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Integration Group for the Safety Case (IGSC)

TOPICAL SESSION PROCEEDINGS OF THE 6TH IGSC MEETING

THE ROLE OF MONITORING IN A SAFETY CASE

Held on 3 November 2004
Issy-les-Moulineaux, France

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FOREWORD

The IGSC (Integration Group for the Safety Case) is an international expert group that was launched four years ago. The IGSC takes initiatives in the area of confidence-building in repository technical safety cases (SC) and their underlying methodological and scientific bases for the purpose of decision-making in repository development. In particular, the IGSC focuses on the strategic and methodological issues of preparing a safety case, the integration of the science that is the basis for a safety case and on the development of that scientific basis.

In the past three years, definite progress has been observed mainly in technical aspects of planning and performing long-term safety evaluations of repository systems. Moreover recently, it has become increasingly evident that repository development will involve a number of stages punctuated by interdependent decisions on whether and how to move to the next stage. These decisions require a clear and traceable presentation of technical arguments that will help in giving confidence in the feasibility and safety of the proposed concept. The depth of understanding and technical information available to support decisions will vary from step to step and to that extend a safety case is a key item to support the decision to move to the next stage in repository development.

Geological disposal is conceived as passively safe, and post-closure safety must rest on the main protective functions of waste isolation and of the limitation and retardation of radionuclide release. Beginning in the period prior to the construction and possibly continuing up to closure and even longer, monitoring of various site and related repository parameters may be part of strategy for the safety case and will help in the review of continuing work. Monitoring may also be implemented to assure societal comfort and acceptance. Some organisations are being in the process of formulating ideas and guidelines concerning monitoring strategy and activities that could be conducted.

Therefore, the Topical Session reported here sought to confirm the need to start thinking about the place of the monitoring in the context of a safety case and to hear from within the IGSC the status of knowledge related monitoring developments in member programmes through a series of presentations on the “role of monitoring in a safety case.” This topical session was organised in the framework of the 6th meeting of the IGSC, held in Issy-les-Moulineaux, France, on 3 November 2004.

39 participants represented national waste management organisations and regulatory authorities from 15 NEA member countries, the IAEA, and the European Commission (EC). The main issues of interest were:

- National strategies and how organisations handle monitoring when making a safety case.
- Which role monitoring plays when making a safety case; presenting a safety case; and taking decision.
- What the expectations are from regulators.

Therefore the aims of the topical session were:

- to provide the key monitoring issues of interest to build confidence in a safety case (e.g.: relationship with the post-closure phase, functions, requirements);
- to determine any actions to be carried out by the IGSC on the elements of a safety case with respect to the monitoring issue.

The presentations showed the progress and remaining questions that could be underscored by the relevant national organisations in developing strategy for handling monitoring. They also confirm the interest in trying to achieve a common view on that topic and in particular on the definition/interpretation of the word “monitoring”.

The proceedings summarise the oral presentations both from implementers, regulators and international projects. They also present the key findings in particular the observed commonalities and differences between NEA member countries on the role of monitoring and of its interpretation in terms of handling and programme of works.

ACKNOWLEDGEMENTS

The NEA expresses its gratitude to:

- Jesus Alonso (ENRESA, Spain) who chaired the Topical Session.
- Juhani Vira (Posiva Oy, Finland) who co-chaired the Topical Session as a rapporteur.
- The speakers for their collaboration, for their interesting and stimulating presentations.
- The IGSC participants for their constructive contribution.

The rapporteur and the NEA-IGSC Secretariat have prepared the proceedings that were reviewed by speakers regarding their own presentation. Jesus Alonso, Abe Van Luik (US-DOE-YM and chair of IGSC until the 6th IGSC meeting) and Hiroyuki Umeki (NUMO and chair of the IGSC) have also reviewed the proceedings.

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PART A

SYNTHESIS

1. INTROUCTION

Assessments of the safety of proposed geological repositories are a key input to the decision-making process regarding the development of these facilities. Accordingly, implementing and regulatory organisations in many of the OECD/NEA countries are involved in the investigation and resolution of issues associated with repository safety and the NEA has been concerned with this issue for several decades.

Most current repository development programmes envisage that repository development will occur in an incremental fashion, with decisions being taken by national authorities at several steps in the development process. It may be envisaged that safety assessments will become progressively more refined at successive stages of the development process, with an expectation of increasing levels of confidence that the assessed levels of safety can be realised in practice.

Repository development programmes in different countries are always at different stages and may be addressing disposal in different geological media using different approaches; therefore opinions can be expected to vary on where key issues remain for a given programme at a given time.

In accordance with current terminology, the safety case for a proposed facility should present the results of the safety assessment together with an illustration of the level of confidence in the results. The safety case should also discuss how levels of uncertainty may be reduced in succeeding development phases.

Within the NEA, the IGSC has, as an essential role, to develop common views on the elements of the safety case. Therefore, since the inauguration of the IGSC in 2000, six meetings were organised with topical sessions to explore several of these key aspects. The concept of a "safety case" has been progressively clarified in a series of initiatives undertaken by the NEA in the past decade, which culminated with the publication of the NEA document on building confidence in a long-term safety case [NEA 1999] and the brochure on the post-closure safety case for geological disposal [NEA 2004].

Generally speaking, the safety case is considered as one of the key requirements in a national repository development programme. To fulfil its role, it needs to be structured, technically argued, and supported, with a clear link to the step-wise decision-making process such that the level of confidence supports the commitments to be made at each relevant step. Deep geological disposal is conceived as passively safe and post-closure safety must rest on the main protective functions of waste isolation and of the limitation and retardation of radionuclide release. Beginning in the period prior to the construction and possibly continuing up to closure and even longer, monitoring of various site and related repository parameters may be part of strategy for safety case and will help in the review of continuing work without compromising the long-term safety. Monitoring may also be implemented to assure societal comfort and acceptance.

Monitoring may include confirmation of the high quality of the engineered barrier systems and of the host formation and/or information about their responses to the construction, operation, or presence of the repository. The plan for monitoring should be carefully considered during the period of site characterisation that precedes it, and most countries that are involved in the development of deep geological repository for radionuclide waste are in the process of formulating ideas and guidelines concerning why, when, and what monitoring activities should be conducted. An important consideration is also how these activities could be undertaken and how they could be reported in a transparent and comprehensive plan for programme development.

The first step in this process of defining a monitoring programme is to define what "monitoring" means in terms of the needs to be satisfied and the activities to be performed. Some national and international organisations have been working to provide such definitions, and some are now planning a programme of work to address the identified needs.

This report summarises the outcomes of a topical session focused on the role of monitoring in a safety case. It was held as part of the 6th plenary meeting of the IGSC. This session took place in Issy-les-Moulineaux, France, on 3 November 2004. It was attended by 39 participants, representing waste management organisations and regulatory authorities from 15 NEA member countries, the IAEA and the European Commission.

The main purpose of this topical session was to create a platform for exchanging views on the key monitoring issues of interest to build confidence in a safety case e.g. relationship with the post-closure phase, functions, requirements, and to determine to what extent the main actions are to be addressed by the IGSC on its ongoing activities on defining the elements of a safety case.

The topical session was indeed mainly aimed at exchanging information on:

- National strategies or programmes in NEA members' countries. Member countries have organisations planning their own strategy, but some are already, to some extend engaged in implementing monitoring activities, e.g. Posiva Oy, US-DOE-YM, Andra.
- Feedback from international projects, e.g. the EC Thematic Network on "The role of Monitoring in a Phased Approach to Geological Disposal of Radioactive Waste", and the IAEA programme of work.
- The expectations of regulators, e.g. SKI.

Part A of this document summarises the material orally presented and provides the main lessons drawn from the presentations and the discussions that followed them. The overheads presented are compiled without any further elaboration by the NEA Secretariat as Part B of the document. Part C gives the list of participants. It is hoped that the document as a whole provides a synthesis of current issues in monitoring of a deep geological disposal facility.

2. SUMMARY OF PRESENTATIONS

a. Why monitoring?

As stated by J. Alonso, ENRESA and chairman of the topical session, safety assessments are performed periodically throughout successive repository phases such as planning, construction, operation, closure and post-closure. They are used to develop and progressively update a safety case, which is a formal compilation of all the evidence, analyses and arguments that substantiate the claim that the repository is safe. A safety case becomes more and more comprehensive and robust as a result of the work carried out and the experience gained including any pre-closure monitoring phase. As part of the step-by-step approach to repository programme development, various stakeholder groups such as regulators (compliance), implementers (support of safety case) and other stakeholders (confidence) call for a large amount of data and information on the site and the repository system. Monitoring programmes can contribute to these needs.

Various types of monitoring can be foreseen with respect to the following main objectives: (i) characterisation (e.g. modelling; system definition), (ii) compliance with requirements, and (iii) performance confirmation (agreement with predictions). Safety after closure is provided by the passive protective functions of the geological environment and the engineered barriers.

The monitoring programmes need to be adapted to several constraints:

- The long-term performance and protection goals set limits to what kind of measurements can be carried out in current or successive phases of repository development. Monitoring devices and monitoring activities shall not represent an undue risk to those fundamental goals.
- Long-term (post-closure) safety should be independent of the monitoring activities (requirement on passive safety). Monitoring provisions should not be regarded as a basis for relaxation of that principle.
- The state-of-the-art in technology, and the course of technology development, set limits to what is possible now and in the future (the need is to apply available technology appropriate to the purpose).
- The slow evolution of key processes (that could last for more than thousands of years) sets limits to what can be observed through practical monitoring programmes (e.g. using mock-up, experiments in URL or in repository itself).
- There are obvious limits to the number of locations where the data can be obtained through monitoring. The quantification of the spatial distribution of any entity is in general made by indirect means (e.g. modelling).

The key considerations as regards to monitoring are:

- The definition of the monitoring strategy and related programme (When? Why? What? Where and How?).
- The soundness of the monitoring programme through a clear identification of its purpose, its limitation and its contingencies.
- The balance between data demands and constraints.

b. **What does monitoring mean?**

From the oral presentations, various definitions or categorisations are being suggested according to the national context and corresponding objectives for monitoring. In some cases, additional words e.g. "surveillance, compliance monitoring, observation..." are utilised in order to better distinguish each of the aims of monitoring activities. In addition, other languages may not have exact matches to any of these English-language terms. The followings list an example of definitions from the various presentations:

- OPG definitions *"see report N° 06819-REP-01200-101106-R00"*

  "Monitoring is the continuous or intermittent observation and recording of condition; in the case of a Deep Geological Repository three categories are suggested:
  - *Baseline Monitoring: to collect initial data about the site conditions for a deep geologic disposal (DGR) facility before any significant site disturbance has occurred in order to have a baseline with which to compare all subsequent compliance and performance monitoring observations and measurements.*
  - *Compliance Monitoring: to ensure that all institutional control long-term (LT) requirements for a DGR are met that involve worker, public and environmental safety.*
  - *Performance Monitoring: to assess the LT validity of the implemented design for a DGR relative to its specific requirements and its intended purpose and to build confidence in the understanding of physical and chemical behaviour processes."*

- Andra definitions *"see slides of the oral presentation at the topical session"*

  "Three main motivations:
  - *Respect of operational safety and regulatory requirements*
  - *Acquisition of data to allow a deeper understanding of processes; models and parameters for LT safety*
  - *Reversibility*

  Two main distinctions:
  - *Observation: linked to giving information for scientific and engineering understanding and the reversibility process*
  - *Surveillance: for operational safety (Classical and nuclear operational safety "Early warning" allowing for needed flexibility to conduct unscheduled maintenance work)"*

- <u>EC definition</u> *" ref: EUR 21025 Thematic network on the role of monitoring in a phased approach to geological disposal of radioactive waste"*

  "The monitoring is continuous or periodic observations & measurements of engineering, environmental, radiological or other parameters and indicators/characteristics, to help evaluate the behaviour of components of the repository system, or the impacts of the repository and its operation on the environment, and to help in making decisions on the implementation of successive phases of the disposal concept".

- <u>IAEA definitions</u>

  In the *IAEA TECDOC 1208 report on "Monitoring of geological repositories for high-level radioactive waste"* ***of 2001,*** monitoring is: "*continuous or periodic observations or measurements of engineering, environmental or radiological parameters, to help evaluate the behaviour of components of the repository system, or the impacts of the repository and its operation on the environment.*"

  In the *IAEA Safety Series report No. 35, on "Surveillance and Monitoring of Near Surface Disposal Facilities for Radioactive Waste"* ***of 2004,*** **monitoring** is defined as "*The measurement of dose or contamination for reasons related to the assessment or control of exposure to radiation or radioactive substances, and the interpretation of the results" and* **surveillance** is defined as "*Activities performed to ensure that conditions at a nuclear facility remain within the authorised limits. For a near-surface repository, surveillance normally continues past the periods of operation and closure".*

c. **<u>How is monitoring handled in national programmes?</u>**

In Finland, Posiva's technical concept for spent fuel disposal is based on passive safety. After the disposal is done, the plan is to close and seal all the access ways to the repository, and the design of the repository system should provide all the necessary safety functions after that. Passive safety is also required by the existing rules and regulations in Finland. Nevertheless, both the Nuclear Energy Act and the specific regulations foresee the possibility of some kind of post-closure monitoring for some period of time. The reasons for these stipulations seem to be related mainly to the safeguards needs, but in the discussions around the Environmental Impact Assessment the desire for long-term monitoring was also related to safety purposes. In any event, according to the present rules the responsibility for post-closure monitoring is left to the State.

Taken the present rules and regulations, Posiva Oy is not planning to rely on post-closure monitoring in the safety cases that will be prepared for the application of the construction license. However, Posiva Oy has implemented a programme for monitoring the effects of the construction and operation of the ONKALO underground rock characterisation facility, the excavation of which started in September 2004. Particular monitoring needs arise from the fact that the ONKALO is being constructed at the actual repository site and it is intended to become a part of the repository.

The main objectives of the ONKALO monitoring programme are related to the need for observing and controlling the changes that will occur in the host rock and surface environment because of the construction and operation activities. The pumping of the inflowing groundwater from the ONKALO means that the ONKALO also acts as a large-scale pumping test, and the monitoring system is needed to collect the information about the related hydraulic and geochemical response of the environment.

The monitoring programme extends to several areas: Geohydraulic, hydrogeochemical and rock mechanical measurements are carried out to follow the changes in the bedrock; in addition an extensive programme is devoted to monitoring possible effects in the surface environment. The main concern is about possible changes in groundwater salinity in the repository host rock. The inflow to the tunnel will probably lead to an up-coning effect of the more saline groundwater under the planned repository. One important objective of the monitoring system is to enable early warning about major changes in the salinity conditions.

In the present mode the role of the ONKALO monitoring system is mainly confirmative and controlling: confirmative as it may increase understanding of the function and long-term relative stability of the host rock; controlling as it enables early observation of changes with negative bearing on long-term safety. Whether it could also be used to provide support for some performance models of the EBS is yet to be developed. In any case, at the moment the direct monitoring of repository performance is not considered possible without seriously compromising safety functions of the disposal concept. Of course, technical developments may change the situation in the future. Posiva Oy is monitoring such developments internationally.

In US, and in particular for the DOE Yucca Mountain repository, monitoring is considered to be a significant element in the Performance Confirmation (PC) programme that focuses on the performance and functionality of the disposal system for the purposes of the licensing decision. Other testing and monitoring programmes may deal with other considerations such as increasing confidence or system optimisation aspects.

The purpose of the performance confirmation is:

- to develop a program of tests, experiments, and analyses to evaluate the adequacy of the information used to demonstrate safety , and
- to demonstrate that the system and the sub-system components (i.e. barriers) are operating as anticipated.

The performance confirmation activities are classified depending on their purpose e.g. engineering testing and evaluation (to verify the robustness and performance of engineered barriers), science testing and evaluation (to confirm modelling capacity, data etc.). For the license update to allow closure, there is a need to show that safety is still to be expected after closure, and that what has been said has been done.

US-DOE has developed a decision analysis approach with aims as followed**:**

- to provide a consistent and sound basis for evaluating and comparing performance confirmation activities;
- to use a formal multi-attribute utility analysis in its first phase to develop test and monitoring "portfolios" and in the second phase for management use. Phase one aims to assess the candidate activities against activity evaluation criteria (defined by the initial workshop participants consisting of technical investigators and performance assessment (PA) analysts and managers). During dedicated workshops, those participants estimate the utility of a specific activity, PA managers providing the necessary management value judgements by reviewing the overall utility. Phase two aims at developing and evaluating alternative portfolios (each candidate activity must demonstrate compliance with basic regulatory requirements and additional requirements such as cost-effectiveness, regulatory robustness and coverage). Phase three consists of selecting portfolios, and phase four consists of

updating the program by, for instance, adding one or more activities on the basis of new information (flexibility principle).

