International Progress Report

IPR-01-32

Äspö Hard Rock Laboratory

Prototype Repository

Hydrogeological, Hydrochemical and temperature measurements in boreholes during the operation phase of the Prototype Repository.

Tunnel Section I

Ingvar Rhén
Torbjörn Forsmark
Lena Torin

VBB VIAK

Ignasi Puigdomenech

KTH

August 2001

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co
Box 5864
SE-102 40 Stockholm Sweden
Tel +46 8 459 84 00
Fax +46 8 661 57 19

Äspö Hard Rock Laboratory

Report no.	No.
IPR-01-32	F63K
Author	Date
I Rhén, T Forsmark, L Torin, I Puigdomenech	01-08-31
Checked by	Date
Lars-Olof Dahlström	01-08-31
Approved	Date
Christer Svemar	01-11-29

Äspö Hard Rock Laboratory

Prototype Repository

Hydrogeological, Hydrochemical and temperature measurements in boreholes during the operation phase of the Prototype Repository.

Tunnel Section I

Ingvar Rhén

Torbjörn Forsmark

Lena Torin

VBB VIAK

Ignasi Puigdomenech

KTH

August 2001

Keywords: Äspö Hard Rock Laboratory, Prototype Repository, instrumentation of boreholes, hydrogeology, hydrochemistry, temperature, tunnel section I

PROTOTYPE REPOSITORY

Deliverable D 4

Hydrogeological, Hydrochemical and
temperature measurements in boreholes
during the operation phase of
the Prototype Repository
Tunnel Section I

Ingvar Rhén
Torbjörn Forsmark
VBB BIAK

Ignasi Puidomenech
KTH

July 2001

EC Contract FIKW-2000-00055

EC-5th EURATOM Framework programme 1998-2002
Key Action: Nuclear Fission

Abstract

The Prototype Repository is an international, EC-supported activity with the objective to investigate, on a full-scale, the integrated performance of engineered barriers and near-field rock of a simulated deep repository. This is done in crystalline rock regarding heat evolution, mechanics, water flow, water chemistry, gas evolution and microbial processes under natural and realistic conditions at approximately 450 m depth below the ground surface. The test site is a 65 m long TBM-bored drift from which six 1.75m diameter deposition holes extended downwards to about 8 m depth in accordance with the KBS-3 concept. The test site is divided in two parts; an inner 40 m long section (Section I) with 4 deposition holes and an outer section (Section II) with two deposition holes. Stiff and tight plugs will separate the sections and Section II from the rest of the Äspö Hard Rock Laboratory.

A large number of boreholes have been drilled to characterize the rock mass. These boreholes will be used for the long-time monitoring of the Prototype Repository. Packers, 1-5 in each borehole, are installed to facilitate monitoring of the water pressure and water chemistry in borehole sections. Temperature sensors are fixed in some of the boreholes by grouting the boreholes. Tubes and cables from the borehole sections are lead to a nearby G-tunnel, where the pressure and temperature are measured and the water is sampled. Hydraulic tests will also be performed from the G-tunnel by flowing of borehole sections (one by one) and measuring the pressure responses.

The report describes the instrumentation of the boreholes in Section I.

Sammanfattning

Prototypförvaret är ett internationellt, EC-stött projekt med syfte att I full skala undersöka den integrerade funktionen hos ingenjörers-barriärer och närfältsberg i ett simulerat slutförvar i kristallint berg med hänsyn till värmeutveckling, mekanik, vattengenomströmning, vattenkemi, gasbildning och mikrobiologi under naturliga och realistiska förhållanden på ca 450m djup. Försöksplatsen är en 65m lång TBM-borrad ort från vilken sex vertikala deponeringshål med 1.75m diameter och 8m djup borrats i enlighet med KBS-3 konceptet. Testplatsen är delad i två delar; en inre 40m lång sektion (sektion I) med 4 deponeringshål och en yttre del (sektion II) med två deponeringshål. Stela och täta pluggar separerar sektionerna och sektion II från resten av Äspölaboratoriet.

Ett stort antal borrhål har borrats för att karakterisera berget. Dessa borrhål kommer att användas för långtidsmoniteringen av Prototypförvaret. Manschetter, 1-5 i varje borrhål, installeras för att möjliggöra instrumentering av vattentryck och vattenkemi i borrhålssektioner. Temperaturgivare gjuts in i vissa borrhål. Tuber och kablar från borrhålssektionerna leds till en parallellt liggande tunnel, G-tunneln, där tryck och temperatur mäts och vattenprov tas. Hydrauliska tester görs också från G-tunneln genom att flöda borrhålsektioner (en i taget) och mäta tryckresponserna.

Denna rapport beskriver instrumenteringen av borrhål i sektion I.

Executive Summary

The Prototype Repository is an international, EC-supported activity with the objective to investigate, on a full-scale, the integrated performance of engineered barriers and near-field rock of a simulated deep repository. This is done in crystalline rock regarding heat evolution, mechanics, water flow, water chemistry, gas evolution and microbial processes under natural and realistic conditions at approximately 450 m depth below the ground surface. The test site is a 65 m long TBM-bored drift from which six 1.75m diameter deposition holes extended downwards to about 8 m depth in accordance with the KBS-3 concept. The test site is divided in two parts; an inner 40 m long section (Section I) with 4 deposition holes and an outer section (Section II) with two deposition holes. Stiff and tight plugs will separate the sections and Section II from the rest of the Äspö Hard Rock Laboratory.

A large number of boreholes have been drilled to characterize the rock mass. These boreholes will be used for the long-time monitoring of the Prototype Repository. Packers, 1-5 in each borehole, are installed to facilitate monitoring of the water pressure and water chemistry in borehole sections. Temperature sensors are fixed in some of the boreholes by grouting the boreholes. Tubes and cables from the borehole sections are lead to a nearby G-tunnel where the pressure and temperature are measured and the water is sampled. Hydraulic tests will also be performed from the G-tunnel by flowing of borehole sections (one by one) and measuring the pressure responses.

In this report the instrumentation of Section I is described. In Section I, 1-2m long bentonite packers are used in the long boreholes and mechanical packers of stainless steel are used in short boreholes. The bentonite packers were made up by compacted bentonite with rubber coverage. For chemical reasons the bentonite is not allowed to be in contact with the surrounding water in the rock mass and the packers have a cover made of polyurethane (PUR-rubber). This rubber also protected the packers against unwanted wetting during transport and installation.

Dilution measurements can be performed in the “circulation sections”. In ”flow sections” the borehole section can be flowed and the pressure is measured through a separate tube. PEEK tubes are connected to the “hydrochemistry sections” to get a diffusion tight system allowing studying the redox conditions. The number of different measurement sections in boreholes in tunnel section I is shown below:

	(No of)
• Pressure measurement sections:	65
• Circulation sections (two tubes):	5
• Flow sections (one or two tube-s):	7
• Hydrochemical sections:	6

Contents

List of Figures

List of Tables

1 Background

1.1 Äspö Hard Rock Laboratory

To prepare for the location of a site and licensing of a spent fuel repository SKB has constructed an underground research laboratory.

In the autumn of 1990, SKB began the construction of Äspö Hard Rock Laboratory (Äspö HRL), see *Figure 1-1,* near Oskarshamn in the south-eastern part of Sweden. A 3.6 km long tunnel was excavated in crystalline rock down to a depth of approximately 460 m, see *Figure 1-2.*

The laboratory was completed in 1995 and research concerning the disposal of nuclear waste in crystalline rock has since then been carried on.

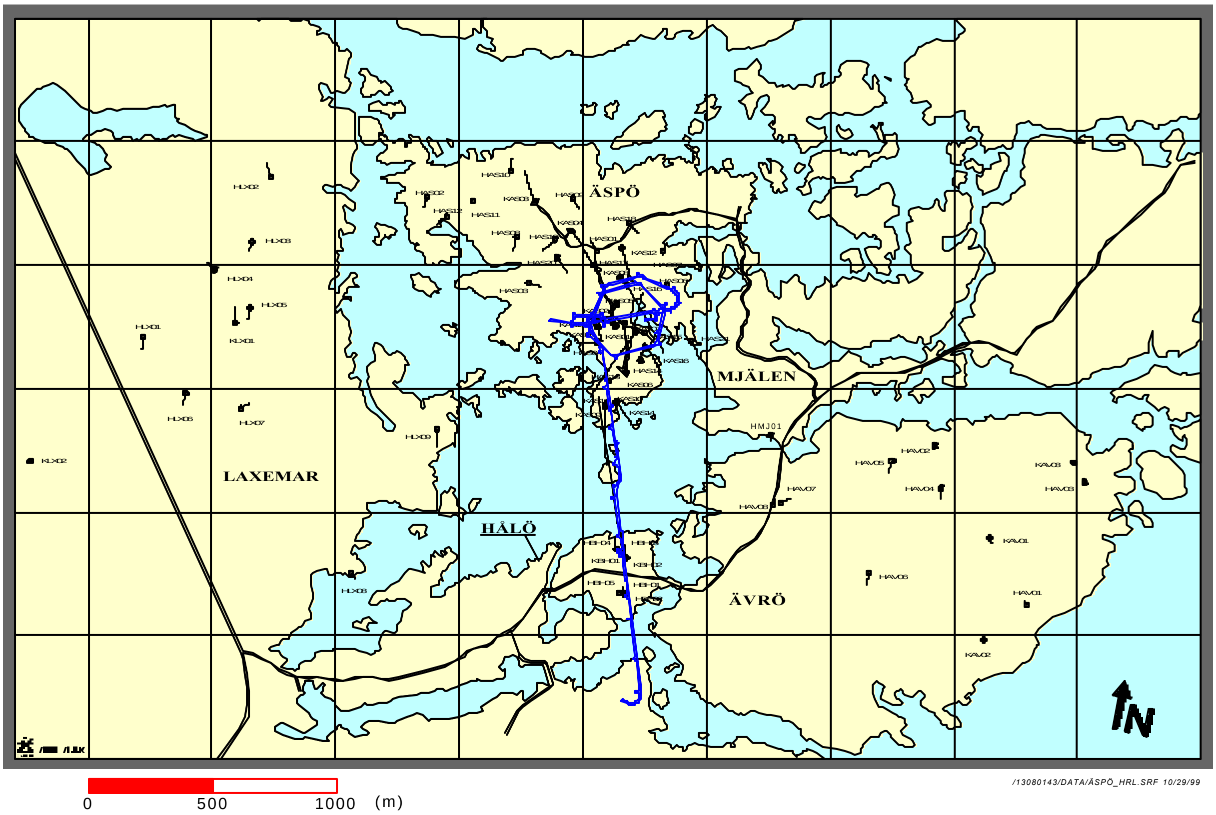


Figure 1-1 Plan view over Äspö Hard Rock Laboratory.

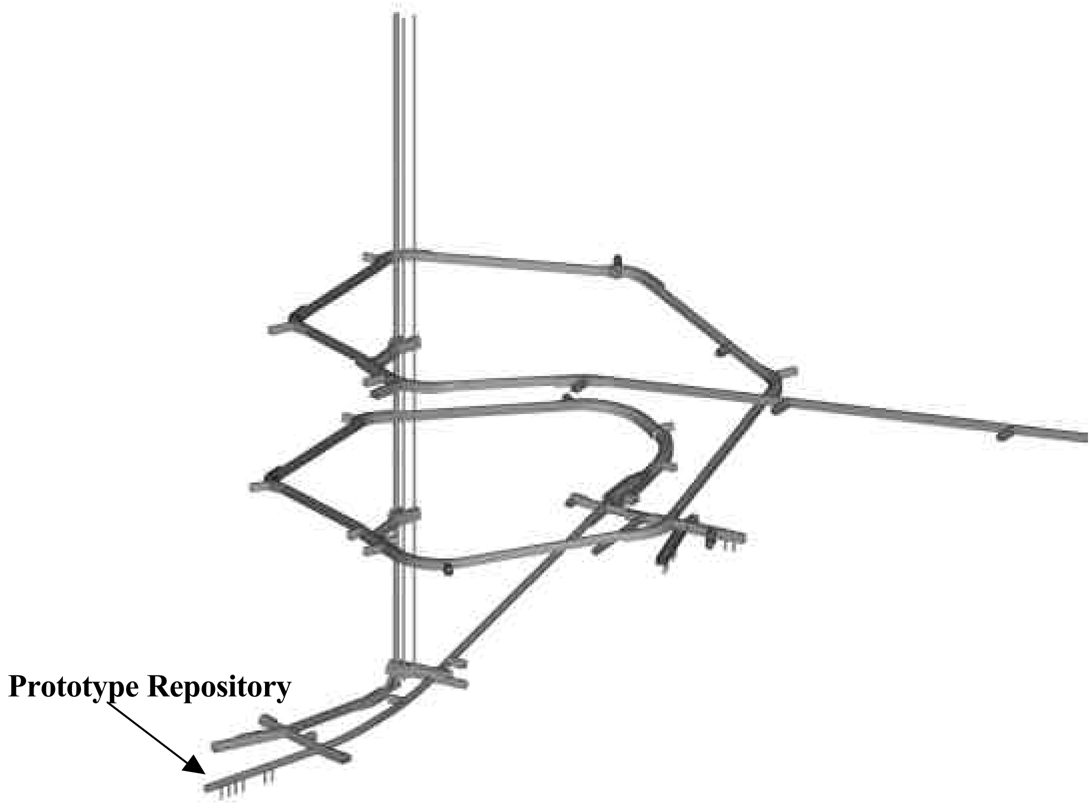


Figure 1-2 Overview of the Äspö tunnel. The Prototype Repository is located at 450 m depth below the ground surface. The vertical lines show the elevator and ventilation shafts from the ground surface.

1.2 Prototype Repository

The Äspö Hard Rock Laboratory is an essential part of the research, development, and demonstration work performed by SKB in preparation for construction and operation of the deep repository for spent fuel. Within the scope of the SKB program for RD&D 1995, SKB has decided to carry out a project with the designation "Prototype Repository Test". The aim of the project is to test important components in the SKB deep repository system on a full scale and in a realistic environment.

The Prototype Repository Test is focused on testing and demonstrating the function of the SKB deep repository system. Activities aimed at contributing to development and testing of the practical, engineering measures required to rationally perform the steps of a deposition sequence are also included. However, efforts in this direction are limited, since these matters are addressed in the Demonstration of Repository Technology project and to some extent in the Backfill and Plug Test.

Project plan and project description of the Prototype Repository are described in Svemar and Pusch (2000) and Persson and Broman (2000).

1.2.1 General objectives

The Prototype Repository should simulate as many aspects as possible of a real repository, for example regarding geometry, materials, and rock environment. The Prototype Repository is a demonstration of the integrated function of the repository components. Results will be compared with models and assumptions to their validity.

The major objectives for the Prototype Repository are:

- To simulate part of future KBS-3 deep repository to the extent possible regarding geometry, design, materials, construction and rock environment except that radioactive waste is simulated by electric heaters.
- To test and demonstrate the integrated function of the repository components under realistic conditions on a full scale.
    - To develop, test and demonstrate appropriate engineering standards and quality assurance methods.
    - To accomplish confidence building as the capability of modelling EBS performance.

The objectives for the characterisation program are:

- To provide a basis for determination of location of the deposition holes.
- To provide data on boundary and rock conditions for enabling the interpretation of the experimental data.

1.2.2 Objectives with this report

The instrumentation of the boreholes is done mainly in two stages. Section I was instrumented during the spring 2001 and Section II will be instrumented during the spring 2002, see *Figure 1-3*. This report describes the instrumentation of Section 1. In Chapter 2, the instrumentation in the boreholes is described and in Chapter 3-7 the purpose, a concept etc. of the measurements are briefly outlined.

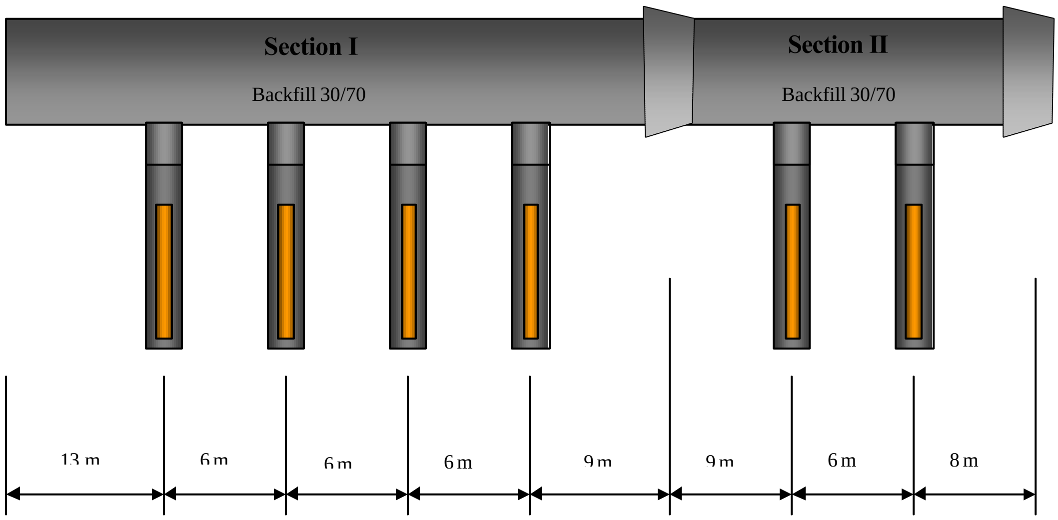


Figure 1-3 Schematic view of the layout of the Prototype Repository and deposition holes (not to scale).

2 Equipment and instrumentation of boreholes

2.1 Overview of instrumentation

During the characterisation of the rock around the Prototype Repository a large number of core boreholes have been drilled, see *Figure 2-1*. Most of these boreholes will be equipped with packer systems to allow for:

- Pressure measurements
- Water sampling
- Dilution measurements
- Interference tests
- Hydro mechanical measurements (HM) and tests

In some of the boreholes temperature measurements will be made. Below is an overview of the instrumentation given:

Section I (as made)	(No of)
• Bentonite packers (1-2 m long, 2-5 packers in each 8-50 m borehole):	49
• Mechanical packers (1 in each 2 m borehole, stainless):	16
• Pressure measurement sections:	65
• Circulation sections (two tubes):	5
• Flow sections (one-two tube-s):	7
• Hydrochemical sections:	6
• HM sections:	0

Boreholes around the outer plug is planned to be drilled and instrumented after the instrumentation of section II.

Section II+ outer plug (as planned) (No of)

- Inflatable + Bentonite packers (1-2 m long, 2-5 in each 8-30 m borehole): 55
- Mechanical packers (1 in each 1-2 m borehole, stainless): 6
- Pressure measurement sections (including measurements around plug): 61
- Circulation sections: 9
- Flow (one tube): 6
- Hydrochemical sections: 0
- HM sections (same as circulation sections): 9

G-tunnel+KA3510A01 (planned)

- Inflatable packers (1m long, 5 in each 50-150 m borehole): 15
- Pressure measurements sections (5 in each borehole): 15
- Flow (one tube, KA3510A01): 1
- Hydrochemical sections (holes from G-tunnel): 2
- Circulation sections (holes from G-tunnel): 2

The tube types between and from packers will be according to below:

- Pressure: Polyamide
- Groundwater flow (Dilution measurements):
  - Circulation (two pipes): Polyamide
  - Pressure: Polyamide
- Hydrochemical
  - Flow: PEEK
  - Pressure: Polyamide

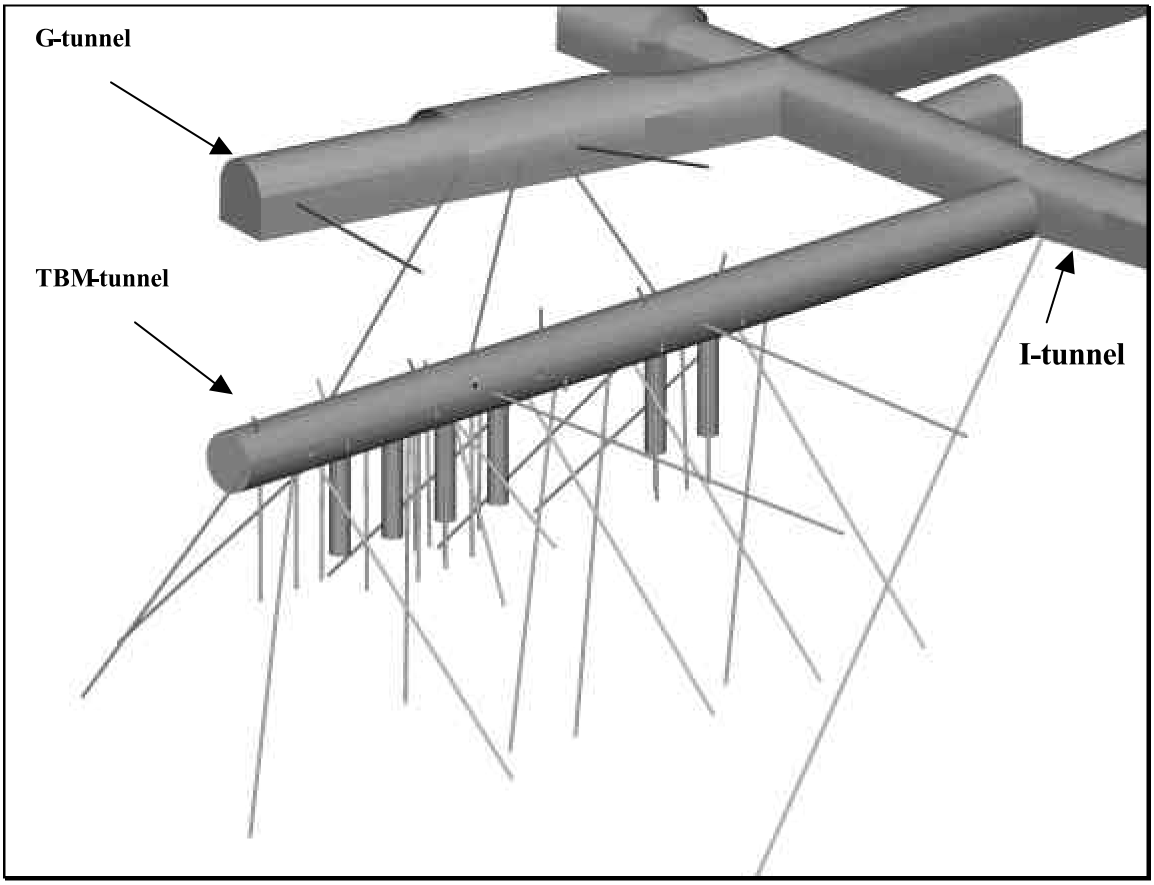


Figure 2-1 View of the drilled core holes in the Prototype Repository. The length from the I-tunnel to the end of the TBM-tunnel is 90 m. The diamter of the TBM tunnel is 5m and the diameter of the deposition holes is 1.75 m. The depth of the deposition holes is 8.37 m in the centre and 8.15 m along the deposition hole wall. The diamter of the core holes is 76 mm except for the short core holes in the roof of the TBM tunnel that have a diamter of 56 mm.

2.2 Instrumentation of Section I

2.2.1 Installation work in the tunnel

Before instrumentation of boreholes begun, the uppermost 100 mm of boreholes in the tunnel floor was enlarged to a diameter of 200 mm to house the anchorage of the equipment, *see Figure 2-2*. A flange was mounted into the enlargement onto which the equipment will be anchored. Boreholes on the walls was not enlarge to house the anchorage for the borehole equipment. The anchorage was mounted directly on the wall covered by a steel plate, see *Figure 2-10.*

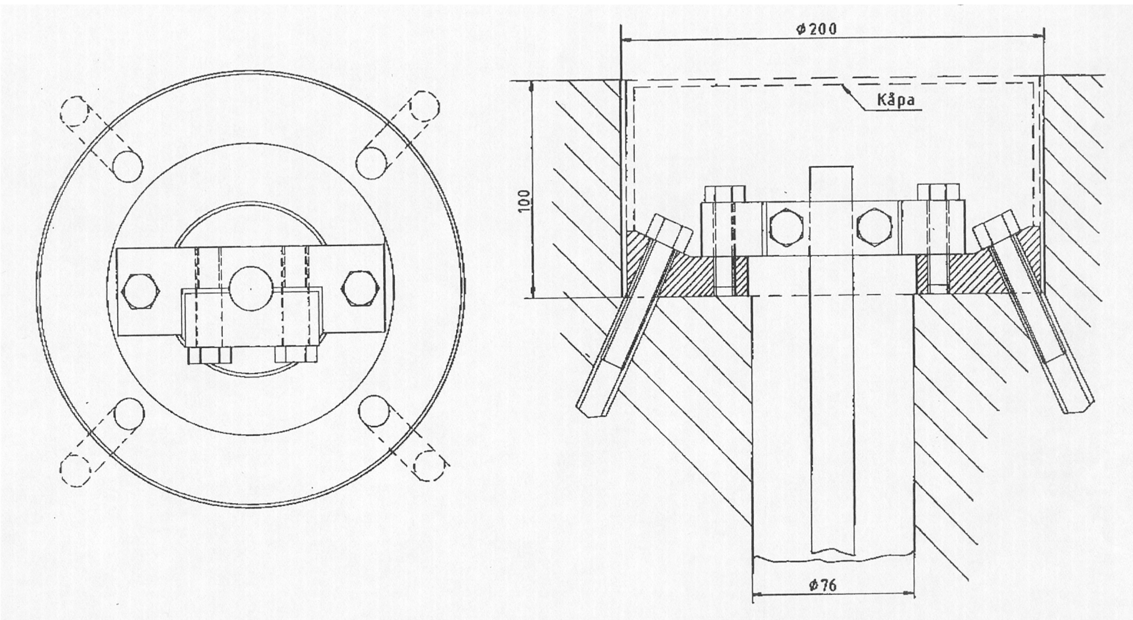


Figure 2-2 Borehole enlargement with anchorage for borehole equipment.

A cover plate was mounted at each borehole to protect the locking device and tube endings.

2.2.2 Borehole installation work and final instrumentation

Instrumentation with bentonite packers

Section I will be in operation for a long time, possibly up to 20 years, and there will be no access to the instruments in the boreholes for a long period. It was decided to develop a new type of packer that was not dependent of an external pressure to seal-off the borehole sections. These packers were made of compacted bentonite with rubber coverage. For chemical reasons the bentonite is not allowed to be in contact with the surrounding water in the rock mass and therefore the packers have a cover made of polyurethane (PUR-rubber). This rubber also protected the packers against unwanted wetting during transport and installation. After installing all packers in a borehole, the compacted bentonite was wetted to make it swell and expanded against the borehole wall. This packer system was used in 14 boreholes with a length between 12 and 50 meters in the tunnel floor and the walls.

Two types of bentonite packers were used, see *Figures 2-3* and *2-4*. The type A was used with a seal length of one or two meters while the type B was used with a seal length of one meter.

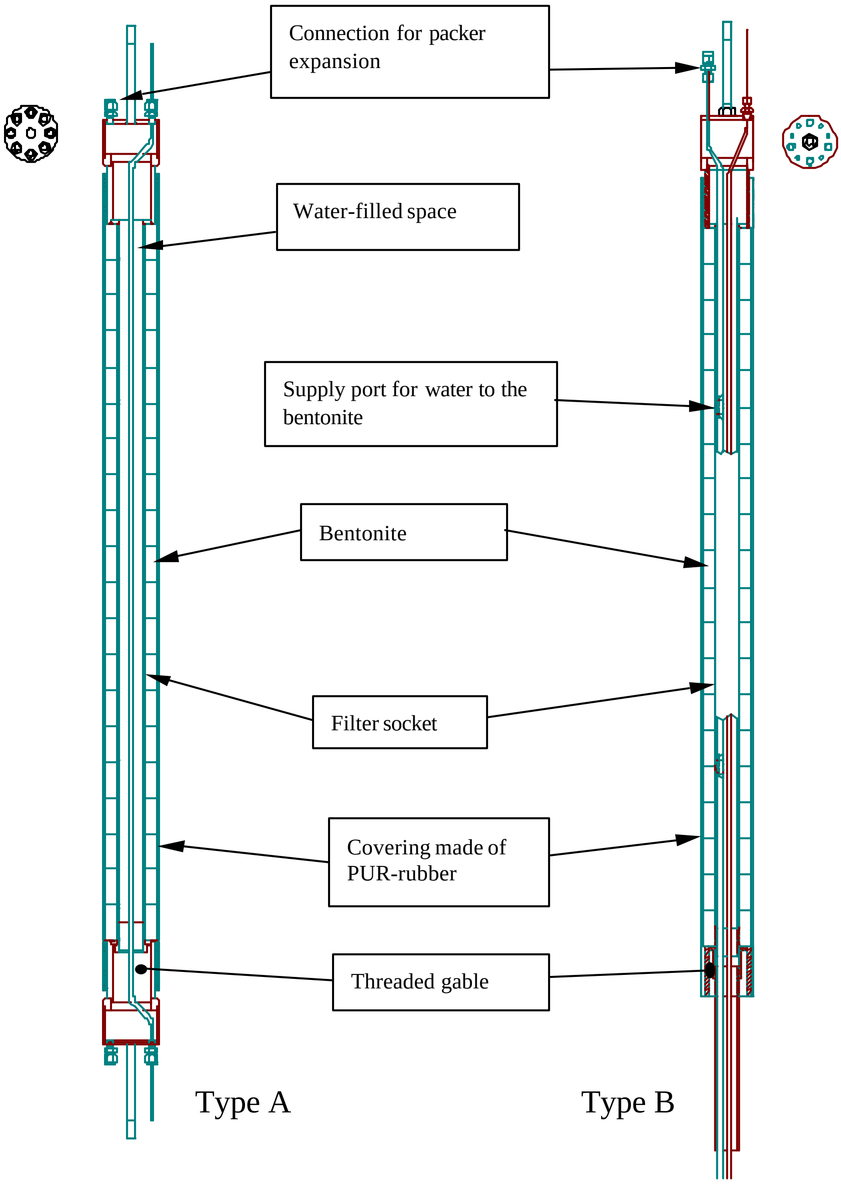


Figure 2-3 Bentonite packers.

Except for the two lead-throughs used to saturate the bentonite with water, the type A packer can have up to six hydraulic lead-throughs and the type B packer can have eight. The type B packer was only used in the outermost position in four boreholes. In the type A packer, the centre pipe was filled with water supplied to the filter socket surrounding the bentonite through a number of holes. In the type B packer the inflation water was supplied through a tube and two ports welded on the inner pipe. The lead-through were either made by 6/4 mm stainless steel pipes or 1/8"/2 mm PEEK tubes. PEEK tubes were used for the sections intended for hydrochemical sampling. All tubes between the packers, building hydraulic lines for pressure measurement and circulation purposes, were made by polyamide with the diameter 6/4 mm (type Tecalan). The lines to the sections intended for hydrochemical sampling were built up by 1/8"/2 mm PEEK tubes.

