Radioactive Waste Management

The Role of Underground Laboratories in Nuclear Waste Disposal Programmes

NUCLEAR ENERGY AGENCY
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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NUCLEAR ENERGY AGENCY

The OECD Nuclear Energy Agency (NEA) was established on 1st February 1958 under the name of the OEEC European Nuclear Energy Agency. It received its present designation on 20th April 1972, when Japan became its first non-European full Member. NEA membership today consists of 27 OECD Member countries: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, the Netherlands, Norway, Portugal, Republic of Korea, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The Commission of the European Communities also takes part in the work of the Agency.

The mission of the NEA is:

- to assist its Member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for a safe, environmentally friendly and economical use of nuclear energy for peaceful purposes, as well as
- to provide authoritative assessments and to forge common understandings on key issues, as input to government decisions on nuclear energy policy and to broader OECD policy analyses in areas such as energy and sustainable development.

Specific areas of competence of the NEA include safety and regulation of nuclear activities, radioactive waste management, radiological protection, nuclear science, economic and technical analyses of the nuclear fuel cycle, nuclear law and liability, and public information. The NEA Data Bank provides nuclear data and computer program services for participating countries.

In these and related tasks, the NEA works in close collaboration with the International Atomic Energy Agency in Vienna, with which it has a Co-operation Agreement, as well as with other international organisations in the nuclear field.

FOREWORD

The Radioactive Waste Management Committee (RWMC) of the Nuclear Energy Agency (NEA) is a forum of senior representatives of operator, regulator, policy-making, and R&D organisations in the field of radioactive waste management. The RWMC provides an important mechanism for co-ordination of international programmes enabling the sharing of experience and development of consensus on the state of the art, as well as the development of specific technical tools. Based on its pool of technical experts, the RWMC is also able to provide timely and authoritative peer reviews. The RWMC thereby assists NEA Member countries in helping provide solutions to radioactive waste problems, and promotes safety in the short- and long-term management of radioactive waste.

This report has been prepared on behalf of the RWMC. Although written by technical specialists, it is meant for a wider audience of decision-makers and interested members of the public. It explains what underground research laboratories (URLs) are, the different types, their locations, the types of research and development that are carried out, their value to national programmes, questions to be considered when deciding when to construct a URL, and the opportunities and benefits of international co-operation in URLs.

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1. INTRODUCTION

The concept of engineered geologic disposal has been developed for the safe long-term management of long-lived radioactive waste. This involves the emplacement of such waste in deep underground repositories that provide for the secure and safe isolation of the waste and, consequently, the protection of humans and the environment (e.g. see NEA 2000a). The concept has been developed after wide-ranging consultation, including consideration of other options. Potential host geologic formations are chosen for their long-term stability and ability to accommodate the waste-disposal facility, protect its engineered long-term safety functions, and prevent or attenuate any eventual release of radioactivity. The engineered system is designed to complement the natural geologic barrier and to provide primary physical and chemical containment of the waste. The overall system is designed to be passively safe in the long term and, thus, to place a minimal burden on future generations. For reassurance purposes, however, as well as to ensure the security of the waste and facility, site supervision and monitoring would continue for some period of time after repository closure.

Implementing and regulatory organisations in many of the NEA Member countries are involved in the investigation and resolution of issues associated with the design, long-term safety, and practical realisation of underground repositories for radioactive waste. The feasibility, safety, and appropriateness of the solution must be demonstrated to the satisfaction of the implementing organisations, the regulatory bodies, the wider scientific and technical community, political decision makers and the general public. This requires practical demonstration of key technical elements and confidence in the decision-making process by which the implementers proceed, their plans are reviewed, and developments authorised. Especially, convincing arguments are required that instil confidence in all parties in the safety of the proposed repositories, taking into account the uncertainties that inevitably exist in forecasting the behaviour of complex natural and engineered systems for long times into the future.

A key element envisaged in all major national radioactive waste disposal programmes is the construction of one or more underground facilities in which characterisation, testing, technology development, and/or demonstration activities will be carried out. Such facilities, generically known as underground research laboratories or URLs[1], are essential to provide scientific and technical information and practical experience that are needed for the design and construction of disposal facilities and, importantly, for the development of the safety case that must be presented at various stages of repository development.

This document provides an overview of:

- the purpose of URLs within repository development programmes;
- the range of URLs that have been developed, or are planned, in NEA Member countries to date;
- the various contributions that such facilities can make to repository development programmes and the development of a safety case;
- considerations on the timing of developing a URL within a national programme; and
- opportunities and benefits of international co-operation in relation to URLs.

1. The term "URL", standing for underground research laboratory or underground rock laboratory, has become the accepted generic term for underground facilities in which activities are carried out in support of repository development programmes.

2. GENERAL PURPOSE AND OVERVIEW OF EXISTING URLs

What is a URL?

A URL is any underground facility in which characterisation, testing, technology development, and/or demonstration activities are carried out in support of the development of underground repositories for radioactive waste. Because some amount of characterisation work will necessarily be carried out in any repository, all repositories themselves automatically qualify as URLs by the definition adopted for this document. A URL may be an elaborate, purpose-built facility in which large research programmes may be carried out over many years, or a quite simple facility, for example, attached to existing underground excavations, in which quite specific investigations may be made. They are located in rocks that are considered to be suitable for repository construction, either nationally or in general, such as granite, salt, clay/shale, and volcanic tuff. They may be constructed at depths of a few hundred to one thousand metres underground, as is usually proposed for waste disposal, or at shallower depths.

URLs provide a foundation for understanding the hydrologic, thermal, mechanical, chemical, and biological characteristics and coupled processes that will control the performance of natural and engineered barriers of a geologic repository. In addition, URLs allow the development of the technology needed for the construction, operation, and closure of a repository, as well as demonstration of that technology and the overall repository concept both to specialists and to the general public. URLs may also be used to verify the long-term performance of engineered barriers and monitoring systems, as well as provide demonstrations of waste-retrieval technology. Importantly, relative to surface-based investigation techniques or laboratory research, a URL provides access to the geologic environment under realistic repository conditions.

Once established, a URL can act as a focus for a dedicated research, development, and demonstration programme related to repository development. URLs also provide the vehicle for international co-operation projects.

The general purpose of URLs

URLs are an integral part of national waste-disposal programmes as they provide important and, at times, critical technical experience, knowledge, and confidence for the strategic elements on which the safety case of a final repository is to be based. The strategy for achieving and demonstrating safety is driven by science and engineering, and consists of three connected elements that need to be defined and developed:

- **Facility siting and disposal-system design**: – siting a repository in a rock mass with favourable isolation properties, developing durable, long-lived waste containers compatible with the geologic environment, and developing robust engineered barriers.
- **Underlying scientific and engineering support**: – organising and conducting a rigorous programme of engineering and scientific investigations to provide the information necessary to design, verify the characteristics, and evaluate the performance of the disposal system.
- **Evaluation of safety**: – developing tools to carry out an analytical evaluation of the performance and safety of the repository for a variety of possible future scenarios.