The performance confirmation activities plan will be regularly revaluated and updated. Actually, from twenty activities, eleven were begun during the site characterisation (e.g. unsaturated zone testing) two of them will be carried out during the construction phase (e.g. seal testing) and seven activities will begin during operations (e.g. corrosion testing, drift inspection).

The path forward for the Yucca-Mountain-DOE performance confirmation is mainly to define activities (what, when, where and how), to establish the expected baseline for performance confirmation activities (required by regulator), to identify and develop test plans and procedures, to develop an integration group to asses data as a whole, and to define process for defining, detecting and reporting variances and for deciding on the appropriate action.

In France, with regards to the monitoring of a reversible repository in a clay host formation, **Andra** utilised international references as input to develop its own strategy and program, e.g. IAEA TECDOC 1208 and DS-154 2004, NEA 2001(reversibility and retrievability), EUR 21025 EN. Additionally, the French safety rule RFSIII.2.f, which aims to provide guidelines but is not a regulatory requirement, deals with "general provisions concerning explorations". The RFSIII.2.f distinguishes between exploration conducted from the surface, investigations to be carried out in the Underground Research Laboratory (URL) and monitoring of changes in the site while the repository is in operation.

The monitoring programme responds to the three main motivations:

1. the respect of operational safety and regulatory requirements;
2. the acquisition of data to improve the understanding of processes and parameters underlying the long term safety assessment; and
3. reversibility.

In that respect, Andra defines monitoring terminology by distinguishing two main activities: (i) observation (for scientific and engineering understanding and reversibility) and (ii) surveillance (related to operational and long term safety).

Surveillance to contribute to the operational safety of a repository, e.g. surveillance of drift stability, fire and radiological hazards, is in line with other classical and nuclear operational safety principles and practices.

Surveillance to contribute to long term safety can provide input to periodic re-evaluations of the safety analysis of a geologic repository, with a view of improving system understanding and confirming data in situ, prior to final closure of the repository. As such, it is in line with the usual regulatory guidance for Nuclear Power Plant (NPP) facilities. While it will not provide direct data on the long-term evolution of the system, it may provide some data, for example related to initial conditions or to an early transient phase, for implementation into long-term evolution models.

This type of surveillance should not be considered as a way to compensate for the lack of knowledge at a previous stage. Indeed, enough confidence in models and parameters contributing to a safety case will have been acquired, for instance in a URL, prior to authorisation and operation of a repository. Such prior knowledge, however, can not be tested on the full pre-closure time scale or length scale of a repository.

The observation of host rock and repository component evolution provides information to stakeholders throughout the pre closure period. Such added knowledge may contribute to improve stakeholder confidence in the process. It is taken into account to support the decisions pertaining to a step-wise, reversible repository management. For example, it may support a decision for disposal cell closure, it allows evaluating the feasibility of waste retrieval at successive stages of a stepwise closure, and it may contribute to update the design of disposal cells or access drifts yet to be built.

Monitoring activities are subject to repository-specific constraints such as: materials must not interfere with operational safety; material must not reduce long term safety significantly; materials must operate under expected environmental conditions. The establishment of monitoring activities will draw on similarities with other systems that are subject to monitoring activities (e.g. monitoring of concrete and clayey structures in dams, steel structures in pipelines, railway tunnels, etc.). The key lessons from those activities point to the importance of the correct interpretation of measurements and the need for redundancy, as well as for pre-testing and careful installation of monitoring equipment. The selection criteria for adequate monitoring methods include safety, robustness and ease of integration in an automatic data acquisition network.

Andra outlined a potential and preliminary monitoring strategy, as part of a repository feasibility study. It is based on available experience gained in other large civil engineering projects. Some of the key elements are as follows. The strategy acknowledges the need to compromise between needs and constraints. It focuses monitoring efforts on a few representative waste disposal cells. It takes into account the evolving nature of a monitoring programme throughout the step-wise process of the pre-closure period. The long term performance of safety functions should not be degraded by monitoring equipment and activities.

As a conclusion**,** monitoring can be viewed as a way to inform the safety case and to provide additional arguments to build confidence in a safety case. It also helps to assess regulatory compliance during the operation phase in line with other nuclear and other classical practices. However, monitoring during the operational period is not intended to support the pre-operational safety case and, therefore, it does not aim to compensate for a lack of confidence in the results of the site characterisation, or the URL experiments. Monitoring is an additional level of the defence-in-depth approach, using technical know-how when available and adapting it to the specific context of deep geological repository.

In Canada, the deep geological repository (DGR) concept presented for a federal environmental assessment (study from 1990-1997) included an overall monitoring approach, which avoided intrusive long-term monitoring that could compromise system safety. A review panel considered that the concept was technically safe but stated that *"… a system of early detection of failures, inside the vault or close to it, should be built into the defence-in-depth approach."* It was recommended that a "modified AECL concept" be adopted, which would include better technologies for safe post-closure monitoring and retrieval. Presently, there are no specific regulatory expectations on monitoring for a DGR; CNSC S-224 provides expectations on nuclear facility environmental monitoring.

In accordance with the two main repository programme phases, two categories of monitoring could be defined:

1. The pre-closure monitoring with the following objectives:
    - Obtain data to assess site suitability and establish baseline for identifying repository effects.

- Demonstrate that repository meets regulatory compliance, performance, and safeguards requirements.
- Detect performance problems so that corrective actions can be taken.
- Allow stakeholders to gain sufficient confidence in performance/safety of repository to proceed to closure.

2. The post-closure monitoring with the following objectives:
   - Demonstrate that the repository continues to meet compliance, performance, and safeguard requirements.
   - Support assumptions made in the safety case.
   - Detect anomalous behaviour so that remedial actions can be taken as necessary.
   - Allow stakeholders to gain confidence in safety of the closed repository.

OPG's strategy on monitoring consists of an approach that covers all phases including long-term monitoring options. This would be a staged approach, with detailed/invasive tests early, and then gradually less intensive/intrusive monitoring as confidence is increased in the repository performance. There would be an extended monitoring phase after operations (e.g. 70 years) in which underground access would be maintained. After closure, any further long-term monitoring would not compromise the passive safety.

d. **What are the regulatory expectations on monitoring?**

Considering regulations expectations in Sweden, SKI presented an example of the evaluation of the role of monitoring in the context of performance confirmation (PC) for the engineered barrier system. A series of long-term experiments in the Äspö hard rock facility (prototype repository, backfill and plug test, long-term buffer experiments) have PC related objectives even if PC does not have a formal role in the same way as in the US programme (PC is defined in USNRC 10CFR Part 63 as: *"the program of tests, experiments and analyses, conducted to evaluate the adequacy of the information used to demonstrate compliance with long-term safety standards for a geological repository.")* The performance confirmation is not mentioned in the Swedish regulations and on monitoring SKIFS 2002 merely provides the following requirement "the *impact on safety measures that are adopted to facilitate monitoring or retrieval ... shall be analysed and reported…"*

A series of workshops about KBS3-EBS has been organised by SKI in order to evaluate different aspects of SKB's programme for development of engineered barriers. In view of testing the performance confirmation (PC) approach to the Swedish context, one of them considered the performance confirmation related activities at the Äspö facility. The other workshops have considered the isolation concept in general and manufacturing as well as testing. The format of these workshops consisted of presentations, questions and informal hearing of the implementer SKB and a summary of SKI's impressions from SKB's responses.

The presentation focused on main conclusions of the workshop dealing with the performance confirmation for the engineered barrier system that took place in 2004. Even direct confirmation of long-term safety can not be achieved, information about certain aspects of the EBS evolution can probably be achieved within a reasonable timescale (early saturation behaviour, thermal evolution, and early chemical evolution). Such results might confirm or contradict the predictive models.

Performance confirmation and long-term monitoring were in general considered as helpful methods to reveal any unexpected feature in the behaviour of the key repository components. The experience gained from the PC and other testing has been valuable in the sense that it has increased the understanding of processes that may occur in a radioactive waste repository and has also enabled the development and demonstration of engineered techniques (e.g. canister emplacement). In a mature programme, almost all activities are related to performance confirmation and may be integrated in a wider programme of Research and Development (R&D) repository development and safety assessment. The Swedish regulators will evaluate the PC activities but most probably will not establish prescriptive PC criteria. Regarding monitoring, it was observed during the workshop that the sufficiency of ongoing long-term experiments may depend on the type and intensity of monitoring during repository construction and initial operation. Monitoring is seen to contribute to confirmation of site specific models but also to inform a decision to continue from initial operation of the repository to regular operations. A demonstration tunnel (a temporary facility in a future repository which would enable e.g. instrumentation of the buffer in spite of real fuel canisters emplaced) should be considered, since it might be an efficient method to meet PC objectives. With regards to further preparations for license application reviews, the workshop suggested developing comprehensive detailed plans tailored to the review of each particular application, establishing a working group devoted to issues related to the buffer and backfill, and assessing in more detail specific examples of SKB's conduct of experiments and modelling work aimed at demonstrating predictive modelling capabilities and confidence building.

1. International projects on monitoring

The EC thematic network on the role of monitoring in a phased approach to the geological disposal of radioactive waste[1] brought together expertise from twelve organisations from ten countries. It was started in 2001 following on from an earlier EC study of retrievability and reversibility (EUR 19145 EN), and completed in 2004 with publication of the final report (EUR 21025 EN).

The project mainly aimed to:

- Understand the approaches to monitoring in each national programme and their dependency on concepts & approaches.
- Distil consensus views and recognise alternative approaches to monitoring.
- Share technical knowledge and experience.
- Communicate views and experiences.

Participants from the projects looked at various definitions of monitoring in relation to a phased approach to disposal, and achieved a consensus on the following: *"Continuous or periodic observations & measurements of engineering, environmental, radiological or other parameters and indicators/characteristics, to help evaluate the behaviour of components of the repository system, or the impacts of the repository and its operation on the environment, and to help in making decisions on the implementation of successive phases of the disposal concept"*. That definition is mainly based on an IAEA definition with a few modifications and, in particular, by adding the fact that monitoring has a role in making decisions**.** Various alternative approaches to make decisions and achieve goals were analysed and the need was stressed for a flexible schedule with a degree of concept flexibility.

1. Excerpt of the NEA confidence document of 1999 *"discrete, easily overviewed steps [that] facilitate the traceability of decisions, allow feedback from the public and/or representatives, promote the strengthening of public and political confidence in the safety of a facility along with trust in the competence of the regulators and implementers of disposal projects."*

The project achieved a consensus on the following principles:

(i) monitoring has a role in underpinning and verification of operational safety (compliance monitoring);

(ii) long-term (post-closure) safety must be assured by design

- it cannot rely on monitoring, although monitoring may be implemented for other reasons
- monitoring must not be detrimental to long-term (post-closure) safety

(iii) monitoring within a phased approach to disposal will inform decisions about moving to the next phase, and will need to encompass wider societal considerations;

(iv) monitoring post-closure may be implemented – it will be maintained for as long as society requires.

The project also provided the following relevant reasons for monitoring: part of scientific investigation programme, safety demonstration, regulatory requirements, nuclear material safeguards, confirmation of key assumptions (in view of post closure safety) and confidence building.

As conclusions the Thematic Network achieved the following main findings**:**

- technology for monitoring already exists and is being implemented in various national programmes. Technologies do have limitations however and these need to be understood;
- the monitoring activities will be different according to the phase reached within the phased disposal programme, and implementers should recognise that the monitoring objectives and techniques will change as they progress through the various phases;
- monitoring activities should be implemented within the framework of a strategy developed to meet the needs of the national programme and societal expectations.

The IAEA provided information on various reports on monitoring issues that are in progress or close to publishing. Monitoring is viewed through safety standards, e.g. RQ 20 on geological disposal. In that document, two paragraphs present the place of monitoring within the step-by-step process, aiming to avoid compromises with the overall level of post-closure safety.

The IAEA is developing a new safety guide DS-334 on geologic disposal discussing the whole life cycle of a geological repository including the safety case and design development, site characterisation, construction, operation, closure, and the post-closure control of the repository. Some sections will also touch on monitoring. Various existing materials are used as sources for establishing the DS-334: the DS-62 (its draft is close to completion on strategies for monitoring), the IAEA technical report on monitoring (monitoring purposes and using monitoring information) and the safety report No.35 on "surveillance and monitoring". This last report looks at the potential linkage between surveillance and monitoring, going through the various phases. Some definitions of the related terms are discussed.

The forthcoming DS-334 will be submitted to the Waste Safety Standards Committee (WAASC) in October 2005 for approval to send to Member States for review. A possible safety report on surveillance and monitoring of geological disposal facilities could be then undertaken.

3. OUTCOMES

- **Terms and concepts**

On the basis of the presentations and discussions at the Topical Session it is evident that various contents and meanings are attached to terms such as monitoring and surveillance. A distinction is usually made between specific monitoring activities and the site characterisation work in general, but the distinction is not always there. As noted in the EC report "on the role of monitoring in phased approach to the geological disposal of radioactive wastes", only repetitious observations or measurements are usually considered as monitoring.

Further, the term "monitoring" in this Topical Session was mainly used for those tests and experiments that were carried out at the real site of the repository, but in some presentations a more general context was taken. Some participants made a sharp distinction between monitoring and surveillance – surveillance meaning broadly the same as "compliance monitoring" and only applicable to licensees – but this distinction may be partly due to the different usages of similar words in different languages.

In addition, it turned out that different definitions were used in various IAEA documents. In some IAEA documents "monitoring" was narrowly related to doses and contaminants only, whereas in other documents a broad definition similar to that endorsed by the EC project was proposed. According to the IAEA usage, "surveillance" was only related to monitoring of compliance.

There also seemed to be some differences in how the scope of the topical session was understood. Some speakers were looking for direct input to safety case from monitoring, whereas others included various indirect considerations as well.

- **Need for monitoring**

There was consensus that pre-closure monitoring is needed. There was also a consensus that the case for long-term safety cannot rest on monitoring Indeed, one key issue concerns the possible interference of monitoring activities with the performance of the disposal system.

Some regulations explicitly denounce any monitoring activity that might affect ("compromise") the long-term safety of the repository, whereas some others leave the door open for some impact as long as it is not significant. In some countries monitoring plays an active role for decision-making and important decisions to move on in the programme will be subject to information from the monitoring activities. In other countries it may have a more or less complementary or confirming role without pre-planned connection to the decision-making process.

However, even in the latter case the programmes will have to allow for the possibility that the monitoring activities bring out information that needs to be taken into account in the implementation. In that sense, any fixed or "linear" design is hardly possible in the long-run, instead, all programmes have to adapt to new information whenever it may appear (flexibility principle). However, different approaches to monitoring may be linked to different geologic media: the risk arising from an abandoned repository may be less for repositories in clay or salt media where self-sealing is possible than for repositories in crystalline rock, where an open access way to the repository is not desirable for passive safety.

- **Roles of monitoring in a safety case**

The monitoring can play various roles in safety cases depending on the step where the programme stands but also on the specific objectives attached to the monitoring programme. Three types of monitoring objectives may be distinguished:

The compliance monitoring:

- to check that the rules and regulations are followed and the actual construction/operation take place according to accepted plans and designs,
- to check that the conditions in the repository and host rock are within expected/approved limits, and
- to ensure that some basic assumptions behind the safety case continue to be valid.

The monitoring for the explicit support of a safety case:

- to obtain qualitative evidence and build confidence – or actually confirm the performance (Performance Confirmation): This may take place in the actual repository using actual waste packages or it may be located in a separate testing ground (possibly at the same site as the actual repository). In the former case, care must be taken to avoid any harmful effects on the site or repository. In general, the possibilities for proving the safety functions of the repository by monitoring activities are judged to be limited by using existing technology, but future developments may relieve some of the present constraints.

The monitoring to detect system/component failures:

- In many countries, the public is interested in disposal systems that – although passive – would still be repairable if observed to fail. Therefore there is interest in monitoring that is able to detect failures. As noted above, technology may not be available for such purposes today, but future technical developments may produce some means to that effect.

