Äspö Hard Rock Laboratory

Status Report

January – March 2000

April 2000

International Progress Report

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Summary

Investigations and experiments

The barrier function of the host rock

The Tracer Retention Understanding (TRUE) aim at further developing understanding of radionuclide migration and retention processes and evaluation of different approaches to modelling such processes. The TRUE-1 tests are performed over distances of about 5 m in a fracture at approximately 400 m depth. The tracer experiments were completed in the end of 1998. A number of laboratory studies to support the interpretation of the breakthrough curves have been completed. The final report of the First TRUE Stage will be filed early April.

The Long-Term Diffusion Experiment is intended as a complement to the *in-situ* dynamic experiments and the laboratory experiments performed within the TRUE Programme. The objectives are to study diffusion into the rock matrix and to obtain data on sorption processes and properties. The experimental concept is based on a large diameter borehole, which exposes a fracture surface. This fracture is packed off with a cap, similar to what was used in the REX experiment. A suitable target fracture has been identified at the 410 m level. The drilling of the telescoped test borehole (diameter 300/200 mm) has been completed. The fracture surface to be tested is irregular and exposes a variety of surficial fracture minerals, including calcite, chlorite and Äspö diorite.

The TRUE-2 experiments will be postponed indefinitely awaiting the outcome of the TRUE-1 seminar this fall and the outcome of the TRUE Block Scale Experiment. The outcome of these activities will be used to make research priorities in light of the upcoming site characterisation programme.

The TRUE Block Scale project aims at studying the tracer transport in a fracture network over distances up to 50 m. Phase A of the Tracer test Stage involved use of two alternative sink sections, including about 70 tracer dilution tests and 8 tracer injections. The results of the tests showed that the sink in KI0023B shows the best prospects of producing breakthroughs with a high mass recovery. During the period, Phase B of the three phases of the Tracer Test Stage was initiated. In this phase two pump rates are employed, starting off with a 50% reduced flow rate in KI0023B:P6 and following Phase B1 the maximum possible flow rate is used throughout Phases B2 and C. In the first three months of 2000 the modelling work focused on an improved characterisation of the TRUE Block Scale site. The results from the characterisation were used in the prediction of the breakthroughs of the Phase A tests. The outcome of the predictions was evaluated in relation to the in situ results by the modelling groups.

The detailed scale redox experiment (REX) studies the behaviour of oxygen that will become trapped in the tunnels when the repository is closed. Final project reports are being written.

The CHEMLAB probe has been constructed and manufactured for validation experiments in situ at undisturbed natural conditions. The start of the radiolysis experiment in the CHEMLAB 1 probe was delayed due to technical malfunction of the equipment. The first experiment to be carried out in CHEMLAB-2 is the migration of actinides, Americium, Neptunium and Plutonium, in a rock fracture. Planning and pre-

testing is done by Institut für Nuklear Endsorchung in Karlsruhe. INE is also carrying out the experiment at Äspö in cooperation with SKB staff and Nuclear Chemistry at KTH.

The objectives for the investigations of degassing of groundwater and two-phase flow are to show if degassing of groundwater at low pressures has significant effects on measurements of hydraulic properties in boreholes and drifts. The final report is now near completion. Consistent results between laboratory and borehole test observations and model predictions have been obtained. Based on both observations and model predictions the conclusion is that degassing will not cause inflow reductions to boreholes. A reduction of inflow to drifts due to degassing can only take place if re-dissolution of gas is relatively slow.

The Matrix Fluid Chemistry experiments has the aim to determine the origin and age of matrix fluids and to establish to what extent the composition of matrix fluid has been influenced by diffusion processes. Since January 2000, activities carried out have involved the continuation of: a) mineralogical/petrophysical studies, b) crush/leaching experiments, c) Äspö diorite permeability test, and d) compilation and interpretation of groundwaters sampled and analysed from the Prototype Repository Experiment. Furthermore, the fluid inclusion programme of study is now in progress with the petrography of the selected samples almost complete.

The Stability and Mobility of Colloids (SMC) Project has been initiated to investigate the potential for colloidal transport in natural groundwater. Studies will be made of colloid concentration at Äspö HRL and the role of bentonite clay as a source for colloid generation. A proposal for main project tasks has been sent for review to experts on colloids.

A set of microbiology research tasks for the performance assessment of high level nuclear waste (HLW) disposal has been identified. A test site, called the MICROBE site, has been prepared at the 450 m level. The programme includes studies on microbial influence on radionuclide migration, microbial corrosion of copper, and microbial production and consumption of gases. The three microbe site boreholes were successfully instrumented in January.

The Task Force is a forum for the organisations supporting the Äspö Hard Rock Laboratory Project to interact in the area of conceptual and numerical modelling of groundwater flow and solute transport in fractured rock. The 13th International Task Force meeting was held at Carlsbad, NM, USA, 8-10 February. Modelling results were presented from Task 4 and 5. Two workshops were held on 11th February in Albuquerque. The aim of the first was to do a strategic assessment of the Task Force work and plans for future work. The second workshop discussed processes and up-scaling as a future Task where the needs of the performance assessment are to be addressed.

Technology and function of important parts of the repository system

The Prototype Repository experiment is located in the last part of the TBM tunnel at the 450 m level and will include 6 deposition holes in full scale. The aims of the Prototype Repository are to demonstrate the integrated function of the repository components and to provide a full-scale reference for comparison with models and assumptions. A positive response has been obtained on the application for funding part of the Prototype Repository through the EU 5th Framework Programme. Documents required for preparing the contract have been supplied to the European Commission.

The retrieval test aims at demonstrating the readiness for recovering of emplaced canisters also after the time when the bentonite has swollen. One hole will be equipped with a canister, buffer and instrumentation. Geological mapping of the two deposition holes was performed in February. All the cylindrical bentonite blocks for the test have been manufactured, and these blocks are stored in the Canister Laboratory in Oskarshamn. The plan on instrumentation of the buffer has been completed and orders for most of these instruments have been placed. The design of the plug to seal the top of the hole was completed in January. It will be a combined concrete/steel plug placed in the hole below the tunnel floor level. This plug will be anchored to the rock by means of nine cable bolts.

The design and construction of the temporary equipment for handling and deposition of the buffer material and canisters for the Canister Retrieval Test and the Prototype Repository will be completed before summer 2000.

The Backfill and Plug Test comprises full scale testing of backfill materials, filling methods, and plugging. The entire test setup with backfilling, instrumentation and building of the plug was finished in the end of September 1999 and the wetting of the 30/70 mixture through the filter mats started in November.

The Demonstration of Repository Technology project aims to show in a perceptible way the different steps in encapsulation, transport, deposition, and retrieval of spent nuclear fuel for specialists and the public. The testing of the deposition machine has been delayed for various reasons but has been ongoing during the reporting period. The inauguration of the demonstration tunnel with its deposition machine took place as scheduled on 9th March 2000.

The Long Term Tests of Buffer Material aim to validate models and hypotheses concerning long term processes in buffer material. The assemblage and placement of the four long-term test parcels and the extra one-year parcel are completed. All parcels were equipped with instruments, bacteria, copper coupons and with radioactive tracers according to plans. Power has been increased in all parcels to correspond to a maximum temperature of around 90ºC. The installation is in principle finished and only small adjustments are planned in the near future, e.g. switch to regulation of power instead of temperature.

A planning meeting for at Task Force on Engineered Barrier Systems (The EBS Task Force) was held at Äspö on March 14-15. The interested parties should by the end of April provide statements of their interest to participate in the EBS Task Force and in such case specify the types of tasks they are interested in. SKB should then prepare a proposal for presentation at the IJC/TEF meeting in May.

International Cooperation

Nine organisations from eight countries are currently (April 2000) participating in the Äspö Hard Rock Laboratory.

During the first quarter of 2000 Posiva has participated in the fieldwork at the Äspö HRL mainly within the Hydrochemical Stability project. The Posiva flowmeter has been tested in the borehole KLX02. In addition to the testing of the equipment the aim of the project was to get information for characterising the hydrology and hydrogeochemistry of the deep saline groundwater.

Facility Operation

A rock stability inspection has identified a few areas at the 420 and 450 m levels where intense reinforcement is necessary. Systematic bolting and mesh/spray concrete will be used.

The project for supervising the facility is now undergoing a four weeks test before it will be handed over from the contractor.

Data Management and Quality systems

A Geographical Information System (GIS) based on ArcInfo and ArcView has been and are still used successfully by SKB in the ongoing feasibility-study projects. A plan to implement GIS as a effective tool in the coming pre-investigation phase has been decided, and as a first step some pre-study data sets have been set up at the Äspö Hard Rock Laboratory as a basis for different pilot cases.

The full implementation of the HMS instrument database as a part of SICADA has been finalised as planned.

RVS version 2.1 has been distributed to the RVS users. This new version embodies about 30 new or improved existing functions. A RVS review project has been initiated.

Groundwater head and chemistry monitoring

The HMS program has been running providing real time data acquisition in support of the various projects undertaken in the Äspö Hard Rock Laboratory. The results from the sampling in April and in October 1999 have been presented in Technical Documents.

Information activities

During the first quarter of 2000, 2061 visitors visited the Äspö HRL. The groups have represented the general public, communities where SKB performs feasibility studies, teachers, students, politicians, journalists and visitors from foreign countries. 1160 represented the six communities were SKB performs feasibility studies.

The official inauguration of ”Urberg 500” took place on March 9. More than 100 people took part in the inauguration.

Contents

1 General

The scientific investigations within SKB's research programme are part of the work conducted to develop and test methods for identification and characterisation of suitable repository sites and for design of a deep repository. This requires extensive field studies of the active processes and properties of the geological barrier and the interaction between different engineered barriers and host rock. The Äspö Hard Rock Laboratory provides an opportunity for research, development and demonstration of these issues in a realistic setting. Important tasks for the Äspö Hard Rock Laboratory are:

- to increase scientific understanding of the safety margins of the deep repository,
- to test and verify technology that provide cost reductions and simplifies the repository concept without compromising safety,
- to demonstrate technology that will be used in the deep repository,
- to provide experience and training of staff, and
- to inform about technology and methods to be used in the deep repository.

A set of Stage Goals have been defined for the work at the Äspö HRL. The Stage Goals were redefined in the SKB Research Development and Demonstration (RD&D) Programme 95, which was submitted to the Swedish Authorities in September 1995. An updated program RD&D Programme 1998 was submitted in September 1998. This programme is the basis for the planning and execution of the current work.

The Stage Goals for the Operating Phase of the Äspö HRL are as follows:

1 Verify pre-investigation methods

demonstrate that investigations on the ground surface and in boreholes provide sufficient data on essential safety-related properties of the rock at repository level.

2 Finalise detailed investigation methodology

refine and verify the methods and the technology needed for characterisation of the rock in the detailed site investigations.

3 Test models for description of the barrier function of the host rock

further develop and at repository depth test methods and models for description of groundwater flow, radionuclide migration, and chemical conditions during operation of a repository and after closure.

4 Demonstrate technology for and function of important parts of the repository system

test, investigate and demonstrate on a full scale different components of importance for the long-term safety of a deep repository system and to show that high quality can be achieved in design, construction, and operation of system components.

2 Methodology for detailed characterisation of rock underground

A programme for detailed characterisation will be devised before detailed characterisation is initiated on a selected site and construction of the surface and underground portions of the deep repository is commenced. In conjunction with the driving of the Äspö tunnel, several different investigation methods have been tried and the usefulness of these methods for detailed characterisation for a deep repository is being evaluated. Preliminary experience from Äspö shows that there is a need for refinement of these methods to enhance the quality of collected data, boost efficiency and improve reliability in a demanding underground environment. Furthermore, the detailed characterisation programme needs to be designed so that good co-ordination is obtained between rock investigations and construction activities.

The objectives are:

- to try out existing and new methods to clarify their usefulness for detailed characterisation. The methods to be tested are chosen on the basis of their potential use within the detailed characterisation programme,
- to refine important methods in a detailed characterisation programme to enhance data quality, efficiency and reliability.

Detailed characterisation will facilitate refinement of site models originally based on data from the ground surface and surface boreholes. The refined models will provide the basis for updating the layout of the repository and adapting it to local conditions. Due to the heterogeneity of the rock, the layout of the repository needs to be adapted to the gradually refined model of rock conditions. This approach has a long tradition in underground construction and it should be used also for a deep repository. During 2000 an updating of the geoscientific models of Äspö HRL will be performed.

2.1 Updating of the geoscientific models of Äspö HRL

Background

Some basic research that is not project-related is conducted at the Äspö HRL. This work is aimed at providing support for the research, development and demonstration projects by conducting and comparing measurements of common interest for all projects. According to SKB's planning, the suitability of geological formations for deep disposal of spent nuclear fuel will be evaluated with the aid of geoscientific models of the site in question, including:

- geological model,
- geohydrological model,
- groundwater chemical model,

- geomechanical model,
- heat transport model,
- radionuclide transport model.

These models are compiled in conjunction with a site investigation and present an aggregate of existing knowledge on a site.

On Äspö, geoscientific information has been systematically collected during the pre-investigation and construction phases. Data continues to be collected from the various tests and projects that are being conducted. The information that has been gathered up to now and including completion of the main tunnel down to a level of 450 metres has been used to devise site-specific models of the conditions on Äspö. The models contain dimensionality, material properties, method for specification of properties in the whole model, boundary conditions, numerical or mathematical tools, and what parameters the model depicts (Olsson et al., 1994). Structure and content are described in greater detail in Rhén et al. (1997). The purpose of constructing these models has primarily been to verify our ability to foresee the properties of a rock mass on the basis of information from completed site investigations.

The existing geological, geohydrological and groundwater chemical models of Äspö will gradually be revised, particularly in the light of the new information that is constantly obtained from the projects described later. A test plan for this modelling exercise, which is given the name GeoMode, was presented in June 1999. The rock mass to be modelled cover the last tunnel spiral from the level of 340 m down to 460 m.

A heat transport model and a radionuclide transport model will also be developed but outside the GeoMode project.

Objectives

The aim of the project is to develop tools for constructing geological, geomechanical, geohydrological and groundwater chemical models as a basis for the different experiments to be conducted at Äspö HRL. The specific objectives are to:

- describe the rock volume in the last tunnel spiral
- define the initial and boundary conditions of importance to the different experiments
- integrate the knowledge for the different disciplines
- develop and refine tools for the model construction

The main goal is to construct an integrated model by June 2001. The individual geological, geomechanical, geohydrological and groundwater chemical models should be presented in June 2000. Necessary tools for input and visualisation of data, e.g. RVS and SICADA, should be further developed until September 2000.

Results

A definition of the boundary conditions for the different subjects has been performed. A screening of data for the different subjects has also be performed. The first visualisation mainly in chemistry has started up. RVS version 2.1 has been taken into operation. A decision has been taken to cancel the GeoMode project in favour to the site characterisation programme.

Planned work

No more work within the GeoMode project will be conducted.

3 Test of models for description of the barrier function of the host rock

3.1 General

The Natural Barriers in the deep geological repository for radioactive wastes are the bedrock, its properties and the on-going processes in the rock. The function of the natural barriers as part of the integrated disposal system can be presented as *isolation, retention* and *dilution*. The common goal of the experiments within Natural Barriers is to increase the scientific knowledge of the safety margins of the deep repository and to provide data for performance and safety assessment calculations. The strategy for the on-going experiments on the natural barriers is to concentrate the efforts on those experiments which results are needed for the planning of the future candidate site investigations, planned to start in 2002. For this focus there is also a need to involve experts of the different geoscientific disciplines into the on-going experiments in order to make them familiar with the work and quality procedures adopted.

Isolation is the prime function of the repository. It is obtained through the co-function of the engineered and the natural barriers. For deep geological disposal, the flow of water to the canister/waste containment is largely determining the magnitude at which the corrosion and the dissolution of the waste form can take place. For a good isolation it is thus necessary to minimise the groundwater flow to the waste containment. Additional conditions that affect the isolation are the chemistry of the groundwater and the mechanical stability of the rock.

Conceptual and numerical groundwater flow models have been developed through the entire Äspö project up to now. During 2000 focus is on further development of the numerical tools used for groundwater flow and transport calculations.

Hydrochemical stability and potential variability is assessed within several ongoing projects. These aim at explaining possible chemical conditions in a repository host rock based on assumption of different climate conditions in the future. The project will be reported during year 2000. Input to this reporting is provided from EQUIP, TASK#5, REX, Matrix Fluid Chemistry and other experiments. Some of these have not been completed yet. For instance the characterisation of the chemistry of water in the pores and micro fractures.

The *retention* of radionuclides dissolved in groundwater is the second most important barrier function of the repository. Retention will be provided by any system and process that interacts with the nuclides dissolved in the groundwater when eventually the water has come in contact with the waste form and dissolved radionuclides. Retention is provided by the physical and chemical processes, which occur in the near-field and far-field. Some elements are strongly retarded while others are escaping with the flowing groundwater. The major emphasis in the safety assessment calculations has therefore been on the weakly retarded nuclides even if they are not dominating the hazard of the waste.

Tracer tests are carried out within experiments in the TRUE-projects. These are conducted at different scales with the aim of identifying detailed scale (5m) and block scale (50m) flow paths, retention of weakly and moderately sorbing tracers and the effect of matrix diffusion. During 2000 the goals are to complete the experimental part of TRUE Block Scale and to start the Long Term Diffusion Experiment (LTDE). Modelling of the experiments is done by several groups associated to the Äspö Task Force for modelling of groundwater flow and transport of solutes.

CHEMLAB experiments are conducted with the moderately and highly sorbing nuclides. Experiments are carried out in simulated near field conditions (bentonite) and in tiny rock fractures. During 2000 experiments including effects of radiolysis will be carried out in the CHEMLAB 1 unit. In the CHEMLAB 2 unit experiments using actinides will be started.

Colloids could affect the transport of radionuclides in the case these exist in a high enough concentration. The investigations made at Äspö and elsewhere give a concentration that it is not possible to detect. That concentration has no impact on the transport of radionuclides. New findings of colloidal transport and the existence of more sensitive instruments are the reasons for a new programme on different aspects of colloid transport.

Microbes are of particular interest since they can directly influence the chemistry of the groundwater, and indirectly transport nuclides attached to them. For continuing the basic studies of the microbes in the Äspö laboratory, a site has been allocated in the J-niche at 430 m dept.

3.2 Tracer Retention Understanding Experiments

Background

The safety of a KBS-3 type repository relies heavily on the engineered barrier system that contains the waste. In the case that the engineered barrier fails, the geosphere provides the remaining waste containment. Realistic estimates and predictions of transport times through the geosphere and release rates to the biosphere are thus critical for any safety assessment. Of particular interest in this regard is the rock adjacent to the canister holes and storage tunnels.

The plans for tracer experiments outlined in the SKB RD&D Programme 92 comprised experiments in the Detailed and Block Scales. The experiments in the Detailed Scale consisted of three; Pore Volume Characterisation (PVC), Multiple-Well Tracer Experiment (MWTE), and the Matrix Diffusion Experiment (MDE). During 1994 detailed Test Plans were prepared for MWTE and MDE. Following review and evaluation the SKB HRL Project management decided to integrate the Detailed and Block Scale experiments within a common framework. This framework is described in a "Program for Tracer Retention Understanding Experiments" (TRUE) (Bäckblom and Olsson, 1994). The basic idea is that tracer experiments will be performed in cycles with an approximate duration of 2 years. At the end of each tracer test cycle, results and experiences gained will be evaluated and the overall program for TRUE revised accordingly.

The general objectives of the TRUE experiments (Bäckblom and Olsson, 1994) are;

- Develop the understanding of radionuclide migration and retention in fractured rock.

- Evaluate to what extent concepts used in models are based on realistic descriptions of rock and if adequate data can be collected in site characterisation.
- Evaluate the usefulness and feasibility of different approaches to model radionuclide migration and retention.

3.2.1 TRUE-1

Final reporting

The final report of the First TRUE Stage will be filed early April.

Complementary analysis of site-specific material in the laboratory

Complementary laboratory investigations using feature A site specific material has been performed and was reported at Task Force Meeting TF#13 in Carlsbad in February. The work presented included;

1) Detailed porosity and diffusivity measurements of Feature A mylonite and altered diorite (KXTT2)

2) Penetration profile studies of the KXTT1 sample, exposed to through diffusion experiment for 3 years

3) Porosity homogeneity and distribution studies using the 14C-labelled MMA impregnation (KXTT3).

1) For the first investigation a sample has been sawed into two parts, altered Äspö diorite (Thickness D=8 mm) and a mylonite sample (D=8 mm), the latter being closest to the fracture surface. The mylonite slab broke in two halves, an outer (D=5 mm) and an inner sample (D=3mm). The water saturation porosities for the three samples are 0.33, 0.54 and 0.41 % (vol), respectively. A "neighbour sample" to the mylonite samples show a porosity of 0.97 %. These samples have also been cast in through diffusion cells and HTO through-diffusion tests similar to those described by Byegård et al. (1998) have been run. Subsequent analysis with homogeneous and heterogeneous model assumptions has shown that a) with a fixed porosity and fitting D_e, only the late time parts agree with the experimental curves. The D_e values are reasonable, b) with simultaneous fitting of porosity and D_e, a good fit is obtained for the complete curve, but the fitted porosities are an order of magnitude too low, c) with fixed porosity and fitting D_e and σ_{De}, the diffusivities are to low, somewhat covered by the relatively high standard deviations of De. In the case of the outer mylonite, the standard deviation is 10.

2) The diffusion cell from KXTT1 which has been exposed to tracer for a period of 1140 days (3 years), has been cut and sliced in a sequential matter to obtain a penetration depth profile. The tracers remaining in the core sample are Na-22, Cs-137 and Ba-133. Each unveiled surface has been photographed and has been subject to autoradiography. Apart from a cutting perpendicular to the axis of diffusion, the sample has been cut along the axis of diffusion.

3) ^{14}C-labelled metamethylacrylate (MMA) has been used to impregnate an intact drillcore sample from KXTT3 (Feature A). The impregnated drillcore is irradiated

with high dose γ-radiation to polymerise the MMA. Subsequently, sawing of the impregnated rock sample has been performed and the porosity, and porosity distribution has been measured by auto-radiography, followed by digital imaging.

The resulting visualisations (photographs with associated autoradiographs and binary mapping of porosity intervals), clearly map increased porosity along the rim zone of Feature A. It should also be mentioned that an individual band of increased porosity also is visible a few cm:s away from the surface in horizons sub-parallel to the fracture surface. Assessment of porosity in a profile perpendicular to the fracture surface show a gradual decrease porosity from about 1-1.3 % in the first 0.3 cm, to about 0.1 % at D=0.5 cm, after which the porosity remains constant to about 1 cm depth. The binary imaging of porosity distribution indicates porosities as high as 2.5%.

3.2.2 Long term Diffusion Experiment (LTDE)

Background

The Long-Term Diffusion Experiment is intended as a complement to the *in-situ* dynamic experiments and the laboratory experiments performed within the TRUE Programme.

The objectives of the planned experiment is to ;

- To investigate diffusion into matrix rock from a natural fracture in situ under natural rock stress conditions and hydraulic pressure and groundwater chemical conditions .
- To obtain data on sorption properties and processes of some radionuclides on natural fracture surfaces
- To compare laboratory derived diffusion constants and sorption coefficients for the investigated rock fracture system with the sorption behaviour observed in situ at natural conditions, and to evaluate if laboratory scale sorption results are representative also for larger scales.

The updated test plan presents an experimental concept centred on establishment of an experimental (large diameter) borehole which exposes a fracture surface. This fracture surface is packed off with a cap, similar to the one used in the REX experiment, cf. Figure 3-1. The intention is to establish an experimental chamber in which a tracer solution is circulated over a period of four years. Performed scoping calculations using available diffusivity data indicates that axial diffusion will range from mm:s for the strongly sorbing tracers to dm:s for the weakly sorbing tracers considered. Apart from tracers used in the TRUE-1 experiment, also PA-relevant tracers (^{99}Tc, ^{237}Np and ^{241}Am) are being proposed. The principal feat of the experiment is to establish axial diffusion from a natural fracture, through the rim zone of fracture mineralisation and alteration, into the unaltered rock matrix, without any advective component (towards the tunnel). This is resolved using a multi-packer system which effectively shields off the gradient. In addition, an intricate pressure regulation system is devised which will effectively allow the pressure in the experiment chamber to adapt to the ambient conditions without causing pressure differences, and hence no advetive transport. The reference pressure is obtained from a packed-off pilot borehole in the immediate vicinity of the large diameter experimental borehole. The former borehole has also been used to identify the target fracture to be investigated.