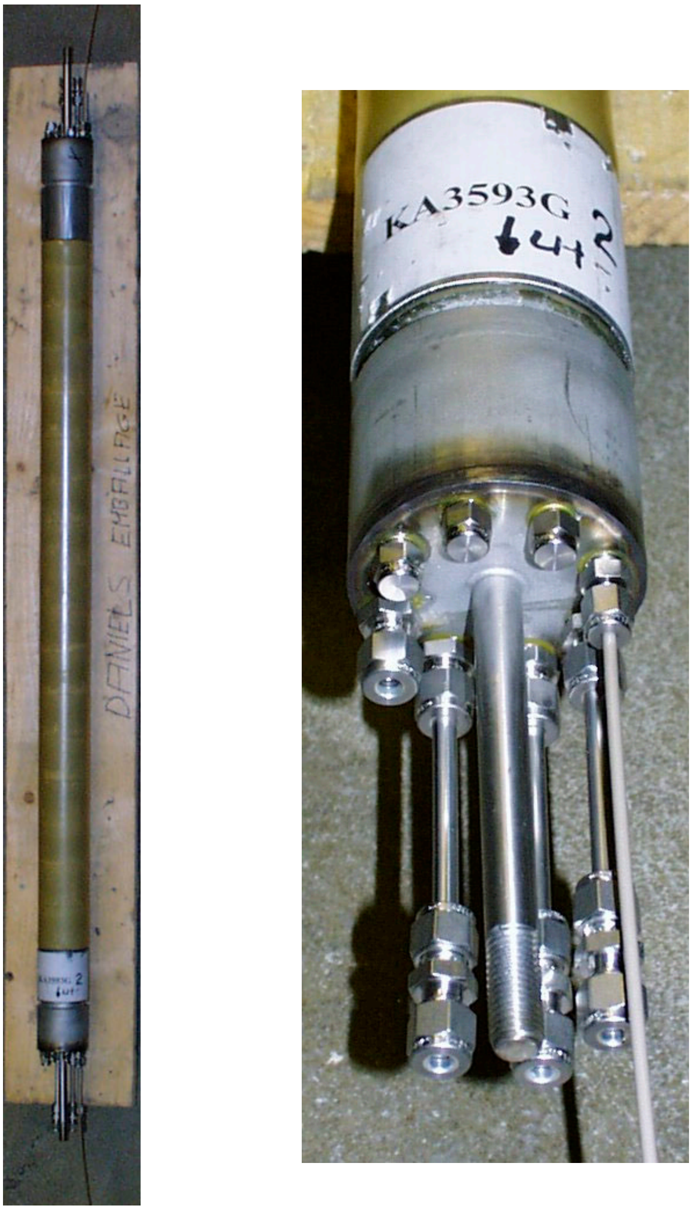


Figure 2-4 Bentonite packers.

Due to the expected high temperature near the deposition holes two boreholes (KA3574A and KA3576A) were equipped with stainless steel pipes instead of polyamide tubes.

In some sections used for circulation or hydrochemistry sampling purposes a dummy, see *Figures 2-5* and *2-6,* was installed to reduce the water-filled volume of the section. Depending on the purpose the dummies were made either by high-density polyethylene (circulation sections) or PEEK (hydrochemistry sections) material. The dummy consists of two parts, to be positioned around the centre rod.

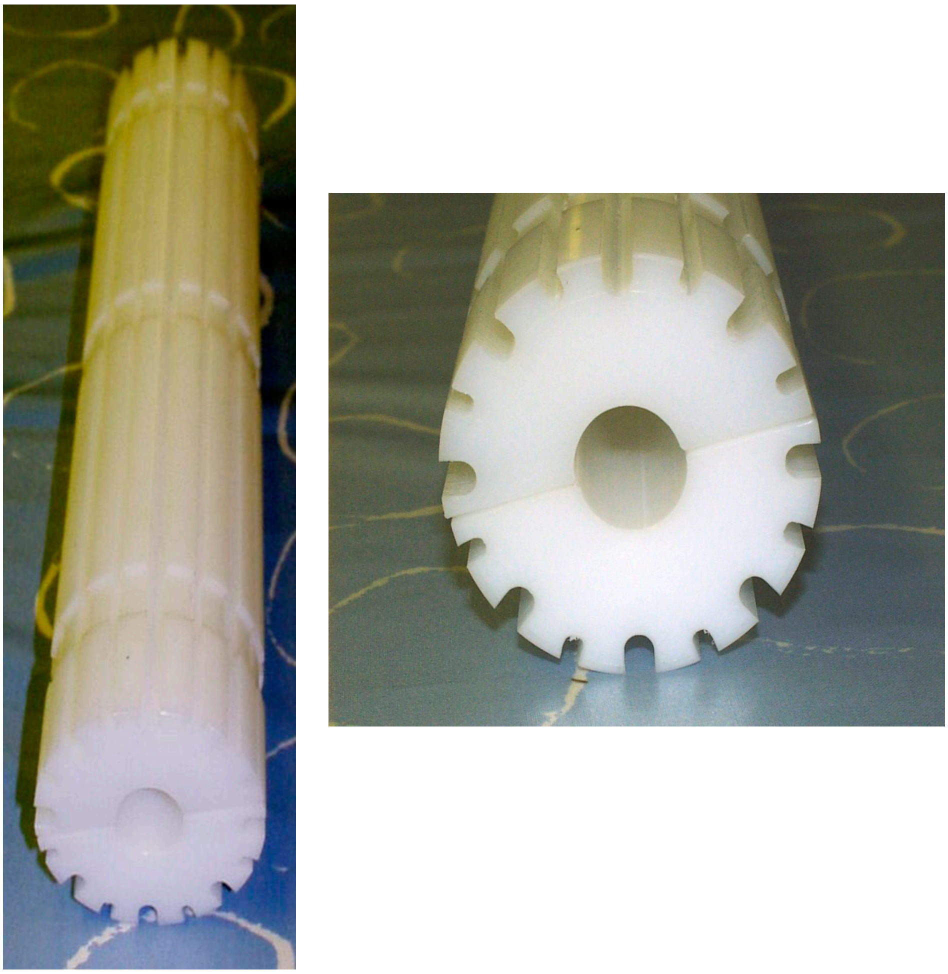


Figure 2-5 Dummy.

The packers were inserted into the borehole with Ø 20 mm massive stainless steel rods. A special designed manual hoisting rig, see *Figures 2-6* to *2-8,* was used to insert the equipment into the boreholes. When the packers were at their correct position the equipment was attached to a locking device mounted on the tunnel wall at the borehole collar. Before insertion, the equipment was cleaned with a cleaner delivering hot steam (100 °C) at high pressure.

Figure 2-6 Rig for the bentonite packer and the dummy installation.

Figure 2-7 Rig for the bentonite packer installation.

Figure 2-8 Rig for the bentonite packer installation.

To expand the packers, water was filled into the system with the help of a pressure vessel (one vessel per borehole) and nitrogen gas. To be able to follow the wetting process standpipes were mounted on the vessels. After de-airation, one of the two tubes circulating water to the bentonite packers was plugged and the water in the system was to be held at a pressure of approximate 10 bar until the water level in the pressure vessels was stabilised. This was expected to take 2 - 3 weeks and thereafter the other tube was cut and plugged. To ensure a good control over the wetting process the expansion was performed in two rounds with seven boreholes in each. During the expansion period, the level in the pressure vessels was measured and after completion, the flow from different borehole sections was measured. An evaluation of these figures was performed to ensure, as far as possible, that the packers had been inflated.

The instrument configuration for the boreholes provided with bentonite packers is summarised in *Table 2-1* and illustrated in the instrumentation drawings found in *Appendix 6*.

Table 2-1 Instrumentation configuration. “Lead-through”: pipes between the packers.

Borehole:sec	Sec. length (m)	Type of section	Type of dummy	Packer length	Lead-through (no:diameter:type)
KA3563G:1	15 – 30.01	P		2 m	1:6/4:PA
KA3563G:2	10 – 13	P		2 m	2:6/4:PA
KA3563G:3	4 – 8	P		1 m	3:6/4:PA
KA3563G:4	1.5 – 3	P, C	HD	1 m	6:6/4:PA
KA3566G01:1	23.5 – 30.01	P		2 m	1:6/4:PA
KA3566G01:2	20 – 21.5	P, C	HD	2 m	4:6/4:PA
KA3566G01:3	12 – 18	P		2 m	5:6/4:PA
KA3566G01:4	7.3 – 10	P		1 m	6:6/4:PA
KA3566G01:5	1.5 – 6.3	P, F		1 m	8:6/4:PA
KA3566G02:1	19 – 30.1	P		1 m	1:6/4:PA
KA3566G02:2	16 – 18	P, C	HD	2 m	4:6/4:PA
KA3566G02:3	12 – 14	P		1 m	5:6/4:PA
KA3566G02:4	8 – 11	P		2 m	6:6/4:PA
KA3566G02:5	1.3 – 6	P, F		1 m	8:6/4:PA
KA3572G01:1	7.3 – 12.03	P		2 m	1:6/4:PA
KA3572G01:2	2.7 – 5.3	P, C	HD	2 m	4:6/4:PA
KA3573A:1	26 – 40.07	P		2 m	1:6/4:PA
KA3573A:2	21 – 24	P, F		2 m	3:6/4:PA
KA3573A:3	14.5 – 19	P		2 m	4:6/4:PA
KA3573A:4	10.5 – 12.5	P, F		2 m	6:6/4:PA
KA3573A:5	1.3 – 8.5	P		1 m	7:6/4:PA
KA3574G01:1	8 –12.03	P		1 m	1:6/4:ST
KA3574G01:2	5.1 – 7	P		1 m	2:6/4:ST
KA3574G01:3	1.8 – 4.1	P, C	HD	1 m	5:6/4:ST
KA3576G01:1	8 – 12.01	P		2 m	1:6/4:ST
KA3576G01:2	4 – 6	P, HC	PE	1 m	2:6/4:ST, 1:1/8"/2:PE
KA3576G01:3	1.3 – 3	P		1 m	3:6/4:ST, 1:1/8"/2:PE
KA3578G01:1	6.5 – 12.58	P		1 m	1:6/4:PA
KA3578G01:2	4.3 – 5.5	P, HC	PE	2 m	2:6/4:PA, 1:1/8"/2:PE
KA3579G:1	14.7 – 22.65	P		1 m	1:6/4:PA
KA3579G:2	12.5 – 13.7	P		1 m	2:6/4:PA
KA3579G:3	2.3 – 11.5	P		2 m	3:6/4:PA
KA3584G01:1	7 – 12	P		2 m	1:6/4:PA
KA3584G01:2	1.3 – 5	P		1 m	2:6/4:PA
KA3590G01:1	16 – 30	P		1 m	1:6/4:PA
KA3590G01:2	7 – 15	P, F, F		1 m	4:6/4:PA
KA3590G01:3	1.3 – 6	P, HC		1 m	5:6/4:PA, 1:1/8"/2:PE
KA3590G02:1	25.5 – 30.01	P, F		2 m	2:6/4:PA
KA3590G02:2	15.2 – 23.5	P		2 m	3:6/4:PA
KA3590G02:3	11.9 – 13.2	P, HC	PE	2 m	4:6/4:PA, 1:1/8"/2:PE
KA3590G02:4	1.3 – 9.9	P		1 m	5:6/4:PA, 1:1/8"/2:PE

Borehole:sec	Sec. length (m)	Type of section	Type of dummy	Packer length	Lead-through (no:diameter:type)
KA3593G:1	25.2 – 30.02	P		1 m	1:6/4:PA
KA3593G:2	23.5 – 24.2	P, HC	PE	1 m	2:6/4:PA, 1:1/8"/2:PE
KA3593G:3	9 – 22.5	P		2 m	3:6/4:PA, 1:1/8"/2:PE
KA3593G:4	3 – 7	P, F		2 m	5:6/4:PA, 1:1/8"/2:PE
KA3600F:1	43 – 50.1	P		1 m	1:6/4:PA
KA3600F:2	40.5 – 42	P, HC	PE	1 m	2:6/4:PA, 1:1/8"/2:PE
KA3600F:3	20 – 39.5	P		2 m	3:6/4:PA, 1:1/8"/2:PE
KA3600F:4	1.3 – 18	P		1 m	4:6/4:PA, 1:1/8"/2:PE

Type of section:

P Pressure measurement
C Circulation possible
HC Hydrochemistry sampling
F Flow

Materials:

PA Polyamide
ST Steel
PE PEEK
HD HD1000 (High Density Polyethylene)

After finalization of instrumentation the borehole was covered with a steel plate in the tunnel floor or a steel box on the tunnel wall, see *Figures 2-9* and *2-10*.

Figure 2-9 Tunnel-floor borehole covered with steel plate.

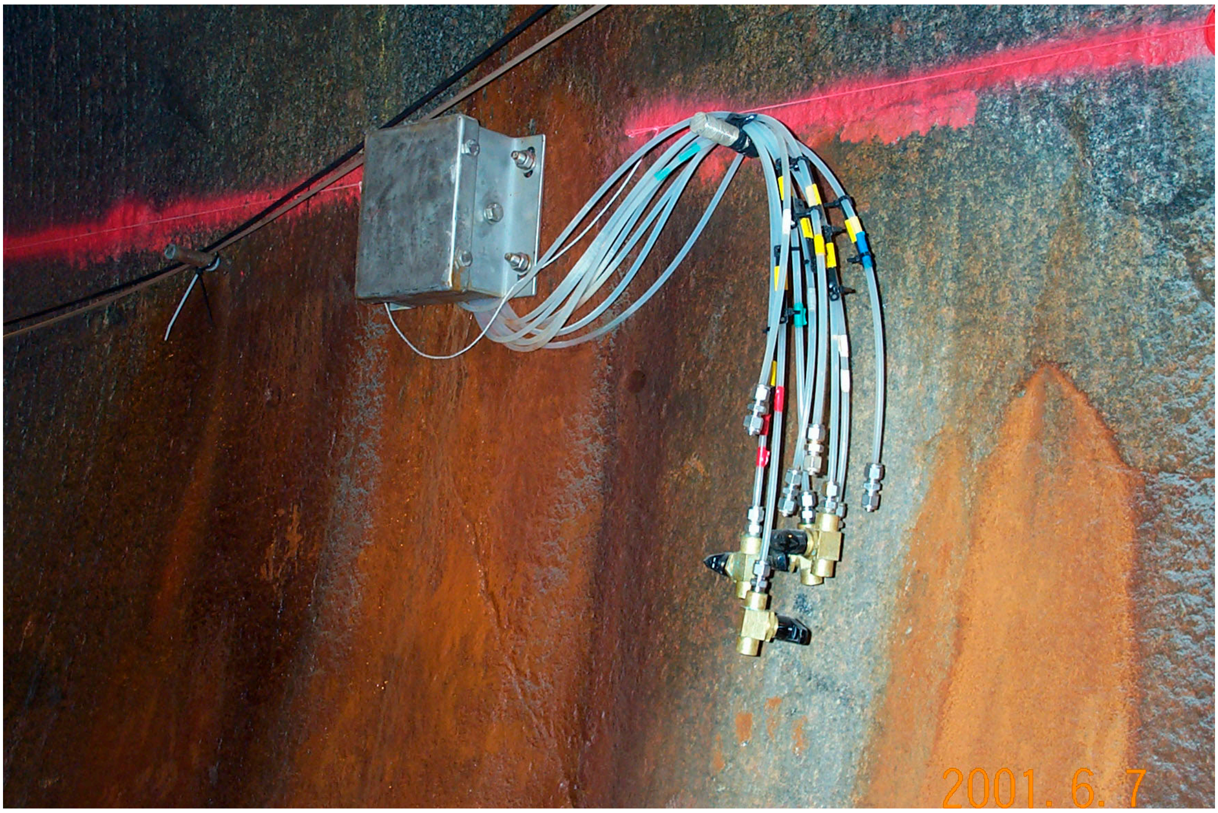


Figure 2-10 Tunnel-wall borehole.

Instrumentation with mechanical packers

Sixteen short boreholes (2 m) in the tunnel roof were equipped with mechanical packers, see *Table 2-2*, *Figures 2-11* to *2-13*. After insertion into the hole, the pulling of a nut on the centre pipe expanded the packer. Since these holes were directed upwards, the de-airation required an extra lead-through connected to a tube ending in the innermost part of the borehole. The de-airation will be made during the backfilling and in boreholes with very little flow one must de-air by filling water through the outer tube.

Table 2-2 Boreholes instrumented with mechanical packers ("Inclination": inclination of the borehole.).

Borehole	Borehole length (m)	Inclination (°)
KA3563A01	2.06	-7.7
KA3563D01	approx. 2	2.8
KA3563I01	2.15	73
KA3566C01	2.1	3.5
KA3568D01	2.3	-2.3
KA3573C01	2.05	34.9
KA3574D01	2.05	12.6
KA3578C01	2.09	-5.4
KA3578H01	1.9	59.1
KA3579D01	2	-1
KA3588C01	2.04	-4
KA3588D01	1.9	-1.8
KA3588I01	1.96	65.6
KA3592C01	2.1	4.4
KA3597D01	2.22	3.1
KA3597H01	2.06	55.1

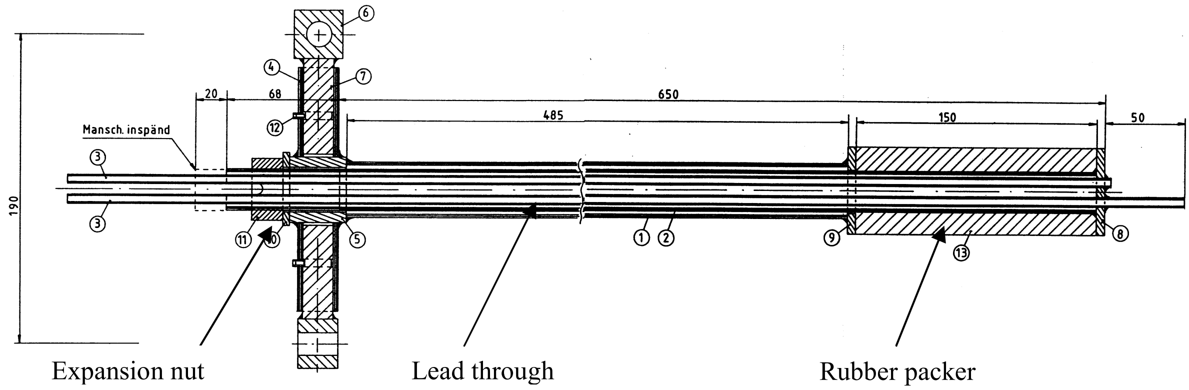


Figure 2-11 Mechanical packer.

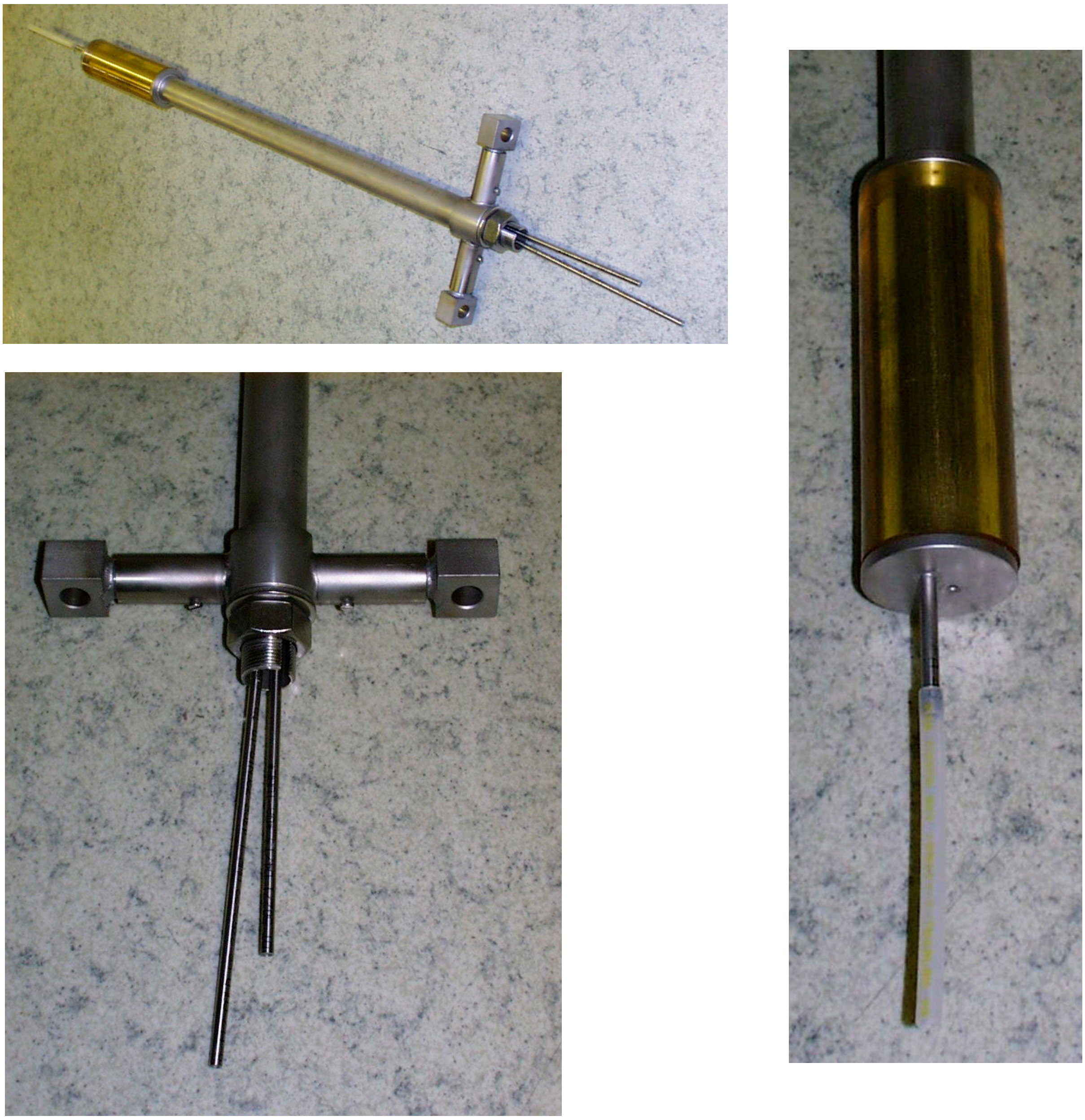


Figure 2-12 Mechanical packer.

Figure 2-13 Mounted mechanical packer.

In *Figures 2-14* to *2-17,* the boreholes with monitoring sections in Prototype Repository Section I are shown. The colours along the boreholes indicate a packer or the type of measurement section:

- GREY, wide cylinder: Packer
- NO COLOUR: Pressure section (P)
- RED: Hydrochemical section (HC) + P
- YELLOW: Flow section (F) + P
- GREEN: Circulation section (C) + P

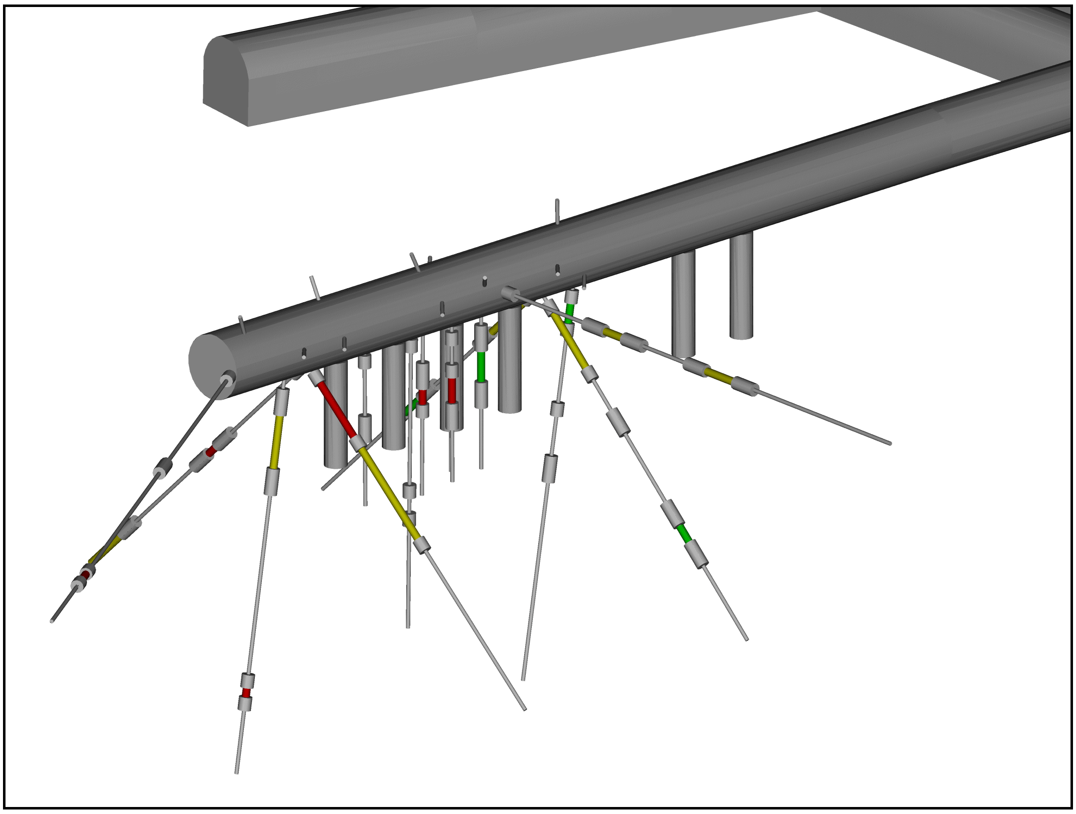


Figure 2-14 Boreholes with monitoring sections in Prototype Repository Section I.

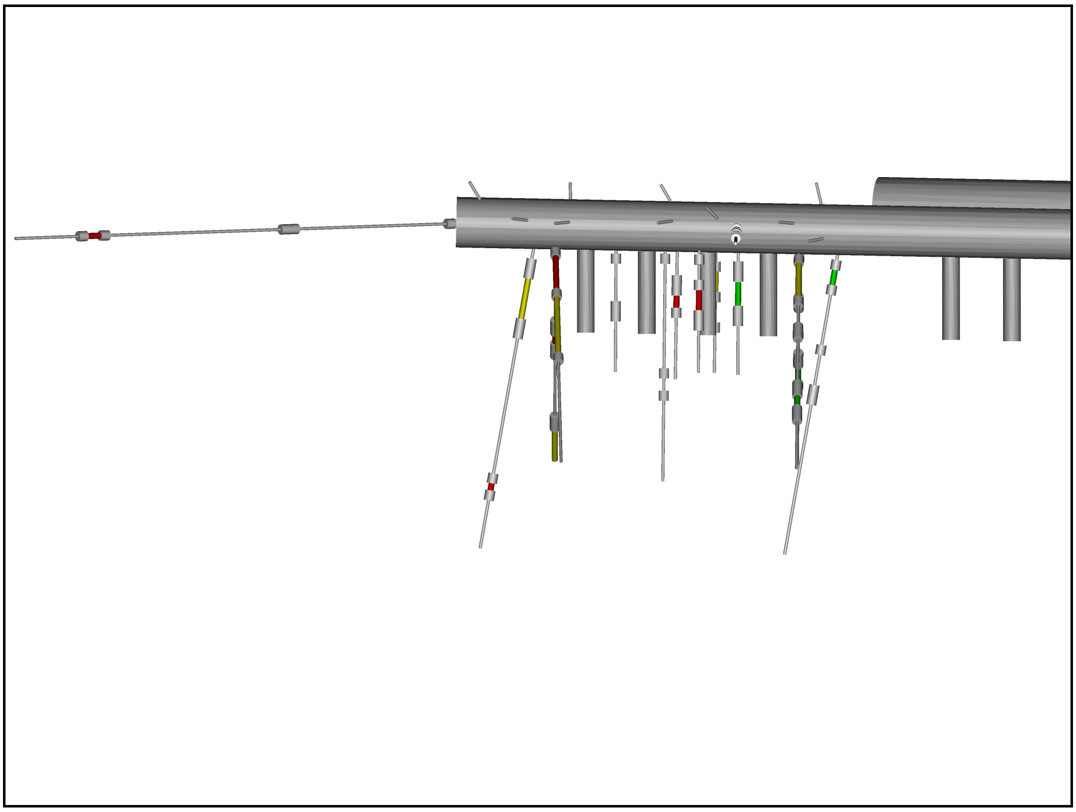


Figure 2-15 Boreholes with monitoring sections in Prototype Repository Section I.

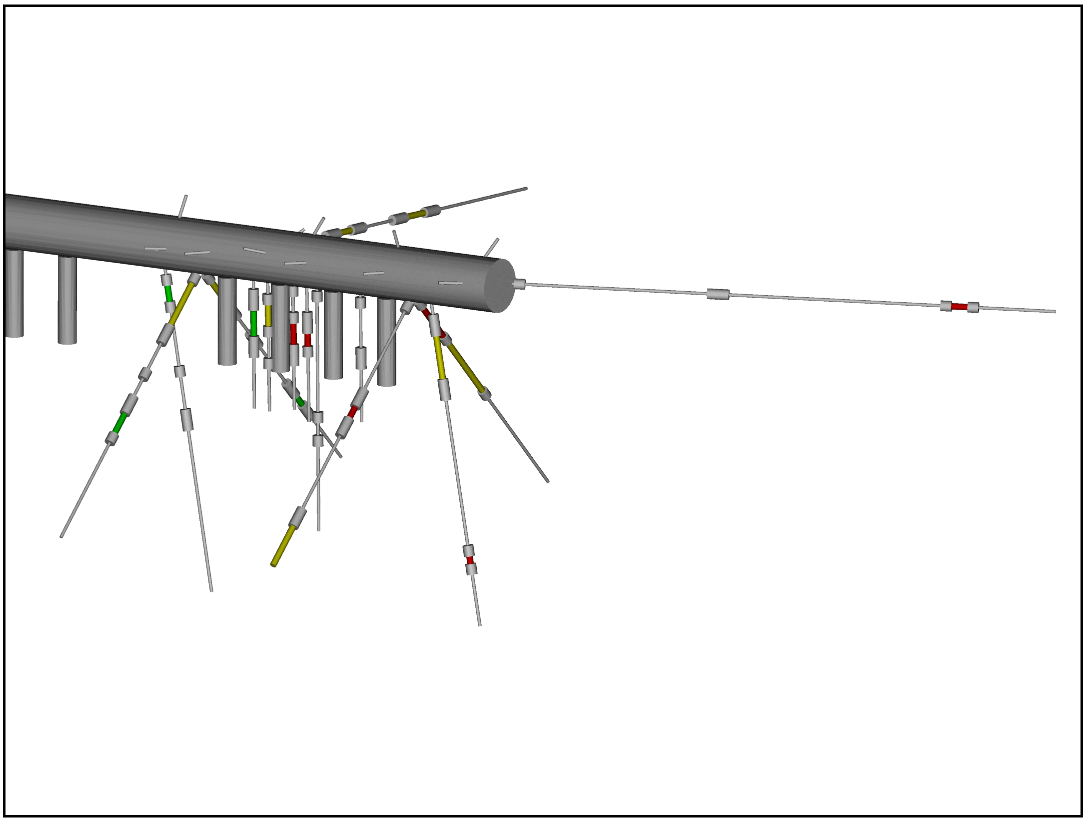


Figure 2-16 Boreholes with monitoring sections in Prototype Repository Section I.

