Non-Radiological Environmental Assessment of the Nirex Phased Geological Repository Concept

Stage 1: Generic Concept Design Assessment

Characterisation Report

March 2007

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List of Abbreviations

AGR: Advanced Gas Cooled Reactor
BE: British Energy
BNG: British Nuclear Group
CoRWM: Committee on Radioactive Waste Management
Defra: Department of Environment, Food and Rural Affairs
DMRB: Design Manual for Roads and Bridges
DTI: Department of Trade and Industry
EIA: Environmental Impact Assessment
ES: Environmental Statement
EU: European Union
GBq: Gigabecquerels
GDSS: Generic Disposal System Specification
HGV: Heavy Goods Vehicle
HLW: High Level Waste
IAEA: International Atomic Energy Authority
IEMA: Institute of Environmental Management and Assessment
ILW: Intermediate Level Waste
kBq: Kilobecquerels
LGV: Light Goods Vehicle
LLW: Low Level Waste
LP: Low Permeability
MoD: Ministry of Defence
NRVB: Nirex Reference Vault Backfill
PGRC: Phased Geological Repository Concept
PPC: Pollution Prevention and Control
PPG: Planning Policy Guidance
PPS: Planning Policy Statement
PWR: Pressurised Waste Reactor
RCF: Rock Characterisation Facility
RSA: Radioactive Substances Act
SEA: Strategic Environmental Assessment
SEPA: Scottish Environment Protection Agency
SILW: Shielded Intermediate Level Waste
UILW: Unshielded Intermediate Level Waste
UKAEA: United Kingdom Atomic Energy Authority
VLLW: Very Low Level Waste
1. Introduction

Background

1.1 The UK has accumulated significant quantities of radioactive waste, most of which have arisen from the nuclear power programme since the 1950’s. Wastes have arisen, and will continue to arise, over the lives of existing nuclear facilities and any developed in the future, and from their eventual decommissioning. In addition, radioactive wastes come from nuclear weapons production and the operation of nuclear submarines, non-nuclear industries and medical, educational and research establishments. Radioactive wastes are classified according to their heat-generating capacity and radioactivity content from very low level through to high level wastes.

UK Policy

1.2 UK policy on radioactive waste management is currently under review by Government. In September 2001, a consultation paper on Managing Radioactive Waste Safely was launched by the Department for Environment, Food and Rural Affairs (Defra), the Scottish Executive, the National Assembly for Wales and the Department of the Environment in Northern Ireland. This set out proposals for developing a policy for managing solid radioactive waste in the UK and included a proposed programme of action for reaching decisions, which was divided into stages. The consultation was completed in March 2002 and the Government announced the next steps in July 2002.

1.3 The Government commissioned a new body, the Committee on Radioactive Waste Management (CoRWM), to undertake a review of management options for higher activity radioactive wastes and to recommend an option, or options, to be taken forward. Following a process of review, assessment and public and stakeholder consultation, CoRWM published its recommendations in July 2006 (CoRWM 2006), identifying geological disposal as the best available option for the long-term management of such waste.

1.4 In October 2006, the Government responded to the CoRWM report, stating that future policy will be based on four key principles:

i) The Nuclear Decommissioning Authority acting as a strong, effective implementing organisation with clear responsibilities and accountabilities;

ii) Strong independent regulation by the statutory regulators: the Health and Safety Executive, the environment agencies and the Office for Civil Nuclear Security;

iii) Independent scrutiny and advice to Government by a successor body, built on CoRWM principles;
iv) Open and transparent partnerships with potential host communities for disposal facilities.

Nirex

1.5 The Nuclear Industry Radioactive Waste Management Executive (NIREX) established in 1982 to research, develop and operate radioactive waste disposal facilities on behalf of the nuclear industry. In 1985, it became a Limited Company - United Kingdom Nirex Limited - known as Nirex. Shares in Nirex were owned by the main waste producers. In July 2004 the government announced its intention to make Nirex independent of industry and under greater government control. Shares in Nirex have been transferred to a new company (Nirex CLG), limited by guarantee and owned by Defra and the Department of Trade and Industry.

1.6 The current Nirex Mission is: “In support of Government policy, develop and advise on safe, environmentally sound and publicly acceptable options for the long-term management of radioactive materials in the UK”.

