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August 2006

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

# Abstract

Boreholes KLX07A and KLX07B are located in the Laxemar subarea. Drilling was made between November 2004 and June 2005 as a part of the site investigation for a possible repository for spent nuclear fuel in Oskarshamn municipality, Sweden.

KLX07A was core drilled to a length of 844.73 metres with N-size (76 mm) equipment. The uppermost section, to the length of 100.3 metres, was constructed as a telescopic section with an inner nominal diameter of 200 mm. As the telescopic section was percussion drilled a second borehole, KLX07B, was drilled nearby in order to obtain a full coverage of core drilling from the surface and downwards. KLX07B was drilled to a length of 200.13 m.

A water inflow of 18 L/min was estimated over the entire length of the telescopic section during percussion drilling.

Thirteen successful pumping tests were performed in KLX07A with wireline equipment, typically with one hundred metre intervals. The resulting transmissivities ($T_M$) varied between $1.2\times10^{-7}$ and $2.2\times10^{-4}$ $m^2/s$. The most transmissive section was between 102 and 197 metres.

Two pumping tests were performed in KLX07B.

Continuous monitoring of drilling parameters and flushing water parameters with the drilling monitoring system was conducted throughout the core drilling phase in KLX07A.

Fourteen water samples for chemical analysis were collected during drilling of KLX07A and KLX07B. Six samples, five in KLX07A and one in KLX07B, had too high drill water content to warrant any further analysis.

An airlift pumping test in the telescopic section performed when borehole KLX07A was drilled to its full length gave a transmissivity ($T_M$) of $5.9\times10^{-4}$ $m^2/s$.

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

Oxidation with weak to medium intensity is common to a drilled length of 760 m, but between 200 m and 410 m the intensity of the oxidation is somewhat elevated. Saussuritization i.e. alteration of calcic plagioclase feldspar to albite, zoisite or epidote has been noted sporadically around 150 m.

The distribution of total fractures in the core is typically in the range of 10–20 fractures/metre with minor sections containing slightly elevated fracture frequencies. Crushed sections, with a fracture frequency >40, notably occurs at 120, 450, 670 and 760 m drilled length.

# Sammanfattning

Borrhålen KLX07A och KLX07B ligger inom delområde Laxemar. Borrningen utfördes mellan november 2004 och juni 2005 som ett led i platsundersökningen för ett möjligt djupförvar för använt kärnbränsle i Oskarshamns kommun.

KLX07A kärnborrades med borrstorlek N (76 mm) till 844,73 meters borrad längd. Den övre delen av hålet, från markytan till 100,3 meter, utfördes som en teleskopdel med ca 200 mm inre diameter. Eftersom teleskopdelen är hammarborrad borrades ett andra hål, KLX07B, i närheten för att få fullständig täckning med kärnborrning från ytan och neråt. KLX07B borrades till en längd av 200,13 m.

Ett vatteninflöde på 18 liter per minut uppskattades över hela teleskopdelen vid hammarborrningen.

Tretton lyckade pumptester med wireline-baserad mätutrustning utfördes normalt var hundrade meter. Uppmätta transmissiviteter ($T_M$) varierade mellan $1,2\times10^{-7}$ och $2,2\times10^{-4}$ $m^2/s$. Den mest transmissiva sektionen var mellan 102 och 197 meter.

Kontinuerliga mätningar av borrningsparametrar och spolvattenparametrar via DMS (Drilling Monitoring System) gjordes under hela kärnborrningsfasen i KLX07A.

Fjorton vattenprover för kemisk analysering togs i samband med borrning i KLX07A och KLX07B. Sex prover, varav fem från KLX07A och ett från KLX07B, hade ett för högt spolvatteninnehåll för att medge ytterligare analysering.

En mammutpumpning i teleskopdelen som gjordes när kärnborrningen utförts till full längd gav en transmissivitet ($T_M$) på $5,9\times10^{-5}$ $m^2/s$.

Litologiskt domineras kärnan av Ävrögranit med mindre inslag av finkornig diorit-gabbro och finkornig granit.

Oxidation med svag till måttlig intensitet är vanlig ner till borrad längd 760 m, men mellan 200 och 410 m är intensiteten på oxidationen något förhöjd. Saussuritisering dvs omvandling av kalcium-rik plagioklasfältspat till albit, zoisit eller epidot har noterats sparsamt vid 150 m.

Fördelningen av totala sprickor i kärnan är oftast kring 10-20 sprickor/meter med mindre partier med något förhöjda sprickfrekvenser. Flera sektioner med krossat berg, med sprickfrekvens > 40, förekommer bla 120, 450, 670 och 760 m borrad längd.

# Contents

# 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. Boreholes KLX07A and KLX07B are located in the central 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. KLX07A was the ninth deep cored borehole within the Oskarshamn site investigation. KLX07B was drilled to a length of 200 m to gain additional geological information. The location of the core drilled boreholes and the water source, HLX10 in the Laxemar subarea is shown in Figure 1-1.

The drilling of KLX07A and KLX07B and all related on-site operations were performed according to a specific activity plan (AP PS 400-04-096), which in turn refers to a number of method descriptions, see Table 1-1.

The activity plans and method descriptions are SKB internal documents.

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

| **Activity plan** | **Number** | **Version** |
|---|---|---|
| Kärnborrning KLX07 | AP PS 400-04-096 | 1.0* |
| **Method descriptions** | **Number** | **Version** |
| Metodbeskrivning för kärnborrning | SKB MD 620.003 | 1.0 |
| Metodbeskrivning för hammarborrning | SKB MD 610.003 | 1.0 |
| Metodbeskrivning för genomförande av hydrauliska enhålstester | 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 pumptest, tryckmätning och vattenprovtagning i samband med wireline-borrning | SKB MD321.002 | 1.0 |
| Mätsystembeskrivning för längdmarkering (spårfräsning) | SKB MD620.009 | 1.0 |
| Instruktion för rengöring av borrhåls-utrustning 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 kvalitetssäkring av DMS data, Oskarshamn | SKB MD 640.008** | 1.0 |
| Instruktion för utsättning och inmätning av borrhål | SKB MD 600.002 | 1.0 |

* Five amendments to AP PS 400-04-096 exist.

** The method description was formally approved on 2005-11-17.

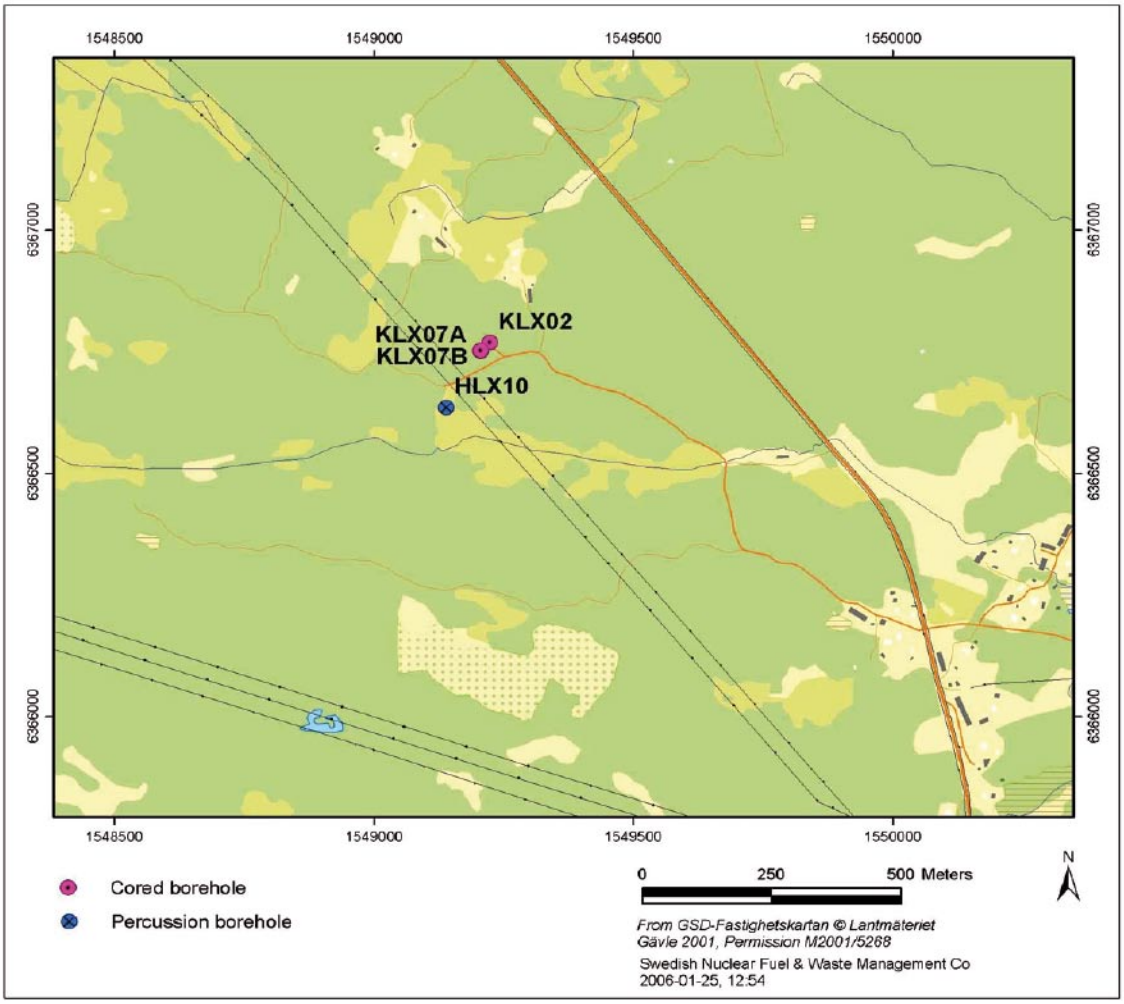


***Figure 1-1.*** *Location of the cored boreholes KLX07A and KLX07B and the water source, percussion boreholes HLX10 in the Laxemar subarea. The cored borehole KLX02 is also shown.*

# 2 Objective and scope

This report will describe the methods employed and the results achieved during the drilling of KLX07A and KLX07B. 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 reasons for drilling the boreholes was to gain geological information at depth in the central part of the Laxemar subarea especially the deformation zone EW007 and to facilitate further investigation at depth in the borehole. The decision to drill KLX07A and KLX07B is given in SKB id no 1032116, dated 2004-11-18.

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.

Detailed information with borehole coordinates and specifications on return water handling was sent to the Regional Authorities, SKB id no 1029749.

# 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.

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.

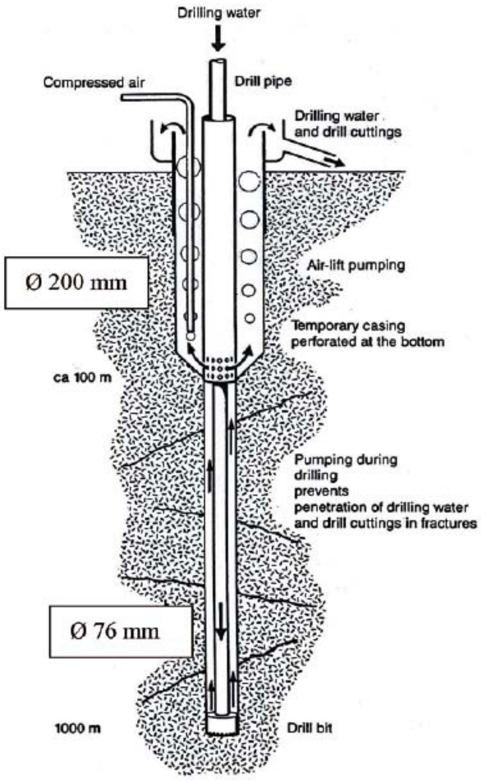


*Figure 3-1.* *A sketch of the telescopic drilling method with air-lift pumping for retrieval of drilling water and cuttings.*

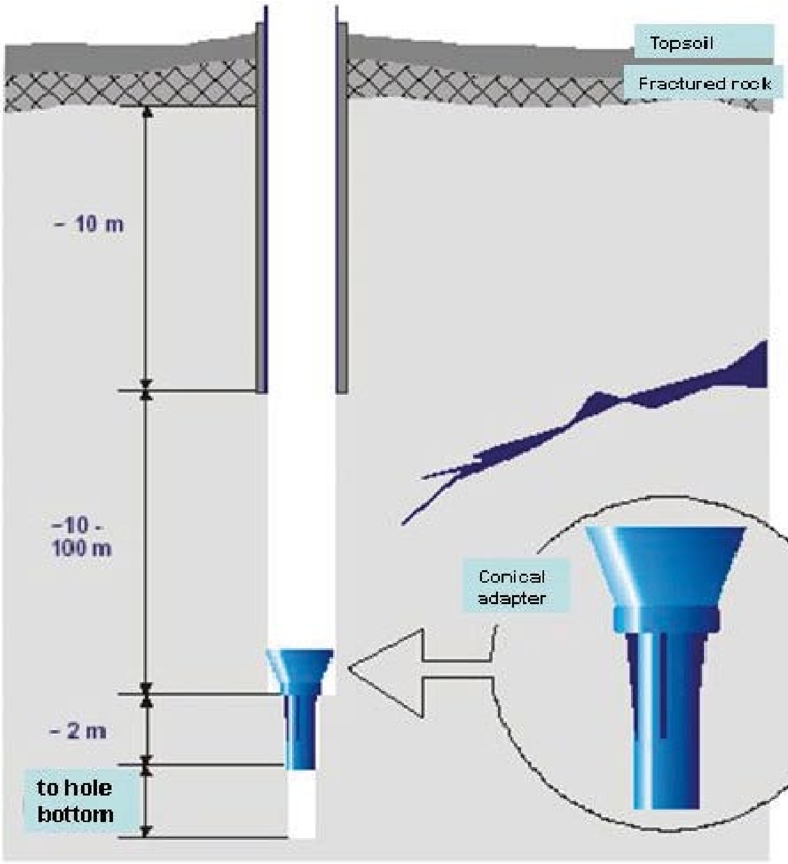


*Figure 3-2.* *Installation of the conical guide.*

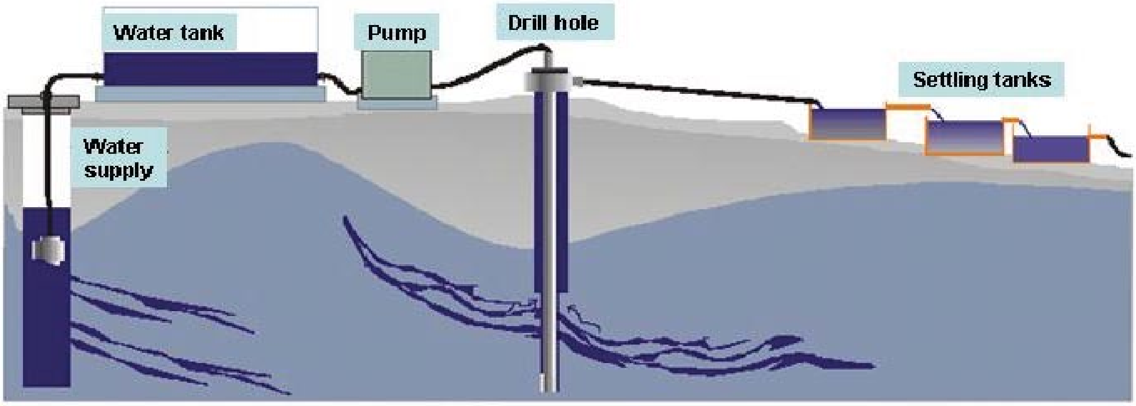


***Figure 3-3.*** *The flushing water system from source to discharge point.*

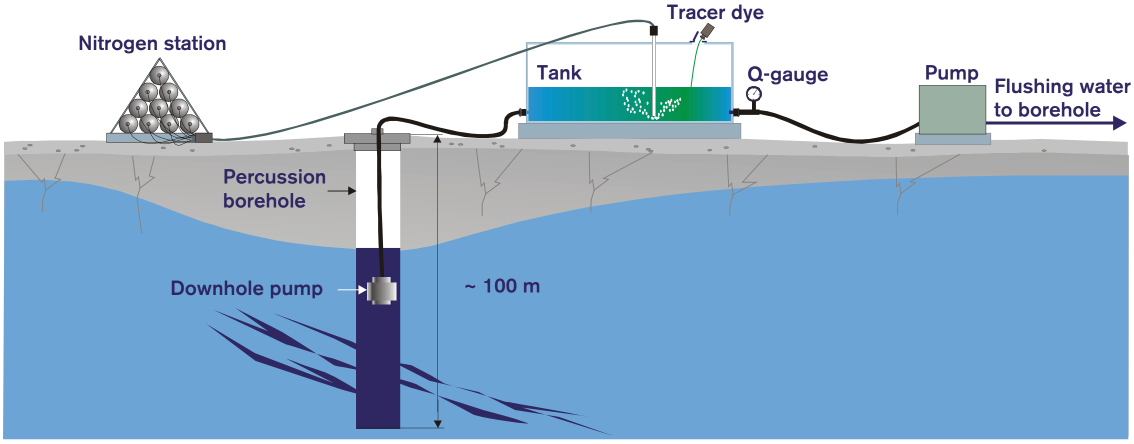


***Figure 3-4.*** *Preparation of flushing water. Uranine is added to the water as a tracer dye. Nitrogen is bubbled through the water to remove dissolved oxygen.*

## 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.

At the end of the percussion drilling phase, a recovery test is made by blowing compressed air to remove the water in the hole. The recovery of the water table is then measured manually.

### 3.2.2 Core drilling

The sampling and measurements during the core drilling phase of KLX07A 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 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 pumping with evaluation of drawdown and/or recovery is 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, i.e. 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).

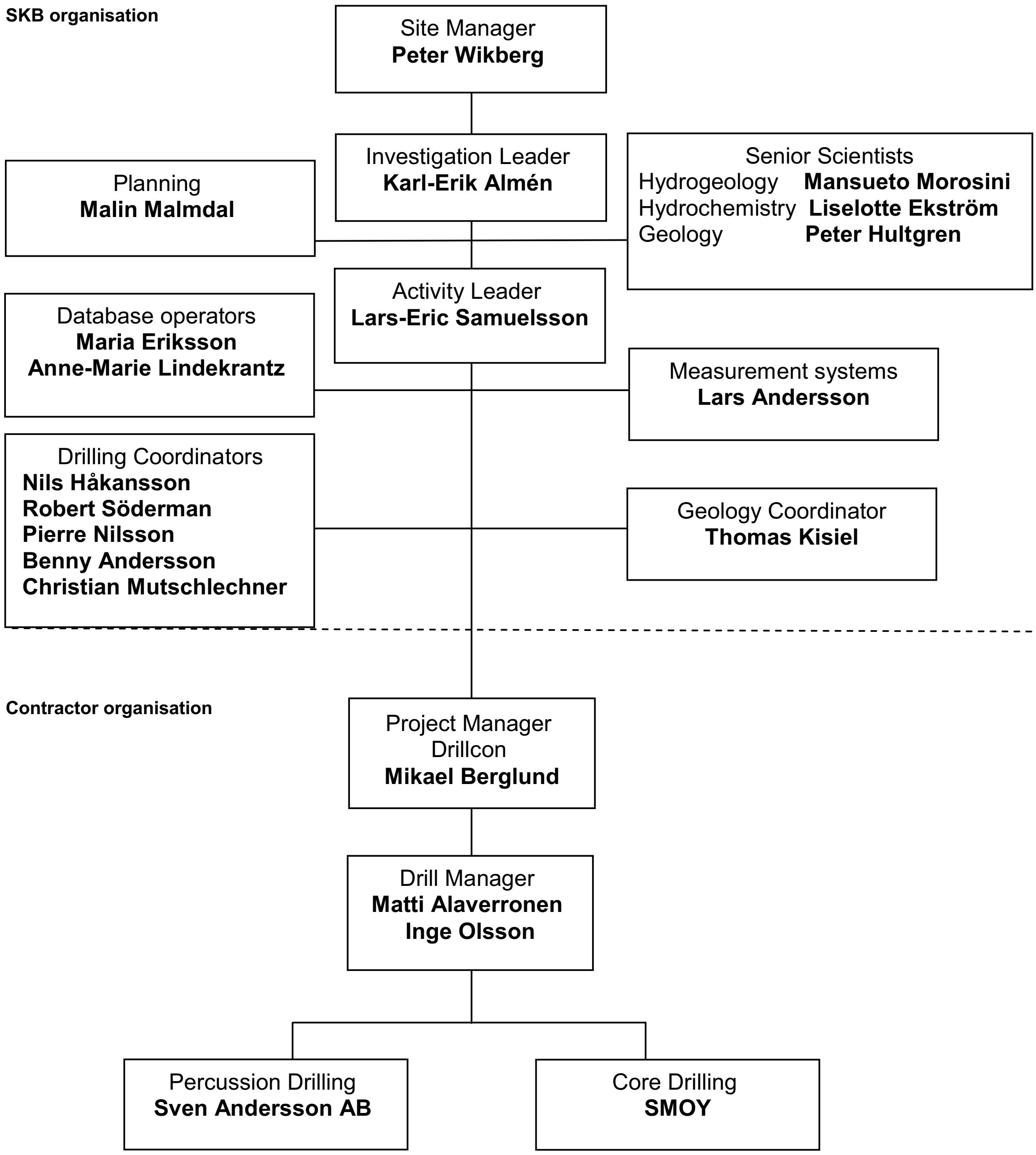
# 4 Contractors and equipment

## 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 in KLX07A was a Comacchio MC15000 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 324×7 mm (non stainless). The casing dimensions are presented here as outer diameter×thickness.

No percussion drilling was done in KLX07B.

## 4.3 Core drilling equipment

Core drilling in KLX07A and KLX07B was made with a B 20 P Atlas Copco 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 Corac N3/50, a triple tube wireline equipment which gives a core diameter of 50.2 mm. The rods were of type NT.

### 4.3.1 Equipment for directional drilling

Directional drilling, i.e. intentional guiding or changing of the drilling direction, was made with a Liwinstone tool for N-size (76 mm) boreholes and Devico Devi-Drill WL-76 mm equipment.

The Liwinstone tool consists of a set of rods that can create an angle between the bit and the drill stem and is entered into the borehole by the conventional method, i.e. not by wireline. The obtainable deviation varies between 0.1 to 0.3 degrees per drilled metre. The core barrel allows for up to 3 metres of recovery. The resulting core has a diameter of 45 mm.

The working procedure for the Liwinstone directional tool is as follows:

- The Liwinstone tool is lowered into the borehole.
- The direction of the tool is adjusted by measurements with a Maxibor equipment.
- The directional rod surrounding the core barrel is fixed to the borehole wall by water pressure (20 bar).
- The rotation of the drill stem, core barrel and drill bit is started and a feed force applied. The outer directional rod does not rotate during drilling.

The lowermost two sections with directional drilling were made with Devico Devi-Drill WL-76 mm equipment. The resulting core diameter is 31.5 mm.

### 4.3.2 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, measurements for absolute pressure and a leakage test of the drill string are done.

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

### Pumping tests

The wireline probe is emplaced at the bottom of the drill stem. A submersible pump 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.

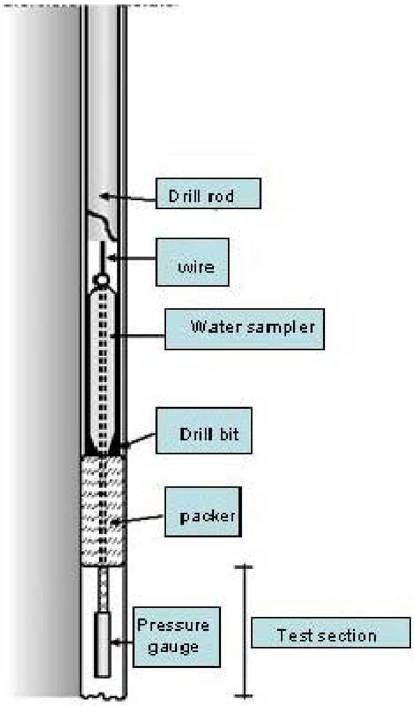


*Figure 4-1.* *The wireline probe and its emplacement in the hole.*

### *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 flowrate during the pumping test exceeds 1 litre per minute.

## 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 procedure for data handling and quality assurance is given method description in 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).
- 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.

*Figure 4-2. The CR23 logging unit for parameters "air-pressure" and "electrical conductivity".*

### 4.3.4 Equipment for deviation measurements

Deviation measurements are performed to keep track on the borehole direction and dip in order to make decisions on whether directional drilling is needed or not.

Deviation measurements are typically made with the Reflex **MAXIBOR™** (non-magnetic) optical equipment at 100 metre intervals and when the hole is drilled to full length. The results from the Maxibor measurements are used for deciding if directional drilling is needed or not. The final run with the Maxibor is stored in the Sicada database and used for orientation of borehole features.

Check-up or in-fill deviation measurements are made with magnetometer/accelerometer methods such as Reflex EZ-AQ/EMS (so called "Easy-shot" with single or multishot capabilities), Devi-Flex or Devico Pee-Wee equipment when needed. Typically the magnetometer/accelerometer methods are employed during and after directional drilling have been made for measuring the change in drilling direction and dip.

### 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 the cutters expand when the water pressure is increased.

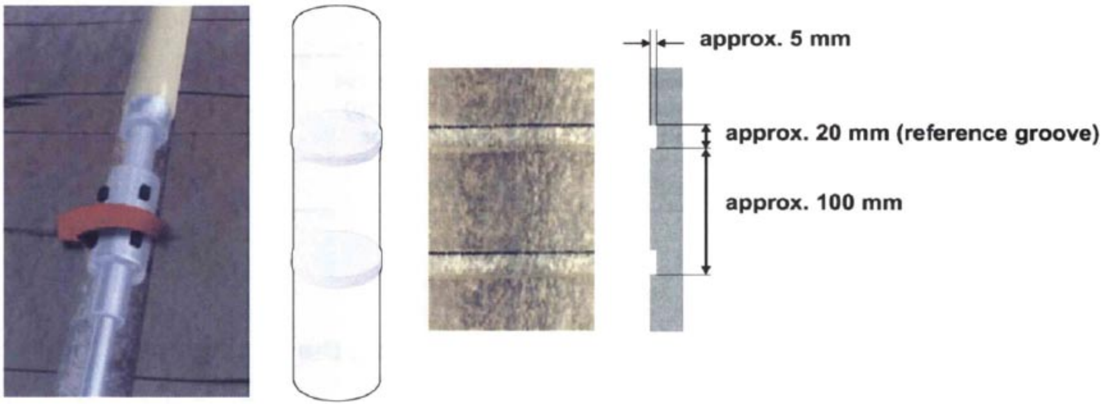


*Figure 4-3.* *The equipment for reaming of reference slots. To the left, the reaming tool with openings for the cutters is shown. The resulting reference slots are illustrated in the three pictures to the right.*

# 5 Execution and results

## 5.1 Summary of KLX07A and KLX07B drilling

A technical summary of the drilling of KLX07A and B is given in Tables 5-1 and 5-2. Graphical presentations of the boreholes after completion are given in Figures 5-1 and 5-2. A summary of drilling progress and borehole measurements is given in Table 5-3 and chronological summary is presented in Table 5-4. Further descriptions of the two main drilling steps, the percussion drilled telescopic section 0–100.46 metres and the core drilled section 100.46–844.73 metres are given in Sections 5.2 and 5.3 respectively. 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. KLX07A Technical summary.**

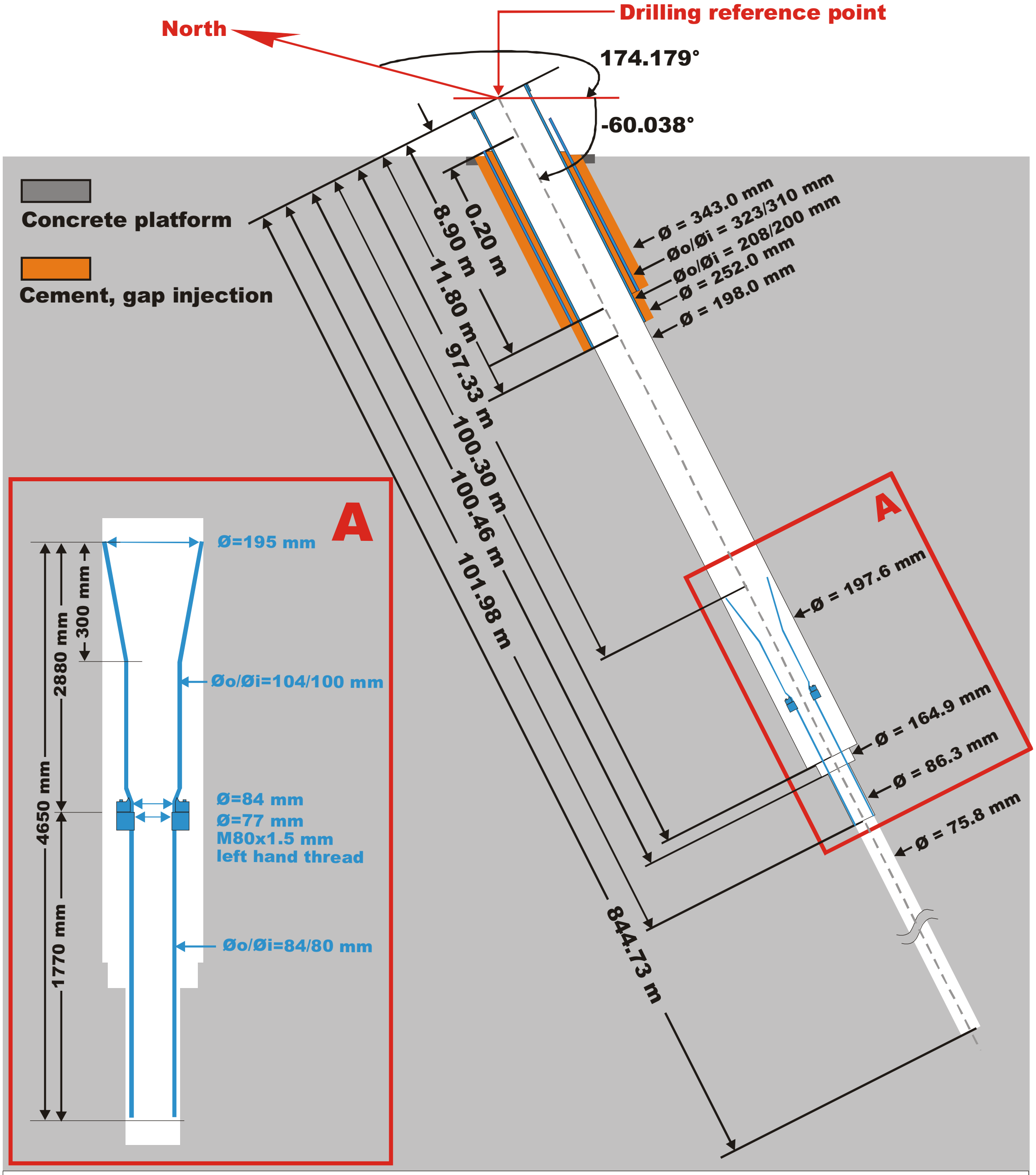
| General | Technical |
|---|---|
| Name of hole: KLX07A | Percussion drill rig: Comacchio MC1500 |
| Location: Laxemar, Oskarshamn Municipality, Sweden | Percussion hole length: 100.3 m (diam 197.6 mm) |
| Contractor for drilling: | 100.46 m (diam 164.9 mm) |
| Drillcon AB | Core drill rig: B 20 P Atlas Copco |
| Subcontractor percussion drilling: | Core drill dimension: N-size (76 mm) |
| Sven Andersson AB | Cored interval: 100.46–844.73 m |
| Subcontractor core drilling: | Average core length retrieved in one run: 2.16 m |
| Suomen Malmi OY (SMOY) | Number of runs: 345 |
| Drill start date: November 23, 2004 | Diamond bits used: 12 |
| Completion date: May 04, 2005 | Average bit life: 62 metres |
| | Position KLX07A (RT90 RH70) at top of casing: |
| | N 6366752.09 E 1549206.86 Z 18.47 (masl) |
| | Azimuth (0–360)/Dip (0–90): |
| | 174.2/–60.0 |
| | Position KLX07A (RT90 RH70) at 837 m length: |
| | N 6366218.95 E 1549259.32 Z –622.35 (masl) |
| | Azimuth (0–360)/Dip (0–90): |
| | 174.4/–50.5 |

**Table 5-2. KLX07B Technical summary.**

| General | Technical |
|---|---|
| Name of hole: KLX07B | Core drill rig: B 20 P Atlas Copco |
| Location: Laxemar, Oskarshamn Municipality, Sweden | Core drill dimension: N-size (76 mm) |
| Contractor for drilling: | Cored interval: 0.10–200.13 m |
| Drillcon AB | Position KLX07B (RT90 RH70) at top of casing: |
| Subcontractor core drilling: | N 6366753.14 E 1549206.76 Z 18.38 (masl) |
| Suomen Malmi OY (SMOY) | Azimuth (0–360)/Dip (0–90): |
| Drill start date: May 23, 2005 | 174.3/–85.0 |
| Completion date: June 03, 2005 | |