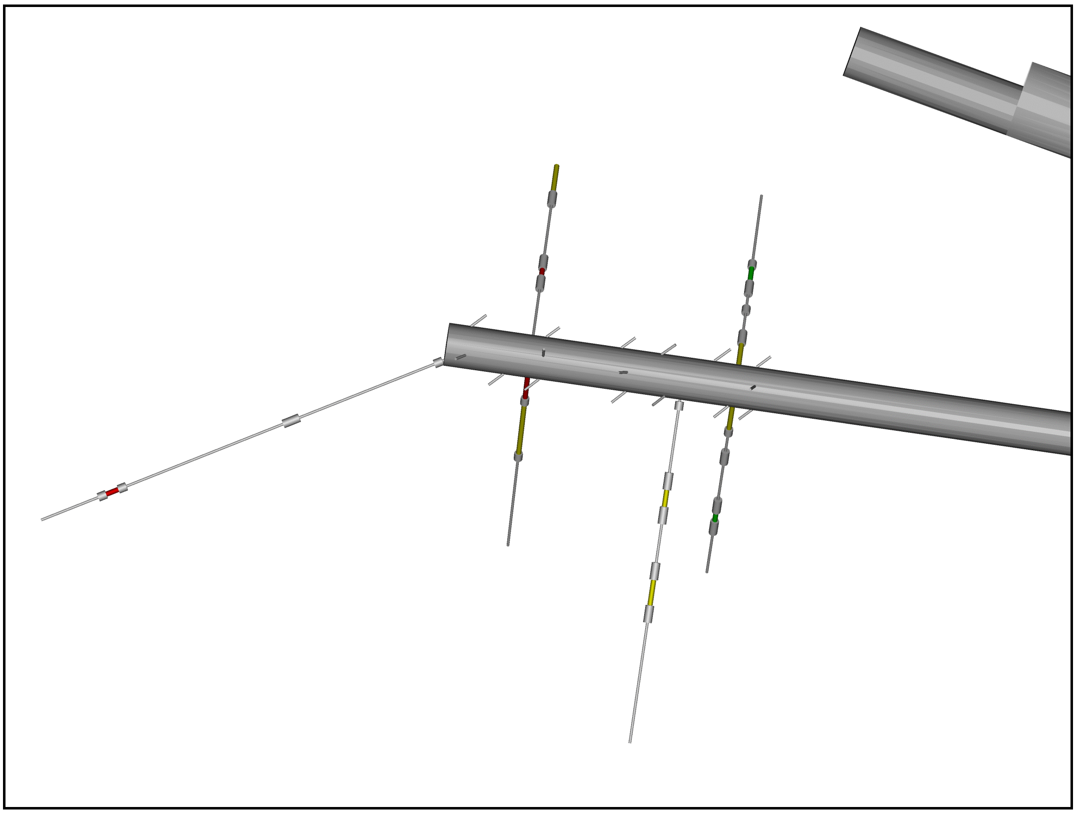


Figure 2-17 Boreholes with monitoring sections in Prototype Repository Section I.

Instrumentation of holes for temperature measurements

The purpose of the temperature measurements is to verify predicted temperature values and to enable analyses of rock thermal properties (thermal conductivity, heat capacity and thermal diffusivity). Thermal properties are obtained primarily for the dominant the rock type Äspö diorite. In addition, the temperature will be measured in the deposition holes.

The measurement of the temperature in the rock is made in 37 points, between the deposition holes and radially from the tunnel. Eight boreholes were drilled, *see Table 2-3*. Six of the holes are vertical and 10 meter deep, while two are sub-vertical towards the South from DA3575G01.

The sensors were mounted on rods with low thermal expansion. Sensors and cables were protected against moisture and water intrusion, as well as mechanical ware. Cement paste was used to secure good contact between the sensors and the borehole wall and to prevent from hydraulic connection along the boreholes.

In *Figures 2-18 to 2-21,* the temperature holes are shown.

Table 2-3 Boreholes for temperature measurements.

Borehole	Length (m)	Inclination to vertical plane (°)	Sensors at borehole depth (m)
KA3571G01	10.00	0	0.5, 2.5, 4.9, 7.3, 10.0
KA3575G06	13.80	22	2.7, 5.3, 8.4, 13.8
KA3575G07	14.70	58	4.7, 9.2, 14.7
KA3577G01	10.00	0	0.5, 2.5, 4.9, 7.3, 10.0
KA3578G02	10.00	0	0.5, 2.5, 4.9, 7.3, 10.0
KA3589G01	10.00	0	0.5, 2.5, 4.9, 7.3, 10.0
KA3592G01	10.00	0	0.5, 2.5, 4.9, 7.3, 10.0
KA3597G01	10.00	0	0.5, 2.5, 4.9, 7.3, 10.0

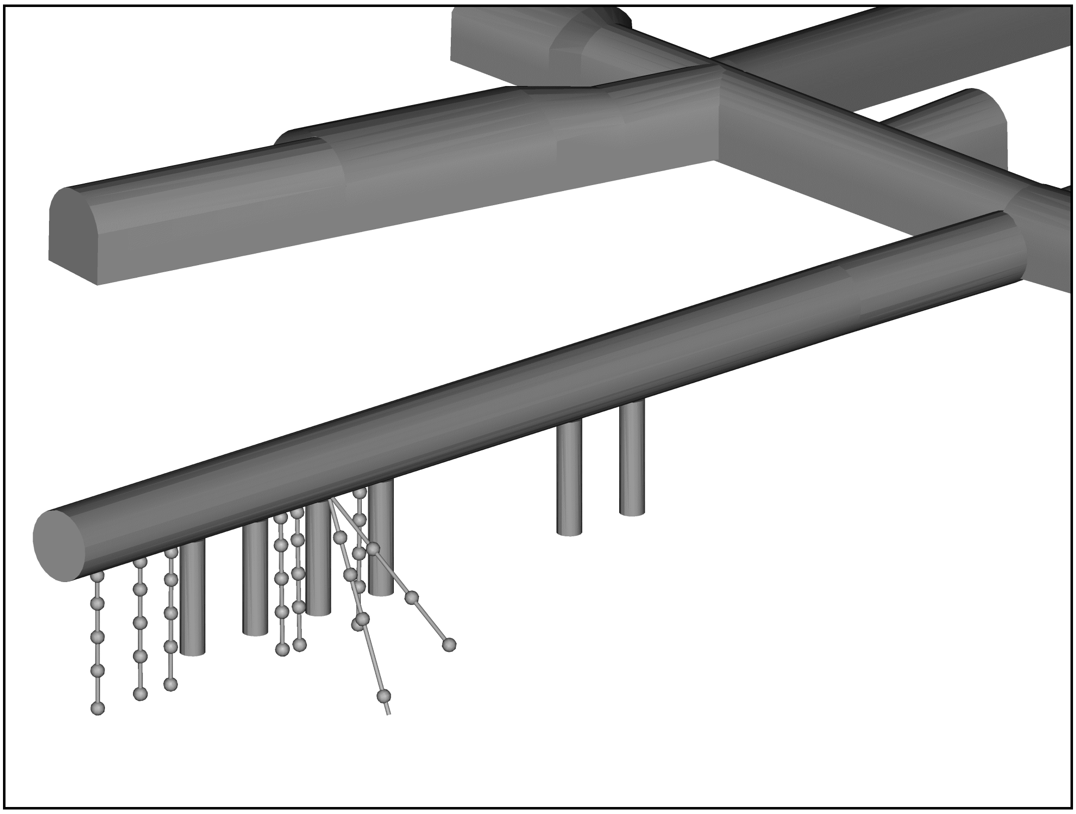


Figure 2-18 Temperature holes in Tunnel A.

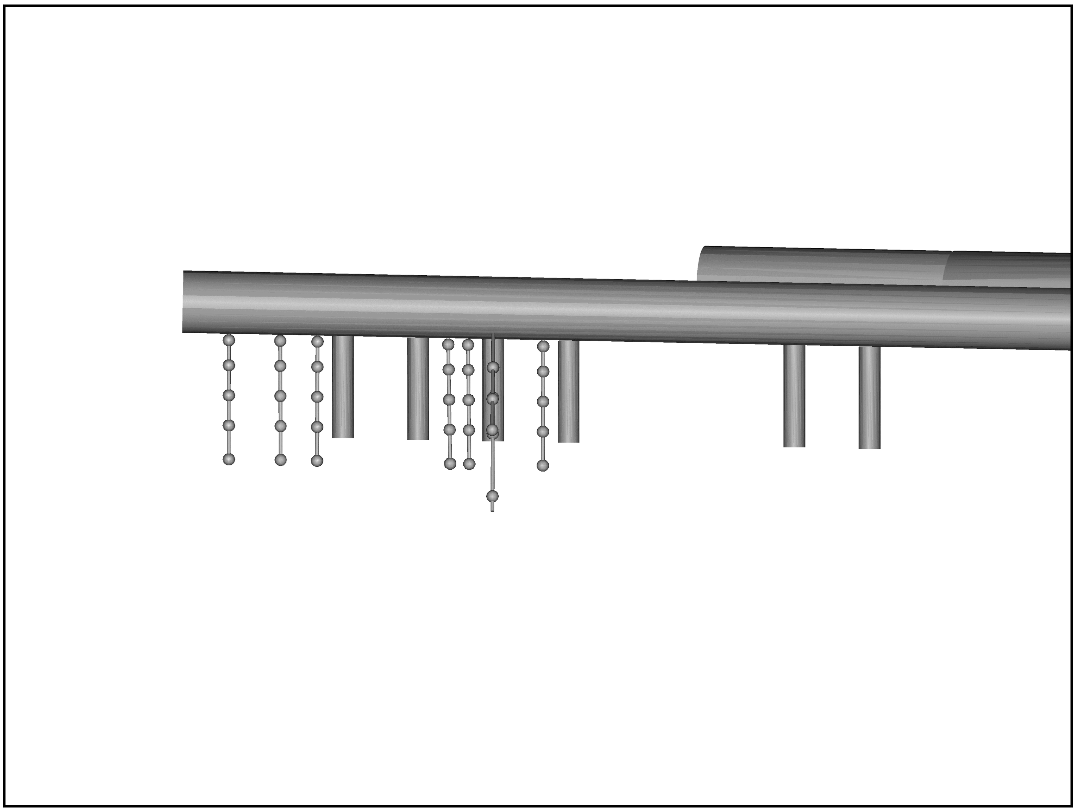


Figure 2-19 Temperature holes in Tunnel A.

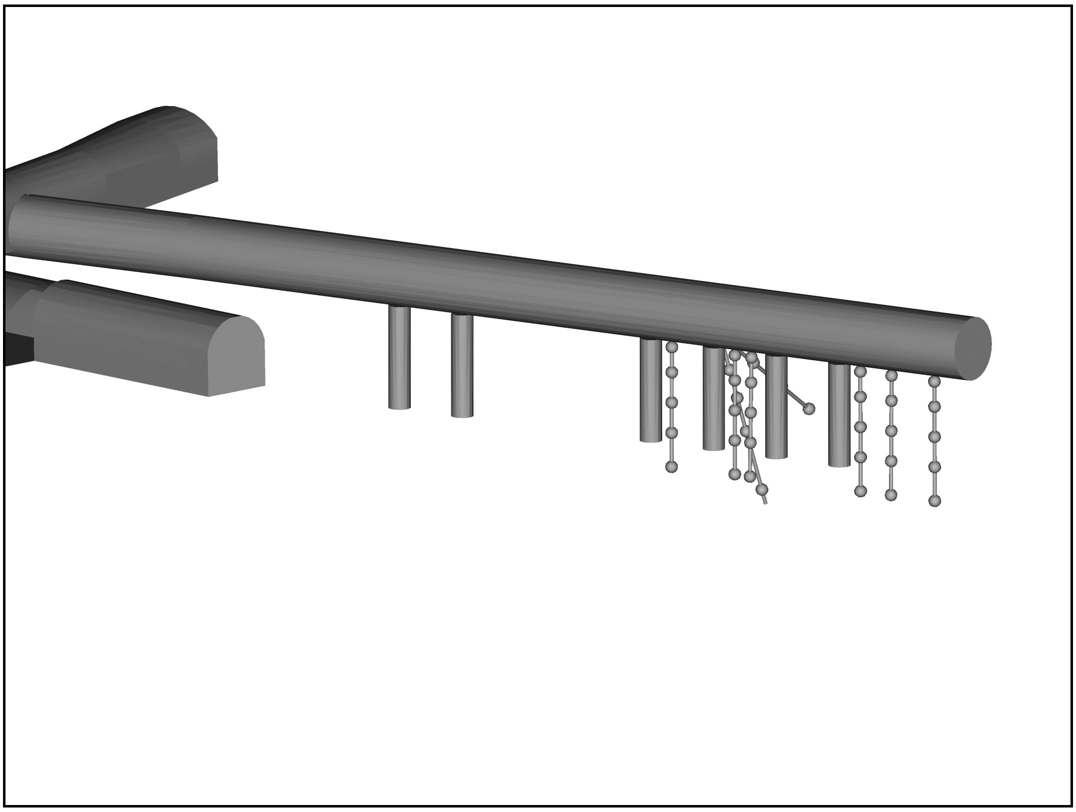


Figure 2-20 Temperature holes in Tunnel A.

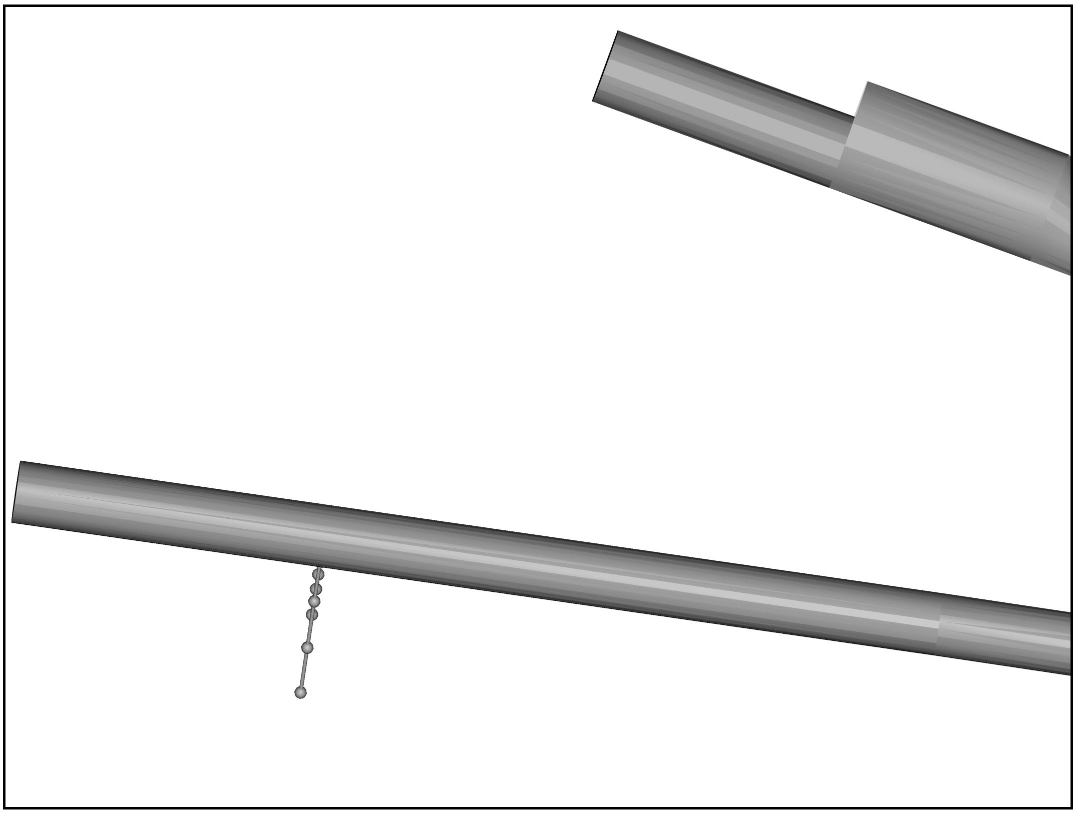


Figure 2-21 Temperature holes in Tunnel A.

Connection to lead-through holes

All instrumentation tubes were finally lead to lead-through holes, see *Figures 2-22* and *2-23*, connecting Tunnel A to Tunnel G. In the G-Tunnel the instrumentation, panels with transducer etc. are situated.

Figure 2-22 Tubes and cables being installed in a lead-through hole.

Figure 2-23 Lead-through holes.

3 Pressure measurements

3.1 Introduction

The hydraulic properties of the rock, geometry of tunnels and depositions holes, water pressure far away from the tunnels and the hydro-mechanical properties of the backfill and buffer govern the saturation of the buffer and backfill. It is important to measure the water pressure in the rock for the interpretation of the measurements in the buffer and backfill and to sample data useful for the modelling of the saturation process.

3.2 Measurements in the boreholes

As shown in Chapter 2 a large number of boreholes will be instrumented with one or several packers. In all packed-off sections, the water pressure will be measured. Each borehole section is connected to a tube of polyamide that via lead-through holes ends in the G-tunnel. All pressure transducers are placed in the G-tunnel to facilitate easy calibration and exchange of transducers that are out of order. The transducers will be connected to the HMS system at Äspö Laboratory and it will be a flexible system for changing the sampling frequency. The maximum scan frequency is 1/second. During periods with no hydraulic tests, preliminary the sampling (storing a value in the data base) frequency will be 2/hour with an automatic increase of the sampling frequency if the pressure change since last registration is larger than 2kPa. During hydraulic tests, the sampling frequency may be up to 1/second.

3.3 Modelling

The pressure measurements will be important for the numerical modelling of the rock mass, buffer and backfill. The first measured data will be useful for defining the initial conditions and the continuous measurements will be useful for future comparison with any predictive modelling involving the rock mass around the Prototype Repository. The pressure measurements during hydraulic tests will also be useful for calibrating and testing the models.

4 Dilution measurements

4.1 Introduction

Groundwater flow rate is one part that governs the transport of solutes and thus plays a role for the hydrochemical evolution of the groundwater. Groundwater flow rate is difficult to measure in a fractured media but the available technique can provide good indications of hydraulic connections if the hydraulic stress field is changed (with a hydraulic test for example) and can also provide approximate flow rates in the rock mass.

4.2 General principles

The groundwater flow in a saturated geological formation can be estimated from dilution measurements, see for example Halevy et al. (1967), Drost et al. (1968), Gaspar and Oncecu (1972) and Gustafsson (1986). Equation 4-1 is generally used for estimating the groundwater flow (filtration velocity or Darcy velocity). It has been developed for porous media but is also used to evaluate dilution measurements in fractured rock. In *Figure 4-2,* the dilution curve is illustrated.

$$q_{bh} = \alpha \cdot q + q_D + q_R = \frac{V}{A \cdot t} \cdot \ln\left(\frac{C}{C_0}\right) \qquad (4\text{-}1)$$

q_{bh} : Tracer dilution velocity in the borehole section (m/s)
α: Correction factor for the hydrodynamic field distortion (-)
q : Filtration velocity in the formation (m/s)
q_D : Apparent velocity due to molecular diffusion of the tracer (m/s)
q_R : Apparent velocity due to effects of vertical current, mechanical mixing etc. (m/s)
V: Dilution (water and tracer filled) volume of the borehole section (m^3)
A: The area of the dilution (measuring) volume cross-section (m^2)
t: Time (s)
C: Tracer concentration at time t (kg/m^3)
C_0: Tracer concentration at time t=0 (kg/m^3)

It should be observed that q in equation 4-1 is also called "Darcy velocity" and should not be confused with the actual transport velocity. The transport velocity is dependent of the kinematic porosity and the transport velocity can thus in crystalline rock be 100 to 10000 greater than q.

The assumption made in equation 4-1 is that the groundwater flow is perpendicular to the borehole section, see *Figure 4-1*. The flow q_R can generally be neglected and the lower measuring limit is then governed by the molecular diffusion of the tracer. The parameter α

depends on the permeability distribution around the borehole. If the permeability is constant around the borehole *á*=2. If the permeability is much greater within radius (r_2) of about 5 times the borehole radius (r_1) compared to outside r_2, *á* becomes about 4. If the permeability is less within radius r_2 compared to outside r_2, *á* may become less than 1. It is assumed that the tracer is perfectly mixed in the borehole section. It is necessary that the circulation-flow rate (Q_m) of the tracer is much greater than q_{bh} A to keep the borehole section well mixed. The time needed for a measurement can be decreased if the volume V_C decreases. By using "dummies" (massive cylindrical bodies with volume V_d) in a borehole section (with total borehole volume V) V_C decreases to V-V_d.

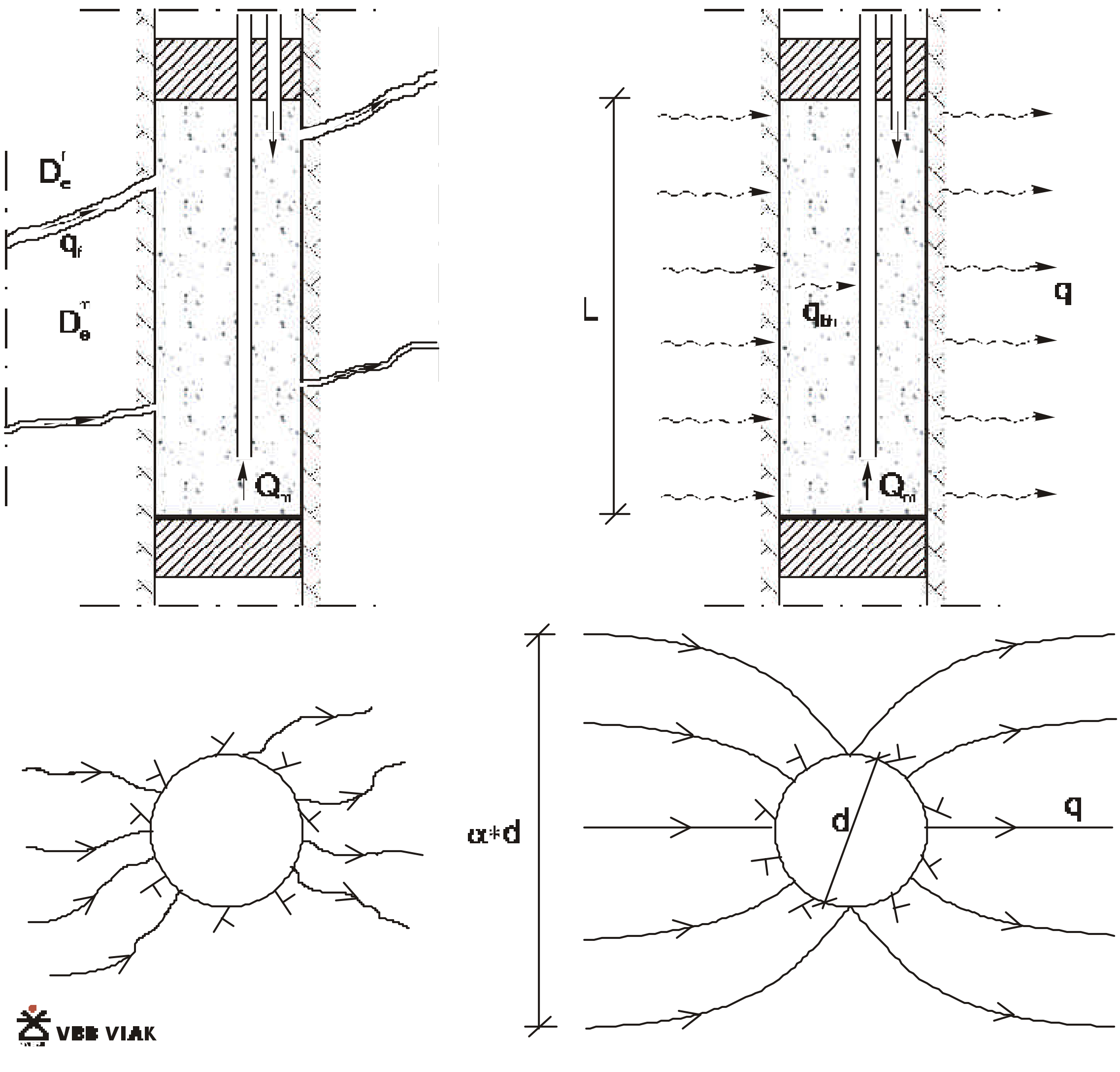


Figure 4-1 Schematic description of dilution measurements. To the left: Flow in fractured crystalline rock. To the right: Ground water flow in a porous medium. L: length of test section. d: diameter of the borehole section. D_e^m: Effective diffusion coefficient of the rock matrix. D_e^f: Effective diffusion coefficient in the fractures.

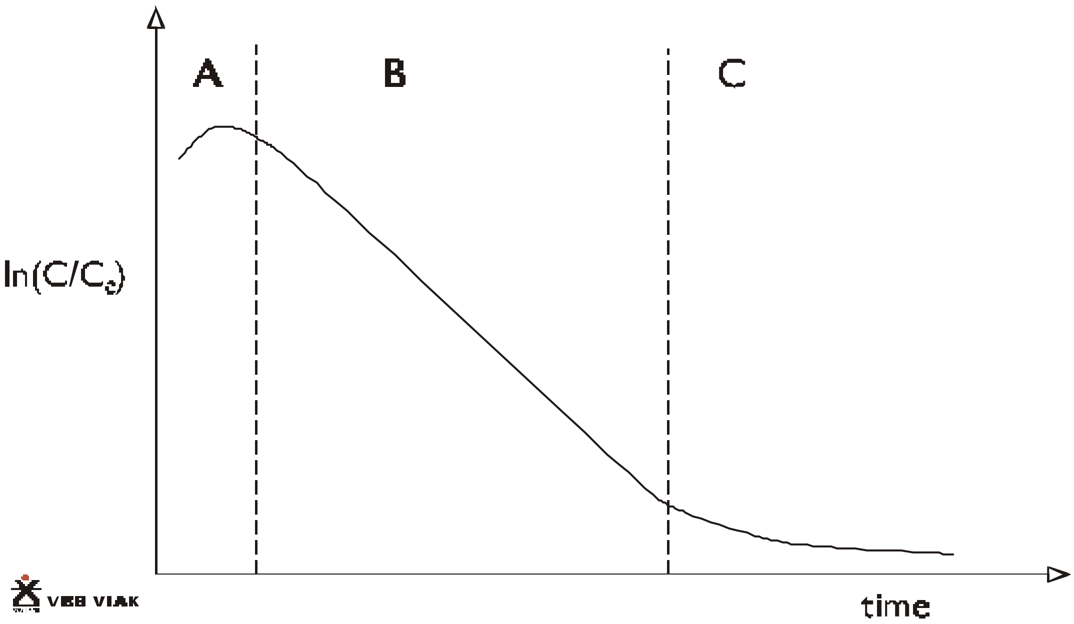


Figure 4-2 Schematic description of a dilution curve. A: Homogenisation in the borehole section. B: Curve used for evaluation of q_{bh}.

Apparent velocity due to molecular diffusion of the tracer can be estimated by equation 4-2 (Halevy et al, 1967).

$$q_D = \frac{\pi \cdot D_e}{r_1} \qquad (4\text{-}2)$$

q_D : Apparent velocity due to molecular diffusion of the tracer (m/s)
D_e: Effective diffusion coefficient of the tracer (m^2/s)
r_1 : Radius of borehole in test section (m)

If q_D can be calculated, it should be included in equation 4-1 when calculating q. However, it may be difficult to estimate D_e for a particular borehole section.

4.3 Measurements in the boreholes

According to Byegård et al. (1998) the effective diffusion coefficient for the rock matrix of Äspö diorite is in the range 4 10^{14} – 1 10^{13} m^2/s. Diffusion coefficient of a tracer in water with an ionic strength less than 0.5 and a temperature of 20-25 C is about 1 10^{-9} – 2 10^{-9} m^2/s.

The measured transmissivities (T) of test sections with 1 or 3 m length (L) in the Prototype Repository are in the range 1 10^{-12} – 5 10^{-6} m^2/s (Rhén and Forsmark, 1998a,b, Forsmark and Rhén, 1998a). The transport aperture is expected to be in the order of 10^{-5} – 10^{-2} m in a test section with 1 or 3 m length (Rhén et al, 1997). Estimated mean flow porosity (n_e) and effective diffusion coefficient of a test section are estimated in *Table 4-1*. Hydraulic conductivity estimated as T/L. Apparent velocity due to molecular diffusion of the tracer, calculated according to equation 4-2, is also shown in *Table 4-1*. Bore diameter assumed is 76 mm.

The hydraulic gradient in the near field of the open tunnel is in the range 10-25 (Forsmark and Rhén, 1998a). It is expected that the hydraulic gradient may be as low as 1-0.1 during the operation phase according to Svensson (2001).

Table 4-1 Estimated mean flow porosity and effective diffusion coefficient as function of transmissivity of a borehole section with length 1-3 m.

Hydraulic conductivity (K)	**Estimated range for flow porosity (n_e)**	**Estimated effective diffusion coefficient (D_e)**	**Apparent velocity due to molecular diffusion of the tracer (q_D)**
(m/s)	**(-)**	**(m^2/s)**	**(m/s)**
10^{-10}	$5\ \ 10^{-6} – 10^{-4}$	$10^{-14} – 10^{-13}$	$10^{-12} – 10^{-11}$
10^{-8}	$10^{-5} – 5\ \ 10^{-4}$	$10^{-14} – 5\ \ 10^{-13}$	$10^{-12} – 5\ \ 10^{-11}$
10^{-6}	$10^{-4} – 5\ \ 10^{-3}$	$10^{-13} – 5\ \ 10^{-12}$	$10^{-11} – 5\ \ 10^{-10}$

Table 4-2 Estimated filtration velocity (q) with assumed hydraulic conductivity (K) and hydraulic gradient (i).

Hydraulic conductivity (K)	**Hydraulic gradient (i)**	**Estimated filtration velocity (q)**
(m/s)		**(m/s)**
10^{-10}	10	10^{-9}
10^{-10}	0.01	10^{-12}
10^{-8}	10	10^{-7}
10^{-8}	0.01	10^{-10}
10^{-6}	10	10^{-5}
10^{-6}	0.01	10^{-8}

Estimated time for dilution measurements is shown in *Figure 4-3*. According to *Table 4-1,* the lowest filtration velocity that can be estimated is about 10^{-11} m/s, assuming that q should be some 10 times greater than q_D and that it is a single fracture (low total flow porosity). As can be seen in the figure the lowest filtration velocity that can be estimated within reasonable time is about 10^{-10} m/s. According to *Tables 4-1* and *4-2* it should be possible to measure flow rates in sections with K around 10^{-11}-10^{-10} m/s in before, or just in the beginning of, the operation phase of the Prototype Repository and in sections with K around 10^{-10}-10^{-9} m/s.

Only a few sections will be measured according to Chapter 2 but the measurements should indicate the magnitude of the flow rates and to some extent the variability of the flow rates.

