Transport Studies Associated With the Selection of a Site for a UK Deep Repository for Disposal of Radioactive Wastes

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1. INTRODUCTION

UK Nirex Ltd (hereafter referred to as Nirex) has been set up by the British nuclear industry to provide facilities for the disposal of solid low level and intermediate level radioactive wastes (LLW and ILW). Nirex is currently seeking to develop a single deep repository for the disposal of both LLW and ILW. It is proposed that a deep repository should be in operation by the early years of the next century and should operate for about 50 years.

The selection procedure to identify a preferred repository site has followed the approach recommended by the International Atomic Energy Agency (IAEA 1983). 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 candidate sites being reduced as the requirements to be satisfied are refined and enhanced.

The deep repository may be sited in any one of a number of areas in the UK with potentially suitable geology. The repository may be:-

- inland
- coastal with tunnels under the sea bed
- accessed from a small island
- accessed from an offshore structure.

Possible sites falling within these categories and having acceptable geology have been considered with the objective of identifying a small number of sites for further detailed investigation. The site selection process undertaken by Nirex began with 'desk studies' based on available data and theoretical knowledge. As the characterisation of favourable areas and of potential sites proceeded, some were eliminated and others emerged as offering potential. Overall, the convergence on a small number of locations 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. These preliminary investigations were completed early in 1989. Sites have been evaluated based on the criteria of safety, geology, planning, repository construction, non-nuclear environmental impact and transport.

The objectives of the transport assessments carried out by Nirex were to:-

- establish the feasibility of various transport modes
- consider the feasibility of providing transport facilities and new or improved infrastructure at potential sites
- assess the environmental impact of transport
- define transport costs
- perform safety assessments.

This paper outlines the options considered for transporting waste and describes how transport was considered in the comparative evaluation of sites.

2. SOURCES AND QUANTITIES OF WASTES

Radioactive wastes arise in the UK from extensive use of radioactive materials in the generation of electricity and in industry, defence, medicine and research. Wastes can be divided into those which arise during day to day working (operational wastes) and those which arise from the dismantling of nuclear facilities (decommissioning wastes).

It is estimated that the following volumes of waste will have to be disposed of over the 50 year life of the repository:-

LLW: 2,000,000 m^3 (1,500,000 m^3 operational wastes, 500,000 m^3 decommissioning wastes).

ILW: 600,000 m^3 (440,000 m^3 operational wastes, 160,000 m^3 decommissioning wastes).

In the UK LLW are wastes with activity not exceeding 4 GBq/tonne alpha activity or 12 GBq/tonne beta/gamma activity and so do not normally require radiation shielding. ILW are wastes with radioactivity exceeding the boundary for LLW, but of lower activity than high level wastes (HLW). HLW are those from the reprocessing of irradiated fuel which generate heat and will be vitrified.

Wastes arise in many parts of the UK from Dungeness on the south east coast to Dounreay on the extreme tip of northern Scotland. Clearly, wherever the repository is sited, there will be a need for a transport system capable of handling movements from a large number of locations (Figure 1).