# Technical data

## Borehole KLX07A



**Drilling reference point**

Northing: 6366752.09 (m), RT90 2,5 gon V 0:-15
Easting: 1549206.86 (m), RT90 2,5 gon V 0:-15
Elevation: 18.47 (m), RHB 70

**Drilling period**

Drilling start date: 2004-11-23
Drilling stop date: 2005-05-04

**Guided Drilling**

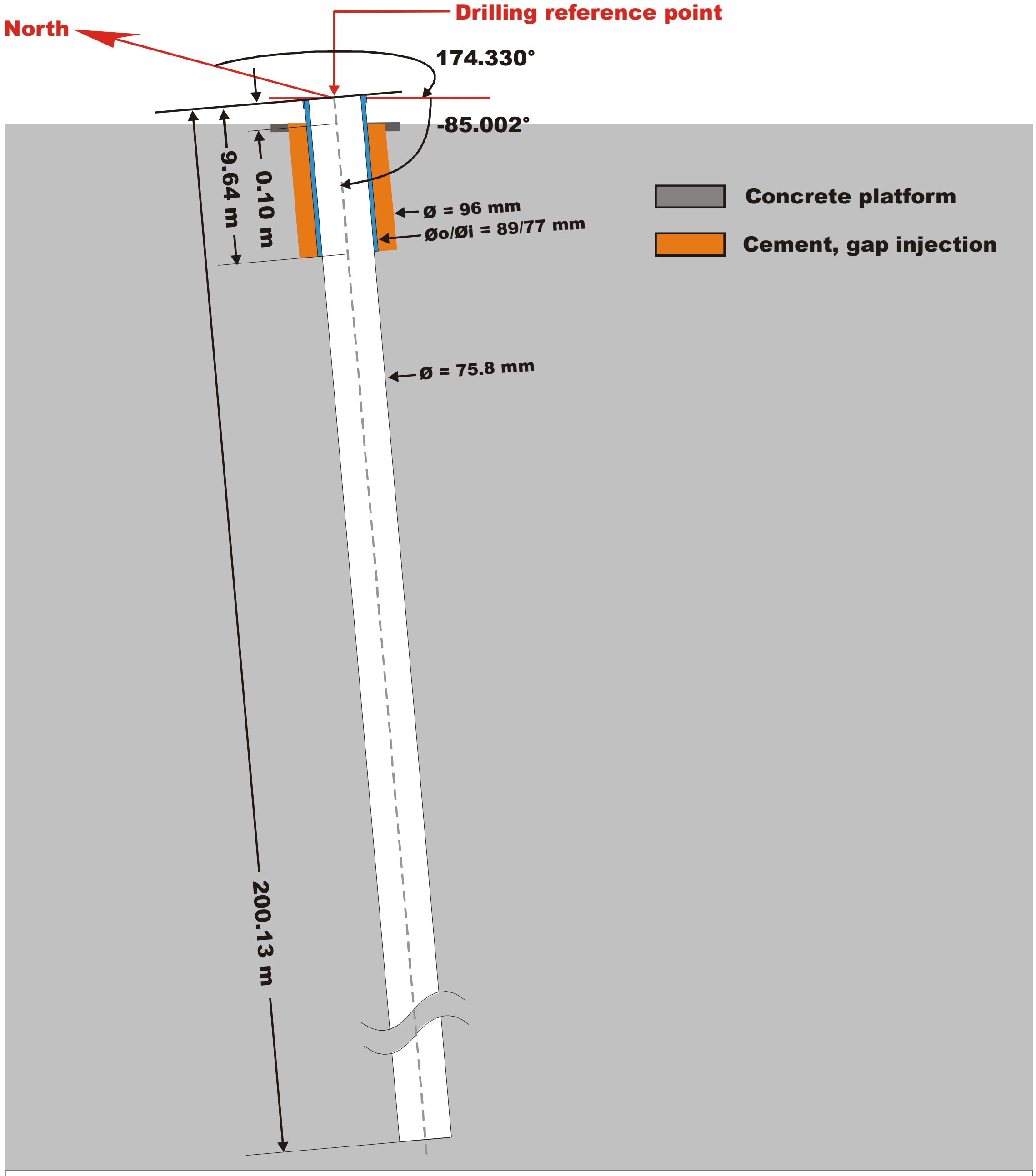
204.67 - 210.02
212.06 - 217.65
226.85 - 232.45
238.57 - 241.09
407.06 - 413.15
416.05 - 426.85
431.06 - 432.55
447.70 - 468.37
469.04 - 552.63

Ver 2005-11-07

***Figure 5-1.*** *Technical data from KLX07A.*

# Technical data

## Borehole KLX07B



**Drilling reference point**

**Northing: 6366753.14 (m), RT90 2,5 gon V 0:-15**

**Easting: 1549206.76 (m), RT90 2,5 gon V0:-15**

**Elevation: 18.38 (m), RHB 70**

**Drilling period**

**Drilling start date: 2005-05-23**

**Drilling stop date: 2005-06-03**

Ver 2005-11-07

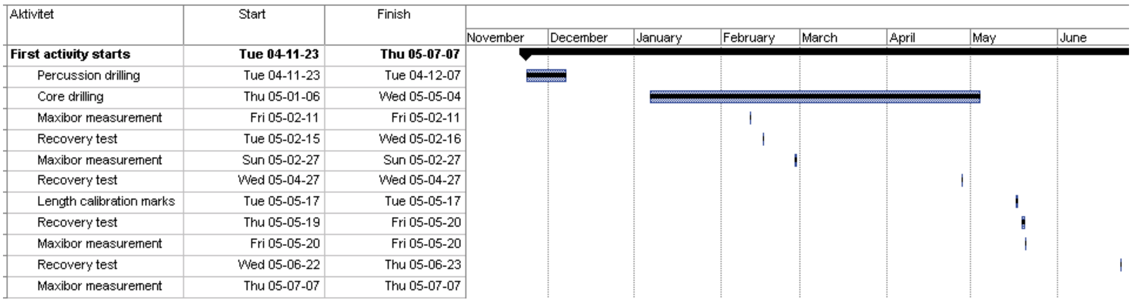
***Figure 5-2.*** *Technical data from KLX07B.*

## Table 5-3. Summary of core drilling progress and borehole measurements in KLX07A.

0 m

| Drilled length, pumping tests and water sampling | Measurements of absolute pressure | Airlift pumping with evaluation of drawdown and/or recovery | Deviation measurement | Miscellaneous |
|---|---|---|---|---|
| 041125 Water flow in 195 mm diam borehole 11.8-100 m was 18 L/min. | 050117 Measurement of absolute pressure 102-205 m. | | 050115 Maxibor 0 - 165 m<br>5 m left<br>21 m up<br>Dip -68° Azim 173° | Drilling induced core loss of 2.51 m between 114 and 117 m |
| 050113 Pumping test 146-155 m. 4.5 L/min at 14 m drawdown. Water sample with 0% drilling water content (DWC). | 050201 Measurement of absolute pressure 195-315 m. | | 050121 Maxibor 0 - 222 m<br>6 m left<br>33 up<br>Dip -49°<br>Azimuth 174° | |
| 050116 Pumping test 102-197 m. 8 L/min at 14 m drawdown. Water sample with 13% DWC. | 050219 Measurement of absolute pressure 315-413 m. | | 050210 Maxibor 0 - 396 m.<br>1.9 m left<br>68 m up<br>Dip -45°<br>Azimuth 181° | |
| 050128 Pumping test, fracture 250-266 m. 8.1 L/min at 17 m drawdown. | | 050215 Airlift pumping 11.8 - 407 m No drillstem in borehole | | |
| 050130. Pumping test 194-294 m. 14.4 L /min with 17 m drawdown. | 050403 Measurement of absolute pressure 411-626 m. | | | |
| 050214. Pumping test 294-407 m 13.8 L/min with 19 m drawdown. Water sample with 8% DWC. | 050406 Measurement of absolute pressure 618-632 m. | | Numerous Maxibor and magnetometer/ acccelerometer measurements made in conjunction with directional drilling, see section 5.3.4 and Appendices 4 and 7. | Directional drilling was made in seven intervals with the Liwinstone method between 204.67 and 432.55 m. |
| 050321 Pumping test 405-537 m. 3.8 L/min with 15 m drawdown. Water sample with 51% DWC. | | | | Directional drilling was made in two intervals with the Devi-Drill method between 447.70 and 552.63 m. |
| 050402 Pumping test 536-614 m. 0.4 L/min with 19 m drawdown. No water sample | 050410 Measurement of absolute pressure 630-641 m. | | | |
| 050405. Pumping test 618-626 m. 1.3 L/min with 13 m drawdown. No water sample | 050422 Measurement of absolute pressure 624-729 m. | | | |
| 050408 Pumping test 630-636 m. 12 L/min with 10 m drawdown. Water sample. | 050428 Measurement of absolute pressure 717-805 m. | | | |
| 050409 Pumping test 637-641 m. 10 L/min with 14 m drawdown. Water sample | | | | |
| 050421 Pumping test 611-716 m. 12.5 L/min with 20 m drawdown. Water sample | | 050427 Airlift pumping 11.8 -799 m. No drillstem in borehole. | | |
| 050427 Pumping test 716-799 m. 12 L/min with 14 m drawdown. Water sample | | | | |
| 050509 Pumping test 798-844 m. 0.8 L/min with 14 m drawdown. No water sample and no pressure measurement | | 050519-050520 Airlift pumping 11.8 -844.73 m | 050520 Maxibor 0-837 m.<br>Right 5.24m<br>Up 143.40m<br>Dip -50.56°<br>Azimuth 174.66° | |

**Table 5-4. Chronological summary of main drilling events.**



| Aktivitet | Start | Finish |
|---|---|---|
| **First activity starts** | **Tue 04-11-23** | **Thu 05-07-07** |
| Percussion drilling | Tue 04-11-23 | Tue 04-12-07 |
| Core drilling | Thu 05-01-06 | Wed 05-05-04 |
| Maxibor measurement | Fri 05-02-11 | Fri 05-02-11 |
| Recovery test | Tue 05-02-15 | Wed 05-02-16 |
| Maxibor measurement | Sun 05-02-27 | Sun 05-02-27 |
| Recovery test | Wed 05-04-27 | Wed 05-04-27 |
| Length calibration marks | Tue 05-05-17 | Tue 05-05-17 |
| Recovery test | Thu 05-05-19 | Fri 05-05-20 |
| Maxibor measurement | Fri 05-05-20 | Fri 05-05-20 |
| Recovery test | Wed 05-06-22 | Thu 05-06-23 |
| Maxibor measurement | Thu 05-07-07 | Thu 05-07-07 |

## 5.2 Drilling, measurements and results in the telescopic section 0–100.46 m

Drilling, reaming and gap injection were made from November 23 to December 3, 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 (0–100.46 metres) of KLX07A was made in steps as described below:

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

- Drilling was made to 8.90 metres length with NO-X 280 mm equipment. This gave a hole diameter of 343 mm and left a casing (323×7 mm diameter) to a length of 8.90 m. The soil depth was 0.5 metres.
- Inner supportive casing for guidance for the drill string was mounted.
- A pilot percussion hole was drilled to a depth of 100.46 metres. The initial diameter of the bit was 165.0 mm and the diameter at full length was 164.9 mm.
- The hole was reamed to diameter 252.0 mm between 8.90 and 11.80 m.
- Stainless casing of 208×4 mm was installed from 0 to 11.80 m.
- Gap injection with low alkali cement based concrete (428 kg/480 litres) was made for both sets of casing as described in Figure 5-3.
- After the concrete had hardened, the hole was reamed from 11.80 to 100.3 m. The initial diameter of the hole was 198.0 mm and the diameter at full length was 197.6 mm. The borehole was rinsed and flushed to remove concrete and water.

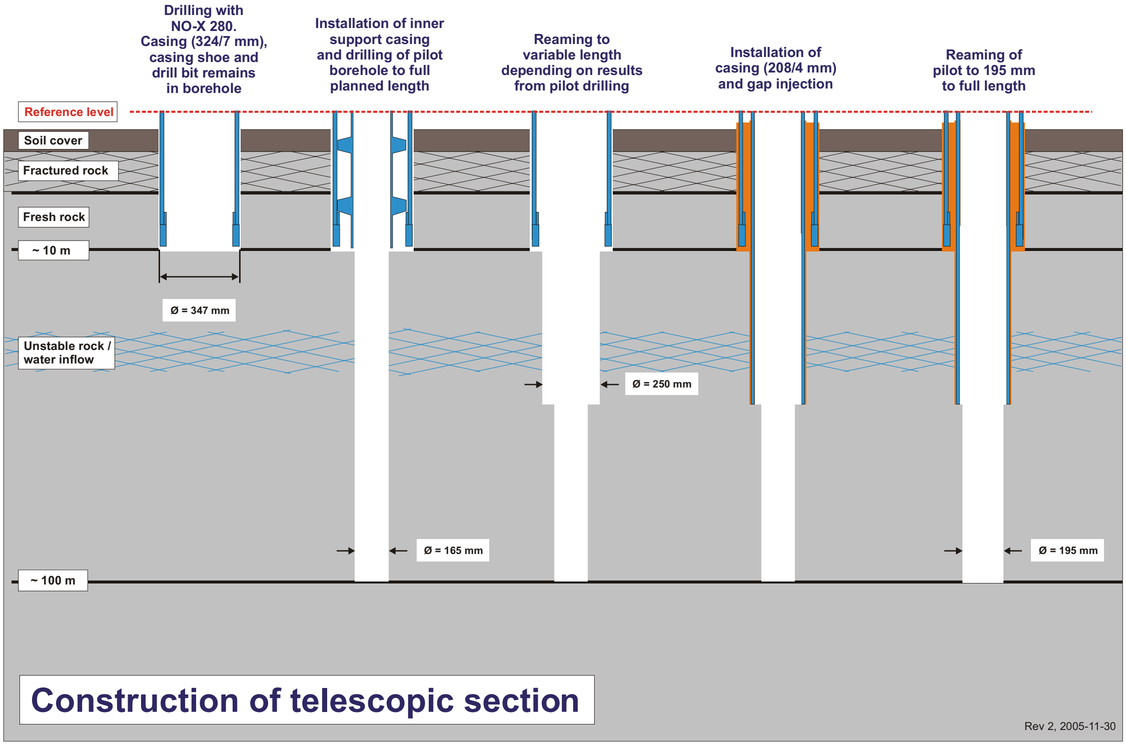


***Figure 5-3.** Construction of the telescopic section. The gap filling cement is introduced between the casing and the rock wall. The drill bit acts as a barrier so that cement does not enter the pilot hole.*

### 5.2.3 Measurements and sampling in the telescopic section

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

- The percussion drilling progress was monitored by the geology coordinator (or 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 manually and observation of changes in water flow was noted.

The preliminary geological results and penetration rate is presented in Figure 5-4.

#### Hydrogeology

The total water yield at full length in the telescopic section (100 m) was 18 L/min. The observations of water yield during percussion drilling of the pilot hole are summarized in Table 5-5.

#### Hydrochemistry

No water samples were collected from the telescopic section in KLX07A.

**Table 5-5. Water yield during percussion drilling.**

| From (m) | To (m) | Observed water flow (L/min) |
|---|---|---|
| 11.88 | 100.3 | 18 |

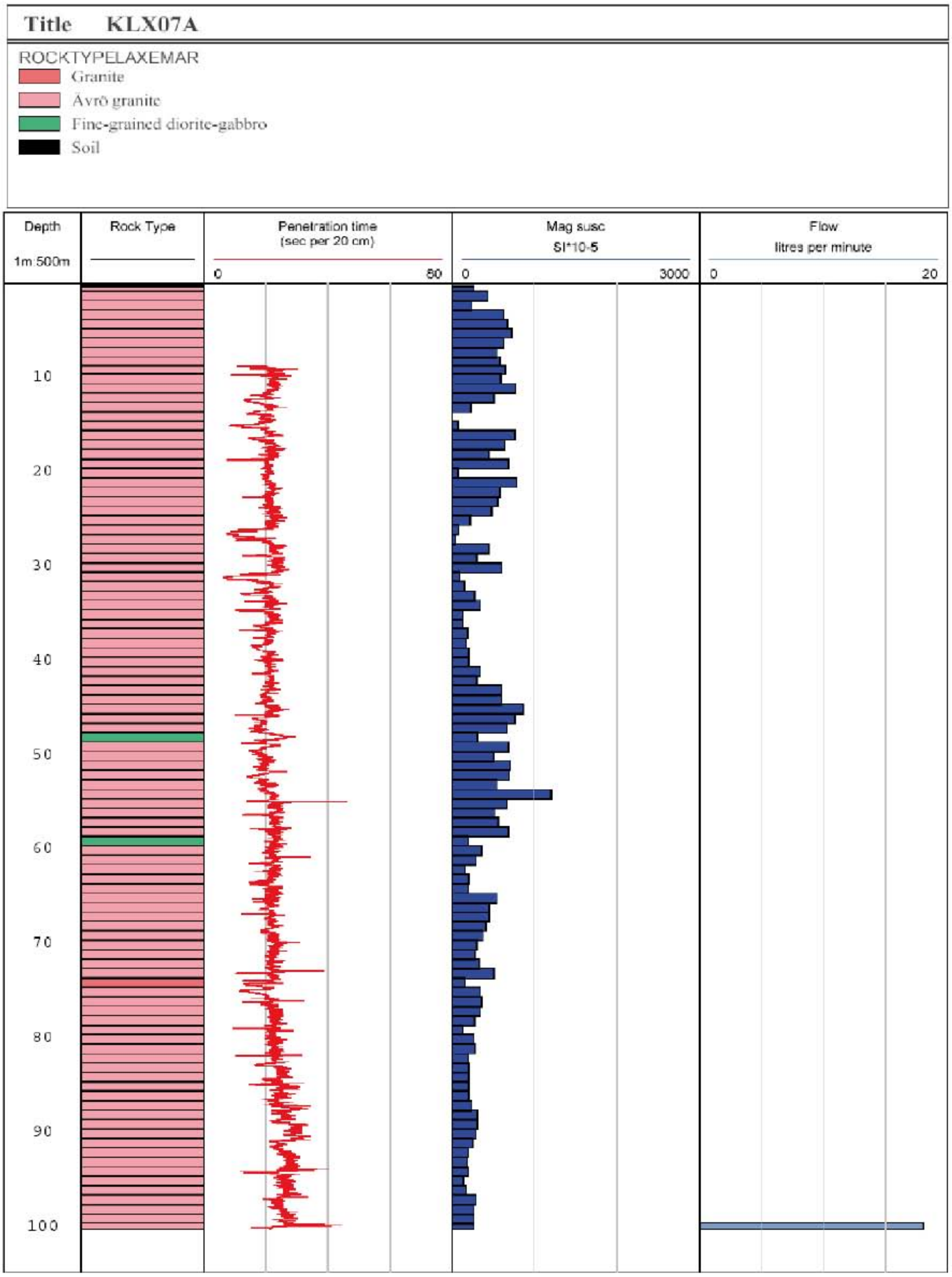


***Figure 5-4.** Preliminary geological results based on logging of drill cuttings and penetration rate from percussion drilling of KLX07A.*

## 5.3 Core drilling KLX07A 100.46–844.73 m and KLX07B

Core drilling in KLX07A was conducted between January 6, 2005 and May 04, 2005.

The main work in KLX07A after drilling the telescopic section consisted of the following steps:

- preparations for core drilling,
- flushing and return water handling,
- core drilling including directional drilling and deviation measurements,
- borehole completion.

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

Borehole KLX07B was core drilled from the surface i.e. no telescopic section was constructed.

### 5.3.1 Preparations

The preparations for core drilling started on December 18, 2004 and consisted of installation of air-lift pumping equipment and supportive casing for alignment of the core drill rods, see Figure 5-5.

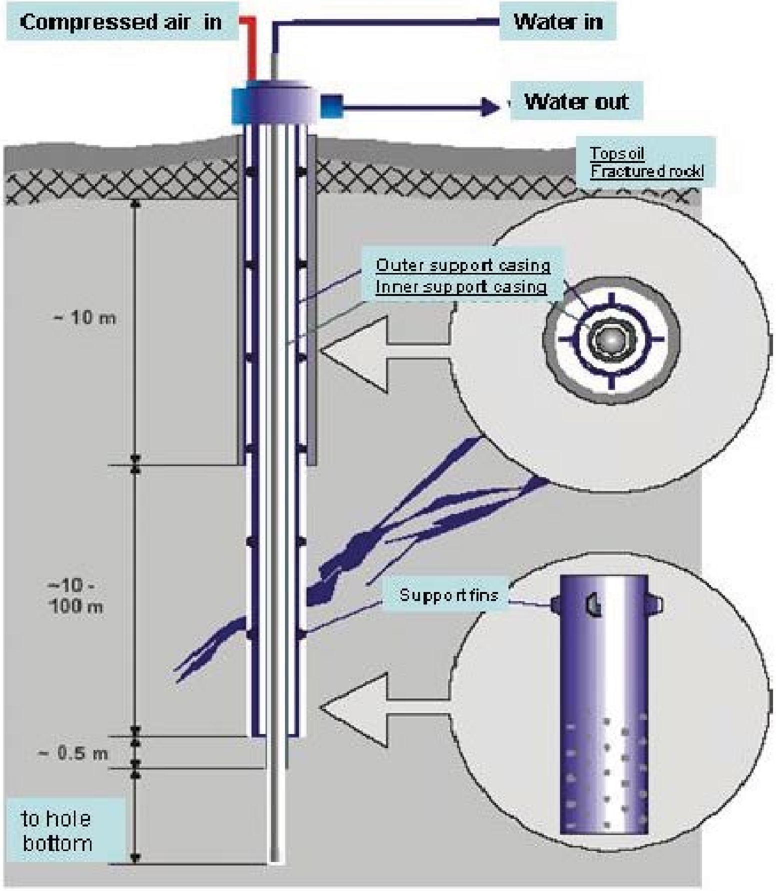


*Figure 5-5. In the telescopic part of the drill hole a temporary installation is made with casing tubes for support and alignment and equipment for air-lift pumping. In the uppermost part the return water discharge header is mounted. The water discharge is led to the settling containers.*

The installation of supportive casing was done in steps:

- An outer casing with a diameter of 98/89 mm, fitted with fins to align with the diameter of the percussion drilled borehole was installed.
- Equipment for air-lift pumping was installed and a discharge header was fitted to collect the return water.
- Drilling was made between 100.46 and 100.98 m with T-86 equipment. An inner supportive casing with diameter 84/77 mm was installed to 100.98 m.

The supportive casings have a perforated section between 99.20 and 99.60 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 HLX10, see Figure 1-1.

Treatment of the flushing water before introduction into the boreholes consisted of removal of oxygen by nitrogen flushing 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 KLX07A and KLX07B is shown in Figure 5-6.

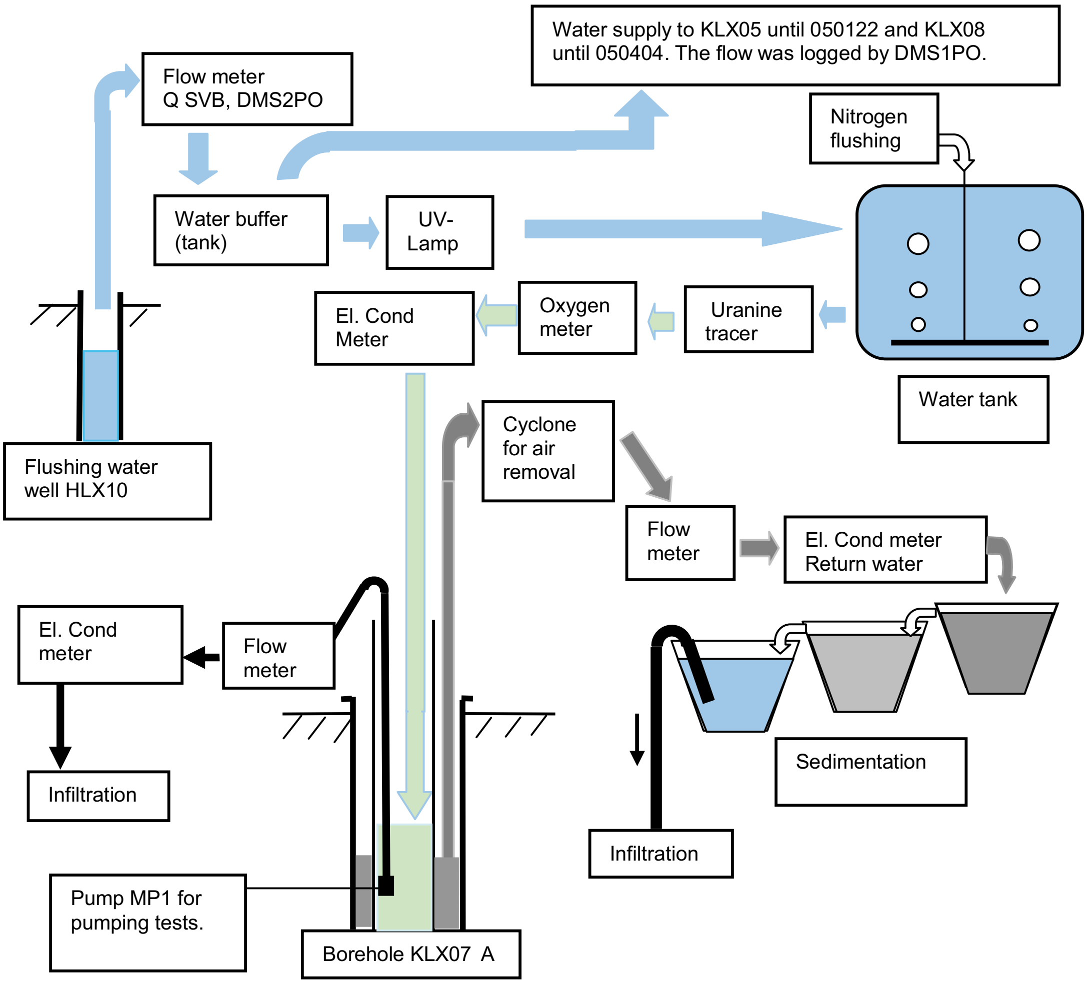


*Figure 5-6. The flushing and return water handling and the emplacement of related monitoring equipment in KLX07A and KLX07B.*

The targeted content for uranine in the flushing water is 0.20 mg/L and the actual average uranine content was 0.20 mg/L, see also Figure 5-10, Figure 5-11 and Section 5.4.2.

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.

### 5.3.3 Drilling and deviation measurements KLX07A

Core drilling with N-size (76 mm) triple-tube, wireline equipment was conducted from 100.98 m to the final length of 844.73 m in KLX07A.

The core drilling progress was routinely followed by deviation measurements with the optical Maxibor method, normally with 100 metre intervals.

The first deviation measurements, performed at ca 200 drilled length i.e. at 100 metres below the percussion drilled section, showed that the borehole tended to shallow substantially. The borehole started with a dip of –60° but at 197 metres the dip had dropped to –48.4°. It was found that the dip in the percussion drilled section (0–100.46 m) was reduced from –60° to ca –50°. Changes in dip of this magnitude have not previously been noted in drilling of any telescopic sections. A direct lesson was that deviation measurements should be done immediately after percussion drilling of telescopic sections in future boreholes.

In order to prevent further reduction in the dip in KLX07A and to try to restore the planned dip, directional drilling was employed in intervals between 204.67 and 552.63 metres. Two different methods were employed for directional drilling, Liwinstone and Devi-drill. The directional drilling was monitored carefully with deviation measurements with both the Maxibor and magnetometer/accelerometer methods.

The deviation measurement results are summarized in Table 5-6, highlighting the inclination and azimuth of the borehole at important positions i.e. start, stop, before and after the directional drillings.

The core diameters and intervals for different drilling dimensions or method of directional drilling are given in Table 5-7.

Horizontal and vertical plots of the results of the final run with the Maxibor method covering the entire length of borehole KLX07A are given in Appendix 4. The results from the final Maxibor measurements are stored in the Sicada database. Final deviation measurements after drilling was completed were made with two methods, Maxibor and Flexit. The results are shown for comparison in Table 5-8.

A total of fourteen drill bits were used for KLX07A, see Figure 5-7.

Further results from drill monitoring i.e. drill penetration rate and various measurements will be presented in Section 5.6 “Drilling monitoring results” and in Appendix 1. The drilling progress over time is shown in Section 5.6, see Figure 5-15.

### 5.3.4 Drilling and deviation measurements KLX07B

KLX07B was drilled with size N from the surface to 15.7 m. The uppermost 9.64 metres were then reamed to 96 mm diameter. A 89/77 mm casing was installed and grouted. After the cement had hardened the drilling continued with size N to full planned length.

In KLX07B two deviation measurements were made as part of the drilling activity, a Maxibor measurement on June 3, 2005 from 0 to192 m and a magnetometer/accelerometer measurement on June 4, 2005 from 35 to195 m. A magnetometer/accelerometer measurement made in July 2005, as part of a geophysical logging activity, is used as deviation data for the borehole.

**Table 5-6. Summary of deviation readings from the final Maxibor measurement.**

| Length in borehole (m) | Inclination, degrees (zero = horizontal) | Azimuth, degrees | Comment |
|---|---|---|---|
| 0 | –60.0 | 174.2 | Start |
| 197 | –48.4 | 172.8 | First deviation measurement |
| 440 | –44.7 | 180.4 | After directional drilling with the Liwinstone method |
| 558 | –52.1 | 174.8 | After directional drilling with the Devi-drill method |
| 837 | –50.5 | 174.4 | Final measurement |

**Table 5-7. Core diameters, borehole diameters and intervals for different drilling dimensions during core drilling.**

| Core diameter (mm) | Borehole diameter (mm) | Interval (m) | Drilling dimension or directional drilling method | Comment |
|---|---|---|---|---|
| 50.2 | 86 | 100.46–101.98 | T-86 | reamed |
| 50.2 | 76 | 101.98–204.67 | N | |
| 45.0 | 76 | 204.67–210.02 | N | directional |
| 50.2 | 76 | 210.02–212.06 | N | |
| 45.0 | 76 | 212.06–217.65 | Liwinstone N | directional |
| 50.2 | 76 | 217.65–226.85 | N | |
| 45.0 | 76 | 226.85–232.45 | Liwinstone N | directional |
| 50.2 | 76 | 232.45–238.57 | N | |
| 45.0 | 76 | 238.57–241.09 | Liwinstone N | directional |
| 50.2 | 76 | 241.09–407.06 | N | |
| 45.0 | 76 | 407.06–413.15 | Liwinstone N | directional |
| 50.2 | 76 | 413.15–416.05 | N | |
| 45.0 | 76 | 416.05–426.85 | Liwinstone N | directional |
| 50.2 | 76 | 426.85–431.06 | | |
| 45.0 | 76 | 431.06–432.55 | Liwinstone N | directional |
| 50.2 | 76 | 432.55–447.70 | | |
| 31.5 | 76 | 447.70–468.37 | Devi-Drill WL 76 | directional |
| 50.2 | 76 | 468.37–469.04 | N | |
| 31.5 | 76 | 469.04–552.63 | Devi-Drill WL 76 | directional |
| 50.2 | 76 | 552.63–844.73 | N | |

**Table 5-8. Comparison of the results between final deviation measurements in KLX07A.**

| Date | Method | Drilled length (m) | Dip | Comment |
|---|---|---|---|---|
| 2005-05-19 | Flexit | 840 | –51,74° | downwards measurement |
| 2005-05-19 | Flexit | 840 | –51,73° | upwards measurement |
| 2005-05-20 | Maxibor | 837 | –50,47° | downwards measurement |
| 2005-05-20 | Maxibor | 837 | –50,56° | upwards measurement |

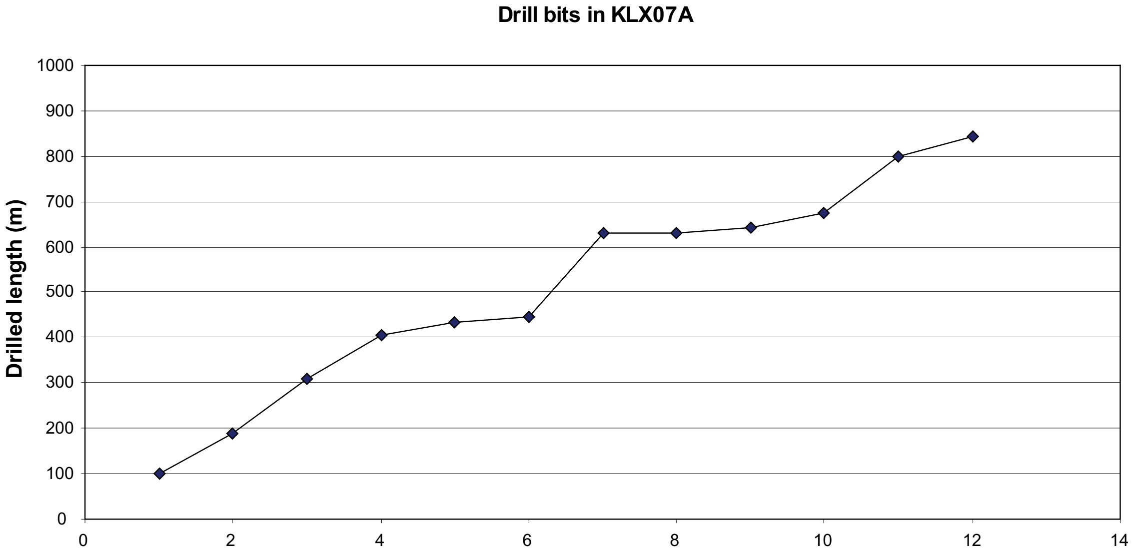


*Figure 5-7. Changes of drill bits during core drilling in KLX07A.*

### 5.3.5 Borehole completion

Reaming of depth reference slots was done at intervals as 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 was removed. The section from 100.46 m to 101.98 m was reamed from 76 to 86 mm diameter.