Although different programmes use somewhat different terminology, the activities carried out in URLs in support of the above goals can be broadly defined as:

- **characterisation** – *in situ* investigations to provide basic understanding of the geologic, hydrogeologic, geochemical, structural, and mechanical properties of the host rock, its response to imposed changes, and data required for safety assessments;
- **testing** – a broad term including: the evaluation of the performance of characterisation methods in order to judge their applicability and reliability during future investigations; tests of engineered materials, excavation methods, etc. which may be used in the development of a repository; and testing of the conceptual and numerical models that are used to assess the performance of the repository system and/or its component parts;
- **technology development** – the development of equipment, techniques, and expertise for characterisation, testing, repository construction, waste emplacement (and retrieval), construction of engineered barriers, and repository closure; and

- **demonstration** – illustration, at full- or reduced-scale and under real and/or simulated repository conditions, of the feasibility of the repository design and of the behaviour and performance of various components of the repository, including, for example, demonstrations of sealing and waste emplacement and retrieval techniques.

Under the last heading, demonstration could also include trial disposals of actual waste in facilities in which the necessary licences had been granted. Thus, a variety of activities may be carried out in URLs, which range from basic research up to development of a pilot waste-disposal facility.

Types of URLs

Although there is a continuum of possibilities for the manner in which a URL might be developed, at least two broad categories can be distinguished:

- facilities that are developed for research and testing purposes at a site that **will not be used** for waste disposal, but provide information that may support disposal elsewhere, here termed "generic URLs"; and
- facilities that are developed at a site that **is considered** as a potential site for waste disposal and may, indeed, be a precursor to the development of a repository at the site, here termed "site-specific URLs".

Generic URLs may be developed to gain general experience of underground construction techniques, model testing, and verification of measurement techniques. They may also be developed to gain information, understanding, and experience related to a specific rock type that is considered as a potential repository host rock at a site, or sites, elsewhere. The type of generic URL to be developed will depend on the stage of the repository development programme. For example, in Switzerland, the general investigations at the Grimsel Test Site were begun in advance of any site or host rock type selection, and this site has continued to be the focus of international research for almost 20 years, whereas the investigations in the Mont Terri road tunnel were begun specifically because this tunnel intercepts a clay formation that is being considered as a potential host rock elsewhere in Switzerland.

The establishment of an underground facility requires a significant investment in infrastructure support, in terms of excavation, construction, and maintenance of underground services and safety. For this reason, most generic URLs developed in NEA Member countries have been developed within, or as extensions to, excavations that exist already, such as mines and tunnels. Using an existing mine or underground access makes use of the initial excavation and in-place mine maintenance and safety infrastructure. It may also be easier to get planning permissions to extend work in an existing mine or tunnel as opposed to the development of a new site.

URLs of this type, which take advantage of the geological and infrastructure opportunities that already exist, are useful to develop experience in techniques relevant to site characterisation and to repository construction, operation, and closure, and to develop understanding and test models. In some cases, the facilities may be limited in their representativeness of conditions in and around an actual repository, but they provide cost-effective opportunities, especially in the early stages of repository programmes.

Table 1 lists and provides basic information on generic URLs in NEA Member countries that take advantage of pre-existing underground excavations.

Within some repository development programmes, the decision may be made to develop a purpose-built generic URL in a specific rock type under consideration for a repository. This requires a very substantial resource commitment, because the full cost of excavation, construction, and services must be borne. On the other hand, greater control will be available, for example, to obtain pre-construction (undisturbed site) data, of underground design, excavation, and construction techniques, and of overall operations. A purpose-built generic URL may also be more easily designed to allow convenient visitor access. Indeed, public and scientific relations may be a significant part of its function within the disposal programme. Generally, assurances will be given that the URL will not ever become part of a repository and this may ease concerns of the local community about construction of the facility.

Table 2 lists and provides basic information on purpose-built generic URLs in NEA Member countries.

If one or more potential repository sites have been identified, then a site-specific URL may be developed to gain information and experience on the repository site. The URL may be constructed either adjacent to, or within, the proposed repository volume, and if repository development proceeds, the URL may be partially or completely subsumed within the repository. Shafts and access ways to the URL may provide secondary or even primary access routes to the repository, if they have been designed as such.

Table 1. **Generic URLs in NEA Member countries that take advantage of pre-existing underground excavations**

URL	Host rock, location, depth	Organisation, remarks	Other NEA countries co-operating in research
Asse Mine	Permian rock salt anticline; Germany; several mining levels between 490 and 800 m, mined cavern at 950 m.	GSF; galleries in former potash and rock salt mine, demonstration facility for LLW and ILW disposal from 1965 to 1978, R&D facility until 1997, backfilling of unused excavations underway.	France, Netherlands, Spain
Tono	Sediments; Japan.	JNC; galleries in former uranium mine, operating since 1986.	Switzerland
Kamaishi	Granite; Japan.	JNC; galleries in former iron-copper mine, completed in 1998.	Switzerland
Stripa Mine	Granite; Sweden; 360-410 m.	SKB; galleries in former iron mine, operated from 1976 to 1992.	Canada, Finland, France, Japan, Spain, Switzerland, UK, USA
Grimsel Test Site (GTS)	Granite; Switzerland; 450 m.	Nagra; gallery from a service tunnel of a hydroelectric project, operating since 1983.	Czech Republic, France, Germany, Japan, Spain, Sweden, USA
Mt. Terri Project	Opalinus clay (hard clay); Switzerland; 400 m.	SNHGS; gallery from a highway tunnel, initiated 1995.	Belgium, France, Germany, Japan, Spain
Olkiluoto Research Tunnel	Granite (tonalite); Finland; 60-100 m.	Posiva; Tunnel adjacent to the Olkiluoto repository for LLW, operating since 1992. Research relevant to spent fuel disposal at this or other sites in Finland.	Sweden
Climax	Granite; USA; 420 m.	DOE; drift mined from existing excavations; spent fuel disposal experiments conducted 1978 to 1983.	
G-Tunnel	Tuff; USA; > 300 m.	DOE; tunnel of weapons-testing excavations; operated from 1979 to 1990.	
Amelie	Bedded salt; France.	ANDRA; galleries in potash mine, operated 1986 to 1992.	
Fanay-Augères	Granite; France.	IPSN; galleries in uranium mine, operated 1980 to 1990.	
Tournemire facility	Sediments (hard clay); France; 250 m.	IPSN; former railway tunnel and adjacent galleries, operating since 1990.	Germany

Table 2. **Generic URLs in NEA Member countries that have been purpose-built**

URL	Host rock, location, depth	Organisation, remarks	Other NEA countries co-operating in research
High-Activity Disposal Experiment Site Underground Research Facility (HADES-URF)	Boom clay (plastic clay); Mol/Dessel, Belgium; 230 m.	GIE EURIDICE; shaft sinking began 1980, operating since 1984 and extended 1998-9.	France, Germany, Japan, Spain
Whiteshell Underground Research Laboratory (URL)	Granite; Lac du Bonnet, Manitoba, Canada; 240-420 m.	AECL; operating since 1984.	France, Hungary, Japan, Sweden, United Kingdom, United States
Mizunami Underground Research Laboratory	Granite; Japan.	JNC; borehole drilling underway.	Switzerland
Horonobe Underground Research Laboratory	Sedimentary rock; Japan.	JNC; construction approved 2000.	
Äspö Hard Rock Laboratory	Granite; Sweden; several depths between 200 and 450 m.	SKB; operating since 1995.	Canada, Finland, France, Germany, Japan, Spain, Switzerland, United Kingdom, United States
Busted Butte	Bedded tuff, Calico Hills Formation; Yucca Mountain, Nevada, USA; 100 m.	USDOE; operating since 1998.	