1.7 Nirex provides advice to the nuclear industry, regulators and the Government. The Nirex role is to:

- Carry out scientific, social and engineering research to help develop safe and environmentally sound options for dealing with radioactive waste in the long term;
- Set specifications and standards, and advise the industry on how to treat and package radioactive waste;
- Develop and maintain the UK National Inventory of radioactive wastes and associated materials;
- Communicate with all stakeholders, including the public, to build understanding and develop ways of addressing the wide range of concerns and views surrounding the management of radioactive waste.

1.8 As part of its work to consider the long-term management of radioactive waste, Nirex has conducted a review of information on options and waste management strategies investigated previously by Nirex and internationally. In addition, Nirex has organised several workshops to discuss specific aspects of the work programme and obtain input into the development of this work. This has included a workshop on strategic and environmental impact assessment and its use in radioactive waste management.

The Nirex Phased Geological Repository Concept

1.9 The Nirex Phased Geological Repository Concept (PGRC) is one of the options on which Nirex conducts research for the long-term management of intermediate level radioactive waste. It is Nirex's current preferred solution and sets the standards against which waste is packaged and conditioned today.
1.10 The Nirex PGRC envisages emplacement of wastes in a facility constructed at depth within a suitable host geology. Successive phases of packaging, emplacement, backfilling and closure build up a multibarrier disposal concept illustrated in Figure 1.1. The concept is generic, and is not specific to any one location or type of geology. It is envisaged to be operated as an underground store initially, where waste would be monitored and retrievable. Decisions about timing of backfilling, sealing and closure of the facility would be left to future generations.

Figure 1.1 Illustration of the Nirex Multi-Border Containment Concept (Nirex, 2003)

Aim of the Non-Radiological Environmental Assessment

1.11 The Nirex PGRC is described in a series of reports, listed at Appendix 1, known as the Generic Documents. These set out the generic disposal system specification, the designs for the transport system and the repository, and the supporting generic safety assessments. Together the documents describe what Nirex believes to be a coherent concept, and a viable option for the long-term management of radioactive waste.

1.12 The safety assessments in the Generic Documents currently concentrate on radiological impacts on humans during the transport and operational phases, and post-closure. Chapter 6 of the Generic Disposal System Specification (GDSS) (Volume 1 Specification and Volume 2 Justification) identifies some of the non-radiological environmental issues and specifies the procedures that should be established and maintained to identify the environmental aspects
of all activities related to the specification, design, implementation and operation of the repository.

1.13 Nirex hosted a workshop on environmental assessment in 2002 (ForthRoad 2002a), following which the Nirex Environmental Assessment Task Team (EATT) published its recommendations for environmental assessment of the PGRC (Nirex 2003b). This report identified the need for a systematic assessment of potential non-radiological effects arising from the Concept, as currently described in the Generic Documents.

1.14 The report recommended that the assessment should consider potential environmental effects (such as land use, emissions, visual impact and traffic) during the transportation and operational phases and post-closure. It was, however, recognised that it may not be possible to quantify the environmental impact of these effects at the generic level. A more detailed, quantitative assessment may therefore only be possible when details of a specific site, or siting options, are available.

1.15 The aim of the non-radiological environmental assessment of the Nirex PGRC at this preliminary generic stage would therefore be to identify the most significant potential environmental effects. This would allow options for reducing or mitigating these effects to be examined during development of the Concept design.

Aims of this Report

1.16 The scope for a preliminary generic Non-Radiological Environmental Assessment has been considered in the Stage 1 Scoping Report (RPS 2005).

1.17 The aim of the current report is to characterise the key stages of the Phased Geological Repository Concept and set out the key assumptions in terms of the repository design and likely activities associated with it in order to form the basis for the Stage 1 environmental assessment of the generic repository concept.

Structure of this Report

1.18 Chapter 2 of this report considers the environmental assessment process in relation to the Nirex PGRC. The subsequent chapters describe the proposed development, split into the following phases:

- Site characterisation;
- Construction;
- Transport;
- Operation;
- Closure and post-closure monitoring.
Acknowledgement

1.19 This report has been prepared by RPS, Oxford office, with the assistance of information provided by staff at Nirex.

1.20 All illustrations of the Nirex Phased Geological Repository Concept itself contained in this report have been provided by Nirex.
2. Environmental Assessment Process

Environmental Assessment and Consent Procedures

2.1 Environmental assessment is the process used to determine the effect of a proposed activity on the environment. In particular, the process is used to identify the likely significant environmental effects of the proposed activity. Environmental assessment can be used at a strategic level, in order to compare different options or alternatives for a proposed activity or to evaluate the effects of proposed plans or strategies, such as local development plans (SEA). At an individual project level, environmental assessment is used as a tool in the decision-making process when determining whether a proposed scheme should be granted planning permission. This is known as Environmental Impact Assessment (EIA). For some schemes, environmental assessment continues during the operational phase. This may be required as a result of conditions on a planning permission or by other statutory controls. For example, the Pollution Prevention and Control (PPC) process requires specific consents for certain operations after planning permission is obtained and sets permissible limits and monitoring regimes within which the scheme must operate.