A steel conical guide was installed in KLX07A between 97.33 m and 100.21 m together with a 84/80 mm casing between 100.21 and 101.98 m. The conical guide tapers from an inner diameter of 195 mm to 77 mm.

The length of the holes was rinsed by flushing with nitrogen gas and a dummy probe was run through the length of the hole to ensure that the hole was unobstructed.

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

**Table 5-9. Depth reference slots (m) in KLX07A.**

| | |
|---|---|
| 110.00 | 500.00 |
| 150.00 | 550.00 |
| 200.00 | 600.00 |
| 250.00 | 650.00 |
| 300.00 | 700.00 |
| 349.00 | 750.00 |
| 400.00 | 800.00 |
| 450.00 | |

## 5.4 Hydrogeological and hydrochemical measurements and results KLX07A 100.46–844.73 m

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

Wireline measurements:

- 15 pumping tests were conducted at various intervals, 13 were successful, see Section 5.4.1.
- 8 measurements for absolute pressure, see Section 5.4.1.
- 14 water samples was successfully collected from 15 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 phase were made, for results see Section 5.4.3.

### 5.4.1 Hydrogeological results from wireline measurements

Results from the wireline tests in KLX07A are presented in Table 5-10 and Figure 5-8.

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

A total of 15 pumping tests were performed, and 13 achieved sufficiently stable conditions for calculating pseudo steady-state transmissivity. The plots from the pumping tests are given in Appendix 5.

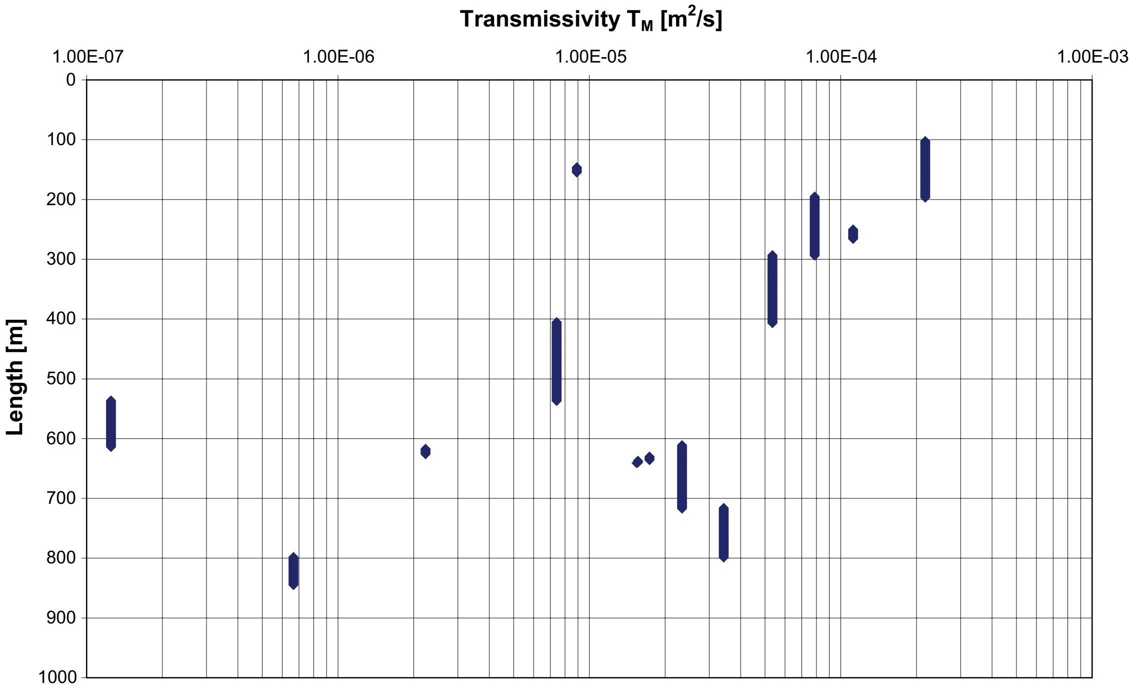


*Figure 5-8. Transmissivity from wireline pumping tests in KLX07A versus borehole length.*

**Table 5-10. Pumping tests with wireline probe in KLX07A.**

| Tested section [m] | Q/s [$m^2$/s] | $T_M$ [$m^2$/s] | Comments |
|---|---|---|---|
| 146.00–155.16 | $9.68\cdot10^{-6}$ | $8.92\cdot10^{-6}$ | Test functionally OK, good data. Pressure in casing in transient recovery phase, unaffected by pumping test. |
| 102.00–196.65 | $1.68\cdot10^{-4}$ | $2.17\cdot10^{-4}$ | Test functionally OK, good data. Pressure in casing in transient recovery phase. |
| 250.00–266.00 | $1.11\cdot10^{-4}$ | $1.12\cdot10^{-4}$ | Test functionally OK, good data. Pressure in casing in transient recovery phase. |
| 194.80–294.00 | $6.05\cdot10^{-5}$ | $7.87\cdot10^{-5}$ | Test functionally OK, good data.<br>Pressure in casing in transient recovery phase. |
| 293.40–407.09 | $4.04\cdot10^{-5}$ | $5.35\cdot10^{-5}$ | Pumping in HLX10 started 17:53, which can be seen in diagram for pressure in casing. Except from that, good test! |
| 405.00–537.63 | $5.50\cdot10^{-6}$ | $7.41\cdot10^{-6}$ | Pressure in casing in transient recovery phase.<br>Values of Q and hp at 02:40, due to drop in flow. |
| 536.56–614.06 | $9.91\cdot10^{-8}$ | $1.25\cdot10^{-7}$ | The flow decreases from 0.4 L/min to 0.1 L/min after approx. 1 h pumping; the change in flow has no significant impact on the pressure in the tested section. |
| 617.85–626.35 | $2.45\cdot10^{-6}$ | $2.23\cdot10^{-6}$ | Test evaluated until 22:05, thereafter highly variable flow.<br>Pressure in casing in transient recovery phase unaffected of pumping test. |
| 629.85–635.81 | $2.03\cdot10^{-5}$ | $1.74\cdot10^{-5}$ | After 2 h and 40 min pumping, at 21:30, a sudden pressure dip occurs in the tested section, which can also be seen in the pressure in casing. A small increase can be seen in the packer pressure. At the same time, the flow decreases approximately 2 L/min. The sudden pressure drop in the borehole, may derive from that the packer does not keep the section fully closed, due to counter acting formation pressure. As a consequence the pressure in the test section decreases, the water pillar above the pump is lowered, and the pressure difference increases, resulting in a lower pumping flow. Evaluation of from the phase before the pressure decreases.<br>Pressure in casing in transient recovery phase. |
| 636.85–641.09 | $1.95\cdot10^{-5}$ | $1.56\cdot10^{-5}$ | Test functionally OK, good data. Pressure in casing in transient recovery phase. |
| 611.70–716.60 | $1.78\cdot10^{-5}$ | $2.34\cdot10^{-5}$ | Test functionally OK, good data. Pressure in casing in transient recovery phase, unaffected of pumping test. |
| 716.60–799.20 | $2.69\cdot10^{-5}$ | $3.43\cdot10^{-5}$ | Test functionally OK, good data. Pressure in casing in transient recovery phase, unaffected of pumping test. |
| 797.85–844.73 | $5.62\cdot10^{-7}$ | $6.65\cdot10^{-7}$ | Pressure in casing in transient recovery phase, unaffected of pumping test. Packer pressure drops suddenly after approximately 1.5 hours pumping. |

The start and stop times for the interval used for evaluation of the pumping tests are given in Table 5-11.

Measurements of the absolute pressure were conducted in eight sections, as specified in Table 5-12 and Figure 5-9.

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.

**Table 5-11. Evaluated test periods.**

| Tested section | Start (YYYY-MM-DD HH:MM) | Stop (YYYY-MM-DD HH:MM) |
|---|---|---|
| 146.00–155.16 | 2005-01-13 15:56 | 2005-01-14 03:57 |
| 102.00–196.65 | 2005-01-16 17:06 | 2005-01-17 03:52 |
| 250.00–266.00 | 2005-01-28 17:30 | 2005-01-29 02:26 |
| 194.80–294.00 | 2005-01-30 15:47 | 2005-01-31 02:27 |
| 293.40–407.09 | 2005-02-14 16:00 | 2005-02-15 02:37 |
| 405.00–537.63 | 2005-03-20 16:40 | 2005-03-21 02:40 |
| 536.56–614.06 | 2005-04-02 15:47 | 2005-04-02 18:28 |
| 617.85–626.35 | 2005-04-05 17:20 | 2005-04-05 22:05 |
| 629.85–635.81 | 2005-04-08 18:48 | 2005-04-08 21:30 |
| 636.85–641.09 | 2005-04-09 18:51 | 2005-04-10 03:28 |
| 611.70–716.60 | 2005-04-21 16:16 | 2005-04-22 02:32 |
| 716.60–799.20 | 2005-04-27 17:45 | 2005-04-28 02:44 |
| 797.85–844.73 | 2005-05-09 16:31 | 2005-05-09 19:40 |

**Table 5-12. Absolute pressure measurements in KLX07A.**

| Tested section | Last pressure reading during build-up [kPa] | Duration of pressure build-up [hours] | Borehole length to pressure gauge [m] |
|---|---|---|---|
| 102.00–204.67 | 804 | 13.1 | 103.10 |
| 194.80–315.25 | 1,487 | 12.6 | 195.90 |
| 314.60–413.15 | 2,403 | 12.9 | 315.70 |
| 410.75–626.06 | 3,090 | 15.0 | 411.85 |
| 617.85–632.06 | 4,591 | 13.8 | 618.95 |
| 629.85–641.24 | 4,690 | 14.0 | 630.95 |
| 624.45–728.78 | 4,630 | 12.9 | 625.55 |
| 716.60–804.56 | 5,388 | 14.1 | 717.70 |

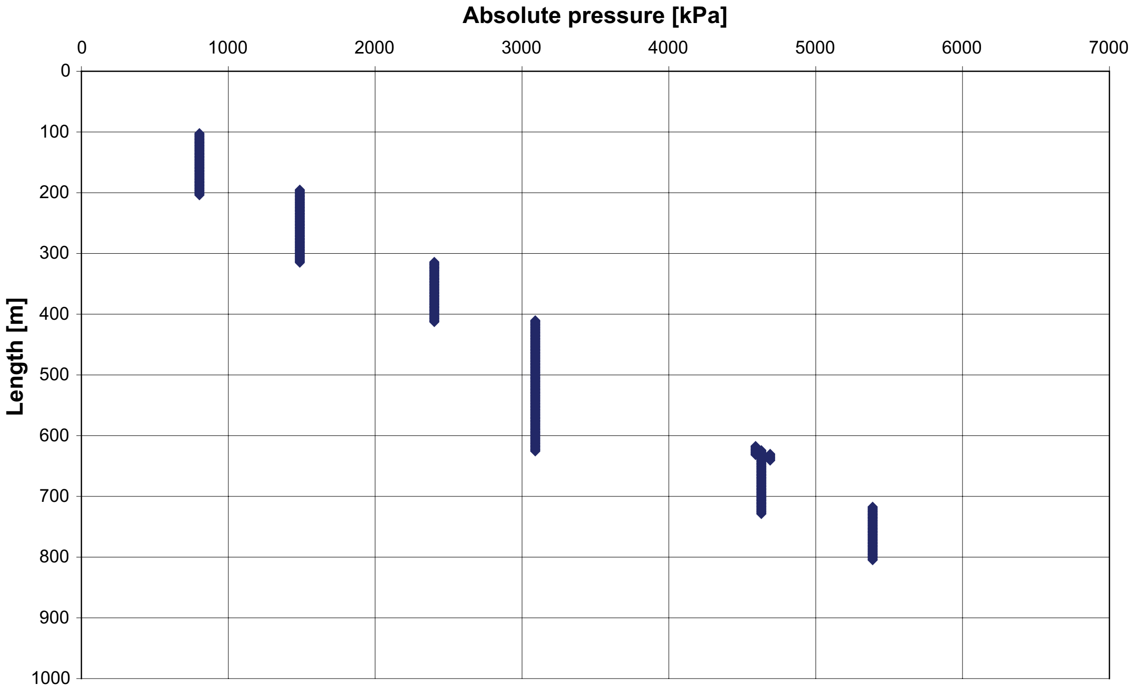


***Figure 5-9**. Absolute pressure measurements from wireline tests in KLX07A versus borehole length. The pressure measurement is made at the location of the upper packer. This can be seen as the upper edge of the sections in the figure form a straight line.*

### 5.4.2 Hydrochemistry

In total, fourteen water samples were collected in connection with core drilling in KLX07A and KLX07B. The times and lengths for the samples are given in Table 5-13.

Sampling and analysis were performed according to the SKB classes specified in Table 5-13. All samples were collected at the drill site as soon as possible after the sampling occasion and prepared and conserved at the Äspö laboratory.

All fourteen samples were intended for analysis according to SKB chemistry class 3, however, samples 10063, 10171, 10248, 10264, 10282 and 10316 were only analysed for drill water percentage. 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.

The samples 10011, 10229 and 10328 were collected as complete class 3 samples (all options included), i.e. the parameters that have not been analysed are saved and stored at the Äspö laboratory. Archive samples have been collected for all class 3 samples in Table 5-13.

Selected analytical results from KLX07A and B are given in Table 5-14. A complete record of analytical results is given in Appendix 2.

The percussion drilled borehole HLX10 was used as a water source during the drilling of KLX07A and B. Samples of total organic content, TOC, has been collected from HLX10 at earlier occasions and results from are reported in /4/ and /7/.

**Table 5-13. Sample dates and length during core drilling in KLX07A and B.**

| SKB sample no | Borehole | Date | Test section, length (m) | SKB chemistry class |
|---|---|---|---|---|
| 10010 | KLX07A | 2005-01-14 | 146.00–155.16 | 3 and all option isotopes |
| 10011 | KLX07A | 2005-01-17 | 102.00–196.65 | 3 (not analysed for isotopes) |
| 10062 | KLX07A | 2005-01-29 | 250.00–266.00 | 3 and all option isotopes |
| 10063 | KLX07A | 2005-01-31 | 194.80–294.00 | 1 (only analysed for drill water percentage) |
| 10078 | KLX07A | 2005-02-15 | 293.40–407.09 | 3 (not analysed for isotopes) |
| 10171 | KLX07A | 2005-03-21 | 405.00–537.63 | 1 (only analysed for drill water percentage) |
| 10228 | KLX07A | 2005-04-09 | 629.85–635.81 | 3 and all option isotopes** |
| 10229 | KLX07A | 2005-04-10 | 636.85–641.09 | 3 (not analysed for main components or isotopes)** |
| 10248 | KLX07A | 2005-04-22 | 611.70–716.60 | 1 (only analysed for drill water percentage) |
| 10264 | KLX07A | 2005-04-28 | 716.60–779.20 | 1 (only analysed for drill water percentage) |
| 10282 | KLX07A | 2005-05-05 | 797.85–844.73 | 1 (only analysed for drill water percentage) |
| 10283 | KLX07A | 2005-05-06 | 797.85–844.73 | 3 (not analysed for main components or isotopes)* |
| 10316 | KLX07B | 2005-05-31 | 9.50–108.41 | 1 (only analysed for drill water percentage) |
| 10328 | KLX07B | 2005-06-04 | 100.00–200.13 | 3 (not analysed for isotopes) |

*Only analysed for pH, conductivity, drill water percentage, alkalinity and chloride.

**Br was not analysed at the Äspö laboratory due to analytical problems.

**Table 5-14. Selected analytical results from water chemistry sampling.**

| Borehole | Sample no | Date | From m | To m | Drill water % | pH | Conductivity mS/m | Cl mg/l |
|---|---|---|---|---|---|---|---|---|
| KLX07A | 10010 | 2005-01-14 | 146.00 | 155.16 | 1.51 | 7.89 | 52.3 | 25.0 |
| KLX07A | 10011 | 2005-01-17 | 102.00 | 196.65 | 11.80 | 7.68 | 44.6 | 22.7 |
| KLX07A | 10062 | 2005-01-29 | 250.00 | 266.00 | 8.78 | 7.94 | 96.4 | 92.4 |
| KLX07A | 10063 | 2005-01-31 | 194.80 | 294.00 | 41.10 | – | – | – |
| KLX07A | 10078 | 2005-02-15 | 293.40 | 407.09 | 8.42 | 7.89 | 81.6 | 100.0 |
| KLX07A | 10171 | 2005-03-21 | 405.00 | 537.63 | 50.90 | – | – | – |
| KLX07A | 10228 | 2005-04-09 | 629.85 | 635.81 | 25.80 | 7.95 | 339.0 | 954.0 |
| KLX07A | 10229 | 2005-04-10 | 636.85 | 641.09 | 42.50 | 7.67 | 281.0 | 763.0 |
| KLX07A | 10248 | 2005-04-22 | 611.70 | 716.60 | 58.40 | – | – | – |
| KLX07A | 10264 | 2005-04-28 | 716.60 | 779.20 | 69.50 | – | – | – |
| KLX07A | 10282 | 2005-05-05 | 797.85 | 844.73 | 62.20 | – | – | – |
| KLX07A | 10283 | 2005-05-06 | 797.85 | 844.73 | 55.90 | 8.07 | 138.0 | 287.0 |
| KLX07B | 10316 | 2005-05-31 | 9.50 | 108.41 | 79.00 | – | – | – |
| KLX07B | 10328 | 2005-06-04 | 100.00 | 200.13 | 37.50 | 8.26 | 50.9 | 20.3 |

### *Monitoring of uranine tracer content*

From KLX07A, a total of 131 samples for laboratory testing of uranine content and electrical conductivity in flushing and returning water were taken along the borehole. The results are shown in Figure 5-10.

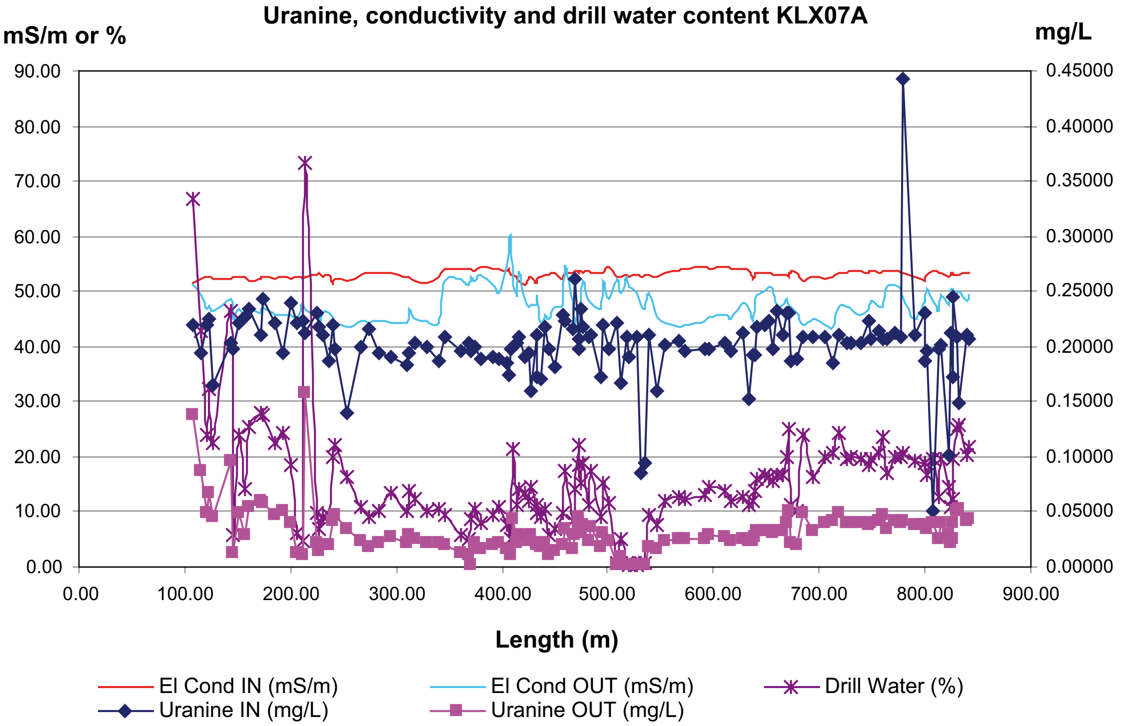


***Figure 5-10**. The uranine concentration, electrical conductivity of flushing water (IN) and returning water (OUT) and drill water percentage in KLX07A during drilling.*

From borehole KLX07B a total of 15 samples were taken and analysed for the above mentioned parameters. The results are shown in Figure 5-11.

A further account on analytical method, chemistry class 3 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 depth. 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 steady state transmissivity, $T_M$, was calculated according to /2/, as well as the specific capacity, *Q/s*. The results are shown in Table 5-15, and stored in the SICADA database as "recovery tests" (code HY050). The tested section is here defined as the section between the lower end of the grouted casing and the borehole bottom.

The plots from the drawdown and recovery tests are given in Figures 5-12, 5-13 and 5-14.

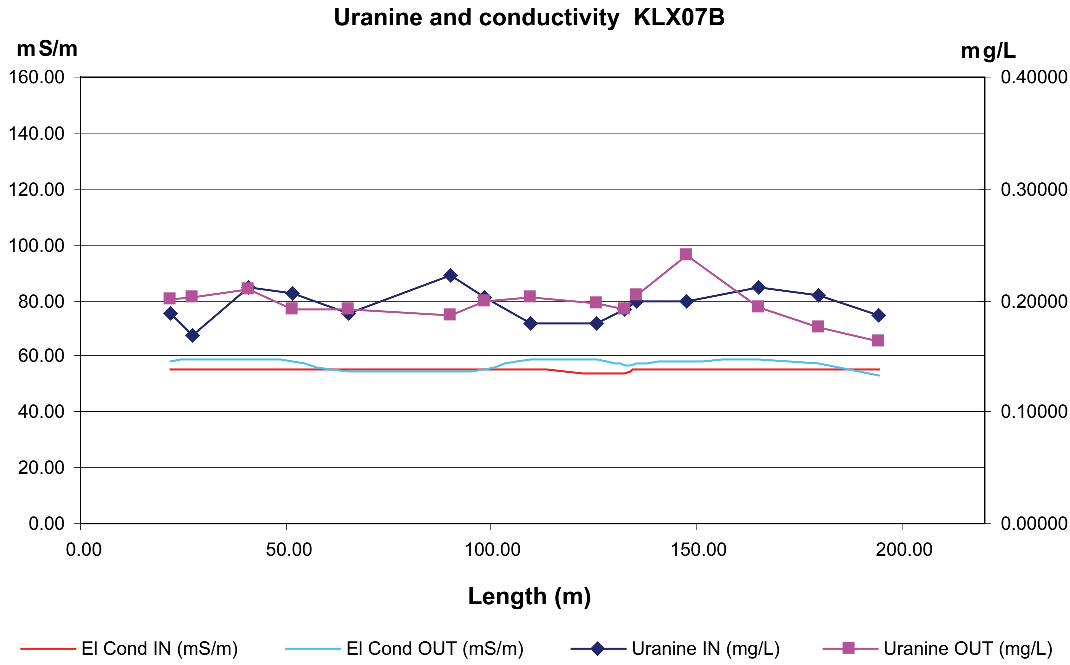


***Figure 5-11**. The uranine concentration and electrical conductivity of flushing water (IN) and returning water (OUT) in KLX07B during drilling.*

**Table 5-15. Results from airlift pumping in KLX07A.**

| Tested section [m] | Flow rate [L/min] | Drawdown [m] | Q/s [m²/s] | $T_M$ [m²/s] | Comments |
|---|---|---|---|---|---|
| 11.80–407.09 | 86.3 | 5.3 | $2.72 \cdot 10^{-4}$ | $4.13 \cdot 10^{-4}$ | No drill stems in the borehole during test.<br>Q derives from accumulated volumes of water in and out.<br>Q = ΣV/dt |
| 11.80–799.20 | 44.5 | 4.6 | $1.61 \cdot 10^{-4}$ | $2.63 \cdot 10^{-4}$ | No drill stems in the borehole during test.<br>Q derives from accumulated volumes of water in and out.<br>Q = ΣV/dt |
| 11.80–844.73 | 90.8 | 4.2 | $3.61 \cdot 10^{-4}$ | $5.91 \cdot 10^{-4}$ | No drill stems in the borehole during test.<br>Q derives from accumulated volumes of water in and out.<br>Q = ΣV/dt |

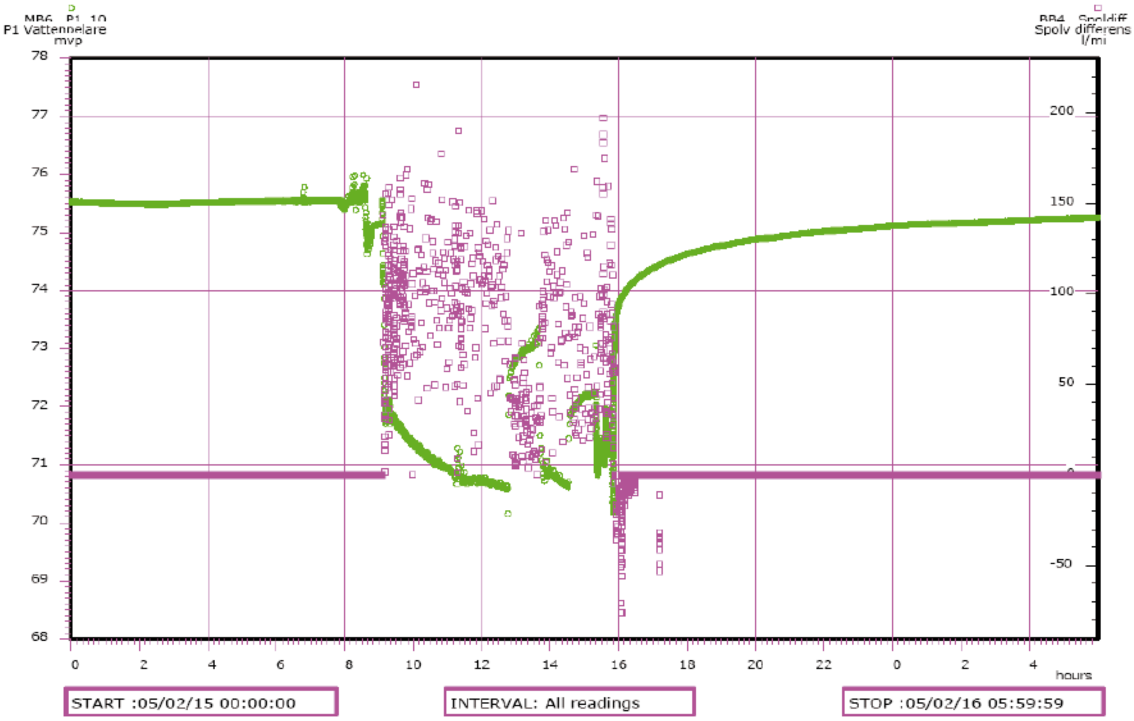


***Figure 5-12.*** *Airlift pumping in KLX07A 11.80–407.09 m. The green line represents the water column in the borehole, the net flow rate (flow out minus flow in) is shown as the pink line.*

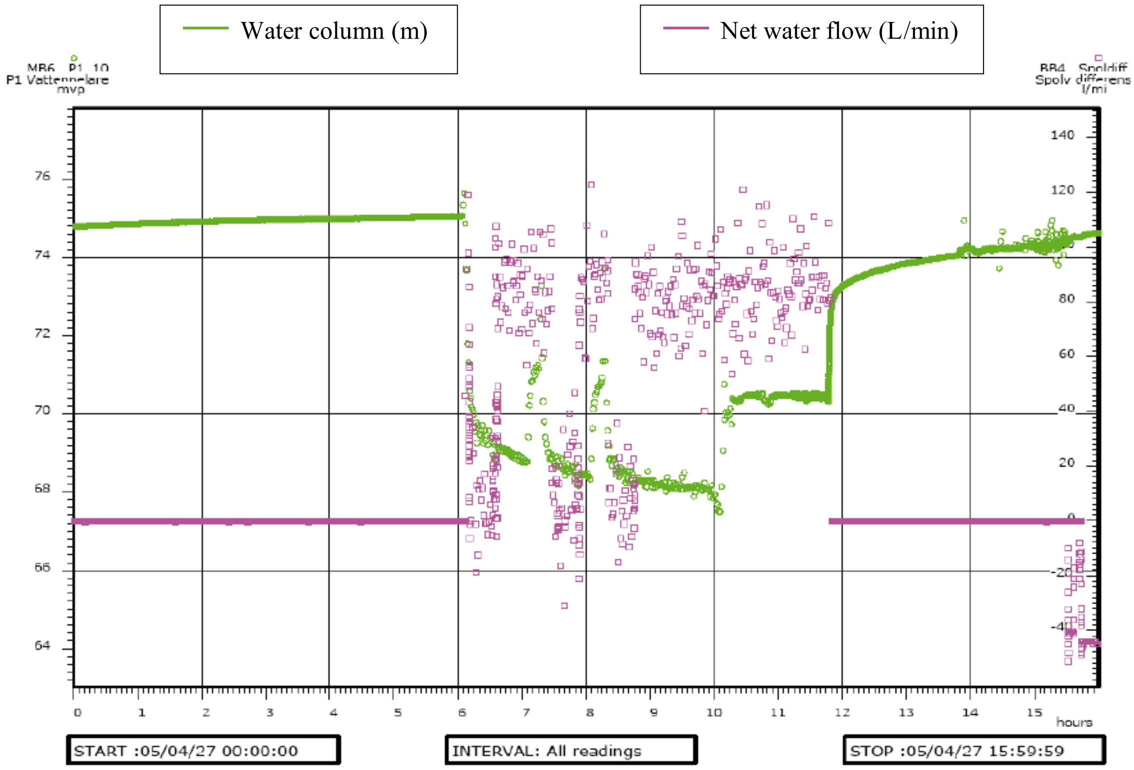


***Figure 5-13.*** *Airlift pumping in KLX07A 11.80–799.20 m. The green line represents the water column in the borehole, the net flow rate (flow out minus flow in) is shown as the pink line.*

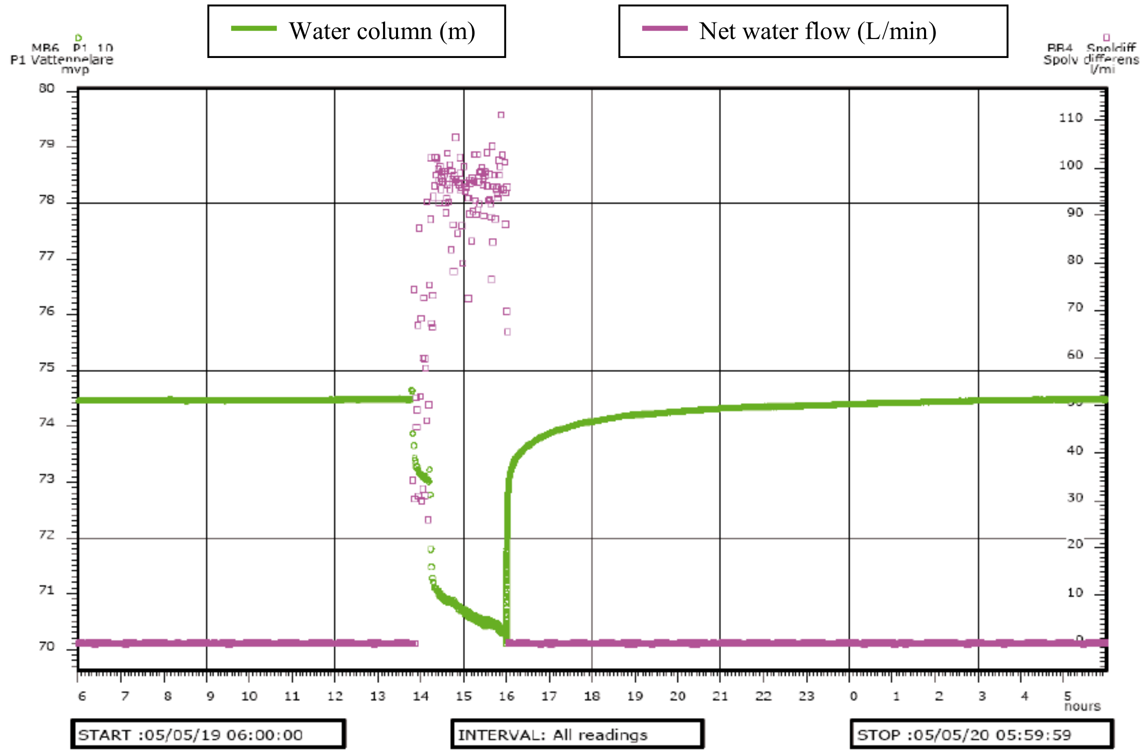


***Figure 5-14.*** *Airlift pumping in KLX07A 11.80–844.73 m. The green line represents the water column in the borehole, the net flow rate (flow out minus flow in) is shown as the pink line.*

### *Hydraulic responses in near-by boreholes*

Near-by located boreholes were checked for possible hydraulic responses from nitrogen gas flushing in KLX07A (050606) and KLX07B (050607). The results are summarised in Table 5-16. The locations of mentioned boreholes are given in Figure 5-19.