Site-specific URLs may be aimed at confirming the suitability of the host rock mass, guiding the site-specific layout and design of the repository, and demonstrating the various technological operations under site-specific conditions. In addition, more general research and development may be carried out as discussed for generic URLs. Some restrictions apply, however, because activities in a site-specific URL must be arranged so as not to be detrimental to the future safety of disposal at the site. A site-specific URL may stay open after its associated repository is closed, providing opportunities for long-term monitoring and verification of engineered barrier and repository performance, or may be closed when the necessary research is complete.

Table 3 provides a list of site-specific URLs in NEA Member countries.

Whatever type of URL is developed, it will likely play a prominent role in the development and presentation of the safety case for a repository and in the enhancement of confidence in the strategy for disposal

Widespread implementation of URLs

As indicated in Tables 1 to 3, URLs have been developed in 10 of the NEA Member countries. Some of these countries have moved from generic URLs to site-specific ones. Finland, France, and Japan are currently planning additional URLs. Several countries do not have their own URLs as yet (Netherlands, Spain, the United Kingdom, and the Czech Republic), but have co-operated or are co-operating in research in various URLs. Thus, almost all of the NEA Member countries with long-lived radioactive waste are engaged in research at URLs even though their repository programmes are at different stages of development.

The accumulated experience of all existing URLs exceeds 250 years of operation. Work in the Asse mine in Germany – the first generic URL – began in 1965; the first purpose-built generic URL was created in 1984 in Canada; and the first site-specific URL was created in 1980 in the Konrad mine in Germany.

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Table 3. **Site-specific URLs in NEA Member countries**

URL	Host rock, location, depth	Organisation, remarks	Other NEA countries co-operating in research
ONKALO	Granite (tonalite); Finland; 500 m.	Posiva; authorised in 2001, construction to begin in 2003.	
Meuse/Haute Marne	Shale (indurated clays), Callovo-Oxfordian Argillites; France; 450-500 m.	ANDRA; potential repository site, shaft construction began 2000.	Japan
Gorleben*	Salt dome; Lower Saxony, Germany; several depths below 900 m.	BfS, DBE; shafts constructed 1985-1990.	
Konrad	Limestone covered with shale; Germany; 800 m.	BfS, DBE; galleries in former iron mine, operating since 1980, in licensing stage for a LLW/ILW repository.	
Morsleben	Salt dome; Germany; several depths below 525 m.	BfS, DBE; former salt and potash mine, repository for LLW and ILW since 1981 (disposal operations terminated in 1998).	
Pécs (Mecsek Mountain)	Indurated clay, Boda Claystone Formation; Hungary; 1000 m.	PURAM; former uranium mine, operated 1995-1999.	
Waste Isolation Pilot Plant (WIPP)	Salt (bedded), Salado Formation; Carlsbad, New Mexico, USA; 655 m.	USDOE; operating since 1982, licensed transuranic (TRU) waste repository since 1999.	Belgium, Canada, France, Germany, Japan, Sweden, United Kingdom
Exploratory Studies Facility (ESF)	Welded tuff, Calico Hills Formation; Yucca Mountain, Nevada, USA; 300 m.	USDOE; *in situ* testing began in 1996; construction of an exploratory side tunnel completed in 1998.	

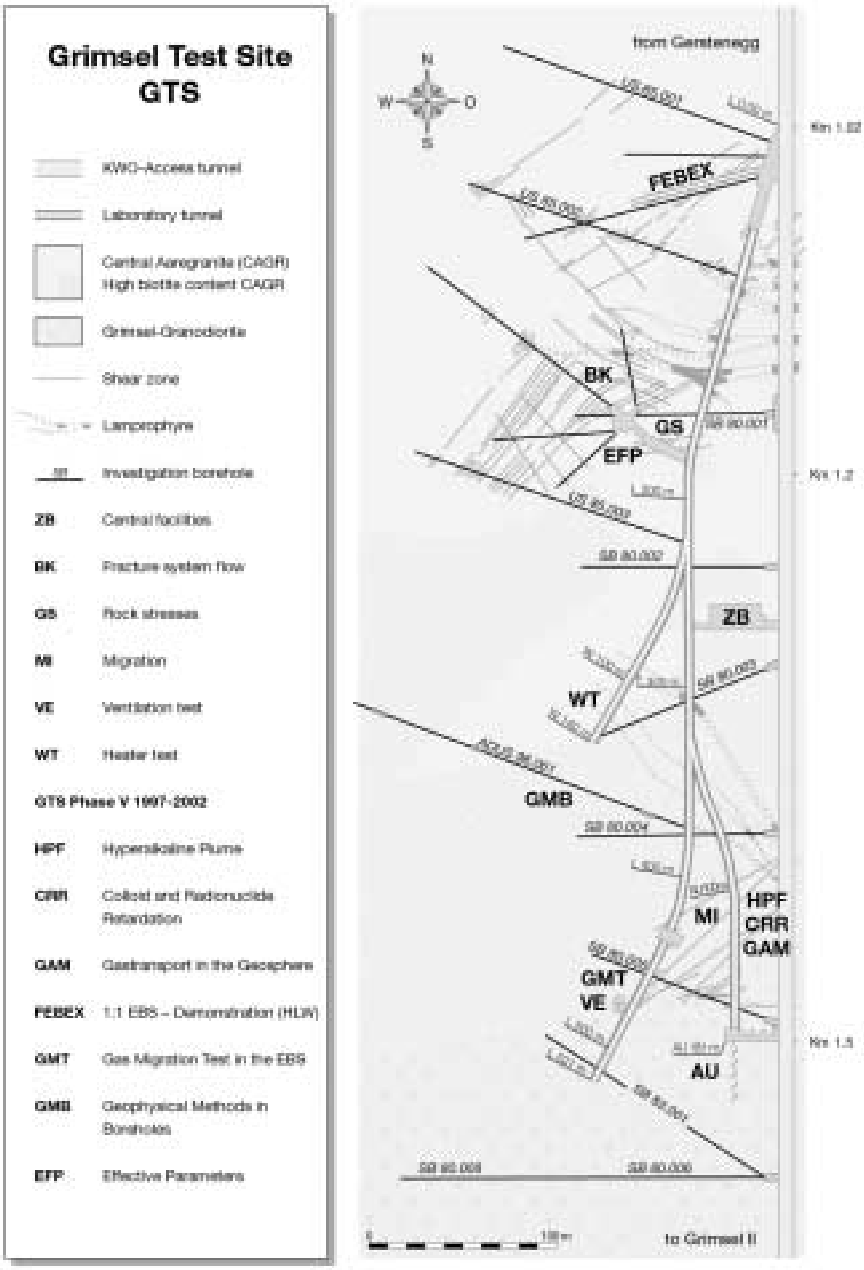
* Exploratory work for potential repository site suspended for 3-10 years by governmental moratorium on 1st October 2000.