Independent of the precise objectives, in the present thinking monitoring activities are considered as a way to inform the safety case but not as a way to compensate for a lack of data. Each decision step must be supported by an adequate amount of information. Subsequent decision steps may be better informed because of monitoring and performance confirmation type activities, but this does not mean the basis for the previous decision step was allowed to be inadequate for that step.

- **Broader perspective**

Besides purely technical reasons, monitoring activities are presently planned as a tool in the stepwise process in which programme decisions are tied to the amount of information and the level of public trust. Comparisons of the observations from the site or the repository system with the predictions and assumptions are thought to contribute to increasing confidence by the public and other stakeholders including decision-makers in the safety of the repository. Such monitoring activities will be useful and even indispensable, but, still, the public may call for more. The call may be for direct demonstration of the repository functions or more control of the future evolution of the repository system.

The request for control is generally expressed in the requirements for retrievability or reversibility and is consistent with the general trend in societal risk discussion to move from assessment and acceptance of risks to the management of risks. Instead of mere acceptance of the proposed risk, means are sought to alleviate the risk should it ever be realized.

The call for direct demonstration of repository functions or for detection of failures would mean higher demands on monitoring techniques. So far, it seems that monitoring can give only indirect or delayed evidence of the correct functioning of the repository system. For more direct proofs new technologies should be developed and tested and active decisions would be needed to invest in such developments.

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PART B

COMPILATION

OF

ORAL PRESENTATIONS

6^{th} MEETING OF THE IGSC

THE ROLE OF MONITORING IN A SAFETY CASE

Point 7.1

J.Alonso

(ENRESA)

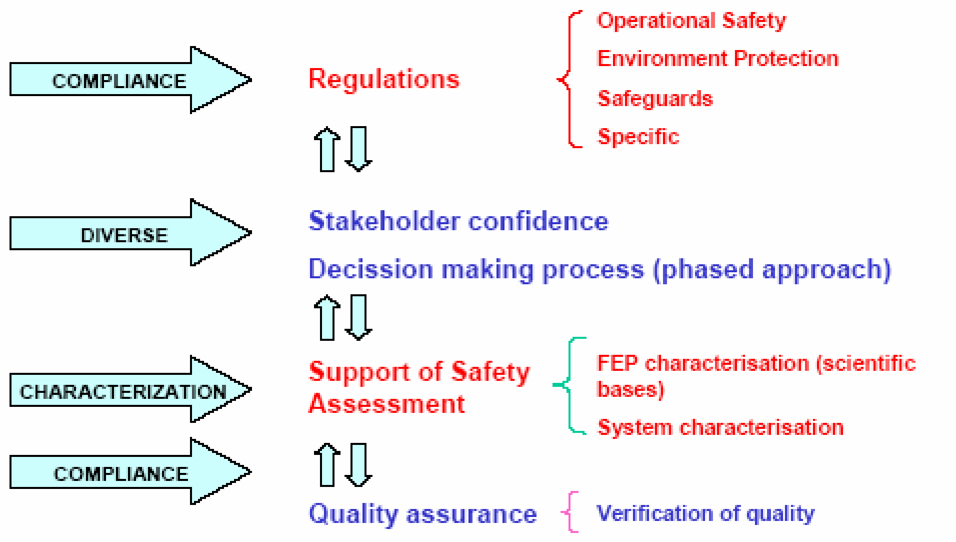
Paris 2-4 November 2004

Scope of IGSC interest on monitoring

- Monitoring vs Safety Case
- Parameters characterising FEP's
- Succesive repository phases
  - Planning (incl. Scientific studies)
  - Site characterisation
  - Construction
  - Operation
  - Post-emplacement
  - Closure
  - Post-closure

Paris, 2-4 November 2004 6^{th} Meeting of the IGSC. The Role of Monitoring in a Safety Case

Bases for monitoring / Sources of requirements



Paris, 2-4 November 2004 — 6th Meeting of the IGSC. The Role of Monitoring in a Safety Case

Types of Monitoring in relation with Safety Assessment

Characterisation

- Phenomenological understanding
- Site description
- Material specification
- System definition
- Predictive modelling

Compliance with requirements

- As required by regulations
- Conformity of activities with specifications

Performance confirmation (agreement with predictions)

- Post-closure Safety is based on predictive modelling
- Passive system (but evolving)
- System robustness
  - Multibarrier principle
  - Uncertainty analysis

Paris, 2-4 November 2004 — 6th Meeting of the IGSC. The Role of Monitoring in a Safety Case

Constraints

- Primordial functions of the repository system

  Provide Safety, especially long term Safety

  but: confidence in Safety is required

- Passive system (post-closure phase)
- Technological development
- Spatial scales: variability / uncertainty
- Time frames

  Evolving environment { Physical, Program, Decissional, Societal/Technical }

  Implementation over/after long periods of time

  Slow evolution of key processes

Paris, 2-4 November 2004 — 6th Meeting of the IGSC. The Role of Monitoring in a Safety Case

Key issues

- Definition of the monitoring programme in the phased approach
  - When?
  - What?
  - Where?
  - How?
- Soundness
  - Hierarchy of objectives
  - Clean identification of:

    Purpose - use

    Limitations

    Contingencies
- Balance between data demands and constraints

Paris, 2-4 November 2004 — 6th Meeting of the IGSC. The Role of Monitoring in a Safety Case

Thematic Network on the role of monitoring in a phased approach to disposal

Steve Barlow

Head of Assessments

UK Nirex Ltd

nirex

Two key issues within the radioactive waste management community are:

- Reversibility and Retrievability

  Concerted Action on retrievability of long-lived radioactive waste EUR19145 EN
- Phased approach to disposal

Thematic Network on the Role of Monitoring in a Phased Approach to Disposal

- 5th EURATOM Framework Programme
- Commenced 1 September 2001
- Participants: 12 organisations from 10 countries
- Final report published March 2004
  - Thematic network on the role of monitoring in a phased approach to geological disposal of radioactive waste EUR21025 EN

Participants

- Nirex, UK
- ANDRA, France
- DBE, Germany
- Enresa, Spain
- Nagra, Switzerland
- NRG, the Netherlands
- ONDRAF, Belgium
- Posiva, Finland
- RAWRA, Czech Rep.
- SCK-CEN, Belgium
- SKB, Sweden
- SAM, UK

Aims of the Project

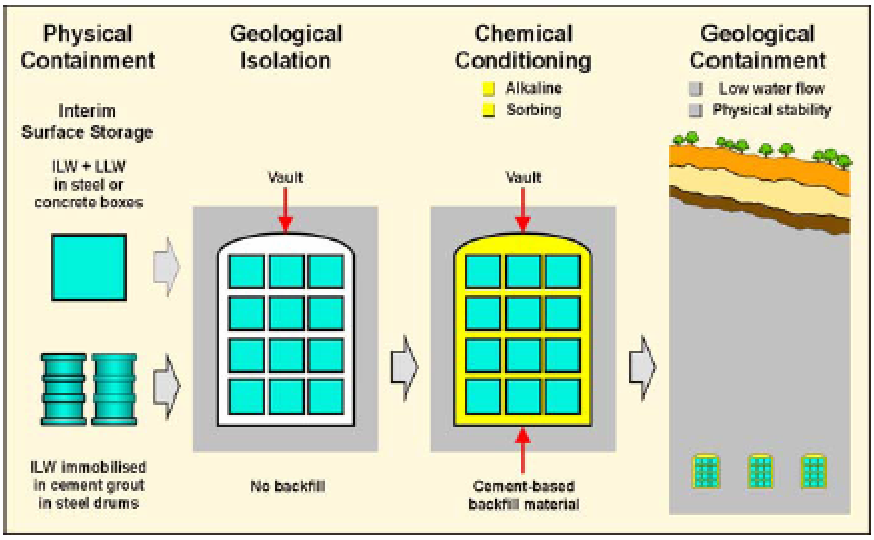
- Understand the approaches to monitoring in each national programme and their dependency on concepts & approaches;
- Distil consensus views and recognise alternative approaches to monitoring;
- Share technical knowledge and experience;
- Communicate views and experiences.

Phased Approach to Disposal

"discrete, easily overviewed steps [that] facilitate the traceability of decisions, allow feedback from the public and/or representatives, promote the strengthening of public and political confidence in the safety of a facility along with trust in the competence of the regulators and implementers of disposal projects."

NEA, Confidence in the long-term safety of Deep Geological Repositories. 1999.

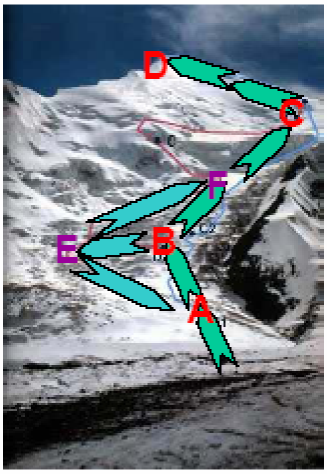
Phased Approach to Disposal



Monitoring

Continuous or periodic observations & measurements of engineering, environmental, radiological or other parameters and indicators /characteristics, to help evaluate the behaviour of components of the repository system, or the impacts of the repository and its operation on the environment, and to help in making decisions on the implementation of successive phases of the disposal concept.

Achieving the Goal



Alternative Approaches

- Linear staging i.e. a clear schedule.
- Adaptive staging i.e. a flexible schedule.

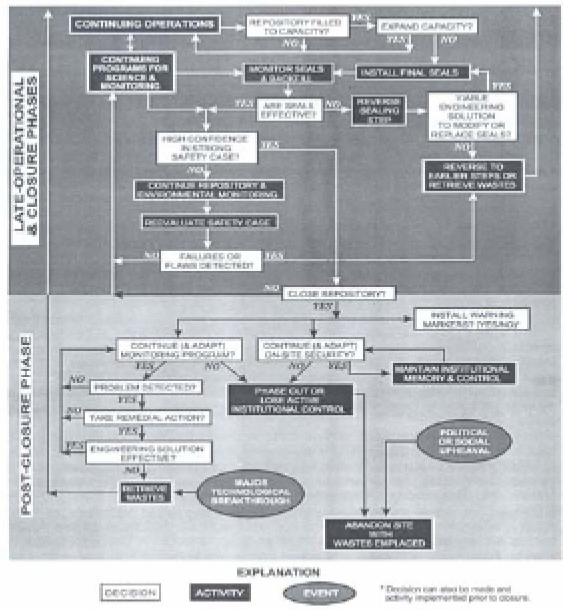
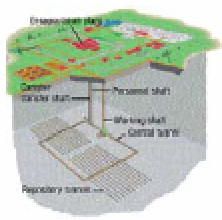


FIGURE 4.3 Committee's examples of decision tree and activities during the late operational, closure, and post-closure phases of a repository program using Adaptive Staging. A variety of monitoring activities is ongoing during these phases.

So is a Consensus Possible?

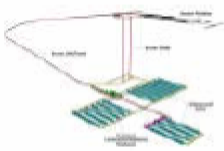
France

Yes, but there is not one answer that fits all



Finland

Sweden



UK

Principles and consensus

- Monitoring underpins & verifies operational safety;
- Long-term safety cannot rely on monitoring;
  - undue burdens should not be placed on future generations
  - cannot assume that they will have capability
- Long-term safety must be assured by design;
- Monitoring must not be detrimental to long-term safety;
- Societal role must be acknowledged
  - monitoring may be carried out for non-technical reasons
  - monitoring may be continued as long as it is required

Reasons for Monitoring

- Scientific and technical investigation programme;
- Demonstrate safe operation of the facility;
- Nuclear material safeguards;
- Confirmation of key assumptions;
- Maintaining the confidence of society (today's or tomorrows)

Report Structure

- Introduction
- Previous work and background
- Strategic aspects of monitoring
- Monitoring from different perspectives
- Monitoring requirements and constraints
- Monitoring methods and techniques
- Summary and conclusions
- Country Annex's

Main Findings from TN

The broader aspects must be acknowledged.

Whilst technology exists limitations must be understood;

Have an explicit reason for monitoring;

Monitoring will be different between stages;

Develop the strategy within the full context of the problem;

ROLE OF MONITORING IN POSIVA'S PROGRAMME FOR SPENT FUEL REPOSITORY

Juhani Vira

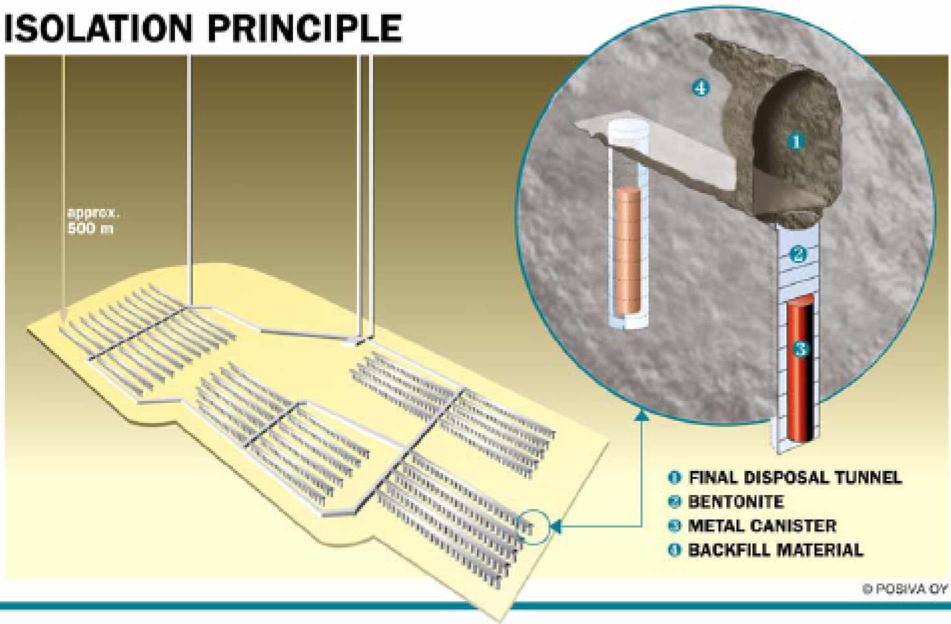
Posiva Oy

NEA/IGSC Meeting on 3 November, 2004

10/2004

KBS-3 CONCEPT

ISOLATION PRINCIPLE



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…

BASIC REQUIREMENTS

- ”Disposal shall be planned so that no monitoring of the disposal site is required for ensuring long-term safety …”
- ”…implementation of spent fuel disposal includes the following phases: ….post-closure monitoring, if required”
- ”…potential post-closure surveillance actions shall not impair the long-term safety”.

(Source: Government Decision 478/1999; STUK YVL Guide 8.4)

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FURTHER NOTICES

- according to the Nuclear Energy Act the possible post-monitoring measures will be defined by the Government
  - STUK YVL Guide 8.4 says the design of the repository must enable measures to preclude actions on repository which would jeopardise safety or effect of safeguards measures
- need for post-closure monitoring was frequently voiced during the EIA discussions
  - the Ministry of Trade and Industry has promised to clarify their position by the time of construction of the repository

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IT IS ALSO REQUIRED THAT

- "The design, excavation, other construction and closure of the underground facility shall be implemented in the best manner with regard to retaining the characteristics of the host rock that are important to long-term safety."

(Source: Government Decision 478/1999)

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IMPLICATIONS FOR POSIVA

- safety concept may not rely on monitoring
- design features with bearing on long-term safety may not be compromised for monitoring purposes
- disposal site must be kept "sufficiently open" for observations
- presently no plans for post-closure monitoring (until further guidance/requirements)
- the disturbance due to excavation (and other implementing actions) to the host rock must be minimised (and this has to be proved)

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CURRENT PROGRAMME STATUS

ONKALO UNDERGROUND ROCK CHARACTERISATION FACILITY

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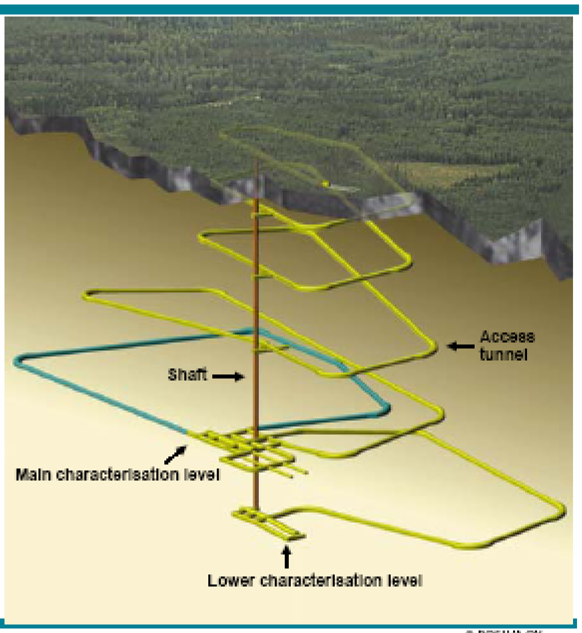
ONKALO: UNDERGROUND CHARACTERISATION AND RESEARCH FACILITY (UCRF)

TECHNICAL INFORMATION

- Excavation volume 330,000 m³
- Access tunnel
  - length 5.5 km
  - inclination 1:10
  - size 5.5 x 6.3 m
- Total length of tunnels 8.3 km
- Diameter of shaft 6 m
- Characterisation levels
  - at a depth of 420 m (main characterisation level)
  - at a depth of 520 m

SHOULD BECOME A PART OF THE REPOSITORY!



