P-04-233

Oskarshamn site investigation

Drilling of cored borehole KSH03

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October 2004

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

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Abstract

Borehole KSH03 is located on the Simpevarp peninsula. Drilling was made between August and November, 2003 as a part of the site investigation for a possible repository for spent nuclear fuel in Oskarshamn municipality, Sweden.

The hole was core drilled to a depth of 1,000.7 metres with 76 mm equipment, this hole was called KSH03A. The uppermost section, to a depth of 100.5 metres, was constructed as a telescopic section with an inner diameter of 200 mm. In order to retrieve core from surface to full depth a separate cored hole was drilled close to the telescopic section from the surface to 100.86 metres, this hole was called KSH03B.

Pumping tests were performed with a wireline equipment, typically with one hundred metres intervals. The resulting transmissivities (T_M) varied between 3×10^{-7} and 8×10^{-4} m^2/s.

An airlift pumping test in the telescopic section performed when the cored hole was drilled to its full length gave a transmissivity (T_M) of 5×10^{-4} m^2/s.

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

Water sampling for chemical analysis were collected during drilling. Only two samples, of four samples taken, from the core drilling phase had a sufficiently low drilling water content to ensure accurate results.

The upper part of the core to a length of 270 metres is dominated by quartz monzodiorite with sections of up to 30 metres of Ävrö granite. From 270 metres to full depth the core consists of Ävrö Granite with intercalated portions of fine-grained granite with up to 20 metres width. Minor segments of granite, diorite/gabbro and pegmatite occur. Oxidation with medium to weak intensity is prevalent in the upper 360 metres of the core. At greater depth both the extent and intensity of oxidation is greatly reduced.

The total fracture frequency is normally less than 20 per metre to ca 190 metres. Several thin crushed sections (ie total fracture frequency > 40 per metre) have been noted between 190 and 290 metres length. This interval also corresponds with an overall increase in total fracture frequency. The total fracture frequency is significantly lower below 290 metres length.

Sammanfattning

Borrhål KSH03 ligger på Simpevarpshalvön. Borrningen utfördes mellan augusti och november 2003 som ett led i platsundersökningen för ett möjligt djupförvar för utbränt kärnbränsle i Oskarshamns kommun.

Hålet kärnborrades med 76 mm utrustning till 1 000,7 meters djup. Detta hål kallades KSH03A. Den övre delen av hålet, från markytan till 100,5 meter, utfördes som en teleskopdel med 200 mm inre diameter. För att erhålla borrkärna från ytan till fullt djup borrades ett andra kärnborrhål från ytan till 100.86 meter, detta hål kallades KSH03B.

Pumptester med wireline-baserad mätutrustning utfördes normalt var hundrade meter. Uppmätta transmissiviteter (T_M) varierade mellan 3×10^{-7} och 8×10^{-4} m^2/s.

Ett pumptest med mammutpumpning i teleskopdelen som gjordes när kärnborrning utförts till full längd gav en transmissivitet (T_M) på 5×10^{-4} m^2/s.

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

Vattenprovtagning för kemisk analysering genomfördes i samband med borrning. Endast två prov, av fyra tagna, från kärnborrningsfasen hade ett tillräckligt lågt spolvatteninnehåll för att ge tillförlitliga resultat.

Den övre delen av kärnan, till 270 meter, domineras av kvartsmonzodiorit med partier på upp till 30 meter av Ävrögranit. Från 270 meter till fullt djup utgörs kärnan av Ävrögranit med inslag av finkornig granit med upp till 20 meters bredd. Mindre partier av granit, diorit/gabbro och pegmatit förekommer. Oxidation med medium till svag intensitet är vanligt förekommande i de övre 360 metrarna av kärnan. På större djup avtar oxidationen betydligt både i intensitet och omfattning.

Den totala sprickfrekvensen är normalt mindre än 20 per meter till ca 190 meter. Flera tunna krosszoner (total sprickfrekvens > 40 per meter) har noterats mellan 190 och 290 meter. Detta intervall sammanfaller med en generell ökning av den totala sprickfrekvensen. Den totala sprickfrekvensen minskar betydligt under 290 meters 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. The Simpevarp subarea of the investigation area in Oskarshamn is situated close to the nuclear power plant at Simpevarp /2/, see Figure 1-1.

Drilling and investigations in boreholes are fundamental activities in order to facilitate characterisation of rock and groundwater properties at depth. KSH03 was the third deep cored borehole within the Oskarshamn site investigation.

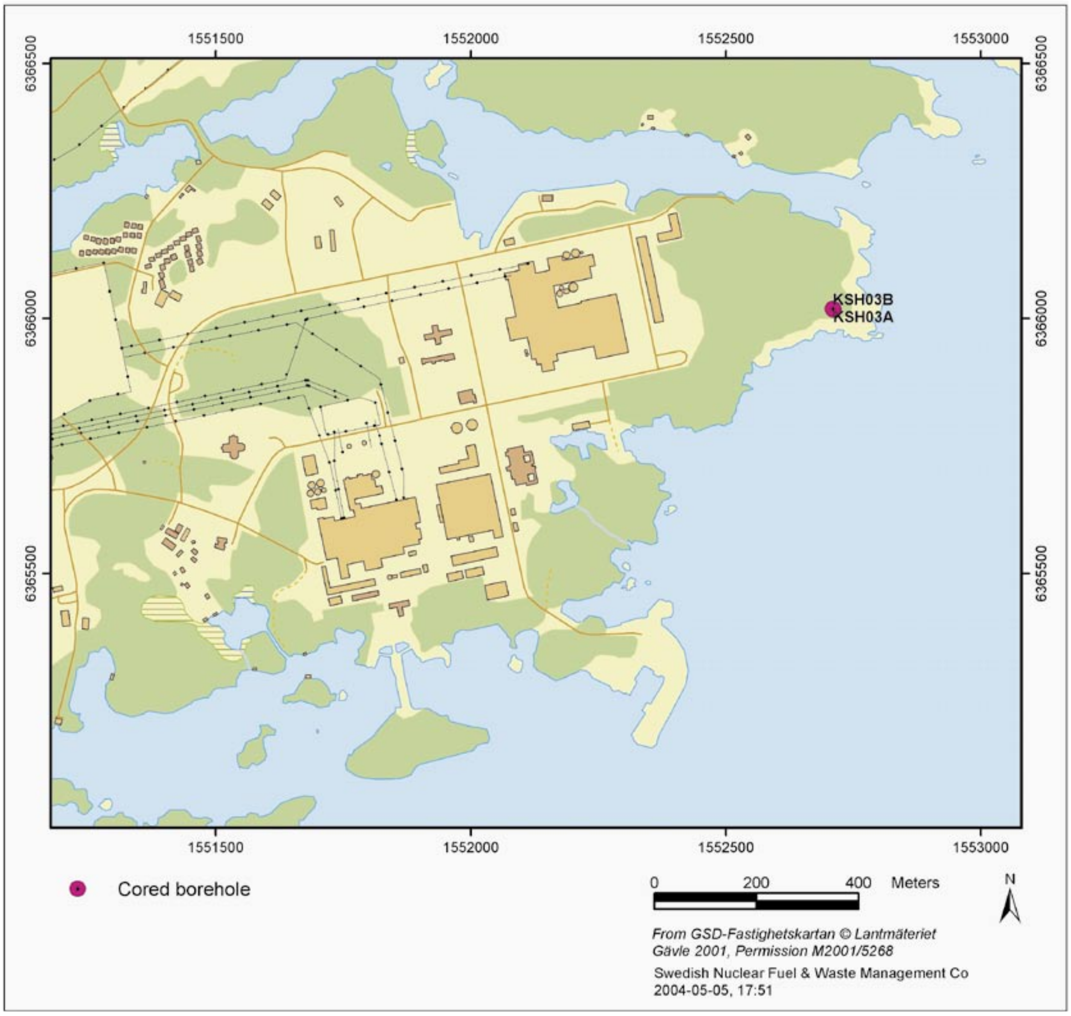


***Figure 1-1.** Locations of the drillholes KSH03A and KSH03B in the Simpevarp subarea.*

The drilling of KSH03 and all related on-site operations were performed according to a specific Activity Plan, which in turn refers to a number of method descriptions, see Table 1-1.

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

Activity plan	Number	Version
Kärnborrning KSH03	AP PS 400-03-021	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 borrhålsutrustning och viss markbaserad utrustning	SKB MD 600.004	1.0
Instruktion för användning av kemiska produkter och material vid borrning och undersökningar	SKB MD 600.006	1.0
Instruktion för borrplatsanläggning	SKB MD 600.005	1.0
Instruktion för spolvattenhantering	SKB MD 620.007	1.0
Instruktion för utsättning och inmätning av borrhål	SKB MD 600.002	1.0

The activity plans and method descriptions are SKB internal documents.

Data collected during the drilling of KSH03 was entered into the Sicada database under field notes 125 and 186, see Table 1-2

Table 1-2. Data references.

Subactivity	Database	Identity number
Drilling KSH03A	SICADA	Field note 125
Drilling KSH03B	SICADA	Field note 186

2 Objective and scope

This report will describe the methods employed and the results achieved during the drilling of KSH03. 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 borehole KSH03 was to gain geological information at depth of the eastern part of the Simpevarp peninsula and to facilitate further investigation at depth in the borehole. The decision to drill KSH03 is included in SKB Report R-01-44 /1/.

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

A notification in accordance with the Environmental Code was issued to the regional authorities on 2003-05-21, SKB id no 1014488. A reply, without objections, was received on 2003-06-13, SKB id no 1015298 (Regional Authority registration no 525-6832-03).

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 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.

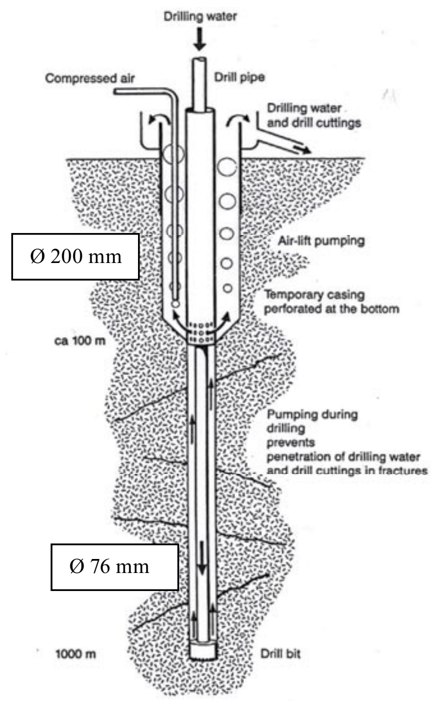


Figure 3-1. *A sketch of the telescopic drilling method with air-lift pumping for retrieval of drilling water and cuttings.*

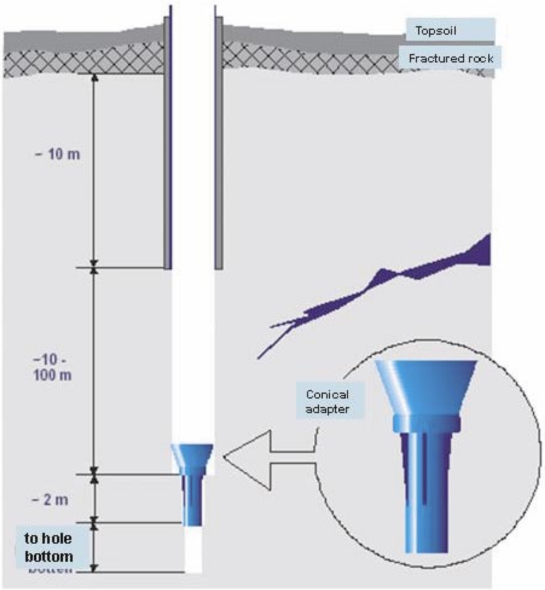


Figure 3-2. Installation of the conical guide.

3.1.1 The flushing water system

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

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

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

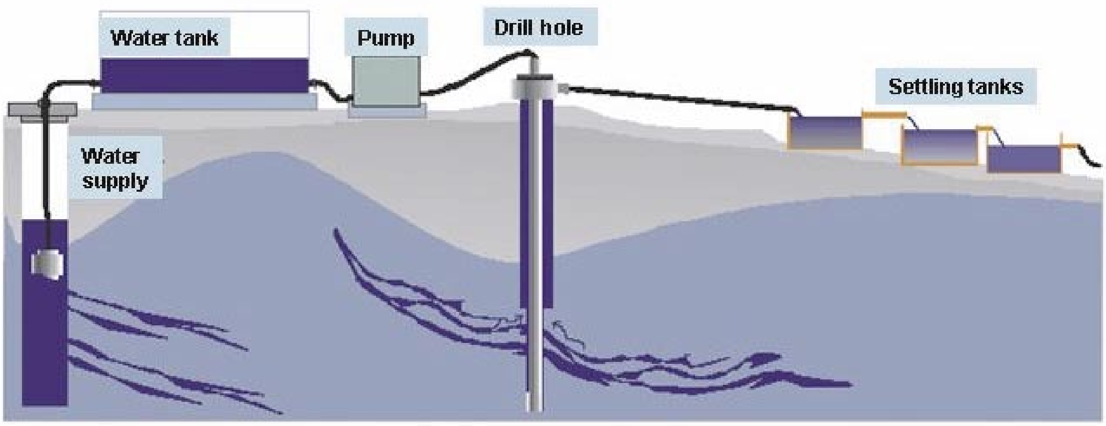


Figure 3-3. The flushing water system from source to discharge point.

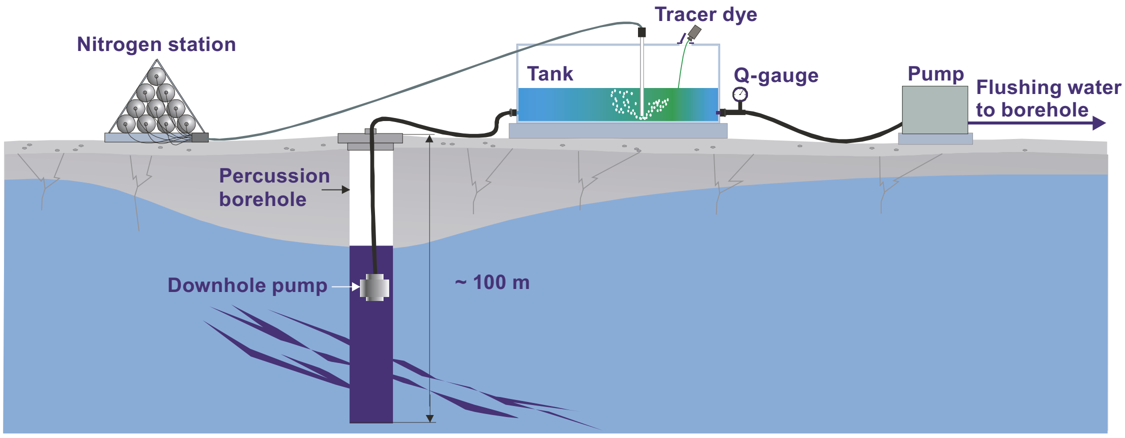


Figure 3-4. *Preparation of flushing water. Uranine is added to the water in the tank as a tracer dye. Nitrogen is bubbled through the water to remove dissolved oxygen.*

3.2 Measurements and sampling during drilling

3.2.1 Percussion drilling

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

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 KSH03 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 wire-line based equipment. The measurements for hydrogeological purposes include pumping tests and measurements of absolute pressure and are normally performed for every 100 metres of drilled length. Sampling of water for chemical analysis is done in conjunction with the hydrogeological measurement where feasible. The wireline tests are done in accordance with SKB Method Description MB 321.002, SKB internal document.

Air lift pumping and recovery tests

Air lift pumping and recovery tests are done with 300 metres intervals, nominally at 400, 700 and 1,000 metres length. The actual levels are adapted to when changes of drill bit, or some other reason to raise the drill stem, occur. After drilling has ceased and the stem removed, the flow of ingoing water is normally stopped. The air lift pumping, however, continues for a period of about two hours. After the air lift pumping has been discontinued the recovery of the water table in the telescopic section is measured.

Water sampling at the surface

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

Drilling monitoring system (DMS)

Drilling is monitored on-line by continuous registration of drill rig parameters (logged every centimetre of bit penetration) and flushing water parameters (logged every 10 seconds). The data is compiled into a database called drilling monitoring system (DMS).

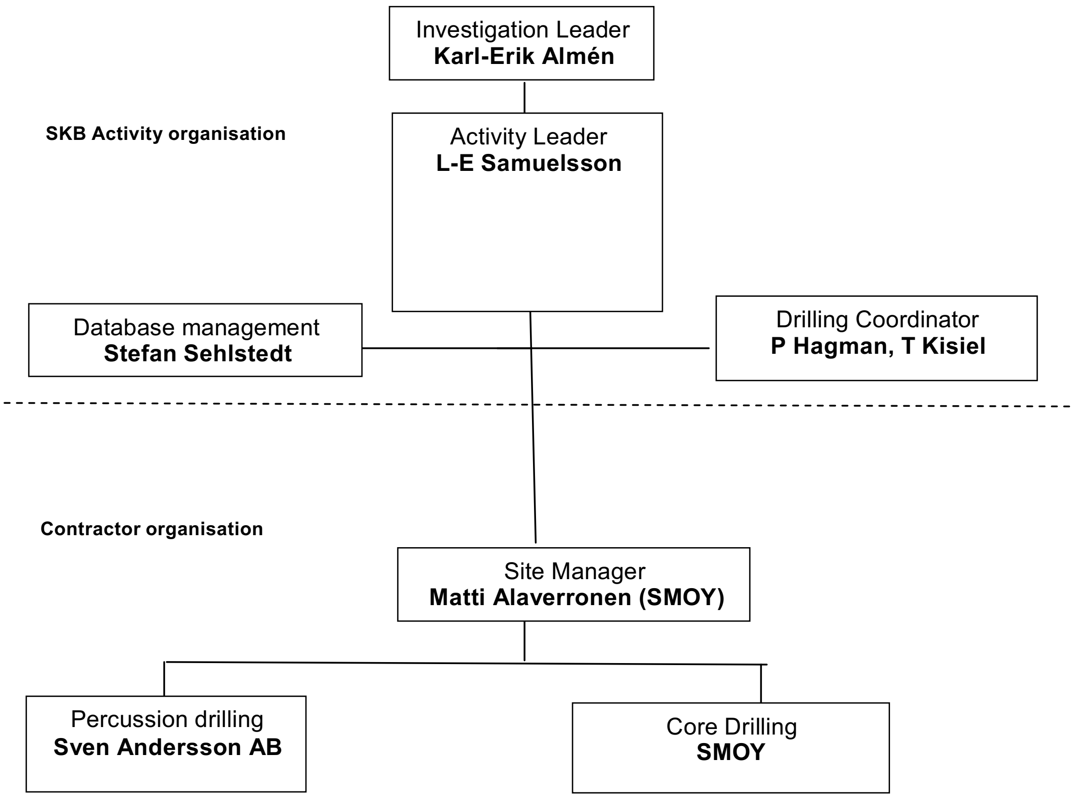
4 Contractors and equipment

4.1 Contractors

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

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

Table 4-1. Drill activity organisation.



4.2 Percussion drilling equipment

The equipment used was a Puntel MX1000 percussion drill rig with an Atlas Copco XRVS 455 Md air compressor. The down-the-hole hammer was a Secoroc 8” or 6” and the drill rods were Driqoneq 114 mm. The casing utilized was St 37 406.5 mm, SS 2343 208×4 mm and 273×4 mm. The casing dimensions are presented as outer diameter and thickness.

4.3 Core drilling equipment

Core drilling in KSH03 was made with a B 20 P Atlas Copco fully hydraulic machine fitted with a modern and environmentally adapted diesel engine. The rods were of the type Corac N3/50 NT with a 76 mm wireline triple tube core barrel system which gives a core diameter of 50.2 mm.

Figure 4-1. *Percussion drilling equipment.*

Figure 4-2. *The KSH03 drill site.*

4.3.1 Wireline measurements equipment

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

Measurements are made with a wireline probe as specified in method description SKB MD 321.002, SKB internal document.

The principal components are:

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

The probe and packer are lowered through the drill stem into position at the drill bit. The test section is between the lower end of the packer and the bottom of the borehole, see Figure 4-3.

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

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

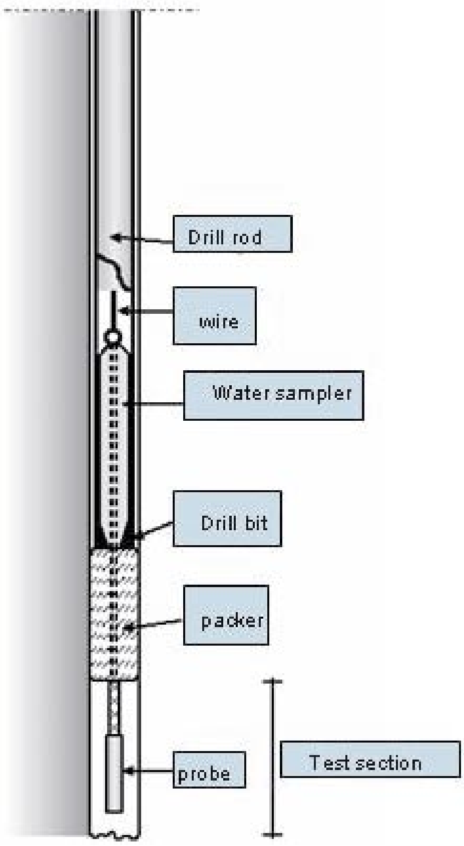


Figure 4-3. The wireline probe and its emplacement in the hole.

Pumping tests

The wireline probe is emplaced at the bottom of the drill stem. A submersible pump is lowered into the upper part of the drill stem at a length of about 40 m. The test section is hydraulically connected to the drill stem by opening a valve in the probe at a pre-determined pressure. This creates a passage between the test section and the water column in the drill stem. The packer remains expanded during the entire test. Water is pumped from the drill stem and the pressure in the test section and packer are recorded in a data logger in the probe. The pumped surface flow rate is recorded to a data logger on the ground surface. The pressure transducer is situated 1.10 m below the lower end of the packer. The test consists of a pressure drawdown phase and a recovery phase. Typically the pumping time is three hours with a recovery phase of the same duration. However, the duration is sometimes adapted to the hydraulic situation of the tested section. The tests are normally carried out in sections of about 100 m length.

Water sampling

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

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

Absolute pressure measurement

The wireline probe is placed in position at the drill bit. The packer is inflated and the pressure build-up in the test section is recorded for a period of at least eight hours, typically this is done overnight. The measuring range for the pressure gauge is 0–20 MPa (± 0.05% FSD).

4.3.2 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 work with formally establishing routines for quality assurance of DMS data is still going on in October 2004. The results presented in this report have been checked in accordance with a work routine that has been in use since October 2003.

The drill rig (MWD) parameters include:

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

The flushing water parameters include:

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

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

4.3.3 Equipment for deviation measurements

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

4.3.4 Equipment for reaming reference slots

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

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

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

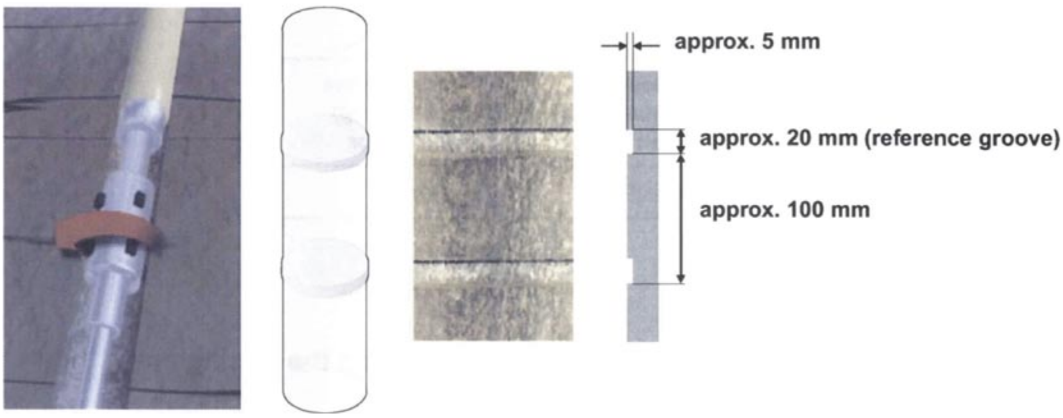


***Figure 4-5.** The equipment for reaming of reference slots. To the left, the reaming tool with openings for the cutters is shown. The resulting reference slots are illustrated in the three pictures to the right.*

5 Execution and results

5.1 Summary of KSH03 drilling

A technical summary of the drilling of KSH03A and the borehole design after completion is given in Table 5-1 and Figure 5-1. A detail of the conical steel guide is given in Figure 5-2. A technical summary of borehole KSH03B is given in Table 5-2 and Figure 5-3.

