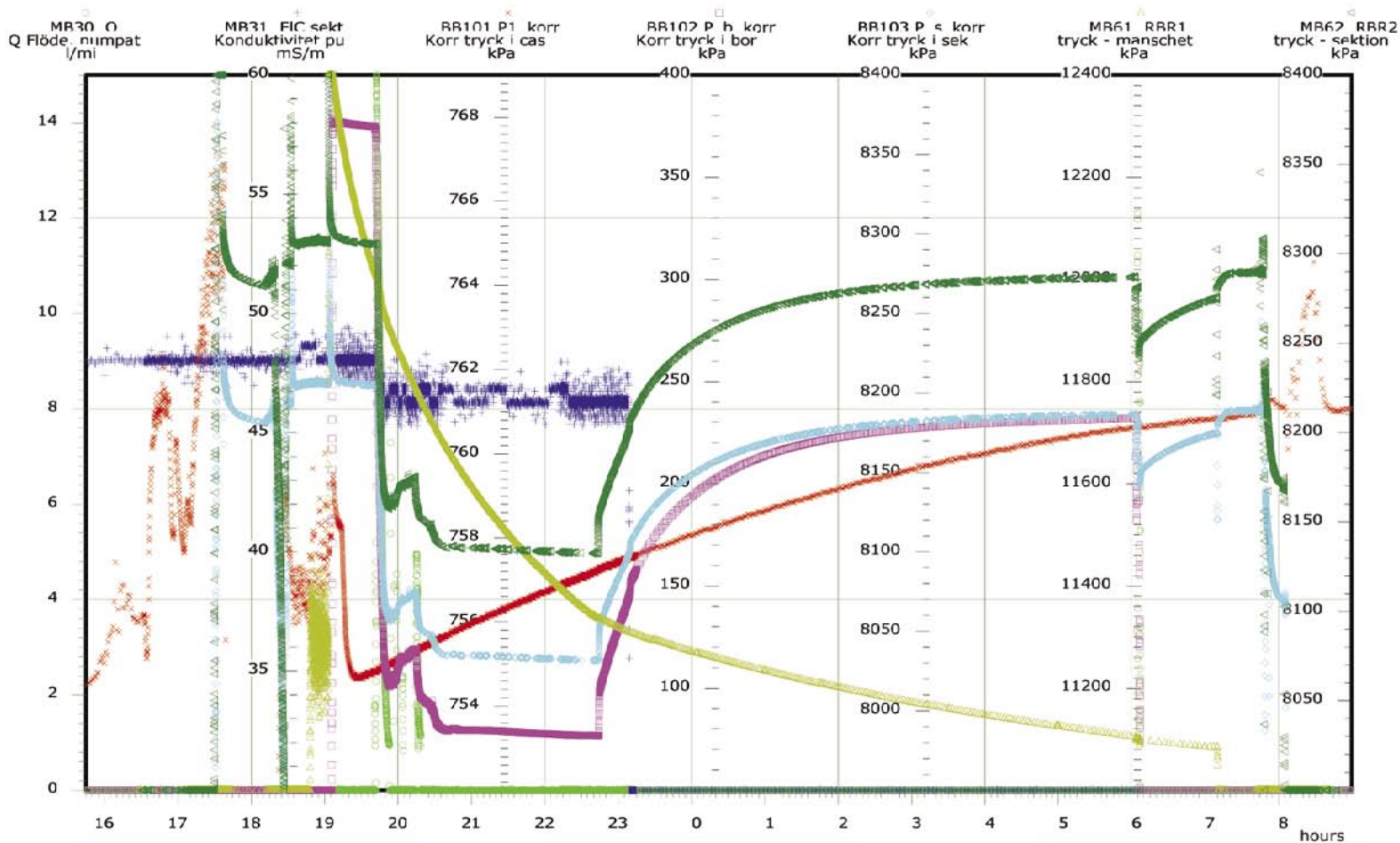
INTERVAL: All readings

STOP : 04/06/20 02:34:59

PLOT TIME : 04/10/08 09:29:34
 PLOT FILE : P_pumptest
 Adjusted for DST

DMS2 PO

Pumping test
 KI X04 849 00-993.49m
