A GENERIC CONCEPT FOR AN INTERMEDIATE LEVEL RADIOACTIVE WASTE REPOSITORY IN GREAT BRITAIN

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ABSTRACT

United Kingdom Nirex Limited (Nirex) is responsible for providing the United Kingdom (UK) with environmentally sound options for the long-term management of intermediate-level and some low-level radioactive waste generated by the Nation's commercial, medical research and defence activities. As part of that service, Nirex provides advice to waste producers on the conditioning and packaging of waste for storage, transport and eventual disposal. Because a specific design and site for a repository have yet to be established, that advice must be based on a generic disposal system concept applicable to a wide range of potential sites in the UK.

In the past, packaging advice has been based on a generic interpretation of site-specific specifications, designs and safety assessments that have been developed by Nirex. Since the refusal of the application for planning permission to build a Rock Characterisation Facility near Sellafield, Nirex has ceased to concentrate investigations on Sellafield as a potential site for a repository. Work since that time has concentrated on developing a generic specification, design and safety assessments to continue to support the provision of packaging advice.

This paper describes how a suite of documents is being developed to demonstrate the viability of the Nirex generic disposal concept and underpin packaging advice. It describes the process for development of the generic disposal concept, outlines some of the key features of the repository design and highlights key results from the safety assessments. The paper also describes how these results can be used by Nirex to support the packaging advice it gives to the waste producers and gives an example of how this can be applied.

BACKGROUND

In March 1997 the then Secretary of State for the Environment decided that Nirex should not be permitted to construct an underground characterisation facility at a site near Sellafield in Cumbria. Since the decision Nirex has ceased investigations [1] at that site and has concentrated on the following areas of activity:

- Provision of advice to waste producers, who are continuing with their programmes of conditioning and packaging raw wastes for surface storage.

- Continuation of a programme of scientific and technical work to reinforce the established sound technical foundations for the future development of a safe repository.

- Participation in Government consultations about the future institutional arrangements for radioactive waste management in the UK.

Waste producers are continuing with their programmes for conditioning, packaging and storing their wastes to reduce risk and reduce dose uptake to their operators.

Nirex has investigated the option of deep geological disposal since the early 1980's under a remit from the UK Government which was in turn based upon a Best Practical Environmental Option (BPEO) study conducted in the mid 1980's. Since the programme for this project was curtailed in 1997, the UK Government is expected to launch a consultation process into the future options for dealing with the UK's radioactive wastes in the spring of 2000.

Nirex recognises that deep geological disposal is only one possible solution for the long-term management of the UK's radioactive wastes and is the option that Nirex has most experience of to date. This experience has been collated into a suite of generic documents. Having established an understanding of the requirements and criteria for one option Nirex believes that it can then build on this to gain an understanding of other options which have a place alongside the deep disposal option under the broader topic of the long-term management of radioactive materials in the UK.

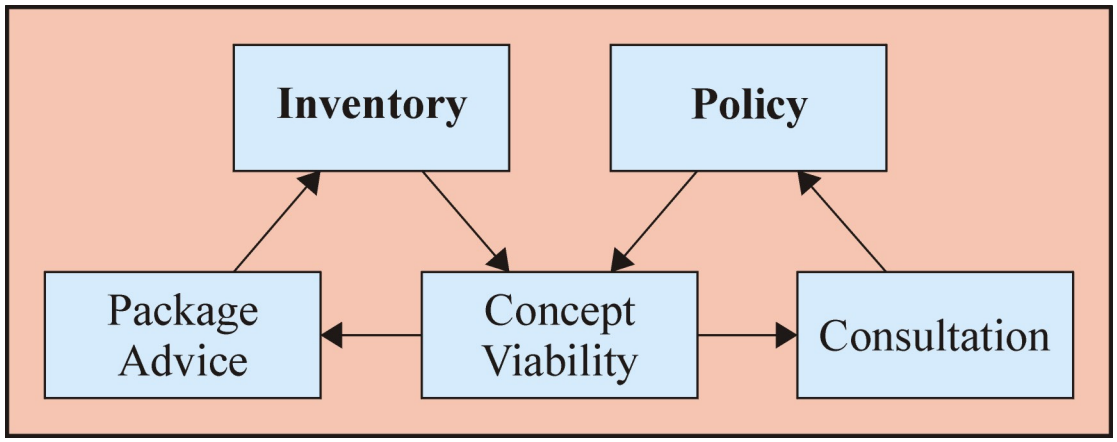

Figure 1 Development of Concept Viability

Figure 1 shows that by setting out the concept viability (in a series of generic documents) this can be used as a credible basis for the packaging advice based on a long term management scenario. As ideas and thoughts develop in the future, changes to the inventory of materials to be considered by Nirex will be discussed and documented via the National Inventory of radioactive wastes.