During flushing in KLX07B a clear response could only be seen in the uppermost section (section 8) in KLX02.

## 5.4.4 Drill water tracer test

During drilling of both KLX07A and KLX07B a fluorescent dye tracer, Rhodamine WT, was added to the drill water with the purpose to try to detect the tracer in the drill water supply well, HLX10. The tracer was added simultaneously and in the same way as the uranine tracer commonly used for detection of drill water in water samples. However, a somewhat higher concentration, 1 mg/l was used to increase the possibility of detecting the tracer in HLX10.

The tests are reported in more detail in a separate report /6/. The results of the test indicate a clear connection between KLX07A and HLX 10. Tracer breakthrough is monitored at drill depth 220 m in KLX07A. However, this depth also almost coincides withe the starting depth of the adding of Rhodamine WT. Thus, a very fast transport of the tracer, possibly within a single fracture zone, is indicated.

The test in KLX07B did not give any significant tracer breakthrough in HLX10 during the drilling period of the borehole.

**Table 5-16. Hydraulic responses from nitrogen gas flushing in KLX07A (050606) and KLX07B (050607).**

| | Section | KLX07A | KLX07B |
|---|---|---|---|
| HLX13 | 1 and 2 | No | No |
| HLX14 | 1 and 2 | No | No |
| HLX20 | 1 and 2 | No | No |
| HLX21 | 1 and 2 | No | No |
| HLX22 | 1 and 2 | No | No |
| HLX23 | 1 and 2 | No | No |
| HLX24 | 1 and 2 | No | No |
| HLX25 | 1 and 2 | No | No |
| HLX30 | 1 and 2 | No | No |
| HLX31 | 1 and 2 | No | No |
| HLX33 | 1 and 2 | No | No |
| KLX02 | 1 | No | No |
| KLX02 | 2 | No | No |
| KLX02 | 3 | No | No |
| KLX02 | 4 | No | No |
| KLX02 | 5 | No | No |
| KLX02 | 6 | No | Yes? |
| KLX02 | 7 | No | Yes? |
| KLX02 | 8 | No | Yes |
| KLX04 | 1 | No | No |
| KLX04 | 2 | No | No |
| KLX04 | 3 | No | No |
| KLX04 | 4 | No | No |
| KLX04 | 5 | No | No |
| KLX04 | 6 | No | No |
| KLX04 | 7 | No | No |
| KLX04 | 8 | No | No |

## 5.5 Hydrogeological and hydrochemical measurements and results in KLX07B 9.50–200.13 m

Two pumping tests were performed in KLX07B, one with and one without the wireline equipment, for results see Table 5-17, the plots are shown in Appendix 8. No measurements for absolute pressure were conducted.

The start and stop times for the interval used for evaluation of the pumping tests are given in Table 5-18.

**Table 5-17. Hydraulic tests in KLX07B.**

| Tested section [m] | Q/s [m²/s] | $T_M$ [m²/s] | Comments |
|---|---|---|---|
| 9.50–108.41 | $7.00 \cdot 10^{-05}$ | $9.11 \cdot 10^{-5}$ | Test without WL-probe i.e. the test was performed as an open-hole test with an MP-1 pump. The evaluation was done on the drawdown-phase only. |
| 100.00–200.13 | $2.04 \cdot 10^{-05}$ | $2.65 \cdot 10^{-05}$ | Manual flow measurement<br>Time: 17:26<br>Q = 9.8 L/min |

**Table 5-18. Evaluated test periods in KLX07B.**

| Tested section | Start (YYYY-MM-DD HH:MM) | Stop (YYYY-MM-DD HH:MM) |
|---|---|---|
| 9.50–108.41 | 2005-05-30 17:25 | 2005-05-30 18:33 |
| 100.00–200.13 | 2005-06-03 16:50 | 2005-06-04 03:01 |

## 5.6 Drilling monitoring results

Further descriptions of the two main drilling steps, the telescope section 0–100.46 metres and the core drilling section 100.46–844.73 metres are given in Sections 5.2 and 5.3 respectively.

### 5.6.1 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 5-15 through 5-17 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.

A brief study of the water pressure, given in Appendix 1, indicates that the expected trend of gradually increasing water pressure with drilled length was not seen in KLX07A. The water pressure was variable until 450 metres. Between 450 and 560 metres the water pressure was stable at 2,500–3,000 kPa. Below 560 metres the pressure was reduced and also less stable.

In order to maintain reasonable size data files, a reduction in the number of points incorporated in the pictures has been done in Figures 5-15 through 5-17. Since DMS data are related to time (i.e. not strictly to borehole length) periods were drilling is not performed are also registered.

Figure 5-15 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.

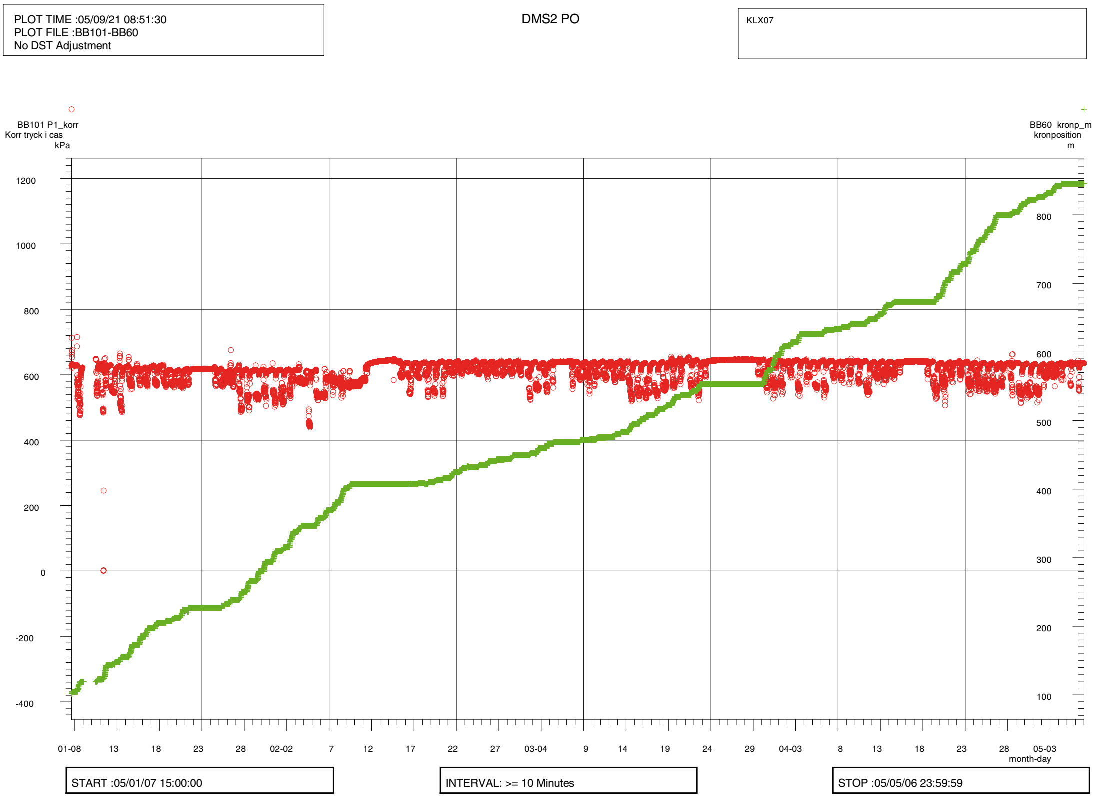


***Figure 5-15.*** *Drill bit position (green) and water level from air-lift pumping (red). The water level is expressed as the pressure in kPa of the water column overlying the pressure gauge i.e. the ambient air-pressure has been subtracted. The pressure gauge is emplaced at 90 metres borehole length. The drill bit position is given in cm×10*$^3$.

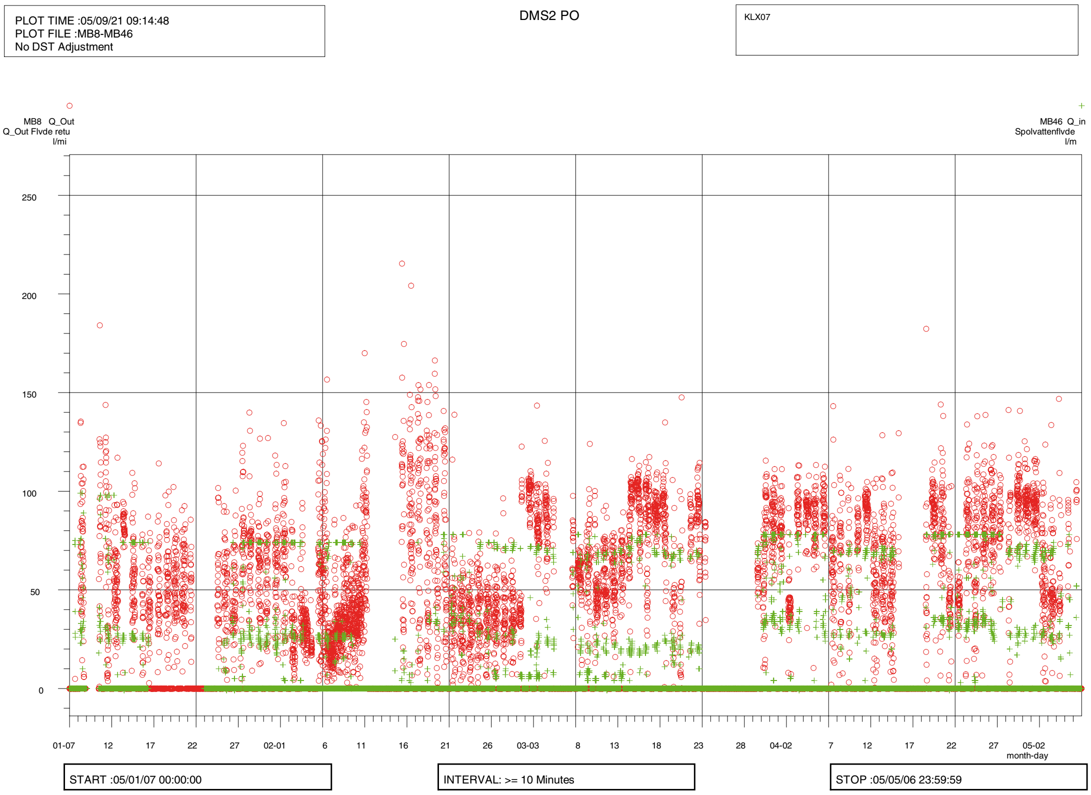


***Figure 5-16.*** *Flushing water flow (green) and return water flow (red) in litres per minute.*

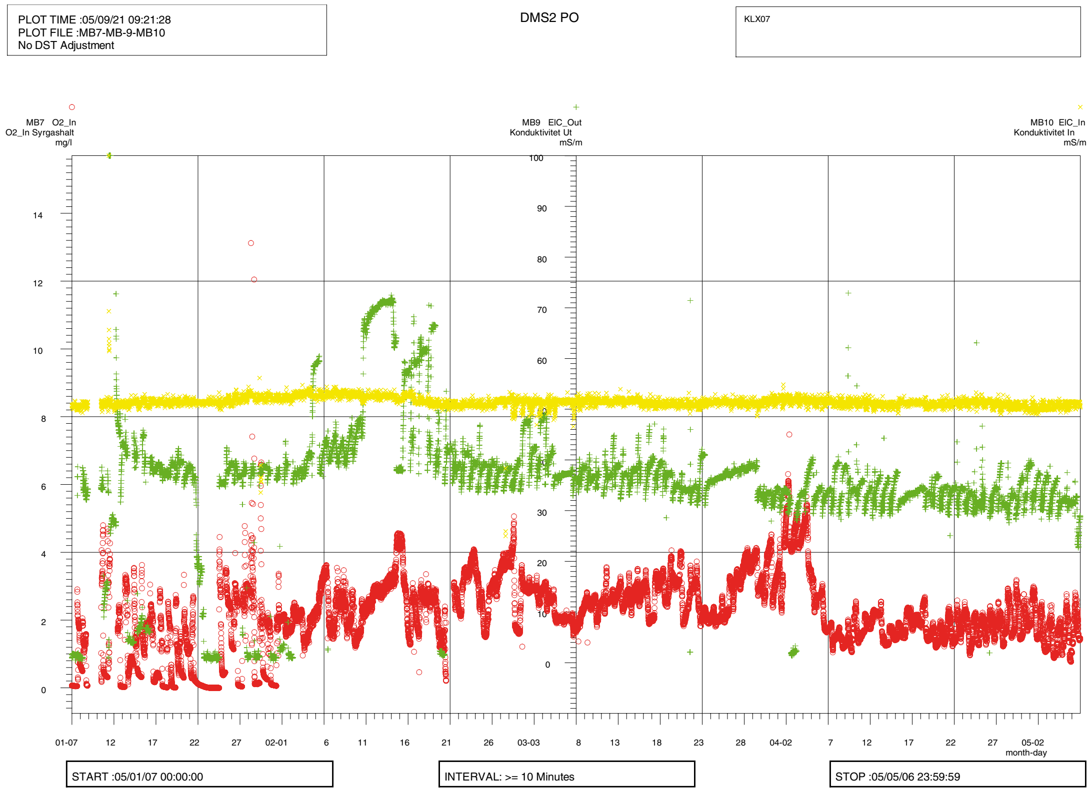


***Figure 5-17.*** *Conductivity of flushing water (yellow) and return water (green). The oxygen content in mg/l of the flushing water (red) is also shown. The oxygen content of the flushing water is normally below 4 mg/l with occasional peaks between 4 and 8 mg/l.*

Figure 5-16 shows the flushing water flow (green) entering the hole and the return water flow (red). It was noted during the drilling of KLX07A that the presence of small air-bubbles in the return water gives a slight overrepresentation of the return water flow. The erratic high return water flows in Figure 5-16 could be explained by this. The flushing water flows (green) show two distinct levels of pumped flow:

- A flow of 25–35 litres/minute corresponding to pumped flow during drilling.
- A flow of 70–80 litres/minute corresponding to the flow while pumping down the core-barrel.

Figure 5-17 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 low, typically below 4 mg/L with occasional peaks between 4 and 8 mg/l. The increase in conductivity in the return water (green) between February 11 and 16, corresponds to a period of no or little drilling progress due to start-up of directional (guided) drilling.

### 5.6.2 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 5-18.

The amount of flushing water consumed during drilling was 1,000 $m^3$, giving an average consumption of ca 1.3 $m^3$ per metre drilled. The amount of effluent return water from drilling in KLX07A was 3,600 $m^3$, giving an average of ca 4.8 $m^3$ per metre drilled.

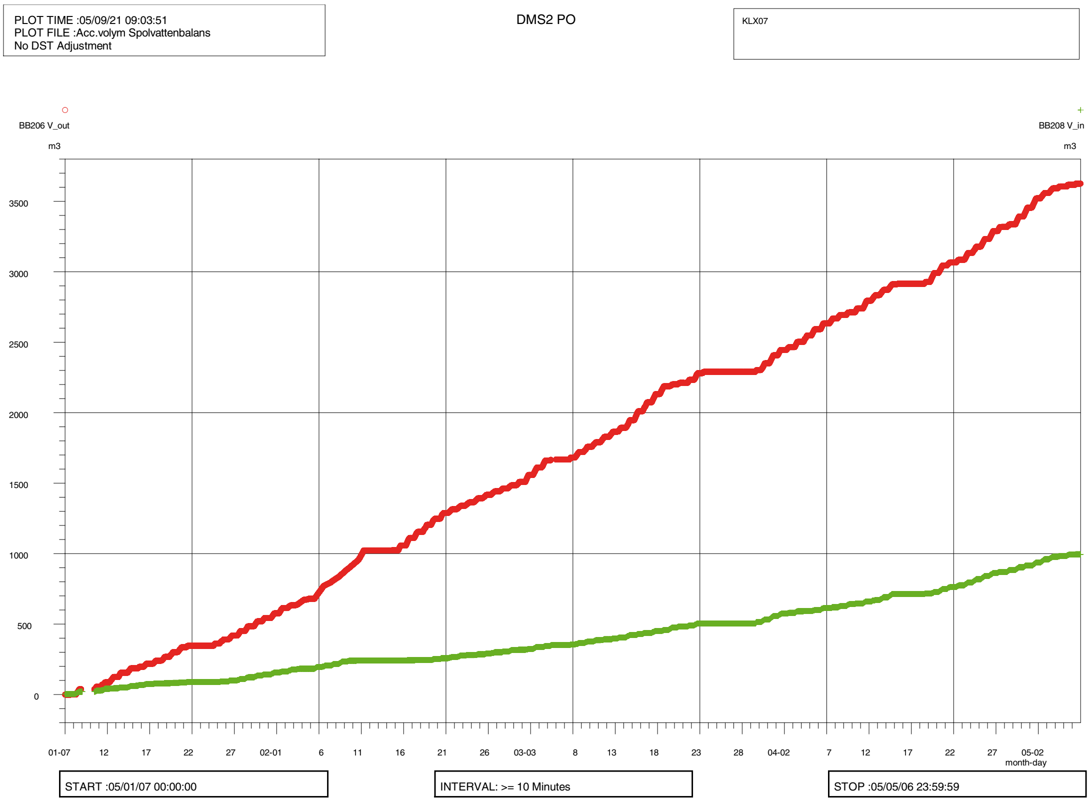


***Figure 5-18.*** *Flushing water balance from KLX07A as recorded by the DMS system. The accumulated volume of the ingoing flushing water is shown in green and the outgoing return water is shown in red.*

### Drill cutting balance

The weight of cuttings in the settling containers amounted to 1,230 kg. The content of suspended material in the return water was not analysed in borehole KLX07A, 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 amount to 1,440 kg. The theoretical amount that should be produced from drilling with 76 mm triple tubing over a length of 750 metres is 5,000 kg assuming a density of 2.65 kg/dm$^3$. This means that about 55% of the 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.

### Uranine tracer balance

The amount of introduced and recovered uranine is presented in Table 5-19 and Table 5-20. The results show that 54% of the introduced uranine was retrieved during drilling of KLX07A.

**Table 5-19. Balance calculation of uranine tracer in KLX07A.**

| | |
|---|---|
| Average uranine content IN (mg/L) | 0.20 |
| Flushing water volume IN (m$^3$) | 1,000 |
| Amount uranine introduced (g) | 200 |
| Average uranine content OUT (mg/L) | 0.03 |
| Return water volume OUT (m$^3$) | 3,600 |
| Amount uranine recovered (g) | 108 |

**Table 5-20. Uranine tracer content in KLX07B.**

| | |
|---|---|
| Average uranine content IN (mg/L) | 0.20 |
| Average uranine content OUT (mg/L) | 0.20 |

Logging of water flows in and out of the borehole with the DMS system was not made in KLX07B.

## 5.7 Geology

A preliminary geological mapping of the core is done as drilling progresses as part of the drilling activity. 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 but the results from the Boremap logging is nevertheless 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, /3/, are shown in Appendix 1.

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

Oxidation with weak to medium intensity is common to a drilled length of 760 m, but between 200 m and 410 m the intensity of the oxidation is somewhat elevated. Saussuritization i.e. alteration of calcic plagioclase feldspar to albite, zoisite or epidote has been noted sporadically around 150 m.

The distribution of total fractures in the core is typically in the range of 10–20 fractures/metre with minor sections containing slightly elevated fracture frequencies. Crushed sections, with a fracture frequency > 40, notably occurs at 120, 450, 670 and 760 m drilled length.

## 5.8 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.

## 5.9 Environmental control

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

All waste generated during the establishment, drilling and completion phases have been removed and disposed of properly. Water effluent from drilling was allowed to infiltrate to the ground in accordance with an agreement with the environmental authorities. The location of the water emission area is shown in Figure 5-18. 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 effluent water, i.e. discharge to the ground, from the core drilling of KLX07A never exceeded the guideline value of 300 mS/m. Typical conductivity values were in the range of 30–80 mS/m, see Figures 5-10 and 5-17.

The uranine content was well below 0.25 mg/l, see Figure 5-10.

The return water conductivity and uranine content were similarly low in KLX07B as can be seen in Figure 5-11.

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

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

### *Drilling of environmental monitoring wells*

Four environmental monitoring wells SSM000214, SSM000215, SSM000216 and SSM000217 were drilled as part of the activity AP PS 400-04-096. However only wells SSM000216 and SSM000217 were emplaced to monitor the water effluence or other possible impact from KLX07A and KLX07B. The other two wells were done as part of this activity for practical purposes only, and are not strictly related to the environmental monitoring of KLX07A or KLX07B. The locations of the wells SSM000216 and SSM000217 are given in Figure 5-19. The technical specifications for the wells SSM000216 and SSM000217 are given in Appendix 7.

### *Reference sampling*

Reference sample of surface soil from the core drill site was not taken since the drilling was performed on an existing drill site, KLX02. Reference samples of ground water from the environmental wells were not taken.

Monitoring of soil ground water levels

Pressure loggers (transducers) for measuring the ground water table were not installed.

## 5.9.1 Consumption of oil and chemicals

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

The concrete consumption was 480 litres in total. The concrete was based on white silica, low alkali cement.

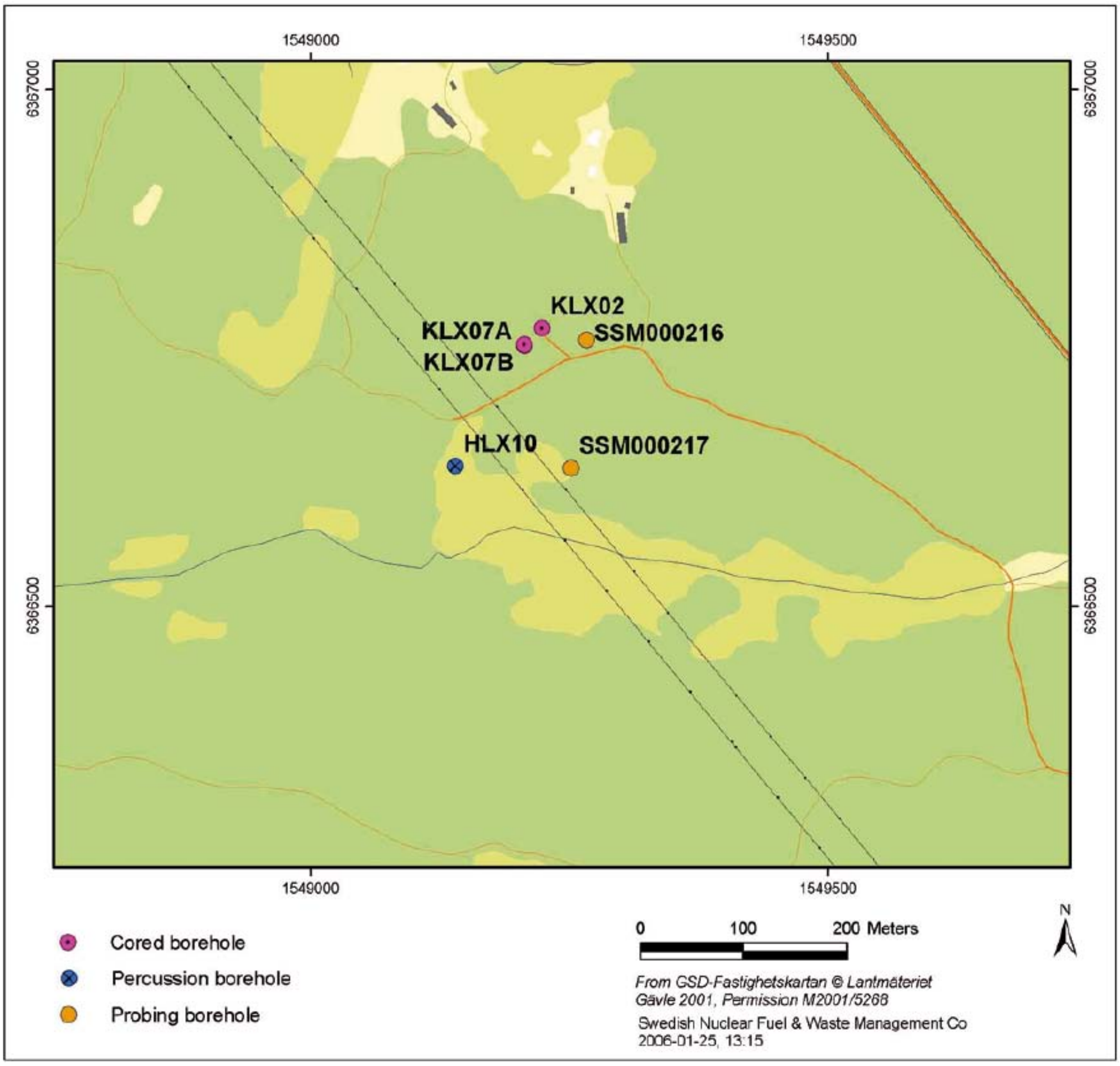


***Figure 5-19**. Location of environmental monitoring wells SSM000216 and SSM000217 in relation to the core drill site for KLX07A and KLX07B. The water source, percussion borehole HLX10 is also shown. The effluent return water was infiltrated to the ground some 100 metres south of the drill site.*

## 5.10 Nonconformities

No reference water samples were taken from the environmental wells, this has been reported a formal nonconformity.

No pressure transducers (loggers) were installed in the environmental monitoring wells SSM000216 or SSM000217, this has been reported a formal nonconformity.

The tightness of the concrete gap injection of the casing in the upper part of the telescopic section was not tested due to a slight modification of drilling procedure. Previous drillings and related testing show that the gap injections fulfil the requirements stated in the method description (SKB MD 620.003 v1.0, internal document) for core drilling.

# 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/ **SKB, 2005.** Boremap mapping of core drilled boreholes KLX07A and KLX07B. SKB P-05-263, Svensk Kärnbränslehantering AB.

/4/ **Ask, Morosini, Samuelsson, Ekström, 2004.** Drilling of cored borehole KSH02, SKB P-04-151, Svensk Kärnbränslehantering AB.

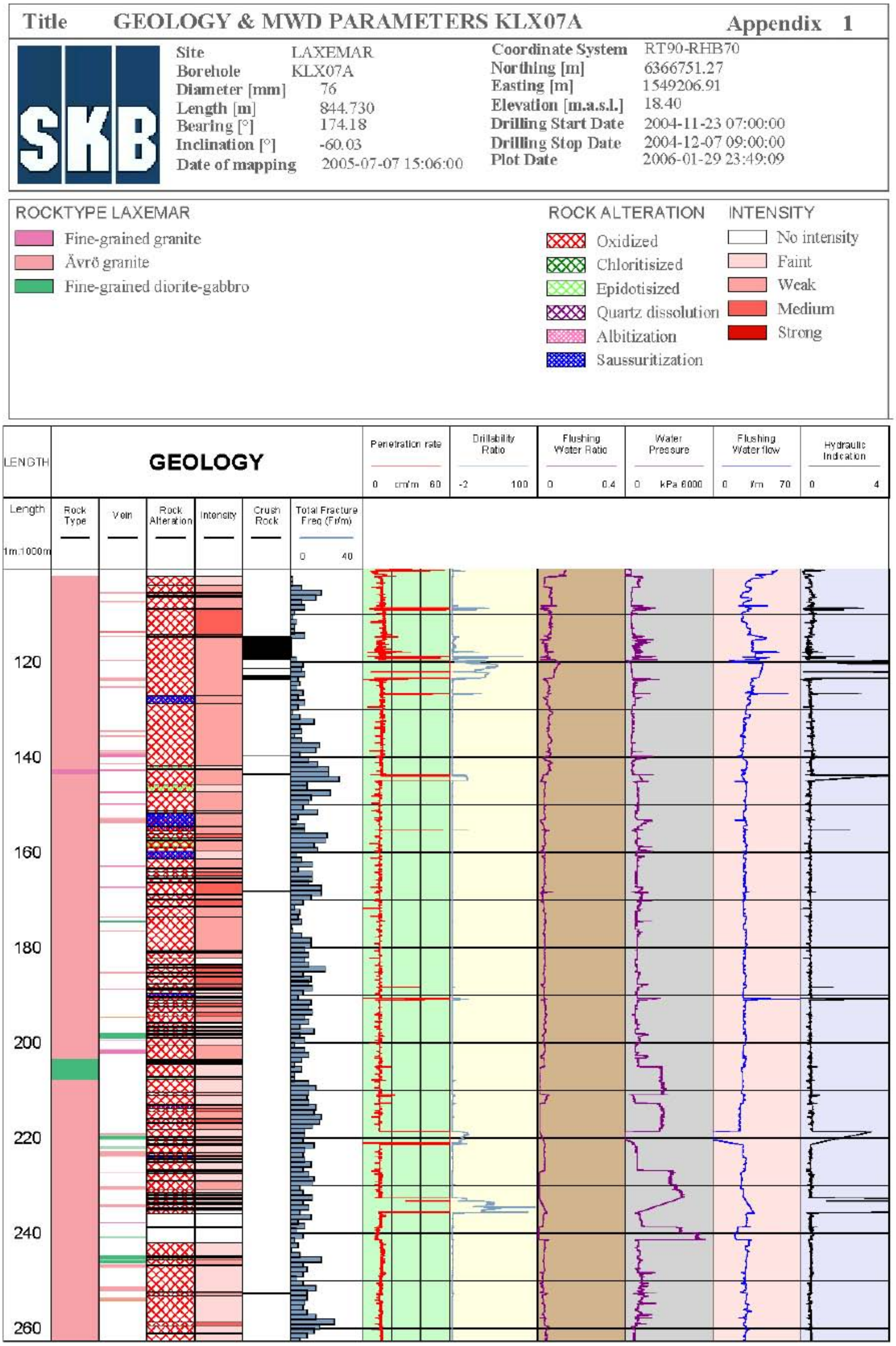
/5/ **Ask, Morosini, Samuelsson, Ekström, Håkanson, 2004.** Core drilling of KSH03, SKB P-04-233, Svensk Kärnbränslehantering AB.

/6/ **Andersson, Wästberg, 2006.** Tracer test during drilling of boreholes KLX07A and KLX07B, SKB P-05-107 (in prep), Svensk Kärnbränslehantering AB.

/7/ **Ask, Morosini, Samuelsson, Ekström, Håkanson, 2005.** Drilling of cored borehole KLX05, SKB P-05-233, Svensk Kärnbränslehantering AB.