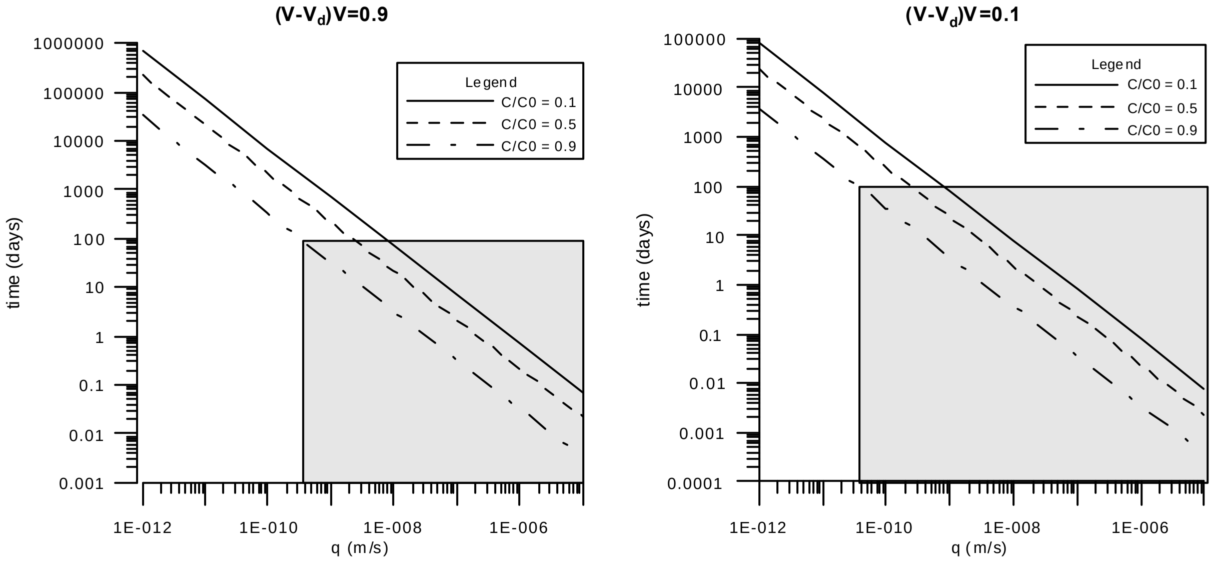


Figure 4-3 The time interval, for 0.1, 0.5 and 0.9 of the initial tracer quantity takes to be carried through borehole out of the formation, for different flow velocities in a borehole section with diameter 76 mm. V: total volume of borehole section. V_d: Volume of dummy and other space filling parts in the borehole section.

4.4 Modelling

The dilution measurements will be useful for the numerical modelling of the rock mass. The first measured data will to some extent be useful for calibration of the model and the continuous measurements will be useful for future comparison with any predictive modelling involving the rock mass around the Prototype Repository.

5 Hydrochemical sampling in the boreholes

5.1 Introduction

Both the chemical stability of backfill material and the corrosion rate of the canister are important areas of uncertainty in repository safety and performance assessment. These are processes that depend on the hydrochemical characteristics of the near field. The solubility and migration characteristics of several radio nuclides are also highly dependent on the chemical composition of the groundwater. Other factors affecting radio nuclide mobility are the hydraulic and mineralogical properties of the rock. A suitable description of the chemical environment is required in order to demonstrate the proper function of the engineered barriers of the Prototype Repository.

Micro organisms have the capability to reduce important groundwater components such as sulphate to sulphide and to produce and consume gases. Relevant microbial reactions should be included in the performance assessment for a HLW repository. The Prototype Repository will not be a sterile environment and microbial activity that influence the hydrochemical situation must, therefore, be studied.

The objectives for the hydrochemical sampling program, which is discussed in Puigdomenech and Pedersen (1999), are:

- Monitoring the chemical/microbial function of the Prototype Repository
- Verification of chemical/microbiological Models & Hypotheses
    - Effect of temperature field on groundwater-rock interactions
    - Bentonite redox chemistry
    - Microbes
    - Colloids
    - Redox

Bentonite packers could possibly induce massive contamination of the Prototype near field with bentonite colloids, and this would jeopardize the chemical monitoring. Therefore, boreholes were instrumented with bentonite packers where the bentonite was enclosed in rubber containers, cf. Section 2.2.2.

To study the redox conditions it is important to prevent O_2 from diffusing into the sampling system. By using PEEK in the tubes, the system is expected to be diffusion tight. Redox conditions will be studied in six sections. It will be possible to sample other sections but only through polyamide tubes.

5.2 Sampling in borehole sections

Sampling will be made close to the deposition holes and up to about 50 m from the TBM tunnel. The sampled section will have transmissivities ranging from 10^{-10} – 10^{-6} m^2/s. The location of these sampling points for hydrochemistry (HC) is described in detail in *Table 2-1*.

In all sections for hydro chemical sampling, all tubes going through the section will be of stainless steel. Sampling tubes will be made of PEEK and if there is a separate tube for pressure measurements in the hydrochemistry section, it will be made of polyamide.

Water samples can easily be taken from flow sections (F) and circulation sections (C). Separate valves on some of the pressure tubes in the G-tunnel coming from the borehole sections where only pressure is measured will make it easy to take water samples from those sections.

The analyses will be done at level Class 4 in accordance with SKB's classification, which includes ^{2}H and ^{18}O determinations. C and S isotope analyses and redox sensitive HS^- and NH_4 will be done routinely. At the closure of the Prototype Repository the hydro chemistry sections will be sampled every week and later on every 6 months.

In the case of packed-off sections for flow measurements, chemical sampling and analyses will be performed at level Class 3 with supplement analyses of ^{2}H and ^{18}O. During the operation of the Prototype Repository, activation sampling will take place every week and later on after consideration.

5.3 Modelling

The aim of the modelling is to determine possible heat-up effects on hydraulic flows and chemical reaction rates, as well as effects from the backfill bentonite on the chemical composition and colloid content of the near-field groundwater. Predictive model results will also be used to check the validity of the model formulation, and of the thermodynamic databases.

Geochemical modelling will concentrate on the data collected from the near-field double packer sections before the backfilling of the Repository, and during operation. The time-span between the activation of Section I and the expected delivery of predictive modelling results is only a couple months. This precludes the utilization of the time-series data from the backfill sampling in predictive modelling. Nevertheless, comparisons between the results of predictive models and measured data should be finished by summer 2003.

6 Flow sections

6.1 Introduction

A large number of hydraulic tests have been performed in the boreholes around the Prototype Repository in order to characterize the hydraulic properties of the rock mass. During the operation of the Prototype Repository interference tests will be made using different flowing borehole sections. The interference tests will be repeated a number of times during the operation period. A few borehole sections considered to be more suitable for flowing have been instrumented with one or two tubes for flowing and a separate tube for pressure measurement.

Besides facilitating hydraulic tests, the flowing sections make it easy to take water samples for chemical analysis.

6.2 Sampling and hydraulic tests in borehole sections

For the long-time hydrogeological monitoring, plastic and steel tubes will be used to enable the process of taking water samples for chemical analyses and hydrogeological tests. The flow in tubes depends on the tube diameter and the friction coefficient of the tube wall. The calculations below indicate the possible flow rates with different tube diameter.

The tubes in the long-term test are about 100 m long. The pressure head between the inflow (pressure in packed-off section) and the outflow is expected to be around 300 m. The temperature in the water is assumed to be between 15°C and 50°C, which gives a kinematic viscosity varying between $1.141*10^{-6}$ m^2/s and $0.556*10^{-6}$ m^2/s. The tube wall is assumed to be smooth. With these facts in the energy equation, the predicted flow was calculated for three different tube diameters: 1 mm, 2 mm and 4 mm. The results from the calculations are presented in *Table 6-1*.

In the tube with 1 mm inner diameter laminar flow will develop and in the tube with 4 mm inner diameter, turbulent flow will develop as in the 50°C water in the 2 mm tube. However, with 15°C water in the 2 mm tube a complicated stadium of something between laminar and turbulent flow will develop. In this case, the outflow has been calculated as if turbulent.

The flow in the 1-mm tube is only 2 % of the flow in the 4 mm tube and the flow in the 2 mm tube is 10-15 % of the flow in the 4 mm tube.

Table 6-1 The table presents the results from the calculations. Q stands for flow rate, Re stands for Reynolds's number, T_{water} stands for the water temperature in the rock and Dtube stands for the inner tube diameter.

		D_{tube}= 1 mm	D_{tube}= 2 mm	D_{tube}= 4 mm
T_{water}= 15°C	Q (m^3/s)	$6,3*10^{-7}$	$5,1*10^{-6}$	$3,5*10^{-5}$
	Q (l/min)	0,038	0,308	2,077
	Re	700	2900	9500
T_{water}= 50°C	Q (m^3/s)	$9,7*10^{-7}$	$5,8*10^{-6}$	$5,1*10^{-5}$
	Q (l/min)	0,058	0,348	3,034
	Re	1650	6600	29000

6.3 Modelling

Hydraulic tests and geological characterization made up to Spring 2001 are the base for setting up numerical groundwater flow models. Interference tests made before year 2000 can be used for calibration of the models. Interference tests made during the operation period may be used for comparison with predicted responses to gain confidence in the models. The repeated interference tests may indicate changes in the hydraulic responses which then may be useful for assessing the THM behaviour of the rock mass.

7 Temperature measurements

7.1 Introduction

The thermal properties of the rock, geometry of tunnels and depositions holes, the undisturbed temperature, thermal properties of the backfill and buffer and the heat generated in the canisters govern temperature evolution in the rock mass, buffer and backfill. It is therefore important to measure the temperature in the rock for the interpretation of the measurements in the buffer and backfill and to sample data useful for the modelling of the thermal process.

7.2 Measurements in the boreholes

As shown in Chapter 2 a few boreholes will be instrumented with several measuring points. These measuring points will mainly serve to confirm that the thermal models behave as expected, as the thermal process and modelling is considered well known.

7.3 Modelling

The temperature measurements will be important for the numerical modelling of the rock mass, buffer and backfill. The first measured data will be useful for defining the initial conditions and the continuous measurements will be useful for future comparison with any predictive modelling involving the rock mass around the Prototype Repository.

REFERENCES

Byegård J, Johansson H, Skålberg M, Tullborg, E-L, 1998. The interaction of sorbing and non-sorbing tracers with different Äspö rock types. Sorption and diffusion experiments in the laboratory scale, SKB TR-98-18

Drost W, Klotz D, Koch A, Moser H, Neumaier F, Rauert W, 1968. Point dilution methods of investigating groundwater flow by means of radioisotopes. Water Resources Research, Vol. 4, No. 1, pp 125-146.

Forsmark T, Rhén I, 1999. Äspö HRL - Prototype Repository Hydrogeology - Drill campaign 3A and 3B. SKB, IPR-00-08

Gaspar E, Oncecu M, 1972. Radioactive tracers in hydrogeology, Elsevier Publ. Comp.,

Gustafsson E, 1986. Bestämning av grundvattenflödet med utspädningsteknik. Modifiering av utrustning och kompletterande fältmätningar, SKB AR 86-21 (In Swedish)

Halevy E, Moser H, Zellhofer O, Zuber A, 1967. Borehole dilution techniques: A critical review. Proceedings of the symposium on isotopes in hydrology in Vienna, 14-18 November 1966. International Atomic Energy Agency

Persson G, Broman O, 2000. Äspö Hard Rock Laboratory, Prototype Repository, Project plan, FIKW-CT-2000-00055, SKB, IPR-00-31

Puigdomenech I, Pedersen K, 1999. Prototype Repository. Test Plan for subtask. Sampling and monitoring of microbial activities and Chemical conditions during 20 year of operation, SKB, IPR-99-34

Rhén I, Gustafson G, Stanfors R, Wikberg P, 1997. Äspö HRL - Geoscientific evaluation 1997/5. Models based on site characterisation 1986-1995. SKB TR 97-06.

Rhén I, Forsmark T, 1998a. Äspö HRL - Prototype Repository Hydrology - Drill campaign 1. SKB PR HRL 98-12.

Rhén I, Forsmark T, 1998b. Äspö HRL - Prototype Repository Hydrology - Drill campaign 2. SKB PR HRL 98-22.

Svemar C, Pusch R, 2000. Äspö Hard Rock Laboratory, Prototype Repository, Project description, FIKW-CT-2000-00055, SKB, IPR-00-30

Svensson U, 2001. Groundwater Flow, Pressure and Salinity around the Prototype Repository, Continuum model No 1, SKB, IPRxxxx (Report in draft)

APPENDIX 1

Monitoring configuration of boreholes in tunnel section I

- The diagram "*Distribution of hydraulic conductivity*" shows results from investigations detailed in Rhén and Forsmark (1998a,b) and Forsmark and Rhén (1999b). The bars show estimates of hydraulic conductivity K_{sec} of sections in each borehole based on flow logging, using a double-packer system, done in the borehole after the completion of drilling.

  The entire borehole was tested during a pressure build-up test and if radial flow occurred the evaluation of the transmissivity (T_{tot}) was made using a radial flow model (Jacob semi-logarithmic evaluation). In some of the holes radial flow could not be identified and a relationship for transforming the specific capacity to a transmissivity value presented in Rhén et al. (1997) was used. See Rhén and Forsmark (1998a,b) and Forsmark and Rhén (1999b) for details.

  The flow rate Q_{sec} of the section were used to scale the evaluated whole borehole transmissivity T_{tot} to get a section transmissivity T_{sec} using the equation below:

  $T_{sec} = [Q_{sec} \cdot T_{tot}] / Q_{tot}$

  Q_{tot} is the flow rate of the whole borehole

  The transmissivity value was later divided by the section length to get the estimate of K_{sec}.

  Some of the borehole sections were tested separately with a pressure build-up test (parts of the borehole with higher inflow rates) and reported in the references above. In most cases these results are similar to the T_{sec} values, but in some cases a difference occurs.

  In a few boreholes it was never performed flow logging with a double packer system. In these cases the cumulative flow (L/min) measured with the UCM flow logg is shown in the figures.

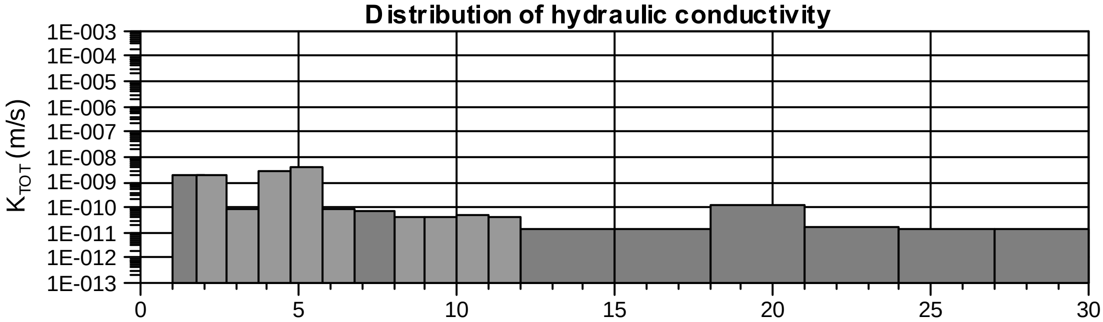
- The diagram "*Distribution of natural open fractures*" shows the result of the analysis of studying BIPS images of the borehole walls. BIPS (Borehole Image Processing System) is a borehole-TV system. The purpose is to indicate where potential water-bearing fractures may be located in the hole. From the image an approximate mean width is estimated. If the fracture is judged open, but less than 1 mm wide the width has been set to 1 mm. It should be observed that the width interpreted from the images can not be used as a hydraulic effective aperture.

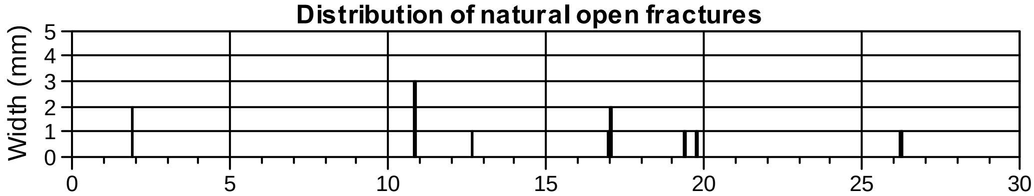
- The packers in the holes are mounted on and positioned by a solid rod as indicated in the diagrams showing the monitoring configuration.

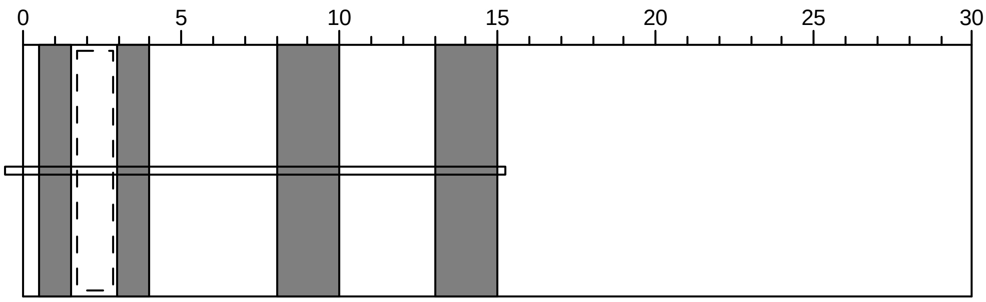
PACKER POSITION

Borehole name: **KA3563G**
Borehole diametre: 76 mm
Borehole length: 30.00 m
Borehole inclination: 80° down

Date design: 2001-08-15
Name: TFK
Remark:







Section secup :	1.5	4	10	15
Section seclow :	3	8	13	30.01
Type of section :	P,C	P	P	P
Type of dummy :	HD	-	-	-
HM anchor secup :	-	-	-	-
HM anchor seclow :	-	-	-	-

Type of measurement section
P : Pressure
C : Circulation
F : Flow
HM : Hydromechanical measurement
HC : Hydrochemistry sampling
T : Temperature
N : No measurements
G : Grouted section

Type of dummy
PE : PEEK
HD : HD1000

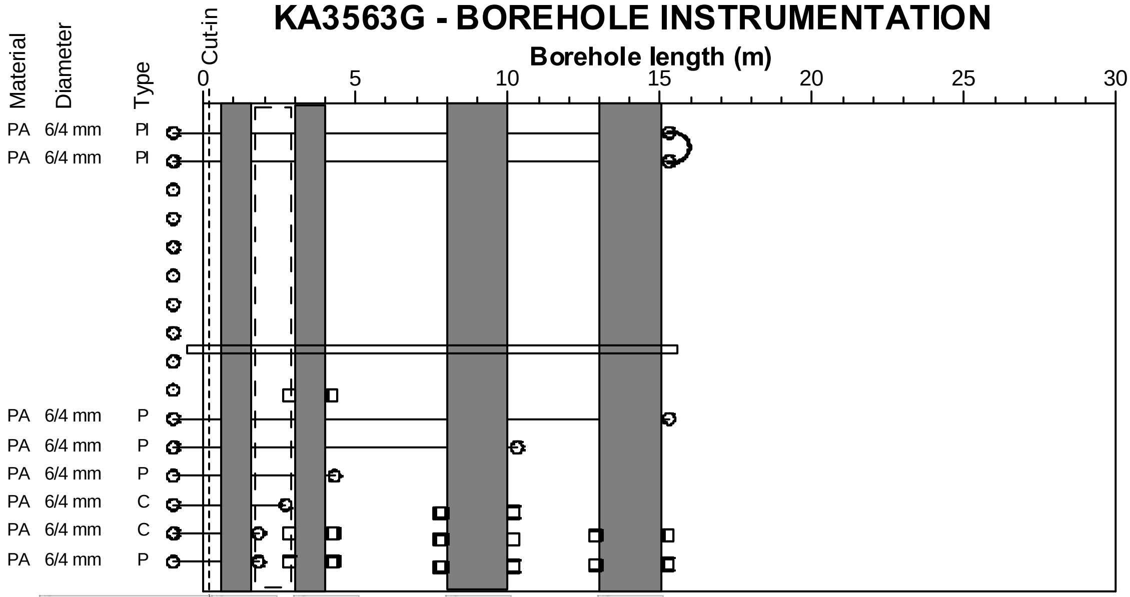
PACKER

DUMMY

VBB VIAK

/1310241/DATA/MONITORING SECTIONS/KA3563G1A.GRF 2001-08-15

KA3563G - BOREHOLE INSTRUMENTATION



Packer type :	A8-1	A8-1	A7-2	A5-2
Secup :	0.5	3	8	13
Seclow :	1.5	4	10	15

Section secup :	1.5	4	10	15
Section seclow :	3	8	13	30.01
Type of section :	P,C	P	P	P
Type of dummy :	HD	-	-	-
HM anchor secup :	-	-	-	-
HM anchor seclow :	-	-	-	-
Cut-in, seclow :	0.2			
Rodholders,seclow :	0.2			
Rod type :	S	S	S	-
Rods à 2 m :	0	1	1	0
Rods à 1 m :	1	1	0	0
Rods à 0.5 m :	0	1	1	0
Rods à 0.3 m :	0	0	0	0
Rods à 0.2 m :	0	0	0	0
Rods à 0.1 m :	0	0	0	0

Packer type: Bentonite

Type	Number of pipes					
	Steel		PEEK			
	φ 6/5 mm	φ 6/4 mm	1/8",2 mm	(m)	(m)	(m)
A8-1	1	7		0.25	1.00	0.25
A8-2	1	7		0.25	2.00	0.25
A8p-1		7	1	0.25	1.00	0.25
A8p-2		7	1	0.25	2.00	0.25
A7-1		7		0.25	1.00	0.25
A7-2		7		0.25	2.00	0.25
A5-1	1	4		0.25	1.00	0.25
A5-2	1	4		0.25	2.00	0.25
A4-1		4		0.25	1.00	0.25
A4-2		4		0.25	2.00	0.25
B10-1,b		10		0.3	1.00	0.2
B10p-1,b		9	1	0.3	1.00	0.2

Type of pipe/section
P : Pressure
C : Circulation
F : Flow
HM : Hydromechanical measurement
HC : Hydrochemistry sampling
T : Temperature
N : No measurements
G : Grouted section

Packertype
H : Hydraulic
B : Bentonite
M : Mechanical

Dummy material
PE : PEEK
HD : HD1000

Pipe
: Plug (unused pipe through packer)
: End point

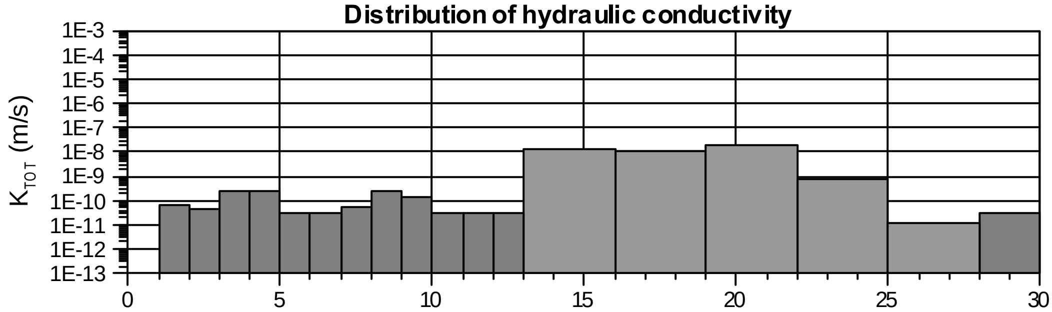
Pipe material
PA : Polyamid
ST : Steel
PE : PEEK

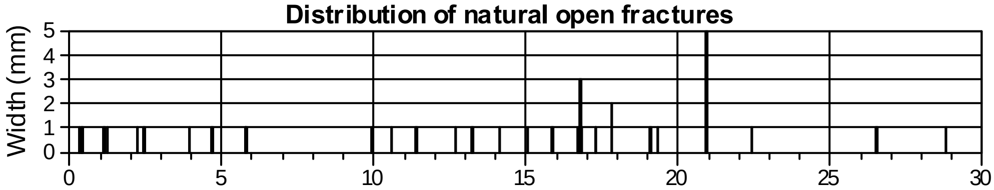
Rod type
S : Steel
A : Aluminium

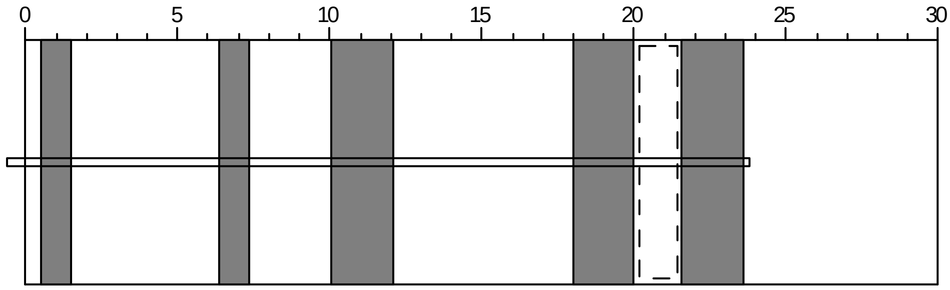
PACKER POSITION

Borehole name: **KA3566G01**
Borehole diametre: 76 mm
Borehole length: 30.01 m
Borehole inclination: 45° down

Date design: 2001-06-14
Name: TFK
Remark:







Section secup :	1.5	7.3	12	20	23.5
Section seclow :	6.3	10	18	21.5	30.01
Type of section :	P,F	P	P	P,C	P
Type of dummy :	-	-	-	HD	-
HM anchor secup :	-	-	-	-	-
HM anchor seclow :	-	-	-	-	-

Type of measurement section
P : Pressure
C : Circulation
F : Flow
HM : Hydromechanical measurement
HC : Hydrochemistry sampling
T : Temperature
N : No measurements
G : Grouted section

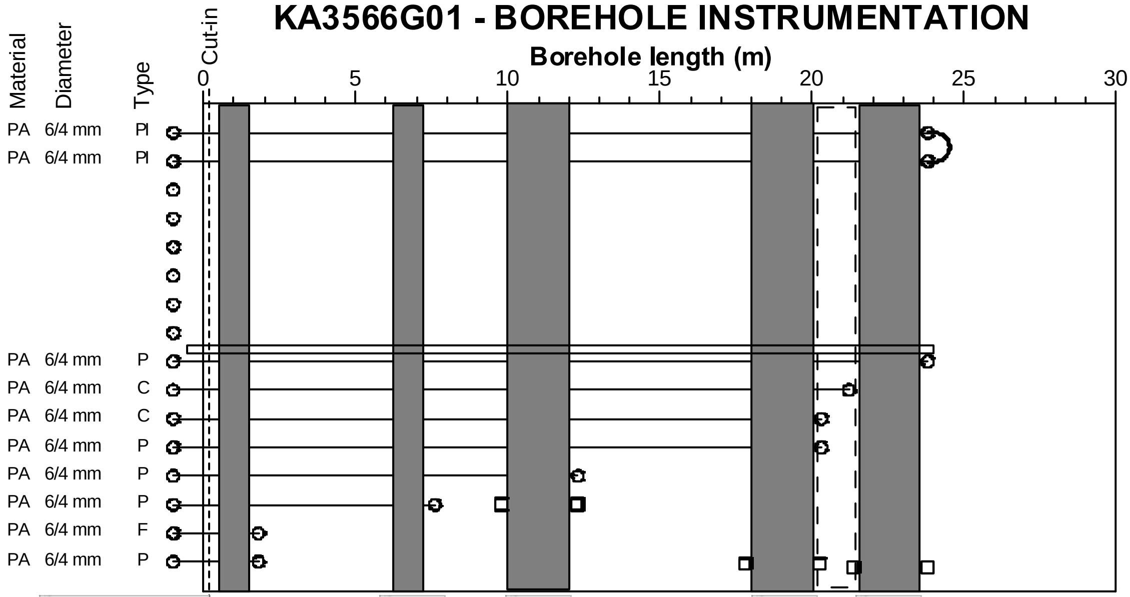
Type of dummy
PE : PEEK
HD : HD1000

PACKER

DUMMY

/1310241/DATA/MONITORING SECTIONS/KA3566G01A.GRF 2001-06-14

KA3566G01 - BOREHOLE INSTRUMENTATION



Packer type :	B,10-1,b	A8-1	A8-2	A7-2	A4-2
Secup :	0.5	6.3	10	18	21.5
Seclow :	1.5	7.3	12	20	23.5

Section secup :	1.5	7.3	12	20	23.5
Section seclow :	6.3	10	18	21.5	30.01
Type of section :	P,F	P	P	P,C	P
Type of dummy :	-	-	-	HD	-
HM anchor secup :	-	-	-	-	-
HM anchor seclow :	-	-	-	-	-
Cut-in, seclow :	0.2				
Rodholders,seclow :	0.2				
Rod type :	S	S	S	S	-
Rods à 2 m :	2	1	2	0	0
Rods à 1 m :	0	0	1	1	0
Rods à 0.5 m :	0	0	1	0	0
Rods à 0.3 m :	1	0	0	0	0
Rods à 0.2 m :	0	1	0	0	0
Rods à 0.1 m :	0	0	0	0	0

Packer type: Bentonite

Type	Number of pipes						
	Steel		PEEK				
	φ 6/5 mm	φ 6/4 mm	1/8",2 mm		(m)	(m)	(m)
A8-1	1	7			0.25	1.00	0.25
A8-2	1	7			0.25	2.00	0.25
A8p-1		7	1		0.25	1.00	0.25
A8p-2		7	1		0.25	2.00	0.25
A7-1		7			0.25	1.00	0.25
A7-2		7			0.25	2.00	0.25
A5-1	1	4			0.25	1.00	0.25
A5-2	1	4			0.25	2.00	0.25
A4-1		4			0.25	1.00	0.25
A4-2		4			0.25	2.00	0.25
B10-1,b		10			0.3	1.00	0.2
B10p-1,b		9	1		0.3	1.00	0.2

Type of pipe/section
P : Pressure
C : Circulation
F : Flow
HM : Hydromechanical measurement
HC : Hydrochemistry sampling
T : Temperature
N : No measurements
G : Grouted section

Packertype
H : Hydraulic
B : Bentonite
M : Mechanical

Dummy material
PE : PEEK
HD : HD1000

Pipe
: Plug (unused pipe through packer)
: End point

Pipe material
PA : Polyamid
ST : Steel
PE : PEEK

Rod type
S : Steel
A : Aluminium

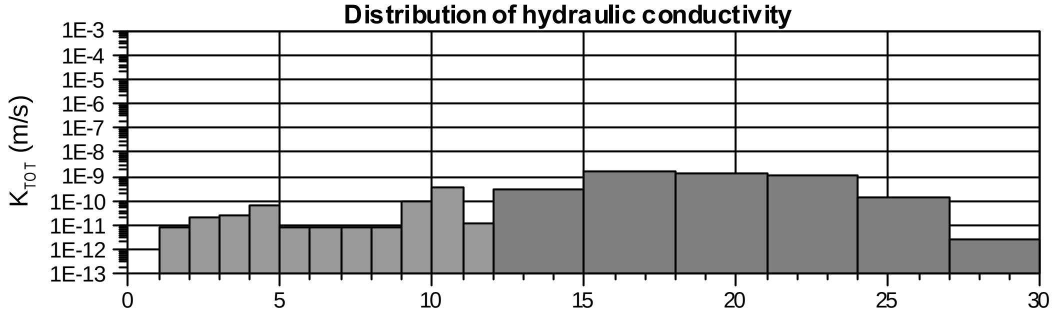
VBB VIAK

/1310241/DATA/MONITORING SECTIONS/KA3566G01B.GRF 2001-06-14

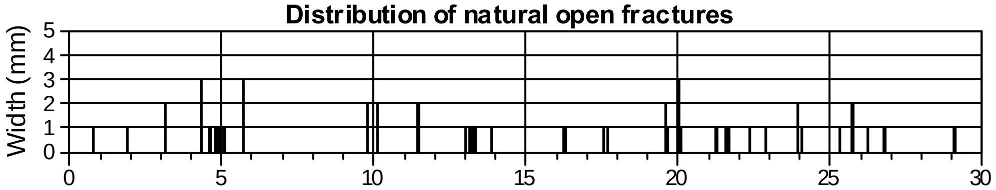
PACKER POSITION

Borehole name: **KA3566G02**	Date design: 2001-06-14
Borehole diametre: 76 mm	Name: TFK
Borehole length: 30.01 m	Remark:
Borehole inclination: 44° down	

