

CONTEXT NOTE

4.2: Monitoring

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FOREWORD

This Context Note is one in a series, prepared by United Kingdom Nirex Limited (Nirex), that summarises the issues, experience and status in each of 30 topic areas that are relevant to the phased development of a geological facility for the long-term management of intermediate-level and certain low-level radioactive waste in the UK – the Nirex Phased Geological Repository Concept (PGRC).

It is the view of Nirex that sufficient work has been done to demonstrate the viability of the generic Nirex Phased Geological Repository Concept: to support packaging advice; and to provide enough confidence to proceed with a site selection process in the UK. The aim of the Context Notes is to provide the documentation to support this view.

The starting point for the notes has been an identification of issues based on extensive examination of reviews and published scrutiny of Nirex work and programmes over the past 20 years. This has been supplemented by more recent discussion meetings with knowledgeable and concerned organisations and discussion meetings within Nirex. The issues have been analysed according to their importance with respect to the future implementation of a geological repository in the UK, screened and sorted into topic areas. Then, for each topic, a Context Note has been prepared that presents the key issues, relevant experience, directions for further development and overall status in the topic area. The Context Notes are intended to provide a focus for discussion of issues and priorities of future work within Nirex, and as a means of communication to stakeholders. The Notes provide support to Nirex Report N/122, which presents an overview of the viability of the Nirex Phased Geological Repository Concept.

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CONTEXT NOTE 4.2: MONITORING

1 THE IMPORTANCE OF MONITORING

Within a “phased approach to disposal”, monitoring will play an important role in providing information to the operator and to society in general, to assist in the safe environmentally sound and publicly acceptable development and operation of the repository; and to support decision making about if and when, to move from one phase to the next. Nirex have been involved in several dialogues in which the public have indicated an expectation that they would expect to see monitoring in place to test whether repository conditions are progressing as expected, and to enable mitigation measures to be put in place should this not be the case.

Nirex have recently led and completed a European Union (EU) Thematic Network Study [1] on the role of monitoring in a phased approach to geological disposal. The study brought together expertise from twelve organisations from ten EU and associated countries. The report detailed monitoring approaches in the countries represented, and identified key principles for monitoring of geological repositories. These principles build on the monitoring requirements and objectives defined by the International Atomic Energy Agency (IAEA). For completeness the principles identified by the Thematic Network are listed here in full:

- *“The operational safety of a geological disposal facility (both radiological and conventional) must be underpinned and verified by monitoring. This is the case for all nuclear facilities.*
- *Long-term (post-closure) safety cannot rely on monitoring after closure. This is for reasons of principle – undue burdens should not be placed on future generations – and for practical reasons – it cannot be assumed that future generations will have the technical capability or interest in carrying out monitoring.*
- *Therefore, long-term safety must be assured by the disposal system design (including the choice of site) and the quality of its implementation. After closure, the disposal system must be passively safe without reliance on monitoring.*
- *To this end, a convincing long-term safety case has to be developed prior to the emplacement of the waste (i.e. monitoring in the post-emplacement phase is not part of the safety case, although it may provide an opportunity to confirm its conclusions).*
- *All monitoring must be implemented in such a way as not to be detrimental to long-term safety. That is, no significant detrimental disturbance of the long-term performance should be introduced by monitoring. (Similarly, there must be no compromise with respect to, long-term safety in order to facilitate the retrievability of the waste.)*
- *The societal role of monitoring must be acknowledged. Monitoring may be carried out for non-technical reasons, for example related to public re-assurance. Such monitoring may be continued as long as it is required by future generations, who may not consider this an ‘undue burden’.*”

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The final report references the IAEA Safety Standards [2], which defines the requirements for monitoring as:

“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 the environment during the operation of the geological disposal facility and to confirm the absence of conditions that would undermine the safety of the geological disposal facility.”