# Appendix 1

## Geology and MWD parameters KLX07A and KLX07B



Title GEOLOGY & MWD PARAMETERS KLX07A Appendix 1

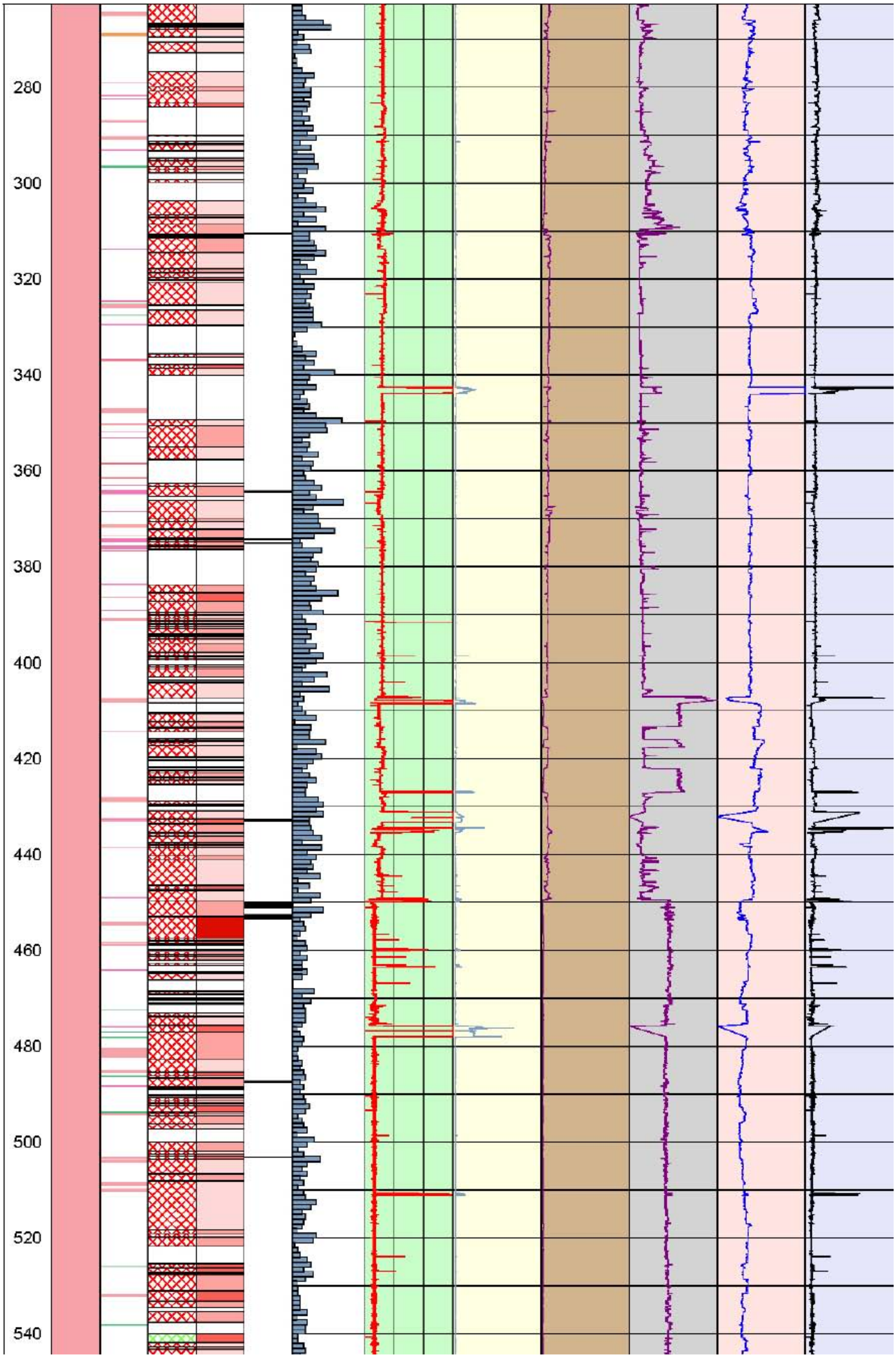
Site LAXEMAR
Borehole KLX07A
Diameter [mm] 76
Length [m] 844.730
Bearing [°] 174.18
Inclination [°] -60.03
Date of mapping 2005-07-07 15:06:00

Coordinate System RT90-RHB70
Northing [m] 6366751.27
Easting [m] 1549206.91
Elevation [m.a.s.l.] 18.40
Drilling Start Date 2004-11-23 07:00:00
Drilling Stop Date 2004-12-07 09:00:00
Plot Date 2006-01-29 23:49:09

ROCKTYPE LAXEMAR
- Fine-grained granite
- Ävrö granite
- Fine-grained diorite-gabbro

ROCK ALTERATION
- Oxidized
- Chloritisized
- Epidotisized
- Quartz dissolution
- Albitization
- Saussuritization

INTENSITY
- No intensity
- Faint
- Weak
- Medium
- Strong


280
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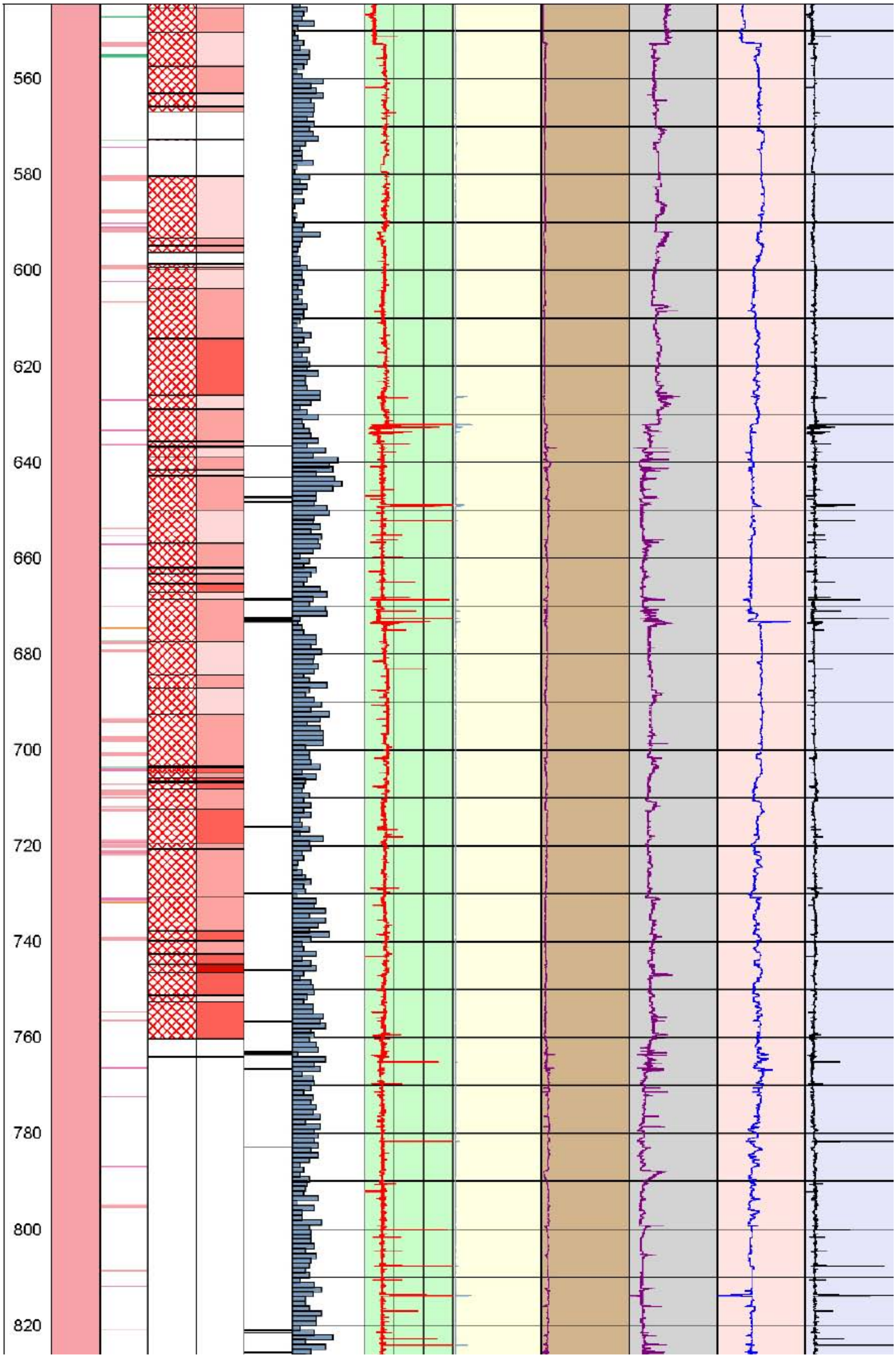
520
540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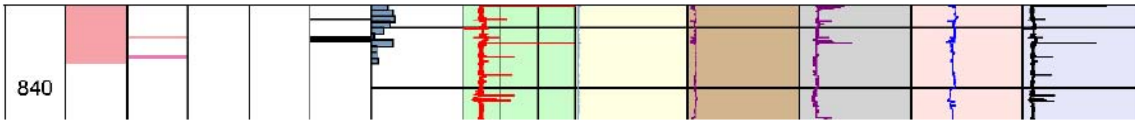
620
640
660
680
700
720
740
760
780
800
820


840

# Appendix 2

## Chemical results

| Borehole | KLX07A | KLX07A | KLX07A | KLX07A | KLX07A | KLX07A | KLX07A | KLX07A | KLX07A | KLX07A | KLX07A | KLX07A | KLX07B | KLX07B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date of measurement | 2005-01-14 | 2005-01-17 | 2005-01-29 | 2005-01-31 | 2005-02-15 | 2005-03-21 | 2005-04-09 | 2005-04-10 | 2005-04-22 | 2005-04-28 | 2005-05-05 | 2005-05-06 | 2005-05-31 | 2005-06-04 |
| Upper section limit (m) | 146.00 | 102.00 | 250.00 | 194.80 | 293.40 | 405.00 | 629.85 | 636.85 | 611.70 | 716.60 | 797.85 | 797.85 | 9.50 | 100.00 |
| Lower section limit (m) | 155.16 | 196.65 | 266.00 | 294.00 | 407.09 | 537.63 | 635.81 | 641.09 | 716.60 | 779.20 | 844.73 | 844.73 | 108.41 | 200.13 |
| Sample_no | 10010 | 10011 | 10062 | 10063 | 10078 | 10171 | 10228 | 10229 | 10248 | 10264 | 10282 | 10283 | 10316 | 10328 |
| Groundwater Chemistry Class | 3 | 3 | 3 | 1 | 3 | 1 | 3 | 3 | 1 | 1 | 1 | 3 | 1 | 3 |
| pH | 7.89 | 7.68 | 7.94 |  | 7.89 |  | 7.95 | 7.67 |  |  |  | 8.07 |  | 8.26 |
| Conductivity mS/m | 52.3 | 44.6 | 96.4 |  | 81.6 |  | 339.0 | 281.0 |  |  |  | 138.0 |  | 50.9 |
| TOC mg/l |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Drill water % | 1.51 | 11.80 | 8.78 | 41.10 | 8.42 | 50.90 | 25.80 | 42.50 | 58.40 | 69.50 | 62.20 | 55.90 | 79.00 | 37.50 |
| Densitet g/cm$^3$ | 0.9966 | 0.9967 | 0.9970 |  | 0.9967 |  | 0.9979 | 0.9976 |  |  |  | 0.9967 |  | 0.9962 |
| Charge balance % | –0.36 | 5.77 | 0.81 |  | –2.55 |  | 4.96 |  |  |  |  |  |  | –1.51 |
| Na mg/l | 85.2 | 68.5 | 177.0 |  | 150.0 |  | 599.0 |  |  |  |  |  |  | 90.2 |
| K mg/l | 3.63 | 6.85 | 8.89 |  | 4.77 |  | 5.61 |  |  |  |  |  |  | 4.30 |
| Ca mg/l | 18.1 | 29.2 | 20.4 |  | 19.7 |  | 177.0 |  |  |  |  |  |  | 13.1 |
| Mg mg/l | 4.6 | 8.8 | 7.3 |  | 4.9 |  | 15.3 |  |  |  |  |  |  | 3.8 |
| $HCO_3$ mg/l Alkalinity | 222 | 216 | 244 |  | 234 |  | 143 | 144 |  |  |  | 193 |  | 218 |
| Cl mg/l | 25.0 | 22.7 | 92.4 |  | 100.0 |  | 954.0 | 763.0 |  |  |  | 287.0 |  | 20.3 |
| $SO_4$ mg/l | 33.8 | 21.6 | 119.0 |  | 76.4 |  | 138.0 | 116.0 |  |  |  |  |  | 37.1 |
| $SO_4$-S mg/l Total Sulphur | 10.00 | 7.93 | 40.90 |  | 25.60 |  | 54.70 |  |  |  |  |  |  | 12.90 |
| Br mg/l | 0.212 | <0.2 | <0.2 |  | 0.595 |  |  |  |  |  |  |  |  | <0.2 |
| F mg/l | 3.05 | 2.25 | 4.90 |  | 3.95 |  | 3.00 | 3.85 |  |  |  |  |  | 3.99 |
| Si mg/l | 8.84 | 27.30 | 25.50 |  | 8.76 |  | 7.14 |  |  |  |  |  |  | 9.05 |
| Fe mg/l Total Iron | 8.01 | 57.50 | 38.80 |  | 9.00 |  | 8.67 |  |  |  |  |  |  | 4.05 |

| **Borehole** | **KLX07A** | **KLX07A** | **KLX07A** | **KLX07A** | **KLX07A** | **KLX07A** | **KLX07A** | **KLX07A** | **KLX07A** | **KLX07A** | **KLX07A** | **KLX07A** | **KLX07B** | **KLX07B** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mn mg/l | 0.34 | 1.01 | 0.55 |  | 0.37 |  | 0.49 |  |  |  |  |  |  | 0.12 |
| Li mg/l | 0.013 | 0.021 | 0.022 |  | 0.017 |  | 0.081 |  |  |  |  |  |  | 0.014 |
| Sr mg/l | 0.180 | 0.259 | 0.282 |  | 0.207 |  | 2.890 |  |  |  |  |  |  | 0.156 |
| PMC % Modern Carbon | 56.85 |  | 55.59 |  |  |  | 54.84 |  |  |  |  |  |  |  |
| C-13 dev PDB | –17.17 |  | –11.72 |  |  |  | –16.62 |  |  |  |  |  |  |  |
| AGE_BP Groundwater age | 4,482 |  | 4,662 |  |  |  | 4,771 |  |  |  |  |  |  |  |
| AGE_BP_CORR | 35 |  | 40 |  |  |  | 30 |  |  |  |  |  |  |  |
| D dev SMOW | –76.3 |  | –79.1 |  |  |  | –80.0 |  |  |  |  |  |  |  |
| Tr TU | 5.0 |  | 3.9 |  |  |  | 3.6 |  |  |  |  |  |  |  |
| O-18 dev SMOW | –10.9 |  | –10.9 |  |  |  | –11.0 |  |  |  |  |  |  |  |
| B-10 B-10/B-11 | 0.2398 |  | 0.2394 |  |  |  | 0.2357 |  |  |  |  |  |  |  |
| S-34 dev SMOW | 20.0 |  | 22.4 |  |  |  | 20.3 |  |  |  |  |  |  |  |
| Cl-37 dev SMOC | 0.11 |  | 0.06 |  |  |  | –0.03 |  |  |  |  |  |  |  |
| Sr-87 Sr-87/Sr86 | 0.71622 |  | 0.71639 |  |  |  | 0.71546 |  |  |  |  |  |  |  |

# Chemistry – analytical method and quality

### SKB Chemistry class 3

| Analysis | Sample bottle | Preparation | SKB label | Laboratory |
|---|---|---|---|---|
| pH, conduktivity, 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 | Filtering membrane filter | red | Analytica |
| C-13, PMC | 2 st 100 ml brown glass | | green | Waterloo |
| S-34 | 1,000 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 boreholes KLX07A and KLX07B. The errors do not exceed ± 5% in any of the samples except for sample 10011 that has a charge balance error of 5.77%.

The charge balance error is not calculated for the samples 10229 and 10283 collected in KLX07A.

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 of $Br^-$ were performed at Analytica on samples 10010 and 10062. The results are stored in SICADA's raw data tables.
- 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.

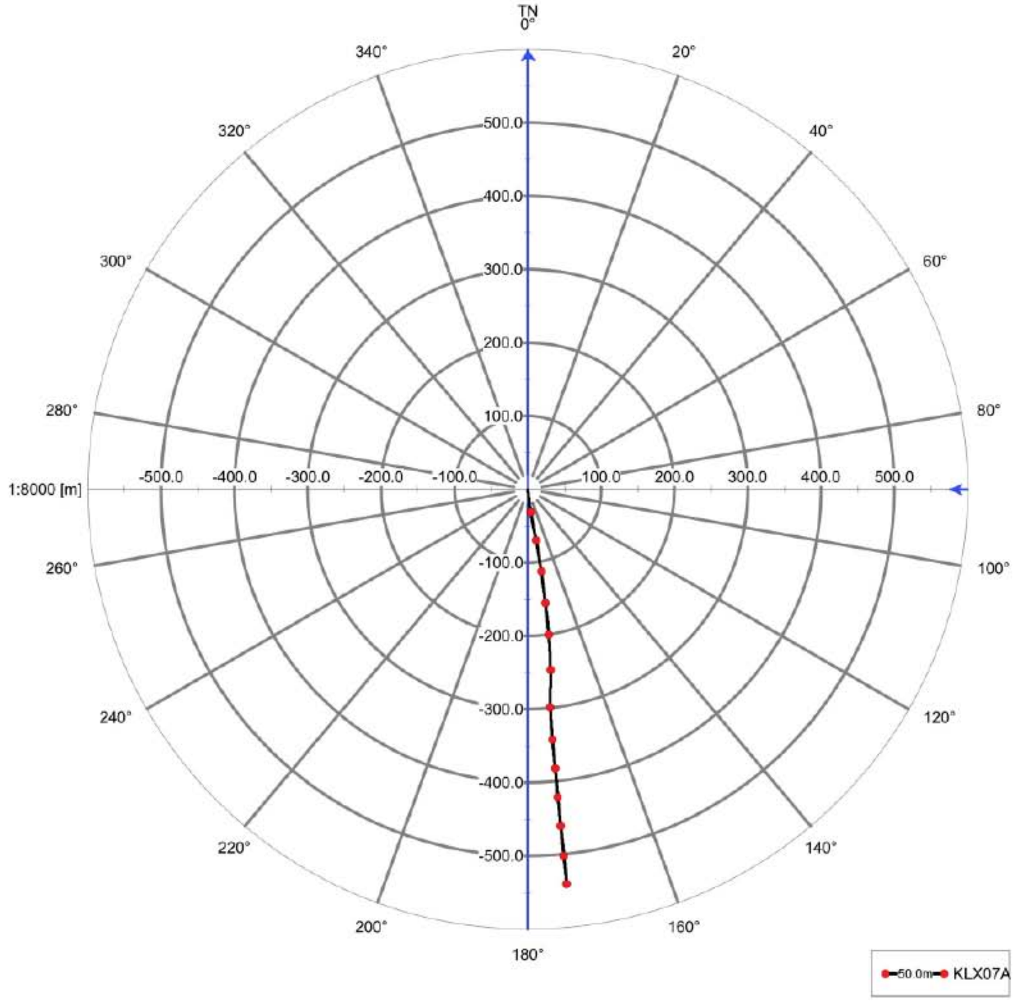
All results from “biochemical” components and special analyses of trace metals and isotopes are inserted directly into primary data tables. In those cases where the analyses are repeated or performed by more than one laboratory, a “best choice” notation will indicate those results which are considered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

# Appendix 4

## Deviation measurements

Deviation measurement — Appendix: 4

| | |
|---|---|
| Site | LAXEMAR |
| Borehole | KLX07A |
| View from above | |



Vertical section / Orthogonal projection

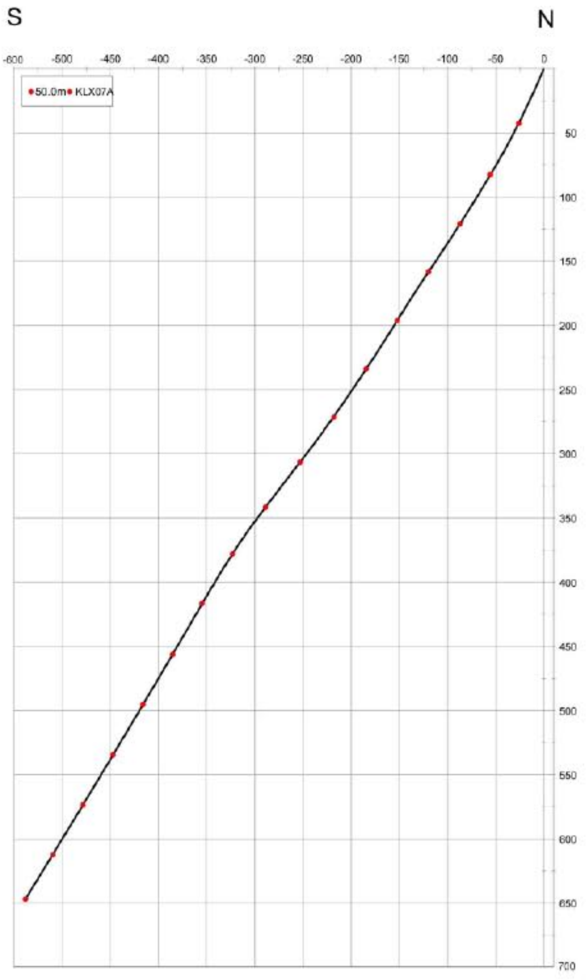
Appendix 4

| | |
|---|---|
| Borehole | **KLX07A** |
| Site | **Laxemar** |
| Coordinate system | **RT90-RHB70** |
| Length | **844.730** |
| Bearing | **174.18** |
| Inclination | **-60.03** |