 Wireline probe



START : 04/06/28 15:45:00

INTERVAL: All readings

STOP : 04/06/29 08:59:59

Absolute pressure measurement

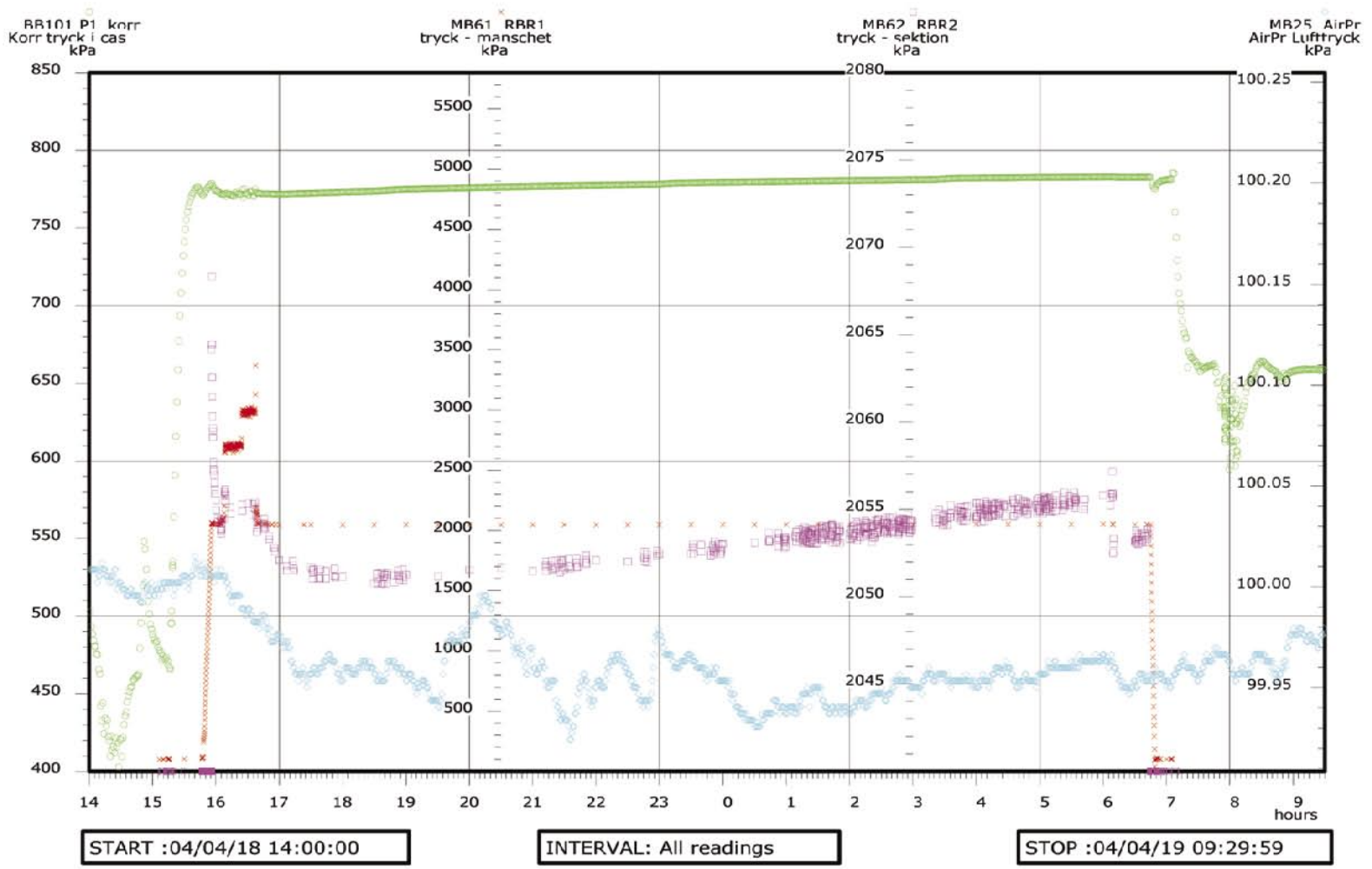
Description of the parameters in the enclosed plots.

