THE SELECTION AND ASSESSMENT OF POTENTIALLY SUITABLE SITES FOR DEEP REPOSITORY DEVELOPMENT

Mr. H. Beale
Head of Technical and Projects Department
United Kingdom Nirex Limited

ABSTRACT

In the United Kingdom the development of a deep mined repository for the disposal of low and intermediate level radioactive wastes rests with UK Nirex Ltd. As with many major developments, site selection is at the very heart of the matter. Therefore, decisions leading to the identification of a suitable site, to their detailed investigation and subsequent assessment, must be made in a logical and rational way and must be justifiable. This paper describes the process which led to two sites (Sellafield in England and Dounreay in Scotland) being chosen for further consideration in terms of repository development.

INTRODUCTION

In the United Kingdom the development of a new disposal route for low and intermediate level radioactive wastes rests with UK Nirex Ltd. Over recent years the Company's interests have become focussed on the development of a single deep repository able to accept over a 50 year operational life some 2 million m^3 of these wastes.

At present the Company's prime objective is to develop such a repository which satisfies the regulatory safety targets while having due regard to the environmental impact and costs of such a development and its associated operations.

As with many major developments, site selection is at the very heart of the matter. Any proposal to develop a repository in the UK will not only be subject to the close scrutiny of the regulatory and statutory bodies, but also to examination in public at a formal public hearing. Therefore, decisions leading to the identification of suitable sites, to their detailed investigation and subsequent assessment, must be made in a logical and rational way and must be justifiable.

This paper describes the process which lead to 2 sites, (the United Kingdom Atomic Energy Authority's site at Dounreay in Caithness, Scotland, and British Nuclear Fuels site at Sellafield in Cumbria, England), being chosen for further consideration and outlines the continuing program to identify one preferred site for repository development.

REGULATORY BACKGROUND

The principles which the Authorizing Departments of Her Majesty's Government intend to apply in considering whether to grant general authorization for a disposal facility such as that proposed by Nirex were published in 1984, 'Disposal Facilities on Land for Low and Intermediate Level Radioactive Waste: Principles for the Protection of the Human Environment' (1). Essentially, general authorization will only be granted for a repository if the Departments concerned are satisfied, to quote, ' ... that the proposed site has been properly chosen, that the facilities can be fully developed, that the wastes proposed for disposal are appropriate to the engineering structure and geological and hydrogeological environment, that their disposal forms a part of the national strategy and that the proposal will secure the protection of man and his environment on a continuing basis'. Accordingly, the Nirex programme of work is being progressed on a broad front.

TECHNOLOGICAL BACKGROUND

Sources and Volumes of Waste

The sources and volumes of existing wastes and future arisings are presented in the United Kingdom Radioactive Waste Inventory, (2), which is regularly updated and published by Nirex and the DoE (Department of the Environment). Detailed information on the nature of the wastes, in terms of their physical and chemical characteristics and the radionuclides they contain, is given in companion volumes (3, 4).

The National Inventory forms the basis for a reference assessment inventory which is being used in the work on waste transport, repository design and safety assessment.

Looking to a repository operational period from 2005 to 2055 the maximum volume of waste requiring disposal in a deep repository is estimated at some $2.6.10^6 m^3$, comprising $2.0.10^6 m^3$ low level waste (LLW) and $0.6.10^6 m^3$ intermediate level waste (ILW).

Waste Conditioning and Packaging

The conditioning and packaging of radioactive wastes is the responsibility of those whose activities give rise to the waste. They must ensure that the waste is conditioned and packaged to meet the requirements for handling, transport and disposal to the satisfaction of Nirex and the Regulatory authorities.

Where appropriate, wastes will be compacted to reduce their volume. Intermediate level wastes will be incorporated in a cementitious monolith which will be free of liquids and particulate matter. This will be achieved by immobilizing the waste in cementious grout.

Standardization of package designs is important in order to simplify the waste transport system, to enable standard mechanical handling equipment to be used at the

repository and to provide for efficient utilization of the disposal vaults within a repository. To that end Nirex is specifying a range of standard packages.

Waste Transport

The radioactive wastes to be disposed of in the proposed Nirex repository arise at widely separated locations throughout the United Kingdom. Therefore an important consideration for Nirex is the development of a waste transport system.

The UK legislation which governs the transport of all radioactive materials is based on the regulations of the International Atomic Energy Agency (5). The Secretary of State for Transport is responsible for assuring compliance with the regulations. These regulations are directed to the radiological protection of the workers concerned and the general public who might be exposed as a result of transport of the waste. Conventional transport risks are also being taken into account by Nirex.

