International
Progress Report

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Äspö Hard Rock Laboratory

Status Report
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Äspö Hard Rock
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SUMMARY

INVESTIGATIONS AND EXPERIMENTS

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 sorbing tracer test STT-2 was started on June 5th, 1998, being the third tracer test with sorbing tracers at the TRUE-1 site. Three conservative tracers and nine weakly sorbing tracers were injected as a four hour long pulse. The in-situ sampling part of STT-2 was officially discontinued early December. The STT-2 test is presently subject to predictive modelling within the Äspö Task Force (Task 4F). The experimental breakthrough data will be presented at the next Task Force meeting in April 1999.

The TRUE Block Scale project aims at studying the tracer transport in a fracture network over distances up to 50 m. The major effort during the period has been compilation and analysis of data for the purpose of the 2nd TRUE Block Scale Review Meeting which was held Nov 17. At this meeting a conceptual model of groundwater flow within the studied block was presented. A plan for future work was presented, discussed and broadly approved by the reviewers.

This Long-Term Diffusion Experiment is intended as a complement to the dynamic in-situ experiments and the laboratory experiments performed in the TRUE Programme. The basic idea is to locate a static tracer experiment to unfractured rock mass with the intention to characterise diffusion of radionuclides into the rock matrix. Work is presently underway to produce a test plan for the experiment.

The CHEMLAB probe has been constructed and manufactured for validation experiments in situ at undisturbed natural conditions. No diffusion experiments were carried out during the last three months, because of problems in the CHEMLAB 1 system. The equipment is currently being repaired.

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. Data from laboratory, field and model investigations addressing groundwater degassing have been summarised and interpreted. The analysis shows that the observed flow reductions indeed are consistent with the degassing hypothesis. Turbulence may be ruled out as a plausible factor contributing to the observed flow reductions.

The hydrochemical stability project is undertaken with the purpose to describe possible scenarios for evolution of groundwater chemistry at Äspö. The pressure build up continues in the matrix fluid borehole KF0051A located in the F-tunnel at the deepest part of the Äspö laboratory. During the first 6 months there is no extractable groundwater. Predictive calculations show that it might take more than a year to obtain a water sample.

The objective of Task 5 is to assess the consistency of groundwater flow models and hydrochemical mixing-reaction models based on Äspö data. The first groundwater flow modelling sequence of Task#5 is completed. New hydrochemical boundary and initial conditions were provided to the modelling groups soon after the 11th Task Force Meeting at Äspö 1-3 September. The reports will be distributed among the modellers before the next working group meeting 2-3 February.

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. General planning of the project has been completed and the Test Plan has been printed and distributed. The field activities of characterisation of the rock mass around the Prototype Repository tunnel have been almost completed. An international workshop was held on December 8-9 with invited representatives from the Äspö Hard Rock Laboratory participants. The aim was to discuss the interest for international participation in the project and to outline a possible basis for an EC application. The outcome was positive and several organisations indicated their interest for participation.

The TBM machine for deposition hole boring was delivered to ÄHRL in October, but was suffering from major electrical and oil-hydraulic manufacturing mistakes resulting in delay of the planned November 4 boring start. The machine was still not running properly at December 31.

The Backfill and Plug Test comprises full scale testing of backfill materials, filling methods, and plugging. The hydraulic testing and the installation of packers in the instrument holes have been finished as well as all other preparations in the rock required before backfilling can start. Backfilling of the test drift will start in January.

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 preparations of the drift required before boring of the four deposition holes have been completed. Similar preparations in the drift for the Retrieval Test have also been completed.

The Long Term Tests of Buffer Material aim to validate models and hypotheses concerning long term processes in buffer material. Reference material and material from defined positions in the A1 and S1 parcels material have been tested and analysed. All tests and analyses except those concerning microstructure have been completed and compilation is in progress. No unexpected results have been observed. The copper analyses have been completed and the results indicate a corrosion rate in the range of what was expected for oxic conditions.

INTERNATIONAL COOPERATION

Ten organisations from nine countries are currently (December 1998) participating in the Äspö Hard Rock Laboratory.

The agreement between SKB and BMBF has been renewed for another four years.

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.

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 September 29, 1995. This programme is the basis for the planning and execution of the work.

The revised Stage Goals for the Operating Phase are defined 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 TEST OF MODELS FOR DESCRIPTION OF BARRIER FUNCTION OF THE HOST ROCK

2.1 GENERAL, Olle Olsson

The rock surrounding the repository constitutes a natural barrier to radionuclides released from a deep geological repository. The most important function of the natural barrier is to provide protection for the engineered barriers in order to ensure isolation of the waste for long periods of time. To provide long term isolation, the waste container and the buffer material need to be placed in a favourable and stable chemical environment. In the event the engineered barriers have been damaged, the ability of the rock to retain and/or retard transport of radionuclides is an important safety factor. The rock mass in combination with the buffer and the waste container are the main components of the multiple barriers on which the repository concept is based.

In this context it is important to be able to understand and describe

- the nature and evolution of the chemical environment for the engineered barriers,
- transport of corrodants to the waste containers, and
- transport of radionuclides through the host rock

in order to assess the safety of a deep repository for spent fuel. Another important aspect is to ensure that the changes in mechanical and chemical conditions induced by construction and operation of the repository before closure do not have negative effects on long term safety.

Performance and safety assessments are based on models describing processes considered to be of relevance for transport of contaminants in fractured rock. These assessment models are being further developed, where necessary, as a part of SKB's program for research and development. In addition, the relationship between model parameters and field data needs to be described more accurately. The issue of conceptual model uncertainty is also a major concern.

In this context, the main purpose of the experiments planned to achieve the third Stage Goal of the Äspö HRL Project, i.e. to test models for groundwater flow and radionuclide migration, is to provide a better basis for the safety assessments required for licensing of the deep repository. Experiments will be performed to:

- improve understanding of important processes affecting radionuclide transport and chemical conditions at repository lever,

- test to what extent model concepts and data provide realistic descriptions of radionuclide transport, and

- evaluate the usefulness and feasibility of different modelling approaches.

A "Task Force on Numerical Modelling of Groundwater Flow and Transport of Solutes" has been formed with representatives of the Äspö HRL Project's international participants. The Task Force offers opportunities for testing alternative modelling approaches to the ones developed within SKB's research and development program.

2.2 TRACER RETENTION UNDERSTANDING EXPERIMENTS, Anders Winberg

2.2.1 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.

2.2.2 TRUE-1

TRUE-1 Conceptual modelling

Work has continued during the period on the conceptual models of the TRUE-1 block and Feature A. The basis of this work has been the joint FCC/TRUE work on the TRUE-1 site as part of the FCC Phase III. For the benefit of the continued evaluation of the TRUE-1 tracer tests with sorbing tracers a technical memorandum detailing the TRUE Project team conceptualisation of the block and Feature A has been compiled and distributed to the Task Force. The result of the updating is that the basic models presented by Winberg et al. (1996) still are valid. However, they have been detailed with regards to the near environment to Feature A. Figure 2-1 shows the updated structural model of the TRUE-1 site.

Tracer test programme

The sorbing tracer test STT-2 was started on June 5th, 1998, being the third tracer test with sorbing tracers at the TRUE-1 site. The test geometry with injection in KXTT4:R3 and pumping in KXTT3:R2 is exactly the same as in STT-1. The difference is that the pumping flow rate has been lowered from 400 ml/min to 200 ml/min. Three conservative tracers (Uranin, HTO, ^{82}Br) and nine weakly sorbing tracers (^{22}Na, ^{42}K, ^{47}Ca, ^{85}Sr, ^{86}Rb, ^{99m}Tc, ^{131}Ba, ^{133}Ba, ^{134}Cs) were injected as a four hour long pulse. The injection function was presented in the previous Status Report for July through September (SKB 1998). The in-situ sampling part of STT-2 was officially discontinued early December. Vital equipment has been demobilised for maintenance.

The STT-2 test is presently subject to predictive modelling within the Äspö Task Force (Task 4F). The experimental breakthrough data will be presenteded at the next Task Force meeting in April 1999.

The reporting of STT-1b has been delayed because of other priorities within the TRUE Project.

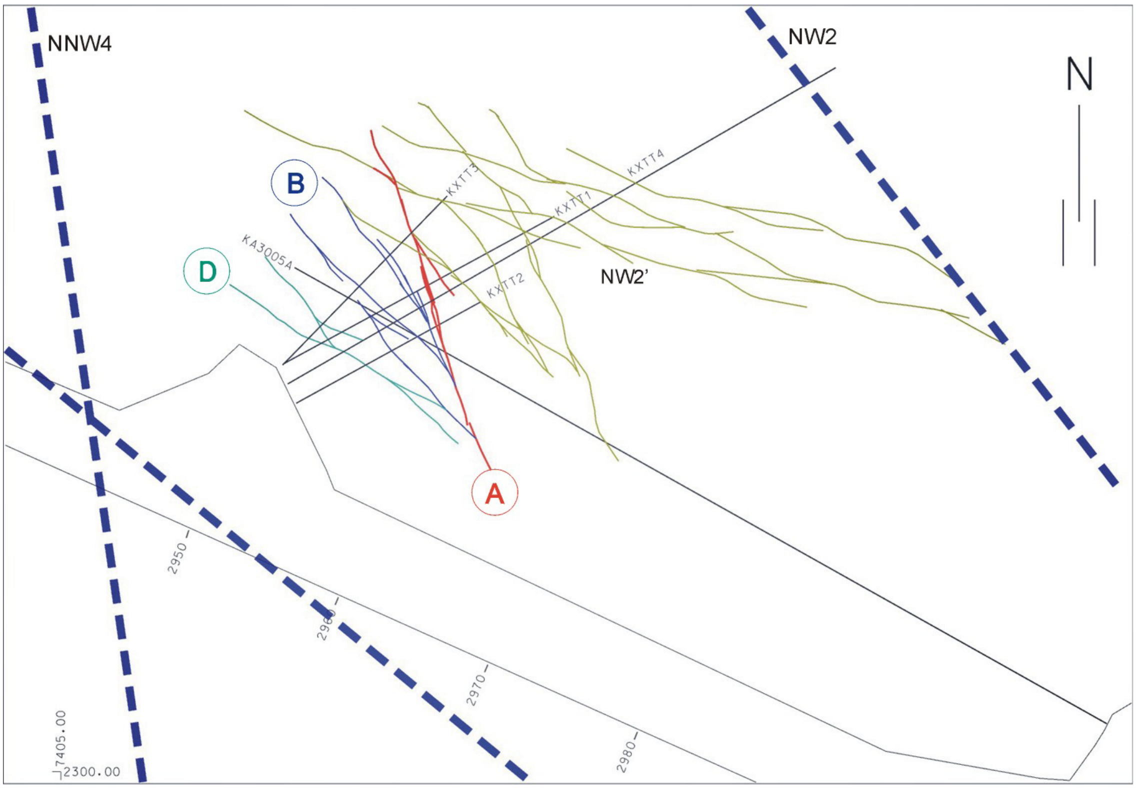

Figure 2-1 *Plan view of updated conceptual structural-geological model of the deterministic structures in the TRUE-1 Rock Block. Horizontal section at Z= - 400 masl . Based on work performed in FCC Phase III (Mazurek et al, in prep).*

2.2.3 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 50 m. 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 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, a series of 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 characterized 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 an 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 breaktrough of tracer from three injection sections.