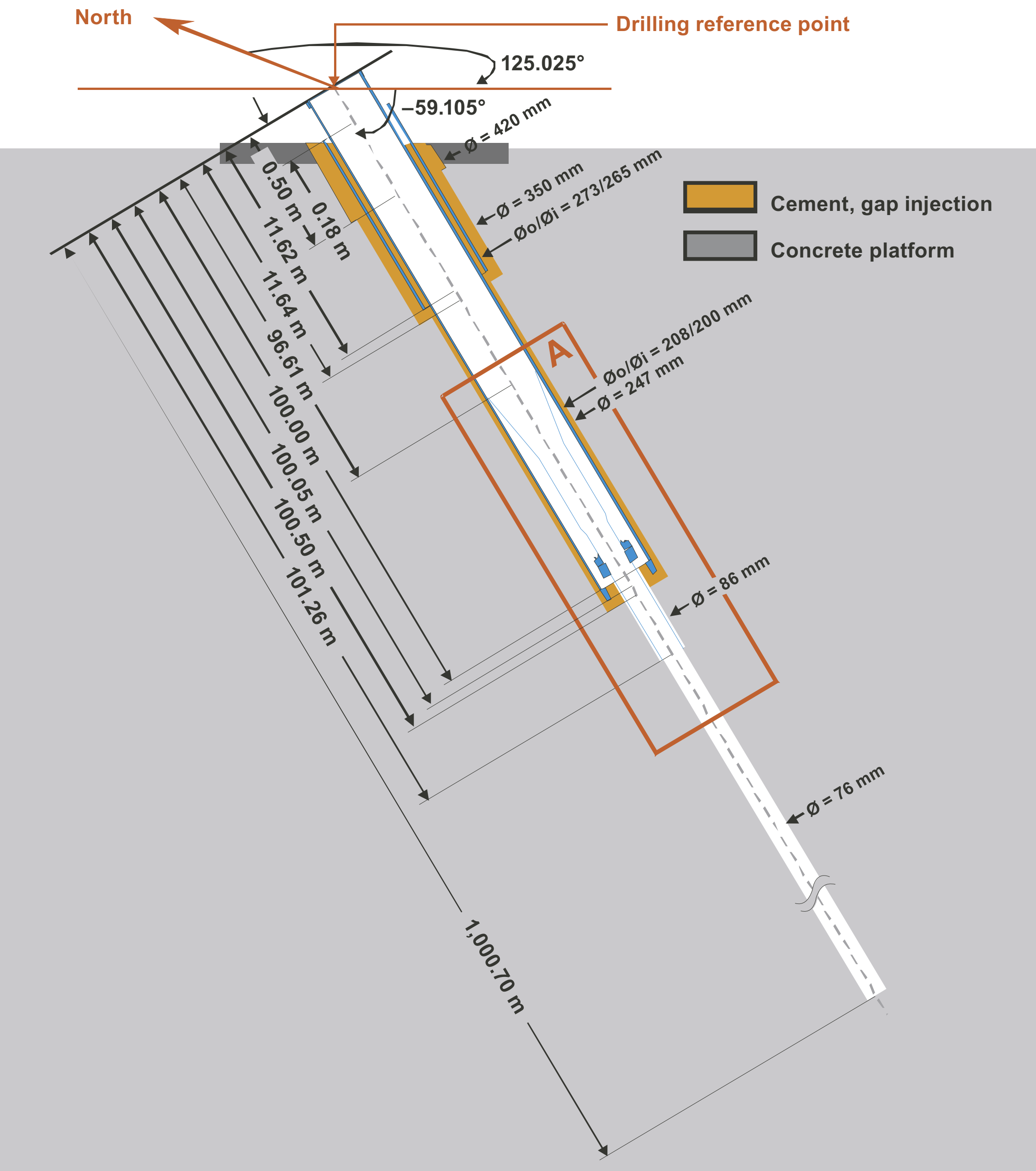
Further descriptions of the two main drilling steps, the telescope section 0–100.5 metres and the core drilling section 100.0–1,000.7 metres are given in Sections 5.2 and 5.3 respectively.

Table 5-1. KSH03A summary.

General	Technical
Name of holes: KSH03A	Percussion drill rig: Puntel MX 1000
Location: Simpevarp, Oskarshamn Municipality, Sweden	Percussion drill hole diameter: 247 mm
Contractor for drilling: Drillcon AB	Casing diameter (inner): 200 mm
Subcontractor percussion drilling: Sven Andersson AB	Percussion hole length: 100.5 m
Subcontractor core drilling: Suomen Malmi OY (SMOY)	Core drill rig: B 20 P Atlas Copco
Drill start date: August 13, 2003	Core drill dimension: 76 mm
Completion date: November 7, 2003	Cored interval: 100.0–1,000.7 m
	Average core length retrieved in one run: 2.82 m
	Number of runs: 319
	Diamond bits used: 12
	Average bit life: 75 m
	Position KSH0 (RT90 RH70) at top of casing: N 6366018.66 E 1552711.17 Z 4.15 (masl)
	Azimuth (0–360)/Dip (0–90): 125.0/–59.1
	Position KSH03A (RT90 RH70) at 996 m length: N 6365575.29 E 1552984.50 Z –822.46 (masl)
	Azimuth (0–360)/Dip (0–90): 180.5/–46.2

Technical data

Borehole KSH03A



Drilling reference point

Northing: 6366018.66 (m), RT90 2,5 gon V 0:-15

Easting: 1552711.17 (m), RT90 2,5 gon V 0:-15

Elevation: 4.15 (m), RHB 70

Drilling period

Drilling start date: 2003-08-13

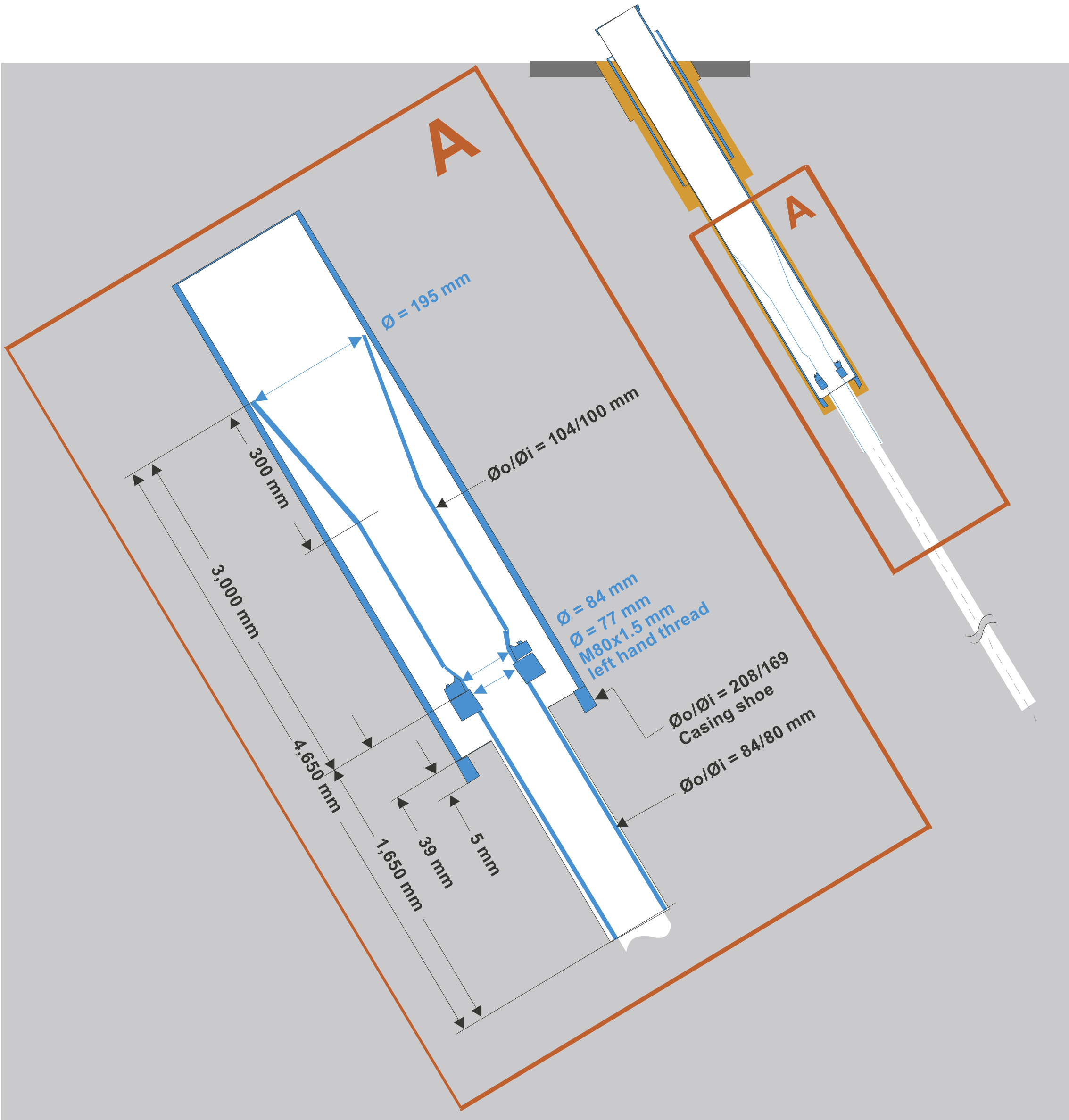
Drilling stop date: 2003-11-07

Figure 5-1. *Technical data from KSH03A.*

Technical data

Borehole KSH03A

Conical Steel Guide



Drilling reference point

Northing: 6366018.66 (m), RT90 2,5 gon V 0:-15

Easting: 1552711.17 (m), RT90 2,5 gon V 0:-15

Elevation: 4.15 (m), RHB 70

Drilling period

Drilling start date: 2003-08-13

Drilling stop date: 2003-11-07

Figure 5-2. *Detail of the conical steel guide in KSH03A.*

In order to retrieve a complete core from surface to full depth an additional drilling was made to 100.86 metres about one metre from the percussion drill hole. The core and the borehole are called KSH03B.

Drilling was made from the surface level with 76 mm core drilling equipment to a length of 10 metres. The hole was subsequently reamed to 96 mm diameter and a casing (89/77 mm) was installed and gap injected. The tightness of the gap injection was tested by manual measurements of water level recovery. No inflow of water could be established.

Drilling with 76 mm diameter was continued to 100.86 m. The geology of KSH03B is presented in Appendix 1.

The reference point during drilling was the concrete pad. The top-of-casing is 11 cm above the concrete pad.

Table 5-2. KSH03B summary.

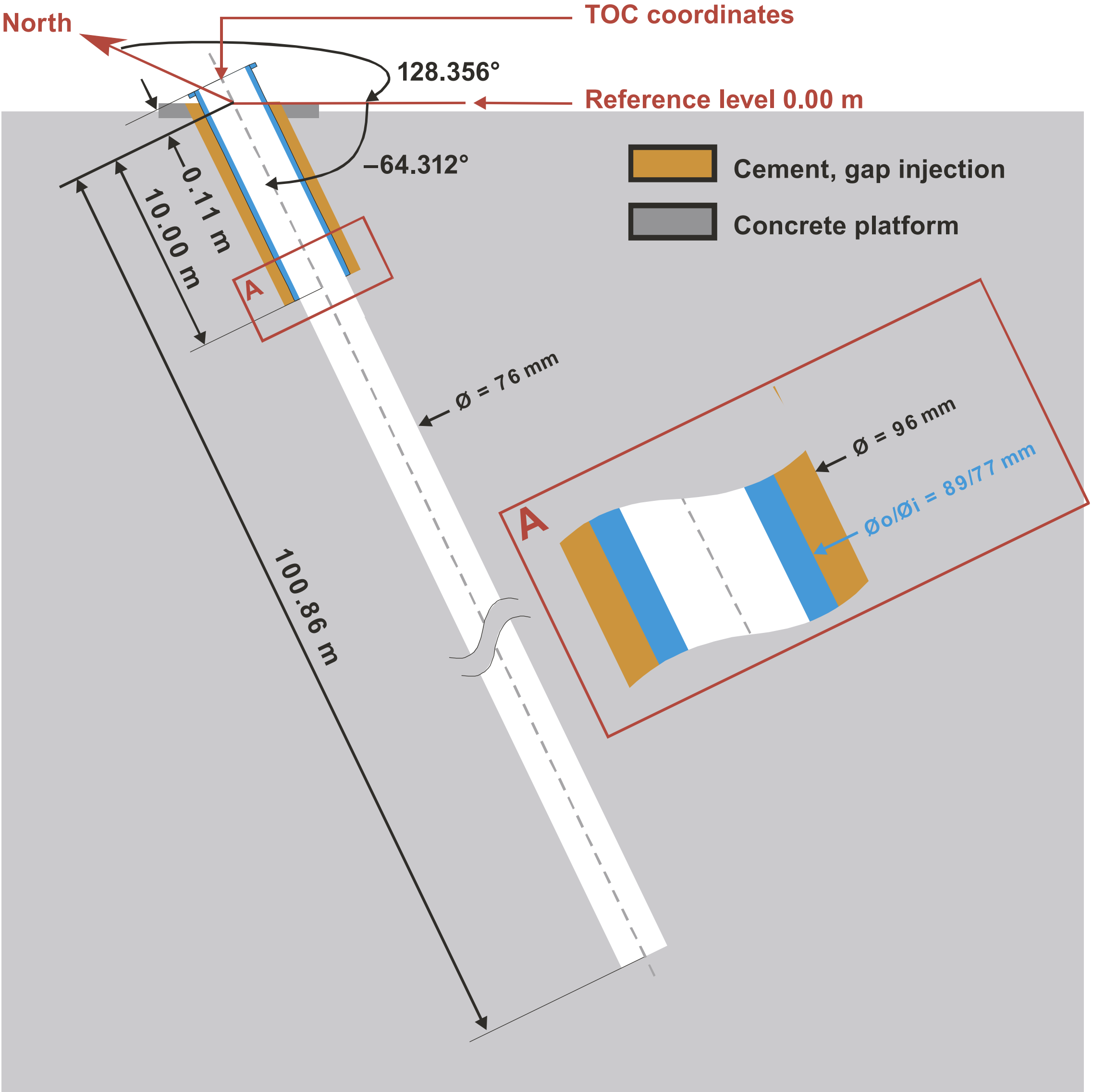
General	Technical
Name of holes: KSH03B	Core drill rig: B 20 P Atlas Copco
Location: Simpevarp, Oskarshamn Municipality, Sweden	Core drill dimension: 76 mm Cored interval: 0–100.86 m
Contractor for drilling: Drillcon AB	Position KSH03B (RT90 RH70) at top of casing: N 6366018.98 E 1552710.70 Z 4.08 (masl)
Subcontractor core drilling: Suomen Malmi OY (SMOY)	Azimuth (0–360)/Dip (0–90): 128.4/–64.3
Drill start date: November 21, 2003	
Completion date: November 26, 2003	

Technical data from borehole KSH03B is given in Figure 5-3.

N.B. Unless otherwise stated the rest of this report will deal with results from KSH03A.

Technical data

Borehole KSH03B



TOC coordinates
Northing: 6366018.984 (m), RT90 2,5 gon V 0:-15
Easting: 1552710.701 (m), RT90 2,5 gon V 0:-15
Elevation: 4.079 (m), RHB 70
Drilling period
Drilling start date: 2003-11-21
Drilling stop date: 2003-11-26

Figure 5-3. *Technical data from borehole KSH03B.*

5.2 Drilling, measurements and results in the telescopic section 0–100.5 m

Drilling, reaming and gap injection were made between August 13 and September 2.

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 (0–100.5 metres) of KSH03A was made in steps as described below and shown in Figure 5-4:

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

- Drilling started from the concrete pad to 0.5 metres depth with NO-X 400 mm equipment. This gave a hole diameter of 420 mm.
- Inner supportive casing for guidance for the drill string was mounted and a pilot percussion hole of 159.5 mm was drilled to a depth of 11.64 metres (to fresh rock). The inner casing was removed and the pilot hole was reamed in two steps to 250 mm and then to 350 mm diameter.
- The casing (273×4 mm diameter) through fractured rock was installed and gap injection with low alkali cement based concrete (393 kg or 440 litres) was made as described in Figure 5-5.
- A set of inner supportive casing with diameter 193.7 mm was installed to a length of 11.63 m.
- A pilot hole with diameter 165 mm was drilled to a length of 100.5 m.
- The 193.7 mm supportive casing was removed and the hole reamed to diameter 248 mm.
- Stainless casing of 208×4 mm was installed from 0 to 100.05 m and gap injection with low alkali cement based concrete (2,035 kg or 2,280 litres) was made as described in Figure 5-6. After hardening the hole was rinsed and flushed to remove concrete and water. The tightness of the concrete gap filling was tested by manual groundwater measurements which confirmed that the water inflow was less than the required 0.5 litres per minute.

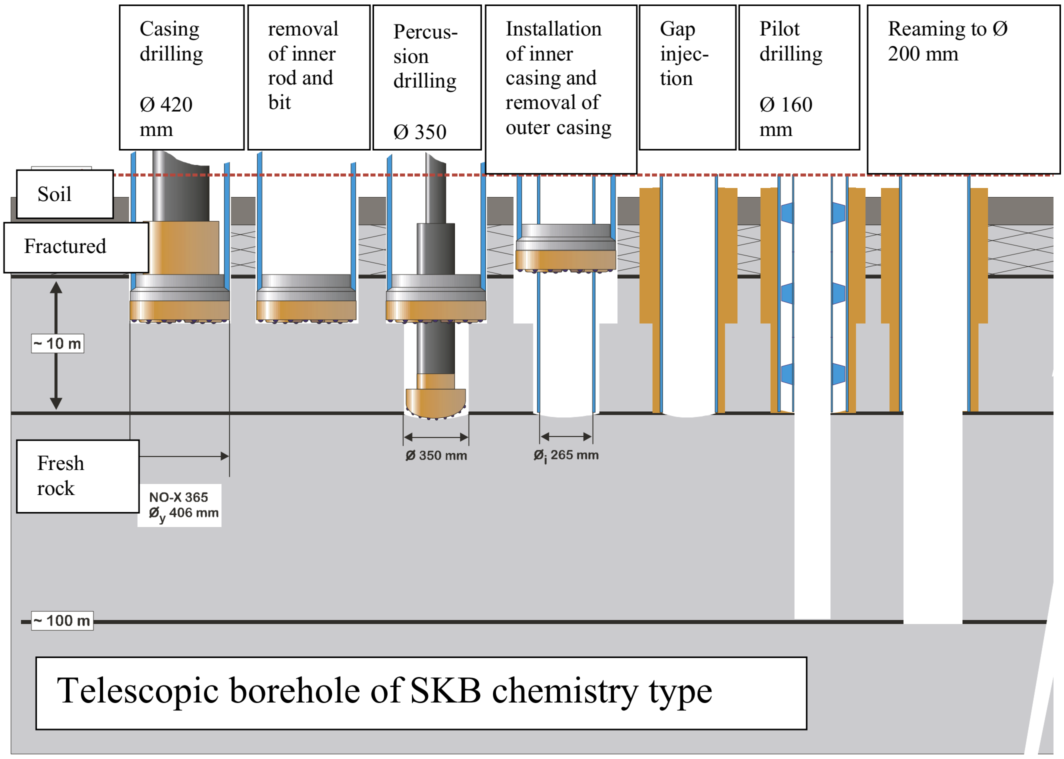


__Figure 5-4.__ Method for drilling and installation of the first 100 metres. In addition to the steps shown in the figure an extra set of casing (208/200 mm) was emplaced in KSH03A.

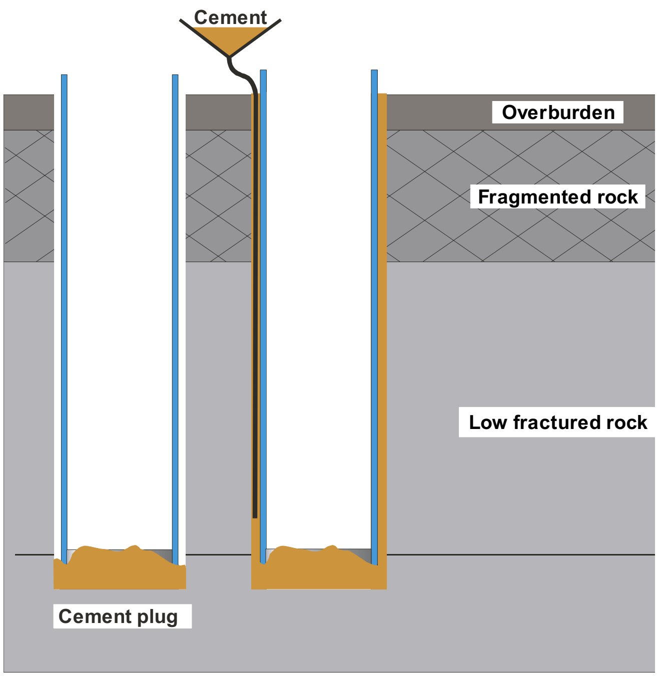


__Figure 5-5.__ Gap injection technique 1. A cement plug is emplaced at the bottom and allowed to harden. The gap filling cement is introduced between the casing and the rock wall.

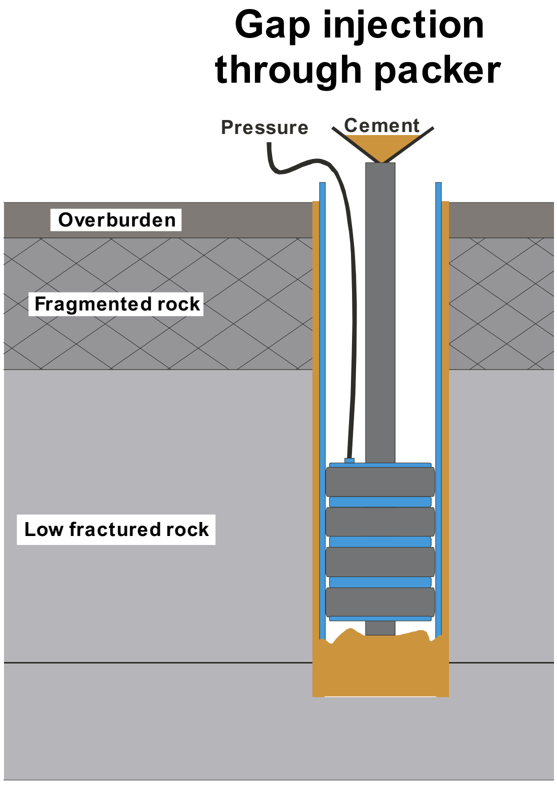


Figure 5-6. *Gap injection technique 2. A packer is emplaced at the bottom of the hole and the concrete is introduced through the packer and forced up between the casing and the rock wall.*

5.2.3 Measurements and sampling in the telescopic section

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

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

The preliminary geological results and penetration rate is presented in Figure 5-7.

