NUMO-TR-15-02

The Underground Investigation Facility (UIF) concept in NUMO's program

March 2016

Nuclear Waste Management Organization of Japan (NUMO)

NUMO-TR-15-02

The Underground Investigation Facility (UIF) concept in NUMO's program

March 2016

Nuclear Waste Management Organization of Japan (NUMO)

This report was prepared by a project team consisting of Yuichi Tomioka, Kimitaka Yoshimura, Hikaru Nishio, Kenichi Kaku and Shigeru Kubota (NUMO) and Irina Gaus, Stratis Vomvoris and Toshihiro Sakaki (Nagra) with contributions from many other individuals.

2016 年 3 月　初版発行

〒108-0014　東京都港区芝 4 丁目 1 番地 23 号　三田 NN ビル 2 階
　原子力発電環境整備機構　技術部
　　　電話 03-6371-4004（技術部）　FAX 03-6371-4102

Science and Technology Department
Nuclear Waste Management Organization of Japan
Mita NN Bldg. 1-23, Shiba 4-chome, Minato-ku, Tokyo 108-0014 Japan

The Underground Investigation Facility (UIF) concept in NUMO's program

Abstract

Nuclear Waste Management Organization of Japan (NUMO) will construct an Underground Investigation Facility (UIF) in the candidate host rock for a future radioactive waste repository during the detailed investigation (DI) stage of the site selection process. The underground investigation facility (UIF) will be used to investigate the geological environment of the host rock, to optimize the techniques for tunnel excavation and emplacement of the engineered barrier system, conduct demonstration tests and perform safety assessments before construction of the repository is initiated. In this report, the conceptual aspects of the UIF location, design, investigation planning, and the different roles of the UIF and generic underground research laboratories (URLs) within the Japanese site selection program are discussed and compared with selected underground facilities in Europe.

Conducting investigations and experiments under the same or similar boundary conditions to the final repository is the main purpose of the UIF. The UIF therefore has to be constructed in the same formation as the candidate host rock. Taking into account the heterogeneous nature of the geology in Japan, it is envisaged that the UIF will be built in the candidate host rock close to the candidate site and it is likely that it will form part of the repository system. In order to preserve the barrier function of the host rock in terms of retaining radionuclides that could be released from the waste in the future, it is essential that disturbances to the host rock, for example from borehole drilling or excavation of test galleries, are kept to a minimum. Therefore, the investigations in the UIF, as well as the facility design and the excavation techniques used, should be selected carefully and optimized, considering minimizing disturbance to the host rock as one of the key criteria.

Generic URLs play an important role in developing investigation techniques and methodologies that are applicable to geological environments that could potentially host a repository site before starting the site selection process. Once the site selection process has started, candidate geological environments will gradually be narrowed down to a few environments for the preliminary investigations (PI) and, following these, for the DI. Investigation techniques can be refined in generic URLs so that they are suitable for use in the geological environment of the host rock formation at one of the selected sites. In addition, long-term host rock-independent investigations of the engineered barrier system can be initiated at an early stage in generic URLs. They can contribute to the knowledge base for the design and safety assessment of the repository, as well as optimization of the investigations that need to be carried out in the UIF.

Contents

Figures

Tables

1. Introduction

The selection of a repository site will be undertaken via a three-stage process based on the Final Disposal Act of 2000. The Nuclear Waste Management Organization of Japan (NUMO) has been conducting open solicitation of municipalities nationwide, seeking areas to carry out feasibility studies on the possible location of a final repository. The feasibility studies will verify that the geological stability of the potential repository sites is not threatened by volcanic activity, active faults or other geological phenomena. Once safe sites have been identified, investigation and selection will then proceed following a three-stage process as illustrated in Fig. 1-1 (NUMO, 2009). The three-stage process consists of a literature survey (LS), preliminary investigations (PI), and detailed investigations (DI). At the LS stage, preliminary investigation areas (PIAs) are selected based on information from existing literature on the candidate areas and the surrounding regions, as part of the open solicitation process. In the PI stage, detailed investigation areas (DIAs) are selected based on field studies such as exploratory investigations and borehole drilling.

The DI stage is divided into two parts: DI(1) and DI(2). During DI(1), investigations are carried out from the ground surface; these include exploratory investigations and borehole drilling. Underground investigations are then conducted in DI(2). For DI(2), NUMO plans to construct an underground investigation facility in each DIA to conduct detailed investigations of the geological environment, develop construction techniques and provide input for safety assessment.

The existing Underground Research Laboratories (URLs) in Japan are being used to develop techniques for investigating the geological, hydrological and geochemical environments of the potential repository sites, and to develop construction and safety assessment technologies. NUMO’s Underground Investigation Facilities (UIFs) will be constructed in the DIAs and will include some functions that overlap with those of the URLs, as well as more site-specific issues that will need to be examined and resolved on site. The UIF is expected to demonstrate and optimize the construction techniques for the repository at the site during construction of the facility. Geological investigations and safety assessment investigations will be consolidated in the UIF.

In this study, the authors investigate the different roles that existing URLs and UIFs have in the Japanese site selection program and highlight problems that should be addressed and resolved before planning the construction of a UIF.

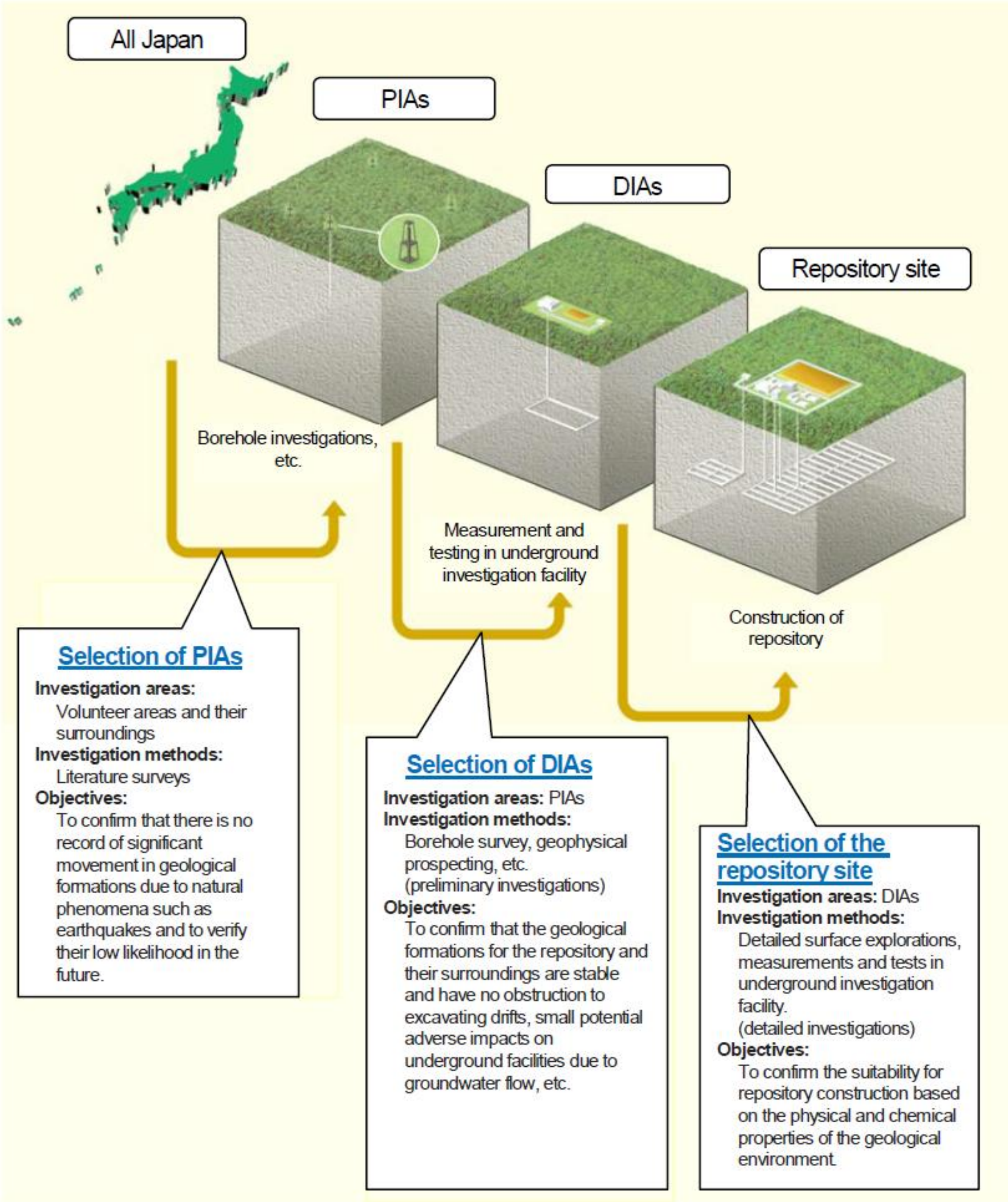


Fig. 1-1 Illustration of the repository site selection process in Japan (NUMO, 2009)

2. Roles and activities of selected URLs in disposal programs

In this chapter, we focus on URLs operating in Europe and investigate the roles these play in the site selection programs in each country. We also look at the type of experiments conducted in the URLs. Additionally, the current status of the site selection programs in some countries is investigated based on recent literature and information obtained at NUMO workshops in 2011 and 2012 (see Appendix).

2.1 URL-related terminology

In this section, terminology related to URLs is presented and classified by the function of the URL in the site selection program, and the terms used to describe NUMO's Underground Investigation Facility are defined.

OECD/NEA (2001a) uses the term URL to describe any underground facility in which analysis, testing, technology development, and/or demonstration activities are carried out to support the development of underground repositories for radioactive waste. However, the terms 'laboratory' and 'research facility' have connotations with Research & Development (R&D) and may both be somewhat inappropriate when referring to actual repositories or those facilities that are located at proposed disposal sites. Several waste disposal organizations, such as Posiva (Finland), use the term URCF (Underground Rock Characterization Facility) or ONKALO (Posiva, 2003a; 2006). NIREX[1] (U.K.) used the term RCF (Rock Characterization Facility) for their planned underground facility and the US Department of Energy (DOE) used ESF (Exploratory Studies Facility) for its Yucca Mountain facility. The choice of terms commonly emphasizes the message the implementing organization would like to convey regarding the URL rather than the actual status of the facility.

NUMO uses the term UIF (Underground Investigation Facility) for the facility that will be constructed during stage DI(2). Using the terms 'investigation' rather than 'research' and 'facility' rather than 'laboratory' indicates that the range of activities planned to take place will be broader than R&D activities. In this report, the term URL will be used as an all-inclusive term for existing underground facilities.

URLs are classified into two categories: generic URLs and site-specific URLs (IAEA, 2001; OECD/NEA, 2013). 'Generic URL' is a term used for facilities developed for research and testing purposes at a site that will not be used for waste disposal but to provide information that may assist disposal planning and operation elsewhere. Generic URLs can be used to gain general experience of underground construction techniques, model testing and verification of measurement techniques.

---

[1] **NIREX does not exist any longer; the implementing organization in U. K. is RWM (Radioactive Waste Management), a wholly owned subsidiary of the Nuclear Decommissioning Authority (NDA).**

Generic URLs can be constructed at depth, such as the Äspö Hard Rock Laboratory (Sweden) and the Mizunami and Horonobe URLs (Japan), or in tunnels near the surface, such as at the Mont Terri Rock Laboratory (Switzerland) and Tournemire (France); others are constructed in existing mine galleries such as Stripa (Sweden) and the Tono and Kamaishi facilities (Japan).

'Site-specific URL' is the term used for facilities located at locations that are considered as potential sites for waste disposal and may be a precursor to the development of a repository at the site.

ONKALO in Finland is constructed at a future repository site and will be part of the repository. The Bure URL is constructed at a future repository site but it will not be part of the repository. The R&D results from the site-specific URLs are expected to apply directly to the design of their respective repositories.

2.2 Brief overview of selected URLs

R&D at URLs began in the 1960s. In the early days, the URLs were established in mine galleries, such as the abandoned mines of Asse and Stripa, or excavated from existing tunnels, such as the Grimsel Test Site (adjacent to the access gallery of a hydropower plant). In the 1980s, URLs were constructed at sites selected specifically for the purpose of R&D on geological repositories; these included the HADES laboratory (Belgium) and the Äspö Hard Rock Laboratory (Sweden). In Japan, the Tono and Kamaishi mines were used for R&D on geological disposal in the 1990s. The Mizunami URL (crystalline rock) and the Horonobe URL (sedimentary rock) were constructed in the 2000s by the Japan Atomic Energy Agency (JAEA) as generic URLs (JAEA, 2014). Details of the selected URLs are listed in Table 2-1.

Table 2-1 Overview of the selected URLs (IAEA, 2001; OECD/NEA, 2001a; 2001b; 2013)

URL Operation	Country Organization	Host rock Depth	Comments
Generic			
Asse Mine 1965-1997	Germany GSF	Permian rock salt anticline 490-800m and 950m	Pre-existing tunnnels
Stripa Mine 1976-1992	Sweden SKB	Granite, Fe mine 360-410m	Pre-existing tunnnels
Grimsel Test Site 1984-	Switzerland Nagra	Grianite 450m	Purpose built; parallel to exsisting tunnels
Tono 1986-2004	Japan PNC/JNC	Sediments, Uranium mine 130m	Pre-existing tunnnels
Kamaishi 1988-1998	Japan PNC/JNC	Granite, Fe mine	Pre-existing tunnnels
Tournemire 1990-	France IRSN	Sediments (shale) 250m	Pre-existing tunnnels
Olkiluoto 1992-	Finland Posiva	Granite (tonalite) 60-100m	Purpose built; parallel to repository facilities
Äspö Hard Rock Laboratory 1995-	Sweden SKB	Granite 200-460m	Purpose built; generic
Mont Terri rock laboratory 1995-	Switzerland Mont Terri Project	Opalinus Clay 400m	Purpose built; parallel to exsisting tunnels
Mizunami Underground Research Laboratory 2004-	Japan JAEA	Granite 500m	Purpose built; generic
Horonobe Underground Research Center 2005-	Japan JAEA	Sedimentary rock 500m	Purpose built; generic
HADES-URF 1980-	Belgium EIG EURIDICE	Boom Clay 230m	Purpose built; site-specific
Site-specific			
Gorleben 1985-1990	Germany BfS、DBE	Salt dome below 900m	Purpose built; site-specific
Meuse/Haute-Marne (Bure URL) 2000-	France Andra	Shale (indurated clays) 450-500m	Purpose built; site-specific
ONKALO, Olkiluoto 2003-	Finland Posiva	Granite (tonalite)	Purpose built; site-specific

2.3 Role of the URLs in the disposal program

This section presents a brief overview of the selected URLs currently operating in Europe and the corresponding national programs.