During the Fall 1998 another borehole, denoted KI0025F02, was drilled from the I-tunnel, between KI0023B and KI0025F.

Overview of activities

The POSIVA flow meter has been successfully used in KI0025F02 to identify the conductive structures/fractures in the borehole with a high degree of detail.

During the hydraulic characterisation of KI0025F02 a new mode and sequence of hydraulic testing was employed. The objective being to better identify and characterise the interpreted structures in the new borehole, in order to optimise instrumentation of the new borehole. These tests have also involved tracer dilution experiments

The analysis of pressure responses during drilling has resulted in a developed hydraulic model where no structural data has been used in the development.

The deterministic structural model is being updated using characterisation data from borehole KI0025F02.

The developed stochastic continuum model has been updated using the Sep'98 structural model and data from the Spring 1998 cross-hole interference tests. Similarly the DFN model has been updated. The latter model has been calibrated to the steady state conditions prior to the March-April interference tests and has subsequently been calibrated to selected interference tests. Subsequently the model has been used to predict some of the cross-hole interference tests involving the new borehole described above.

The major effort during the period has been compilation and analysis of data for the purpose of the 2nd TRUE Block Scale Review Meeting which was held Nov 17. At this meeting a conceptual model of groundwater flow with in the studied block was presented. In addition the prospects for performing tracer tests were discussed. On the basis of these presented prospects the need for an additional exploration borehole was discussed, and a plan for future work was presented.

Site characterisation

Figure 2-2 shows an example of the results of the POSIVA flowmeter, logged in a continuous detailed logging mode. In the figure a number of hydraulic structures are identified, their respective location given by the length coordinate of the single point resistivity anomaly. A comparison between the borehole TV imaging, BIPS, and the flow log shows a very good correspondence.

As part of the transient flow and pressure build-up tests in KI0025F02 two cross-hole interference tests (focused on Structure #6 and #20) performed with tracer dilution tests in sections KI0023B:P6 (Structure #13), KI0025F:R4 (Structure #20) and KA2563A:R5 (Structure #20). The objectives of these tests provide detailed information about the hydraulic characteristics of hydraulic structures intersected by KI0025F02.

These tracer dilution tests showed distinct changes in flow rates in 4 of the 6 dilution tests. One example is shown in Figure 2-3. The borehole was subsequently instrumented with a multi-packer system of ANDRA/Solexperts design. After borehole completions a cross-hole test was performed with pumping in KI0023B:P6 with tracer dilution tests in KI0025F02:P3 (Structure #13), KI0025F02:P5 (Structure #20) and KI0025F02:P8 (Structure #9), this in order to study the effect of reversing the direction of flow on the change in flow rate. The latter measure assumed to be a direct measure of the possibility to conduct actual tracer tests. The performed tests constitute a repetition of Test ESV-1c performed in the spring. The observed responses, this time also adding on responses in KI0025F02 and KA3510A, confirm the present structural model. In addition the responses observed in KI0025F02 confirm the preliminary interpretation made on the basis of the preceding two tests in KI0025F02.

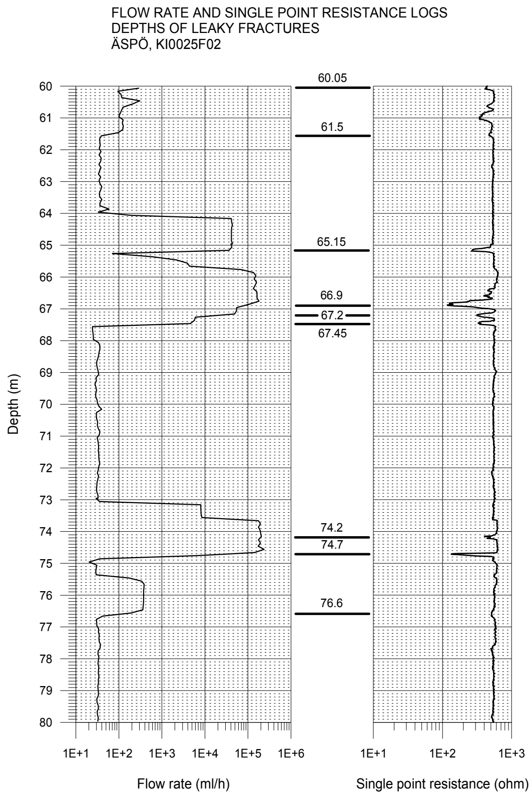

Figure 2-2 *Example results from continuous detailed logging with the POSIVA DIFF flow meter.*

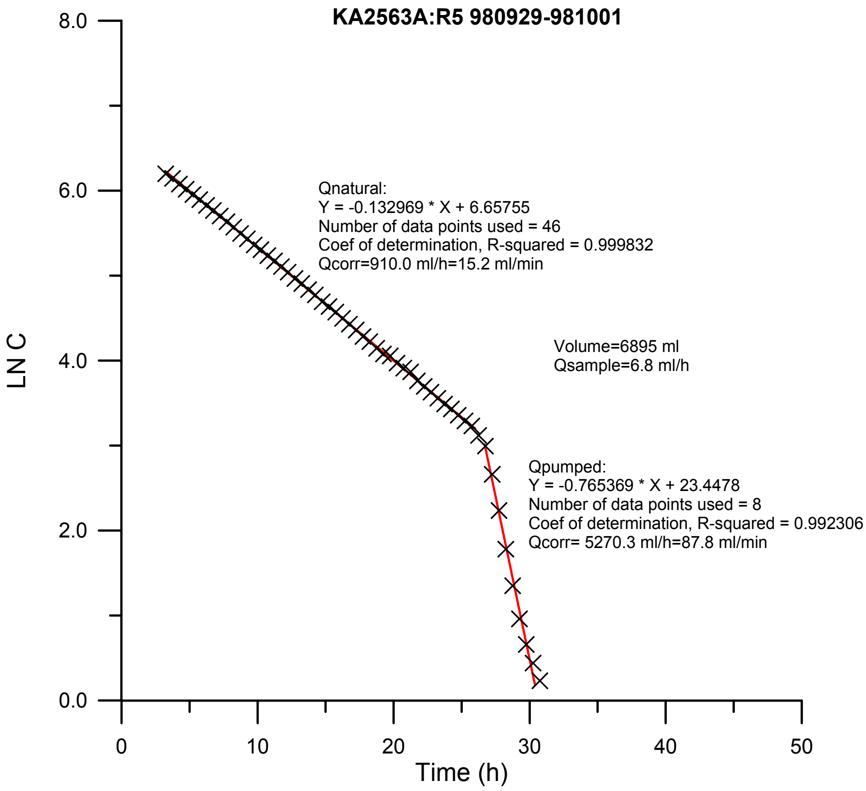

Figure 2-3 *Tracer dilution curve for borehole section KA2563A:R5 (Structure #20) before and during pumping in section 73.3-77.3 m in KFI0025F02 (Structure#20).*

Hydraulic model

Using the pressure response data, a number of conductors with a high hydraulic conductivity compared to the surrounding rock, and with consistent distance-drawdown relationships have been identified. Three main types of distinct conductors were identified from the analysis:

1) A near-collar, major NW zone readily identified in all boreholes (including KA3510A, KA3573A and KA3600F). The width of this zone is in the order of tens of metres.

2) Three well defined discrete conductors traceable between KI0023B, KI0025F and KA2563A.

3) One isolated conductor connecting the bottom of KI0023B with the bottom of KA2511A.

In addition to these inferred conductors, a conductive feature appears to provide hydraulic connections along the length of KA2511A.

Preliminary analyses of the performed cross-hole interference tests consider both drawdown and time to pressure response as complementary measures of connectivity. Comparison of drawdown from the pumping to the observation intervals is an obvious measure of connection, but it may be dependent on the network geometry and boundary conditions for the individual conductor.

Figure 2-4 shows a conceptual model of major connections within the investigated rock volume. This model generally agrees well with the patterns of responses that were observed during drilling. The green lines connect the strongest responding intervals, and define three conductors in addition to the shallow conducting interval. These are the same conductors that were identified using the pressure responses to drilling.

The major conductors in Figure 2-4 are not the only connections in the block, but simply represent the strongest connections based on drawdown and diffusivity. The shallowest of the three conductors is well connected to the shallow conducting interval, while the deeper two conductors are relatively isolated. Furthermore, the plan view tends to emphasise steeply dipping conductors over gently dipping features. Nonetheless, any dominance exerted by sub-horizontal features would tend to obscure the strong NW-SE anisotropy noted in the pattern of pressure responses.

In addition to the conductors described above, Figure 2-4 identifies two, anomalous hydraulic connections which we denote as ”anomalous hydraulic connections ”. The latter are regarded as highly diffusive connections between non-adjacent monitoring intervals of the same hole. Pressure transmissions along such a connection must jump monitoring intervals and other conducting features.

Equipment or borehole effects have been considered among the possible explanations of the noted anomalous hydraulic connections. While such effects are currently considered unlikely, further tests of the equipment may be devised to provide confirmation of equipment performance.

Structural model update (Feb ’99)

During the period work has been done on updating the deterministic structural model using data from KI0025F02. The new update of the structural model is under way , but is not yet complete.

Review Meeting

At the review meeting in mid November the current understanding of the TRUE Block Scale rock volume was presented. This included a conceptual model description of groundwater flow in terms of its direction and magnitude. This model was supported by existing measurements of hydraulic head, geophysical logs, hydrogeochemical data and the performed numerical modelling of groundwater flow. The prospects for future tracer tests in the block scale was discussed in light of the available tracer dilution test data from various cross-hole test campaigns.