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ONKALO MONITORING PROGRAMME: OBJECTIVES

- aims at
  - observing changes in host rock that can be of importance for the long-term performance of the repository or its assessment
  - obtaining data that can help in understanding local features and processes
  - obtaining information on the response of rock to construction activities (”large-scale pumping test”)
  - obtaining information of relevance to environmental impact or occupational health and safety
- reference: the current baseline reported in 2003

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ONKALO MONITORING PROGRAMME: PRIORITIES

- survey of processes that may be induced by ONKALO construction activities indicated 24 processes of high significance
- safety concept puts main emphasis on
  - relative stability of the host rock conditions (predictability)
  - long-term isolation by the engineered barrier system
- main concerns
  - inducing adverse hydrogeochemical conditions (in particular salinity changes)
  - chemical messing of the site conditions (introduction of harmful chemical substances)

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ONKALO MONITORING PROGRAMME: REQUIREMENTS (3)

- monitoring system should reveal
  - changes in groundwater salinity conditions at the planned repository depth
  - unintended fast pathways from/to repository area
  - anomalous chemical or hydraulic characteristics
  - anomalous rock-mechanical conditions

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IMPLEMENTATION: GEOCHEMISTRY

- sampling from open deep boreholes
- sampling and online measurements in multi-packered deep boreholes
- sampling from groundwater observation tubes and shallow boreholes
- sampling and online measurements of tunnel inflow water
- sampling and online measurements at ONKALO groundwater stations

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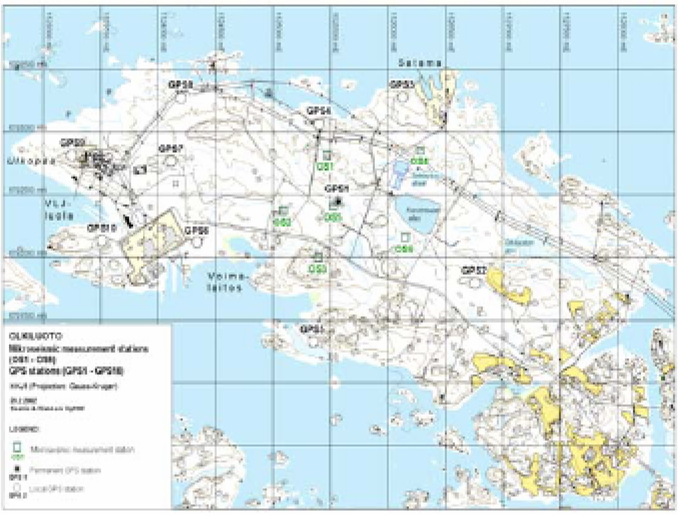
IMPLEMENTATION: ROCK MECHANICS

- GPS-network
- microseismic net-work
- precise levelling
- extensometers
- convergence measurements
- loads on rock bolts
- stress changes
- rock damage (AE)
- temperature



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IMPLEMENTATION: HYDRO(GEO)LOGY

- precipitation, infiltration, run-off (incl. snow and ground frost measurements)
- groundwater table
- hydraulic head
- fracture flow
- ONKALO water balance
- evolution of saline water interface

10/2004

IMPLEMENTATION: SURFACE ENVIRONMENT

- vegetation inventory and properties
- animal inventory
- aerial and satellite imagery
- noice
- drinking water quality and water table (private wells)
- sea water quality and water table

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USE OF MONITORING INFORMATION

- further characterisation of the site properties
  - learning from prediction-outcome comparisons
  - learning from the response to construction activities (e.g.,large-scale pumping effects)
- part of the Quality Management System (QMS)
  - set to comply with requirements for nuclear facilities
- control of disturbances
  - expected range of observations defined
  - action levels defined
  - decision procedures defined for response to safety-critical information (CEIC = Coordination of Engineering Design, Investigations and Construction)

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MONITORING AND SAFETY CASE

POTENTIAL ROLES:

- confirmative: enhances the understanding of the site characteristics
  - to support the description of the site evolution and to assess the future stability of site conditions
- controlling: helps control the disturbance caused by the construction and operation activities
  - to allow reliance on the (positive) site properties required by the safety concept
- indicative: may give supporting (or disqualifying) information on the function of the site for the performance assessment
  - e.g., redox, pH buffering, rock mechanical behaviour
- reassuring: could strengthen the public trust in safety of disposal (help manage the risk)

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MONITORING: PERSPECTIVES

- at the present mainly confirmative and controlling roles
- in the future may provide limited evidence on the function of important processes in the rock
- information about the performance of the EBS would be appreciated but cannot be promised, yet
  - with the present technology this would require that some parts of the repository be kept open (which would most likely be against STUK safety requirements)
  - however, there is time to develop methods
- monitoring of the (int'l) technical and institutional developments is important!

10/2004

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

YUCCA MOUNTAIN PROJECT

A Performance Confirmation Program Planning Approach

Presented to: **Integration Group for the Safety Case, Sixth Plenary Meeting, Topical Session on Monitoring**

Presented by: **Abraham van Luik**
Prepared by: **Deborah Barr**
Office of Repository Development
U.S. Department of Energy
Las Vegas, Nevada

November, 2004
Paris, France

Outline of Presentation

- **Objectives of a Performance Confirmation Program**
- **Testing and Monitoring Categories**
- **Decision Analysis Approach**
- **Performance Confirmation Activities**
- **Path Forward**

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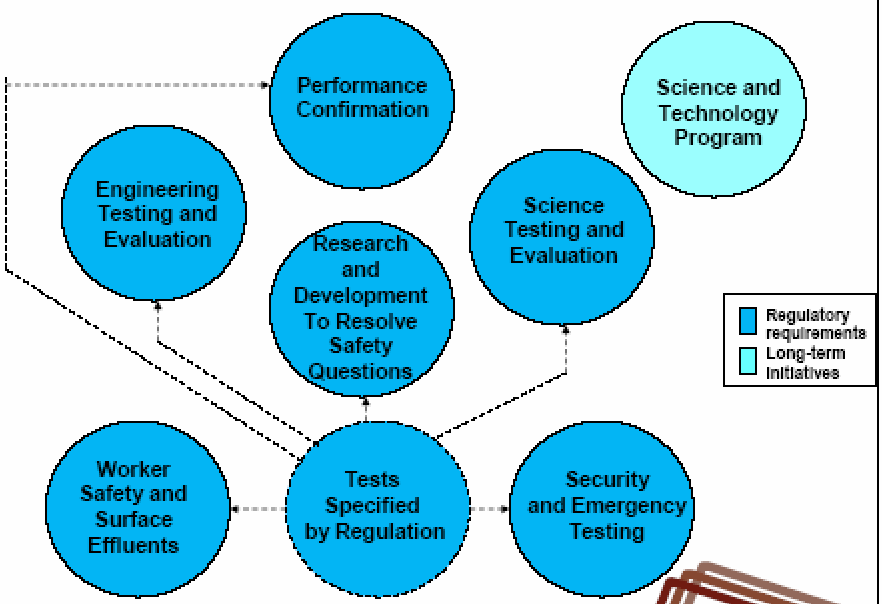
Purpose of Performance Confirmation

- Performance confirmation is a program of tests, experiments, and analyses is conducted to evaluate the adequacy of the information used to demonstrate safety
- A performance confirmation program should demonstrate that the system and the sub-system components (i.e., barriers) are operating as anticipated

Performance Confirmation Activities



Performance Confirmation is Not the Only Testing and Monitoring Program

- **The Performance Confirmation Program focuses on**
  - Activities specifically designed to confirm the technical basis for the licensing decision
  - Testing the functionality of the barriers and total system performance
- **Other testing and monitoring programs focus on**
  - Increasing confidence
  - Meeting other regulatory requirements
  - Optimizing the waste isolation processes, specifically by exploring technological improvements that could enhance performance and reduce costs

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Decision Analysis Approach

- Provides a consistent, logical, defensible basis for evaluating and comparing activities considered for inclusion in the Performance Confirmation Program
- Explicitly acknowledges that tradeoffs among different objectives and goals may be necessary
- Uses a formal multi-attribute utility analysis in its first phase to develop test and monitoring "portfolios" in a second phase for management use
  - A technically sound mathematical approach for evaluating alternatives where more than one objective is important
  - Has been used by federal agencies, and private companies since the late 1970s to evaluate complex decision problems
- Additional phases involved management reviews and adjustments stemming from applying value-judgments
- A final phase will be the continued reevaluation and updating of this plan

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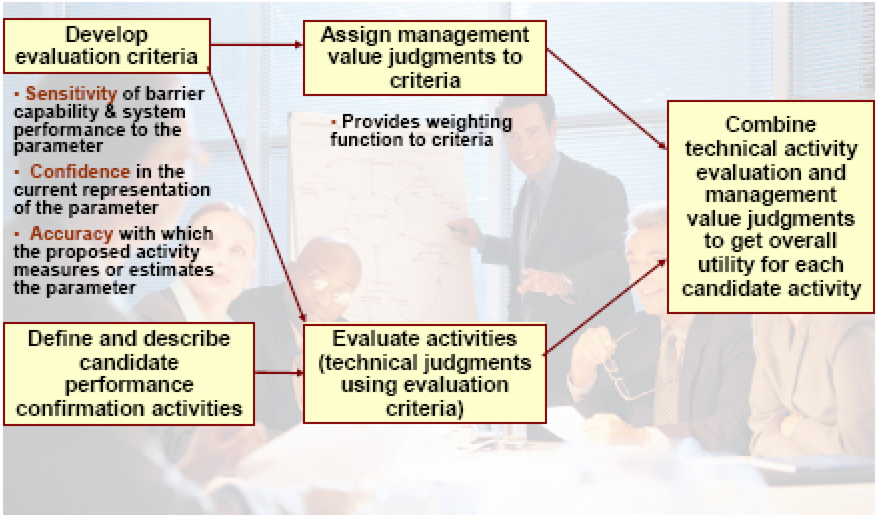
Phase 1: Evaluating Candidate Activities



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Activity Evaluation Criteria

- At an initial workshop three criteria were defined, to be used in estimating the potential impact of a performance confirmation activity on the performance confirmation program:
  - Barrier capability and system performance sensitivity to the parameter
  - Confidence in the current representation of the parameter
  - Accuracy with which the proposed activity measures or estimates the parameter
- Workshop participants included:
  - Technical investigators with various areas of expertise
  - Performance assessment analysts and managers

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A Detailed Set of Questions was Developed Around Each Criterion

- The goal of the questionnaire was to elicit technical input on how well proposed parameters and activities meet the three criteria
- The goal of the questionnaire was to improve consistency across model areas
- Workshops were held with each group of technical experts
- During the workshops
  - Each group developed a comprehensive list of parameters to be considered
  - For each parameter identified, the group defined one or more data acquisition methods that could be implemented to provide information on that parameter
  - Several activities were evaluated in each workshop by the group, using the questionnaire

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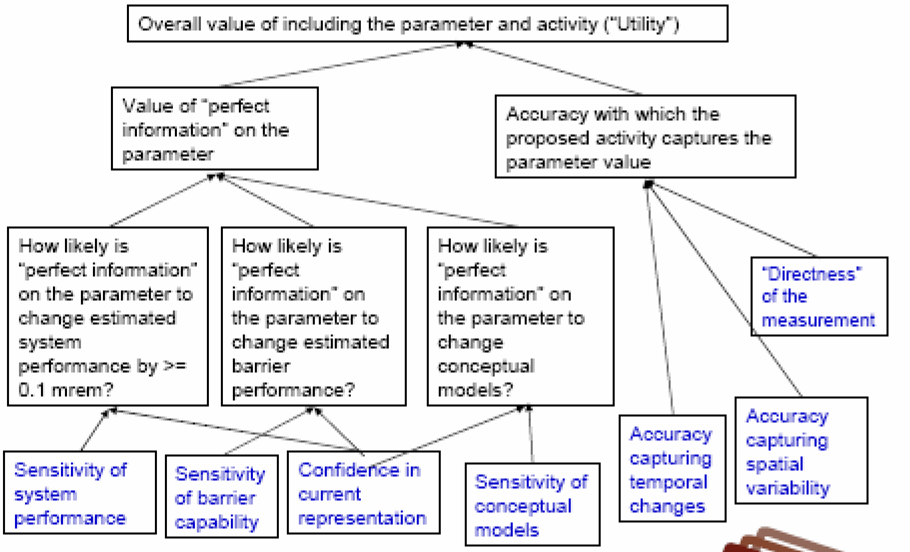
Estimating the Utility of a Specific Activity



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Performance Assessment Managers Provided the Necessary Management Value Judgments

- Managers reviewed the overall process and endorsed the specific criteria being used to evaluate activities
- Managers answered a series of tradeoff questions, designed around the technical questions used in the questionnaire, to establish management value judgments about the relative importance of the criteria
- Management value judgment used in conjunction with the technical judgments to establish the overall utility for each activity
- Participants included the manager of the performance assessment project and the manager and/or deputy for related subprojects: natural systems, engineered systems, performance assessment strategy and scope, and the performance confirmation manager

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Phase 2: Developing and Evaluating Alternative Portfolios

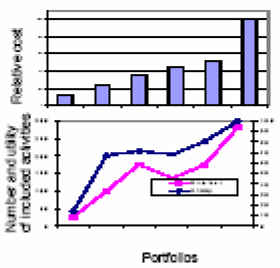
Develop portfolio philosophies → Define activities included in each portfolio → Evaluate portfolios

- Basic requirement: any portfolio must meet regulatory requirements
- Beyond the basic requirement, consider portfolios defined around:
  - Cost-effectiveness
  - Testing specific hypotheses
  - Maximizing regulatory robustness and coverage
  - Maximizing in situ activities
  - Maximizing off-footprint activities
  - Maximizing use of pre-emplacement data

- Using the results of Phase 1, assign activities to portfolios based upon the portfolio philosophy.

Portfolio A	Portfolio B
Activity 1	Activity 1
Activity 2	Activity 3
Activity 6	Activity 4
Activity 12	Activity 6
Activity 22	Activity 11
. . .	. . .

- Portfolios are compared in terms of regulatory robustness, overall utility scoring (cost effectiveness), and cost.