The cost of URLs

The construction of URL facilities is time-consuming and expensive, as indeed is all underground work. Construction of URLs may be especially demanding because special excavation techniques may be used in order to limit disturbance to the rock, and because quality assurance procedures must be followed that are typical of laboratory conditions. Construction costs for a URL may easily be on the order of 100 Million Euros and, once a URL is started, a significant portion of a disposal programme's budget may be used to support it. Andersson (1999) reports that four European URLs spend between 5 Million and 11 Million Euros annually on research and development. Thus, the construction of a URL is not a decision taken lightly in any country. Indeed, the construction of a URL represents a tangible commitment to research and development in support of repository development. The fact that URLs are so widely implemented and used despite their cost is an indication of their value to national disposal programmes.

Other benefits of URLs

Besides delivering important information for science and technology, a URL may contribute to acceptance of a repository. URLs can increase public confidence in the waste-disposal concepts as well as in the capability of implementers to develop waste-disposal facilities. At the same time, a regulator can increase their own visibility by being active in a URL programme, so that society has greater confidence in their ability and reliability to regulate a repository. Information and experience gained from URLs can help to shift discussions, both between implementers and regulators and between implementers and the wider public, from a "soft" theoretical basis, on which firm decisions are difficult to reach, to a "hard" factual basis more conducive to decision making. In light of these factors, work done in the URLs of other countries, while perhaps of equal technical value, may have much lower programmatic value because it is not as relevant or responsive to national or societal concerns or goals.


Grimsel Test Site
GTS
KWO-Access tunnel
Laboratory tunnel
Central Aaregranite (CAGR)
High biotite content CAGR
Grimsel-Granodiorite
Shear zone
Lamprophyre
Investigation borehole
ZB Central facilities
BK Fracture system flow
GS Rock stresses
MI Migration
VE Ventilation test
WT Heater test
GTS Phase V 1997-2002
HPF Hyperalkaline Plume
CRR Colloid and Radionuclide Retardation
GAM Gastransport in the Geosphere
FEBEX 1:1 EBS – Demonstration (HLW)
GMT Gas Migration Test in the EBS
GMB Geophysical Methods in Boreholes
EFP Effective Parameters
from Gerstenegg
N
W
O
S
FEBEX
BK
GS
EFP
ZB
WT
GMB
MI
HPF
CRR
GAM
GMT
VE
AU
to Grimsel II

3. THE SEVERAL CONTRIBUTIONS OF URLs

The key function served by a URL that cannot be otherwise met is to provide access to the geologic environment under realistic repository conditions. This access is necessary to develop methodologies and equipment for *in situ* characterisation and allow staff to obtain expertise in their application. *In situ* access allows characterisation of the geosphere properties and conditions that will affect repository performance. A URL provides a facility to perform experiments to develop data sets for model testing and to develop and demonstrate technologies for repository construction, waste emplacement, and backfilling and sealing under realistic conditions. These technologies and expertise are then transferable to actual repositories. A URL also provides non-technical or ancillary benefits. Chief among these is the enhanced confidence that may be created within the general scientific community and among the public at large in the disposal technology demonstrated in the URL. Finally, URLs provide an important opportunity to engage in international collaborations with a variety of benefits.

The evolution of work performed in URLs

The types and amounts of work performed in URLs have evolved with time. When work in the first URLs began, 25-30 years ago, much of the sophisticated technology required for nuclear waste repositories was in its infancy. Development of equipment and testing methodologies, as well as basic engineering feasibility studies and collection of fundamental geologic data, were the priorities. Today, those types of activities are receiving decreasing emphasis because of the information now available. Efforts are now directed more towards adapting and optimising the equipment and techniques developed at other sites to the specific conditions at each particular site.

The work carried out in URLs has also evolved in parallel with the needs and results of iterative safety assessment studies, so that it now focuses on reducing uncertainties and increasing confidence in the safety case. For example, tests may be carried out to distinguish between alternative conceptual models or to develop improved scientific understanding of specific processes. Increased emphasis is also being placed on full-scale demonstration-type experiments related to engineered barrier systems and on long-term and large-scale tracer tests.

Examples of work performed in URLs

Examples of work that has been performed at URLs are given in Table 4 and the general classes of work are discussed below:

Develop methods, equipment and experience in underground characterisation and monitoring techniques

Characterisation of the underground environment from within a URL requires equipment and procedures different from that commonly used for surface-based investigations. Each repository programme also has its own unique concerns that necessitate some degree of invention and innovation. URLs provide the opportunity to develop and test the tools that will be needed for characterisation of a repository and, just as important, allow personnel to gain proficiency with those tools and form effective teams. URLs also provide the opportunity to develop and test whatever monitoring systems might be required around a repository.

Another important aspect of developing capability and experience in underground characterisation is the quality assurance (QA) procedures that are developed and tested at the same time. Tested and effective QA procedures are critical underpinnings of a license application for a repository.

Determine reliability of surface-based methods of site characterisation

Before construction of a URL begins, surface-based site-characterisation methods provide data that are used to develop first, a conceptual model, and second, a numerical model(s) of the site. Subsequent excavation of the URL provides the opportunity to test predictions made on the basis of those models, such as the occurrence of fracture zones. Linkages can also be developed between the characterisation parameters measured from the surface (e.g., in boreholes or surface-based geophysical surveys) with those measured from within the URL. In this way, those surface-based methods and/or models that are successful (or useful) in predicting underground conditions can be differentiated from those that are not and carried forward into the repository siting and characterisation programme. The ability to predict subsurface conditions accurately is one key in demonstrating the feasibility of finding an acceptable repository site.

Provide data for performance assessment and repository design

Whether generic or site-specific, a URL allows the collection of characterisation data that complement the data obtained from surface-based investigations and laboratory experiments. These data may be collected at any depth in the access tunnels and shafts, allowing much more than characterisation of only the potential repository horizon. These data can be used to develop and test models of repository and geosphere performance, allowing an understanding to be developed of the sensitivity of various performance measures to variations in measured characterisation parameter values. The URL data have the added value of reflecting conditions more representative of actual repository (i.e., near-field) conditions than borehole data. Tests can be conducted over larger volumes of rock within a URL than in a borehole, allow development of upscaling rules, and can be better focused on characterising heterogeneity and reducing remaining uncertainties. In some formations, sampling of pore water can only be performed effectively from within a URL.

In the case of a site-specific URL, the better understanding of existing lithological variations, important structures, and other heterogeneity that can be obtained underground is also essential to the final design of the repository. In addition, some forms of monitoring and definition of baseline conditions before repository construction can only be performed from within a site-specific URL.

Test and develop conceptual and numerical models

The URL provides an environment for the testing and development of models at various levels of detail. This includes models to be used in repository design and optimisation of layout, such as models of geomechnical and thermal response and models of the hydrogeologic regime, as well as models to be used in safety assessment, such as models of solute and contaminant transport.