2.2 These levels of environmental assessment are illustrated in Figure 2.1 below:

*Figure 2.1: Environmental Assessment Processes*

<table>
<thead>
<tr>
<th>UK Procedure</th>
<th>Environmental Assessment</th>
<th>Approach</th>
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<tbody>
<tr>
<td>SEA</td>
<td>Strategic level, Plans and Programmes</td>
<td>Objectives, indicators, targets</td>
</tr>
<tr>
<td>EIA</td>
<td>Project level</td>
<td>Thresholds, criteria, significance of impacts, duration and location</td>
</tr>
<tr>
<td>(Stage 1, Stage 2, Stage 3)</td>
<td></td>
<td>Discharge limits, monitoring</td>
</tr>
<tr>
<td>PPC</td>
<td>Operational level</td>
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Strategic Environmental Assessment (SEA)

2.3 Directive 2001/42/EC of the European Union requires environmental assessment of plans or programmes, such as those which are prepared for energy, industry or waste management and which set the framework for future development consent of projects listed in Annexes I and II of the EIA Directive. This Directive has been implemented in the UK by the Environmental Assessment of Plans and Programmes Regulations 2004, the Environmental Assessment (Scotland) Act 2005, the Environmental Assessment of Plans and Programmes (Wales) Regulations 2004 and the Environmental Assessment of Plans and Programmes (Northern Ireland) 2004. A number of guidance documents have been published on SEA,

2.4 SEA can be defined as the formalised, systematic and comprehensive process of evaluating the environmental impacts of a strategic action and its alternatives, including the preparation of written reports on the findings of that evaluation, and the use of the findings in publicly accountable decision making.

**Environmental Impact Assessment**

2.5 The European Union Council Directive 85/337/EEC, amended by Directive 97/11/EC, requires the preparation of an EIA for certain types of projects likely to have significant effects on the environment. This helps to ensure that the importance of the predicted effects, and the potential for reducing them, are properly understood by the relevant authorities, statutory consultees and general public. Directive 85/337/EEC has been further amended by Directive 2003/35/EC relating to the requirements for public participation.

2.6 The Nirex PGRC would be an ‘Annex 1’ project under Directive 97/11/EC (referred to in this report as the EIA Directive). This Annex refers to schemes that always require Environmental Impact Assessment and includes:

- Installations designed solely for the final disposal of radioactive waste (Para. 3b);
- Installations designed solely for the storage (planned for more than 10 years) of irradiated nuclear fuels or radioactive waste in a different site than the production site (Para 3b).

2.7 In addition, a range of other projects are listed under Annex 2 of the Directive, which refers to schemes that may require EIA, depending on the significance of the likely impacts. These include, for example, the construction of railways, roads, harbours and ports, pipelines, wastewater treatment plants, groundwater abstraction, deep drillings and installations for energy generation.

2.8 The EIA Directive is implemented in the UK by the Town and Country Planning (Environmental Impact Assessment) (England and Wales) Regulations 1999 (Statutory Instrument 1999 No. 293), the Environmental Impact Assessment (Scotland) Regulations 1999 (Scottish Statutory Instrument 1999 No. 1) and the Planning (Environmental Impact Assessment) Regulations (Northern Ireland) 1999 (Statutory Rule 1999 No. 73). Additional regulations implement the Directive for projects that are permitted under other legislation in the UK, e.g. equivalent legislation under the Transport and Works Act or Electricity Act.
Pollution Prevention and Control


2.10 The Regulations control the operation of any installation or mobile plant carrying out any of the activities listed in Schedule 1 to the Regulations. This includes, for example, waste management facilities. Installations or mobile plant used to carry out activities listed in Schedule 1 are subject to integrated pollution control by the Environment Agency, Scottish Environment Protection Agency (SEPA), Department of the Environment (Northern Ireland) or the local authority, depending on the activity undertaken. This control requires a permit to operate an installation or mobile plant covered by the Regulations. The basic requirement for the content of permits is to impose emission limit values based on the best available techniques. The disposal of non-radioactive substances arising from the Nirex PGRC and other related activities could fall within the Pollution Prevention and Control Regulations.