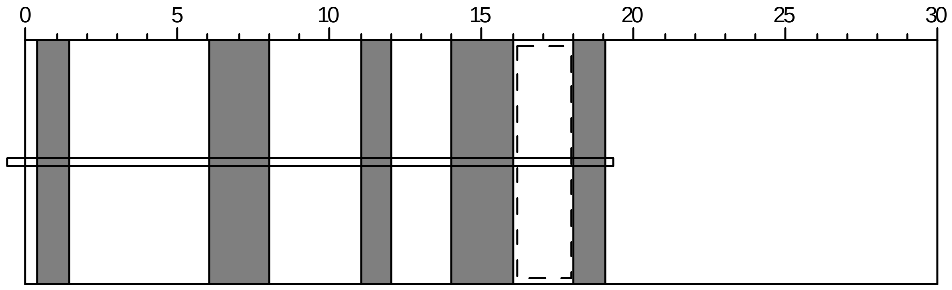
Distribution of hydraulic conductivity



Distribution of natural open fractures



Borehole length (m)



Section secup :	1.5	8	12	16	19
Section seclow :	6	11	14	18	30.01
Type of section :	P,F	P	P	P,C	P
Type of dummy :	-	-	-	HD	-
HM anchor secup :	-	-	-	-	-
HM anchor seclow :	-	-	-	-	-

<u>Type of measurement section</u>
P : Pressure
C : Circulation
F : Flow
HM : Hydromechanical measurement
HC : Hydrochemistry sampling
T : Temperature
N : No measurements
G : Grouted section

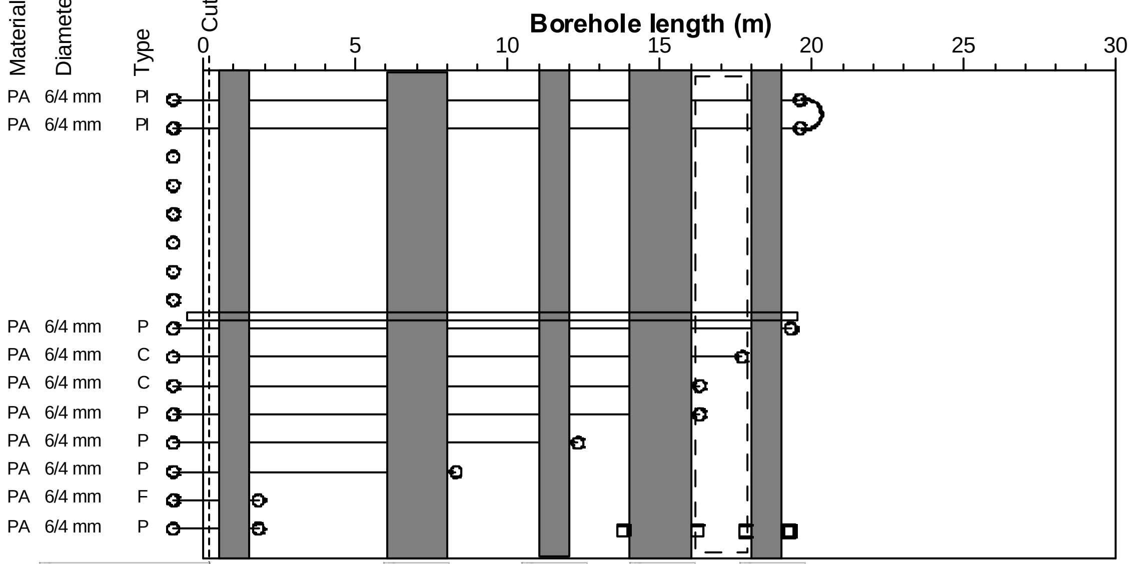
<u>Type of dummy</u>
PE : PEEK
HD : HD1000

PACKER

DUMMY

/1310241/DATA/MONITORING SECTIONS/KA3566G02A.GRF 2001-06-14

KA3566G02 - BOREHOLE INSTRUMENTATION



Packer type :	B10-1,b	A8-2	A7-1	A7-2	A4-1
Secup :	0.5	6	11	14	18
Seclow :	1.5	8	12	16	19

Section secup :	1.5	8	12	16	19
Section seclow :	6	11	14	18	30.01
Type of section :	P,F	P	P	P,C	P
Type of dummy :	-	-	-	HD	-
HM anchor secup :	-	-	-	-	-
HM anchor seclow :	-	-	-	-	-
Cut-in, seclow :	0.2				
Rodholders,seclow :	0.2				
Rod type :	S	S	S	S	-
Rods à 2 m :	2	1	0	0	0
Rods à 1 m :	0	0	1	1	0
Rods à 0.5 m :	0	1	1	1	0
Rods à 0.3 m :	0	0	0	0	0
Rods à 0.2 m :	0	0	0	0	0
Rods à 0.1 m :	0	0	0	0	0

Packer type: Bentonite

Type	Number of pipes						
	Steel		PEEK				
	φ 6/5 mm	φ 6/4 mm	1/8",2 mm		(m)	(m)	(m)
A8-1	1	7			0.25	1.00	0.25
A8-2	1	7			0.25	2.00	0.25
A8p-1		7	1		0.25	1.00	0.25
A8p-2		7	1		0.25	2.00	0.25
A7-1		7			0.25	1.00	0.25
A7-2		7			0.25	2.00	0.25
A5-1	1	4			0.25	1.00	0.25
A5-2	1	4			0.25	2.00	0.25
A4-1		4			0.25	1.00	0.25
A4-2		4			0.25	2.00	0.25
B10-1,b		10			0.3	1.00	0.2
B10p-1,b		9	1		0.3	1.00	0.2

Type of pipe/section
P : Pressure
C : Circulation
F : Flow
HM : Hydromechanical measurement
HC : Hydrochemistry sampling
T : Temperature
N : No measurements
G : Grouted section

Packertype
H : Hydraulic
B : Bentonite
M : Mechanical

Dummy material
PE : PEEK
HD : HD1000

Pipe
: Plug (unused pipe through packer)
: End point

Pipe material
PA : Polyamid
ST : Steel
PE : PEEK

Rod type
S : Steel
A : Aluminium

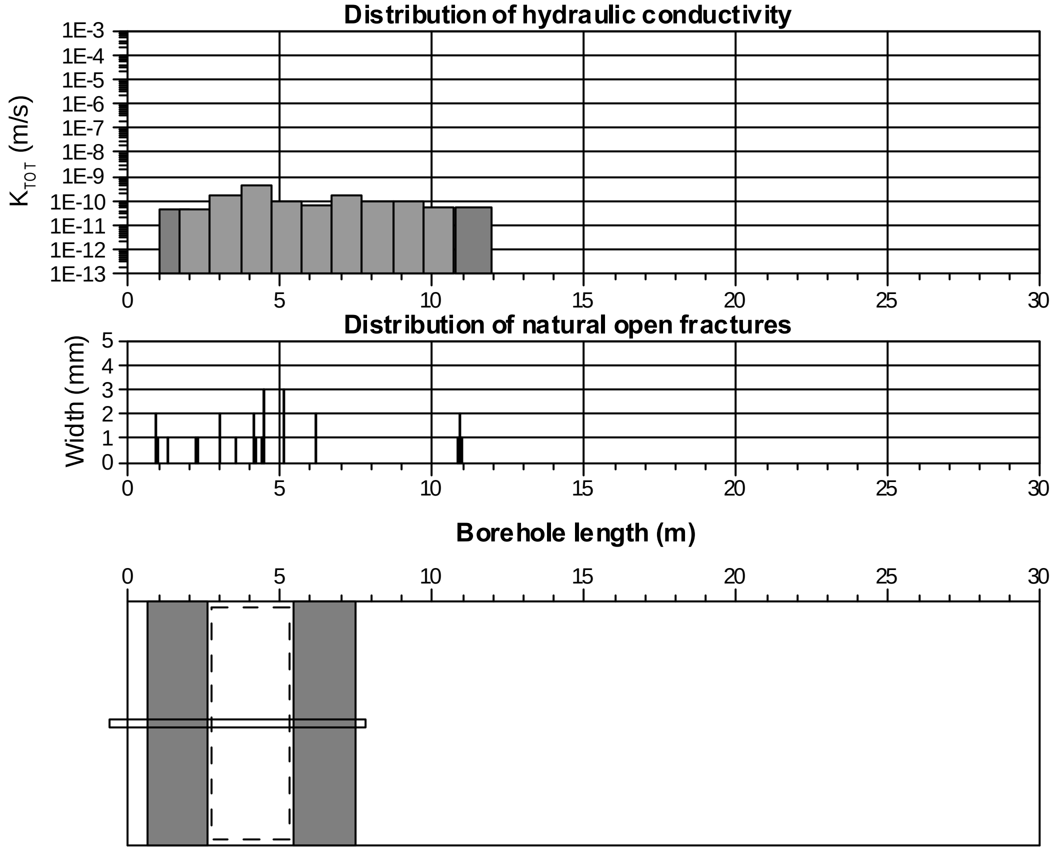
VBB VIAK

/1310241/DATA/MONITORING SECTIONS/KA3566G02B.GRF 2001-06-14

PACKER POSITION

Borehole name: **KA3572G01**
Borehole diametre: 76 mm
Borehole length: 12.03 m
Borehole inclination: 90° down

Date design: 2001-06-14
Name: TFK
Remark:



Section secup :	2.7	7.3
Section seclow :	5.3	12.03
Type of section :	P,C	P
Type of dummy :	HD	-
HM anchor secup :	-	-
HM anchor seclow :	-	-

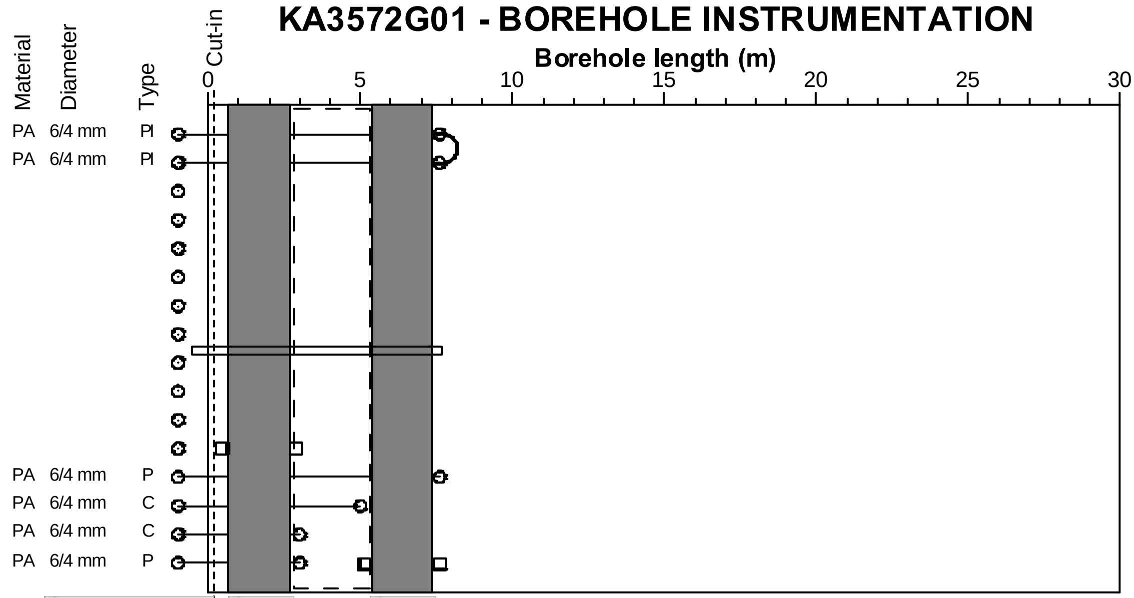
Type of measurement section
P : Pressure
C : Circulation
F : Flow
HM : Hydromechanical measurement
HC : Hydrochemistry sampling
T : Temperature
N : No measurements
G : Grouted section

Type of dummy
PE : PEEK
HD : HD1000

PACKER

DUMMY

/1310241/DATA/MONITORING SECTIONS/KA3572G01A.GRF 2001-06-14



Packer type :	A7-2	A4-2
Secup :	0.7	5.3
Seclow :	2.7	7.3

Section secup :	2.7	7.3
Section seclow :	5.3	12.03
Type of section :	P,C	P
Type of dummy :	HD	-
HM anchor secup :	-	-
HM anchor seclow :	-	-
Cut-in, seclow :	0.2	
Rodholders,seclow :	0.2	
Rod type :	S	-
Rods à 2 m :	1	0
Rods à 1 m :	0	0
Rods à 0.5 m :	0	0
Rods à 0.3 m :	0	0
Rods à 0.2 m :	0	0
Rods à 0.1 m :	1	0

Packer type: Bentonite

Type	Number of pipes						
	Steel		PEEK				
	ϕ 6/5 mm	ϕ 6/4 mm	1/8",2 mm		(m)	(m)	(m)
A8-1	1	7			0.25	1.00	0.25
A8-2	1	7			0.25	2.00	0.25
A8p-1		7	1		0.25	1.00	0.25
A8p-2		7	1		0.25	2.00	0.25
A7-1		7			0.25	1.00	0.25
A7-2		7			0.25	2.00	0.25
A5-1	1	4			0.25	1.00	0.25
A5-2	1	4			0.25	2.00	0.25
A4-1		4			0.25	1.00	0.25
A4-2		4			0.25	2.00	0.25
B10-1,b		10			0.3	1.00	0.2
B10p-1,b		9	1		0.3	1.00	0.2

Type of pipe/section
P : Pressure
C : Circulation
F : Flow
HM : Hydromechanical measurement
HC : Hydrochemistry sampling
T : Temperature
N : No measurements
G : Grouted section

Packertype
H : Hydraulic
B : Bentonite
M : Mechanical

Dummy material
PE : PEEK
HD : HD1000

Pipe
: Plug (unused pipe through packer)
: End point

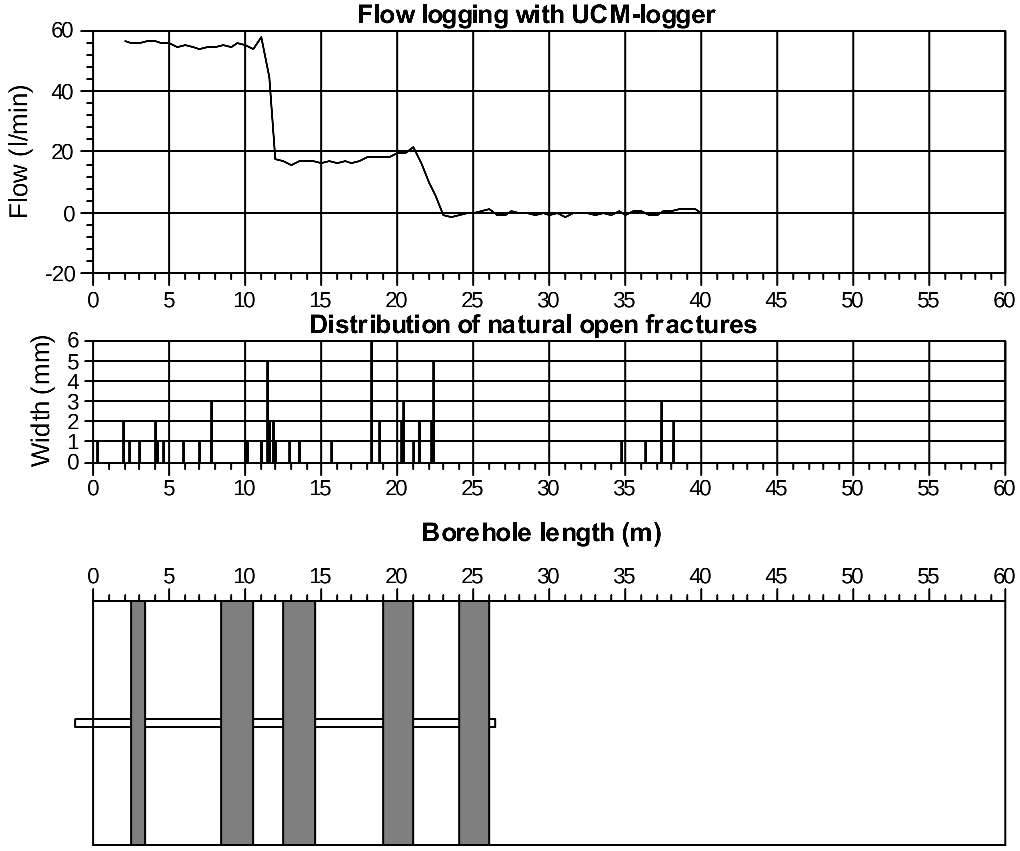
Pipe material
PA : Polyamid
ST : Steel
PE : PEEK

Rod type
S : Steel
A : Aluminium

PACKER POSITION

Borehole name: **KA3573A**
Borehole diametre: 76 mm
Borehole length: 40.07 m
Borehole inclination: 2° down

Date design: 2001-06-14
Name: TFK
Remark: No cut-in, casing



Section secup :	3.4	10.5	14.5	21	26
Section seclow :	8.5	12.5	19	24	40.07
Type of section :	P	P,F	P	P,F	P
Type of dummy :	-	-	-	-	-
HM anchor secup :	-	-	-	-	-
HM anchor seclow :	-	-	-	-	-

Type of measurement section
P : Pressure
C : Circulation
F : Flow
HM : Hydromechanical measurement
HC : Hydrochemistry sampling
T : Temperature
N : No measurements
G : Grouted section

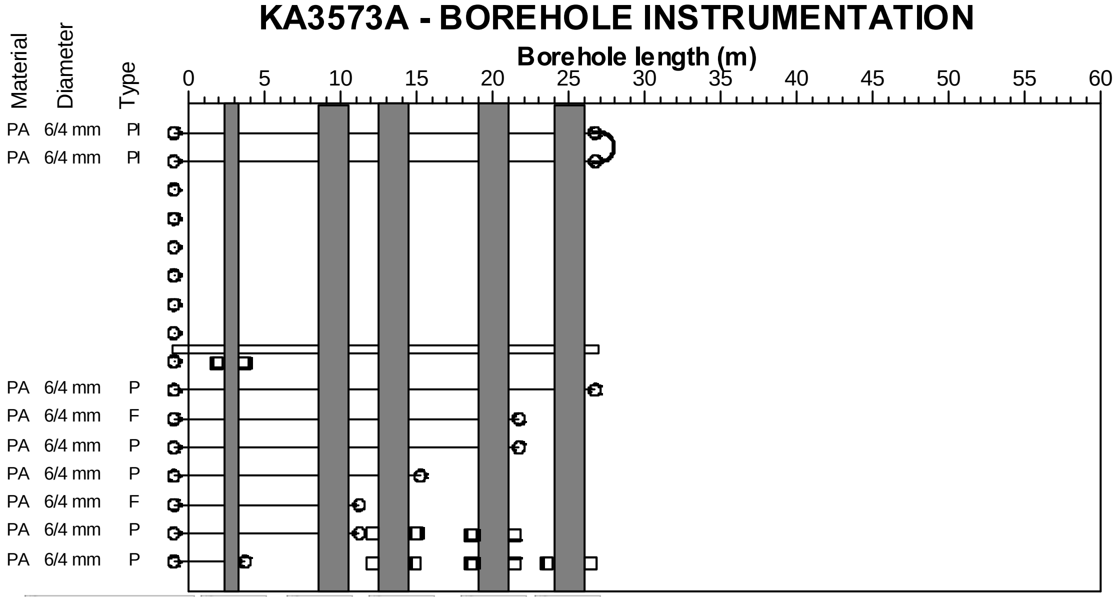
Type of dummy
PE : PEEK
HD : HD1000

PACKER

DUMMY

/1310241/DATA/MONITORING SECTIONS/KA3573A1A.GRF 2001-06-14

KA3573A - BOREHOLE INSTRUMENTATION



Packer type :	B10-1,b	A8-2	A8-2	A7-2	A4-2
Secup :	2.4	8.5	12.5	19	24
Seclow :	3.4	10.5	14.5	21	26

Section secup :	3.4	10.5	14.5	21	26
Section seclow :	8.5	12.5	19	24	40.07
Type of section :	P	P,F	P	P,F	P
Type of dummy :	-	-	-	-	-
HM anchor secup :	-	-	-	-	-
HM anchor seclow :	-	-	-	-	-
Cut-in, seclow :	0.2				
Rodholders,seclow :	0.2				
Rod type :	S	S	S	S	-
Rods à 2 m :	2	0	2	1	0
Rods à 1 m :	0	1	0	0	0
Rods à 0.5 m :	1	1	0	1	0
Rods à 0.3 m :	0	0	0	0	0
Rods à 0.2 m :	0	0	0	0	0
Rods à 0.1 m :	1	0	0	0	0
Rods à 0.05 m :	1	0	0	0	0

Packer type: Bentonite

Type	Number of pipes					
	Steel		PEEK			
	φ 6/5 mm	φ 6/4 mm	1/8",2 mm	(m)	(m)	(m)
A8-1	1	7		0.25	1.00	0.25
A8-2	1	7		0.25	2.00	0.25
A8p-1		7	1	0.25	1.00	0.25
A8p-2		7	1	0.25	2.00	0.25
A7-1		7		0.25	1.00	0.25
A7-2		7		0.25	2.00	0.25
A5-1	1	4		0.25	1.00	0.25
A5-2	1	4		0.25	2.00	0.25
A4-1		4		0.25	1.00	0.25
A4-2		4		0.25	2.00	0.25
B10-1,b		10		0.3	1.00	0.2
B10p-1,b		9	1	0.3	1.00	0.2

Type of pipe/section
P : Pressure
C : Circulation
F : Flow
HM : Hydromechanical measurement
HC : Hydrochemistry sampling
T : Temperature
N : No measurements
G : Grouted section

Packertype
H : Hydraulic
B : Bentonite
M : Mechanical

Dummy material
PE : PEEK
HD : HD1000

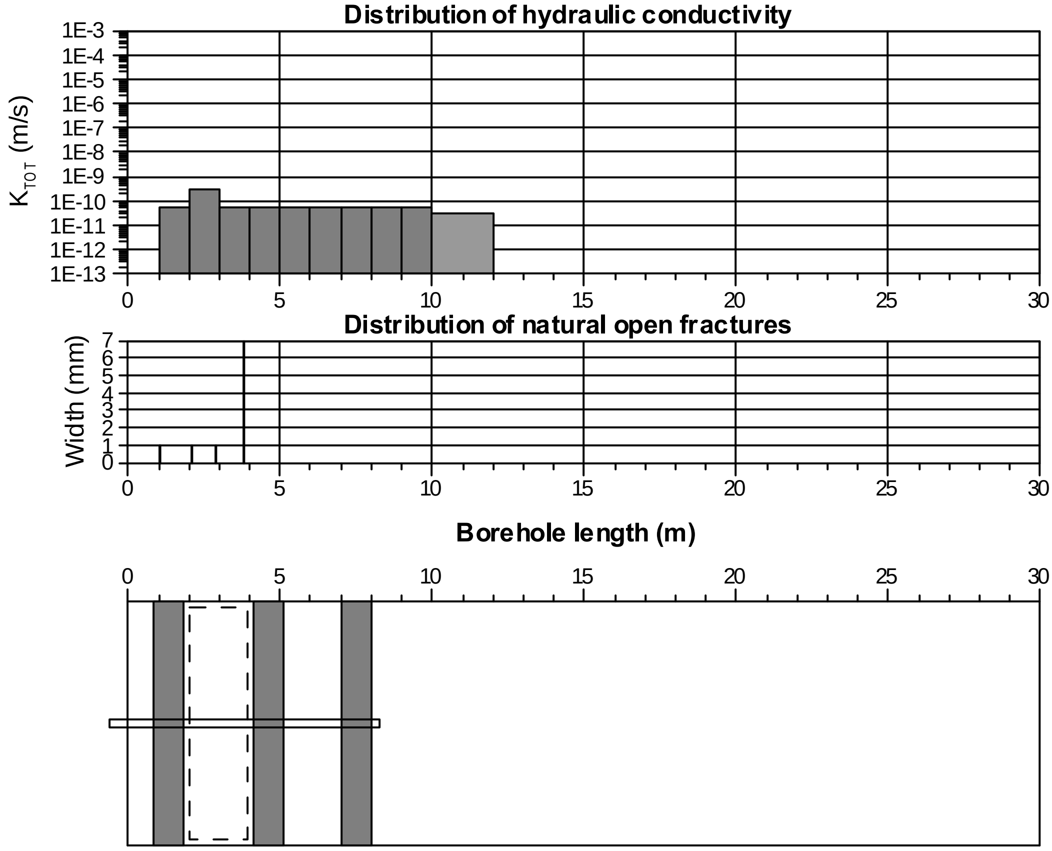
Pipe
: Plug (unused pipe through packer)
: End point

Pipe material
PA : Polyamid
ST : Steel
PE : PEEK

Rod type
S : Steel
A : Aluminium

PACKER POSITION

Borehole name: **KA3574G01**	Date design: 2001-06-14
Borehole diametre: 76 mm	Name: TFK
Borehole length: 12.03 m	Remark:
Borehole inclination: 89° down	

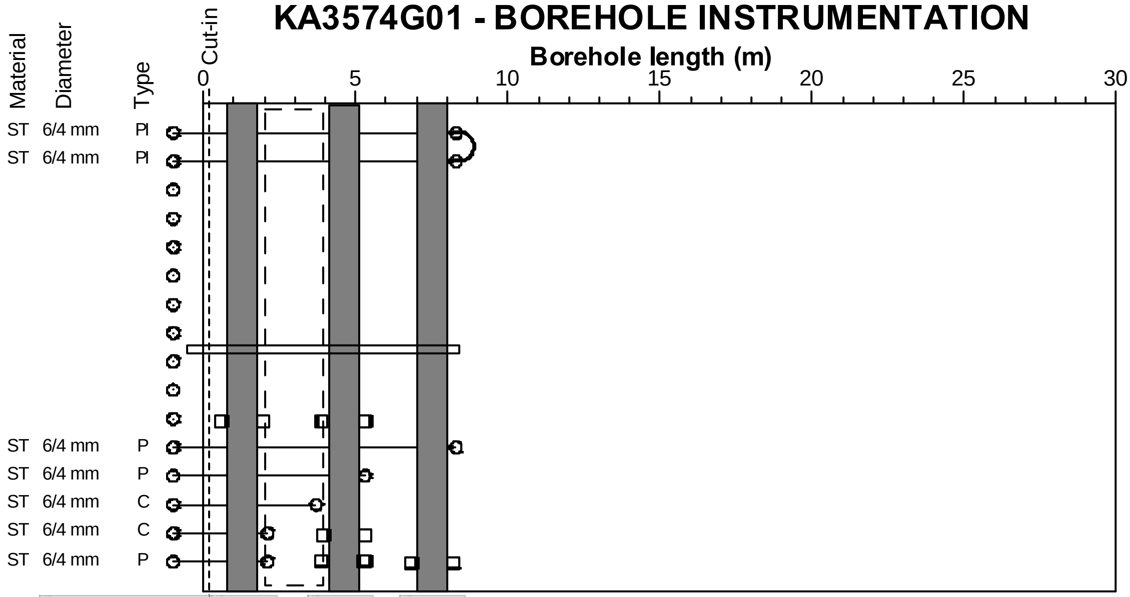


Section secup :	1.8	5.1	8
Section seclow :	4.1	7	12.03
Type of section :	P,C	P	P
Type of dummy :	HD	-	-
HM anchor secup :	-	-	-
HM anchor seclow :	-	-	-

Type of measurement section	Type of dummy
P : Pressure	PE : PEEK
C : Circulation	HD : HD1000
F : Flow	
HM : Hydromechanical measurement	
HC : Hydrochemistry sampling	PACKER
T : Temperature	
N : No measurements	
G : Grouted section	DUMMY

/1310241/DATA/MONITORING SECTIONS/KA3574G01A.GRF 2001-06-14

KA3574G01 - BOREHOLE INSTRUMENTATION



Packer type :	A8-1	A7-1	A4-1
Secup :	0.8	4.1	7
Seclow :	1.8	5.1	8

Section secup :	1.8	5.1	8
Section seclow :	4.1	7	12.03
Type of section :	P,C	P	P
Type of dummy :	HD	-	-
HM anchor secup :	-	-	-
HM anchor seclow :	-	-	-
Cut-in, seclow :	0.2		
Rodholders,seclow :	0.2		
Rod type :	S	S	-
Rods à 2 m :	0	0	0
Rods à 1 m :	1	1	0
Rods à 0.5 m :	1	0	0
Rods à 0.3 m :	1	0	0
Rods à 0.2 m :	0	2	0
Rods à 0.1 m :	0	0	0

Packer type: Bentonite

Type	Number of pipes					
	Steel		PEEK			
	φ 6/5 mm	φ 6/4 mm	1/8",2 mm	(m)	(m)	(m)
A8-1	1	7		0.25	1.00	0.25
A8-2	1	7		0.25	2.00	0.25
A8p-1		7	1	0.25	1.00	0.25
A8p-2		7	1	0.25	2.00	0.25
A7-1		7		0.25	1.00	0.25
A7-2		7		0.25	2.00	0.25
A5-1	1	4		0.25	1.00	0.25
A5-2	1	4		0.25	2.00	0.25
A4-1		4		0.25	1.00	0.25
A4-2		4		0.25	2.00	0.25
B10-1,b		10		0.3	1.00	0.2
B10p-1,b		9	1	0.3	1.00	0.2

Type of pipe/section
P : Pressure
C : Circulation
F : Flow
HM : Hydromechanical measurement
HC : Hydrochemistry sampling
T : Temperature
N : No measurements
G : Grouted section

Packertype
H : Hydraulic
B : Bentonite
M : Mechanical

Dummy material
PE : PEEK
HD : HD1000

Pipe
: Plug (unused pipe through packer)
: End point

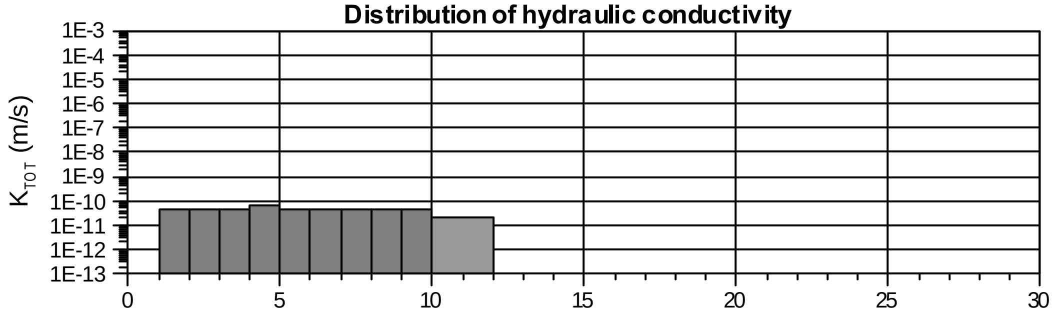
Pipe material
PA : Polyamid
S T : Steel
PE : PEEK