Develop methods, equipment and experience in repository construction, operation and closure, and in waste retrieval

A URL allows development, demonstration, and quality assurance of technologies for repository construction, repository operation, waste emplacement, engineered barriers, and backfilling and sealing under realistic conditions. For example, design and construction of any repository will have to be adapted to the specific heterogeneities encountered at a site. Construction of a URL allows determination of the feasibility of the methods proposed for that adaptation. It also allows testing of the design-as-you-go concept proposed by SKB and Posiva, in which the exact locations of tunnels and waste canisters are not determined until enough rock has been exposed to select optimal locations for them. If the potential for reversibility of the disposal decision is an element of the overall disposal programme, a URL also offers the opportunity to develop, test, and demonstrate equipment and methodologies for waste removal.

A URL also allows for study of the interactions of materials that might be used in repository construction and waste packaging with engineered barriers and the host rock under representative in situ conditions that include different possible thermal regimes. The geomechanical effects of different mining methods can also be evaluated within a URL. At the same time as these evaluations and demonstrations are performed, the QA procedures that will need to be in place during development and operation of a repository can be developed and tested. Personnel will also gain valuable experience during all of these activities.

URLs can be beneficial to regulators

In addition to the many benefits provided directly to implementing agencies, URLs can also be highly beneficial to regulators. Participation in a URL programme can allow a regulator to develop and/or improve the dialogue with the implementer and public on a later repository project. Recognising the different positions that a URL may have within the step-wise approach to the development of a repository programme, the discussion of the results of a URL programme can increase the general understanding of what is to be broadly achieved at the next steps. However, a regulator must be careful not to be perceived as compromising its independence in this dialogue by making it transparent and open to the public.

A URL programme, in particular one in a generic URL at the earlier stages of repository development, has an important role in the regulatory context, in that it supplies information that is of direct relevance to the regulatory authorities in their assessment of the general feasibility of the proposed disposal concept. In terms of the system design and the strategy that will need to be followed for testing and implementing such a system, it is an R&D programme carried out under *in situ* conditions that is likely, in many situations, to be more convincing than one carried out elsewhere.

A URL can also provide a vehicle for a regulator to develop and test its own models for use in evaluating a repository. The data provided by a URL programme may allow a regulator to perform an independent safety assessment for a repository, to identify key areas in which to focus for an actual safety assessment submitted by an implementing agency. This type of exercise can provide valuable experience and training for the personnel who will be performing the regulatory assessment of a repository.

URLs build confidence in repository programme

A URL serves a variety of confidence-building functions. A URL can serve to build confidence within the sponsoring waste-management programme in both the efficacy of the disposal concept and the feasibility of its implementation by providing key data and experience, as well as an “integration vehicle” of the various aspects of the programme, necessitating multidisciplinary team work. A visible and active role by a regulator in a URL programme can increase its recognition and credibility so that society has greater confidence in its ability and reliability to regulate a repository. A URL can help to build confidence within the technical community at large by allowing interactions with the academic community, waste-management organisations from other countries, and other scientific peers. It also allows demonstration of the overall disposal concept, including repository construction and operation technologies, waste emplacement, backfilling, sealing, and monitoring systems, to the public and non-technical decision makers. In this way, it can serve as a public, visible “dress rehearsal” for the selection, characterisation, construction, operation, and closure of an actual repository.

URLs can be used to show how actual repository facilities would look and function, enabling the public to see the work as it is being done, talk with the people actually doing the work, get credible responses to their questions from the researchers, and get understandable explanations of the research being done underground. This leads to enhanced credibility of the entire programme. In addition, the URL siting and construction allow the implementing agency to develop and refine public-interaction methods, while developing working relationships with groups and stakeholders that will likely be involved in future repository development.

URLs attract international collaboration

URLs can also act as an enticement for collaboration to other international waste-management programmes (see also Section 5). Opening a

URL to international collaboration and co-operation brings qualified research staff together from multiple countries, which leads to a broader competence base than any one country might be able to muster on its own. In addition, international collaboration can provide a broader financial base, allowing more valuable work to be performed in a URL than the host country might be able to afford on its own.

Table 4. **Technical information obtained from URLs**

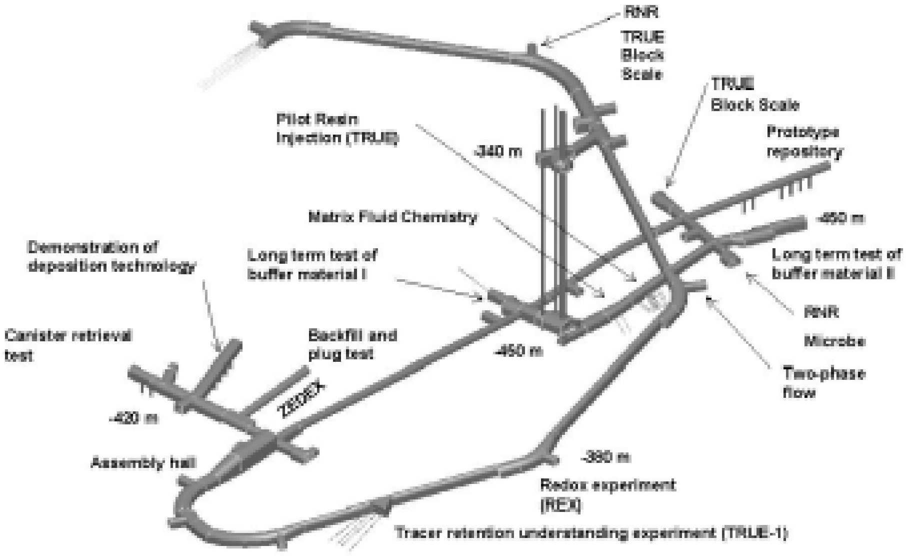
Objectives	**Examples**
Development of methods and equipment for underground characterisation and testing of the reliability of the different methods	• Ventilation experiment, cross-hole hydraulic and seismic tests, borehole radar, and Validation Drift experiments at Stripa; • Extensometer development at URL*, Canada; • Development of equipment and procedures for brine permeability tests in halite at WIPP; • Brine migration test at Asse.
Determine reliability of surface-based methods of site characterisation	• Comparison of permeability-test results from deep boreholes with *in situ* permeability tests at WIPP; • Comparison of pre-excavation predictions to properties found in tunnel at Äspö.
Application of site-exploration strategies and strategies to adapt underground systems as more information is acquired.	• Fracture mapping and hydraulic measurements to select locations for full-scale deposition holes in Olkiluoto Research Tunnel; • Application of geophysical methods at Grimsel, Tournemire and Stripa.
Testing and development of conceptual and numerical models of processes potentially relevant to radionuclide transport through rock.	• Radionuclide Retardation Project at Grimsel; • Unsaturated zone transport tests at Yucca Mountain; • Solute transport and diffusion experiments at URL, Canada; • Gas-threshold-pressure tests at WIPP; • Tracer retention programme at Äspö.
Quantification of impacts of excavation on local system.	• Excavation-damaged zone experiments at Äspö, Grimsel, and WIPP; • Disturbed zone studies around blasted tunnel and drilled disposal holes in Olkiluoto Research Tunnel.

* See Appendix for definitions of acronyms.