Other Relevant Legislation

2.11 Radioactive waste management facilities are also subject to the following legislation.

*The Radioactive Substances Act 1993*

2.12 The Radioactive Substances Act 1993 (RSA 93) provides the framework for controlling the creation and disposal of radioactive wastes so as to protect the public from hazards which may arise from their disposal to the environment. RSA 93 imposes requirements for registration of the use of radioactive materials and for authorisation of accumulation or disposal of radioactive wastes. This includes the disposal of low level and intermediate level solid radioactive wastes to specialised land-based facilities. The operator of such a facility is required to apply for authorisation under Section 13 of the Act.

2.13 Responsibility for granting an authorisation rests in England and Wales with the Environment Agency, in Scotland with the Scottish Environment Protection Agency, and in Northern Ireland with the Environment and Heritage Service, an agency within the Department of the Environment for Northern Ireland.

2.14 Guidance on the application of RSA 93 to authorisations by the Environment Agencies to disposal facilities that would include the Nirex PGRC is given in the joint publication: *Disposal Facilities on Land for Low and Intermediate Level Radioactive Wastes: Guidance on*
Requirements for Authorisation (EA 1998). This includes guidance on the limits and conditions applied to authorisations.

Town and Country Planning Act

2.15 Under the Town and Country Planning Act 1990, Town and Country Planning Act (Scotland) 1997 and the Planning (Northern Ireland) Order 1991, planning permission would be required for the proposed repository facility. The UK planning system is currently undergoing reform in accordance with the Planning and Compulsory Purchase Act 2004.

Nuclear Installations Act 1965 (as amended)

2.16 The Nuclear Installations Act requires a license for the operation of nuclear installations. It is expected that the operation of a repository system would be licensed and regulated by the Nuclear Installations Inspectorate (NII), under the Nuclear Installations Act. The Act allows conditions to be attached to a nuclear site licence in the interests of safety and the management of radioactive waste.

The Ionising Radiations Regulations 1999

2.17 The Ionising Radiations Regulations cover the general radiation protection of workers and the public from work activities involving ionising radiations. They include a duty to keep exposures as low as reasonably practicable and set limits on such exposure.

International Atomic Energy Authority Transport Regulations

2.18 The transport of radioactive wastes would be carried out in accordance with the International Atomic Energy Authority (IAEA) Regulations for the Safe Transport of Radioactive Material (1996), as implemented in the UK by the radioactive material (road transport) Regulations 2002 (SI 2002 No 1093).

Euratom Treaty 1957

2.19 The Treaty establishing the European Atomic Energy Community (Euratom treaty) was drafted in the 1950s. Under Article 37 the European Commission would need to deliver an opinion on the scope for radioactive contamination of the territory of other Member States before a disposal authorisation could be granted.
Assessment of Options for Long-term Radioactive Waste Management

2.20 The Committee on Radioactive Waste Management (CoRWM) has undertaken a review of radioactive waste management options and published recommendations to Government for a long-term solution. To date no SEA has been undertaken and the work undertaken by CoRWM falls outside the scope of the SEA Regulations. Nevertheless, the assessment of waste management options has taken into account information on the environmental effects of the options considered.

2.21 In the course of its work, Nirex has identified a range of possible options for the long-term management of radioactive waste (Nirex 2002a). Of these options, some have not been considered in detail as they are unsuitable for the waste type, cannot be implemented in the UK or do not comply with international agreements or treaties. Nirex has focused its future work programme on the remaining options. Information relating to the environmental, social and economic effects has been made available to inform the assessment of options undertaken by CoRWM (Nirex 2003a).

2.22 It is anticipated that an SEA will be undertaken at a future stage of the Managing Radioactive Waste Safely process. In addition, under most of the relevant regulations requiring EIA, it will also be a requirement of any Environmental Statement ultimately prepared for the Nirex PGRC or any other option to consider ‘alternatives’. Strictly speaking this requirement only applies to alternatives considered by the applicant bringing forward the Environmental Statement but such consideration would be in the context of policy development by the Government, including the outcome of the CoRWM review and the Government response.