● Interval

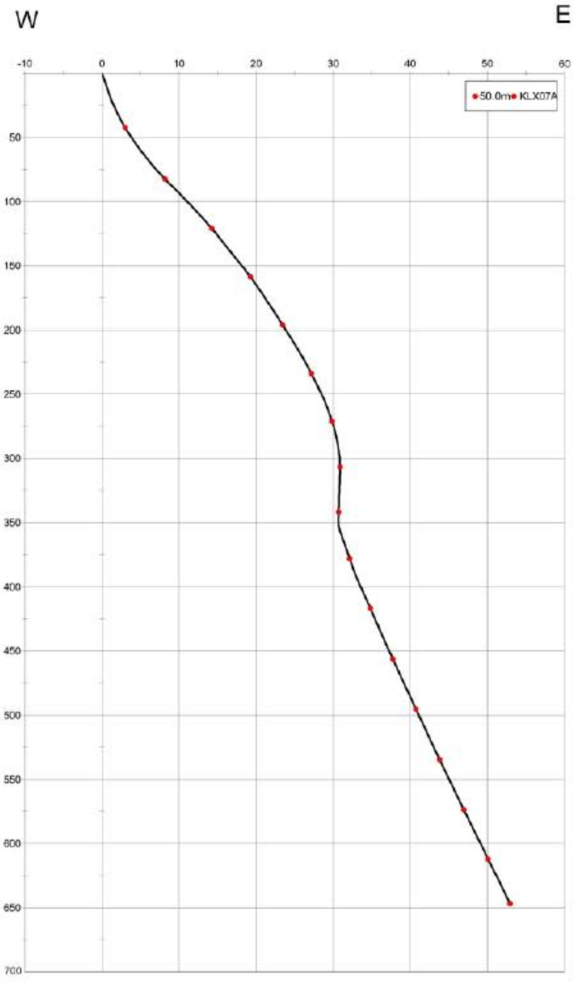
NORTHING

6366752.09



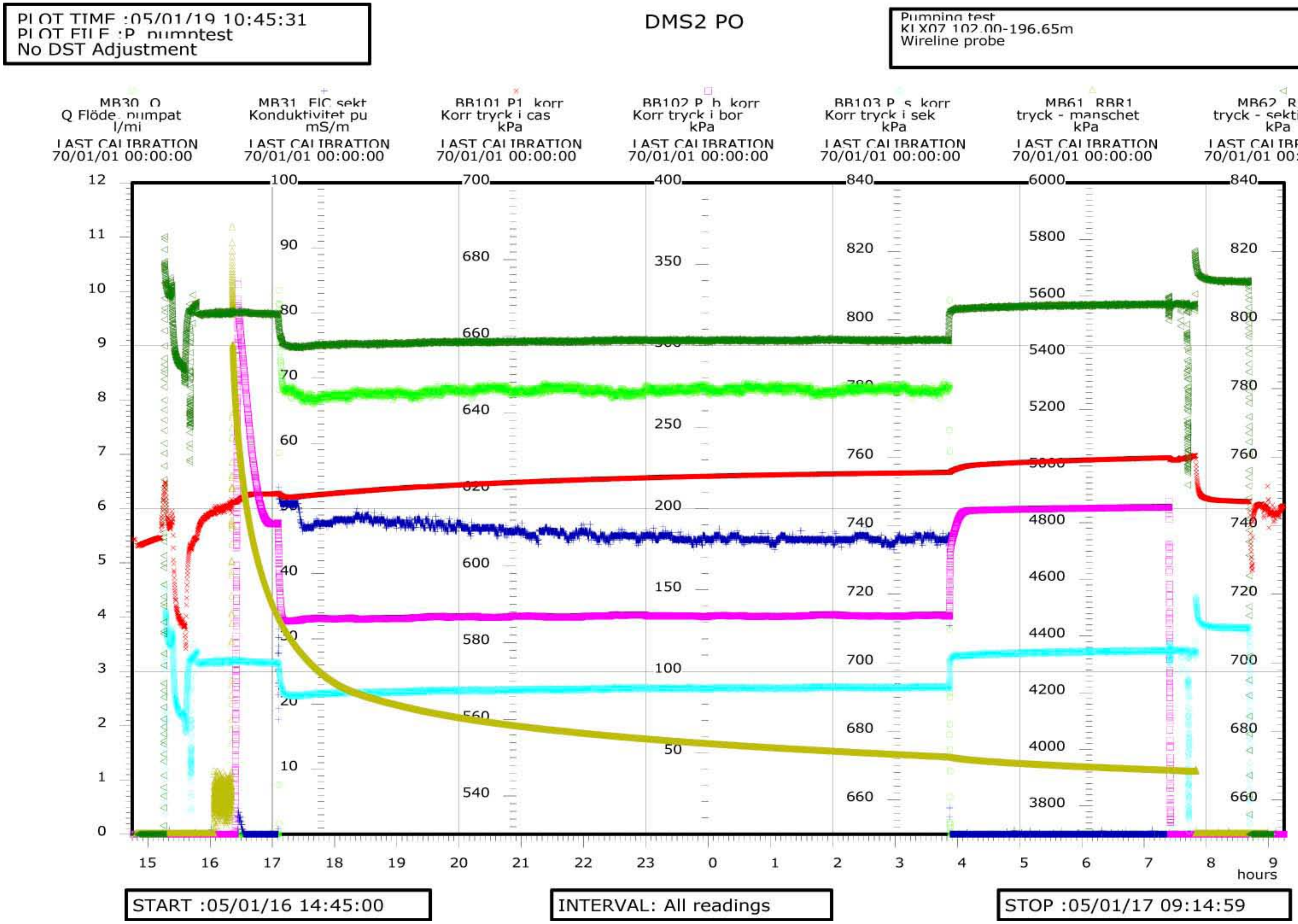
EASTING

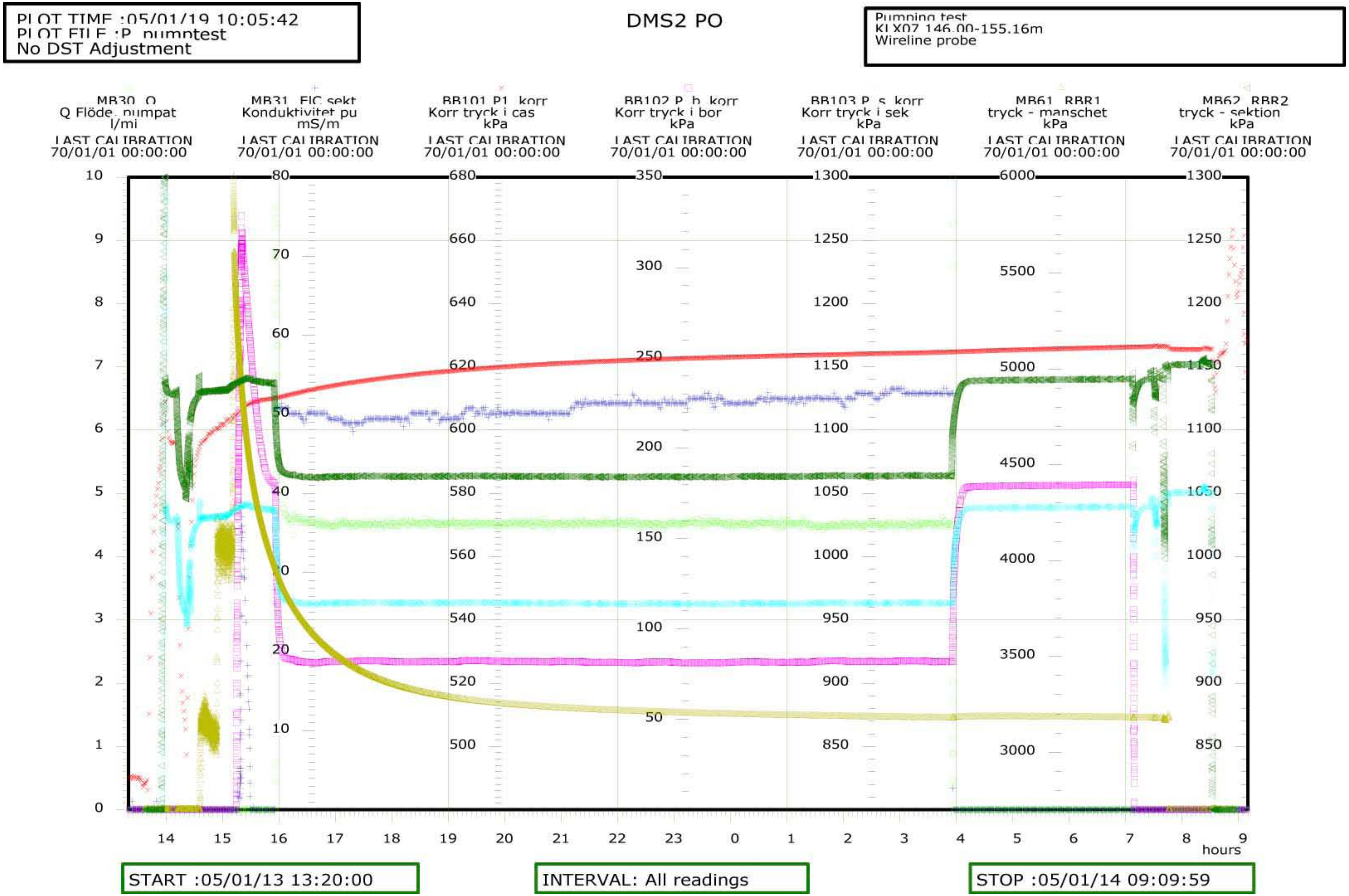
1549206.86

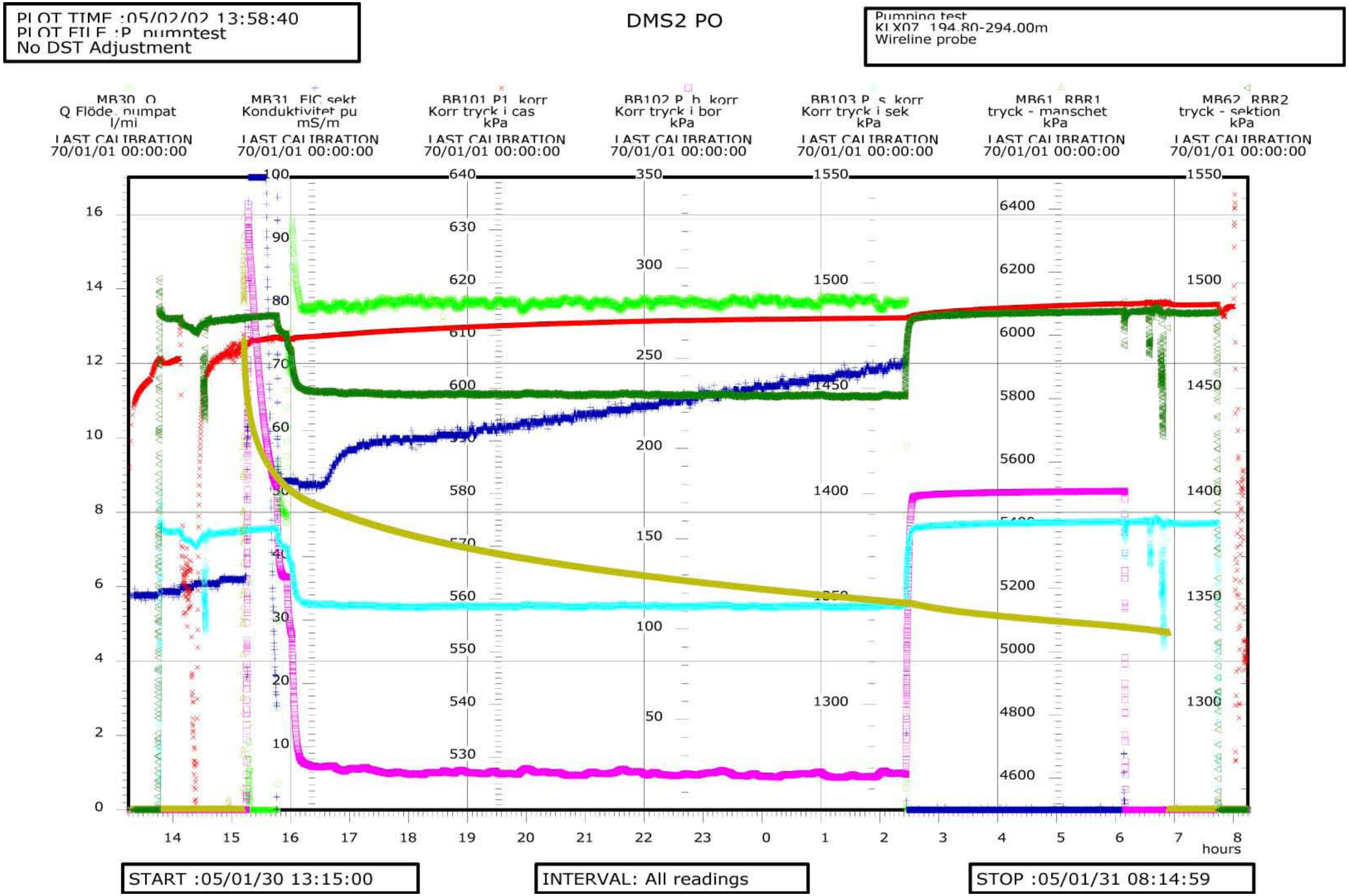


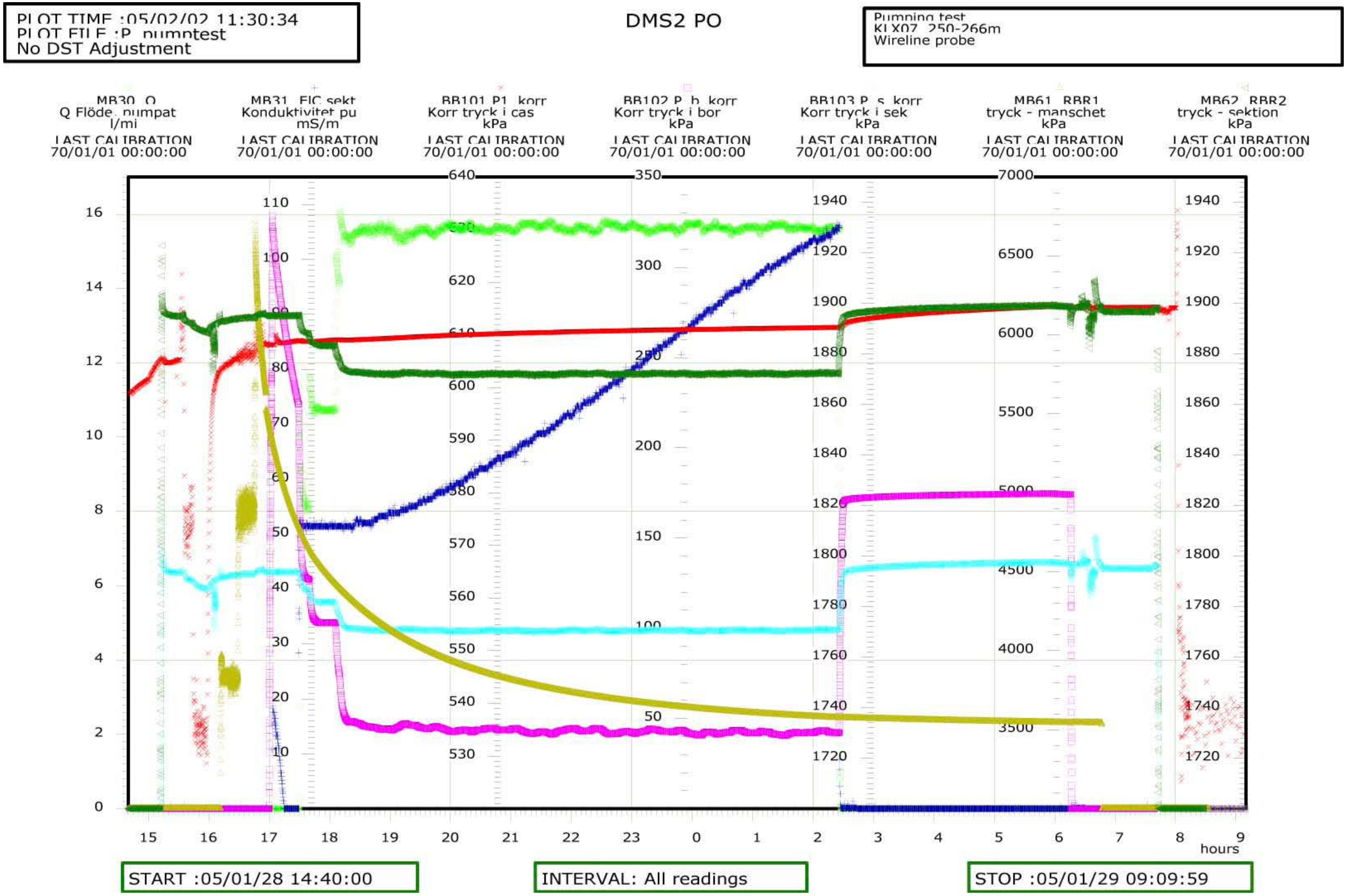
## Appendix 5

# Wireline pumping tests in KLX07A




PLOT TIME :05/01/19 10:05:42
PLOT FILE :P_pumptest
No DST Adjustment
DMS2 PO
Pumping test
KLX07 146.00-155.16m
Wireline probe
MB30 Q
Q Flöde, pumpat
l/mi
LAST CALIBRATION
70/01/01 00:00:00
MB31 EC sekt
Konduktivitet pu
mS/m
LAST CALIBRATION
70/01/01 00:00:00
BB101 P1 korr
Korr tryck i cas
kPa
LAST CALIBRATION
70/01/01 00:00:00
BB102 P_b korr
Korr tryck i bor
kPa
LAST CALIBRATION
70/01/01 00:00:00
BB103 P_s korr
Korr tryck i sek
kPa
LAST CALIBRATION
70/01/01 00:00:00
MB61 RBR1
tryck - manschet
kPa
LAST CALIBRATION
70/01/01 00:00:00
MB62 RBR2
tryck - sektion
kPa
LAST CALIBRATION
70/01/01 00:00:00
10
9
8
7
6
5
4
3
2
1
0
80
70
60
50
40
30
20
10
680
660
640
620
600
580
560
540
520
500
350
300
250
200
150
100
50
1300
1250
1200
1150
1100
1050
1000
950
900
850
6000
5500
5000
4500
4000
3500
3000
1300
1250
1200
1150
1100
1050
1000
950
900
850
14
15
16
17
18
19
20
21
22
23
0
1
2
3
4
5
6
7
8
9
hours
START :05/01/13 13:20:00
INTERVAL: All readings
STOP :05/01/14 09:09:59

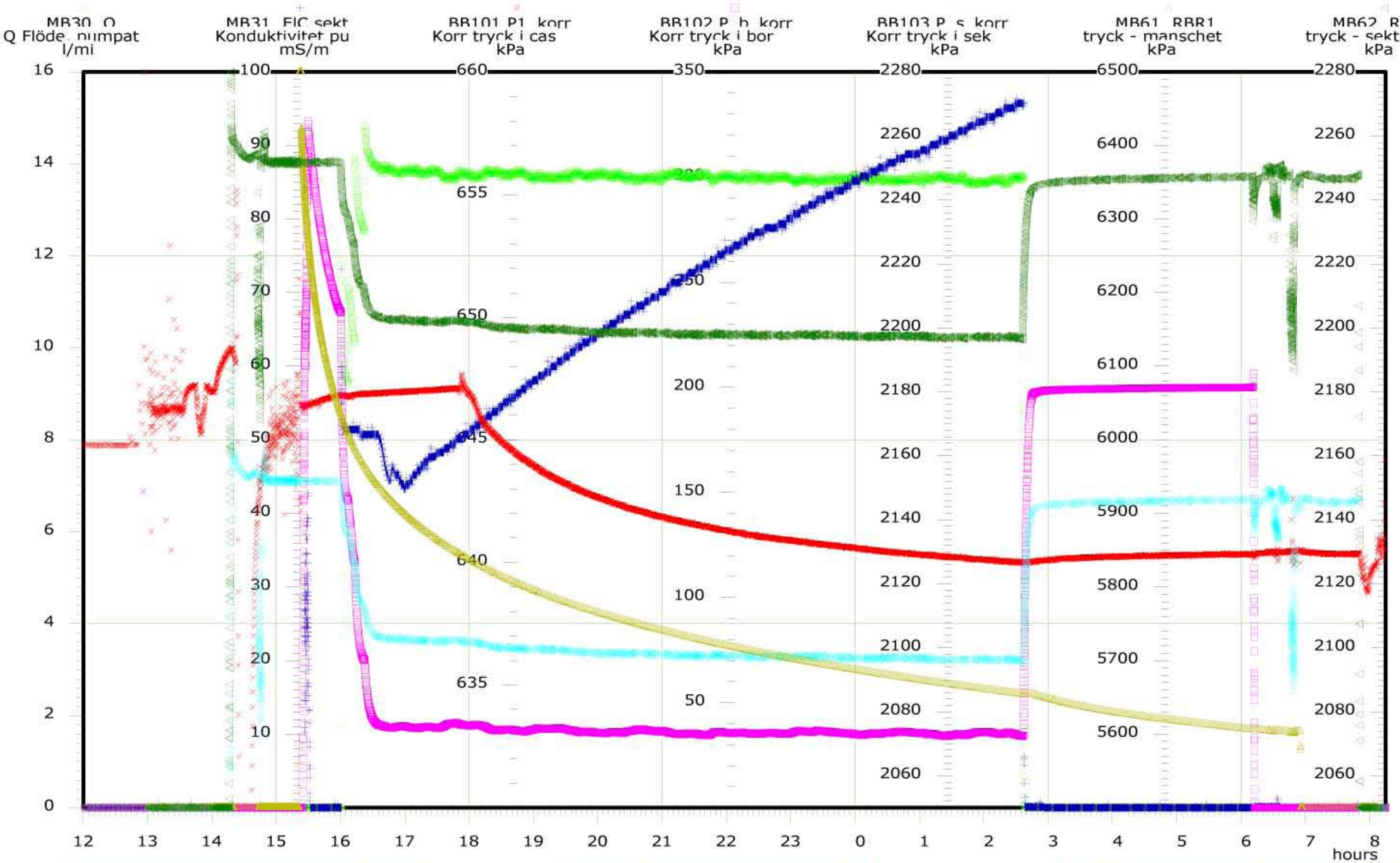

PLOT TIME :05/02/02 13:58:40
PLOT FILE :P_pumptest
No DST Adjustment
DMS2 PO
Pumping test
KLX07 194.80-294.00m
Wireline probe
MB30_Q
Q Flöde, pumpat
l/mi
LAST CALIBRATION
70/01/01 00:00:00
MB31_EC sekt
Konduktivitet pu
mS/m
LAST CALIBRATION
70/01/01 00:00:00
BB101 P1_korr
Korr tryck i cas
kPa
LAST CALIBRATION
70/01/01 00:00:00
BB102 P_b_korr
Korr tryck i bor
kPa
LAST CALIBRATION
70/01/01 00:00:00
BB103 P_s_korr
Korr tryck i sek
kPa
LAST CALIBRATION
70/01/01 00:00:00
MB61_RBR1
tryck - manschet
kPa
LAST CALIBRATION
70/01/01 00:00:00
MB62_RBR2
tryck - sektion
kPa
LAST CALIBRATION
70/01/01 00:00:00
0
2
4
6
8
10
12
14
16
100
90
80
70
60
50
40
30
20
10
640
630
620
610
600
590
580
570
560
550
540
530
350
300
250
200
150
100
50
1550
1500
1450
1400
1350
1300
6400
6200
6000
5800
5600
5400
5200
5000
4800
4600
1550
1500
1450
1400
1350
1300
14
15
16
17
18
19
20
21
22
23
0
1
2
3
4
5
6
7
8
hours
START :05/01/30 13:15:00
INTERVAL: All readings
STOP :05/01/31 08:14:59


PLOT TIME :05/02/02 11:30:34
PLOT FILE :P_pumptest
No DST Adjustment
DMS2 PO
Pumping test
KLX07_250-266m
Wireline probe
MB30_Q
Q Flöde, pumpat
l/mi
LAST CALIBRATION
70/01/01 00:00:00
MB31_EC sekt
Konduktivitet pu
mS/m
LAST CALIBRATION
70/01/01 00:00:00
BB101_P1_korr
Korr tryck i cas
kPa
LAST CALIBRATION
70/01/01 00:00:00
BB102_P_b_korr
Korr tryck i bor
kPa
LAST CALIBRATION
70/01/01 00:00:00
BB103_P_s_korr
Korr tryck i sek
kPa
LAST CALIBRATION
70/01/01 00:00:00
MB61_RBR1
tryck - manschet
kPa
LAST CALIBRATION
70/01/01 00:00:00
MB62_RBR2
tryck - sektion
kPa
LAST CALIBRATION
70/01/01 00:00:00
16
14
12
10
8
6
4
2
0
110
100
90
80
70
60
50
40
30
20
10
640
630
620
610
600
590
580
570
560
550
540
530
350
300
250
200
150
100
50
1940
1920
1900
1880
1860
1840
1820
1800
1780
1760
1740
1720
7000
6500
6000
5500
5000
4500
4000
3500
1940
1920
1900
1880
1860
1840
1820
1800
1780
1760
1740
1720
15
16
17
18
19
20
21
22
23
0
1
2
3
4
5
6
7
8
9
hours
START :05/01/28 14:40:00
INTERVAL: All readings
STOP :05/01/29 09:09:59

PLOT TIME :05/03/02 12:49:11
PLOT FILE :P pumptest
No DST Adjustment

# DMS2 PO

Pumping test
KLX07 293.40-407.09m
Wireline probe



START :05/02/14 12:00:00

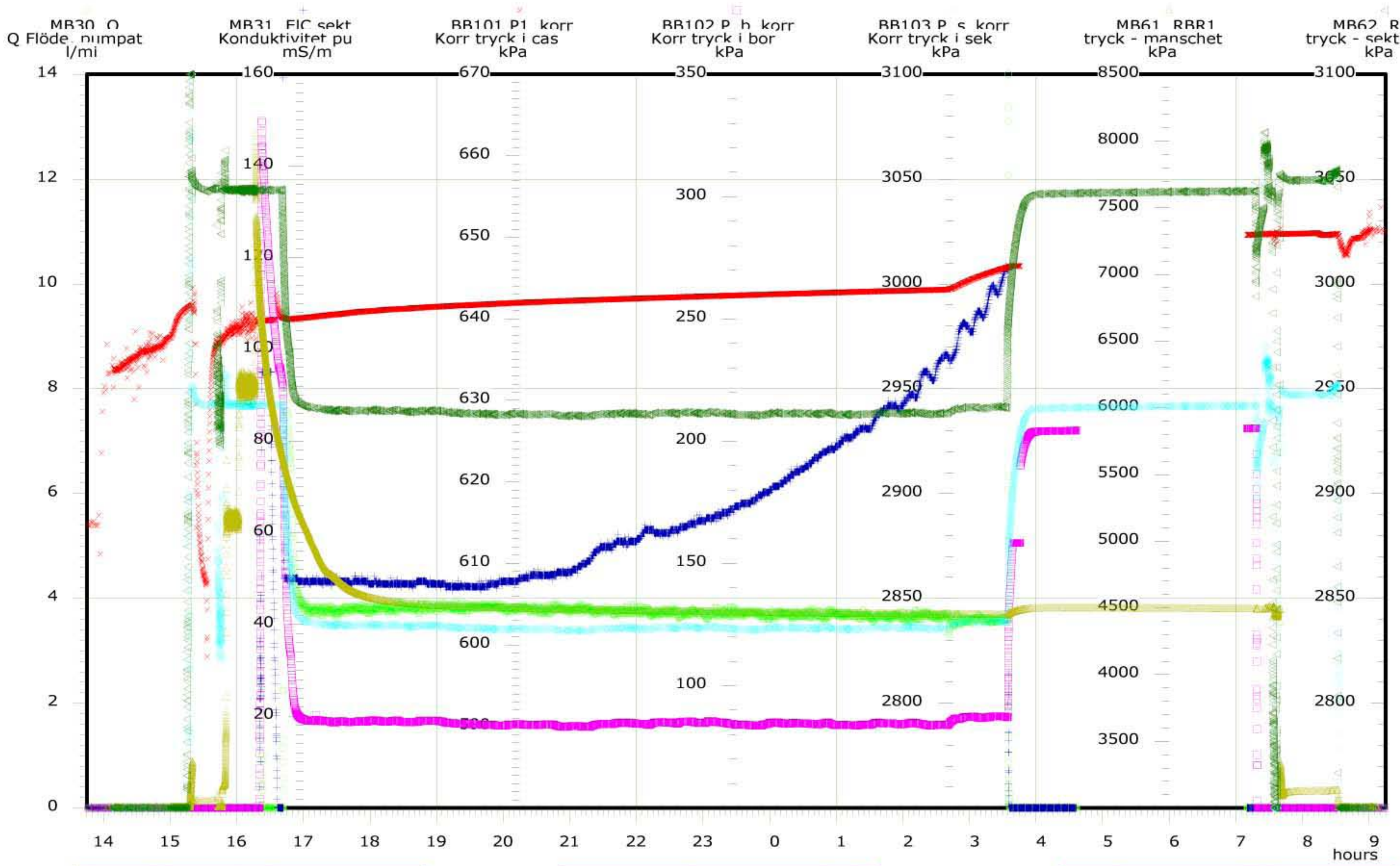
INTERVAL: All readings

STOP :05/02/15 08:14:59

PLOT TIME :05/03/30 10:15:54
PLOT FILE :P_pumptest
No DST Adjustment

# DMS2 PO

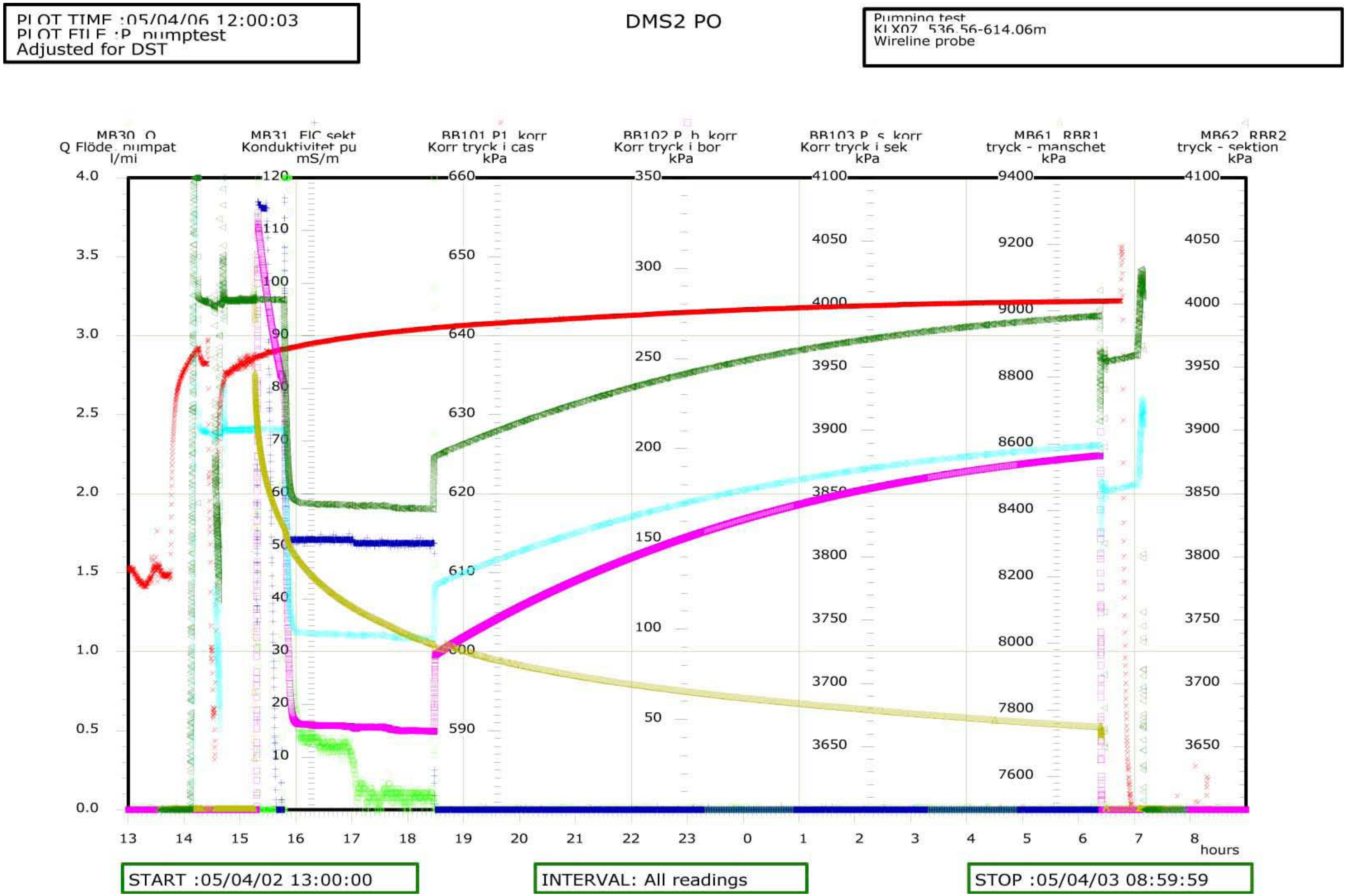
Pumping test
KLX07 405.00-537.63m
Wireline probe



START :05/03/20 13:45:00

INTERVAL: All readings

STOP :05/03/21 09:14:59



PLOT TIME :05/04/06 12:00:03
PLOT FILE :P pumptest
Adjusted for DST

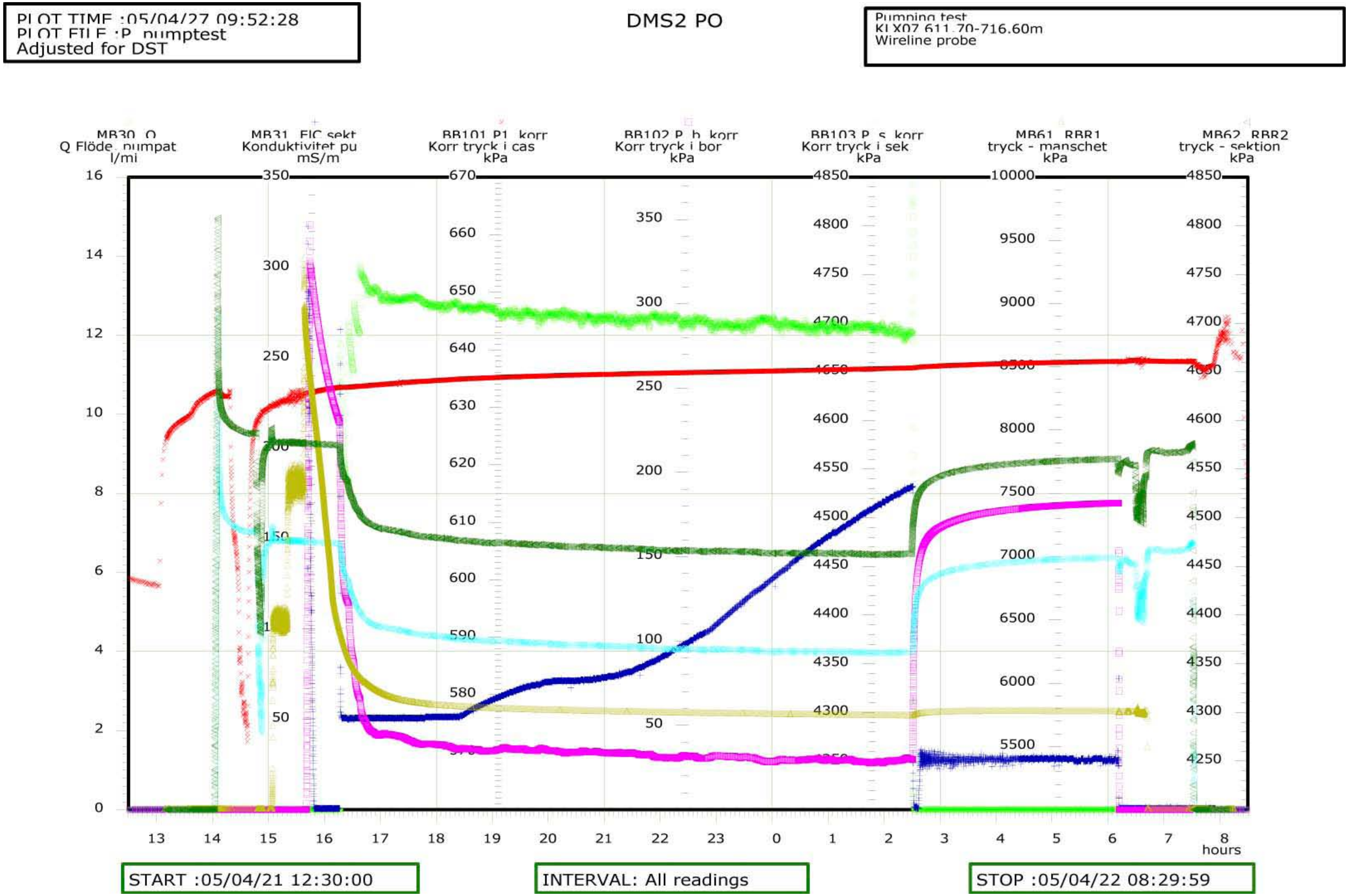
## DMS2 PO

Pumping test
KLX07 536.56-614.06m
Wireline probe

START :05/04/02 13:00:00

INTERVAL: All readings

STOP :05/04/03 08:59:59


PLOT TIME :05/04/27 09:52:28
PLOT FILE :P_pumptest
Adjusted for DST
DMS2 PO
Pumping test
KLX07 611.70-716.60m
Wireline probe
MB30_Q
Q Flöde, pumpat
l/mi
MB31_EIC sekt
Konduktivitet pu
mS/m
BB101_P1_korr
Korr tryck i cas
kPa
BB102_P_b_korr
Korr tryck i bor
kPa
BB103_P_s_korr
Korr tryck i sek
kPa
MB61_RBR1
tryck - manschet
kPa
MB62_RBR2
tryck - sektion
kPa
16
14
12
10
8
6
4
2
0
350
300
250
200
150
100
50
670
660
650
640
630
620
610
600
590
580
570
350
300
250
200
150
100
50
4850
4800
4750
4700
4650
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4500
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7000
6500
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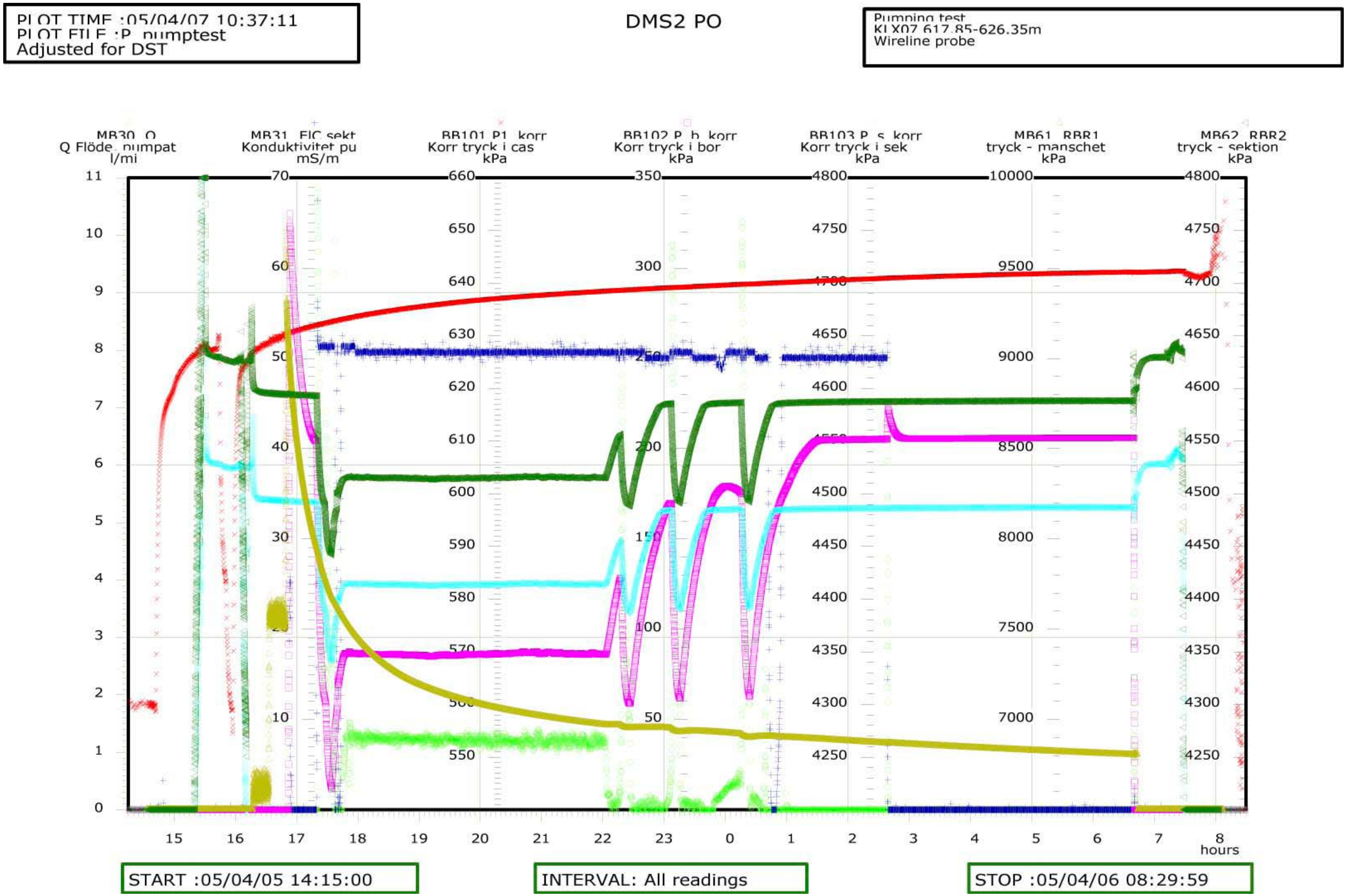
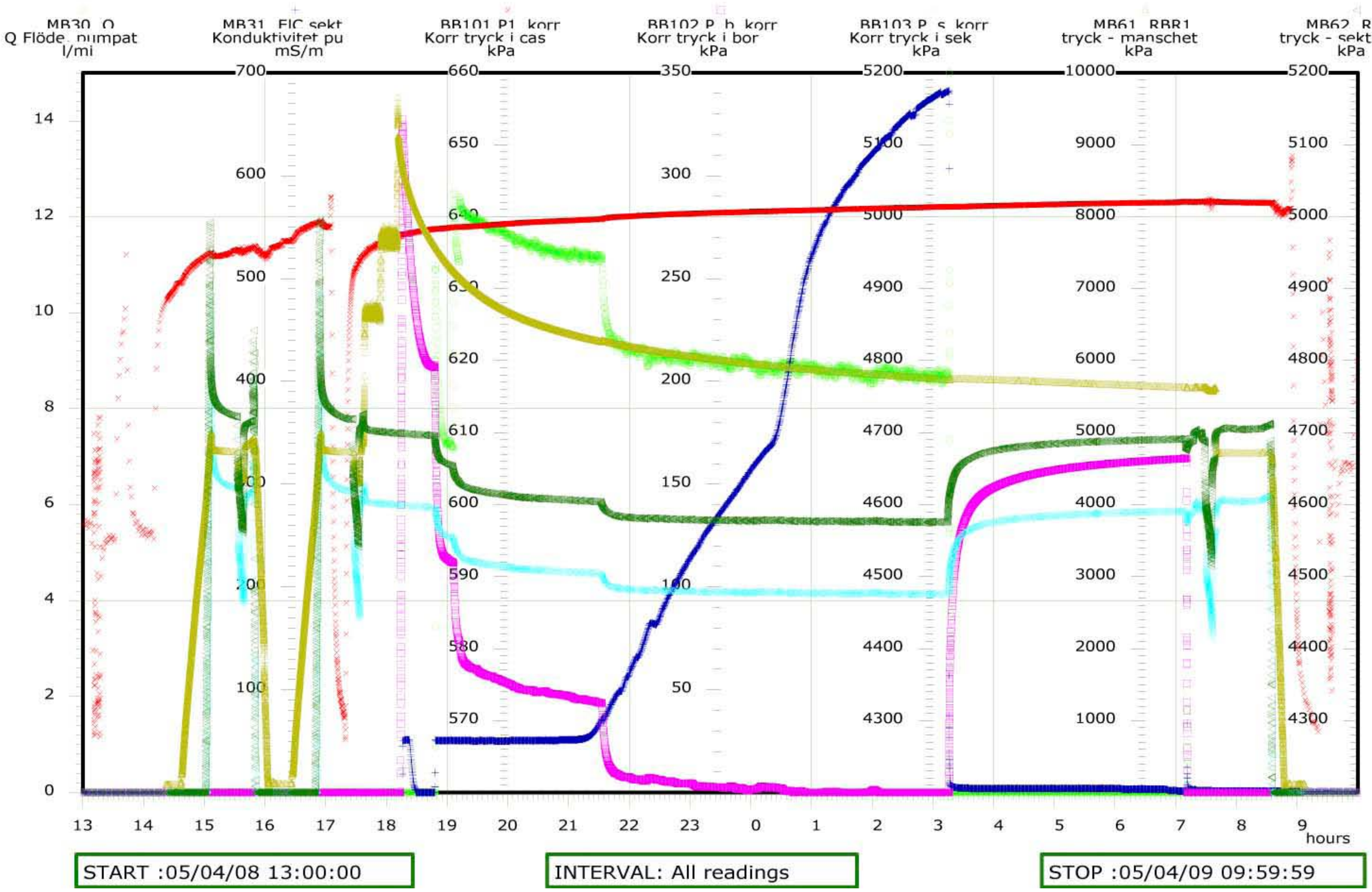
4800
4750
4700
4650
4600
4550
4500
4450
4400
4350
4300
4250
13
14
15
16
17
18
19
20
21
22
23
0
1
2
3
4
5
6
7
8
hours
START :05/04/21 12:30:00
INTERVAL: All readings
STOP :05/04/22 08:29:59