Table 4. **Technical information obtained from URLs (continued)**

Objectives	Examples
Further development and testing of excavation techniques.	• Demonstration of technical feasibility of drilling galleries in plastic clays at HADES; • Comparison of tunnel boring machine to drill and blast excavation techniques at Äspö and Grimsel; • Demonstration of deep borehole drilling technique at Asse; • Studies of the performance of disposal technologies at Olkiluoto.
Simulation of effects caused by emplacement of radioactive waste (heat, nuclide release, mechanical impact).	• Study of the effect of heat and radiation on clay at HADES; • Thermal simulation of drift emplacement at Asse; • Heater tests at Stripa, Yucca Mountain, WIPP, and Grimsel; • Thermal-structural interactions tests at WIPP; • Thermal-mechanical-hydraulic tests at URL, Canada.
Experiments related to long-term processes, post-operational phases, corrosion, geomechanical stability, etc.	• Concept demonstration for disposal in clay at HADES; • Coupled thermal-hydraulic-mechanical processes test at Kamaishi; • Materials interface interactions tests at WIPP; • Backfill and material behaviour at Asse; • Thermal-mechanical-hydraulic tests at URL, Canada.
Demonstration of engineered-barrier systems (feasibility).	• Borehole sealing and buffer mass tests at Stripa; • Full-scale engineered barriers experiments at Grimsel; • Development of borehole seals for HLW canisters at Asse; • Buffer and container testing at URL, Canada; • Small-scale seal performance tests at WIPP; • Repository sealing experiments at HADES.

Experimental Sites at Äspö HRL



4. THE STRATEGIC ROLE AND TIMING OF URLS

URLs can play an important role at different stages in a repository programme, and this contribution may continue throughout the full cycle of repository development and even after repository closure. Internationally, a general trend can be expected over time that leads from development of generic URLs (including purpose-built facilities), to URLs aimed at investigating rock types of specific national interest, to URLs at potential repository sites, and, finally, to test disposal facilities or full-scale repositories. Nationally, however, different strategies may be followed and there are questions to be asked both about the need for national URLs and timing of development.

Step-wise repository development and the role of URLs

The planning, technical development, and associated research, siting, construction, licensing, operation, and eventual closure of a geologic disposal facility are expected to take place over a period of several decades. This development should be managed in a step-wise fashion in which, at each step, the accumulated body of experience and information should be reviewed to decide whether sufficient experience and information exists in order to confirm or revise previous plans and execute the next step. In particular, the experience and information will be incorporated into a safety case that should give a reasonable assurance of the ultimate safety of the facility that is sufficient to pass the regulatory or societal tests that are applicable at each stage.

The detailed enactment of a step-wise approach within each national programme may be different, and the national constraints will differ, e.g. in terms of waste-management policy, organisational responsibilities, geological opportunities within national borders, and budgets for research and development. Thus, the plan for development of URLs within each country will be different depending, for example, on whether use can be made of experience in other countries (including collaboration in other national URL programmes), the siting approach (including whether alternative geologic environments are to be evaluated), and the opportunities for URL development at locations of geological interest (taking account of difficulties in gaining the necessary permission for a URL).

The following broad stages of a repository development programme can be defined, with examples of the work in URLs that might be necessary to support each stage:

Concept development

- research to understand general characteristics and processes in relevant geologic environments in order to develop generic models of rock and hydrogeologic response, transport of contaminants, and overall repository performance;
- initial development and testing of excavation techniques and material specifications, e.g. for backfill and sealing, and monitoring techniques.

Site selection and characterisation

- testing of site-characterisation techniques to ascertain their capabilities and accuracy under field conditions;
- characterisation of specific host rocks or sites;
- development of site models and testing against observed responses to excavation;
- refinement of excavation techniques, material specifications, and monitoring techniques.

Repository development

- development of waste-emplacement (and retrieval) methods;
- refinement and testing of monitoring techniques;
- testing of waste-handling equipment;
- trial waste emplacement, backfilling, and sealing.

Repository operation and closure

- continued refinement of techniques and instrumentation;
- post-emplacement monitoring.

National strategies for URL development

Within each national programme, the requirements indicated above will be fulfilled by a combination of national URLs and collaboration and experience in URLs in other countries. Thus, not all countries will develop a purpose-built generic URL, but most countries will develop one or more generic URLs to investigate specific rock types of national interest, and all major repository developments will be preceded by development of a site-specific URL. The following questions need to be addressed within each national repository development programme:

How pressing is the need to dispose of waste?

> Some countries may delay constructing a URL because final disposal of waste is not contemplated for several decades or more. In this case, it will be advantageous to follow developments in other countries, perhaps collaborating in programmes in foreign URLs, to have the benefit of as much knowledge and experience as possible when a national URL is needed. Even if the need is not pressing, a national generic URL may pay dividends in developing technical expertise and also assisting in gaining acceptance of underground disposal.
>
> If, on the other hand, disposal of waste is a pressing concern, then the time might be right to proceed with either a URL aimed at specific host rock types, or a site-specific URL if a site has been selected.

Is a URL needed to develop and test a disposal concept?

> Construction of, and experimentation within, a URL may be needed to develop, test, and demonstrate a particular disposal concept before a decision can be made to construct a repository based on that concept.

Can desired information be obtained by co-operating in work performed in the URL of another country?

> Most countries that currently have URLs offer the possibility for co-operative work with other countries. Provided that the information and experience are transferable from an existing URL to a particular repository concept (e.g. same type of host rock), performing work in an existing URL in another country may be a cost- and time-effective solution during the period before a national URL is available.

Is going underground the most efficient way to satisfy research and testing needs?

> Development of a repository requires research and testing that may be impossible without working in an underground environment. These capabilities may include specific technologies (e.g. for permeability testing or waste emplacement), understanding of processes, and experience in a variety of underground operations. As time goes by, more of this type of information and experience may be available from other URLs (unless none exist in the rock type of interest), which may help assist small or less advanced programmes, but the need for underground access and experience prior to repository construction will never disappear entirely.

Can an existing underground facility be adapted for generic URL work in a cost-effective manner?

> Existing underground facilities (e.g., mines, tunnels) may provide an opportunity to develop techniques, equipment, and/or expertise in a cost-effective manner that will be useful in future repository development. While an existing excavation may not serve the same range of functions as a new excavation, it may allow rapid progress in certain areas.

Is the overall waste-disposal programme sufficiently advanced to provide continuity when the URL work under consideration is completed?

> If too long a period of time elapses between development of technology and expertise in a URL and opportunities for their continued application, valuable work and trained personnel can be lost. Thus, ideally, a continuous programme of work should be mapped from the first URL to a final repository before URL work begins.

Timing of site-specific URL development

A number of technical and administrative matters should be considered when deciding when to develop a site-specific URL:

Are specific data needed that can only be obtained in a site-specific URL?

> At some point, performance-assessment modelling, engineering design, and other aspects of a repository programme require detailed information that can only be obtained underground at the repository site. If the lack of

this information is stalling the programme, and all necessary preconditions have been met, building a site-specific URL is appropriate.

Have all necessary data been collected before the system is disturbed?