2.3.1 Belgium

(1) Current status of the disposal program

In Belgium, category B and C waste (ONDRAF/NIRAS, 2011), namely high-level and/or long-lived intermediate-level waste, will be disposed of in geological repositories in poorly indurated clay. The Belgian Nuclear Research Center SCK•CEN began studying nuclear waste disposal in

1974. The research focused on the Boom Clay formation, which is distributed under the Mol/Dessel nuclear site. R&D coordination was taken over by ONDRAF/NIRAS, which has been responsible for radioactive waste management in Belgium since the early 1980s. It proposed the disposal of radioactive waste in geological repositories in poorly indurated clays (Boom Clay was recommended, with Ypresian clays as an alternative).

The safety aspects of the project were presented in the SAFIR and SAFIR 2 reports, which were reviewed internationally (OECD/NEA, 2003; ONDRAF/NIRAS, 2011). The review did not identify any major technical or scientific problems and confirmed that further Research, Development and Demonstration (RD&D) should continue. The need to develop political and social support, a clear decision-making process and a clear legislative framework was identified in the review process.

The decision of the Belgian government on a specific long-term management option is still pending. The Waste Plan (ONDRAF/NIRAS, 2011) seeks the decision in principle that disposal of high-level radioactive waste (HLW) in Belgium can be implemented in poorly indurated clays but does not identify a site or a host rock.

(2) The role of the URL in the disposal program

In 1980, SCK•CEN started the construction of the underground laboratory HADES. HADES was constructed in Boom Clay at a depth of 225 m and was extended in two phases: (a) the construction of a second access shaft in 1997-1999 and (b) the excavation of the connecting gallery in 2001-2002. A new gallery was constructed in 2007 for the PRACLAY heating experiment. The experiment was launched in 2011 and the heating phase started in 2014. The laboratory is managed by EIG EURIDICE, the Economic Interest Grouping of ONDRAF/NIRAS and SCK•CEN.

The current role of HADES in ONDRAF/NIRAS's program can be summarized under four headings:

a) Technical/scientific needs of ONDRAF/NIRAS and the regulator

HADES fulfils the technical/scientific needs of the program in terms of high-quality data, specific boundary conditions and international cooperation. Currently there are no regulatory requirements to be fulfilled at HADES, but it is expected that key aspects of the safety issues will need to be demonstrated in-situ.

b) Monitoring strategy

Experience from 30 years of URL operations and long-running experiments help in developing the monitoring strategy for the disposal site.

c) Acceptance and trust

Visits to the URL and communication around the URL help to build confidence in the quality of the RD&D.

d) Knowledge transfer

The URL plays an essential role in scientific knowledge transfer as, after 30 years of operation, a generation change has taken place.

The focus of HADES is expected to move from its current role, which started with basic data collection, to integrated research aimed at confirmation and demonstration.

In the long-term, its role is expected to evolve from mainly technical-scientific aspects towards monitoring development, training, communication and optimization/testing of new technologies (SCK•CEN, 2014).

2.3.2 Finland

(1) Current status of the disposal program

Posiva, which was founded in 1995 by the nuclear electricity utilities Teollisuuden Voima Oy (TVO) and Fortum Power and Heat Oy (Fortum), formerly Imatran Voima Oy (IVO), is responsible for concept development and site selection for the disposal of spent nuclear fuel.

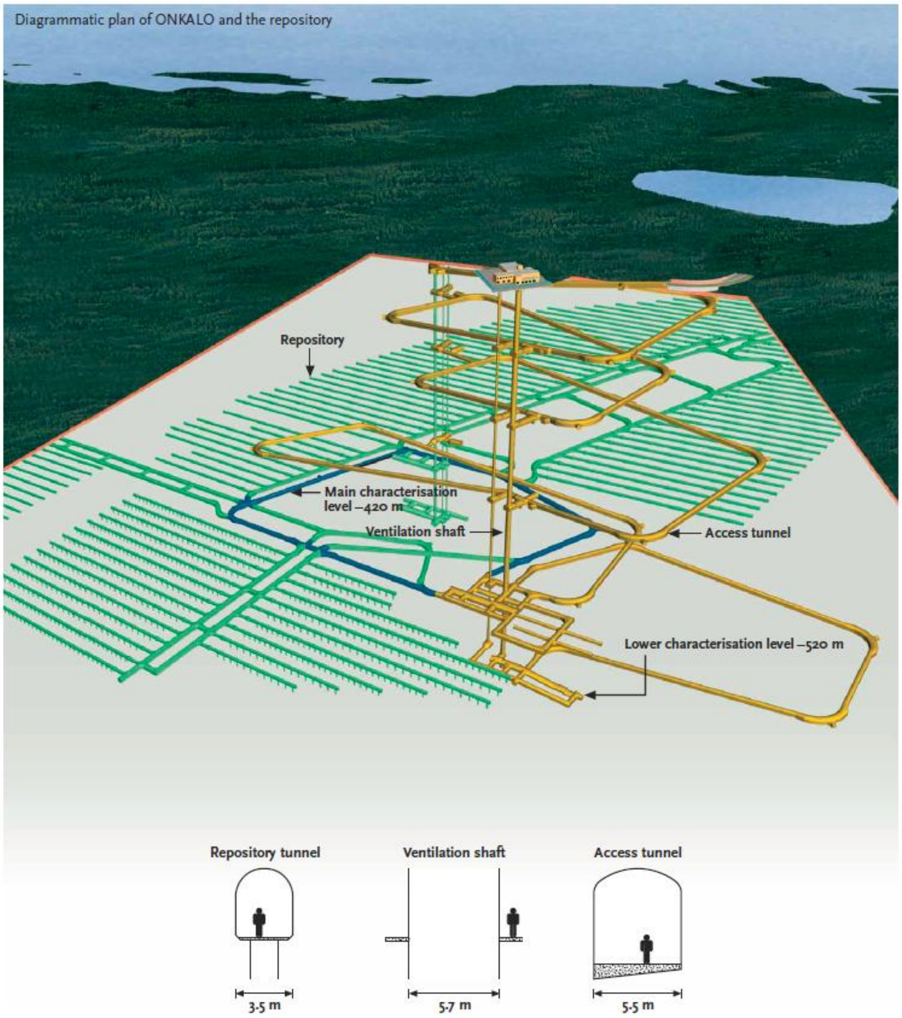


Fig. 2-1 Schematic illustration of ONKALO and disposal facilities (Posiva, 2006)

Finland has been preparing for the final disposal of spent nuclear fuel since 1983. Based on the screening of study areas, detailed site investigations and environmental impact assessments, in 1999

Posiva submitted an application to the government for a decision in principle to select Olkiluoto in the municipality of Eurajoki as the site of the final disposal facility for spent nuclear fuel and long-lived intermediate-level radioactive waste (ILW). As the municipality of Eurajoki gave its consent to locating the disposal facility in the area and the Radiation and Nuclear Safety Authority's (STUK) safety assessment found that there were no objections to the decision, in December 2000 the Finnish government duly issued a decision in favor of the project. The Finnish parliament approved the decision in 2001. In 2004, construction of the Underground Rock Characterization Facility ONKALO (Fig. 2-1) began; since its completion, investigations on site characterization, engineering feasibility and long-term safety studies have been carried out (Posiva, 2006), allowing Posiva to apply for a construction license in 2012. The license was granted by the Finnish government in November 2015 (Posiva, 2015). Disposal of spent fuel should start in the early 2020s.

(2) The role of the URL in the disposal program

Posiva has been preparing 3-year plans for management of the nuclear waste from the Olkiluoto and Loviisa plants since 2003. The newest version is YJH-2012 (Posiva, 2013). The 3-year plans cover future research, technical design and development work, as well as assessments of the state of nuclear waste management, with the emphasis on the preparations for the disposal of spent nuclear fuel. Reports published after the 2006 version were reviewed by STUK.

ONKALO has been used to confirm the suitability of the Olkiluoto bedrock as a host rock for a geological repository, to obtain further information for the detailed design of the repository and to assess long-term safety and construction engineering solutions. ONKALO is also allowing repository technology to be tested under actual conditions. Before constructing ONKALO, Finnish R&D for underground nuclear waste disposal was conducted in the URLs of foreign countries, mainly the Äspö HRL in Sweden, as well as in the underground facility in Olkiluoto for low- and intermediate-level radioactive waste (L/ILW) in Finland.

ONKALO was not intended solely for research purposes, but was also designed to serve as an access route to the repository when it is constructed.

During the construction and operation of ONKALO at the selected site of Olkiluoto, it was essential to maintain favorable host rock conditions with respect to the long-term safety of the planned repository. In practice, this is a challenging task, as some disturbance to the host rock is inevitable and the question is often how to balance such negative effects against the extra effort needed to prevent or mitigate them. In ONKALO, efficient procedures were applied by defining long-term critical safety functions that need to be adhered to and letting these guide the design and implementation of the facility (Posiva, 2002; 2003b). The most important safety functions are related to:

- Groundwater management
- Control of foreign materials
- Controlling the excavation disturbed zone (EDZ)
- Drilling boreholes

Practical rules have been established to ensure that the critical safety procedures are implemented and any issues are dealt with by the ONKALO management group and reported semi-annually. The Finnish safety authority STUK supervises ONKALO as if it were a nuclear facility. In this capacity, STUK makes audits to Posiva to approve the work described above.

2.3.3 France

(1) Current status of the disposal program

Since 1999, the French National Radioactive Waste Management Agency (Andra) has been carrying out investigations at its Meuse/Haute-Marne laboratory site to study the possibility of implementing an underground repository for high-level and long-lived radioactive waste. The geological formation under consideration consists of a stiff clay rock, the Callovo-Oxfordian formation, located at a depth of 500 m. Andra reported their findings on potential waste management solutions in the Dossier 2005 report (Andra, 2005). Since then, within the French legal framework, steps have been taken towards submitting a license application in 2017. Andra aims to obtain the license by 2020, construct the repository by 2025 and start with the pilot phase and initiate the emplacement of the waste and operation of the repository by 2029 (Andra, 2014).

Based on the geological excavations carried out in the region, a “transposition zone” was defined, with properties assumed to be equivalent to those of the URL and with characteristics suitable for hosting the repository. Within the transposition zone, a smaller “interest zone” was defined where the planned repository will be located. The Meuse/Haute-Marne laboratory is located very close to the repository, but it is not intended to become part of the repository and is thus not an in-situ URL in the strict sense.

(2) The role of the URL in the disposal program

The R&D strategy of Andra is described in the Development Plan of the HAVL Project (Andra, 2014). The HAVL Project encompasses all the investigations and studies carried out by Andra to meet the requirements of the Planning Act of 28 June 2006 concerning the storage and disposal of high-level and long-lived ILW. The major input to the Project is the Dossier 2005 report, which discusses the feasibility of reversible deep geological disposal of radioactive waste based on studies and investigations carried out between 1991 and 2005, particularly at the Meuse/Haute-Marne URL. The project is also reviewed on a yearly basis by the National Review Board created by the Planning Act of 28 June 2006 and by the French Nuclear Safety Authority (ASN) according to a schedule established jointly by both parties.

Two 500m deep shafts provide access from the surface to the argillite host rock (Fig. 2-2). The main shaft is 5 m in diameter and allows access of personnel and equipment, material extraction and ventilation. The 4 m diameter auxiliary shaft located 100 m from the main shaft serves the ventilation system and provides mine safety as well as a second access for lowering equipment. From the shafts, the laboratory has two levels of access drifts at depths of 445 and 490 m. The 500 m of drifts at the

490 m depth constitute the key experimental level of the laboratory. The experimental zones are located in a specific area to allow construction and drift-fitting work to take place at the same time (Delay, 2006).

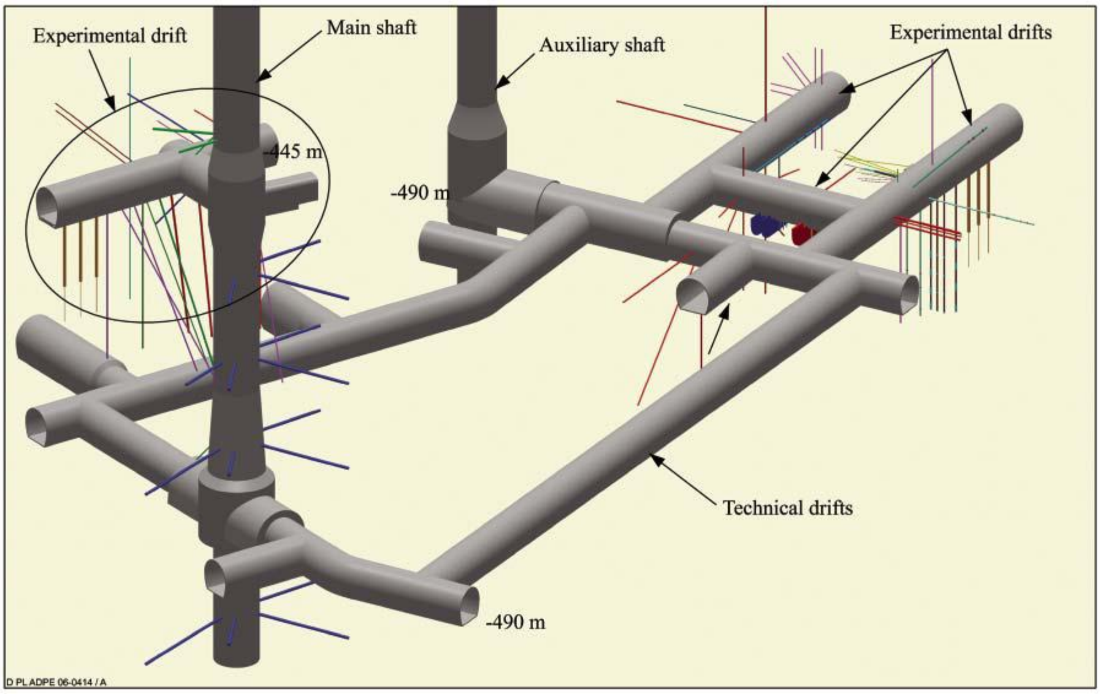


Fig. 2-2 Layout plan of the Bure URL (Delay et al., 2011)

The objectives of the URL for 1999 - 2005 were mainly to achieve the in situ characterization of the physical and chemical properties of the rock. The results of this research are presented in the report "2005 Argile" (Andra, 2005).

The 2008-2015 scientific and technical programs of the URL were focused on the following:

a) Demonstrating the suitability of the argillaceous rock as a repository host rock.
- Properties (permeability, porewater geochemistry, diffusion and retention parameters) and representativeness of the parameters acquired from samples.
- Argillaceous rock behavior.

b) Deformation of the rock mass and feasibility of constructing the shafts, drifts and vaults
- Feasibility of constructing and supporting the disposal system components (strong hydro-mechanical coupling within the argillaceous rocks).

c) Rock-material interaction, dewatering/saturation, gas migration
- Acquiring new scientific data needed for the design of the disposal facility (thermal and hydromechanical behavior) and for safety assessment (migration properties and variability of large-scale clay properties)

d) Demonstration experiments
- Design and test operational procedures in the drifts, vaults and other infrastructure, also during closure of the facility.

- Carry out real-scale experiments to evaluate the technical feasibility of a deep disposal facility.

