UK NIREX COMMENCES DEEP SITE INVESTIGATIONS

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ABSTRACT

Radioactive waste management policy in the United Kingdom is the responsibility of the Government. United Kingdom Nirex Ltd. has the task of developing a national radioactive waste repository for low and intermediate level wastes in accordance with this policy. Its program includes the waste arisings, not only from the nuclear industry, whose members are shareholders in Nirex, but also those from medical and other users of radioactive materials.

A major national discussion program has given a large cross-section of those concerned about radioactive waste management an opportunity to contribute to the evolving policy. An assessment of the technical requirements and public reaction has led to Nirex recommending the investigation of two sites, one in the north of England and the other in the north of Scotland. The procedure used for the national discussion program is dealt with elsewhere in the Conference (Ref. 1). At the two sites during 1989 surface surveys have been completed and the location of the initial boreholes has been defined. At one site the part of the deepest borehole, with a planned depth of 1,700 meters, has been drilled.

The design of the repository is moving from the generic stage to the specific items which are independent of the local site properties. The waste receipt building, container handling facilities, underground cavern ventilation, and waste retrievability are being addressed.

The conditioning of wastes is in progress for initial storage at the waste producers site and eventual deep disposal. The definition of a range of standard package and waste transport container designs is well advanced and has taken account of coordination of the requirements of the customer organizations. This will result in the production of the essential, fully proven containers and transport systems.

The program is supported by comprehensive research and development, not only of the properties of the waste and various man-made and natural barriers to waste migration, but also of the relevant natural analogues used to support the safety assessment of the repository.

INTRODUCTION

In the United Kingdom the nuclear industry created a separate organization, UK Nirex Ltd., to provide a comprehensive long-term radioactive waste disposal service for low and intermediate level solid radioactive wastes arising from all radioactive operations in the country. The high-level wastes are to be vitrified and stored for some 50 years. The low and intermediate wastes are to be emplaced in a deep underground repository and the developments during 1989 towards this objective are presented.

Following two years of intensive research, design development, analysis of suitable environments, and public discussion by the company, the UK Government accepted the Nirex recommendation that sites at Sellafield in Cumbria, in the North of England, and Dounreay in Caithness, in the north of Scotland, should be given priority over others to see if one or the other is suitable on detailed analysis for the siting of a deep repository. Both sites, with others, had shown up well in the sifting of a short-list of possible sites. They had the particular merit of being in areas where there is already some measure of local support for nuclear operations, and it was concluded that they should be fully evaluated before further consideration of the other possibilities.

It will not be easy to pursue radioactive waste disposal in the UK in the foreseeable future, for there remains a wide gulf between technical and popular perceptions of the risks. Nevertheless, the company's policies are now much better understood and have attracted a fair measure of support in parliament and the media. Internationally, the company's work is very highly regarded and is in the mainstream of world development.

The technical program during 1989 concentrated on the investigation required for the two identified sites. The drilling of test boreholes requires formal planning permission and for the Sellafield site, a planning application had been submitted in March 1988. Permission on appeal was granted in March 1989. For Dounreay the planning application was made in April 1989 and after refusal an appeal was lodged in 1989. The outcome is still awaited. Drilling work has been carried out at Sellafield and other geophysical and non-nuclear environmental assessment studies have been continued at both sites.

The design and research programs for the repository and the waste containers have been continued. The public information operations of the company have backed up

those of the site owners at Sellafield and Dounreay and have been maintained nationally in addition.

THE SELECTED SITES

The selection of sites for further investigation was made by following the approach recommended by the International Atomic Energy Agency. The process consists of three stages:

1. A national search to define suitable areas of the country,
2. Identification and investigation of candidate sites,
3. Choice of a site, based on the results of the investigations in stage 2.

In stage 1, the search for potential disposal center sites considered about 30% of the UK, including large areas of the east and west coasts of England, the Midlands, Southern England and the north-east of Scotland.