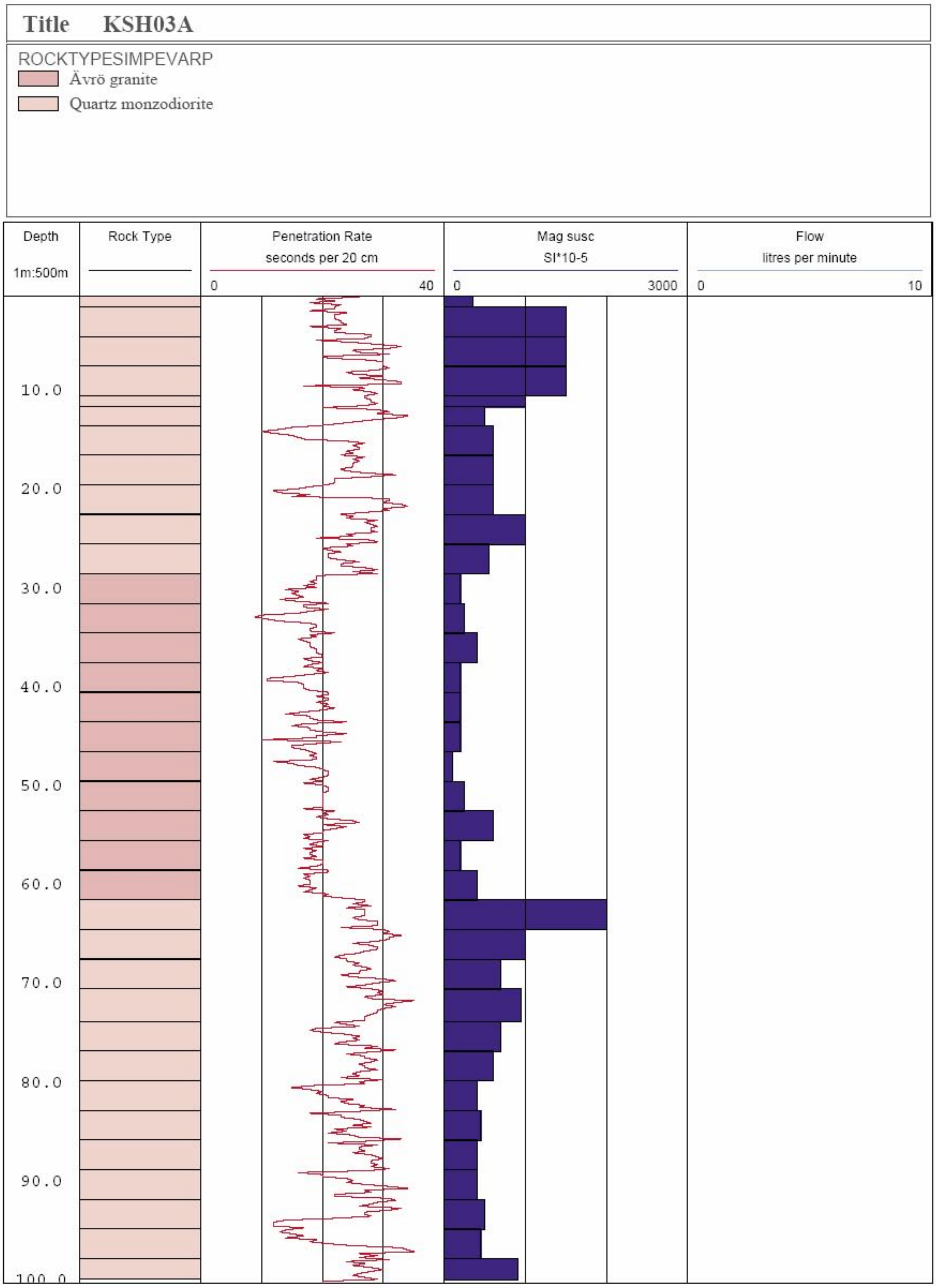


Figure 5-7. *Preliminary geological results and penetration rate from percussion drilling of KSH03A.*

Hydrogeology

No noticeable changes in water flow and colour of return water could be recorded during drilling.

A separate hydraulic test of the percussion drilled part of KSH03A was made by Geosigma AB between August 20 and August 26 after the hole was reamed to 247 mm diameter but before the 208/200 mm casing was installed and gap injected.

This hydraulic test was not at part of the drilling activity and is reported in full in /3/.

Hydrochemistry

Three water samples were collected. Sampling and analysis of samples 5799, 5800 and 5801 were performed according to SKB class 3 with isotopes options according to Table 5-3. Selected results are given in Table 5-4 and a complete account is given in Appendix 2.

Table 5-3. Sample dates and length during percussion drilling in KSH03.

SKB no	Date	Test section, length (m)	SKB chemistry class
5799	2003-08-21	0.00–100.60	3 and isotope options Deuterium, Tritium, O-18, Cl-37 and B-10
5800	2003-08-21	0.00–100.60	3 and isotope options Deuterium, Tritium, O-18, Cl-37 and B-10
5801	2003-08-21	0.00–100.60	3 and isotope options Deuterium, Tritium, O-18, Cl-37 and B-10

Table 5-4. Selected analytical results from samples 5799, 5800 and 5801.

Sample no	pH	Conductivity (mS/m)	Cl (mg/l)
5799	7.68	248.5	644.4
5800	7.77	171.8	329.3
5801	7.72	204.6	510.0

5.3 Core drilling 100.0–1,000.7 m

Core drilling in KSH03A was conducted between September 3, 2003 and November 7, 2003.

The main work in KSH03A after pre-drilling of the telescopic section consisted of the following steps:

- preparations for core drilling,
- drilling,
- deviation measurements,
- borehole completion.

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

5.3.1 Preparations

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

The installation of supportive casing was done in two steps:

- An outer casing with a diameter of 98/89 mm, fitted with fins to align with the diameter of the stainless 200 mm (inner diameter) casing was installed to a length of 100.00 m.
- Equipment for air-lift pumping was installed and a discharge header was fitted to collect the return water.
- Drilling was made between 100.00 and 101.26 m with T-86 equipment. An inner supportive casing with diameter 84/77 mm was installed to 101.26 m.

The supportive casings have a perforated section between 99.4 and 99.6 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.

The return water from drilling was led to a series of sedimentation containers in order to collect sludge before discharge to the Baltic, see Figure 5-10.

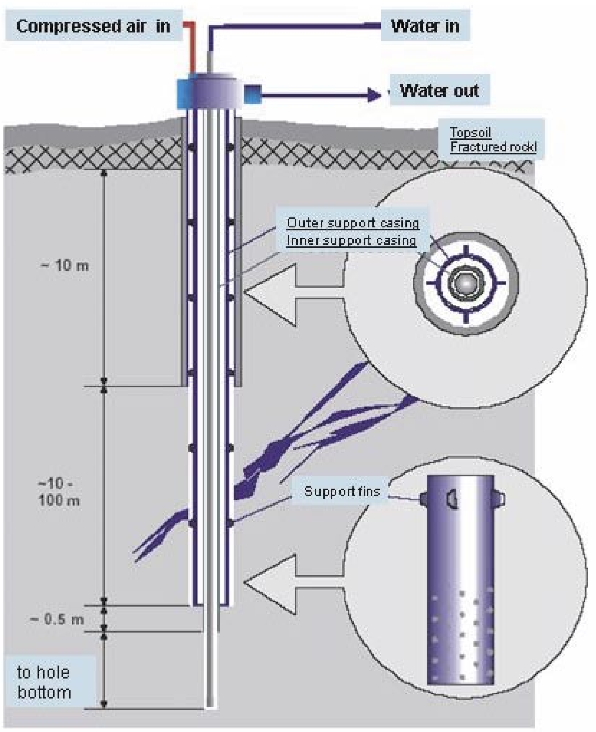


Figure 5-8. *In the telescopic part of the drill hole a temporary installation is made with casing tubes for support and alignment and equipment for air-lift pumping. In the uppermost part the return water discharge header is mounted. The water discharge is led to the settling containers.*

Figure 5-9. *The air-lift pumping system.*

Figure 5-10. The flushing water discharge containers. The sludge and cuttings are allowed to settle in the containers.

5.3.2 Drilling

Core drilling with 76 mm triple-tube, wireline equipment commenced on September 12 and was conducted from 101.26 m to the final length of 1,000.7 m which gave a core of 50.2 mm diameter.

The drilling progress over time is shown in Section 5.5, see Figure 5-16.

A total of twelve drill bits were used for KSH03A, see Figure 5-11.

The elasticity of the drill stem was not measured during the drilling of KSH03A.

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

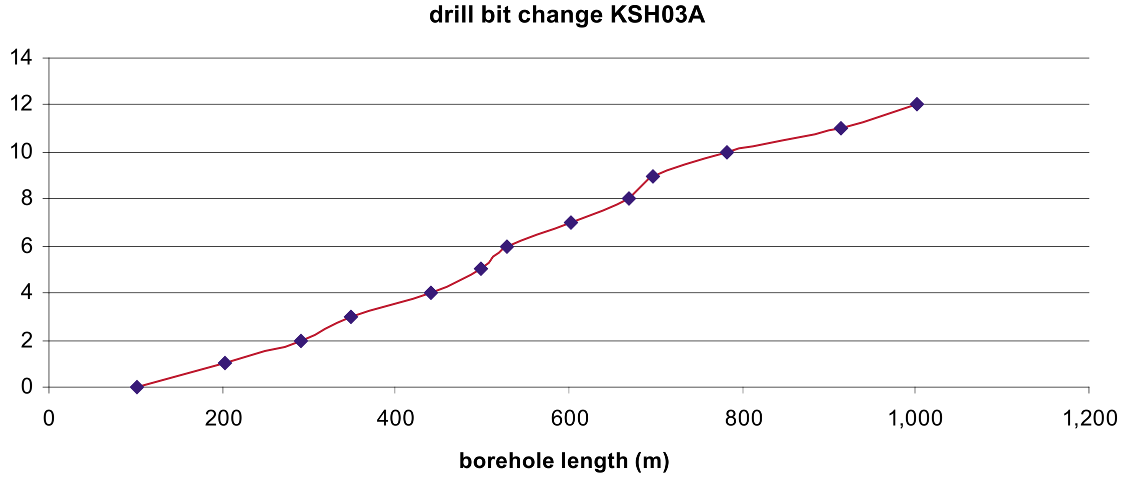


Figure 5-11. *Changes of drill bit during core drilling in KSH03A.*

5.3.3 Deviation measurements

Two plots of the results of the final run with the Maxibor method covering the entire length of borehole KSH03A is given in Appendix 4. A deviation measurement of KSH03B was also made.

5.3.4 Borehole completion

Reaming of depth reference slots was done at intervals as shown in Table 5-5. The depth reference slots are used for depth calibration of down-hole equipment for subsequent investigations in the hole.

Table 5-5. Depth reference slots.

110.00	550.00
150.00	600.00
200.00	650.00
250.00	700.00
300.00	750.00
350.00	800.00
400.00	850.00
450.00	900.00
500.00	950.00

The presence of the depth reference slots have been confirmed by caliper log measurements.

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

A steel conical guide was installed between 96.61 m and 99.61 m depth together with a 84/80 mm casing between 99.61 and 101.26 m. The conical guide tapers from an inner diameter of 195 mm to 77 mm.

The length of the hole was rinsed by flushing nitrogen gas five times. A total of 50.8 m^3 of water was flushed out of the hole. A dummy probe was run through the length of the hole to ensure that the hole was unobstructed.

The borehole was secured by mounting a lockable steel cap fastened to the concrete pad. All equipment was removed, the site cleaned and a joint inspection was made by representatives from SKB and the contractor to ensure that the site had been satisfactorily restored.

5.4 Hydrogeological and hydrochemical measurements and results 100.0–1,000.7 m.

The performed measurements can be summarised as follows:

Wireline measurements:

- Ten pumping tests resulting in eight completely successful tests were conducted, see Section 5.4.1.
- Seven measurements of absolute pressure, see Section 5.4.1.
- Water samples were successfully collected from four of the ten 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 and recovery tests were made, see Section 5.4.3.

5.4.1 Hydrogeological results from wireline measurements

Results from the wireline pumping tests in borehole KSH03A are presented in Table 5-6.

The pumping tests are evaluated with steady-state assumption in accordance with Moye /4/. The flow rate at the end of the drawdown phase is used for calculating the specific capacity (Q/s) and transmissivity (T_M), where "Q" is the flow rate in litres/min, "s" is the drawdown in kPa and "T_M" is the transmissivity according to /4/.

Eight tests, out of a total of ten pumping tests performed, achieved sufficiently stable conditions for calculating pseudo steady-state transmissivity.

Table 5-6. Pumping tests with the wireline probe in KSH03A.

Tested section From (m)	To (m)	Comments	Q/s (m^2/s)	T_M (m^2/s)
		Low flow rate in section made it difficult to regulate the flow rate. The scan time was erroneously set in the in-situ data logger which resulted in insufficient amount of pressure data for analysis the test. Flow is 0.6 l/min and drawdown in tested section is not known. Maximum drawdown is to bottom of hole i.e. to 202.35 m. Hence Q/s > 0.6/202.35.		
151	202.35		> 5×10^{-8}	
199.6	291.88	Test functionally OK. Stable flow of Q = 3.7 l/min. Pseudo stationary conditions after 30 min of pumping.	6.0×10^{-4}	7.8×10^{-4}

Tested section From (m)	To (m)	Comments	Q/s (m²/s)	T_M (m²/s)
290.6	411.61	Test functionally OK. Stable flow 1.2– > 0.9 l/min. Pseudo-stationary after 30 min of pumping! No pressure change after pump is stopped due to wrong scan time. Transient evaluation not possible.	$1.3\ 10^{-4}$	$1.8\ 10^{-4}$
409.5	508.26	Test functionally OK. Stable flow 0.6 l/min after 20 min of pumping! Large temporal gaps between pressure points in the drawdown phase due to erroneously set scanning in data logger. Probably event logging invoked rather than regular sampling. Transient evaluation of drawdown phase not possible but OK for the recovery phase.	4.5×10^{-7}	$5.8\ 10^{-7}$
506.18	601.7	Test functionally OK! Stable flow 1.3– > 0.8 l/min. Pseudo-stationarity after 20 min pumping. Large temporal gaps between pressure point in the drawdown phase due to erroneously set scanning in data logger. Probably event logging invoked rather than regular sampling. Transient evaluation of drawdown phase not possible but OK for the recovery phase.	$5.1\ 10^{-7}$	$6.6\ 10^{-7}$
599.53	697.6	Test functionally OK. Good test.	$2.2\ 10^{-7}$	$2.8\ 10^{-7}$
697.9	787.99	Relatively good test. Stable flow at 0.9 l/min. Pseudo stationarity after 30 min pumping! Some gaps in pressure data makes transient evaluation of the drawdown phase more complicated. Data during the recovery phase is good and transient evaluation should be possible.	$4.2\ 10^{-5}$	$5.4\ 10^{-5}$
788.35	892.55	Test functionally OK.	$2.5\ 10^{-6}$	$3.3\ 10^{-6}$
892.22	1,000.7	Failed test. No pressure data in the in situ logger.		
890.55	1,000.7	Test functionally OK.	$3.4\ 10^{-7}$	$4.5\ 10^{-7}$

Graphical results from the tests are shown in Figure 5-12 and in full in Appendix 5.

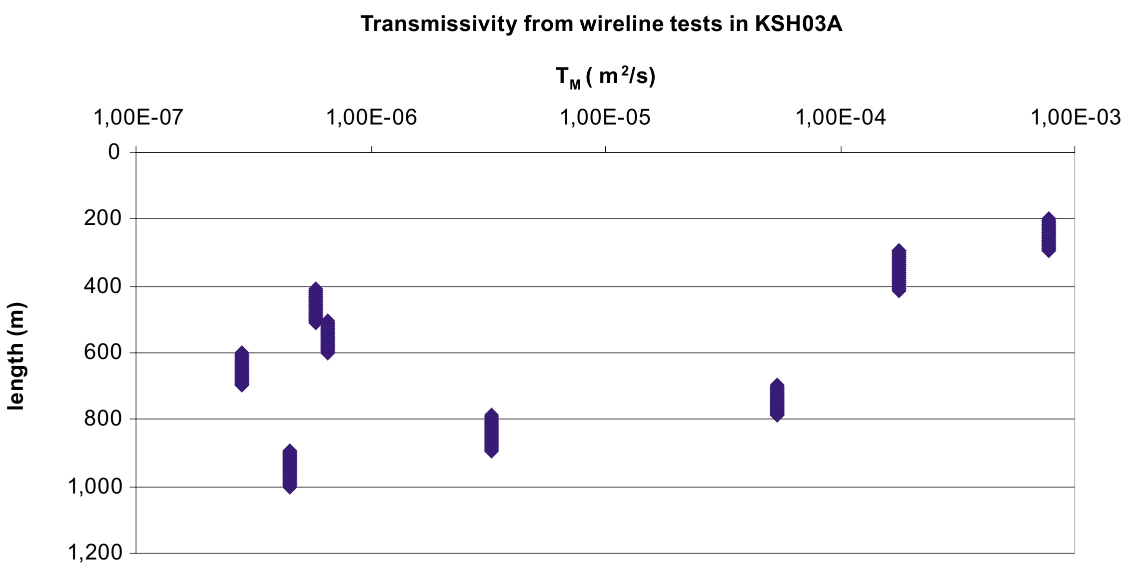


Figure 5-12. *Transmissivity vs length in KSH03A.*

Absolute pressure measurements were performed in seven sections as specified in Table 5-7.

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

Table 5-7. Absolute pressure measurements in KSH03A.

Tested section		Last pressure reading during buildup	Duration of pressure buildup	Borehole length to pressure gauge
From (metres below top of casing)	To (metres below top of casing)	(kPa)	(h)	(metres below top of casing)
290.6	349.28	2,482	c 10	291.7
409.5	508.26	3,485	c.12	410.6
506.45	601.7	4,290	c 34	507.55
599.53	697.6	5,072	c 5	600.63
697.9	787.77	5,890	c 12	698.0
788.35	892.55	6,640	c 11	789.45
890.55	1,000.7	7,455	c 12	891.65

Graphical results from the tests are shown in Figure 5-13 and in full in Appendix 6.

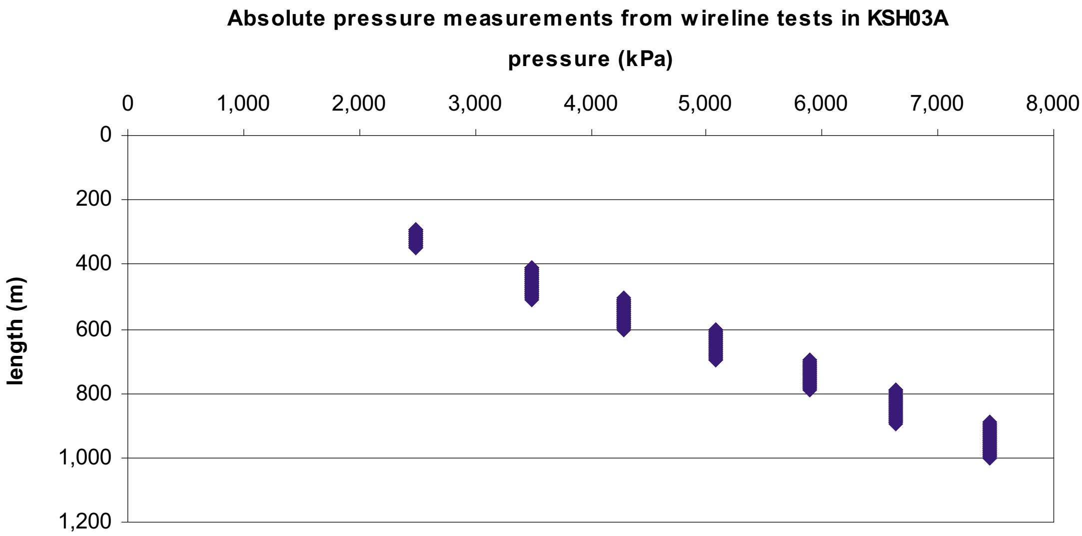


***Figure 5-13.** Measurements of absolute pressure from wireline tests in KSH03A.*

5.4.2 Hydrochemistry

In total, four water samples were collected with the wireline probe in connection with core drilling in KSH03A. The times and lengths for the samples are given in Table 5-8.

Table 5-8. Sample dates and length during core drilling in KSH03A.

SKB no	Date	Test section, length (m)	SKB chemistry class
5860	2003-09-21	200.60–291.88	3 and all option isotopes except S-34
5908	2003-10-16	599.00–698.00	3
5912	2003-10-23	698.00–788.00	3
5964	2003-10-31	788.00–893.00	3

Sampling and analysis were performed according to SKB class 3 with isotopes according to Table 5-8. Cations and isotopes were not analysed in samples 5912 and 5964 due to the very high concentration of drilling water.

In sample 5908 cations and isotopes were not analysed due to insufficient amount of water.

Selected analytical results from KSH03A and the water source, HSH03, are given in Table 5-9. A complete record of analytical results is given in Appendix 2.

The samples 5860 and 5858 are analysed for Cl-37 but the results from these analyses have not yet been recieved. The Cl-37 results are therefore not included in this report and they will only be reported in SICADA.

Table 5-9. Analytical results from water chemistry sampling.

Borehole	Sample no	Date	From m	To m	Drilling water %	pH	Conductivity mS/m	Cl mg/l
KSH03A	5860	2003-09-21	200.60	291.88	22.48	7.37	1,433.0	5,075.8
KSH03A	5908	2003-10-16	599.00	698.00	0.56	7.59	305.5	882.8
KSH03A	5912	2003-10-23	698.00	788.00	90.12	7.57	343.3	985.2
KSH03A	5964	2003-10-31	788.00	893.00	92.10	7.61	358.5	1,044.8
HSH03	5858	2003-09-16	0.00	200.00	0.03	8.02	199.1	462.9

Sample 5858, from the water source HSH03, were not analysed for TOC. However, HSH03 was used as water source also for the drilling of KSH01 and the results from the TOC analyses from HSH03 at that time are reported in /5/. The concentration of total organic carbon (TOC) in the three samples was considered acceptable for the groundwater to be used as flushing water for the core drilled part of KSH01, as for the cored drilled part of KSH03, without further filtration measures to lower the organic carbon content.

The amount of suspended material in the last sedimentation container was analysed in samples 5965, 5966, 5967 and 5968. This was done in order to determine suspended material in the out-going water. The results are given in Table 5-10.

Table 5-10. The amount of suspended material in samples from the last sedimentation container.

Borehole	Sample no	Date	Activity type	Suspended material (mg/l)
KSH03A	5965	2003-11-03	WC142	450.00
KSH03A	5966	2003-11-04	WC142	420.00
KSH03A	5967	2003-11-05	WC142	310.00
KSH03A	5968	2003-11-06	WC142	420.00

A total of 8 samples were taken after drilling along the flushing water system in order to determine the microorganism content within the system. The results are reported in /6/.

A total of 46 samples for laboratory testing of uranine content and electrical conductivity in flushing and returning water were taken along the borehole. Due to technical problems with the dosage equipment, uranine was not inserted to the flushing water between 312 and 569 m. The problem took a few weeks to rectify but reoccurred towards the end of the hole. The results are shown in Figure 5-14.