Once the license application has been submitted in 2017, and before the operational phase commences in 2029, the following activities are planned to take place in the laboratory:

- Continue to improve the disposal processes during the first construction phase of the facilities, before moving progressively from cold testing (2025) to initiation of waste emplacement.
- Develop monitoring methods to manage reversibility after the repository has been commissioned in 2029 and the operational phase has started. The interest in ongoing experiments in the URL will be addressed.

An ongoing objective of the URL will be staff training in all aspects of underground operations and safety during the development of the facility and throughout its operational lifetime.

2.3.4 Sweden

(1) Current status of the disposal program

The Swedish nuclear waste disposal program started in the 1970s. The Swedish Nuclear Fuel and Waste Management Company (SKB), established by a group of Swedish nuclear power companies, is responsible for radioactive waste disposal in Sweden. SKB plans to dispose of the spent nuclear fuel at a depth of around 500 m in crystalline rock.

The Swedish program has evolved through the following main phases:

- 1976-1984: URL experiments and studies conducted at the Stripa mine.
- 1980s: The Swedish system is established. URL research at Stripa is continued.
- 1990s: Feasibility studies conducted in eight municipalities, full-scale experimental studies take place at the Äspö HRL and at the Canister Laboratory.
- 2000s: Surface site investigations are conducted at two potential sites. Full-scale experiments are being conducted at the pilot plant at the Bentonite Laboratory.
- 2009: SKB selects the site of Forsmark (Municipality of Östhammar) for the spent fuel repository.

SKB submitted a license application for the Forsmark site in March 2011. The encapsulation plant will be built in Oskarshamn, while the final repository will be constructed at Forsmark. Operation of the repository is planned to begin in the early 2030s (SKB, 2013b).

(2) The role of the URL in the disposal program

The Äspö Hard Rock Laboratory (Äspö HRL), built during 1990-1995, is situated in Äspö, north of the Oskarshamn nuclear power plant. The underground laboratory consists of a tunnel from the Simpevarp peninsula, where the Oskarshamn nuclear power plant is located, to the southern part of Äspö. At Äspö, the main tunnel descends in two spiral turns to a depth of 460 m. The various experiments are conducted in niches in the short tunnels that branch out from the main tunnel (SKB, 2010).

The establishment of the Äspö HRL was divided into three phases: the pre-investigation phase, the construction phase and the operational phase.

The pre-investigation phase (1986-1990) focused on obtaining information to help determine the ultimate location of the laboratory site. The natural conditions of the bedrock were described and predictions made of the geological, hydrogeological, geotechnical and rock mechanical conditions to be encountered during excavation of the laboratory. This phase also included planning for the construction and operational phases.

During the construction phase (1990-1995), comprehensive investigations and experiments were performed in parallel with the construction of the laboratory. The excavation of the main access tunnel and the construction of the Äspö Research Village were completed.

The operational phase began in 1995. A preliminary outline of the program for this phase was provided in SKB's RD&D Program 1992. Since then, the program has been revised every 3 years; the detailed basis for the period 2011-2016 is described in SKB´s RD&D Program 2010 (SKB, 2010).

The following staged goals were initially defined for the work at the Äspö HRL (SKB, 2013b).

Verify pre-investigation methods

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

Finalize detailed investigation methodology

- Refine and verify the methods and the technology needed for characterization of the rock in the detailed site investigations.

Test models of the barrier functions under natural conditions

- Further develop and test methods and models of groundwater flow, radionuclide migration and chemical conditions at repository depth during repository operation as well as after its closure.

Demonstrate the technology and function of important components of the repository system

- Perform full-scale tests to investigate and demonstrate the different components of the repository and the importance for the long-term safety measures at the facility; show that high quality can be achieved in the design, construction and operation of the repository components.

With the selection of the repository site at Forsmark, the Äspö laboratory became an off-site URL with different geological properties to those of the on-site facility. However, most of the experiments conducted at Äspö will not have to be repeated in the on-site URL. Only experiments where differences in rock properties between the on- and off-site URLs may affect the conclusions will have to be repeated in the on-site laboratory to validate the original results. In the future, the off-site facility will be used to train personnel who will work in the spent fuel repository. SKB therefore expects the Äspö laboratory to remain operational at least until the spent fuel repository is put into operation.

While SKB has established a technically feasible prototype design and layout for the KBS-3V repository (Andersson et al., 2005) and has demonstrated that this technology conforms to the stated design premises, technical development is still ongoing. A detailed design of the various repository components adapted to an industrialized process and designed to fulfil specific requirements relating to quality, cost and efficiency has yet to be developed. The layout of the repository also needs to be adapted to the local conditions encountered when constructing the repository at depth. These potentially improved solutions should result in at least the same level of safety as the current prototype design being considered in the safety assessment that is part of the license application.

2.3.5 Switzerland

(1) Current status of the disposal program

Deep geological disposal is required by law for all types of radioactive waste in Switzerland. Nagra, the National Cooperative for the Disposal of Radioactive Waste, was established in 1972 by all the radioactive waste producers in Switzerland. It is responsible for the planning, construction and operation of deep geological repositories for all categories of Swiss radioactive waste. Nagra also operates the national waste inventory database and advises the producers on waste conditioning procedures.

In 2002, Nagra submitted the "Entsorgungsnachweis" (Nagra, 2002a; 2002b; 2002c) feasibility study (project Opalinus Clay) for spent nuclear fuel, HLW and long-lived ILW to the Federal Council; the project demonstrates the technical feasibility of constructing a deep geological repository in the Opalinus Clay in Switzerland. The Federal Council approved the Entsorgungsnachweis project in June 2006.

Repository sites are selected in accordance with the conceptual part of the Sectoral Plan for Deep Geological Repositories (SFOE, 2008), which was approved by the Federal Council in April 2008. The purpose of the Sectoral Plan is as follows.

- To act as a planning instrument showing how the Federal Government intends to fulfil its responsibilities that impact on spatial planning.
- To coordinate cantonal and national spatial planning strategies.
- To ensure early involvement of the Cantons, neighboring countries and the public in the process.

The site selection process, which is divided into three stages, is managed by the Swiss Federal Office of Energy (SFOE). In the first stage of the Sectoral Plan process, Nagra proposed geological siting regions where, from a scientific and technical perspective, safe geological repositories could be constructed. The SFOE announced Nagra's proposals for suitable siting regions in November 2008 and the federal safety authorities and other expert bodies reviewed and approved the proposals: 6 siting regions for the L/ILW repository and 3 siting regions for the HLW repository, all of them with clay-rich sediments as potential host rocks. The proposals were reviewed by the authorities, submitted to broad public consultation and finally approved by the Federal Council in November 2011.

The aim of the now ongoing Stage 2 of the Sectoral Plan process is to narrow down the number of siting regions to at least two each for the L/ILW and the HLW repository. Nagra's proposals for repository sites, including the corresponding surface facilities, were submitted and published by the SFOE in January 2015: the two regions "Jura Ost" and "Zürich Nordost" were proposed for further investigation in Stage 3 of the process (Nagra 2014). Both regions are suitable for the disposal of L/ILW and HLW, as well as for constructing a so-called combined repository for both waste categories. Nagra's proposals are currently being reviewed by the safety authorities. The decision of the Swiss government is expected around 2018.

A schematic illustration of a repository for SF/HLW/ILW is shown in Fig. 2-3.

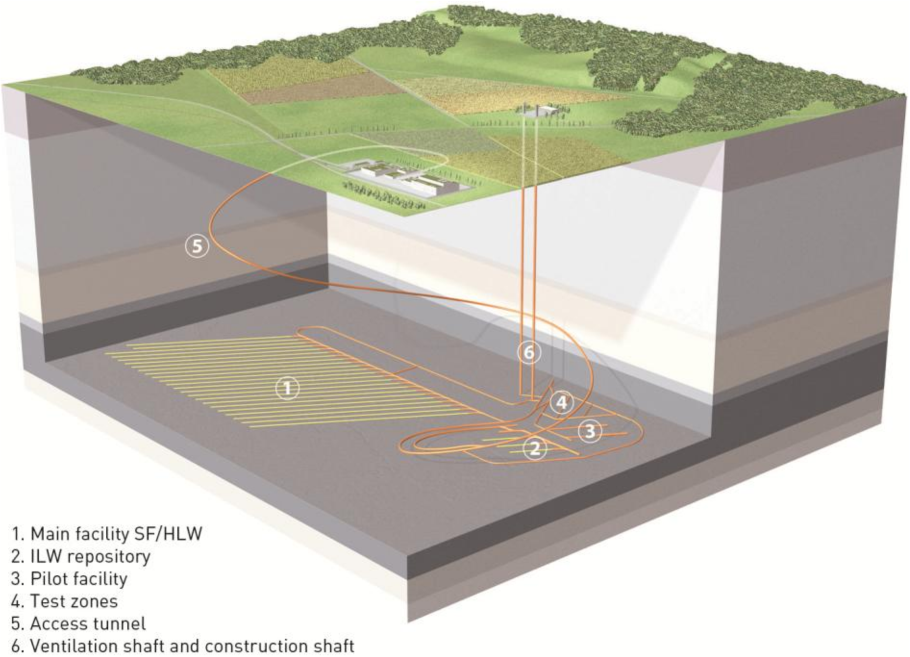


Fig. 2-3 Schematic illustration of the repository for SF/HLW/ILW (Nagra, 2014)

(2) The role of the URL in the disposal program

Two generic URLs operate in Switzerland: the Grimsel Test Site (GTS) in crystalline rocks (granite/granodiorite) owned and operated by Nagra since 1984, and the Mont Terri Rock Laboratory in sedimentary rock (Opalinus Clay) owned by the Republic and Canton of Jura and managed by the Federal Office of Topography (Swisstopo) since 1996. Both URLs are international RD&D platforms where collaboration is both desirable and valuable.

The main objectives of the URL studies in Switzerland are:

- Investigating the characteristics of potential host rocks.
- Developing understanding of the processes occurring in the rock at various depths.
- Developing understanding of the processes that occur when the emplaced repository components interact with the surrounding rock and groundwater.
- Developing and verifying upscaling procedures from modeling and laboratory experiments to full-scale testing.
- Testing components, techniques and instruments relevant to repository development.
- Developing and testing models of various processes.
- Confirming that the models perform well and demonstrating that all the repository components meet the requirements.

- Training competent and skilled staff.

For both the crystalline and the sedimentary rock programs, it was recognized that many issues related to radionuclide migration, repository construction and engineered barrier system (EBS) behavior have to be studied in situ:

- GTS: the development of Project Gewähr (Nagra, 1985) to assess the crystalline rock sites in Northern Switzerland made it clear that URL studies would be important for the future development of repositories in Switzerland.
- Mont Terri: the positive results from sedimentary studies in the 1990s pointed to the Opalinus Clay as a suitable potential formation; the Mont Terri location was suitable as a generic URL in the potential host rock.

Studies focusing on the EBS performed at the GTS provide results that are independent of the host rock and are transferable to sedimentary rocks (e.g. the Full-scale Engineered Barriers Experiment (FEBEX) and the Gas-Permeable Seal Test GAST at the GTS). Both the GTS and the Mont Terri URLs are easily accessible (limited infrastructure needed) and presented opportunities to develop understanding in situ without having to wait for a disposal site URL.

Nagra's present program of work at the URLs was developed through the RD&D program and the Waste Management Program, taking into account safety-related requirements, input from reviews and the time required to obtain the results.

Definitive site selection and the decision of the Federal Council on the general licence - and with this the end of the third stage of the Sectoral Plan process - is expected for 2027. This decision of the Federal Council on the general licence has to be approved by Parliament and is subject to an optional national referendum (around 2029). Construction of an underground test area as part of the rock characterization (RCF) is expected to start shortly after that date. Analysis of the rock stress and the implications for the construction, excavation disturbance and liners will be carried out in the RCF at the disposal site. In contrast, the present URL studies should ensure that technologies are available to carry out these investigations. The Swiss disposal concept, monitored deep geological disposal, includes the construction of a pilot facility. According to the Swiss Nuclear Energy Ordinance (KEV, 2004), the geological and hydrogeological conditions of the pilot repository must be comparable to those of the main facility, and its construction and the emplacement procedure for the waste and backfill material must correspond to those of the main facility.

The pilot repository should be initiated as the first part of repository operation. It will be monitored in detail in order to observe the temporal evolution of the repository system and thus:

- ensure that any potentially unfavorable developments can be recognized at an early stage and the necessary measures taken.
- confirm long-term safety with a view to closure.

The pilot facility is not a URL; models of the repository system components should be tested and validated based on previous experiments either at the surface or in off-site URLs, where much more intensive and intrusive instrumentation can be used.

2.4 Examples of activities in URLs

Many types of investigations are conducted in URLs. In this section, we present brief overviews of selected URL investigations classified into four categories: evaluation of the geological environment, engineering aspects, safety assessment and demonstration tests.

2.4.1 Evaluating the geological environment

(1) CRIEPI's Fractured Rock Studies (C-FRS) (GTS)

Objectives:

The aim of this experiment was to demonstrate the performance of newly developed technologies for fracture characterization and tracer testing. The relevant parameters of the investigations are fracture aperture and geometry.

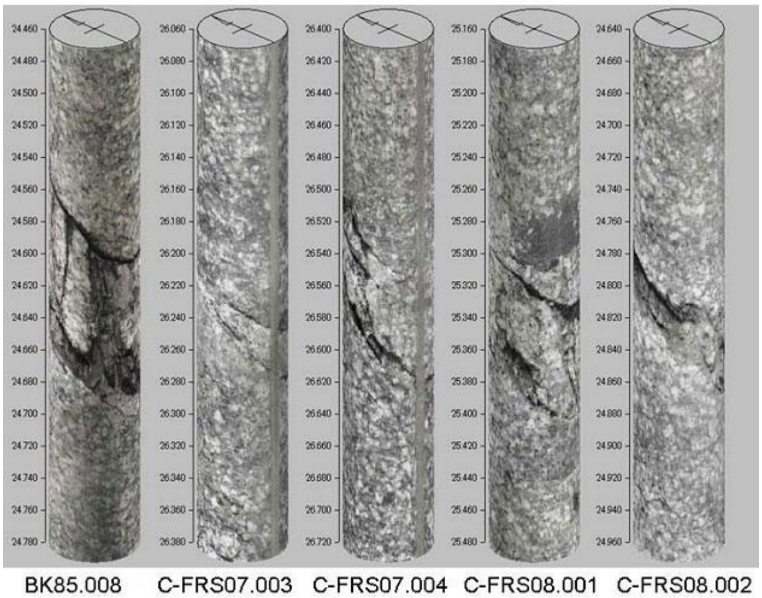


Fig. 2-4 Sample images of target fractures taken by high resolution borehole camera (Nagra, 2013a)

Brief overview:

The following methods were applied in the experiment.

- High-resolution borehole camera images (Fig. 2-4).
- Analysis of dissolved radon.
- Various tracer tests.
- Borehole-to-borehole acoustic tomography.