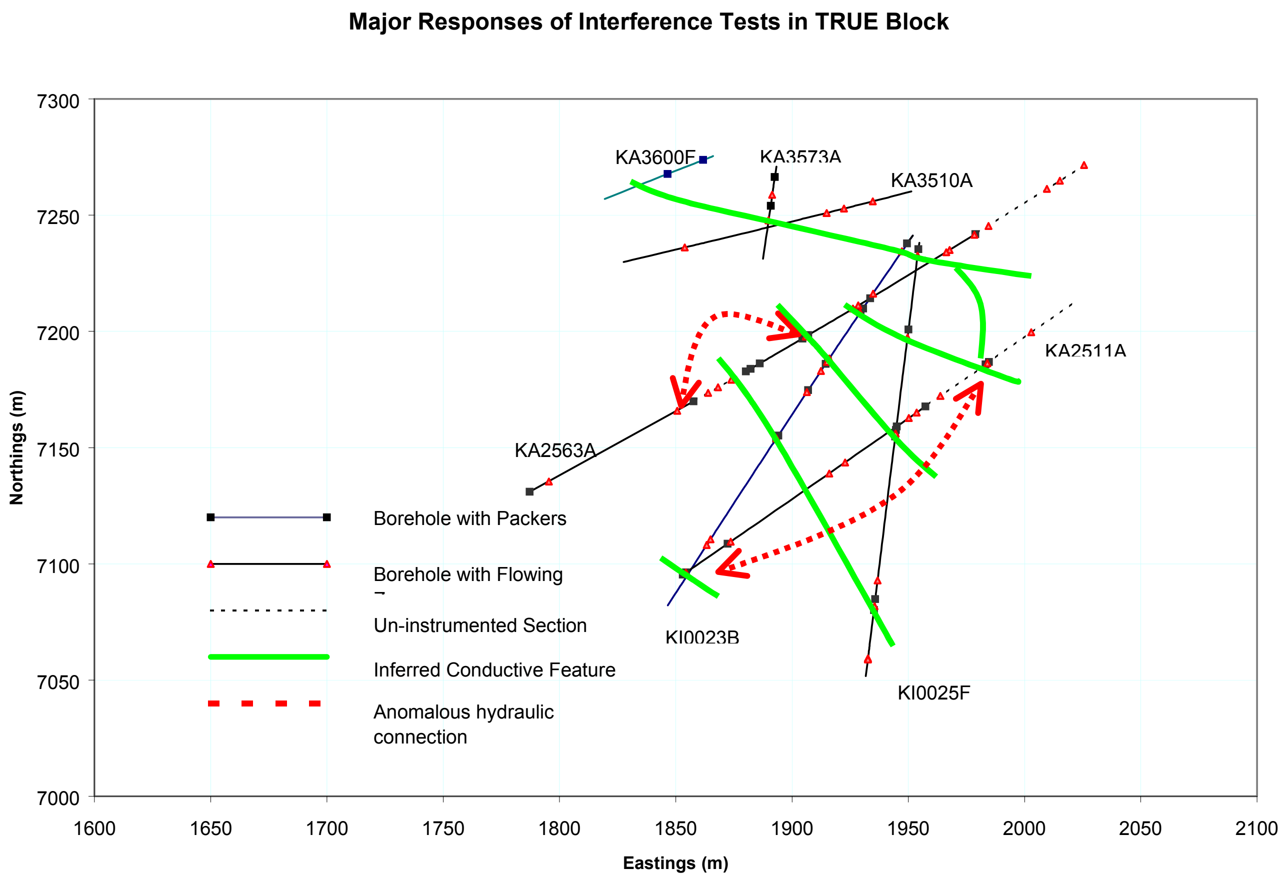

Figure 2-4 *Hydraulic conceptual Model of the TRUE Scale rock volume based on pressure interference tests. Please note that the conductor at the bottom of KI0023B is based on drilling responses, as there were no interference tests run on those intervals. Also the location of the deepest conductor in KA2563A is based on drilling responses as this interval of the borehole was not instrumented during the pressure interference tests. The solid green line corresponds to the observed strongest hydraulic connections. The hatched red lines indicate observed anomalous hydraulic connections.*

It was shown that;

1) an interconnected network of deterministic conductive structures has been identified that may be observed in a number of boreholes. The structures are relatively well known geometrically and structurally. Consistency in hydraulic connectivity is proven from observation of pressure responses during drilling and from hydraulic cross-hole interference tests,

2) relatively well-defined hydraulic structures have been identified which constitute the boundaries to the outlined block,

3) the transmissivity range of the structures making up the identified network less than $7*10^{-7}$ m^2/s,

4) a conceptual model has been developed for natural groundwater flow in the structures supported by geometrical, structural and hydraulic field data. Additional support is provided by performed numerical modelling and independent chemical data,

5) a number of candidate sections for establishing source and sink sections for future tracer experiments are available in the existing borehole array,

6) tracer tests can be successfully performed in the identified network of structures at a length scale in excess of 16 m over reasonable time frames, as evidenced by the results from one flow path.

Given the above findings the following amendments to the overall project objectives were presented;

- Perform transport experiments in a network of structures made up of Structures #13, #9, #20, and possibly #6,

- Evaluate transport parameters from the performed tracer tests,

- Evaluate, to the extent possible, the effects on solute transport exerted by the heterogeneity within the fracture network (fracture intersections and heterogeneity within individual structures).

It was proposed that the a satisfactory understanding of the structural and hydraulic model of the investigated block, which provide a satisfactory list of possible combinations of sources and sinks for tracer tests. As a first alternative for continued approach, the project team proposed not to drill another exploration borehole at this time, but rather to take the step into the tracer tests, although preceded by pre-tests verifying the conceived number of sink and source sections.

This proposal was welcomed by both reviewers, Jane Long of MacKay School of Mines, and Wolfgang Kinzelbach, ETH, Zurich, CH. Both reviewers recommended continued calibration of existing numerical models to existing cross-hole data, definition of hypotheses to be tested by future tests. In addition that these tests also should be tested prior to field application, using the numerical models. It was also identified that one key element relevant to performance assessment is the relative role of fracture intersections in the transport of solutes.

2.2.4 Long term Diffusion Experiment (LTDE), Anders Winberg

This Long-Term Diffusion Experiment is intended as a complement to the dynamic in-situ experiments and the laboratory experiments performed in the TRUE Programme. The basic idea is to locate a static tracer experiment to unfractured rock mass with the intention to characterise diffusion of radionuclides into the rock matrix. Work is presently underway to produce a test plan for the experiment. The experimental objectives include investigation of matrix diffusion *in situ* under natural mechanical, chemical and hydraulic conditions. In addition derived diffusivities will be compared with the corresponding parameters derived in the laboratory. The experimental concept put forward will include two different approaches to meet the project objectives. The two approaches include injection of tracers with subsequent sampling over a period of about 4 years followed by over-coring and sampling for tracer distribution. The second approach includes an initial tracer injection similar to the one described immediately above. The difference being that following 0.5-1 years, the tracer solution would be exchanged with a non-spiked solution. The successive back-diffusion of tracer from the matrix rock will be studied for about 3-4 years. In addition the natural back-diffusion of naturally occurring natural tracers (gases), assumed to saturate the rock, will studied.

During the past 6 months scoping calculations have been performed by Oregon State University and Chalmers University of Technology under the lead of Prof. Roy Haggerty, OSU. These scoping calculations have included use of the heterogeneous (multi-rate) diffusion concept that allows inclusion of heterogeneity in diffusivity. Preliminary results from these scopings show that;

- When using a homogeneous diffusion model, there is a danger of overestimating the diffusivity from results influenced by heterogeneous diffusion. In order to avoid use of too high diffusivities in the performance assessment, a very important task of the LTDE experiment should therefore be to address the question of heterogeneous diffusion.

- The experiments that are best suited to obtain information on heterogeneous diffusion are the natural gas tracer diffusion experiment (i.e., studies of the diffusion of tracers already abundant in the rock matrix) or back diffusion studies of synthetic tracers. The over-coring or the observation borehole options do not provide as good possibilities for studying heterogeneous diffusion.

- Calculation has shown that breakthrough (through diffusion) can be obtained within realistic time frame in an observation borehole at a distance of 0.2 from the injection borehole (continuously flushed).

The plans of the experiment will be subject to review in March 1999.

2.2.5 Planned work

1th Quarter, 1999

TRUE-1 reporting

- Finalization of reporting

TRUE-2

- Preliminary site selection

- Drilling and characterisation of pilot boreholes (SELECT-2)

LTDE

- Finalisation of Test Plan
- Review meeting (presentation of test Plan)
- Site selection

TRUE Block Scale

Preliminary Characterisation Stage

- Finalisation of reporting of Preliminary Characterisation Stage

Detailed Characterisation Stage

- Optimisation of instrumentation in KA2511A and KA2563A (reaming of KA2563A is an option)
- Definition of hypotheses to be tested by experiments
- Feasibility analysis of hypotheses using numerical models
- Tracer test design
- Mineralogical analyses
- Continued model calibration
- Improved visualisation of planned experimental area.

2.3 THE REX EXPERIMENT, Ignasi Puigdomenech

2.3.1 Background

A block scale redox experiment was carried out in a fracture zone at 70 m depth in the entrance tunnel to Äspö. In spite of massive surface water input, the fracture zone remained persistently anoxic. The main conclusion from that study was that the increased inflow of relatively organic-rich shallow groundwater instead of adding dissolved oxygen, it added organic compounds that acted as reductants in the deeper parts of the fracture zone. These conclusions are specific to this particular fracture zone, experimental conditions and the time scale (3 years) of the experiment, but are probably also relevant for other conductive fracture zones.

The detailed scale redox experiment (REX) is planned to focus the question of oxygen that is trapped in the tunnels when the repository is closed. Questions regarding the role of oxygen in this context are:

- Will oxygen penetrate into the rock matrix during construction and operation?
- If yes, how much of the rock will be oxidised and how long time will it take before oxygen is consumed?
- What happens to the oxygen in the backfill/buffer: how much is consumed by the rock, and how much by the buffer?

The REX project focuses on the first two of these questions, especially the second one. The third question is not included in the experiment.