The publication of Nirex's view of the viability of the concept can be used in the consultation process referred to above and other options for waste management will be evaluated and added into the suite of credible options following a policy decision based on compatibility with Nirex's accepted remit which may develop during the consultation process.

Hence the generic documents are considered to be "live documents" and provide a means of documenting what we know today about the deep disposal option and how we develop the thinking to expand our consideration of other options as part of the wider issue of long-term management of radioactive waste. The generic documents focus on our experience to date and hence the rest of this paper refers to just the one option, that of deep disposal.

ITERATIVE DEVELOPMENT OF DISPOSAL SYSTEM

Deep disposal provides a management option for radioactive waste that is consistent with meeting our responsibility to future generations. A staged retrievable approach, that involves long term storage, provides the option to proceed towards disposal, and ultimately repository closure at a measured pace. At each stage, time would be available to build sufficient confidence before moving to the next stage, whilst retaining the ability to retrieve waste and pursue an alternative option if that were available and preferred.

The specification and design of the disposal system develop as an iterative process which is assessed in terms of performance requirements at each stage. Each iteration starts with the issue of a generic disposal systems specification (GDSS). A conceptual design is then prepared to meet the requirements specified in the GDSS, and work is carried out to resolve issues that the GDSS has raised. Following this, the design is assessed in terms of operational and post-closure safety and an assessment of the safety of transporting waste to a repository site is carried out. Where the findings of these assessments indicate a need or benefit in modifying the specification and design they are fed back as revisions to the GDSS which then initiates further iterative development of the disposal concept.

The development of the specification, design and safety assessments supports the demonstration of the viability of the disposal concept. It provides the opportunity for consultation to help in the development of policy matters as well as supporting packaging advice. It also enables the impact on the disposal concept of revisions to policy, or changes to the types and volumes of waste, to be assessed, prior to policy changes being implemented. Changes in the waste inventory or policy/regulations on waste management can then be fed back into the specification to enable the concept to be revised or re-assessed as appropriate. This iteration process ensures that the disposal concept remains current and viable and therefore capable of continuing to provide packaging advice.

To enable the waste producers' plans for waste packaging to be consistent with eventual disposal requirements it is necessary to maintain the repository concept to provide a basis for assessing and advising on the impacts of the wasteform and packaging on repository operation and long-term safety. The documentation which describes and assesses the generic repository concept is summarised below. The generic repository concept incorporates many of the principles applied to the Sellafield concept [2] but recognises the potential for different repository solutions which could be applied to a wide range of potential sites in the UK.

SCOPE & CONTENT OF GENERIC DOCUMENTS

A suite of documents is being developed that applies the Company's understanding of the disposal system performance requirements in a generic way. The documents will be used (see Figure 1) to underpin waste packaging advice, to demonstrate the viability of the Nirex disposal concept and may also be used to support the development of a framework for site selection.

The suite of documents comprises:

1. Generic Disposal System Specification (GDSS)

2. Generic Transport System Design (GTSD)
3. Generic Repository Design (GRD)
4. Generic Transport Safety Assessment (GTSA)
5. Generic Operational Safety Assessment (GOSA)
6. Generic Post-closure Performance Assessment (GPA)

It should be recognised that all of the generic documents are "live documents" which will be updated and improved in the light of Nirex's ongoing scientific and engineering programmes and to respond to changes in Government policy, regulation, best practice and waste management policy.

Generic Disposal Systems Specification (GDSS)

The GDSS covers a large number of interacting variables relating to the waste, its packaging, transport and disposal. It includes constraints imposed on the system by regulations, planning (land use) and legislation, as well as the requirements of the waste producers (nature and quantity of waste for disposal) and those within Nirex having responsibility for specific aspects of system performance. It also integrates results from Nirex's scientific and technical programmes, including site characterisation information, to provide a unified and justified system specification for use in design work, operational and post-closure safety requirements, and environmental impact assessment.