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Rationale for Portfolios

- Each candidate activity contributes to demonstrating compliance with one or more regulatory requirements
- The best portfolio does not necessarily result from ranking activities by utility, cost, or the ratio of utility to cost
  - Some regulatory requirements are not captured by the technical judgments and management value judgments input to the utility
  - Activity evaluations do not account for potential synergies
- Some costs cannot be assigned to individual activities (e.g., observation drift construction and remotely operated vehicle development)
- Portfolios of performance confirmation activities can be evaluated for regulatory compliance and for total cost

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Phase 3: Selecting the Portfolio

Select the portfolio → **Reevaluate the activities (as a whole) included in each portfolio** → **Document the Performance Confirmation Program**

Select the portfolio:
- Management selected a base portfolio using a cost-effectiveness philosophy
- The base portfolio was modified to increase its regulatory robustness and coverage, using information from the hypothesis-testing philosophy

Reevaluate the activities (as a whole) included in each portfolio:
- Activities were removed if they were more appropriate for other testing programs (e.g., drift shadow studies)
- Activities were removed if they were focused on phenomena not included in the system-level model
- An activity was added to compensate for lack of coverage due to a removed set of activities
- An activity was added to increase the spatial representativeness of thermal test data

Document the Performance Confirmation Program:
- *Performance Confirmation Plan* documents the performance confirmation program development

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Phase 4: Updating the Program

Reevaluate the program activities as needed → Document the Performance Confirmation Program

– Activities will be added, modified, or changed based on new information

– *Performance Confirmation Plan* documents Phases 1 through 4 of performance confirmation program development

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Performance Confirmation Activities

- The process led to a series of twenty Performance Confirmation activities and tests
- Of these twenty , eleven were begun during site characterization:
  - Precipitation monitoring
  - Seepage monitoring
  - Subsurface water and rock testing
  - Unsaturated zone testing
  - Saturated zone monitoring
  - Saturated zone alluvium testing
  - Subsurface mapping
  - Seismicity monitoring
  - Construction effects monitoring
  - Corrosion testing
  - Waste form testing

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Performance Confirmation Activities
(continued)

- Two of the twenty activities and tests are planned to begin during construction:
  - Saturated zone fault zone hydrology testing
  - Seal testing
- The remaining seven activities and tests are planned to begin during operations:
  - Drift inspection
  - Thermally accelerated drift near-field monitoring
  - Dust buildup monitoring
  - Thermally accelerated drift environment monitoring
  - Thermally accelerated drift thermal-mechanical effects monitoring
  - Waste package monitoring
  - Corrosion testing of thermally accelerated drift samples

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Path Forward

- Define activities (what, when, where, and how)
- Establish expected baseline for performance confirmation activities (required by regulator)
- Identify and develop needed test plans and procedures
- Develop Integration Group to assess data as a whole
- Define process for defining, detecting, and reporting variances and for deciding on the appropriate action

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Monitoring of IL/HL, LL waste repository in a clay formation : Objectives, technical know-how, implementation strategy

Arnaud Grévoz, Stefan Mayer, Jean-Philippe Dubois, Andra, Fr.

6th IGSC Meeting on 2 - 4 November 2004

Outline

- Context of Andra's studies
- International references and regulatory requirements regarding monitoring
- Objectives of a monitoring program
- Technical know-how
- A possible implementation strategy
- Conclusions

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Context - General

- French law mandates current studies on *the feasibility of irreversible or reversible disposal in deep geological formations, supported by results obtained in underground research laboratories.*
- In 1998, the French Government emphasized the need to study the feasibility of a reversible disposal process.
- A « *feasibility report* » is to be submitted by the end of 2005.
  - Its aim is to propose repository concepts, to study if they can be constructed, operated and closed safely, and to evaluate if their long term evolution meets requirements.
- The report is to rely as much as possible on concepts that are robust to uncertainties and on well established construction / operation techniques.
  - No optimization is expected

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Context - General

- A parliamentary debate is expected in 2006 regarding different avenues for the management of IL and HL LL wastes (P&T, repository, long-term storage)
- If the French Parliament decides to go on with the project, further developments could be :
  - Technical demonstrations at a large scale inside the URL
  - Experimental validations of models, surface observations
  - Technical optimization
- The regulatory process that could lead to the authorization of a repository facility is not defined

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Context - Monitoring

- The presentation will focus on **monitoring of a reversible repository in a clay host rock.**
- Level of detail is commensurate with a feasibility study

A few references… (list not exhaustive) (1)

IAEA Tecdoc 1208 : *Monitoring of geological repositories for high level radioactive waste*, 2001

- ✓ "Monitoring the environment of such repositories is not therefore expected to reveal any increase of radioactivity due to the repository; it is planned and intended for other purposes."
- ✓ "Monitoring a deep geological repository and its environment would be carried out principally as an **aid to decision making.**"
- ✓ "Thus, an important aspect of monitoring during the operational phase and any subsequent pre-closure period, **is to enhance understanding of those aspects of the safety case that it is feasible to address over a period of several decades.**"
- ✓ "In general, the approach will be to accumulate information from the construction and operation stages to allow the design of the repository to be checked, refined and, where necessary, modified."
- ✓ "In some cases, monitoring may be used to provide information about the retrievability of the waste, if such an option is included in the disposal strategy of the country."
- ✓ "It is clearly preferable that any monitoring system, whether devised for use during operation or after closure, should not intrude into the barriers designed to contain radionuclides."

IAEA DS154 (Draft Safety Requirements), 2004

- ✓ Requirement 21 : Monitoring programmes

  "5.29. Monitoring will be required during each step of disposal facility development. Purposes may include providing baseline information for later assessments, **assurance of operational safety** and facility operability, and **measurements to confirm conditions consistent with long term safety.**"

A few references… (list not exhaustive) (2)

NEA RWMC : Reversibility and Retrievability in Geologic Disposal of Radioactive Waste, 2001

- ✓ "For instance, a **license or permission for the construction and operation of a repository** (i.e., for the emplacement of radioactive waste packages) **will be reviewed at specified intervals in order to verify that adequate assurance of the long-term safety of the repository is preserved.**"
- ✓ "the application of nuclear safeguards to a repository in which the wastes remain "retrievable" has not been worked out yet and deserves further attention;"
- ✓ "Beginning in the period prior to construction, and continuing up to closure, monitoring of various site and repository parameters will provide information for safety assessment. This may include confirmation of natural site conditions, understanding of the response of the natural system to the presence of the repository, and the early evolution of the engineered elements."
- ✓ "The plan for monitoring related to performance should be carefully considered and reasoned arguments applied so that the relevance of measured parameters to eventual long-term safety is known."
- ✓ "During the operational period, and any extended open period that follows it, monitoring of rock stability, the underground environment, and waste package conditions will be needed."
- ✓ "The claim of retrievability implies monitoring to check to continued feasibility of the waste retrieval option over the period for which it is claimed."

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A few references… (list not exhaustive) (3)

EUR 21025 EN : Thematic network on the role of monitoring in a phased approach to geological disposal of radioactive waste, 2004

- ✓ "[…] and the subject of monitoring is now perceived as one of increasing importance as some repository programmes approach the phase of construction."
- ✓ "All the participants of this Thematic Network agree on the importance of monitoring related to establishing baseline conditions, maintaining operational safety, compliance (including safeguards) and in support of model confirmation regarding post-closure safety."
- ✓ "The extent of monitoring should be limited to that which could reveal useful results for the decision making process or for the confirmation of safety."
- ✓ "This report emphasizes that there is already extensive experience of monitoring related to the field of radioactive waste disposal from site investigations, experiments in URLs and relevant experiences from operating other nuclear facilities. Relevant experience also comes from outside this field, for example, from the monitoring of large engineered structures, such as dams and underground openings, which has taken place over many decades."
- ✓ **"The extent of monitoring that is either appropriate or useful to implement is, however, a sensitive question and depends on implementation strategies."**

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A few references… (list not exhaustive) (4)

National Research Council : One step at a time – The staged development of geologic repositories for high-level radioactive waste, 2003

- ✓ "Adaptive Staging cannot exist without adequate monitoring."
- ✓ "While Adaptive Staging calls for a measured pace of program development and implementation, its objective is not to delay the program but to assure careful consideration of what is being learned and to focus on program progress rather than on meeting pre-arranged rigid milestones."
- ✓ "Iterative assessment of the safety case is the fulcrum around which decisions are made. **This means that the safety case is used in Adaptive Staging as a management tool to guide the implementer's actions during repository development.**"
- ✓ "The decision-making process separating stages is referred to as a "Decision Point". A Decision Point is not just a "point" in time, but a process involving analyses, review, and evaluations, as well as the consequent decisions for future actions."

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A few references… (list not exhaustive) (4)

- ✓ **"The commitment to systematic learning is reflected in an on-going program monitoring the engineered and natural barriers of the repository system."**
- ✓ "Information derived from monitoring can help the implementation to determine whether the repository is behaving as predicted, and [provide] quantitative, reliable information for future decision-making. Current attention in many repository programs is directed toward answering the challenging questions of what and how to monitor in the closure and post-closure phases."
- ✓ "Pre-closure monitoring goals include: […] baseline measurements […] analyzing actual system (and component) performance […] decision-making, including improvements in system performance […] (compliance) […] safeguarding nuclear materials […] ensure responsibility […] societal confidence […] health of workers […]"
- ✓ "A credible, comprehensive monitoring program […] takes on increased value and importance under Adaptive Staging because monitoring allows for systematic learning."
- ✓ "Monitoring must link to both the performance confirmation and to the long-term science and technology programs."
- ✓ "Continued future advances in monitoring is a major reason why a repository monitoring program must be Adaptive and allow incorporation of new and better technologies and methodologies."

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Regulatory requirements

- Fundamental safety rule (RFS III.2.f, 1991), which is a guideline and not a regulatory requirement, deals with « *general provisions concerning site explorations* ».
- It distinguishes between :
  - **Exploration conducted from the surface** (surface exploration, survey drillings, study of materials extracted from drillings)
  - **Investigations to be carried out in the URL** (both in situ and on samples)
  - **Monitoring « changes in the site while the repository is in operation »**
- *"Given the anticipated length of time for repository operation and the disturbances this could cause, it seems important to monitor changes in relevant site and engineered component specific parameters. Adequate instrumentation must be installed early on, to ensure monitoring of the site and engineered components begins prior to repository operations."*
- Some requirements are host rock – specific : granite, shale, salt and clay.

General objectives of a monitoring program

- During the construction / operational phase, the monitoring program is linked to :
  - ✓ the respect of operational safety and regulatory requirements
  - ✓ the acquisition of data to allow for a deeper understanding of models and parameters underlying the long term safety assessment
  - ✓ reversibility,
- Andra distinguishes between :
  - ✓ observation (linked to giving information for scientific and engineering understanding and the reversibility process)
  - ✓ surveillance (linked to safety)
- These objectives, however, do not lead to three disconnected monitoring programmes :
  - ✓ for example, drift deformation could provide information pertaining to reversibility (adequate space to transfer canisters), operational safety (risk of drift collapse), and long-term safety (EDZ evolution)

Surveillance for operational safety

- Uses of monitoring results for operational safety :
  - ✓ Surveillance : **Classical and nuclear operational safety**
  - ✓ **"Early warning" allowing for needed flexibility to conduct unscheduled maintenance work**
- Examples of information linked to operational safety :
  - ✓ Fire and radiological hazards surveillance
  - ✓ Monitoring of mechanical and dimensional stability,
  - ✓ Monitoring of ventilation levels,
  - ✓ Measurement of the presence of radioactive gases, build-up of hydrogen concentrations,
  - ✓ Monitoring of thermal and other working environmental conditions…

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Surveillance for long term safety

- It must be coherent with the fact that, at this stage, the operation of the facility has been authorized, and therefore enough confidence exists in the models and parameters
- It must not be understood as a way to compensate for a lack of confidence in the previous stages, nor as a mere confirmation of data already acquired
- However nuclear facilities are required by regulation to revise periodically their safety analysis in the light of « feedback » from past operations, with a view of improving system understanding and optimizing safety. The same on-going process can be envisioned for a geological repository

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Surveillance for long term safety (2)

- Monitoring provides :
  - ✓ **NO direct data on long term evolution** (at time scales greater than either operational phase, time of institutional control, or material life time)
  - ✓ **Additional information on site characterization** (on-going site characterization, hydrogeology, spatial variability of rock properties, etc.)
  - ✓ **Additional information on short-term** disturbance of the host formation
  - ✓ **Information on intermediate-term** (~ decade to century) in-situ evolution
- **Uses of this information for possible reevaluation of long term safety cases** :
  - ✓ Verify respect of safety related design criteria (limits of local temperature, of remaining void spaces…)
  - ✓ In-situ data at a local scale, on every part of the repository
  - ✓ Confirmation of data related to long term evolution models
    - ➢ Thermal field
    - ➢ Hydrological near-field (desaturation)
    - ➢ Host rock elasto-plastic response
    - ➢ Growth or reduction of EDZ
    - ➢ Geochemical near-field perturbations

Observation linked to reversibility

- Reversibility and the step-wise approach requires that decisions (to go on with the next phase of the disposal process, to wait or to go back to a previous stage) should be based on the best available information.
- **Uses of monitoring results for reversible, step-wise repository management** :
  - ✓ Confirmation or re-assessment of component operational life time; examples :
    - ➢ Observed load, corrosion… less than anticipated ⇒ prolonged life time
    - ➢ Need to seal drift (to satisfy long term safety requirements…) ⇒ loss of operational life time
  - ✓ Assess conditions for a potential waste canister retrieval (mechanical integrity, ease of operation, physical conditions in disposal drift…)
  - ✓ Assess flexibility to modify (delay, adjust…) disposal process
  - ✓ Assess repository component and near-field evolutions to contribute to possible design evolution (modular construction)

Constraints

- Monitoring is subject to repository specific constraints :
  - ✓ Material must not interfere with operational safety (cables, data acquisition stations, operator traffic…)
  - ✓ Material must not reduce long term safety significantly (mechanical, hydrological or chemical footprint…)
  - ✓ Material must operate under expected environmental conditions (heat, humidity, pressure, radiation, lack of access…)
  - ✓ Cost (choice of material, density and distribution of monitoring equipment…)

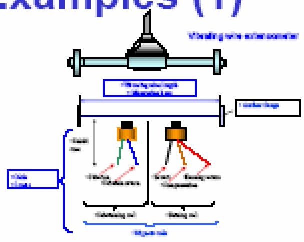
Technical know-how : Basis

- **Similarities with other monitored structures**
  - ✓ Monitoring of concrete structures (hydroelectric dams, nuclear power plants, railway tunnels…)
  - ✓ Monitoring of steel structures (pipelines…)
  - ✓ Monitoring of clayey materials (clay based dams, swelling buffer experiments…)
  - ✓ …
- **Key lessons**
  - ✓ Ensure data interpretation will be unambiguous
  - ✓ Combine several methods, as appropriate (visual inspection, topographical data, sample analysis, sensor data…)
  - ✓ Possible redundancy of important or difficult measurements
  - ✓ Test monitoring equipment under expected environmental conditions
  - ✓ Care during equipment installation (influence on life time, accuracy, and correct interpretation)
  - ✓ …

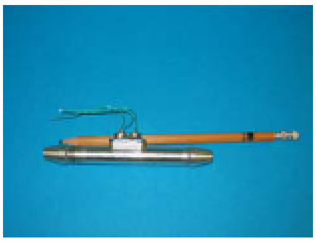
Technical know-how : Requirements

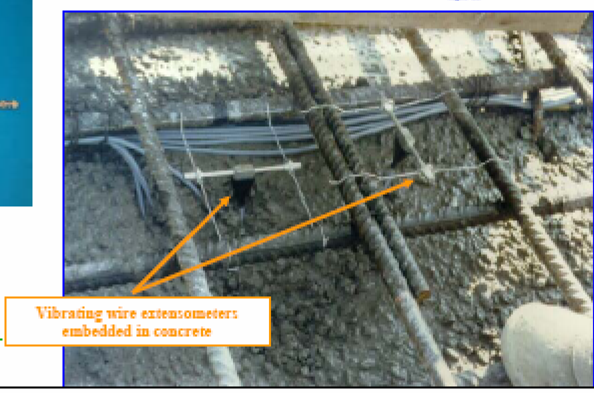
- Selection criteria
  - ✓ Safety
    - ➢ (No significant long term) disturbance of containment barriers
    - ➢ (No significant long term) chemical disturbance
    - ➢ Adapted to operational safety (ease of construction, no interference with construction and operation activities…)
    - ➢ …
  - ✓ Robustness
    - ➢ Accuracy (no drift)
    - ➢ Life time (50 years common, 100 appear reasonable)
      - Or possibility of maintenance (access…)
    - ➢ Resistance to repository environment (temperature, humidity, radiation only inside waste emplacement tunnels…)
      - Appears demanding only inside a waste emplacement tunnel
  - ✓ Other
    - Ease of integration in an automated data acquisition network
    - …

Technical know-how : Examples (1)



- Vibrating wire sensors (temperature, deformation …)
  - Widespread use in concrete structures
  - Continuous operation for ~50 years in dams
  - Significant % remain in operation (most failures are early, due to installation)





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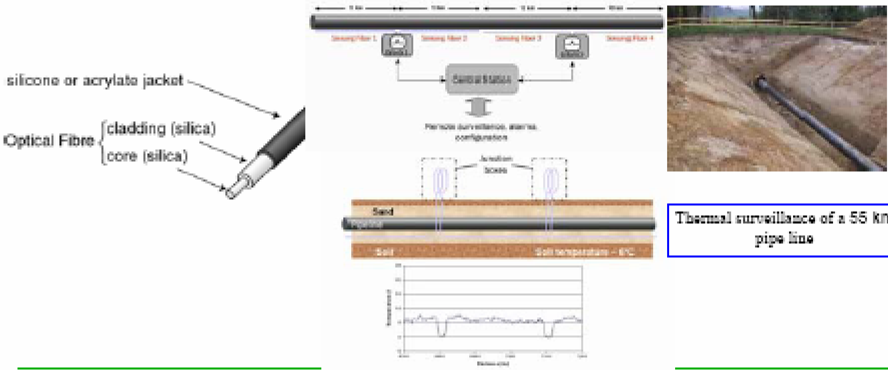
Technical know-how : Examples (2)