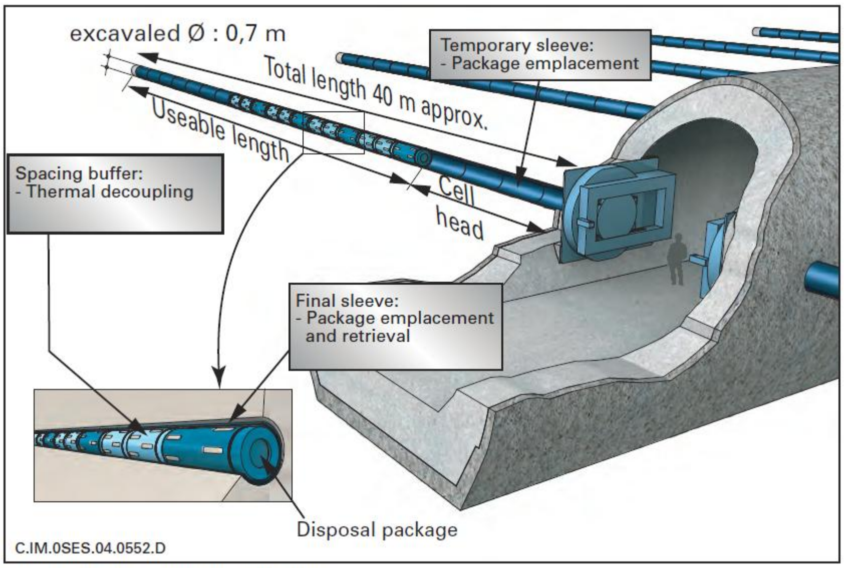
The experimental program required a relatively simple and very well understood geological environment in fractured rock.

Information from a number of geophysical and hydraulic experiments was combined and interpreted to provide a comprehensive picture of the geological features at depth and the local hydrogeological conditions (Nagra, 2013a).
Test period: 2007-2012

2.4.2 Engineering studies

(1) Demonstrating the geotechnical capacity to excavate and case a disposal cell (Bure URL)
Objectives:

The engineering concepts for this method for C-type high-level radioactive waste disposal were developed in France (Fig. 2-5). The aim of this experiment was to develop and demonstrate the techniques for drilling and casing the horizontal deposition boreholes.



C waste cell while in operating configuration

Fig. 2-5 Illustration of the concept for a C waste disposal cell (Andra, 2005)

Brief overview

Andra employed the services of a drilling company (CSM-Bessac) for excavation trials in the Bure URL underground facilities. A specifically patented Tunnel Boring Machine (TBM) was designed, fabricated, installed in situ and put into operation (Bosgiraud et al., 2010). The first three trial holes which were drilled between April and May 2009 produced some encouraging results.

- A depth of 20 m (half the reference target length) was reached and the borehole was cased.
- An open hole was maintained to monitor the change in the behavior of the clay formation.
- The drilling parameters (weight on bit, rotating speed, rate of penetration) were measured and progressively improved.

Test period: 2009-present

(2) Full-scale emplacement demonstration experiment (Mont Terri Rock Laboratory)

Background and objectives

This is a long-term full-scale emplacement (FE) demonstration experiment simulating the effect of the temperature produced by the waste. A good understanding of the thermo-hydro-mechanical (THM) processes of the EBS and host rock system is required to design this experiment. Additionally, techniques such as the emplacement of the steel canisters, bentonite backfill and rail system have to be developed. The repository-induced THM coupled effects on the host rock will be investigated as a whole.

Brief overview

A starter niche was constructed in 2011 and an emplacement gallery (50 m long, 3 m in diameter) was excavated in 2012. Observation boreholes were drilled and measuring instruments installed (currently six boreholes). These boreholes are being used for monitoring the pore pressure evolution around the gallery. Three dummy steel canisters (scale of 1:1, including a heating source) were emplaced on a bentonite bed and measurement equipment was installed in the open space around the canisters. The gap between the canisters and rock was backfilled with granular bentonite and the test section was sealed with a concrete plug. Heating will start and the heat will propagate through the bentonite towards the rock. The granular backfill will be naturally saturated and the experiment monitored. The experiment will run for at least 10 years (Fig. 2-6).

Test period: 2011-2020 (planned)

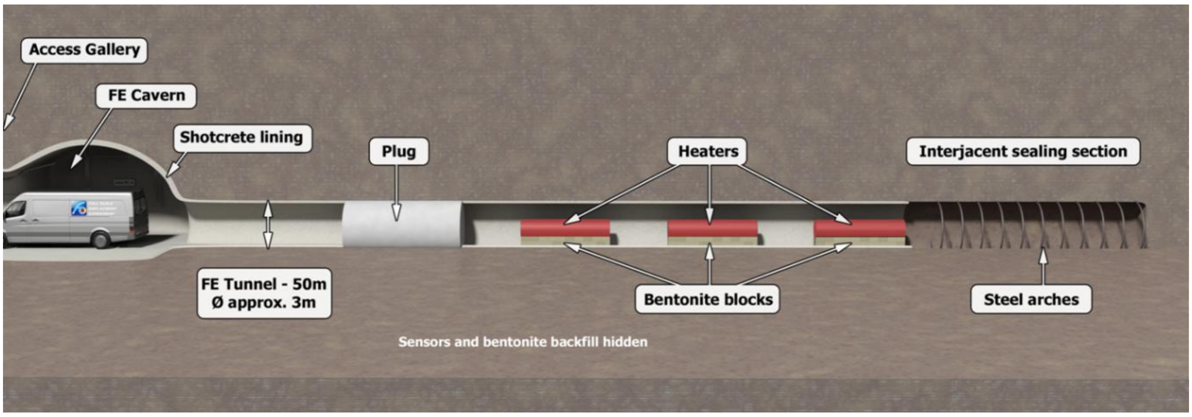


Fig. 2-6 Schematic illustration of the FE layout (Vomvoris, et al., 2013)

(3) Full-scale Engineered Barrier Experiment (FEBEX) / Dismantling Project (FEBEX-DP) (Grimsel Test Site)

FEBEX has been one of the longest running 1:1 scale heating experiments under in-situ conditions. It was initiated at Nagra's Grimsel Test Site in 1997 by the Spanish/ENRESA HLW program and was run under the auspices of an international partner consortium. The experiment was designed to demonstrate the feasibility, manufacturing, handling and assembly of an engineered barrier system

(EBS). A further aim was to develop numerical models and codes for assessing the THM and thermo-hydro-geochemical (THG) behavior of the near-field of a deep geological disposal facility.

Brief overview

Two heaters were placed in a horizontal granitic host rock drift, surrounded by a bentonite block buffer (compacted FEBEX bentonite, Serrata clay, Ca-rich) and kept at a temperature of 100°C. Numerous sensors were used to monitor the buffer and host rock performance. In 2002, the outer heater was retrieved and an extensive sampling program was performed, while the second heater was left in place. The 5-year running time of the outer part of the experiment yielded valuable information, specifically confirming the feasibility of constructing an EBS and predictions of an early hydration and saturation phase of the buffer.

The second heater - kept for another 13 years at 100°C - allowed further investigation of the early stage buffer hydration and saturation phase. In 2015, the second heater was dismantled under the FEBEX-DP consortium (**F**ull scale **E**ngineered **B**arrier **EX**periment - **D**ismantling **P**roject). The objectives of dismantling the second heater in 2015 were:

- Characterization of the key physical properties (density, water content) of the barrier and their distribution and comparison with results from the partial dismantling and model predictions.
- Characterization of corrosion and microbiological effects on the heater, instruments and coupons resulting from evolving redox conditions and saturation states, including gas analysis.
- Characterization of mineralogical interactions at material interfaces (cement-bentonite, iron-bentonite, rock-bentonite) by macro- and micro-level studies.
- Assessment of sensor performance and durability.
- Increasing the understanding of the THM and thermo-hydro-chemical (THC) processes through integration of monitoring and dismantling results.

Test period: 1996-2016

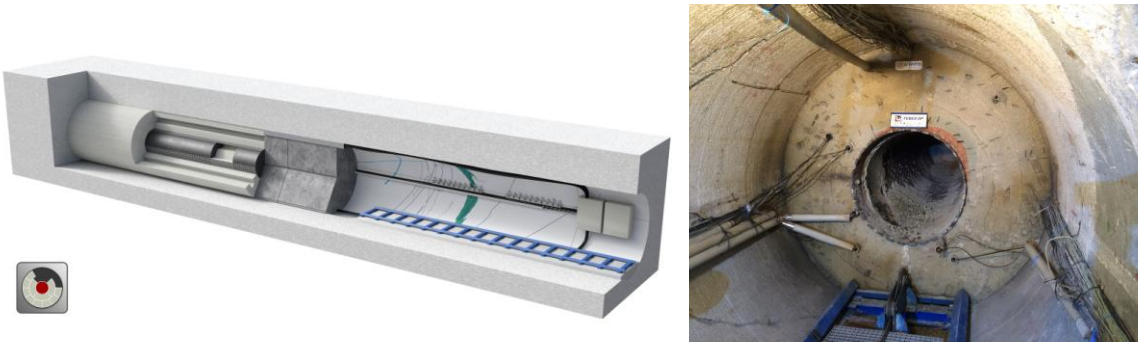


Fig 2-7 Schematic illustration of the FEBEX experiment showing the heater and dummy canister surrounded by a bentonite block buffer and closed by a shotcrete plug (left); bentonite buffer with open heater section (right) (Nagra, 2015)

2.4.3 Safety assessment

(1) Diffusion, retention and perturbation experiments (DR) (Mont Terri Rock Laboratory)

Background and objectives

An important part of safety assessment is estimation of molecular diffusion and sorption in the Opalinus Clay. The characteristic properties of different radionuclides were investigated based on borehole experiments (Fig. 2-8).

Brief overview

The first in-situ tests involved injecting and circulating low-concentration radioactive tracer cocktails in a packed-off borehole. After a period of 2 to 5 years depending on the test, the central borehole was overcored and the core removed. Planar sections were sawn from the overcore and activities were measured along profiles perpendicular to the borehole. From 2015, a new diffusion experiment was set up where a specially designed x-ray fluorescence (XRF) probe will be used to detect the in-situ progression of tracers circulated in a central borehole.

Results of the tests carried out so far have clearly shown that the Opalinus Clay has an excellent retention capacity for radionuclides. The radionuclides migrate very slowly and their concentration decreases significantly over distance.

Test period: 2010-2025

Fig 2-8 Preparation of the site before the injection of a tracer solution (Mont Terri Project, 2013)

(2) Alternative Buffer Material experiment (ABM) (Äspö HRL)

Background and objectives

The objective of the ABM project is to study clay materials that were assessed as potential buffer materials in laboratory tests. Ultimately, this experiment will evaluate whether these materials can meet the safety requirements. Three test parcels with different combinations of clay materials are installed in boreholes at the Äspö HRL. The parcels are heated carefully to increase the temperature in the buffer materials to 130°C. The heaters in two parcels were activated first and the heaters in the third parcel were activated when the buffer was fully saturated. The main objectives are to:

- Compare the mineral stability and physical properties of different buffer materials in laboratory tests of the reference materials, but also after exposure in field tests performed under realistic repository conditions.
- Identify possible problems with manufacturing and storage of bentonite blocks.
- Study the interaction between metallic iron and bentonite. This may occur during storage because the central heaters are placed in tubes made of straight carbon steel and the tubes are in direct contact with the buffer.

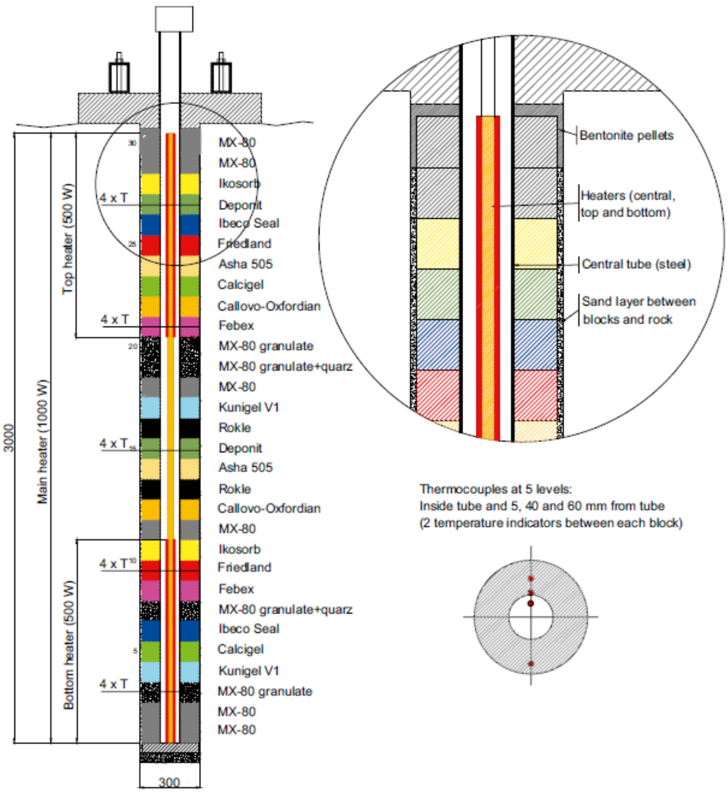


Fig. 2-9 Cross-section of a schematic illustration of the ABM test (Svensson, et al., 2011)

<u>Brief overview of the experiment</u>

Three test parcels containing a heater, central tube, pre-compacted clay buffer blocks, instruments and parameter controlling equipment were emplaced in vertical boreholes with a diameter of 300 mm and a depth of 3 m (Fig. 2-9). The target temperature for all three parcels was 130°C. Test parcel 1 was retrieved in 2009 (Svensson et al., 2010), 30 months after installation and after about 18 months of heating at the intended test temperature. Parcel 2 was retrieved at the beginning of 2013 and parcel 3 is scheduled to be retrieved in 2015. To retrieve the parcels, boreholes were drilled to a depth of 3.2 m (each test parcel was 3.0 m long) in the rock surrounding the parcel. The rock layer covering the clay was about 10 cm thick. This seam drilling was completed with two core-drilled holes, which were used for installation of wire sawing equipment. With this equipment it was possible to saw off the rock column at the bottom and the rock column including the bentonite blocks could then be lifted up to the surface. Immediately after retrieval, the rock column was cut into segments and the bentonite blocks were uncovered. Samples from the different bentonite materials were sent out to all participating organizations for analysis (Svensson et al., 2011).

Test period: 2006-present

(3) Hyperalkaline Plume in Fractured Rock (HPF) experiment (GTS)

Background and objectives

Cement is a major component of the engineered barrier system in the proposed underground repositories; the barriers are used to immobilize the waste and to backfill the repository. The interaction between the hyperalkaline solutions derived from the degradation of the cement and the repository host rock may change the physical and chemical properties of the host rocks. The HPF project at the GTS addressed this issue in a fractured granite rock environment.

The HPF project included an underground field experiment (injection of a hyperalkaline solution in a hydraulic dipole setting and tracer transport experiments), small-scale laboratory experiments and structural and mineralogical characterization. To understand the interaction of the hyperalkaline solution with the fractured shear zone at the GTS, the laboratory and underground field experiments were analyzed by means of numerical modeling.