The objectives of the experiment are:

- How does oxygen trapped in the closed repository react with the rock minerals in the tunnel and deposition holes and in the water conducting fractures?
- What is the capacity of the rock matrix to consume oxygen?
- How long time will it take for the oxygen to be consumed and how far into the rock matrix and water conducting fractures will the oxygen penetrate?

The emphasis of the project is on a field experiment involving motionless groundwater in contact with a fracture surface. To this aim a ≈20 cm borehole has been drilled in the Äspö tunnel at 2861 m. Additional field data (hydrochemical and bacteriological) are required to establish the boundary conditions for the experiments.

The field study is being supported by laboratory experiments to determine oxygen reaction rates and mechanisms with Äspö samples (both for inorganic and microbially mediated processes). A replica experiment will be performed in France with the other half of the fracture surface obtained in the drilling procedure.

2.3.2 New results

The field and replica experiments have continued with the experimental protocol that consists of injections of groundwater containing added amounts of molecular oxygen. The consumption rates of O_2 will be assessed and a model proposed.

2.4 RADIONUCLIDE RETENTION (INCLUDE CHEMLAB), Peter Wikberg

2.4.1 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 reliezed from the waste form. The retention is mainly caused by the chemical character of the radionuclides themselves, 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 of 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. Therefore these sorption processes could well be considered irreversible and thus the migration of the nuclides will stop as soon as the source term is ending. Natural analogue studies of an ancient reactor in Gabon have given results that show the mobility of plutonium to be within a few dm to metres until it decayed.

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 be able to demonstrate the results of the laboratory studies in situ, where the natural contents of colloids, of organic matter, of bacteria etc. are present in the experiments. Laboratory investigations have difficulties to simulate these conditions and are therefore dubious as validation exercises. The CHEMLAB probe, see Figure 2-5, has been constructed and manufactured for validation experiments in situ at undisturbed natural conditions.

Objectives

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

- To validate the radionuclide retardation 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 retardation properties of the relevant radionuclides

Experimental concept

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

- Diffusion of radionuclides in bentonite clay
- Migration of redox sensitive radionuclides
- Radionuclide solubility and actinide speciation
- Desorption of radionuclides from the rock
- Migration from buffer to rock
- Radiolyses
- Batch sorption experiments
- Spent fuel leaching

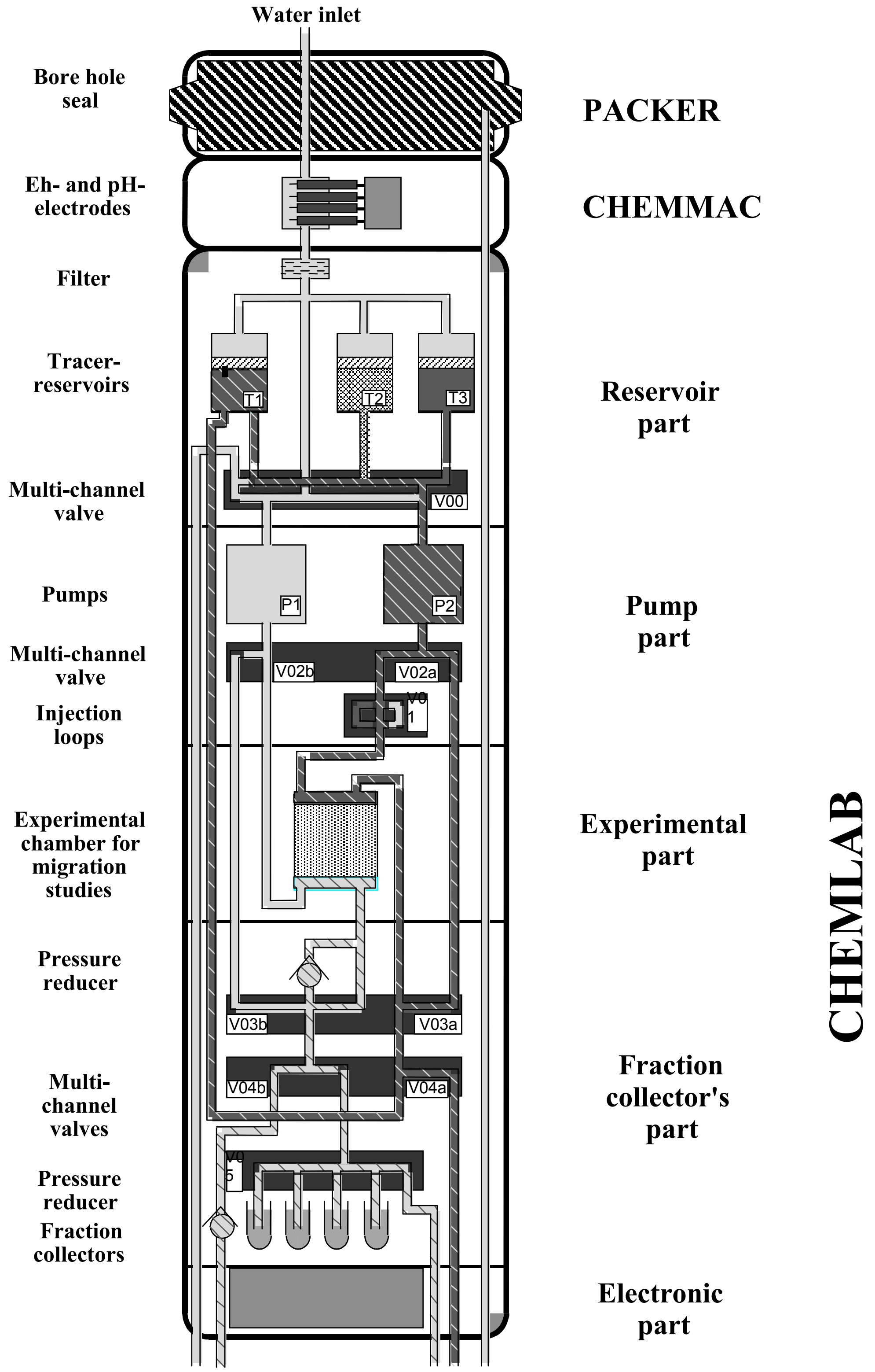

Figure 2-5 *Schematic illustration of the CHEMLAB probe*

2.4.2 New results

No diffusion experiments were carried out during the last three months, because of problems in the CHEMLAB 1 system. The equipment is repaired and the remaining diffusion experiments will be conducted as soon as the reason for the leakage into the probe has been found out.

The construction of CHEMLAB 2 has been delayed because of the reparation of CHEMLAB 1.

New rock fractures have been drilled from tunnel section 2195A. These will be used for the pre-experiments and for the CHEMLAB redox sensitive and actinide nuclide migration experiments.

2.4.3 Planned work

- Complete diffusion experiments
- Start manufacturing of CHEMLAB 2
- Continue preparation for actinide and redox sensitive nuclide experiments

2.5 DEGASSING AND TWO-PHASE FLOW, Jerker Jarsjö

2.5.1 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.

This project was originally performed as one of the bilateral cooperation projects between USDOE and SKB for studies at the Äspö Hard Rock Laboratory in the Areas of Site Characterisation and Repository Performance. Contributions to the project have also been provided by NAGRA and PNC. A revision of the project scope was made as a consequence of the USDOE leaving the Äspö HRL cooperation in April 1996.

2.5.2 New results

We have summarised and interpreted data from laboratory, field and model investigations addressing groundwater degassing. We have used the data as a basis for hypothesis testing, in order to investigate whether (or in which cases) the observed effects can be attributed to degassing, and whether these effects are consistent with degassing related models. We also test whether the observed effects can be attributed to other phenomena than degassing, such as turbulence.

Degassing hypothesis

The extent of the low pressure zone X_{low}, were the water pressure is lower than the bubble pressure, provides an upper limit for the size of the zone around boreholes and drifts where groundwater degassing possibly can occur. One may hypothesise that effects of degassing, such as flow reductions, will (only) be observed as long as X_{low} is greater than a certain length. In the following, we will test this degassing hypothesis through the performance of a consistent interpretation of field and laboratory results in terms of the low-pressure zone extent.

Table 2-1 shows estimates of X_{low} for six different degassing tests or observations. The first four tests shown in Table 1 are borehole tests performed at the Äspö Hard Rock Laboratory. The two last tests refer to drift inflow measurements in the Stripa mine and laboratory tests conducted in rock fracture replicas, respectively. Table 1 furthermore indicates in which cases the measured inflow was reduced, possibly as a result of groundwater degassing.

Table 2-1 Estimates of the low pressure zone extent X_{low}.

Test or observation	X_{low} (m)	Reduced inflow?
Single-well test in borehole P2[a]	**0.020**	no
Single-well test in borehole P4[a]	**0.0017**	no
Dipole test (P4-P8)[a]	**$\geq$0.4**	**yes**
Pilot hole test (single-well test)[b]	**0.0061**	no
Stripa drift observation[c]	**0.79**	**yes**
Laboratory tests[d]	**0.056**	**yes**

[a] from Jarsjö and Destouni (1997)
[b] from Geller and Jarsjö (1995)
[c] from Olsson (1992)
[d] Laboratory tests with CO_2-gas in replicas of natural rock fractures, from Jarsjö and Geller (1996)

Table 2-1 shows that the extent of the low-pressure zone during the dipole test was at least 0.4 metres, or two orders of magnitude greater than the corresponding extents for the single-well tests, where degassing did not cause observable flow reduction. Furthermore, Table 1 shows that the value of X_{low} for the laboratory tests (where degassing was the certain cause for observed flow reductions) and the Stripa drift observation (where degassing was one of the plausible causes for the observed flow reduction) was also greater than for these single-well tests, where no flow reductions were observed. Hence, in all three experiments where degassing either did certainly cause the flow reduction (i.e., the laboratory test), or was the most likely cause for the flow reduction (i.e., the dipole test), or was hypothesised to have caused observed inflow reductions (i.e., the Stripa observations), the value of X_{low} is larger than for the three tests where degassing did not cause any significant inflow reductions. The probability for this X_{low}–outcome to occur randomly, i.e., to occur even if there was no degassing based relation between observed flow reductions low pressure zone extent, is only 5% (3/6*2/5*1/4). This implies that our degassing hypothesis can be accepted on a 0.05 significance level.

