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Oskarshamn site investigation

Drilling of cored borehole KSH02

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September 2004

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

Abstract

Borehole KSH02 is located on the Simpevarp peninsula. Drilling was made between January and June, 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 1,001 m with 76 mm equipment. The uppermost section, to a depth of 66 m, was constructed as a telescopic section with an inner diameter of 200 mm.

Several attempts for measuring rock stresses with the overcoring method was done in conjunction with core drilling, however only one successful measurement was attained. The resulting stresses were considerably lower than expected and the results should be used with caution.

Pumping tests were performed with a wireline measurements equipment, typically with one hundred metres intervals. The resulting transmissivities (T_M) varied between 2×10^{-7} and 8×10^{-6} 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^{-6} 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 one sample from the core drilling phase had a sufficiently low drilling water content to ensure accurate results.

The core is dominated by fine-grained dioritoide with minor intercalations of pegmatite. Between 550 and 720 m several sections of fine-grained granite with a width along core of up to 20 m occur. The total fracture frequency is normally less than 20 per metre. Some crushed sections (i.e. total fracture frequency > 40 per metre) have been noted at 50, 290, 500, 710 and 740 m length. The total fracture frequency is greatly reduced below 900 m.

The main nonconformity was that the telescopic section was built to a depth of 66 m instead of the intended 100 m.

Sammanfattning

Borrhål KSH02 ligger på Simpevarpshalvön. Borrningen utfördes mellan januari och juni 2003 som ett led i platsundersökningen för ett möjligt djupförvar för utbränt kärnbränsle i Oskarshamns kommun.

Hålet kärnborrades med 76 mm utrustning till 1 001 m djup. Den övre delen av hålet, från markytan till 66 m, utfördes som en teleskopdel med 200 mm inre diameter.

Ett antal försök att mäta bergspänningarna med överborrningsmetoden gjordes i samband med kärnborrning, dock erhölls endast en lyckad mätning. De uppmätta spänningarna var dock betydligt lägre än förväntat och resultaten bör användas med försiktighet.

Pumptester med wireline-baserad mätutrustning utfördes normalt var hundrade meter. Uppmätta transmissiviteter (T_M) varierade mellan 2×10^{-7} och 8×10^{-6} 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^{-6} 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 ett prov från kärnborrningsfasen hade ett tillräckligt lågt spolvatteninnehåll för att ge tillförlitliga resultat.

Borrkärnan domineras av finkorning dioritoid med mindre inslag av pegmatit. Mellan 550 och 720 m finns flera partier med finkornig granit med en bredd på upp till 20 m längs kärnan. Den totala sprickfrekvensen är normalt mindre än 20 per meter. Vissa sektioner med krossat berg (med en total sprickfrekvens> 40 per meter) har noterats vid 50, 290, 500, 710 och 740 m längd. Den totala sprickfrekvensen minskar kraftigt under 900 m.

Den främsta avvikelsen var att teleskopdelen fick byggas till 66 m djup istället för det avsedda djupet på 100 m.

Contents

1 Introduction

SKB, the Swedish Nuclear Fuel & Waste Management Company, performs site investigations in order to evaluate the feasibility of locating a deep repository for spent nuclear fuel /1/. The investigations are performed in two Swedish municipalities: Östhammar and Oskarshamn. 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. KSH02 was the second deep cored borehole within the Oskarshamn site investigation.

The drilling of KSH02 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.

Data collected during the drilling of KSH02 was entered into the Sicada database under field note 30, see Table 1-2.

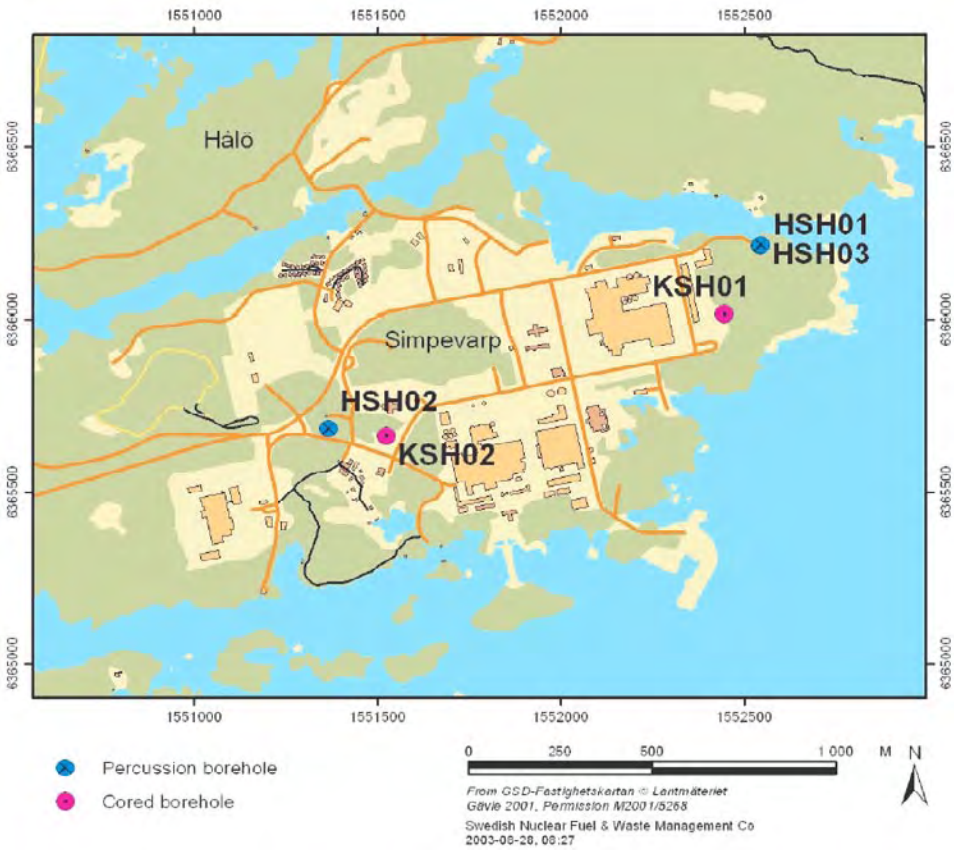


Figure 1-1. *Locations of the first drillholes in the Simpevarp subarea. Percussion drilled holes are marked "HSH" and cored boreholes are marked "KSH". This report will be confined to the drilling of KSH02.*

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

Activity plan	Number	Version
Kärnborrning KSH02	AP PS 400-02-019	1.0
Hydrauliska tester 0–50 och 0–100 m KSH02	AP PS 400-03-006	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 enhålstrester	SKB MD 321.003	1.0
Metodbeskrivning för registrering och provtagning av spolvattenparametrar samt borrkax under kärnborrning	SKB MD 640.001	1.0
Metodbeskrivning för 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
Method description for in-situ stress measurements by means of overcoring using the Borre probe	SKB MD 181.001	1.0

The activity plans and method descriptions are SKB internal documents.

Table 1-2. Data references.

Subactivity	Database	Identity number
Drilling KSH02	SICADA	Field note 30

2 Objective and scope

This report will describe the methods employed and the results achieved during the drilling of KSH02. A number of related activities, such as wireline hydraulic tests, water sampling and monitoring of drilling parameters that were performed in conjunction with drilling will also be reported here. Results from the overcoring measurements for determining rock stress have been published in a separate SKB report, P-04-23 /5/.

The main reasons for drilling borehole KSH02 was to gain geological information at depth of the central part of the Simpevarp peninsula and to facilitate further investigation at depth in the borehole. The decision to drill KSH02 is included in SKB report R-01-44 /1/.

The hole was constructed as a “telescope hole”, which means that the upper, normally, 100 m section of the hole has a wider diameter than the lower, main core drilled part of the hole.

A notification in accordance with the Environmental Code was issued to the regional authorities on 2002-04-04, SKB id no 1005354. A reply, without objections, was received on 2002-06-19, SKB id no 1006724 (Regional Authority registration no 525-4380-02).

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 m 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 m and 1,000 m, see Figure 3-1. The effect of drawdown is dependent on the depth and capacity of major groundwater conductors.

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

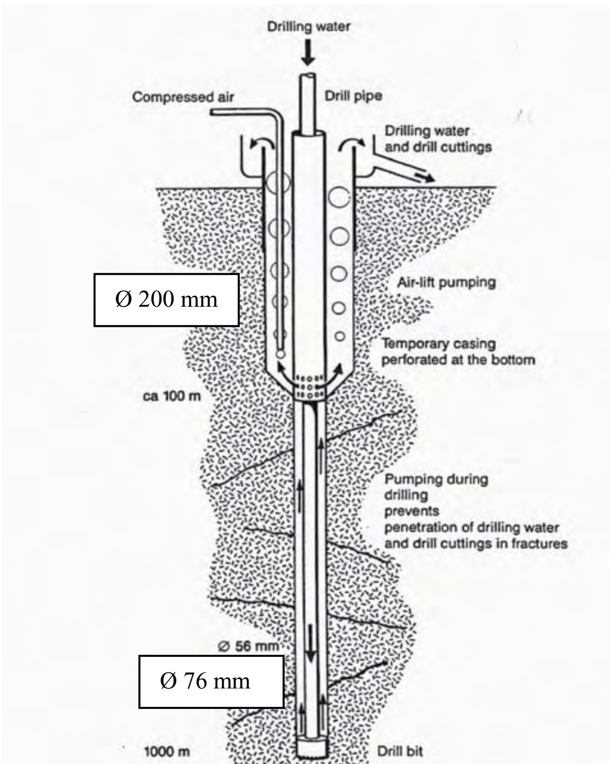


Figure 3-1. *A sketch of the telescopic drilling method with air-lift pumping for retrieval of drilling water and cuttings.*

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.

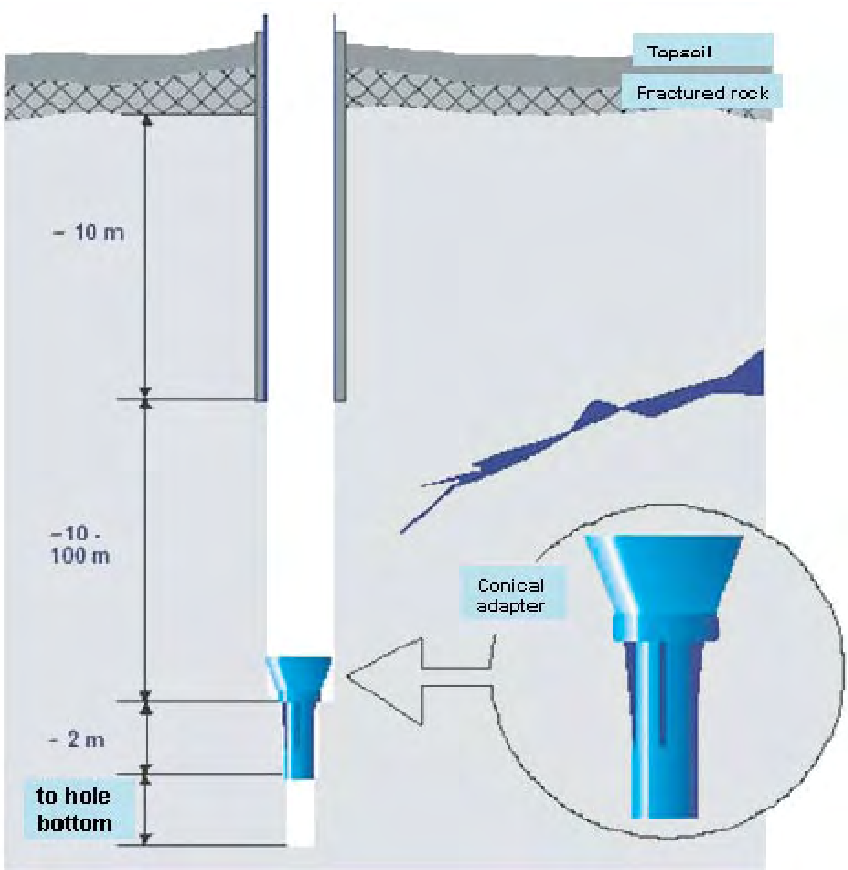


Figure 3-2. *Installation of the conical guide.*

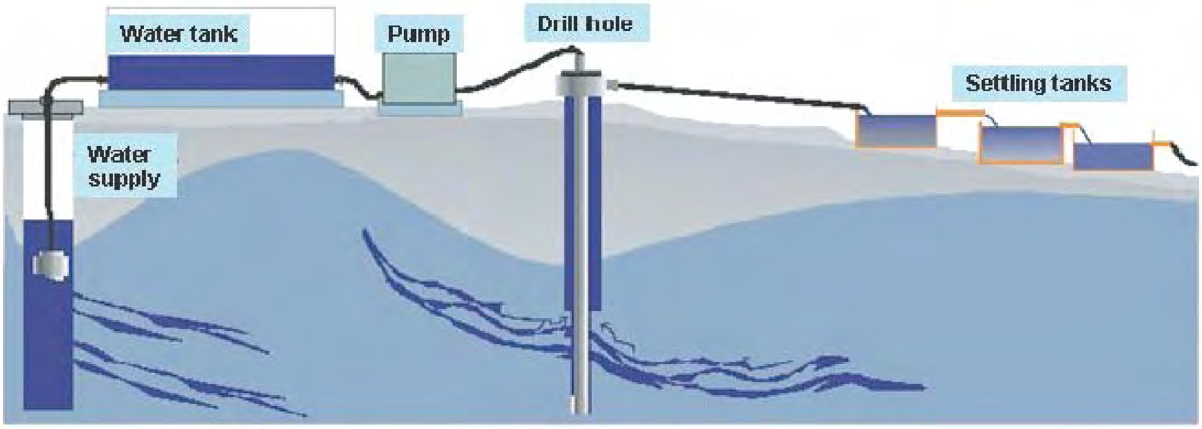


Figure 3-3. The flushing water system from source to discharge point.

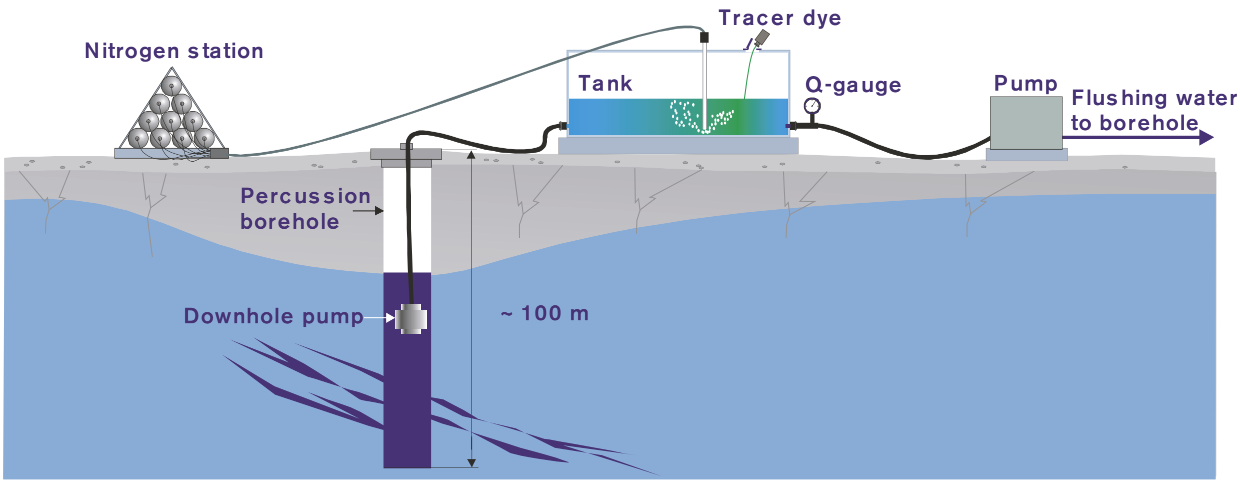


Figure 3-4. *Preparation of flushing water. Uranine is added to the water in the tank as a tracer dye. Nitrogen is bubbled through the water to remove dissolved oxygen.*

3.2 Measurements and sampling during drilling

3.2.1 Percussion drilling

Drill cuttings are collected manually during percussion drilling. If water occurs in the hole, the return water flow and colour is noted and a water sample taken. 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 KSH02 consisted of:

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

Overcoring rock stress measurements

Three-dimensional overcoring rock stress measurements are based on measuring strains when a sample of rock is released from the rock mass and the stresses acting upon it. The in situ stresses can be calculated from the measured strains and with knowledge of the elastic properties of the rock. Only a brief account of the methods employed and results obtained will be included in this report as a complete account is given in SKB report P-04-23 /5/.

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 m 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 10 to 30 m intervals, normally at the end of each core drilling day. After drilling has ceased, 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, i.e. the water entering and returning from the borehole at the surface, are taken at 10 to 20 m 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

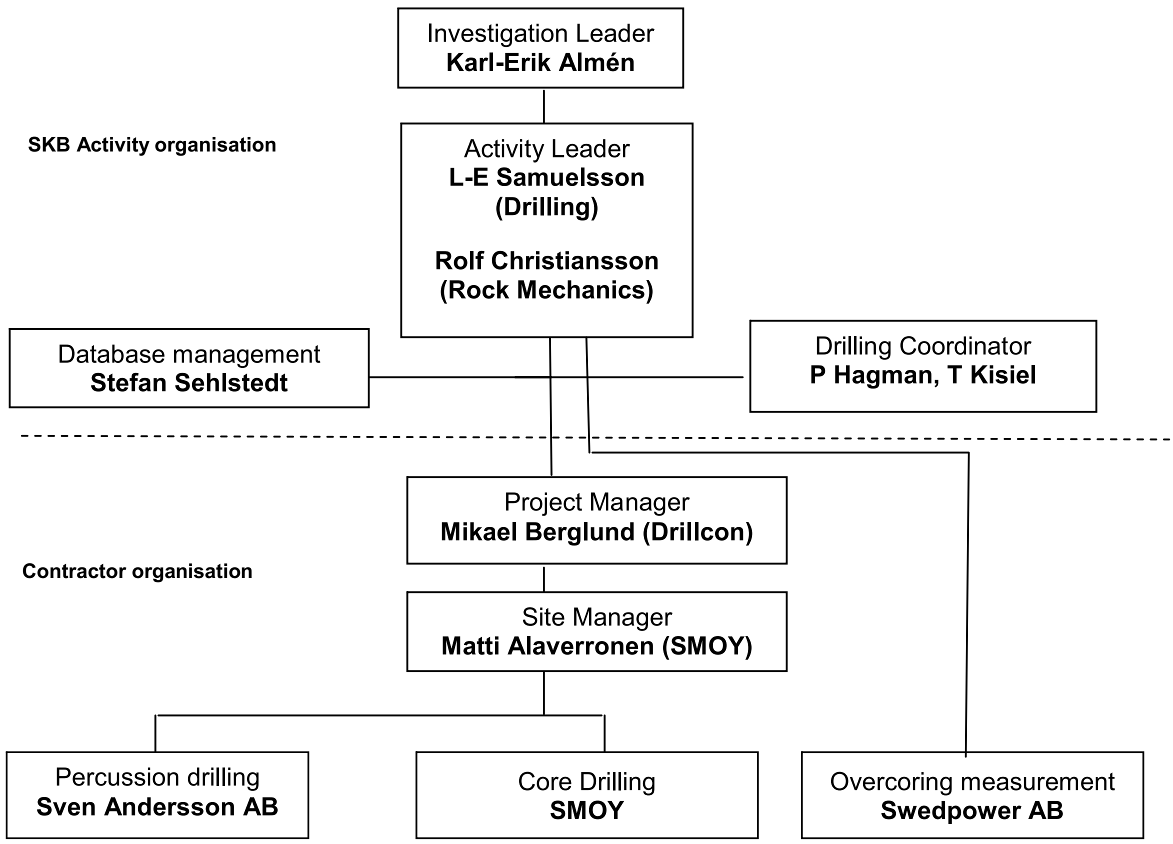
4.1 Contractors

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.

The overcoring rock stress measurements were performed by Swedpower 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 ("NO-X 365"), SS 2343 208×4 mm and 273×4 mm. The casing dimensions are presented as outer diameter and thickness.

Figure 4-1. The KSH02 drill site.

4.3 Core drilling equipment

Core drilling in KSH02 was made with a B 20 P Atlas Copco fully hydraulic machine fitted with a modern and environmentally adapted diesel engine. The rods were of the type Corac N3/50 NT with a 76 mm wireline triple tube core barrel system which gives a core diameter of 50.2 mm.

4.3.1 Equipment for overcoring measurements

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

- pilot hole drilling equipment for wireline core drilling, including planing tool,
- inspection tool (test probe) with built-in borehole cleaning brush,
- Borre probe with built-in data logger,
- set of strain gauges (to be mounted on the Borre probe),
- glue (for bonding strain gauges to the borehole wall),
- cell adapter (installation tool),
- biaxial test equipment including load cell, pressure gauge, hydraulic pump and strain indicator, and
- portable computer.

Execution of measurements

Overcoring stress measurement using the Borre probe involves:

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

The procedure for stress measurement using the Borre probe is briefly summarized in Figure 4-2. Further description of equipment and procedure is given in /5/.

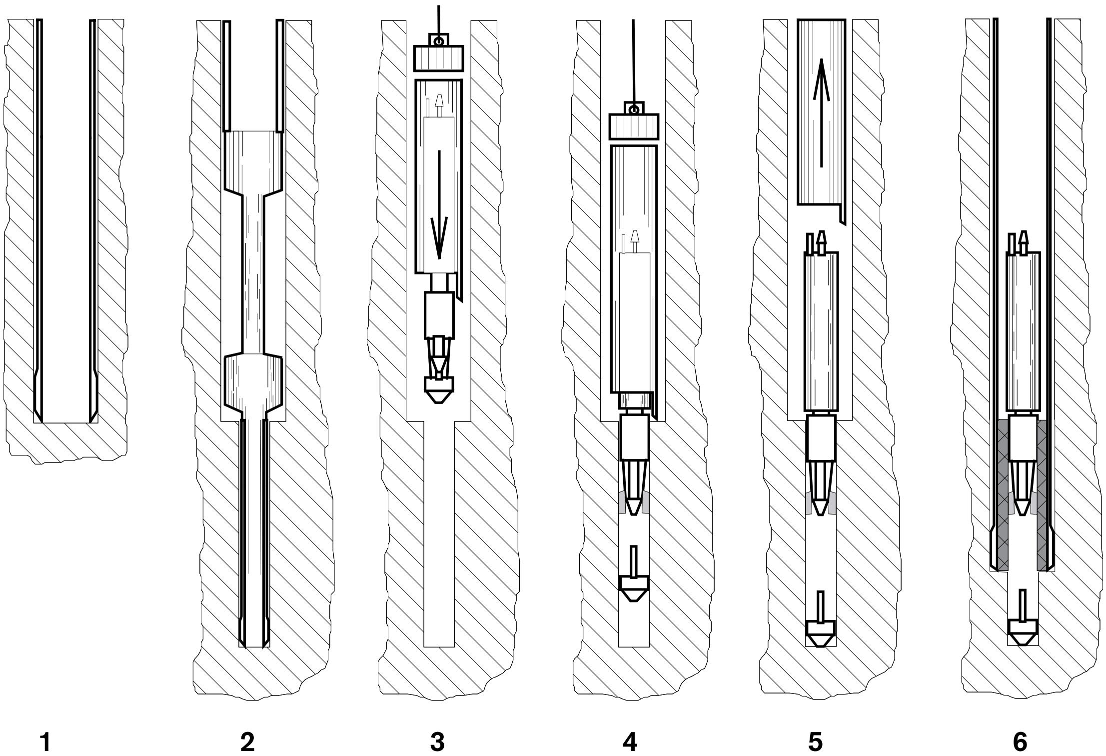


Figure 4-2. *Installation and measurement procedure with the Borre probe:*

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

4.3.2 Wireline measurements equipment

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

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 drillstem),
- a flow meter (placed at the ground surface).

The probe and packer are lowered through the drillstem 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 drillstring 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.