Rod type
S : Steel
A : Aluminium

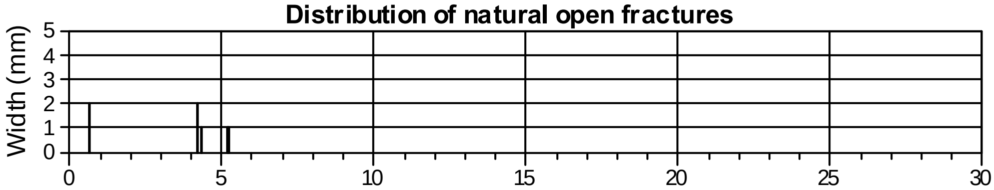
PACKER POSITION

Borehole name: **KA3576G01**	Date design: 2001-06-14
Borehole diametre: 76 mm	Name: TFK
Borehole length: 12.01 m	Remark:
Borehole inclination: 89° down	

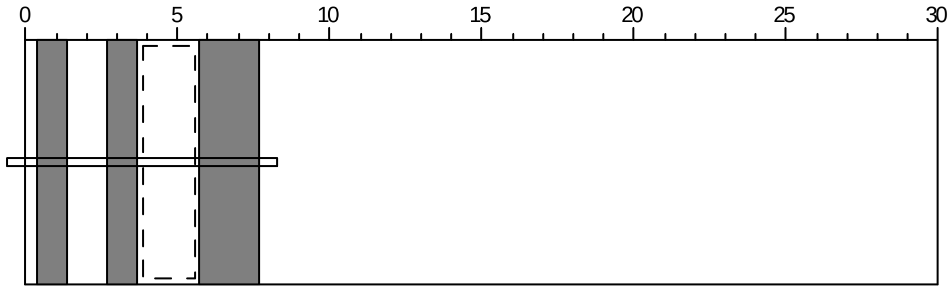
Distribution of hydraulic conductivity



Distribution of natural open fractures



Borehole length (m)



Section secup :	1.37	3.87	7.87
Section seclow :	2.87	5.87	12.01
Type of section :	P	P,HC	P
Type of dummy :	-	PE	-
HM anchor secup :	-	-	-
HM anchor seclow :	-	-	-

Type of measurement section
P : Pressure
C : Circulation
F : Flow
HM : Hydromechanical measurement
HC : Hydrochemistry sampling
T : Temperature
N : No measurements
G : Grouted section

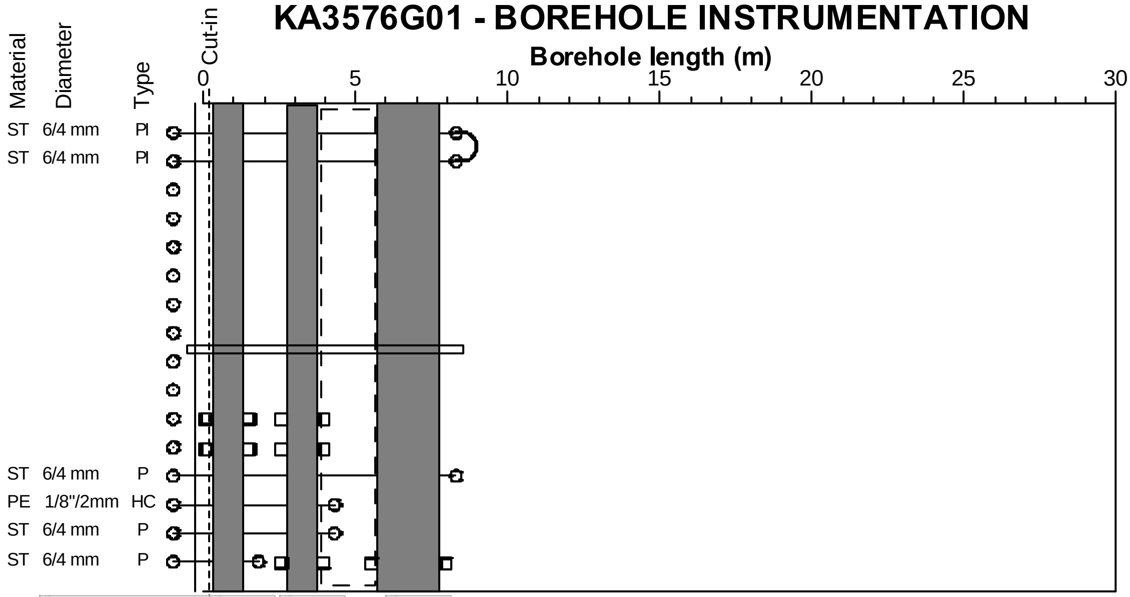
Type of dummy
PE : PEEK
HD : HD1000

PACKER

DUMMY

/1310241/DATA/MONITORING SECTIONS/KA3576G01A.GRF 2001-06-14

KA3576G01 - BOREHOLE INSTRUMENTATION



Packer type :	A8p-1	A8p-1	A4-2
Secup :	0.37	2.87	5.87
Seclow :	1.37	3.87	7.87

Section secup :	1.37	3.87	7.87
Section seclow :	2.87	5.87	12.01
Type of section :	P	P,HC	P
Type of dummy :	-	PE	-
HM anchor secup :	-	-	-
HM anchor seclow :	-	-	-
Cut-in, seclow :	0.2		
Rodholders,seclow :	0.2		
Rod type :	S	S	-
Rods à 2 m :	0	0	0
Rods à 1 m :	1	1	0
Rods à 0.5 m :	0	1	0
Rods à 0.3 m :	0	0	0
Rods à 0.2 m :	0	0	0
Rods à 0.1 m :	0	0	0

Packer type: Bentonite

Type	Number of pipes						
	Steel		PEEK				
	ϕ 6/5 mm	ϕ 6/4 mm	1/8",2 mm		(m)	(m)	(m)
A8-1	1	7			0.25	1.00	0.25
A8-2	1	7			0.25	2.00	0.25
A8p-1		7	1		0.25	1.00	0.25
A8p-2		7	1		0.25	2.00	0.25
A7-1		7			0.25	1.00	0.25
A7-2		7			0.25	2.00	0.25
A5-1	1	4			0.25	1.00	0.25
A5-2	1	4			0.25	2.00	0.25
A4-1		4			0.25	1.00	0.25
A4-2		4			0.25	2.00	0.25
B10-1,b		10			0.3	1.00	0.2
B10p-1,b		9	1		0.3	1.00	0.2

Type of pipe/section
P : Pressure
C : Circulation
F : Flow
HM : Hydromechanical measurement
HC : Hydrochemistry sampling
T : Temperature
N : No measurements
G : Grouted section

Packertype
H : Hydraulic
B : Bentonite
M : Mechanical

Dummy material
PE : PEEK
HD : HD1000

Pipe
: Plug (unused pipe through packer)
: End point

Pipe material
PA : Polyamid
ST : Steel
PE : PEEK

Rod type
S : Steel
A : Aluminium

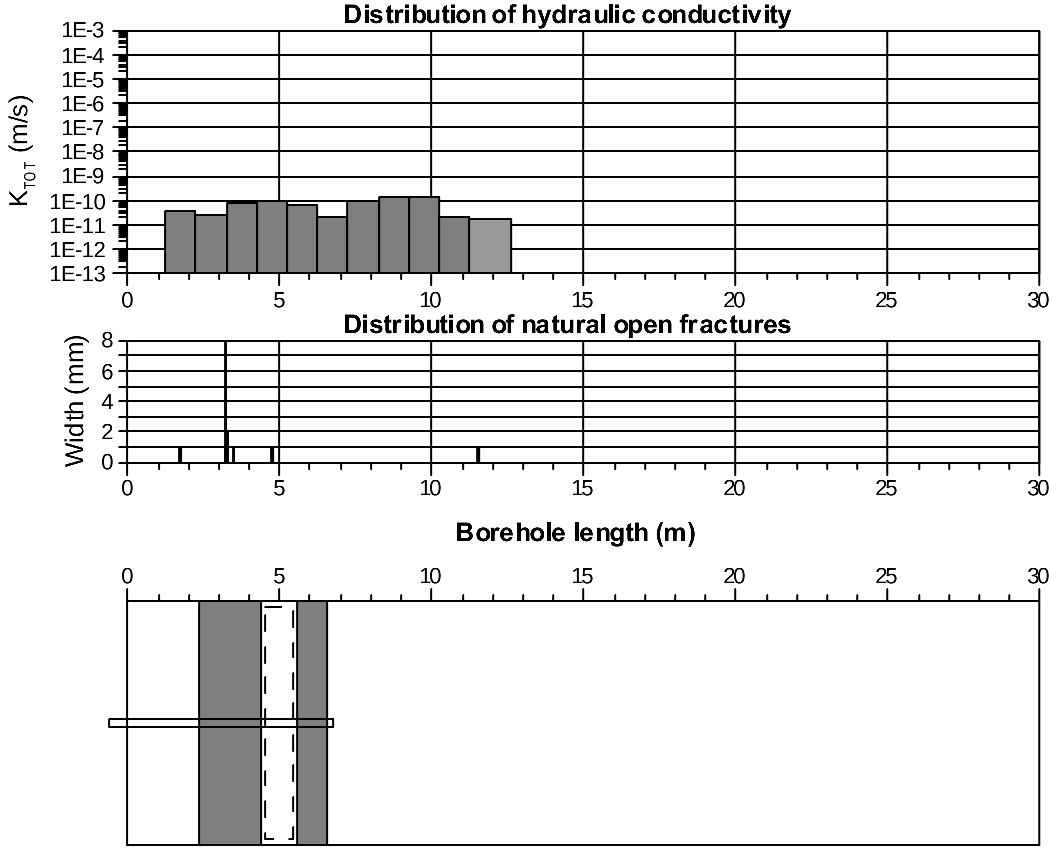
VBB VIAK

/1310241/DATA/MONITORING SECTIONS/KA3576G01B.GRF 2001-06-14

PACKER POSITION

Borehole name: **KA3578G01**
Borehole diametre: 76 mm
Borehole length: 12.58 m
Borehole inclination: 89° down

Date design: 2001-06-14
Name: TFK
Remark:



Section secup :	4.3	6.5
Section seclow :	5.5	12.58
Type of section :	P,HC	P
Type of dummy :	PE	-
HM anchor secup :	-	-
HM anchor seclow :	-	-

Type of measurement section
P : Pressure
C : Circulation
F : Flow
HM : Hydromechanical measurement
HC : Hydrochemistry sampling
T : Temperature
N : No measurements
G : Grouted section

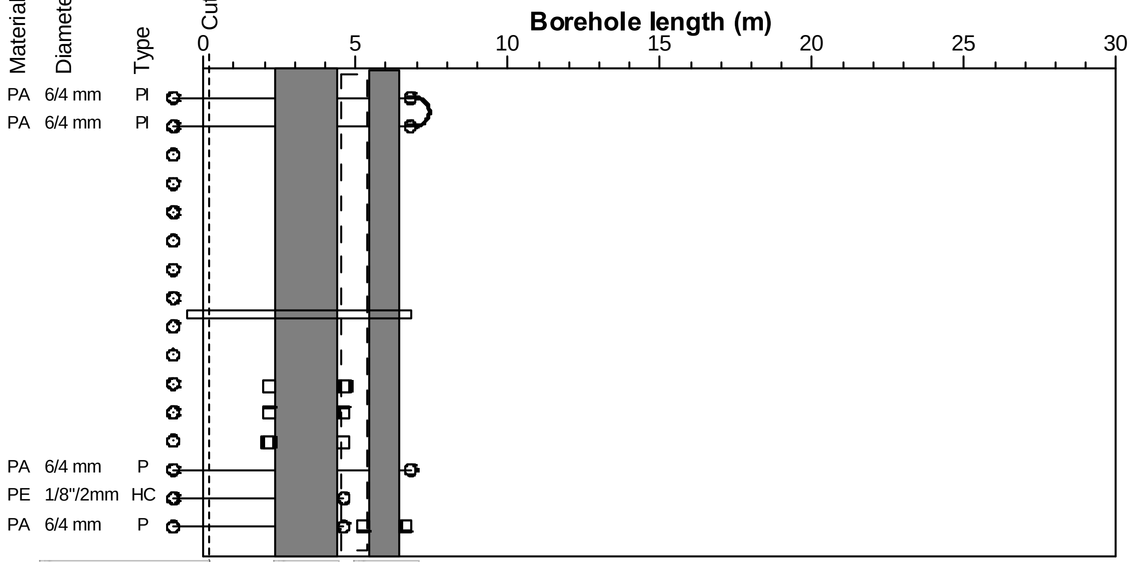
Type of dummy
PE : PEEK
HD : HD1000

PACKER

DUMMY

/1310241/DATA/MONITORING SECTIONS/KA3578G01A.GRF 2001-06-14

KA3578G01 - BOREHOLE INSTRUMENTATION



Packer type :	A8p-2	A4-1
Secup :	2.3	5.5
Seclow :	4.3	6.5

Section secup :	4.3	6.5
Section seclow :	5.5	12.58
Type of section :	P,HC	P
Type of dummy :	PE	-
HM anchor secup :	-	-
HM anchor seclow :	-	-
Cut-in, seclow :	0.2	
Rodholders,seclow :	0.2	
Rod type :	S	-
Rods à 2 m :	0	0
Rods à 1 m :	0	0
Rods à 0.5 m :	1	0
Rods à 0.3 m :	0	0
Rods à 0.2 m :	1	0
Rods à 0.1 m :	0	0

Packer type: Bentonite

Type	Number of pipes					
	Steel		PEEK			
	ϕ 6/5 mm	ϕ 6/4 mm	1/8",2 mm	(m)	(m)	(m)
A8-1	1	7		0.25	1.00	0.25
A8-2	1	7		0.25	2.00	0.25
A8p-1		7	1	0.25	1.00	0.25
A8p-2		7	1	0.25	2.00	0.25
A7-1		7		0.25	1.00	0.25
A7-2		7		0.25	2.00	0.25
A5-1	1	4		0.25	1.00	0.25
A5-2	1	4		0.25	2.00	0.25
A4-1		4		0.25	1.00	0.25
A4-2		4		0.25	2.00	0.25
B10-1,b		10		0.3	1.00	0.2
B10p-1,b		9	1	0.3	1.00	0.2

Type of pipe/section
P : Pressure
C : Circulation
F : Flow
HM : Hydromechanical measurement
HC : Hydrochemistry sampling
T : Temperature
N : No measurements
G : Grouted section

Packertype
H : Hydraulic
B : Bentonite
M : Mechanical

Dummy material
PE : PEEK
HD : HD1000

Pipe
: Plug (unused pipe through packer)
: End point

Pipe material
PA : Polyamid
ST : Steel
PE : PEEK

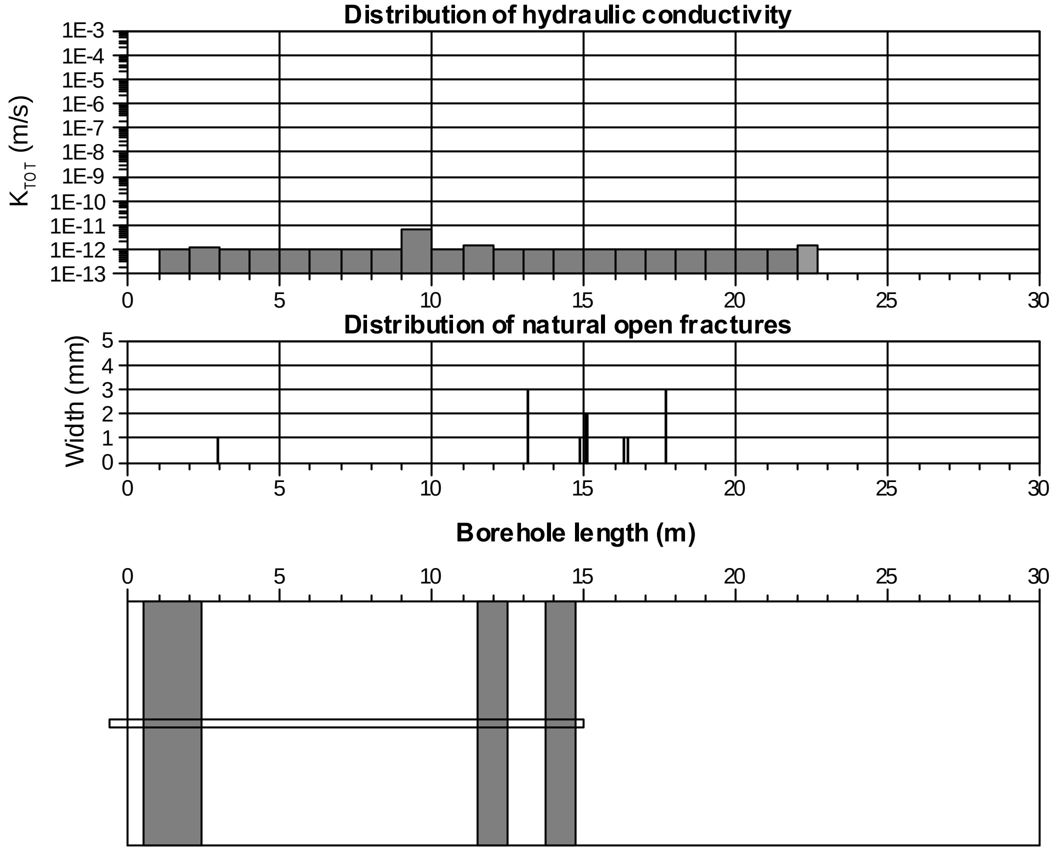
Rod type
S : Steel
A : Aluminium

VBB VIAK

/1310241/DATA/MONITORING SECTIONS/KA3578G01B.GRF 2001-06-14

PACKER POSITION

Borehole name: **KA3579G**	Date design: 2001-06-14
Borehole diametre: 76 mm	Name: TFK
Borehole length: 22.65 m	Remark:
Borehole inclination: 89° down	



Section secup :	2.5	12.5	14.7
Section seclow :	11.5	13.7	22.65
Type of section :	P	P	P
Type of dummy :	-	-	-
HM anchor secup :	-	-	-
HM anchor seclow :	-	-	-

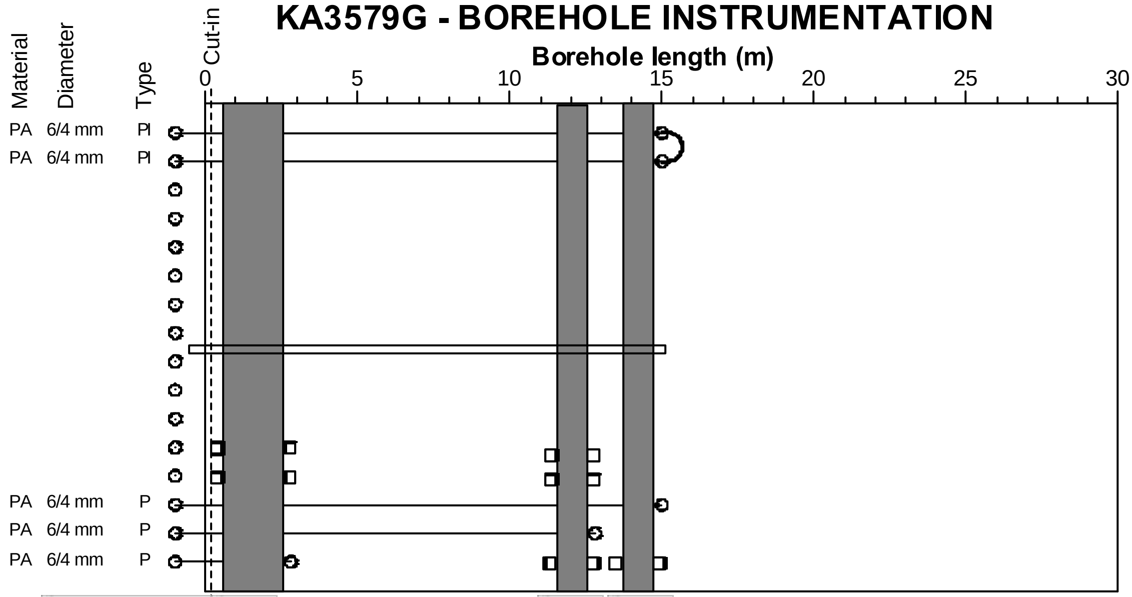
Type of measurement section
P : Pressure
C : Circulation
F : Flow
HM : Hydromechanical measurement
HC : Hydrochemistry sampling
T : Temperature
N : No measurements
G : Grouted section

Type of dummy
PE : PEEK
HD : HD1000

PACKER

DUMMY

KA3579G - BOREHOLE INSTRUMENTATION



Packer type :	A7-2	A7-1	A4-1
Secup :	0.5	11.5	13.7
Seclow :	2.5	12.5	14.7

Section secup :	2.5	12.5	14.7
Section seclow :	11.5	13.7	22.65
Type of section :	P	P	P
Type of dummy :	-	-	-
HM anchor secup :	-	-	-
HM anchor seclow :	-	-	-
Cut-in, seclow :	0.2		
Rodholders,seclow :	0.2		
Rod type :	S	S	-
Rods à 2 m :	4	0	0
Rods à 1 m :	0	0	0
Rods à 0.5 m :	1	1	0
Rods à 0.3 m :	0	0	0
Rods à 0.2 m :	0	1	0
Rods à 0.1 m :	0	0	0

Packer type: Bentonite

Type	Number of pipes					
	Steel		PEEK			
	φ 6/5 mm	φ 6/4 mm	1/8",2 mm	(m)	(m)	(m)
A8-1	1	7		0.25	1.00	0.25
A8-2	1	7		0.25	2.00	0.25
A8p-1		7	1	0.25	1.00	0.25
A8p-2		7	1	0.25	2.00	0.25
A7-1		7		0.25	1.00	0.25
A7-2		7		0.25	2.00	0.25
A5-1	1	4		0.25	1.00	0.25
A5-2	1	4		0.25	2.00	0.25
A4-1		4		0.25	1.00	0.25
A4-2		4		0.25	2.00	0.25
B10-1,b		10		0.3	1.00	0.2
B10p-1,b		9	1	0.3	1.00	0.2

Type of pipe/section
P : Pressure
C : Circulation
F : Flow
HM : Hydromechanical measurement
HC : Hydrochemistry sampling
T : Temperature
N : No measurements
G : Grouted section

Packertype
H : Hydraulic
B : Bentonite
M : Mechanical

Dummy material
PE : PEEK
HD : HD1000

Pipe
: Plug (unused pipe through packer)
: End point

Pipe material
PA : Polyamid
S T : Steel
PE : PEEK

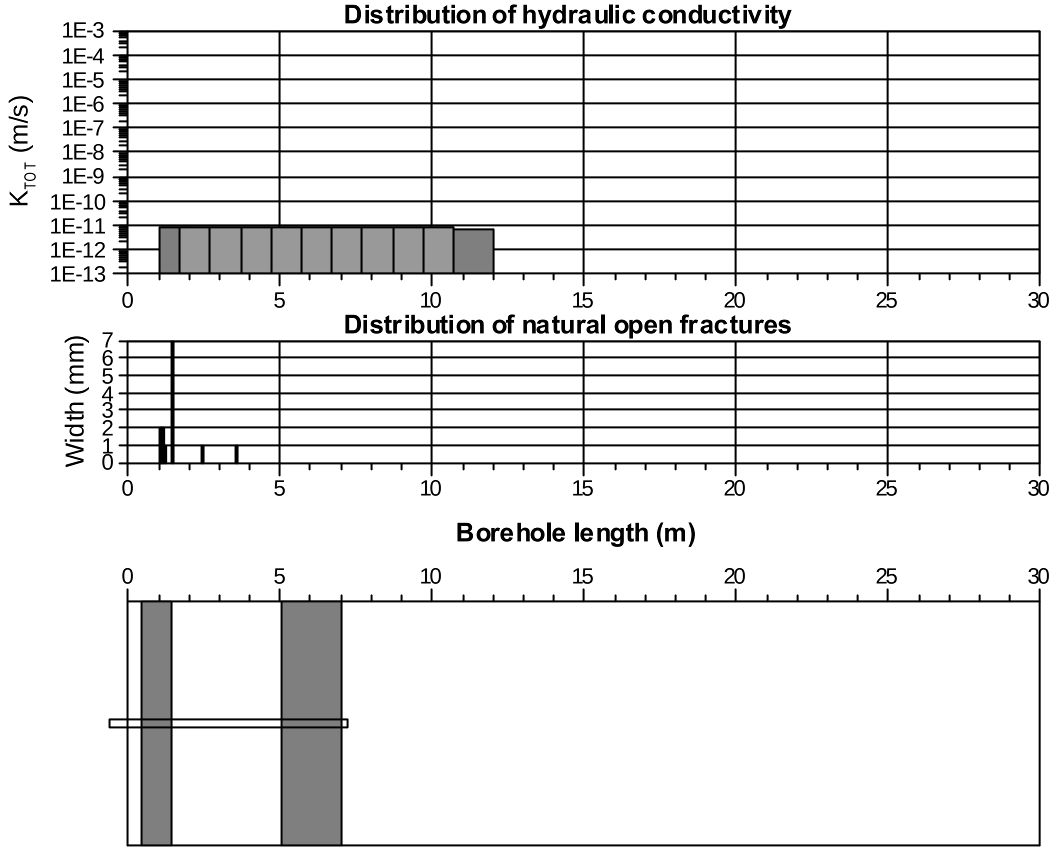
Rod type
S : Steel
A : Aluminium

VBB VIAK

/1310241/DATA/MONITORING SECTIONS/KA3579G1B.GRF 2001-06-14

PACKER POSITION

Borehole name: **KA3584G01**	Date design: 2001-06-14
Borehole diametre: 76 mm	Name: TFK
Borehole length: 12.00 m	Remark: Fracture at 1.45 m
Borehole inclination: 89° down	



Section secup :	1.4	7
Section seclow :	5	12
Type of section :	P	P
Type of dummy :	-	-
HM anchor secup :	-	-
HM anchor seclow :	-	-

<u>Type of measurement section</u>
P : Pressure
C : Circulation
F : Flow
HM : Hydromechanical measurement
HC : Hydrochemistry sampling
T : Temperature
N : No measurements
G : Grouted section

<u>Type of dummy</u>
PE : PEEK
HD : HD1000

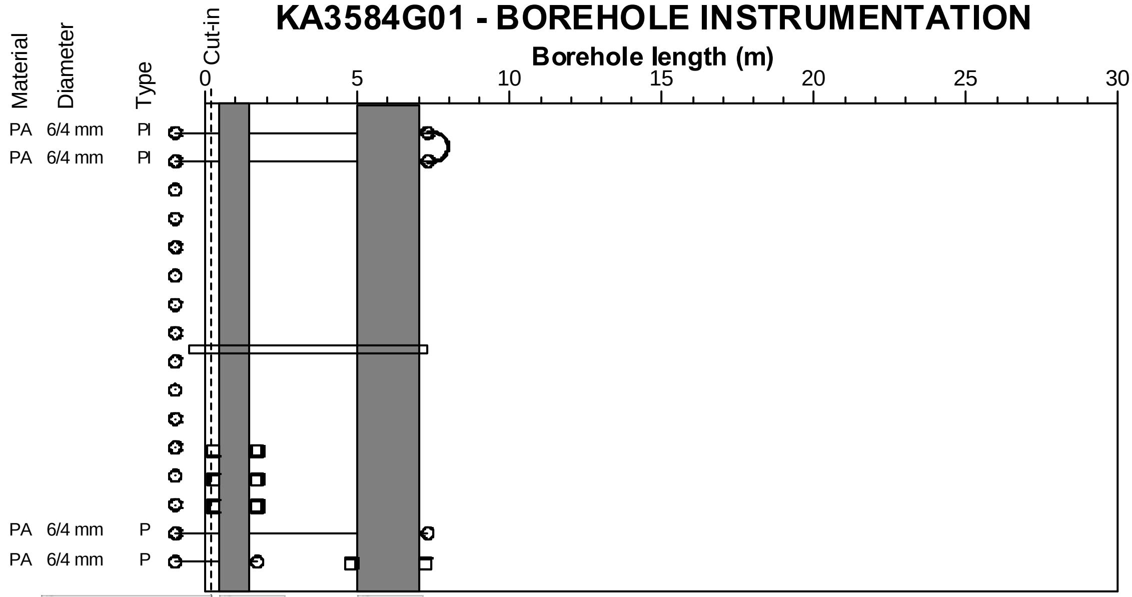
PACKER

DUMMY

/1310241/DATA/MONITORING SECTIONS/KA3584G01A.GRF 2001-06-14

VBB VIAK

KA3584G01 - BOREHOLE INSTRUMENTATION



Packer type :	A7-1	A4-2
Secup :	0.4	5
Seclow :	1.4	7

Section secup :	1.4	7
Section seclow :	5	12
Type of section :	P	P
Type of dummy :	-	-
HM anchor secup :	-	-
HM anchor seclow :	-	-
Cut-in, seclow :	0.2	
Rodholders,seclow :	0.2	
Rod type :	S	-
Rods à 2 m :	1	0
Rods à 1 m :	1	0
Rods à 0.5 m :	0	0
Rods à 0.3 m :	0	0
Rods à 0.2 m :	0	0
Rods à 0.1 m :	1	0

Packer type: Bentonite

Type	Number of pipes						
	Steel		PEEK				
	φ 6/5 mm	φ 6/4 mm	1/8",2 mm		(m)	(m)	(m)
A8-1	1	7			0.25	1.00	0.25
A8-2	1	7			0.25	2.00	0.25
A8p-1		7	1		0.25	1.00	0.25
A8p-2		7	1		0.25	2.00	0.25
A7-1		7			0.25	1.00	0.25
A7-2		7			0.25	2.00	0.25
A5-1	1	4			0.25	1.00	0.25
A5-2	1	4			0.25	2.00	0.25
A4-1		4			0.25	1.00	0.25
A4-2		4			0.25	2.00	0.25
B10-1,b		10			0.3	1.00	0.2
B10p-1,b		9	1		0.3	1.00	0.2

Type of pipe/section
P : Pressure
C : Circulation
F : Flow
HM : Hydromechanical measurement
HC : Hydrochemistry sampling
T : Temperature
N : No measurements
G : Grouted section

Packertype
H : Hydraulic
B : Bentonite
M : Mechanical

Dummy material
PE : PEEK
HD : HD1000

Pipe
: Plug (unused pipe through packer)
: End point

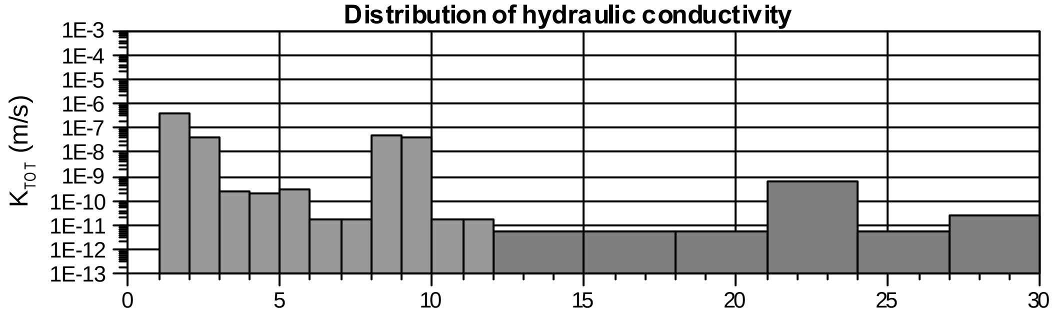
Pipe material
PA : Polyamid
ST : Steel
PE : PEEK