The characterisation of the large diameter borehole includes ia. measurements with various electrical geophysical logs (resistivity). The idea being to enable coupling between the electrical resistivity and diffusivity. In addition the core will be analysed using mineralogical, petrophysical and geochemical methods.

During the period a formal decision has been taken by SKB to run LTDE as laid out in the developed test plan for the project.

A suitable target fracture has been identified in borehole KA3065A02 at a depth of 9.81 m. This structure constitutes a chlorite splay (141/81) to a main fault, the latter on which slicken lines on the surface are evident. It shows mylonitic character in diorite/greenstone with an increasing alteration towards the fault centre. The total inflow at this zone is about 16 l/min. The target structure constitutes the lower fringe of the zone and is followed by a long > 0.5 m long intact piece of Äspö diorite.

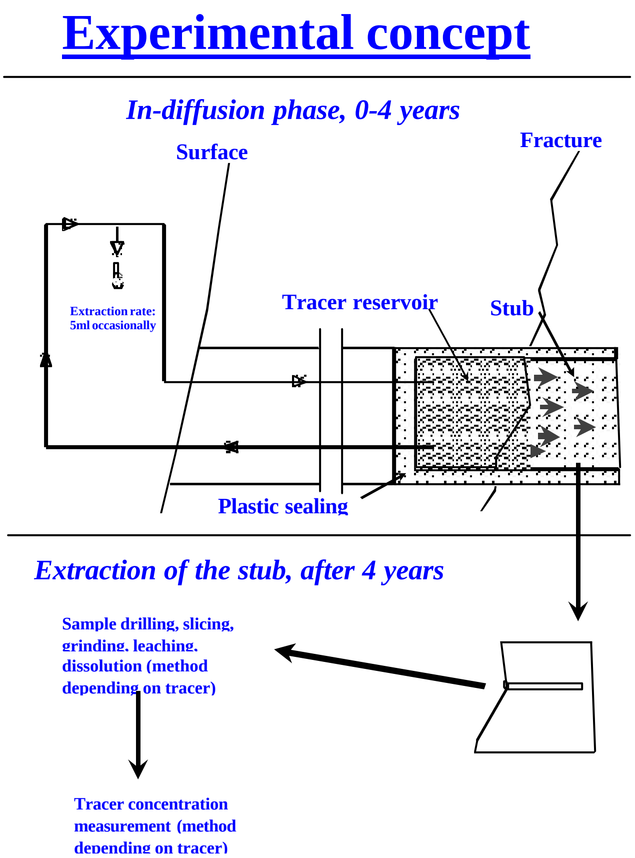


Figure 3-1 *Schematic of LTDE experimental concept including injection borehole in contact with a fracture surface, combined with excavation and penetration profile studies*

Construction and manufacturing of prototypes of downhole borehole and sampling and monitoring equipment has been initiated. Samples of the proposed material used for the downhole equipment (PEEK and polyurethane) have been analysed at CTH-Nuclear Chemistry in Gothenburg to characteristics and possible influence on the experiment. As a result CTH have confirmed usage of the tested materials for the sealing. A mock-up borehole has been manufactured of a steel tube trying to imitate the inner part of the borehole involving the core stub. The sealing rubber has been manufactured and tested in a mock-up borehole. The final construction, manufacturing and testing are going to be done when the actual geometry of the stub in the LTDE borehole is known.

A tentative geometry for the planned telescoped (300mm/200mm) large diameter borehole, KA3065A03, has been derived using a RVS model of the target rock volume.

Results

During the period the telescoped borehole, denoted KA3065A03, has been drilled parallel to the pilot borehole KA3065A02, cf. Figure 3-2. Drilling with 300 mm (280 mm core) was made to a depth of 9.25 m. After grading at the end of the borehole and preparation conical transition portion, the borehole was continued with 196.5 mm (177 mm core) down to a depth of 10.40 m. The drilling of the telescoped borehole has been performed with a strong element of interactivity on site using characterisation (borehole imaging) data and structural modelling based on the RVS system. The structural and geological model was successively updated and the projected depth to the target structure adjusted accordingly. Overall, the correspondence between the predictions and outcomes are good, with the exception of the innermost parts of KA3065A03. Follow up of the predictions was here also partly impaired by degassing which produced poor visibility BIPS images. This in combination with an apparent convergence of structures seen in KA3065A02 resulted in a stub, which is about 0.16 m long. This should be compared with the desired 0.05 m stub.

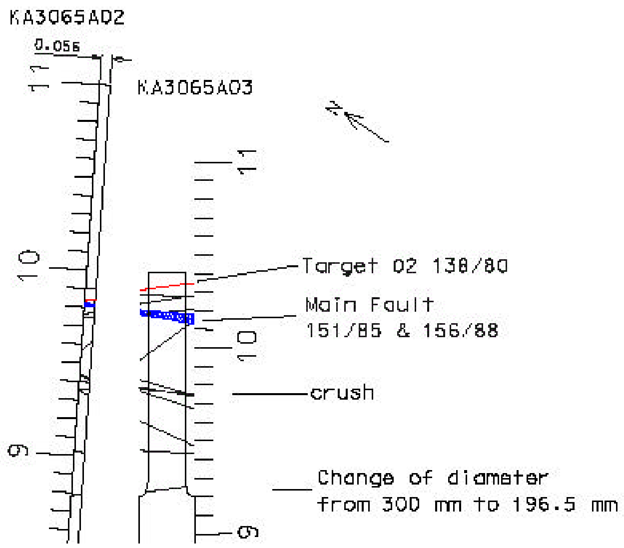


Figure 3-2 *Plan view of 76 mm pilot borehole KA3065A02 and telescope drilled large diameter (300/196.5 mm) borehole. Structures interpreted in pilot borehole projected onto large diameter borehole.*

In order to check up on the competence of the remaining stub and to check whether a partly sealed target structure is contained in the stub, borehole endoscopy with a 6 mm camera head was conducted in the 9.75 mm slot at 7 stations (linear profile along the stub perimeter) around the perimeter of the stub. In addition a remote-controlled vehicle with a movable camera head was run in the borehole to inspect water leakage and to inspect the surface of the stub. The surface has also been surveyed geodetically using a laser instrument. The conclusion is that the surface is irregular in relief and exposes a variety of surficial fracture minerals, including calcite, chlorite and Äspö diorite. The "mate of the stub" is partially broken but has partially been reconstructed. The reconstructed stub will be used for geochemical and thin section analyses.

Plans for further work

Structural modelling of the area in the close proximity of the target structure reconciling the difference between the projected model and the outcome, including a detailed description of the stub. The remaining characterisation work in the borehole will be completed.

In order to finalise the design of the borehole equipment, packer locations and number of packers will be decided. Further, an attempt will be made to produce a cast imprint of the stub relief, in order to customise the shape of the PEEK lid which will connect to the cylindrical packer made of polyurethane.

A customised container will be devised to host the regulation and sampling equipment. Various components of the regulation and sampling equipment will be tested in the laboratory.

An application for a permit to use selected radionuclides will be prepared.

3.2.3 Second TRUE Stage (TRUE-2)

The TRUE-2 experiments will be postponed indefinitely awaiting the outcome of the TRUE-1 seminar this fall and the outcome of the TRUE Block Scale Experiment. The outcome of these activities will be used to make research priorities in light of the upcoming site characterisation programme.

3.2.4 TRUE Block Scale

Background

Work on the TRUE Block Scale Project started in mid 1996. This subproject of TRUE broadens the perspective from an address of a singular feature in TRUE-1, to flow and transport processes in a network of fractures and a spatial scale between 10 and 50m. The specific objectives of the TRUE Block Scale Project are to;

1) increase understanding and the ability to predict tracer transport in a fracture network,

2) assess the importance of tracer retention mechanisms (diffusion and sorption) in a fracture network,

3) assess the link between flow and transport data as a means for predicting transport phenomena,

A set of desired experimental conditions have been defined and a flexible iterative characterisation strategy has been adopted. The project is divided into a five basic stages;

- Scoping Stage
- Preliminary Characterization Stage
- Detailed Characterization Stage
- Tracer Test Stage
- Evaluation (and reporting) Stage

The total duration of the project is approximately 4.5 years with a scheduled finish at the end of the year 2000. The project was originally organised as a multi-partite project involving ANDRA, NIREX, POSIVA, and SKB. During 1997, also ENRESA and PNC have joined the project.

During 1997, two boreholes, KI0025F and KI0023B, have been drilled using the triple-tube method from the I-tunnel at L=3/510 m in the access tunnel. These boreholes, 75 mm in diameter, are gently inclined (I=20 degrees) and complement the existing 56 mm boreholes, KA2511A and KA2563A, the latter drilled as a pilot borehole as part of the TRUE Block Scale Scoping Stage. The latter boreholes have been drilled with a higher inclination from a higher elevation in the laboratory. The boreholes have been characterised using different geological, geophysical and hydrogeological methods. Based on the collected data the structural model of the block has been updated sequentially.

During 1998 the Preliminary Characterisation Stage was concluded with elaborate cross-hole interference tests which involved all available boreholes in the investigated rock block. The primary aim of the tests was to investigate the hydraulic connectivity with the block, and specifically the existence, relative role of northeasterly and subhorizontal structures. In addition the tests involved performance of tracer dilution tests in selected test sections, whereby not only the drawdown due to an applied disturbance was obtained, but also the change in flow rate through the selected sections. One of the pumpings was driven long enough to study breakthrough of tracer.

The cross-hole interference data together with 3D seismic data were used together with data from KI0023B to produce the September 1998 structural model update.

During the Fall 1998 another borehole, denoted KI0025F02, was drilled as part of the Detailed Characterisation Stage from the I-tunnel, between KI0023B and KI0025F, was characterised and completed. In this hole the POSIVA flow log was used for the first time in the project. In addition a series of short time cross-hole interference tests and associated tracer dilution tests were performed.

The status of the project per November 1998 was presented at the 2nd TRUE Block Scale Review Seminar held Nov 17, in Stockholm. At this meeting, apart from presenting a conceptual model of groundwater flow, the project group also presented their tentative strategy for upcoming future tracer tests.

During the Spring of 1999 an intensive planning effort has been conducted which has resulted in definition of the important issues of the planned future tracer tests. A set of hypotheses related to the issues of conductive geometry, heterogeneity and retention have been put forward in a Tracer Test Programme. Further design calculations related to the effects of fracture intersections have been performed. In addition, a series of Pre-tests, in essence a series of three interference tests with associated tracer dilution tests have been performed. As a final field activity a multi-injection tracer test was performed which demonstrated breakthrough from four out of four injection sections, two of which showed high recovery in pathways involving multiple structures (>1)). The Tracer Test Programme also defines a tentative strategy for the future tracer tests which will be conducted in three consecutive phases, A through C. The first Phase, A, is a test of alternative sink sections, combined with complementary tracer dilution tests. Phase B will focus on the selected sink section, tests over both short and longer distances. Initiation of tests with weakly sorbing tests over longer distances and He may be foreseen towards the end of Phase B. The final phase, C, is fully devoted to tests with sorbing tracers.

A new 76 mm borehole, KI0025F03, was drilled in early August 1999 with the primary purpose of providing additional injection points for tracer, short flow paths for sorbing tracers and as a means of verifying the reconciled March'99 model. The projected locations of interpreted structures have largely been verified by observed structures and inflows in the borehole, as well as observed pressure responses in neighbouring packed-off boreholes.

After performed characterisation the borehole was packed off in 9 sections. Five sections are equipped to allow injection/abstraction of water and tracer. Two sections will be equipped with steel tubing to allow injection of He without risking diffusion through the lines.

During the Fall of 1999 drilling and characterisation was performed in the last of the boreholes, KI0025F03. Characterisation has included flow and pressure build-up tests with observation of pressure responses in the neighbouring boreholes. The qualitative interpretation showed responses consistent with the reconciled March'99 structural model. The borehole was subsequently instrumented with a multi-packer system consisting of 9 sections, two of which prepared with metal lines for injection of helium as a tracer.

Phase A of the Tracer test Stage involved use of two alternative sink sections, including about 70 tracer dilution tests and 8 tracer injections. The results of the tests, coassessed with existing results from previous tests, indicated that the sink in KI0023B shows the best prospects of producing breakthroughs with a high mass recovery. This sink will be performed in the subsequent Phase B which is includes demonstration of high mass recovery and test of helium as a tracer.

The Phase A tests have been preceded by model predictions using the existing DFN, Channel network and stochastic continuum models which has been updated with the March'99 structural model and all available information including the interference and tracer dilution tests which are part of the Phase A tests.

Results

Laboratory work

Material from ia the new borehole KI0025F03 has been sampled and will be analysed for chemical composition, uranium series, porosity. The results will be integrated with already ongoing analyses.

Phase A Tracer Test A-4

The injections were performed as decaying pulses during pumping in KI0023B:P6 (#21). In one injection (section KI0025F03:P5), the tracer solution was exchanged with non-traced water in order to shorten the tail of the breakthrough curve. The removal of tracer resulted in a reduction of about 90 % of the mass in the tracer injection loop.

Tracer breakthrough was detected in the sink section KI0023B:P6 from two of the three injections performed and the resulting breakthrough curves are presented in Figure 3-3. No breakthrough from the injection of Rhodamine WT in section KI0025F03:P7 was detected at pump stop after 165 hours.

Tracer mass recovery was for Amino-G Acid calculated in two different ways. Common for both methods was that the tracer mass recovered in the pumping borehole was determined by integration of the breakthrough curves for mass flux (mg/h) versus time (h). The injected mass was determined in the same way but also by weighing the tracer solution vessel during the injection procedure. In injection section KI0025F03:P5 (Uranine) a tracer exchange procedure was made. Unfortunately no samples were taken of the tracer solution exchanged why it is not possible to calculate the injected mass by weighing.

The mass recovery for Amino-G Acid calculated from integration is higher than the one calculated by weighing (Table 3-1). A large portion of the tail of the breakthrough curves still remains to be recovered, and it is therefore likely that the mass recovery would have increased by another 20-30 % in case the pumping had been prolonged.

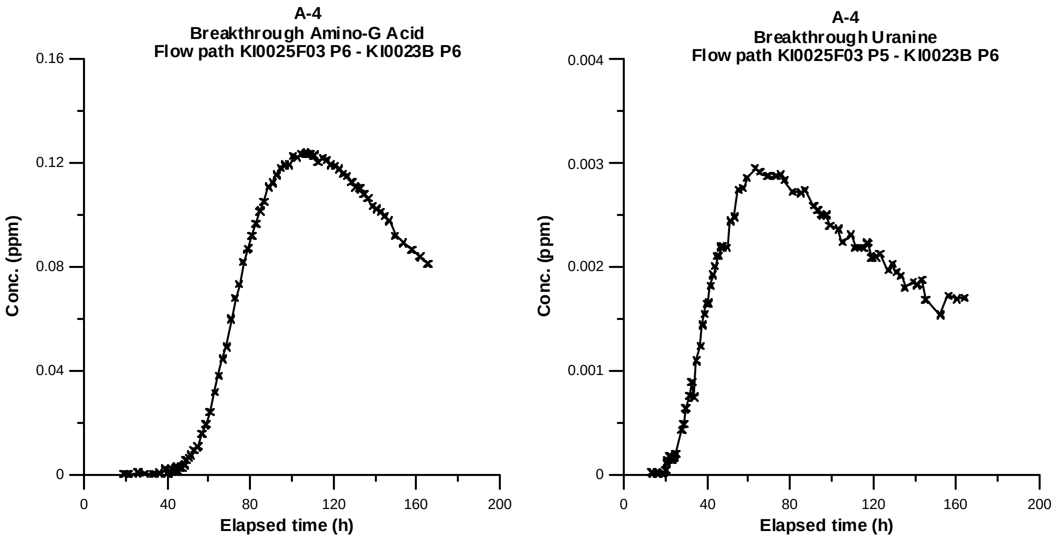


Figure 3-3 *Tracer breakthrough in KI0023B:P6 during test A-4. Note that the axis scales differ between the plots*

Table 3-1. Tracer mass recoveries from pumping section KI0023B:P6 during test A-4.

Inj #	Section	Structure	Tracer	R_i (%)	R_w (%)	Sampling time (h)
1	KI0025F03:P6	22	Amino-G Acid	48	34	165
2	KI0025F03:P7	23?	Rhodamine WT	no bt	no bt	165
3	KI0025F03:P5	20	Uranine	38	-	164

R_i=recovery calculated by integration
R_w=recovery calculated by weighing

no bt= no breakthrough

Phase A tracer test A-5

In the case of test A-5 the breakthrough of tracer was monitored both in the sink section KI0025F03:P5 (#20) and in borehole section KI0023B:P7 where the short-circuit between structure #6 and #20 occurs. Tracer breakthrough in section KI0025F03:P5 was detected from four of the five injections performed and the resulting breakthrough curves are presented in Figure 3-4. The breakthrough and injection curves are also plotted together (as mass flux versus time, log-log) in the same plot in Appendix 1. There was no breakthrough detected from the tracer Uranine injected in section KI0025F02:P3. No tracer breakthrough was found in KI0023B:P7 during the pumping period.

The pumping was stopped on January 14th, 2000 after a pumping period of 38 days.

Tracer mass recovery was calculated similarly to what was done for test A-4. The mass recoveries calculated from integration were constantly higher than the ones calculated by weighing (Table 3-2). In one case, Naphtionate injected in KI0025F02:P5, the recovery calculated from integration was >100 % which is unrealistic. One explanation for this may be that a larger volume is injected in the section (5-10 ml/min) than it is possible to withdraw with the sampling equipment (1.67 ml/min). This creates an overpressure and tracer solution is pushed into the fracture and is never counted for in the samples and concentration measurements. The injected mass determined by integration is then underestimated resulting in too high figures of the mass recoveries.

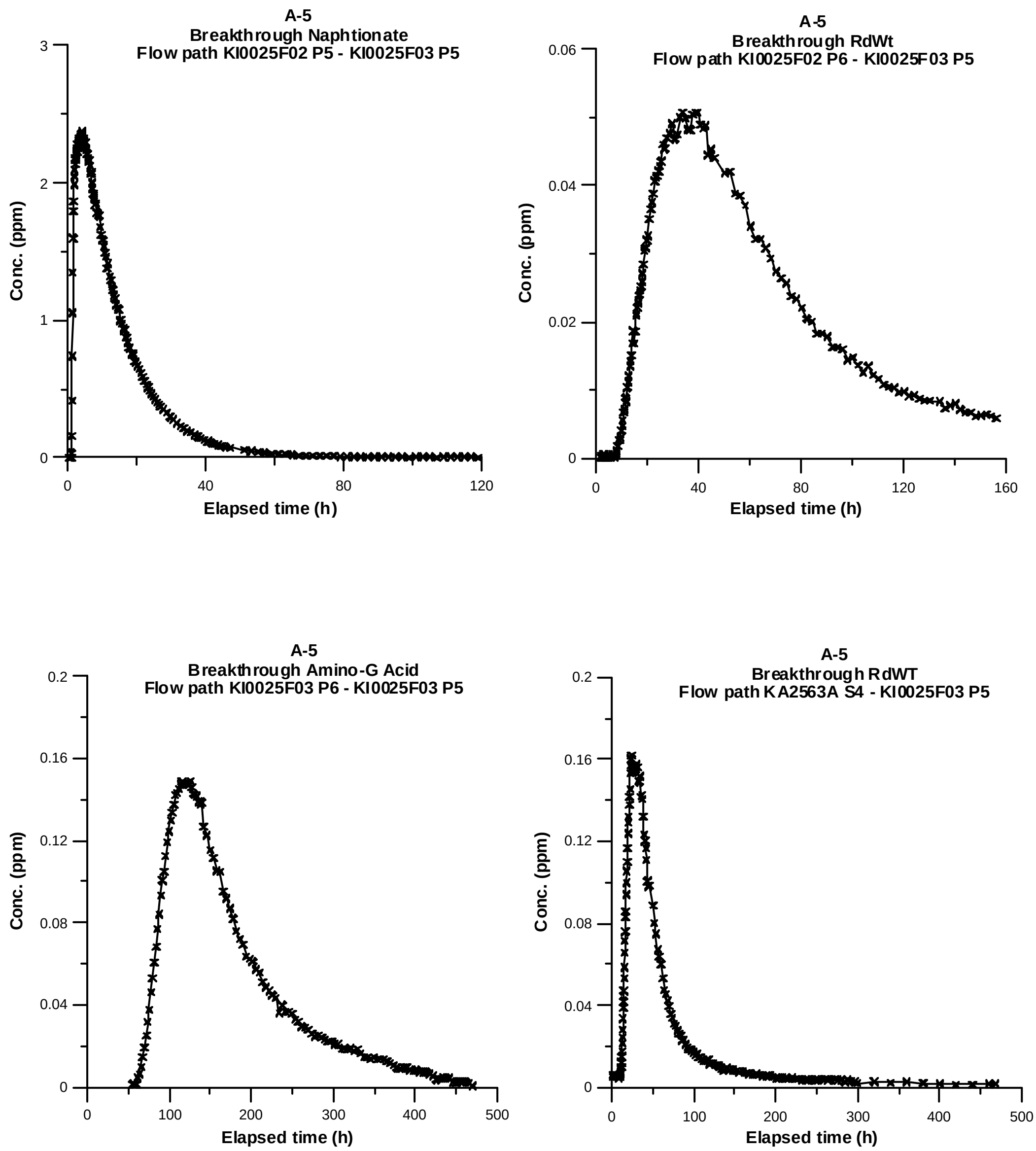


Figure 3-4 *Tracer breakthrough in KI0025F03:P5 during test A-5. Note that the axis scales differ between the plots*

The tracer mass recovery for Amino-G Acid (KI0025F03:P6) was, when calculated by integration, quite high, but was much lower when calculated by weighing. The mass recovery of Rhodamine WT from KI0025F02:P6 only reaches about 30-40 % . A portion of the tail of the breakthrough then still remains to be recovered though it is not likely the tracer mass recovery would have raised up to 100 %. The mass recovery of Rhodamine WT from KA2563A:S4 only reaches about 50-60 % which is in the same order as in the performed pre-test PT-4 (50 %). Finally, no breakthrough of Uranine from KI0025F02:P3 was detected when sampling stopped after 640 hours.

Table 3-2 Tracer mass recoveries from pumping section KI0025F03:P5 during test A-5.

Inj #	Section	Structure #	Tracer	R_i (%)	R_w (%)	Sampling time (h)
1	KI0025F02:P3	13,21	Uranine	no bt	no bt	639
2	KI0025F02:P5	20	Naphtionate	127	97	157
3	KI0025F02:P6	22	Rhodamine WT	41	27	156
4	KI0025F03:P6	22	Amino-G Acid	91	57	470
5	KA2563A:S4	20	Rhodamine WT	64	47	468

R_i=recovery calculated by integration
R_w=recovery calculated by weighing

no bt= no breakthrough

Phase B tracer tests B1

During the period, the second of the three phases of the Tracer Test Stage has been initiated. In this phase two pump rates are employed, starting off with a 50% reduced flow rate in KI0023B:P6 and following Phase B1 the maximum possible flow rate is used throughout Phases B2 and C. A difference compared to previous tests is that dipole flow geometry is employed, this to effectively enter the tracer into the fracture. In addition, helium (He-3) dissolved in water is used for the first time as a conservative tracer with a high diffusivity relative to eg. Uranine, enabling demonstration of matrix diffusion.

The test geometry, tracers and pump rates used in the first three tracer injections (B-1a, b and c) are listed in Table 3-3. After testing the pressure responses resulting from different injection rates it was decided to increase the injection rates in the two first test to 50 and 20 ml/min, respectively, compared to the originally planned 10 ml/min.