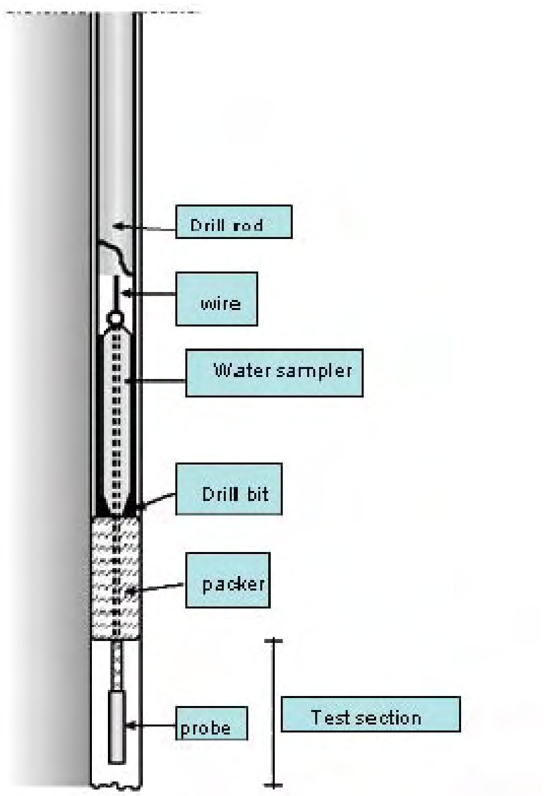


Figure 4-3. *The wireline probe and its emplacement in the hole.*

Pumping tests

The wireline probe is emplaced at the bottom of the drillstem. A submersible pump is lowered into the upper part of the drillstem at a length of about 40 m. The test section is hydraulically connected to the drillstem 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 drillstem. The packer remains expanded during the entire test. Water is pumped from the drillstem 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 drillstem. 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).

4.3.3 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 work with formally establishing routines for quality assurance of DMS data is still going on in September 2004. The results presented in this report have been checked in accordance with a work routine that are 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 in (mg/l).
- Flow of return flushing water (l/min).
- Electrical conductivity of flushing water in (mS/m).
- Electrical conductivity of return water (mS/m).
- Air pressure (kPa).

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

4.3.4 Equipment for deviation measurements

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

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.

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

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

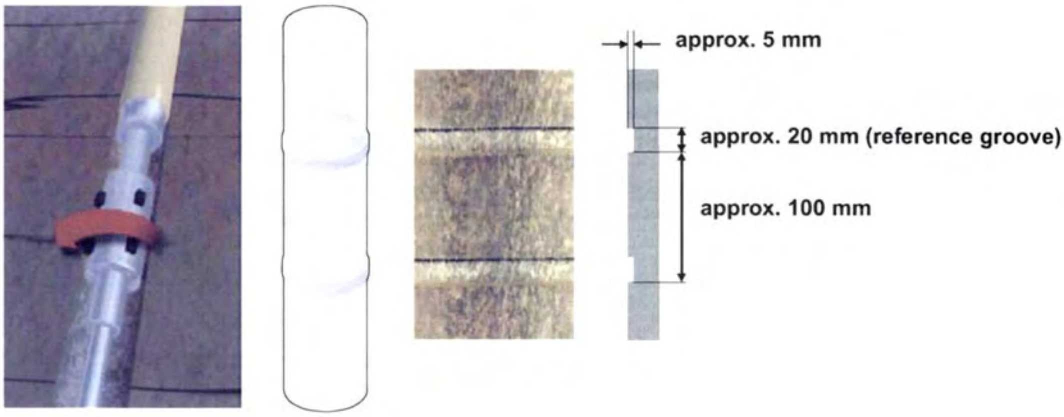


Figure 4-5. *The equipment for reaming of reference slots. To the left, the reaming tool with openings for the cutters is shown. The resulting reference slots are illustrated in the three pictures to the right.*

5 Execution and results

5.1 Summary of KSH02 drilling

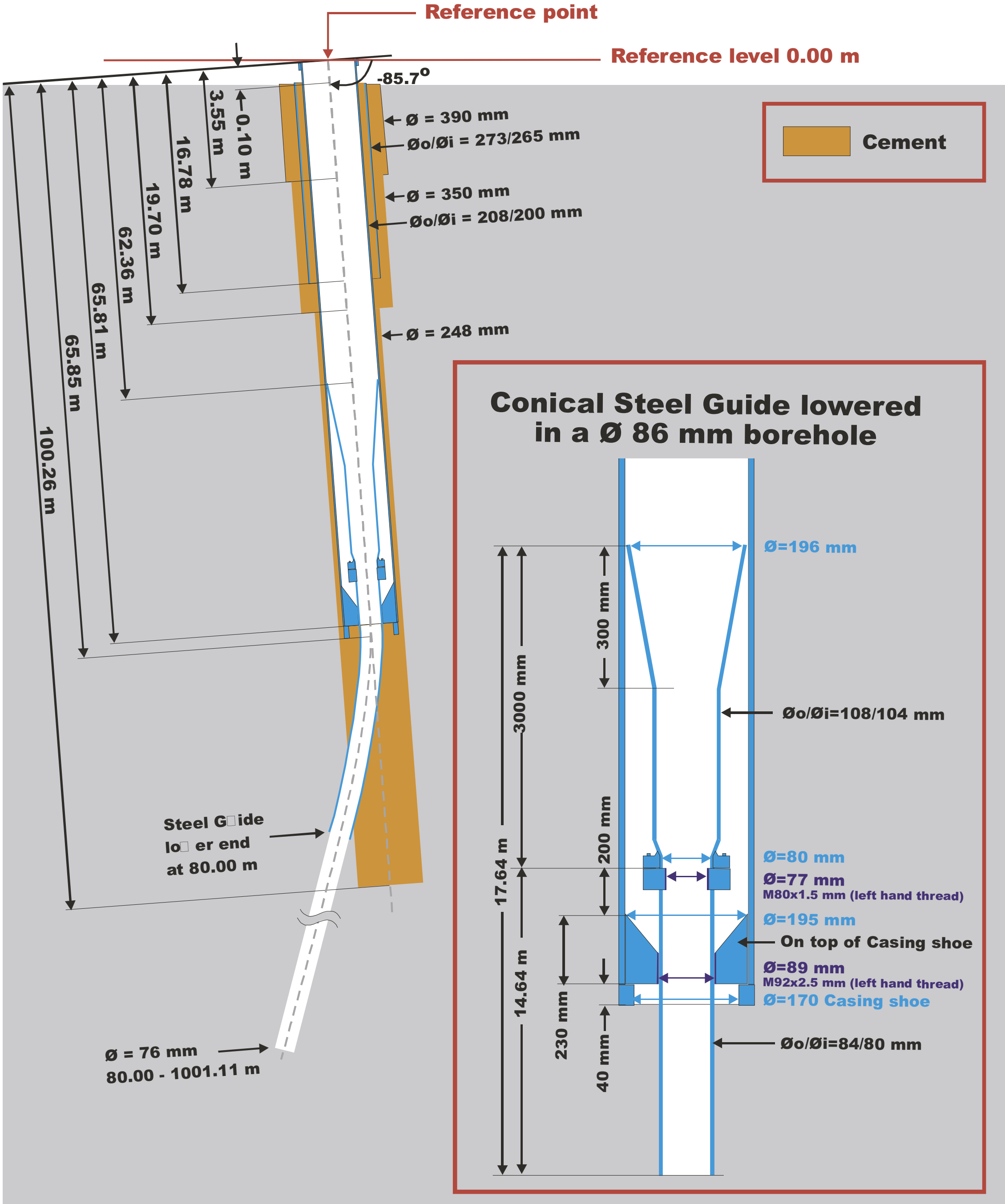
A technical summary of the drilling of KSH02 and the borehole design after completion is given in Table 5-1 and Figure 5-1. Further descriptions of the two main drilling steps, the telescope section 0–66 m and the core drilling section 66–1,000 m are given in sections 5.2 and 5.3 respectively.

Table 5-1. KSH02 summary.

General	Technical
Name of holes: KSH02	Percussion drill rig Puntel MX 1000
Location: Simpevarp, Oskarshamn Municipality, Sweden	Percussion drill hole diameter 248 mm
Contractor for drilling	Casing diameter (inner) 200 mm
Drillcon AB	Percussion hole length 65.8 m (100.5 m)
Subcontractor percussion drilling	Core drill rig B 20 P Atlas Copco
Sven Andersson AB	Core drill dimension 76 mm
Subcontractor core drilling	Cored interval 16.04–1,001.11 m
Suomen Malmi OY (SMOY)	Average core length retrieved in one run 2.44 m
Drill start date January 22, 2003	Number of runs 403
Completion date June 11, 2003	Diamond bits used 10
Contractor overcoring rock stress measuerements	Average bit life 98 m
Swedpower AB	Position KSH02 (RT90 RH70) at top of casing:
	N 6365658.33 E 1551528.93 Z 5.48 (masl)
	Azimuth (0–360)/Dip (0–90)
	330.7/–85.7
	Position KSH02 (RT90 RH70) at 996 m length:
	N 6365713.72 E 1551531.04 Z –988.72 (masl)
	Azimuth (0–360)/Dip (0–90)
	44.7/–86.8

Technical data

Borehole KSH02



Drilling reference point

Northing:	6365658.33 (m), RT90 2,5 gon V 0:-15
Easting:	1551528.93 (m), RT90 2,5 gon V 0:-15
Elevation:	5.48 (m), RHB 70

Orientation

Bearing:	330.7°
Inclination:	-85.7°

Drilling period

Drilling start date:	2003-01-27
Drilling stop date:	2003-05-28

Figure 5-1. *Technical data from KSH02.*

5.2 Drilling, measurements and results in the telescopic section 0–66 m

Drilling, reaming and gap injection were made between January 22 and March 3.

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 (0–66 m) of KSH02 was made in steps as described below and shown in Figure 5-2:

Drilling was initialised by Sven Andersson AB and consisted of the following items between January 22 and January 28:

- Drilling through the overburden to 3.55 m depth with NO-X 365 mm equipment. This gave a hole diameter of 420 mm. A casing of diameter 406.5 mm was installed. A soil depth of 3 m was recorded.
- Inner supportive casing for guidance for the drill string was mounted and a pilot percussion hole of 163.8 mm was drilled to a depth of 19.78 m (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 through overburden (406.5 mm) to a length of 3.55 m was removed.
- The casing (273×4 mm diameter) through fractured rock was installed and gap injection with cement was made as described in Figure 5-3.

Between January 28 and February 8 the following steps were performed by SMOY:

- An inner supportive casing with diameter 98/87 mm, fitted with fins for alignment was installed to a length of 16.04 m.
- Core drilling with T-86 equipment was made from 16.04 to 16.70 m.
- An inner casing (84/77 mm) to a length of 16.70 m was installed.
- Core drilling with 76 mm equipment was made to a length of 100.5 m.

The percussion drilling was continued by Sven Andersson AB between February 14 and March 3 with steps as outlined below:

- The double set of casings for core drilling was removed.
- A set of inner supportive casing with diameter 193.7 mm was installed to a length of 17.17 m.
- The cored hole was reamed in two steps (137 mm and 165 mm) to a length of 100.4 and 100.3 m respectively.
- The 193.7 mm supportive casing was removed and the hole reamed to 248 mm between 17.17 and 100.26 m.

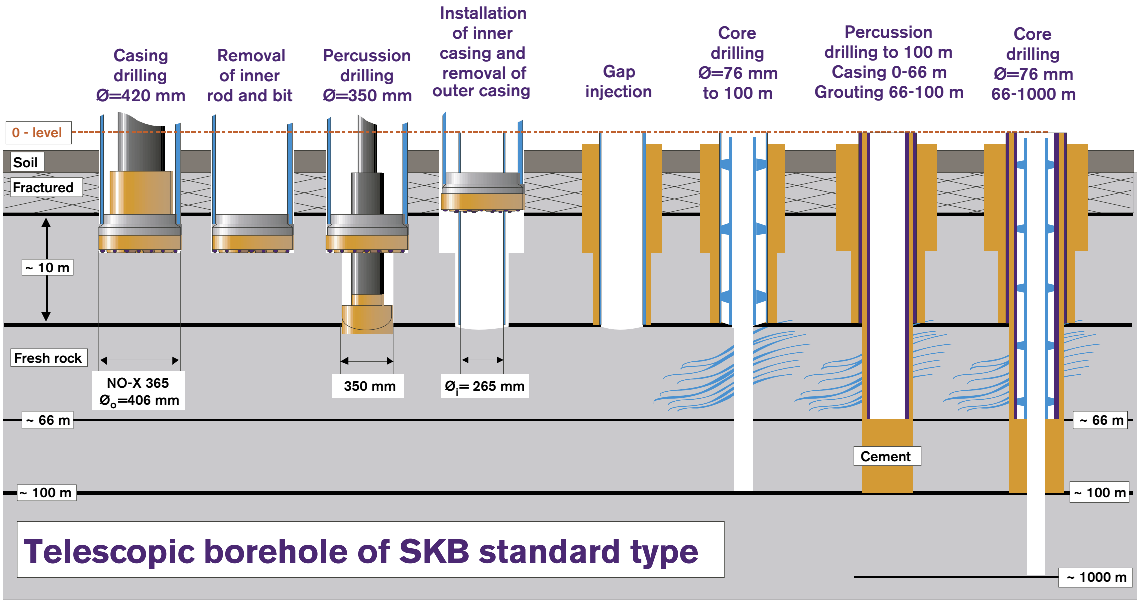


Figure 5-2. *Method for drilling the telescopic borehole KSH02.*

- Stainless casing of 208×4 mm was installed between 0 and 65.83 m. The emplacement of casing, which was made with an ODEX hammer, got stuck along the borehole wall and could reach no further.
- The hole was injected with 6 tonnes of cement i.e. filled from 100.3 to 12.5 m. Gap injection, between the 208×4 mm and 273×4 mm casings, was made from surface to 12.5 m.
- After hardening the cement was removed by drilling to a length of 65.81 m. The hole was rinsed and flushed to remove concrete and water. The tightness of the concrete gap filling was tested by a subsequent manual groundwater measurement which confirmed that the water inflow was less than 0.5 litres per minute. The recovery of the water table in KSH02 was 4.85 m, corresponding to a volume of 150 litres, over a period of 2,705 minutes, which gives an inflow rate of 0.05 litres per minute.

The gap injection method is shown in Figure 5-3.

5.2.3 Measurements and sampling in the telescopic section

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

- Three soil samples were collected at 0.9, 1.85 and 3.10 m.

The penetration rate during percussion drilling was not measured as a complete core exists from 16 m and down to 100.5 m. Samples of drill cuttings during percussion drilling were not taken.

Hydrogeology

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

Two pumping tests were made in the percussion drilled part.

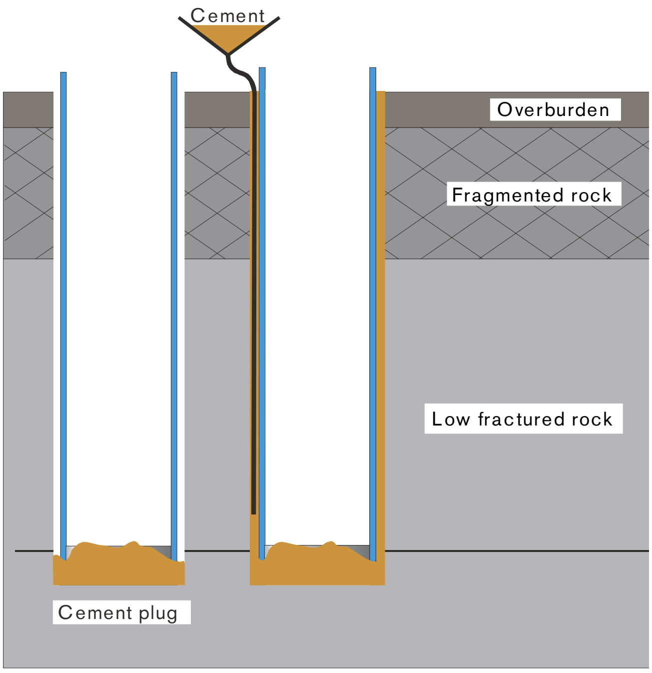


Figure 5-3. *Gap injection technique – a cement plug is emplaced at the bottom and allowed to harden. The gap filling cement is introduced between the casing and the rock wall.*

The upper part of the borehole was tested by pumping at 50 m and 100 m respectively, in accordance with activity plan AP PS 400-03-006. Both the drawdown and recovery phase of the tests were analysed through transient test methodology. The resulting hydraulic parameters are summarised in Table 5-2.

Hydrochemistry

One water sample was collected, see Table 5-3.

Sampling and analysis of sample 3888 were performed according to SKB class 3. Selected results are given in Table 5-4 and a complete account is given in Appendix 2.

Table 5-2. Summary of hydraulic test evaluation in percussion drilled part of KSH02.

Tested section	Pumping rate (L/min)	Total draw-down (m)	Steady state analysis* Q/s (m^2/s)	TM (m^2/s)	Transient analysis* TLf (m^2/s)	TLs (m^2/s)
19.75–49.9 m	3.8	24.5	2.5×10^{-6}	2.8×10^{-6}	1.2×10^{-6}	5.6×10^{-7}
19.75–100.5 m	12	41.3	5.0×10^{-6}	6.4×10^{-6}	7.0×10^{-7}	4.0×10^{-7}

*) T_M based on Moye, T_{Lf} based on flowphase log-log analysis and T_{Ls} is based on log-log recovery analysis.

Table 5-3. Sample dates and length during percussion drilling in KSH02.

SKB number	Date	Test section, length (m)	SKB chemistry class
3888	2003-02-10	6.65–100.50	3 and isotope option B10

Table 5-4. Selected analytical results from sample 3888.

Sample no	Drill water %	pH	Conductivity mS/m	Cl mg/l
3888	26.64*	8.35	64.5	27.4

* The presence of drill water, i.e. with a uranine content, in this sample can be explained by the fact that core drilling utilizing water with a uranine tracer was done prior to reaming and sampling.

5.3 Core drilling 66–1,001 m

Core drilling in KSH02 was conducted between March 3, 2003 and June 11, 2003.

The main work in KSH02 after pre-drilling to 65.8 m depth consisted of the following steps:

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

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

5.3.1 Preparations

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

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 65.8 m.
- Equipment for air-lift pumping was installed and a discharge header was fitted to collect the return water.
- Drilling was made between 65.85 and 67.25 m with T-86 equipment. An inner supportive casing with diameter 84/77 mm was installed to 67.25 m.

The supportive casings have a perforated section between 65.2 and 65.4 m 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 60 m.

The discharge header was fitted to collect the return water.

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 5-6.

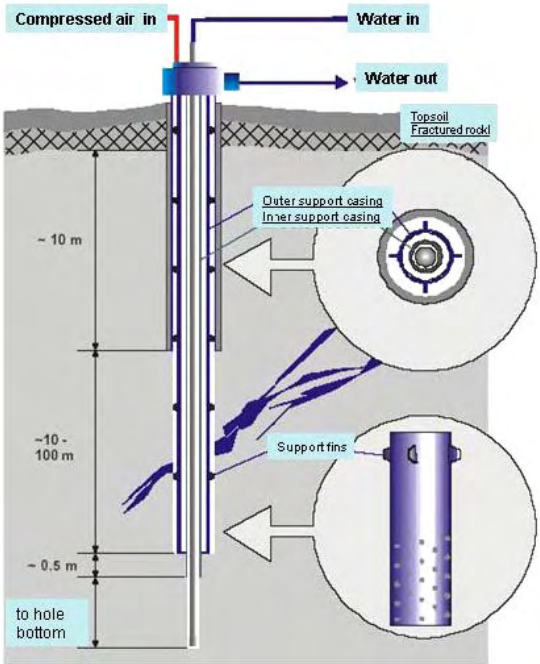


Figure 5-4. *In the telescopic part of the drill hole a temporary installation is made with casing tubes for support and alignment and equipment for air-lift pumping. In the uppermost part the return water discharge header is mounted. The water discharge is led to the settling containers.*

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

Figure 5-6. 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 March 10 and was conducted from 67.25 m to the final length of 1,001.11 m which gave a core of 50.2 mm diameter. The interval between 67.25 m and 73.30 m was drilled in cement. After 73.30 the cored hole gradually diverged into bedrock.

The drilling progress over time is shown in section 5.5 Figure 5-12.

A total of ten drill bits were used for KSH02, see Figure 5-7.

The elasticity of the drill stem expressed as the difference in length between a hanging and a standing set of drill rods is presented in Figure 5-8. The method for conducting this test was to note the length of the drill stem standing at the bottom of the hole i.e. without any downward pressure on the string. A small, consistent rotational torque was applied to the drill stem and the rods slowly lifted. When rotation of the stem could be observed, the drill string was considered as hanging freely and the difference in length was noted.

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

Figure 5-7. Changes of drill bit during wire-line drilling.

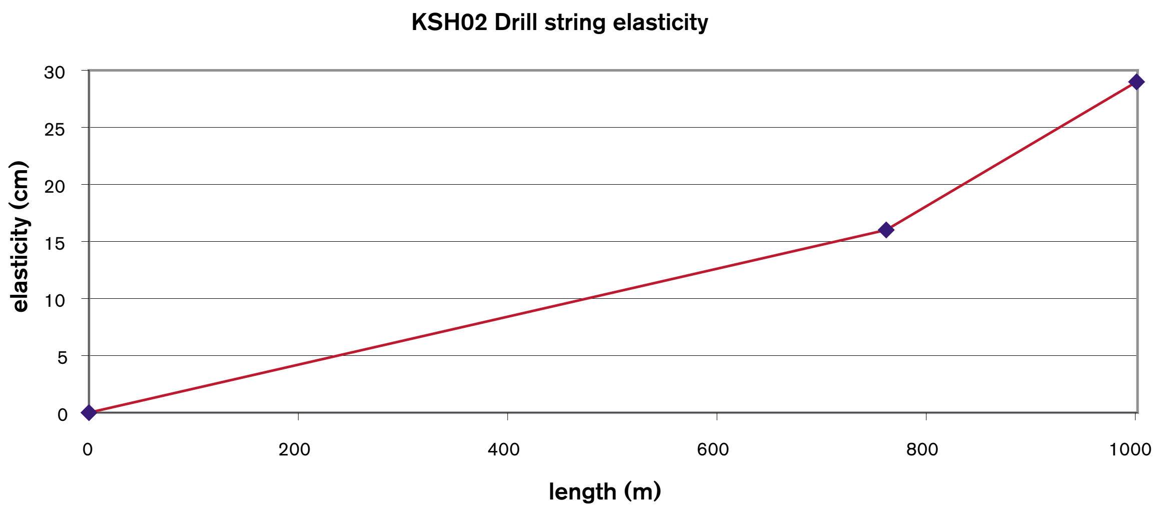


***Figure 5-8.** Elasticity of the drill rods expressed as the difference between the length of a hanging and a standing drill stem.*

5.3.3 Overcoring measurements

Measurements were attempted at two length intervals: at 250–300 m and at 447–463 m. Out of fifteen attempts only one successful measurement was attained. The measured rock stress, with the maximum principal stress at 8.5 MPa and the minor principal stress close to zero, was significantly lower than expected and the obtained value should be used with caution.

The overcoring rock stress measurements are reported in a separate report /5/ and will not be commented further in this report.

Figure 5-9. The Borre overcoring equipment.

5.3.4 Deviation measurements

A deviation measurement covering the telescopic section was made with the accelerometer method between 15 and 99 m.

Deviation measurements with the Maxibor method were made four times during the drilling of KSH02.

A plot of the results of the final run covering the entire borehole is given in Appendix 4.

5.3.5 Borehole completion

Reaming of depth reference slots was done at intervals as shown in Table 5-5. The purpose for the depth reference slots was to be 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 final core drilling activities consisted of removal of the inner 84/77 casing and reaming with T-86 mm between 67.25 and 80.00 m.

After all core drilling activities were concluded, the air lift pumping equipment was removed, a steel conical guide was installed between 62.36 m and 65.85 m depth and casing with 84/80 mm was installed between 65.36 and 80.00 m. The conical guide tapers from an inner diameter of 195 mm to 76 mm.

Table 5-5. Depth reference slots.

105.00 m	571.00 m
153.00 m	624.00 m
203.00 m	674.00 m
256.00 m	727.00 m
317.00 m	780.00 m
362.00 m	830.00 m
415.00 m	852.00 m
468.00 m	900.00 m
519.00 m	950.00 m

The length of the hole was rinsed by flushing nitrogen gas twice. A total of 7 m^3 of water was flushed out of the hole.

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 66–1,001 m

The performed measurements can be summarised as follows:

Wireline measurements:

- Eleven pumping tests were conducted, see section 5.4.1.
- Nine measurements of absolute pressure, see section 5.4.1.
- Water samples were successfully collected from three of the eleven 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

A total of 72 air lift pumping and recovery tests were made. The results from the final air-lift pumping test are shown in section 5.4.3.