Channel	Parameter	Unit	Description
BB101	Pressure	kPa	Pressure of the water column in the telescopic section subtracted with the ambient air pressure.
MB61	Pressure–packer	kPa	Inflation pressure in packer.
MB62	Pressure–section	kPa	Pressure of the water column in the test section ie at depth in the borehole. Not corrected for ambient air pressure.
MB25	Air pressure	kPa	

PI OT TIME : 04/10/06 15:55:40
PI OT FILE : P tryck_i_sektion
No DST Adjustment

DMS2 PO

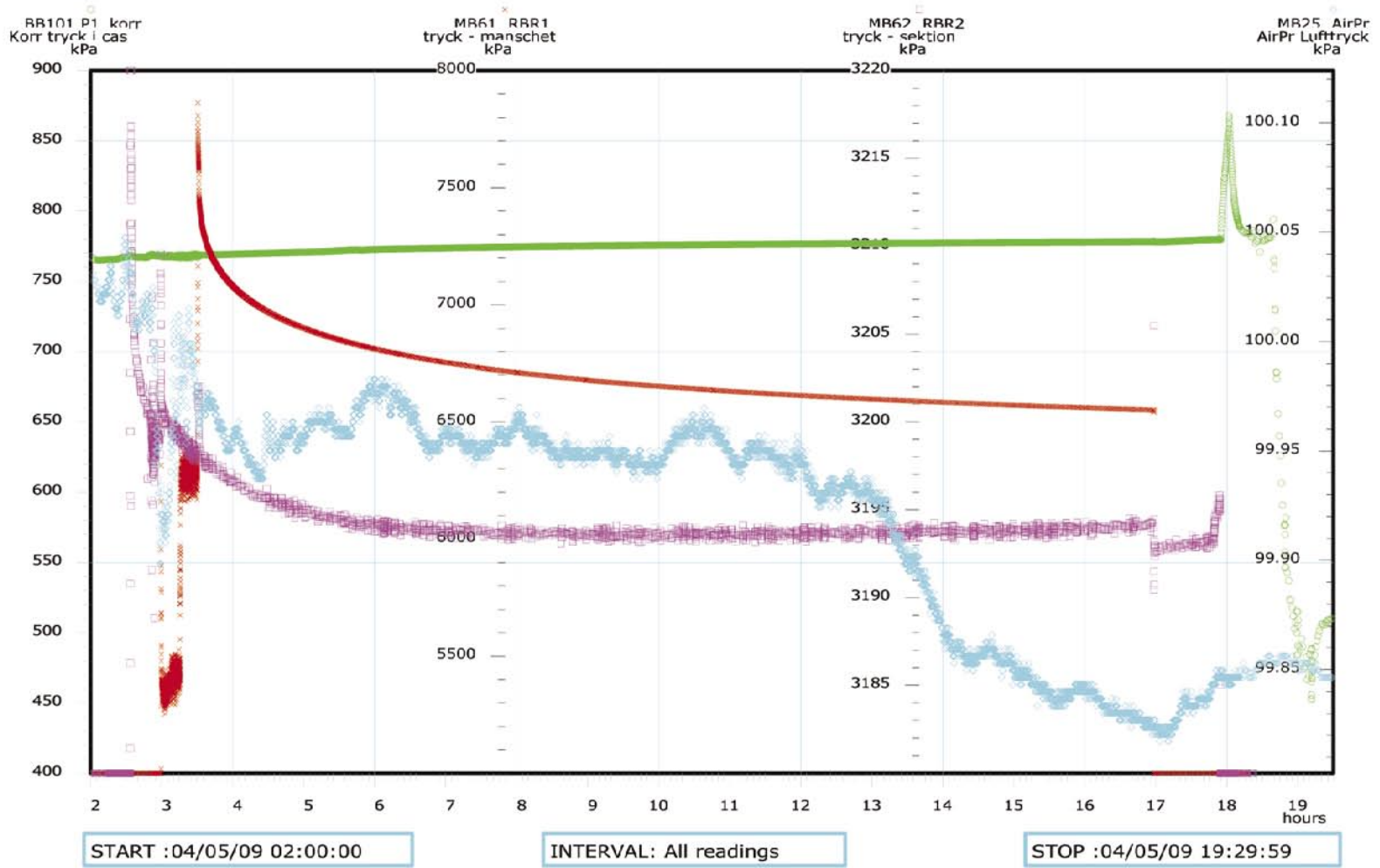
Absoluttryckmätning i sektion
KI X04 210.00-344.17m
wl-sond