Table 3-3. Performance of Phase B-1 tracer tests. The structural interpretation and notation refers to the updated and reconciled March 2000 model (Doe & Hermanson, in prep). Distance within brackets are calculated along the structures.

Test #	Flow path	Structures	Flow geometry	Inj. Flow (ml/min)	Pump flow (ml/min)	Tracer	Distance
B-1a	KI0025F03:P5 – KI0023B:P6	20,21	Dipole	50	1200	Helium, Uranine	14 (16)
B-1b	KI0025F03:P6 – KI0023B:P6	22,20,21	Dipole	20	1200	Amino G	15 (73)
B-1c	KI0025F02:P5 – KI0023B:P6	20,21	Dipole	10	1200	RdWT	21 (21)

The performance of the tests has been disturbed by problems with the injection pumps used for creating the dipole flow. A serious experimental problem also occurred when tracer breakthrough of Uranine from a previous injection during Phase A (A-5) in KI0025F02:P3 was detected.

The analysis of the tracer breakthrough is ongoing. The injection of Helium shows a fast first arrival of about 6.5 hours and a peak around 35 hours with about 90% mass recovery after one week (168 hours). The breakthrough from injection in KI0025F03:P6 is significantly slower with a first arrival of about 45 hours, a peak around 110 hours. The breakthrough from KI0025F02:P5 also shows a fast first arrival of about 14 hours and a peak also around 110 hours. Analysis of the input function and mass recovery is ongoing.

Tracer tests Phase C

During the period preparations have been started up to prepare the site for the planned tests with radioactive sorbing tracers. This includes dressing of two containers for injection and pumping and layout of the site in zones including fencing in of the respective zones. An application to the Swedish Radiation Protection Board (SSI) has also been prepared for use of radioactive sorbing tracers.

Structural model update

The Phase A tracer tests provided additional information concerning the hydraulic connectivity of the TRUE-Block Scale rock block, which provided the basis for clarifying a number of issues. The updated model include a) removal of the hydraulic connections provided by sub-horizontal features, b) Dividing Structure #13 into two distinct hydraulic units, without hydraulic connection between them, and c) adding a new deterministic structure, #23.

Numerical modelling

Stochastic Continuum Model

In the first three months of 2000 the modelling work focused on an improved characterisation of the TRUE Block Scale site. The results from the characterisation were used in the prediction of the breakthroughs of the Phase A tests. The outcomes of the predictions were evaluated in relation to the in situ results by the modelling groups from Valencia and Barcelona and actions were made in order to overcome problems encountered during the Phase A predictions. Moreover, preparations started for the next modelling step.

The inverse modelling of groundwater flow in the Block Scale rock volume continued along the same lines as employed during 1999. No fundamental changes in the model were imposed. The conditioning was extended to comprise eight simulations. Seven simulations were also conditioned to five short-term transient hydraulic tests. One simulation was conditioned to the results of the Phase A1, A2 and A3 tests. Compared with the initial simulations the main improvements are a good reproduction of the experimental head data and to transient head information. It is interpreted that the new structural model (March '99) (especially the introduction of Structures 21 and 22) helped in improving the fit between the measured and simulated heads

The single realisation which was the most conditioned to head information was used to predict the (transient) head responses to the Phase A4 and A5 tests. The obtained results (calibrated conductivities, calibrated boundary conditions, structural model and prediction results of A4 and A5) were subsequently supplied to the UPC modelling team for modelling of transport.

The UPC transport model includes the structures 5, 6, 7, 8, 13, 15, 18,19, 20, 21 and 22. The conductivity values obtained by the UPV simulation have been transformed to the finite element grid of the transport model. In addition, the prescribed heads at the boundary are also taken from a simulation of the flow with the corresponding flow rates for each test. As there is a large uncertainty in transport parameters, we employed for predictions the parameter values obtained from the calibration of one of the PT-4 tracer tests. The final finite element grid consists of 4620 nodes and 11869 elements, whose size ranges approximately between 8 m3 and 400 m3.

In the cases where the in situ tests showed no recovery (two cases), the simulations showed a very small recovery (below detection limit). In the rest of the cases where recovery was seen in situ, differences are found in the peak time, but mainly in the recovery, which in general, is lower in the predictions than evaluated for the in situ tests (see two examples in figure 3-5).

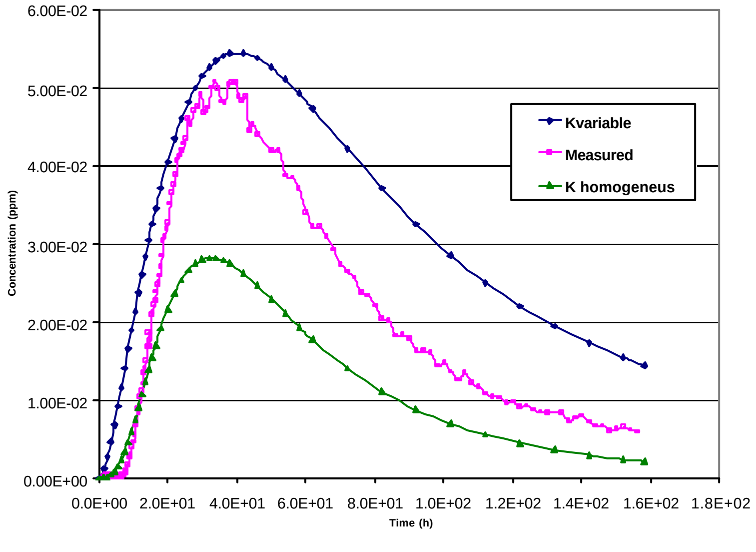


Figure 3-5 *UPV/UPC prediction. Graph showing a comparison between predicted and measured breakthrough for injection in KI002XX:P6 when pumping in KI00234B:P6*

DFN model

Predictive modelling for Phase A is now complete. Several models were employed to describe the uncertainty in the measured parameters. The models considered combine consideration of uncertainty in boundary conditions (two different boundary conditions), and uncertainty in variability of transmissivity on the fracture planes (two different geostatistical model were employed).

The evaluation phase of the work is under way with the calibration work performed using the results of the Phase A tracer test. An illustration of how this is progressing is illustrated in Figure 3-6. This shows one of the tracer tests in which the source section characteristics are dominated by the source. However, calibration, shown in red, has been achieved using only the effective property derived from the results of tracer test PT-4.

Channel Network Model

The JNC team DFN/CN model was updated to incorporate the "reconciled" March 1999 structural model (Doe, 2000). The model consists of 27 individual structural features (faults, fractures, gouge zones and greenstone belts) within the 150 m scale TRUE Block Scale region, together with stochastic/conditioned background fractures. Some of these larger structural features are assumed to extend to the 500 m scale model boundary conditions, which are based on reference values provided. The model was conditioned by matching the location and transmissivity of both numbered structures and background fractures to the results of Posiva flow logs, BIPS image logs, and packer tests, as applicable. The boundary conditions did not produce the correct values for head within the model. This is not an issue as long as drawdown is the focus of the analysis.

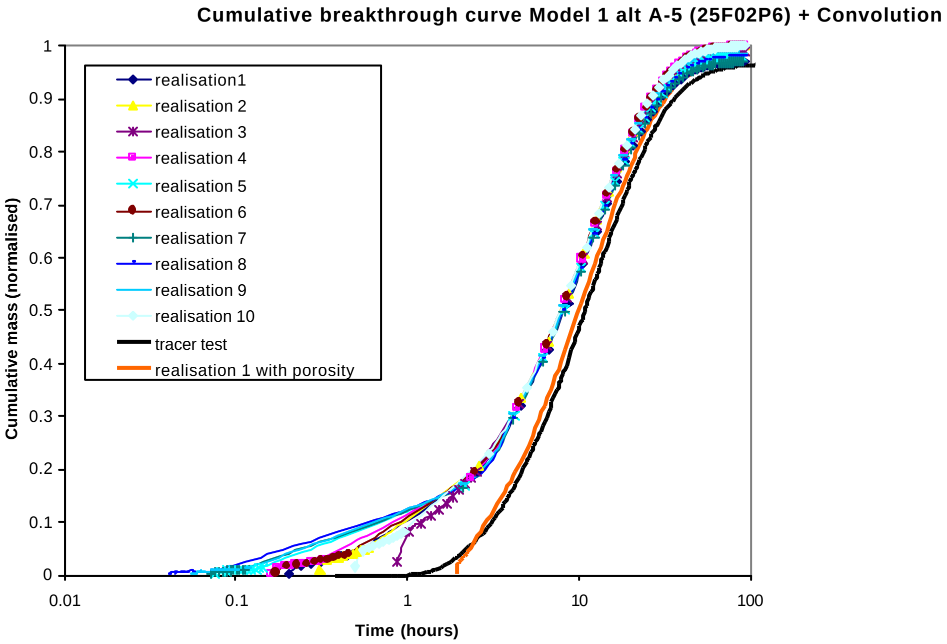


Figure 3-6 *Prediction of A5 (injection in KI0025F03) with effective property obtained from test A-4.*

The CN model was calibrated to results of pre tests PT-1, PT-2, PT-3, and PT-4, expressed in terms of distance-drawdown and breakthrough curves. The CN model was also calibrated to the distance-drawdown results of Phase A test A-4.

The model was used to predict tracer breakthroughs for tests A-4 and A-5. These predictions used the same basic properties which were successful (Cladouhos, 1999) in predicting tracer transport in "Feature A" at the TRUE-1 site in the northern part of the Äspö laboratory. The predictions included diffusion effects, but assumed that all tracers are conservative. No FIZ effects were included due to time constraints. Figure 3-7 illustrates the results of predictive modeling for test A-5.

The JNC/Golder team assisted in tracer test data during the reporting period. In particular, the JNC/Golder team examined the tracer responses from A-4 and A-5 tracer tests, and found evidence for a) longer travel time for pathways which may be related to fracture intersection zones, and b) greater dilution or loss of mass for pathways which may be related to fracture intersection zones. This may be consistent with the FIZ hypothesis of greater transport aperture along fracture intersection zones, as was found in a few of the FIZ sensitivity studies carried out during 1999.

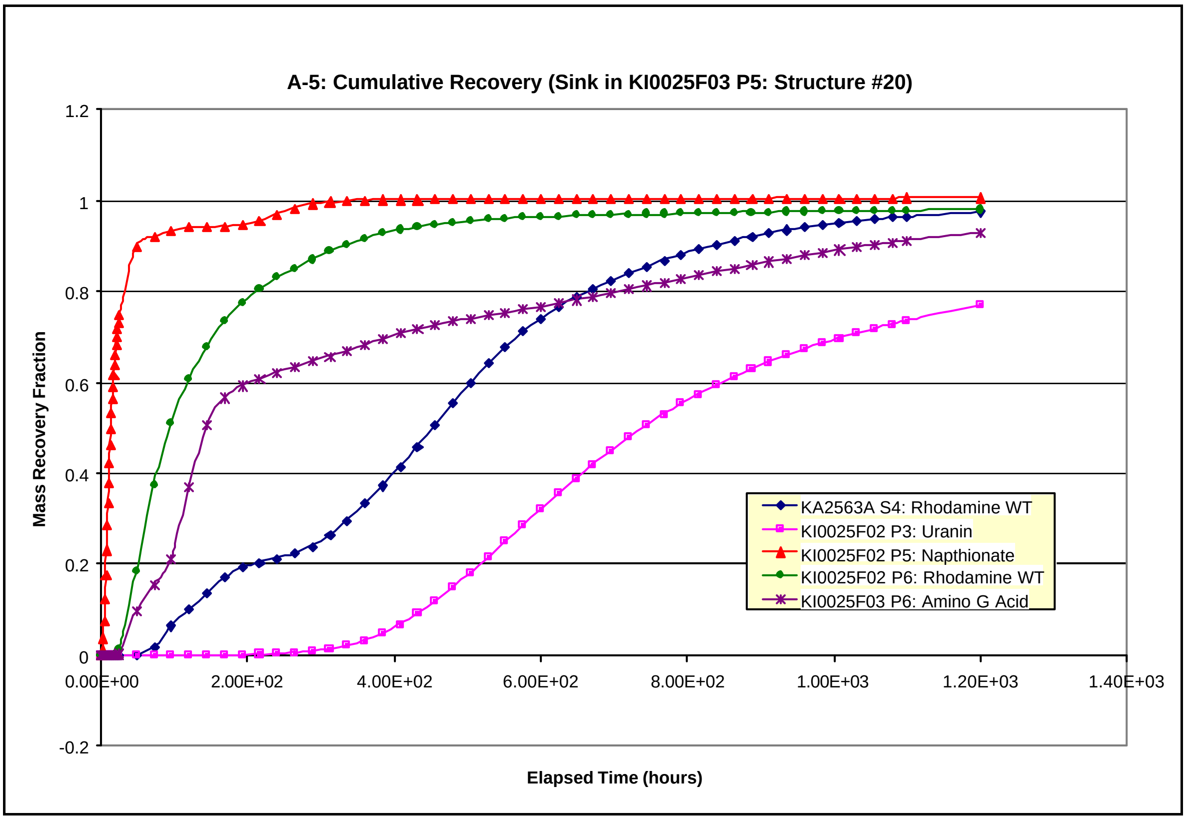


Figure 3-7 *JNC/Golder Channel Network Phase A Prediction for A-5 Tracer Test (Sink in Structure #20)*

Planned work

2nd quarter 2000

LTDE

- Site characterisation
- Preparation of site (container)
- Start up of laboratory work
- Application to SSI

TRUE Block Scale

Tracer Test Stage

- Performance of Phase B2 tracer tests
- Updating of models with Phase B results
- Preparation of site (zonation, fences etc.)
- Preparation for Phase C tests
- Permit from SSI

3.3 Radionuclide retention

Background

The retention of radionuclides in the rock is the most effective protection mechanism if the engineering barriers have failed and the radionuclides have been released from the waste form. The retention is mainly caused by the chemical properties of the radionuclides, the chemical composition of the groundwater, and to some extent also by the conditions of the water conducting fractures and the groundwater flow.

Laboratory studies on solubility and migration of the long lived nuclides e.g. Tc, Np, and Pu indicate that these elements are so strongly sorbed on the fracture surfaces and into the rock matrix that they will not be transported to the biosphere until they have decayed. In many of these retention processes the sorption could well be irreversible and thus the migration of the nuclides will stop as soon as the source term is ending.

Laboratory studies under natural conditions are extremely difficult to conduct. Even though the experiences from different scientists are uniform it is of great value to demonstrate the results of the laboratory studies in situ, where the natural contents of colloids, organic matter, bacteria, etc. are present in the experiments. Laboratory investigations have difficulties to simulate these conditions and are therefore dubious as validation exercises. The CHEMLAB borehole has been constructed and manufactured for validation experiments in situ at undisturbed natural conditions. Figure 3-8 illustrates the principles of the CHEMLAB 1 and CHEMLAB 2 units.

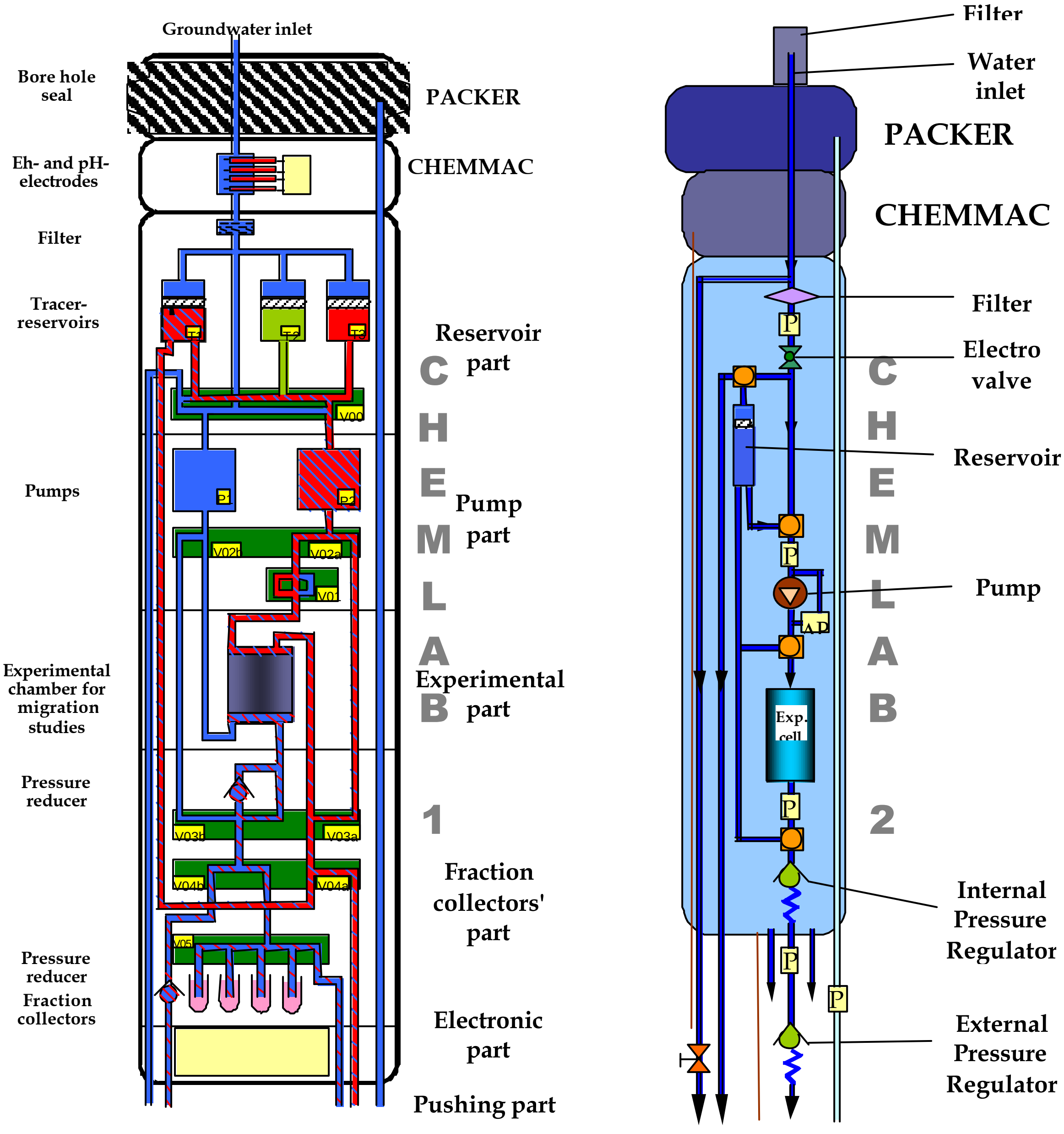


Figure 3-8 *Schematic illustration of CHEMLAB 1 and 2.*

Objectives

The objectives of the Radionuclide Retention (CHEMLAB) experiments are:

- To validate the radionuclide retention data which have been measured in laboratories by data from in situ experiments in the rock
- To demonstrate that the laboratory data are reliable and correct also at the conditions prevailing in the rock
- To decrease the uncertainty in the retention properties of relevant radionuclides

Experimental concept

CHEMLAB is a borehole laboratory built in a probe, in which migration experiments can be carried out under ambient conditions regarding pressure and temperature and with the use of the formation groundwater from the surrounding rock.

Initially one "all purpose" unit was constructed in order to meet any possible experimental requirement. This unit CHEMLAB 1 has been used for the "diffusion in bentonite" experiments and will now be used for similar experiments including the effects of radiolysis. Others to follow are:

- Migration from buffer to rock
- Desorption of radionuclides from the rock
- Batch sorption experiments

The CHEMLAB 2 unit is a simplified version of CHEMLAB 1, designed to meet the requirements by experiments where highly sorbing nuclides are involved. These are:

- Migration of redox sensitive radionuclides and actinides
- Radionuclide solubility
- Spent fuel leaching

New Results

The start of the radiolysis experiment in the CHEMLAB 1 probe was delayed due to technical malfunction of the equipment.

The first experiment to be carried out in CHEMLAB-2 is the migration of actinides, Americium, Neptunium and Plutonium, in a rock fracture. Planning and pre-testing is done by Institut für Nuklear Endsorchung in Karlsruhe. INE is also carrying out the experiment at Äspö in cooperation with SKB staff and Nuclear Chemistry at KTH.

The final reporting from the diffusion experiments is delayed due to difficulties in analyses of the Technetium profile in the bentonite plug. The report is expected to be available by the mid of 2000.

Planned Work

- Start of the actinide experiment in CHEMLAB 2
- Start of the radiolyses experiment in CHEMLAB 1

- Final report of the diffusion experiments

3.4 Two-phase flow

Background

The objectives for the investigations of degassing of groundwater and two-phase flow are:

- To show if degassing of groundwater at low pressures has significant effects on measurements of hydraulic properties in boreholes and drifts.
- To study and quantify other processes causing two-phase flow near excavations in regionally saturated rocks such as air invasion due to buoyancy and evaporation.
- To show under what conditions two-phase flow will occur and be significant. Conditions expected to be of importance are gas contents, chemical composition of groundwater, fracture characteristics (aperture distribution and transmissivities), and flow conditions.
- To get a measure of time scales required for resaturation of a repository.
- To develop technology for measurements of parameters under unsaturated conditions.

This knowledge is essential for understanding observations of hydraulic conditions made in drifts, interpretation of experiments performed close to drifts and performance of buffer mass and backfill, particularly during emplacement and repository closure.

In-situ testing of degassing and changes in hydraulic conductivity has been performed by measuring the inflow to a borehole at different pressures. Non-linearities in the flow-pressure relationship should be indicative of two-phase flow effects.

New results

A final summarising degassing report was prepared, synthesising and interpreting results from both experimental and theoretical degassing studies. Below follows new results from the interpretation of borehole experiments and drift observations.

Interpretation of borehole experiments

Table 3-4 shows the parameter values used in the modelling of the degassing experiments in boreholes (see further Section 3.2 of Jarsjö and Destouni, 1998, for a description of the degassing model). The values of the fracture boundary pressure p_{bound}, the borehole pressure during the degassing test p_{bh}, the bubble pressure p_b and the borehole radius r_w correspond to experimental conditions reported in Geller and Jarsjö (1995) and Jarsjö and Destouni (1997a). We have assumed radial flow conditions and a radius of influence R of 150 metres in all cases. We also assumed a standard deviation value of ln a ($s_{\ln a}$, where a denotes the fracture aperture) of 0.8 in all cases. This is within the range of standard deviation values for rock fracture apertures previously reported by Hakami (1995). Furthermore, we estimated the mean value of ln a ($m_{\ln a}$) on basis of measured fracture transmissivity values, through the cubic law.

Table 3-4 Parameter values used in the modelling of the degassing experiments in boreholes (Figure 3-9).

Experiment	r_w (mm)	R (m)	$m_{\ln a}$	$s_{\ln a}$	p_{bound} (kPa)	p_b (kPa)	p_{bh} (kPa)
SWT/P2[a]	28	150	-3.8	0.8	2000	160	36
SWT/P4[b]	28	150	-4.0	0.8	1000	121	115
DT/P4-P8[c]	28	150	-4.0	0.8	1000	957	107
PHT[d]	42.5	150	-2.2	0.8	3000	167	120

[a] Single-well test in borehole P2 (Jarsjö and Destouni, 1997a).
[b] Single-well test in borehole P4 (Jarsjö and Destouni, 1997a).
[c] Dipole test – boreholes P4 and P8 (Jarsjö and Destouni, 1997a).
[d] Pilot hole test in borehole KA2512A (Geller and Jarsjö, 1995).

Figure *3-9* shows that the modelled relative transmissivity values T_{rel} (i.e., the transmissivity under degassing conditions divided by the saturated transmissivity) agree well with the experimental observations in the different boreholes. However, some of the parameters used in the modelling of the relative transmissivity (Table 3-4) were based on rather rough and non site-specific estimates, such as the R-value and the $s_{\ln a}$-value. With the aim to investigate whether or not the model results shown in Figure *3-9* are sensitive to the assumed values of these parameters, and whether or not more general conclusions can be drawn regarding degassing effects in the vicinity of boreholes, we will in the following show more generally how the modelled relative transmissivity is affected by different plausible parameter values (given in Table 3-5). We then consider a range of parameter values that are relevant for rock fractures intersecting boreholes at depths between 20 and 600 metres (Table 3-5). We have furthermore used the borehole pressure during the degassing test p_{bh} as a reference point at 0 kPa and assumed a value of 0.2 for the model parameter α. It was previously shown that the model results are relatively insensitive to α, at least for values between 0.05 and 0.4. The results are furthermore not affected by the absolute values of the parameters r_w and R, but depend only on the ratio r_w/R.