Non-Radiological Environmental Assessment for the Nirex Phased Geological Repository Concept

2.23 Deep geological disposal in the form of the Nirex PGRC is the on-going core of the Nirex work programme. A range of information is available relating to the generic concept design, including assessments of the transport systems and safety. As described in Chapter 1 of this report, it is considered that there is a need for a systematic assessment of potential non-radiological effects associated with the Concept. This assessment process would ensure that appropriate information is readily and openly available throughout the development of the Nirex PGRC. This information will:

- Allow full consideration of the likely environmental impacts of the Nirex Phased Geological Repository Concept;
- Inform the Concept development and decision-making processes; and
- Ensure the requirements of the relevant SEA and EIA legislation can be met.
Nirex has therefore developed a staged approach to non-radiological environmental assessment. As discussed in Chapter 1 of this report, this work is focussing on the non-radiological environmental assessment as this was identified to be less developed than other assessment areas (Nirex 2003b, ForthRoad 2002a). Radiological impacts would be considered separately. The staged approach to non-radiological assessment is described below.

Stage 1

The Stage 1 Environmental Assessment is intended to identify the main non-radiological environmental impacts and constraints associated with the Nirex PGRC, taking into consideration the system specification, repository design and transport system design and responses to consultations Nirex has conducted. This assessment is to be carried out for the generic concept and does not therefore take any site specific considerations into account. This assessment process would complement the information in the existing generic documents.

This assessment is intended to inform the evaluation of options for the long-term management of radioactive waste. In particular, the assessment would be available to inform any future SEA.

Stage 2

The Stage 2 Environmental Assessment will identify the environmental factors and effects to be taken into account when considering options for the siting of a deep geological repository. The focus at this stage will be on obtaining sufficient environmental information on alternative siting options to assist in future decision making on site selection and implementation.

At this stage, no decision has been taken regarding the UK’s preferred option(s) for the long-term management of radioactive waste. The Stage 2 assessment would be carried out for the Nirex PGRC, if this was one of the UK’s preferred long-term management options identified by the Review of the UK Radioactive Waste Management Policy. However, it is intended that the framework for Stage 2 assessment set out in this document could be adapted for the assessment of other options, if required.

Stage 3

The Stage 3 Environmental Assessment would comprise an EIA to address the requirements of the EIA Directive and the associated UK Regulations. This would be carried out for a single, site specific, long-term waste management option selected following the Stage 2 assessment. Separate assessments would be required if a number of options or sites were being proposed for implementation. The framework set out in this document is focussed on the Nirex PGRC. However, as for Stage 2, it is intended that a similar approach could be
adopted for other options, if required. Stage 3 would include the production of an environmental management plan for implementation during site characterisation and the construction, operation and closure of the facility.

2.30 Environmental assessment legislation and good practice require the provision of a description of the project that is the subject of the assessment. This document describes the key stages of the Phased Generic Repository Concept in order to form the basis for the Stage 1 environmental assessment.
3. The Nirex Phased Geological Repository Concept

Introduction

3.1 Since its inception, Nirex has researched a number of approaches to the long-term management of radioactive waste. By 1987 it had concluded that most long-lived radionuclides could be sufficiently isolated for the very long timescales required by putting them in a purpose-built facility deep underground.

3.2 This formed the basis for what has evolved into the Nirex Phased Geological Repository Concept, which is used as the benchmark against which to judge the adequacy of radioactive waste packaging proposals developed by waste producer organisations.

3.3 Nirex and Defra maintain and publish a national radioactive waste inventory of existing wastes and forecast future waste arisings. Nirex has used the 2001 United Kingdom Radioactive Waste Inventory as the starting point for the latest design of the Nirex Phased Geological Repository Concept, but has made adjustments to focus in on the wastes it needs to address.

3.4 This report describes the Nirex Phased Geological Repository Concept in terms suitable to form the basis of the Stage 1 generic environmental assessment. This is based on information from the following sources:

- The series of Generic Documents describing the Nirex Phased Geological Repository Concept;
- Additional information provided by Nirex regarding the Phased Geological Repository Concept, including Context Notes and other supporting documents;
- Information relating to proposals for similar projects elsewhere (e.g. USA, Finland, France);
- Information relating to other large construction projects.