- Fiber optics (temperature, deformation…)
  - Increasingly widespread applications (~10 years)
  - Monitoring and transmission over long distances
  - Robust if correctly installed
  - Ease of integration in data acquisition network
  - Evolution of signal processing without changing sensor
  - Several methods (Bragg micro grating, Raman, Michelson, Brillouin…)



Thermal surveillance of a 55 km pipe line

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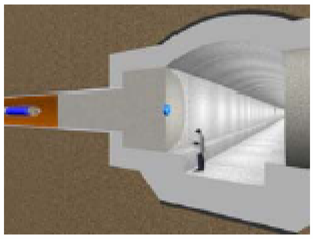
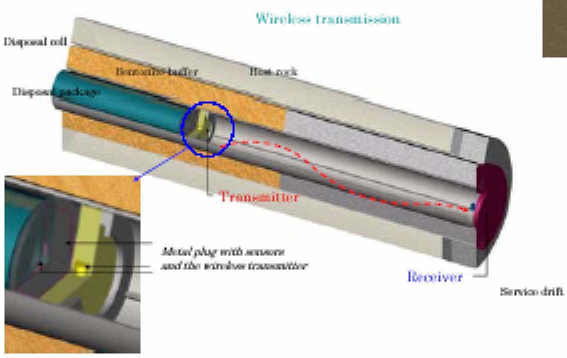
Technical know-how : Examples (3)

- Wireless transmission
  - Industrial (Oil drilling, Japanese airport) and URL (Bures) applications
  - Integrity of engineered barrier
  - But: Limited life time, difficult transmission environment (steel tube), possible chemical perturbation





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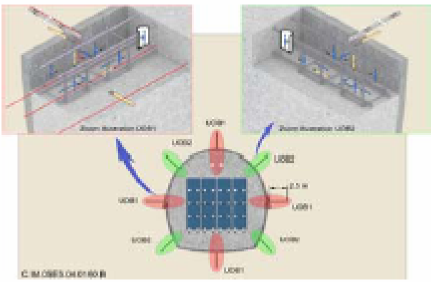
Example : Monitoring in a B-type waste tunnel

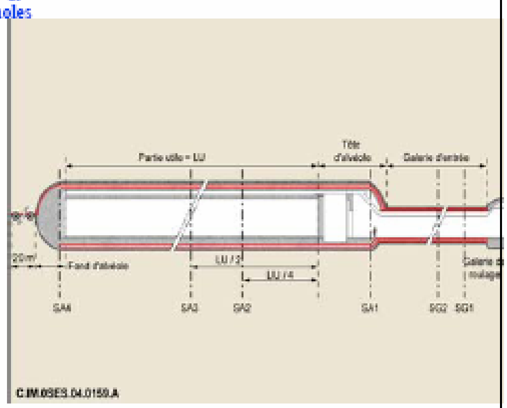
Instrumentation of a cross-section

- Similar protocol for all monitoring units
- Temperature, deformation, and pressure measurements
- Vibrating wire, fiber optic and other sensor technology
- Embedded in concrete liner and in near-field bore holes

A « heavily instrumented » waste tunnel

- Several cross-sections
- Distributed FO temperature measurements
- R&D on distributed FO deformation measurements





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Guidelines for implementation strategy

- Based on URL and other relevant civil (transportation, mining, petroleum, nuclear…) engineering experience
- **Compromise between data wants and technology**
  - ✓ **Respect of long term performances of safety functions (barriers, etc..)**
- No basis to specify complete monitoring system (what architecture, which technology, which operations relevant in 50 years?...)
- **Intensity of monitoring likely to evolve during disposal process** (modular context)
  - ✓ Denser monitoring in first module(s) (or other typical repository component; similarity to pilot facility)
  - ✓ Analysis of monitoring results, use similarity of components and homogeneity of environment
  - ✓ Potentially sparser monitoring of successive modules, focused on key items, focused on reproducing parts of first module results
  - ✓ Potential evolution of technology

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Conclusions regarding the link between the monitoring program and the safety case

- **The monitoring program should be seen as a way to inform the safety case as it evolves** during the various stages of the operations; in this sense it can provide additional confidence to the assessments
- **Part of it is meant to assess regulatory compliance during operation**, and so is largely inspired by practices in other facilities (nuclear and others)
- **However operational monitoring is not used to support the pre-operational safety case**. Its purpose is not to compensate for a lack of confidence in site characterization data, in URL experiments, or in the safety case.

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Conclusions regarding the link between the monitoring program and the safety case (2)

➢ **The monitoring program is an additional level of a defense in depth approach**
  - ✓ Commensurate with common practice in nuclear facilities
  - ✓ Adapted to operations in an underground environment
  - ✓ Adapted to long term safety relevant information…
    (data that can confirm consistence with long term safety)

- Technical objectives are site-specific and are selected based on their importance to a reversible management and to the safety case.
- Technical know-how is available to seed the monitoring program
- Initial monitoring intensity and technology may evolve during the step-wise approach to disposal

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GEOLOGICAL DISPOSAL SAFETY STANDARDS

MONITORING, SURVEILLANCE AND THE SAFETY CASE

Phil Metcalf

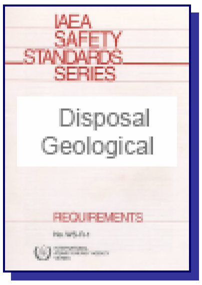
Sixth Meeting of the Integration Group for the Safety Case (IGSC)

2-4 November 2004, Paris

International Atomic Energy Agency

Requirement 20: Monitoring programmes

A programme of monitoring shall be defined and carried out prior to and during the construction and operation of the geological disposal facility. This shall be designed to collect and update the information needed to confirm the presence of the conditions necessary for the safety of workers and members of the public and protection of environment during the operation of the geological disposal facility and to confirm the absence of conditions that would undermine the post closure safety of the geological disposal facility.



International Atomic Energy Agency

A.1.53. Monitoring is required during each step of the geological disposal facility development and operation. The purposes include providing baseline information for later assessments, assurance of operational safety and facility operability, and confirmation that conditions are consistent with post closure safety. Monitoring programmes must be designed and implemented so as not to reduce the overall level of post closure safety.

A.1.54. A discussion of monitoring related to post closure safety of disposal facilities is given in reference [19]. Plans for monitoring aimed at providing assurance of post closure safety must be drawn up before construction of the geological disposal facility to indicate possible monitoring strategies, but these need to remain flexible and if necessary revised and updated during the development and operation of the facility.

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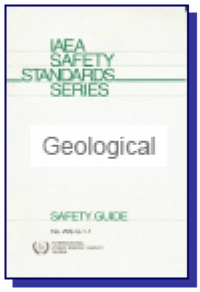

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OVERVIEW OF GEOLOGICAL DISPOSAL AND ITS IMPLEMENTATION

- The geological disposal concept
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- Management systems
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- Safeguards

REPOSITORY CLOSURE AND POST-CLOSURE CONTROL

- Considerations related to the decision to permanently close the repository
- Competing post-closure demands and requirements

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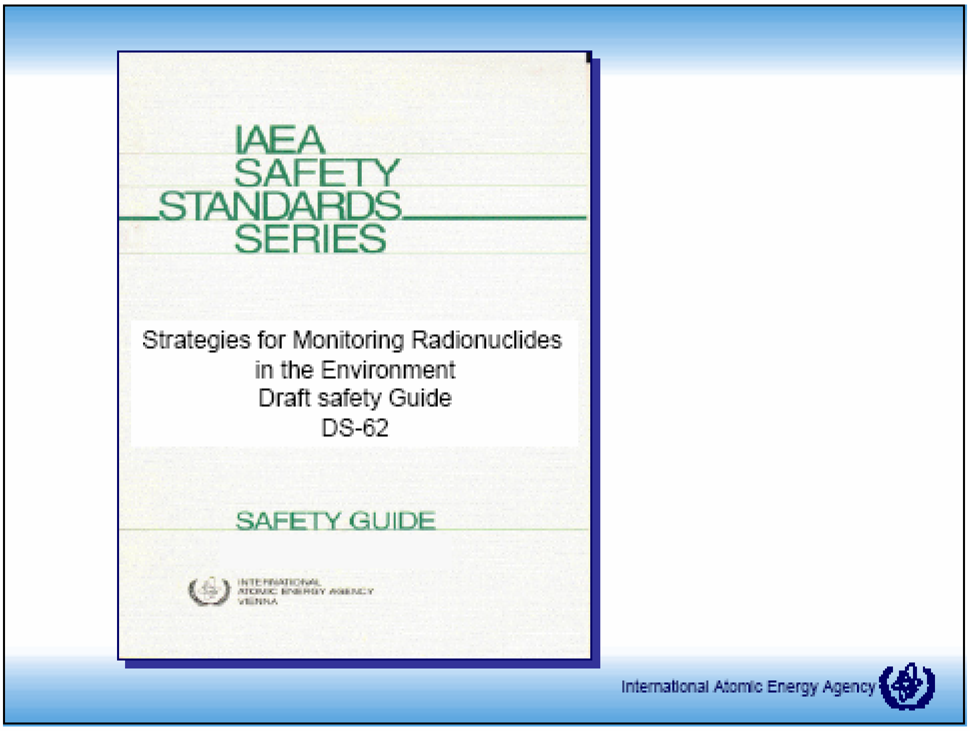
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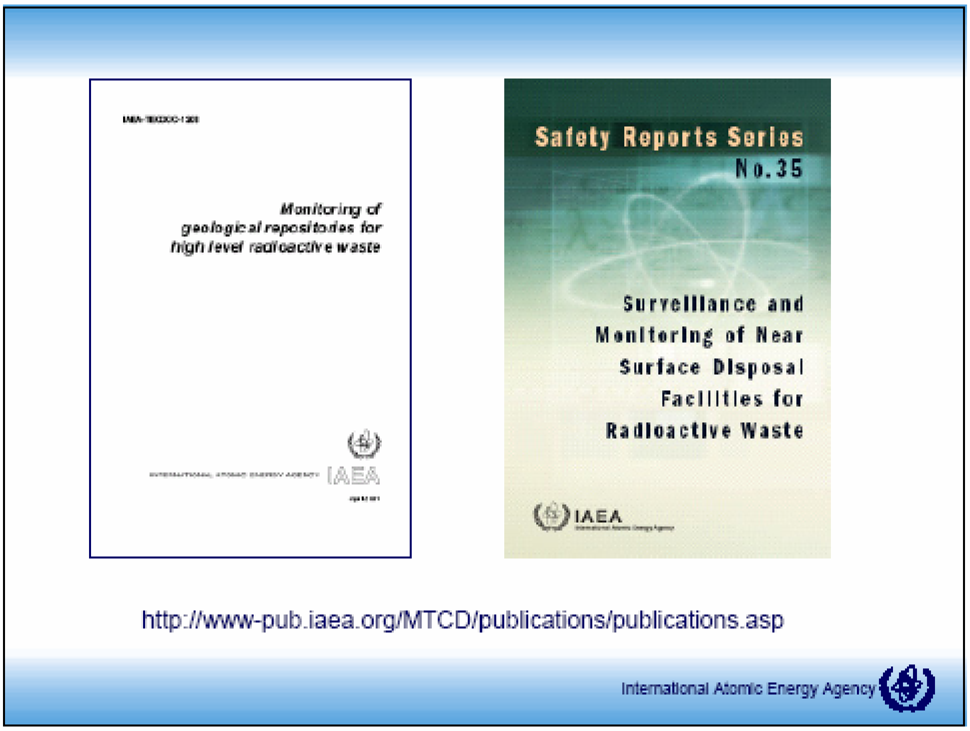
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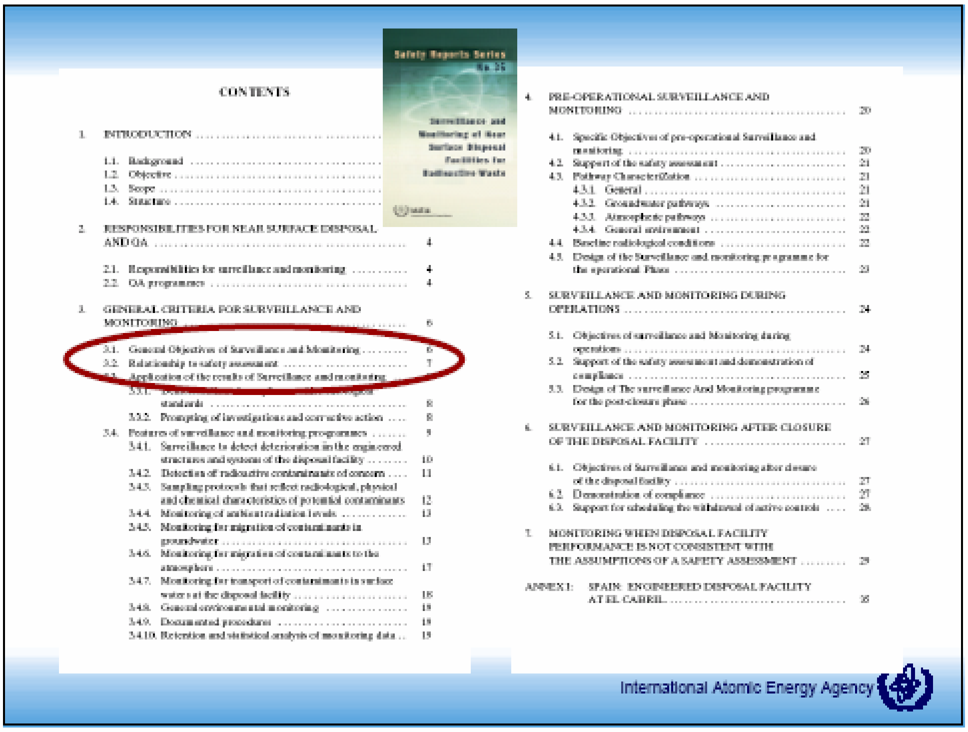

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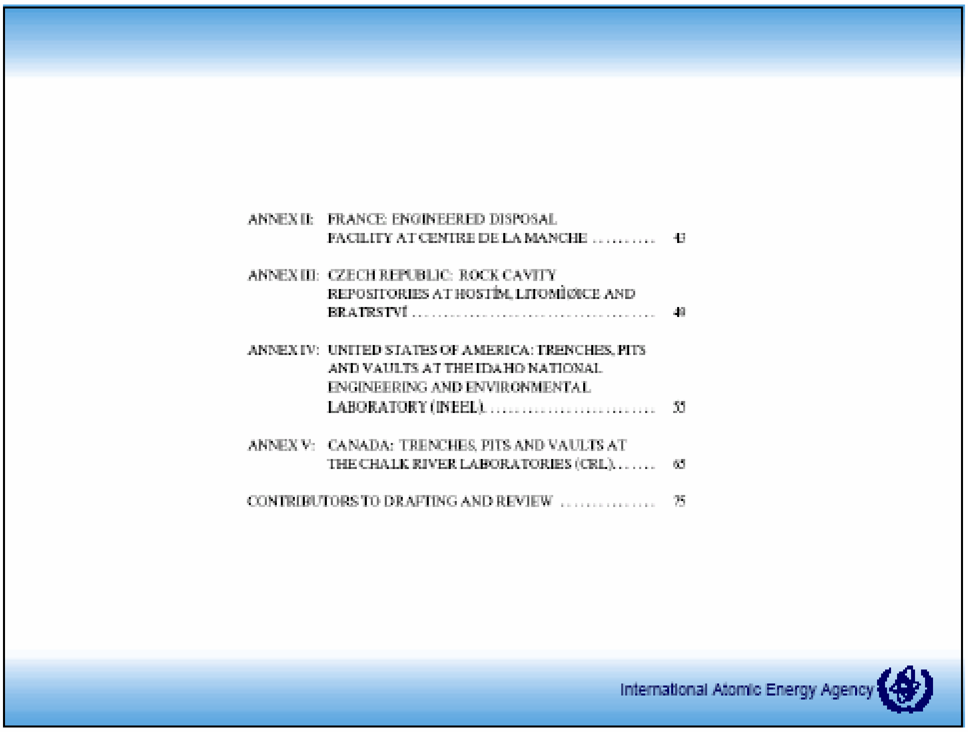

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International Atomic Energy Agency

DESIGN DEVELOPMENT FOR GEOLOGICAL DISPOSAL FACILITIES

- Conceptual design
- Detailed design
- Waste acceptance criteria
- **Surveillance and monitoring programmes**

SITE CHARACTERISATION

- Site characterisation
- Other research activities
- Safety case development
- Integration of knowledge
- Assessments and evaluations
- Scientific investigations during the construction, operational, and post-closure phases

CONSTRUCTION, OPERATION AND CLOSURE and CONSTRUCTION PERIOD

- Overview
- Flexibility in design
- Excavation disturbance
- As-built design and the updated safety case

International Atomic Energy Agency

Surveillance and Monitoring Programmes

1.1 Monitoring is defined as [26]

The measurement of dose or contamination for reasons related to the assessment or control of exposure to radiation or radioactive substances, and the interpretation of the results.