Road, rail and sea are all possible modes of transport. The choice will depend to a large degree on the siting of a repository. Rail is likely to be the preferred mode of transport to a mainland repository site although of course transport by sea may prove important for a coastal repository. Road transport is an option for smaller, lighter packages and will be favored by small waste producers because of its flexibility.

While the principal requirement is for a system to convey packaged wastes from the various sources to the Nirex repository, facilities must also be provided for the transport of materials and personnel to and from the site and, if necessary, for the removal of spoil.

Apart from consideration of safety, the environmental impact and cost of establishing a transport system, and its operation for the 50 year period envisaged, are also being addressed.

Repository Design

The overall performance of the repository and, in particular, its post- closure radiological safety, will be crucially dependent upon the successful integration of the engineered structure and its geological setting. Furthermore, the technical constraints presented by the specific characteristics of sites must be accommodated in the design of the engineered facilities.

From the outset of the Nirex deep repository development programme, work has been carried out on the engineering design aspects. Specifically the Company has commissioned specialist consultants to prepare conceptual designs and cost estimates for a repository in locations

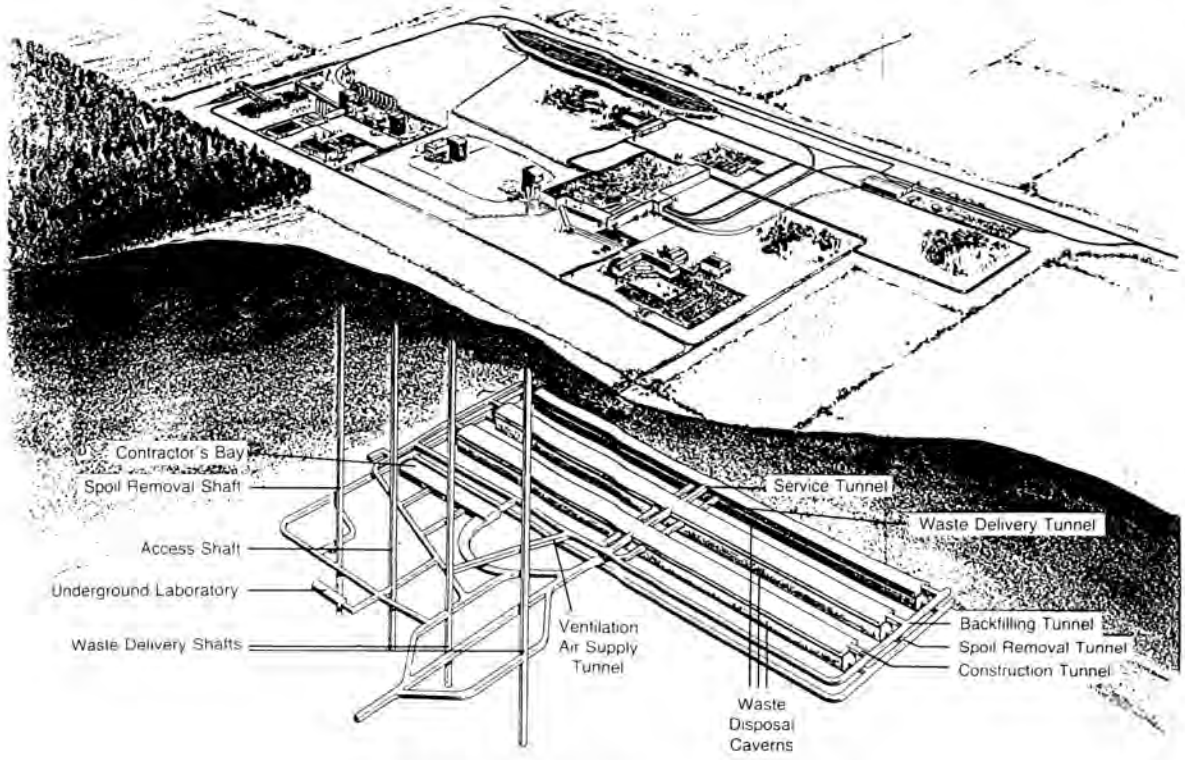

Fig. 1. Cavern Repository in Hard Rock.

representative of the generic geological settings advocated by Nirex's geological consultants (6).

The technical requirements are reflected in the economics of the various options arising from matching the different designs and sites. The ability of Sellafield and Dounreay to accommodate one or other of the conceptual designs is, therefore, an important consideration in their further evaluation. The concept illustrated in Fig. 1 is thought to be the most appropriate for these locations.