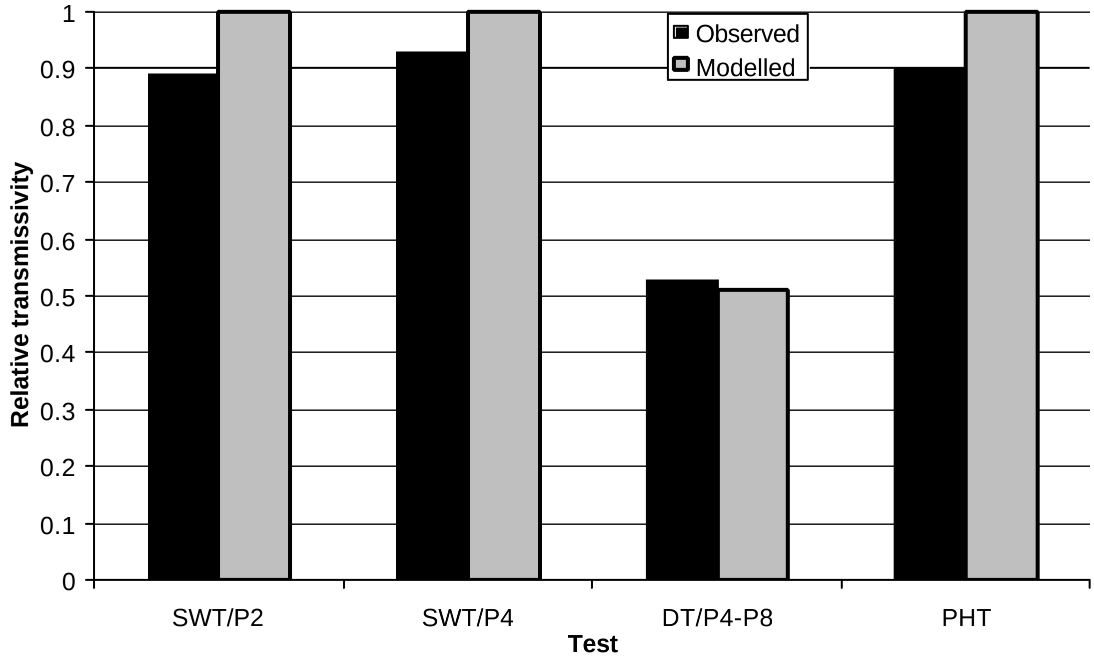


Figure 3-9 *Observed (black bars) and modelled (grey bars) relative transmissivities for the degassing experiments in boreholes*

Figure *3-10* shows the modelled relative transmissivity for the eight hypothetical cases listed in Table 3-5, as a function of the bubble pressure (normalised by the boundary pressure). The figure shows that the relative transmissivity curves are very similar for the different cases 1 to 8, which indicates that the model results are insensitive to the r_w/R, $m_{\ln a}$, $s_{\ln a}$ and p_{bound} values within the considered ranges. This also implies that the model predictions of the borehole tests (Figure 3-9) are robust for these parameter ranges.

As Figure *3-10* furthermore shows, the p_b/p_{bound} ratio (on the x-axis) considerably influences the relative transmissivity, but only if the ratio is relatively large (more than about 0.8). For values below 0.8, T_{rel} is close to unity and flow reductions due to groundwater degassing are negligible. Under natural conditions at the Äspö HRL, the gas contents at atmospheric pressure are relatively low, around 3% (sometimes even considerably lower). The gas consists mainly of nitrogen, implying bubble pressure values of about 260 kPa for a gas content of 3%. At 200 metres depth, the borehole pressure at no flow (or boundary pressure p_{bound}) is approximately equal to the hydrostatic water pressure of 2000 kPa. The above-mentioned p_b/p_{bound} ratio is hence around 0.13, which is far below the value of 0.8. Hence, based on both the borehole test observations and the consistent model predictions, we conclude more generally that groundwater degassing will not cause considerable inflow reductions in fractures intersecting open boreholes, under natural conditions.

Table 3-5 Parameters for the modelled cases in Figure 3-10. Numbers in bold indicate differences from Case 1.

Case	r_w/R	R (m) for r_w=0.03m	m_{lna}	s_{lna}	p_{bound} (kPa)	p_b (kPa)
1	$2{\cdot}10^{-4}$	150	-4	0.8	2000	0 to 2000
2	$2{\cdot}10^{-4}$	150	**-1**	0.8	2000	0 to 2000
3	$2{\cdot}10^{-4}$	150	-4	**0.2**	2000	0 to 2000
4	$2{\cdot}10^{-4}$	150	**-1**	**0.2**	2000	0 to 2000
5	$\mathbf{2{\times}10^{-3}}$	**15**	-4	0.8	2000	0 to 2000
6	$\mathbf{2{\times}10^{-5}}$	**1500**	-4	0.8	2000	0 to 2000
7	$2{\cdot}10^{-4}$	150	-4	0.8	**200**	**0 to 200**
8	$2{\cdot}10^{-4}$	150	-4	0.8	**6000**	**0 to 6000**

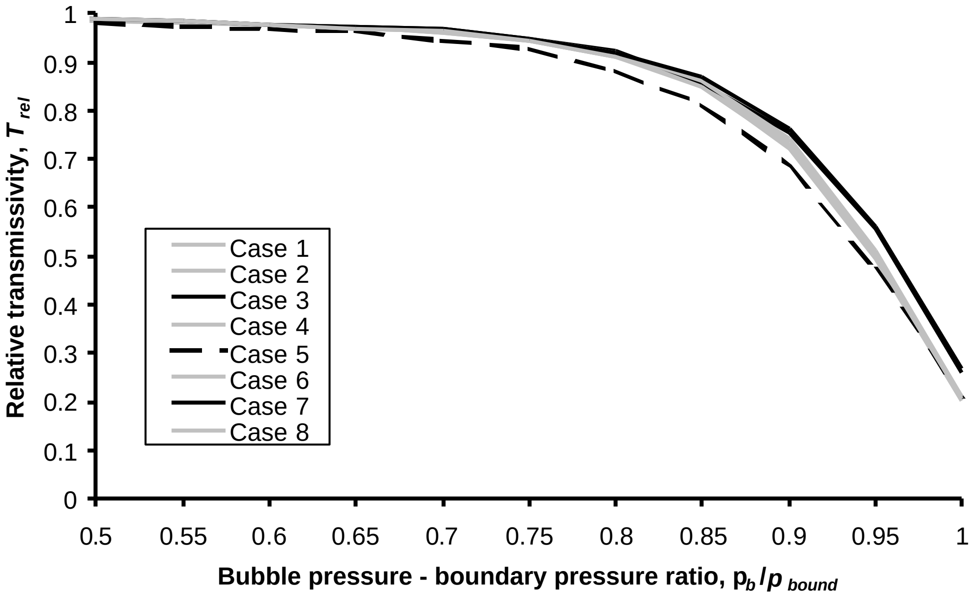


Figure 3-10 *Relative transmissivity as a function of the bubble pressure – boundary pressure ratio, for the different hypothetical fractures and boundary conditions listed in Table 3-5.*

Interpretation of drift observations

The relatively large inflow reductions observed during the Stripa simulated drift experiment (SDE; see Olsson, 1992) were possibly a result of groundwater degassing, although there were also other possible causes for the observed flow reductions. The gas content in the water was about 3% and the hydrostatic water pressure was 2300 kPa, implying a bubble pressure p_b of 260 kPa and a relatively low p_b/p_{bound} ratio (see previous section) of 0.11. Both experimental and model results show that degassing would not cause considerable transmissivity or flow reductions around boreholes for such a low ratio. In this section, we consider the different conditions that may prevail around drifts, and model the outcome of the Stripa SDE.

Drifts and tunnels intersect more fractures per unit length than boreholes. The hydraulic conditions in the vicinity of drifts and tunnels may be quite complex, with considerable variability in the hydraulic properties. Furthermore, as shown in Jarsjö and Destouni (1997b), the water pressures around drifts are typically significantly lower than those around open boreholes at the same radial distances. This implies that for a given bubble pressure, the extent of the low-pressure zone X_{low} (where degassing can occur; defined as the zone where the water pressure is lower than the gas bubble pressure) is considerably larger around drifts than around boreholes. Hence, a developed gas-containing zone is likely to be larger around drifts than around boreholes, which may affect the local conditions within that zone. For instance, a larger gas containing zone extent implies that less flowing volume of water is available per unit volume of gas, such that gas re-dissolution may take longer time as the pressures increase above the bubble pressure again.

Considering the above-mentioned differences between drifts and boreholes, we investigated

- the effect of increased variability in the transmissive properties, and
- the effect of slow gas re-dissolution

in the modelling of degassing around drifts.

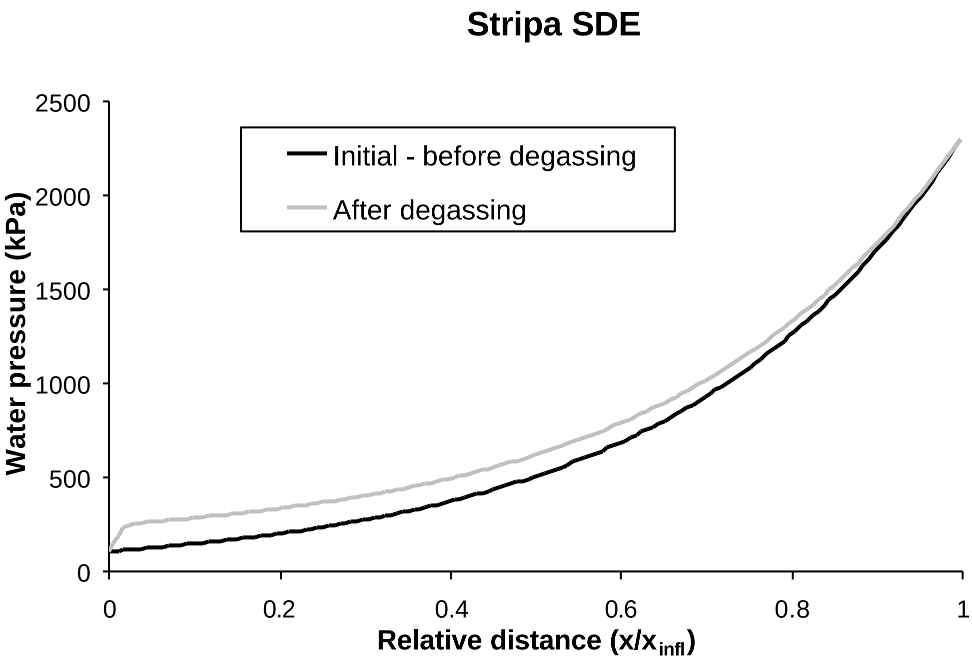


Figure 3-11 *Water pressures before groundwater degassing (black line) and after (grey line) as a function of the relative distance from the drift wall, located at $x/x_{inf}=0$. The modelled relative transmissivity was close to unity (0.94).*

We modelled the Stripa SDE, first assuming that the transmissivity was higher close to the drift wall than further away from the drift wall. We further assumed a fracture boundary pressure p_{bound} of 2300 kPa, a borehole pressure during the degassing test p_{bh} of 110 kPa and a bubble pressure p_b of 260 kPa, which is consistent with the experimental conditions reported in Olsson (1992). For this case, Figure 3-11 shows the modelled water pressures before groundwater degassing (black line) and after (grey line). The x-axis shows the relative distance x/x_{infl} from the drift wall, located at $x/x_{infl}=0$; x_{infl} is the distance to the outer boundary, at which water pressures no longer are influenced by the drawdown in the drift. The grey line indicates that the water pressure gradient is much steeper close to the drift wall after degassing. The reason is that the transmissivities are reduced locally close to the wall, due to the presence of a gas phase, for water pressures that are lower than the bubble pressure (of 260 kPa). Because of this steepness, the zone of reduced transmissivities is small (x/x_{inf}<0.033; Figure 3-11) and the effective, relative transmissivity T_{rel} for the whole domain (0<x/x_{inf}<1) is close to unity (0.94). The transmissivity reduction is hence negligible in this case. Similar results were obtained also for other assumptions than the above-mentioned regarding the variability of the transmissive properties of the rock mass. For instance, assuming a lower transmissivity close to the drift wall, we obtained a T_{rel}-value of 0.96. The results are in contrast to the Stripa SDE observations of considerable transmissivity reductions.

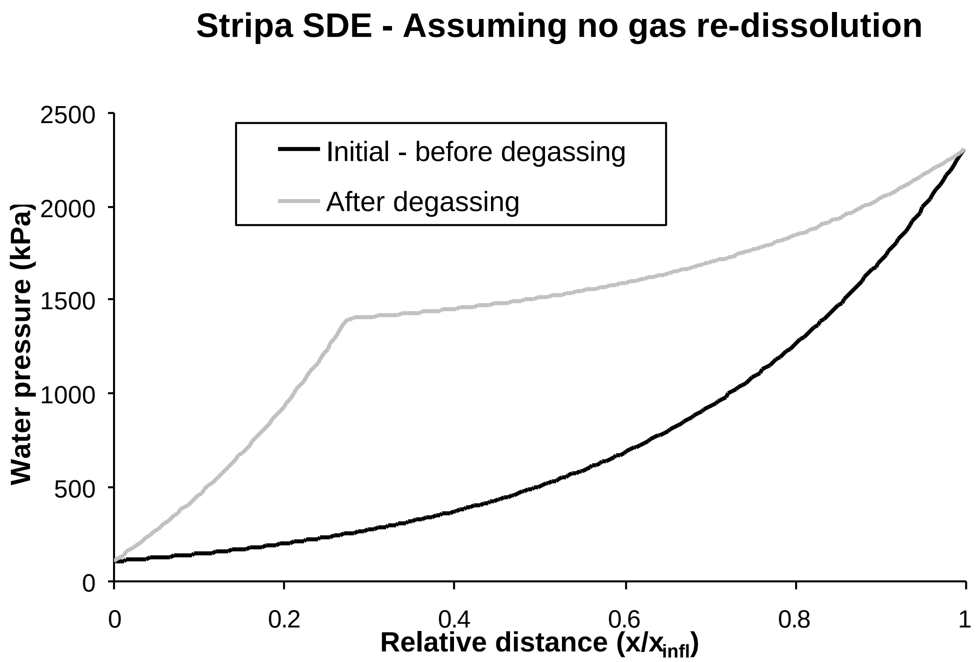


Figure 3-12 *Water pressures before groundwater degassing (black line) and after (grey line) as a function of the relative distance from the drift wall, located at x/x_{inf}=0. Conditions are the same as in Figure 3-11, except for an assumption of no gas re-dissolution. The modelled relative transmissivity is in this case 0.44.*

We now modified the degassing model to account for the possible effect of a relatively slow gas re-dissolution around drifts (see discussion above). We assumed, as we also did in the previous modelling, that gas initially forms where the water pressure is lower than the bubble pressure. For the example shown in Figure *3-12*, with a bubble pressure p_b of 260 kPa, gas then forms in the zone where the initial pressure (black line) is lower than p_b, i.e., for x/x_{inf}<0.28. As a result of this gas phase formation, the transmissivity is reduced along the distance x/x_{inf}<0.28, resulting in increased pressure gradients. Assuming that no gas is re-dissolved due to this local pressure increase, the pressures at degassing conditions is indicated by the grey line in Figure *3-12*. The resulting relative transmissivity T_{rel} is then 0.44, indicating considerably reduced flowrates.

The modelled conditions are exactly the same in Figure 3-11 as in Figure *3-12*, except that in Figure 3-11, the gas is assumed to re-dissolve as soon as the local pressure increases above the bubble pressure, resulting in a considerably smaller zone of reduced transmissivities. Whereas the model assumption used in Figure 3-11 resulted in consistent results between degassing model predictions and borehole and laboratory observations, the model does not reproduce the observations of the Stripa simulated drift experiment, unless relatively slow gas re-dissolution is assumed; Figure *3-12* shows the limiting case that the gas is not re-dissolved at all.

Concluding remarks

In summary, consistent results between laboratory observations and borehole test observations on the one hand, and model predictions on the other hand, were obtained using the model assumption that the gas re-dissolves as the water pressure increases above the bubble pressure. Based on both observations and model predictions, we conclude more generally that groundwater degassing will not cause considerable inflow reductions in fractures intersecting open boreholes, under natural conditions. The only plausible degassing-based explanation for the observed inflow reductions during the Stripa simulated drift experiment is that the gas re-dissolution was relatively slow, once the gas phase had formed.

Planned work

The finalisation of the summarising technical report on groundwater degassing was delayed and is now scheduled for the end of March, 2000. This report will also include findings regarding the relevance of various two-phase flow relations for fractured rock applications, in a more general sense (including the relations originally developed for degassing applications). This latter work is carried out within the German-Swedish programme at the Äspö HRL, mainly in cooperation with the group of R. Helmig at the Institute for Computer Applications in Civil Engineering (CAB), Braunschweig, Germany.

3.5 Hydrochemistry modelling/Hydrochemical stability

Background

The chemical properties of the groundwater affect the canister and buffer stability and the dissolution and transport of radionuclides. It is therefore important to know the possible changes and evolution of the groundwater chemistry during the repository life time. Important questions concern the understanding of the processes which influence and control the salinity, occurrence, character and stability of both saline and non-saline groundwaters.

At present this project is carried out within the framework of the Äspö agreement between SKB and Posiva. It also covers the technical parts of the participation in the EC EQUIP project and the modelling Task #5 within the framework of the Äspö Task Force for modelling of groundwater flow and transport of solutes.

Objectives

The objectives of this project are:

- To clarify the general hydrochemical stability (= groundwater chemistry of importance for canister and bentonite durability and radionuclide solubility and migration)
- To describe the possible scenarios for hydrochemical evolution at Äspö over the next 100.000 years, separated into time slabs of 0-100, 100-1000, 1000-10000 and 10.000-100.000 years.
- To develop a methodology to describe the evolution at candidate repository sites, e.g. Olkiluoto.

Model concepts

Geochemical interpretation of groundwater-rock interaction along flow paths makes use of the results from groundwater chemical investigations, i.e. chemical constituents, isotopes and master variables pH and Eh in combination with the existing mineralogy, petrology and termodynamic data. Useful tools for these calculations are reaction path codes like NETPATH and equilibrium-mass balance codes like EQ 3/6. These codes are frequently used in hydrochemical studies.

A newly developed concept and code, M3, start from the assumption that it is mixing and not chemical reactions that is the dominating process affecting the chemical composition of the groundwater within the investigated system. The principal assumptions behind this concept is that the varying hydraulic conditions of the past have created the complex mixing pattern presently observed. When the effects of mixing has been evaluated, mass balance calculations (resulting from chemical reactions) are then made to explain the difference between the ideal mixing and the observations.

The modelling strategy for the Hydrochemical Stability project involve:

- Identification of the dominant (chemical) processes for Finnish and Swedish sites.
- Geochemical mixing for Äspö and Olkiluoto.
- Site intercomparison and comparison between the M3 and NETPATH techniques based on data from Olkiluoto.
- Transient hydrodynamic modelling for Äspö and Olkiluoto.

The intention with the strategy is to be able to compare the results of the traditional hydrochemical modelling with the results from M3 and to compare the outcome of the hydrodynamic modelling with the results from M3. The latter comparison is done within the Task #5 of the Äspö Task Force for modelling of groundwater flow and transport of solutes.

The Equip project has the specific objective to trace the past hydrochemical conditions through investigation of (calcite)fracture filling minerals. The outcome will be used to check the conclusions from hydrogeological and hydrochemical models.

New Results

Task #5: All modelling groups presented their modelling results at the 13th Task Force meeting in February 2000.

EQUIP: The draft of the final report has been compiled by the project co-ordinator together with scientists from the individual organisations.

Modelling: All calculations have been completed. Results will be included into the3 final report and published in separate technical documents.

KLX02: Completed groundwater sampling from four deep sections in the borehole, using the Posiva PAVE sampling unit. Reporting of results of analyses is made in a technical document.

Planned work

- Modelling reports for Task#5 will be published in the ICR series. Evaluation of the outcome will be started.
- The final report of the Hydrochemical Stability project will be sent for review.
- Report the results of KLX02 sampling and analyses will be published as a Technical Document.

3.6 Matrix Fluid Chemistry

Background

Knowledge of matrix fluids and groundwaters from rocks of low hydraulic conductivity will complement the hydrogeochemical studies already conducted at Äspö, for example, matrix fluids are suspected to contribute significantly to the salinity of deep formation groundwaters. It will also provide a more realistic chemical input to near-field performance and safety assessment calculations, since deposition of spent fuel will be restricted to rock volumes of similar hydraulic character.

Objectives

The main objectives of the task are:

- to determine the origin and age of the matrix fluids,
- to establish whether present or past diffusion processes have influenced the composition of the matrix fluids, either by dilution or increased concentration,
- to derive a range of groundwater compositions as suitable input for near-field model calculations, and
- to establish the influence of fissures and small-scale fractures on fluid chemistry in the bedrock.

Experimental concept

The experiment has been designed to sample matrix fluids from predetermined, isolated borehole sections. The borehole was selected and drilled on the basis of: a) rock type, b) mineral and geochemical homogeneity, c) major rock foliation, d) depth, e) presence and absence of fractures, and f) existing groundwater data from other completed and on-going experiments at Äspö. Special equipment has been designed to sample the matrix fluids ensuring: a) an anaerobic environment, b) minimal contamination from the installation, c) minimal dead space in the sample section, d) the possibility to control the hydraulic head differential between the sampling section and the surrounding bedrock, e) in-line monitoring of electrical conductivity and uranine content, f) the collection of fluids (and gases) under pressure, and g) convenient sample holder to facilitate rapid transport to the laboratory for analysis.

Migration of matrix fluids will be facilitated by small-scale fractures and fissures. Therefore the matrix fluid chemistry will be related to the chemistry of groundwaters present in hydraulically-conducting minor fractures ($K = 10^{-10}$-$10^{-9} ms^{-1}$), since it will be these groundwaters that may initially saturate the bentonite buffer material.

New results

Since January 2000, activities carried out have involved the continuation of: a) mineralogical/petrophysical studies, b) crush/leaching experiments, c) Äspö diorite permeability test, and d) compilation and interpretation of groundwaters sampled and analysed from the Prototype Repository Experiment. Furthermore, the fluid inclusion programme of study is now in progress with the petrography of the selected samples almost complete.

Mineralogy

General mineralogical characterisation of the drillcore from borehole Section 4 (4.66-5.26 m), sampled for matrix fluid (see below), have been completed by the University of Bern, Switzerland and by Terralogica AB, Sweden. Additional samples from borehole Section 2 (8.85-9.55 m), earmarked for fluid sampling, and the drillcore in general, have been prepared for mineralogical, fluid inclusion and petrophysical studies. These studies are now nearing completion. Preliminary results from the complete drillcore suggests that two main rock-types may be present (possibly of differing porosity), an Äspö porphyritic diorite type adjacent to the tunnel, and an Ävrö Granite type away from the tunnel, with the transition being located somewhere between borehole Sections 2 and 4. Furthermore, there is a suggestion of partly open, small-scale fractures (~ 1 mm) intersecting (and parallel to) the borehole close to Section 4. This feature, together with possible porosity differences, may be an explanation why borehole Section 4 has already been filled with water, whilst Section 2 is still accumulating fluid. It may explain also why fracture-type waters have been found in Section 4, rather than matrix fluid (see below).

Crush/leaching experiments

Three crush/leach sequences from the same drillcore material (immediately adjacent to Section 4 towards the tunnel) have been completed by the University of Waterloo and, independently, two sequences by the University of Bern on the same material. There was good agreement between the first crush/leach of Waterloo and the Bern sample; both samples represented approximately similar size fractions. The composition of the *in situ* pore water (i.e. matrix fluid) from the Bern sample, calculated from these experiments, ranged from 61 000 to 89 000 mg/L Cl; the Waterloo calculations are forthcoming.