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

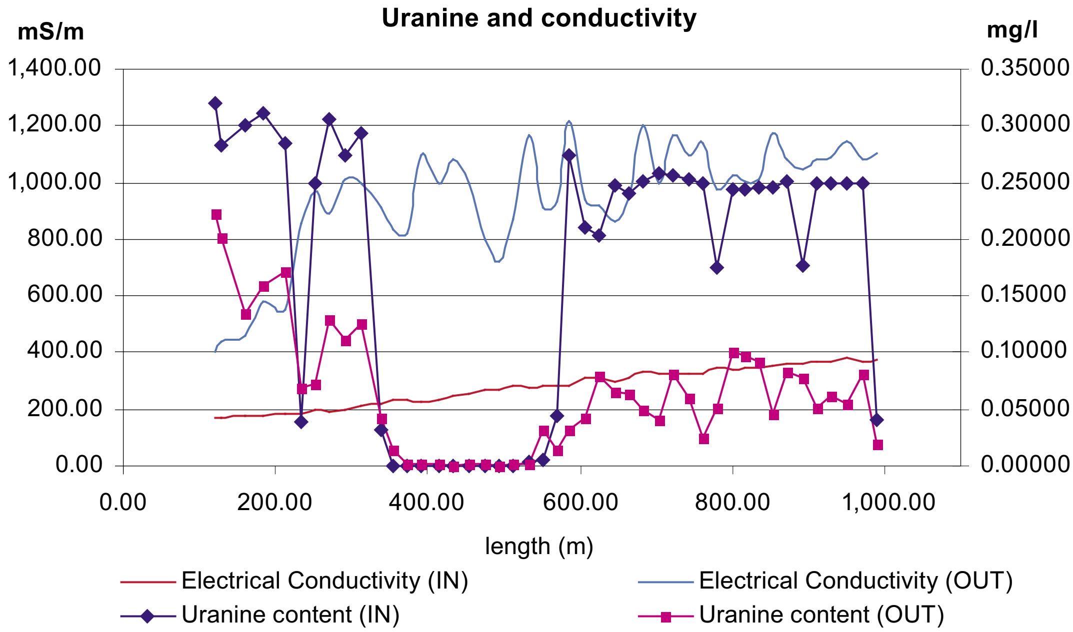


Figure 5-14. *The uranine concentration and electric conductivity of flushing water (IN) and returning water (OUT) in KSH03A during drilling. Due to technical problems with the dosage equipment, uranine was not inserted in the flushing water between 312 and 569 m. The problem took a few weeks to rectify but reoccurred shortly before 1,000 m.*

5.4.3 Air lift pumping results

After drilling to full depth the borehole was flushed with water and airlift pumping tests were conducted for a period of about 33 minutes for the drawdown phase. The net outflow was about 180 l/min for the later part of the pumping causing a total drawdown of 9 m. The airlift pumping and recovery curve is shown in Figure 5-15.

From this a steady state transmissivity was calculated according to /4/, $T_M = 5.4 \times 10^{-4}$ m²/s and a specific capacity of $Q/s = 3.33 \times 10^{-4}$ m²/s.

Air lift pumping tests were performed in the uppermost part of the cored borehole and when the hole was drilled to full depth. Transmissivities, according to /4/, were calculated on the drawdown phase. The results are given in Table 5-11.

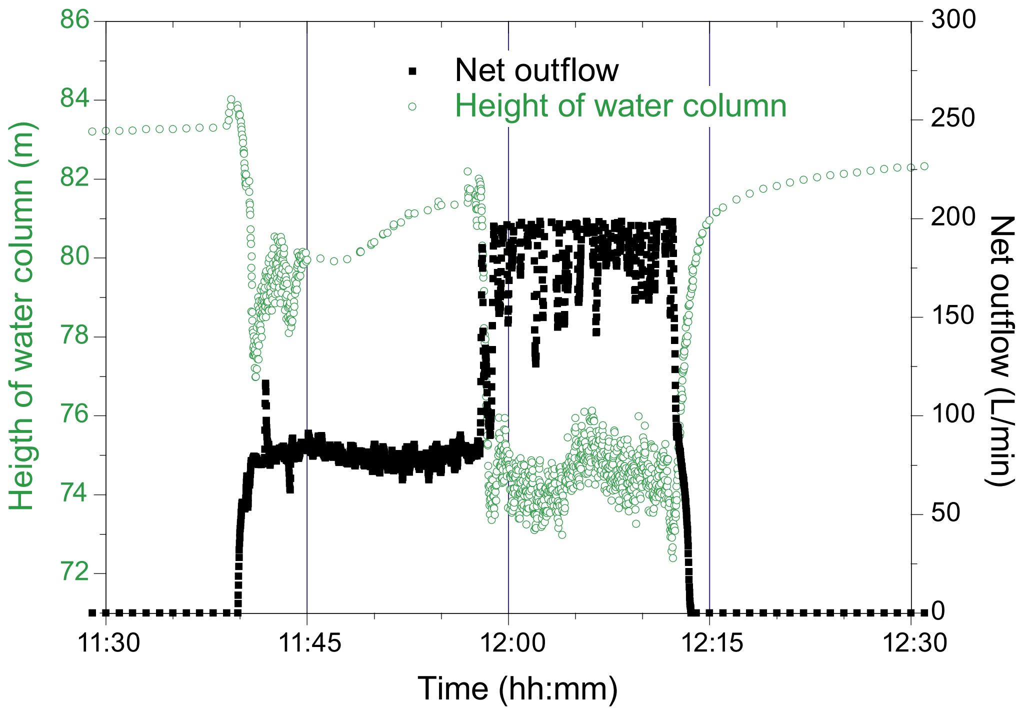


Figure 5-15. *Air lift pumping in KSH03A 101.26–1,000.7 m showing the net outflow rate and the height of the water column in the telescopic part of the borehole. The pressure transducer was positioned 90 metres below top of casing. The flow rate was measured at the ground surface.*

Table 5-11. Specific capacity and transmissivity derived from air lift pumping tests conducted in borehole KSH03A.

Section	T_M (m²/s)
101.26–105.0 m	8.0 10^{-6}
101.26–157.7 m	4.8 10^{-5}
101.26–1,000.7 m	5.4 10^{-4}

5.5 Drilling monitoring results

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 5-16 through 5-18 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 drillstem).
- Hydraulic indication – this parameter is defined as penetration rate divided by flushing water flow.

In order to maintain reasonable size data files, a reduction in the number of points incorporated in the pictures has been done in Figures 5-16 through 5-18.

Figure 5-16 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 5-17 shows the flushing water flow (green) entering the hole and the return water flow (red).

Figure 5-18 shows the conductivity of the ingoing flushing water (yellow). The conductivity of the return water (green) shows high peak values that should, in theory, correspond with the presence of saline formation water at depth. The oxygen content of the flushing water (red) is normally low, however several notable exceptions exist. The oxygen meter occasionally indicated relatively high levels (5–10 mg/l) due to technical problems. Only a minute portion of the actual flow passed the oxygen meter. The oxygen level in the flushing water was probably less than 4 mg/l.

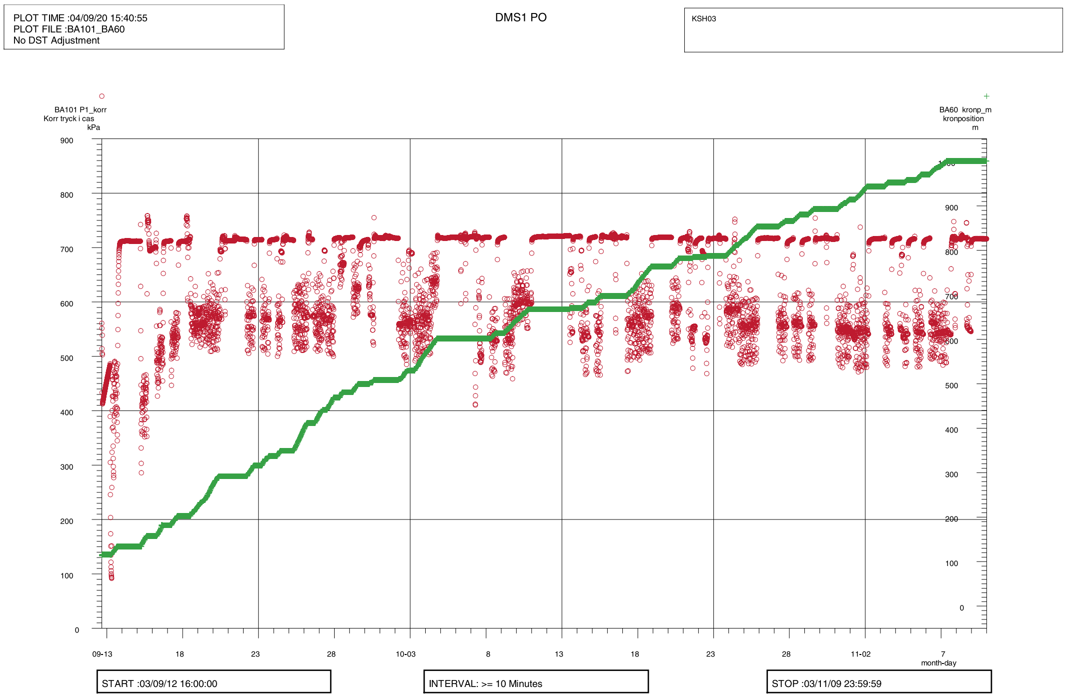


Figure 5-16. *Drill bit position (green) and water level from air-lift pumping (red). The water level is expressed as the pressure in kPa of the water column overlying the pressure gauge ie the ambient air-pressure has been subtracted. The pressure gauge is emplaced at 90.0 metres borehole length. The drill bit position is given in cm×10³.*

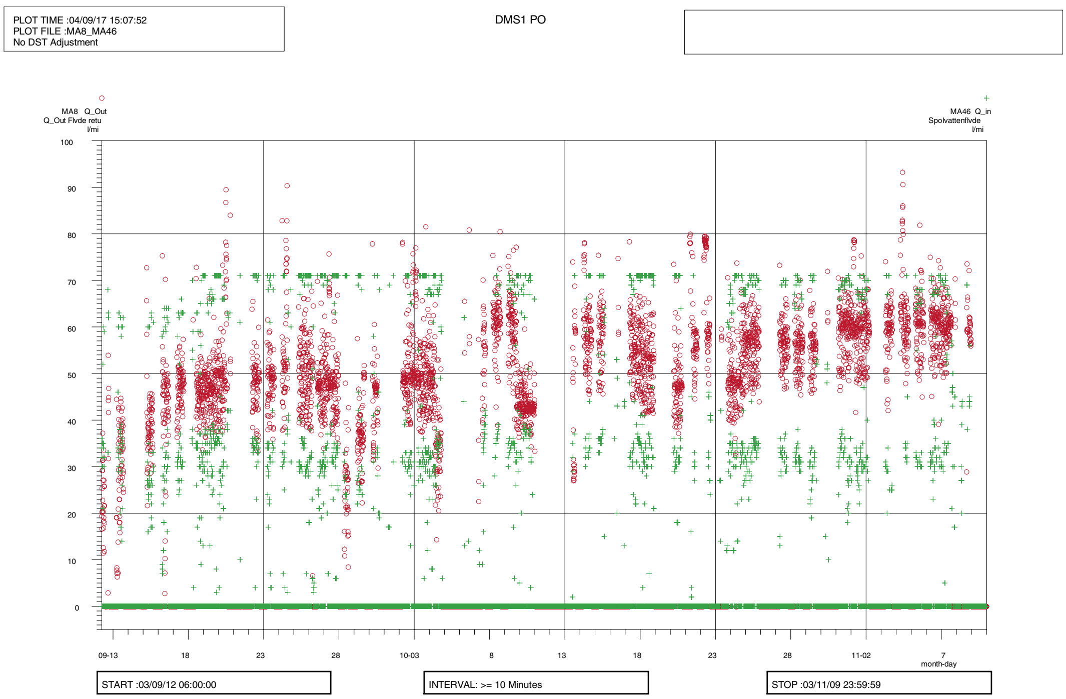


Figure 5-17. *Flushing water flow (green) and return water flow (red) in litres per minute.*

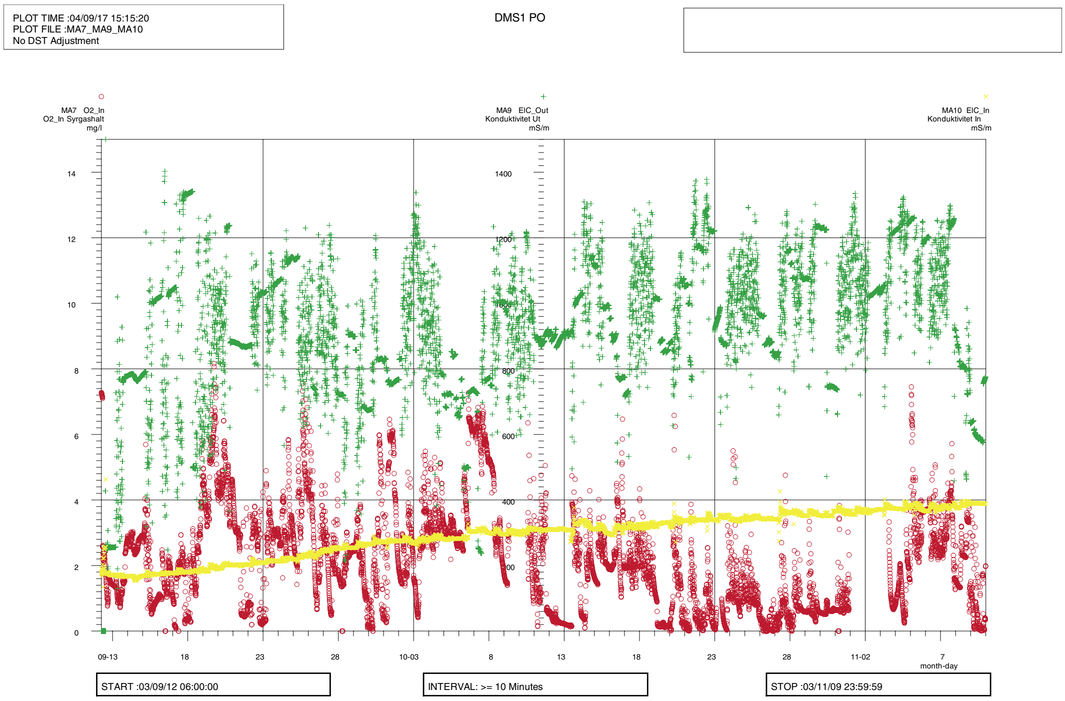


Figure 5-18. *Conductivity of flushing water in mS/m (yellow) and return water (green). The oxygen content in mg/l of the flushing water (red) is also shown.*

5.6.2 Measurements of flushing water and drill cuttings

A calculation of accumulated water flow based on water flow measurements from the DMS system (continuous readings) is given in Figure 5-19.

The amount of effluent return water from drilling in KSH03A was 1,800 m^3, giving an average consumption of 2 m^3 per metre drilled.

The weight of cuttings in the settling containers amounted to 1,900 kg. The theoretical amount that should be produced from drilling with 76 mm triple tubing over a length of 900 metres is 5,700 kg assuming a density of 2.65 kg/dm^3.

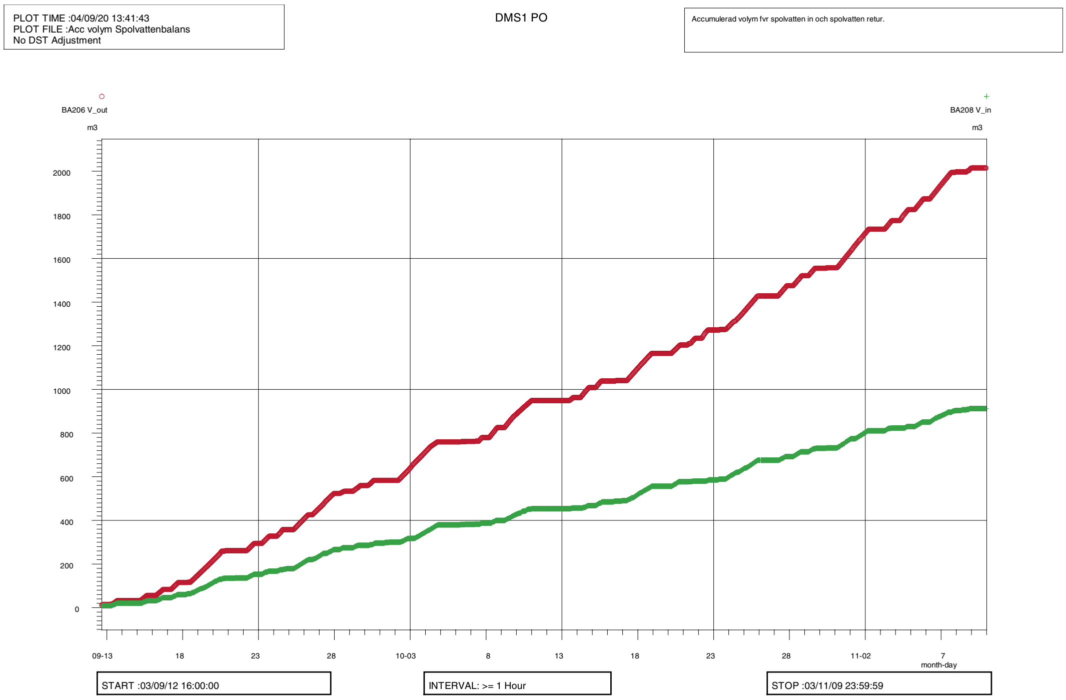


***Figure 5-19.** Flushing water balance from KSH03A as recorded by the DMS system. The accumulated volume of the ingoing flushing water is shown in green and the outgoing return water is shown in red.*

5.6 Geology

The geological results, based on the Boremap logging /7/, are shown in Appendix 1.

The upper part of the core to a length of 270 metres is dominated by quartz monzodiorite with sections of up to 30 metres of Ävrö granite. From 270 metres to full depth the core consists of Ävrö Granite with intercalated portions of fine-grained granite with up to 20 metres width. Minor segments of granite, diorite/gabbro and pegmatite occur. Oxidation with medium to weak intensity is prevalent in the upper 360 metres of the core. At greater depth both the extent and intensity of oxidation is greatly reduced.

The total fracture frequency is normally less than 20 per metre to ca 190 metres. Several thin crushed sections (ie total fracture frequency > 40 per meter) have been noted between 190 and 290 metres length. This interval also corresponds with an overall increase in total fracture frequency. The total fracture frequency is significantly lower below 290 metres length.

5.7 Data handling

Data collected by the drilling contractor and the SKB drill coordinators were reported in daily logs and other protocols and delivered to the Activity Leader. The information was entered to SICADA (SKB database) by database operators. The field note number for entry into SICADA is:

- KSH03A Field note Simpevarp 125.
- KSH03B Field note Simpevarp 186.

5.8 Environmental control

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

All waste generated during the establishment, drilling and completion phases have been removed and disposed of properly. Water effluent from drilling was led to the Baltic Sea in accordance with an agreement with environmental authorities.

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.

5.8.1 Consumption of oil and chemicals

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

The concrete consumption was 2,400 kg in total. The concrete was based on white silica, low alkaly cement.

5.9 Nonconformities

Date	Reported by	Nonconformity
2003-10-10	Matti Alaverronen, SMOY	On October 3 at 23.03 the logged length of the hole was 262.65 metres. The correct value should have been 562.63 metres. The erroneous values were logged until 2003-10-04 at 02:02 when correct values (568.90 metres) were entered by the drill crew.
2003-12-29	Matti Alaverronen, SMOY	Drilling of KSH03B from the ground surface to fresh rock was done with other dimensions than the ones described in the Activity Plan. The hole was drilled with NQ3/50 to 10 metres. The hole was then reamed to 96 mm and a stainless steel casing of diameter 89/77 mm was installed. Gap injection was subsequently made with low alkali concrete.
2004-04-20	Stefan Sehlstedt, SKB	The reference level for measurements during drilling in hole KSH03B (and KSH01B) has not been top-of-casing. Instead the reference level for drilling was the surface of the concrete pad.

6 References

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

/2/ **SKB, 2001.** Geovetenskapligt program för platsundersökning vid Simpevarp. SKB R-01-44, Svensk Kärnbränslehantering AB.

/3/ **SKB, 2004.** Pumping tests and flow logging in boreholes KSH03A and HSH02. SKB P-04-212, Svensk Kärnbränslehantering AB.

/4/ **Moye D G, 1967.** Diamond drilling for foundation exploration. Civil Eng. Trans., Inst. Eng, Australia.

/5/ **SKB, 2004.** Drilling of cored borehole KSH01. SKB P-03-113, Svensk Kärnbränslehantering AB.

/6/ **SKB, 2004.** Control of microorganism content in flushing water used for drilling 2003-11-25. SKB P-04-038, Svensk Kärnbränslehantering AB.

/7/ **SKB, 2004.** Boremap mapping of core drilled boreholes KSH03A and KSH03B. SKB P-04-132, Svensk Kärnbränslehantering AB.

Appendix 1

Geology and MWD parameters KSH03A

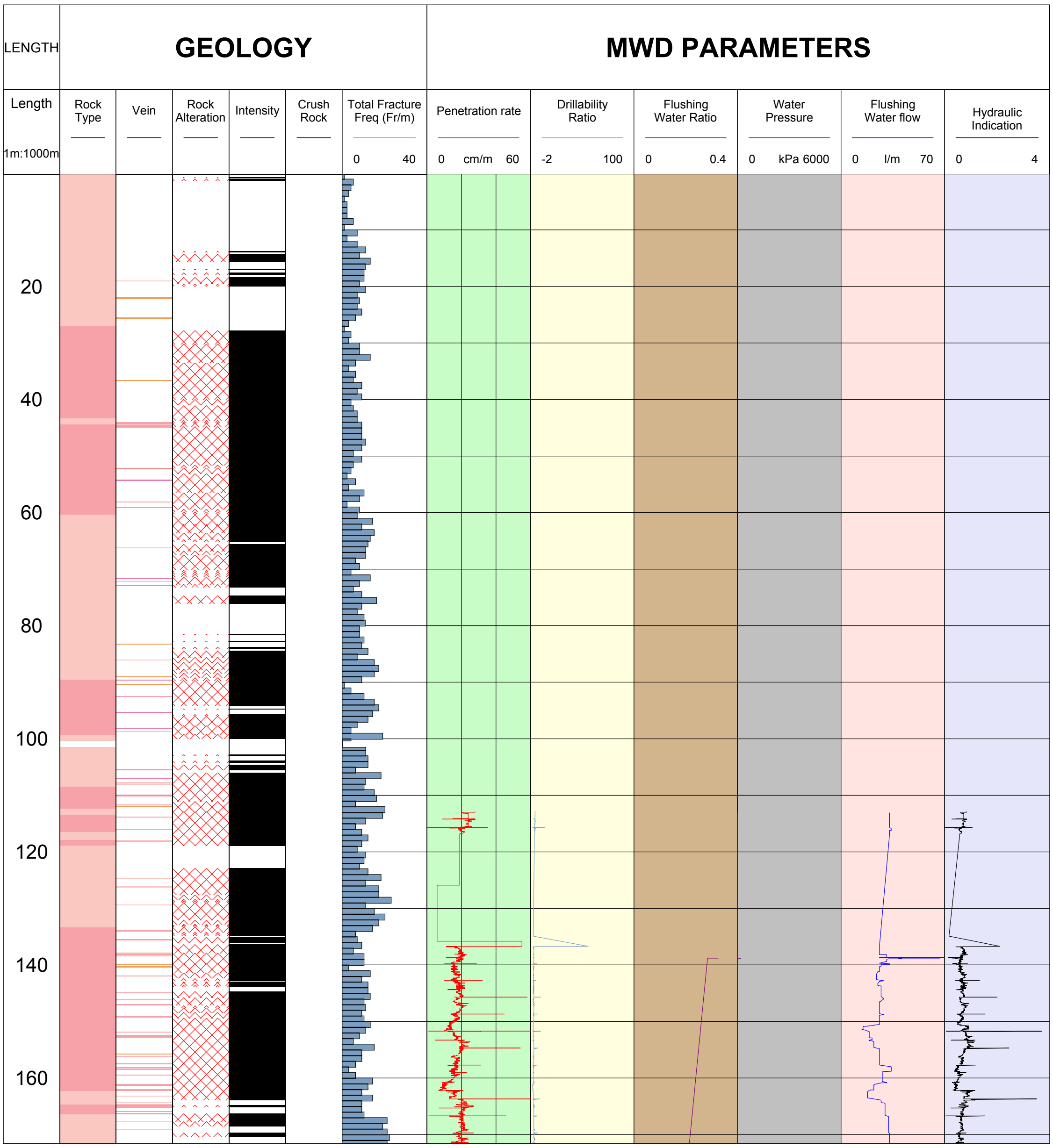
Title	GEOLOGY & MWD PARAMETERS KSH03A + B	Appendix 1