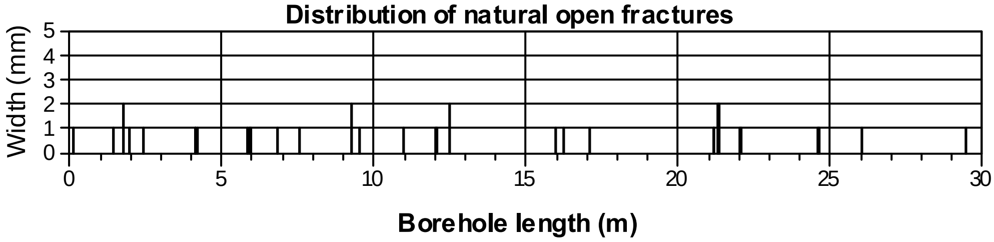
Rod type
S : Steel
A : Aluminium

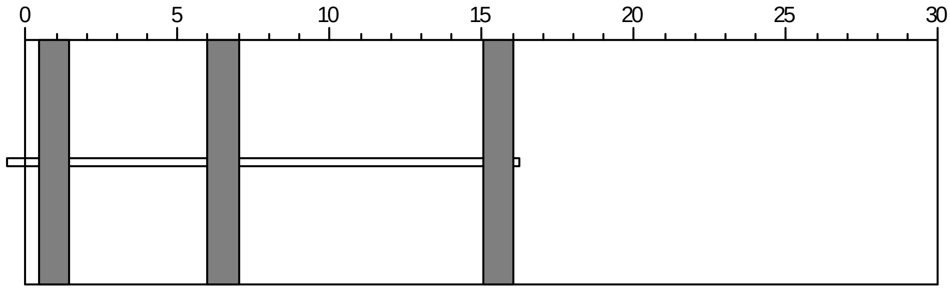
/1310241/DATA/MONITORING SECTIONS/KA3584G01B.GRF 2001-06-14

PACKER POSITION

Borehole name: **KA3590G01**	Date design: 2001-06-14
Borehole diametre: 76 mm	Name: TFK
Borehole length: 30.06 m	Remark:
Borehole inclination: 44° down	







Section secup :	1.5	7	16
Section seclow :	6	15	30
Type of section :	P,HC	P,F,F	P
Type of dummy :	-	-	-
HM anchor secup :	-	-	-
HM anchor seclow :	-	-	-

Type of measurement section
P : Pressure
C : Circulation
F : Flow
HM : Hydromechanical measurement
HC : Hydrochemistry sampling
T : Temperature
N : No measurements
G : Grouted section

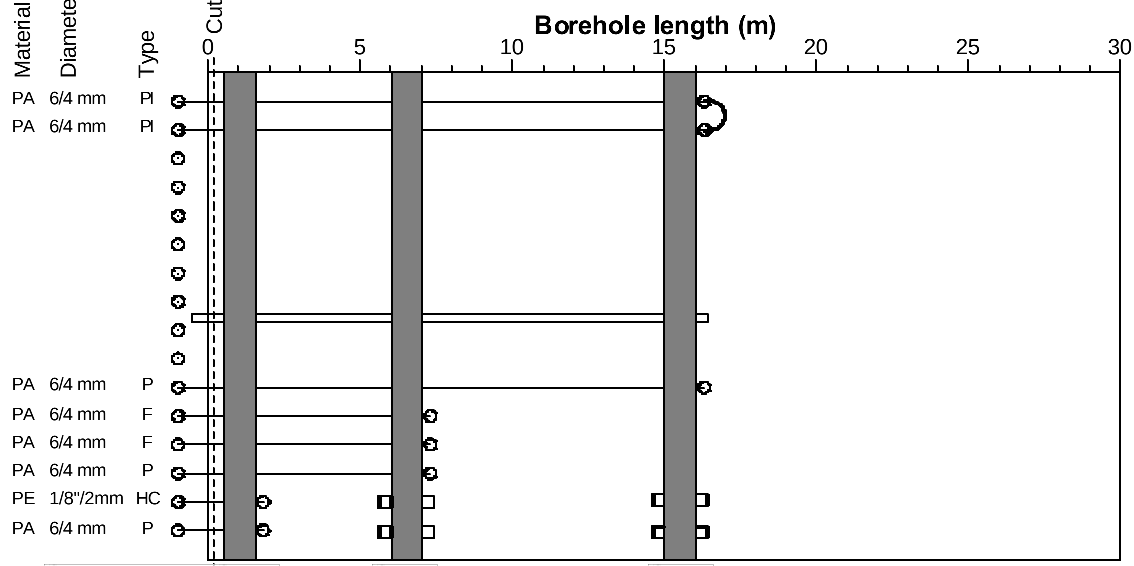
Type of dummy
PE : PEEK
PEH : PEH

PACKER

DUMMY

/1310241/DATA/MONITORING SECTIONS/KA3590G01A.GRF 2001-06-14

KA3590G01 - BOREHOLE INSTRUMENTATION



Packer type :	B10p-1,b	A7-1	A4-1
Secup :	0.5	6	15
Seclow :	1.5	7	16

Section secup :	1.5	7	16
Section seclow :	6	15	30
Type of section :	P,HC	P,F,F	P
Type of dummy :	-	-	-
HM anchor secup :	-	-	-
HM anchor seclow :	-	-	-
Cut-in, seclow :	0.2		
Rodholders,seclow :	0.2		
Rod type :	S	S	-
Rods à 2 m :	2	3	0
Rods à 1 m :	0	1	0
Rods à 0.5 m :	0	1	0
Rods à 0.3 m :	0	0	0
Rods à 0.2 m :	0	0	0
Rods à 0.1 m :	0	0	0

Packer type: Bentonite

Type	Number of pipes					
	Steel		PEEK			
	ϕ 6/5 mm	ϕ 6/4 mm	1/8",2 mm	(m)	(m)	(m)
A8-1	1	7		0.25	1.00	0.25
A8-2	1	7		0.25	2.00	0.25
A8p-1		7	1	0.25	1.00	0.25
A8p-2		7	1	0.25	2.00	0.25
A7-1		7		0.25	1.00	0.25
A7-2		7		0.25	2.00	0.25
A5-1	1	4		0.25	1.00	0.25
A5-2	1	4		0.25	2.00	0.25
A4-1		4		0.25	1.00	0.25
A4-2		4		0.25	2.00	0.25
B10-1,b		10		0.3	1.00	0.2
B10p-1,b		9	1	0.3	1.00	0.2

Type of pipe/section
P : Pressure
C : Circulation
F : Flow
HM : Hydromechanical measurement
HC : Hydrochemistry sampling
T : Temperature
N : No measurements
G : Grouted section

Packertype
H : Hydraulic
B : Bentonite
M : Mechanical

Dummy material
PE : PEEK
HD : HD1000

Pipe
: Plug (unused pipe through packer)
: End point

Pipe material
PA : Polyamid
ST : Steel
PE : PEEK

Rod type
S : Steel
A : Aluminium

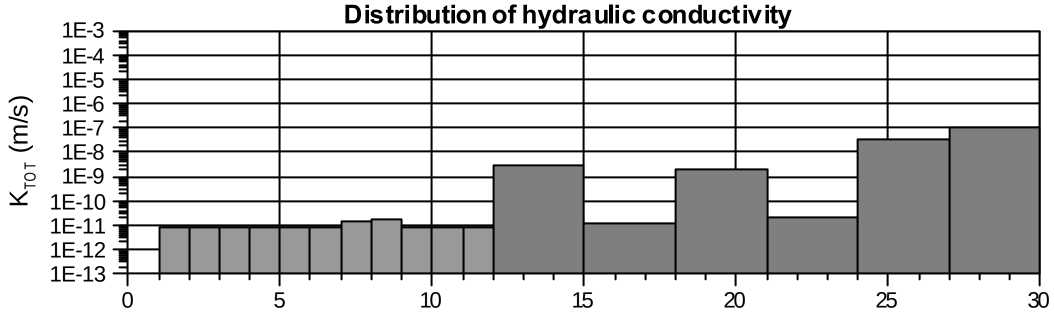
VBB VIAK

/1310241/DATA/MONITORING SECTIONS/KA3590G01B.GRF 2001-06-14

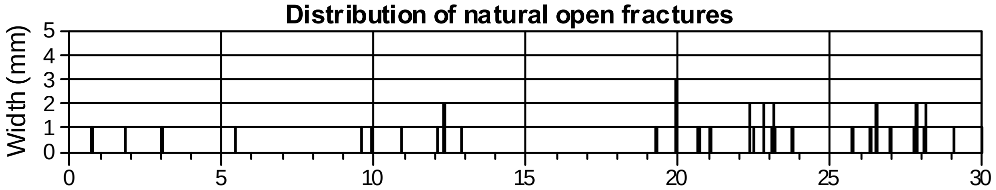
PACKER POSITION

Borehole name: **KA3590G02**	Date design: 2001-06-14
Borehole diametre: 76 mm	Name: TFK
Borehole length: 30.05 m	Remark:
Borehole inclination: 44° down	

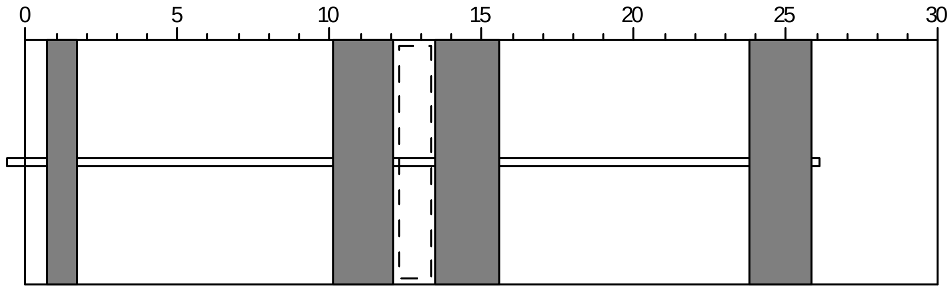
Distribution of hydraulic conductivity



Distribution of natural open fractures



Borehole length (m)



Section secup :	1.65	12.05	15.35	25.65
Section seclow :	10.05	13.35	23.65	30.01
Type of section :	P	P,HC	P	P,F
Type of dummy :	-	PE	-	-
HM anchor secup :	-	-	-	-
HM anchor seclow :	-	-	-	-

<u>Type of measurement section</u>
P : Pressure
C : Circulation
F : Flow
HM : Hydromechanical measurement
HC : Hydrochemistry sampling
T : Temperature
N : No measurements
G : Grouted section

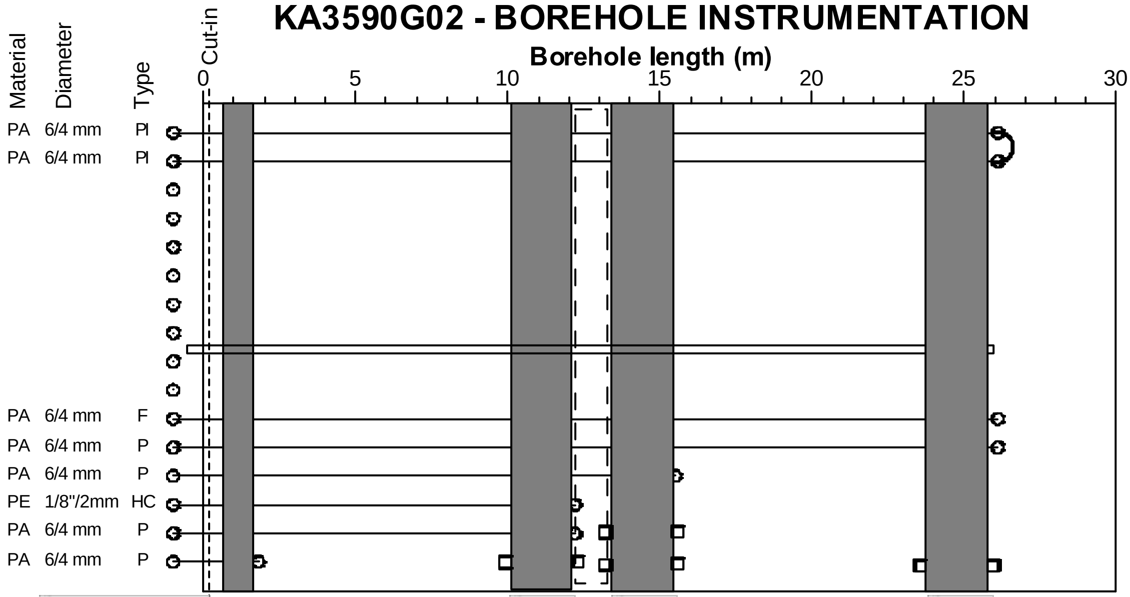
<u>Type of dummy</u>
PE : PEEK
HD : HD1000

PACKER

DUMMY

/1310241/DATA/MONITORING SECTIONS/KA3590G02A.GRF 2001-06-14

KA3590G02 - BOREHOLE INSTRUMENTATION



Packer type :	B10p-1,b	A8p-2	A7-2	A5-2
Secup :	0.65	10.05	13.35	23.65
Seclow :	1.65	12.05	15.35	25.65

Section secup :	1.65	12.05	15.35	25.65
Section seclow :	10.05	13.35	23.65	30.01
Type of section :	P	P,HC	P	P,F
Type of dummy :	-	PE	-	-
HM anchor secup :	-	-	-	-
HM anchor seclow :	-	-	-	-
Cut-in, seclow :	0.2			
Rodholders,seclow :	0.2			
Rod type :	S	S	S	-
Rods à 2 m :	3	0	3	0
Rods à 1 m :	1	0	1	0
Rods à 0.5 m :	1	1	1	0
Rods à 0.3 m :	1	1	1	0
Rods à 0.2 m :	0	0	0	0
Rods à 0.1 m :	1	0	0	0

Packer type: Bentonite

Type	Number of pipes					
	Steel		PEEK			
	φ 6/5 mm	φ 6/4 mm	1/8",2 mm	(m)	(m)	(m)
A8-1	1	7		0.25	1.00	0.25
A8-2	1	7		0.25	2.00	0.25
A8p-1		7	1	0.25	1.00	0.25
A8p-2		7	1	0.25	2.00	0.25
A7-1		7		0.25	1.00	0.25
A7-2		7		0.25	2.00	0.25
A5-1	1	4		0.25	1.00	0.25
A5-2	1	4		0.25	2.00	0.25
A4-1		4		0.25	1.00	0.25
A4-2		4		0.25	2.00	0.25
B10-1,b		10		0.3	1.00	0.2
B10p-1,b		9	1	0.3	1.00	0.2

Type of pipe/section
P : Pressure
C : Circulation
F : Flow
HM : Hydromechanical measurement
HC : Hydrochemistry sampling
T : Temperature
N : No measurements
G : Grouted section

Packertype
H : Hydraulic
B : Bentonite
M : Mechanical

Dummy material
PE : PEEK
HD : HD1000

Pipe
: Plug (unused pipe through packer)
: End point

Pipe material
PA : Polyamid
ST : Steel
PE : PEEK

Rod type
S : Steel
A : Aluminium

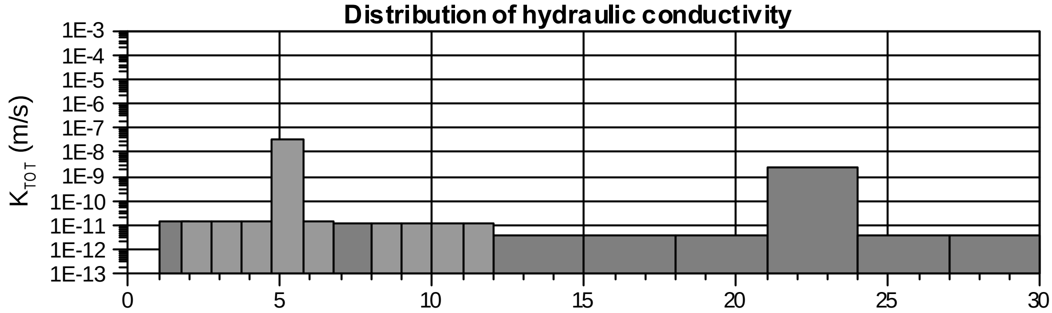
VBB VIAK

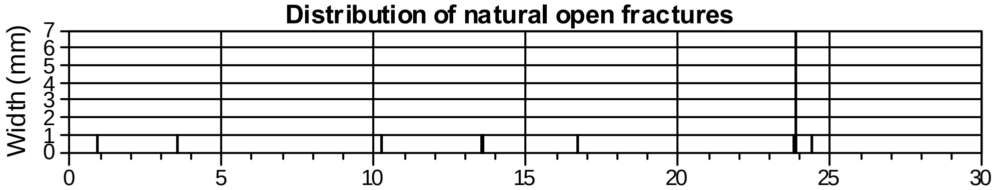
/1310241/DATA/MONITORING SECTIONS/KA3590G02B.GRF 2001-06-14

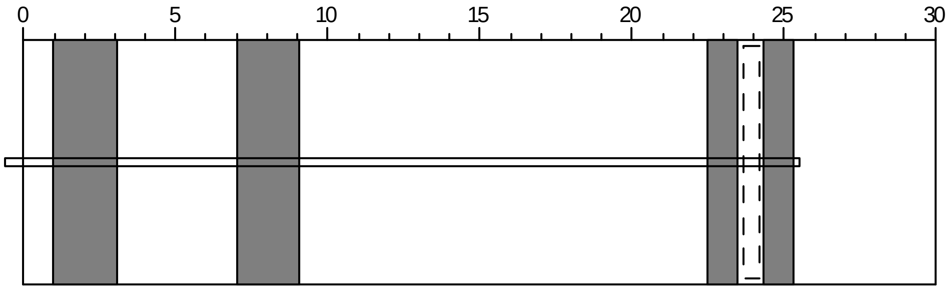
PACKER POSITION

Borehole name: **KA3593G**
Borehole diametre: 76 mm
Borehole length: 30.02 m
Borehole inclination: 80° down

Date design: 2001-06-14
Name: TFK
Remark:







Section secup :	3	9	23.5	25.2
Section seclow :	7	22.5	24.2	30.02
Type of section :	P,F	P	P,HC	P
Type of dummy :	-	-	PE	-
HM anchor secup :	-	-	-	-
HM anchor seclow :	-	-	-	-

Type of measurement section
P : Pressure
C : Circulation
F : Flow
HM : Hydromechanical measurement
HC : Hydrochemistry sampling
T : Temperature
N : No measurements
G : Grouted section

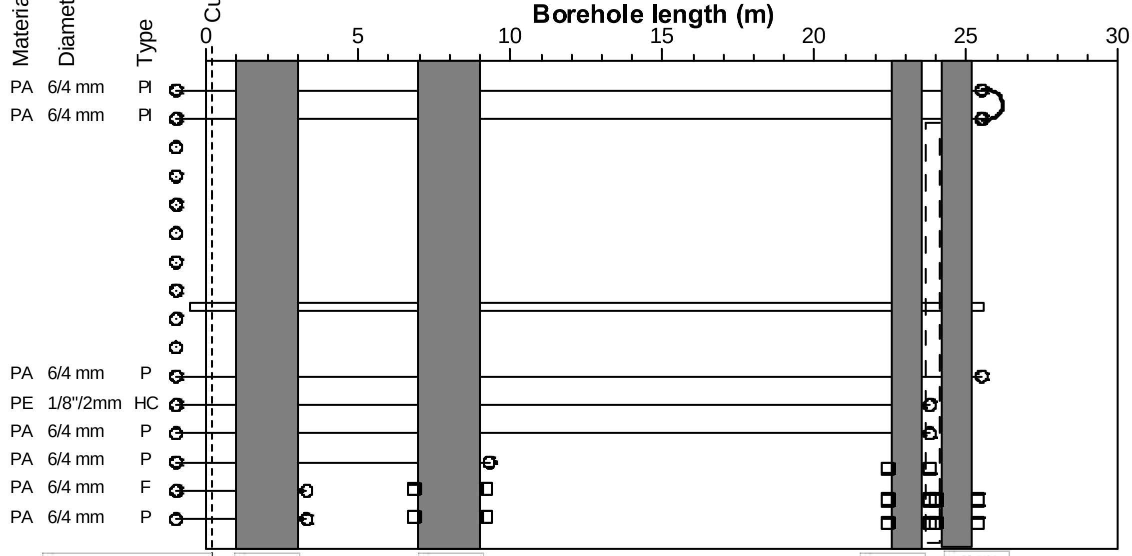
Type of dummy
PE : PEEK
PEH : PEH

PACKER

DUMMY

/1310241/DATA/MONITORING SECTIONS/KA3593G1A.GRF 2001-06-14

KA3593G - BOREHOLE INSTRUMENTATION



Packer type :	A8p-2	A8p-2	A8p-1	A4-1
Secup :	1	7	22.5	24.2
Seclow :	3	9	23.5	25.2

Section secup :	3	9	23.5	25.2
Section seclow :	7	22.5	24.2	30.02
Type of section :	P,F	P	P,HC	P
Type of dummy :	-	-	PE	-
HM anchor secup :	-	-	-	-
HM anchor seclow :	-	-	-	-
Cut-in, seclow :	0.2			
Rodholders,seclow :	0.2			
Rod type :	S	S	S	-
Rods à 2 m :	1	6	0	0
Rods à 1 m :	1	1	0	0
Rods à 0.5 m :	1	0	0	0
Rods à 0.3 m :	0	0	0	0
Rods à 0.2 m :	0	0	1	0
Rods à 0.1 m :	0	0	0	0

Packer type: Bentonite

Type	Number of pipes					
	Steel		PEEK			
	φ 6/5 mm	φ 6/4 mm	1/8",2 mm	(m)	(m)	(m)
A8-1	1	7		0.25	1.00	0.25
A8-2	1	7		0.25	2.00	0.25
A8p-1		7	1	0.25	1.00	0.25
A8p-2		7	1	0.25	2.00	0.25
A7-1		7		0.25	1.00	0.25
A7-2		7		0.25	2.00	0.25
A5-1	1	4		0.25	1.00	0.25
A5-2	1	4		0.25	2.00	0.25
A4-1		4		0.25	1.00	0.25
A4-2		4		0.25	2.00	0.25
B10-1,b		10		0.3	1.00	0.2
B10p-1,b		9	1	0.3	1.00	0.2

Type of pipe/section
P : Pressure
C : Circulation
F : Flow
HM : Hydromechanical measurement
HC : Hydrochemistry sampling
T : Temperature
N : No measurements
G : Grouted section

Packertype
H : Hydraulic
B : Bentonite
M : Mechanical

Dummy material
PE : PEEK
HD : HD1000

Pipe
: Plug (unused pipe through packer)
: End point

Pipe material
PA : Polyamid
ST : Steel
PE : PEEK

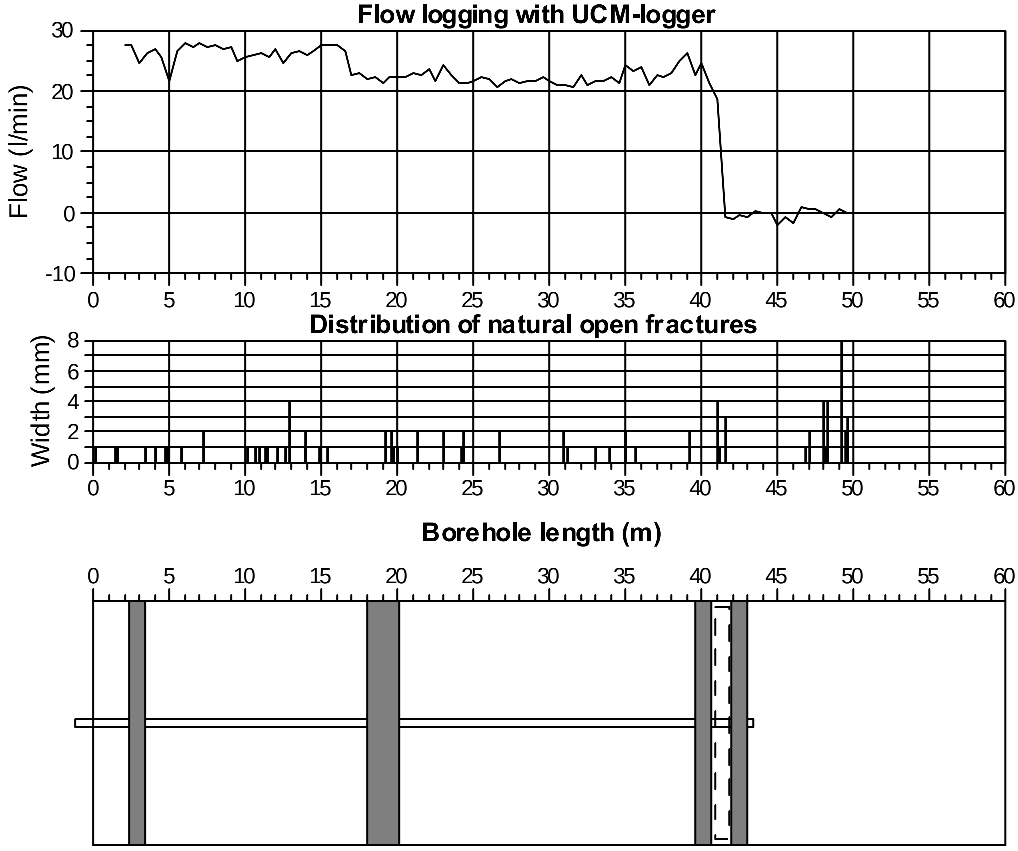
Rod type
S : Steel
A : Aluminium

VBB VIAK

/1310241/DATA/MONITORING SECTIONS/KA3593G1B.GRF 2001-06-14

PACKER POSITION

Borehole name: **KA3600F**	Date design: 2001-06-14
Borehole diametre: 76 mm	Name: TFK
Borehole length: 50.10 m	Remark: No cut-in, casing
Borehole inclination: 2° down	



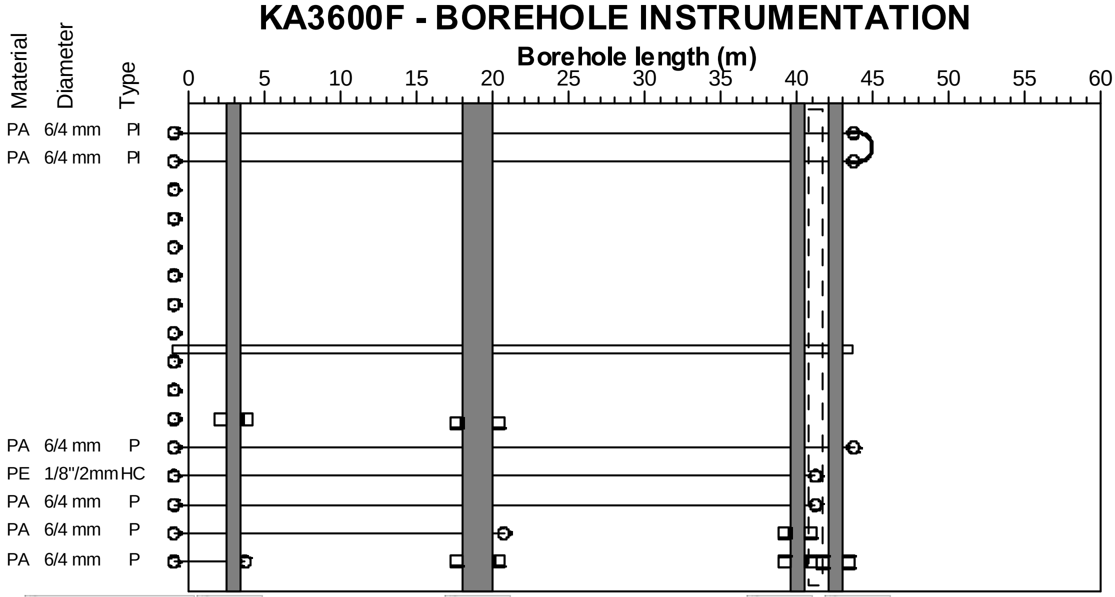
Section secup :	3.4	20	40.5	43
Section seclow :	18	39.5	42	50.1
Type of section :	P	P	P,HC	P
Type of dummy :	-	-	PE	-
HM anchor secup :	-	-	-	-
HM anchor seclow :	-	-	-	-

<u>Type of measurement section</u>
P : Pressure
C : Circulation
F : Flow
HM : Hydromechanical measurement
HC : Hydrochemistry sampling
T : Temperature
N : No measurements
G : Grouted section

<u>Type of dummy</u>
PE : PEEK
HD : HD1000
PACKER
DUMMY

/1310241/DATA/MONITORING SECTIONS/KA3600F1A.GRF 2001-06-14

KA3600F - BOREHOLE INSTRUMENTATION



Packer type :	A8p-1	A8p-2	A8p-1	A4-1
Secup :	2.4	18	39.5	42
Seclow :	3.4	20	40.5	43

Section secup :	3.4	20	40.5	43
Section seclow :	18	39.5	42	50.1
Type of section :	P	P	P,HC	P
Type of dummy :	-	-	PE	-
HM anchor secup :	-	-	-	-
HM anchor seclow :	-	-	-	-
Cut-in, seclow :	0.2			
Rodholders,seclow :	0.2			
Rod type :	S	S	S	-
Rods à 2 m :	7	9	0	0
Rods à 1 m :	0	1	1	0
Rods à 0.5 m :	0	0	0	0
Rods à 0.3 m :	0	0	0	0
Rods à 0.2 m :	0	0	0	0
Rods à 0.1 m :	1	0	0	0

Packer type: Bentonite

Type	Number of pipes					
	Steel		PEEK			
	φ 6/5 mm	φ 6/4 mm	1/8",2 mm	(m)	(m)	(m)
A8-1	1	7		0.25	1.00	0.25
A8-2	1	7		0.25	2.00	0.25
A8p-1		7	1	0.25	1.00	0.25
A8p-2		7	1	0.25	2.00	0.25
A7-1		7		0.25	1.00	0.25
A7-2		7		0.25	2.00	0.25
A5-1	1	4		0.25	1.00	0.25
A5-2	1	4		0.25	2.00	0.25
A4-1		4		0.25	1.00	0.25
A4-2		4		0.25	2.00	0.25
B10-1,b		10		0.3	1.00	0.2
B10p-1,b		9	1	0.3	1.00	0.2

Type of pipe/section
P : Pressure
C : Circulation
F : Flow
HM : Hydromechanical measurement
HC : Hydrochemistry sampling
T : Temperature
N : No measurements
G : Grouted section

Packertype
H : Hydraulic
B : Bentonite
M : Mechanical

Dummy material
PE : PEEK
HD : HD1000

Pipe
: Plug (unused pipe through packer)
: End point

Pipe material
PA : Polyamid
ST : Steel
PE : PEEK

Rod type
S : Steel
A : Aluminium

VBB VIAK

/1310241/DATA/MONITORING SECTIONS/KA3600F1B.GRF 2001-06-14

APPENDIX 2

Position of measurement sections along boreholes in tunnel section I

The table of hydro holes presented in this appendix consists of 4 columns described below:

Borehole	-	Borehole name
Section secup	-	The upper (closest to tunnel) end of the observation section (m)
Section seclow	-	The lower end of the observation section (m)
Measurement	-	Index of which kind of measurement is done in this section
		P - Pressure measurement
		C - Water circulation measurements
		F - Flow measurements
		HC - Hydrochemistry sampling

The table of temperature holes presented in this appendix consists of 4 columns described below:

Borehole	-	Borehole name
Borehole length	-	The length of the borehole (m)
Inclination to vertical plane	-	The lower end of the observation section (degree)
Sensors at borehole depth	-	The position of the temperature sensors in the hole (m)

HYDRO HOLES Borehole	Section Secup (m)	Section Seclow (m)	Measurement
KA3600F	1.3	18	P
KA3600F	20	39.5	P
KA3600F	40.5	42	P, HC
KA3600F	43	50.1	P
KA3597H01	0.65	2	P
KA3597D01	0.65	2	P
KA3593G	3	7	P, F
KA3593G	9	22.5	P
KA3593G	23.5	24.2	P, HC
KA3593G	25.2	30.02	P
KA3592C01	0.65	2	P
KA3590G02	1.3	9.9	P
KA3590G02	11.9	13.2	P, HC
KA3590G02	15.2	23.5	P
KA3590G02	25.5	30.01	P, F
KA3590G01	1.3	6	P, HC
KA3590G01	7	15	P, F
KA3590G01	16	30	P
KA3588I01	0.65	2	P
KA3588D01	0.65	2	P
KA3588C01	0.65	2	P
KA3584G01	1.3	5	P
KA3584G01	7	12	P
KA3579G	2.3	11.5	P
KA3579G	12.5	13.7	P
KA3579G	14.7	22.65	P
KA3579D01	0.65	2	P
KA3578H01	0.65	2	P
KA3578G01	4.3	5.5	P, HC
KA3578G01	6.5	12.58	P
KA3578C01	0.65	2	P
KA3576G01	1.3	3	P
KA3576G01	4	6	P, HC
KA3576G01	8	12.01	P
KA3574G01	1.8	4.1	P, C
KA3574G01	5.1	7	P
KA3574G01	8	12.03	P
KA3573D01	0.65	2	P
KA3573C01	0.65	2	P
KA3573A	1.3	8.5	P
KA3573A	10.5	12.5	P, F
KA3573A	14.5	19	P
KA3573A	21	24	P, F
KA3573A	26	40.07	P
KA3572G01	2.7	5.3	P, C
KA3572G01	7.3	12.03	P
KA3568D01	0.65	2	P
KA3566G02	1.3	6	P, F
KA3566G02	8	11	P
KA3566G02	12	14	P
KA3566G02	16	18	P, C
KA3566G02	19	30.01	P
KA3566G01	1.5	6.3	P, F

KA3566G01	7.3	10	P
KA3566G01	12	18	P
KA3566G01	20	21.5	P, C
KA3566G01	23.5	30.01	P
KA3566C01	0.65	2	P
KA3563I01	0.65	2	P
KA3563G	1.5	3	P, C
KA3563G	4	8	P
KA3563G	10	13	P
KA3563G	15	30.01	P
KA3563D01	0.65	2	P
KA3563A01	0.65	2	P

TEMPERATURE HOLES

Borehole	Hole length (m)	Inclination to vertical plane (°)	Sensors at hole depth (m)
KA3571G01	10	0	0.5, 2.5, 4.9, 7.3, 10.0
KA3575G06	13.8	22	2.7, 5.3, 8.4, 13.8
KA3575G07	14.7	58	4.7, 9.2, 14.7
KA3577G01	10	0	0.5, 2.5, 4.9, 7.3, 10.0
KA3578G02	10	0	0.5, 2.5, 4.9, 7.3, 10.0
KA3589G01	10	0	0.5, 2.5, 4.9, 7.3, 10.0
KA3592G01	10	0	0.5, 2.5, 4.9, 7.3, 10.0
KA3597G01	10	0	0.5, 2.5, 4.9, 7.3, 10.0

APPENDIX 3

Coordinates of boreholes

In tunnel section II new boreholes may be drilled and the final monitoring is not yet decided.