5.4.1 Hydrogeological results from wireline measurements

Results from the wireline pumping tests in borehole KSH02 are presented in Table 5-6 and Figure 5.10.

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 L/min, “s” is the drawdown in kPa and “T_M” is the transmissivity according to /4/.

Table 5-6. Pumping tests with the wireline probe in KSH02.

Tested section		Comments	Q/s (m²/s)	TM (m²/s)
81.1 m	–192.22 m	Flowrate stabilization is not achieved during the flow phase. The flowrate continues to decrease from 24 to 4 litres per minute.	(3.0×10^{-6})	(3.9×10^{-6})
192 m	–312.99 m	Initial large decrease in flow rate but stabilizes at about 7L/min.	(3.2×10^{-6})	(4.2×10^{-6})
312 m	–408.78 m	Highly variable pressure prior to and during the test as well as variable flow. A manually measured flow of Q=0.95 litre/min allows a rough calculation of the specific capacity and transmissivity.	(9.0×10^{-7})	(1.2×10^{-6})
411.85 m	–467.07 m	Test functionally OK	2.1×10^{-6}	2.6×10^{-6}
411.15 m	–547.52 m	Test functionally OK	2.2×10^{-6}	2.9×10^{-6}
509 m	–600.15 m	Test functionally OK	2.3×10^{-6}	3.0×10^{-6}
600 m	–700 m	Test functionally OK	1.6×10^{-6}	2.1×10^{-6}
737 m	–755.17 m	Test functionally OK	5.8×10^{-7}	6.0×10^{-7}
699 m	–803.15 m	Test functionally OK	2.0×10^{-6}	2.6×10^{-6}
791 m	–910.13 m	Test functionally OK	3.6×10^{-7}	4.8×10^{-7}
909 m	–1,001.11 m	Test functionally OK	6.1×10^{-6}	7.9×10^{-6}

The values in brackets should be seen as indications of the actual values.

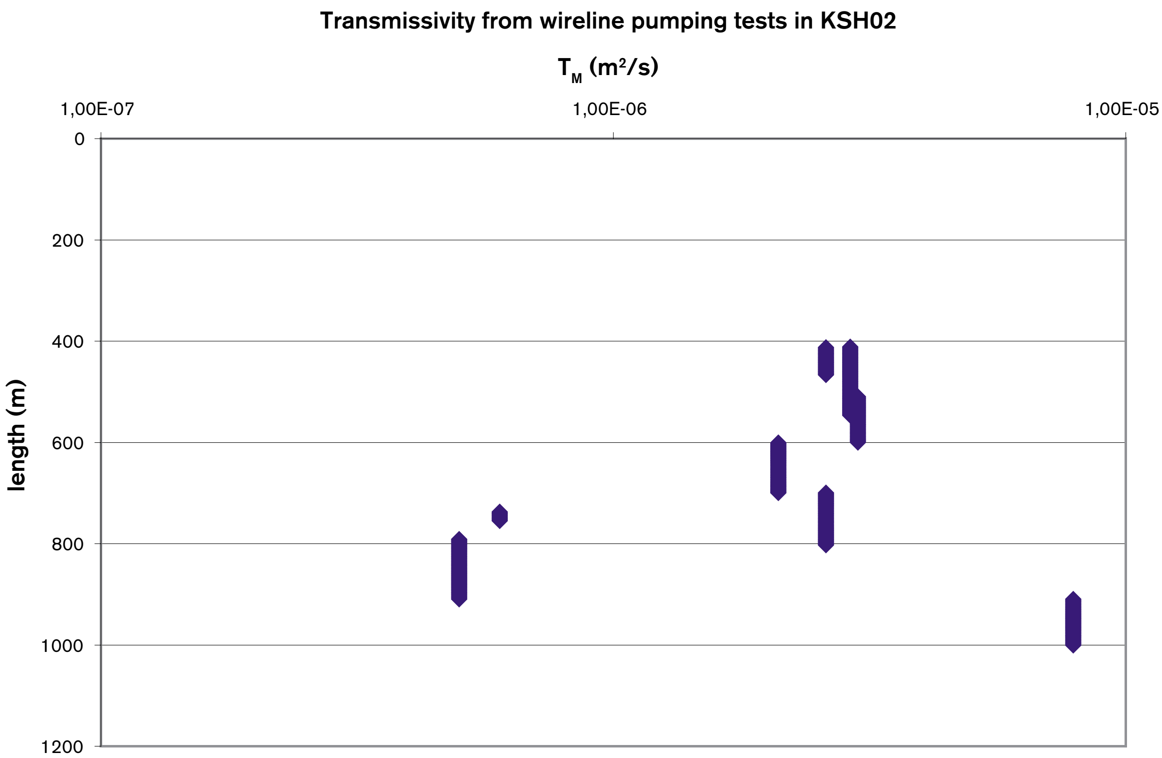


Figure 5-10. *Transmissivity from wireline pumping tests in KSH02 versus borehole length.*

Eight tests, out of a total of eleven pumping tests performed, achieved sufficiently stable conditions for calculating pseudo steady-state transmissivity. The three uppermost sections displayed varying flowrates and drawdowns and the calculations of specific capacity and transmissivity in these tests should be considered as indications of the actual values.

Graphical results from all tests are shown in Appendix 5.

Absolute pressure measurements were performed in nine sections as specified in Table 5-7 and Figure 5-11. The plots are given in Appendix 6.

Table 5-7. Absolute pressure measurements.

Tested section From (metres)	To (metres)	Last pressure reading during buildup (kPa)	Duration of pressure buildup hours	Borehole length to pressure gauge metres
81.1	192.22	800	14.9	82.2
192	312.99	1,850	17.8	193.1
312	408.78	3,110	12.6	313.1
410.15	511.63	4,069	25.3	411.25
509	600.15	5,060	15.8	510.1
600	700	5,950	12.1	601.1
699	794.25	6,905	14.3	700.1
791	910.13	7,822	13.2	792.1
909	1,001.11	9,038	14.8	910.1

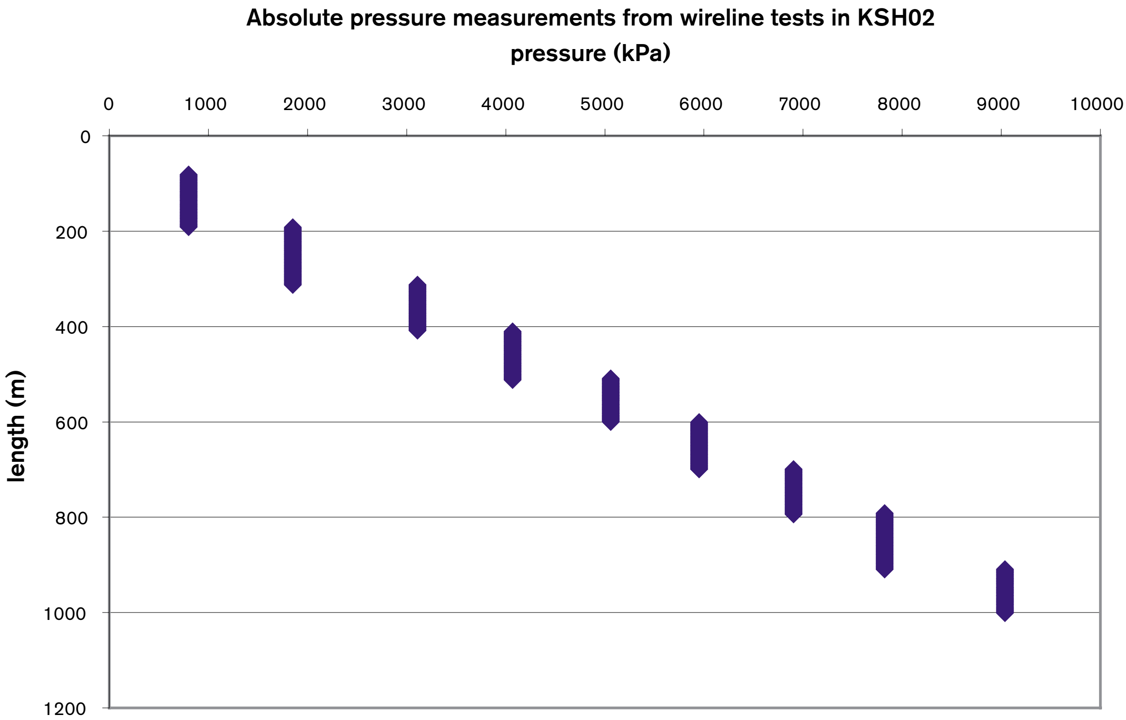


Figure 5-11. Absolute pressure measurements from wireline tests in KSH02 versus borehole length.

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 changes in pressure, salinity and temperature.

5.4.2 Hydrochemistry

In total, three water samples were collected with the wireline probe in connection with core drilling in KSH02. Sampling and analysis were performed according to SKB class 3. Cations and isotopes were not analysed in samples 3827 and 3833 due to high concentration of drilling water. The drilling water content is a reflection on how successful the sampling is. A low percentage of drilling water implies that the amount of pristine formation water is high in the sample.

Selected analytical results from KSH02 and the water source, HLX10, are given in Table 5-8. A complete record of analytical results is given in Appendix 2.

The concentration of total organic carbon (TOC) in the sample from HLX10 was 2.9 mg/litre. This value was considered acceptable for the groundwater to be used as flushing water for the core drilled part of KSH02 without further filtration measures to lower the organic carbon content.

A total of 46 samples for laboratory testing of uranine content and electrical conductivity in flushing and returning water were taken at the surface as the drilling progressed. The results are shown in Figure 5-12.

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

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

Borehole	Sample no	Date	From m	To m	Drilling water %	pH	Conductivity mS/m	Cl mg/l	TOC mg/l
KSH02	3832	2003-04-09	411.85	467.07	5.56	7.08	1,709	6,425.9	
KSH02	3827	2003-05-08	738.00	755.17	52.41	7.14	677	2,157.5	
KSH02	3833	2003-05-14	699.00	803.15	52.99	7.41	1,035	3,532.9	
HLX10	3901	2003-03-12			0.03	8.1	33.2	5.6	
HLX10	3903	2003-03-12			0.02	8.23	46.7	6.2	
HLX10	3904	2003-03-12			0.02	8.23	38.7	6.3	2.9

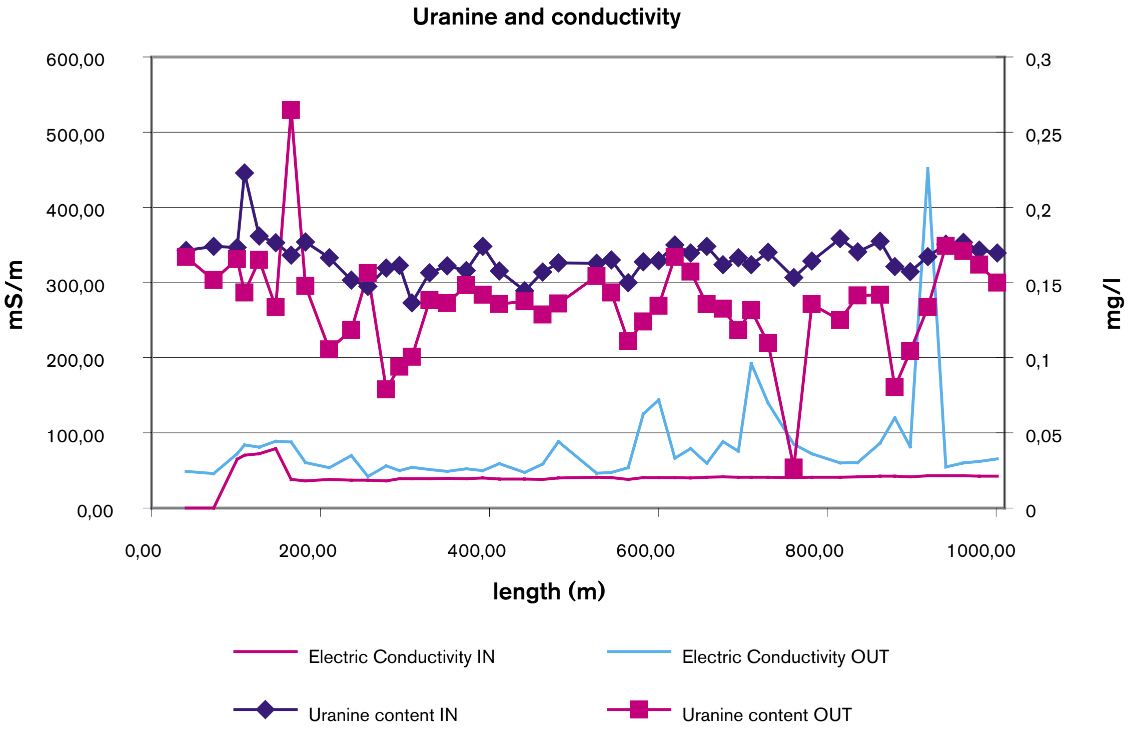


Figure 5-12. *The uranine concentration and electric conductivity of flushing water (IN) and returning water (OUT) in KSH02 during drilling.*

5.4.3 Air lift pumping results

After drilling to full depth the borehole was flushed with water and an airlift pumping test was conducted for a period of about 2 hours. The net outflow (Q_{out}–Q_{in}) during pseudo steady-state conditions, prior to pumpstop was 5.7 litres per minute. The drawdown phase is shown Figure 5-13.

The specific capacity and steady state transmissivity was calculated according to /4/. The results are shown in Table 5-9.

Table 5-9.

Tested section	Flowrate (L/min)	Drawdown (m)	Steady state analysis Q/s (m²/s)	TM (m²/s)
100.3–1,001.11 m	5.7	30.4	3.1×10^{-6}	5.1×10^{-6}

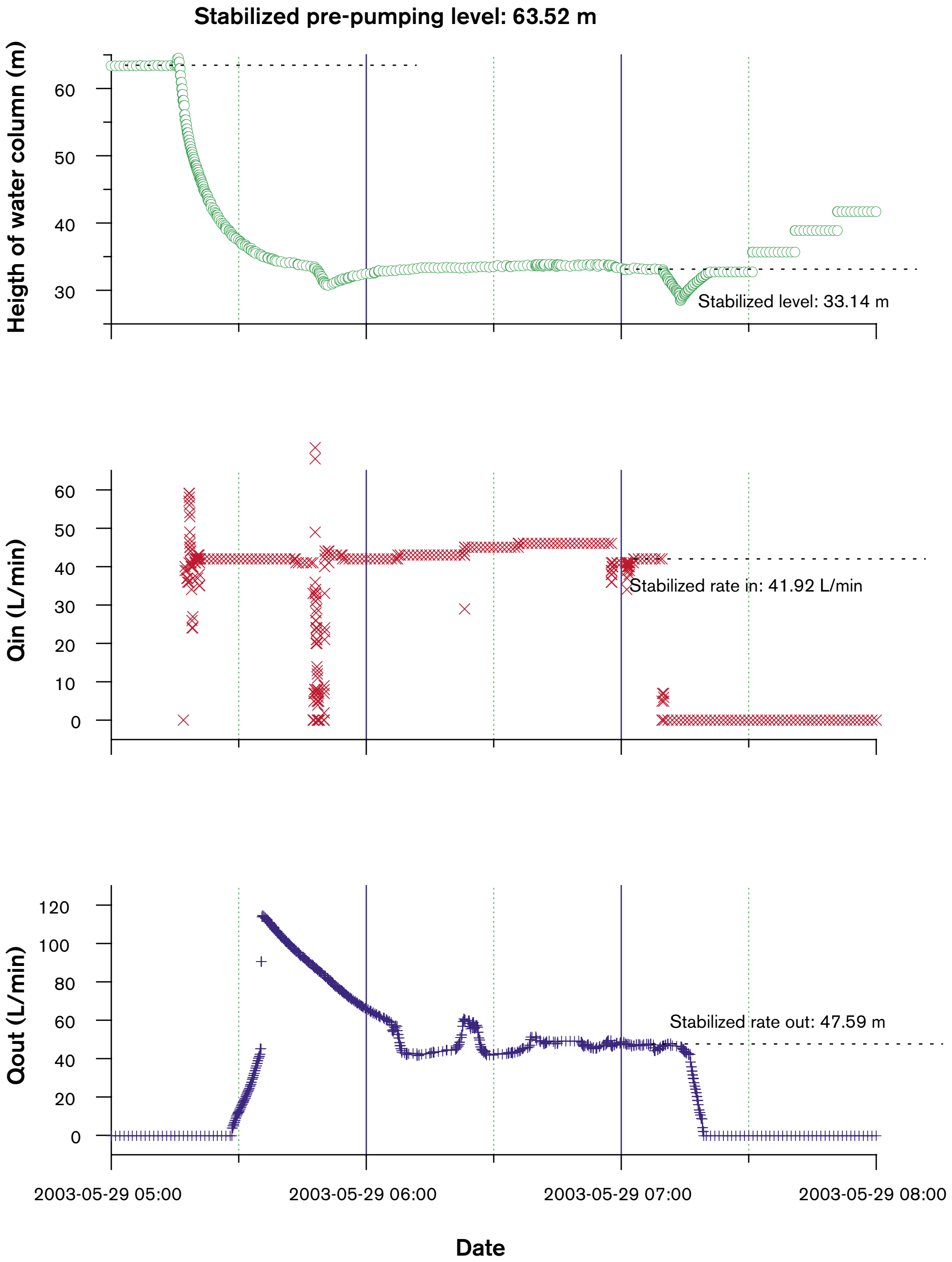


Figure 5-13. *Air lift pumping results in KSH02 between 100.3 and 1,001.11 m. The gauge measuring the "flow-rate out" (blue) was positioned after the settling tank causing the delay in readings between the "flow-rate in" (red) and "height of the water column" (green). The "flow-rate in" was measured on the surface before entering the borehole and the "height of water column" was measured in the telescopic section where the pressure transducer was positioned 60 m below top of casing.*

5.5 Drilling monitoring results

5.5.1 Drill monitoring system DMS

The DMS database contains substantial amounts of drilling monitoring data. A selection of results primarily from the monitoring of the flushing water parameters are presented in Figures 5-14 through 5-16 below.

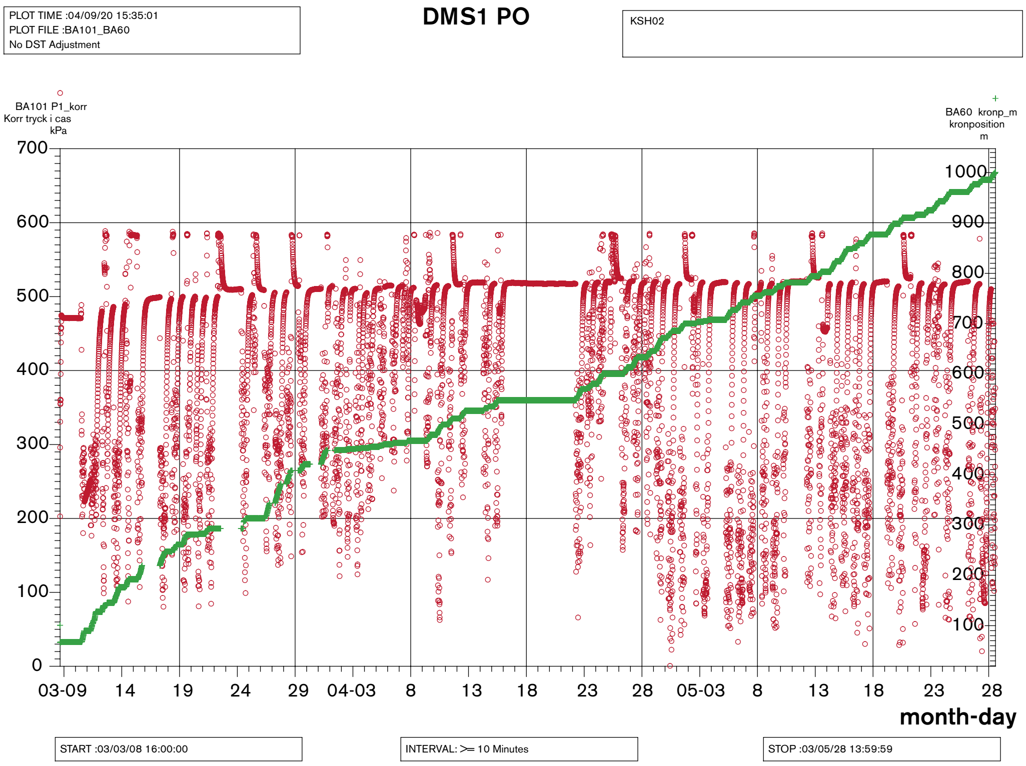


***Figure 5-14.** Drill bit position (green) and water level from air-lift pumping (red). The water level is expressed as the pressure in kPa of the water column overlying the pressure gauge i.e. the ambient air-pressure has been subtracted. The pressure gauge is emplaced at 60.0 m borehole length. The drill bit position is given in cm × 10^3.*

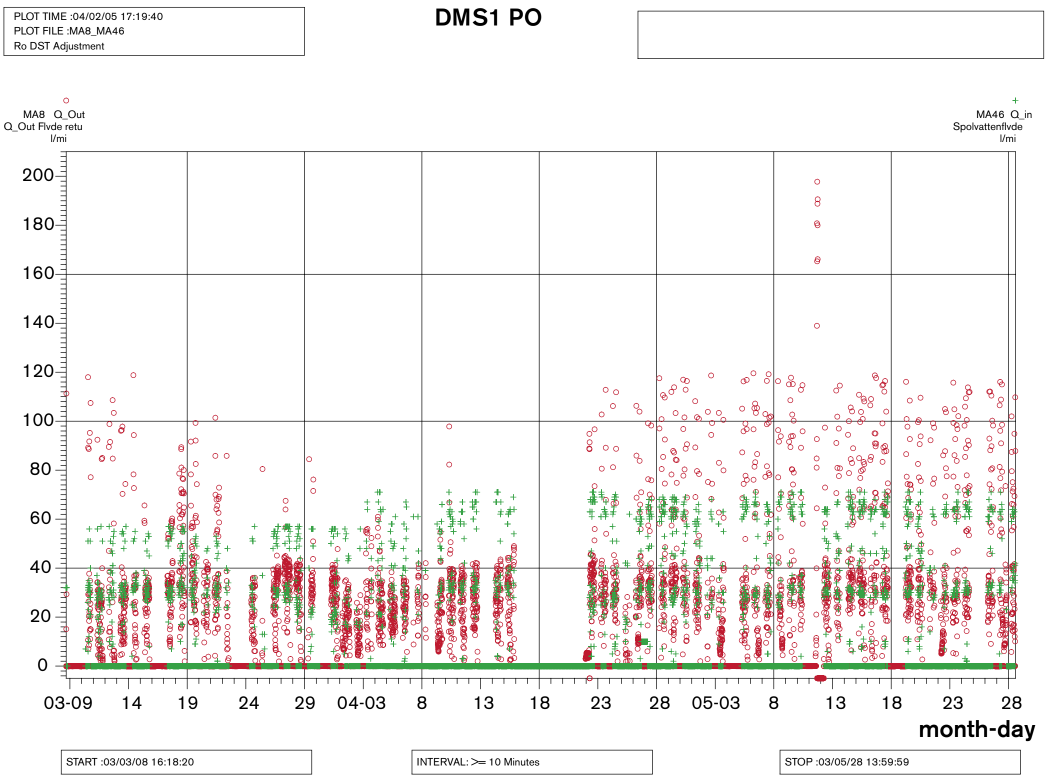


***Figure 5-15.** Flushing water flow (green) and return water flow (red) in litres per minute.*

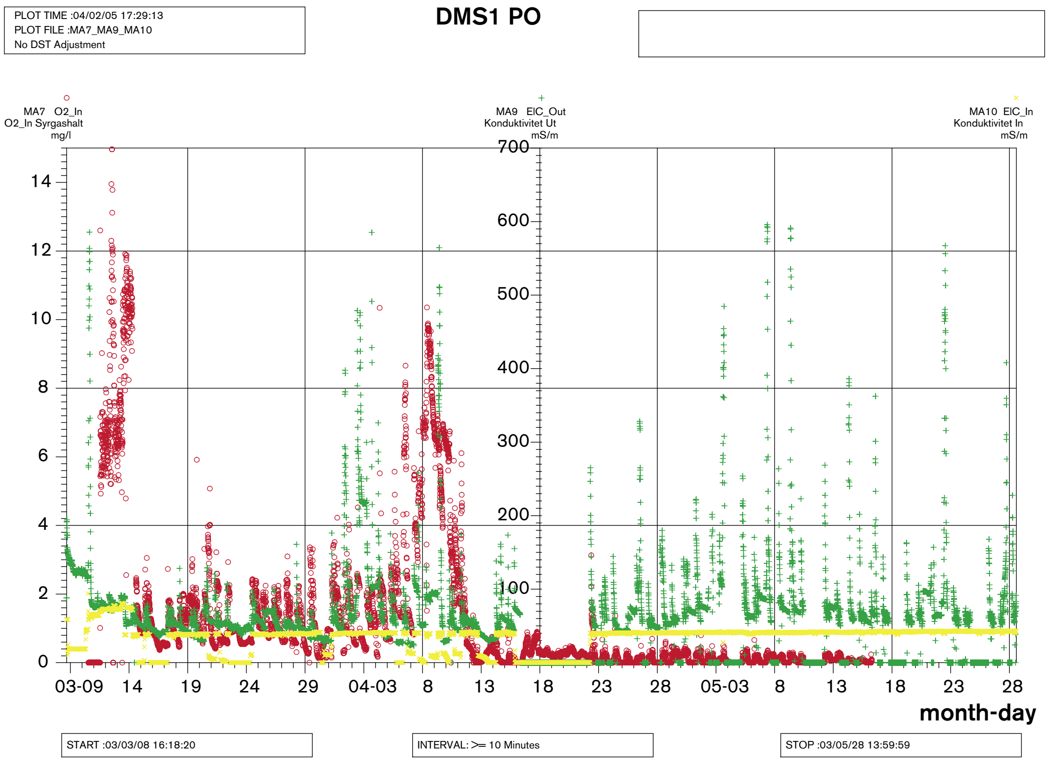


Figure 5-16. *Conductivity of flushing water in mS/m (yellow) and return water (green). The oxygen content in mg/l of the flushing water (red) is also shown.*

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 drillstem).
- 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 5-14 through 5-16.