Excavation of a URL (or repository) has significant, long-lasting effects on the surrounding geologic environment. Before excavation begins, baseline hydrogeologic conditions (principally hydraulic head) must be established and all experiments that only can be done in an undisturbed system must have been completed. Enough data should be collected from hydraulic tests and other sources to develop models that can be used to predict the effects of excavation.

Have all technical, logistical, and regulatory preconditions been met?

One of the areas in which URLs are valuable is in the information that can be obtained on how excavation affects the properties of the host rock. This requires that surface-based monitoring systems are in place (and baseline conditions defined as described above), that monitoring equipment is ready to be installed underground as soon as the excavations are open, and that personnel availability and other logistical details are worked out.

In addition to these technical and logistical preconditions, different aspects of the development (e.g. shaft construction, drift construction, ventilation systems) may have separate regulatory requirements and/or authorities. In order to avoid costly delays, all regulatory requirements should be discussed well in advance, so that they can be met on predictable schedules, consistent with the technical and logistical requirements of the work.

Is the programme ready to demonstrate full capability to build a repository?

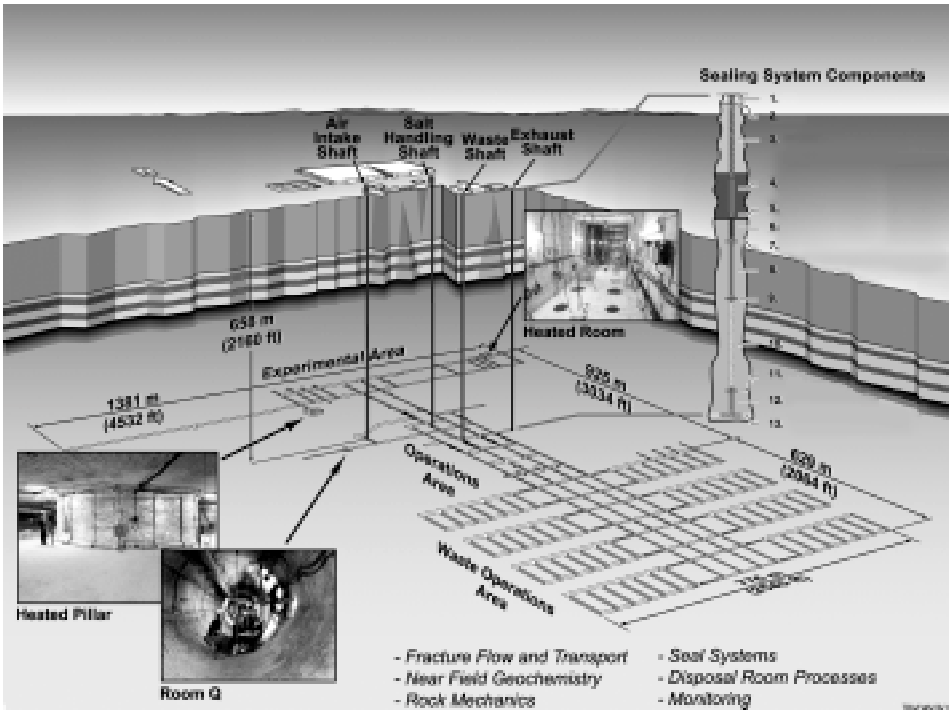
One role a URL can fill is to demonstrate the capability to site, construct, operate, and close a repository. Regulations in some countries may require construction of a URL before a repository can be built. Once a programme is ready to demonstrate the necessary capabilities, going underground may be appropriate.

Future roles of URLs

At present, only one repository for long-lived waste is in operation (the WIPP in the USA), so the continuing role of a URL after a repository begins operation is not well known from experience. But we can foresee important future roles, even after repository closure. For example, disposal of simulated waste could be performed in a site-specific URL in parallel with the disposal of actual waste in a repository. Over the operational period of the repository, and even beyond, the performance of the waste canisters, backfill, and other engineered barriers could be verified in the URL by a variety of means, some intrusive, that would not be possible or desirable in the repository. Should retrieval of the waste ever become an objective, the simulated waste in the URL could be used as a test bed for further refining methods, equipment, and experience. Likewise, aspects of geosphere performance, such as water-inflow rates and growth of the excavation-damaged zone, could be monitored over a period of decades in a URL to verify, or revise, assumptions made for safety analyses.

Another possibility is the development of pilot disposal facilities within a repository, where the pilot disposal of a fraction of the waste to be disposed may be subject to more intense initial monitoring (e.g. Wildi *et al.* 2000). This experience may be used to give confidence to proceed, after a period, with full-scale disposal or the experience may lead to modifications of emplacement and/or backfill techniques etc.

Cut-away view of the Waste Isolation Pilot Plant



Sealing System Components

1. Compacted earthen fill
2. Concrete plug
3. Compacted earthen fill
4. Rustler compacted clay column
5. Concrete plug
6. Asphalt column
7. Upper concrete-asphalt waterstop
8. Upper Salado compacted clay column
9. Middle concrete-asphalt waterstop
10. Compacted salt column
11. Lower concrete-asphalt waterstop
12. Lower Salado compacted clay column
13. Shaft station monolith

5. INTERNATIONAL CO-OPERATION

The costs involved in the development and operation of a URL, and the possibility of sharing existing knowledge and experience, can make international co-operation in underground studies advantageous. International co-operation promotes exchange of ideas, creativity, and better quality research. The collective demand from several organisations reinforces the meeting of milestones and adhering to budgets. Countries involved in international co-operation projects in URLs are listed in Tables 1 to 3. The benefits of international co-operation in URLs include:

Expanded talent pool

International co-operation projects allow the best scientists, in terms of both ability and experience, from numerous countries to work together. This expansion of the talent pool allows for cross-fertilisation of ideas and more rapid advancement of research.

Expanded contacts and know-how transfer

A direct benefit of the trend towards collaborative international projects in URLs is the development of international and interdisciplinary contacts and know-how transfer that may be valuable in other aspects of repository development, such as site characterisation and performance assessment.

Cost-effective

All parties to international co-operation projects gain by obtaining research results that they do not have to pay for fully themselves. The host country of the URL obtains the results of effort contributed by other participants, which can be not only of generic value, but also valuable site-specific data from having studies conducted in their own URL. The non-host countries can learn from the example of others, gain practical experience, and develop their technical and managerial expertise, all of which should make their own repository programmes more efficient when they reach the URL stage. International co-operation in specific experiments performed in URLs, such as tests of seal concepts in crystalline rock, also avoids expensive duplication of complex research.

International recognition and increased confidence

Opening a URL to international co-operation boosts the international recognition and credibility of the host programme. This promotes confidence in the host programme by demonstrating openness to outside experts and promoting peer review and dissemination of results to a broader community. These initiatives indicate to the public, technical experts, and other stakeholders that there is international agreement on the important issues and approaches to addressing them.

6. CONCLUSIONS

Development of an underground research laboratory and/or participation in underground R&D activities in other countries are useful steps towards disposal of radioactive waste in deep geologic formations. URLs provide important and, at times, critical technical knowledge and confidence for facility siting and design, underlying engineering support, and evaluation of safety. Certain types of information and experience necessary for characterisation, construction, and operation of a geologic repository can only be obtained through access to the underground environment. Similarly, confidence in the facility design, host-rock suitability, and engineering feasibility can only be gained through underground verification. All of these factors are of importance in building the safety case for a repository.