Repository Safety

The repository will be operated in accordance with the relevant sections of the Health and Safety at Work Act and the transport system in accordance with relevant legislation. Disposal of the waste will be subject to the requirements of the Radioactive Waste Substances Act. The evidence from the safety analyses which have been carried out indicates that, in common with other industries, conventional safety is an important factor.

The disposal of radioactive wastes in a deep repository is designed to provide a high degree of radiological protection by isolating the material from the environment of man. During the operational lifetime of the repository it will be treated as a licensed nuclear site and Nirex will be required to ensure that operations are undertaken in compliance with statutory requirements, regulations and official guidance.

As part of the conceptual design work preliminary estimates were made of the radiation doses to the workforce and the general public. The estimated doses were all well within the regulatory requirements applied to nuclear licenced sites in the UK.

The repository is required to continue to provide protection from the radioactive wastes long after the facility is closed and sealed. The DoE Principles Document (1) includes the target that the risk to an individual in a year should be less than that associated with a dose of 0.1mSv : about one chance in a million (of fatal cancer). The Nirex safety assessment studies are aimed at developing the confidence required that radionuclides from the emplaced waste will not enter the environment in sufficient concentration to be of any concern in terms of radiological safety.

These assessments of safety in the long term take account of the four main pathways by which radionuclides could conceivably enter the environment, namely:

- groundwater transport;
- intrusion by people;
- gaseous transport;
- natural disruptive events.

The assessment process is carried out in two complementary phases (7). First, deterministic models are used to represent processes in considerable detail. These computations are carried out with best estimates of the values of the data, and in addition sensitivity studies are undertaken to examine the implications of uncertainties that exist in many of the data. 'What if?' computations are also undertaken in which hypothetical assumptions are made to explore the robustness of the assessment against gross deviations of the system from expected behavior.

In the second phase of computation, the effects of data uncertainty are examined in a structured way, using a probabilistic approach. A large number of simulations are undertaken, in which parameter values are selected from probability distribution functions. In this way, a more comprehensive survey of the implications of data uncertainty can be achieved.

In the UK safety assessments have to address the very long term future; many thousands of years. Inevitably the level of uncertainty attaching to predictions about the very distant future will be greater than for shorter times. Different pathways and processes are expected to be important at different times in the future. It is, therefore, helpful to think of the assessment in terms of a number of different time frames. This matter is dealt with in another paper at this Conference (8).

Much of the assessment work carried out to date has necessarily been generic in character but it has enabled the radiological safety of the different repository concepts to be evaluated and compared.

THE PRINCIPLES OF SITE SELECTION

Nirex has followed the approach recommended by the International Atomic Energy Agency (IAEA) (9) in seeking to identify a preferred site for a waste repository. This requires locations to be evaluated initially on the basis of geological and environmental information and on societal considerations. Furthermore, the IAEA recommends that an evaluation should proceed in stages from generic to specific site assessments carried out in progressively increasing detail, the number of candidates being reduced as the requirements to be satisfied are refined and enhanced.

Essentially, three stages are involved:

- a search on a national scale to define favorable areas of the country; followed by,
- the identification of specific candidate sites for comparative evaluation and the selection of outstanding prospects for physical exploration to confirm their suitability; and,
- the final choice based on the results of geophysical investigation and other studies.

The principal requirement is that the design of the repository and its location must together provide the requisite level of radiological safety. This is especially important

from the standpoint of post-closure radiological safety after the safeguards of institutional management must be assumed to have lapsed. There are various ways and margins by which the requisite standards may be achieved and potentially suitable candidates need to be compared in terms of other important issues such as the economics and general environmental impact of the project.

The complexities of the site selection process arise, in the main, not from intrinsic technical problems but from the multiplicity of factors which have to be considered and their interactive nature. Furthermore, while the values and the importance that should be attached to some of the factors may be determined quantitatively, the evaluation of others, although based on expert opinion, is, necessarily, subjective.

The site selection process undertaken by Nirex began with 'desk studies' based on available data and theoretical knowledge. As the characterization of favorable areas and of potential sites proceeded, some were eliminated and others emerged as offering potential. Overall, the convergence on a small number of outstanding candidates has enabled increasingly detailed appraisals to be undertaken of relevant matters specific to each site. The use of this procedure has progressively reduced the number of sites to be carried forward for consideration.