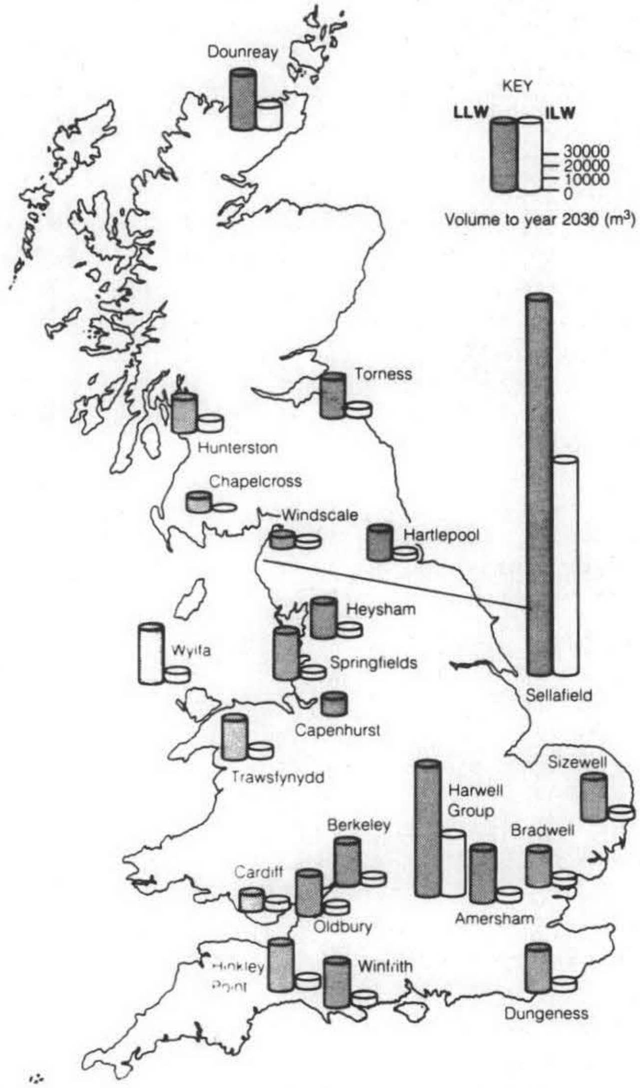


Figure: 1 Total ILW & LLW waste production by volume

Figure 2 illustrates the Nirex standard waste containers for LLW and ILW (SMITH 1988). LLW in 200 litre drums will be transported in ISO type freight containers. The 500 litre drums and 3 m^3 boxes for ILW will be transported in reusable shielded transport containers which have a range of shield thicknesses. The size and weight of packaging will govern the type of land transport which can be used. For the lighter packages, containing for example operational LLW and certain types of operational ILW which do not require a great degree of shielding, the use of road transport would be feasible. However many of the packages are likely to be in excess of 25 tonnes which would put the lorry in excess of the current UK weight limit for road transport (Gross Vehicle Weight of 38 tonnes) (DEPARTMENT OF TRANSPORT 1978). Rail or sea transport is therefore necessary for the heavier packages.

possibility of full trainloads being assembled at a series of marshalling yards. Each train would have a maximum trailing load of 1000 tonnes and would typically be 12 wagons in length. Empty containers would be returned by rail with the overall turnaround time, including testing and inspection, being about two weeks.

Road Transport

Road transport will be a component of any transport system since some waste producing sites are remote from railheads. Where individual sites produce only small quantities of waste, road transport will be favoured since it offers the advantages of cost and flexibility. Due to the restriction on the weights that conventional road transport can cope with (i.e. effective load of 25 tonnes) it is not considered that road transport could ever become the dominant mode.

Sea Transport

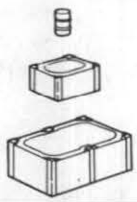
There are two very different types of sea transport operations which Nirex have considered. One applies to coastal or island sites while the other applies to offshore structures.

Preliminary technical, operational, economic and environmental assessments of sea transport have indicated that the preferred approach for shipping to a coastal or island port would be from a range of ports (possibly about 6-8) whose location would be chosen in order to reduce land movements to a reasonable minimum.

The typical transport operation would be based on a ship of 100 m length, 16.5 m breadth, 5.0 m draught, utilising a lift on-lift off (LO-LO) design with a twin gantry, over the side crane system which reduces the need for quayside facilities. Three such ships, each with a 2,500 tonne payload would be required. These would collect from three or four ports on each round trip.

Transport to an offshore repository accessed via shafts into the sea bed has also been examined. Due to the level of sea swell it would be difficult to transfer waste packages from a conventional ship to a platform, so the concept incorporates the use of a semi-submersible crane vessel (SSCV) - Figure 3. Such vessels are currently used to assist in the construction of North Sea oil rigs off the UK coast and are designed such that once in position they can be partly submerged to a depth of about 30 m in order to give stability.

Due to the slow speed of these vessels and the large draught required, it would not be practical for them to visit a number of different ports and a dedicated facility would be needed to be constructed at a location where deep water is available. Waste packages would be brought to the port by road and rail and would be loaded into 'megacrates' weighing, when full, some 2000 tonnes. These would be reusable crates, which would be used to reduce the number of transfer operations to the platform. The SSCVs would transport up to seven of these crates at a time.