A number of other factors were brought to bear in stage 2. These included transport, and the constructability and long-term safety of a waste center in different types of geology. Socio/economic impact was also considered as were the views expressed by the public and elected representatives during the national discussion of the issues fostered by Nirex. This broad approach narrowed down the number of areas under consideration. The remainder were then the subject of further analysis over a range of technical, social and economic factors.

As a result of this process, two locations were selected for further investigation. The Nirex site selection process is the subject of a separate paper to this conference (2).

SELLAFIELD, CUMBRIA

One of the main reasons for selecting Sellafield as a potential location is the fact that about half of Britain's radioactive waste is either stored or produced at the BNFL site. As a result, transport costs would be kept to a minimum, and very little would be required in the way of additional transport access. The Sellafield site already has adequate road and rail access.

The traditional industries of Cumbria are mining and heavy industry, and these skills, together with the local nuclear experience could be valuable in a program of disposal center construction and operation.

The local geology is more complex than at the other potential location (Fig. 1) but there is confidence that the groundwater movement can be successfully calculated and predicted. The formation of interest for disposal center

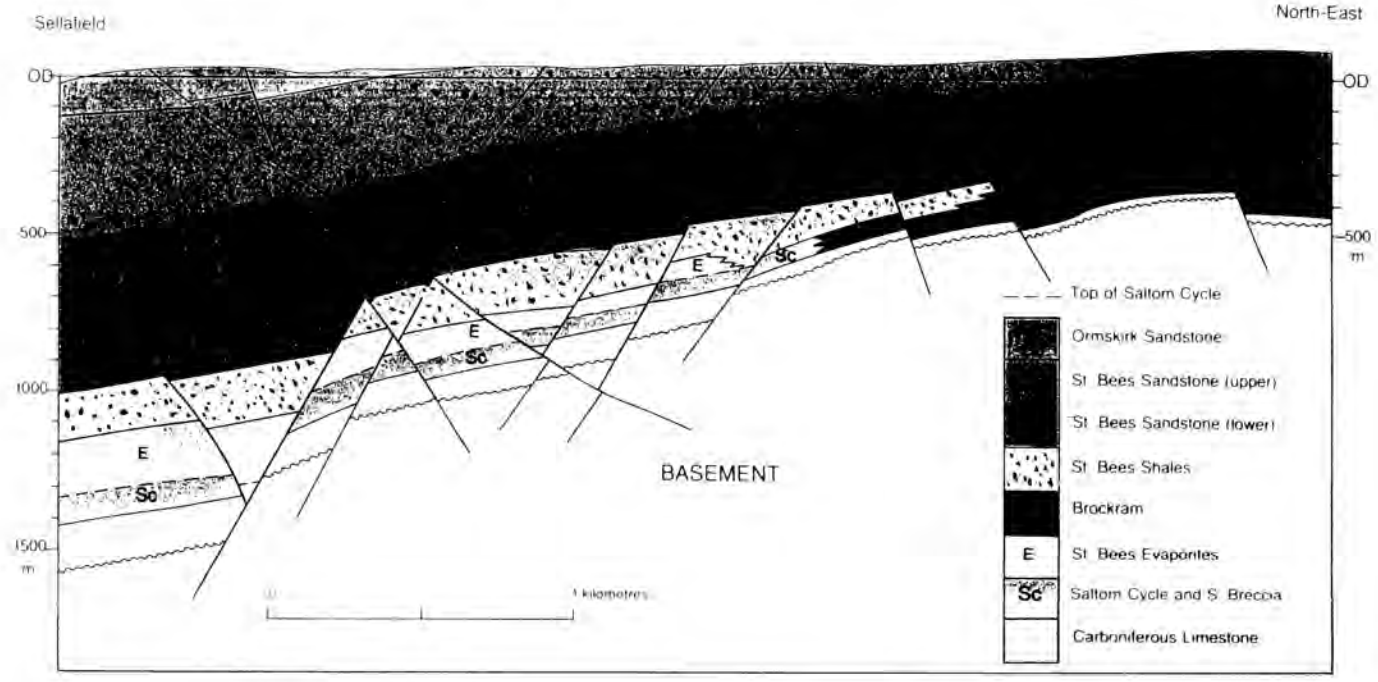

Fig. 1. Predicted Cross-section of the Geology in a North-Easterly Direction from Sellafield.

construction is the Borrowdale Volcanic series, which is a hard rock.