THE SPECIFIC SITE SELECTION PROCESS

The search for sites worthy of consideration as candidates to host the deep repository was initially concentrated on those areas of the country having favorable geological and hydrogeological features from the stand point that the groundwater pathway of a site chosen for a repository must be geologically stable and possess, ideally, a natural hydrogeological regime in which:

- the movement of groundwater is very slow and in a direction leading to dilution by mixing with other, preferably deeper, waters or the sea; and,
- pathways for return of groundwater to the human environment are long.

Five generic environments offering such characteristics were proposed, as illustrated in Fig. 2.

Maps showing the distribution in Britain of such geological areas (10) were scrutinised to identify locations of the size and apparent current usage, which, superficially, appeared suitable.

In all, over 500 locations were identified which, on first appraisal, appeared to offer potential for the development. These sites were then subjected to evaluation using the sequential sieving process illustrated in Fig.3. Each stage of this process involved consideration of the candidates with respect to a particular feature and the elimination of those which were unlikely to satisfy the requirements (11).

When the number of candidate sites had been reduced to 40, the procedure adopted was to require each of a number of specialist consultants to consider, from the stand point of their own area of disciplinary expertise, the merits of each site in relation to each of the disposal concepts which it could potentially satisfy. Thus, each site was assessed for each relevant setting with respect to the following factors:

- geological and hydrogeological characteristics;
- engineering design and construction, including: technical feasibility, geological constraints, capital and operating costs;
- transport, including: technical issues, environmental impact and capital and operating costs;
- conventional safety during construction, operation and transport;
- radiological safety during transport, operation and post-closure;
- planning, environmental, social and economic implications.

This process lead to the elimination of 22 sites, leaving 17 to be carried forward.

The ranking of these sites to determine the priority of their further evaluation needed to be based, logically, on a comparative assessment of the extent to which each of the candidates met the various objectives of a deep repository project, namely:

- to ensure that the repository complies with the statutory requirements for radiological safety;
- to minimize the risks to safety from conventional causes;
- to minimize the total cost of construction, operation and closure of the repository and its transport systems;
- to minimize the sensitivity of the project to variations arising from uncertainties;
- to minimize any adverse impacts on the community locally and nationally;
- to maximize any benefits to the community;
- to minimize any adverse impact on the environment or future access to mineral resources.

Multi-attribute decision analysis provides a means by which problems of this kind may be formulated and analyzed. Having reviewed the American experience (12, 13, 14) this methodology was adopted with advice from the Decision Analysis Unit of the London School of Economics and Political Science (LSE). The application of this tech-

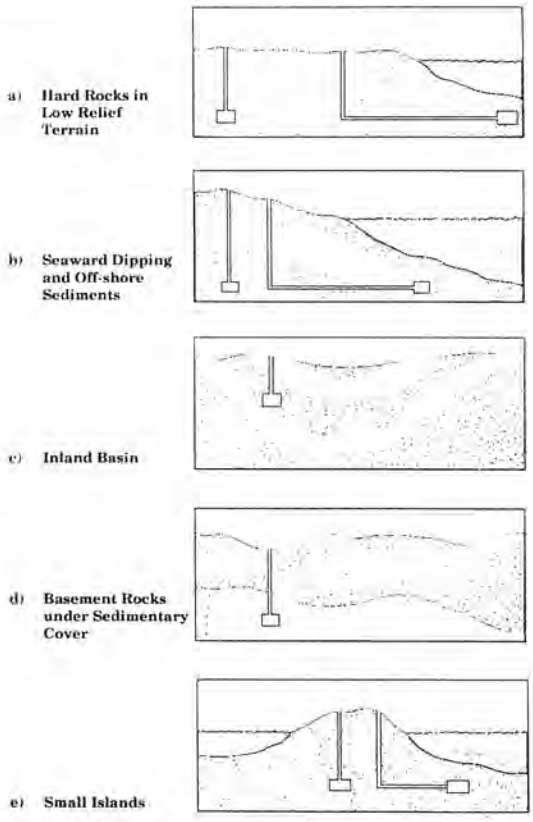

Fig. 2. Suitable Geological Environments for a Deep Repository (Schematic not to scale).