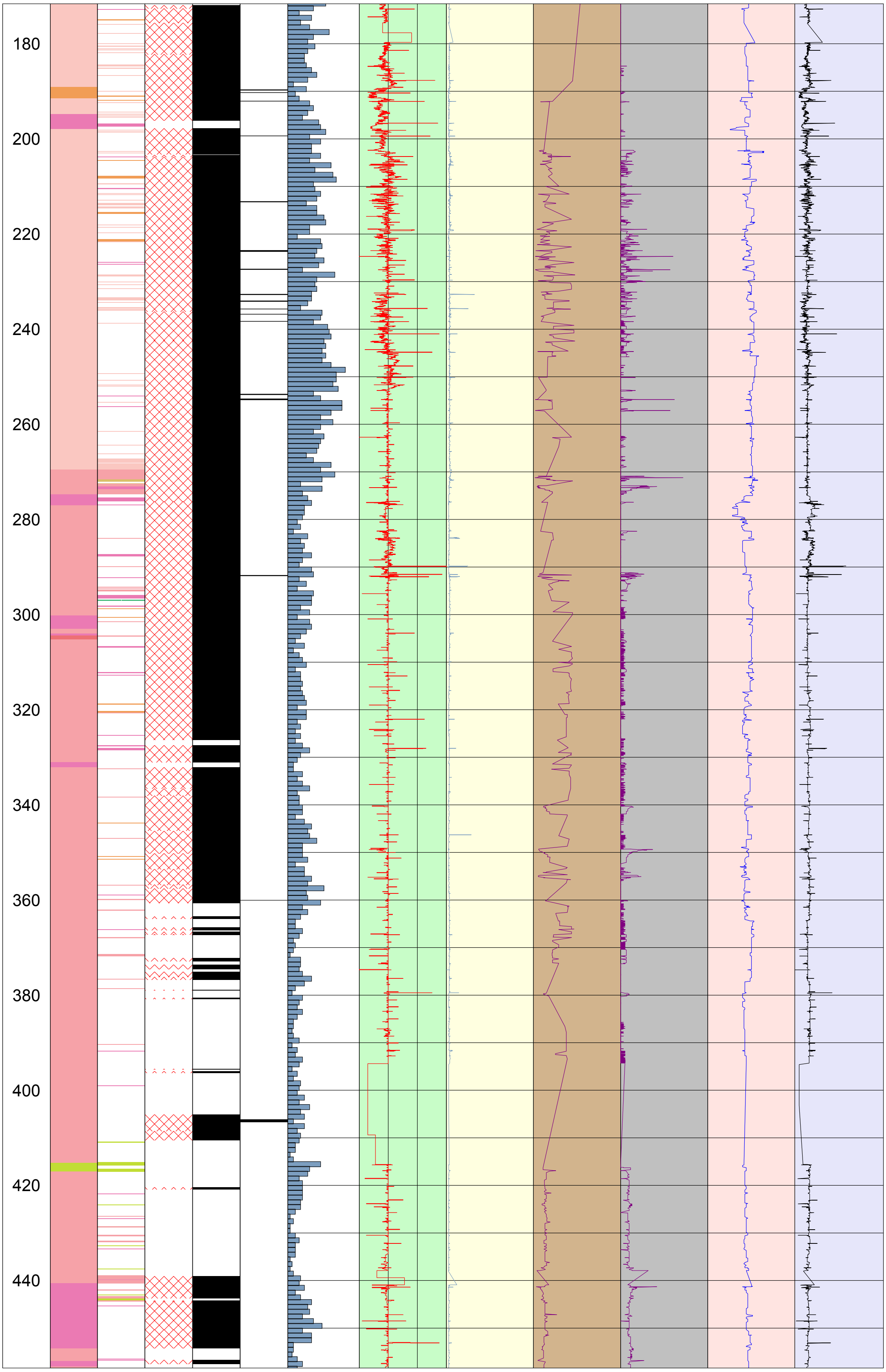
Site	SIMPEVARP	**Coordinate System**	RT90-RHB70
Borehole	KSH03A + B	**Northing [m]**	6366018.66
Diameter [mm]	76	**Easting [m]**	1552711.17
Length [m]	1000.700	**Elevation [m.a.s.l.]**	4.15
Bearing [°]	125.02	**Drilling Start Date**	2003-08-13 07:00:00
Inclination [°]	-59.09	**Drilling Stop Date**	2003-11-07 08:30:00
Date of mapping	2004-01-16 10:45:00	**Plot Date**	2004-10-11 21:04:14

ROCKTYPE SIMPEVARP
- Fine-grained granite
- Pegmatite
- Granite
- Ävrö granite
- Quartz monzodiorite
- Diorite / Gabbro

ROCK ALTERATION
- Oxidized
- Epidotisized

INTENSITY
- Faint
- Weak
- Medium

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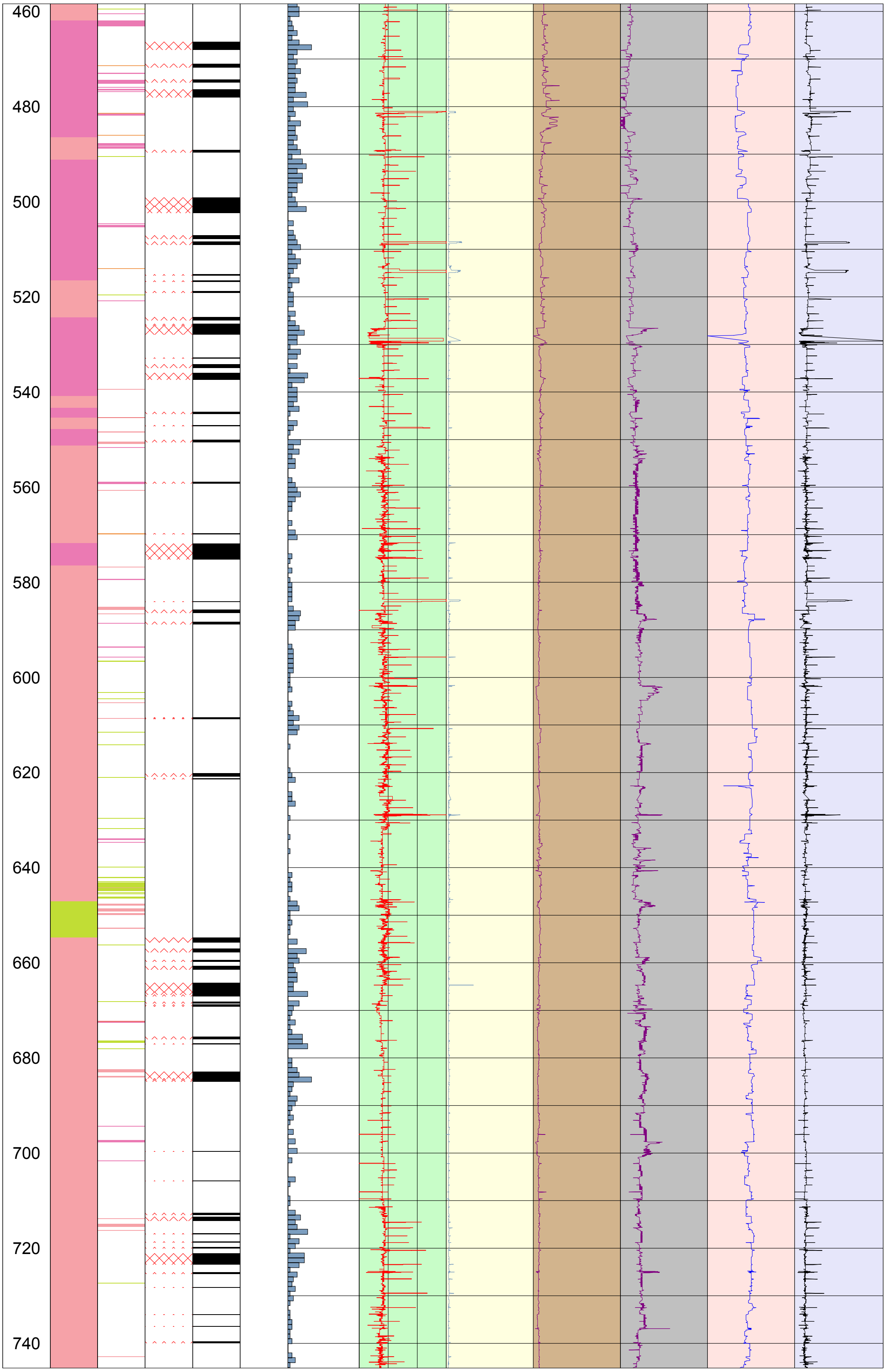
200
220
240
260
280
300
320
340
360
380
400
420
440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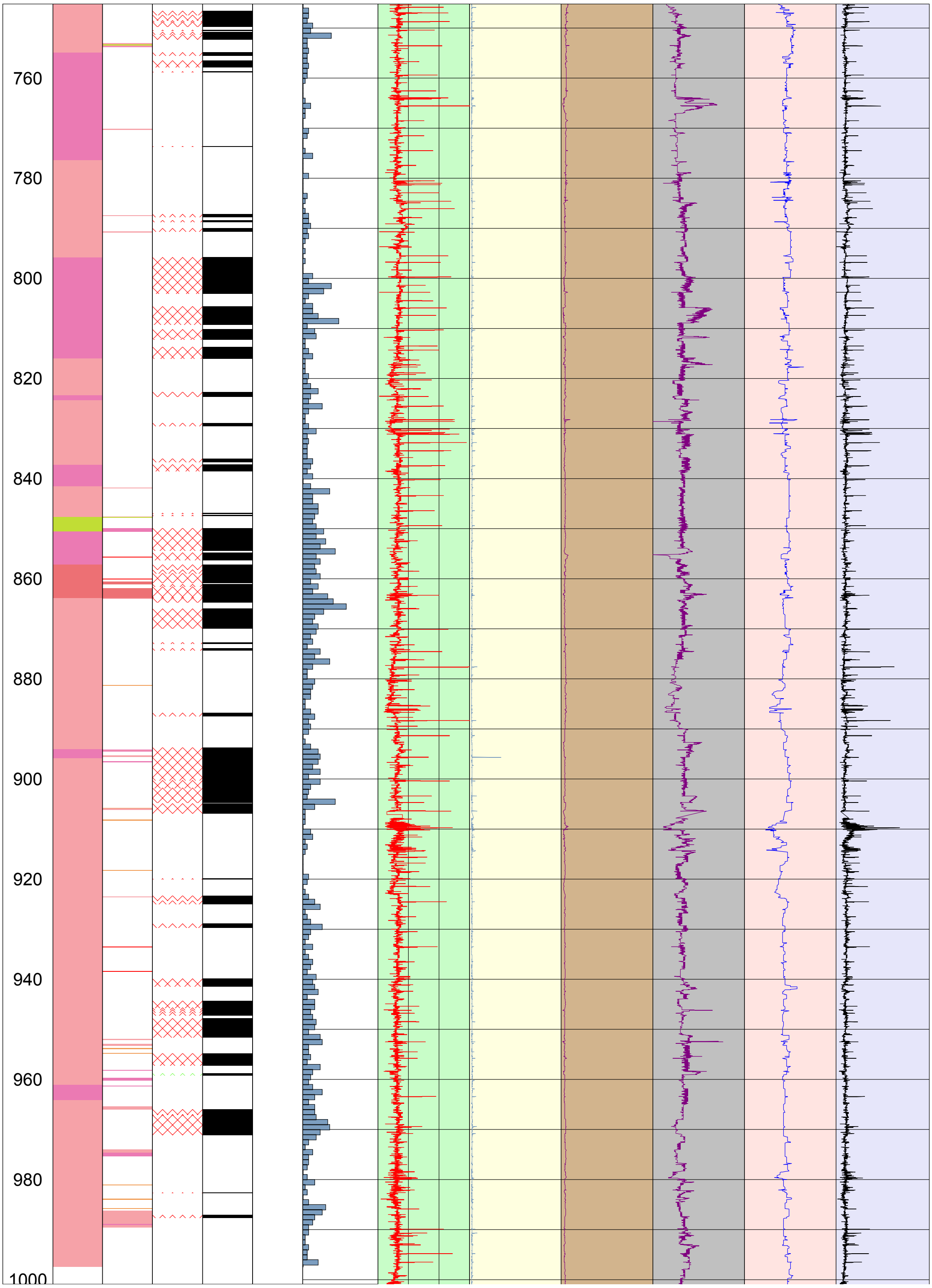
480
500
520
540
560
580
600
620
640
660
680
700
720
740


760
780
800
820
840
860
880
900
920
940
960
980
1000

Appendix 2

Chemical results

Borehole	KSH03A	KSH03A	KSH03A	KSH03A	KSH03A	KSH03A	KSH03A	HSH03
Date of measurement	2003-08-21	2003-08-21	2003-08-21	2003-09-21	2003-10-16	2003-10-23	2003-10-31	2003-09-16
Upper section limit	0.00	0.00	0.00	200.60	599.00	698.00	788.00	0.00
Lower section limit	100.60	100.60	100.60	291.88	698.00	788.00	893.00	200.00
Sample_no	5799	5800	5801	5860	5908	5912	5964	5858
Groundwater Chemistry Class	3	3	3	3	3	3	3	3
pH	7.68	7.77	7.72	7.37	7.59	7.57	7.61	8.02
Conductivity mS/m	248.5	171.8	204.6	1433.0	305.5	343.3	358.5	199.1
TOC mg/l	7.1	7.5	7.4					
Drill water %				22.48	0.56	90.12	92.10	0.03
Na mg/l	345.0	254.0	292.0	1680.0				312.0
K mg/l	7.65	6.87	6.94	11.10				4.93
Ca mg/l	124.0	68.1	93.8	1340.0				66.1
Mg mg/l	29.1	18.0	22.8	78.7				12.1
HCO3 mg/l Alkalinity	236	238	240	47	149	156	161	205
Cl mg/l	644.4	329.3	510.0	5075.8	882.8	985.2	1044.8	462.9
SO4 mg/l	74.15	50.94	63.71	511.37	125.46	138.30	151.68	
SO4_S mg/ Total Sulphur	27.80	21.50	24.40	152.00				29.80
Br mg/l	2.48	1.36	2.01	20.76	3.68	4.03	4.33	1.90
F mg/l	1.03	1.16	1.10	0.91	1.24	1.21	1.14	1.87
Si mg/l	4.8	5.1	4.8	4.0				4.9
Fe mg/l Total Iron	0.250	3.100	0.204	0.715				0.035
Mn mg/l	2.52	1.90	2.08	0.70				0.12
Li mg/l	0.035	0.026	0.030	0.494				0.037
Sr mg/l	1.56	0.87	1.18	21.10				1.03
PMC % Modern Carbon				40.80				61.00
C-13 dev PDB				–18.7				–17.8
AGE_BP Groundwater age				7155				3920
D dev SMOW	–73.1	–73.9	–74.3	–68.8				–78.3
Tr TU	9.90	9.60	8.80	2.80				7.50
O-18 dev SMOW	–9.90	–10.00	–9.80	–9.20				–10.70
B-10 B-10/B-11	0.240	0.240	0.240	0.240				0.233
S-34 dev SMOW								21.1
Cl-37 dev SMOC	0.12	0.05	0.14					
Sr-87 Sr-87/Sr86				0.716				0.715

Appendix 3

Chemistry – analytical method and quality

Analysis	Sample bottle	Preparation	SKB label	Laboratory
pH, conduktivity, alkalinity	250 ml	Filtering Pallfilter	green	Äspö/field
Anions (F-, Br-, Cl-, SO42-)	250 ml	Filtering Pallfilter	green	Äspö/field
Uranine	100 ml brown glass		green	Äspö/field
Main components (except Fe, Mn)	Analytica's 100 ml acid washed	1 ml HNO3 suprapur, filtering membrane filter	red	Analytica
Archive samples	2 ea 250 ml	Filtering Pallfilter	green	
Option				
Deuterium, O-18	100 ml square		green	IFE
Tritium	1000 ml dried	Flooded at least once	green	Waterloo
Sr-87	100 ml square		green	IFE
Cl-37	Same as for Tritium		green	Waterloo
B-10	Same as for main components	Filtering membrane filter	red	Analytica
C-13, PMC	2×2 st 100 ml brown glass		green	Waterloo and Uppsala
S-34	1,000 ml		green	IFE

Quality of the analyses

The charge balance errors give an indication of the quality and uncertainty of the analyses of the major components. The relative charge balance errors are calculated for the selected sets of data from the borehole. The errors do not exceed ± 5% in any of the samples (5799, 5801, 5858 and 5860) which is fully satisfactory. The sample 5858 was not analysed for SO_4^{2-} so the charge balance error for this particular sample is a bit uncertain.

In sample 5800 the relative charge balance error are 5.14%.

The samples 5912 and 5964 were not analysed for main components due to the high concentration of flushing water. The relative charge balance errors could not be calculated for these samples.

The sample 5908 were not analysed for main components due to possible lack of water. Therefore the relative charge balance error could not be calculated for this sample.

Figures A1 and A2 illustrate the consistency of the analyses. The figures are based on the data from KSH03A presented in Appendix 2. Electric conductivity values are plotted versus chloride concentrations in Figure A1.

The bromide and chloride concentrations are plotted in Figure A2. A plot of bromide versus chloride serves as a rough quality control of the bromide analyses.

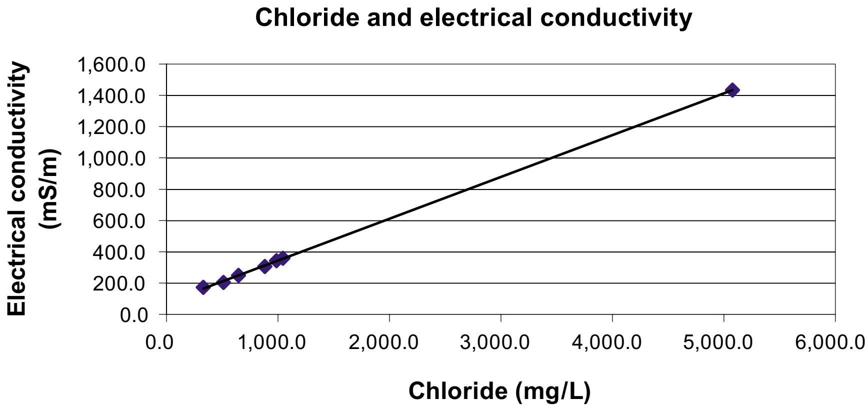


Figure A1. *Plot of electric conductivity versus chloride concentration.*

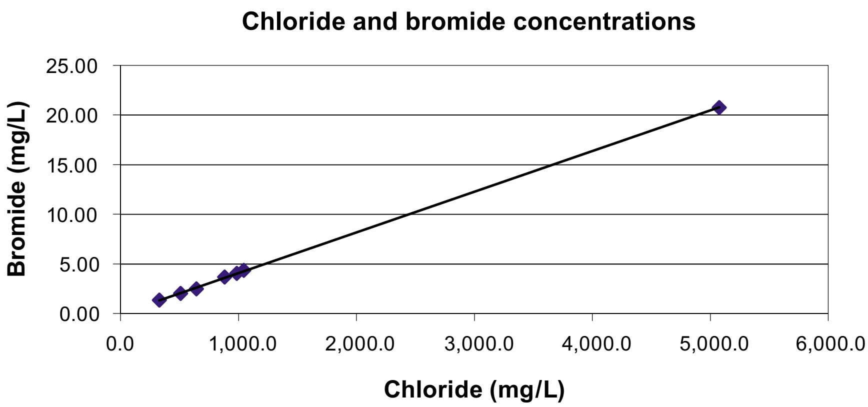


Figure A2. *Plot of bromide concentrations versus chloride concentrations.*

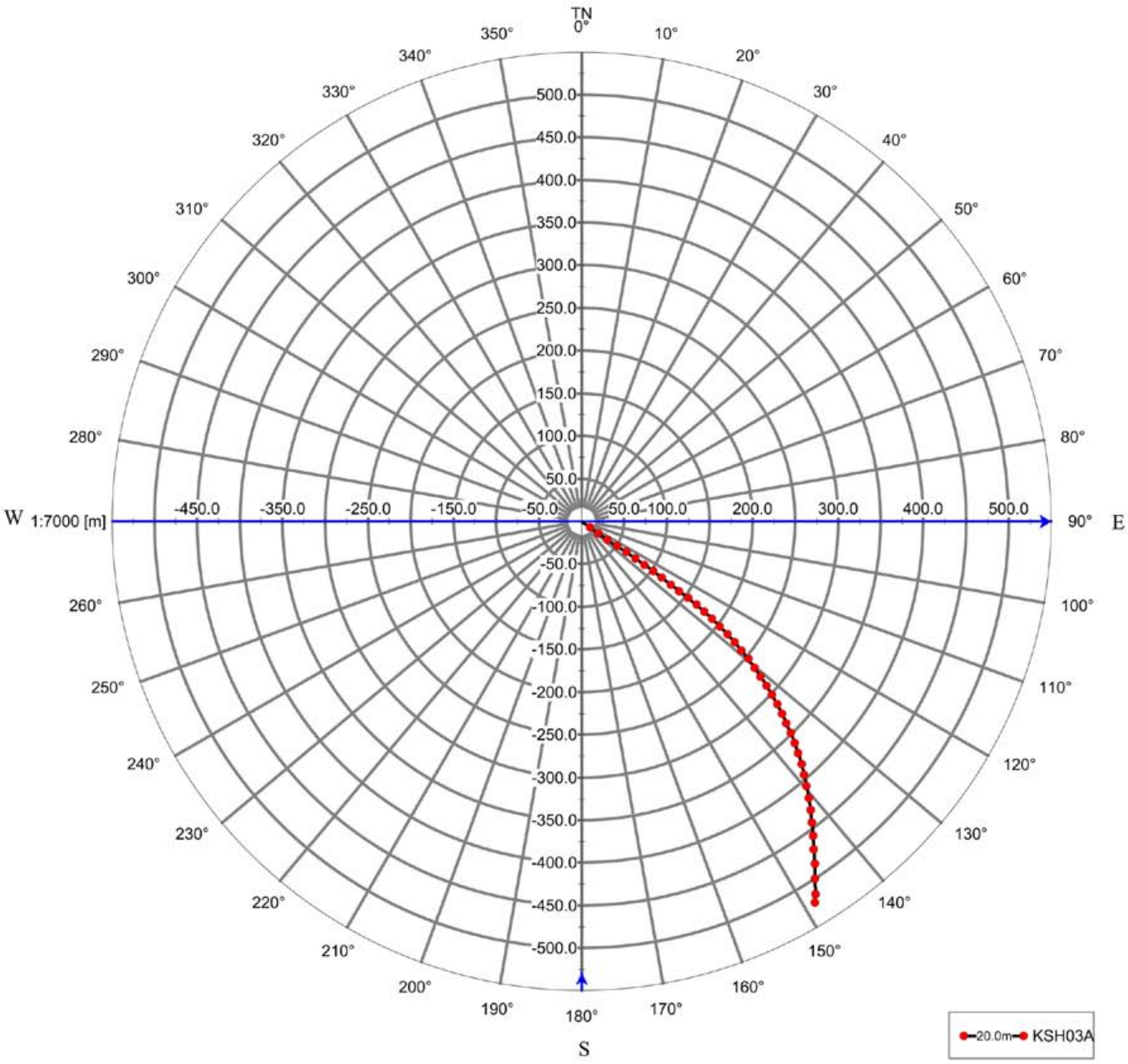
The following routines for quality control and data management are generally applied for hydrogeochemical analysis data, independent of sampling method or sampling object.

- Several components are determined by more than one method and/or laboratory. Control analyses by an independent laboratory are normally performed as a standard procedure on every five or ten collected samples. Control analyses were not done in this case because of the small number of samples taken.
- All analytical results were stored in the SICADA database. The chemistry part of the database contains two types of tables, raw data tables and primary data tables (final data tables).
- Data on basic water analyses are inserted into raw data tables for further evaluation. The evaluation results in a final reduced data set for each sample. These data sets are compiled in a primary data table named "water composition". The evaluation is based on:
  - Comparison of the results from different laboratories and/or methods. The analyses are repeated if a large disparity is noted (generally more than 10%).
  - Calculation of charge balance errors. Relative errors within ± 5% are considered acceptable. For surface waters errors of ± 10%.
  - Rel. Error (%) = $100 \times \frac{(\sum \text{cations(equivalents)} - \sum \text{anions(equivalents)})}{(\sum \text{cations(equivalents)} + \sum \text{anions(equivalents)})}$
  - General expert judgement of plausibility based on earlier results and experiences.