Brief overview

The basic concept of the HPF field experiment was to alter a portion of the shear zone (a permeable planar structure) in the GTS by percolating a hyperalkaline fluid for a long period of time (over 2 years) and examining the effects on the primary mineralogy, hydrology and transport properties of the shear zone. This was achieved by setting up a dipole flow-field, with continuous monitoring of fluid chemistry, and performing intermittent tracer tests (with and without radionuclides) within the dipole. Finally, safety-relevant radionuclides (^{131}I, ^{24}Na, ^{82}Br) were injected along with a high-pH solution which represented a “young” cement fluid, followed by excavation (resin injection and overcoring; Fig. 2-10) and laboratory-based analysis (radiochemical, mineralogical and structural) of the shear zone. This challenging experiment employed novel materials and techniques for on-line monitoring of hydraulic parameters, electrochemical parameters and spectrometric detection of gamma-emitting tracers under extreme high-pH conditions of around 13.2.

The results suggest that the shear zone was gradually blocked and increasingly larger fractures contributed to the flow-field. Originally, the breakthrough curve was quite diffuse because the transport was spread over a wide range of water-conducting features. The later breakthrough curves showed a much more defined peak and faster breakthrough times, indicating that the transport is concentrated in a few larger fractures. The evolution of the injection pressure at a constant pumping rate of 1 mL/min shows a steady increase after the initial injection of high-pH fluid. This pressure increase is a result of the gradual decrease in the overall transmissivity of the shear zone, presumably due to blocking of the smaller fractures (as noted above). A corresponding decrease in the passive outflow rate can be observed at the extraction site.

Test period: 1998-2006

Fig. 2-10 Overcoring the test intervals (Nagra, 2013b)

2.4.4 Demonstration tests

(1) Prototype Repository (Äspö HRL)

Background and objectives

The Prototype Repository is used to demonstrate the integrated function of the repository based on the KBS-3V concept (Andersson et al., 2005); it provides a full-scale reference for testing of models of individual components as well as the complete repository system.

The project was initially supported financially by the European Commission from 2000 to 2004. The continuing operation is funded by SKB. The retrieval test, which started in 2011, is being conducted in cooperation with Posiva.

Brief overview

The layout involves six deposition holes, four in the inner section and two in the outer section of the repository (Fig. 2-11). The relative humidity, pore pressure, total pressure and temperature in different parts of the test area are monitored. The monitoring data indicate that the backfill in both sections of the tunnel is saturated and that there is a different degree of saturation in the buffer in the deposition holes. The excavation of the backfill in Section II began in 2011 (Dahlström, 2009).

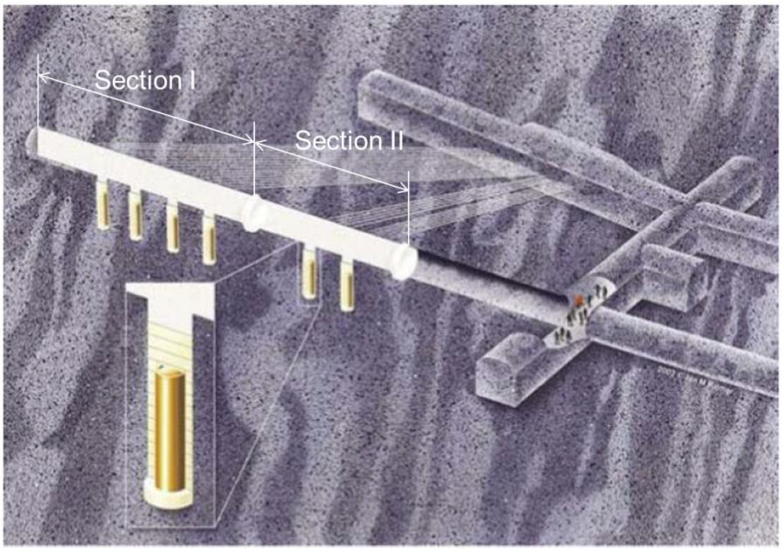


Fig. 2-11 Layout of the Prototype Repository (modified from SKB, 2012)

The test was performed in the innermost section of the TBM tunnel at the −450 m level. Canisters with dimensions and weight as specified in the current plans for the final repository and with heaters to simulate the thermal energy output from the spent nuclear fuel were positioned in the holes and surrounded by a bentonite buffer. The deposition holes are placed at intervals of 6 m (between centers). This distance was set considering the thermal diffusivity of the rock mass and the maximum acceptable temperature of the buffer. The deposition tunnel was backfilled with a mixture of bentonite and crushed rock (30:70). A massive concrete plug, designed to withstand full water and swelling pressures, separates the test area from the open tunnel system and a second plug separates the two sections. This layout provides two almost independent test sections. Instrumentation is used to monitor various processes and properties in the canister, buffer, backfill and the near-field rock. Examples of processes that are studied include:

- Water uptake in the buffer and backfill
- Temperature distribution (in the canisters, buffer, backfill and rock)
- Displacement of the canister
- Swelling pressure and displacement in the buffer and backfill
- Stress and displacement in the near-field rock
- Water pressure build-up and pressure distribution in the rock
- Gas pressure in the buffer and backfill
- Chemical processes in the rock, buffer and backfill
- Bacterial growth and migration in the buffer and backfill

The outer test section was decommissioned in 2011 after approximately 8 years of water uptake of the buffer and backfill.

Altogether, more than 1,000 sensors and transducers were installed in the rock, buffer and backfill to measure the temperature, pore pressure and total pressure in different parts of the test area.

Furthermore, the displacement of the canisters in the deposition hole and the stress and strain in the rock were recorded. The water saturation process is recorded by measuring the relative humidity in the pore system of the backfill and the buffer, which can be converted to total suction. Transducers were installed to measure the stresses and strains in the rock around the deposition holes caused by the heating from the canisters. The water pressure in the boreholes in the rock close to the tunnel, the total pressure, pore pressure and relative humidity in the backfill were also recorded. An ultrasonic monitoring system was installed around deposition hole 6 (monitoring since 1999). Many of the sensors for measuring total pressure, relative humidity and pore pressure in deposition hole 1 are currently indicating that the buffer around the canister is close to saturation, while the buffer above and below the canister is not saturated.

Fig. 2-12 Core drilling of the buffer. A template was used to obtain the correct position of the cores (SKB, 2012)

Section I was backfilled and plugged in 2001 and section II was filled and plugged in 2003. After 8 years of monitoring, the excavation of the backfill in section II started in 2011 (Fig. 2-12). Some difficulties were encountered in section I (SKB, 2012); however, with continuous monitoring, excavations are planned to begin in this section 20 years from the time when monitoring started.
Test period: 2000-present

(2) Gas Permeable Seal Test (GAST) (GTS)
Objectives
The main aim of the plugs and the seal in a L/ILW repository are to increase the gas transport capacity of the backfilled underground structures without compromising the radionuclide retention capacity of the engineered barrier system. This design option is called an “Engineered Gas Transport System” (EGTS). It involves specially designed backfill and sealing materials such as high-porosity mortars as backfill materials for the emplacement caverns and sand/bentonite (S/B) mixtures with a bentonite content of 20-30% for backfilling other underground structures and for the seals.

The GAST experiment focuses on the specific issue of seal behavior during saturation and the gas transport capacity in the later gas invasion phase. Nagra's RD&D related to the EGTS established the main aims of GAST as follows.

- To demonstrate the effective functioning of gas permeable seals on a realistic scale and with realistic boundary conditions.
- To validate and, if necessary, improve the current conceptual models for the resaturation and gas invasion processes into S/B seals.
- To determine the upscaled gas/water permeabilities of S/B seals.

Secondary objectives include:

- To evaluate in-situ emplacement techniques and the necessary QA measures to be applied.
- To apply novel monitoring methods, in particular seismic tomography.

Brief overview

An 8 m long buffer made of layered sand/bentonite was emplaced between two gravel packs (for water and gas injection/circulation) with a concrete plug for reinforcement. Water injection will be either one-sided from the cement plug or double-sided, while gas injection will only be performed from the far end of the tunnel. Once saturated, gas will be injected into the gravel pack. A series of laboratory experiments is being performed in parallel with the field experiment. In May 2012, the final component of the experiment, namely the concrete plug with a maximum diameter of 4 m and a thickness of 2 m, was installed. The concrete plug should be capable of withstanding a water pressure of up to 50 bars and will allow testing of the seal under hydraulic conditions that are expected in a repository at a depth of 500 m (Figs. 2-13 and 2-14).

Test period: 2010-2018

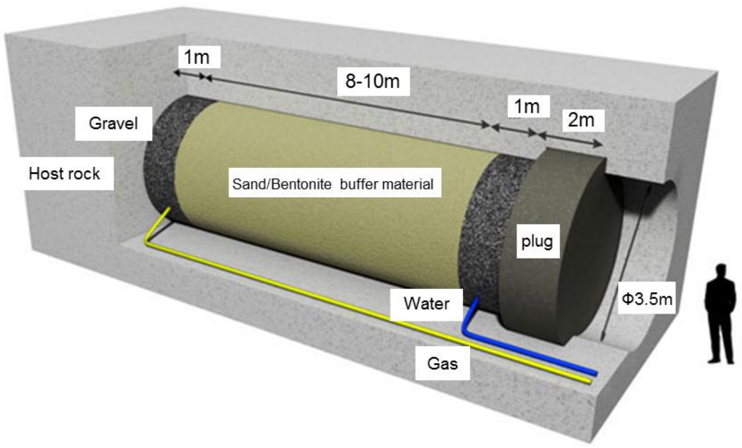


Fig. 2-13 Schematic illustration of the GAST layout (modified from Nagra, 2013c)

Fig. 2-14 Installation of the instrumentation for GAST (Nagra, 2013c)

(3) Full-scale Demonstration of Plugs and Seals (DOPAS) (Äspö HRL and others)

Objectives

The DOPAS project is a demonstration test focused on R&D of alternative materials for plugs and seals in a spent fuel disposal facility.

Brief overview

The project develops the design basis of plugs and seals, including new technology for the plug and seal materials and for the assembly and construction of the structures. Full or partial design of the structures is implemented and five plug and seal tests are performed. In addition, the performance of the tested plugs will be assessed based on their safety requirements. A further task of the project is to communicate with the scientific community and report on the project development and results at international scientific conferences and events. In 2016, during the final project year, DOPAS will organize an international scientific seminar on sealing technology for geological radioactive waste disposal.

One milestone of the DOPAS project is the Full Scale Seal project (FSS) (in collaboration with the FE experiment at the Mont Terri Rock Laboratory). Andra is responsible for the FSS project, for which it built a drift model at Saint-Dizier near the Bure URL. The layout of FSS is shown in Fig. 2-15 (DOPAS, 2013).

Test period: 2012-2016 (planned)

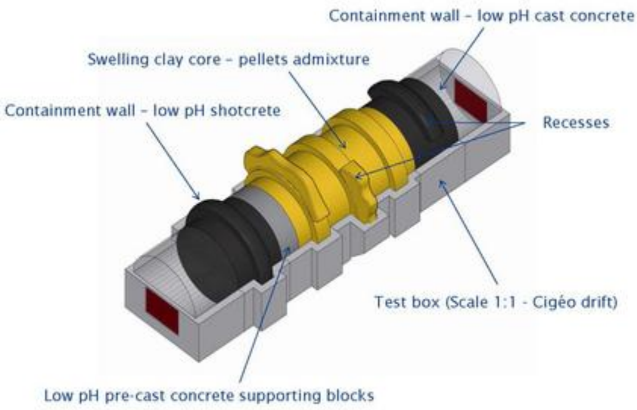


Fig. 2-15 Layout of the FSS experiment (DOPAS, 2013)

(4) Multi-Purpose Test (MPT) (Äspö HRL)

Background and objectives

SKB and Posiva are jointly developing the horizontal deposition concept KBS-3H as a possible alternative to the vertical reference design KBS-3V (SKB, 2012). An important part of the current project phase of KBS-3H is the Multi-Purpose Test (MPT) which has been ongoing at the Äspö HRL since 2011 at the -220 m level. The MPT has two main objectives.

- To test the system components in full scale, combining all the components to verify the design.
- To assess the ability to manufacture full-scale components, carry out installation and monitor the initial system behavior.

Brief overview

The components, weighing up to 46 tons, will be installed using a horizontal deposition machine. After installation, the test conditions will be monitored over 400 days before the test is dismantled and sampled. The test will be carried out in a 20 m section of the full-face drift with a diameter of 1.85 m (Fig. 2-16) at the -220 m level, which implies that the hydraulic boundary conditions will differ from those foreseen at the typical repository depth.

Test period: 2011-present

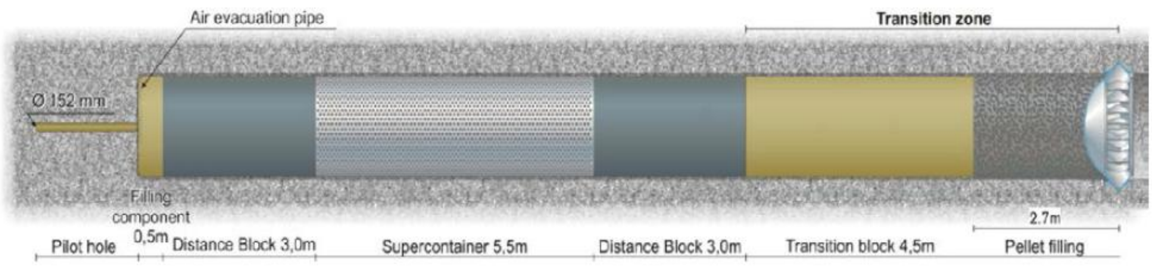


Fig. 2-16 Schematic illustration of the MPT layout (SKB, 2013a)

(5) Demonstration test using the deposition machine (Äspö HRL)

Background and objectives

Full-scale demonstration tests of the fully automatic operation of the deposition machine are in progress at the Äspö HRL and the Canister Laboratory in Oskarshamn.

The equipment that performs the deposition of the canister containing the spent fuel into the vertical deposition hole of the KBS-3V system is required to lift, turn and handle 25 to 27 tons with an accuracy of ±5 mm in all directions and at all times, and to repeat the operation 6,000 times. There must not be any kind of damage to the canister during the deposition operations and the canisters should be kept in a radiation shield tube until the deposition is completed.

Brief overview

The development of the deposition machine has been in progress since 2003. Since 2010, a newly developed machine, Magne, has been undergoing tests (Fig. 2-17). Recorded test runs of the full-scale tests were started at the end of 2010 and continued through to 2012. Once several full test cycles of 40 depositions had been performed without interruption or error, the tests were regarded as completed. Approximately 220 completed depositions were made during the long-term test period and fine adjustment of the software was made. The objectives of the project phase that ended recently were to perform long-term tests with the machine and to develop the navigation and positioning systems. In the next phase, the hoist and the grapple unit will be further developed, as well as the deposition vehicle Magne and the operation and production control systems (SKB, 2012; SKB, 2013a).