Figure 5-14 depicts the drill bit position (green) over time and the water level (red) in the telescope part of the drill hole. The water level, given as pressure of the overlying water column reflects the air-lift pumping activity in the hole.

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

Figure 5-16 shows the conductivity of the ingoing flushing water (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 typically low, however two notable exceptions exist. Between March 12 and 14 the oxygen content varied between 5 and 15 mg/l. On March 14 the oxygen meter was adjusted and the oxygen level fell to a stable level at 2 mg/l. Between April 6 and 9 the oxygen meter showed too high values (5–10 mg/l) because the meter was placed so that a suction effect occurred. The emplacement of the meter and surrounding fittings was rectified and the oxygen readings fell to a low, stable and correct level. Minor fluctuations can also occur because the oxygen content is registered during periods when there is no actual water flow.

5.5.2 Measurements of flushing water and drill cuttings

A calculation of accumulated water flow based on water flow measurements from the DMS system (continuous readings) is given in Figure 5-17. The data has been corrected from non-existing flows during periods when no drilling was made. A slightly steeper gradient on the return water flow can be seen indicating that the amount of return water should be some 300 m³ more than the ingoing flushing water.

The flushing water consumed during drilling of KSH02 amounted to about 1,200 m³, giving an average consumption of 1.2 m³ per metre drilled.

The weight of cuttings in the settling containers amounted to 2,450 kg. The theoretical amount that should be produced from drilling with 76 mm triple tubing over a length of 900 m is 5,700 kg.

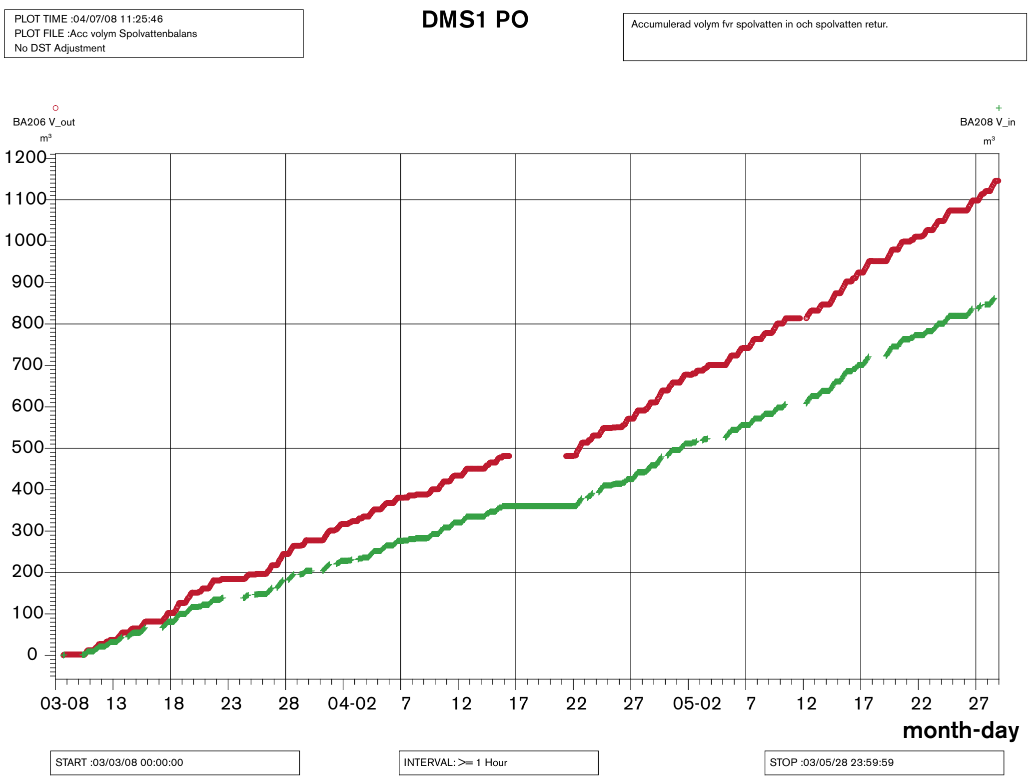


Figure 5-17. *Flushing water balance from KSH02 as recorded by the DMS system. The accumulated volume of the ingoing flushing water is shown in green and the outgoing return water is shown in red.*

5.6 Geology

The geological results, based on the Boremap logging /3/, are shown in Appendix 1.

The core is dominated by fine-grained dioritoide with minor intercalations of pegmatite. Between 550 and 720 m several sections of fine-grained granite with a width along core of up to 20 m occur. Rock alteration as faint to medium intensity oxidation is not uncommon between 200 and 750 m length.

The total fracture frequency is normally less than 20 per metre. Some crushed sections (i.e. total fracture frequency > 40 per metre) have been noted at 50, 290, 500, 710 and 740 m length. The total fracture frequency is greatly reduced below 900 m 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:

- KSH02 field note Simpevarp 30.

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 7,600 kg in total. The concrete was based on standard cement.

The interval from the surface to 12.5 m length was gap filled between the outer casing and the rock-wall with 1,250 kg of concrete, with a water/cement ratio of 0.6.

The percussion drilled hole was back-filled with concrete from 100.3 m to 12.5 m. For this purpose 6,350 kg of concrete with a water/cement ratio of 0.44 was used.

5.9 Nonconformities

Date	Reported by	Nonconformity
2003-01-27	M Berglund, Drillcon	The 265 mm casing was only emplaced to a length of 16.5 m due to a displacement of the hole along a fracture
2003-02-21	M Berglund, Drillcon	The 208 mm casing was emplaced to 65.88 m as opposed to the planned 100 m. The section below 66 m was filled with concrete and the telescopic section was constructed to a length of 65.81 m.
2003-04-08	Jonny Sjöberg and Ulf Lindros, Swedpower	The protective cone fell down into the borehole in conjunction with rock stress measurements. The probe got stuck at 287 m due to a cave-in and had to be drilled away.
2003-06-02, 2003-07-21	Matti Alaverronen, SMOY	The reference slots were not all emplaced with the planned 50-metre interval. Their locations were, however, documented.
	M Berglund, Drillcon	
2003-06-04	Matti Alaverronen, SMOY	The design of the steel conical guide was modified and extended 15 m.

6 References

/1/ **SKB, 2001.** Platsundersökningar. Undersökningsmetoder och generellt genomförande-program 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.** Boremap mapping of core drilled borehole KSH02. SKB P-04-131, Svensk Kärnbränslehantering AB.

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

/5/ **SKB, 2004.** Overcoring rock stress measurements in borehole KSH02. SKB P-04-23, Svensk Kärnbränslehantering AB.

Appendix 1

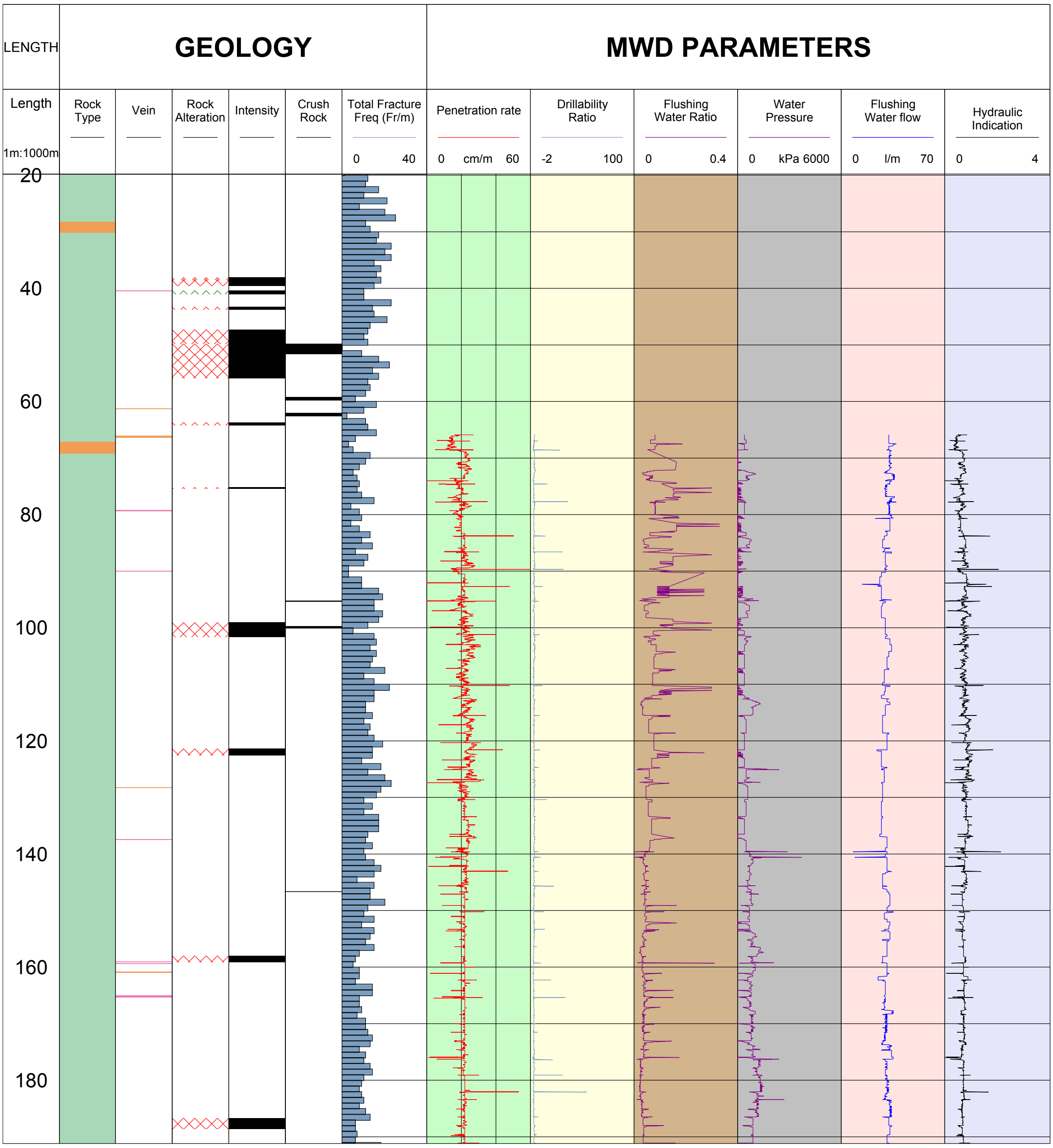
Title **GEOLOGY & MWD PARAMETERS KSH02**

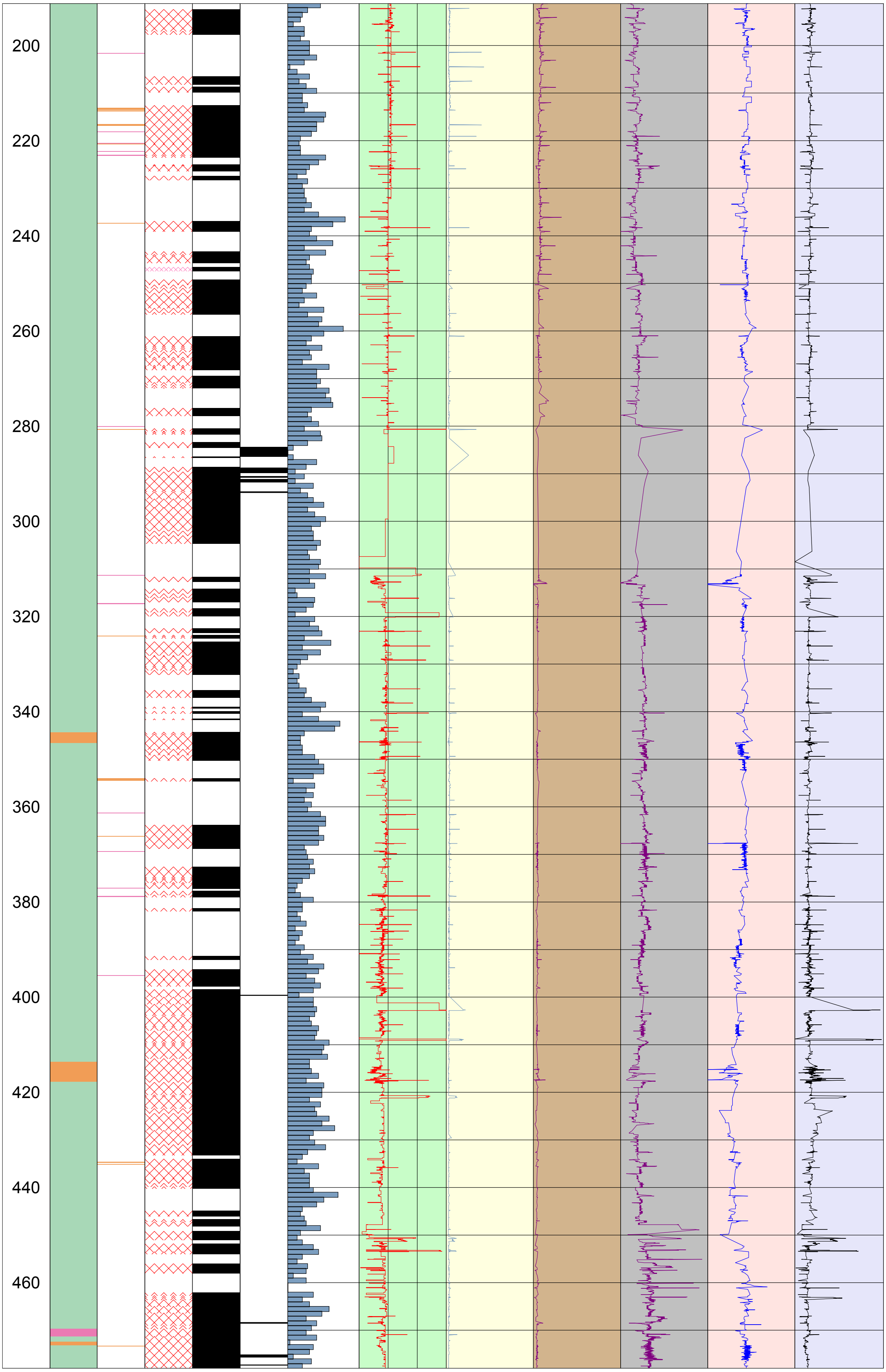
Site	SIMPEVARP	**Coordinate System**	RT90-RHB70
Borehole	KSH02	**Northing [m]**	6365658.33
Diameter [mm]	76	**Easting [m]**	1551528.93
Length [m]	1001.110	**Elevation [m.a.s.l.]**	5.48
Bearing [°]	330.68	**Drilling Start Date**	2003-01-22 07:00:00
Inclination [°]	-85.67	**Drilling Stop Date**	2003-06-11 15:10:00
Date of mapping	2004-03-15 09:53:00	**Plot Date**	2004-04-27 21:00:36

ROCKTYPE SIMPEVARP
- Fine-grained granite
- Pegmatite
- Fine-grained dioritoid
- Fine-grained diorite-gabbro

ROCK ALTERATION
- Oxidized
- Chloritisized
- Albitization

INTENSITY
- Faint
- Weak
- Medium
- Strong

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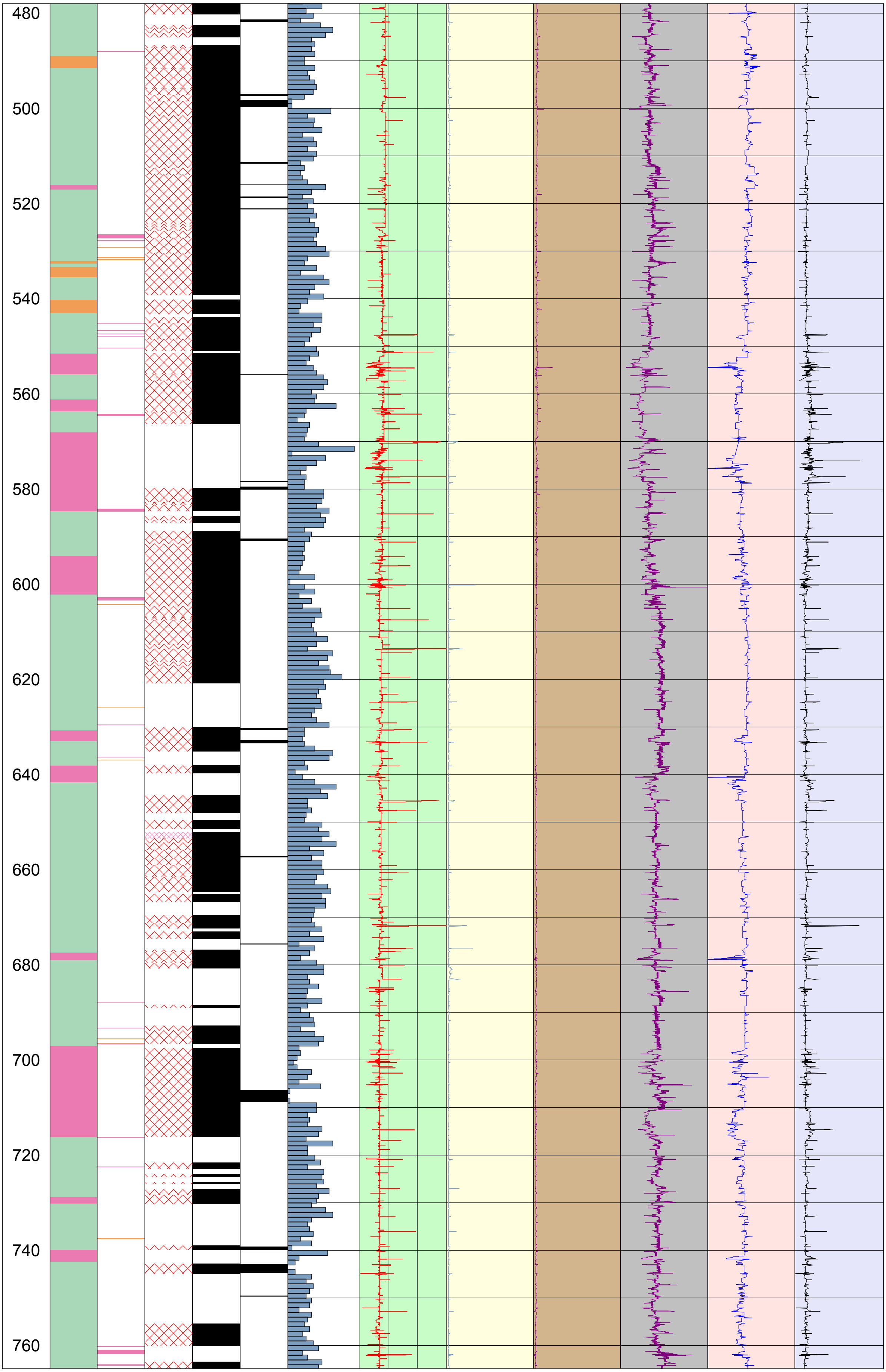
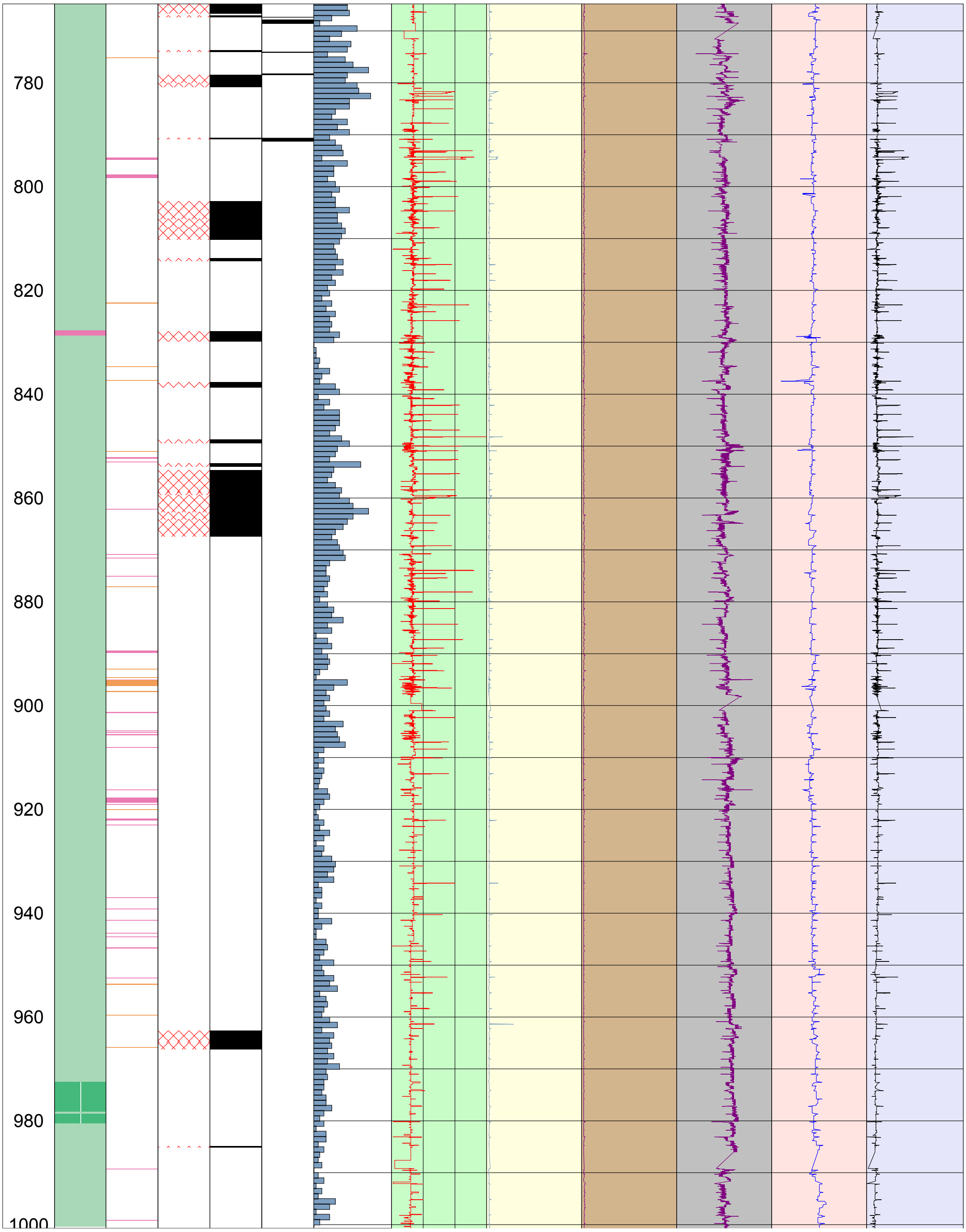
440
460


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	KSH02	KSH02	KSH02	KSH02	HLX10	HLX10	HLX10
Date of measurement	2003-02-10	2003-04-09	2003-05-08	2003-05-14	2003-03-12	2003-03-12	2003-03-12
Upper section limit	6.65	411.85	738.00	699.00			
Lower section limit	100.50	467.07	755.17	803.15			
Sample_no	3888	3832	3827	3833	3901	3903	3904
Groundwater Chemistry Class	3	3	3	3	3	3	3
pH	8.35	7.08	7.14	7.41	8.1	8.23	8.23
Conductivity mS/m	64.5	1,709	677	1,035	33.2	46.7	38.7
TOC mg/l							2.9
Drill water %	26.64	5.56	52.41	52.99	0.03	0.02	0.02
Na mg/l	112	2,450					67.7
K mg/l	3.58	11.2					2.81
Ca mg/l	18.7	1,280					12.9
Mg mg/l	4.2	9.7					4.4
HCO3 mg/l Alkalinity	245	29	101	89	178	202	198
Cl mg/l	27.4	6,425.9	2,157.5	3,532.9	5.6	6.2	6.3
SO4 mg/l	75.78	176.69	92.32	157.6	14.52	18.02	17.84
SO4_S mg/l Total Sulphur	22.7	59.7					6.48
Br mg/l	0.58	46.5	15.49	30.77	–0.2	0.21	–0.2
F mg/l	1.96	2.11	2.31	1.88	1.78	2.8	2.75
Si mg/l	6.8	3.8					5.7
Fe mg/l Total Iron	1.1	3.07					0.098
Mn mg/l	0.06	0.19					0.06
Li mg/l	0.02	0.276					0.006
Sr mg/l	0.24	21.5					0.12
PMC % Modern Carbon							
C-13 dev PDB							
AGE_BP Groundwater age							
D dev SMOW		–93.4					
Tr TU		–0.8					
O-18 dev SMOW		–12.6					
B-10 B-10/B-11	2.43E–01	2.40E–01					
S-34 dev SMOW		18.2					
Cl-37 dev SMOC		3.60E–01					
Sr-87 Sr-87/Sr86		7.20E–01					

Appendix 3

Chemistry – analytical method

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

Quality of the analyses

The charge balance errors give an indication of the quality and uncertainty of the analyses of the major components. The relative charge balance errors are calculated for the selected sets of data from the borehole. The errors do not exceed ± 5% in any of the samples (3888 and 3832) which is fully satisfactory.