The GDSS provides a common source of data for use in repository design and safety assessments. A separate volume records the justification for all requirements, constraints and data set down in the specification.

The specification for the 'disposal system concept' sets out certain basic assumptions that are to be made about the type of disposal system to be adopted. These assumptions are based upon the Nirex view of the type of disposal system that is likely to prove optimum for the kinds of waste requiring disposal, and for the broad kinds of disposal environments that are likely to be available.

An example of the type of assumption arising from the iteration process is that the specification calls for repository development between depths of 300m and 1000m. These have been derived as follows:

- The 300m limit provides a nominal 150m for long-term (glacial) erosion and a further 150m for stress effects and weathering.

- The depth limit of 1000m has been assessed as a generally reasonable depth limit relative to ease of access, manageable rock stresses and acceptable ambient rock temperatures.

Generic Transport System Design

Radioactive waste is produced at a number of sites throughout the UK. After packaging, radioactive wastes will eventually require transport to a repository site. That site may be a variety of locations where suitable attributes with regard to safety and other factors can be demonstrated. The transport of radioactive material within the UK is governed by specific legislation which requires that standards of safety laid down by the International Atomic Energy Agency (IAEA) [3] are met. A key principle of the transport regulations is that safety is inherent in the design of transport packages. The prime considerations dictated by the presence of radioactive material are the protection of the public from radiation hazards. This is achieved by ensuring:

- containment of the radioactive contents;
- control of external radiation levels;
- prevention of criticality;
- prevention of damage caused by heat (generated by the waste or in the event of an accident resulting in fire).

Not all packaged radioactive materials pose the same risk. As a result different transport package designs can be used depending on the amount of radioactivity to be transported and the nature of the hazard. For example, some transport packages carrying particularly hazardous forms of ILW are designed to withstand accidents involving severe impacts and fires, the 'Type B' standard. Other transport packages which carry less hazardous material, such as LLW, are designed to the less demanding 'Industrial Package' standard. In all cases, however, the transport packaging is designed to ensure that any releases from the packages or doses to the work force and public are within internationally agreed acceptable limits.

Generic Design

The overall objective of the Generic Repository Design is to produce concept design solutions that meet the requirements of the GDSS while also being suitable for a range of potential geological environments.

In more detail, the key objectives are:

- To continue to underpin waste packaging advice to customers by establishing the range of viable disposal solutions, and ensuring that waste packaging proposals are consistent with them. The design will also provide a means for Nirex to evaluate the impacts of waste packaging proposals on overall repository safety and performance to inform the preparation of waste packaging advice.

- To demonstrate the viability of the disposal concept in a variety of geological environments.
- To provide input to the preparation of generic operational and post-closure safety assessments.
- To provide information that may be required as part of the UK Government's forthcoming review of radioactive waste management policy.