PLOT TIME :05/04/07 10:37:11
PLOT FILE :P_pumptest
Adjusted for DST
DMS2 PO
Pumping test
KLX07 617.85-626.35m
Wireline probe
MB30_Q
Q Flöde, pumpat
l/mi
MB31_EC sekt
Konduktivitet pu
mS/m
BB101_P1_korr
Korr tryck i cas
kPa
BB102_P_b_korr
Korr tryck i bor
kPa
BB103_P_s_korr
Korr tryck i sek
kPa
MB61_RBR1
tryck - manschet
kPa
MB62_RBR2
tryck - sektion
kPa
11
10
9
8
7
6
5
4
3
2
1
0
70
60
50
40
30
20
10
660
650
640
630
620
610
600
590
580
570
560
550
350
300
250
200
150
100
50
4800
4750
4700
4650
4600
4550
4500
4450
4400
4350
4300
4250
10000
9500
9000
8500
8000
7500
7000
4800
4750
4700
4650
4600
4550
4500
4450
4400
4350
4300
4250
15
16
17
18
19
20
21
22
23
0
1
2
3
4
5
6
7
8
hours
START :05/04/05 14:15:00
INTERVAL: All readings
STOP :05/04/06 08:29:59

PLOT TIME :05/04/13 14:07:24
PLOT FILE :P_pumptest
Adjusted for DST

## DMS2 PO

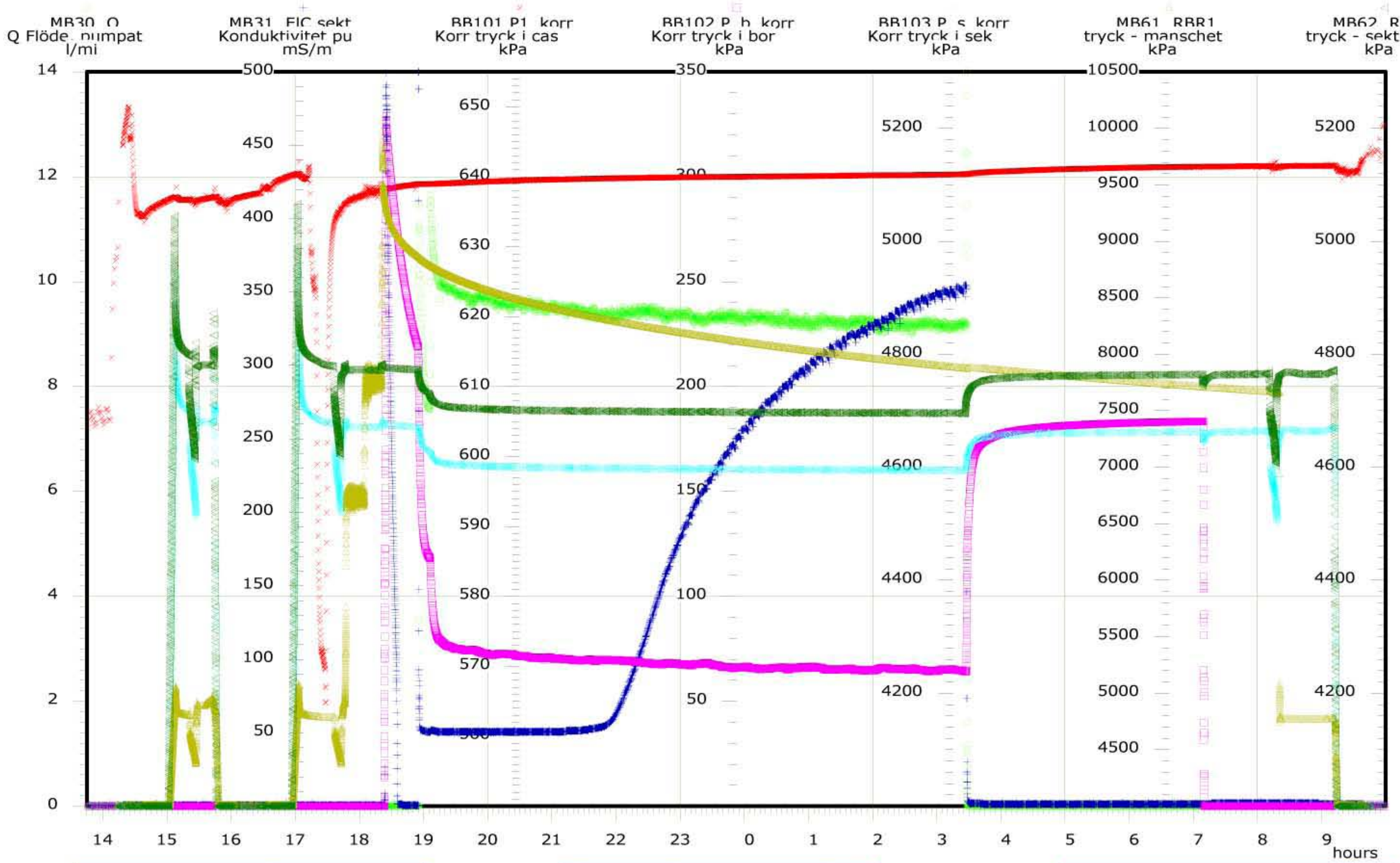
Pumping test
KLX07 629.85-635.81m
Wireline probe



PLOT TIME :05/04/14 07:43:26
PLOT FILE :P_pumptest
Adjusted for DST

# DMS2 PO

Pumping test
KLX07 636.85-641.09m
Wireline probe



START :05/04/09 13:45:00

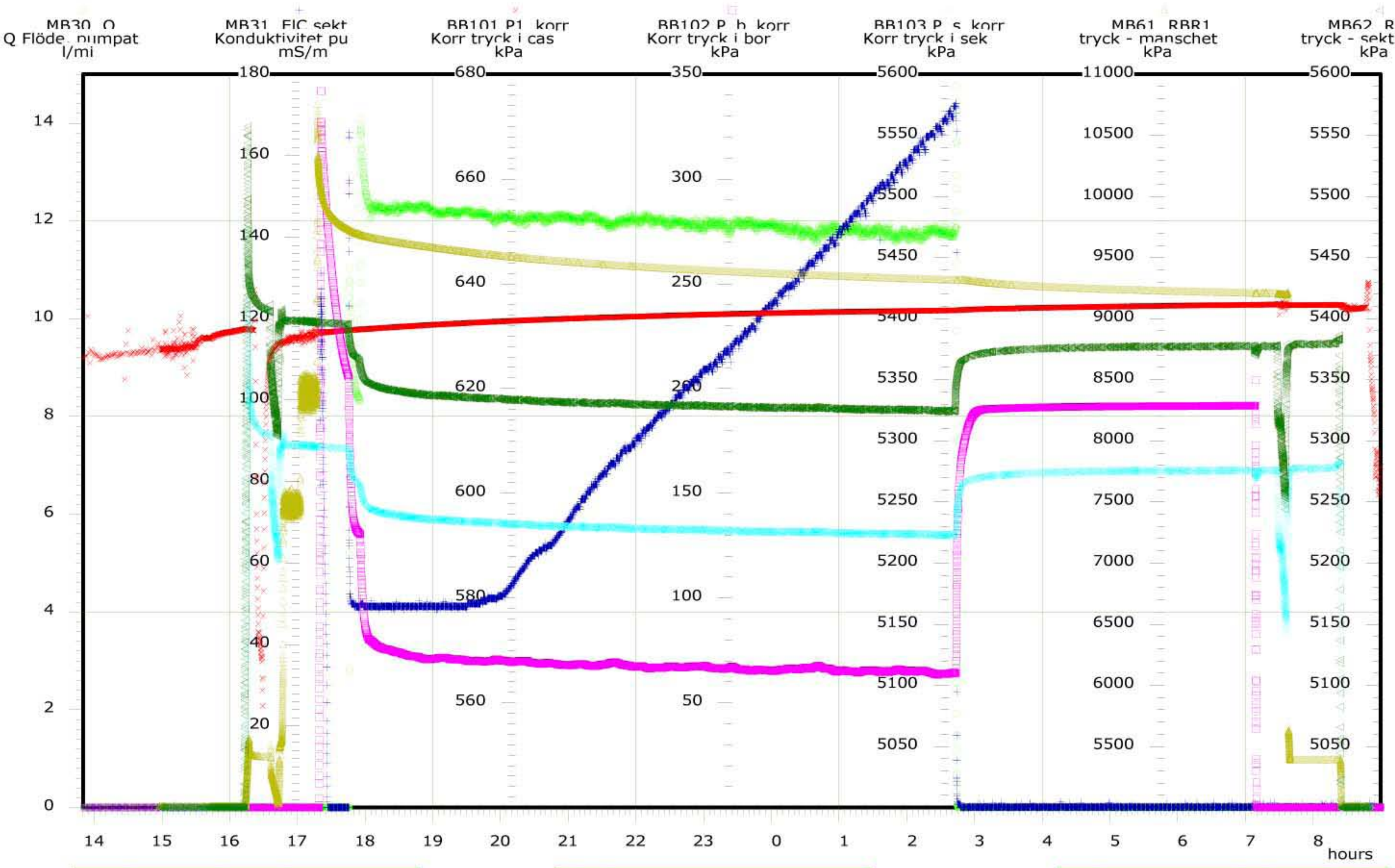
INTERVAL: All readings

STOP :05/04/10 09:59:59

PLOT TIME :05/05/02 10:38:41
PLOT FILE :P pumptest
Adjusted for DST

# DMS2 PO

Pumping test
KLX07 716.60-799.20m
Wireline probe



START :05/04/27 13:50:00

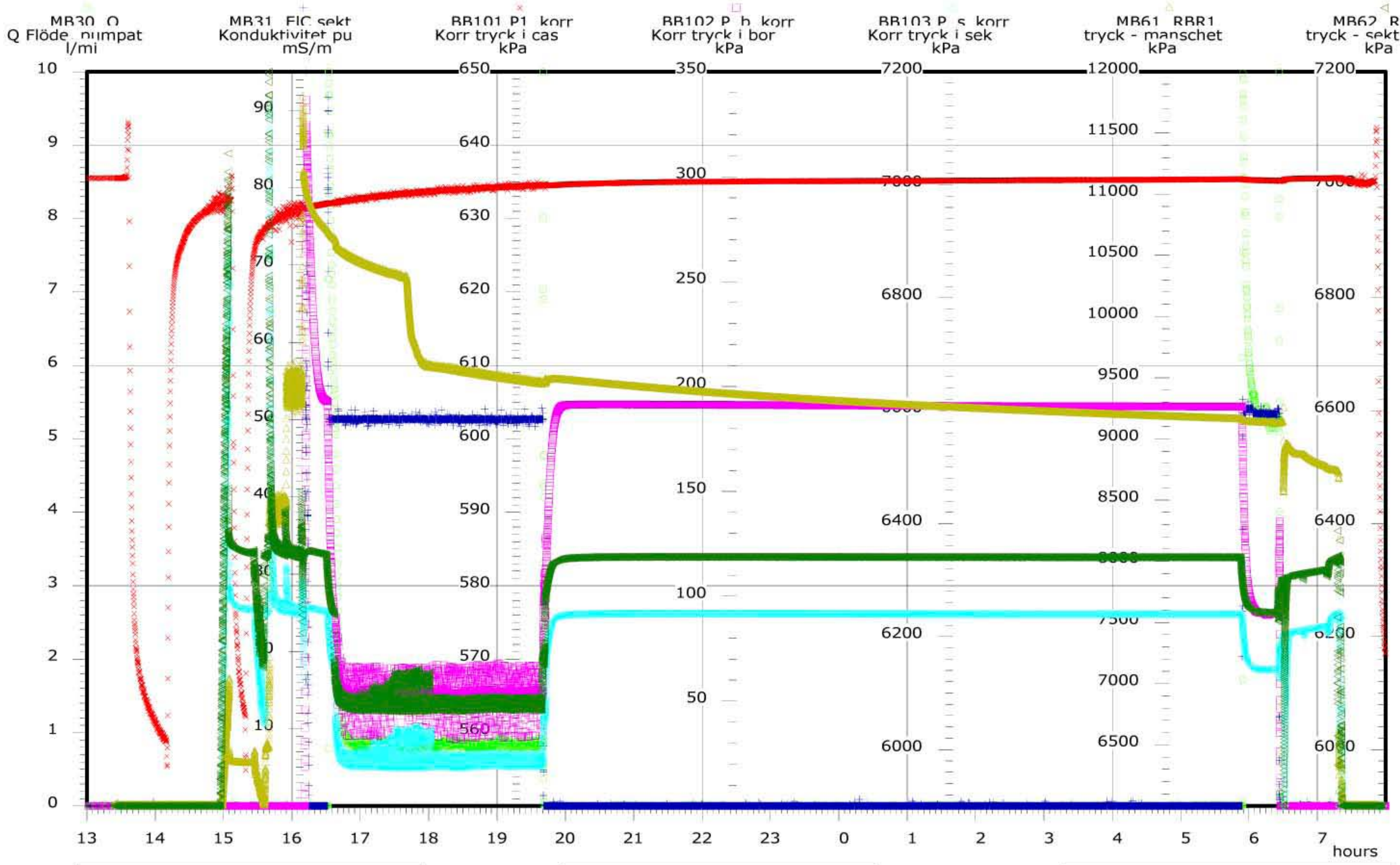
INTERVAL: All readings

STOP :05/04/28 08:59:59

PLOT TIME :05/05/10 12:25:21
PLOT FILE :P pumptest
Adjusted for DST

# DMS2 PO

Pumping test
KLX07 797.85-844.73m, 3rd test
Wireline probe



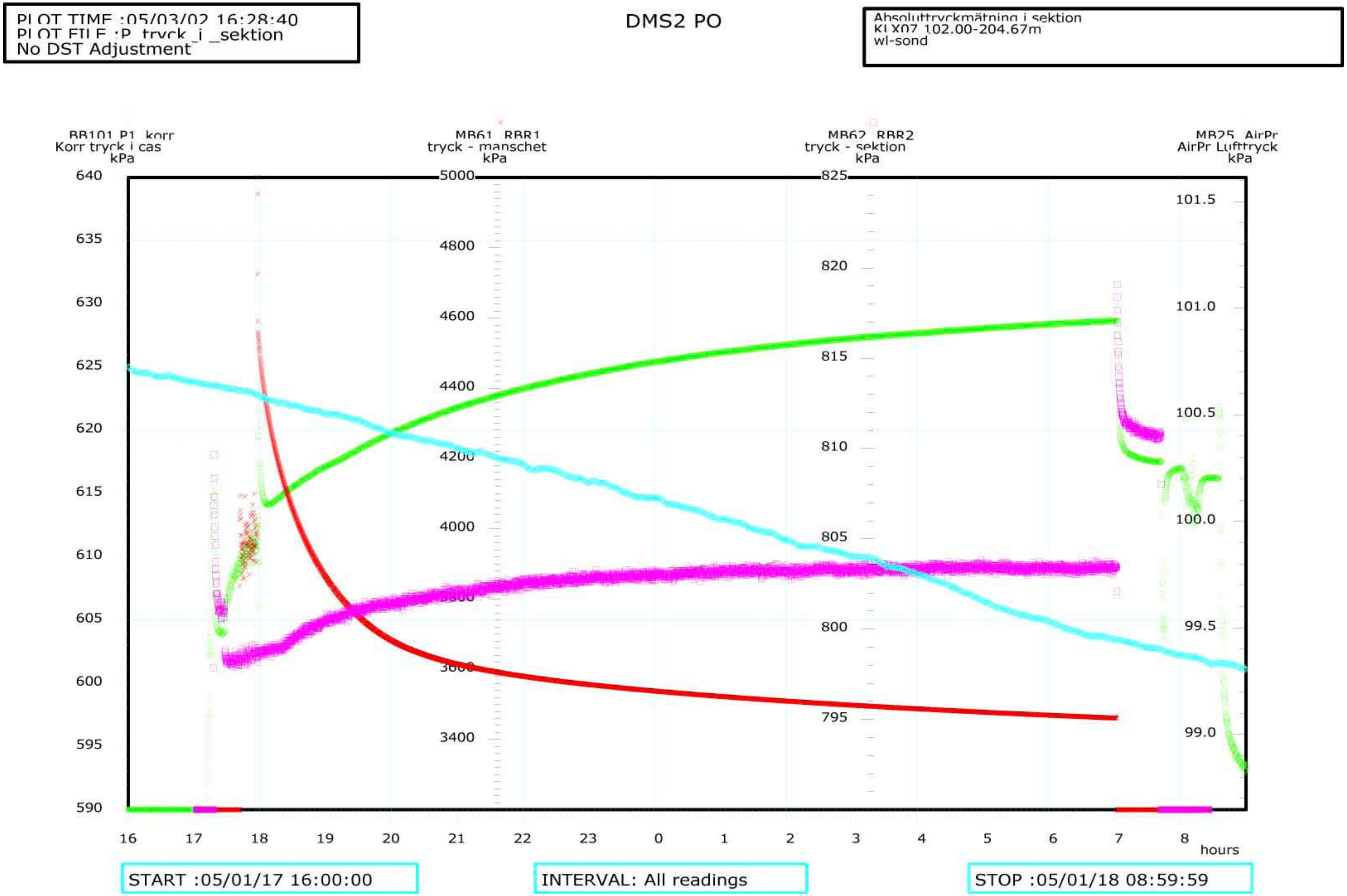
START :05/05/09 13:00:00

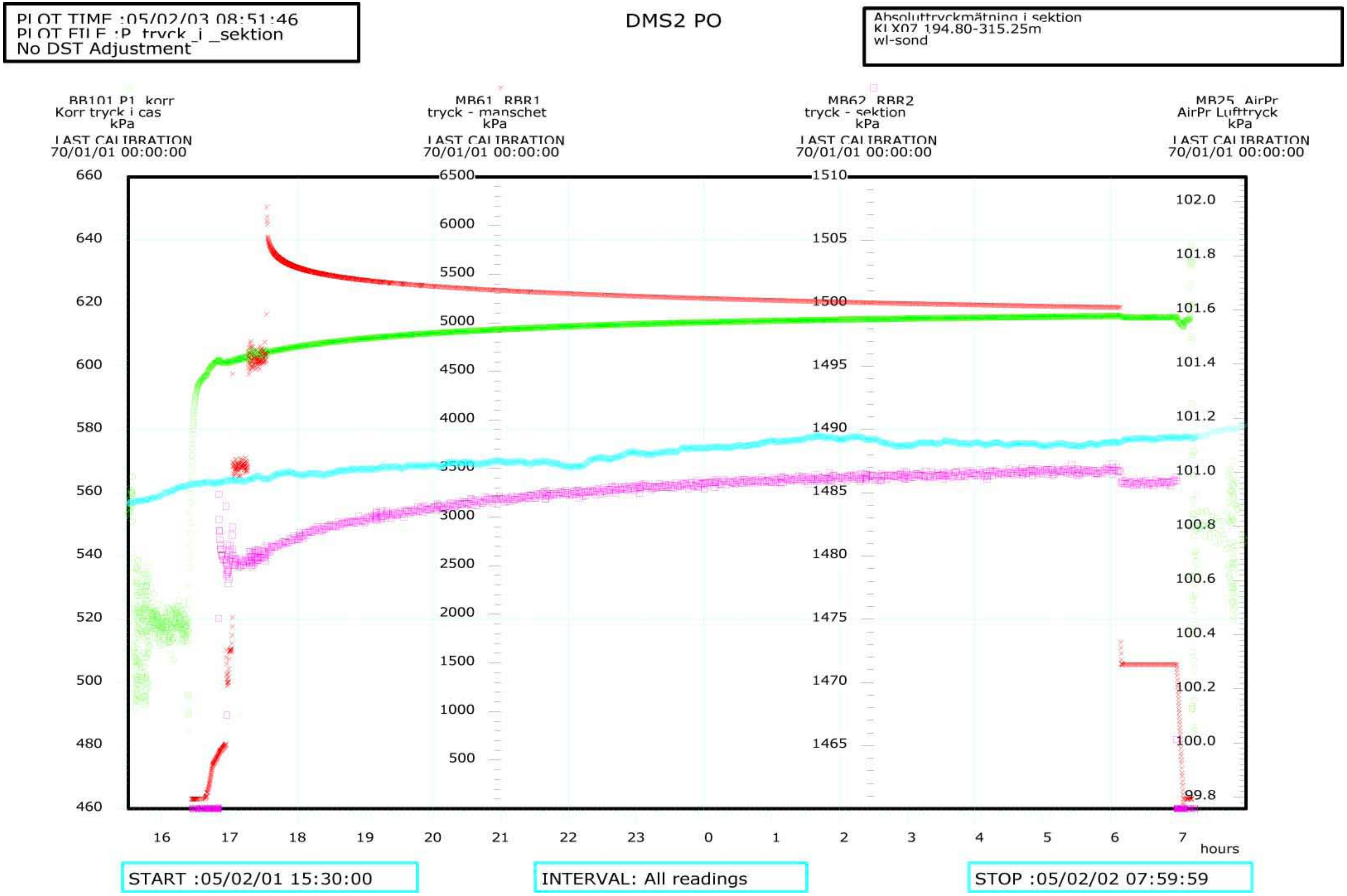
INTERVAL: All readings

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

# Appendix 6

## Time series of absolute pressure measurements

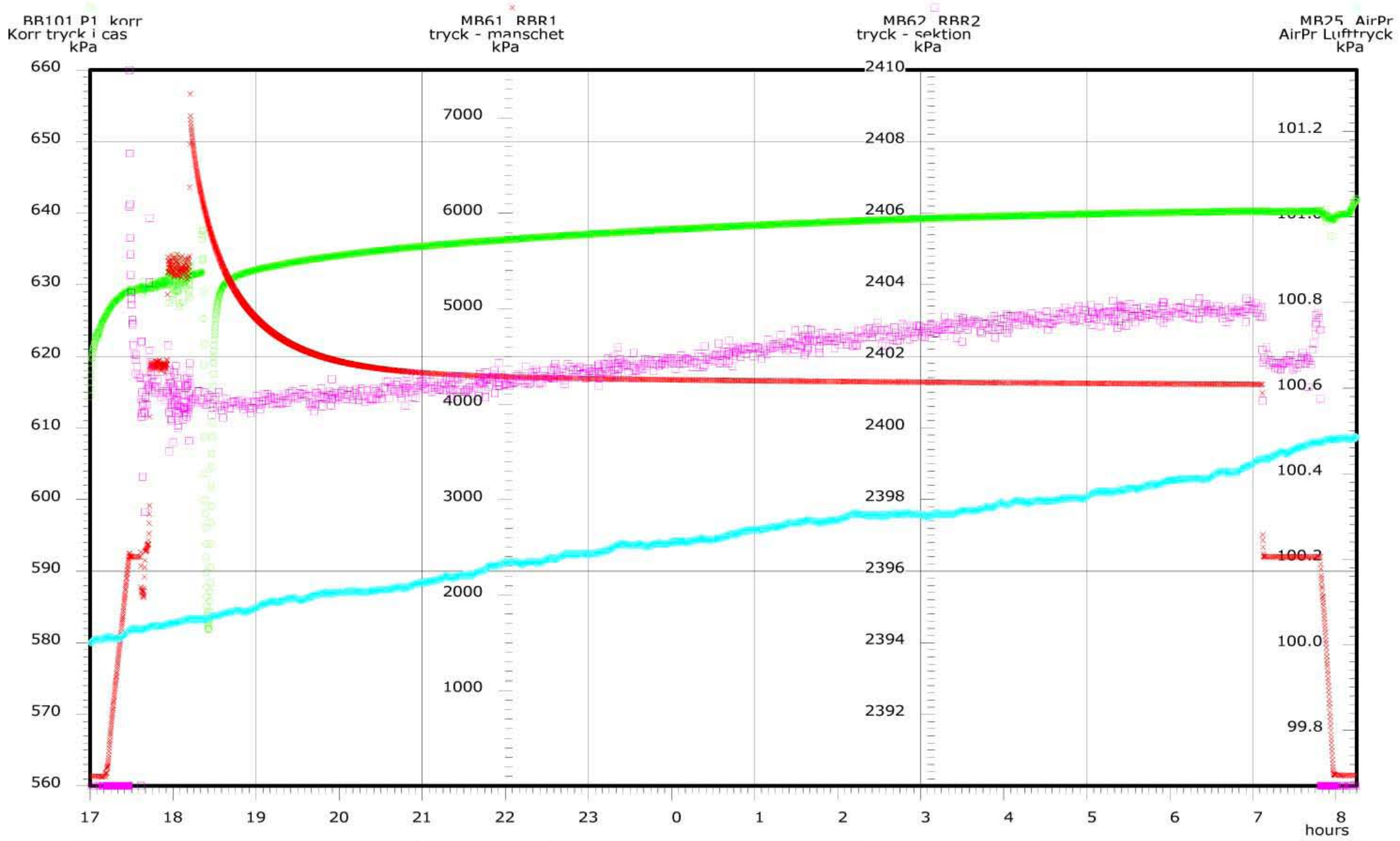



PLOT TIME :05/02/03 08:51:46
PLOT FILE :P_tryck_i_sektion
No DST Adjustment
DMS2 PO
Absoluttryckmätning i sektion
KLX07 194.80-315.25m
wl-sond
BB101_P1_korr
Korr tryck i cas
kPa
LAST CALIBRATION
70/01/01 00:00:00
MB61_RBR1
tryck - manschet
kPa
LAST CALIBRATION
70/01/01 00:00:00
MB62_RBR2
tryck - sektion
kPa
LAST CALIBRATION
70/01/01 00:00:00
MB25_AirPr
AirPr Lufttryck
kPa
LAST CALIBRATION
70/01/01 00:00:00
660
640
620
600
580
560
540
520
500
480
460
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
1510
1505
1500
1495
1490
1485
1480
1475
1470
1465
102.0
101.8
101.6
101.4
101.2
101.0
100.8
100.6
100.4
100.2
100.0
99.8
16
17
18
19
20
21
22
23
0
1
2
3
4
5
6
7
hours
START :05/02/01 15:30:00
INTERVAL: All readings
STOP :05/02/02 07:59:59

PLOT TIME :05/03/02 13:23:14
PLOT FILE :P_tryck_i _sektion
No DST Adjustment

# DMS2 PO

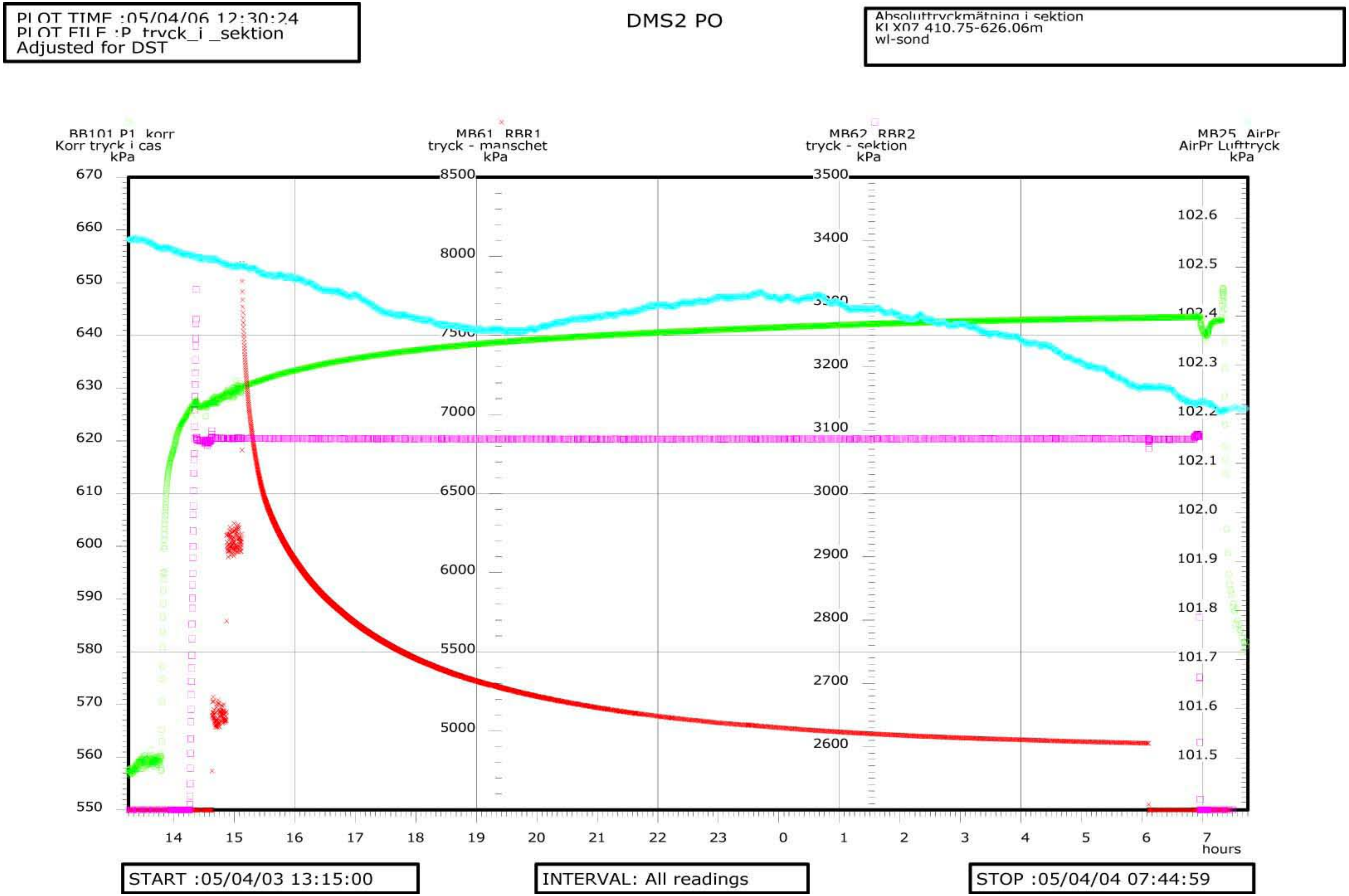
Absoluttryckmätning i sektion
KLX07 314.60-413.15m
wl-sond