Turbulence hypothesis

The occurrence of turbulence can imply non-linear relations between borehole pressure and flowrate. The reported degassing tests were performed at low borehole pressures, implying high pressure gradients and relatively high flowrates. Hence, we need to investigate whether the plausible onset of turbulence effects at these relatively high flowrates have influenced the interpretation of the degassing tests. Specifically, we want to find out whether turbulence effects provide another plausible explanation for the observed non-linear relations between borehole pressure and flowrate during the dipole test (see discussion above), in addition to the explanation provided by the degassing hypothesis (accepted at the 0.05 significance level). We will therefore compare the conditions prevailing during the dipole test both with the conditions prevailing during the other degassing tests (where linear flow conditions prevailed implying no or negligible turbulence effects) and with studies specifically addressing turbulence in fractures. The basis of this comparison is provided by Reynolds number (Re), defined as:

$$\mathrm{Re} = \frac{Dv}{\upsilon}$$

where D is the hydraulic diameter, v is the pore water velocity and υ is the kinematic viscosity. In analogy with Fourar et al. (1993) we use the relation $D=2a_h$, where a_h is the hydraulic fracture aperture. One can then estimate Re on basis of the fracture transmissivity T and the hydraulic gradient $\mathrm{d}\phi/\mathrm{d}r$ (with Re being proportional to the product $T\cdot\mathrm{d}\phi/\mathrm{d}r$).

The critical Re-value for which turbulence effects start to evolve differs from medium to medium. In porous media, it is commonly assumed that turbulence causes considerable effects for Reynolds numbers greater than 100, whereas it is assumed that no turbulence effects will occur for Reynolds numbers less than some value between 1 and 10. Further, for flow in pipes the critical value of Re between laminar and turbulent flow is around 2000. For fractured rock, experimental results reviewed by Romm (1966) showed an onset of turbulence effects for Re about 2400.

The gradients $\mathrm{d}\phi/\mathrm{d}r$ for the case of radial borehole inflow increase considerably with decreasing radial distance r to the borehole/ well centre. The highest gradient $(d\phi/dr)_{\max}$ is obtained at the wall of the borehole/ well, i.e., at $r=r_w$ (where r_w is the well radius). Since $\mathrm{Re} \propto T\cdot(d\phi/dr)$, Re will also be a function of r, with the highest value $\mathrm{Re}=\mathrm{Re}_{\max}$ at $r=r_w$.

Table 2-2 Estimates of the maximum values of Reynolds number ($\mathrm{Re}_{\max}$).

Borehole test	T (m^2/s)	$\left(\frac{d\phi}{dr}\right)_{\max}$	$\mathrm{Re}_{\max}$	Linear pressure-flowrate relation?
Single-well test in P2	$6.6\cdot10^{-9}$	820	11	yes
Single-well test in P4	$3.6\cdot10^{-9}$	370	3	yes
Dipole test (P4-P8) before degassing test	$4.4\cdot10^{-9}$	900	8	no
Dipole test (P4-P8) after degassing test	$2.3\cdot10^{-9}$	900	4	no
Pilot hole test (single-well test)	$5.6\cdot10^{-7}$	830	930	yes

Table 2-2 summarises the values of T, $(d\phi / dr)_{max}$ and Re_{max} for the degassing borehole tests that have been conducted in the field. The *T*-values were obtained assuming a radius of influence r_0 of 150 metres. As shown in Table 2, the fracture transmissivity was considerably higher in the Pilot hole test than in the other degassing tests, and the maximum hydraulic gradients were around 800-900 for all tests, with the exception of the single-well test in borehole P4. As a result, the Re_{max} values were in the range 3-11 for all the tests conducted in boreholes P2, P4 and P8, whereas the corresponding value for the Pilot hole test was orders of magnitude higher (Table 2). During the dipole test, where a non-linear pressure-flowrate relation was observed, the values of Re_{max} were between 4 and 8, which is within the range of Re_{max} -values for the P2 and P4 tests (3 to 11), where the pressure–flowrate relation was linear. Furthermore, the Re_{max} -values of 4-8 for the dipole test are much lower than the Re_{max} -value of 930 for the Pilot hole test (in which turbulence effects were absent), and the Re-values of up to 2400 for which the pressure-flowrate relation was linear in the experiments summarised by Romm (1966). Hence, we can conclude that the conditions prevailing during the dipole degassing test were such that we can not expect turbulence effects to influence the pressure-flowrate relation and the experimental outcome.

In summary, we conclude that turbulence may be ruled out as a plausible factor contributing to the observed flowrate reductions during the borehole degassing tests. Furthermore, the hypothesis that there is a relation between the low pressure zone extent X_{low}, (which is a measure of the size of the zone where groundwater degassing can possibly occur) and the occurrence flow reductions was accepted at the 0.05 significance level, showing that the observed flow reductions indeed are consistent with degassing related models.

2.5.3 Planned work

Continue to work on the final project report and the integrated analysis of obtained results (to be included in the final report). The final report is scheduled for March, 1999.

2.6 HYDROCHEMISTRY MODELLING/HYDROCHEMICAL STABILITY, Peter Wikberg

2.6.1 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.

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 thermodynamic 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 code M3 assumes a complete and complex mixing of the water in the bedrock. Identified end-members or reference waters are mixed in proportions to describe all other observations. The principal assumptions behind this concept are that the varying hydraulic conditions of the past have caused the complex mixing pattern presently observed. Mass balance calculations are then made to explain the difference between the ideal mixing and the observations.

Both types of codes will be used in the modelling of hydrochemical stability. Additional experimental work is carried out to investigate the chemical properties of the matrix fluid.

2.6.2 New results

The pressure build up continues in the matrix fluid borehole KF0051A located in the F-tunnel at the deepest part of the Äspö laboratory. During the first 6 months there is no extractable groundwater. Predictive calculations show that it might take more than a year to obtain a water sample. Therefore emphasis will be put on analysing the drill cores from this borehole and others in addition to the groundwater.

A review meeting of the Test Plan was held 14-15 December. Slight modifications were made as a result of the discussions.

The first groundwater flow modelling sequence of Task#5 is completed. New hydrochemical boundary and initial conditions were provided to the modelling groups soon after the 11th Task Force Meeting at Äspö 1-3 September. The reports will be distributed among the modellers before the next working group meeting 2-3 February.

EQUIP is in progress much along the plans. A project meeting was held 4-5 October where it was agreed to compile information from the completed work packages into a common format. Joel Casanova, BRGM, promised to do uranium series analyses for all groups within EQUIP.

Future investigations in the deep borehole KLX 02 include the testing of Posivas Difference flow measurements and PAVE groundwater sampling equipment to depths of 1400 m. In addition to testing of equipment the results of the measurements are essential for the understanding of the hydrogeological, hydrogeochemical properties of the borehole and its surrounding. The third goal of the investigation is to provide additional knowledge to the understanding of the origin and the stability of the deep highly saline groundwater below 1100 m depth in KLX 02.

2.6.3 Planned work

- Start the mineralogical analyse for the Matrix Fluid project
- Conduct the first re-iteration of Task#5 modelling
- Contiune analyses of calcites for EQUIP
- Start the difference flow measurements in the deep borehole KLX02

3 DEMONSTRATION OF TECHNOLOGY FOR AND FUNCTION OF IMPORTANT PARTS OF THE REPOSITORY SYSTEM

3.1 GENERAL, Olle Olsson

The safety of a repository is determined by:

- the properties of the site,
- the design of the barriers,
- the quality of execution of the deep repository.

A KBS-3-type deep repository is supposed to hold about 4500 canisters in rock caverns at a depth of about 500 m. The different barriers (canister, buffer, rock) work together to isolate the waste. Backfilling/plugging of tunnels, shafts and boreholes limits the flow of groundwater via the potential flow paths opened up by the construction and investigation work, thereby making it more difficult for corrodants and any escaping radionuclides to be transported up to or away from the canisters/waste. All of this work with barriers, plugs etc. must be executed with a given minimum quality.

The Äspö HRL provides an opportunity for demonstrating technology that will provide this necessary quality.

3.2 THE PROTOTYPE REPOSITORY, Christer Svemar, Lars-Olof Dahlström

3.2.1 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.

3.2.2 New results

General planning of the project has been completed and the Test Plan has been printed and distributed. Detailed planning of the Prototype Repository has been continued during the period.

Detailed planning of the Prototype Repository has continued in accordance to the time schedule during the period. Order on manufacturing of roadbed in the tunnel and on deposition machine for the canister/heater unit have been placed after quotation inquirers and evaluation of the answers. The order on the roadbed went to Tellus AB of Oskarshamn and of the deposition machine to Elajo AB also of Oskarshamn. Deliveries are scheduled for February 1999 (roadbed) and June 1999 (deposition machine).

A project group has been established. The group is in principle composed of the task leaders representing the activities involved in the project. The group has been established in order to co-ordinate and plan all activities considering the scientific subject fields from planning to handling of data etc.

An international workshop was held on December 8-9 with invited representatives from the Äspö Hard Rock Laboratory participants. The aim was to discuss the interest for international participation in the project and to outline a possible basis for an EC application. The outcome was positive and several organisations indicated their interest for participation. Official commitments are planned to be submitted to ÄHRL in January 1999. The possibilities for an EC application was also discussed in Brussels in a CLUSTER workshop on November 19-20.

The field activities of characterisation of the rock mass around the Prototype Repository tunnel have been almost completed. Only some interference and flow tests remain (have been postponed to January 1999 due to interference with activities in the TRUE Block Scale site). Reporting of thermal and mechanical results has been completed and is in progress regarding upgrading of the hydraulic model

Core boring of the holes around the two outer deposition holes for acoustic emission, rock mechanical and hydraulic response during boring and later during the thermal period have been completed. These were the last holes for instrumentation from the tunnel in the project plan.

Type of instruments, number of and location in the buffer, backfill and rock have been analysed and a compilation of suitable types and preliminary costs has been made. A preliminary lay-out has been presented. Final selection and decision on number of each type of instrument are schedule for January 1999 immediately followed by purchasing procedure. Instruments for measurement of rock response during boring have, however, already been purchased.

Manufacturing of canisters is proceeding. The full-scale test of temperature distribution in a canister was completed in a first phase in Kockum´s plant in Malmö. It indicated clearly that the temperature gradient from the heater to the copper mantle will be sufficiently low – a couple of tens of degrees and not a couple of hundreds of degrees - for providing a safe margin to the highest temperature (about 400^oC) that is recommended for the heater elements. This finding will be used in the continuing planning for heater design and canister furnishing.