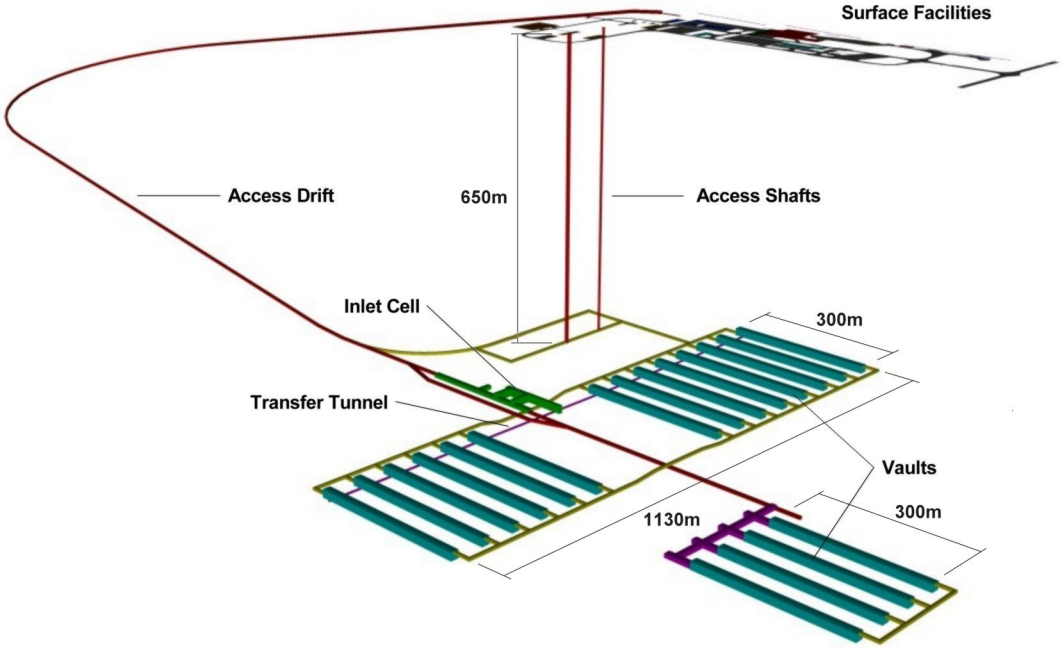

Figure 2 Generic Repository Concept

Developing the Generic Repository Design also improves understanding of the design process itself. The design concepts are presented on a sound engineering basis, with sufficient detail to support the viability of the solutions proposed. However, the design has not yet been fully optimised, so at this stage the details reflect a solution, which is viable but should only be regarded as likely or typical of the final repository solution. This is particularly relevant to generic solutions, as specific factors such as geology, surface topographical features and location of existing services, structures etc. are site dependant and could influence the final configuration and performance of the facility.

The GDSS sets out a series of general requirements for the repository design and operation. The generic design in addressing these requirements, describes, where necessary, provisions or solutions to meet these requirements. In situations where such requirements set out in the GDSS are self-explanatory and it is more appropriate for these to be detailed at a later stage of design development, then the inclusion of these within the design is assumed.

To meet the above objectives, the generic repository design is developed primarily as a Generic Reference Design. There are also a number of possible variations on this design, aimed at

accommodating a range of constraints arising from siting, rock types and amount of waste. These have been considered as four main variants, which have been developed to reflect that alternate solutions can be applied where conditions dictate.

The Generic Reference Design is assumed as a stand-alone development on a single surface site, with one drift and two shafts developed to a depth of 650m, mid-way between the assumed maximum and minimum depth with a capacity of 263,000m^3. The geological environment is assumed low permeability hard rock, with a cover layer of low permeability sedimentary rock and a surface layer of high permeability sedimentary rock.

Variant designs have been considered as follows:

1. A variant for maximum envisaged waste volume of 513,000m^3. This variant provides for higher throughput rates, larger repository and increased inventory.

2. A variant which addresses situations where, due to the thickness of overlying permeable strata, drift access would not be viable and package transfer underground would be via a vertical shaft with implications for throughput rate and maximum package size and weight.

3. A variant where due to shallower repository depths access would be by drift only.

4. A variant which recognises that contributing factors such as geology and rock quality may limit the scale of the underground openings and necessitate the development of smaller cross-section inlet cells and vaults for waste handling and disposal.

In addition to the four main design variants consideration is given to the option of waste emplacement in silos (short vertical shafts) instead of horizontal vaults; and also to the potential for sharing surface facilities with a neighbouring nuclear site, or splitting the surface site into two different areas.

The key features of the generic repository design have centred around ensuring that the provision of a single facility for the management of the UK's ILW can be achieved with good safety standards. To ensure that options are left open for future generations the whole process has been designed to be carried out in a staged, reversible way, such that the wastes are capable of being easily monitored and retrieved.