The other location selected for investigation is at Dounreay in Caithness, in the north-east of Scotland.

DOUNREAY

It is believed that the UKAEA site at Dounreay offers potentially suitable hard rocks for the development of a disposal center. If a center were constructed it would be in the hard rock of the Moine metasediments or the Reay Diorite. The geology of this area (Fig. 2) is predictable and there is confidence that the groundwater flow can be modelled. Water movement in these rocks is expected to be low because of the flatness of the landscape. The relatively simple geology increases confidence in long-term predictions and also allows some flexibility in the choice of disposal center design.

In the wider region there is a large workforce with nuclear-related experience. Depending on the future of the Dounreay establishment some of this experience may be available to Nirex, during the construction and operation stages of the waste center.

POST-CLOSURE SAFETY

The post-closure radiological safety of a deep repository sited in basement hard rock at Sellafield has been assessed and the provisional results are outlined below. The activities associated with the construction and operation of a repository including transport of personnel and large amounts of material will give rise to conventional and radiological risks over a short timescale. These have also been assessed to ensure that the relevant regulatory safety requirements can be satisfied.

Calculations of the annual dose to an individual arising from the migration of radionuclides into the biosphere by the groundwater pathway have been carried out. The calculations, which take account of uncertainty in the available data, are based on the use of the computer code MASCOT. This probabilistic safety analysis is supported by complimentary computations and assessments to take account of factors not explicitly included in the current MASCOT Program.

For the first 10,000 years after repository closure, it is expected that radionuclides migrating in groundwater would emerge into a marine biosphere. Over this period the highest annual individual dose is estimated to be less than 10^{-6} mSv (one millionth of 1 mSv). Beyond 10,000 years, considerations of climate change and consequent reductions in sea level suggest that radionuclides migrating in groundwater would emerge into a terrestrial biosphere for substantial periods of time. The maximum annual individual dose is estimated to occur between 10,000 and one million years after closure in postulated boreal conditions and is