Permeability test

Since August 1999 a high pressure experimental set-up has been operating at the University of Waterloo. This experiment is essentially trying to force double distilled (Ultrapure) water through a drillcore portion (100x50 mm) in order to extract unbound, intragranular matrix fluid. Up until October 1999 no movement was observed; some activity was observed in November, which subsequently slowed down. A small movement was observed in February but no matrix fluid has been yet sampled; monitoring is continuing.

Sampling and analysis of matrix fluid

The sample from borehole Section 4 has been analysed. The data show clearly that the water originates from a system of intersecting small-scale fractures, possibly combined with a very small contribution from interconnected pore flow or diffusion into the sampling section. Comparison of the sampled water with typical fracture-derived groundwaters (i.e.. Prototype Experiment – see below) indicate, in general, similar ranges of major and trace element values. There is significantly more Mg in the fracture-derived groundwaters which may reflect a small marine influence caused by the hydraulic drawdown during tunnel construction.

Unfortunately the ^{14}C data cannot be used since sample contamination occurred. Rubber corks used to seal the flask during collection of the matrix water, obtained from the laboratory at the nearby nuclear power facility, were subsequently shown to be contaminated. The $\delta^{13}C$ value of –26.8 ‰ PDB indicates biogenic activity, probably *in situ*; this is supported by the high HCO_3 content (170-200 mg/L).

Microbial activity is generally evidenced, probably due to some residual contamination in the sampled section following borehole activities. Viable counts of sulphate-reducing bacteria (SRB), which gave rise to the smell of H_2S, and iron-reducing bacteria (IRB), were both positive.

Borehole Section 2 (8.85-9.55 m) has been showing a small, but steady pressure increase since February 1999, with a slightly more marked increase since October, 1999 to the present time. This will be allowed to continue until adequate matrix fluid has accumulated (total section volume of 245 mL). The much slower accumulation of fluid in this section, plus the absence of large fluid volumes in the adjacent Section 1 (already opened), may suggest a more representative matrix fluid composition than collected from borehole Section 4.

Fracture groundwaters sampled within the Prototype Experiment

Groundwater samples have been collected from fractures of low transmissivity in coordination with the Prototype Experiment. The analyses are now complete and have been reported in TD-00-10 The data indicate that there is no clear correlation between transmissivity (sampled fractures ranged from 10^{-10}-10^{-6} m^2s^{-1}) and the major ion chemistry; all samples have been influenced by the hydraulic drawdown caused by tunnel construction. This is evidenced by the general incursion of young, meteoric-derived water and perhaps some marine component. The results show that even lower transmissivities (< 10^{-10} m^2s^{-1}) need to be studied.

Fluid inclusion studies

The nature of the matrix fluid may be strongly influenced by leakage of saline fluids from fluid inclusions which, at Äspö, are commonly included in matrix quartz. Four research groups (Universities of Stockholm, Bern and Waterloo, together with a group from Kivitieto, Oulu, Finland, sponsored by Posiva) are participating in characterising the fluid inclusions; this collaboration will also function as an interlaboratory exercise with the intention of deriving a common methodology for the description, analysis and interpretation of fluid inclusion populations.

Some preliminary fluid inclusion studies have been reported by the University of Bern, Switzerland. Highly saline fluid inclusion populations (indicating the presence of a Na-Ca-(Mg)-Cl type fluid) have been identified in coarse-grained magmatic quartz and in fine-grained recrystallised quartz. Salinity ranges from 8.2-20.9 wt% $NaCl_{eq}$ in the former types and from 4.3-10.8 wt% $NaCl_{eq}$ in the latter types. In addition, several other fluid inclusion types containing NaCl and $CaCl_2$ (± $MgCl_2$) were found to be common to both quartz hosts. Non-fluorescent gas-rich inclusions (CO_2 or CH_4) have also been revealed.

Combining the results from the crush/leach experiments (described above), the aqueous extracts yield salinities in the range of the highly saline fluid inclusions. These results, together with Br/Cl and Sr-isotope data, indicate that a mixture of interstitial water and fluid inclusion fluid could act as a high salinity source, potentially explaining the presence of deep, highly saline groundwaters at Äspö.

Hydraulic considerations

Hydraulic characterisation of the bedrock matrix hosting the borehole is an important repository performance assessment issue since little is known about the transmissive nature of crystalline rock in the interval 10^{-14}-10^{-10} m^2s^{-1}. Long-term monitoring of the various isolated borehole sections, coupled with known times of water accumulation, have confirmed earlier predictions of matrix transmissivity (i.e. around 10^{-14} m^2s^{-1}). In addition, predictions of matrix water volume expected after a time interval of up to a year, based on a transmissivity of 10^{-14} m^2s^{-1}, was close to that finally obtained in Section 4, even though the presence of a nearby partly open small-scale fracture is suspected.

Planned work

- Based on the petrographic results, sample splits will now be distributed to each of the four groups for fluid inclusion characterisation studies.
- Continuation of the permeability test.
- Calculations will be carried out to further constrain flow/diffusion rates in the bedrock hosting the matrix borehole. These calculations will also address the estimated transmissivity of the small-scale fractures that appear to have contributed to the water chemistry obtained in borehole Section 4.
- Internal reporting of the petrographical studies.
- Internal reporting of the crush/leach experiments.
- The present status of the experiment will be documented as a International Cooperation Report.

3.7 Colloids

Background

Colloids are small particles in the size range 10^{-3} to 10^{-6} mm these colloidal particles are of interest for the safety of spent nuclear fuel because of their potential for transporting radionuclides from a faulty repository canister to the biosphere.

Therefore, SKB has for more than 10 years conducted field measurements. The outcome of those studies performed nationally and internationally concluded that the colloids in the Swedish granitic bedrock consist mainly of clay, silica and iron hydroxide and that the mean concentration is around 20-45 ppb which is considered to be a low value. The low colloid concentration is controlled by the large attachment factor to the rock which reduces stability and the transport capacity of the colloids in the aquifer.

It has been argued that e.g plutonium is immobile owing to its low solubility in groundwater and strong sorption onto rocks. Field experiments at the Nevada Test Site, where hundreds of underground nuclear tests were conducted, indicate that plutonium is associated with the colloidal fraction of the groundwater. The $^{240}Pu/^{239}Pu$ isotope ratio of the samples established that an underground nuclear test 1.3 km north of the sample site is the origin of the plutonium. Based on these results SKB decided to initiate a project in the Äspö-HRL to study the Stability and Mobility of Colloids (SMC).

Objectives

The objectives of the SMC project is to:

1) Verify the colloid concentration at Äspö-HRL

2) Investigate the potential for colloidal transport of nuclides in natural groundwater flow paths

3) Study the role of bentonite clay as a source for colloid generation

4) Demonstrate the colloid stability/instability at prevailing conditions

Experimental concept

Two nearby boreholes at HRL will be selected for the SMC experiment. One of the boreholes will be used as an injection borehole and the borehole downstream will be used as a monitoring borehole. The boreholes intersect the same fracture and have the same basic geological properties. The experiment will be performed in association with the TRUE-trace experiment programme

The boreholes and the optimum time for the experiment will be selected in co-operation with the co-ordinator for the TRUE experiment.

The natural background colloid content will be measured on-line from both boreholes by using a modified laser based equipment which has been developed by INE in Germany. The advantage is that the resolution of this equipment is higher compared with standard equipment of this type. It is therefore possible to detect natural colloid contents at much lower concentrations than previously possible. The outcome of these measurements will be compared with standard type of filtration performed on-line at the boreholes in order to be able to compare/transform these results to all the earlier colloid sampling campaigns at Äspö.

After assessing the natural colloid content in the groundwater bentonite clay will be dissolved in ultra pure water to form colloidal particles. These clay colloids will be labeled with a nuclide together with a water conservative tracer. The mixture will be injected into the injection borehole. From the monitoring borehole the colloidal content will be measured with the laser, the water will be filtered and the amount of tracers will be measured. The following results are of interest 1) is the colloid content lower after the transport, 2) is the nuclide association irreversible on the colloids and 3) is the bentonite clay a potential source for colloid generation. The outcome of this exercise is used to check the calculations in the safety assessment report TR 91-50 to be used in future colloid transport modelling.

New Results

A proposal for main project tasks was sent for review among experts on colloids. Review comments were used to focus the programme on issues that were not previously handled by other programmes.

Planned Work

A meeting will take place to discuss the differences and similarities with the colloid transport experiment CRR presently on-going at Grimsel test site.

3.8 Microbe

Background

A set of microbiology research tasks for the performance assessment of high level nuclear waste (HLW) disposal has been identified. Those with a potential for study at the MICROBE site are:

Microbial influence on radionuclide migration. To what extent can bacterial dissolution of immobilised radionuclides and production of complexing agents increase radionuclide migration rates?

Microbial corrosion of copper. Bacterial corrosion of the copper canisters, if any, will be a result of sulphide production. Two important questions arise: Can sulphide producing bacteria survive and produce sulphide in the bentonite surrounding the canisters? Can bacterial sulphide production in the surrounding rock exceed a performance safety limit?

Microbial production and consumption of gases. Will bacterial production and consumption of gases like carbon dioxide, hydrogen, nitrogen and methane influence the performance of repositories?

These tasks have been addressed in a range of projects, of which several is ongoing. Important conclusions have been obtained based on laboratory and field data. While some results seem very solid with general applicability, others are pending inspection at in situ conditions. This is especially true for data generated at the laboratory only. In situ generated data must be obtained for microbial activities in the far- and near-field environment at realistic HLW repository conditions. This can only be achieved at an underground site, developed for microbiological research, using circumstantial protocols for contamination control during drilling and operation. An in situ site allows experiments at natural pressure with correct gas content in groundwater which is of great importance for microbial activity and very difficult to obtain in vitro. Such a site was drilled in May 1999 in the J-niche at Äspö HRL, 450 m underground. Three boreholes were produced.

Objectives

The major objectives for the microbe site are:

To assay microbial activity in groundwater at in situ conditions. Influence on redox conditions, radionuclide migration and gas composition and consumption will be in focus.

To establish data on hydrogen generation and flow in granitic rock environments. The flow of hydrogen form where it is produced will determine the possible rate of long term microbial subterranean activity.

To enable experiments where the engineered barriers, bentonite, backfill and copper can be investigated for the influence of microorganisms at realistic and controlled conditions with a significant knowledge about the microbiology of the groundwater used.

To generate accurate data about rates of microbial reactions at repository conditions for performance assessment calculations.

Experimental concept

The microbe site consists of three core drilled boreholes, KJ0050F01, J0052F01 and KJ0052F03, intersecting water conducting fractures at 12.7, 43.5 and 9.3 m respectively. Each borehole will be equipped with packer systems in January 2000 that allow controlled sampling of respective fracture. Special attention will be directed towards the use of clean, non-contaminating instrumentation. An underground laboratory, approximately 7 x 2.5 m will be installed in January 2000 close to the site and will be equipped with a large anaerobic chamber and possibility for set up of on line GC measurement of dissolved gases. Tubing from the boreholes will be connected to the box, allowing for anaerobic sampling in the box. The microbe site will, to the extent possible, simulate real aquifer conditions.

New results

The microbe site boreholes KJ0050F01, J0052F01 and KJ0052F03 were successfully instrumented in January. An underground container was installed in the vault during February.

A class 5 chemical analysis was sampled during February. Analysis is ongoing.

The total numbers of microorganisms and the most probable numbers of iron reducing bacteria (IRB), manganese reducing bacteria (MRB) sulphate reducing bacteria (SRB), heterotrophic and autotrophic acetogens and heterotrophic and autotrophic methanogens are presently being evaluated after sampling in February, concomitant with sampling for the chemical characterisation. Analysis is ongoing.

Planned work

The container will be equipped for microbiological field work during May/June. It will have an anaerobic chamber and will be connected to the boreholes via circulation systems. It will also be connected to the boreholes via PEEK tubing.

A system that allows circulation of groundwater under full formation pressure will be designed. This system should enable work with microbes at very close to in situ conditions.

3.9 The Task Force on modelling of groundwater flow and transport of solutes

Background

The Task Force shall be a forum for the organisations supporting the Äspö Hard Rock Laboratory Project to interact in the area of conceptual and numerical modelling of groundwater flow and solute transport in fractured rock. In particular, the Task Force shall propose, review, evaluate and contribute to such work in the project. The work within the Task Force is being performed on well defined and focused Modelling Tasks. The table show on-going tasks

Task No	Modelling Issues	Cooperating organisations
4E	Modelling of tracer test with sorbing tracers in one fracture.	ANDRA, BMWi, CRIEPI, DOE, JNC, NAGRA, POSIVA, SKB
4F	As Task 4E but with half the flowrate.	ANDRA, BMWi, CRIEPI, DOE, JNC, NAGRA, POSIVA, SKB
4G	Resolving discrepancies and issues identified from the full suite of tests 4A-4F.	Proposal for this task is on review with the Task Force Delegates.
5	Compare and integrate hydrology and chemistry through modelling of Äspö tunnel drainage impact on hydraulic and chemical parameters.	ANDRA, BMWi, CRIEPI, ENRESA, JNC, POSIVA, SKB

New results

13th Task Force meeting

The 13th International Task Force meeting was held at Carlsbad, NM, USA, 8-10 February. Modelling results were presented from Task 4 and 5. Two workshops were held on 11th February in Albuquerque. The first to do a strategic assess the Task Force work and plan for future work. The second workshop to discuss processes and up-scaling for a future Task where the needs of the performance assessment are to be addressed.

Task No 4E

A joint report for Task 4E and 4F is ongoing. The report on the deconvolution of the breakthrough curves for Task 4E (STT1 and STT-1b) has been published.

Task No 4F

Modelling has been ongoing for this task within most of the modelling teams. Deconvolution of breakthrough curves is on-going.

Task 4G

The proposal for a new sub-task, 4G, was discussed at the 13th International Task Force meeting which. has been compiled by the Task Force secretariat which is on review with the Task Force Delegates. Design a new tracer injection equipment and perform a tracer test with conservative tracer in Feature A in the TRUE-1 block.

Task No 5

Modelling for this task continued and results presented at the 13th Task Force meeting.

Published reports

The following reports were published,

- Elert, M., Svensson, H., 1999. Deconvolution of breakthrough curves from TRUE-1 tracer tests (STT1 and STT1b) with sorbing tracers. Äspö Task Force Task 4E. International Progress Report IPR-99-35, Stockholm, Sweden.
- Morosini, M. (ed), 1999. Proceedings from the 12th Task Force meeting at Gimo, Sweden, April 20-22, 1999. Äspö Task Force. International Progress Report IPR-99-22, Stockholm, Sweden.

Planned work

For the next quarter we plan to perform the following tasks:

- Commence modelling for Task 4G
- Publish the results of the deconvolution of breakthrough curves from Task 4F
- Produce the draft final report for Task 4E&F
- Produce the final modelling report for Task 5

4 Demonstration of technology for and function of important parts of the repository system

4.1 General

Stage goal 4 of the Äspö HRL is to demonstrate technology for and function of important parts of the repository system. This implies translation of current scientific knowledge and state-of-the-art technology, into engineering practice applicable in a real repository.

It is important that development, testing and demonstration of methods and procedures, as well as testing and demonstration of repository system performance, is conducted under realistic conditions and at appropriate scale. A number of large-scale field experiments and supporting activities are therefore planned to be conducted at Äspö HRL. The experiments focuses on different aspects of engineering technology and performance testing, and will together form a major experimental program.

With respect to *technology demonstration* important overall objectives of this program are:

- To furnish methods, equipment and procedures required for excavation of tunnels and deposition holes, near-field characterisation, canister handling and deposition, backfilling, sealing, plugging, monitoring and also canister retrieval.
- To integrate these methods and procedures into a disposal sequence, that can be demonstrated to meet requirements of quality in relation to relevant standards, as well as practicality.

With respect to *repository function*, objectives are:

- To test and demonstrate the function of components of the repository system.
- To test and demonstrate the function of the integrated repository system.

4.2 Prototype Repository

Background

Particular aspects of the repository concept have previously been tested in a number of in-situ and laboratory tests. There is a need to test and demonstrate the integrated function of the repository in full scale and with state-of-the art technology. It is envisaged that this technology can be tested, developed and demonstrated in the Prototype Repository. The design, construction and testing of the prototype repository is aimed at a simulated deposition sequence starting from detailed characterisation of the host rock to resaturation of the backfilled deposition holes and tunnel. The Prototype

Repository experiment is located in the inner part of the TBM tunnel at 450 m level and will include 6 deposition holes in full scale.

The aims of the Prototype Repository are:

- To demonstrate the integrated function of the repository components and to provide a full-scale reference for comparison with models and assumptions.
- To develop and test appropriate engineering standards, quality criteria and quality systems.

The Prototype Repository will be a long-term test divided into two sections, separated by a concrete plug. One section is planned to be decommissioned after about 5 years and the second section after more than 10 years.

New results

The application for EC funding of the Prototype Repository project was submitted in 1999 concerning the time from April 1 of 2000 up to December 2003. The application included eight other organisations and asked for 50% funding of SKB´costs during that period and between 10% and 100% funding for the other organisations contributions. In January the Commission announced that the application has been selected by EC for funding but only to a smaller extent than was asked for, approximately half of the asked sum. The consequence is a modification of the EC part of the Prototype Repository and minor changes in the over all plans for the whole project. Contract signing is now estimated to take place around July 1st, 2000, and a kick-off meeting – together with the Cluster Repository Project, which also was selected for EC funding – has been scheduled to take place in September at Äspö. Some of the organisations which were listed as subcontractors in the application shall according to EC regulations be partners in the contract instead (executing scientific work compared to supplying equipment or other goods). The list of participants then is 13 as follows (9 in the application):

- SKB
  - GeoDevelopment
  - VBB VIAK
  - Clay Technology
- POSIVA, Finland
  - VTT
- ENRESA, Spain
- AITEMIN, Spain (associated with ENRESA)
- CIMNE, Spain (associated with ENRESA)
- GRS, Germany
- BGR, Germany
- UWC (University of Wales)
- JNC, Japan

The Project Group, consisting of basically Task Leaders, met regularly during the period (approx. once each six weeks) with the objective to conclude on techniques and methods for construction details and installation issues.

Physical activities in the Prototype Repository tunnel has been limited to water sampling for determination of the redox conditions, and measurement of in-flowing water both into the tunnel and into each deposition hole with specific attention to the spots were the water enters.

The reporting of results from the geoscientific characterisation phase has continued. It concerns:

- Geological characterisation using the Rock Visualisation System (RVS) as modelling tool
- Thermal properties of the rock
- Hydraulic predictions of inflow based on Discrete Fracture Network modelling
- Results from acoustic emissions measurements during boring
- Rock mechanical properties, in situ stresses and mechanical response to the boring of the deposition holes
- Redox conditions in the rock

The pre-test of the deposition sequence has continued, but slower than planned due to the later arrival of the equipment. The system for air conditioning in the deposition hole – maintaining a relative humidity between 75 and 80% - has been purchased.

The analysis of data from measurements of cutter forces during boring of the second deposition holes in the Canister Retrieval Test tunnel has continued at Luleå Technical University with the last parts of the final report.:

Planned work

Detail planning of different parts of the Prototype Repository project will continue during the period. Main design issues are the design of the plugs and the slots these need, and the design of all handling of cables and tubes including lead-throughs. Main decisions on design and type of components to Section I have to be made and the purchase processes started. These decisions concern

- instrumentation plan including chemical samplers in the buffer, instruments in the canisters, thermocouples in rock, possible mechanical sensors in rock and needed number of cables out from the test tunnel
- heaters to canisters and design of cable handling
- consequent need for lead-through holes and their locations
- method for lead-through of cables
- location of permanent packers in investigation holes
- supplementary investigation holes in the tunnel

The remaining geoscientific field work is to measure the elastic properties of the rock in the Prototype Repository tunnel in situ and to measure the magnitude and direction of in situ stresses with another method than the overcoring method earlier used, in order to get a second observation. Detailed hydraulic characterisation of the six bored deposition holes has started and will continue during the period with the aim of establishing the inflow regime as boundary conditions for the predictive THM modelling on buffer saturation and swelling.

Remaining rock work prior to installation of bentonite blocks and canisters are excavation of the two slots for the plugs and boring of lead-throughs to the adjacent G-tunnel for cables and tubes from all instruments, gas and water sampling unit, and heaters in the canisters. These two activities are interconnected as the excavation requires dismantling of the roadbed at the places for the slots, which also requires disconnection of tubes from the hydraulic measurement sections in the 31 different exploration holes in the tunnel.

4.3 Backfill and Plug Test

Background

The *Backfill and Plug Test* includes tests of backfill materials and emplacement methods and a test of a full-scale plug. It is a test of the integrated function of the backfill material and the near field rock in a deposition tunnel excavated by blasting. It is also a test of the hydraulic and mechanical functions of a plug. The test is partly a preparation for the Prototype Repository.

The entire test setup with backfilling, instrumentation and building of the plug was finished in the end of September 1999 and the wetting of the 30/70 mixture through the filter mats started in November.

New results

Fig 4-1 shows an illustration of the experimental setup. The following main work has been carried out during the first quarter of 2000:

Due to leakage between the bottom filter mats (probably through the fractured floor) the wetting strategy was changed. It was initially decided to fill every second mat and use the mat in-between for de-airing. However, some of the bottom mats, which were intended for de-airing, were due to the leakage filled with water from the neighbouring mats. Therefore all bottom and central mats were filled with water and the top mats used for de-airing.

The filter mats have been pressurised with 100-200 kPa water pressure during the first quarter of 2000.

- Water saturation, water pressure and swelling pressure in the backfill and water pressure in the surrounding rock have been continuously measured and recorded.

- The artificial water inflow into the filters has been continuously measured. Totally about 22 m^3 have entered the 30/70 backfill, which correspond to about half the required quantity until complete saturation. However, a large part of this water has probably escaped through the floor to the outer test part. This is also indicated by the measurements from the psychrometer gauges installed in the backfill.

- Some supplementary laboratory tests and modelling of the water saturation of 30/70 have started.

- Reporting of the experimental setup have started.

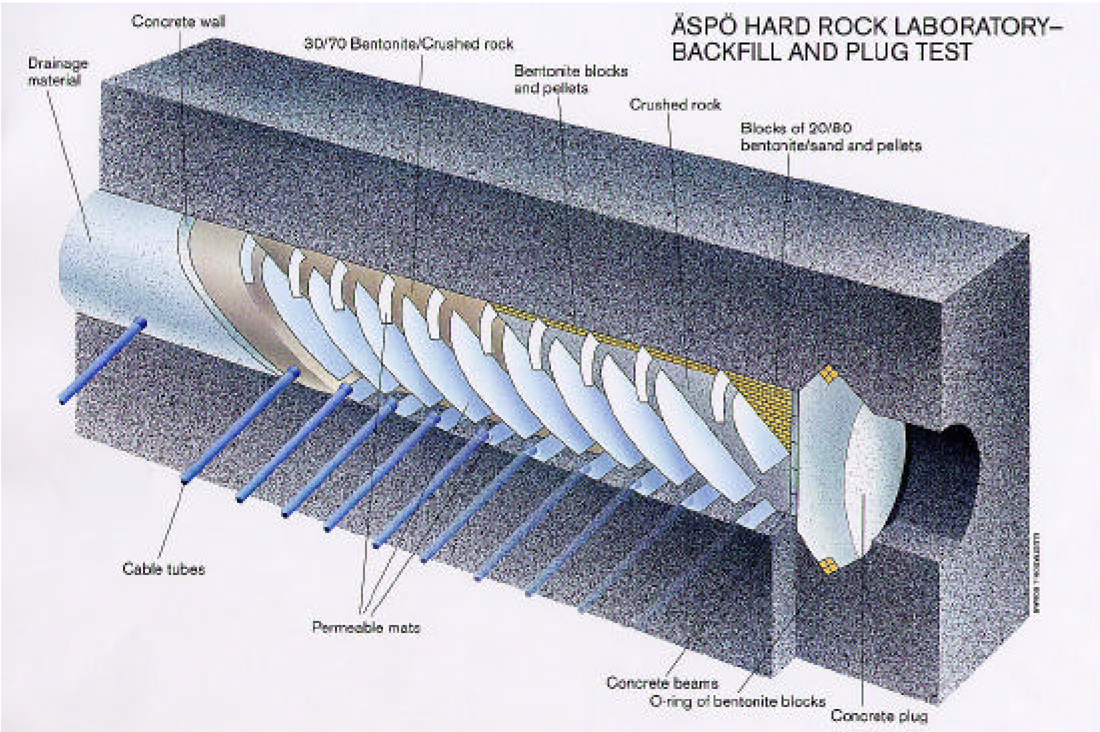


Figure 4-1 *Illustration of the experimental setup of the Backfill and Plug Test.*

Planned work

In the second quarter of 2000 the following main work is planned:

- Continuing registration and following up of the water inflow into the backfill from the permeable mats.