Test period: 2003-present

Fig. 2-17 Magne, the deposition machine (SKB, 2012)

3. Clarifying the roles of the URLs and UIF in the disposal program in Japan

In this chapter we examine the design concepts for the UIF according to its function compared to URLs and discuss the roles of the UIF in the site selection, construction and long-term safety assessment of the repository. Figures illustrating the classification concepts and the roles of the UIF in the site selection program are also presented.

3.1 Design concepts for a UIF

In this section, various design concepts for a UIF are discussed in relation to its function compared to URLs.

3.1.1 The role of the UIF in the Japanese program compared to URLs in Europe

Because the UIF in Japan will be constructed in a potential host rock at a site in a DIA, the UIF can be classified as a site-specific URL.

Two site-specific URLs shown in Table 2-1 are the Bure URL and ONKALO. They are located in the potential host rock in a specific potential repository area, a concept identical to that of the UIF in NUMO's program.

ONKALO was built with the intention to use it as part of the future repository and investigations carried out in it are primarily direct investigations of the host rock. Before constructing ONKALO, Posiva conducted experiments and investigations in generic URLs such as the Äspö HRL in Sweden, Olkiluoto or the Grimsel Test Site. Posiva applies techniques and methodologies developed in these generic URLs to the actual disposal environment in ONKALO. Because of ONKALO's future inclusion in the disposal facility, it was necessary to design an investigation and construction program aimed at minimizing damage or disturbance to the host rock environment and preserving the natural barrier performance (Posiva, 2002; 2003b). During the construction and operation of the disposal facility, experiments in ONKALO will continue, but they will be restricted by the activities in the disposal facility or by operation schedules (Jalonen T et al., 2014).

The Bure URL is located in a 30 km^2 area, which defines the zone in which the potential repository could be included. The URL was constructed at a depth of 500 m in the Callovo-Oxfordian layer, which is the potential host rock for the repository. Positioned some distance from the location of the planned repository, the Bure URL will not be part of the repository. Since the Callovo-Oxfordian layers where the URL and the planned repository are located are considered to have the same geological properties, the results from the majority of the experiments and investigations conducted in the URL are transferable to the repository and will not need to be repeated.

The Bure site-specific URL has many advantages because activities such as R&D, investigations and demonstration tests can be conducted in the host rock environment without restrictions or any risk of damaging or disturbing the host rock in such a way that would compromise the performance of the future repository system. The repository design and construction schedule does not affect the investigations in the URL and the planning of the activities can be very flexible. Moreover, activities in the Bure URL, for example related to optimization, can continue without restrictions when the operation of the repository starts.

Site-specific URLs constructed close to the potential final repository must not unduly affect the environment of the future repository (e.g. have a negative impact on host rock performance) and, if the URLs were to become part of the final repository, a number of requirements would apply (e.g. construction, stability measures, use of cement, borehole sealing requirements) and have to be adhered to. Activities that do not necessarily have to be performed on-site (for example testing of emplacement procedures, host rock-independent EBS experiments) should be carried out at off-site subsurface facilities or dedicated surface laboratories (SKB, 2014). The repository site should be preserved in its original condition as far as possible.

In the Japanese site selection program, the selection of the host rock will occur in the later stages when the number of potential sites has narrowed down to one or a few areas. Therefore, it is unlikely that there will be a URL built in the same geology as that of the promising candidate site for the final repository. In this context, activities related, for example, to broadly applicable underground characterization techniques and development of methodologies that are not specific to the host rock or the potential site should be carried out in generic URLs. Once the host rock is known and a UIF has been established, the focus should be on those activities necessary for obtaining information that depends strongly on the host rock and its specific environment.

3.1.2 Types of UIF

Two possible types of UIF are considered in relation to the conditions in Japan.

(1) Type 1: The UIF is part of the disposal facility

For type 1, direct investigation of the host rock can achieve better understanding of the geological environment of the repository site. However, activities in the UIF should be planned so as to ensure that the performance of the host rock barrier is not compromised and potential damage or disturbance of the host rock is avoided. In addition to these restrictions resulting from the long-term performance requirements, it is likely that additional restrictions will apply due to the repository design or construction and operation schedules.

(2) Type 2: The UIF is not part of the disposal facility

For type 2, the UIF is built at the repository site but at some distance from the repository. The UIF and the repository will have separate access tunnels, thereby minimizing the effect of the construction and operation schedule on the activities in the UIF. The distance between the UIF and repository is important and should be determined based on the knowledge gained up to the DI(1) stage, to ensure that they are not too close (to avoid host rock damage and disturbance) but also not too far apart, to ensure the transferability of host rock properties determined in the UIF to the repository.

As geological heterogeneity is prevalent in Japan, a type 2 UIF could be advantageous in extending the investigation area and, for example, identifying and mapping hidden faults in the siting area, but this has to be weighed against ensuring that representative information for the host rock properties will be obtained.

The features and restrictive conditions of the various types of UIFs are summarized in Table 3-1.

Table 3-1 Features and restrictive conditions for the two types of UIF

Type	Features and advantages	Disadvantages	Existing URL
Type 1	- The UIF will be part of the repository. - Direct investigation of the host rock can provide a better understanding of the geological environment of the repository site.	- Host rock damage and disturbance may occur during investigations and experiments in the UIF. - Activities in the UIF may be limited by repository design or construction and operation schedules.	ONKALO (Finland)
Type 2	- The UIF is built at the repository site but at some distance from the repository. - If the UIF is far enough from the repository, damage and disturbance of the host rock can be prevented.	- If the UIF and repository are too close, host rock damage and disturbance may occur; if they are too far from each other, the evaluation of the host rock in the UIF may not be relevant to the repository. - If an unforeseen geological structure (e.g. hidden fault) is identified during construction, additional investigations and tests may need to be conducted in the repository instead of the UIF.	Bure URL (France)

The process for selecting the type of UIF is summarized in the flow diagram in Fig. 3-1.

Key elements of the selection process are the availability of a sufficiently large volume of the potential host rock and its expected homogeneity. The latter is important for the determination of the appropriate distance, if it is decided that a type 2 UIF should be constructed.

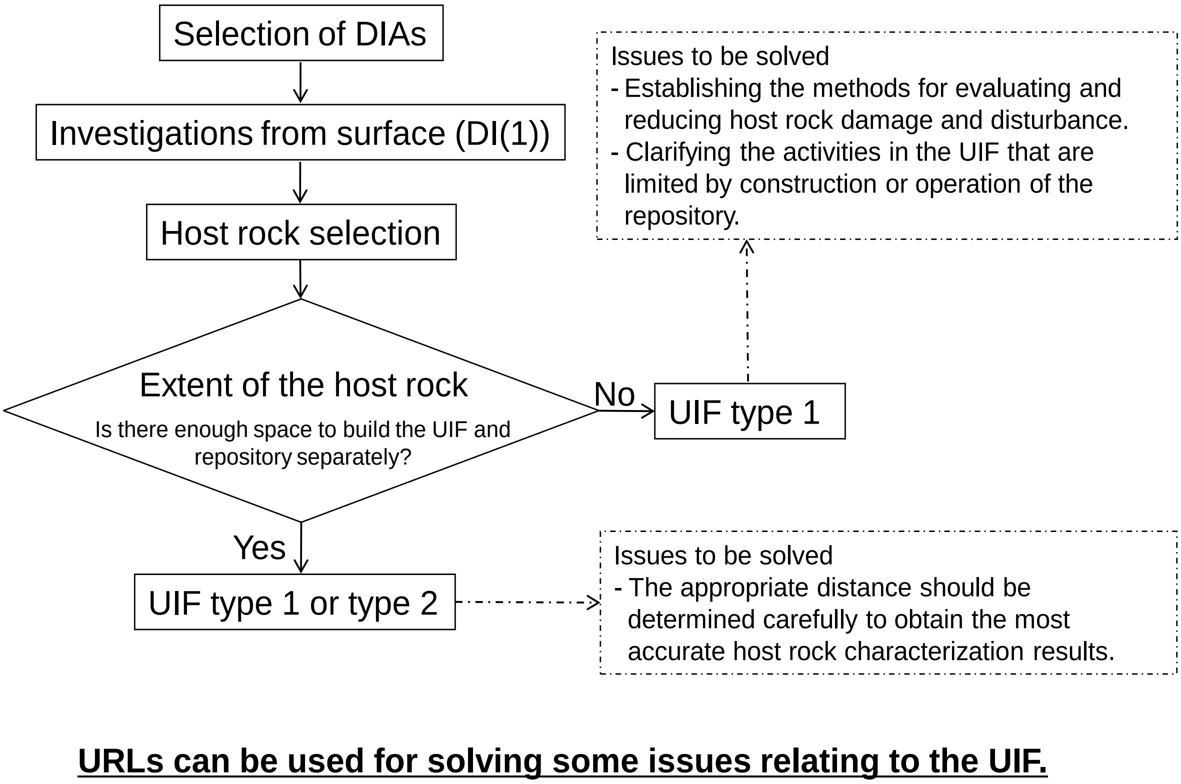


Fig. 3-1 Flowchart for selecting the type of UIF

3.2 The roles of generic URLs and the UIF

In this section, the respective roles of the generic URLs and the UIF are discussed and classified by categories of activities. The relevant issues are identified by the difference in the role of the generic URLs and the UIF at each stage of site selection.

3.2.1 Role-sharing of activities between generic URLs and the UIF

As mentioned in chapter 2, technical methods for evaluating the geological environment, engineering feasibility, safety assessment and demonstration tests have been developed in URLs in Europe. Additionally, repository management systems have been developed and training of professional and technical staff has been conducted in the URLs. As discussed in the previous section, research on issues of site selection or repository construction should be carried out in the generic URLs when feasible, with only some selected activities conducted in the UIF to prevent damage and disturbance to the host rock.

Table 3-2 Role-sharing of generic URLs and the UIF

URL	R & D	Host rock investigation	Demonstration test	optimization	Personnel training, management
Generic URL	✔	✓	✓	✓	✔
UIF	✓	✔	✔	✔	✓

Legend: ✔play a major role, ✓as necessary

Table 3-2 shows the role-sharing of activities and techniques in the generic URLs and the UIF during the construction and operation of the repository.

R&D for site selection, construction or operation of the repository is conducted in generic URLs in Japan and other countries. If additional R&D issues are raised during or after the DI(2) stage, then the R&D will be conducted in the UIF. However, all the required techniques should be developed where possible in the generic URLs. Transferability of the techniques developed in the generic URLs to the actual repository environment should be considered carefully before the design and construction of the UIF.

Demonstration tests verify the performance of the developed techniques and should ultimately be conducted in the actual repository environment such as the UIF, if the demonstration is strongly related to the host rock properties. The same consideration applies to optimization of the techniques for site investigation and repository construction. A technique developed in the generic URLs should be tailored and optimized in the UIF for its application to the particular host rock. Personnel training and establishing the management system for operational safety and confidence-building with stakeholders can be conducted in generic URLs. Although the UIF can play the same role in this respect as the generic URL, repository construction and operation will likely result in restrictions of the UIF activities. Therefore, generic URLs are considered to be better suited for personnel training and establishing the management system than UIFs.

3.2.2 The contribution of generic URLs and UIFs to technology development

Common activities carried out in the generic URLs and UIFs with respect to investigations for site characterization and selection, construction, operation and closure of the repository are discussed by classifying these into three categories: (1) technologies for investigation and evaluation of the geological environment; (2) technologies for design, construction, operation and closure of the repository; (3) technology for long-term safety assessment.

(1) Technologies for investigating and evaluating the geological environment

During the PI and DI(1) stages, the geological environment of the site is progressively characterized in more detail through surface and borehole investigations. The results of these studies lead to the selection of the UIF site (NUMO, 2011; 2013). The investigations during the construction and operation of the UIF further contribute to the characterization of the geological environment and are expected to confirm the overall findings from the surface investigations. The type and extent of these investigations should be selected so that no host rock damage and disturbance occurs, a particular concern if the UIF is constructed as part of, or close to, the repository site.

Such a planning approach was followed at ONKALO, where Posiva estimated in advance the impact of damage and disturbance to the host rock that would be caused by construction and operation of the UIF at the future repository site (Posiva, 2002; 2003b). In the UIF design phase, NUMO will also evaluate the impact of UIF construction and investigation activities on the host rock. Such impacts could be addressed and clarified in advance in generic URLs.

(2) Technologies for design, construction, operation and closure of the repository

Technologies for the design, construction, operation and closure of the repository have been developed in conventional surface laboratories and generic URLs (NUMO, 2011; 2013). To define and verify the final specifications of the engineered barrier and repository facilities, various demonstration tests relating to emplacement techniques, retrievability of the waste packages and plugging and backfilling technology will be conducted in the UIF.

Japan has performed much research and gained practical experience in constructing road, railway and mining tunnels in different types of geological settings. The Mizunami underground research laboratory and the Horonobe underground research center (Table 2-1) were established by JAEA (JAEA, 2014). Although the techniques for tunnel excavation and construction are considered to be well established (NUMO, 2011), investigations related to optimization and selection of those methods that will minimize the disturbance to the host rock will be performed in the UIF.

A brief overview of a deposition machine case study is presented in subsection 2.4.4. Since the performance of the deposition machine is basically independent of the geology, the final trials can be completed in the UIF, but most of the development of this type of machine can be carried out in conventional laboratories and generic URLs, with the focus of the related activities in the UIF on demonstration and confirmation of its operation.

The planning of the UIF investigations should consider and assess the transferability of results from investigations in surface laboratories or generic URLs to the actual repository and optimize the UIF design accordingly.

(3) Technology for long-term safety assessment

Information related to the geological environment of potential sites and knowledge related to engineering aspects of the repository, for example the design and performance of engineered barrier systems, will be accumulated progressively throughout the three-stage site selection process. Long-term safety assessments will reflect the level of knowledge at each stage. This knowledge, the corresponding databases and the scenarios and models considered will be continuously updated (NUMO, 2011; 2013), reaching the highest level of maturity with the data obtained in the UIF. In parallel, safety assessment techniques, such as modeling and experiments to obtain in-situ data, should be developed in surface laboratories and generic URLs until the final stages of project.

Examples of experiments and investigations for long-term safety assessments are presented in subsection 2.4.3. The cases in subsection 2.4.5, such as the Prototype Repository in the Äspö HRL and the DR-A test at Mont Terri, provided parameters that were used in long-term safety assessment. These types of tests generally need to run for a long time to obtain reliable results.

The durations of the tests introduced in chapter 2 are summarized in Fig. 3-2. The number of years estimated for the three site selection steps is also shown in Fig. 3-2 for comparison. The longest-running test has been underway for more than 19 years; other long-running tests have been ongoing for around 10 years or more. It is essential that safety assessments are based on a robust database and long-term experiments make a significant contribution to such robustness.

As discussed above, testing in a UIF should not damage or disturb the host rock. This is also true for long-term tests, but because such effects may only become noticeable at a later stage, modification and repetition of them can be very time-consuming. Therefore, the test methods and procedures should be well established in the generic URLs before testing in the UIF.