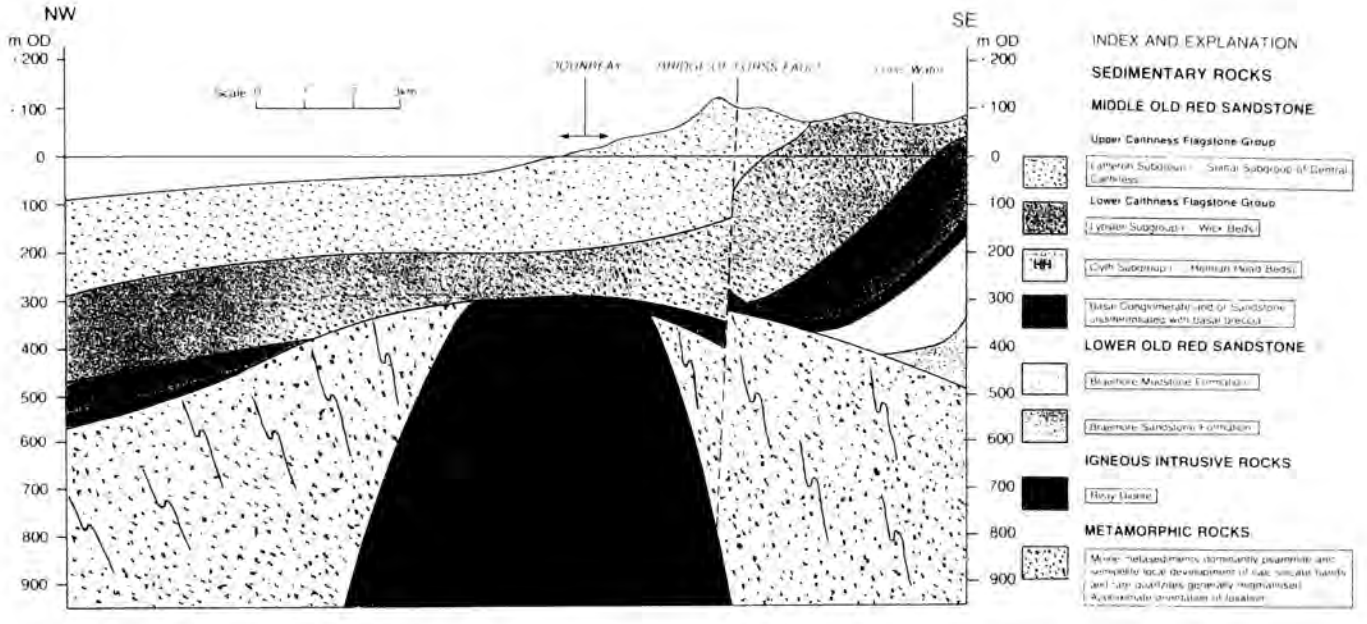

Fig. 2. Predicted Cross Section of the Geology at Dounreay.

0.02 mSv. This estimate is derived from calculations carried out using the MASCOT program, which suggested a peak annual individual dose occurring between 100,000 and 100 million years after closure of 0.0003 mSv. However, there are a number of effects that are not currently addressed in MASCOT, and the impact of these on the calculated individual annual dose has been superimposed. The main characteristics of the site influencing this estimate are summarized below.

Because the detailed ground investigations have only just commenced, there is considerable uncertainty about the geological strata and their hydrogeological parameters and hence in the groundwater return time. Therefore, the likely range of possible groundwater return times has been explored by varying the permeability and porosity of the various strata independently in the postulated geological succession. A deterministic model (NAMMU) specifically designed for the purpose, is used to characterize in 1, 2 or 3 dimensions the groundwater flow regimes.

Although the repository would be constructed in the underlying basement, 70% of the groundwater return time is spent in the low permeability, high porosity barrier provided by the postulated layer of anhydrite and shales which overlie the basement downstream of the repository location. Because there are uncertainties about the properties of the barrier layers and basement rock, there is the possibility of higher leach rates of radionuclides from the repository because the flow in the overlying sandstones could lead to the propagation of groundwater driving heads into the basement. Although this effect could be ameliorated by constructing the repository at greater depth in the basement hard rock, there would be penalties in terms of technical difficulty.

Preliminary calculations show that the heat output of short-lived radionuclides in the waste could lead to temperatures in a repository at Sellafield of about 80°C. The temperatures reached are dependent on detailed design and waste packing facilities and would decrease relatively rapidly with time as the radionuclides decayed and the heat diffused into the surrounding rock. This temperature could influence the chemical barrier provided by the near field.

Radionuclide retardation has been taken to be the same as the moderate levels expected for hard rock. This assumption is doubtful for the anhydrite layer, which is a simple mineral providing few sorption sites, and for the St. Bees sandstone, since the quartz is also a simple mineral. Thus, in the present assessments there may have been some over estimation of radionuclide retardation but detailed ground investigations will yield relevant data.

Since the basement at Sellafield is taken to be a hard fractured rock, the permeability is expected to be sufficiently high that gas generated in the repository could escape without disturbing the geology. Also, there should be resistance to land form change due to tectonic movement on the longest time-frame. However, there is some question over the effect on the groundwater flow if the present superficial deposits were eroded, possibly by glacial action.