- Continuing registration and following up of the water pressure in the rock and the saturation process and swelling pressure in the backfill.

- Continuing supplementary modelling and laboratory testing of 30/70.

- Continuing reporting of the experimental setup.

4.4 Demonstration of repository technology

The development and testing of methodology and equipment for the encapsulation and deposition of spent fuel in the deep repository is an important part of SKB´s programme. In addition to the technical aspects, it is also important to be able to show in a perceptible way the different steps in encapsulation, transport, deposition, and retrieval of spent fuel for specialists and the public. As part of the overall programme an Encapsulation Laboratory has been constructed in Oskarshamn and was taken in operation late 1998. Demonstration of deposition and retrieval of canisters will be made at the Äspö Hard Rock Laboratory. The demonstration project complements the Prototype Repository, the Canister Retrieval Test and the Backfill and Plug Test which focus on the integrated function of the engineered barriers in a realistic environment.

Demonstration of Repository Technology is organised as a project under the Facilities Department. Development of equipment for handling and deposition of canisters will be the responsibility of the Deep Repository Department while the Äspö HRL will be responsible for the field activities. The description below focuses on the work that will be performed at the Äspö HRL.

The objective of the demonstration of repository technology are:

- To develop and test methodology and equipment for encapsulation and deposition of spent nuclear fuel,
- to show in a perceptible way for specialist and the public the different steps in encapsulation, transport, deposition, and retrieval of spent fuel and
- to develop and test appropriate criteria and quality systems for the deposition process.

The demonstration of deposition technology will be made in a new tunnel south of the ZEDEX drift excavated by drill and blast. This location is expected to provide good rock conditions, a realistic environment for a future repository, and allow transport of heavy vehicles to this area.

New results

The installation of the full size deposition machine for deposition of copper canisters started in June 1999. The picture below shows the deposition machine on the test bed at the manufactures workshop in May 1999.

The installation of the machine was completed during the autumn of 1999. The testing of the deposition machine has been delayed for various reasons but has been ongoing during the reporting period. The inauguration of the demonstration tunnel with its deposition machine took place as scheduled on 9th March 2000.

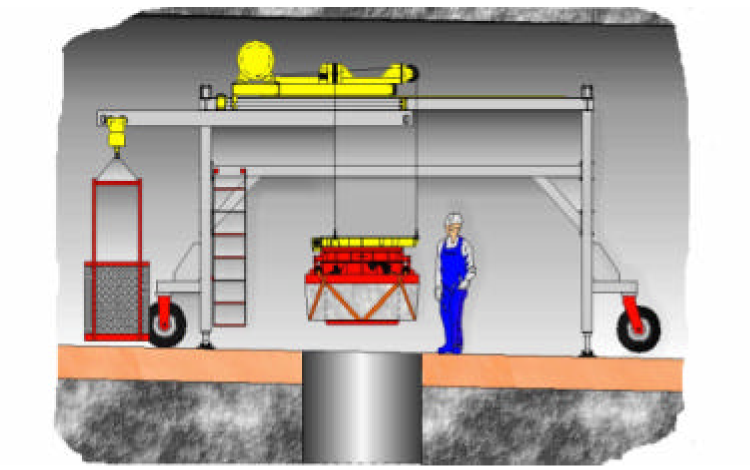
The design and construction of the temporary equipment for handling and deposition of the buffer material and canisters for the Canister Retrieval Test and the Prototype Repository will be completed before summer 2000.

The main data of the deposition machine are as follows:

Height: 4.6 m
Width: 3.7 m
Length: 11.5 m

Weight: 160 metric tons including the weight of the copper canister. The total weight of the demonstration machine at Äspö is about 140 metric tons

The gantry crane with tools for emplacement of the bentonite buffer into to deposition hole and the small deposition machine that will be used for these experiments are shown in the illustration below.



The main data and features of the gentry crane are as follows:

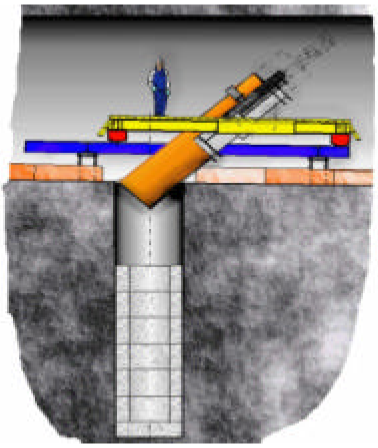
Height: 4.3 m
Width: 2.8 m
Length: 8.5 m

Lifting capacity:

Main hoist = 3 metric tons
Auxiliary hoist = 1 metric tons.

The auxiliary hoist with the small circular working cage can be lowered inside the pile of bentonite rings down in the deposition hole. One ring of compacted bentonite is shown in the lifting tool of the gentry crane.

Illustration of the gantry crane for handling of the compacted buffer material



The main data of the deposition machine are as follows:

Height:	3 m
Width:	3.5 m
Length:	8.7 m

Weight: 13 metric tons excluding the copper canister.

The limited height in the prototype repository requires that the canister is tilted down into the deposition hole.

Illustration of the small deposition machine.

Planned work

Some modification is planned during April and May 2000 and the final site testing of the deposition machine is scheduled for completion during May and the machine will be handed over from the supplier to SKB end of May. After that SKB will operate the machine for demonstration and for testing of the deposition process.

Development work of the equipment needed in the future deep repository will also continue based on experiences from the ongoing work at Äspö. The different machines and transport and auxiliary equipment needed are planned developed to at leased to a feasibility stage as part of the ongoing design studies of the deep repository. Some of the equipment may also be designed and constructed and tested at the Äspö HRL at a later stage for verification of the function and suitability of the equipment.

4.5 Canister Retrieval Test

Background

SKB’s strategy for the disposal of canisters with the spent nuclear fuel is based on an initial emplacement of about 10% of the number of canisters followed by an evaluation of the result before any decision is made on how to proceed. One outcome can be that the result is not accepted and that the canisters have to be recovered. In such case some, if not all, canisters can be surrounded by a saturated and swollen buffer, which holds the canister in such a grip that the canister can not just be pulled up. First the bentonite grip has to be released, for which two alternative principles can be applied; remove or shrink the bentonite. Then the canister is free to be lifted up to the tunnel and placed in a radiation shield. A concern is any type of radioctive contamination that the bentonite has been exposed to.

The retrieval test is aiming at demonstrating the readiness for recovering of emplaced canisters also after the time when the bentonite has swollen. The process covers the retrieval up to the point when the canister is safely emplaced in a radiation shield and ready for transport to the ground surface. The test is separated into two phases; Design and Set-up, and the actual Retrieval Test.

New results

The project has many Task Leaders and others in the organisation, who are also engaged in the Prototype Repository. The discussions of scientific and technical solutions therefore take place in Project Group Meetings common for both projects. These meetings have been held regularly during 1999 and 2000 with a frequency of one per approx. six weeks. Since November a project Managing Group has been organised with frequent meetings, every two weeks, consisting of the Project Manager, the two Assistant Project Managers (for Science and for Methods and Techniques) and the Project Co-ordinator. A meeting concerning the practical realisation of the project was summoned in March, where representatives from all disciplines participated. All theses meetings are documented in minutes.

Quality plans (activity plans) including descriptions of methods for the accomplishment of the test have been finalised for most of the planned activities in accordance with the schedule. Remaining activity plans are under preparation.

Geological mapping of the two deposition holes was performed in February.

All the cylindrical bentonite blocks for the two holes have been made, and these blocks are stored in the Canister Laboratory in Oskarshamn. The dimensions of the bentonite blocks were controlled at Ystad and in Oskarshamn, and indicated an increase in height of the blocks by 2-4 mm. Bentonite pellets for filling of the void between rock and bentonite blocks in the deposition holes have also been produced.

The plan on instrumentation of the buffer has been completed and orders for most of these instruments have been placed.

The design of the canisters has been completed and manufacturing of the two canisters ordered from Kockums. One new decision is that the canisters and heaters will not be grounded for corrosion protection or protection of other installed tests due to the relatively short term of the test.

The design of the plugs was completed in January. The work on the design of the plugs on top of the holes has concentrated on a combined concrete/steel plug placed in the hole below the tunnel floor level. This plug will be anchored to the rock by means of nine cable bolts, which can resist a swelling pressure from the bentonite of up to 10 MPa (design pressure is 5 MPa). Three of the cable bolts will be equipped with stress measuring devices to be able to trace the stress development from the swelling bentonite on the plug. The plug will be cast in-situ in a cone shaped steel-mould attached to the bore hole wall. This design is meant to reduce plug friction and hence facilitate measuring of stress development in the bentonite. The procurement process for plugs and rock anchoring has been initiated.

The proposed artificial watering system with permeable mats on the rock wall has been studied with the result that about 1/3 of the rock surface should be covered in order to provide for a homogeneous saturation of the buffer. Possible fabricates of mats have been tested in the laboratory. Before installation of mats, the hole-walls behind the mats have to be smoothened by grouting to avoid damage on the pipes under pressure. Procurement of mats and watering system is ongoing.

A plan for lead-through slots in the deposition hole walls has been prepared and procurement for the work is done.

Planned work

Start of installation of bentonite blocks was planned to launch in April but has been postponed until mid August. The start is linked to the completion of the testing of the deposition process and the equipment to be used. This project needs the crane for handling the bentonite blocks and the “small” deposition machine; the first mentioned was subjected to function tests at site in early January, and the second requires repairs and adjustments in accordance to findings during the first tests under ground. The crane failed the test and was returned to the work shop for correctional adjustments. The crane was back at site in March for completing function tests. The repairs and adjustments on the “small” deposition machine are scheduled to be finalised in early May. The test of the deposition process is scheduled to be completed before July 2000.

The geological characterisation report from the deposition holes will be finalised during spring. Additional geological information may be obtained from cores, if the holes for thermocouples in the rock are drilled radially out from the bore holes.

After mapping and drilling of instrumentation holes radially outward, a horizontal concrete slab will be cast at the bottom of the holes, slots are made for cables in the walls and the permeable mats are attached to the rock wall, all activities made as part of the preparation prior to start of block installation. Another preparatory activity is to seal-off the tunnel by a temporary wall so that the air in the holes may be conditioned by a dehumidifier and ventilation to contain a relative humidity of 75-80% compared to the natural 85-90%, the reason being to prevent the bentonite from sorbing water and consequent swelling.

Purchase of instruments, materials and services continues.

4.6 Long term test of buffer material (LOT)

Background

Bentonite clay has been proposed as buffer material in several concepts for HLW repositories. In the Swedish KBS3 concept the demands on the bentonite buffer are to serve as a mechanical support for the canister, reduce the effects on the canister of a possible rock displacement, and minimise water flow over the deposition holes.

The decaying power from the spent fuel in the HLW canisters will give rise to a thermal gradient over the bentonite buffer by which original water will be redistributed parallel to an uptake of water from the surrounding rock. A number of laboratory test series, made by different research groups, have resulted in various buffer alteration models. According to these models no significant alteration of the buffer is expected to take place at the prevailing physico-chemical conditions in a KBS3 repository neither during nor after water saturation. The models may to a certain degree be validated in long term field tests. Former large scale field tests in Sweden, Canada, Switzerland and Japan have in some respects deviated from possible KBS3 repository conditions and the testing periods have generally been dominated by initial processes, i.e. water uptake and temperature increase.

The present test series aims at validating models and hypotheses concerning physical properties in a bentonite buffer material and of related processes regarding microbiology, cation transport, copper corrosion and gas transport under conditions similar to those in a KBS3 repository. The expression ”long term” refers to a time span long enough to study the buffer performance at full water saturation, but obviously not ”long term” compared to the lifetime of a repository. The objectives may be summarised in the following items:

- Data for validation of models concerning buffer performance under quasi-steady state conditions after water saturation, e.g. swelling pressure, cation transport and gas penetration.
- Check of existing models concerning buffer-degrading processes, e.g. illitisation and salt enrichment.
- Information concerning survival, activity and migration of bacteria in the buffer.
- Check of calculation data concerning copper corrosion, and information regarding type of corrosion.
- Data concerning gas penetration pressure and gas transport capacity.
- Information which may facilitate the realisation of the full scale test series with respect to clay preparation, instrumentation, data handling and evaluation.

The testing philosophy for all tests in the series (Table 4-1) is to place prefabricated units of clay blocks surrounding heated copper tubes in vertical boreholes. The test series are performed under realistic repository conditions except for the scale and the controlled adverse conditions in three tests.

The test series have been extended, compared to the original test plan, by the A0 parcel in order to replace the part which was lost during the uptake of the previous A1 parcel.

Adverse conditions in this context refer to high temperatures, high temperature gradients over the buffer, and additional accessory minerals leading to i.a. high pH and high potassium concentration in clay pore water. The central copper tubes are equipped with heaters in order to simulate the effect of the decay power from spent nuclear fuel. The heater effect are regulated or kept constant at values calculated to give a maximum clay temperature of 90°C in the standard tests and in the range of 120 to 150°C in the adverse condition tests. Test ”parcels” containing heater, central tube, clay buffer, instruments, and parameter controlling equipment are placed in boreholes with a diameter of 300 mm and a depth of around 4 m.

Table 4-1. Lay out of the ongoing Long Term Test series.

Type	No.	T °C	Controlled parameter	Time years
A	0	120<150	T, [K^+], pH, am	1
A	2	120<150	T, [K^+], pH, am	5
A	3	120<150	T	5
S	2	90	T	5
S	3	90	T	>>5

A = adverse conditions S = standard conditions
T = temperature [K^+] = potassium concentration
pH = high pH from cement am = accessory minerals added

Temperature, total pressure, water pressure and water content, are measured during the heating period. At termination of the tests, the parcels will be extracted by overlapping core-drilling outside the original borehole. The water distribution in the clay will be determined and subsequent well-defined chemical, mineralogical and physical testing will be performed.

New Results

The original optical fibres in the open tunnel have been exchanged to a protected and more robust construction. The damaged fibres are thereby exchanged and the sensors belonging to them seem to work properly. The new installation permits simple exchange, if necessary e.g. due to ageing.

Ground-water from a bore-hole in the northern wall has been connected to the upper part of the four long term test parcels in order to simulate water coming from a back-filled tunnel. The water-pressure is around 1.2 MPa and the inlet is via titanium tubes and filters. The one year test parcel (A0) has been contacted to the groundwater by filter inlets in three directions at three levels in order to speed up the saturation. Power has been increased in all parcels to correspond to a maximum temperature of around 90ºC. Figure 4-2 shows the measured relative humidity (upper curves) in the A3 parcel after placement. The steep increase in RH in the beginning of February is due to the filling of the slot between bentonite and rock with ground water. The lower curves show the temperature increase due to the stepwise power increase.

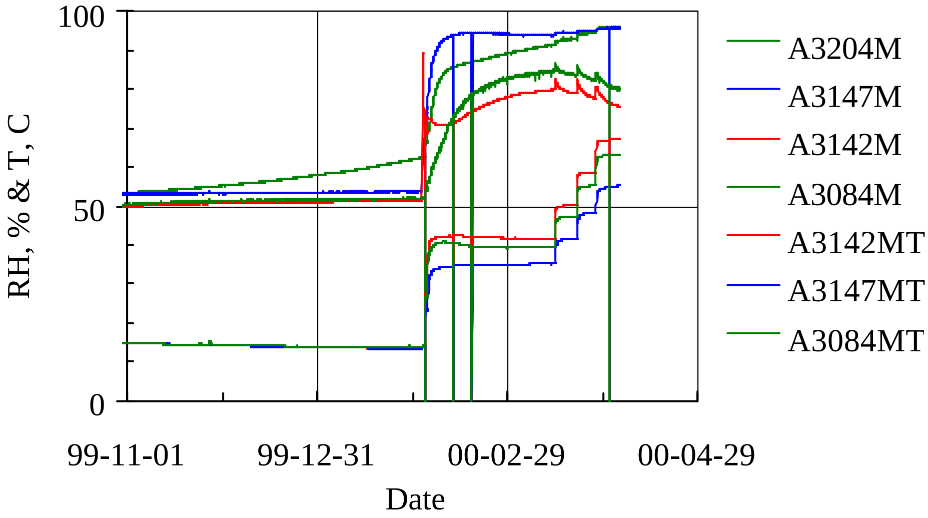


Figure 4-2 *Relative humidity and temperature in the A3 parcel during the period***.**

A system for read off and remote control by means of internet has been installed. Supervision and collecting of data are thereby possible from Clay Technology in Lund.

Planned work

The installation is in principle finished and only small adjustment is planned in the near future, i.a. switch to regulation of power instead of temperature. The monitored water pressure, total pressure, temperature and moisture in the parcels will regularly be analysed, and monthly backup will be made during the test period. Supplementary laboratory work will be made concerning gas penetration pressure and characterisation of the original bentonite material. Chemical analyses of ground-water and if possible of water from the "passive" filters in the bentonite will be made regularly during the test period.

5 Äspö facility operation

5.1 Facility operation

The ”five year inspection” of the underground facility has been completed. The result pointed out a few areas were intense reinforcement is necessary. Systematic bolting and mesh/spray concrete will be used. The work is planned to take place in May and June and will be done mainly in the nights to avoid inconvenience for other activities.

The electrical supply to the facility comes today from two different sources. The underground part is supplied direct from the nuclear power station, while the Äspö village gets its electricity from an airborne net on the mainland. The latter is a relatively weak net and especially during the autumn and winter, there are several cuts in the delivery. A new cable from the nuclear station to Äspö is now in progress and will be in operation during May

The project for supervising the facility is now undergoing a four weeks test before it will be handed over from the contractor.

During the spring there will be a change in the responsibility for workers safety at Äspö. This also includes more help from occupational health engineers from the nuclear power company, OKG.

A new operation manager will take over late this spring and some minor changes in the organisation might occur.

The geometry of the guiders in the hoist shaft has been measured. This has never been done before and will be of great value in the future to ensure that no movements take place in the shaft.

Due to the rather heavy traffic on the small road to Äspö additional meeting spots will be built this summer. This will be of benefit for the heavy trucks and busses with visitors.

5.2 Data management and data systems

Background

The regulatory authorities are following SKB’s siting work. Before each new stage, they *examine and review the available data.* A repository will never be allowed to be built and taken into service unless the authorities are convinced that the safety requirements are met. Hence, SKB is conducting *general studies* of the entire country and *feasibility studies* in 5-10 municipalities. *Site investigations* will then be conducted on a couple of specific sites. With the result of the studies as supporting material, SKB will then apply for permission to carry out *detailed characterisation* of one of the sites. The licence application for detailed characterisation will include a *safety assessment* and the results will be reviewed under the Act on Nuclear Activities and the Act concerning the

Management of Natural Resources by the regulatory authorities, the municipality and the Government.

Management of investigation data is a highly demanding and critical task in the presented licensing process. The safety assessment must be based on correct and relevant data sets. Hence, the data management routines need to be focused on the following aspects in a long term perspective:

- traceability,
- accessibility,
- data security and
- efficiency (system integration and user friendly applications).

A high quality baseline for the safety assessment will be established if the aspects specified above are met. The data needed in a typical safety assessment have been reported in Andersson et al /1998/.

The different parts of SKB's Data Management System will be improved in conjunction with the ongoing and planned activities in SKB' siting work. This to fulfil the requirements expected from the regulatory authorities and the internal organisation as well. The current status and the actual plans of GIS, SICADA and RVS is presented in the following subsections.

New results

GIS

A Geographical Information System (GIS) based on ArcInfo and ArcView has been and are still used successfully by SKB in the ongoing feasibility-study projects. GIS will also be an important tool in the planning and performance of the pre-investigation phase. A plan to implement GIS as a effective tool in the coming pre-investigation phase has been decided, and as a first step some pre-study data sets have been set up at the Äspö Hard Rock Laboratory as a basis for different pilot cases.

An external GIS-expert at VBB VIAK AB has delivered a report as planned. The report includes recommendations concerning selection of hardware, software and other related matters.

SICADA

The full implementation of the HMS instrument database as a part of SICADA has been finalised as planned. Some new improvements have also been introduced, and the set of data has been complemented.

A set of new improvements in SICADA have been specified and purchased according to established and well working routines between SKB and Ergodata AB. This new development stage will take place during the first half of year 2000. Until now the improvements with the highest priority have been delivered for testing.

The licensing routines for CA/Ingres II and other CA-products has caused severe problems during 1999, but CA(Computer Associates) has recently released a new server side supported licensing method. We are planning to implement this method in January

2000. This means that we do not need to handle complex individual licenses on individual PC clients.

The major problems associated with the access to SICADA trough an encrypted IP-tunnel have been solved, but some external consultants have still problems to come through their own firewalls.

RVS

RVS version 2.1 has been distributed to the RVS users. This new version embodies about 30 new or improved existing functions. Some of these functions are described briefly in the following text.

The unique *Object List* has been improved. As a result it will be more easy to have an overview of all active objects in a model or set of visualisations. As an example all borehole visualisations are stored as sub-objects to the borehole it self. A new column, named *user*, has also been inserted in the Object List. This column stores the name of the person who have created a certain object in the model. Some other columns in the list has been renamed in order to be more understandable.

The new feature *Work Set* has been introduced to make it possible for the user to reduce the amount of borehole data in the local database. As an additional positive effect the number of boreholes in some lists are shortened as wanted.

In the previous version a discontinuity surface, describing a single fracture plane, was automatically extended to the borders of the modelled rock mass. This restriction has been removed. *A discontinuity is now extended by rules given by the user*. It is also possible to *remodel discontinuities*.

Earlier imported *DGN-files can now be reloaded* if they have been updated in standard MicroStation/J during the modelling process.

The *on-line help* has been refined by using a commercial software called AuthorIT. This software helps the administrator to manage the complete set of information needed in a User´s manual. When the help information have been set up and configured, it is easy to produce HTML-documents, to be executed from any dialogue window in the RVS application, or printed documents.

A RVS review project has been initiated. The review is carried out by Dr Matthew White and Dr Andy Lind at QuantiSci Ltd in England. The aim with this project is to have an independent opinion of the capabilities, but even lack of capabilities, available in the Rock Visualisation System.

Planned work

GIS

The following subjects will be under consideration during the next period (April-June 2000):

- The new GIS reference group within SKB will be operative.

- Selection and implementation of hardware and software platforms for GIS applications (as a part of the responsibility of the reference group).
- Test and implement applications that will utilise the power of GIS and then implement them.
- Set up of a complete set of GIS data for the areas focused on in the feasibility studies for some municipalities.

SICADA

The ongoing development stage, running during the first half of year 2000, will be completed.

A new application for extraction of data from SICADA will be purchased during the spring 2000. The programming work will hopefully start up in June 2000.

More personnel resources are needed to manage the still growing amount of information in the database. A data administrator should be recruited as soon as possible.

RVS

RVS version 2.2 will be purchased in April 2000. The plan is then to start up the final delivery test in June 2000, and the new version will be delivered to the user in August 2000.

A RVS review project performed by QuantiSci will be completed in June 2000. The outcome, experiences and recommendations, of this project will be used as a basis when planning new versions of the system.