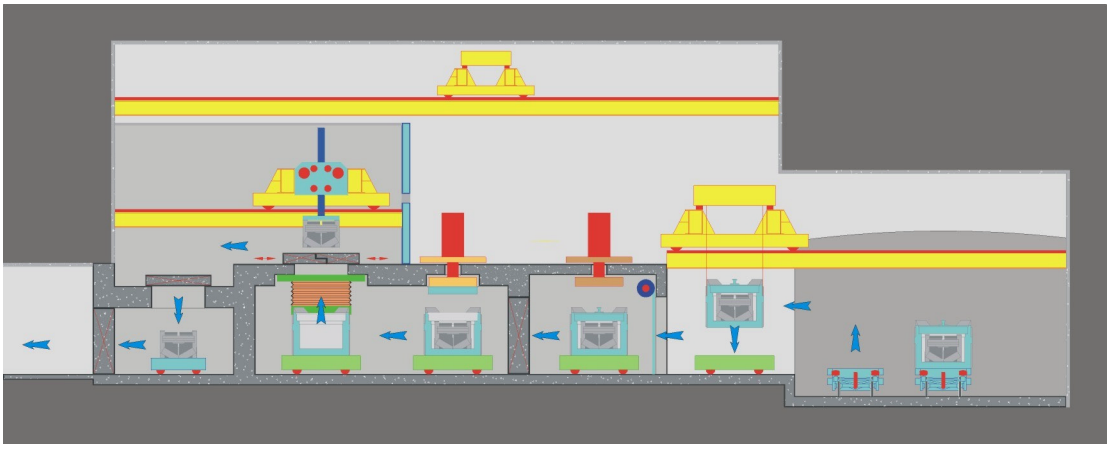

Figure 3 Removal of Waste Package from Transport Container at Inlet Cell

The following are some of the most relevant design features which would contribute to providing safe repository operation:

- Unshielded ILW packages would be retained in their transport containers up to the point of direct transfer into shielded inlet cell where the waste package would be removed from its transport container.

- The provision of remote uncoupling of rail wagons would reduce radiological dose to operators.

- The provision of shielded bays in the transport container handling and maintenance handling areas.

- The design of the crane transfer and handling system for packages would minimise lift heights.

- The provision of an independent ventilation system for construction and operation with the maintenance of positive pressure in construction areas and negative pressures in emplacement areas maintaining safety in any combination of fan failure scenarios.

- At all stages of repository operation, retrieval of the waste packages is a straightforward reversal of the emplacement process, enabling the decision on closure to be taken at an appropriate time.