The doses currently predicted for the groundwater pathway are based on present knowledge of the solubilities and sorption characteristics of the radionuclides present in the waste. There are indications that these characteristics could be adversely affected by the chemical effects of organic material in the waste. Research is being undertaken to quantify this effect further and to determine whether any change in waste processing would reduce the impact.

The repository design associated with the hard rock host geology in the Sellafield basement is the same as for Dounreay and the same risks for human intrusion might be expected. However, there may be some potential for the future exploitation of high enthalpy geothermal energy in this region. The estimated areal drill frequency reflects this possibility in a value twice that assessed for low relief hard rock.

Using best estimate values the maximum risk for the group representing geotechnical workers handling contaminated cores extracted from the repository is approximately 8×10^{-9} (8 in a billion), per year, while for site occupants it is evaluated as 3×10^{-9} (3 in a billion) per year. However, taking preliminary account of potential parameter uncertainties, the expectation value of risk to site occupants rises above that for the geotechnical worker group, to a value of around 2×10^{-8} (20 in a billion) per year.

A similar assessment has been completed for the other site at Dounreay and here the value of the maximum annual individual dose at about 40,000 years is estimated to be 0.06 mSv and the intrusion risk 10^{-8} (10 in a billion) per year. Hence, the assessments show the two sites to have similar safety potential.

The regulatory requirements in the UK for post closure safety are dealt with in a paper to this Conference (3). This paper raises the question of how best to deal with assessments for the very long future timescales for which the prediction of the data has such large uncertainties which may mean for some future timeframes quantitative approaches are unrealistic.

FIELD INVESTIGATIONS

Before the exploratory investigations could be specified, a better understanding of the prognosis of the geology at the sites was required. All existing geological data were collected, collated and interpreted. In addition, a preliminary vibroseis seismic survey was carried out at both

sites. The prognosis of geology for the sites were as in Figs. 1 and 2, as stated above.

The aims of the exploratory investigations were established as:

- Establish the 3D geological structure of the sites and surrounds on land and offshore, to a depth of about 2,000 m in order to place the site in its regional geological context.
- Establish the disposition of the rock formations and definitions of the main structures which may affect groundwater flow within the region.
- Establish basic physical properties of the formations penetrated by the boreholes.
- Establish a simple preliminary hydraulic head profile to the depth of the boreholes.
- Establish the geochemistry of some of the waters of the formation.
- Establish the position and form of the saline interface.
- Make an initial interpretation of the paleofluxes within the formations.
- Obtain rock samples for geotechnical testing.
- Obtain fracture density distributions and orientation within the rocks.

From these aims and the prognoses the content of the investigations was established as:

- Two boreholes greater than 1,000 m deep.
- Borehole testing and sampling for:

  Hydrogeology, Geochemistry, Rock cores and cuttings, and Borehole geophysical logging.
- Regional geophysical surveys, 25 km x 25 km, including:

  Land seismic survey,

  Marine seismic survey,

  Transition zone seismic survey,

  Land gravity survey,

  Marine gravity survey

  Aeromagnetic survey, and

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- Laboratory analysis of:

  Rock samples,

  Mud samples,

  Groundwater samples, and

  Fractures and fracture infill materials.

Both sites are situated on the edge of basins which are being explored for hydrocarbon deposits. Therefore, there exists a possibility that gas might be present. Full pressure control equipment will be used on all of the boreholes. Drilling mud for weighting purposes will be necessary at Sellafield and this will cause some problems with contamination of samples. A tracer will be used in the drilling fluid to assess contamination levels.