Bentonite purchase has been planned and a visit was paid to Volclay Ltd´s plant in ENGLAND, where the American Wyoming bentonite is landed in Europe. The aim was to establish knowledge of all handling and treatment steps of the MX 80 quality before it is shipped to Sweden. Earlier visits to USA have studied the handling at the mine. One outcome of the contact is that ÄHRL has acquired information on the vast reserves and their qualities in Wyoming. SKB`s need in a repository is only a fraction of estimated reserves.

A preliminary plan for manufacturing of blocks has been presented. It includes mixing of the bentonite with water in Rörstrand´s plant at Lidköping and pressing of blocks in campaigns in Hydroweld´s plant at Ystad.

The TBM machine for deposition hole boring was delivered to ÄHRL in October, but was suffering from major electrical and oil-hydraulic manufacturing mistakes resulting in delay of the planned November 4 boring start. The machine was still not running properly at December 31.

Laboratory testing to determine rock mechanical properties has started and is conducted by Luleå Technical University.

Result of modelling considering crack propagation due to stress redistribution and thermo - mechanical loading has been incorporated in the Prototype Repository project.

Modelling of mechanical and hydrogeological conditions has continued and results have been presented as draft reports.

3.2.3 Planned work

Detail planning of the Prototype Repository project will continue during the period. Main technical matters are

- characterization of bored deposition holes
- instrumentation plan including chemical samplers in the buffer, instruments in the canisters and needed number of cables out from the test tunnel
- electrical supply to heaters
- consequent need for lead-through holes and their locations
- sequence for emplacement of bentonite blocks, bentonite pellets, possible artificial addition of water, backfill in upper part of holes and backfilling of tunnel as well as plan for testing of key handling steps and deposition machine
- plug design

The planned characterisation of the experimental site before boring of the deposition holes will be completed. The experimental data from the field activities will be evaluated and reported. Modelling of the test site is continuously going on, and the model will be presented during the period. A summary report on modelling results including evaluation of methods, results and analyses is planned to be presented.

Based on the summarising results, the thermal and mechanical model will be updated.

Planning for characterisation of the deposition holes will continue and a program presented. The characterisation include, geometric measurements (laser scanning and BIPS), mapping of lithology and structures, hydrogeology etc. Special efforts will be taken to evaluate the EDZ, considering its depth and its mechanical and hydraulic properties.

Laboratory testing to evaluate thermal and mechanical properties will be completed and reported in January.

In late January and the beginning of February, the postponed interference test will be performed in the inner section of the Prototype, including 13 exploration and pilot holes. The result will give valuable information about the hydraulic system around the Prototype.

The instrumentation program for monitoring in backfill and buffer during operation is decided and orders on instrument manufacturing are placed.

Heater design will be completed and orders on manufacturing of these will also be placed.

Installation of rock mechanical instruments to monitor rock mechanical response during boring of the deposition holes will be installed.

The roadbed will be delivered and installed in the tunnel in February.

Design of the plugs meeting the experiment objectives and suitable for TBM drift will start.

Boring of the six deposition holes in the Prototype Repository are still planned to start in late March 1999, providing the machine starts to operate properly in early January. Then a change in the boring plan is possible to make so that the machine is moved to the Prototype Repository after boring of the four holes in the tunnel for Demonstration of Repository Technology The two holes in the tunnel for the Canister Retrieval Test are then made last.

A project meeting is held on January 28-29.

3.3 BACKFILL AND PLUG TEST, Lennart Börgesson

3.3.1 Background

A project with full scale testing of backfill materials, filling methods, and plugging, called the *Backfill and Plug Test,* is running. The test is located to the ZEDEX drift. Preparations for the test started in 1995 and have continued during 1996 and 1997 with modelling, instrument testing, development of compaction technique, plug design, and laboratory testing. In the latter part of 1997 and the first part of 1998 the fieldwork has started with drilling of holes for rock instrumentation and through connections.

3.3.2 New results

The following main work has been carried out during the fourth quarter of 1998:

- The hydraulic testing and the installation of packers in the instrument holes have been finished

- The installation of steel tubes in the through connection holes have been finished

- 46 old boreholes have been sealed with bentonite cylinders and cement

- The first part of the plug has been built.

- All other preparations of the rock for the backfilling have been finished

3.3.3 Planned work

In the first quarter of 1999 the following main work is planned:

- Preparation of packages of instruments, cables, and Tecalan tubes for the first through connections.
- Backfilling of the inner part of the drift with crushed rock and drainage materials. This part will not be used for the tests. It will end with a concrete layer.
- Installation of drainage pumps in the drainage material
- Building of the inclined concrete layer that separates the inner drained part from the first test part
- Compaction of blocks for the backfill and for the bentonite o-ring in the plug
- Setting up the data collection house and installation of the data collection system
- Backfilling of the 30/70 test sections with inclined compaction and installation of filter mats etc.
- Installation of all instruments in the 30/70 backfill with all cables and tubes led through the through connection holes to the data collection house

3.4 DEMONSTRATION OF REPOSITORY TECHNOLOGY, Stig Pettersson

3.4.1 Background

The development and testing of methodology and equipment for encapsulation and deposition of spent nuclear 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 nuclear fuel for specialists and the public. As part of the overall programme an Encapsulation Laboratory is under construction in Oskarshamn and it will be put in operation late 1998. Demonstration of deposition and retrieval of canisters will be made in the Äspö Hard Rock Laboratory. The demonstration project complements the Prototype Repository 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 objectives 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 specialists and the public the different steps in transport, deposition, and retrieval of spent nuclear 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 allows transport of heavy vehicles to the test area.

3.4.2 New results

The 65 m deep core-drilled hole has been grouted, and the grooves for the rail to the deposition machine have been filled with concrete. These activities complete the preparation for boring of the deposition holes.

The evaluation and reporting of the data from geophysical measurements in the pilot holes and the 65 m deep hole, all with a diameter of 76 mm, are in progress.

3.4.3 Planned work

Boring of the four deposition holes will start as soon as the machine is working properly and the two test holes in the Assembly Hall have been completed. The delay of the boring program is affecting the planning in such a way that the two outer holes have to be bored in the first place, so that installation of the rails for the deposition machine can be made in accordance with the time schedule. Otherwise a time delay has to be faced in the project as well as in the VISA project. The inner two holes can be bored in parallel to the installation of the rails, which has to start in mid February in order to be ready for taking load in late March when the deposition machine is delivered.

This planning requires that the contractor Drillcon Raise AB can manage to bore one approved hole in the Assembly Hall before mid January.

The geological characterisation data will be compiled and reported.

3.5 CANISTER RETRIEVAL TEST, Christer Svemar

3.5.1 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.

3.5.2 New results

The instrumentation in the holes for acoustic emission and rock mechanical response during boring is made in parallel with the similar instrumentation in the Prototype Repository. The instruments have been ordered.

3.5.3 Planned work

The instruments for measurements during boring in the holes around the deposition holes are installed.

Planning and design of the instrumentation program for monitoring in buffer during operation is as well carried out in parallel with the work for the Prototype Repository. Decisions on instrumentation and ordering will continue to be carried out in parallel..

The equipment for emplacement of canister and buffer, which was ordered for the Prototype Repository, will also be used in this project.

The purchase of bentonite and planning for block compaction also includes the need of the Canister Retrieval Test.

3.6 LONG TERM TEST OF BUFFER MATERIAL, Ola Karnland

3.6.1 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 minimize 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, radionuclide 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 summarized 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. illitization 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 realization of the full scale test series with respect to clay preparation, instrumentation, data handling and evaluation.

The testing philosophy for all planned tests in the series (Table 3-1) is to emplace prefabricated units of clay blocks surrounding heated copper tubes in vertical boreholes. The test series will be 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 A1 parcel.

Table 3-1. Lay out of the planned 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

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 will be equipped with heaters in order to simulate the decay power from spent nuclear fuel. The heater effect will be 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 will be placed in boreholes with a diameter of 300 mm and a depth of around 4 m .

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

3.6.2 New Results

Reference material and material from defined positions in the A1 and S1 parcels material have been tested and analyzed.

The following physical properties have been determined for the parcel material (test technique within brackets):

- water ratio (oven drying),
- density (weighing in paraffin oil),
- hydraulic conductivity, (oedometer),
- swelling pressure, (oedometer),
- bending strength (beam test),
- shear strength (triaxial cell),

and the following mineralogical properties (methods within brackets):

- element content in the bulk and clay fraction material (ICP-AEM),
- cation exchange capacity (CEC, Chapman´s and Cu-trien method),
- mineralogical composition in bulk and clay (XRD, SEM-EDX),
- microstructure, (TEM and SEM-EDX).

All tests and analyses except those concerning microstructure have been completed and compilation is in progress. No unexpected results have been observed. Supporting laboratory tests concerning CEC determination techniques have been made in order improve the determinations with respect to time and accuracy.

A preliminary report concerning the bacteria analyses have been prepared by Gothenburg University group. The major conclusion is that only spore forming species survived the exposure and in an inactive state.

Analyses at KTH concerning the tracer elements cobalt and cesium have been completed and the results indicate expected discrepancies between the two elements. Calculations and reporting are presently being made.

The copper analyses have been completed and the results indicate a corrosion rate in the range of what was expected for oxic conditions.

3.6.3 Planned work

The planning and construction work for the remaining four test parcels have started. Investigation holes will be core-drilled and test concerning inflow and water-pressure will be made during the spring. The successive drilling of test holes are planned to be made by use of hammer drilling technique.

Supporting laboratory tests concerning gas will be made parallel to the construction and running of the five new parcels during the rest of the year. The installation of the first remaining parcel is planned to start in May 1999.

4 ÄSPÖ FACILITY OPERATION

4.1 PLANT OPERATION, Olle Zellman

Equipment to clean up oil spill has been bought to avoid oil pollution in the tunnel and its surroundings. The equipment has been placed at suitably located places underground.

Special sheets to prevent water dripping from the roof have been mounted in the Assembly Hall at the –420 m level.

A special tunnel inspection focused on the mechanical stability took place during the period. Most parts of the tunnel were in god condition but several small nisches needed immediate scaling and in some cases even bolting. The normal program for scaling and rock support continued after schedule.

Blasting for a new rescue chamber at the –420 m level started. This chamber will also be used as a conference room in the future.

A new fan, including ventilation tubes, has been mounted in the D-tunnel because of the coming experiment ”back fill and plug test”.

The pump pits has been reworked to avoid air to reach the pumps. The water coming from above is now lead through a pipe to a level well below the head of the water in the pit. A mobile diesel powered generator has been purchased. The intention is that it should work as a back up for the pumps in the drainage system in case of electricity failure.