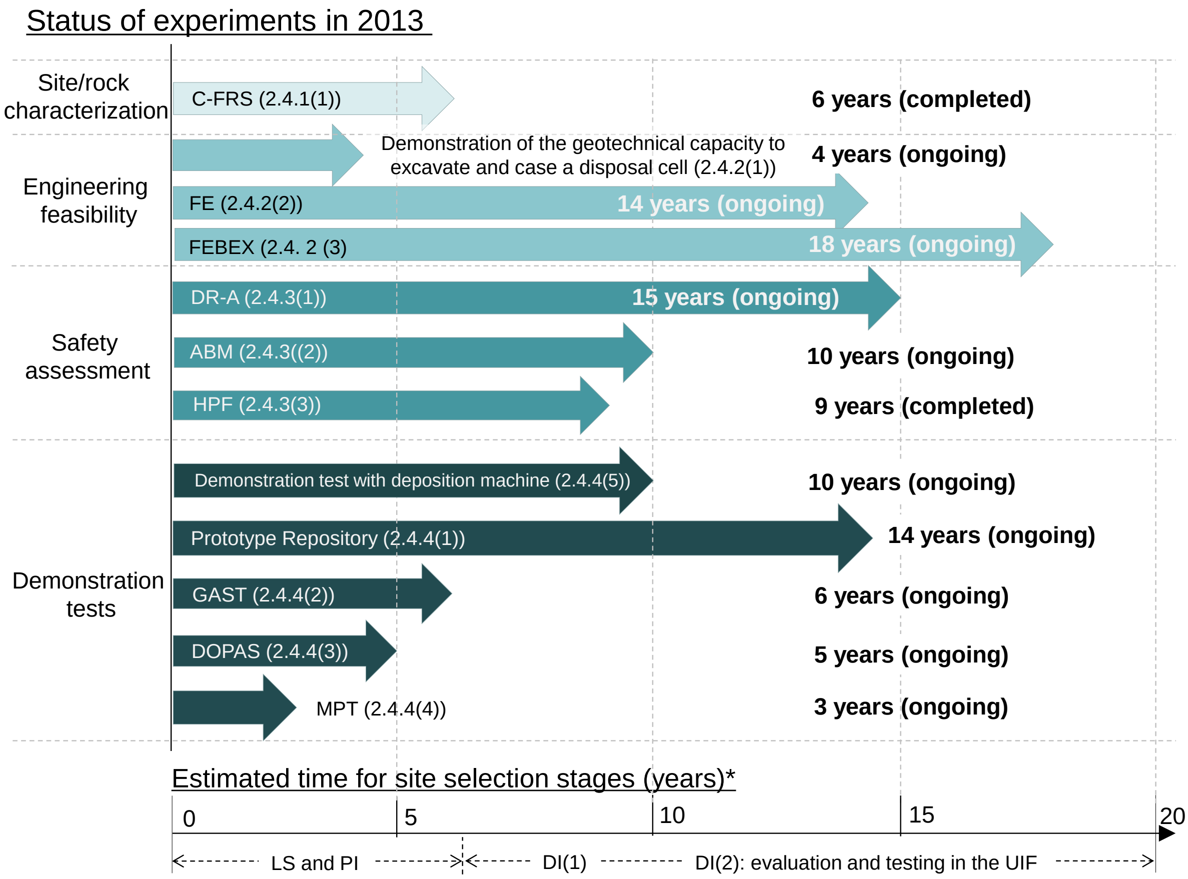


Fig. 3-2 Duration of the tests presented in this study

*** Estimated time for site selection stages: these have not been clearly defined. The durations of the stages may alter due to the situation of the candidate site. They were estimated based on the overall plan for site selection of NUMO (NUMO, 2009).**

3.2.3 The role of URLs in identifying issues arising in each stage of site selection

The final repository site will be identified via the three-stage selection process (Figure 1-1). The UIF is constructed during stage DI(2). In this subsection, role-sharing between generic URLs and UIFs is discussed for the different site selection stages.

(1) Pre-Literature Survey stage

During the Pre-Literature Survey stage, NUMO prepares the R&D plan for the URLs and collects technical information in cooperation with universities and research institutes in Japan and other countries. The activities in underground facilities at this stage are conducted in the generic URLs. Because the host rock has not yet been specified, the R&D in the URLs takes into account a wide range of environmental conditions.

(2) Literature Survey stage

At this stage there are several potential repository sites. Since the host rock may not be identified at this stage, the R&D in the URLs takes into account a wide range of environmental conditions, along with the Pre-Literature Survey results.

(3) Preliminary Investigation stage

This stage still has to address several potential repository sites. As in the previous stages, the host rock may still be undetermined. Field investigations are conducted in this stage. As the investigations progress, the geological properties of the candidate sites are collected and the test boundary conditions in the generic URLs are adjusted and updated based on the data obtained and lessons learned in the PI. Some aspects of the investigations and experimental conditions in the UIF will be clarified during this stage.

(4) Detailed Investigation stage

During the DI stage, field investigations at the surface continue from the PI stage. The location of the repository is selected and the repository design is finalized. The design concept for the UIF is determined and construction started. The planned activities are assigned to generic URLs or the UIF before the UIF design concept is finalized.

If problems arise during the experiments in the UIF, the generic URLs can play an important role in resolving these problems in stage DI(2).

3.2.4 Role-sharing between generic URLs and UIFs in the site selection program

A flowchart showing the investigations conducted in the URLs or UIF is presented in Fig. 3-3. The various issues addressed by the investigations conducted in the generic URLs and the UIF become clearer with time as the potential host rock options are gradually narrowed down. NUMO will revise the investigation plan as necessary.

Investigations are carried out in the generic URLs until the UIF is constructed. After UIF construction, prototype testing and experiments that depend on the geological environment will be conducted in the UIF, while host-rock independent investigations, testing or optimizing technologies could still be performed in generic URLs. Thus cooperation and synergies between the generic URLs and the UIF will continue until the final operational stage of the repository.

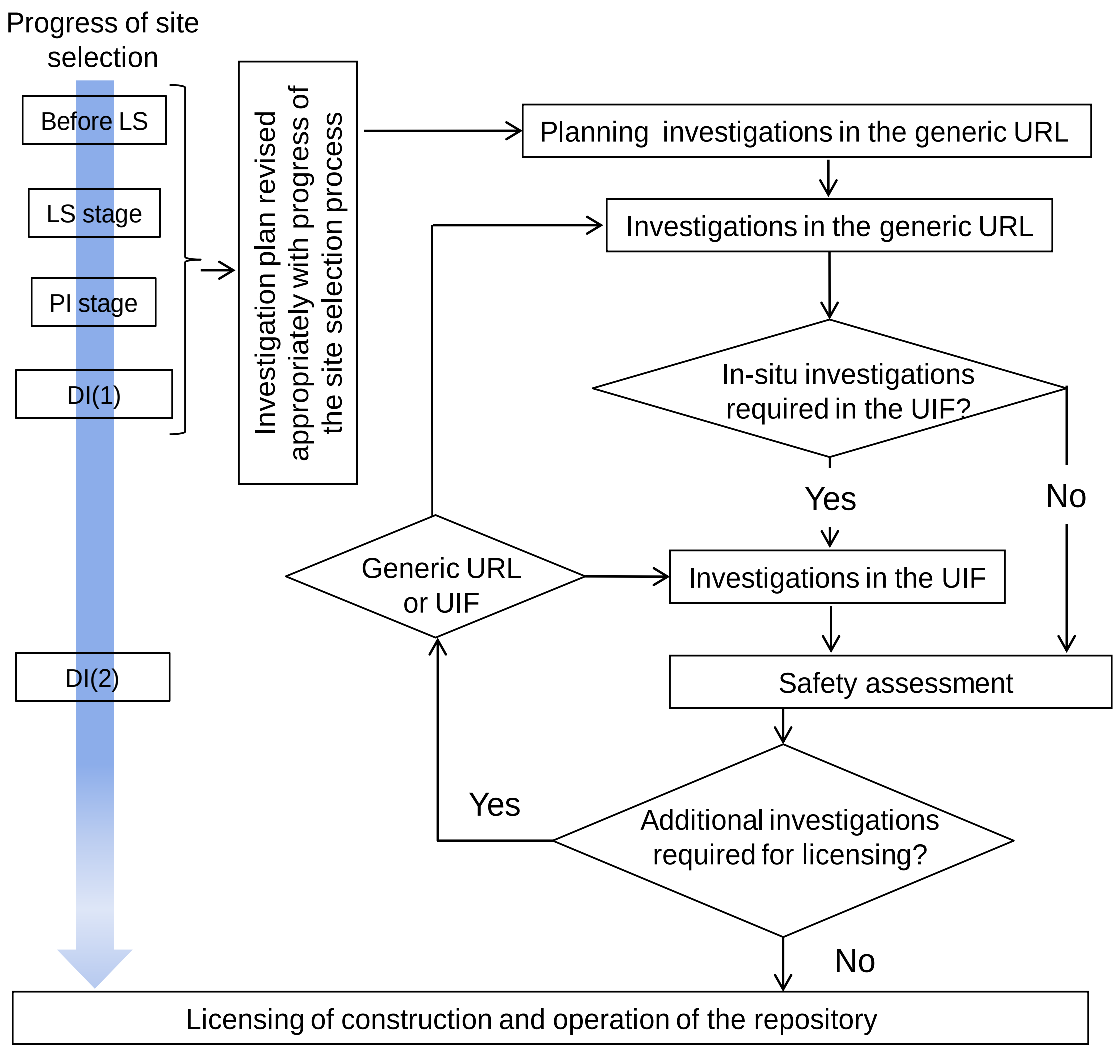


Fig. 3-3 Flowchart of the investigations conducted in URLs and UIFs

4. Summary

In this report, concepts for the UIF and the role-sharing between the generic URLs and the UIF in the context of the Japanese site selection program are discussed against the background of information on European site selection programs and URLs.

UIFs are classified into two types: (1) UIF that will be part of the future repository and (2) UIF built close to the repository. The choice between the two types of UIF will depend on the level of heterogeneity and the extent of the host rock at the candidate site. To maintain the high performance level of the natural barrier, activities in the UIF that may damage or disturb the host rock environment should be minimized. When possible, investigations should be conducted in generic URLs rather than in the UIF.

The program for underground research may change as new issues arise during the progress of the site selection program. The generic URLs still play an important role even after construction of the UIF as there are fewer restrictions placed on URL experiments compared with those in the UIF.

Acknowledgement

This report was produced as part of the collaboration work between NUMO and Nagra, namely the PAU-DI project (FY2011-2012). The authors would like to thank all the participants in the workshops that were held as part of this collaboration work for their helpful advice.

REFERENCES

Andersson, C., Barcena, I., Bono, N., Boergesson, L., Cleall, P., Forsmark, T., Gunnarsson, D., Johannesson, L.-E., Ledesma, A., Liedtke, L., Luukkonen, A., Pedersen, K., Puigdomenech, I., Pusch, R., Rhen, I., Rothfuchs, T., Sanden, T., Sineriz, J.-L., Sugita, Y., Svemar, C. and Thomas, H. (2005): Full-Scale Testing of the KBS-3V Concept for the Geological Disposal of High-Level Radioactive Waste: Prototype Repository-Final report-, European Commission, Nuclear Science and Technology, EUR 21924, 2005.

Andra (2005): Dossier 2005 Argile, Evaluation of the Feasibility of a Geological Repository in an Argillaceous Formation. 266VA.

Andra (2014): Programme de R&D 2013-2016. Executive Summary. ANDRA, Chatenay-Malabry (in French). http://www.andra.fr/download/site-principal/document/editions/542.pdf

Bosgiraud, J.-M., Guénin, J.-J., Delort, D., Roulet, A. and Glénet, O. (2010): Technical Milestones for Emplacing Vitrified Waste Canisters into Horizontal Disposal Drifts in a Clay Host Formation - 10019. WM 2010 Conference, March 7-11, 2010, Phoenix, Arizona.

Dahlström, L.-O. (2009): Experiences from the Design and Construction of Plug II in the Prototype Repository, SKB Report, R-09-49.

Delay, J. (2006): Overview of Current and Planned Activities in the French Underground Research Laboratory at Bure, in TOPSEAL 2006: Transactions, International Topical Meeting, Olkiluoto Information Centre, Finland, 17-20 September 2006, http://www.euronuclear.org/events/topseal/transactions/TopSeal-Transactions.pdf. (2013.11.26).

Delay, J., Lesavre, A., Wileveau, Y. (2011): The French underground research laboratory in Bure as a precursor for deep geological repositories, The Geological Society of America Reviews in Engineering Geology XIX 2008.

DOPAS (2013): DOPAS Project: Demonstration of Plugs and Seals, The FSS Experiment (Full Scale Seal), http://www.Posiva.fi/dopas/wp_3/experiment_1_fss (2013.11.29).

IAEA (2001): The Use of Scientific and Technical Results from Underground Research Laboratory Investigations for the Geological Disposal of Radioactive Waste, IAEA-TECDOC-1243.

JAEA (2014): http://www.jaea.go.jp/index.html. (2014.8.13).

Jalonen T., Aaltonen I., Äikäs T. (2014): Going Underground for Testing and Demonstration: Challenge of Implementation of a Disposal System. - WM2014 Conference, March 2-6, 2014, Phoenix, Arizona, USA. Paper 14546.

KEV (2004): Regulatory Oversight Report 2004, Swiss Federal Nuclear Safety Inspectorate (in German). http://www.ensi.ch/en/wp-content/uploads/sites/5/2011/08/aufsib04d.pdf

Mont Terri Project (2013): http://www.mont-terri.ch/internet/mont-terri/en/tools/ongoing/Activities.Parsys.87870.DownloadList.66153.DownloadFile.tmp/newsreport01.pdf.

Nagra (1985): Project Gewähr 1985: Nuclear Waste Management in Switzerland: Feasibility Studies and Safety Analyses. Nagra Gewähr Bericht NGB 85-09.

Nagra (2002a): Projekt Opalinuston: Konzept für die Anlage und den Betrieb eines geologischen Tiefenlagers: Entsorgungsnachweis für abgebrannte Brennelemente, verglaste hochaktive sowie langlebige mittelaktive Abfälle. NTB 02-02.

Nagra (2002b): Projekt Opalinuston: Synthese der geowissenschaftlichen Untersuchungsergebnisse: Entsorgungsnachweis für abgebrannte Brennelemente, verglaste hochaktive sowie langlebige mittelaktive Abfälle. NTB 02-03.

Nagra (2002c): Project Opalinus Clay: Safety Report: Demonstration of Disposal Feasibility for Spent fuel, Vitrified High-level Waste and Long-lived Intermediate-level Waste (Entsorgungsnachweis). NTB 02-05.

Nagra (2013a): http://www.grimsel.com/gts-phase-vi/c-frs/c-frs-introduction. (2013.11.22).

Nagra (2013b): http://www.grimsel.com/gts-phase-v/hpf/hpf-introduction. (2013.12.5).

Nagra (2013c): http://www.grimsel.com/gts-phase-vi/gast/gast-introduction. (2013.12.24).