Before borehole drilling can commence on either site, planning consent had to be sought and granted. At Dounreay the planning application was made in August 1989 and a reply is anticipated in March 1990. At Sellafield the application for borehole 1 was made in March 1988 and permission granted during March 1989. The application for borehole 2 was made during October 1989 and a reply is anticipated in March/April 1990. Consent has been granted for borehole 1 at Sellafield, and this borehole was drilled during the summer of 1989. The borehole was successfully drilled and tested to 1,189 m. However, severe problems with the conditions led to a decision not to proceed with drilling to the programmed depth of 1,700 m. This borehole was drilled using conventional rotary drilling techniques and was deviated approximately 23° to hit target formations. The deviation was necessary as the surface site directly overlying the target formation was not available for use. The problems with hole condition and breaking drill strings were encountered in the deviation within the abrasive St. Bees sandstone. Key seating and washouts were experienced. However, the borehole was successfully drilled and tested to 1,189 m and the data are at present being processed and interpreted.

Early results show that:

- The sequence of rocks is as predicted.
- Hydrogeology, full hydrostatic head is present to at least 1,000 m.
- Geochemistry, saline groundwater is present to at least 1,000 m.
- Extensive data on the properties of the rocks have been gained from core and wireline geophysical testing.
- Rock and water samples have been obtained for detailed laboratory analysis which will provide further data on hydrogeological geochemistry, rock strength and rock quality.

ENVIRONMENTAL SOCIO-ECONOMIC ASSESSMENTS

In addition to the radiological assessment and engineering design of a repository, there is a requirement to carry out environmental and socio-economic assessments to consider non-nuclear matters. This is in order to support a planning application to develop a repository which in the United Kingdom comes under the Town and County Planning Acts as outlined in the document of the DoE (UK), namely, Principles for the Protection of the Human Environment. It is also to comply with the European Commission directive on the assessment of the effects of development on the environment (85/337/EEC). To this end, Nirex has engaged consultants to assess the impacts of a repository and of the transport of waste on the environment and local community.

The first step of this work is to produce a baseline report for each site which gives a description of the environment in its current state. This involves collecting easily available information and consulting with a wide range of bodies, including Local Authorities, Government Departments, Conservation Groups, Water Authorities, Tourist Boards, the Meteorological Office, Ordinance Survey and Industrial or Development Boards. This information is supplemented by fieldwork which studies landscape, ecology, transport density, economic structure and population. The baseline reports are intended to provide a 'snapshot' of each site at a given time. Nirex and its consultants have already collected much of this information at Sellafield and will cover the same requirements at Dounreay.

The next step is to consider how the development of a repository and its associated infrastructure would change the baseline situation. The impact of development on the environment and socio-economic structure is then evaluated using quantitative and subjective evaluation. Account is taken of other development planned in the area by considering local Structure Plans. Other probable changes to an area are also anticipated where there may be an impact, for example job losses or alterations to the local natural environment.

This stage clearly involves close liaison with repository designers not only to understand the nature of the project in order to evaluate the impact, but also to comment on design proposals and make suggestions that will both mitigate the impact on the environment and where possible lead to benefit to the local community. The process is thus iterative.

Nirex regards it as being very important to consider the well being of the environment and the maintenance of a local community structure. That is why the non-nuclear environmental and economic assessment has always formed a valuable part of the project from the earliest conceptual stage and during site selection and will do so in all future phases of the project.

RESEARCH AND DEVELOPMENT

The research program of Nirex continues on a broad basis but mainly contributes to the database for the long-term post-closure radiological safety assessments and a few areas are discussed below:

The Effects of Organic Materials in Wastes

A major concern of Nirex during the year was the potential increase in risk due to complexation effects arising from the products of microbial, chemical or radiolytic degradation of organic constituents of the wastes under repository conditions, possibly aggravated by the presence of organic material in the geosphere. These effects include an increase in solubility, under near-field conditions, and a reduction of sorption, in the near- and far-fields, of certain radionuclides important to the safety case, notable Sn-126, U-238 (and its daughters) and Pu-239.

A wide range of organic materials including plastics and ion exchange resins are involved but cellulosic materials appear to be particularly potent sources and, moreover, are present in large quantities in the waste. Only a small proportion of such cellulosic material (0.03%) appears to be sufficient to produce a marked effect: For example, an increase in solubility of plutonium of approximately x 10^4. Analyses of postulated scenarios suggest that these effects will need careful consideration for the performance assessments of the repository.