The disturbance on the radio frequency used by the fire brigade is now localised and eliminated. Electrical outlets for engine heaters in cars was installed. This will positively effect the emissions from cars during the winter.

Four of the staff has been educated in ”hot works”.

4.2 PROGRAM FOR MONITORING OF GROUNDWATER CHEMISTRY, Anna Säfvestad

4.2.1 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.

4.2.2 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.

4.2.3 New results

Sampling was undertaken on two occasions, in March and in October 1998. Many project specific samples were taken in addition to the "monitoring samples". Class 2 samples were collected from all weirs including the pond.

4.2.4 Planned work

The results from the Monitoring program undertaken since 1994 will be presented in a report in the beginning of 1999. The results from the monitoring in October will be presented in a Technical Note in February 1999. The next sampling occasion is scheduled to take place in April, 1999.

4.3 TECHNICAL SYSTEMS, Thomas Karlsson

4.3.1 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 tunnelling work and the increased number of monitoring points.

4.3.2 New results

In the tunnel the installation of ultrasonic-transducers in the weir to measure the water level has been done.

There has been some technical problems with the modems, which collect data from the loggers in the boreholes, at the surface boreholes. In the borehole

KAS09, KAS07 and KAS06 we have changed modem type to a radio type which works much better.

In October we got a new borehole KI0025F02 in the TRUE Block Scale project connected to HMS.

4.3.3 Planned work

Evaluation of presentation system for the HMS-system will be made during spring 1999 and the evaluation will be done together with the facility operation.

The boreholes HAS03 and HAS11 are planned to be disconnected from the HMS-system. There will be only manual control in these boreholes in the future.

A new measurement server will be installed during spring 1999 to take care of data from the Backfill and Plug Test.

5 INTERNATIONAL COOPERATION

5.1 CURRENT INTERNATIONAL PARTICIPATION IN THE ÄSPÖ HARD ROCK LABORATORY, Monica Hammarström

Ten organizations from nine countries are currently (December 1998) participating in the Äspö Hard Rock Laboratory.

In each case the cooperation is based on a separate agreement between SKB and the organization in question. Table 5-1 shows the scope of each organizations participation under the agreements.

Most of the organizations 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.

The agreement between SKB and BMBF was renewed for another four years.

Table 5-1 Scope of international cooperation

Organization	Scope of participation
Atomic Energy of Canada Limited, **AECL**, Canada.	*Under discussion*.
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*
Agence Nationale pour la Gestion des Dechets Radioactifs, **ANDRA**, France.	Detailed investigation methods and their application for modelling the repository sites Test of models describing the barrier function of the bedrock
The Power Reactor and Nuclear Fuel Development Co, **PNC**, Japan.	Test models for groundwater flow and radionuclide migration: 1. Tracer retension understanding experiments (TRUE) 2. Disturbed zone effects 3. Degassing and two-phase flow conditions 4. Redox experiment in detailed scale 5. Radionuclide retension. Demonstrate construction and handling method. Test important parts of the repository system. Cooperation regarding the Kamaishi mine in-situ experiments concerning earthquakes.
The Central Research Institute of the Electric Power Industry, **CRIEPI**, Japan.	Application of: 1. Fault activity evaluation method. 2. Groundwater dating and flow. 3. Geochemical environmental evaluation methods (REX experiment). 4. Groundwater/radionuclide migration analysis methods (TRUE experiment).

Organization	**Scope of participation**
United Kingdom Nirex Limited, **NIREX**, Great Britain	TRUE Block Scale
Nationale Genossenschaft für die Lagerung Radioaktiver Abfälle, **NAGRA**, Switzerland	Groundwater flow and radionuclide migration. Disturbed zone effects (Degassing of groundwater and 2-phase flow, drift excavation effects). Construction/testing integration, TBM technique. Data flow management, documentation.
Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie **BMBF**, 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-situe tests using methods and equipment similar to those used in the Grimsel investigations.
Empresa Nacional de Residuos Radiactivos **ENRESA**, Spain	Test of models for groundwater flow and radionuclide migration, (TRUE Block Scale) Demonstration of technology for and function of important parts of the repository system, (Backfill and Plug Test)
Sandia National Laboratories, USA	Tracer Retention Understanding Experiment (TRUE) TRUE 1 Experiments TRUE 2 Experiments Long-Term Diffusion Experiment Modelling Task Force

6 OTHER MATTERS

6.1 DOCUMENTATION, Ingela Månson

During the period October-December, 1998, the following reports have been published and distributed:

6.1.1 Äspö International Cooperation Reports

Mahara Y, Igarashi T, Miyakawa K, Kiho K, Tanaka Y, Hasegawa T
Dynamic changes in groundwater conditions casued by tunnel construction at the Äspö Hard Rock Laboratory, Sweden
ICR 98-04

6.1.2 Äspö Progress Reports

Olsson O et al., Äspö Hard Rock Laboratory.
Status Report April-June 1998.
PR HRL-98-21

Rhén I, Forsmark T, 1998.
Prototype repository. Hydrogeology – Drill campaign 2.
PR HRL-98-22

Birgersson L, 1998.
Heat as a tracer. Compilation regarding the possibility to use heat as tracer in the TRUE project.
PR HRL-98-23

Dahlström L-O, 1998.
Test plan for the prototype repository.
PR HRL-98-24

Olsson O et al., Äspö Hard Rock Laboratory.
Status Report July-September 1998.
PR HRL-98-25

Jansson M, Eriksen T, 1998.
Test plan for Chemlab experiments. Radiolysis.
PR HRL-98-26

Jansson M, Eriksen T, 1998.
Test plan for Chemlab experiments. Migration of Redox Sensitive Radionuclides.
PR HRL-98-27

Sundberg J, Gabrielsson A, 1998.
Field measurements of thermal properties of the rocks in the prototype repository at Äspö HRL.
PR HRL-98-28

Hermanson J, Stigsson M, Wei L, 1998.
A discrete fracture network model of the Äspö Zedex tunnel section.
PR HRL-98-29

No Technical Documents

22 Technical Notes

6.2 SCHEDULES, Jan Olof Dahlström

Current Master Schedules are enclosed.

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Bäckblom G, Olsson O, 1994.
Program for tracer retention understanding experiments.
PR 25-94-24

Fourar, M., Bories, S., Lenormand, R. and Persoff, P., 1993.
Two-phase flow in smooth and rough fractures: Measurement and correlation by porous-medium and pipe flow models, Water Resour. Res., 29 (11), 3699-3708.

Geller J.T., and Jarsjö, J., 1995. Groundwater degassing and two-phase flow: Pilot hole test report.
SKB Äspö HRL Internat. Cooperation Rep. 95-03.

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

Jarsjö, J. and Geller, J.T., 1996.
Groundwater degassing: Laboratory experiments in rock fracture replicas with radial flow.
SKB Äspö HRL Progress Report HRL-96-12.

Mazurek, et al, in prep.

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

Romm, E. S., 1966. Fluid Flow in Fractured Rocks (in Russian), Nedra Publishing House, Moscow. (Engl. transl., W. R. Blake, Bartlesville, Okla., 1972.)

Winberg, Anders, et al 1996.
First TRUE Stage – Tracer Retention Understanding Experiments Descriptive structural-hydraulic models on block and detailed scales of the TRUE-1 site
ICR 96-04