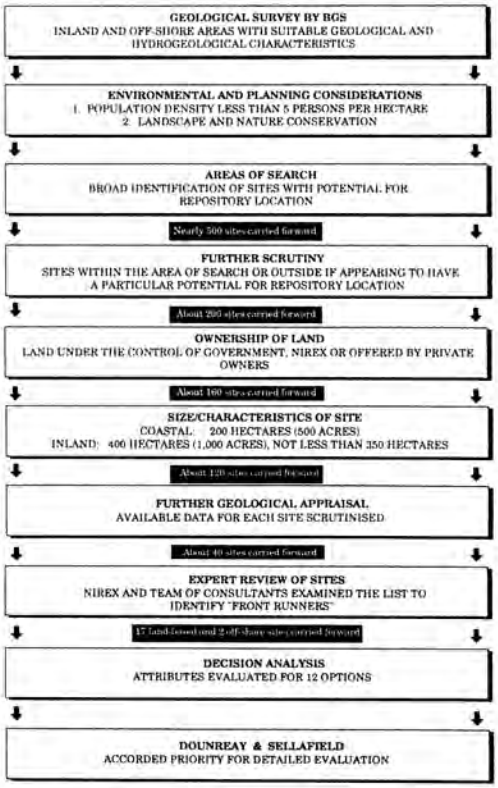

Fig. 3. Sieving Process for Site Selection.

nique as an aid to site selection involved the collective consideration of the issues by specialists from Nirex and its main consultants.

While the final stages of site selection were founded upon this approach, Nirex also sought to explore the broader social context in which it is required to discharge its technical responsibilities. Consequently, the decision was taken to stimulate an extensive dialogue with all interested parties by publishing an account of our proposals (15).

As the site selection work progressed in parallel with the discussion process it became clear that the various sites under consideration could be divided into two categories: those where there is a measure of support for nuclear activities in the local community and those where there is not. In considering the results of the site selection and public discussion processes, the Board of Directors of UK Nirex Ltd, in February 1989, recommended to the Government that detailed evaluation including physical exploration should be directed initially to the areas of Sellafield and Dounreay. It was felt that it would be best to explore first those sites where there is some measure of local support for nuclear activities. The Government's acceptance of the Company's recommendation was announced in March 1989.

SITE INVESTIGATIONS

The decision to investigate these sites was necessarily formulated from information, some of which is of a theoretical or generic character, which needs to be verified by specific analysis and testing. The geological prognosis for the sites is that both are underlain by about 500m of sedimentary rocks, principally sandstone, over hard basement rocks. It is the latter which is of interest as a repository host rock. To confirm the current understanding of the geological characteristics the first step will be to sink two boreholes at each location and conduct a regional geophysical survey. The borehole investigations will consist of the following:

- fully cored boreholes to obtain high quality continuous core;
- hydrogeological testing in the boreholes;
- geochemical sampling of the groundwater from the borehole and pore fluids from the core material;
- geophysical logging of the boreholes;
- initial geotechnical assessment of the rock mass for construction purposes.

The core samples will provide material for laboratory testing and the boreholes will provide access to the underlying structures for hydrogeological and geological testing. The geophysical survey includes comprehensive surface and aerial surveys using modern techniques to determine the extent of the potential host formations.

In parallel with the geological investigations the present conceptual designs of a repository are being developed further to meet the specific features of the candidate sites. This work will also enable operational safety cases to be formulated and provide updated cost information. The post-closure radiological safety studies will be focused on the two sites and will benefit from the acquisition of specific information on the characteristics of the geological environments underlying these sites. Development of the mathematical modelling of the processes involved and of the safety assessment methodologies will continue.

The Nirex safety assessment research programme will be continued in order to provide the essential scientific understanding and data required to underwrite the repository development and the safety case.

The planning, environmental and socio-economic factors relevant to the two sites will be studied in greater detail. The investigation will include the physical impact and likely effects on the communities in the localities concerned. This will involve focussing attention on the land use and development impacts likely to arise from repository construction and operational and an assessment of the socio-economic consequences. Discussions will continue with the local authorities and other involved organizations to take account of local concerns.

Work on the transport system required to support the repository will be continued and focussed on the two candidate sites. This will include investigation of the environmental impact, safety and the costs of transport.

These preliminary investigations are now well underway at Sellafield. At Dounreay planning permission for the drilling has not yet been obtained from the Local Authority and as a consequence the geological investigations, which are a critical activity on the programme, have not yet begun.

THE NEXT STEPS

Given a favorable outcome from the above preliminary site investigations a preferred site will be chosen and a further phase of more detailed investigations will be embarked upon. The results of this will lead to the preparation of a Detailed Environmental and Radiological Assessment and Pre-Construction Safety Report which will accompany a planning application to construct a repository at a site. This application would result in a Public Inquiry. The stage of formal authorization and licensing to operate will not be reached until the facility has been constructed and further final safety documentation has been submitted

by Nirex. By this time some 15 years of geological investigations will have been completed.

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