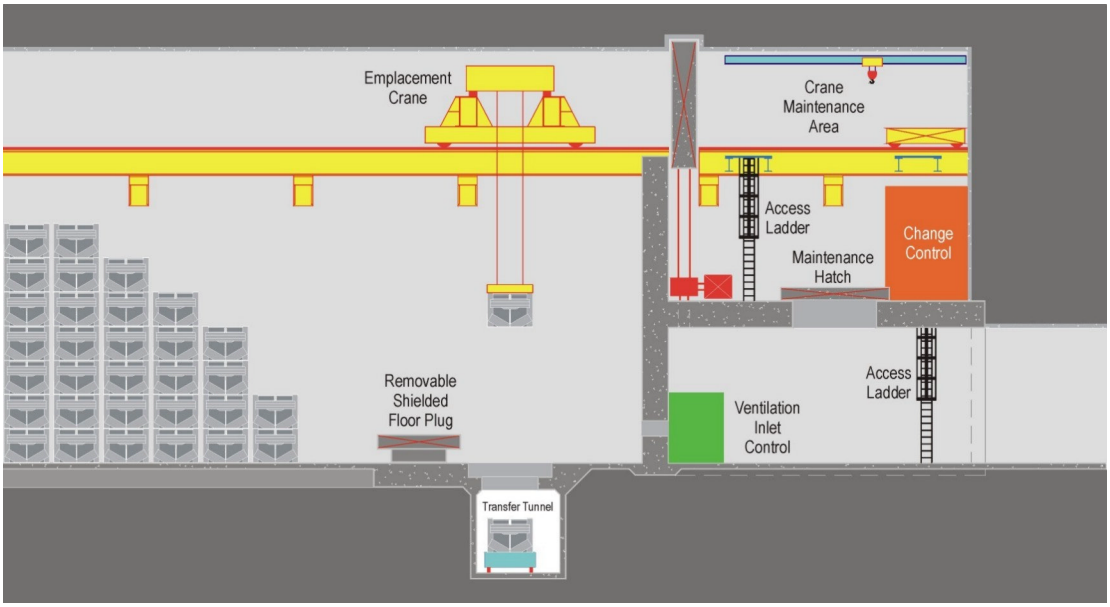

Figure 4 Unshielded ILW Waste Emplacement in Vault

Generic Transport Safety Assessment

Transport of radioactive waste to a repository will involve the regular movement of a relatively large number of packages on regularly used routes. These routes may be widely dispersed where the packages leave waste producing sites and gradually converge as the routes approach the location of any potential repository. IAEA Regulations [3] place requirements on the inherent safety of the transport package and there are no legal requirements to carry out a transport safety assessment. However the Regulations also require (Section II, Para 202) that '*Radiation exposure from the handling, storage and transport of radioactive of radioactive material shall be kept as low as reasonably achievable, economic and social factors being taken into account*.' It is therefore necessary and important to assess the potential dose to the public and transport workers from this regular movement of waste so that it can be demonstrated that the risks and doses are acceptably low and in compliance with Nirex radiological targets.

The radioactive nature and quantities of the wastes will have an effect on the type of package, package dose and number of package movements, all of which are key parameters in the determination of transport risks. From the radioactive waste inventory representative waste streams can be formulated and best estimate risks and doses calculated in a Generic Transport Safety Assessment (GTSA). The results obtained will be representative of a transport operation to a repository regardless of location, and can be used to demonstrate that all radiation exposure is within Nirex radiological protection targets (and as low as reasonably achievable).

In order to offer advice to waste producers on the acceptability of their packaging proposals for transport, an assessment must be carried out to confirm that the risks are very low and comply with the requirements of the Radiological Protection Policy Manual (RPPM) [4]. It is not practical to calculate the risks associated with transporting every waste stream and so

representative waste streams, which bound the characteristics of particular wastes, are used to allow the risks for individual wastes to be assessed.

If the proposal waste stream has not been included in the GTSA the methodology of the GTSA needs to be followed to determine whether the inclusion of this waste stream would significantly affect the results. It needs to be determined whether the waste is represented by any of the existing groupings, or whether it becomes a representative waste stream itself. In either case the data for the waste stream must be checked for changes to risk resulting from its inclusion in a group or its adoption as a representative waste stream.

Generic Operational Safety Assessment

Nirex have prepared a RPPM [4] and Nuclear Design Safety Principles (NDSPs) [5], which set down radioactive protection policy and criteria and the safety principles to be applied to design, operation and closure of the repository. The generic operational safety assessment (GOSA) is an assessment of the safety of applying the generic design to the operation of the repository. By carrying out the assessment, Nirex can identify the hazards associated with repository and from assessment of the hazards and safety provisions can determine the risk to repository operators and the public. The GOSA will contain the following main elements:

- Design Basis Analysis - a deterministic and conservative analysis to demonstrate that the 'fault tolerance' of the generic design concept is such that no unacceptable dose or risk would result from any identified fault sequence. The fault tolerance stems from the inherent safety and defence-in-depth provided by the generic design.

- Planned Operational Discharge Assessment - an assessment of the dose implications of routine aerial discharges from the repository. The design basis is such that no routine radioactive liquid discharges will be made from the repository.

- Operational Dose Assessment - assessment of doses to repository workers from routine radioactive operations within the repository site.

- Probabilistic Safety Assessment - assessment of the risks (conventional and radiological) of potential hazards arising during the operation of the repository.

- Severe Accident Analysis - analysis carried out to demonstrate that the generic design is sufficiently far away from any 'cliff-edge effects' that could result in large releases, doses or risks.

- Criticality Safety Assessment - an assessment of potential hazards that could increase the potential for criticality incidents during the operational life of the repository.

- Conventional Safety Assessment - assessment to confirm that general safety considerations have been taken account of in the development of the generic design, proposed construction operation and closure methods.

In general terms the GOSA provides a reference case against which the operational safety implications of packaging proposals can be assessed. In order to facilitate such assessments the dose and risk calculations for the reference case assessment are being recorded in an ACCESS database. The database allows 'what-if' analyses to be carried out by changing input parameters (e.g. radionuclide inventory, impact release fraction, fire release fraction) to examine the acceptability of a given packaging proposal.

Generic Post-closure Performance Assessment

The generic post-closure performance assessment (GPA) presents an assessment of risks following repository closure for the Nirex repository concept. The GPA describes the features and processes within the repository system that contribute to post closure safety. However, since no disposal route currently exists, advice based on a detailed site specific safety case is not appropriate. The GPA has therefore been developed for a hypothetical site that is suitably generic and has properties that are realistically founded. The main factors in using the GPA to support packaging advice are as follows:

- Advice based on a disposal site with extremely good properties (with respect to long term post closure performance) may permit simple packaging solutions which in the short term would be very cost efficient. However, a site with such properties may not be achieved in practice leading to aborted site investigation costs and the ultimate need for costly repackaging.