Coordinate system: Äspö local North map system.

Hole	Hole chainage	NORTHING X (m)	EASTING Y (m)	Z (m)	Hole category	Prototype section	Comments
DA3545G01	0.00	7 269.530	1 920.500	-449.041	D	2	Hole depth in centre=8.37
DA3545G01	8.37	7 269.535	1 920.486	-457.41	D	2	
DA3551G01	0.00	7 270.382	1 914.560	-448.921	D	2	Hole depth in centre=8.37
DA3551G01	8.37	7 270.385	1 914.560	-457.29	D	2	
DA3569G01	0.00	7 272.939	1 896.743	-448.562	D	1	Hole depth in centre=8.37
DA3569G01	8.37	7 272.935	1 896.741	-456.93	D	1	
DA3575G01	0.00	7 273.792	1 890.804	-448.443	D	1	Hole depth in centre=8.37
DA3575G01	8.37	7 273.790	1 890.798	-456.81	D	1	
DA3581G01	0.00	7 274.644	1 884.865	-448.323	D	1	Hole depth in centre=8.37
DA3581G01	8.37	7 274.645	1 884.872	-456.69	D	1	
DA3587G01	0.00	7 275.496	1 878.926	-448.204	D	1	Hole depth in centre=8.37
DA3587G01	8.37	7 275.486	1 878.917	-456.57	D	1	
KA3510A	0.00	7260.892	1953.796	-448.696	H	2	
KA3510A	3.00	7260.235	1951.287	-450.203	H	2	
KA3510A	6.00	7259.579	1948.777	-451.711	H	2	
KA3510A	9.00	7258.925	1946.268	-453.218	H	2	
KA3510A	12.00	7258.269	1943.759	-454.727	H	2	
KA3510A	15.00	7257.615	1941.250	-456.236	H	2	
KA3510A	18.00	7256.966	1938.738	-457.742	H	2	
KA3510A	21.00	7256.324	1936.223	-459.247	H	2	
KA3510A	24.00	7255.690	1933.705	-460.749	H	2	
KA3510A	27.00	7255.056	1931.188	-462.253	H	2	
KA3510A	30.00	7254.422	1928.671	-463.757	H	2	
KA3510A	33.00	7253.789	1926.153	-465.261	H	2	
KA3510A	36.00	7253.155	1923.636	-466.765	H	2	
KA3510A	39.00	7252.523	1921.118	-468.269	H	2	
KA3510A	42.00	7251.892	1918.600	-469.772	H	2	
KA3510A	45.00	7251.261	1916.081	-471.276	H	2	
KA3510A	48.00	7250.633	1913.562	-472.779	H	2	
KA3510A	51.00	7250.007	1911.043	-474.283	H	2	
KA3510A	54.00	7249.382	1908.523	-475.786	H	2	
KA3510A	57.00	7248.758	1906.003	-477.289	H	2	
KA3510A	60.00	7248.136	1903.482	-478.792	H	2	
KA3510A	63.00	7247.515	1900.961	-480.295	H	2	
KA3510A	66.00	7246.896	1898.440	-481.797	H	2	
KA3510A	69.00	7246.277	1895.917	-483.299	H	2	
KA3510A	72.00	7245.660	1893.394	-484.800	H	2	
KA3510A	75.00	7245.044	1890.870	-486.300	H	2	
KA3510A	78.00	7244.429	1888.345	-487.799	H	2	
KA3510A	81.00	7243.815	1885.820	-489.298	H	2	
KA3510A	84.00	7243.201	1883.294	-490.796	H	2	
KA3510A	87.00	7242.589	1880.768	-492.294	H	2	
KA3510A	90.00	7241.979	1878.242	-493.792	H	2	
KA3510A	93.00	7241.370	1875.715	-495.290	H	2	
KA3510A	96.00	7240.763	1873.187	-496.788	H	2	
KA3510A	99.00	7240.157	1870.659	-498.285	H	2	
KA3510A	102.00	7239.550	1868.131	-499.782	H	2	
KA3510A	105.00	7238.945	1865.602	-501.278	H	2	
KA3510A	108.00	7238.340	1863.073	-502.773	H	2	
KA3510A	111.00	7237.736	1860.543	-504.268	H	2	
KA3510A	117.00	7236.529	1855.481	-507.255	H	2	
KA3510A	150.00	7229.890	1827.641	-523.683	H	2	
KA3510A	150.06	7229.878	1827.590	-523.713	H	2	
KA3539G	0.00	7268.774	1927.266	-449.191	H	2	
KA3539G	30.01	7269.135	1922.308	-478.786	H	2	
KA3542G01	0.00	7268.608	1923.435	-449.074	H	2	
KA3542G01	30.04	7247.594	1920.218	-470.298	H	2	
KA3542G02	0.00	7269.604	1923.540	-449.070	H	2	
KA3542G02	30.01	7290.987	1925.883	-469.996	H	2	

Hole category

D=Deposition Hole

H=Monitoring Hole, Investigation Hole, Long Hole

P=Monitoring Hole, Investigation Hole, Short Hole

I= Investigation Hole

T=Temperature Hole

LT= Lead-Through Hole

KA3543A01	0.00	7266.837	1921.611	-446.801	**P**	2	
KA3543A01	2.06	7265.629	1919.943	-446.830	**P**	2	
KA3543I01	0.00	7269.402	1921.940	-444.084	**P**	2	
KA3543I01	2.06	7268.739	1921.756	-442.142	**P**	2	
KA3544G01	0.00	7270.224	1921.445	-448.952	**H**	2	
KA3544G01	12.00	7270.224	1921.445	-460.952	**H**	2	
KA3545G	0.00	7 269.60	1 921.28	-449.10	**I**	2	Gone, at position of deposition hole
KA3545G	8.04	7269.60	1920.06	-457.01	**I**	2	Gone, at position of deposition hole
KA3546G01	0.00	7268.819	1919.555	-448.894	**H**	2	
KA3546G01	12.00	7268.771	1919.543	-460.894	**H**	2	
KA3548A01	0.00	7267.473	1917.175	-446.576	**H**	2	
KA3548A01	3.00	7264.509	1916.738	-446.738	**H**	2	
KA3548A01	6.00	7261.546	1916.303	-446.902	**H**	2	
KA3548A01	9.00	7258.581	1915.867	-447.065	**H**	2	
KA3548A01	30.00	7237.835	1912.816	-448.206	**H**	2	
KA3548D01	0.00	7272.404	1917.543	-445.865	**P**	2	
KA3548D01	2.06	7273.654	1919.178	-445.768	**P**	2	
KA3548G01	0.00	7269.928	1917.518	-449.000	**H**	2	
KA3548G01	3.00	7269.935	1917.542	-452.000	**H**	2	
KA3548G01	6.00	7269.935	1917.544	-455.000	**H**	2	
KA3548G01	9.00	7269.941	1917.566	-458.000	**H**	2	
KA3548G01	12.01	7269.947	1917.588	-461.010	**H**	2	
KA3550G01	0.00	7271.088	1915.503	-448.770	**H**	2	
KA3550G01	12.03	7271.028	1915.347	-460.799	**H**	2	
KA3551G	0.00	7 270.39	1 915.43	-448.93	**I**	2	Gone, at position of deposition hole
KA3551G	8.04	7 270.37	1 913.99	-456.80	**I**	2	Gone, at position of deposition hole
KA3552A01	0.00	7268.134	1912.430	-446.623	**P**	2	
KA3552A01	2.06	7266.912	1910.774	-446.723	**P**	2	
KA3552G01	0.00	7269.678	1913.606	-448.773	**H**	2	
KA3552G01	12.01	7269.606	1913.690	-460.782	**H**	2	
KA3552H01	0.00	7269.918	1912.573	-443.984	**P**	2	
KA3552H01	2.10	7269.873	1911.467	-442.199	**P**	2	
KA3553B01	0.00	7273.100	1912.554	-446.550	**P**	2	
KA3553B01	2.02	7274.681	1912.780	-447.787	**P**	2	
KA3554G01	0.00	7270.279	1911.531	-448.835	**H**	2	
KA3554G01	30.01	7249.286	1908.511	-470.067	**H**	2	
KA3554G02	0.00	7271.306	1911.654	-448.820	**H**	2	
KA3554G02	30.01	7292.314	1914.672	-470.037	**H**	2	
KA3557G	0.00	7271.259	1909.495	-448.847	**H**	2	
KA3557G	30.04	7271.349	1905.049	-478.556	**H**	2	
KA3563A01	0.00	7269.845	1901.729	-447.061	**P**	1	
KA3563A01	2.06	7268.639	1900.082	-447.336	**P**	1	
KA3563D01	0.00	7274.672	1902.147	-446.155	**P**	1	
KA3563D01	2.01	7275.86	1903.766	-446.068	**P**	1	
KA3563G	0.00	7272.200	1903.528	-448.694	**H**	1	
KA3563G	30.00	7272.920	1898.340	-478.233	**H**	1	
KA3563I01	0.00	7272.440	1901.919	-443.642	**P**	1	
KA3563I01	2.15	7272.087	1901.398	-441.586	**P**	1	
KA3566C01	0.00	7270.165	1898.849	-445.562	**P**	1	
KA3566C01	2.10	7268.883	1897.191	-445.434	**P**	1	

KA3566G01	0.00	7272.005	1899.636	-448.566	**H**	1	
KA3566G01	30.01	7250.985	1896.388	-469.737	**H**	1	
KA3566G02	0.00	7272.998	1899.806	-448.568	**H**	1	
KA3566G02	30.01	7294.461	1902.714	-469.341	**H**	1	
KA3568D01	0.00	7275.377	1897.276	-445.830	**P**	1	
KA3568D01	2.30	7276.716	1899.144	-445.921	**P**	1	
KA3569G	0.00	7 272.99	1 897.64	-448.57	**I**	1	Gone, at position of deposition hole
KA3569G	8.04	7272.98	1896.29	-456.45	**I**	1	Gone, at position of deposition hole
KA3571G01	0.00	7 273.232	1 894.749	-448.527	**T**	1	
KA3571G01	10.00	7 273.339	1 894.721	-458.526			
KA3572G01	0.00	7273.358	1893.802	-448.512	**H**	1	
KA3572G01	12.00	7273.298	1893.742	-460.512	**H**	1	
KA3573A	0.00	7270.896	1893.281	-446.068	**H**	1	
KA3573A	3.00	7267.931	1892.840	-446.171	**H**	1	
KA3573A	6.00	7264.965	1892.402	-446.280	**H**	1	
KA3573A	9.00	7261.998	1891.969	-446.392	**H**	1	
KA3573A	40.07	7231.275	1887.485	-447.552	**H**	1	
KA3573C01	0.00	7271.294	1891.464	-445.132	**P**	1	
KA3573C01	2.05	7270.267	1890.134	-443.958	**P**	1	
KA3574D01	0.00	7276.116	1891.143	-445.120	**P**	1	
KA3574D01	2.05	7277.250	1892.791	-444.674	**P**	1	
KA3574G01	0.00	7274.504	1891.733	-448.332	**H**	1	
KA3574G01	12.00	7274.444	1891.577	-460.331	**H**	1	
KA3575G	0.0	7273.90	1891.67	-448.48	**I**	1	
KA3575G	8.04	7274.12	1890.42	-456.38	**I**	1	
KA3575G06	0.00	7272.718	1890.647	-448.207	**T**	1	
KA3575G06	15.10	7267.054	1889.76	-462.176	**T**	1	
KA3575G07	0.00	7272.44	1890.6	-448.064	**T**	1	
KA3575G07	13.55	7261.36	1888.927	-455.682	**T**	1	
KA3576G01	0.00	7273.104	1889.874	-448.274	**H**	1	
KA3576G01	12.01	7272.960	1889.778	-460.283	**H**	1	
KA3577G01	0.00	7 274.081	1 888.803	-448.401	**T**	1	
KA3577G01	10.00	7 273.920	1 888.887	-458.399	**T**	1	
KA3578C01	0.00	7271.850	1887.023	-445.337	**P**	1	
KA3578C01	2.09	7270.579	1885.375	-445.532	**P**	1	
KA3578G01	0.00	7274.219	1887.842	-448.384	**H**	1	
KA3578G01	12.58	7274.156	1887.641	-460.962	**H**	1	
KA3578G02	0.00	7 274.295	1 887.235	-448.372	**T**	1	
KA3578G02	10.00	7 274.247	1 887.391	-458.371	**T**	1	
KA3578H01	0.00	7274.074	1887.146	-443.378	**P**	1	
KA3578H01	1.90	7274.017	1886.171	-441.748	**P**	1	
KA3579D01	0.00	7276.885	1886.525	-445.429	**P**	1	
KA3579D01	2.00	7278.054	1888.147	-445.464	**P**	1	
KA3579G	0.00	7274.422	1886.684	-448.366	**H**	1	
KA3579G	22.65	7274.535	1886.457	-471.015	**H**	1	
KA3581G	0.00	7274.70	1885.71	-448.33	**I**	1	Gone, at position of deposition hole
KA3581G	8.04	7274.84	1884.55	-456.25	**I**	1	Gone, at position of deposition hole
KA3584G01	0.00	7275.076	1881.877	-448.246	**H**	1	
KA3584G01	12.00	7274.944	1881.793	-460.245	**H**	1	

KA3586G01	0.00	7275.93	1879.49	-448.15	**I**	1	Gone, at position of deposition hole
KA3586G01	8.00	7276.02	1879.31	-456.14	**I**	1	Gone, at position of deposition hole
KA3587G	0.00	7275.596	1879.895	-448.208	**I**	1	Gone, at position of deposition hole
KA3587G	8.04	7275.773	1878.475	-456.120	**I**	1	Gone, at position of deposition hole
KA3588C01	0.00	7273.255	1876.954	-445.443	**P**	1	
KA3588C01	2.04	7272.025	1875.333	-445.585	**P**	1	
KA3588D01	0.00	7278.152	1877.826	-445.237	**P**	1	
KA3588D01	1.90	7279.241	1879.382	-445.296	**P**	1	
KA3588G01	0.00	7275.07	1878.34	-448.10	**I**	1	Gone, at position of deposition hole
KA3588G01	8.00	7275.00	1878.26	-456.10	**I**	1	Gone, at position of deposition hole
KA3588I01	0.00	7275.924	1877.473	-443.338	**P**	1	
KA3588I01	1.96	7276.729	1877.547	-441.553	**P**	1	
KA3589G01	0.00	7 275.801	1 876.931	-448.148	**T**	1	
KA3589G01	10.00	7 275.828	1 876.893	-458.148			
KA3590G01	0.00	7275.410	1875.889	-448.063	**H**	1	
KA3590G01	30.06	7254.076	1873.397	-469.093	**H**	1	
KA3590G02	0.00	7276.412	1876.052	-448.080	**H**	1	
KA3590G02	30.05	7297.885	1879.046	-468.888	**H**	1	
KA3592C01	0.00	7273.859	1872.861	-445.254	**P**	1	
KA3592C01	2.10	7272.621	1871.172	-445.092	**P**	1	
KA3592G01	0.00	7 276.223	1 873.982	-448.079	**T**	1	
KA3592G01	10.00	7 276.230	1 874.025	-458.079			
KA3593G	0.00	7276.375	1873.859	-448.073	**H**	1	
KA3593G	30.02	7276.856	1868.598	-477.625	**H**	1	
KA3597D01	0.00	7279.350	1869.120	-445.096	**P**	1	
KA3597D01	2.22	7280.669	1870.902	-444.978	**P**	1	
KA3597G01	0.00	7 276.804	1 869.935	-448.026	**T**	1	
KA3597G01	10.00	7 276.758	1 869.927	-458.026	**T**	1	
KA3597H01	0.00	7276.032	1868.465	-443.177	**P**	1	
KA3597H01	2.06	7275.606	1867.367	-441.487	**P**	1	
KA3600F	0.00	7275.456	1866.012	-445.583	**H**	1	
KA3600F	3.00	7274.343	1863.228	-445.679	**H**	1	
KA3600F	6.00	7273.236	1860.441	-445.774	**H**	1	
KA3600F	9.00	7272.133	1857.653	-445.862	**H**	1	
KA3600F	50.10	7257.020	1819.452	-447.068	**H**	1	
HG0020A01	0.00	7297.41	1941.63	-446.30	**LT**		
HG0020A01	3.00	7294.95	1939.91	-446.46	**LT**		
HG0020A01	6.00	7292.49	1938.20	-446.61	**LT**		
HG0020A01	9.00	7290.03	1936.49	-446.76	**LT**		
HG0020A01	12.00	7287.57	1934.78	-446.92	**LT**		
HG0020A01	15.00	7285.11	1933.07	-447.08	**LT**		
HG0020A01	31.84	7271.30	1923.48	-447.98	**LT**		
HG0021A01	0.00	7297.65	1940.83	-446.29	**LT**		
HG0021A01	3.00	7295.21	1939.10	-446.38	**LT**		
HG0021A01	6.00	7292.76	1937.37	-446.47	**LT**		
HG0021A01	9.00	7290.31	1935.64	-446.56	**LT**		
HG0021A01	12.00	7287.86	1933.91	-446.65	**LT**		
HG0021A01	15.00	7285.41	1932.18	-446.74	**LT**		
HG0021A01	18.00	7282.96	1930.45	-446.84	**LT**		
HG0021A01	21.00	7280.51	1928.72	-446.93	**LT**		
HG0021A01	31.72	7271.76	1922.53	-447.26	**LT**		
HG0022A01	0.00	7297.95	1940.12	-446.29	**LT**		

HG0022A01	3.00	7295.51	1938.38	-446.43	**LT**
HG0022A01	6.00	7293.08	1936.63	-446.58	**LT**
HG0022A01	9.00	7290.64	1934.89	-446.73	**LT**
HG0022A01	12.00	7288.20	1933.15	-446.88	**LT**
HG0022A01	15.00	7285.76	1931.40	-447.02	**LT**
HG0022A01	33.44	7271.60	1921.26	-447.90	**LT**
HG0022A02	0.00	7298.12	1940.01	-445.26	**LT**
HG0022A02	3.00	7295.72	1938.21	-445.45	**LT**
HG0022A02	6.00	7293.32	1936.42	-445.64	**LT**
HG0022A02	32.74	7271.94	1920.47	-447.41	**LT**
HG0023A01	0.00	7298.58	1938.58	-445.43	**LT**
HG0023A01	3.00	7296.21	1936.74	-445.63	**LT**
HG0023A01	6.00	7293.85	1934.91	-445.84	**LT**
HG0023A01	33.53	7272.16	1918.06	-447.80	**LT**
HG0023A02	0.00	7298.84	1937.90	-444.89	**LT**
HG0023A02	3.00	7296.55	1935.97	-445.09	**LT**
HG0023A02	6.00	7296.55	1934.04	-445.30	**LT**
HG0023A02	34.27	7272.70	1915.87	-447.26	**LT**
HG0024A01	0.00	7298.85	1937.43	-445.44	**LT**
HG0024A01	3.00	7296.21	1936.74	-445.63	**LT**
HG0024A01	6.00	7294.34	1933.49	-445.84	**LT**
HG0024A01	35.06	7272.52	1914.40	-447.79	**LT**
HG0024A02	0.00	7299.10	1937.03	-444.78	**LT**
HG0024A02	3.00	7296.87	1935.04	-444.99	**LT**
HG0024A02	6.00	7294.63	1933.05	-445.20	**LT**
HG0024A02	35.21	7272.91	1913.63	-447.33	**LT**
HG0025A01	0.00	7299.03	1936.69	-445.41	**LT**
HG0025A01	3.00	7296.84	1934.65	-445.61	**LT**
HG0025A01	6.00	7294.65	1932.61	-445.80	**LT**
HG0025A01	36.00	7272.77	1912.19	-447.81	**LT**
HG0025A02	0.00	7299.24	1936.47	-444.72	**LT**
HG0025A02	3.00	7297.08	1934.40	-444.93	**LT**
HG0025A02	6.00	7294.92	1932.33	-445.13	**LT**
HG0025A02	36.20	7273.20	1911.46	-447.26	**LT**
HG0025A03	0.00	7299.20	1936.23	-445.41	**LT**
HG0025A03	3.00	7297.49	1933.76	-445.55	**LT**
HG0025A03	6.00	7295.79	1931.30	-445.69	**LT**
HG0025A03	43.76	7274.52	1900.16	-447.58	**LT**
HG0026A01	0.00	7299.40	1935.99	-444.78	**LT**
HG0026A01	3.00	7297.73	1933.50	-444.92	**LT**
HG0026A01	6.00	7296.07	1931.01	-445.07	**LT**
HG0026A01	44.10	7274.95	1899.35	-447.05	**LT**
HG0026A02	0.00	7299.62	1935.75	-445.36	**LT**
HG0026A02	3.00	7297.99	1933.24	-445.48	**LT**
HG0026A02	6.00	7296.37	1930.72	-445.60	**LT**
HG0026A02	45.51	7275.03	1897.51	-447.35	**LT**
HG0027A01	0.00	7299.78	1934.93	-445.30	**LT**
HG0027A01	3.00	7298.26	1932.35	-445.41	**LT**
HG0027A01	6.00	7296.73	1929.77	-445.54	**LT**
HG0027A01	9.00	7295.21	1927.19	-445.66	**LT**
HG0027A01	12.00	7293.69	1924.60	-445.79	**LT**
HG0027A01	15.00	7292.17	1922.02	-445.91	**LT**
HG0027A01	18.00	7290.65	1914.26	-446.04	**LT**
HG0027A01	21.00	7289.14	1916.85	-446.16	**LT**
HG0027A01	24.00	7287.62	1914.26	-446.29	**LT**
HG0027A01	48.07	7275.52	1893.48	-447.36	**LT**
HG0028A01	0.00	7299.95	1934.46	-444.66	**LT**
HG0028A01	3.00	7298.45	1931.87	-444.78	**LT**
HG0028A01	6.00	7296.95	1929.27	-444.91	**LT**
HG0028A01	9.00	7295.45	1926.67	-445.04	**LT**
HG0028A01	48.42	7275.89	1892.50	-446.84	**LT**
HG0028A02	0.00	7300.23	1934.00	-445.31	**LT**
HG0028A02	3.00	7298.75	1931.39	-445.41	**LT**

HG0028A02	6.00	7297.28	1928.78	-445.52	**LT**
HG0028A02	9.00	7295.81	1926.17	-445.63	**LT**
HG0028A02	49.70	7275.99	1890.66	-447.22	**LT**
HG0029A01	0.00	7300.19	1933.56	-444.66	**LT**
HG0029A01	3.00	7298.77	1930.92	-444.78	**LT**
HG0029A01	6.00	7297.35	1928.28	-444.90	**LT**
HG0029A01	9.00	7295.93	1925.64	-445.02	**LT**
HG0029A01	50.50	7276.43	1889.04	-446.82	**LT**
HG0029A02	0.00	7300.51	1933.07	-445.35	**LT**
HG0029A02	3.00	7299.09	1930.43	-445.45	**LT**
HG0029A02	6.00	7297.68	1927.78	-445.55	**LT**
HG0029A02	9.00	7296.27	1925.14	-445.66	**LT**
HG0029A02	51.73	7276.38	1887.35	-447.27	**LT**
HG0030A01	0.00	7300.65	1932.79	-444.58	**LT**
HG0030A01	3.00	7299.26	1930.13	-444.69	**LT**
HG0030A01	6.00	7297.88	1927.47	-444.79	**LT**
HG0030A01	9.00	7296.50	1924.81	-444.90	**LT**
HG0030A01	52.19	7276.76	1886.44	-446.66	**LT**
HG0030A02	0.00	7300.88	1932.00	-445.31	**LT**
HG0030A02	3.00	7299.51	1929.33	-445.40	**LT**
HG0030A02	6.00	7298.15	1926.67	-445.50	**LT**
HG0030A02	9.00	7296.78	1923.99	-445.59	**LT**
HG0030A02	53.43	7276.75	1884.37	-447.23	**LT**
HG0031A01	0.00	7300.99	1931.62	-444.58	**LT**
HG0031A01	3.00	7299.65	1928.94	-444.68	**LT**
HG0031A01	6.00	7298.30	1926.26	-444.79	**LT**
HG0031A01	9.00	7296.96	1923.58	-444.89	**LT**
HG0031A01	53.55	7277.22	1883.68	-446.58	**LT**
HG0032A01	0.00	7301.31	1930.79	-444.53	**LT**
HG0032A01	3.00	7299.98	1928.10	-444.64	**LT**
HG0032A01	6.00	7298.65	1925.41	-444.74	**LT**
HG0032A01	9.00	7297.32	1922.73	-444.85	**LT**
HG0032A01	54.28	7277.45	1882.08	-446.60	**LT**
HG0032A02	0.00	7301.56	1930.46	-445.26	**LT**
HG0032A02	3.00	7300.29	1927.75	-445.36	**LT**
HG0032A02	6.00	7299.02	1925.03	-445.46	**LT**
HG0032A02	9.00	7297.75	1922.31	-445.56	**LT**
HG0032A02	12.00	7296.49	1919.59	-445.66	**LT**
HG0032A02	15.00	7295.23	1916.87	-445.77	**LT**
HG0032A02	18.00	7293.98	1914.15	-445.87	**LT**
HG0032A02	21.00	7292.72	1911.43	-445.98	**LT**
HG0032A02	24.00	7291.47	1908.70	-446.09	**LT**
HG0032A02	57.74	7277.53	1878.01	-447.43	**LT**
HG0033A01	0.00	7302.01	1928.74	-445.10	**LT**
HG0033A01	3.00	7300.77	1926.01	-445.20	**LT**
HG0033A01	6.00	7300.77	1923.28	-445.29	**LT**
HG0033A01	9.00	7298.30	1917.81	-445.39	**LT**
HG0033A01	12.00	7297.07	1917.81	-445.48	**LT**
HG0033A01	15.00	7295.84	1915.08	-445.58	**LT**
HG0033A01	18.00	7294.61	1912.34	-445.68	**LT**
HG0033A01	21.00	7293.39	1909.61	-445.77	**LT**
HG0033A01	58.98	7278.16	1874.85	-447.10	**LT**
KG0021A01	0.00	7297.915	1941.001	-445.153	**H**
KG0021A01	3.00	7295.726	1939.160	-444.246	**H**
KG0021A01	6.00	7293.539	1937.317	-443.338	**H**
KG0021A01	9.00	7291.353	1935.476	-442.427	**H**
KG0021A01	48.82	7262.334	1911.037	-430.334	**H**
KG0023A01	0.00	7298.42	1939.36	-445.36	**LT**
KG0023A01	3.00	7296.03	1937.55	-445.57	**LT**
KG0023A01	6.00	7293.65	1935.74	-445.79	**LT**
KG0027A01	0.00	7299.66	1935.40	-445.08	**LT**
KG0027A01	3.00	7298.10	1932.84	-445.19	**LT**
KG0027A01	6.00	7296.54	1930.28	-445.29	**LT**
KG0033A01	0.00	7301.76	1929.81	-445.08	**LT**

KG0033A01	3.00	7300.52	1927.08	-445.19	**LT**
KG0033A01	6.00	7299.27	1924.36	-445.29	**LT**
KG0048A01	0.00	7307.032	1915.444	-444.494	**H**
KG0048A01	3.00	7304.877	1913.490	-443.762	**H**
KG0048A01	6.00	7302.724	1911.533	-443.030	**H**
KG0048A01	9.00	7300.574	1909.572	-442.305	**H**
KG0048A01	54.69	7267.818	1879.695	-431.259	**H**