Geological disposal of long-lived radioactive wastes is intended to isolate radionuclides from the accessible environment in such a way that the long-term safety of the disposal system should require no further actions on the part of future generations. Thus, for example, the long-term safety of the disposal system should be assured by the engineered and natural barriers and not require continual monitoring of its behaviour. This is not to say that people in the future might not want to monitor the repository in some way, but its safety would not depend on them being willing, or able, to do so. The system should be designed to be intrinsically and passively safe, that long-term safety would not depend on monitoring. However, as outlined above, there may be technical and social reasons to continue to monitor the facility.

The principal method that repository developers use to build confidence in geological disposal is the development of a comprehensive safety case [3]. The safety case includes a detailed safety assessment and presentation of a series of arguments aimed at demonstrating confidence in long-term safety. These arguments include discussion of many aspects of the repository project, for example the intrinsic robustness of the multi-barrier system, quality assurance and quality management, and comparisons with familiar examples and natural analogues. A further input into enhancing confidence in the safety case is the use of monitoring and characterisation throughout all phases to confirm key performance criteria, which can be used to test and refine models of long-term safety.

During the potentially long period prior to repository closure, both future operators and other sectors of future society would need to make critical decisions about how, when and if to implement various steps in the management of the repository system. A primary objective of monitoring is to provide information to assist in making those decisions. In this context, the key purposes of monitoring of deep disposal systems has been developed by the International Community [4] and are listed below:

- *to provide information for making management decisions in a stepwise programme of repository construction, operation and closure;*
- *to strengthen understanding of some aspects of system behaviour used in developing the safety case for the repository and to allow further testing of models predicting those aspects;*
- *to provide information to give society at large the confidence to take decisions on the major stages of the repository development programme and to strengthen confidence, for as long as society requires, that the repository is having no undesirable impacts on human health and the environment;*
- *to accumulate an environmental database on the repository site and its surroundings that may be of use to future decision makers;*
- *to address the requirement to maintain nuclear safeguards, should the repository contain fissile material such as spent fuel or plutonium-rich waste.*

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Context Note 2.8 [5] provides an example of an institutional framework and decision-making process which could be applied to help to ensure the safe, long-term management of a waste management facility; how this could be applied to the implementation of a period of underground storage; and any subsequent decisions to move from that to the closure of the facility and a programme of monitoring after closure.

2 RELEVANT EXPERIENCE

Monitoring could have several useful technical applications in the potentially extensive period up to the eventual closure of a geological repository, which may occur many decades after the start of the repository development programme. There may also be a valid, and extremely strong, social requirement to demonstrate aspects of technical knowledge and safety at all stages, up to and even after repository closure. This too, may require monitoring activities and could impact decisions on closure.

Prior to embarking on work to define its monitoring strategy, Nirex held two workshops in order to understand further stakeholder concerns regarding monitoring and retrievability. The first workshop was held in December 2000, and was with interested stakeholders who have no financial links with the UK nuclear industry [6]. The second workshop, held in February 2001, was with representatives from the nuclear industry or companies that are (or have been) involved in work for the nuclear industry [7].

Responses to the comments received at the two workshops were presented in a Nirex Report [8]. Nirex has used the feedback from these workshops and from other consultations to help direct its studies on monitoring.

2.1 UK Experience

2.1.1 Establishing Monitoring of Baseline Conditions

An important aspect of the Nirex Phased Geological Repository Concept (PGRC) is that monitoring would be carried out at all stages of the repository development in order to provide assurance of the current and possible future safety, and to provide input to the technical and societal decision making related to the repository development. Nirex has developed substantial expertise in some types of monitoring that would be necessary during the development of a repository, e.g. in relation to waste characterisation and site investigation.

Nirex recently commissioned a study [9] to identify monitoring options taking a broad view of the possible information requirements. The objective of this report was to establish, for the Nirex Generic Repository Concept, potential requirements for monitoring and the options available for such monitoring.

This was the first step in the development of an overall strategy for monitoring within a phased disposal concept. The report covers potential requirements for monitoring during all stages of the development of the disposal system. It considers a broad range of potential monitoring including:

- the establishment of baseline condition;
- system performance at the time of monitoring;
- the provision of data to be used in repository design and the evaluation of long-term performance, and;

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- monitoring in the broader sense including non-technical assurance and monitoring of regulatory and social developments that may impact on the repository project.