PILOT TIME :04/10/07 07:33:23
PILOT FILE :P_trvck_i_sektion
No DST Adjustment

DMS2 PO

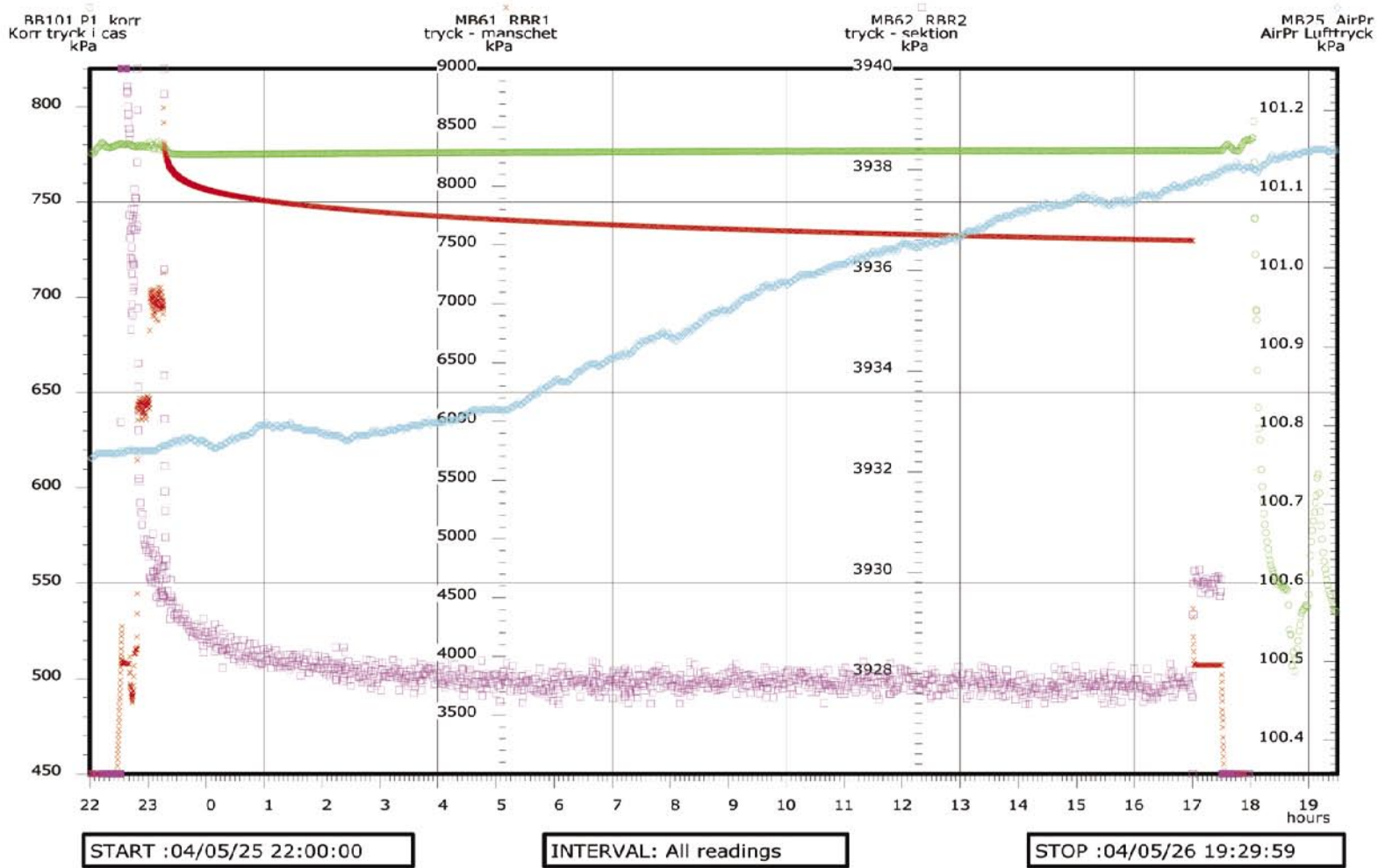
Absoluttryckmätning i sektion
K1 X04 329.00-418.95m
wl-sond