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

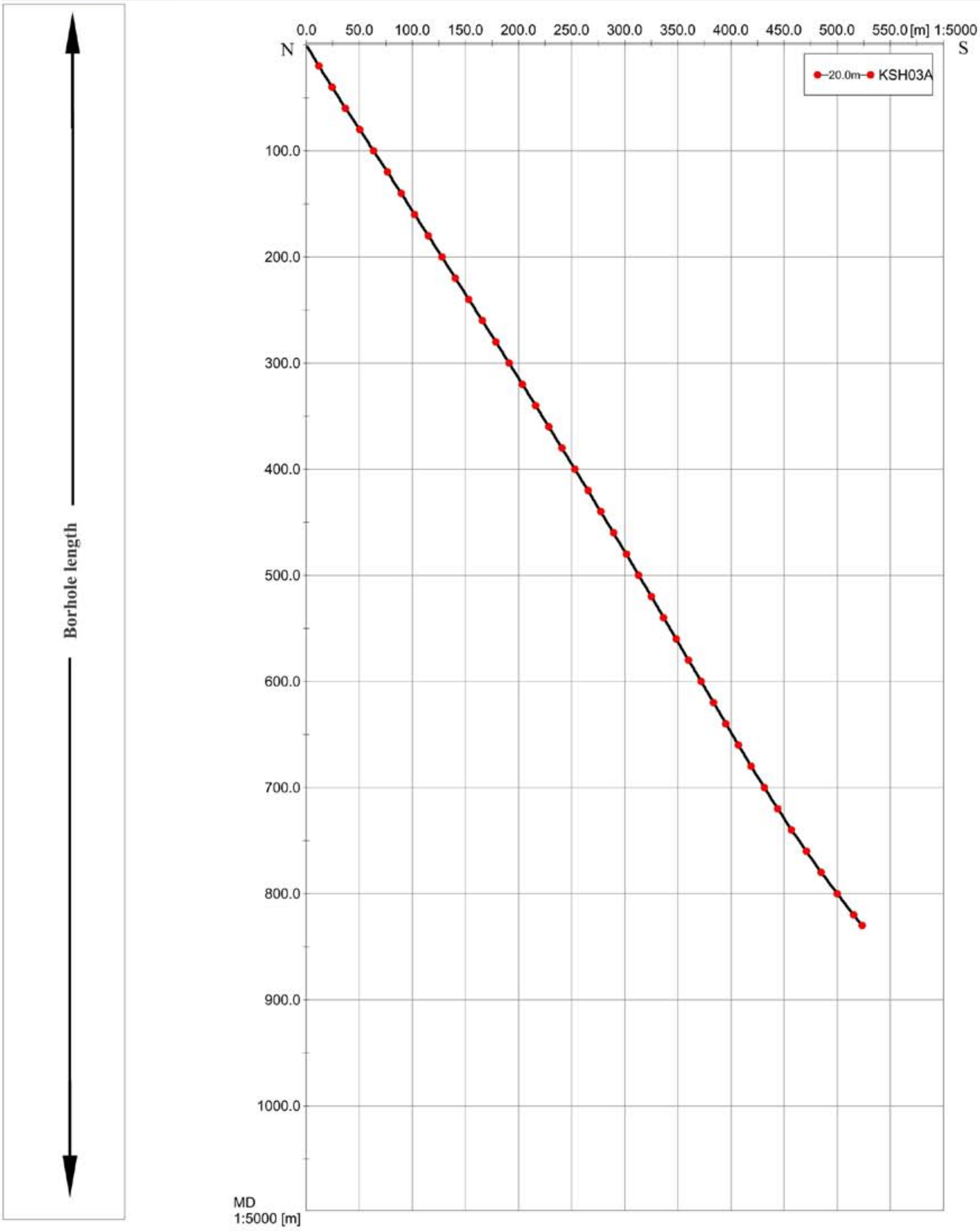
Deviation measurements

Deviation measurement		Appendix: 4
Site	SIMPEVARP	
Borehole	KSH03A	
View from above		



Deviation measurement Appendix: 4

Site SIMPEVARP
Borehole KSH03A
Vertical Section



Appendix 5

Wireline pumping tests

Description of the parameters in the enclosed plots.

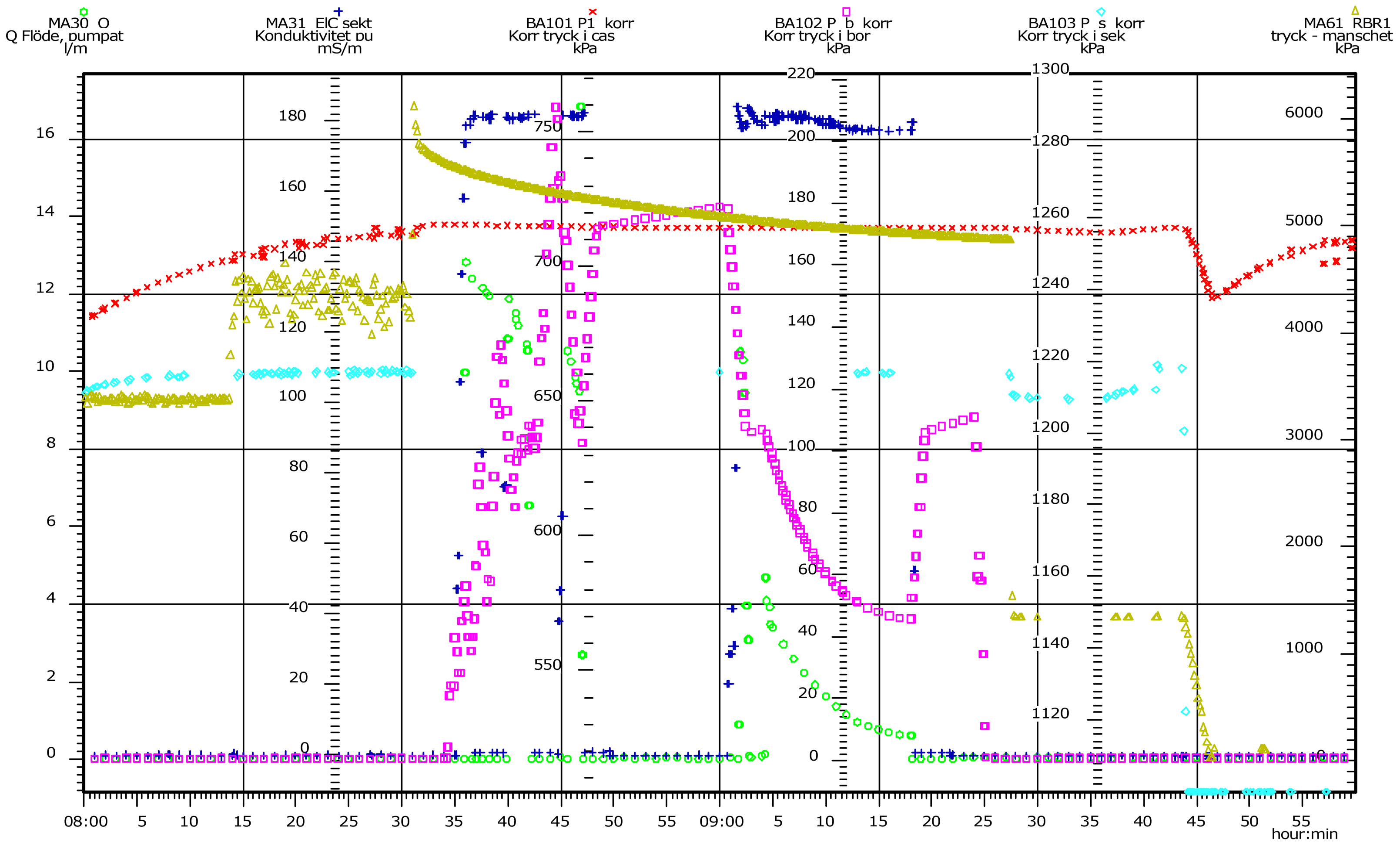
Channel	Parameter	Unit	Description
MA30	Water flow	Litre/minute	Flow of water pumped up from the borehole during the test.
MA31	Electrical conductivity	mS/m	Elctrical conductivity in the pumped out water
BA101	Pressure	kPa	Pressure of the water column in the telescopic section subtracted with the ambient air pressure.
BA102	Pressure	kPa	Pressure of the water column in the test section ie at depth in the borehole, subtracted with the ambient air pressure.
BA103	Pressure – section	kPa	Pressure of the water column in the test section ie at depth in the borehole, subtracted with the ambient air pressure.
MA61	Pressure – packer	kPa	Inflation pressure in packer