Results from monitoring could be key factors in providing the confidence needed to progress from one stage to the next in a repository development programme. Thus, the justification for monitoring needs to consider the contribution to public acceptability as well as purely technical requirements. Public views may influence the design of some aspects of the monitoring programmes.

The aim of the report was to identify the potential options available for such monitoring. The report considered:

- **why** the monitoring may be required;
- **what** parameters may require monitoring, and;
- **how** these parameters can be monitored.

In considering the requirements of a monitoring programme, and in particular those that would be required to assist in a decision-making process of when to implement various phases and to build public confidence, Nirex has defined in [10] the following monitoring objectives:

- *“To establish the undisturbed conditions of a potential site and hence provide a baseline against which to compare the future evolution of the system.*
- *To provide information on the host environment for use in the design of the repository and in performance assessment modelling.*
- *To confirm that predictions from modelling and calculations match expectations and provide appropriate reassurance.*
- *To indicate how the engineered and natural barriers are performing.*
- *To determine the impact of the repository on workers, the public and the environment.*
- *To demonstrate that the waste remains retrievable.*
- *To address the requirements for ‘Safeguards’.*”

2.1.2 Pre-Closure Monitoring

During the construction and operational phase of the development of a repository, there would be routine monitoring. In addition, monitoring techniques would be refined for use in the post-closure phase. During the pre-closure phase there would be:

- Planned preventative maintenance and routine condition monitoring of plant and equipment.
- Monitoring of rock movement:
 - from the start of construction, to determine and confirm the expected behaviour of the surrounding rock;
 - to measure the actual behaviour and compare with expectations.

Any differences from actual to expected could reflect conservative design assumptions or be a trigger for some form of further action such as rock bolting to increase tunnel support to ensure tunnel stability.

- Package monitoring:
 - records and confirmation at despatch;

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- monitoring and checking on receipt;
- selective monitoring within inlet cells;
- condition monitoring of packages within vault over prolonged time periods:
 - during emplacement operations, and;
 - periods of care and maintenance.
- periodic recovery of packages for closer monitoring and inspection which could include:
 - visual examination;
 - surface temperature monitors and corrosion probes;
 - dimensional survey to measure changes of the package;
 - non-destructive examination of critical features e.g. structural welds;
- the use of dummy materials to enhance understanding of structural and package changes over time, such as:
 - corrosion coupons; and
 - dummy packages.
- A range of routine monitoring during the repository construction, such as groundwater inflow, and measurement of the geochemistry of the groundwater;
- Development of monitoring methods for the post closure phase;
- Determination and validation of operational performance of monitoring devices for the post closure phase;
- Development and building of confidence in monitoring data prior to the post closure phase. The PGRC would provide sufficient time for:
 - An initial stage of testing and development where monitoring techniques may be adapted to the in situ conditions;
 - A second stage of demonstration where the operational performance of monitoring devices would be determined.

2.1.3 Post-Closure Monitoring

The Nirex PGRC includes provision for monitoring following sealing and closure of the repository. However, uncertainty has been expressed about the extent to which a repository may be monitored during the post-closure phase [6] [7] [11]. There are two key uncertainties with respect to the feasibility of monitoring geological repositories following closure:

- The ability for monitoring to provide the information that is required: The containment systems within the repository are designed to be very effective, especially in the short-term (the first few thousand years after closure), and therefore, monitoring would not be expected to detect failure of the containment system. However, there are changes to the disposal system that can be monitored and this requires consideration of *what* to monitor, and *when*.
- The ability to actually conduct such monitoring: Many observers note that monitoring of the repository is both difficult and uncertain. This is partly due to the requirement that monitoring must not affect the passive safety of the

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repository. Therefore, it is necessary to use non-intrusive techniques and/or direct measurement with remote transmission of results. This requires consideration of *how* to monitor the repository.