For Low-Level Wastes	Description	Application	Max. external dimensions (m) (provisional)
	200 litre drum	The normal container for most operational wastes	0·61 OD x 0·863
	3m³ LLW box	For operational and decommissioning wastes unsuitable for 200 litre drums	2·15 x 1·5 x 1·3
	12m³ LLW box	For large items of decommissioning wastes	4·0 x 2·4 x 1·85

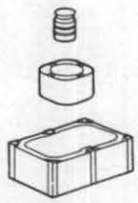
For Intermediate-Level Wastes	Description	Application	Max. external dimensions (m)
	500 litre drum	The normal container for most ILW	0·8 OD x 1·2
	3m³ ILW box	For wastes unsuitable for 500 litre drums	1·72 x 1·72 x 1·2
	12m³ concrete box	For large items of decommissioning wastes	4·0 x 2·4 x 1·85

Figure: 2

The estimated total weight of wastes (including transport containers) to be transported is as follows:-

LLW: 4M tonnes (2.4M t operational wastes, 1.6M t decommissioning wastes).

ILW: 11M tonnes (10.2M t operational wastes, 0.8M t decommissioning wastes).

3. POTENTIAL TRANSPORT SYSTEM

The choice of transport mode for radioactive wastes will be largely determined by the location of the repository. An inland repository would need to use rail or road transport. For a coastal repository, sea transport may be an option. A repository sited on an island or accessed from an offshore structure would obviously require sea transport, although road and/or rail transport would also be needed to move wastes from the producing sites to the ports to be used for despatch. (For a further description of the potential transport modes see APPLETON et al MAY 1989).

Rail Transport

Were all of the wastes to be moved by rail there would be, on average over the repository lifetime, some 10 train movements per week (plus an equal number of empty return journeys). If lorries were to be used for the transport of the lighter packages the number of train movements would be reduced to about 7, but there would be an additional requirement for some 80 lorry movements per week in each direction. Initially there will be some clearance of waste backlogs and the above transport movements could be up to 50% higher.
The rail transport operation would involve a trunk haul system with trains collecting waste from some nuclear sites and with the

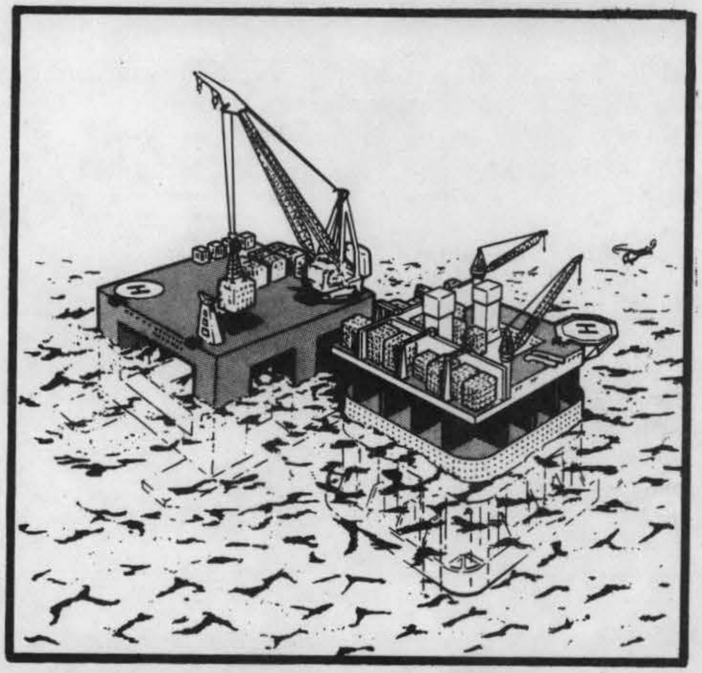


Figure: 3 Semi-submersible crane vessel at offshore structure

4. TRANSPORT OF SPOIL, CONSTRUCTION MATERIALS AND LABOUR

In addition to the movement of waste materials it will be necessary to import bulk construction materials to the site and export spoil from it. Very large quantities of concrete will be needed and materials such as cement, pulverised fuel ash (PFA) and blast furnace slag (BFS) will need to be imported in bulk quantities. Other transport will be required for construction materials, for the supply of steel, plant, machinery, services and general supplies.

It is estimated that during the initial construction phase, the repository will require some 250 lorry loads of material per week, reducing to about 140 lorry loads during the 50 year operational phase. If materials were to be imported by rail there would be the need for 5 trains per week during the construction phase reducing to 2-3 train loads per week in the operational phase. The volumes of spoil produced from the excavation will be high (typically 15-20 Mm^3). Some sites may require the use of some of this spoil within the site for landscaping or for harbour infill, however, most of the spoil will need to be removed, and transported to a suitable land-fill site; probably by rail. This task could involve about 5 train loads per week throughout the projected 50 year life of the repository.