PLOT TIME :03/12/14 11:30:07

PLOT FILE :P_pumptest

DMS1 PO

Pumping test
KSH03. 151.00 - 202.35m
Wireline sond



START :03/09/18 08:00:00

INTERVAL: All readings

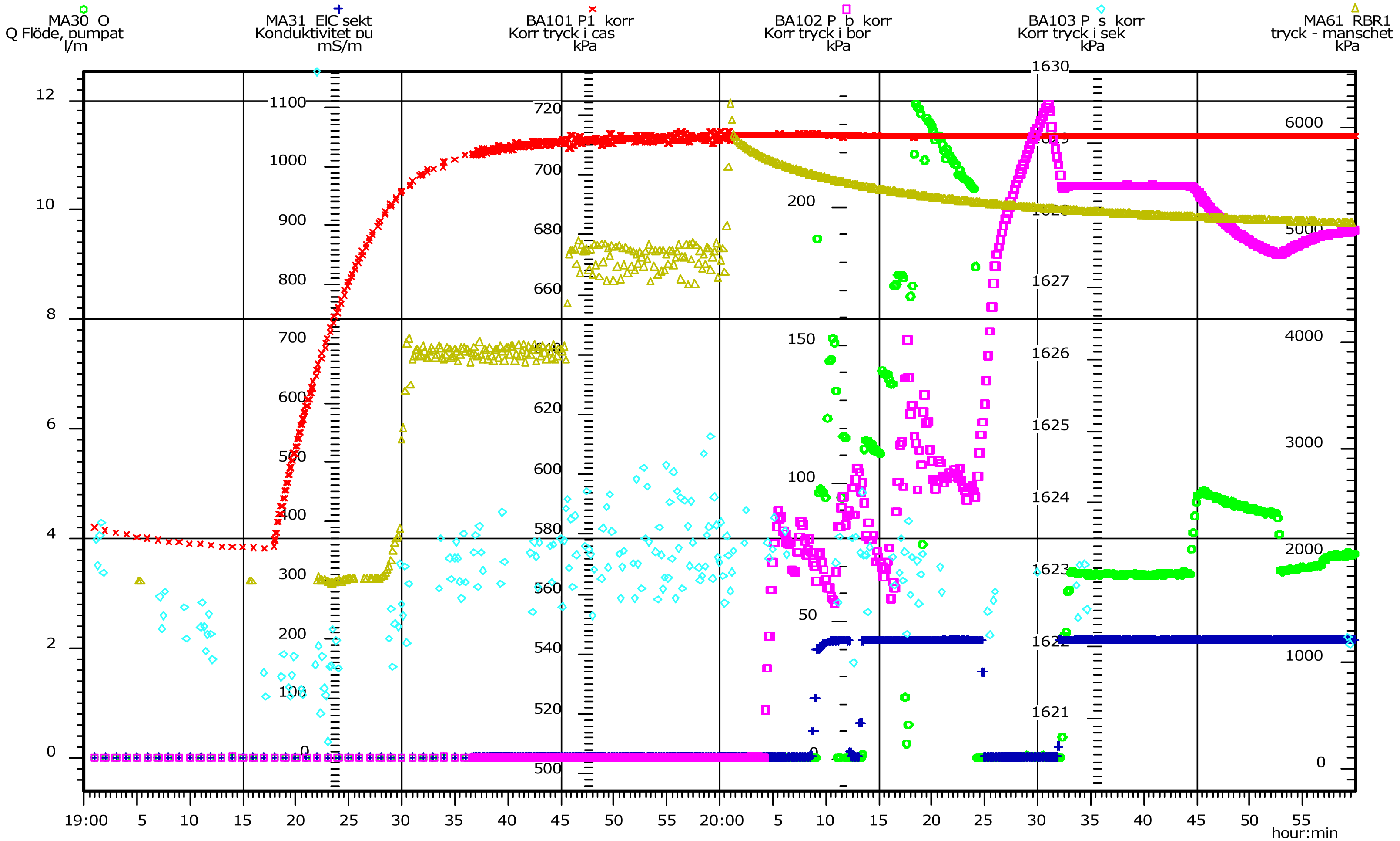
STOP :03/09/18 09:59:59

PLOT TIME :03/12/14 12:49:01

PLOT FILE :P_pumptest

DMS1 PO

Pumping test
KSH03. 199.60 - 291.88m
Wireline sond



START :03/09/20 19:00:00

INTERVAL: All readings

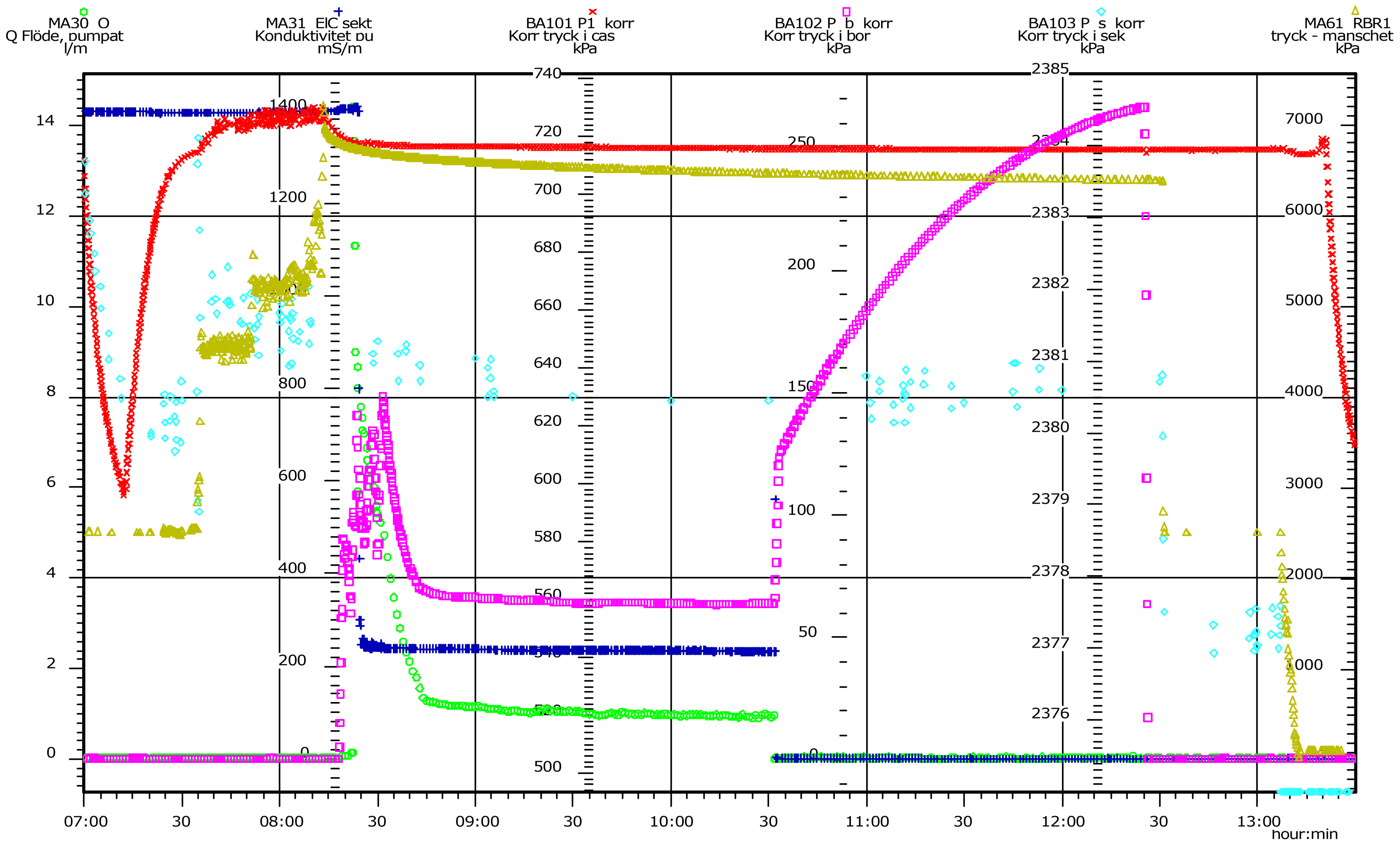
STOP :03/09/20 20:59:59

PLOT TIME :03/12/14 13:27:09

PLOT FILE :P_pumptest

DMS1 PO

Pumping test
KSH03, 290.60 - 411.61m
Wireline sond



START :03/09/26 07:00:00

INTERVAL: All readings

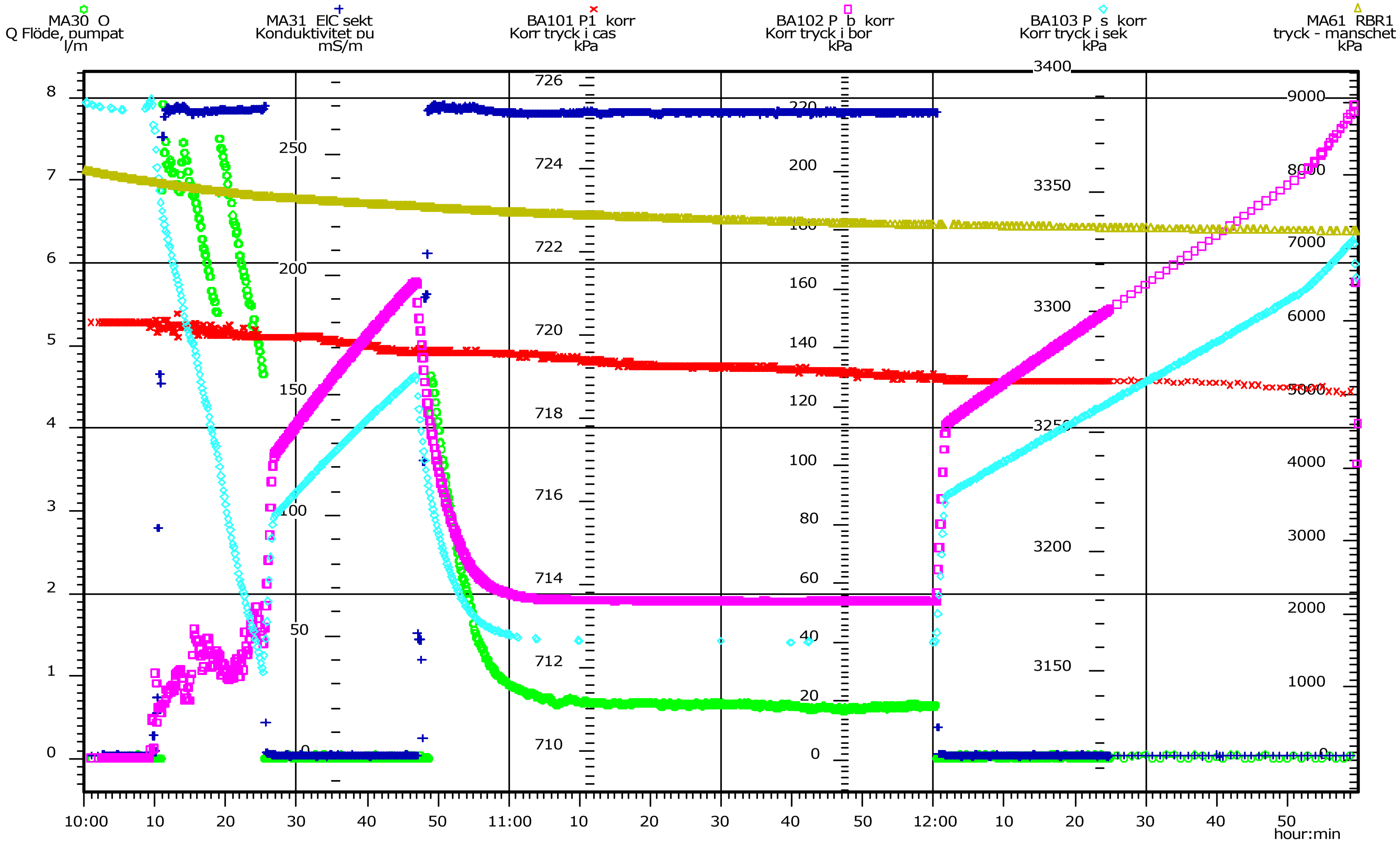
STOP :03/09/26 13:29:59

PLOT TIME :03/12/14 13:59:02

PLOT FILE :P_pumptest

DMS1 PO

Pumping test
KSH03. 409.50 - 508.26m
Wireline sond



START :03/10/01 10:00:00

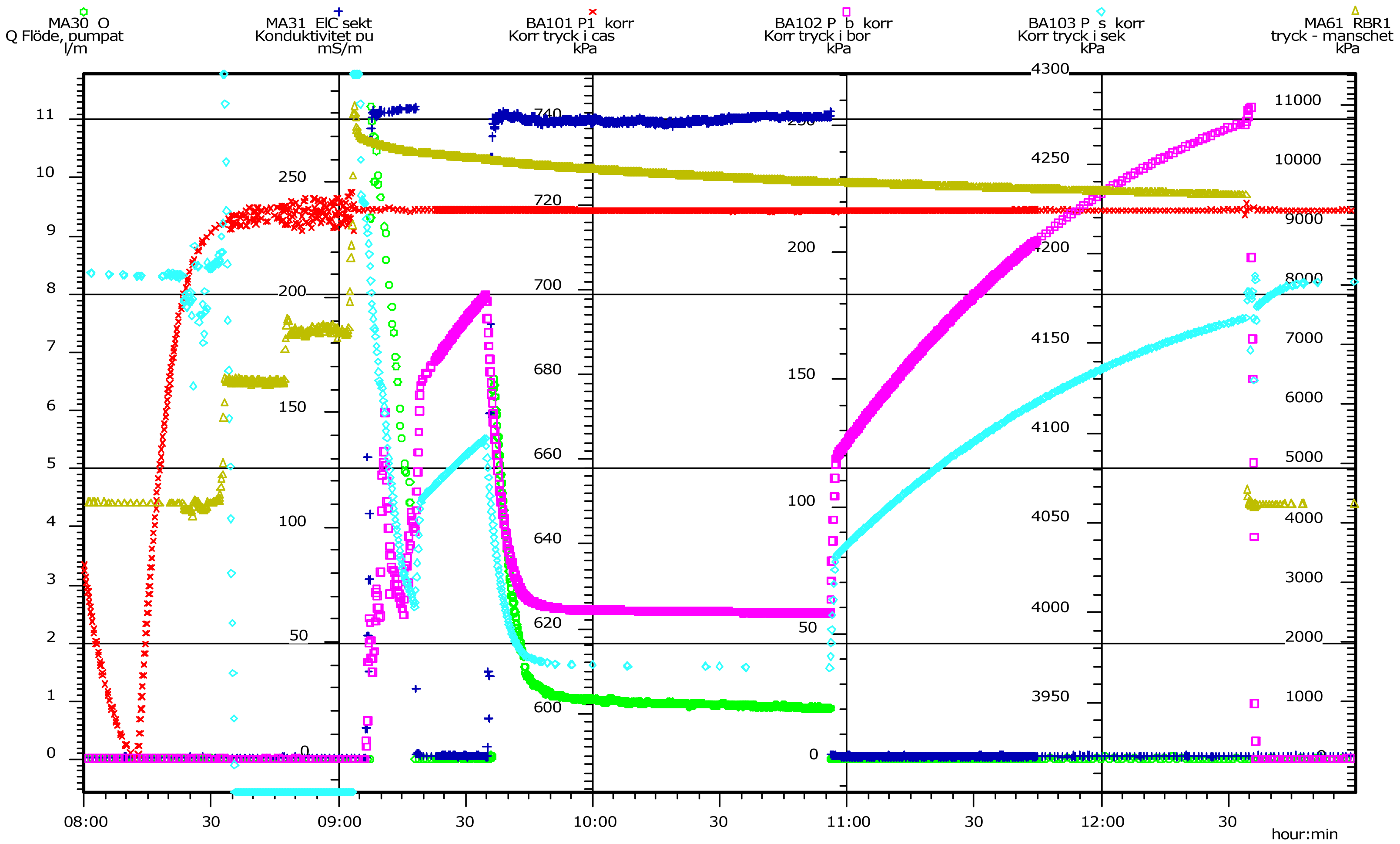
INTERVAL: All readings

STOP :03/10/01 12:59:59

PLOT TIME :03/12/14 14:26:08
PLOT FILE :P_pumptest

DMS1 PO

Pumping test
KSH03. 506.18 - 601.70m
Wireline sond



START :03/10/06 08:00:00

INTERVAL: All readings

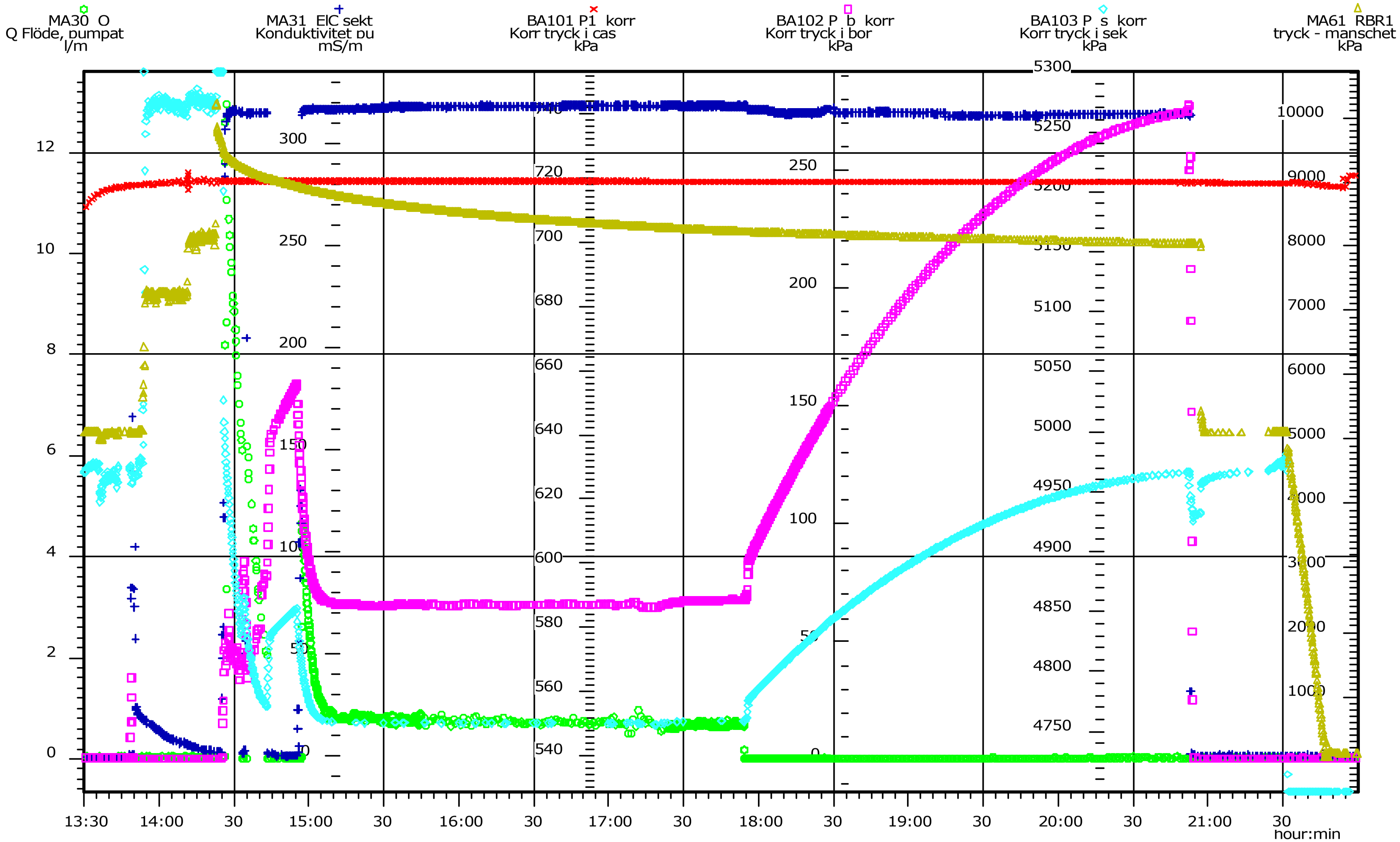
STOP :03/10/06 12:59:59

PLOT TIME :03/12/14 14:47:10

PLOT FILE :P_pumptest

DMS1 PO

Pumping test
KSH03, 599.53 - 697.60m
Wireline sond



START :03/10/16 13:30:00

INTERVAL: All readings

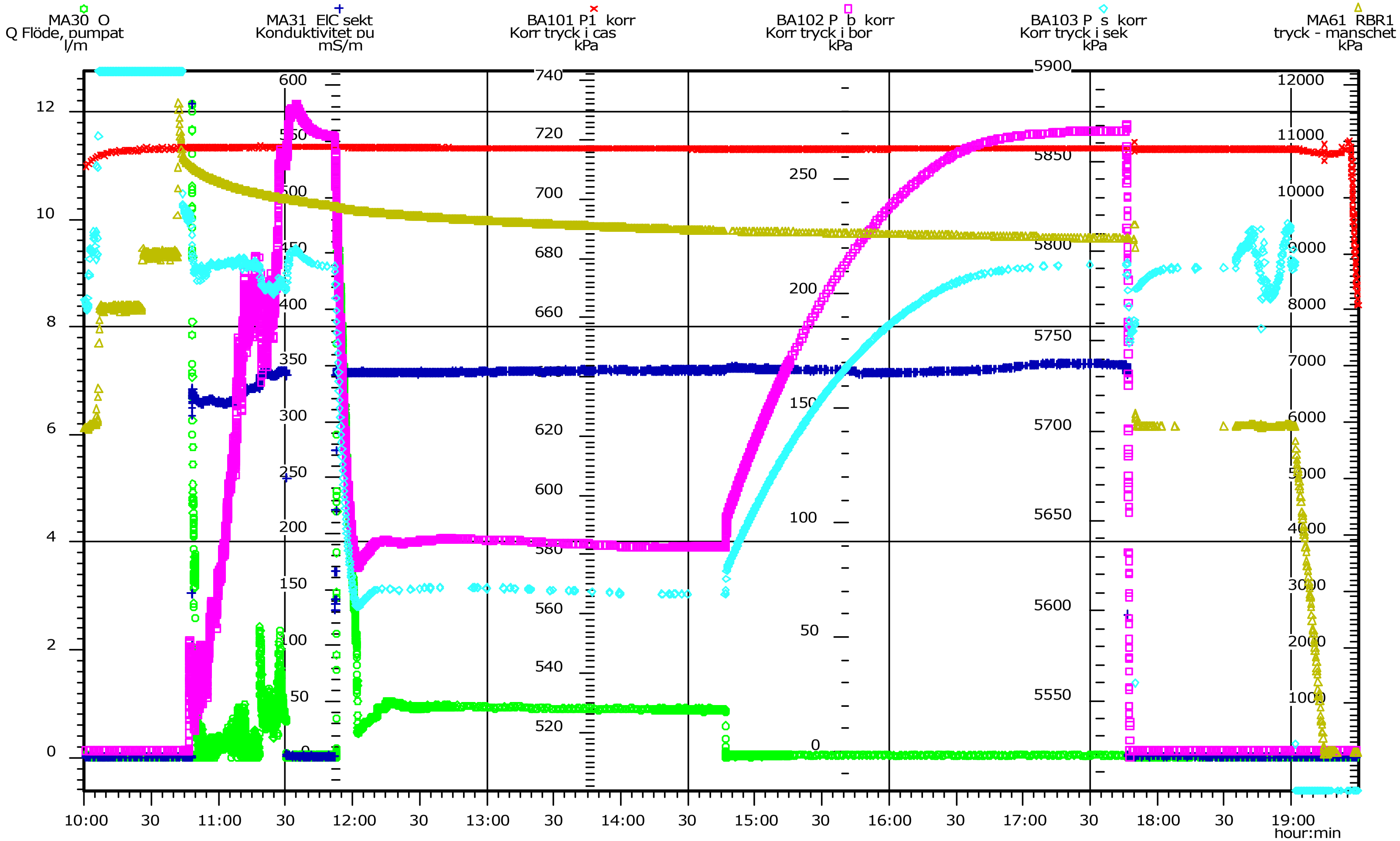
STOP :03/10/16 21:59:59

PLOT TIME :03/12/14 15:02:50

PLOT FILE :P_pumptest

DMS1 PO

Pumping test
KSH03, 697.90 - 787.99m
Wireline sond



START :03/10/23 10:00:00

INTERVAL: All readings

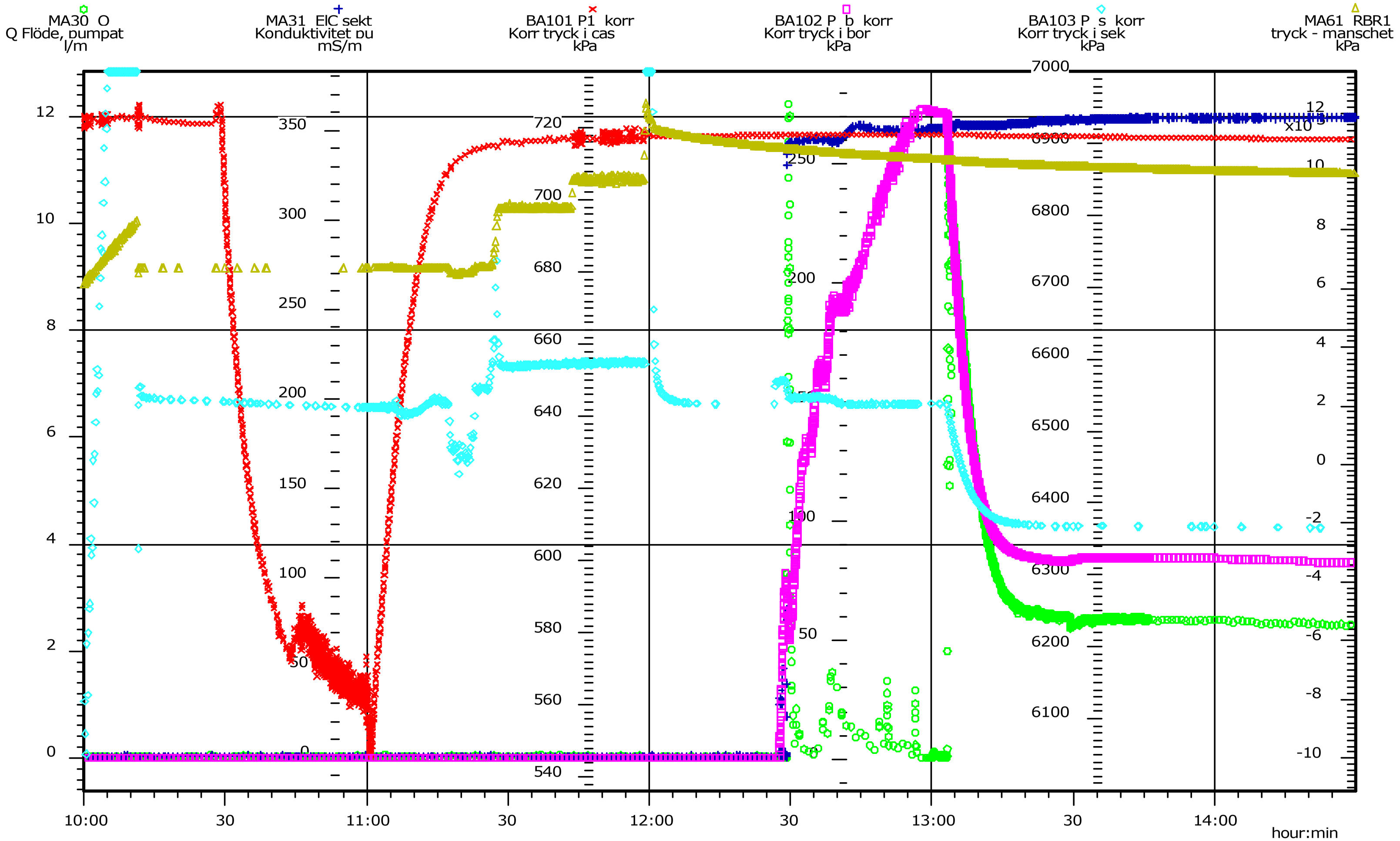
STOP :03/10/23 19:29:59

PLOT TIME :03/12/14 15:31:53

PLOT FILE :P_pumptest

DMS1 PO

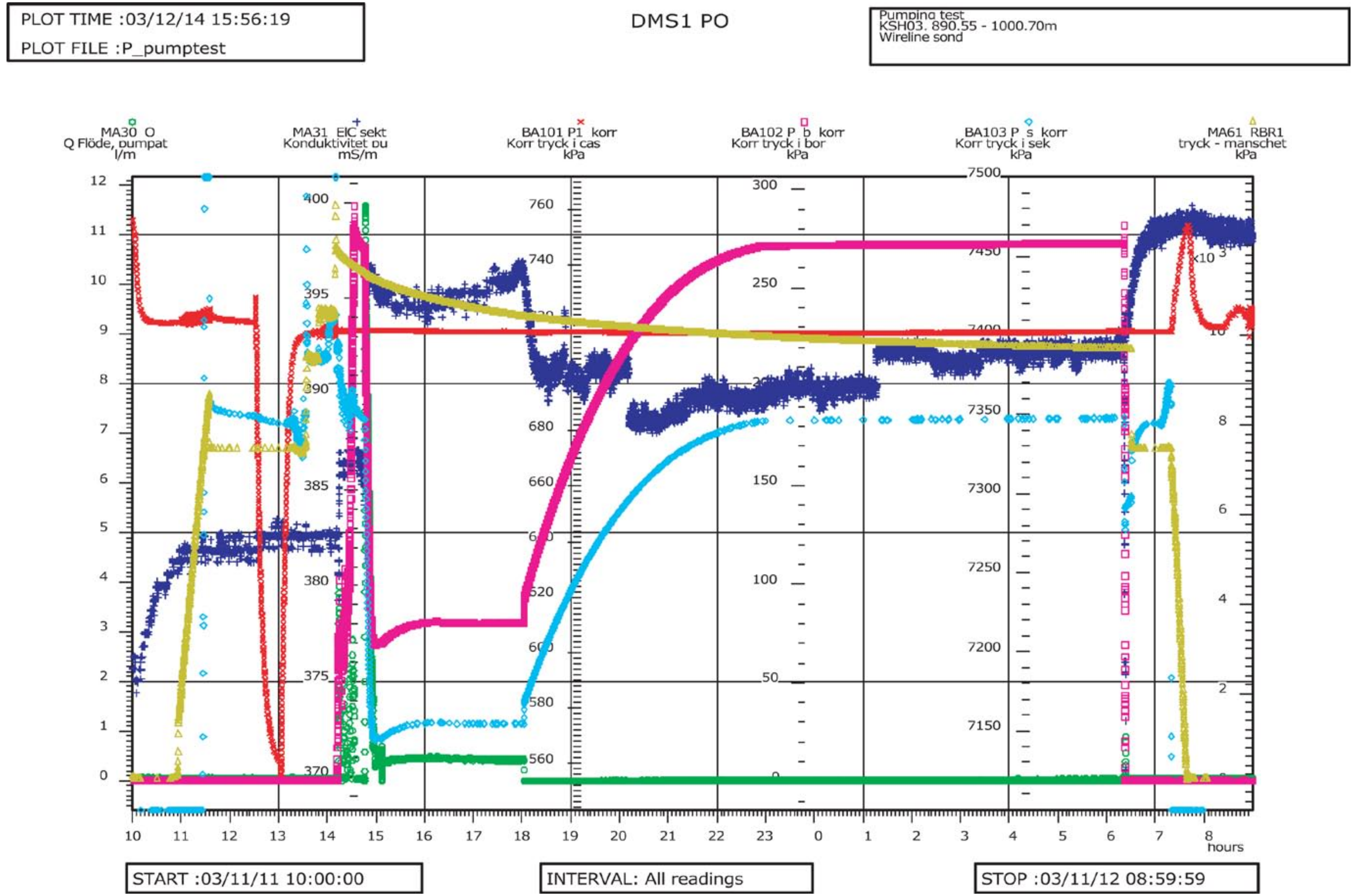
Pumping test
KSH03. 788.35 - 892.55m
Wireline sond



START :03/10/30 10:00:00

INTERVAL: All readings

STOP :03/10/30 14:29:59

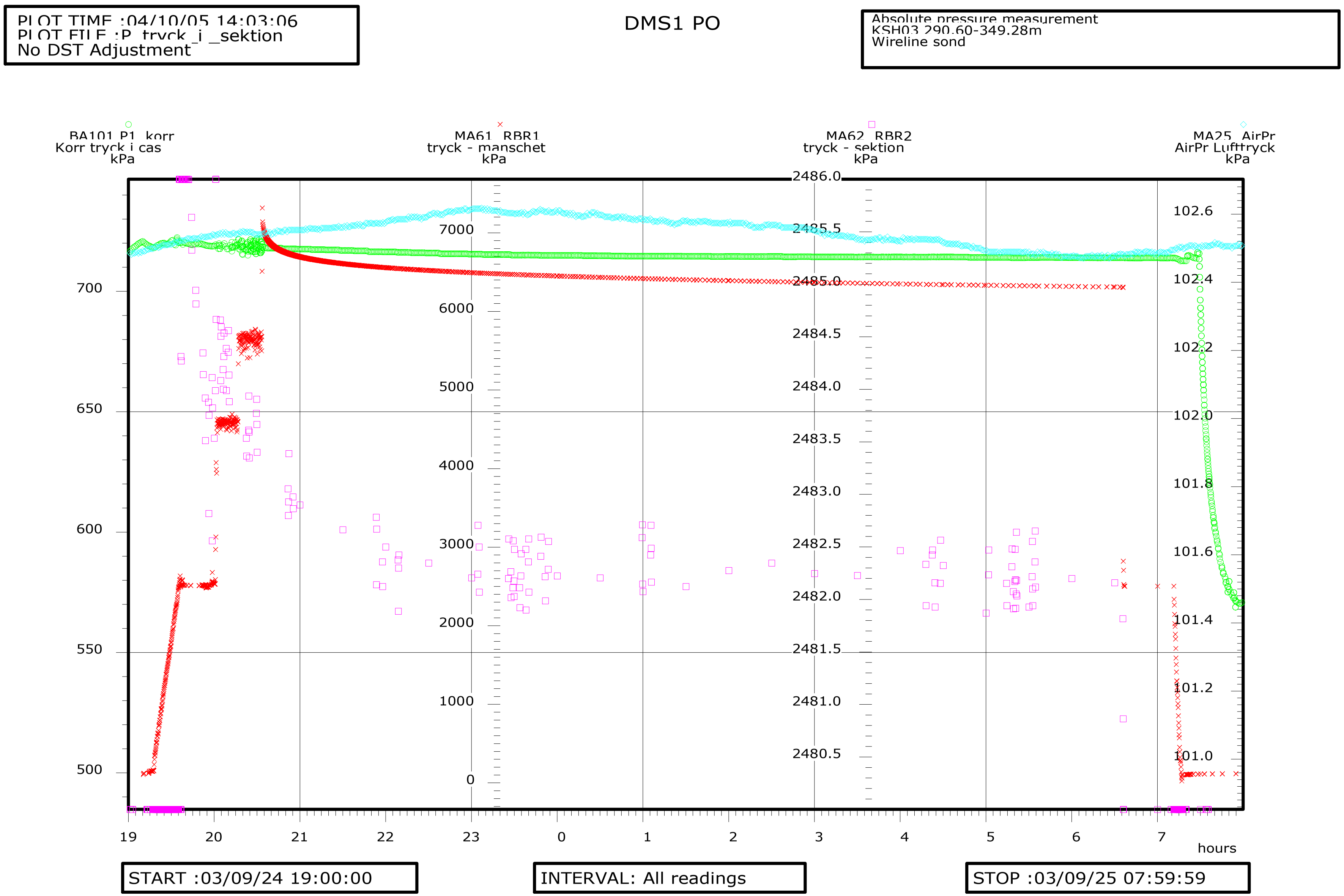

PLOT TIME :03/12/14 15:56:19
PLOT FILE :P_pumptest
DMS1 PO
Pumping test
KSH03. 890.55 - 1000.70m
Wireline sond
MA30 Q
Q Flöde, pumpat
l/m
MA31 EIC sekt
Konduktivitet pu
mS/m
BA101 P1 korr
Korr tryck i cas
kPa
BA102 P b korr
Korr tryck i bor
kPa
BA103 P s korr
Korr tryck i sek
kPa
MA61 RBR1
tryck - manschet
kPa
x10 3
hours
START :03/11/11 10:00:00
INTERVAL: All readings
STOP :03/11/12 08:59:59

Appendix 6

Time series of absolute pressure measurements in borehole KSH03A

Description of the parameters in the enclosed plots.