APPENDIX A

MASTER SCHEDULES

MASTER SCHEDULE ÄSPÖ

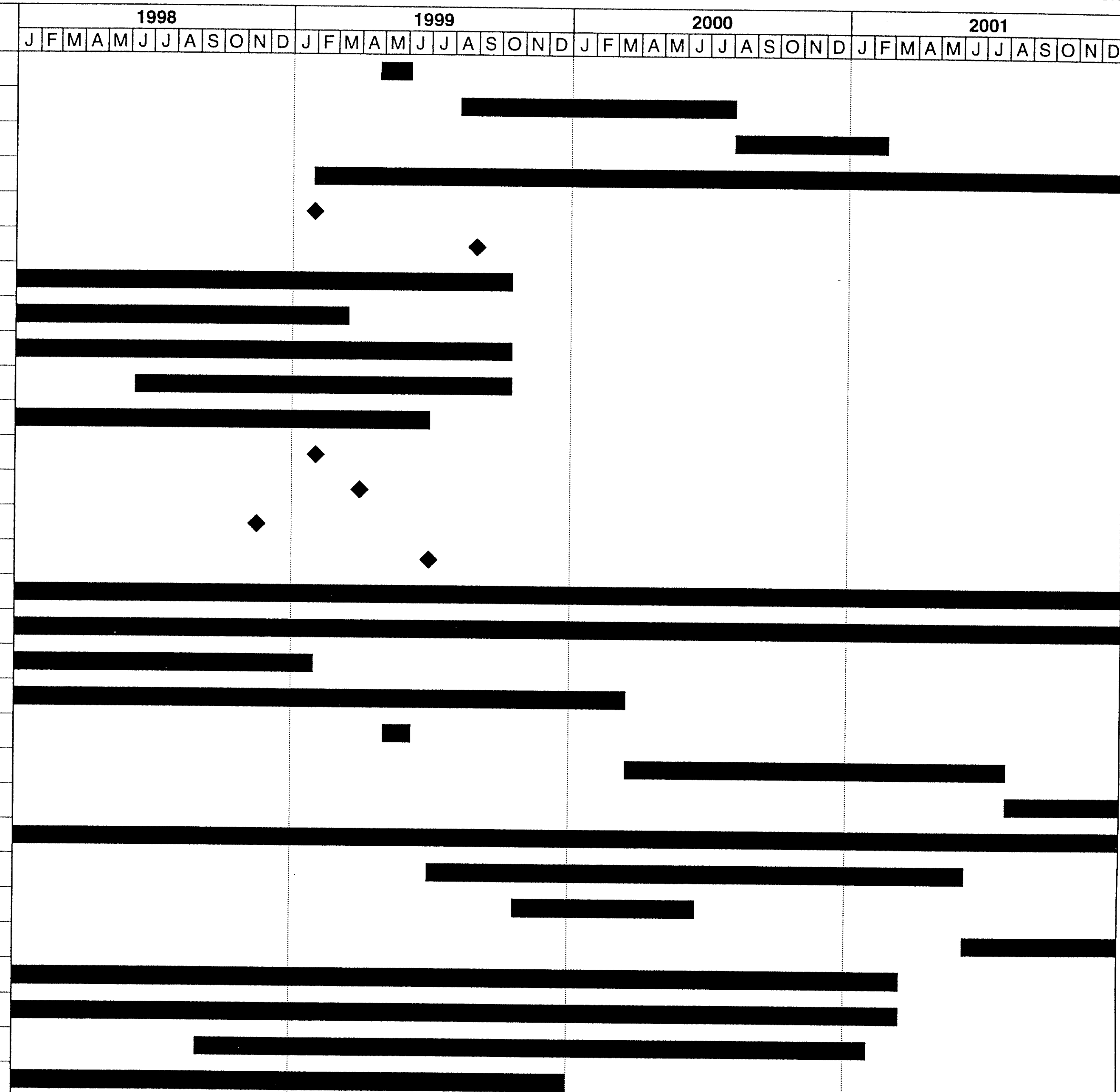
Äspö Plan Right
Version 3.0

	Activity
2	**VERIFICATION OF PRE-INVESTIGATION METHODS**
2.3	CODE DEVELOPMENT/MODELLING
2.4	PUBLISHING OF RESULTS
3	**METHOD. FOR DETAILED CHARACT. OF ROCK UNDERGROU**
3.3	ROCK VISULATIZATION SYSTEM
	Program and reports etc
	Update of system manuals Ver 1.1
	Update of system manuals Ver 1.2
	Update of system manuals Ver 1.3
	Update of system manuals Ver 1.4
	Update of system manuals Ver 2.0
4	**TEST OF MODELS FOR GROUNDWATER FLOW AND**
	RADIONUCLIDE MIGRATION
4.2	FRACTURE CHARACTERIZATION AND CLASSIFICATION
4.3	TRACER RETENTION UNDERSTANDING EXPERIMENTS
	TRUE-1
	Analysis of results and reporting of TRUE-1
	TRUE-2
	STT-2 tracer experiment
	Tracer experiment
	TRUE BLOCK SCALE EXPERIMENT
	PRELIMINARY CHARACTERIZATION STAGE
	PRELIMINARY CHARACTERIZATION STAGE - Phase III
	Reporting of Preliminary Characterization Stage
	Detailed Characetrization Stage
	Detailed Characetrization Stage, Phase I
	Drill Bh#4 KI0025F02
	Detailed Characterization Stage, Phase II

MASTER SCHEDULE ÄSPÖ

Äspö Plan Right
Version 3.0

	Activity
	Drill and characterization of BH#5
	Experimental Stage
	Evaluation Stage
	LONG TERM DIFFUSION EXPERIMENT
	Testplan
	Start experiment
4.4	THE REX -EXPERIMENT
	Laboratory Investigations
	Field Investigations
	Field Experiment in KA2861A
	Program and reports etc
	CEA Lab. experiments 2st report
	Univ. Bradford. Final report
	MicrobeRex. Final report
	REX Final Report report
4.5	RADIONUCLIDE RETENTION
	CHEMLAB I
	Diffusion experiments
	Radiolysis experiment
	Radiolysis 1
	Migration from the buffer to the rock
	Radionuclide solubility, batch sorption
	CHEMLAB II, New Chemlab probe
	Redox sensitive nuclides
	Desorption from rock
	Spent fuel experiment
4.6	HYDROCHEMICAL STABILITY
	Matrix fluid chemistry
	Water sampling and analyses
	KLX 02 resampling



MASTER SCHEDULE ÄSPÖ

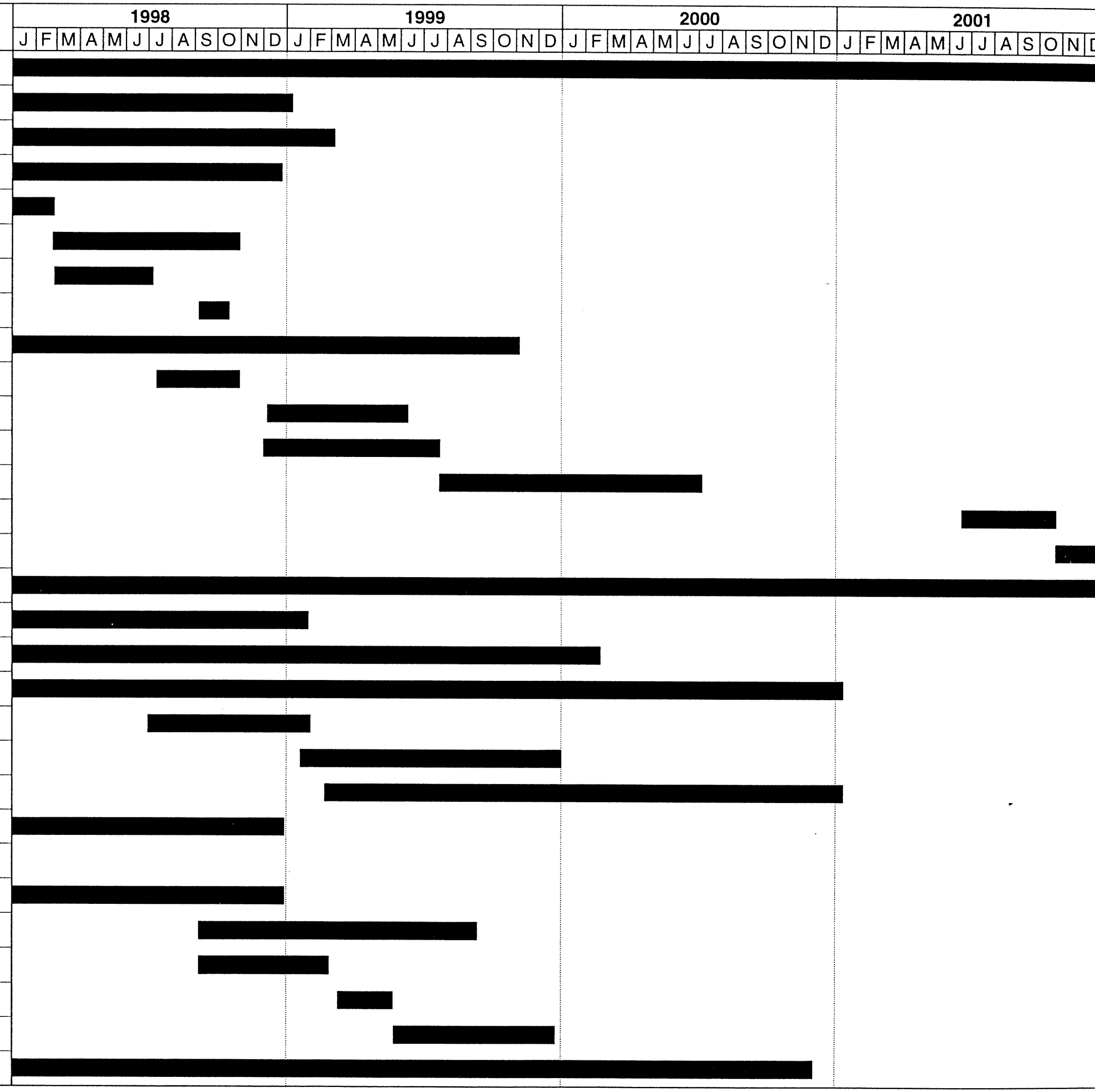
Äspö Plan Right
Version 3.0

	Activity
	Modelling
4.7	PROGRAM FOR MONITORING OF GROUNDWATER CHEMISTRY
	GROUNDWATER CHEMISTRY MONITORING
	Water sampling
	FLOWMETER TESTS
	Posiva in KA3510 and KA2598A
	FORMATIONWATER
	Drill new hole
4.8	DEGASSING AND TWO-PHASE FLOW
	Gas injection tests
	Two-phase tests
4.9	THE TASK FORCE ON MOD. OF GROUND. FLOW AND TRANSP. OF SOLUTE
	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 Force meeting 11
	Task Force meeting 12
	Task Force meeting 13
5	DEMONSTRATION OF TECHNOLOGY FOR AND FUNCTION OI
	IMPORTANT PARTS OF THE REPOSITORY SYSTEM
5.2	BACKFILL AND PLUG TEST
	Design and planning
	Instrument development and testing
	Laboratory testing
	System for flow testing

MASTER SCHEDULE ÄSPÖ

Äspö Plan Right
Version 3.0

	Activity
	Modelling
	Backfilling technique
	Plug design & preparations
	Characterization
	Hole drilling
	Through connections
	Slot drilling and excavation
	Hydraulic testing
	Set-up of experiment in drift
	Install rock instrumentation
	Backfilling&instrument, drift
	Plug construction
	Water saturation
	Backfill excavation
	Evaluation & reporting
5.3	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 boring
	Preparation
	Deposition hole boring
	Characterization dep holes
	Canister manufacturing



MASTER SCHEDULE ÄSPÖ

Äspö Plan Right
Version 3.0

	Activity
	Bentonite block production
	Emplacement machine
	Roadbed
	Backfilling and Plug construction
	Monitoring and testing
5.4	**TECHNOLOGY DEMONSTRATION**
	Demotunnel
	Detailed geomapping
	Pilot hole characterization
	Deposition hole boring
	Preparations Demo
	Deposition hole boring
	Characterization dep. hole
	TBM-hall
	Pilot hole characterization
	Deposition hole boring
	Preparations TBM
	Boring 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"
5.5	**Long Term Test of Buffer Material**
	Pilot tests, S1, A1
	Long Term Tests
	Characterization
	Heating tests
	Reporting

MASTER SCHEDULE ÄSPÖ

Äspö Plan Right
Version 3.0

	Activity
	emplacement S2:A3
5.6	CRACKS CAUSED BY MECHANICAL EXCAVATION
	Fieldtest inÄspö HRL
5.7	CANISTER RETRIEVAL TEST
	Design and planning
	Modelling
	Instrument developing and testing
	Rock instrumentation
	Installation for dep hole boring
	Testing of deposition technique
	Characterisation
	Tunnel investigation
	Pilot borehole investigation
	Instrumentation holes
	Deposition hole boring
	Preparations
	Deposition hole boring
	Characterisation of dep holes
	Canister manufacturing
	Bentonite block production
	Test commissioning
	Reporting of test set-up
	Saturation
7	ÄSPÖ FACILITY OPERATION
	New rescue chamber
	Alarm- and telesystem
	Operations monitoring (proj alfa)
	New redundant drainage system