The samples 3827 and 3833 were not analysed for main components. The relative charge balance errors could not be calculated for these samples.

Figures C1 and C2 illustrate the consistency of the analyses. The figures are based on the data presented in Appendix 2. Electric conductivity values are plotted versus chloride concentrations in Figure C1.

The bromide and chloride concentrations are plotted in Figure C2. A plot of bromide versus chloride serves as a rough quality control of the bromide analyses.

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).

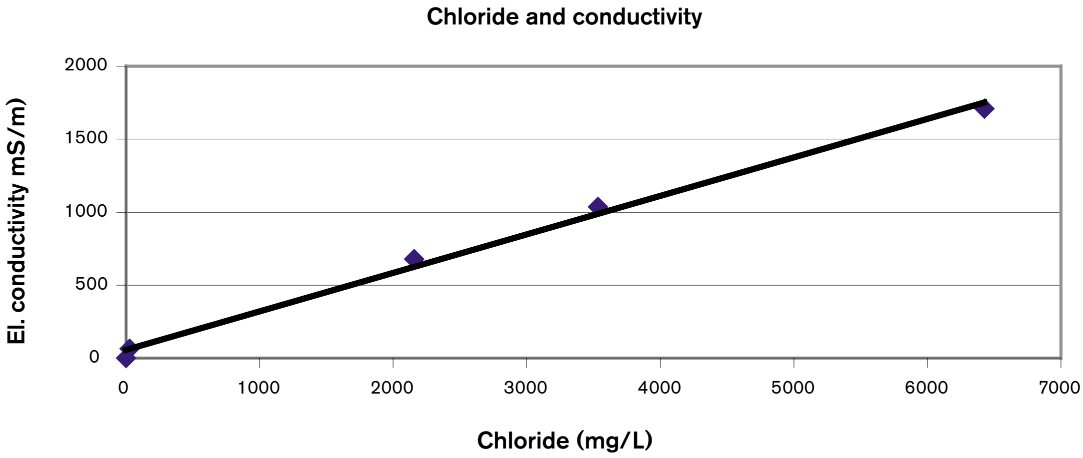


Figure C1. *Plot of electric conductivity versus chloride concentration.*

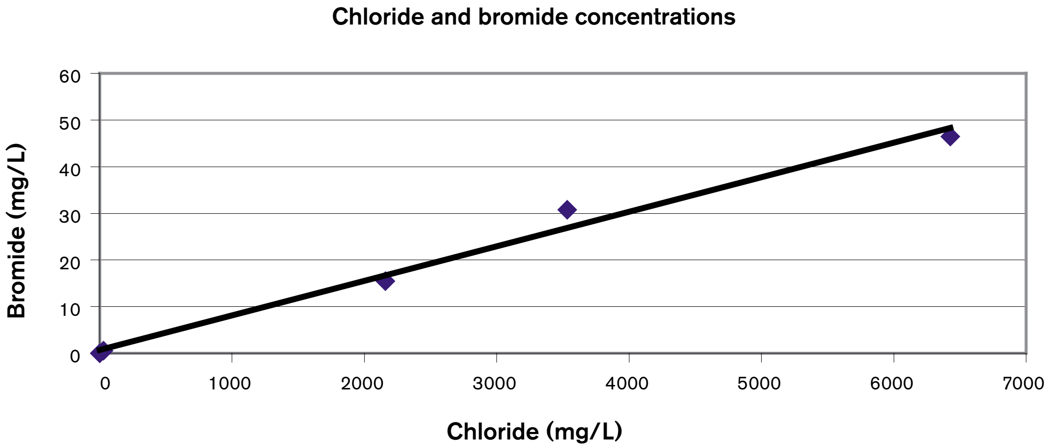


Figure C2. *Plot of bromide concentrations versus chloride concentrations.*

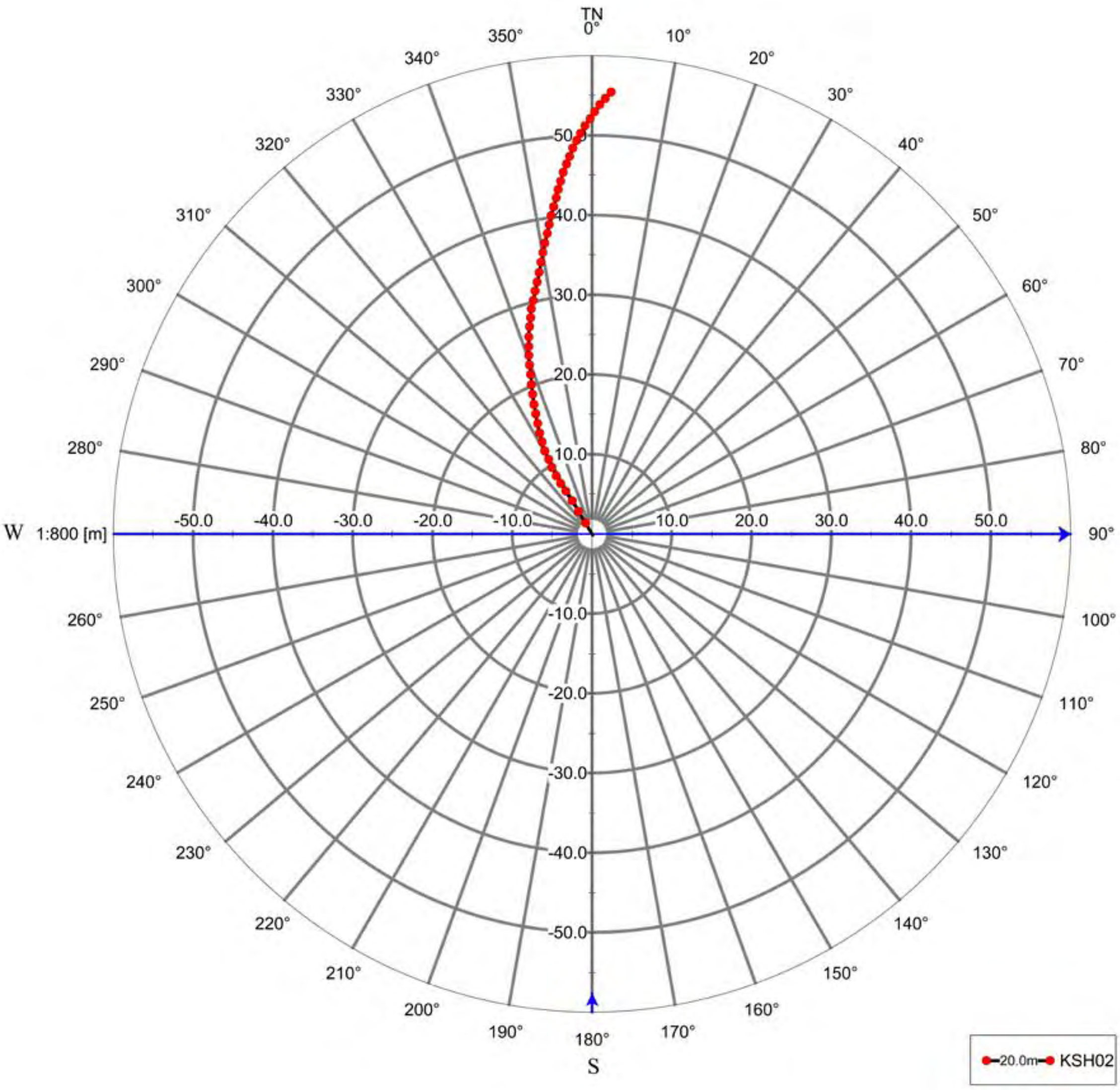
- Data on basic water analyses are inserted into raw data tables for further evaluation. The evaluation results in a final reduced data set for each sample. These data sets are compiled in a primary data table named "water composition". The evaluation is based on:
- Comparison of the results from different laboratories and/or methods. The analyses are repeated if a large disparity is noted (generally more than 10%).
- Calculation of charge balance errors. Relative errors within ± 5% are considered acceptable. For surface waters errors of ± 10%.
- $\text{Rel. Error (\%)} = 100 \times \frac{(\sum \text{cations(equivalents)} - \sum \text{anions(equivalents)})}{(\sum \text{cations(equivalents)} + \sum \text{anions(equivalents)})}$
- General expert judgement of plausibility based on earlier results and experiences.

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

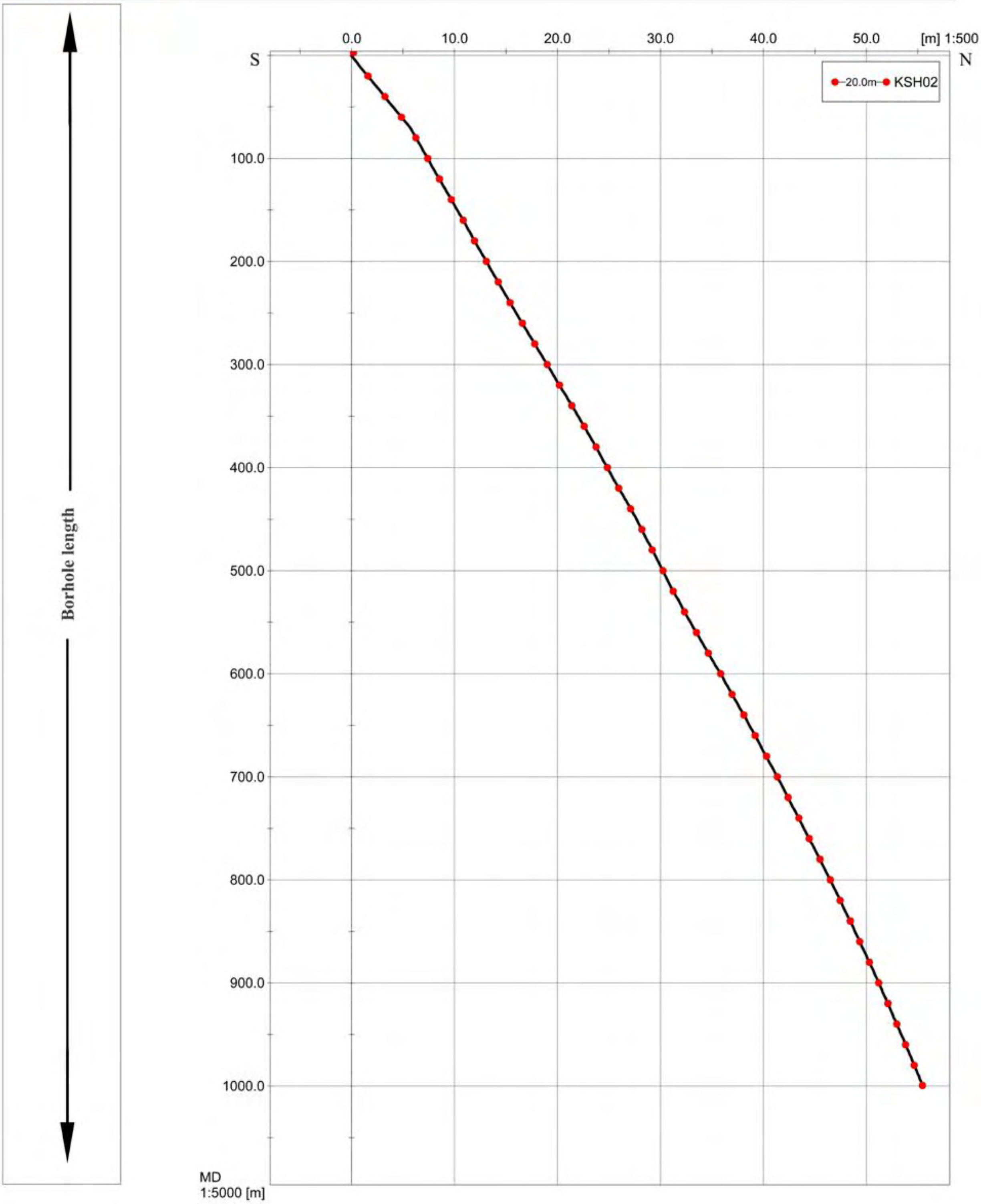
Deviation measurement

Site SIMPEVARP
Borehole KSH02
View from above



Deviation measurement	Appendix: 4

Site SIMPEVARP
Borehole KSH02
Vertical Section



Appendix 5

Wireline pumping tests

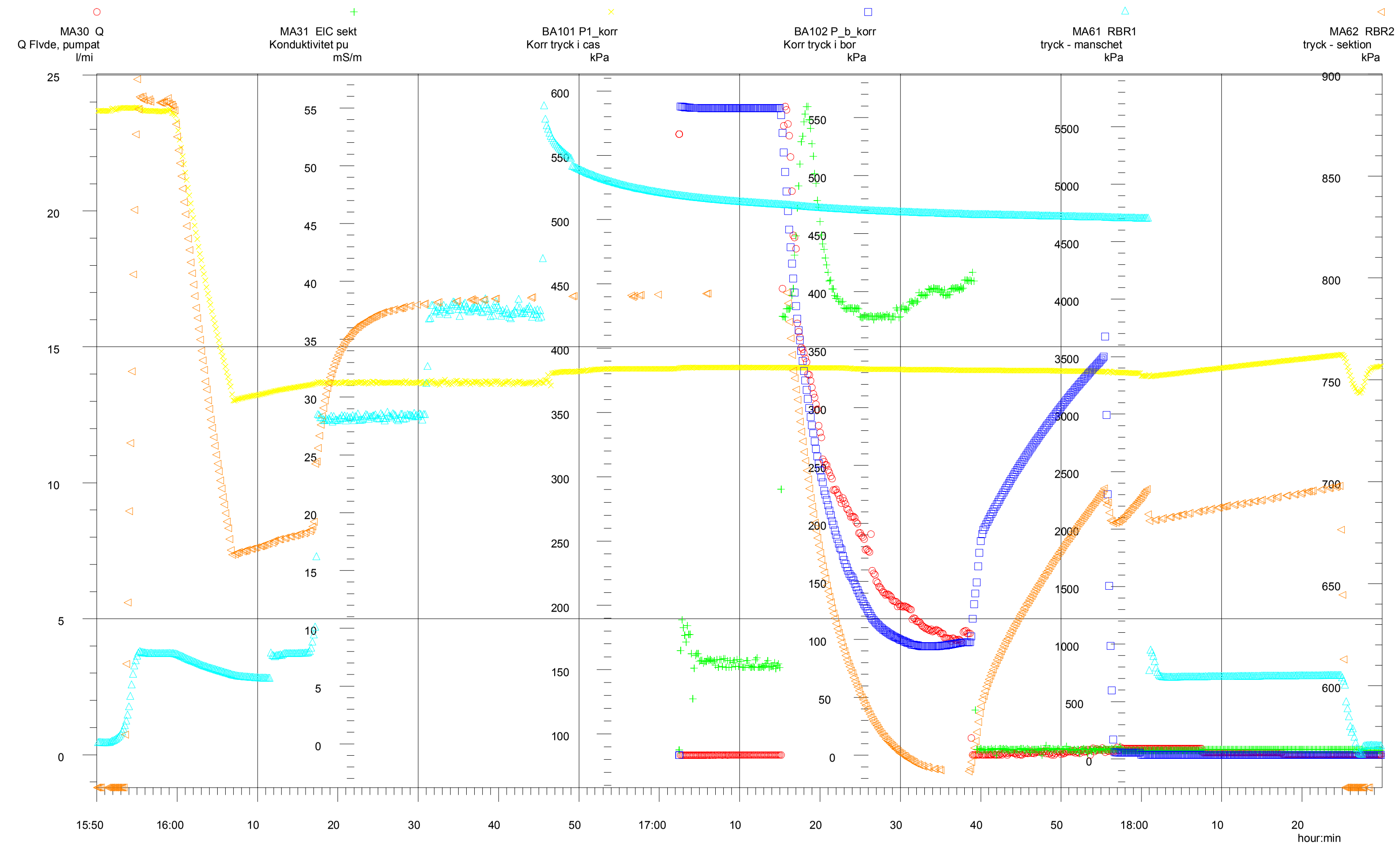
Description of the parameters in the enclosed plots.

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 i.e. at depth in the borehole, subtracted with the ambient air pressure.
MA61	Pressure – packer	kPa	Inflation pressure in packer
MA62	Pressure – section	kPa	Pressure of the water column in the test section ie at depth in the borehole. Not corrected for ambient air pressure

PLOT TIME :04/07/05 12:42:10
PLOT FILE :P_pumptest
No DST Adjustment

DMS1 PO

Pumping test
KSH02 81.10-192.22m
Wireline sond



START :03/03/14 15:50:00

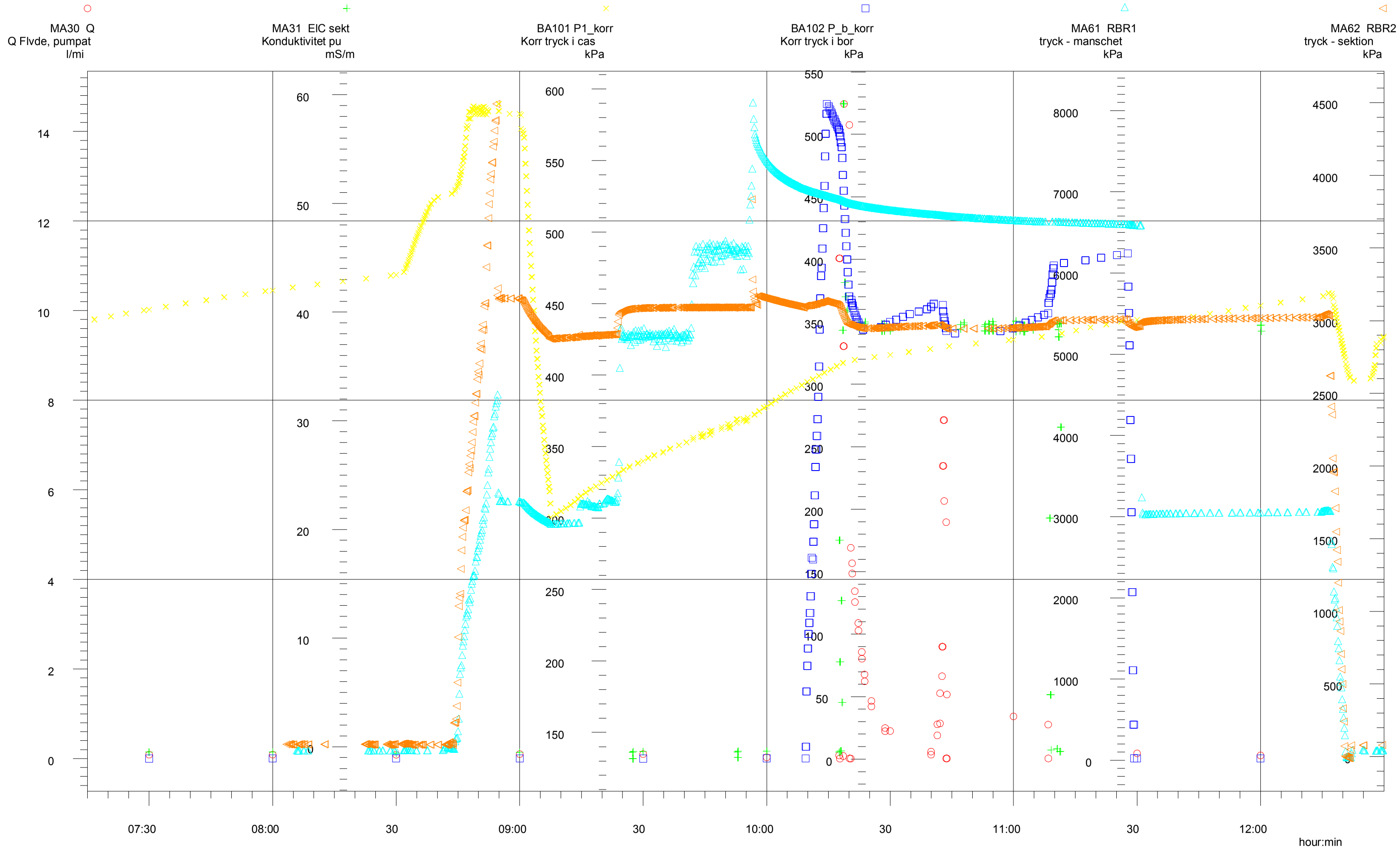
INTERVAL: All readings

STOP :03/03/14 18:29:59

PLOT TIME :04/07/07 10:41:29
PLOT FILE :P_pumptest
No DST Adjustment

DMS1 PO

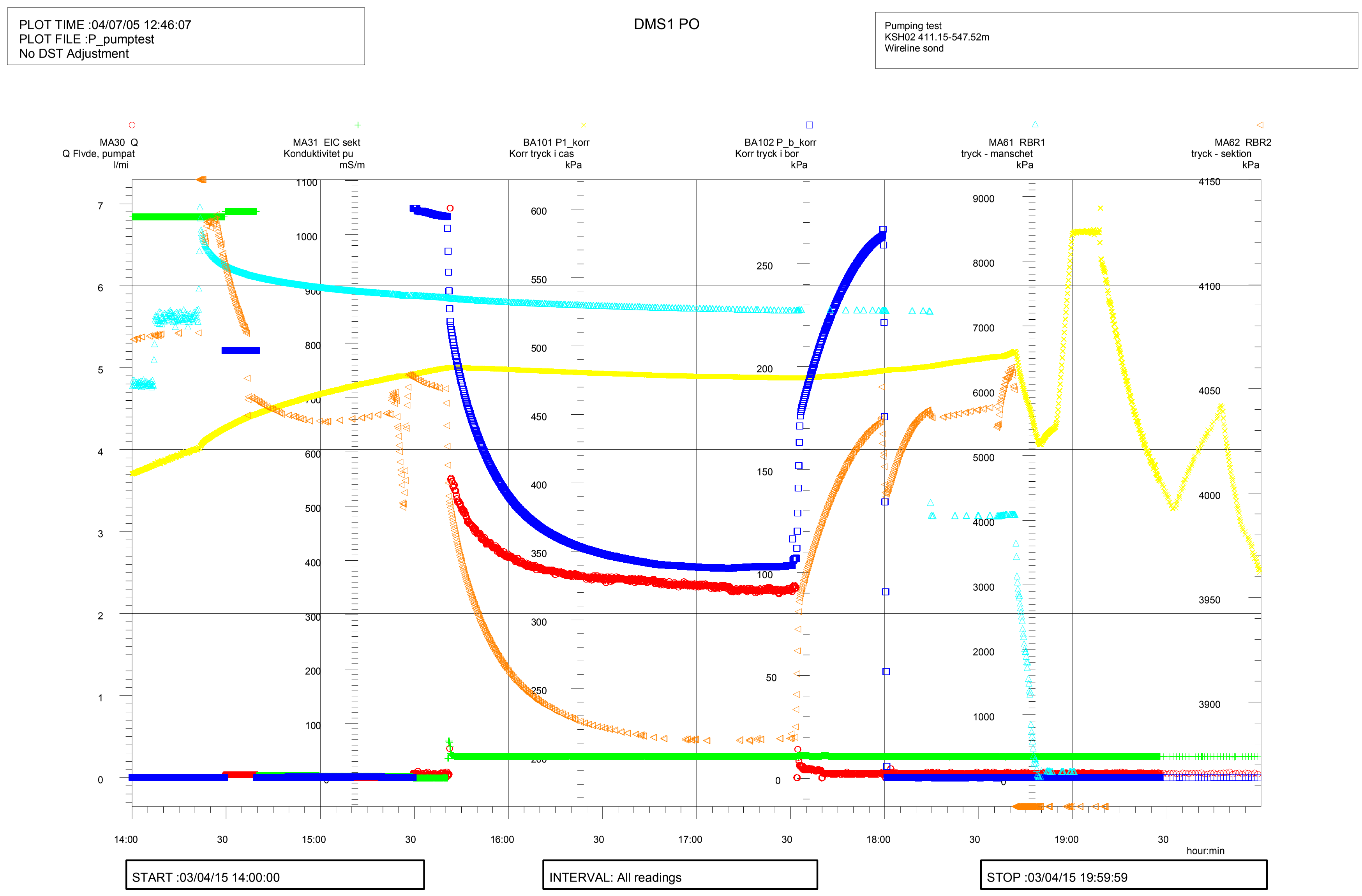
Pumping test
KSH02 312.00-408.78m
Wireline sond