Nirex has readily acknowledged these uncertainties and consequently commissioned contractor studies to determine the feasibility of monitoring the post-closure evolution of the repository and the repository's impact on the surrounding environment, by identifying techniques through which this monitoring might be conducted. The results from this study are presented in a Summary Report [12] and in an accompanying, more detailed Project Report [13].

The feasibility of post-closure monitoring was assessed by consideration of the plans for post-closure monitoring in other national radioactive waste management programmes, and by consideration of geophysical monitoring techniques applied in other industries, principally the oil and gas industry and the mining industry.

Fourteen national radioactive waste management programmes were reviewed. The plans for post-closure monitoring in these programmes are highly variable. Some programmes have considered the issue of post-closure monitoring in detail. Countries that are planning to implement a comprehensive post-closure monitoring programme do so with the objective of improving the understanding of the repository system evolution, for performance confirmation, and as an aid to decision-making (for example, on whether to, and when to, end monitoring, or to retrieve the waste). Other programmes are principally considering post-closure monitoring for safeguards and public acceptability reasons, and do not see post-closure monitoring as a technically-driven activity.

Following closure, monitoring of a geological repository for assurance, such as monitoring radionuclide concentrations in water and/or gas phases, may be readily achieved by borehole-based and surface-based instrumentation. Although such monitoring would not be able to detect individual waste packages not performing to specification, such monitoring would allow the application of risk management options in the unlikely event of there being an unexpected response to such monitoring.

There are a large number of potential monitoring technologies available for monitoring the response of a geological repository to closure [13]. The feasibility of applying these techniques depends on site-specific and repository concept-specific factors.

Monitoring techniques are available for four key areas of the repository system [13]:

Repository-Based Techniques: These techniques include instruments used to monitor the physical and chemical environment of the engineered barriers. Such instruments are routinely applied during operation of the facility and a number of underground research laboratory experiments have been monitored by extensive instrumentation systems. Examples are provided in [14], [15] and [16].

The requirement for passive safety of the repository following closure is usually taken to indicate that monitoring the repository through wires connected to the surface is not acceptable. Techniques exist for the remote transmission of data through-the-earth (TTE) telemetry – this has also been referred to as “wireless” monitoring. There are two principal concerns with the use of TTE telemetry or “wireless” monitoring. First, the electromagnetic signal that is used to transmit data is attenuated by transmission through solid rock and distances of only 100m may be achieved. This concern may be overcome by transmission of the information through relay stations emplaced in the backfilled access routes to the repository. Secondly, there is a limit to the operating life of the remote power source used to transmit data.

However, research and development of long-term power supplies is a key requirement before TTE telemetry systems can be suggested as a potential method

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for relaying repository-based monitoring data. ANDRA (France) and RWMC (Japan) have been working on the development of “wireless” monitoring with particular emphasis on the operating life of the power source. The use of this technology provides the opportunity for remote monitoring of emplaced waste (without reliance on hard-wiring) over several tens of years but there is a realistic limit to both the power source and the instrumentation remaining operational.

One project in which research and development into remote monitoring systems is being undertaken is the Engineering Studies and Demonstration of Repository Designs (ESDRED) of which Nirex is a partner with nine other European radioactive waste management agencies. The focus of the 5-year ESDRED Programme, which will continue through to 2008, is the construction of full-scale technological prototypes of geological repositories to conduct practical demonstration of a range of key activities related to the effective emplacement of buffer and waste packages within underground facilities. Included within the ESDRED programme is the development and demonstration of non-intrusive monitoring techniques, which Nirex are leading. This programme will apply the use of existing technology, applying geophysical techniques used in mining and oil industry exploration and surveillance. The technique proposed is to use seismic tomography within boreholes located away from the prototype demonstration to monitor the key performance characteristics.

The development of non-intrusive monitoring provides the potential for monitoring to be continued away from the waste emplacement location, which would be sealed and inaccessible. Access to the monitoring systems would therefore be maintained without the need to disturb the demonstration.