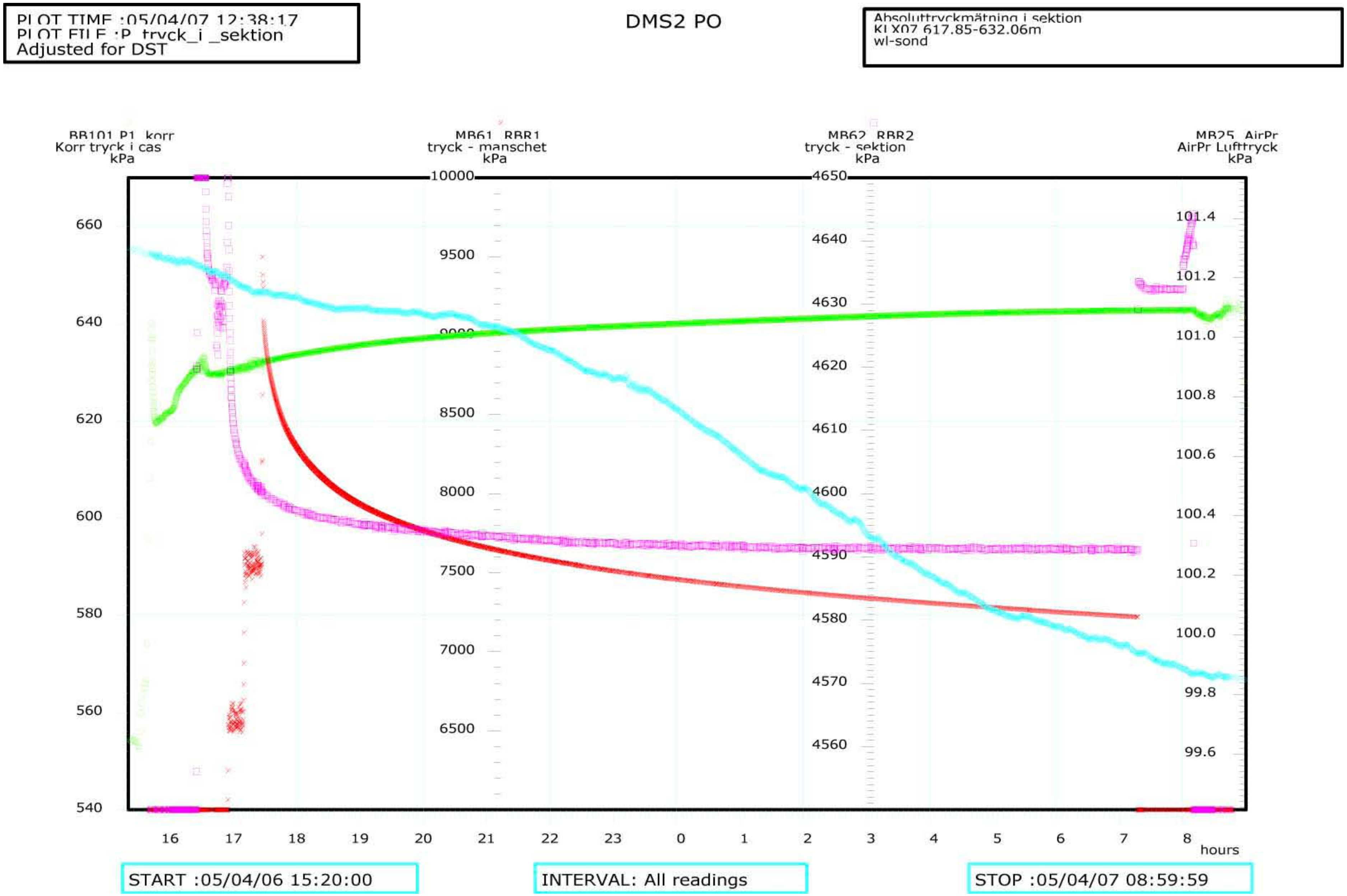


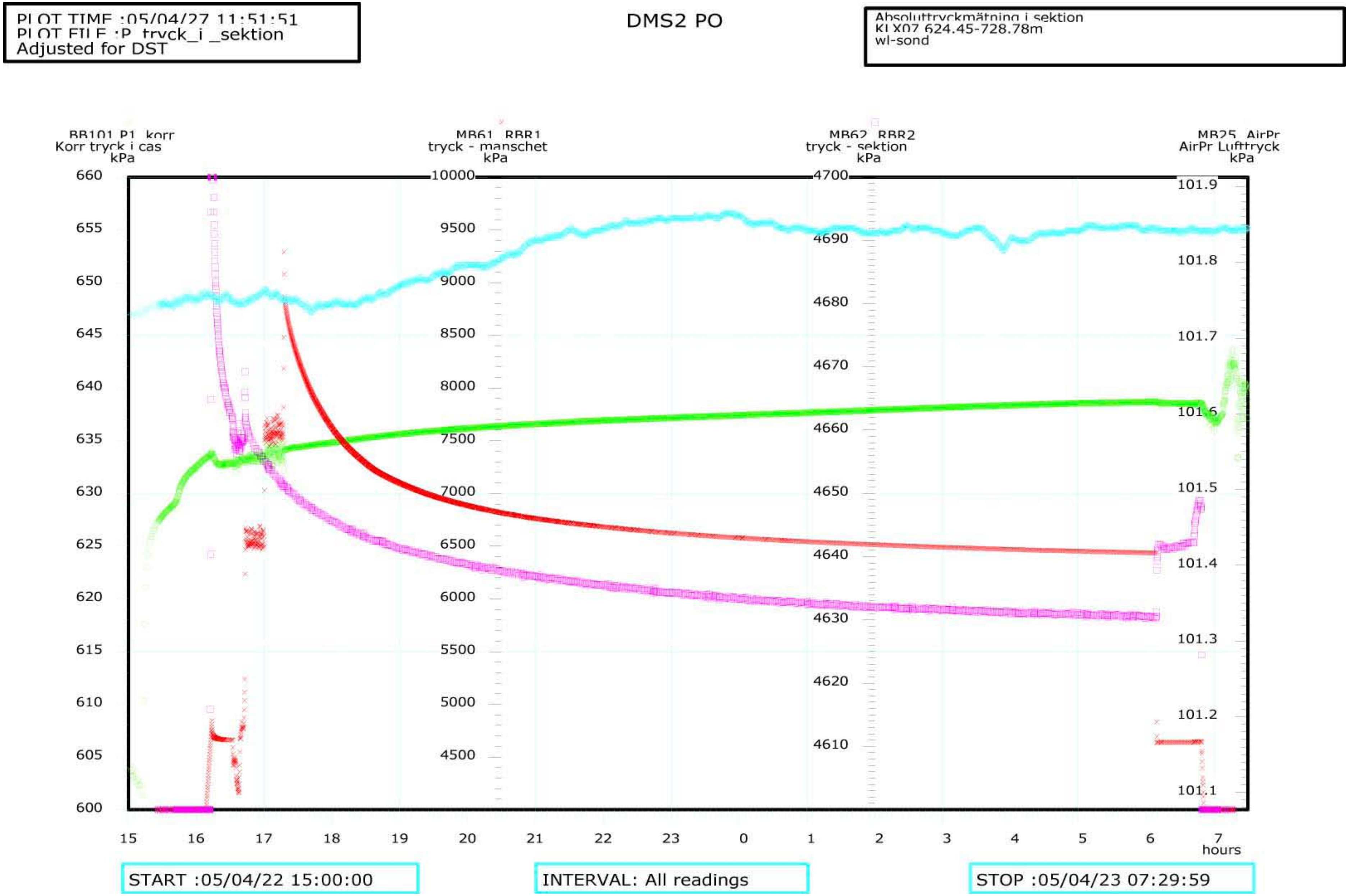
START :05/02/19 17:00:00

INTERVAL: All readings

STOP :05/02/20 08:14:59


PLOT TIME :05/04/06 12:30:24
PLOT FILE :P_tryck_i _sektion
Adjusted for DST
DMS2 PO
Absoluttryckmätning i sektion
KLX07 410.75-626.06m
wl-sond
BB101_P1_korr
Korr tryck i cas
kPa
MB61_RBR1
tryck - manschet
kPa
MB62_RBR2
tryck - sektion
kPa
MB25_AirPr
AirPr Lufttryck
kPa
670
660
650
640
630
620
610
600
590
580
570
560
550
8500
8000
7500
7000
6500
6000
5500
5000
3500
3400
3300
3200
3100
3000
2900
2800
2700
2600
102.6
102.5
102.4
102.3
102.2
102.1
102.0
101.9
101.8
101.7
101.6
101.5
14
15
16
17
18
19
20
21
22
23
0
1
2
3
4
5
6
7
hours
START :05/04/03 13:15:00
INTERVAL: All readings
STOP :05/04/04 07:44:59

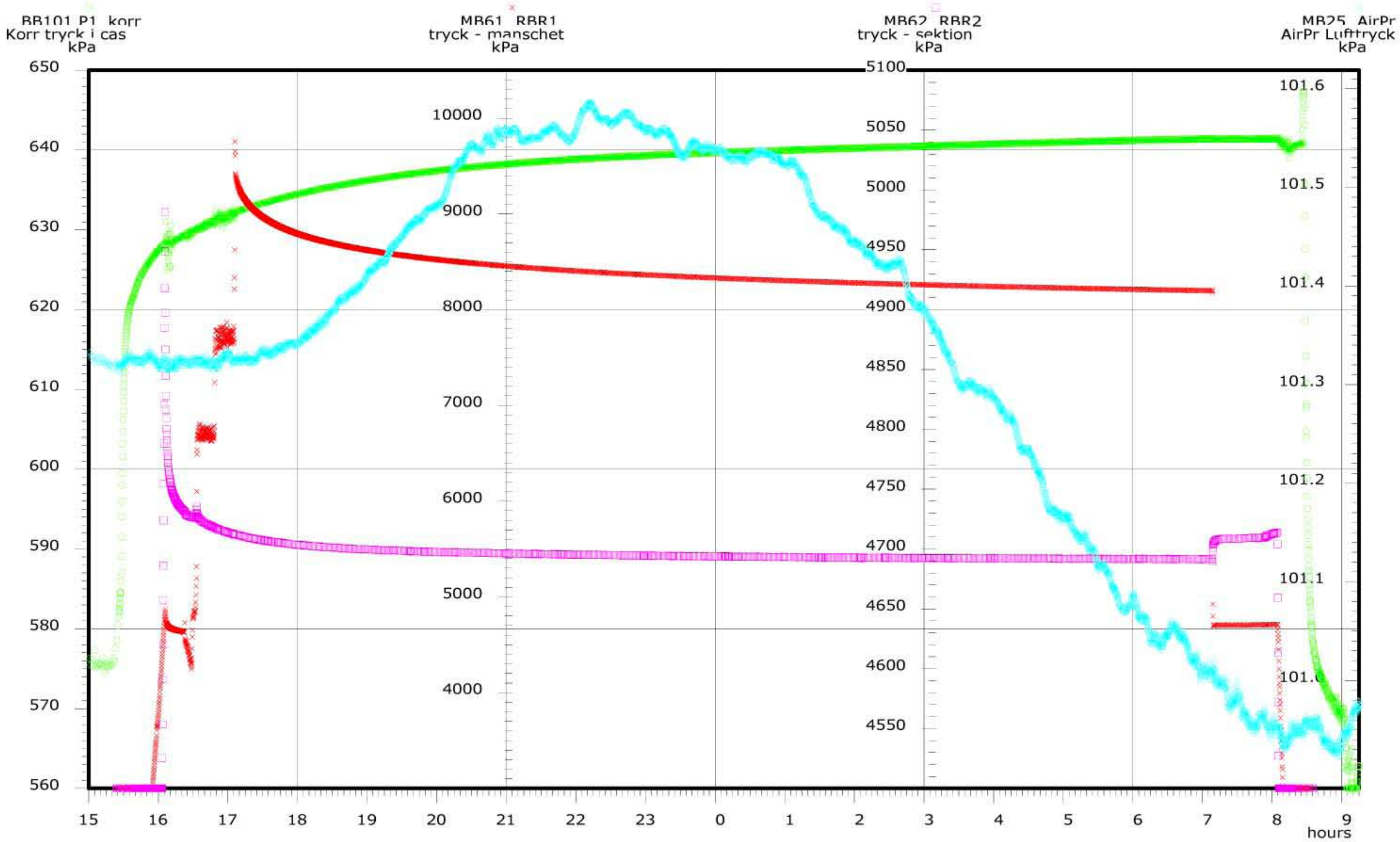

PLOT TIME :05/04/07 12:38:17
PLOT FILE :P_tryck_i _sektion
Adjusted for DST
DMS2 PO
Absoluttryckmätning i sektion
KLX07 617.85-632.06m
wl-sond
BB101 P1 korr
Korr tryck i cas
kPa
MB61 RBR1
tryck - manschet
kPa
MB62 RBR2
tryck - sektion
kPa
MB25 AirPr
AirPr Lufttryck
kPa
660
640
620
600
580
560
540
10000
9500
9000
8500
8000
7500
7000
6500
4650
4640
4630
4620
4610
4600
4590
4580
4570
4560
101.4
101.2
101.0
100.8
100.6
100.4
100.2
100.0
99.8
99.6
16
17
18
19
20
21
22
23
0
1
2
3
4
5
6
7
8
hours
START :05/04/06 15:20:00
INTERVAL: All readings
STOP :05/04/07 08:59:59


PLOT TIME :05/04/27 11:51:51
PLOT FILE :P_tryck_i _sektion
Adjusted for DST
DMS2 PO
Absoluttryckmätning i sektion
KLX07 624.45-728.78m
wl-sond
BB101_P1_korr
Korr tryck i cas
kPa
MB61_RBR1
tryck - manschet
kPa
MB62_RBR2
tryck - sektion
kPa
MB25_AirPr
AirPr Lufttryck
kPa
660
655
650
645
640
635
630
625
620
615
610
605
600
10000
9500
9000
8500
8000
7500
7000
6500
6000
5500
5000
4500
4700
4690
4680
4670
4660
4650
4640
4630
4620
4610
101.9
101.8
101.7
101.6
101.5
101.4
101.3
101.2
101.1
15
16
17
18
19
20
21
22
23
0
1
2
3
4
5
6
7
hours
START :05/04/22 15:00:00
INTERVAL: All readings
STOP :05/04/23 07:29:59

PLOT TIME :05/04/14 08:15:11
PLOT FILE :P_tryck_i _sektion
Adjusted for DST

# DMS2 PO

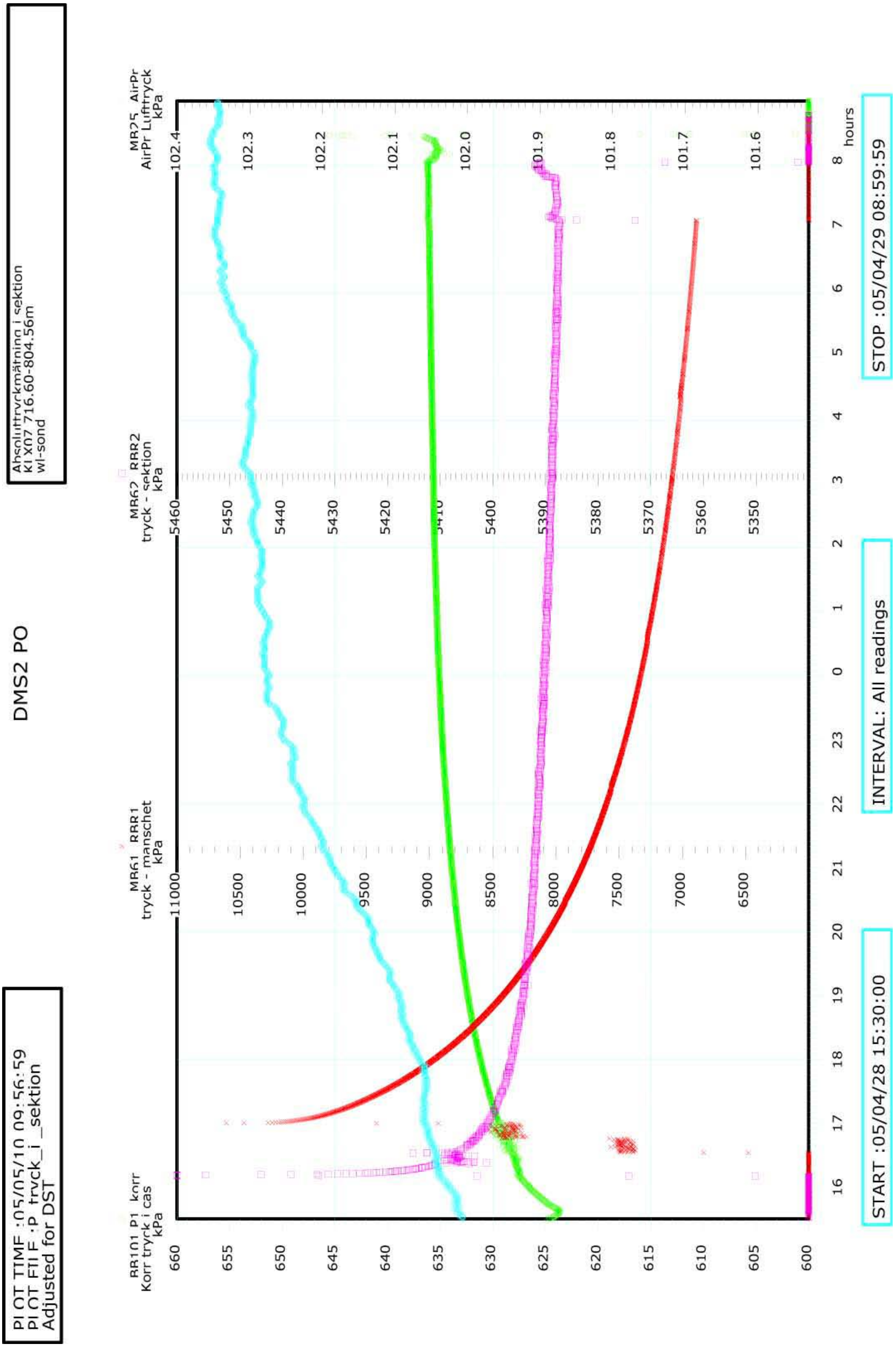
Absoluttryckmätning i sektion
KLX07 629.85-641.24m
wl-sond



START :05/04/10 15:00:00

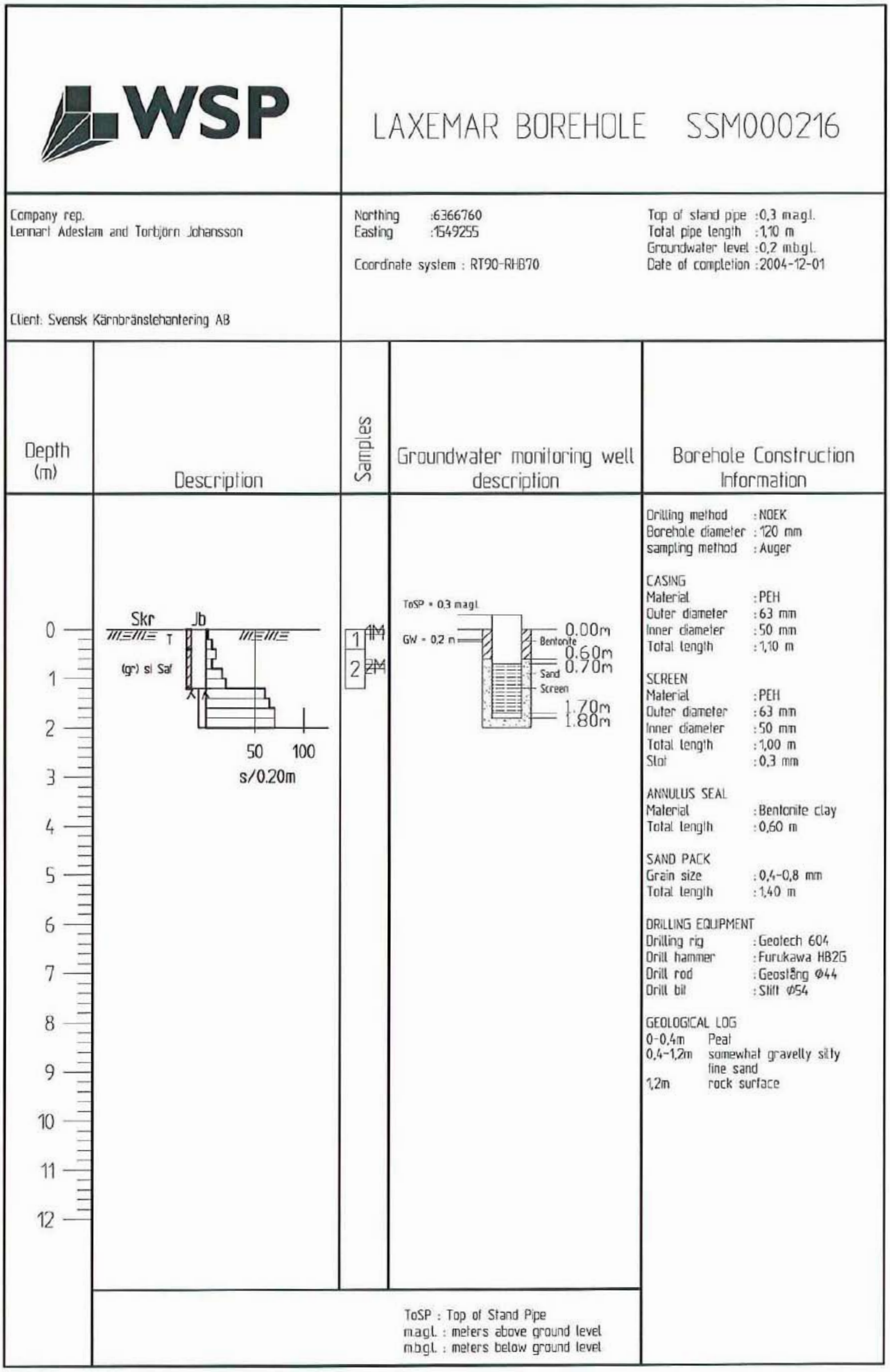
INTERVAL: All readings

STOP :05/04/11 09:14:59


PLOT TIME :05/05/10 09:56:59
PLOT FILE :P_tryck_i_sektion
Adjusted for DST
DMS2 PO
Absoluttryckmätning i sektion
KI X07 716.60-804.56m
wl-sond
RB101 P1_korr
Korr tryck i cas
kPa
MB61_RBB1
tryck - manschet
kPa
MB62_RBB2
tryck - sektion
kPa
MB25_AirPr
AirPr Lufttryck
kPa
660
655
650
645
640
635
630
625
620
615
610
605
600
11000
10500
10000
9500
9000
8500
8000
7500
7000
6500
5460
5450
5440
5430
5420
5410
5400
5390
5380
5370
5360
5350
102.4
102.3
102.2
102.1
102.0
101.9
101.8
101.7
101.6
16
17
18
19
20
21
22
23
0
1
2
3
4
5
6
7
8
hours
START :05/04/28 15:30:00
INTERVAL: All readings
STOP :05/04/29 08:59:59

## Appendix 7

## Technical specifications for environmental monitoring wells



WSP

LAXEMAR BOREHOLE SSM000216

Company rep.
Lennart Adestam and Torbjörn Johansson

Client: Svensk Kärnbränslehantering AB

| | |
|---|---|
| Northing | :6366760 |
| Easting | :1549255 |
| Coordinate system | : RT90-RHB70 |

| | |
|---|---|
| Top of stand pipe | :0,3 m.a.g.l. |
| Total pipe length | :1,10 m |
| Groundwater level | :0,2 m.b.g.l. |
| Date of completion | :2004-12-01 |

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

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

CASING

| | |
|---|---|
| Material | : PEH |
| Outer diameter | : 63 mm |
| Inner diameter | : 50 mm |
| Total length | : 1,10 m |

SCREEN

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

ANNULUS SEAL

| | |
|---|---|
| Material | : Bentonite clay |
| Total length | : 0,60 m |

SAND PACK

| | |
|---|---|
| Grain size | : 0,4-0,8 mm |
| Total length | : 1,40 m |

DRILLING EQUIPMENT

| | |
|---|---|
| Drilling rig | : Geotech 604 |
| Drill hammer | : Furukawa HB2G |
| Drill rod | : Geostång Ø44 |
| Drill bit | : Stift Ø54 |

GEOLOGICAL LOG

| | |
|---|---|
| 0-0,4m | Peat |
| 0,4-1,2m | somewhat gravelly silty fine sand |
| 1,2m | rock surface |

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

# LAXEMAR BOREHOLE SSM000217

Company rep.
Lennart Adestam and Torbjörn Johansson

Client: Svensk Kärnbränslehantering AB

Northing :6366636
Easting :1549236

Coordinate system : RT90-RHB70

Top of stand pipe : 0.7 m.a.g.l.
Total pipe length : 4,10 m
Groundwater level : 0,7 m.b.g.l.
Date of completion : 2004-12-02

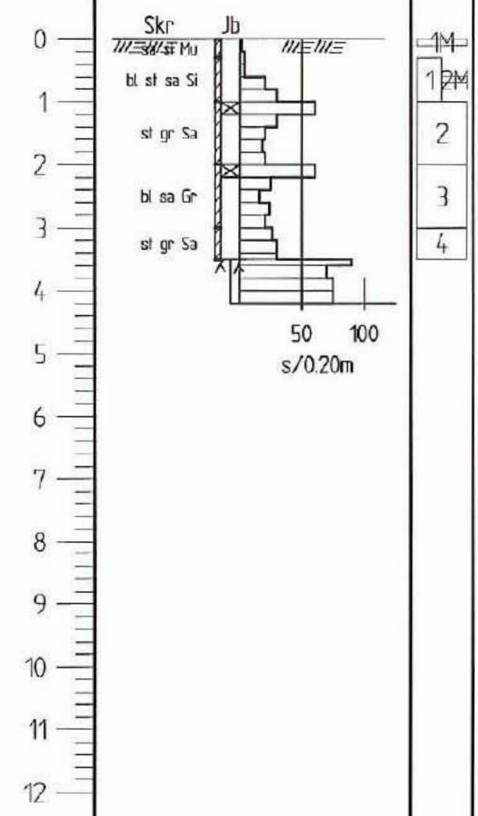
Depth (m)

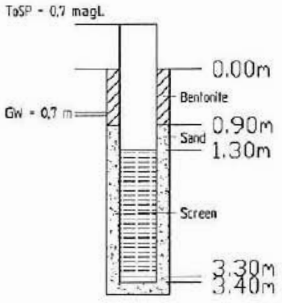
Description

Samples

Groundwater monitoring well description

Borehole Construction Information





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

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

SCREEN
Material : PEH
Outer diameter : 63 mm
Inner diameter : 50 mm
Total length : 2,00 m
Slot : 0,3 mm

ANNULUS SEAL
Material : Bentonite clay
Total length : 0,90 m

SAND PACK
Grain size : 0,4-0,8 mm
Total length : 2,70 m

DRILLING EQUIPMENT
Drilling rig : Geotech 604
Drill hammer : Furukawa HB2G
Drill rod : Geostång Ø44
Drill bit : Stift Ø54

GEOLOGICAL LOG

| | |
|---|---|
| 0-0,3m | Sandy silty topsoil |
| 0,3-1,0m | boulder- and cobble-bearing sandy silt |
| 1,0-2,0m | cobble-bearing gravelly sand |
| 2,0-3,0m | boulder-bearing sandy gravel |
| 3,0-3,5m | cobble-bearing gravelly sand |
| 3,5m | rock surface |

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

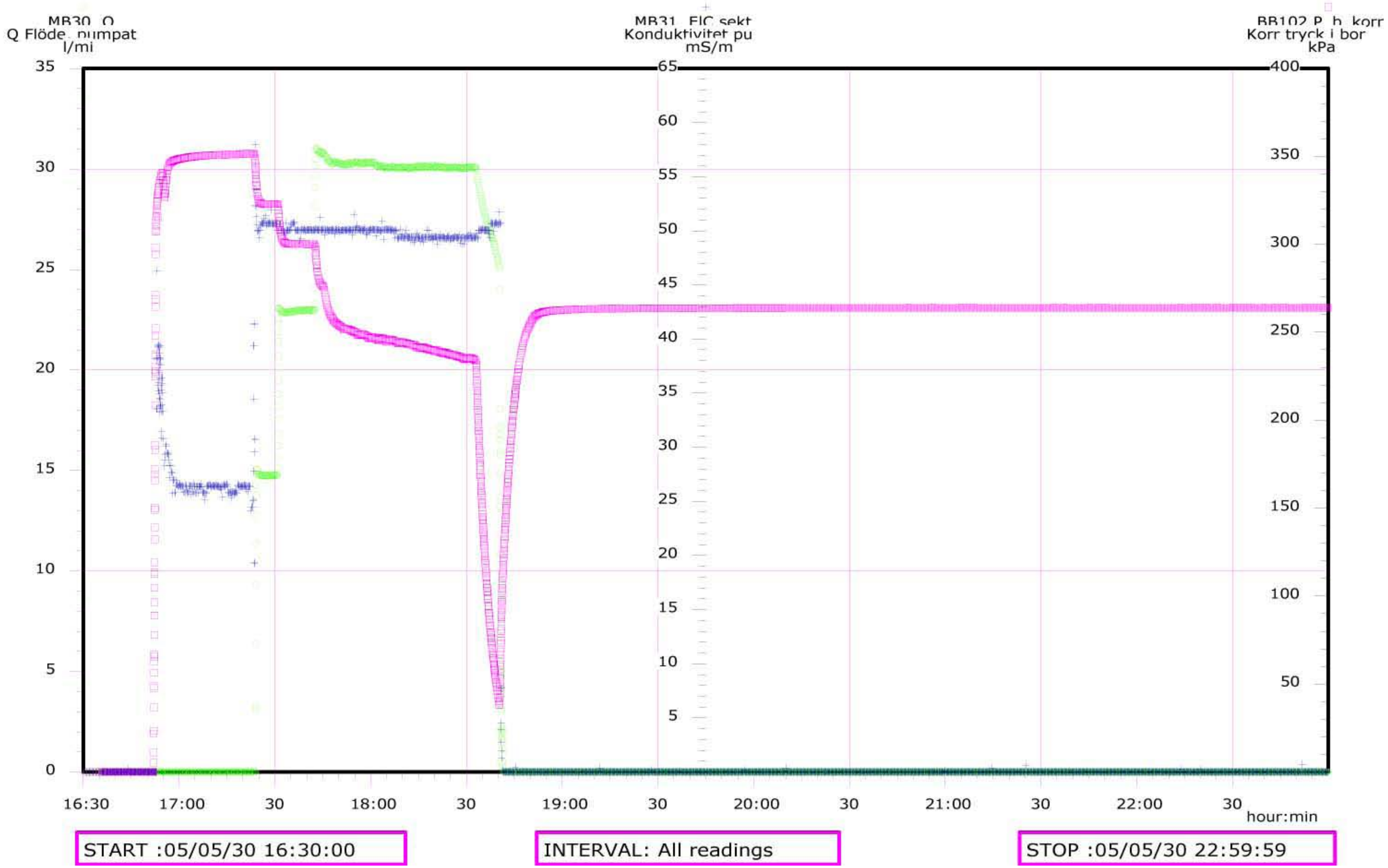
## Appendix 8

# Wireline pumping tests in KLX07B

PLOT TIME :05/06/09 13:04:28
PLOT FILE :P_pumptest
Adjusted for DST

DMS2 PO

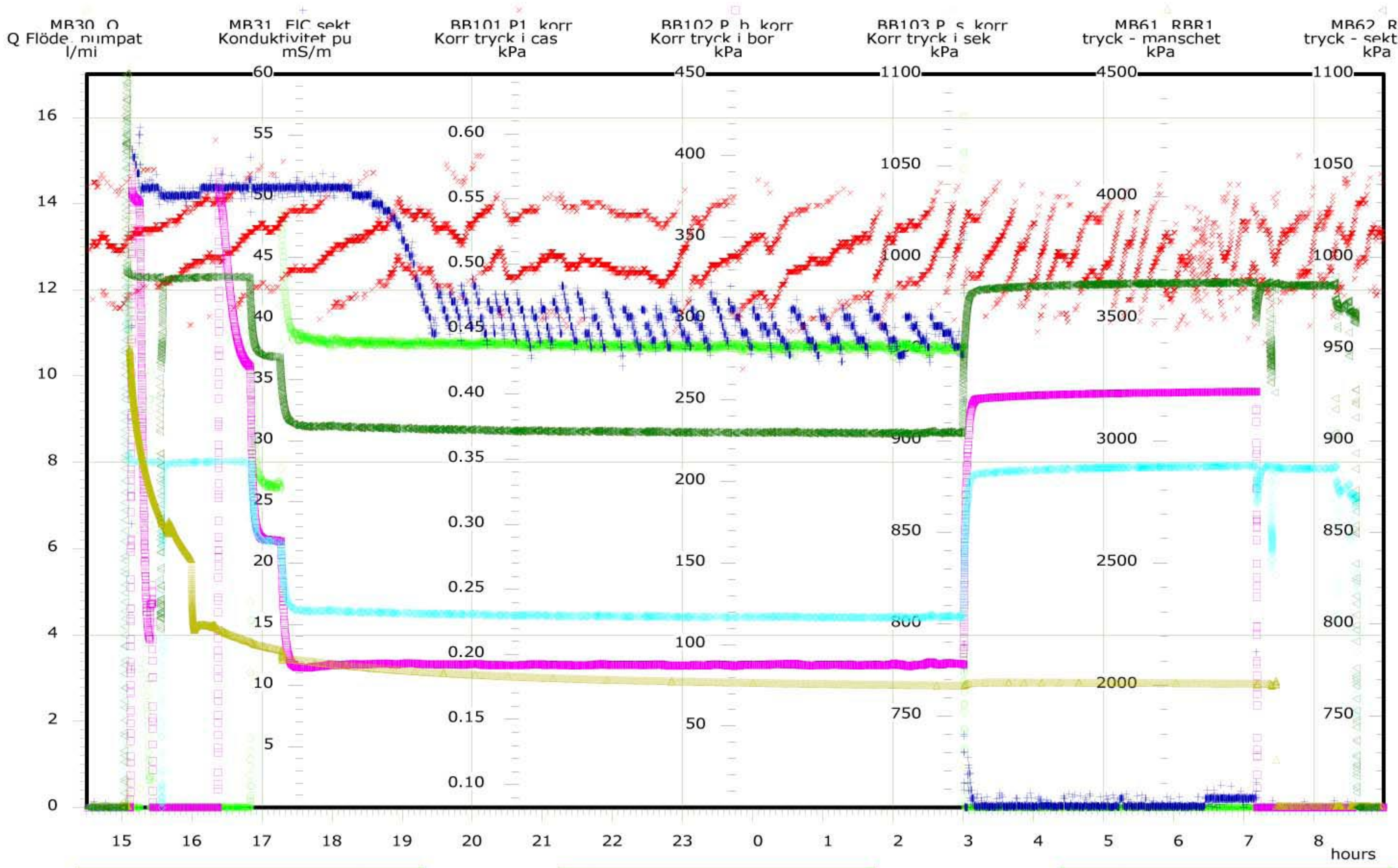
Pumping test
KLX07B 9.50-108.41m



PLOT TIME :05/06/09 13:28:03
PLOT FILE :P_pumptest
Adjusted for DST

# DMS2 PO

Pumping test
KLX07B 100.00-200.13m
Wireline probe



START :05/06/03 14:30:00

INTERVAL: All readings

STOP :05/06/04 08:59:59