For land based sites the number of employees at the repository is estimated to be around 350 and most of these are likely to commute by car. For off-shore and island sites the movement of men would need to be by helicopter and would typically involve daily flights between the repository and mainland, with employees working conventional off-shore practices of 2 weeks on/2 weeks off.

5. PRINCIPLES OF SITE SELECTION

The transport aspects of the repository formed an important part of the site selection process. These were addressed in increasing detail as attention converged on fewer candidate sites.

The initial sieving of sites was undertaken on the basis of ranking within similar groupings (i.e. to produce a "best of breed"). These initial assessments took account of costs, land availability, environmental effects and proximity to adjacent populations and transport. At the latter stages of site selection a decision making tool was required to aid the task of focusing on a more limited number of sites. A Consultant from the Decision Analysis Unit of London School of Economics with experience in the development and use of evaluation models was appointed to develop an appropriate methodology to aid this process. The model recommended was based on a multi-attribute decision analysis methodology which had been proven in practice and used in the United States for a similar site selection process. (KEENEY 1987). A mathematical model was then developed to describe the system.

The model was structured to draw together all the relevant issues. Weightings which reflected the relative importance of each factor were adopted and sensitivity testing was undertaken to assess the effect of varying these weightings.

6. SITE SELECTION PARAMETERS

The assessments of the transport elements were considered under four major impacts, which were also used for the consideration of the geological, construction and environmental issues. The four main groups were (i) Cost, (ii) Robustness, (iii) Safety and (iv) Environmental. The transport attributes are listed in Table 1.

Table 1 Transport Assessment Attributes

(i)	a)	Transport Construction Cost
	b)	Transport Operating Cost
(ii)	a)	Transport Robustness - Known Technology
	b)	Transport Robustness - Flexibility
	c)	Transport Robustness - Consents
(iii)	a)	Safety to Public
(iv)	a)	Environmental Effect on National Community
	b)	Environmental Impact on Local Population
	c)	Physical/Environmental Impact - Landscape
	d)	Physical/Environmental Impact - Ecology

These attributes are now discussed in turn, quoting as examples sites located at Sellafield, Dounreay, and island and an off-shore structure.

(i) **Costs** Costs were estimated in two separate parts, namely:-

- Capital costs to implement the system, including the cost of new infrastructure(roads, rail links, ports) and the cost of ships, reusable waste containers, rail wagons, cranes etc.

- Annual operating costs, including of freight charges, maintenance etc.

The capital costs were estimated at 1988 prices and covered a range from £85M for an inland site with existing good rail access, such as Sellafield, to over £400M for an off-shore site requiring the provision of a SSCV and new port facilities. The annual operating costs, which are the dominant component of total costs, were averaged over the 50 year period and ranged from £15M for Sellafield, (where much of the waste is already located) to £30M for Dounreay where very long transport haul distances would be involved.

(ii) **Robustness** Three factors were used to reflect the robustness of the proposed transport system. Factors were derived for each site on the basis of a preference scale.

a) **Known Technology** - This parameter was used to reflect the use of well tried and tested technology. The top value was ascribed to a system totally reliant on conventional road or rail transport, i.e. Sellafield and Dounreay. The lowest value was ascribed to off-shore sites involving the use of a SSCV as this involves many previously untried concepts. Island sites involving shipping were scored in between as much of the system is well tried.

b) **Flexibility** - This parameter was used to reflect the flexibility that could exist in the transport operation to change mode or route if required, so as to be able to overcome breakdown in the system or industrial disputes. The top score was assigned to any site which had adjacent rail and port facilities. An island was ranked high since there was a flexibility of ports and operators. Sellafield would be totally reliant on rail and was ranked lower while an off-shore site reliant on SSCV shipment through a single port was ranked lower still. However the worst case was assigned to Dounreay which was totally dependent on a very long section of remote rail line, subject to a single operator with little potential for a port.

c) **External Consents** - This reflected the need to acquire land and obtain planning consents for facilities outside the bounds of the proposed repository. Sellafield scored well as little additional transport infrastructure would be required. Island sites fared almost as well since any new port would be remote from populations. Dounreay would require a long section of new railway line and so scored much lower. An off-shore platform site represents the worst case since this would, most probably, require a very extensive port to be purpose built on the mainland with associated infrastructure.