Borehole-Based Techniques: A staged programme of monitoring following closure that included a progressive stepping back from the repository provides a suitable platform for including borehole-based techniques in the monitoring strategy used post-closure. Borehole-based techniques could be used to monitor the system response to closure. Techniques that could be applied include measurement of groundwater properties (e.g. pressure, temperature and chemistry), micro-seismicity and acoustic emission monitoring, vertical seismic profiling, borehole radar, seismic tomography and wireline logging. Borehole-based monitoring might be undertaken via open or sealed boreholes.

It would be anticipated that the monitoring would be consistent with the response to closure predicted by the expected evolution model, for example recovery of groundwater pressures indicating saturation of the repository over a timescale consistent with the predictions of the expected evolution model. Recovery of the geological environment in response to closure depends on site-specific and repository-specific conditions. However, many processes (e.g. groundwater flow) are likely to recover from the perturbation caused by repository construction, operation and closure over periods suitable for monitoring (e.g. years to decades). Continuation of a monitoring programme would be considered within a decision-making process developed as part of the programme of long-term institutional control [5].

Surface-Based Techniques: A number of surface-based techniques might be useful for monitoring post-closure depending on site-specific and repository concept-specific conditions. For example, time-lapse 3D seismic reflection surveying is now used in the oil and gas industry to track water, oil and gas movement in the sub-surface [17], and may be applicable to monitoring gas migration from a geological repository.

Airborne Techniques: Similarly, a number of airborne techniques might be useful for monitoring post-closure. For example, satellite-base interferometry is now used to define ground surface elevation changes to an accuracy of millimetres [18], and may be useful to detect ground surface elevation changes as a result of thermal expansion or settlement. Recently Lawrence Livermore National Laboratory has

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applied this technology to study London's Jubilee line underground rail extension, revealing a previously undetected 2 centimetre subsidence above the tunnel [19]. Monitoring of such processes would feed into confirmation that the response, post-closure, is as predicted by the expected evolution model.

Therefore, there are many monitoring techniques that build confidence in long-term safety by demonstrating predictability of the system. However, a key aspect of maintaining public confidence in the post-closure safety of a geological repository is in the use of monitoring as part of a transparent decision-making process.

2.2 International Monitoring Experience

The EU Thematic Network Study [1] identifies potential monitoring strategies and requirements during all phases of the implementation of a disposal system, including site investigation and characterisation, facility construction and operation, steps leading to closure of the facility and any post-closure monitoring that may be carried out.

In all, ten countries national concepts for the disposal or long-term management of radioactive waste were under consideration, although the level of advancement of concepts, related research and technical development differed.

Four different types of monitoring were identified at the outset of the project. These provided the basis for initial collaborative tasks carried out by subgroups within the Thematic Network and subsequently presented to all participants and discussed in plenary mode. The types of monitoring considered were:

- the establishment of baseline conditions (baseline conditions are the *in situ* undisturbed conditions of a site prior to disturbance caused by site characterisation, construction and operation);
- monitoring for compliance with regulatory and requirements or other criteria and standards;
- monitoring to support evaluations and assessments of repository performance;
- the broader aspects of monitoring – this includes a range of subjects which, whilst not necessarily of direct relevance to the technical development of a repository, are of value in implementing a disposal programme. These may include monitoring related to other areas of science and technical capability, legal matters and societal values.

In addition, more strategic aspects of monitoring were discussed and additional tasks were defined to cover monitoring requirements, monitoring techniques and practicalities, and the interpretation of monitoring measurements.

Additional documentation has been produced by the International Community [4] further assessing the purposes for monitoring geological repositories at the different stages of a repository programme, the use that may be made of the information obtained and the techniques that might be applied. Nirex is actively involved in the current and future work plans of the international community (see Section 3 below).

Nirex are currently undertaking work to develop an illustrative post-closure monitoring programme based on the use of applicable monitoring techniques. It is intended for this work to provide a basis for a wide-ranging discussion of how a post-closure monitoring programme could be developed. This would include how the components of a post-closure monitoring programme might link to the different phases of repository development, such as site investigation, construction, operation and closure, which provide significant scope for baselining the natural conditions of the repository site. The work is also considering how monitoring techniques might be

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integrated into a programme and how this programme could address high-level requirements.