Nagra (2014): Nationale Genossenschaft für die Lagerung radioaktiver Abfälle (2014): SGT Etappe 2: Vorschlag weiter zu untersuchender geologischer Standortgebiete mit zugehörigen Standortarealen für die Oberflächenanlage: Sicherheitstechnischer Bericht zu SGT Etappe 2 : Sicherheitstechnischer Vergleich und Vorschlag der in Etappe 3 weiter zu untersuchenden geologischen Standortgebiete. Nagra Technischer Bericht NTB 14-01. Nagra, Wettingen (in German with an English summary).
http://www.nagra.ch/de/cat/publikationen/technischeberichte-ntbs/ntbs-2014-2015/download center.htm#

Nagra (2015): Nagra-HP, http://www.grimsel.com/gts-phase-vi/febex-dp/febex-dp-introduction. (2015.12.31).

NUMO (2009): Information Package for Open Solicitation of Volunteering for Areas to Explore the Feasibility of Constructing a Final Repository for High-level Radioactive Waste - Siting Factors for the Selection of Preliminary Investigation Areas (Supporting Document No. 2).

NUMO (2011): Safety of the Geological Disposal Project 2010 - Safe Geological Disposal Based on Reliable Technologies, NUMO-TR-11-01 (in Japanese).

NUMO (2013): Safety of the geological disposal project 2010 - Safe Geological Disposal Based on Reliable Technologies, English Summary, NUMO-TR-13-05.

OECD/NEA (2001a): The Role of Underground Laboratories in Nuclear Waste Disposal Programmes, Radioactive Waste Management Committee of Nuclear Energy Agency NEA, Organization for Economic Co-operation and Development, OECD.

OECD/NEA (2001b): Going Underground for Testing, Characterization and Demonstration (a Technical Position Paper). NEA/RWM(2001)6/REV, JT00108467, Radioactive Waste Management Committee of Nuclear Energy Agency NEA, Organization for Economic Co-operation and Development, OECD.

OECD/NEA (2003): SAFIR2: Belgian R&D Programme on the Deep Disposal of High-Level and Long-Lived Radioactive Waste, an International Peer Review, 80p.

OECD/NEA (2013): Underground Research Laboratories (URL), NEA/RWM/R(2013)2, Radioactive Waste Management Committee of Nuclear Energy Agency NEA, Organization

for Economic Co-operation and Development, OECD.
ONDRAF/NIRAS (2011): Waste Plan for the Long-Term Management of Conditioned High-Level and / or Long-Lived Radioactive Waste and Overview of Related Issues, NIROND 2011-02E.
Posiva (2002): Establishing Baseline Conditions and Monitoring during Construction of the Olkiluoto URCF Access Ramp, Posiva 2002-07.
Posiva (2003a): ONKALO Underground Rock Characterization Facility- Main Drawings Stage, Working Report 2003-26.
Posiva (2003b): Assessment of Disturbances Caused by Construction and Operation of ONKALO, Posiva 2003-06.
Posiva (2006): ONKALO - Underground Rock Characterization Facility at Olkiluoto, Eurajoki, Finland. Posiva Brochure.
Posiva (2013): YJH-2012, Nuclear Waste Management at Olkiloto and Loviisa Power Plants: Review of Current Status and Future Plans for 2013-2015.
Posiva (2015): Final disposal of spent nuclear fuel in Olkiluoto. Posiva Oy, Helsinki. http://www.posiva.fi/files/1960/Posiva_yleisesite_2011_EN.pdf
SCK•CEN (2014): http://science.sckcen.be/en/Facilities/HADES, (2014.05.14).
SKB (2010): RD&D Programme 2010. Programme for Research, Development and Demonstration of Methods for the Management and Disposal of Nuclear Waste. SKB Technical Report TR-10-63.
SKB (2012): Äspö Hard Rock Laboratory Annual Report 2011, SKB Technical Report, TR-12-03.
SKB (2013a): Äspö Hard Rock Laboratory Annual Report 2012, SKB Technical Report, TR-13-10.
SKB (2013b): RD&D Programme 2013. Programme for research development and demonstration of methods for the management and disposal of nuclear waste, SKB Technical Report, TR-13-18. http://www.skb.com/publication/2670359/TR-13-18.pdf
SKB (2014): Äspö Hard Rock Laboratory Annual Report 2013, SKB Technical Report, TR-14-17.
SFOE (2008): Sectoral Plan for Deep Geological Repositories, Conceptual Part, Swiss Federal Office of Energy, Legal Services and Safety Division. 89p. http://www.skb.com/publication/2720398/TR-14-17.pdf
Svensson, D., Sanden, T., Kaufhold, S. and Sellin, P. (2010): Alternative Buffer Material Experiment- Experimental Concept and Progress. Proceedings of Clays in Natural & Engineered Barriers for Radioactive Waste Confinement, 47th International Meeting, March 2010, Nantes, France, 55-56.
Svensson, D., Dueck, A., Nilsson, U., Olsson, S., Sanden, T., Lydmark, S., Jägerwall, S., Pedersen, K. and Hansen, S. (2011): Alternative Buffer Material, Status of the ongoing Laboratory Investigation of Reference Materials and Test Package 1, SKB Technical Report, TR-11-06.
Vomvoris, S., Claudel, A., Blechschmidt, I. and Müller, H.R. (2013): The Swiss Radioactive Waste Management Program - Brief History, Status, and Outlook, Journal of Nuclear Fuel Cycle and Waste Technology, 1, 9-27, Doi: http://dx.doi.org/10.7733/jnfcwt.2013.1.1.9.

APPENDIX

nagra.

National Cooperative
for the Disposal of
Radioactive Waste

Hardstrasse 73
5430 Wettingen
Switzerland

Tel +41 56 437 11 11
Fax +41 56 437 12 07
www.nagra.ch

Agenda

NUMO International Workshop

Role of URLs in the European Programmes for Waste Disposal

Date:	14-15 November 2011
Place:	Nagra offices, UD 3 (basement), Wettingen, Switzerland
Participants:	NUMO: H. Tsuchi, K. Yoshimura, K. Kaku, S. Kubota.
	Nagra: I. Blechschmidt, I. Gaus, A. Gautschi, L. Johnson, A. Martin, S. Vomvoris, P. Zuidema (part of the meeting), P. Blaser (consultant).
	SKB: C. Svemar
	Andra: J. Delay
	Posiva: T. Aikas
	ONDRAF/NIRAS: P. Depreter
	Consultant: A. Hooper

Background of the workshop

NUMO, the Japanese implementer, initiated a project on the planning of activities that will become part of the Detailed Investigation Stage, a crucial step in the Japanese approach toward site selection and investigation. In the second part of this stage an underground investigation facility at the selected location is envisaged. During the Workshop it is NUMO's intention to draw form existing international experience and expertise from organizations with a strong URL programme.

Objectives

- Outlining the role of the URLs in the different national programmes, how the activities are directed and guided by the R&D programmes of the respective organizations, the synergies among on-site and off-site URLs, and how the results feed back into the overall strategy of a programme.
- Analysing the different approaches with respect to the roles of URLs between the implementers, their planning phases, and how the interaction between the national programme and the URL activities can be organized or optimized.

Monday 14 November 2011

Time	Topic	Lead
14:00 - 14:10	Welcome	K. Yoshimura/NUMO
14:10 - 14:20	Introduction and agenda	I. Gaus/Nagra
14:20 - 14:40	NUMO's programme - Planned activities for Underground Investigation Facilities	K. Yoshimura/NUMO
14:40 - 15:20	Hades facility and the Belgian Programme	P. Depreter/ONDRAF
15:20 - 15:40	*Coffee break*	
15:40 - 16:20	Aspö Rock Laboratory and the Swedish programme*	C. Svemar - SKB
16:20 - 17:00	Onkalo and the Finish Programme*	T. Aikas - Posiva
17:00 - 18:00	Discussion: connection between the progress in the national programme and the role of the URL's	Lead Nagra-NUMO/All

Tuesday 15 November 2011

08:30	*Pick up from the Duparc Hotel*	
09:00 – 09:40	GTS and Mont Terri URL and the Swiss programme*	L. Johnson - Nagra
09:40 - 10:20	Bure and Mont Terri URL and the French programme*	J. Delay - Andra
10:20 - 10:50	*Coffee break*	
10:50 - 12:00	Discussion: interaction between SA/R&D requirements, planning of URL activities and feedback to the national programme	Lead Nagra-NUMO/All
12:00 - 13:00	*Lunch*	
13:00 - 13:40	The Sellafield experience: what to retain from it?*	A. Hooper/Consultant
13:40 - 14:45	Discussion: decision making and planning for URL construction - required preliminary activities	Lead Nagra-NUMO/All
14:45 - 15:00	Closing remarks	H.Tsuchi/S. Vomvoris
15:00	*Departure of the participants*	

* 25' presentation and 15' discussion

nagra

National Cooperative
for the Disposal of
Radioactive Waste

Hardstrasse 73
5430 Wettingen
Switzerland

Tel +41 56 437 11 11
Fax +41 56 437 12 07
www.nagra.ch

Agenda

NUMO-Nagra Workshop

Defining and implementing Large Scale Demonstration Experiments

Date: 14. – 15. November 2012

Place: Gasthof Sternen Kloster, Wettingen, Switzerland

Contact: Irina Gaus (irina.gaus@nagra.ch, +41 79 430 73 42)

Participants:

NUMO	A. Deguchi, K. Kaku, Y. Kitagawa, K. Yoshimura, Y. Yamamoto
Nagra	I. Gaus, L. Johnson, A. Martin, H. Müller, J. Rueedi, T. Sakaki, S. Vomvoris, P. Blaser (consultant)
SKB	J. Andersson
Posiva	J. Vira
Andra	P. Lebon
Niras/Euridice	P. De Preter, M. Van Geet
JAEA	H. Umeki
Solexperts	T. Fierz
CIMNE	B. Garitte
RWMC	H. Asano
Obayashi Corp.	H. Kawamura, T. Kikuchi
Dia Corp.	M. Yoshimura
Shimizu Corp.	S. Kobayashi
Kajima Corp.	T. Sasakura

Objectives of the Workshop:

- Defining the requirements for large scale demonstration projects based on the respective R&D programme of the participating implementing organisations
- Identify the main lessons learned for the implementation of large scale demonstration projects.
- Focused discussions on how to plan the projects, define the objectives, instrumentation strategy and optimize and integrate the results.

Target questions to be addressed in the presentations and discussions:

Session 1 -Defining large demonstrations based on RD&D and design requirements

1. How to go from RD&D needs and/or design requirements to the definition of the experiment?
2. Who finally decides on the concepts of the experiments, is there an iteration/optimisation process between requirements and objectives and concept development?
3. What are the most significant RD&D and/or design needs currently in your stage of the programme that require large scale URL experiments (prioritization)?
4. When and in which stage of the programme is international collaboration preferred and why?
5. What needs to be demonstrated on the large scale and why, what can be addressed in the lab/small scale?

Session 2 - Implementation of large scale URL experiments

1. What is required next to the experiment itself or even before the experiment starts (lab studies, modelling, off-site tests, survey of tools/methodologies)?
2. To what extent should the expected outcomes of the experiment (what it is expected to show, and what has not been taken into account) be agreed with other stakeholders before the experiment starts?
3. How to deal with upcoming additional goals after the experiment has started
4. What should be kept in the hands of the implementer, what can/should be contracted out.
5. How to best formulate the requirements to the instrumentation teams to optimise instrument design
6. What is the best management structure for these experiments (core team (how many people), expert committee, data acquisition/analysis/review team)?
7. How should the data (raw data and interpreted data) be handled/stored/utilized?
8. Experience, lessons learned from budgeting of the experiments and budget evolution during the construction/running of the experiments.

Session 3 - Implementation of large scale URL experiments – case studies

For this session <u>an outline</u> for the case presentations is suggested and detailed discussion during the presentation will be encouraged.

1. Requirements (RD&D, design) to which the experiment is responding
2. Objectives of the experiment
3. Management structure and implementation plan
4. Overview of the experiment (methods and procedures) and main outcomes so far
5. What went well and one should do it like that in the future.
6. What went not so well and can be improved.
7. Are the objectives being met? Do the results agree with the prediction?

***Outcome of the workshop**:* a summary of the workshop addressing the questions above will be prepared by Nagra. Speakers will be given the opportunity to comment the draft version before the final version is distributed to all participants.

Wednesday 14 November

Pickup from the hotel Duparc 8:20 – Hotel Linde 8:30

	Opening of the workshop	9:00-9:10	I. Gaus / Nagra
	Welcome by NUMO	9:10-9:20	A. Deguchi / NUMO
	Welcome by Nagra	9:20-9:30	S. Vomvoris /Nagra
Session 1: Defining large scale URL experiments based on R&D and design requirements			
1	Experience from the SKB programme with a focus on design	9:30-9:55	J. Andersson / SKB
2	Experience from the ANDRA programme	9:55-10:20	P. Lebon / Andra
3	Experience from the Nagra programme with a focus on R&D	10:20-10:45	L. Johnson / Nagra
	Coffee Break	10:45-11:15	
4	Experience from the Posiva programme	11:15-11:40	J. Vira /Posiva
5	NUMO's programme and planned activities	11:40-12:05	K. Yoshimura / NUMO
	Lunch	12:05-13:20	
6	Experience from ONDRAF/NIRAS' programme	13:20-13:45	M. Van Geet / ONDRAF
7	Discussion and conclusions on session 1	13:45 -14:15	Lead: Nagra
	Coffee Break	14:15-14:45	
Session 2: Implementation of large scale URL experiments – part 1			
1	Main guidance/aspects for instrumentation of URL experiments based on over 20 years experience	14:45-15:25	T. Fierz / Solexperts
2	Discussion: how to control finances, react to additional requirements and keep high scientific quality.	15:25–16:05	Lead Nagra
	Group picture then guided Tour in the Sternen Kloster	*16:15 -17:00*	
	End of Day 1 – transfer to the Hotel	*17:00*	

Thursday 15 November

Pickup from the hotel Duparc 8:20 – Hotel Linde 8:30

Session 2: Implementation of large scale URL experiments – part 2			
3	Influence of experimental factors on parameter determination of the EBS and the host rock	09:00-09:40	B. Garitte / CIMNE-Nagra
4	Planning and implementing of URL experiments – Horonobe and Mizunami experience	09:40-10:05	H. Umeki / JAEA
5	Planning and implementing of URL experiments - Bure/Mont Terri experience	10:05-10:30	P.Lebon / Andra
	Coffee Break	10:30-11:00	
6	Development of repository operation technologies in full scale; current status of Japanese programs for HLW disposal.	11:00-11:25	H. Asano / RWMC
7	Discussion and conclusion in Session 2	11:25-11:50	Lead Nagra
	Lunch	11:50-13:05	
Session 3: Implementation of large scale experiments – case studies			
1	The Full Scale Demonstration experiment at the Mont Terri URL	13:05-13:40	H. Müller /Nagra
2	The PRACLAY experiment at the HADES URL	13:40-14:15	P. Depreter / EURIDICE
3	Wrap up and conclusions of the workshop	14:15-14:45	Lead Nagra
	End of Day 2 – Transfer to the Hotel/Train Station	14:50	

原子力発電環境整備機構

(略称：原環機構)

Nuclear Waste Management Organization of Japan(NUMO)