(iii) **Safety** Transport safety assessments were carried out for the movement of radioactive wastes, construction material and spoil. Risks were considered as the conventional risks associated with all freight movements and radiological risks which related only to the movement of radioactive wastes. Conventional risks were calculated from published casualty statistics and varied between 0.2 and 0.6 per year, with those sites having the longest haul experiencing the greatest number of accidents. The radiological risks were calculated using the methodology described by APPLETON et al JUNE 1989. These were much smaller than (about 1% of) the conventional transport risks for any given movement. A weighting for the transport safety attribute was established from considering the UK Government valuation of life for road accidents at around £0.5M per fatality.

(iv) Environmental Impact

a) **National Community** - Away from the immediate vicinity of the repository the environmental effect of increased road or rail traffic will be virtually negligible. However it was recognised that there could be a social impact due to be a perceived risk arising from the movement of radioactive waste material past where people live. A measure of this was made by calculating the number of train kms of movement passing through urban areas on route between production sites and the repository. In this comparison island sites fared best as waste was only being carried to adjacent ports (value 10,000 urban train kms per year), whereas Dounreay with long haul distances had a much higher value (80,000 urban train kms per year).

b) **Local Population** - A wide range of impacts on the local communities were examined. These impacts result from the construction of new transport infrastructure and from the operation of a transport system and included:-

- Impact on existing transport infrastructure arising from increased traffic.
- Demolition of buildings and the acquisition of land.
- Disruption to the local population during construction works.
- Noise, vibration and air pollution arising from traffic using the new transport facilities and its effect on adjacent communities.
- Severance caused by the new transport facilities (road and rail) and its effect on farming activities and their viability.
- The impact on the local economy in terms of resource sterilisation of the land taken to construct the new transport facilities and effects on local tourism/fisheries/agriculture, etc.

c) **Landscape** - The effect of any new transport facility on the landscape of the area was assessed. Those sites requiring major infrastructure improvements such as a rail link to Dounreay or port for an off-shore site fared poorly.

d) **Ecology** - The amount of disruption to the local ecology was measured in terms of the amount of land that would be required for transport infrastructure development. As with other effects this was greatest where the infrastructure was longer. Disruptions to any designated areas, e.g. Sites of Special Interest, Areas of Outstanding Natural Beauty, Heritage Coastlines, were also considered.

7. THE DECISION PROCESS

The decision analysis model brought together the transport assessments described above with the results of analyses undertaken on geological factors and the construction, safety and environmental impacts of the repository.

Transport operations to Dounreay and Sellafield were shown to be relatively straightforward since they would most likely involve only land transport. The cost of transport to Sellafield would be about half that to Dounreay, since about half the wastes to be disposed of originate from Sellafield. Sea transport to an island would result in similar costs to land transport to a mainland site, but it would be a more complex operation since it would require a land transport operation from a production site to the port and a sea transport operation to the repository, both of which must be co-ordinated. Transport to an off-shore structure would be expensive, complex and would require a significant development from existing technology.

The outcome of the decision process has been that, as an initial step, Nirex will carry out further investigations for Dounreay and Sellafield. In doing so the possibility has not been ruled out of investigating other locations at a later stage.

8. CONCLUSIONS

Transport was an important factor considered in the process of selecting sites for a deep repository in the UK. The transport of construction materials, spoil and personnel was considered in addition to the transport of radioactive wastes.

9. REFERENCES

APPLETON, P R, BENNETT, D and EASTMAN, C R, "Radioactive Waste Transport to a Nirex Deep Repository". Proceedings of Radioactive Waste Management 2, Brighton, UK, 2-5 May 1989. British Nuclear Energy Society.

APPLETON, P R, BENNETT, D, EGAN, M J and POULTER, D R, "Probabalistic Safety Assessment for Radioactive Material Transport - A Perspective and Example Application from the UK. PATRAM '89. Washington DC, 11-16 June 1989.

DEPARTMENT OF TRANSPORT The Motor Vehicle (Construction and Use) Regulations 1978. Department of Transport No 1017/78 and subsequent amendments.

IAEA "Disposal of Low and Intermediate Level Radioactive Wastes in Rock Cavities", Safety Series No 59, IAEA. 1983.

KEENEY, RALPH L. "An Analysis of the Portfolio of Sites to Characterise for Selecting a Nuclear Repository". Risk Analysis, Vol.7, No.2, 1987.

SMITH, M J S. "The Packaging and Transport of Radioactive Wastes". The Nuclear Engineer, Vol.29, No.2, 1988.