An interface between FracMan/MAFIC and RVS will be programmed by Golder Grundteknik AB. The programming work will be completed before the end of June 2000. FracMan/MAFIC is owned and developed by Golder Associates Inc.

5.3 Program for monitoring of groundwater head and flow

Background

The Äspö HRL operates a network for the monitoring of groundwater head, flow in the tunnel and electrical conductivity, as the core parameters. This system goes under the acronym of HMS (Hydro Monitoring System). Water levels and pressure head are collected from surface drilled and tunnel drilled boreholes. Additionally, the electrical conductivity of the water in some borehole sections and in the tunnel water is measured. The network includes boreholes on the islands of Äspö, Ävrö, Mjälen, Bockholmen and some boreholes on the mainland at Laxemar.

Data is transferred by means of radiolink, cable and manually to a dedicated computerised database. The HMS computer system runs on Pentium computers with the

Windows NT operating system where a real time engine is accessing the HMS database. This engine provides integrated data acquisition, monitoring, data logging and report generation.

New results

The HMS program has been running real time data acquisition in support of the various project undertaken in the Äspö Hard Rock Laboratory.

This support consists of providing data from boreholes affected by an experiment and of utilizing the HMS infrastructure for collection and monitoring of experiment specific data. The system has been utilized mainly by the Geomode, TRUE and the Prototype Respository projects.

Produced a plan for the overall evaluation and assessment of the HMS. This work will be part of the Testplan for the groundwater monitoring of the geoscientific site characterization program.

Planned work

For the next quarter it is planned to

- Continued support to various projects
- Start the overall evaluation and assessment of the HMS.

5.4 Program for monitoring groundwater chemistry

Background

During the construction phase of the Äspö Hard Rock Laboratory, different types of water samples were collected and analysed with the purpose of monitoring the groundwater chemistry and its evolution as the construction proceeded. The samples were obtained from the cored boreholes drilled from the ground surface and from percussion and cored boreholes drilled from the tunnel.

Objectives

At the beginning of the operational phase, sampling was replaced by a groundwater chemistry monitoring program, aiming to sufficiently cover the hydrochemical conditions with respect to time and space within the Äspö HRL. This program should provide information for determining where, within the rock mass, the hydrochemical changes are taking place and at what time stationary conditions have been established.

New results

The results from the sampling in April and in October have been presented in Technical Documents TD-00-10 and TD-00-12.

Planned work

The monitoring programme has been reduced to one sampling period a year. Next sampling occasion is scheduled to take place w039 and 040.

5.5 Technical systems

Background

The monitoring of groundwater changes (hydraulic and chemical) during the construction of the laboratory is an essential part of the documentation work aiming at verifying pre-investigation methods. The great amount of data calls for efficient data collection system and data management procedures. Hence, the Hydro Monitoring System (HMS) for on-line recording of these data have been developed and will continuously be expanded along with the tunneling work and the increased number of monitoring points.

New results

The installation of the presentation system is continued as planned, during April the test period are starting. After the testperiod SKB take over the system. The system consist of two parts an PLC (Programable logic controller) and the Process system.

The PLC is made by Siemens and the Process system is made by IC(Intouch).

The weirs in the tunnel has been calibrated.

The equipment in borehole KLX01 at the surface has been disconnected from electricity supply and is now powered by battery and suncells.

Planned work

The presentation system will be in full operation during Summer 2000.

The borehole HAS 04 are going to get a new packer system.

The equipment in borehole KBH02 is going to be disconnected from electricity supply and is going to be driven by battery and a sun-cell.

5.6 Information

Background

The information group´s main goal is to create public acceptance for SKB in cooperation with other departments in SKB. This is achieved by giving information about SKB, the Äspö HRL and the SKB siting programme. The visitors are also given a tour of the Äspö HRL. Today there are one visitor´s administrator and four public relations officers stationed at the Äspö HRL.

New results

During the first quarter of 2000, 2061 visitors visited the Äspö HRL. The groups have represented the general public, communities where SKB performs feasibility studies, teachers, students, politicians, journalists and visitors from foreign countries. 1160 represented the six communities were SKB performs feasibility studies.

Urberg 500

The official inauguration of ”Urberg 500” took place on March 9. More than 100 people took part in the inauguration.

SKB and OKG have started a project group. The project group will be working for a common booking central and booking system. An external project leader has been hired to run the project.

A safety/instruction video for consultants concerning work and safety under ground is under production.

6 International cooperation

6.1 Current international participation in the Äspö Hard Rock Laboratory

Nine organisations from eight countries are currently (April 2000) participating in the Äspö Hard Rock Laboratory.

In each case the cooperation is based on a separate agreement between SKB and the organisation in question. Table 6-1 shows the scope of each organisation's participation under the agreements.

Most of the organisations are interested in groundwater flow, radionuclide transport and rock characterization. Several organisations are participating in the Äspö Task Force on groundwater flow and radionuclide migration, which is a forum for cooperation in the area of conceptual and numerical modelling of groundwater flow and solute transport in fractured rock.

Table 6-1. Scope of international cooperation

Organization	Scope of participation
Agence Nationale pour la Gestion des Déchets Radioactifs, **ANDRA**, France.	Detailed investigation methods and their application for modelling the repository sites Test of models describing the barrier function of the bedrock Demonstration of technology for and function of important parts of the repository system
Bundesministerium für Wirtschaft und Technologie, **BMWi**, Germany	Two-phase flow investigations including numerical modelling and model calibration Participation in the Task Force on modelling of groundwater flow and transport of solutes by using "German" computer codes Participation in the geochemical modelling efforts in the Äspö HRL Work related to transport and retention of radionuclides and colloids in granitic rock In-situ geoelectrical measurements with respect to water saturation of rock masses in the near field of underground tunnels Work on design and performance of in-situ tests using methods and equipment similar to those used in the Grimsel investigations

Organization	Scope of participation
Empresa Nacional de Residuos Radiactivos, **ENRESA**, Spain	Test of models describing the barrier function of the bedrock (TRUE Block Scale) Demonstration of technology for and function of important parts of the repository system, (Backfill and Plug Test)
Japan Nuclear Cycle Development Institute, **JNC**, Japan. The Central Research Institute of the Electronic Power Industry**, CRIEPI,** Japan	The Tracer retention understanding experiments (TRUE) The detailed scale redox (REX) experiment Radionuclide retention experiments Task Force on modelling of groundwater flow and transport of solutes. Prototype repository project. Long-term test of buffer materials
Nationale Genossenschaft für die Lagerung Radioaktiver Abfälle, **NAGRA**, Switzerland	Test of models describing the barrier function of the bedrock Demonstration of technology for and function of important parts of the repository system
United Kingdom Nirex Limited, **NIREX**, Great Britain	TRUE Block Scale
POSIVA , Finland.	Detailed investigation methods and their application for modelling the repository sites Test of models describing the barrier function of the bedrock Demonstration of technology for and function of important parts of the repository system - *Prototype repository*
USDOE/**Sandia National Laboratories**, USA	Test of models describing the barrier function of the bedrock

6.2 Summary of work by participating organisations

6.2.1 Work performed by Posiva Oy

Posiva Oy is looking forward to the decision in principle of the Council of State. Posiva's application for this policy decision was submitted to the Government on May 1999. In the application the Olkiluoto site in the municipality of Eurajoki, Southwestern Finland was proposed site for the deep repository for the spent fuel.

According to the Nuclear Energy Act, the Radiation and Nuclear Safety Authority (STUK) has to in it's statement and in its preliminary safety appraisal, as well as the council of the host municipality, support the application. The statement of STUK and the statement of the municipality of Eurajoki were both given on January 2000. Both statements were positive. An appeal to the local administrative court, however, submitted by local citizens. The court's decision whether the statement of the municipality is applicable to a complaint is expected in couple of months. At the moment the Ministry of Trade and Industry is preparing a summary for the Council of State on the basis of the hearing carried out and statements received.

Fieldwork at Äspö HRL

During the first quarter of 2000 Posiva has participated in the fieldwork at the Äspö HRL mainly within the Hydrochemical Stability project. The Posiva flowmeter, see Figure 6-1, has been tested in the borehole KLX02. In addition to the testing of the equipment the aim of the project was to get information for characterising the hydrology and hydrogeochemistry of the deep saline groundwater.

Flow measurements

The flow measurements were carried out in borehole KLX02 at Laxemar on February 2^{nd} – March 1^{st}, 2000. The fieldwork was conducted by PRG-Tec Oy.

The field program consisted of the following:

- DIFF normal mode measurements 200 –1400 m without pumping the borehole.
- Fresh waterhead measurements 1400 - 200 m without pumping the borehole.
- DIFF normal mode measurements 200-1400 m with pumping the borehole.
- Fresh waterhead measurements 1400 - 200 m with pumping the borehole.

DIFF normal mode measurements were performed with 3 m section length and 3 m depth increments. Flow rate into the borehole or out from the borehole within the section was measured. Temperature and electrical conductivity of the borehole water was measured simultaneously. Single point resistance (fracture location) was also logged with high depth resolution during the DIFF measurements.

The objective of the measurements was to determine hydraulic conditions in the borehole. The main feature discovered was that the flow direction in the measured depth range of 200-1200 m was from the borehole into the bedrock when the borehole was in natural state (without pumping). Pumping reversed the flow direction. There was not any flow detected under 1200 m depth. Hydraulic head and hydraulic conductivity was interpreted from the measured flow and fresh water head values, see Figure 6-2.

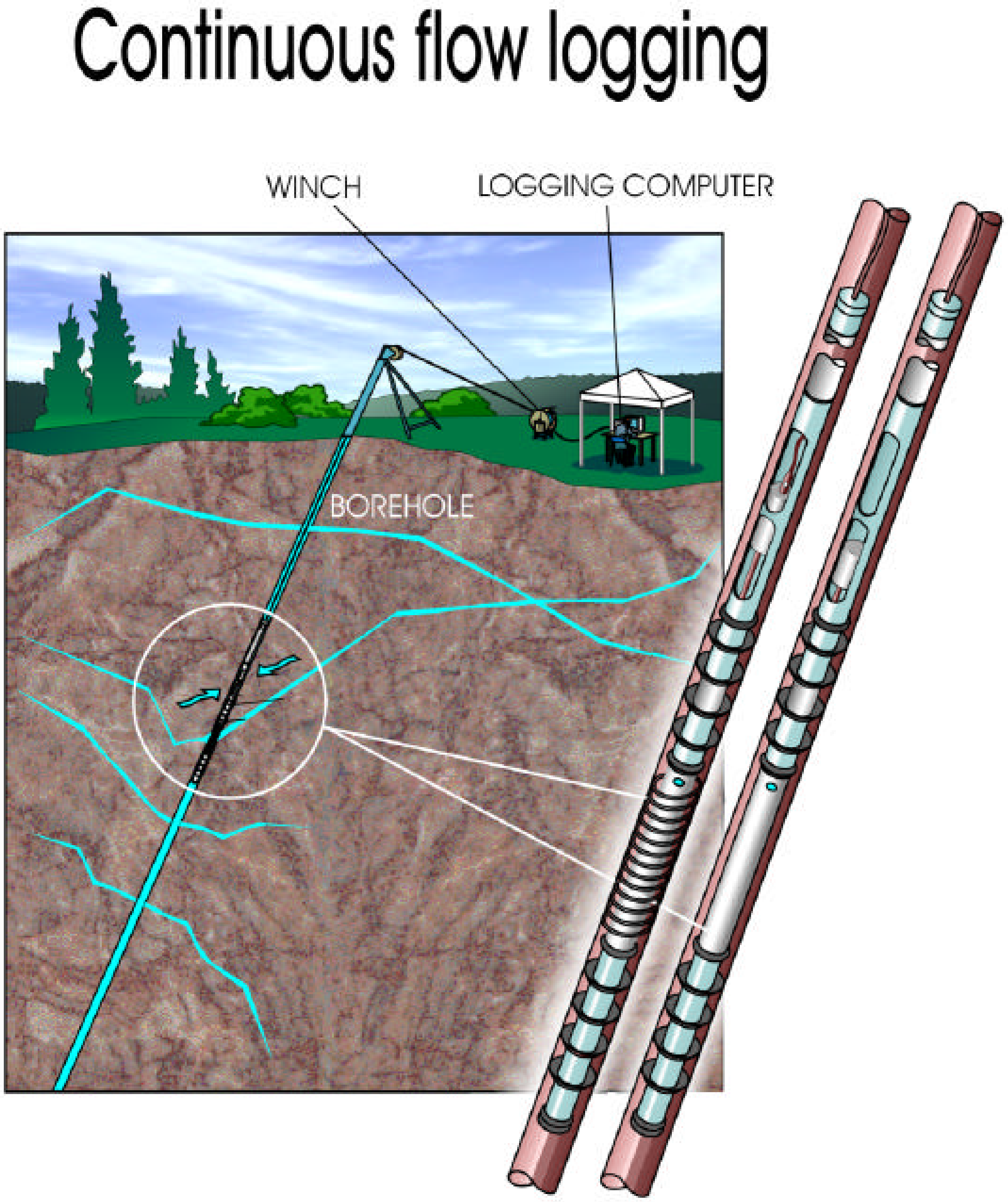


Figure 6-1 *Principle of the Posiva flowmeter. With the probe on the left the electrical conductivity (EC) and temperature of the borehole water are measured simultaneously. The difference flow (DIFF) measurements are done with the probe on the right. The single point resistance is logged with high depth resolution during the DIFF measurements.*

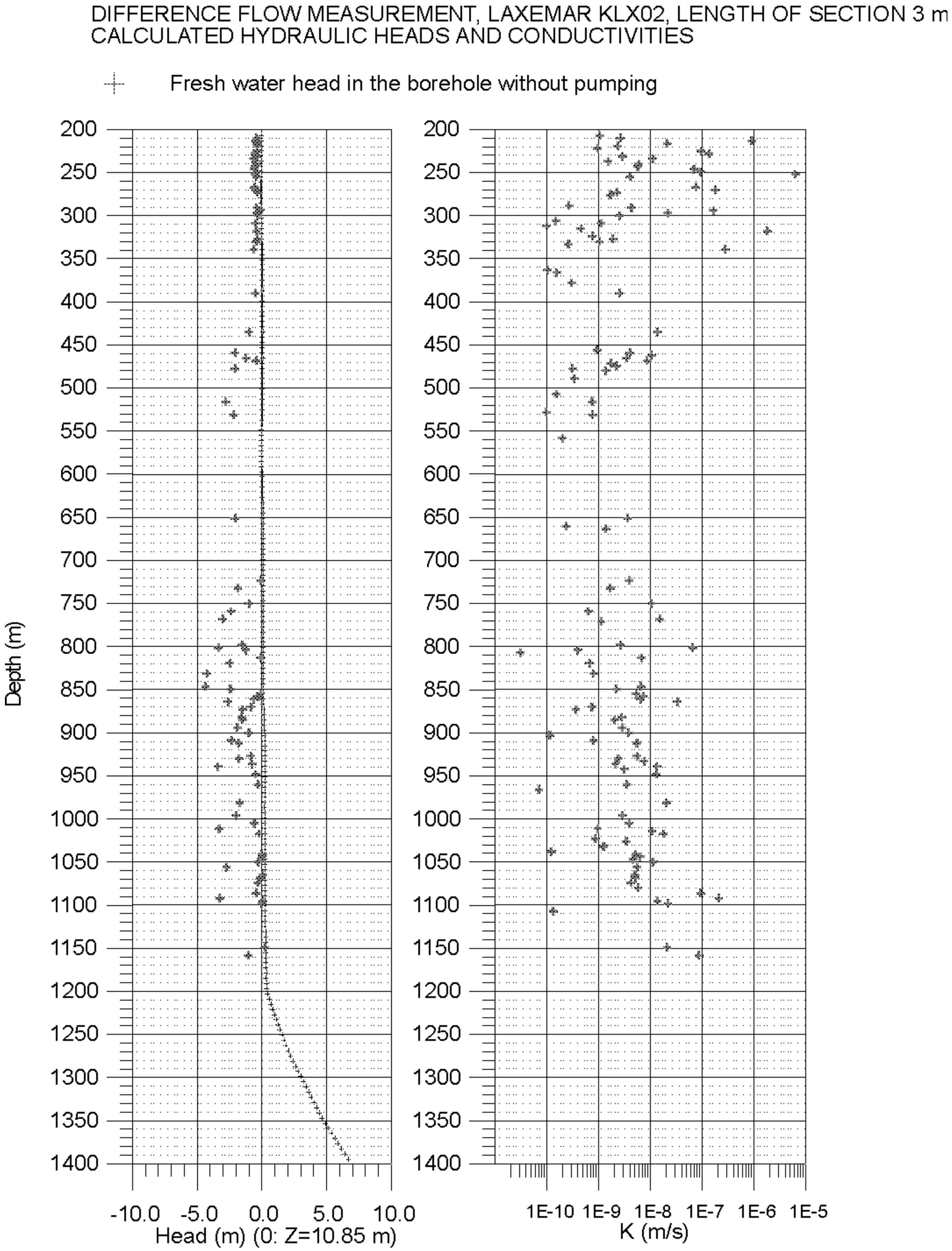


***Figure 6-2** Hydraulic head and conductivity of the borehole KLX02 was interpreted from the measured flow and fresh water head values.*

Planned fieldwork

As a part of the Joint Project between Posiva and SKB the testing of the Posiva flowmeter will continue in borehole KLX02 in May 2000 with the second campaign for difference flow measurements in detailed mode. A methodology study (at the borehole section 400-600 m) will be added to the second campaign.

EQUIP-project

The partly EC-funded, three year project EQUIP (Evidences from Quaternary Infillings for Palaeohydrology) started in 1997 after British Geological Survey (BGS) had observed that zoning of calcite fracture minerals may reflect effects of ancient climatic changes on hydrogeochemical conditions. Posiva has participated in the project as a part of the Hydrochemical Stability project.

The aims of the Finnish part in the EQUIP project were 1) to study the most recent calcite generations sampled from hydrologically conductive fractures that also have hydrochemical background data and 2) to evaluate these observations against the models of hydrogeochemical evolution and groundwater flow of the Olkiluoto site. Perhaps due to the high pressures of flushing water during the drilling activities, practically no fracture minerals were observed in the conductive fractures. Therefore the 35 calcite samples studied in the project represent the immediate vicinity of conductive fractures.

The latest calcites representing most clearly precipitation in an open fracture were found at the depth level of approximately 80-400 m. Presently brackish, SO_4-rich groundwaters with the strongest signs of the ancient Litorina seawater have been observed at 100-300 m. The latest calcites are only 10-50 μm thick scaly or partly idiomorphic. They have higher Fe contents compared to the older generations. The contents of main and trace elements and partly also those of the REE are on typical levels, helping to distinguish the latest calcites from the older ones.

The latest calcites contain generally no, or only extremely small and few fluid inclusions, allowing no T_h and T_m measurements and no estimate on the salinity or temperature of the groundwaters from which the latest calcites were precipitated.

The $^{87}Sr/^{86}Sr$ data of the calcites refer to dissolved strontium, apparently originating from plagioclase dissolution. The Sr-isotope study also pointed clearly out how demanding it is to sample the extremely thin layers of the latest calcite. The ^{18}O isotopes of the fracture calcites at Olkiluoto suggest equilibrium with the currently observed groundwaters. However, the ^{13}C results refer to disequilibrium with the present groundwaters and also indicate that the calcites could not have formed from the Litorina seawaters. There are a few positive ^{13}C values suggesting effects of microbiological processes, possibly hydrogen-driven methanogenesis and/or acetogenesis. There is no clear indication of calcite precipitation from groundwaters infiltrated during cooler than the present climate.

According to the results, the methanogenetic conditions may have been at much higher levels (about 100 m) than the deep level (400-500 m) observed currently in hydrochemical and geomicrobiological studies. When Olkiluoto became part of the present hydrological circulation at 3000-2500 BP, the methanogenetic conditions apparently moved slowly first somewhat downwards and then laterally into the west, below the Baltic Sea.

Due to the very low general levels of uranium in the fracture calcites at Olkiluoto and especially due to the extreme thinness of the latest calcite generation, no USD analyses was done to achieve some estimation of the crystallisation times of the calcites. However, the Fe-rich calcite fillings of the latest generation are apparently older than the establishment of the present-day hydrological circulation system at about 3000-2500 BP. The content of Fe in the SO_4-rich, Litorina-derived groundwater is buffered to a very low level by sulphate reduction and precipitation of iron sulphides on the fracture walls. In addition, the $\delta^{13}C$ values of aqueous dissolved inorganic carbon at these depths today are clearly negative, compatible with sulphate reduction, while the latest fracture calcites are characterised with variable and in some cases even positive $\delta^{13}C$ values.

The final reporting of the project is in progress.