3 FUTURE WORK

3.1 Non-Intrusive Monitoring Techniques

Nirex is currently a partner organisation within a joint European Integrated Project known as Engineering Studies and Demonstration of Repository Design (ESDRED), which is scheduled to be completed in 2008. Within this study, Nirex is leading aspects of the work on the practical demonstration of non-intrusive monitoring techniques. Such non-intrusive techniques are required to avoid the potential degradation in the engineered barrier systems associated with using conventional electric or fibre optic cables, which must pass through or around seals and bulkheads. Non-intrusive techniques also avoid the problems associated with the failure of monitoring sensors, which for conventional (intrusive) monitoring could only be renewed or replaced by disturbing the engineered barrier systems.

The work has included an assessment of the applicability of techniques used within the oil and gas and minerals exploration industry to improve the capability to more accurately interpret data. Work is currently progressing on a proposal for a practical evaluation of the use of seismic tomography for non-intrusive monitoring in an underground research facility.

The benefit of developing effective non-intrusive monitoring such as that proposed within ESDRED is that information can be gained about the waste after it has been emplaced, without reliance on inaccessible instrumentation. Using techniques such as “wireless” monitoring coupled with non-intrusive techniques would provide good information about the performance of the system prior to closure and provide a very effective means of “calibrating” and developing confidence in the non-intrusive system by providing confirmatory information. Such an approach would mean that there would be more confidence in the information from such non-intrusive applications applied after closure. The programme within ESDRED provides a step towards the development of such techniques, which would ultimately build confidence in a monitoring programme prior to and after closure.

3.2 Post-Closure Monitoring

Following up on the work currently being undertaken on the illustrative post-closure programmes, it is proposed to conduct further technical review and development. This could include wider consultation to support further development of illustrative monitoring concepts which would improve the available information on applicable techniques for post-closure monitoring, identify areas where techniques might be beneficially developed, and support decision-making on the definition of future monitoring programmes.

This work would be progressed on the clear understanding that the PGRC would be developed without any dependence on monitoring for long-term safety.

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4 CONCLUSIONS

There are two key messages which should be emphasised with regards to monitoring the Nirex Phased Geological Repository Concept:

- Nirex has developed substantial expertise in some of the types of monitoring that would be necessary during the development of a repository, e.g. in relation to waste characterisation and site investigation.
- Nirex is actively engaged with international sister organisations in developing monitoring strategies for long-term radioactive waste management.

Conclusions from Nirex's research into monitoring are:

- Prior to closure of the repository, monitoring would provide information and data to confirm the basis for a comprehensive safety case;
- A key requirement of international and UK national guidance is that a geological repository is passively safe, and that long-term safety does not depend on monitoring;
- International and UK national guidance states that monitoring must not reduce the overall level of safety of the repository;
- International and national guidance assumes that monitoring post-closure would only be undertaken for assurance purposes.

However, future generations may require that a repository is monitored following closure and Nirex are developing suitable approaches to post-closure monitoring through the development of monitoring strategies and participation in European research projects. Requirements for post-closure monitoring are:

- A repository can be monitored for assurance, for example for radionuclide migration. It is expected that such monitoring would not detect any measurable response but would be used to confirm that expectation. Such monitoring could be undertaken at any stage in the future, as long as records of the repository remain.
- The post-closure response to repository closure can be monitored through an integrated system located in the repository, in boreholes, on the surface, and using airborne techniques. The results of this monitoring can, via comparison with an expected evolution model, demonstrate that the repository system has responded to closure as expected, and thereby contribute to building confidence in long-term safety.
- A further key element in building confidence is the development of a transparent decision-making process that defines trigger values to indicate when actions are required, and includes a schedule for periodic assessment of repository performance.

Key issues have been identified from internal and external reviews of the current Nirex Generic Repository Design, and collated together under three principle headings, which are outlined in the following subsections. Table 1 summarises these key issues, evaluates their implications and provides comment on the current status of work undertaken both nationally and internationally in these areas.