PILOT TIME : 04/10/07 07:40:59
PILOT FILE : P_trvck_i_sektion
No DST Adjustment

DMS2 PO

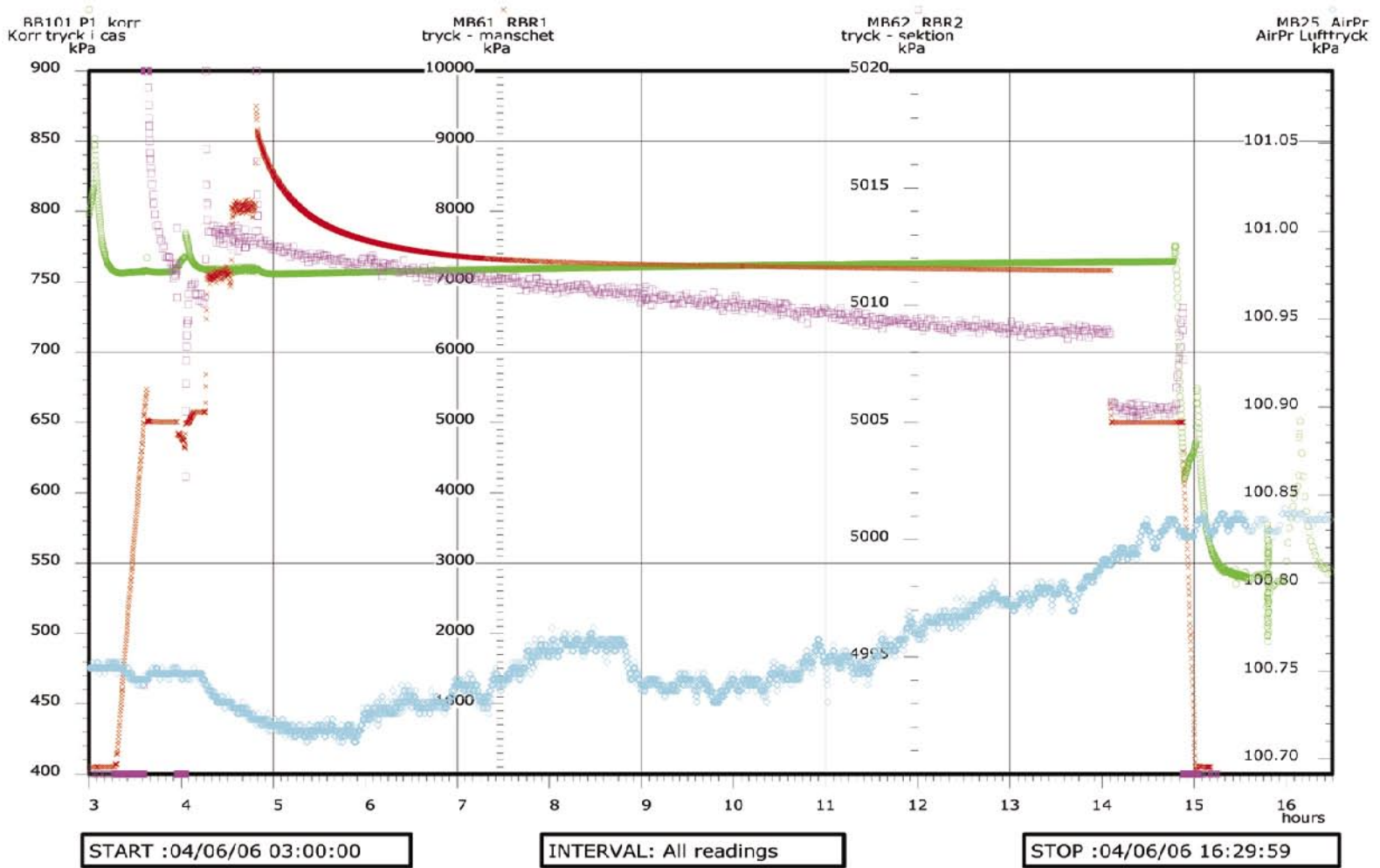
Absoluttryckmätning i sektion
K1 X04 402.00-522.65m
wl-sond