START :03/03/29 07:15:00

INTERVAL: All readings

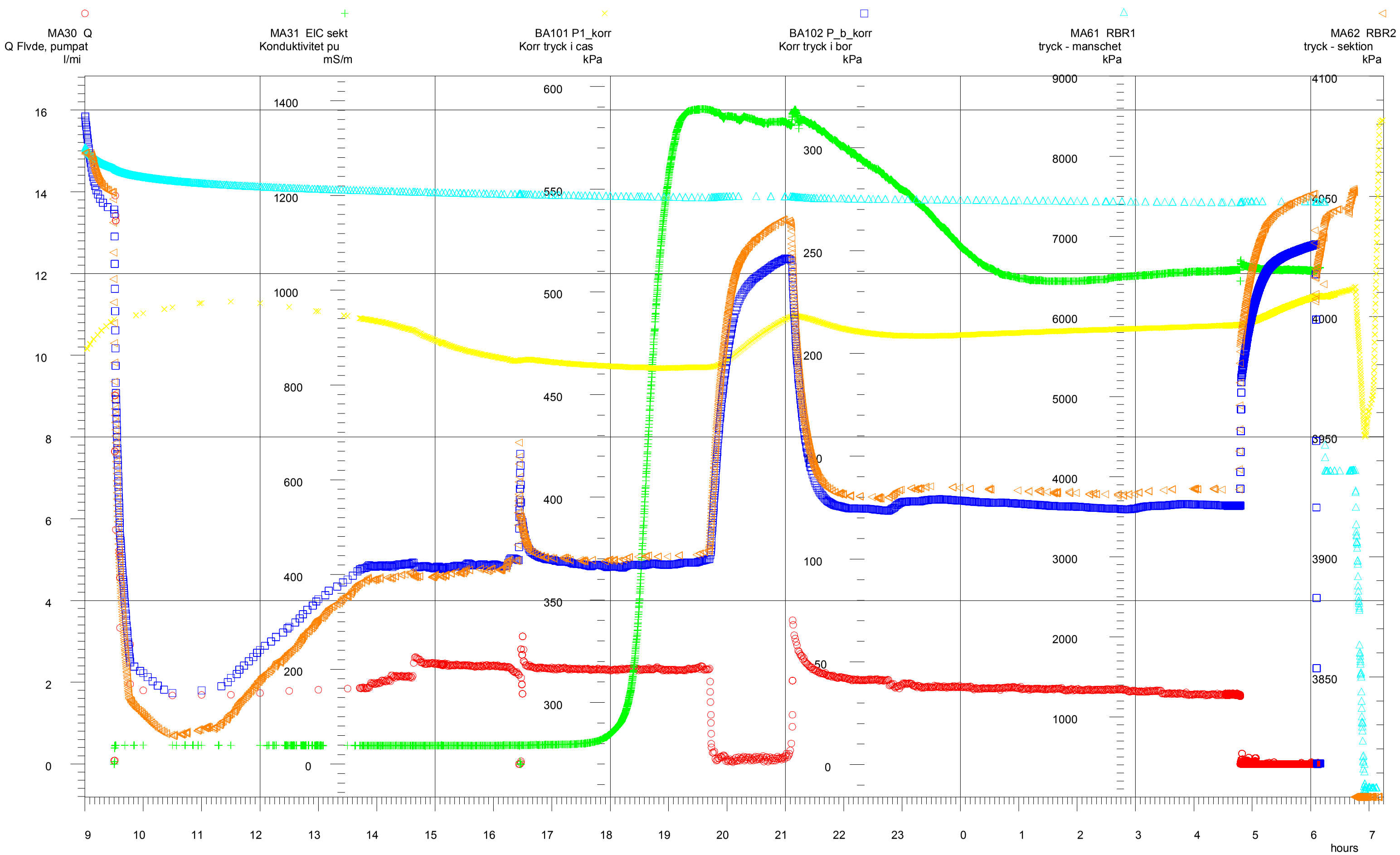
STOP :03/03/29 12:29:59


PLOT TIME :04/07/05 12:46:07
PLOT FILE :P_pumptest
No DST Adjustment
DMS1 PO
Pumping test
KSH02 411.15-547.52m
Wireline sond
MA30 Q
Q Flvde, pumpat
l/mi
MA31 EIC sekt
Konduktivitet pu
mS/m
BA101 P1_korr
Korr tryck i cas
kPa
BA102 P_b_korr
Korr tryck i bor
kPa
MA61 RBR1
tryck - manschet
kPa
MA62 RBR2
tryck - sektion
kPa
hour:min
START :03/04/15 14:00:00
INTERVAL: All readings
STOP :03/04/15 19:59:59

PLOT TIME :04/07/05 13:05:16
PLOT FILE :P_pumptest
No DST Adjustment

DMS1 PO

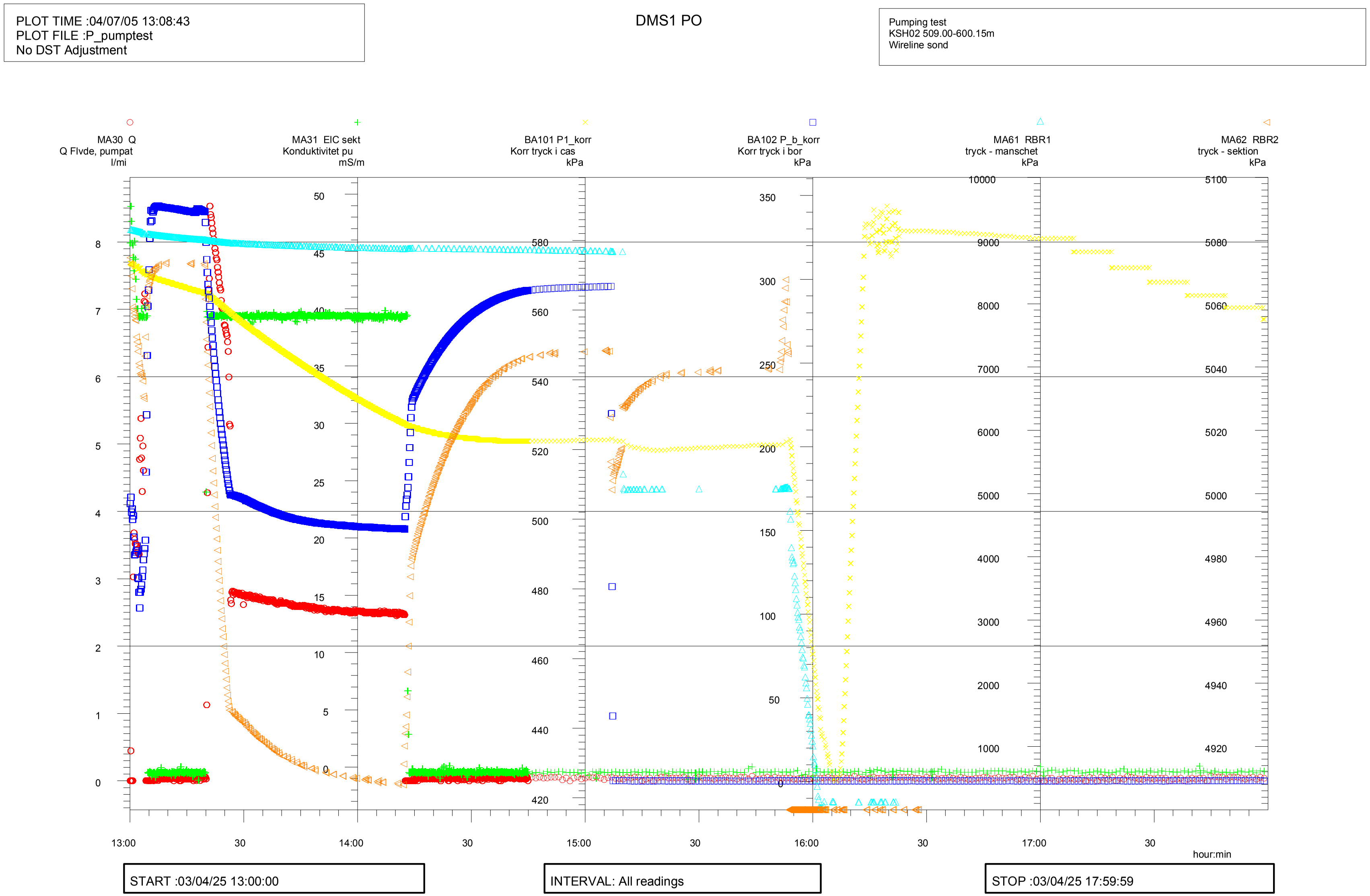
Pumping test
KSH02 411.85-467.07m
Wireline sond



START :03/04/08 09:00:00

INTERVAL: All readings

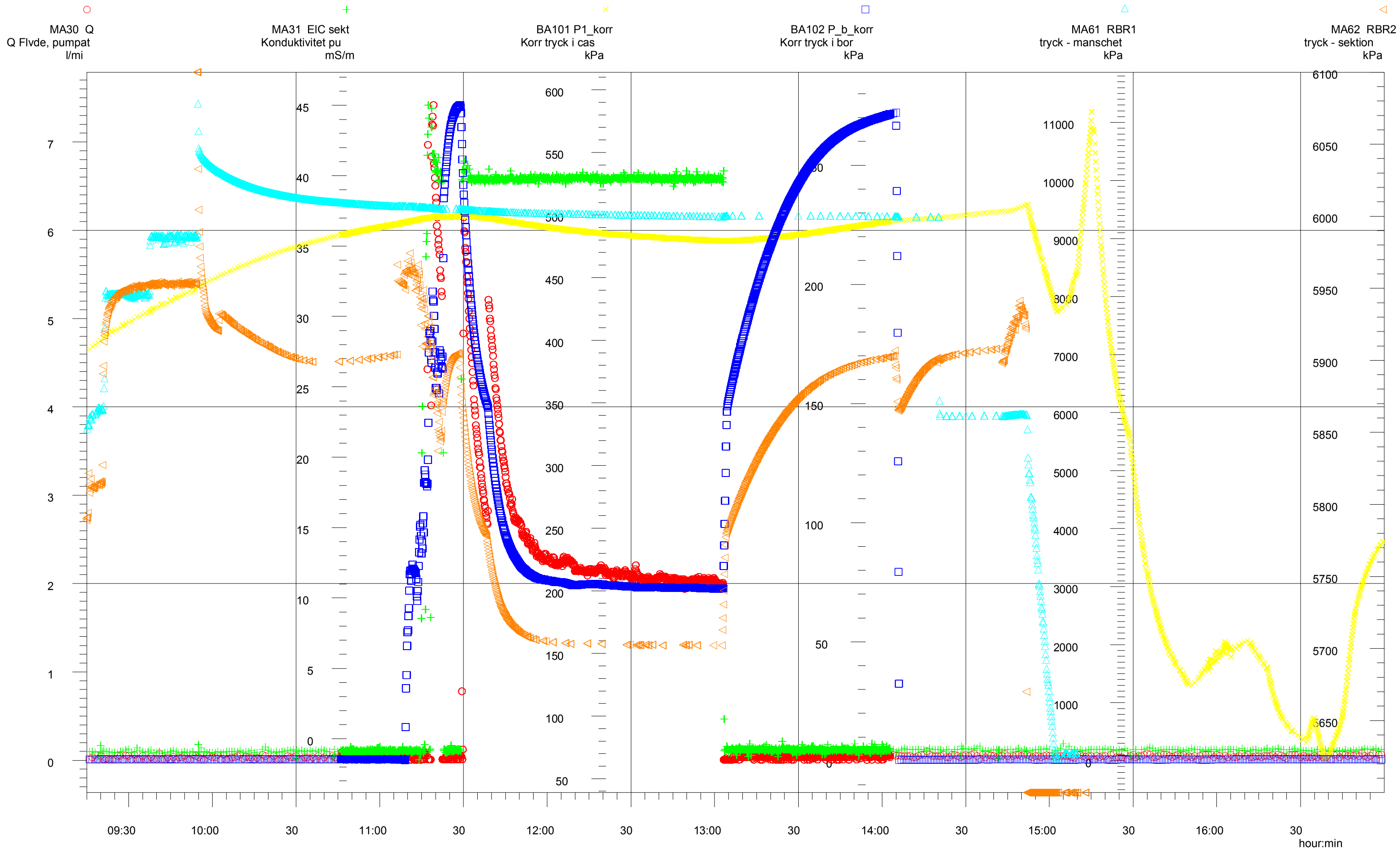
STOP :03/04/09 07:14:59


PLOT TIME :04/07/05 13:08:43
PLOT FILE :P_pumptest
No DST Adjustment
DMS1 PO
Pumping test
KSH02 509.00-600.15m
Wireline sond
MA30 Q
Q Flvde, pumpat
l/mi
MA31 ElC sekt
Konduktivitet pu
mS/m
BA101 P1_korr
Korr tryck i cas
kPa
BA102 P_b_korr
Korr tryck i bor
kPa
MA61 RBR1
tryck - manschet
kPa
MA62 RBR2
tryck - sektion
kPa
13:00
30
14:00
30
15:00
30
16:00
30
17:00
30
hour:min
START :03/04/25 13:00:00
INTERVAL: All readings
STOP :03/04/25 17:59:59