1.2 And surveillance is defined as [26]

Activities performed to ensure that conditions at a nuclear facility remain within the authorised limits. For a near-surface repository, surveillance normally continues past the periods of operation and closure.

International Atomic Energy Agency

1.1 The starting point in planning all monitoring activities is the safety case, which should contain a clear monitoring plan that describes the rationale underlying the monitoring activities. A programme of surveillance and monitoring should form part of the safety case and should commence before a disposal facility becomes operational - usually during the site characterisation programme. The repository design may also include a period of subsurface monitoring of the disposal facility after the waste has been emplaced but before the access tunnels or shafts have been backfilled and sealed.

1.2 As the disposal programme moves from one phase to the next, the objectives of the surveillance and monitoring programme will change and additional surveillance and monitoring activities will be added [27]. Some of these activities will continue through into the period of post-closure institutional control. Through the various phases of facility development, the surveillance and monitoring objectives should be set to allow the surveillance and monitoring programme to build confidence in the safety case by testing assumptions and demonstrating compliance. For example, reference [27] lists the main objectives of the post-closure surveillance and monitoring phase as:

- to show compliance with reference levels established by the Regulatory Body for the purposes of providing protection of human health and environment;
- to confirm, as far as possible, relevant assumptions made in the safety assessment;
- to provide indications of any malfunctioning of the containment leading to unpredicted radionuclide releases; and
- to provide reassurance to concerned persons living in the vicinity of the waste disposal facility.

International Atomic Energy Agency

1.3 An important principle of the surveillance and monitoring of facilities is that the programme should be designed and implemented so as not to reduce the overall level of post-closure safety. The surveillance and monitoring programme should not place an undue burden on the Operator by being too elaborate.

1.4 As part of the site characterisation phase, a baseline of environmental, radiation and activity concentration levels should be established for the purpose of subsequently determining the changes (if any) brought about by the emplacement of the waste. These data might include results from borehole testing such as pressure and flow, surface radiological data such as gamma radiation fields, radionuclide content of airborne dust, and radionuclide (including radon) content of the soils, water and air on and around the site. These data should be used to gain an understanding of likely radionuclide transfer pathways, especially in areas where radionuclides from the facility could discharge. The monitoring should also cover wider environmental information such as local ecology, chemical pollutants, population habits and density, local agriculture, and natural and artificial features of the environment that might affect radionuclide transfer pathways [27].

1.5 The results of pre-disposal surveillance and monitoring should assist in building confidence in the safety and post-closure performance of the facility and aid decisions for its future development. The monitoring programme should also be useful in creating the geosphere and biosphere models to be used in post-closure safety assessment.

International Atomic Energy Agency

1.6 Where there is a possibility that migration of radionuclides could reach an aquifer, consideration should be given to monitor the aquifer for potential radionuclide releases using boreholes sunk into the water bearing horizons (even though releases of activity are not expected to occur, except possibly in the distant future). Such monitoring boreholes should be sealed after use.

1.7 The Regulatory Body should provide guidance on the establishment of a surveillance and monitoring programme to be used to (i) demonstrate compliance with the regulatory constraints and any other licence conditions, (ii) monitor any releases of radioactivity to the environment, and (iii) assess the environmental impact of construction, operation, closure and post-closure activities. This programme would normally be carried out by the Operator who would take the necessary actions to ensure that the requirements established by national authorities are met. The Regulatory Body should:

- check the surveillance and monitoring data provided by the Operator;
- regularly review surveillance and monitoring arrangements including arrangements for emergency monitoring;
- audit the management systems; and
- provide evidence that can satisfy public opinion that there are no unauthorised sources of exposure.

International Atomic Energy Agency

1.8 In addition, the Regulatory Body should carry out an independent surveillance and monitoring programme.

1.9 If the waste management concept foresees a pilot or demonstration facility within the repository, where a small amount of waste is emplaced in a separate storage room equipped with monitoring instrumentation or having borehole accesses to the near-field barriers, the Operator should backfill and seal this facility at the earliest possible time in order to have the best chance of obtaining information to guide the further emplacement activities.

International Atomic Energy Agency

SCHEDULE FOR DS 334

- TECHNICAL MEETING VIENNA 29 NOVEMBER – 3 DECEMBER
- REPORT TO WASSC MARCH 2005
- SUBMIT TO WASSC FOR APPROVAL TO MEMBER STATES OCTOBER 2005
- POSSIBLE SAFETY REPORT ON SURVEILLANCE AND MONITORING OF GEOLOGICAL DISPOSAL FACILITIES

International Atomic Energy Agency

Role of monitoring: An example of an evaluation in the context of the engineered barriers

6th Meeting of the IGSC
2-4 November 2004

- Performance Confirmation for the Engineered Barrier System (EBS): Workshop at Oskarshamn 12-14 May 2004
- Relationship between Performance Confirmation (PC) and monitoring?
- Expectations from a regulator
- Focus on engineered barriers of the KBS-3 concept
- Context of the Swedish Programme

Series of workshops about the KBS-3 EBS

2002:	Long-term integrity aspects (SKI Report 2003:29)
2003:	Manufacturing, testing and QA (SKI Report 2004:26)
2004:	Performance Confirmation EBS
	Long-term evolution of Buffer and Backfill
2005:	Canister: copper corrosion issues Canister: mechanical integrity issues Safegurad issues
2006:	Model for spent fuel corrosion Model for evolution of defective canister (not decided)

SKi

3 2005-02-01 IGSC 2004

Format of workshops

- Two and a half days (SKB attend during one day)
- Day one: general presentations by consultants and researchers engaged by SKI (independent from SKB)
- Day one: formulation of question to SKB (in working groups)
- Day two: presentations by SKB
- Day two: informal hearing with SKB
- Day three: summery of impressions from SKB´s responses, identification of outstanding issues, ways forward

SKi

4 2005-02-01 IGSC 2004

Background to Monitoring

Definition (IAEA 2001): "*.... continuous or periodic observations or measurements of engineering, environmental or radiological parameters, to help evaluate the behaviour of components of the repository system, or the impacts of the repository and its operation on the environment.*"

Reasons:

- Provision of safeguards for fissile materials
- Characterisation of baseline conditions
- Verification of operational safety and quality
- System understanding and performance confirmation
- Public acceptability
- Aid in decision-making
- ……

5 2005-02-01 IGSC 2004

SKi

Swedish regulations:

SKIFS 2002:1 8§: The impact on safety measures that are adopted to facilitate monitoring of retrieval…. shall be analysed and reported

Corresponding Guidelines: The safety report.. should show that these measures ... have a minor or negligible impact…. Or should show that the measures result in an improvement of safety

SSIFS 1998:1 8§: A repository shall be primarily designed with respect to its protective capability.

Performance confirmation not mentioned in Swedish regulations

6 2005-02-01 IGSC 2004

SKi

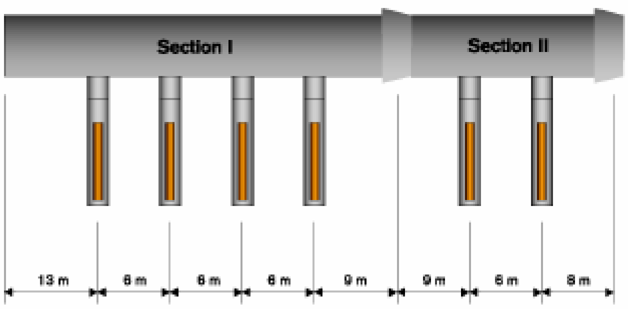
Why workshop about performance confirmation (PC) for the engineered barrier

- Test an idea from the US programme.
- SKB have a series of long-term experiments at Äspö aimed at evaluation of EBS performance
- How critical are these tests to be for the Swedish programme?
- Two experiments particularly relevant in PC context:
  - Prototype repository
  - Backfill and plug test

7 2005-02-01 IGSC 2004

SKi

Prototype repository Äspö URL

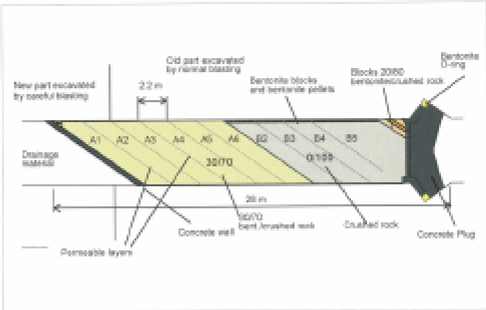


"...simulate part of a future KBS-3 repository to the extent possible with respect to geometry, design, materials, construction and rock environment except that radioactive waste is simulated by electrical heaters, and to test and demonstrate the integrated function of the repository components."

8 2005-02-01 IGSC 2004

SKi

Backfill and plug test



• *Develop and test different materials and compaction techniques for backfilling of tunnels excavated by blasting.*
• *Test the function of the backfill and its interaction with the surrounding rock in a tunnel excavated by blasting.*
• *To develop techniques for building tunnel plugs and test plug function.*

SKi

9 2005-02-01 IGSC 2004

Other PC relevant tests in the context of the EBS

- Long-term test of buffer materials (LOT)
- Äspö pillar stability experiment
- Temperature buffer test (TBT)
- Canister retrieval test (CRT)
- Gas transport in buffer test (LASGIT)
- …

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10 2005-02-01 IGSC 2004

Background Performance Confirmati

US Nuclear Regulatory Commission (USNRC) 10 CFR Part 63:
"Performance Confirmation may be defined as the programme of tests, experiments and analyses, conducted to evaluate the adequacy of the information used to demonstrate compliance with long-term safety standards for a geological repository."

Possible Components:
- Site Characterisation
- Laboratory testing
- Testing in underground research laboratories (URLs)
- Testing in dedicated demonstration-alcoves at repository sites
- Large-scale engineering demonstations
- Monitoring

11 2005-02-01 IGSC 2004 SKi

Opinions about performance confirmation (PC)

" ...confirmation of long-term performance of repository not possible because of the long time-scales involved - the term is misleading"

"... PC might be seen as a means of allowing positive licensing decisions in spite of unresolved PA issues"

"..PC aimed at ensuring that certain types of data and models are fit-for-purpose"

".. PC and/or long-term monitoring is a method to reveal any unexpected behaviours or the key repository components"

12 2005-02-01 IGSC 2004 SKi

Relevance of PC – WS main observations

- SKB has a series of PC related tests but does not have a definition for PC and does not use it for a subset of their programme
- In a mature programme, almost all activities related to PC..
- PC integrated in a wider programme of R&D, repository development and safety assessment
- In Sweden, the regulators will evaluate PC activities but most probably not establish prescriptive PC criteria.

13 2005-02-01 IGSC 2004

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Relevance of PC – WS main observations II

- Sensitivity to site specific conditions: ..which experiments have to be repeated at actual repository site?
- Planning of the Äspö experiments compatible with a schedule to assist licensing steps?
- Formal procedures for building confidence in data and models sufficient? (e.g. predictive modelling, evaluation criteria)
- Statistical validity of experimental data (esp. regarding groundwater flow)
- Relevance of ongoing experiment for the horizontal design (KBS-3H)

14 2005-02-01 IGSC 2004

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Monitoring – WS main observations

- Sufficiency of ongoing long-term experiments may depend on the type and intensity of monitoring during repository construction and initial operation
- Monitoring for confirmation of site specific models
- Monitoring to inform a decision to continue from initial to regular operations
- Monitoring after closure primarily a matter for the Swedish state
- Use of a monitored demonstration tunnel with real fuel, canister, buffer and backfill in place

SKi

Selected technical issues

- Handling of the wide range of water inflows to tunnels and deposition holes
- Times for buffer saturation from decades to possibly thousands of years?: Implications are not clear, a strategy is needed
- Use of alternative buffer materials (not MX-80): Confirmation of their expected behaviours
- Backfill performance may not be as good as expected: What are implications, necessary requirements? What is a sufficient experimental and observational basis for alternative materials and emplacement methods?

SKi

SKB's view of monitoring (SKB R-04-13)

- Confirms that Swedish regulations should be fulfilled (no or very limited impact of monitoring)
- Primary Baseline conditions: collection of undisturbed data
- Understanding site: changes during construction should be monitored and analysed
- Monitoring during repository operation matter for discussion
- "Passive" strategy suggested with emphasis of verification of requirements rather than "active" where monitoring results are used for optimisation purposes

17 2005-02-01 IGSC 2004

SKi

SKB's view of monitoring (SKB R-04-13) II

- No monitoring of canister and buffer
- Experience from monitoring of CLAB, SFR, Äspö (monitoring of bedrock conditions and monitoring of barrier performance)
- Monitoring as an aid in decision-making: monitoring results may be indicators, but decisions based on safety assessments
- Monitoring to ensure high standard of construction and operational safety
- Monitoring of environmental impact

19 2005-02-01 IGSC 2004

SKi

Role of Monitoring

NEA IGSC Meeting
3 November 2004

Paul Gierszewski
Nuclear Waste Management Division
OPG

ONTARIO POWER GENERATION

Canadian historical context

- Environmental Assessment of DGR concept – '90-97
- Concept included an overall monitoring approach, but avoided intrusive long-term monitoring that could compromise safety
- Review Panel considered concept technically safe, but from social acceptability view stated that "… a system of early detection of failures, inside the vault or close to it, should be built into the defence-in-depth approach."
- Recommended a "Modified AECL concept" which would include "better technologies for safe postclosure monitoring and retrieval".

ONTARIO POWER GENERATION 1

Regulator expectations

- CNSC S-224/G-224 (draft) Environmental monitoring program at Class I nuclear facilities and uranium mines and mills.
  - Demonstrates that adequate measures have been taken to protect the environment and to keep public doses ALARA
  - Risk-based approach (low, medium, high)
  - May involve Pathways contaminant monitoring or Biological effects monitoring
- No specific requirements for DGR

ONTARIO POWER GENERATION 2

Stakeholder expectations

- NWMO survey of issues historically raised in EAs at nuclear sites over past 17 years:
  - Public wants explicit inclusion of monitoring regimes designed and implemented around public and local involvement.
- Proposed L&ILW deep repository
  - Is my water safe?