- Conversely packaging advice based on relatively poor site properties may result in over-engineering of packages, high costs and worker doses with no long-term benefit if a more realistic site properties were assumed and eventually found at a specific repository site.

To achieve this balance the properties of a hypothetical 'bounding' site have been adopted which are intended to be representative of what might be sought as part of a site selection process and achieved at a real repository site.

WASTE PACKAGING SPECIFICATION & GUIDANCE

To enable the waste producers' plans for waste packaging to be consistent with eventual disposal requirements it is necessary to maintain the repository concept to provide a basis for assessing and advising on the impacts of the wasteform and packaging on repository operation and long-term safety. In support of this remit, Nirex has defined packaging standards and developed a methodology [6] to give confidence that wastes which are conditioned and packaged will be suitable for safe storage, transport, handling and eventual disposal.

In the case of an operational disposal facility, waste packages would be expected to meet the requirements of Conditions for Acceptance or Waste Acceptance Criteria, which would be produced and issued by the facility operator. Waste Acceptance Criteria will take account of

detailed design considerations, finalised safety cases, operational and transport factors, the terms of the disposal authorisation, site license conditions and statutes in force at the time.

Much of the information needed to develop definitive Waste Acceptance Criteria will not be available until shortly before disposal operations begin but the Waste Package Specification [6] is intended to assist waste producers in developing waste packaging plans in advance of the Waste Acceptance Criteria becoming available. The purpose of the Waste Package Specification is to outline the requirements for packaged wastes to be compatible with plans for interim storage, transport, handling and eventual disposal at a deep waste repository. The Specifications define the envelope within which waste packaging concepts should be developed in order to have confidence that the packages will be compatible with the requirements for interim storage, transport, handling and disposal at a future repository. It is the intention that the Specifications will eventually be incorporated into the Waste Acceptance Criteria for a specific repository.

CONCLUSIONS

Waste producers are conditioning and packaging waste now for engineered storage in anticipation of eventual deep geological disposal. In the absence of a site-specific repository, it is important that Nirex can provide waste producers with packaging advice which will minimise the risk of packages being unsuitable for future disposal. The development of the generic specification, design and safety assessments enables Nirex to develop a framework for assessing individual waste packaging proposals and providing appropriate advice without compromising the ability to accept the packaged waste at a future repository. The use of assessment tools will enable this support to packaging advice to be suitably streamlined and the updating and development of the generic documentation will enable the process of radioactive waste management to progress effectively in the absence of a site-specific repository.

The use of bounding conditions in developing the generic concept provides a means of defining a suitably representative range of conditions for a repository in order to reduce uncertainty and ensure that advice on waste packaging can achieve to the required safety standards while remaining cost-effective.

REFERENCES

1 '*Current Status of the United Kingdom Programme for the Deep Disposal of Radioactive Waste*' John Holmes, John Mathieson, Graham Fairhall, Charles Boyle, ICEM, The 7th International Conference on Radioactive Waste Management and Environmental Remediation. Nagoya, Japan. September 1999.

2 '*Sellafield Repository Design Concept'* United Kingdom Nirex Limited, Report no: N/98/01. October 1998. ISBN 1-84029-2199.

3 '*Regulations for the Safe Transport of Radioactive Material, 1985 Edition (As amended 1990)'* International Atomic Energy Agency, Safety Series No. 6. Vienna 1990.

4 '*Radiological Protection Policy Manual (RPPM)'* United Kingdom Nirex Limited, Report No: NA/98/002. December 1998.

5 '*Nuclear Design Safety Principles (NDSPs)'* United Kingdom Nirex Limited, Report No: NA/98/003. November 1998.

6 '*The Packaging of waste for safe Storage, Transport, Handling and Disposal*' United Kingdom Nirex Limited, Report No: N/006. October 1999

7 '*Waste Package Specification for Intermediate Waste*' United Kingdom Nirex Limited, Report No: N/007. October 1999.