The significance of the enhancement of radionuclide mobility by organic materials is very dependent upon the characteristics of the site assumed for the repository, especially the groundwater return time. However, to demonstrate that the hydrogeology of a proposed site is good enough to compensate for the organics effect would require extensive exploration. It is therefore necessary either to postpone a decision on acceptability of cellulose and ion exchange resins in the Nirex repository and to explore ways of reducing their influence.

Research is in hand directed at establishing whether the observed deleterious effects of organics in the waste will be maintained over long times under repository conditions. The possibility that microbial processed might serve to destroy the complexants is being investigated.

Gas Migration

Experiments and modelling have enabled the rates of generation of hydrogen from steel corrosion, and methane and carbon dioxide from degradation of organic constituents, to be predicted. Some of these gasses will be carried away by solution in groundwater, but the remainder will need to be allowed to escape without pressurizing the

repository. It is already clear that gas may be dissipated harmlessly through a few small fissures, or a permeable zone in the structure. It may, however, influence groundwater movement locally, and this effect is being studied. Radionuclide migration may also occur as a result of the gas generated in the repository, which contains a small proportion of radioactive constituents, moving out of the 'near-field' and through the 'far-field' to the biosphere. The work includes the development of improved methods of estimating the amounts of tritium, carbon-14 and trace gaseous radionuclides likely to arise.

Biosphere

Many radionuclides will have decayed to innocuous levels of activity in the very long times taken to reach the biosphere. However, the longest-lived species, although delayed, may eventually enter the biosphere, at low rates and low concentrations, and it is important to understand their behavior in order to predict the doses to which they may give rise. Furthermore, the existing extensive data on the behavior of radionuclides in the biosphere need to be supplemented to take account of the fact that the origin of the activity is underground and that radionuclides not hitherto of interest need to be considered. The program, therefore, includes the development of a surface hydrology model to include radionuclide transport and investigation of movement through vegetation in the water-spoil-plant system. The work is concentrated on the behavior of technetium-99, iodine-129, chlorine-36 and the actinides, all of which are predicted to be of significance, and is being extended to include isotopes of radium, calcium, lead and carbon.

PARALLEL ACTIVITIES

The following on-going areas of the Nirex program are just as important as the development work for the repository itself but as they have not gone through an important stage this year they are not dealt with in detail. They have, however, continued to make steady progress.

Work has continued on the development of waste packages, particularly of the reusable shielded transport container concepts for transporting intermediate-level waste. A study has been carried out to categorize all waste streams in terms of shielding requirements so that a discrete range of transport containers of different shielding thicknesses can be defined.

The company has continued to carry out transport studies in order to provide improved information on transport costs for each major waste category and to provide support to the work on site selection. This input to the site selection process has addressed the transport of radioactive wastes, construction material, spoil and personnel including the practicalities of road, rail and sea transport to sites; the need for new transport infrastructure; overall costs; environmental impact; and safety. This work has focussed on the Dounreay and Sellafield sites.

The public relations program undertaken by the company is divided into two distinct areas:

- A national, broadly-based information program, and
- Local community programs in the two areas being investigated as possible repository sites.

The national program is undertaken solely by the company while the local programs are handled by British Nuclear Fuels plc and the United Kingdom Atomic Energy Authority who have strong local ties and contacts at Sellafield and Dounreay, respectively. Company staff support these local programs with publications, attendance at consultative meetings, manning exhibitions, and other activities as necessary.

CONCLUSIONS

Nirex has commenced site investigation for a deep repository for low and intermediate radioactive wastes. The initial two sites to be explored are at Sellafield in the north of England and Dounreay in the north of Scotland. A clear program of work has been established on a sound basis which should lead to the establishment of the case for a deep repository for the nation's low and intermediate radioactive waste.

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