PI OT TIME :04/10/06 15:49:57
PI OT FILE :P tryck_i_sektion
No DST Adjustment

DMS2 PO

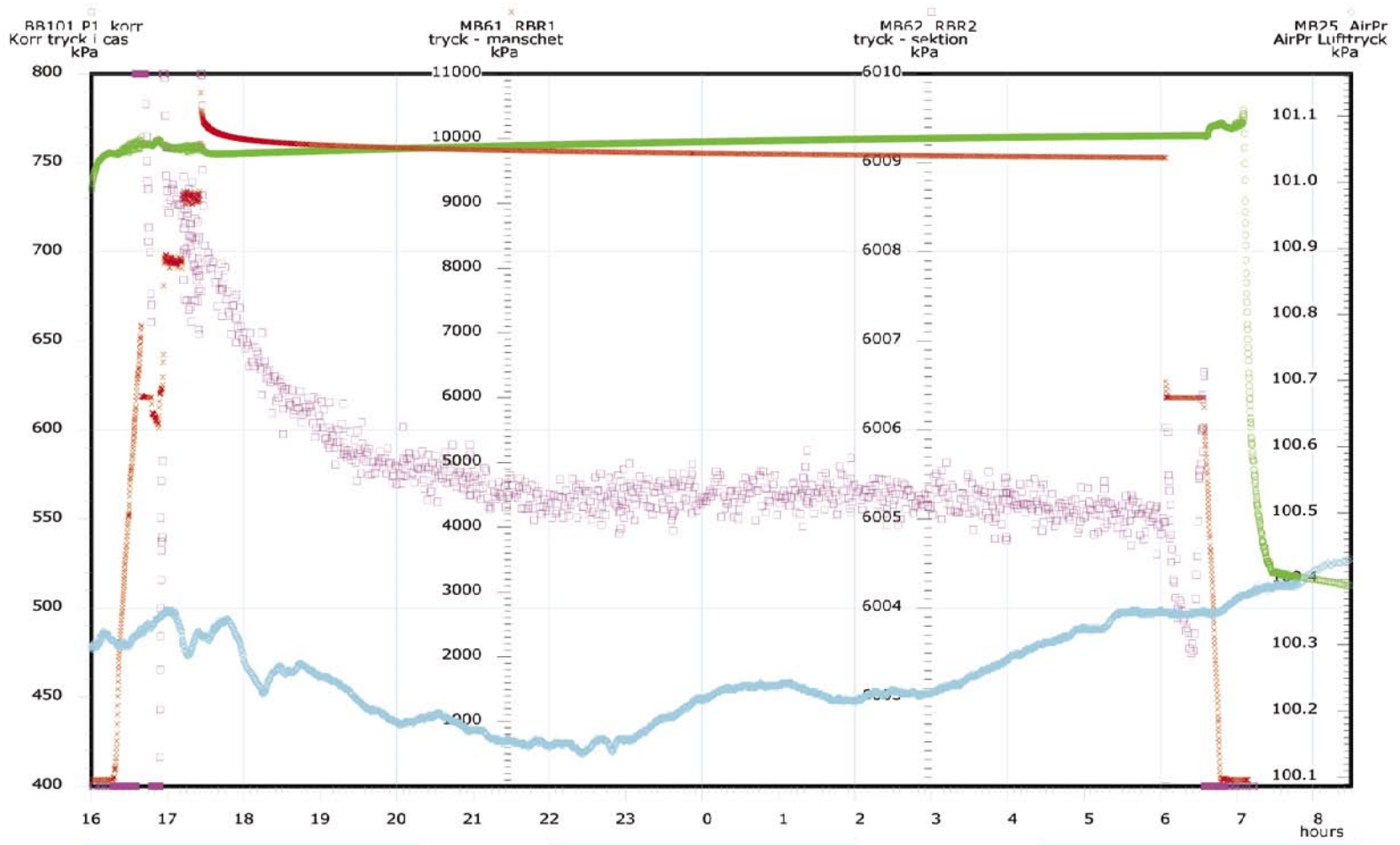
Absoluttryckmätning i sektion
KI X04 513.15-639.26m
wl-sond



PI OT TIME :04/10/06 15:43:53
PI OT FILE :P tryck_i_sektion
No DST Adjustment

DMS2 PO

Absoluttryckmätning i sektion
KI X04 615.00-701.16m
wl-sond



START :04/06/11 16:00:00

INTERVAL: All readings

STOP :04/06/12 08:29:59