PLOT TIME :04/07/05 12:34:41
PLOT FILE :P_pumptest
No DST Adjustment

DMS1 PO

Pumping test
KSH02 600.00-700.00m
Wireline sond



START :03/05/02 09:15:00

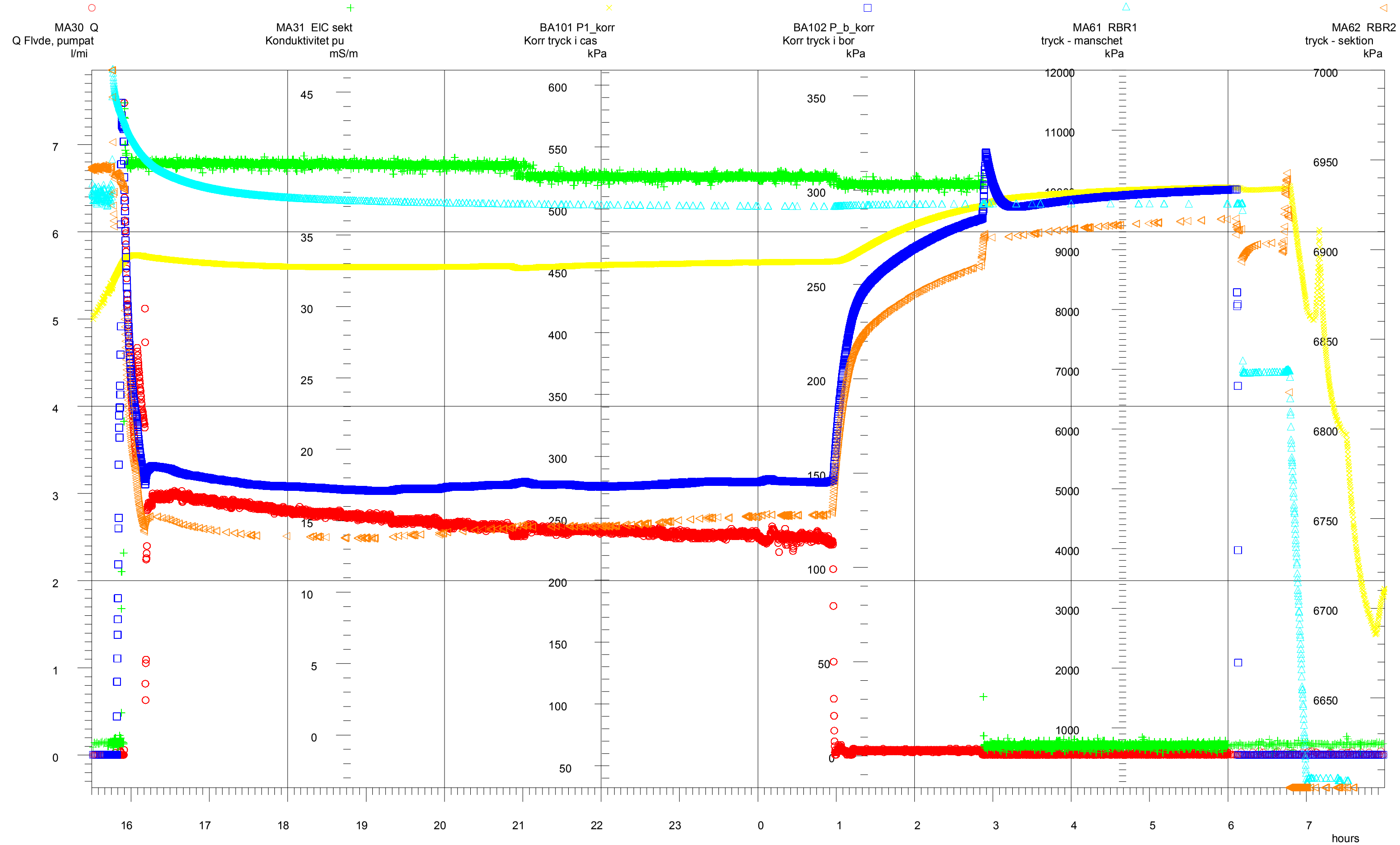
INTERVAL: All readings

STOP :03/05/02 16:59:59

PLOT TIME :04/07/05 13:12:44
PLOT FILE :P_pumptest
No DST Adjustment

DMS1 PO

Pumping test
KSH02 699.00-803.15m
Wireline sond



START :03/05/13 15:30:00

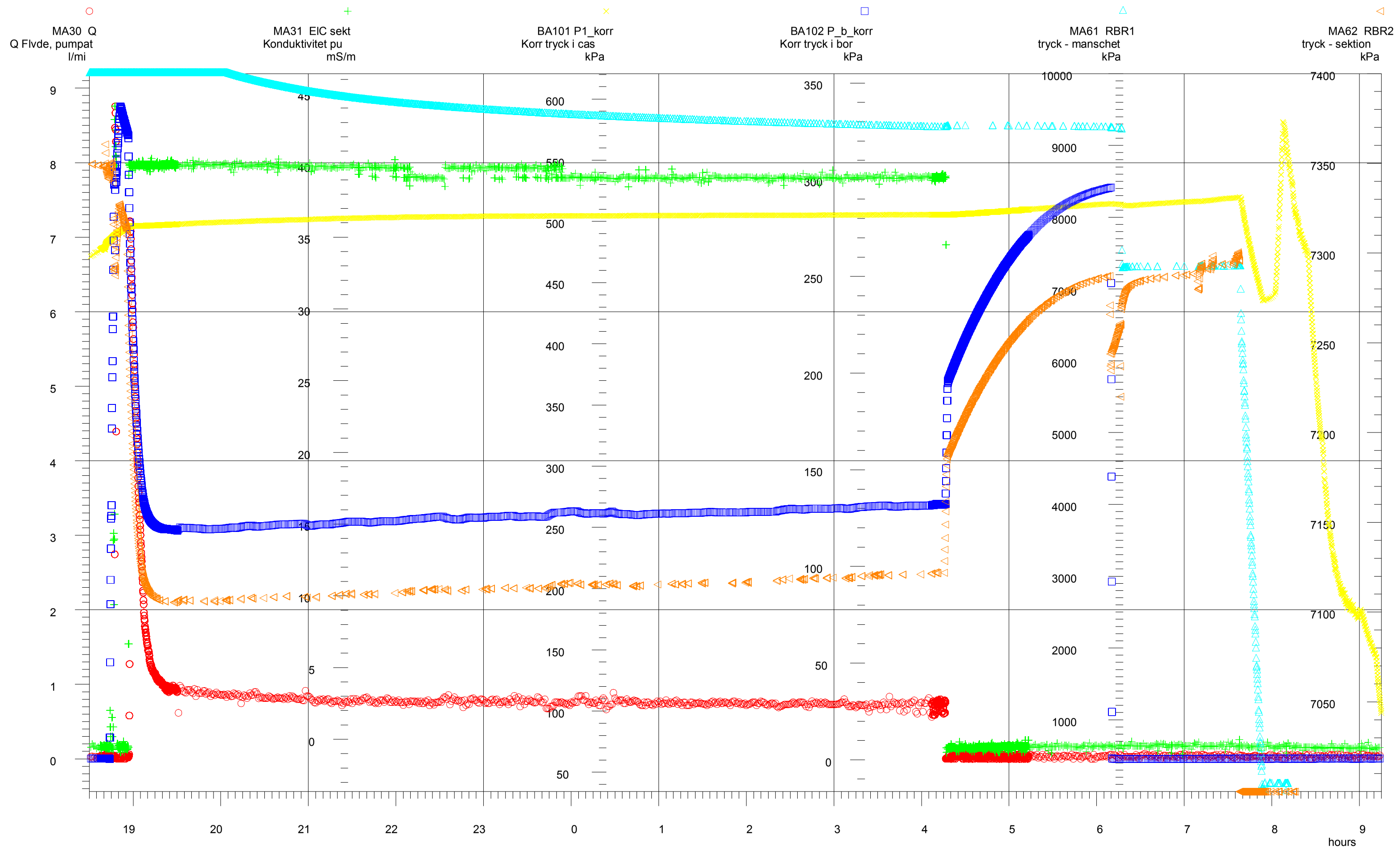
INTERVAL: All readings

STOP :03/05/14 07:59:59

PLOT TIME :04/07/05 12:58:00
PLOT FILE :P_pumptest
No DST Adjustment

DMS1 PO

Pumping test
KSH02 737.00-755.17m
Wireline sond



START :03/05/07 18:30:00

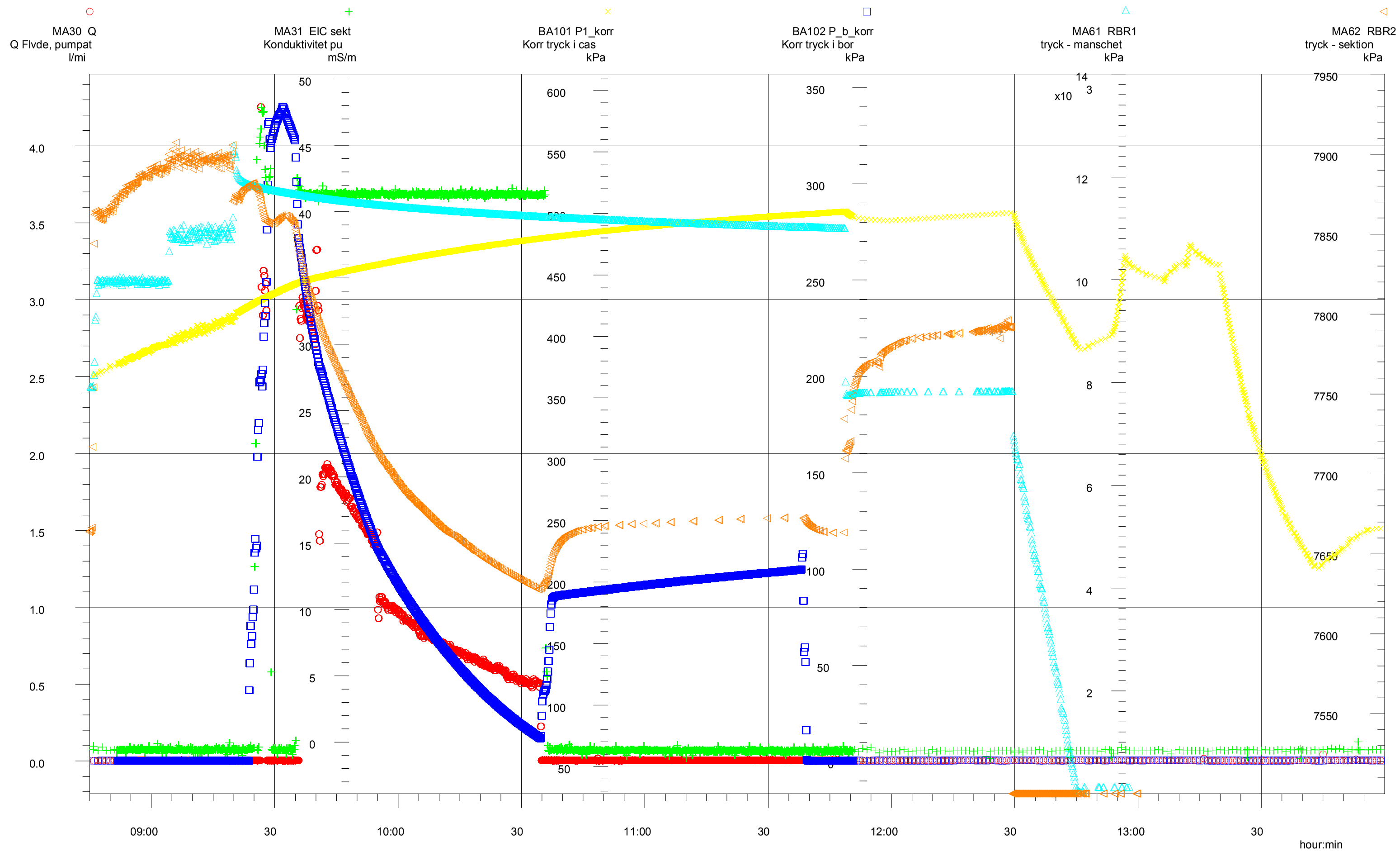
INTERVAL: All readings

STOP :03/05/08 09:14:59

PLOT TIME :04/07/05 12:52:09
PLOT FILE :P_pumptest
No DST Adjustment

DMS1 PO

Pumping test
KSH02 791.00-910.13m
Wireline sond



START :03/05/21 08:45:00

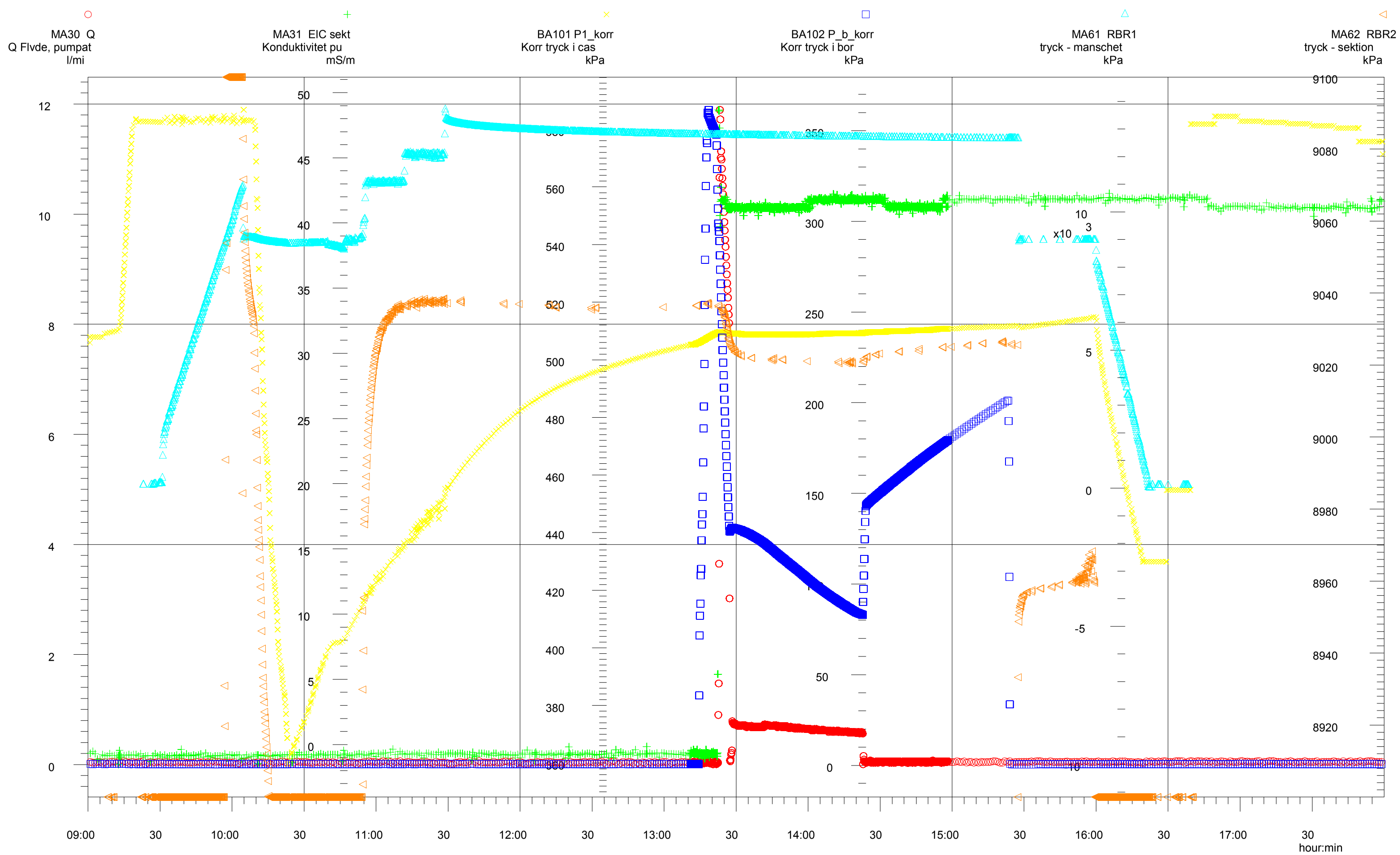
INTERVAL: All readings

STOP :03/05/21 13:59:59

PLOT TIME :04/07/05 12:25:47
PLOT FILE :P_pumptest
No DST Adjustment

DMS1 PO

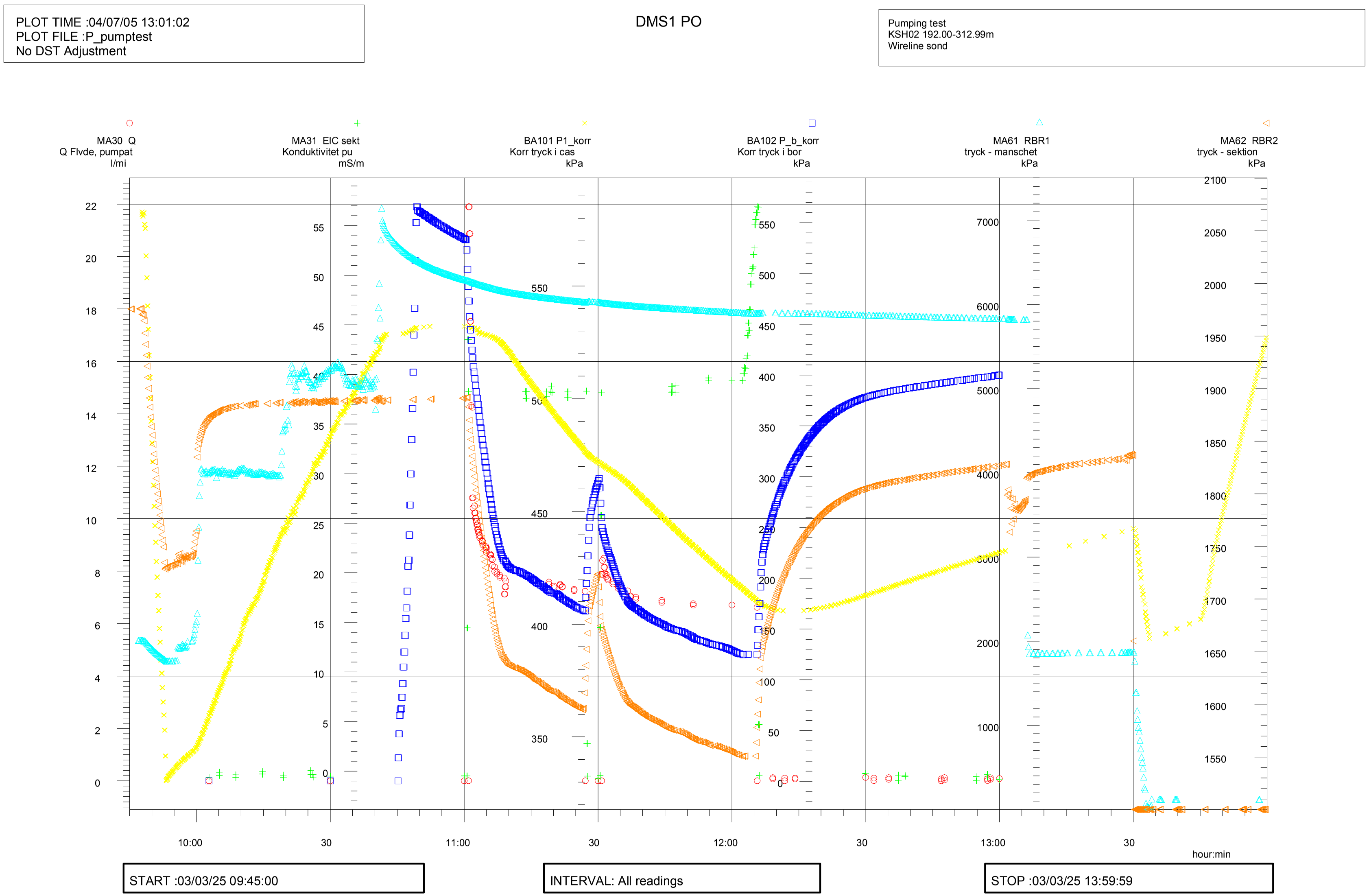
Pumping test
KSH02 909.00-1001.11m
Wireline sond



START :03/05/30 09:00:00

INTERVAL: All readings

STOP :03/05/30 17:59:59


PLOT TIME :04/07/05 13:01:02
PLOT FILE :P_pumptest
No DST Adjustment
DMS1 PO
Pumping test
KSH02 192.00-312.99m
Wireline sond
MA30 Q
Q Flvde, pumpat
l/mi
MA31 EIC sekt
Konduktivitet pu
mS/m
BA101 P1_korr
Korr tryck i cas
kPa
BA102 P_b_korr
Korr tryck i bor
kPa
MA61 RBR1
tryck - manschet
kPa
MA62 RBR2
tryck - sektion
kPa
10:00
30
11:00
30
12:00
30
13:00
30
hour:min
START :03/03/25 09:45:00
INTERVAL: All readings
STOP :03/03/25 13:59:59

Appendix 6

Absolute pressure measurement

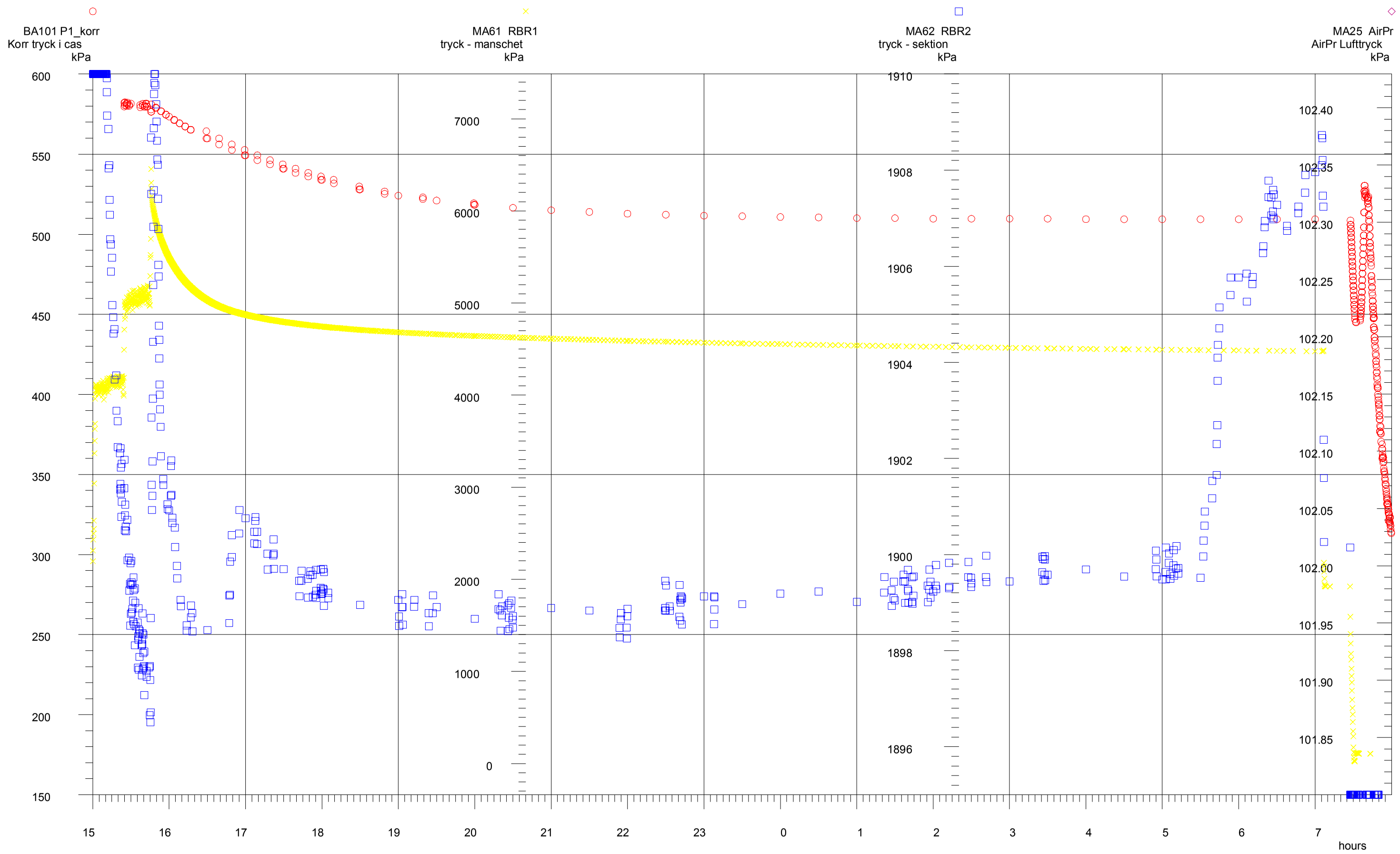
Description of the parameters in the enclosed plots.

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 :04/07/05 14:14:40
PLOT FILE :P_tryck_i _sektion
No DST Adjustment