ONTARIO POWER GENERATION 3

Objectives of pre-closure monitoring

- Obtain data to assess site suitability and establish baseline for identifying repository effects
- Demonstrate that repository meets regulatory compliance, performance, safeguards requirements
- Detect performance problems so that corrective actions can be taken
- Allow stakeholders to gain sufficient confidence in performance/safety of repository to proceed to closure

ONTARIOPOWER GENERATION

4

Objectives of post-closure monitoring

- Demonstrate the repository continues to meet compliance, performance, safeguard requirements
- Support assumptions made in the safety case
- Detect anomalous behavior so that remedial actions can be taken as necessary'
- Allow stakeholders to gain confidence in performance/safety of the closed repository

ONTARIOPOWER GENERATION

5

Strategy

- Present an approach that covers all phases, including long-term monitoring options
- Staged approach with detailed/invasive tests early on, then gradually pulling away as we develop confidence in performance.
- Extended monitoring phase (eg. 70 yrs in current plans)
- Long-term monitoring must not compromise passive safety

ONTARIO POWER GENERATION 6

Staged approach

- Preclosure (Siting/Const./Ops)
  – Surface characterization
  – Surface biosphere/environmental monitoring
  – Surface deep boreholes
  – Underground rock laboratory/tests
  – Component/demonstration tests
- Preclosure (Extended monitoring)
  – Instrumented containers in dedicated test area
  – Monitoring boreholes within the facility

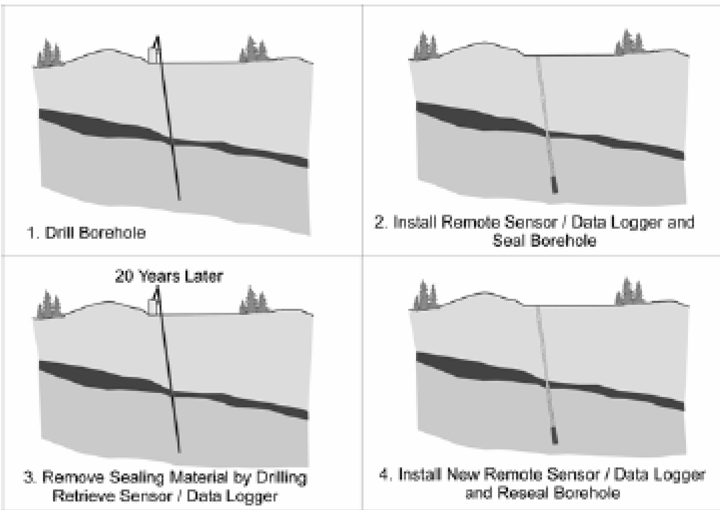
ONTARIO POWER GENERATION 7

Staged approach (2)

- Decomm./closure
  - Instrumented container tests closed; used fuel emplaced without intrusive monitors
  - Within-facility boreholes closed
  - Most surface deep boreholes closed.
- Postclosure
  - Surface-based monitoring
  - Biosphere/environmental monitoring
  - Surface deep boreholes?
    (Sealed replaceable dataloggers?)

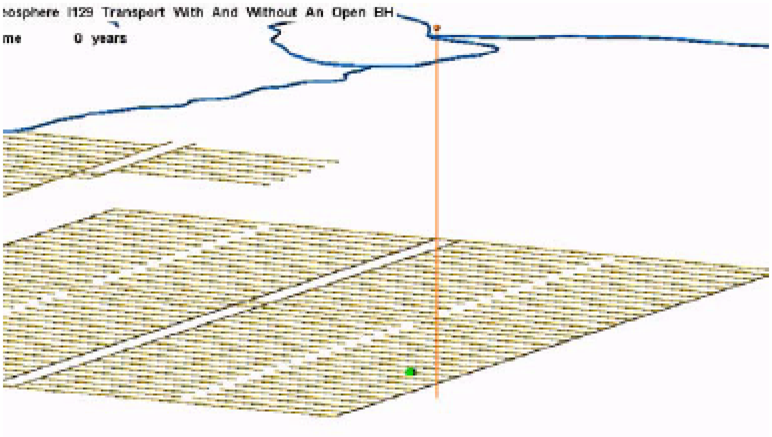
ONTARIO POWER GENERATION 8

Postclosure Remote Data Logger concept



ONTARIO POWER GENERATION 9

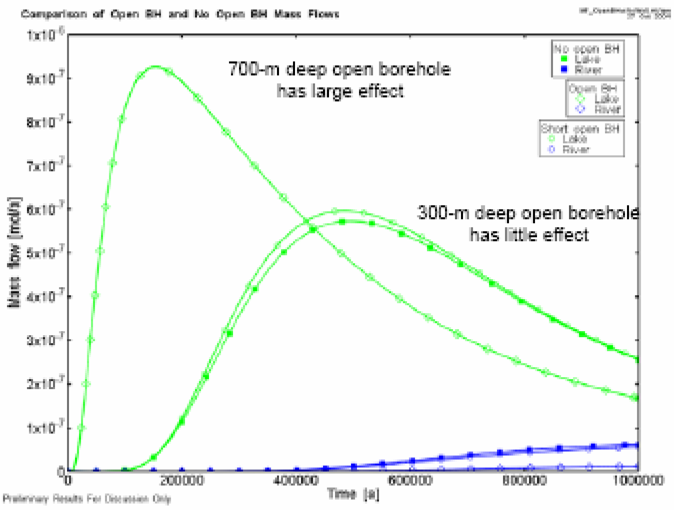
Open borehole – How close is too close?
- Example - Repository in SFR granite at 660 m



ONTARIO POWER GENERATION

10

Effect of open borehole – 0, 300, 700 m depth



ONTARIO POWER GENERATION

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Recent Canadian Monitoring R&D

Monitoring approach

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ONTARIO POWER GENERATION

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PART C

LIST OF PARTICIPANTS

BELGIUM

DE PRETER, Peter
ONDRAF/NIRAS
Avenue des Arts, 14
B-1210 Bruxelles
Tel: +32 (0)2 212 10 49
Fax: +32 (0)2 218 51 65
Eml: p.depreter@nirond.be

MARIVOET, Jan
SCK•CEN
Boeretang 200
B-2400 Mol
Tel: +32 (0)14 33 32 42
Fax: +32 (0)14 32 35 53
Eml: jmarivoe@sckcen.be

CANADA

FLAVELLE, Peter
Wastes and Geosciences Division
Canadian Nuclear Safety Commission
P.O. Box 1046, Station B, 280 Slater Street
Ottawa, Ontario K1P 5S9
Tel: +1 613 995 3816
Fax: +1 613 995 5086
Eml: flavellep@cnsc-ccsn.gc.ca

GIERSZEWSKI, Paul
Ontario Power Generation
Long-Term Waste Management Technology
700 University Avenue, (H16 B20)
H16 E27 Toronto M5G IX6
Tel: +1 416 592 2346
Fax: +1 416 592 7336
Eml: paul.gierszewski@
opg.com

CZECH REPUBLIC

KONOPASKOVA, Sona
Radioactive Waste Repository Authority (RAWRA)
Dlazdena 6
110 00 Praha 1
Tel: +420 2 21 42 1518
Fax: +420 2 21 42 1544
Eml: Konopaskova@rawra.cz

FINLAND

PALTEMAA, Risto
Radiation and Nuclear Safety Authority (STUK)
P.O. Box 14
FIN-00881 Helsinki
Tel: +358 (0)9 759 88 313
Fax: +358 (0)9 759 88 670
Eml: risto.paltemaa@stuk.fi

VIRA, Juhani
Posiva Oy
Töölönkatu 4
FIN-00100 Helsinki
Tel: +358 (0)9 2280 3740
Fax: +358 (0)9 2280 3719
Eml: juhani.vira@posiva.fi

FRANCE

GREVOZ, Arnaud
Andra
1-7, rue Jean Monnet
F-92298 Chatenay-Malabry Cedex
Tel: +33 (0)1 4611 8035
Fax: +33 (0)1 4611 8013
Eml: arnaud.grevoz@andra.fr

MAYER, Stefan
Andra
1-7 rue Jean Monnet
F-92298 Chatenay-Malabry Cedex
Tel: +33 (0)1 46 11 80 72
Fax: +33 (0)1 46 11 83 38
Eml: stefan.mayer@anda.fr

RAIMBAULT, Philippe Direction Générale de la Sûreté Nucléaire et de la Radioprotection (DGSNR) 10, Route du Panorama, Robert Schumann - BP 83 F-92266 Fontenay-aux-Roses Cedex	Tel: Fax: Eml:	+33 (0)1 4319 7015 +33 (0)1 4319 7166 philippe.raimbault@ asn.minefi.gouv.fr
SERRES, Christophe IRSN/DSU/SSD BP 17 F-92265 Fontenay-aux-Roses, Cedex	Tel: Fax: Eml:	+33 (0)1 58 35 91 64 +33 (0)1 58 35 71 35 christophe.serres@irsn.fr

GERMANY

NOSECK, Ulrich Gesellschaft für Anlagen- und Reaktorsicherheit (GRS)mbH Theodor-Heuss-Str. 4 D-38122 Braunschweig	Tel: Fax: Eml:	+49 (0)531 8012 247 +49 (0)531 8012 200 nos@grs.de
ROEHLIG, Klaus-Juergen Gesellschaft für Anlagen- und Reaktorsicherheit (GRS)mbH Schwertnergasse 1 D-50667 Köln	Tel: Fax: Eml:	+49 (0)221 2068 796 +49 (0)221 2068 939 rkj@grs.de
WOLLRATH, Juergen Bundesamt für Strahlenschutz (BfS) Postfach 10 01 49 D-38201 Salzgitter	Tel: Fax: Eml:	+49 (0)1888 333 1964 +49 (0)1888 333 1605 JWollrath@BfS.de

HUNGARY

NAGY, Zoltan Public Agency for Radioactive Waste Management (PURAM) H-7031 Paks P.O. Box 12	Tel: Fax: Eml:	+36 75 519 536 +36 75 519 589 nagyzoltan@axelero.hu

JAPAN

KIMURA, Hideo JAERI Tokai-mura, Naka-gun Ibaraki-ken 319-11 95	Tel: Fax: Eml:	+81-29-282-5941 +81-29-282-5842 hkimura@ popsvr.tokai.jaeri.go.jp
UMEKI, Hiroyuki Nuclear Waste Management Organization of Japan (NUMO) Mita NN Bldg., 1-23, Shiba 4-Chome, Minat Tokyo 108 0014	Tel: Fax: Eml:	+81 (0)3 4513 1503 +81 (0)3 4513 1599 humeki@numo.or.jp

KOREA (REPUBLIC OF)

KANG, Chul-Hyung Total System Performance Assessment Korea Atomic Energy Research Institute (KAERI) P.O. Box 105, Yusong Daejon 305-600	Tel: Fax: Eml:	+82 (0)42 868 2632 +82 (0)42 868-2035 chkang@kaeri.re.kr

NETHERLANDS

O'SULLIVAN, Patrick J. Radioactive Waste and Nuclear Research and Consultancy Group (NRG) Postbus 25 NL-1755 ZG Petten	Tel: Fax: Eml:	+31 224 564533 +31 (0)224 568491 osullivan@nrg-nl.com

SPAIN

ALONSO, Jesus ENRESA Calle Emilio Vargas, 7 E-28043 Madrid	Tel: Fax: Eml:	+34 91 566 8108 +34 91 566 8165 jald@enresa.es

SWEDEN

DVERSTORP, Björn Department of Waste Management and Environmental Protection Swedish Radiation Protection Authority (SSI) S-102 40 Stockholm	Tel: Fax: Eml:	+46 8 7297 248 +46 8 7297 108 Bjorn.Dverstorp@ssi.se
HEDIN, Allan Swedish Nuclear Fuel & Waste Management Co. (SKB) Box 5864 S-102 40 Stockholm	Tel: Fax: Eml:	+46 (0)8 459 85 84 +46 (0)8 661 57 19 allan.hedin@skb.se
JENSEN, Mikael Swedish Radiation Protection Institute (SSI) S-171 16 Stockholm	Tel: Fax: Eml:	+46 (0)8 72 97 100 +46 (0)8 72 97 162 mikael.jensen@ssi.se
STROMBERG, Bo Office of Nuclear Waste Swedish Nuclear Power Inspectorate (SKI) S-106 58 Stockholm	Tel: Fax: Eml:	+46 8 698 8485 +46 8 661 9086 bo.stromberg@ski.se

SWITZERLAND

FRANK, Erik Swiss Federal Nuclear Safety Inspectorate (HSK) CH-5232 Villigen-HSK	Tel: Fax: Eml:	+41 (56) 310 39 45 +41 (56) 310 39 07 erik.frank@hsk.psi.ch
HADERMANN, Jürg Paul Scherrer Institute (PSI) Waste Management Laboratory OBUA/2 CH-5232 Villigen-PSI	Tel: Fax: Eml:	+41 56 310 2415 +41 56 310 2821 joerg.hadermann@psi.ch
SCHNEIDER, Jürg NAGRA Hardstrasse 73 CH-5430 Wettingen	Tel: Fax: Eml:	+41 (56) 437 13 02 +41 (56) 437 13 17 schneider@nagra.ch

UNITED KINGDOM

BAKER, Andy
Environment Agency
Ghyll Mount, Gillan Way
Penrith
UK-Cumbria CA11 9BP
Tel: +44 (0)1768 866666
Fax: +44 (0)1768 865606
Eml: andy.baker@environment-agency.gov.uk

BARLOW, Stephen
UK Nirex Ltd
Curie Avenue
Harwell, Didcot
UK-Oxfordshire OX11 0RH
Tel: +44 (0)1235 825 419
Fax: +44 (0)1235 820 560
Eml: steve.barlow@nirex.co.uk

HOOPER, Alan J.
Chief Scientific Advisor
UK Nirex Ltd
Curie Avenue
Harwell, Didcot
UK-Oxfordshire OX11 0RH
Tel: +44 (0)1235 825 401
Fax: +44 (0)1235 820 560
Eml: alan.hooper@nirex.co.uk

WATTS, Len
BNFL
R101 Rutherford House
Risley,Warrington
UK-Cheshire WA3 6AS
Tel: +44 (0)1925 834344
Fax: +44 (0)1925 8320161
Eml: len.watts@bnfl.com

UNITED STATES OF AMERICA

SAGAR, Budhi
CNWRA - Southwest Research Institute, CNWRA
Post Office Drawer 28510
6220 Culebra Road
USA-San Antonio, TX 78238
Tel: +1-210-522-5252
Fax: +1-210-522-5155
Eml: bsagar@swri.org

VAN LUIK, Abraham E.
U.S. Department of Energy
Office of Repository Development
1551 Hillshire Drive
USA-Las Vegas, NV 89134
Tel: +1 (702) 794-1424
Fax: +1 (702) 794-1435
Eml: abe_vanluik@notes.ymp.gov

International Organisations

METCALF, Phil
International Atomic Energy Agency (IAEA)
Wagramer Strasse 5
P.O. Box 100
A-1400 Vienna
Tel: +43 1260022676
Fax: +43 126007
Eml: p.metcalf@iaea.org

RAYNAL, Michel
European Commission (EC)
DG-RTD/J4
B-1049 Brussels
Tel: +32 (0)2 296 61 78
Fax: +32 (0)2 295 49 91
Eml: michel.raynal@cec.eu.int

NILSSON, Karl-Frederik (EC Observer)
European Commission (EC)
Joint Research Center Institute for Energy
Postbus 2
NL-1755 ZG Petten
Tel: +31 224 56 5420
Fax: +31 224 56 5621
Eml: karl-fredrik.nilsson@jrc.nl

OECD/Nuclear Energy Agency
12, Boulevard des Iles
F-92130 Issy-les-Moulineaux

PESCATORE, Claudio
Principal Administrator
Radioactive Waste Management
Tel: +33 (0)1 45 24 10 48
Fax: +33 (0)1 45 24 11 10
Eml: claudio.pescatore@oecd.org

RIOTTE, Hans
Head of Division
Radiation Protection and
Radioactive Waste Management
Tel: +33 (0)1 45 24 10 40
Fax: +33 (0)1 45 24 11 10
Eml: hans.riotte@oecd.org

VOINIS, Sylvie
Administrator
Radioactive Waste Management
Tel: +33 (0)1 45 24 10 49
Fax: +33 (0)1 45 24 11 45
Eml: sylvie.voinis@oecd.org

Apologies received from

BAEKELANDT, Luc
FANC
Belgium

HAUTOJARVI, Aimo (replaced by VIRA, Juhani)
Posiva Oy
Finland

BRENNECKE, Peter
BfS
Germany

SERVA, Leonello
APAT
Italy

BUDAY, Gabor (replaced by NAGY, Zoltan)
PURAM
Hungary

PEKAR, Anton
VUJE Trnava, Inc.
Slovak Rep.

VIGFUSSON, Johannes (replaced by FRANK, Erik)
HSK
Switzerland

ZUIDEMA, Piet (replaced by SCHNEIDER, Jürg)
Nagra
Switzerland

CADY, Ralph
NRC
USA

LOUVAT, Didier (replaced by METCALF, Phil)
IAEA

LIEVEN, Thierry
CEA
France

VIENO, Timo
VTT PROCESSES
Finland

WALLNER, Manfried
BGR
Germany

VENTURA, Giancarlo
ENEA
Italy

HANUSIK, Vaclav
VUJE Trnava, Inc.
Slovak Rep.

RUIZ LOPEZ, Carmen
CSN
Spain

CHARLES, Christophe
US DOE
USA

ZVONAR, Cynthia
US DOE
USA

LEVICH, Robert
US DOE
USA

BRUNO, Gérard
IRSN
France