7 Other matters

Documentation

During the period January-March 2000, the following reports have been published and distributed:

7.1.1 Äspö International Cooperation Reports

Shao H, Liedtke L, 1999
Modelling the reactive - radioactive and sorbing tracer tests in fractured rock
Äspö Task Force, Task 4E and 4F
ICR 99-03

7.1.2 Äspö International Progress Reports

Sundberg J, Gabrielsson A, 1999
Laboratory and field measurements of thermal properties of the rocks in the prototype repository at Äspö HRL
IPR-99-17

Autio J, Kirkkomäki T, Siitari-Kauppi M, Timonen J, Laajalahti M, Aaltonen T, Maaranen J, 1999
Use of the 14c-pmma and he-gas methods to characterise xcavation disturbance in crystalline rock
IPR-99-18

Morosini M (ed), 1999
Proceedings from the 12^{th} Task Force Meeting at Gimo, Sweden, April 20-22, 1999
Äspö Task Force on Modelling of Groundwater Flow and Transport of Solutes.
IPR-99-22

Elert M, Svensson H, 1999
Deconvolution of breakthrough curves from TRUE-1 tracer tests (STT-1 and STT-1b) with sorbing tracers. Äspö Task Force, Task 4E.
IPR-99-35

Byegård J, Johansson H, Andersson P, Hansson K, Winberg A, 1999
Test plan for the long term diffusion experiment.
IPR-99-36

Smellie J, 2000
Test plan for Sampling of matrix fluids from low conductive bedrock.
IPR-00-01

Rhén I, Forsmark T, 2000
High-permeability features (HPF)
IPR-00-02

Äspö Hard Rock Laboratory, 2000
Status Report October-December 1999.
IPR-00-03

14 **Technical Documents**

9 **International Technical Documents**

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SKB Progress Report PR 25-94-24

Geller, J.T. and Jarsjö, J., 1995. Groundwater degassing and two-phase flow: Pilot hole test report.
SKB International Cooperation Report 95-03

Hakami, E., 1995. Aperture distribution of rock fractures. Ph. D. thesis, Royal Institute of Technology, Department of Civil and Environmental Engineering, Division of Engineering Geology, Stockholm

Jarsjö, J. and Destouni, G., 1997a. Groundwater degassing: Pilot injection - withdrawal field tests with gas saturated water.
SKB Progress Report HRL-97-02

Jarsjö, J. and Destouni, G., 1997b. Conditions for fracture transmissivity reduction due to degassing of groundwater: analytical expressions, numerical simulations and analysis of laboratory and field data.
SKB Progress Report HRL-97-03

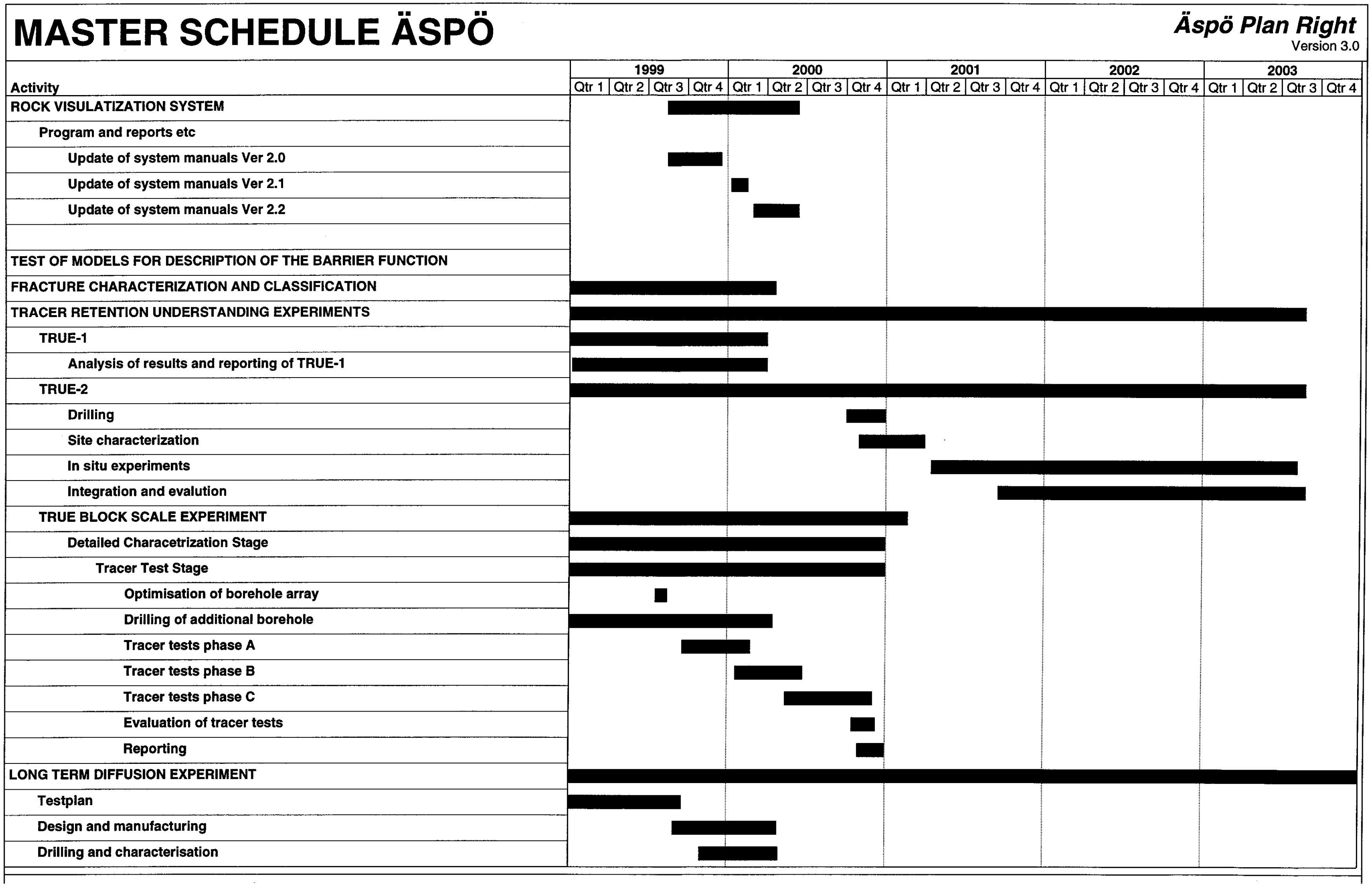
Jarsjö, J. and Destouni, G., 1998. Groundwater degassing in fractured rock: Modelling and data comparison.
SKB Technical Report TR-98-17

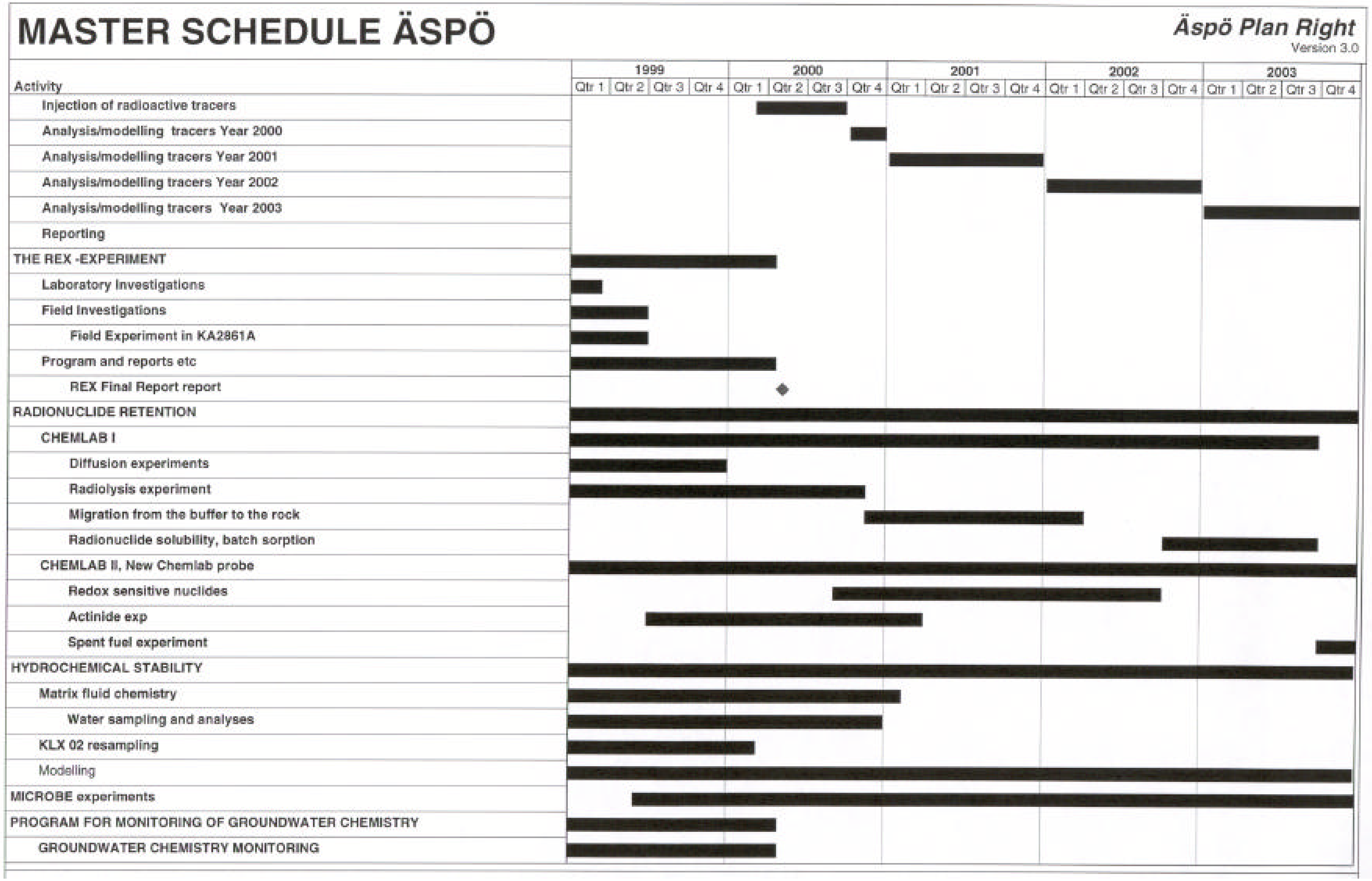
Olsson O, Bäckblom G, Gustafson G, Rhén I, Stanfors R and Wikberg P, 1994. The structure of conceptual models with application to the Äspö HRL Project.
SKB Technical Report 94-08

Olsson, O. (Editor), 1992. Site characterisation and validation - Final Report.
SKB Stripa Project Technical Report 92-22

Rhén I (ed), Gustafson G, Stanfors R and Wikberg P, 1997. ÄSPÖ HRL - Geoscientific evaluation 1997/5. Models based on site characterization 1986-1995.
SKB Technical Report 97-06

Appendix A


MASTER SCHEDULE ÄSPÖ
Äspö Plan Right
Version 3.0
Activity
1999
2000
2001
2002
2003
Qtr 1
Qtr 2
Qtr 3
Qtr 4
ROCK VISULATIZATION SYSTEM
Program and reports etc
Update of system manuals Ver 2.0
Update of system manuals Ver 2.1
Update of system manuals Ver 2.2
TEST OF MODELS FOR DESCRIPTION OF THE BARRIER FUNCTION
FRACTURE CHARACTERIZATION AND CLASSIFICATION
TRACER RETENTION UNDERSTANDING EXPERIMENTS
TRUE-1
Analysis of results and reporting of TRUE-1
TRUE-2
Drilling
Site characterization
In situ experiments
Integration and evalution
TRUE BLOCK SCALE EXPERIMENT
Detailed Characetrization Stage
Tracer Test Stage
Optimisation of borehole array
Drilling of additional borehole
Tracer tests phase A
Tracer tests phase B
Tracer tests phase C
Evaluation of tracer tests
Reporting
LONG TERM DIFFUSION EXPERIMENT
Testplan
Design and manufacturing
Drilling and characterisation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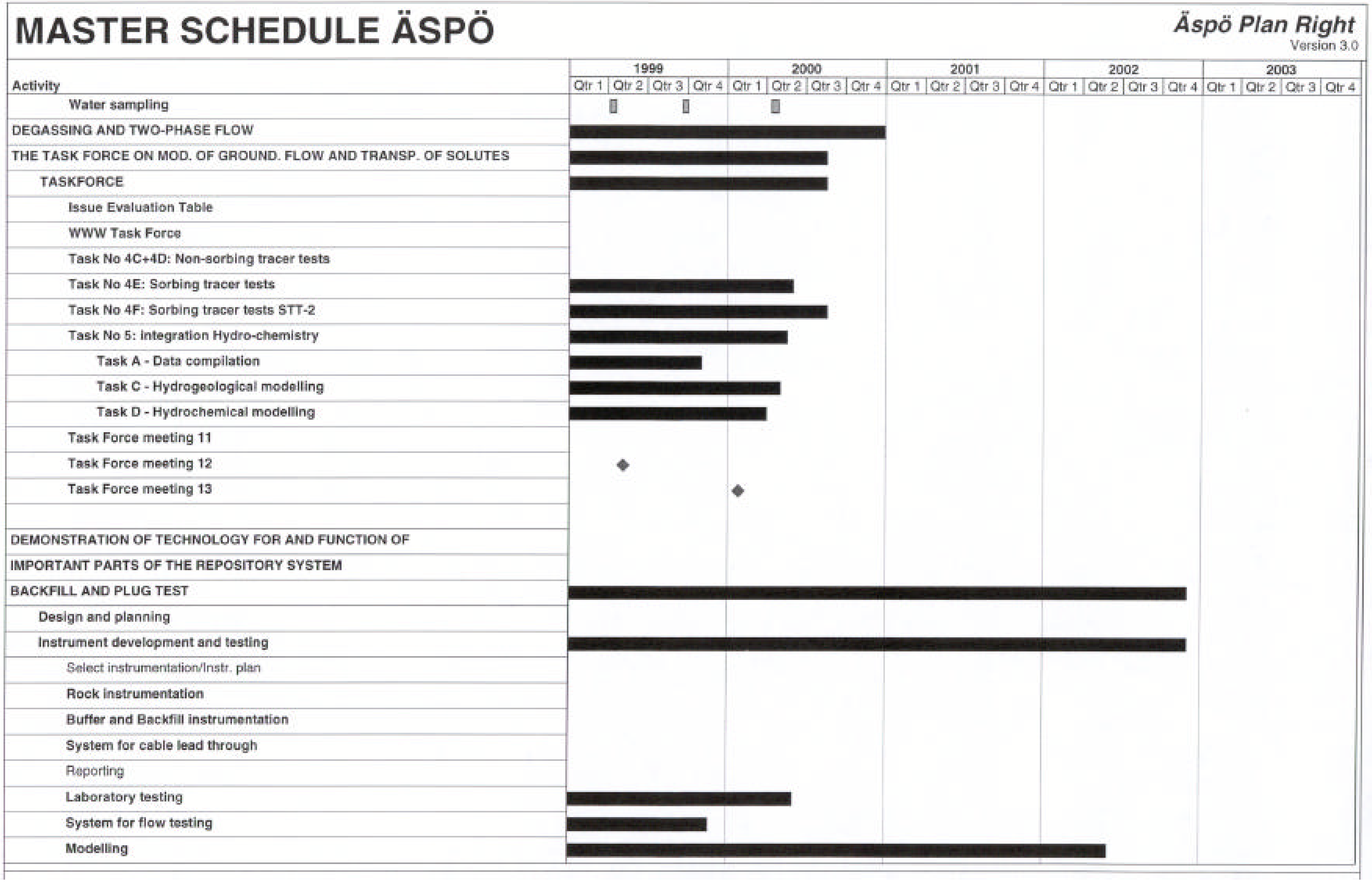
Qtr 4
Injection of radioactive tracers
Analysis/modelling tracers Year 2000
Analysis/modelling tracers Year 2001
Analysis/modelling tracers Year 2002
Analysis/modelling tracers Year 2003
Reporting
THE REX -EXPERIMENT
Laboratory Investigations
Field Investigations
Field Experiment in KA2861A
Program and reports etc
REX Final Report report
RADIONUCLIDE RETENTION
CHEMLAB I
Diffusion experiments
Radiolysis experiment
Migration from the buffer to the rock
Radionuclide solubility, batch sorption
CHEMLAB II, New Chemlab probe
Redox sensitive nuclides
Actinide exp
Spent fuel experiment
HYDROCHEMICAL STABILITY
Matrix fluid chemistry
Water sampling and analyses
KLX 02 resampling
Modelling
MICROBE experiments
PROGRAM FOR MONITORING OF GROUNDWATER CHEMISTRY
GROUNDWATER CHEMISTRY MONITORING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Qtr 1
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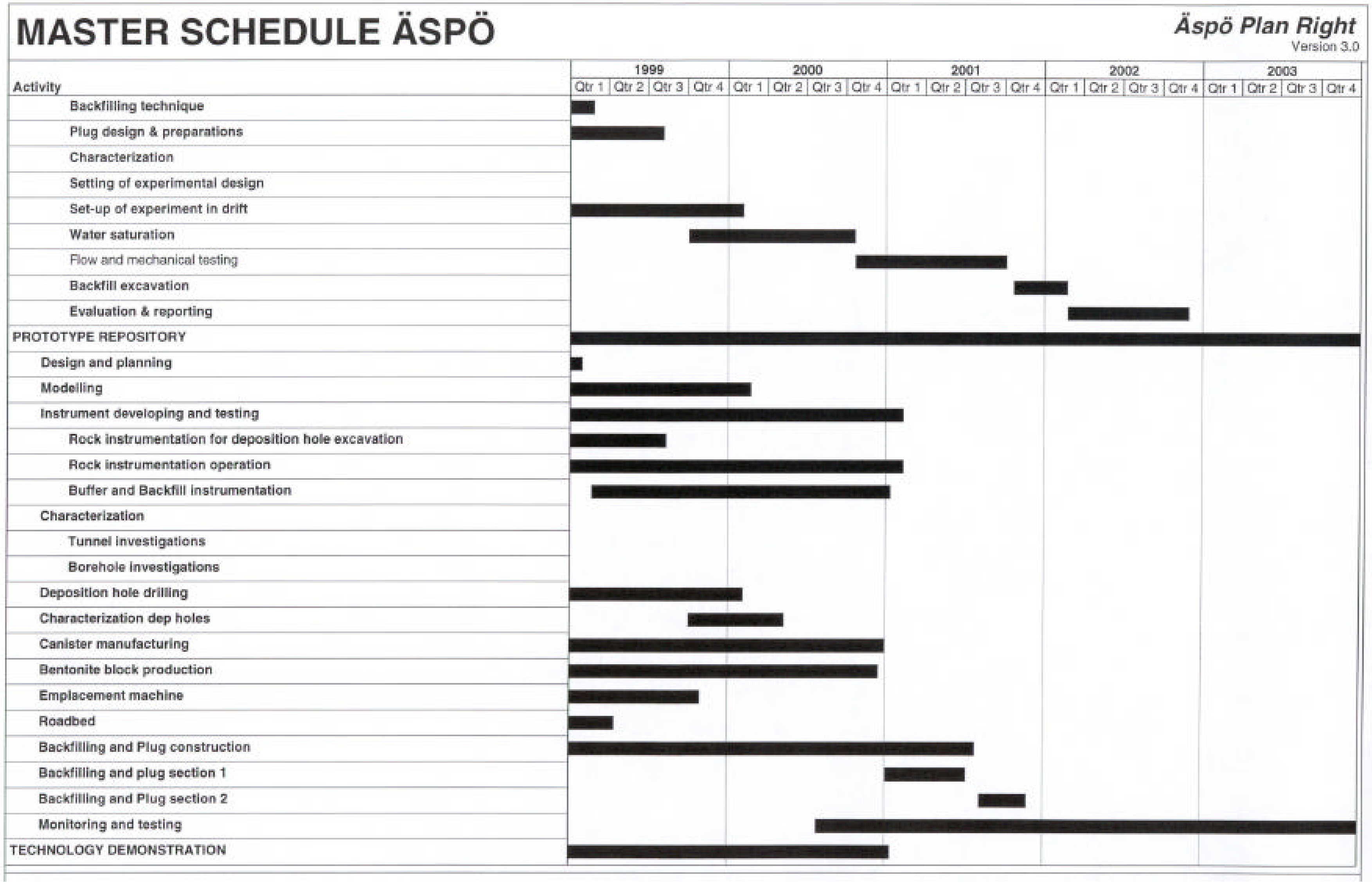
Qtr 3
Qtr 4
Water sampling
DEGASSING AND TWO-PHASE FLOW
THE TASK FORCE ON MOD. OF GROUND. FLOW AND TRANSP. OF SOLUTES
TASKFORCE
Issue Evaluation Table
WWW Task Force
Task No 4C+4D: Non-sorbing tracer tests
Task No 4E: Sorbing tracer tests
Task No 4F: Sorbing tracer tests STT-2
Task No 5: Integration Hydro-chemistry
Task A - Data compilation
Task C - Hydrogeological modelling
Task D - Hydrochemical modelling
Task Force meeting 11
Task Force meeting 12
Task Force meeting 13
DEMONSTRATION OF TECHNOLOGY FOR AND FUNCTION OF
IMPORTANT PARTS OF THE REPOSITORY SYSTEM
BACKFILL AND PLUG TEST
Design and planning
Instrument development and testing
Select instrumentation/Instr. plan
Rock instrumentation
Buffer and Backfill instrumentation
System for cable lead through
Reporting
Laboratory testing
System for flow testing
Modelling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Version 3.0
Activity
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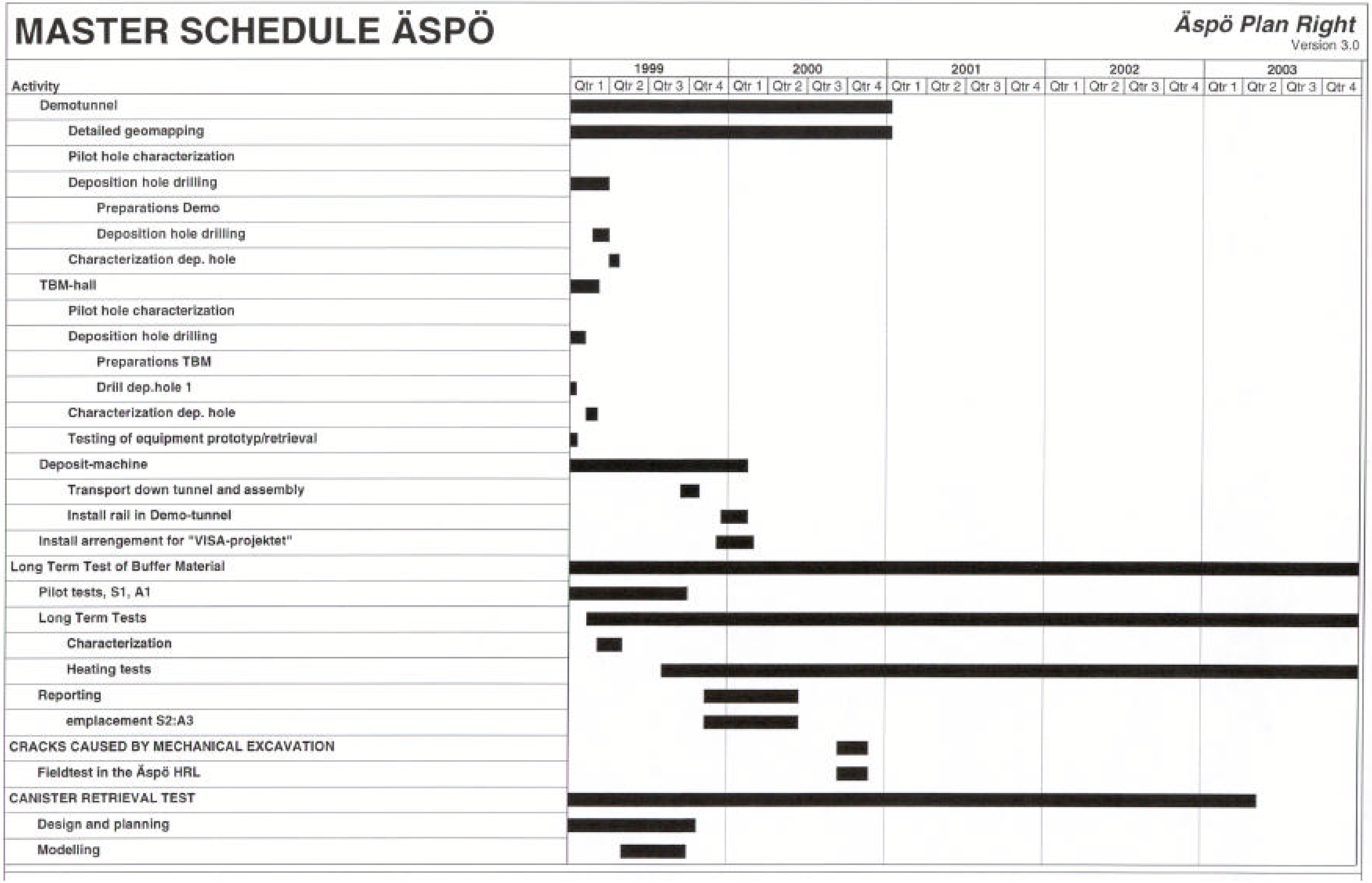
Qtr 1
Qtr 2
Qtr 3
Qtr 4
Backfilling technique
Plug design & preparations
Characterization
Setting of experimental design
Set-up of experiment in drift
Water saturation
Flow and mechanical testing
Backfill excavation
Evaluation & reporting
PROTOTYPE REPOSITORY
Design and planning
Modelling
Instrument developing and testing
Rock instrumentation for deposition hole excavation
Rock instrumentation operation
Buffer and Backfill instrumentation
Characterization
Tunnel investigations
Borehole investigations
Deposition hole drilling
Characterization dep holes
Canister manufacturing
Bentonite block production
Emplacement machine
Roadbed
Backfilling and Plug construction
Backfilling and plug section 1
Backfilling and Plug section 2
Monitoring and testing
TECHNOLOGY DEMONSTRATION


MASTER SCHEDULE ÄSPÖ
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Activity
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Qtr 1
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Qtr 3
Qtr 4
Demotunnel
Detailed geomapping
Pilot hole characterization
Deposition hole drilling
Preparations Demo
Deposition hole drilling
Characterization dep. hole
TBM-hall
Pilot hole characterization
Deposition hole drilling
Preparations TBM
Drill dep.hole 1
Characterization dep. hole
Testing of equipment prototyp/retrieval
Deposit-machine
Transport down tunnel and assembly
Install rail in Demo-tunnel
Install arrengement for "VISA-projektet"
Long Term Test of Buffer Material
Pilot tests, S1, A1
Long Term Tests
Characterization
Heating tests
Reporting
emplacement S2:A3
CRACKS CAUSED BY MECHANICAL EXCAVATION
Fieldtest in the Äspö HRL
CANISTER RETRIEVAL TEST
Design and planning
Modelling


MASTER SCHEDULE ÄSPÖ
Äspö Plan Right
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Activity
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Qtr 1
Qtr 2
Qtr 3
Qtr 4
Instrument developing and testing
Rock instrumentation
Buffer instrumentation
Testing of deposition technique
Characterisation
Tunnel investigation
Pilot borehole investigation
Instrumentation holes
Deposition hole drilling
Preparations
Deposition hole drilling
Characterisation of dep holes
Canister manufacturing
Bentonite block production
Test installation
Saturation