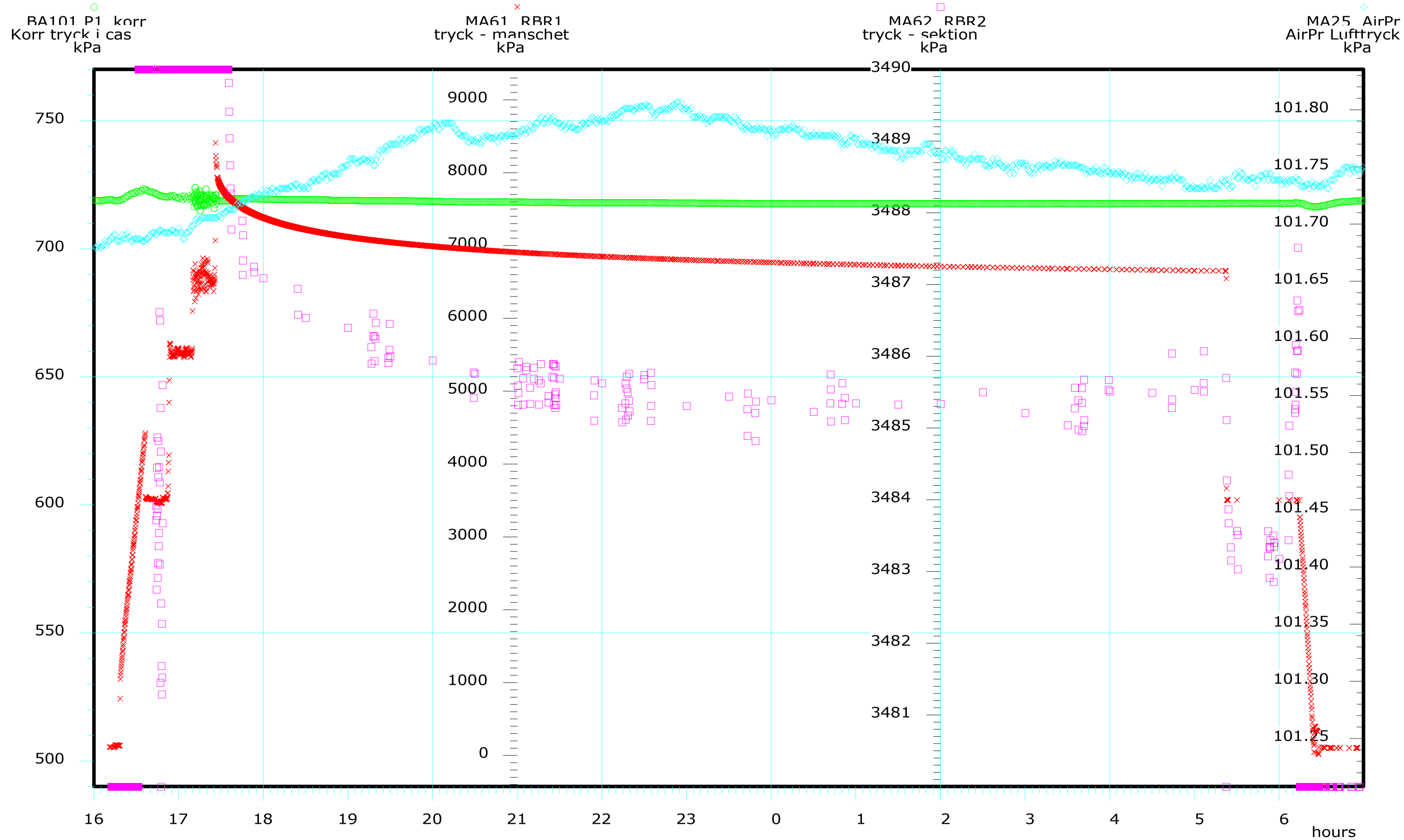
Channel	Parameter	Unit	Description
BA101	Pressure	kPa	Pressure of the water column in the telescopic section subtracted with the ambient air pressure.
MA61	Pressure – packer	kPa	Inflation pressure in packer.
MA62	Pressure – section	kPa	Pressure of the water column in the test section ie at depth in the borehole. Not corrected for ambient air pressure.
MA25	Air pressure	kPa	


PLOT TIME :04/10/05 14:03:06
PLOT FILE :P_tryck_i _sektion
No DST Adjustment
DMS1 PO
Absolute pressure measurement
KSH03 290.60-349.28m
Wireline sond
BA101 P1 korr
Korr tryck i cas
kPa
MA61 RBR1
tryck - manschet
kPa
MA62 RBR2
tryck - sektion
kPa
MA25 AirPr
AirPr Lufttryck
kPa
700
650
600
550
500
7000
6000
5000
4000
3000
2000
1000
0
2486.0
2485.5
2485.0
2484.5
2484.0
2483.5
2483.0
2482.5
2482.0
2481.5
2481.0
2480.5
102.6
102.4
102.2
102.0
101.8
101.6
101.4
101.2
101.0
19
20
21
22
23
0
1
2
3
4
5
6
7
hours
START :03/09/24 19:00:00
INTERVAL: All readings
STOP :03/09/25 07:59:59

PLOT TIME :04/10/05 14:09:59
PLOT FILE :P_tryck_i _sektion
No DST Adjustment

DMS1 PO

Absolute pressure measurement
KSH03 409.50-508.26m
Wireline sond



START :03/09/30 16:00:00

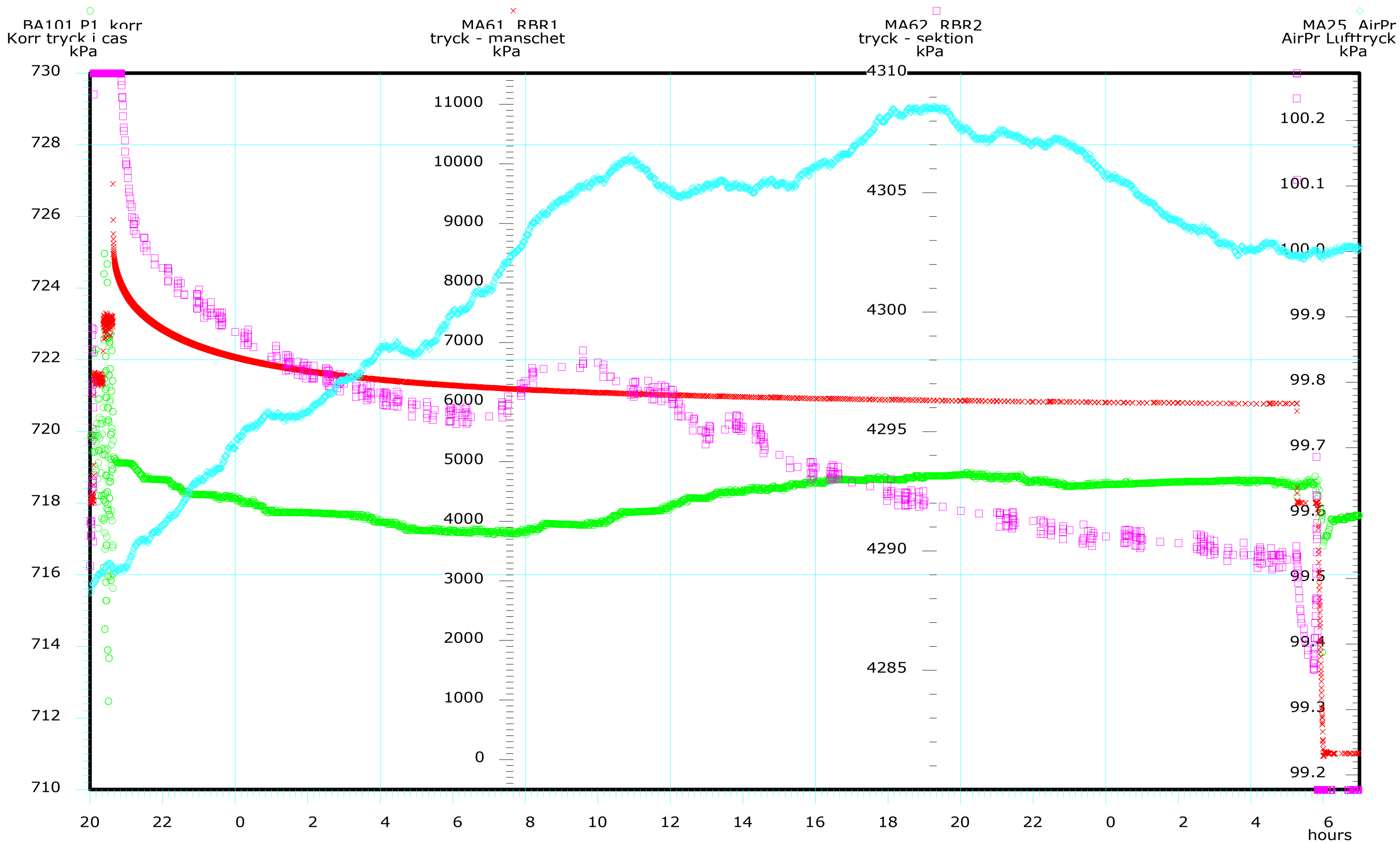
INTERVAL: All readings

STOP :03/10/01 06:59:59

PLOT TIME :04/10/05 14:12:49
PLOT FILE :P_tryck_i _sektion
No DST Adjustment

DMS1 PO

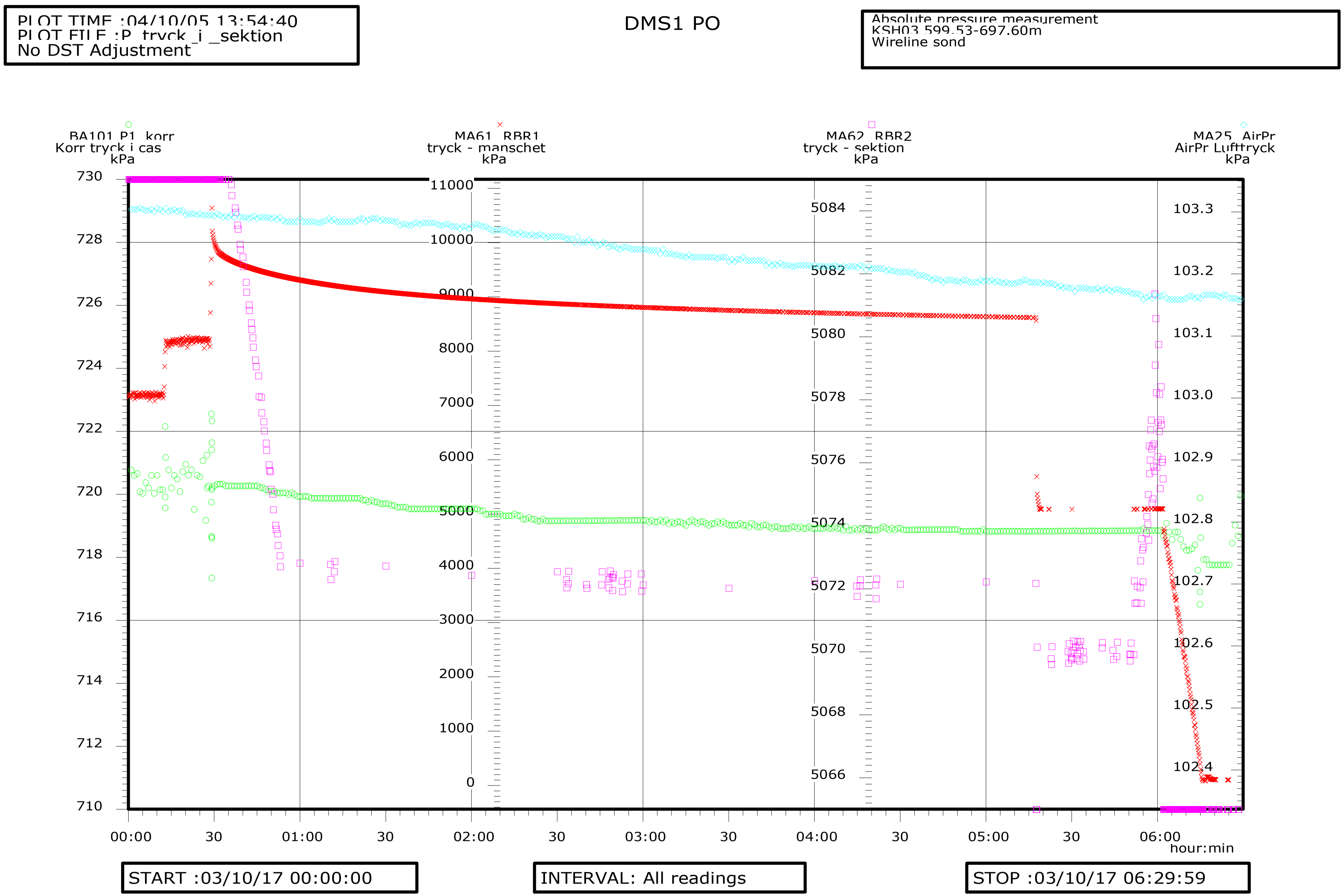
Absolute pressure measurement
KSH03 506.45-601.70m
Wireline sond



START :03/10/04 20:00:00

INTERVAL: All readings

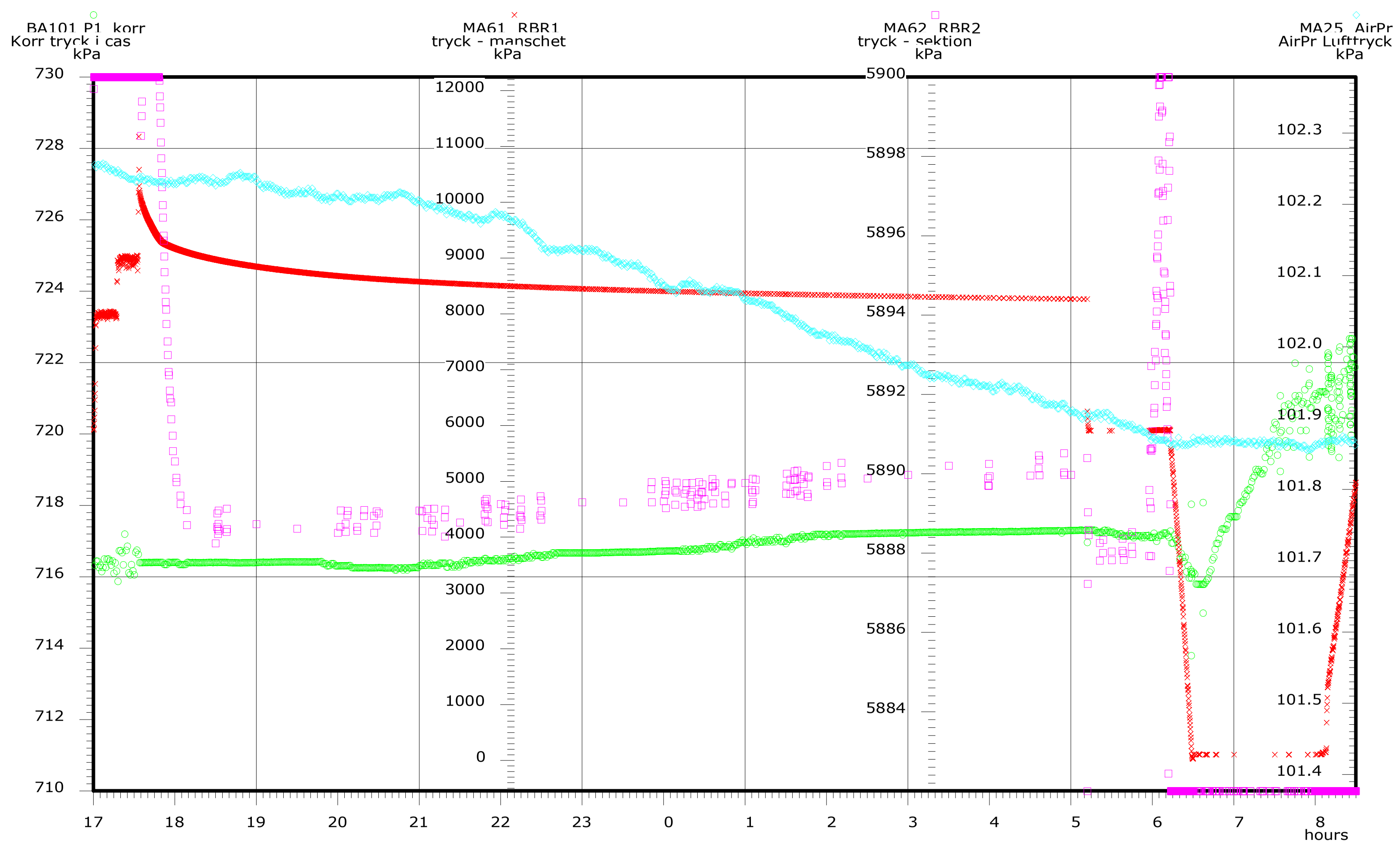
STOP :03/10/06 06:59:59


PLOT TIME :04/10/05 13:54:40
PLOT FILE :P_tryck_i _sektion
No DST Adjustment
DMS1 PO
Absolute pressure measurement
KSH03 599.53-697.60m
Wireline sond
BA101 P1 korr
Korr tryck i cas
kPa
MA61 RBR1
tryck - manschet
kPa
MA62 RBR2
tryck - sektion
kPa
MA25 AirPr
AirPr Lufttryck
kPa
730
728
726
724
722
720
718
716
714
712
710
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
5084
5082
5080
5078
5076
5074
5072
5070
5068
5066
103.3
103.2
103.1
103.0
102.9
102.8
102.7
102.6
102.5
102.4
00:00
30
01:00
30
02:00
30
03:00
30
04:00
30
05:00
30
06:00
hour:min
START :03/10/17 00:00:00
INTERVAL: All readings
STOP :03/10/17 06:29:59

PLOT TIME :04/10/05 13:58:30
PLOT FILE :P_tryck_i _sektion
No DST Adjustment

DMS1 PO

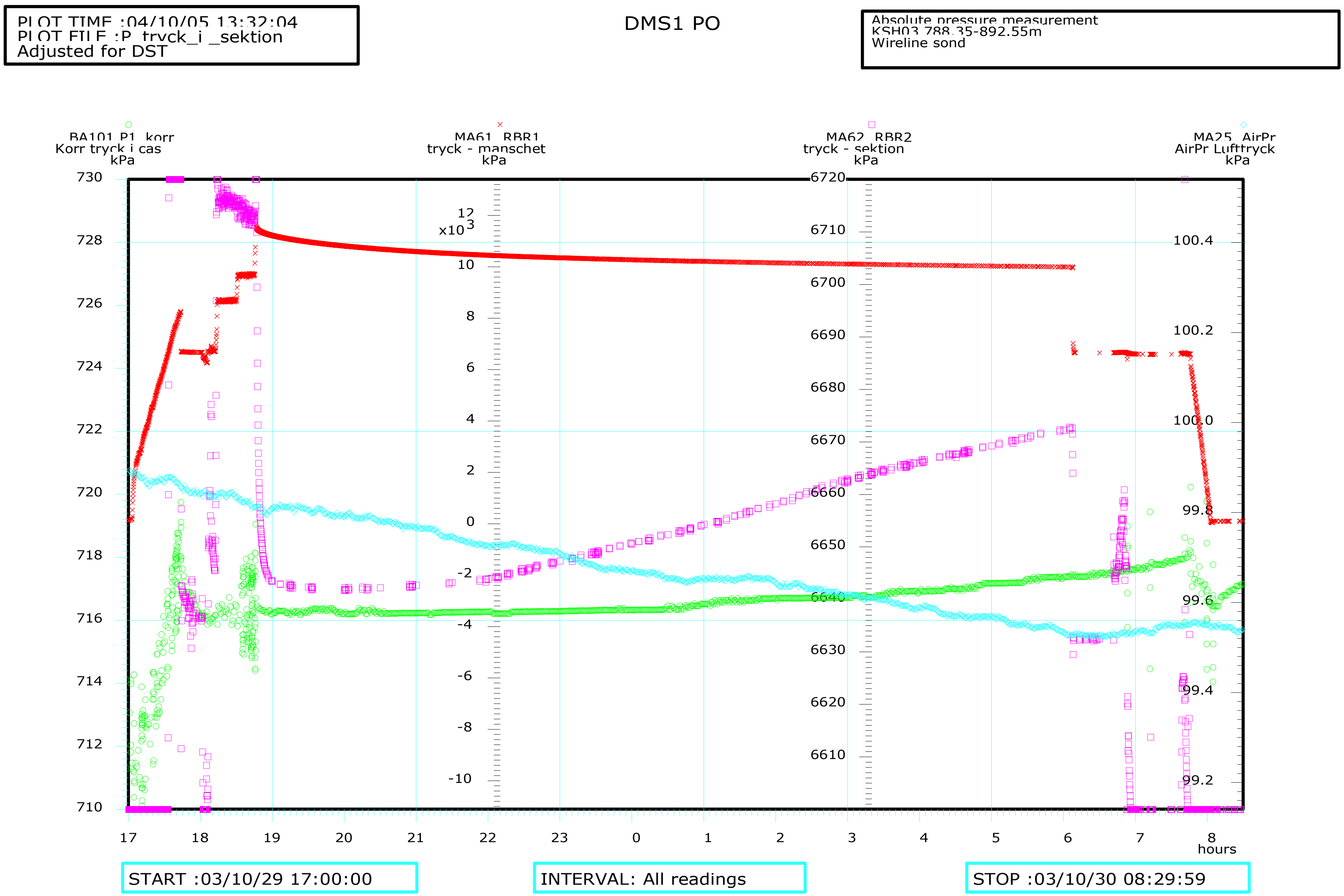
Absolute pressure measurement
KSH03 697.90-787.77m
Wireline sond

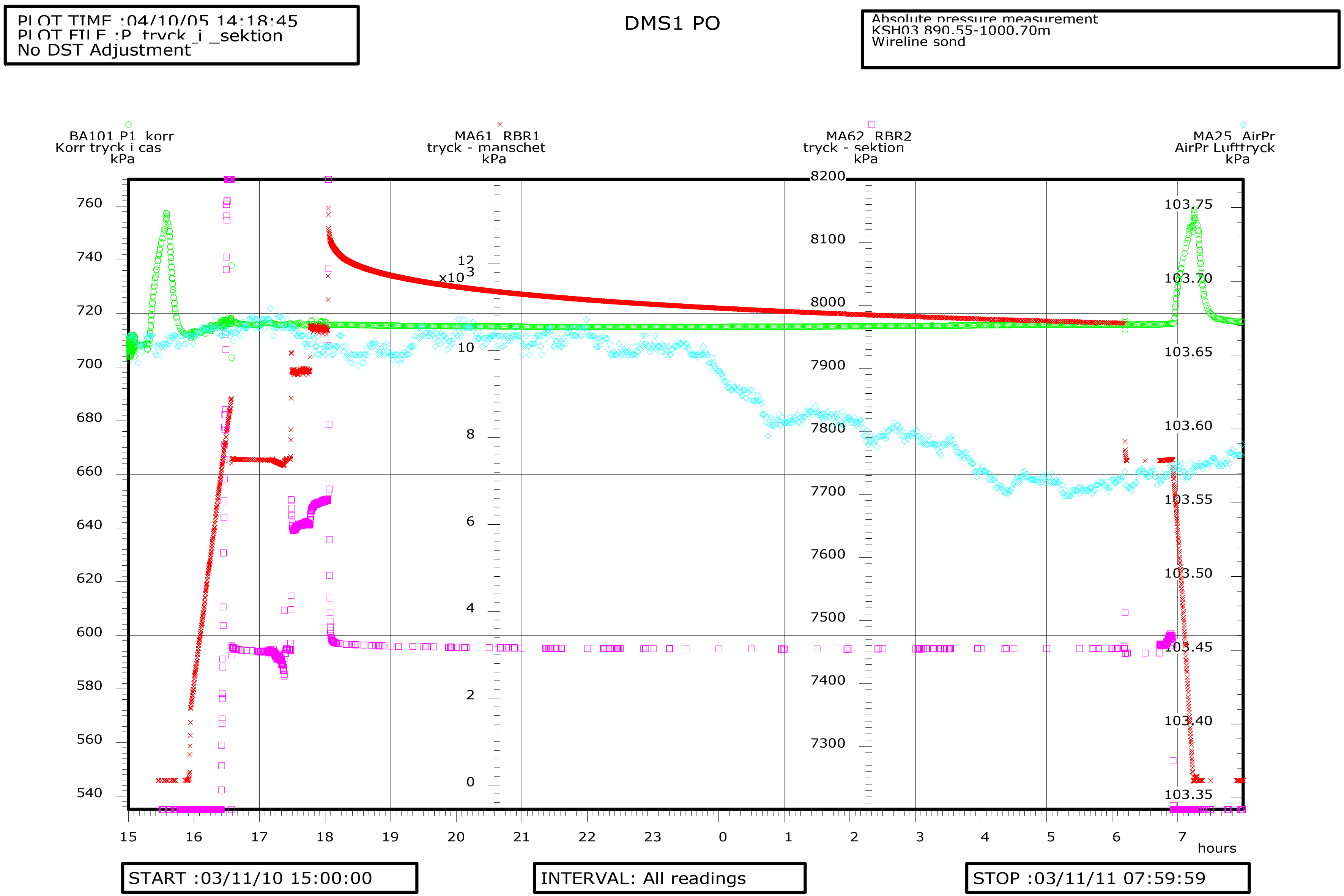


START :03/10/22 17:00:00

INTERVAL: All readings

STOP :03/10/23 08:29:59


PLOT TIME :04/10/05 13:32:04
PLOT FILE :P_tryck_i _sektion
Adjusted for DST
DMS1 PO
Absolute pressure measurement
KSH03 788.35-892.55m
Wireline sond
BA101 P1 korr
Korr tryck i cas
kPa
MA61 RBR1
tryck - manschet
kPa
MA62 RBR2
tryck - sektion
kPa
MA25 AirPr
AirPr Lufttryck
kPa
730
728
726
724
722
720
718
716
714
712
710
12
x10 3
10
8
6
4
2
0
-2
-4
-6
-8
-10
6720
6710
6700
6690
6680
6670
6660
6650
6640
6630
6620
6610
100.4
100.2
100.0
99.8
99.6
99.4
99.2
17
18
19
20
21
22
23
0
1
2
3
4
5
6
7
8
hours
START :03/10/29 17:00:00
INTERVAL: All readings
STOP :03/10/30 08:29:59


PLOT TIME :04/10/05 14:18:45
PLOT FILE :P_tryck_i _sektion
No DST Adjustment
DMS1 PO
Absolute pressure measurement
KSH03 890.55-1000.70m
Wireline sond
BA101_P1_korr
Korr tryck i cas
kPa
MA61_RBR1
tryck - manschet
kPa
MA62_RBR2
tryck - sektion
kPa
MA25_AirPr
AirPr Lufttryck
kPa
hours
START :03/11/10 15:00:00
INTERVAL: All readings
STOP :03/11/11 07:59:59