4.1 Monitoring Timescales

The issues raised relate mainly to the decision to close the repository and when repository monitoring should cease.

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Nirex are involved in work both in the UK and internationally which will help to define more closely the strategies and regimes of monitoring throughout the operational life. Monitoring would be carried out to confirm and refine models for safe construction and operation and to support key parameters used in assessing long-term safety. This information would provide the basis for decisions related to moving from one phase to the next and ultimately to a decision on closure of the repository or retrieval of the waste.

4.2 Monitoring Definition

The issues raised relate to the meaning and scope of 'monitoring' for all phases of the concept.

Nirex recently commissioned work to discuss the process by which a repository post-closure monitoring programme may be developed. Currently work is in progress to determine the feasibility of post-closure monitoring of a repository based on the Nirex Phased Geological Repository by developing an illustrative post-closure monitoring programme.

4.3 Monitoring Parameters

The key issues relate to understanding which repository parameters would be monitored, and what is the justification for doing so. Further issues relate to the criteria that would be used to make decisions on waste retrieval.

Further work is planned to define what parameters would be required to be monitored, some of which would be site specific. The criteria for decisions on waste retrieval could be wider than purely technical reasons associated with repository performance. A decision on waste retrieval could result if monitoring information demonstrated that certain parameters were outside expectations to the extent that resultant reassessment of safety indicated that safety performance could not be met.

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Table 1 Issues Associated with Retrievability

Issue	Evaluation	Status
<p>1. Monitoring Timescales Should monitoring continue after closure and for how long.</p>	<p>Implications of monitoring throughout the life of the repository are;</p> <ul style="list-style-type: none"> - Never being an end point to monitoring. 	<p>Monitoring would be undertaken during all the phases of the Nirex Phased Geological Repository Concept, including a period after closure. Results from monitoring would be assessed, and used to help society decide whether to continue, reduce or cease the monitoring regime. Monitoring would be undertaken to indicate the absence of change as no change is expected.</p> <p>Nirex recently co-ordinated an EU Study [1] on the role of monitoring in a phased approach to the geological disposal of radioactive waste, with the following objectives;</p> <ul style="list-style-type: none"> • improve both the understanding of the role of and the options for monitoring within a phased approach to the deep geological disposal of radioactive waste and: • to identify how much monitoring can contribute to decision-making, operational and post-closure safety and confidence in our understanding of the repository development. <p>Work is continuing both within the UK and Internationally to assess the feasibility of monitoring the post-closure evolution of the repository and surrounding environmental impact.</p>
<p>2. Monitoring Definition The meaning and scope of 'monitoring' should be clarified for all phases of the concept.</p>	<p>Implications of monitoring throughout the phases of the repository are;</p> <ul style="list-style-type: none"> - What to monitor in each phase 	<p>Nirex are currently undertaking work to develop an illustrative post-closure monitoring programme based on the use of applicable monitoring techniques.</p> <p>It is intended that this could provide a basis for a wide-ranging discussion on how a post-closure monitoring programme might be developed. The work should illustrate how the components of a post-closure monitoring programme might link to the different phases of repository development, such as site investigation, construction, operation and closure, which provide significant scope for baselining the natural conditions of the repository site. This work should provide a basis for discussion and development of what should be monitored throughout the phases of the</p>

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Issue	Evaluation	Status
		repository.
<p>3. Monitoring Parameters</p> <p>Nirex may wish to state more explicitly which repository parameters would be monitored, the justification for doing so, and the criteria that would be used to make decisions on waste retrieval.</p>	<p>Implications of monitoring throughout the phases of the repository are;</p> <ul style="list-style-type: none"> - What are the important parameters to monitor and what information is required at each phase 	<p>The work discussed above to develop an illustrative approach could be developed further to address in more detail the likely nature and scope of monitoring requirements and how they might be achieved, applying available monitoring techniques.</p> <p>Further work is also planned to identify how the techniques for Post Closure Monitoring could be applied to a Post Closure Monitoring Plan that considers the evolution of the repository over protracted timeframes.</p>

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5 REFERENCES

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