URLs may be either at sites where no waste will ever be stored and only research will be performed, or site-specific, in which case the scientific investigations and other activities are intended to be precursors to repository construction and operation. URLs offer an excellent opportunity to integrate multiple disciplines (e.g., geology, hydrology, engineering), build technical teams, and gain practical experience that will be invaluable in future development of a repository. URLs also offer an unparalleled opportunity to demonstrate the disposal concept and technical feasibility of a repository programme, and instil confidence in the public that a repository programme has a valid basis and is being pursued in a responsible manner by a trustworthy implementer.

URLs are useful in attracting international co-operation. This provides a wider talent pool to draw upon, expanded contacts and know-how transfer that can be useful in other areas of repository development, a cost-effective way to perform experiments as expenses are shared among nations, wider international and technical recognition, and increased confidence both in the waste-management organisation and in the feasibility of geologic disposal.

The work performed in URLs has evolved with time. Development of equipment and testing methodologies and experiments to enhance understanding of key processes, as well as basic engineering feasibility studies and collection of fundamental geologic data, were priorities in the first URLs. Efforts are now directed more towards adapting and optimising the equipment and techniques developed at other sites to the specific conditions at each particular site, developing data sets for model testing, and on reducing uncertainties and increasing confidence in the safety case. Increased emphasis is also being placed on full-scale demonstration-type experiments related to engineered barrier systems.

URLs may have important future roles during repository operations and after repository closure. URLs may be used as surrogate repositories in parallel with the disposal of actual waste in a repository. Over the operational period of the repository, and even beyond, the performance of waste canisters, backfill, and other engineered barriers could be verified by a variety of means, some intrusive, in the URL that would not be possible or desirable in the repository. Should retrieval of the waste ever become an objective, the URL could be used as a test bed for development of methods, equipment, and experience. Likewise, aspects of geosphere performance could be monitored over a period of decades in a URL to verify, or revise, assumptions made for safety analyses.

The value of URLs in enhancing public confidence can be considerable. By opening a URL to public visits, the public may see the technologies being developed and employed, meet and talk with the scientists and engineers involved in the project, have their questions and concerns addressed directly, and experience for themselves the isolation provided by the deep geologic setting. This can create a level of confidence and acceptance of a repository programme that no amount of documents can provide. For this reason alone, a URL may be a necessary condition for any successful repository programme.

FURTHER READING

General reading

Andersson, J. 1999. *A Study on the Co-operation of Research in Underground Facilities within the EU on Aspects of Disposal of Radioactive Waste*. EC DOC.XII-53-99. 14 p.

McCombie, C., and W. Kickmaier. 2000. "Underground Research Laboratories: their roles in demonstrating repository concepts and communicating with the public". *Euradwaste 1999, Radioactive waste management strategies and issue*s, Fifth European Commission Conference on Radioactive Waste Management and Disposal and Decommissioning, Luxembourg, 15 to 18 November 1999; European Commission Report EUR 19143, 274-281.

NEA 1999. *Confidence in the Long-term Safety of Deep Geological Repositories – Its Development and Communication.* OECD/NEA. Paris, France.

NEA 2000a. *Geological Disposal of Radioactive Waste: Review of Developments in the Last Decade*. OECD/NEA; Paris, France.

NEA 2000b. *Progress Towards Geologic Disposal of Radioactive Waste: Where Do We Stand?*. OECD/NEA; Paris, France.

Savage, D. (ed.). 1995. *The Scientific and Regulatory Basis for the Geological Disposal of Radioactive Waste*. John Wiley and Sons, Chichester, 437 p.

Wildi, W., D. Appel, M. Buser, F. Dermange, A. Eckhardt, P. Hufschmied, H.-R. Keusen, and M. Aebersold. 2000. *Disposal Concepts for Radioactive Waste, Final Report*. Federal Office of Energy. Bern, Switzerland.

Technical reading

Fairhurst, C., F. Gera, P. Gnirk, M. Gray, and B. Stillborg. 1993. *OECD/NEA International Stripa Project, Overview Volume I, Executive Summary*; SKB, Stockholm, Sweden.

Haijtink, B., and C. Davies (compilers). 1998. *In situ* testing in underground research laboratories for radioactive waste disposal. *Proceedings of a CLUSTER seminar*, Alden Biesen, Belgium, 10-11 December 1997. European Commission Report EUR 18323.

IAEA (in preparation). *The Use of Results Obtained from Underground Research Laboratory Investigations*. IAEA-TECDOC, IAEA, Vienna, Austria.

Kickmaier, W., and I. McKinley. 1997. "A review of research carried out in European rock laboratories". *Nuclear Engineering and Design*, 176, 75-81.

NEA 2001. *Going Underground for Testing, Characterisation and Demonstration*. NEA/RWM/(2001)6/REV; OECD/NEA; Paris, France.

Olsson, O. 1998. "The role of the Äspö Hard Rock Laboratory in the Swedish nuclear waste programme"; *Proceedings of Waste Management '98.*

SKB 1996. *Äspö Hard Rock Laboratory, 10 Years of Research*; SKB, Stockholm, Sweden.

USDOE 2001. Proceedings of the Conference on Geologic Repositories: Facing Common Challenges. October 31 – November 3, 1999, Denver, Colorado. U.S. Department of Energy.

APPENDIX: DEFINITIONS OF ACRONYMS

AECL	Atomic Energy of Canada Limited, Canada
ANDRA	National Agency for Radioactive Waste Management, France
BfS	Federal Office for Radiation Protection, Germany
DBE	German Specialized Engineering Company for Final Disposal of Radioactive Waste
ESF	Exploratory Studies Facility, Yucca Mountain, USA
GIE EURIDICE	Groupement d'Interet Economique – European Underground Research Infrastructure for Disposal of Nuclear Waste in Clay Environment, Belgium
GSF	National Research Center for Environment and Health, Germany
GTS	Grimsel Test Site, Switzerland
HADES	High-Activity Disposal Experiment Site, Mol, Belgium
ILW	Intermediate-Level Waste
IPSN	Nuclear Protection and Safety Institute, France
JNC	Japan Nuclear Cycle Development Institute (former PNC)
LLW	Low-Level Waste

Nagra	National Co-operative for the Disposal of Radioactive Waste, Switzerland
NEA	Nuclear Energy Agency of the OECD, Paris, France
OECD	Organisation for Economic Co-operation and Development, Paris, France
Posiva	Radioactive waste management company in Finland
PURAM	Public Agency for Radioactive Waste Management, Hungary
QA	Quality Assurance
R&D	Research and Development
SEDE	NEA Co-ordinating Group on Site Evaluation and Design of Experiments for Radioactive Waste Disposal
SNHGS	Swiss National Hydrological and Geological Survey
SKB	Nuclear Fuel and Waste Management Company, Sweden
TRU	Transuranic waste
URF	Underground Research Facility, Mol, Belgium
URL	Underground Rock (or Research) Laboratory, generic and Lac du Bonnet, Canada
USDOE	United States Department of Energy
WIPP	Waste Isolation Pilot Plant, Carlsbad, New Mexico, United States

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