DMS1 PO

Absolute pressure measurement
KSH02 192.00-312.99m
Wireline sond



START :03/03/25 15:00:00

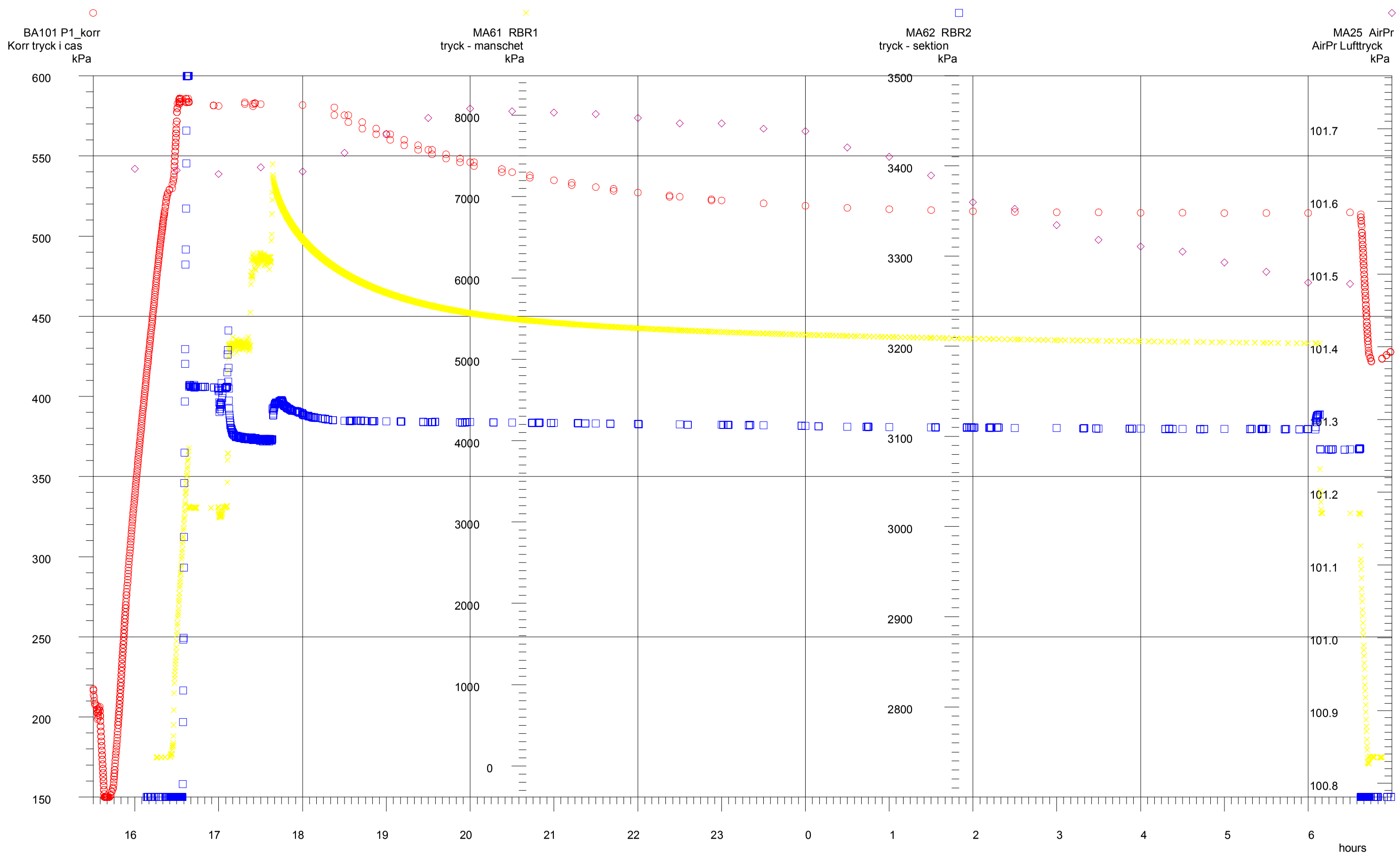
INTERVAL: All readings

STOP :03/03/26 07:59:59

PLOT TIME :04/07/05 14:16:40
PLOT FILE :P_tryck_i _sektion
No DST Adjustment

DMS1 PO

Absolute pressure measurement
KSH02 312.00-408.78m
Wireline sond



START :03/03/28 15:30:00

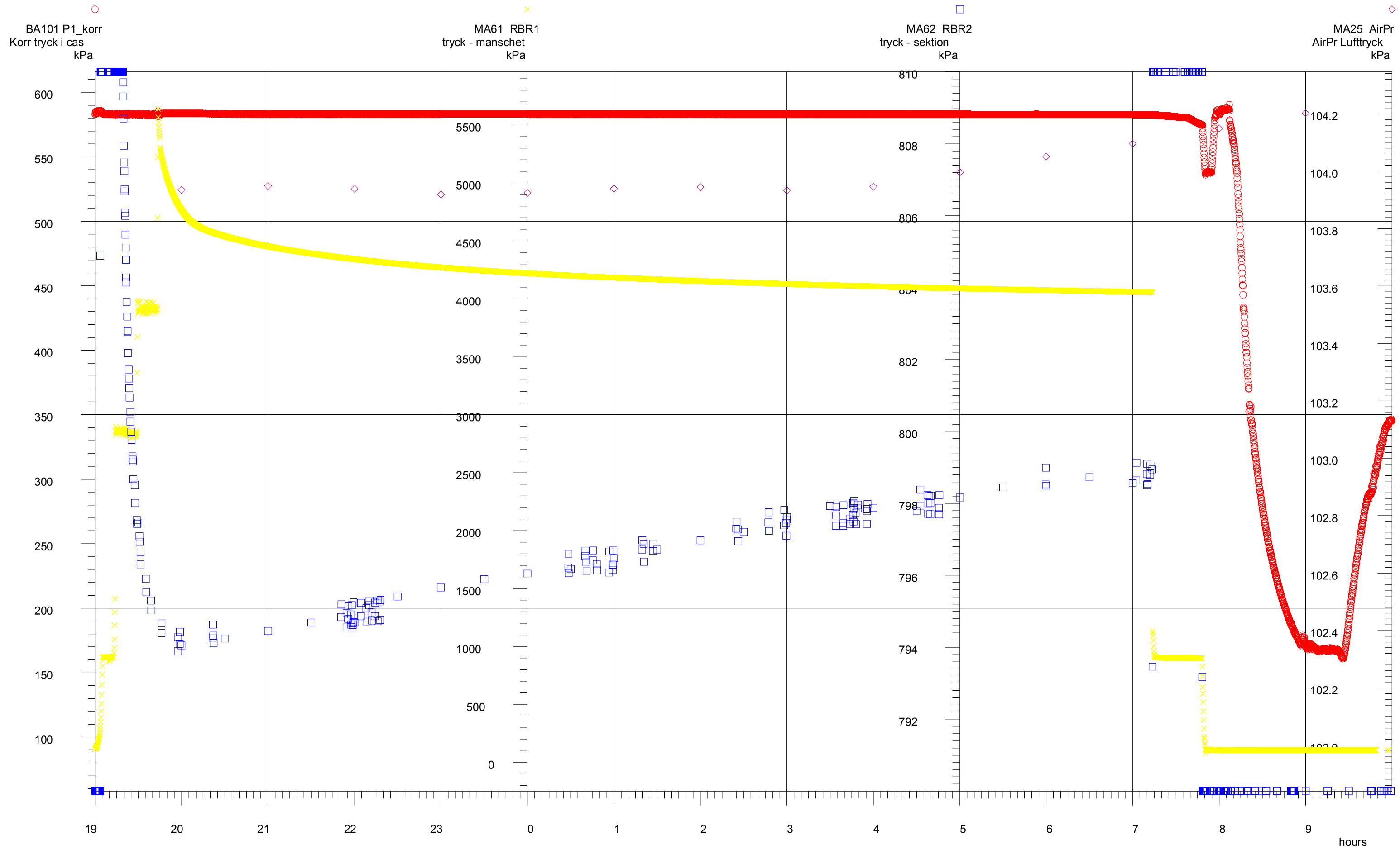
INTERVAL: All readings

STOP :03/03/29 06:59:59

PLOT TIME :04/07/07 10:46:52
PLOT FILE :P_tryck_i _sektion
No DST Adjustment

DMS1 PO

Absolute pressure measurement
KSH02 81.10-192.20m
Wireline sond



START :03/03/14 19:00:00

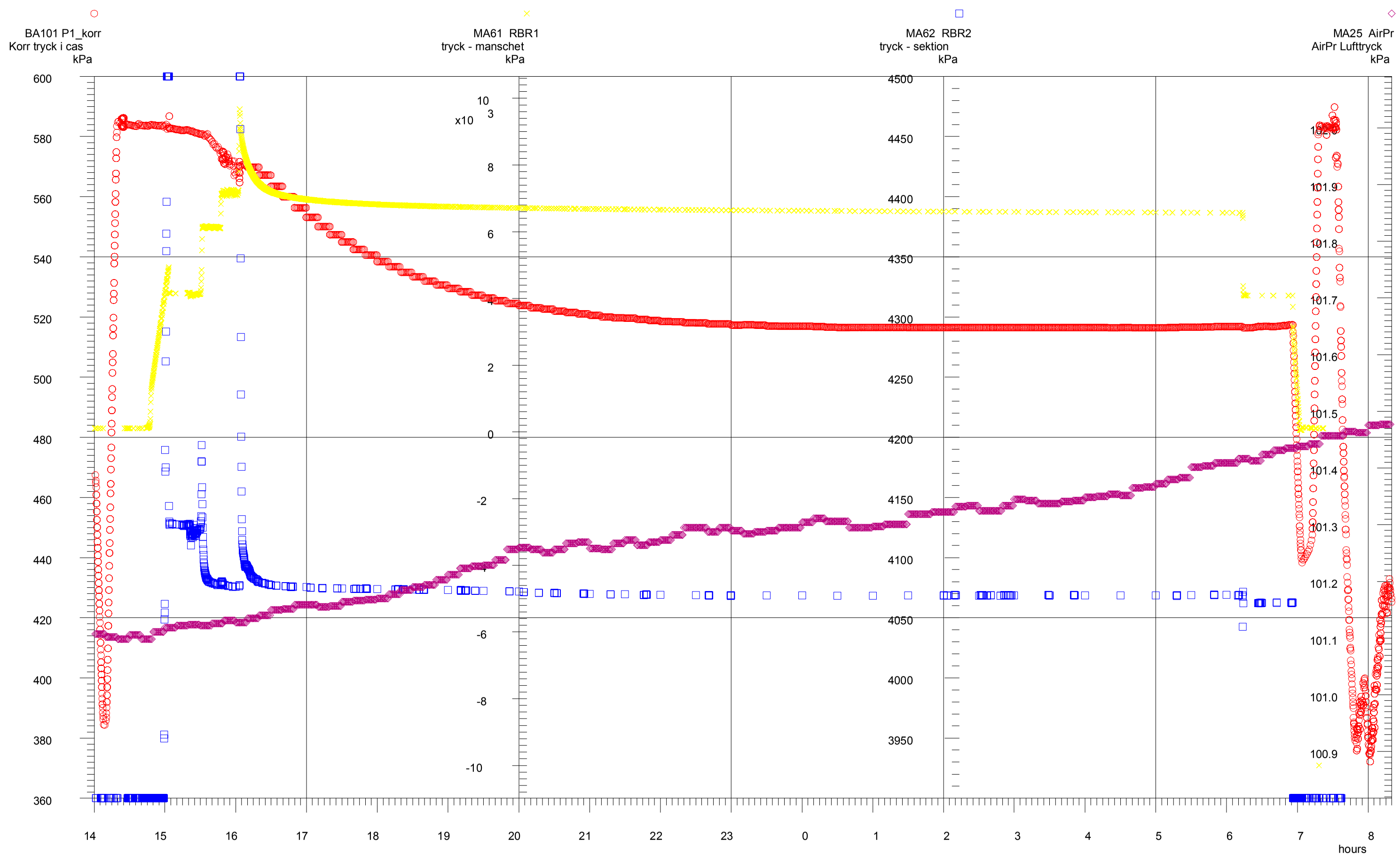
INTERVAL: All readings

STOP :03/03/15 09:59:59

PLOT TIME :04/07/05 14:18:58
PLOT FILE :P_tryck_i _sektion
No DST Adjustment

DMS1 PO

Absolute pressure measurement
KSH02 410.15-511.63m
Wireline sond



START :03/04/11 14:00:00

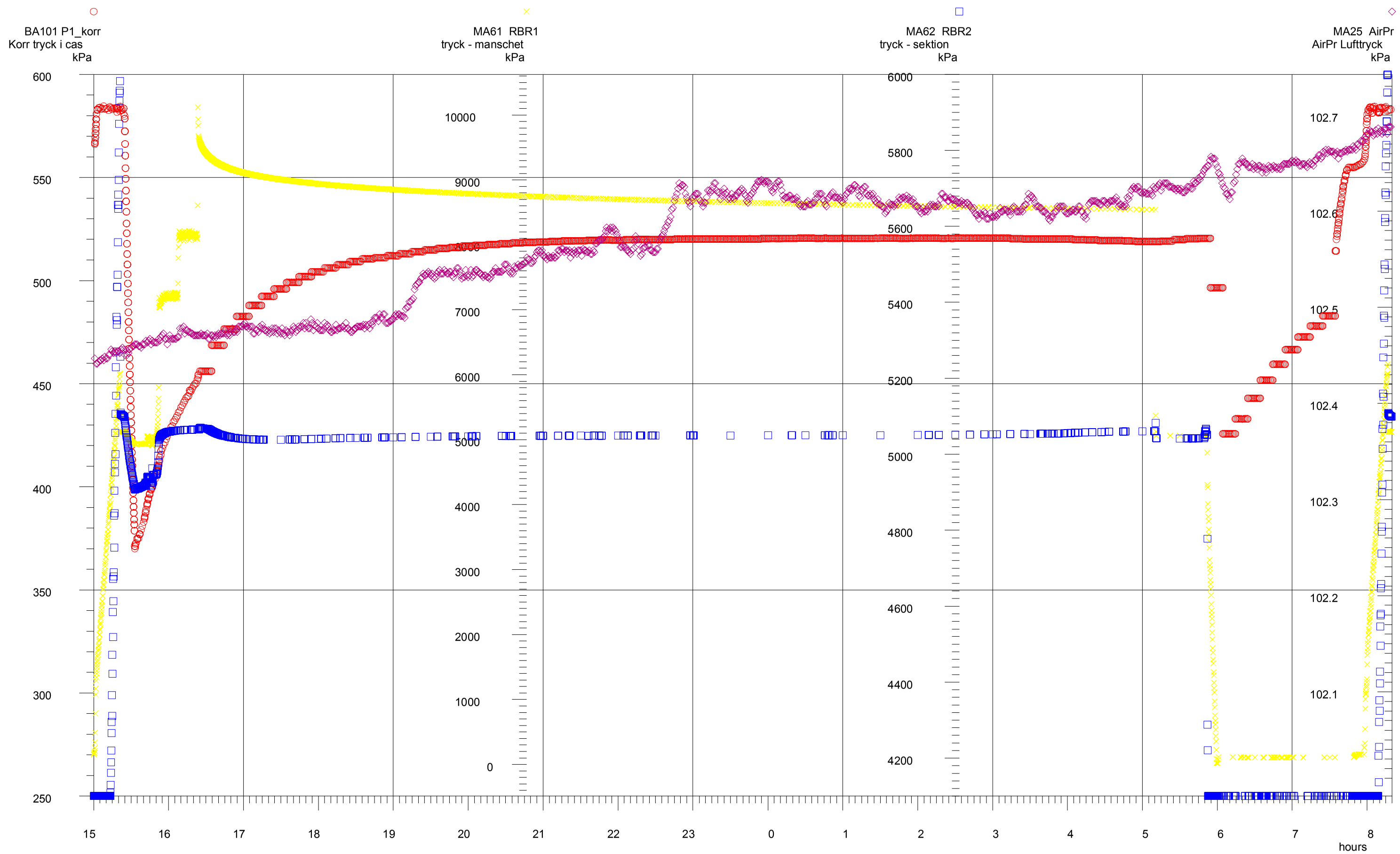
INTERVAL: All readings

STOP :03/04/12 08:19:59

PLOT TIME :04/07/05 14:21:03
PLOT FILE :P_tryck_i _sektion
No DST Adjustment

DMS1 PO

Absolute pressure measurement
KSH02 509.00-600.15m
Wireline sond



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

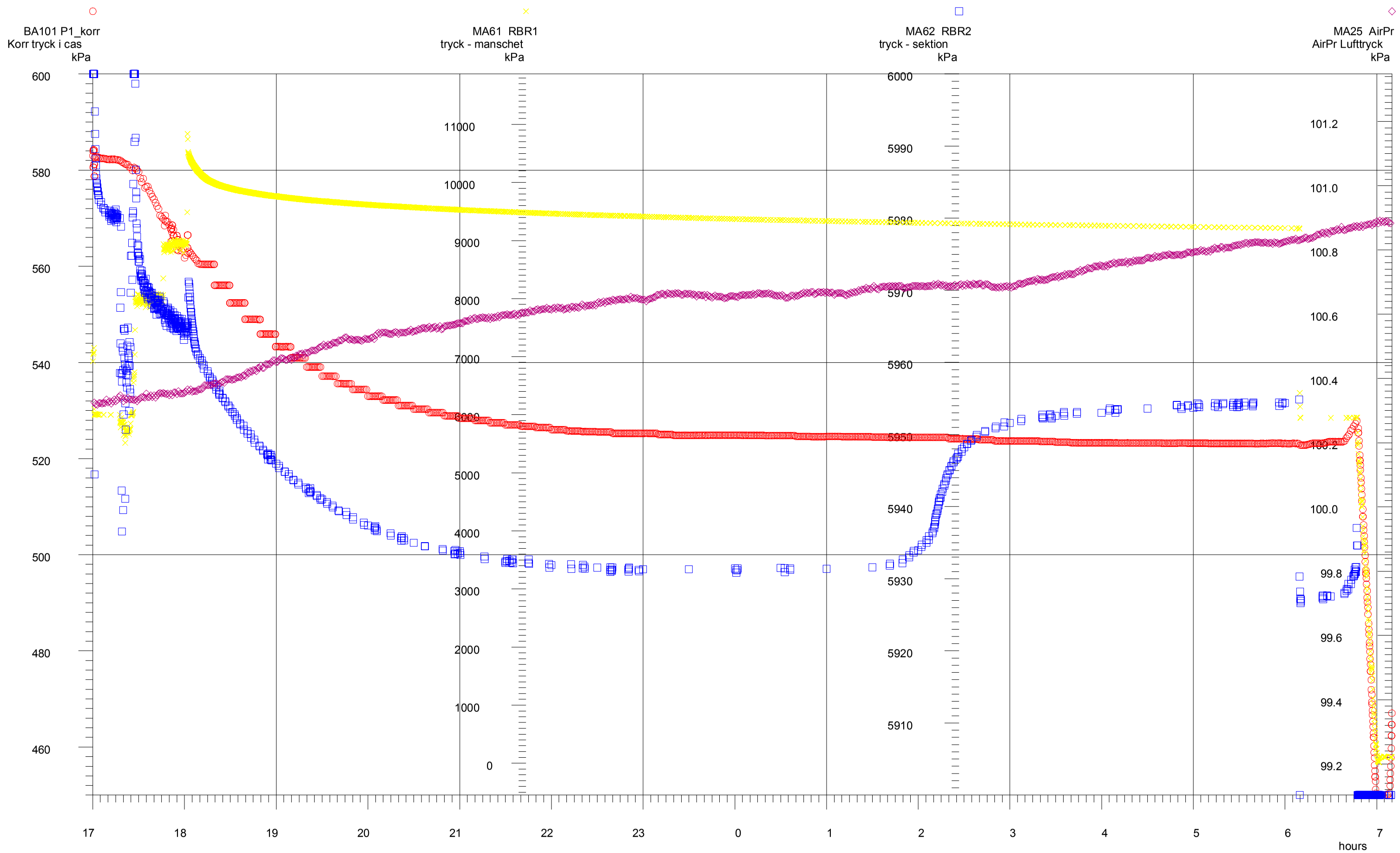
INTERVAL: All readings

STOP :03/04/25 08:19:59

PLOT TIME :04/07/05 14:04:54
PLOT FILE :P_tryck_i _sektion
No DST Adjustment

DMS1 PO

Absolute pressure measurement
KSH02 600.00-700.00m
Wireline sond

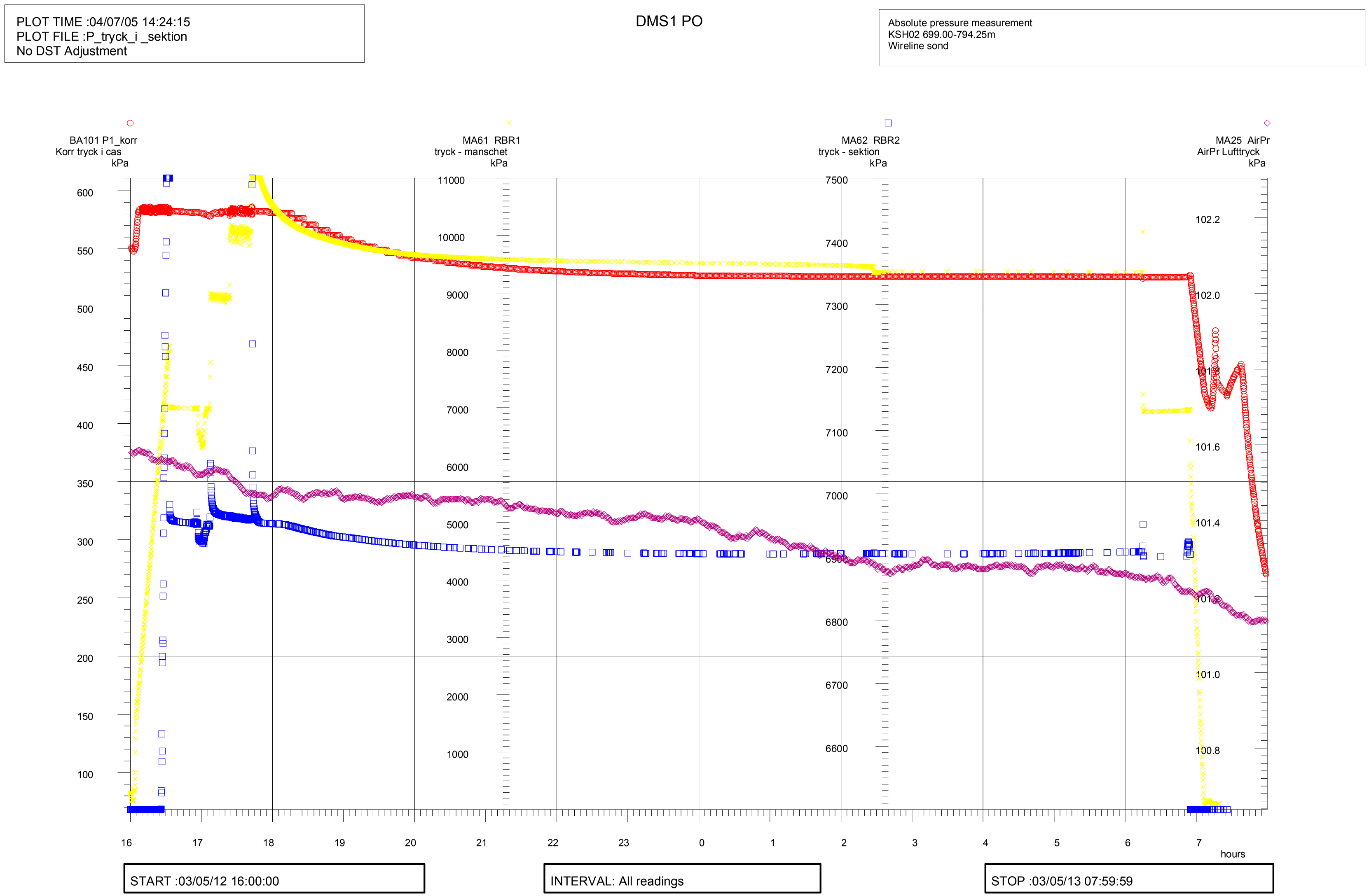


START :03/05/01 17:00:00

INTERVAL: All readings

STOP :03/05/02 07:09:59

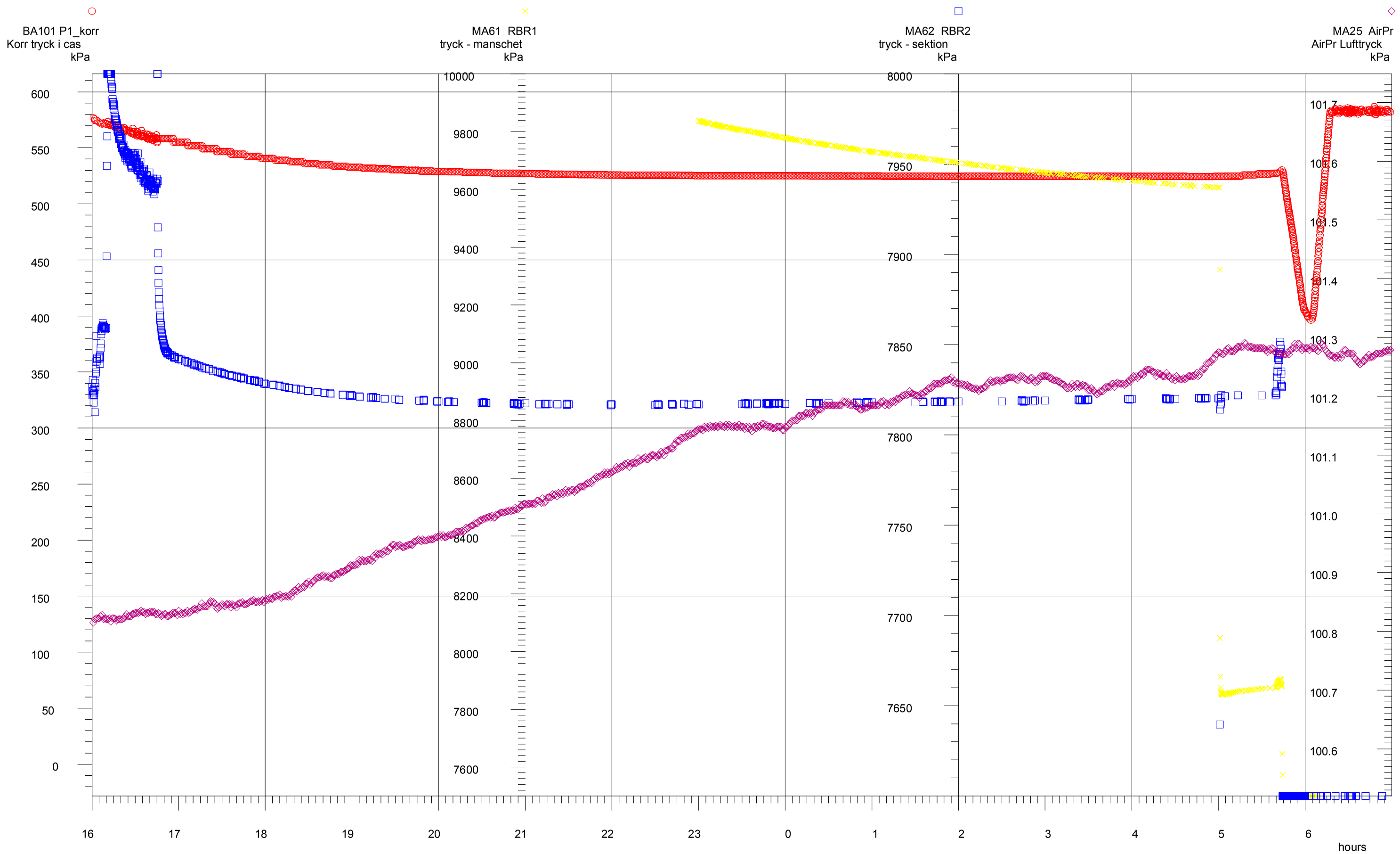
DMS1 PO


PLOT TIME :04/07/05 14:24:15
PLOT FILE :P_tryck_i _sektion
No DST Adjustment
Absolute pressure measurement
KSH02 699.00-794.25m
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
600
550
500
450
400
350
300
250
200
150
100
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
7500
7400
7300
7200
7100
7000
6800
6700
6600
102.2
102.0
101.6
101.4
101.0
100.8
16
17
18
19
20
21
22
23
0
1
2
3
4
5
6
7
hours
START :03/05/12 16:00:00
INTERVAL: All readings
STOP :03/05/13 07:59:59

PLOT TIME :04/07/05 14:30:08
PLOT FILE :P_tryck_i _sektion
No DST Adjustment

DMS1 PO

Absolute pressure measurement
KSH02 791.00-910.13m
Wireline sond



START :03/05/20 16:00:00

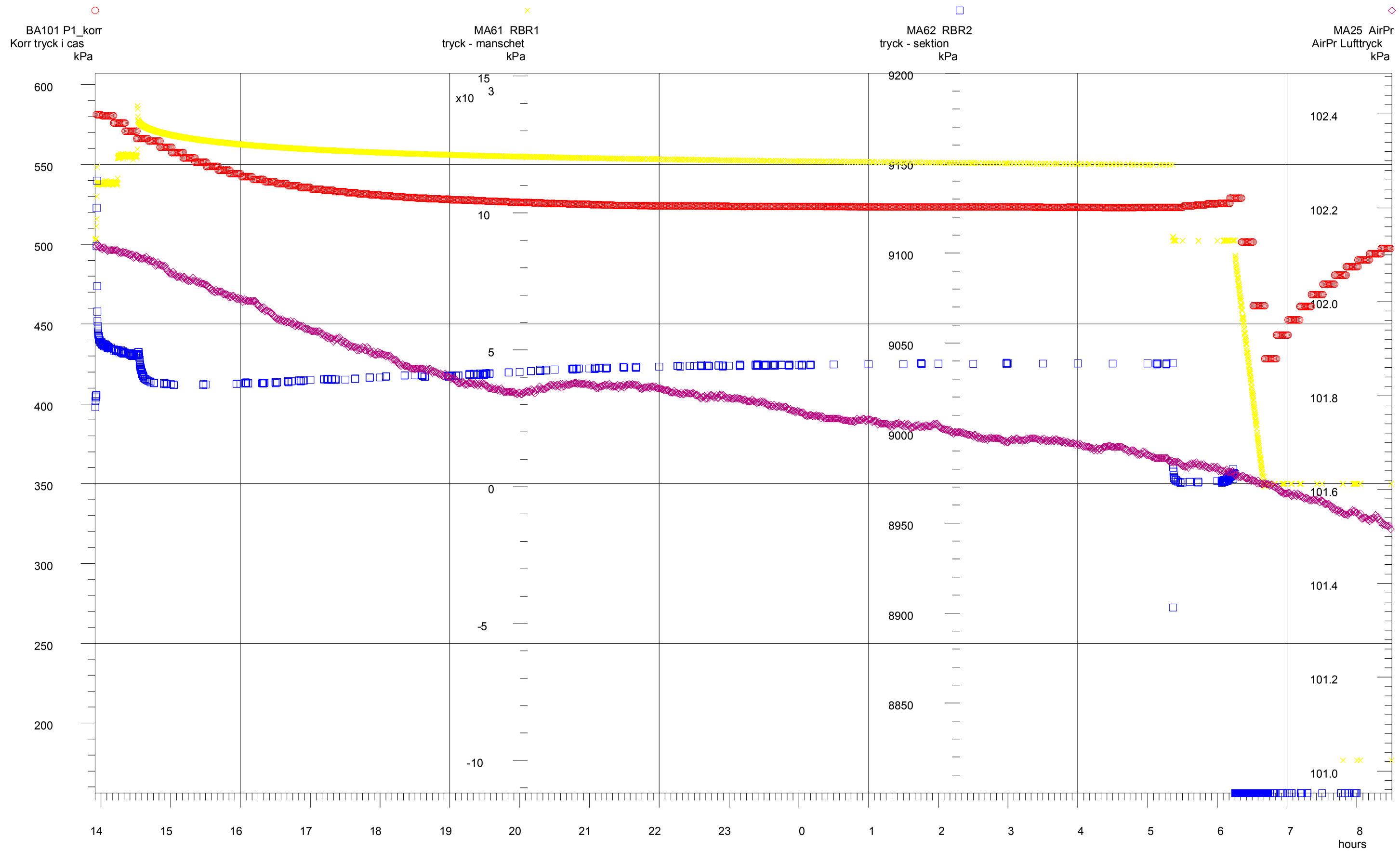
INTERVAL: All readings

STOP :03/05/21 06:59:59

PLOT TIME :04/07/05 14:34:30
PLOT FILE :P_tryck_i _sektion
No DST Adjustment

DMS1 PO

Absolute pressure measurement
KSH02 909.00-1001.11m
Wireline sond



START :03/05/29 13:55:00

INTERVAL: All readings

STOP :03/05/30 08:29:59