3.5 This chapter provides an overview of the Nirex Phased Geological Repository Concept. The relevant project parameters and assumptions made for the purpose of the Stage 1 generic environmental assessment are described for each phase of the Concept in the following chapters.
Overview of The Concept

From Waste Identification to Storage and Closure

3.6 The Concept includes a number of phases. For the purposes of environmental assessment these are defined as:

- Site Characterisation: Desktop, non-intrusive and intrusive site survey, including borehole and surface-based investigation work.
- Construction: Construction of an underground investigation facility (Rock Characterisation Facility (RCF)) and continued construction of the repository facility. This would include construction transport, including movement of materials and construction personnel.
- Transport. The transport of waste packages to the facility. This includes a transport system planned and designed to facilitate the movement of packaged wastes to the repository. In addition the packaging and surface storage of packaged wastes prior to transport are included within this phase.
- Operation: The main operational phase of the facility, comprising emplacement of waste and ongoing care and maintenance. This would include the transport requirements associated with the facility operations (e.g. movements of operational personnel).
- Closure and Post-Closure Monitoring: The final sealing and closure of the repository, the decommissioning and dismantling of the surface facilities and closure of the site, including a period of post-closure monitoring.

3.7 The packaging and surface storage of waste represents the current situation, while Government policy on radioactive waste management is under review. Following CoRWM’s recommendations the waste will continued to be packaged and stored whilst the preferred option is developed further and a site is selected.

3.8 Selection of the preferred site would allow site characterisation and the initial construction activities to proceed at the chosen site. Once key infrastructure is in place, construction of additional vaults would continue concurrently with waste emplacement.

3.9 The last step (closure) would constitute deep geological disposal of the waste, which is intended to provide long-term isolation of the radioactivity in order to protect human health and the accessible environment. Each preceding step would be reversible.

3.10 A key strength of the PGRC is that it allows future generations to make their own decisions, in the light of all the information then available, and under the minimum possible number of constraints imposed by the original design. Each successive step towards repository sealing
and closure will be reversible, and there is time before each decision to gather information and build confidence before moving to the next phase.

3.11 Each of these phases is described in more detail in the following chapters of this report.

**Multi-barrier Containment Concept**

3.12 The PGRC includes successive phases of packaging, emplacement, backfilling and repository sealing and closure to build up a multi-barrier repository concept that makes use of a combination of engineered and natural barriers to provide:

- Physical containment by immobilisation and packaging of wastes in steel or concrete containers;
- Geological isolation by emplacement of the waste packages in vaults excavated deep underground within a suitable geological environment;
- Chemical conditioning by backfilling the vaults with a cement-based material at a time determined by future generations;
- Geological containment achieved by the suitable geological environment, after final sealing and closure of the repository at a time determined by future generations.

3.13 The multi-barrier containment system is illustrated at Figure 1.1.

**Waste Types**

3.14 The UK has accumulated significant amounts of radioactive waste, most of which have arisen from the nuclear power programme since the 1950's, with smaller quantities coming from medical, industrial, research and defence activities. Wastes will arise over the lives of existing nuclear facilities, and any developed in the future, and from their eventual decommissioning. Radioactive wastes are classified according to their heat-generating capacity and radioactivity content as shown in Table 3.1.

*Table 3.1: Radioactive Waste Categories*

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<th>Category</th>
<th>Description</th>
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<tr>
<td>Very low level waste (VLLW)</td>
<td>(dustbin disposal). (Each 0.1m$^3$ of material containing less than 400 kilobecquerels (kBq) of beta/gamma activity or single items containing less than 40 kBq beta/gamma activity).</td>
</tr>
<tr>
<td>Low level wastes (LLW)</td>
<td>containing radioactive materials other than those acceptable for disposal with ordinary refuse, but not exceeding 4 gigabecquerels per tonne (GBq/te) of alpha or 12 GBq/te of beta/gamma activity.</td>
</tr>
<tr>
<td>Intermediate level wastes (ILW)</td>
<td>containing radioactive materials with radioactivity levels exceeding the upper boundaries for low level wastes set out above, but which do not require heat generation to be taken into account in the design of storage or disposal facilities.</td>
</tr>
<tr>
<td>High level, or heat-generating, waste (HLW)</td>
<td>in which the temperature may rise significantly as a result of their radioactivity. This factor has to be taken into account in designing storage or disposal facilities.</td>
</tr>
</tbody>
</table>
3.15 Within this waste categorisation system only intermediate level waste and certain low level waste that is not suitable for disposal to existing near surface facilities, is assumed to form part of the current Nirex Phased Geological Repository Concept.

**Solid Waste Origins**

3.16 The major site operators and waste production processes are:

- **British Energy** (BE) – from the operation and eventual decommissioning of advanced gas cooled reactor (AGR) power stations and the pressurised waste reactor (PWR) power station at Sizewell, and from the management of spent nuclear fuel;
- **British Nuclear Group** (BNG) – from uranium ore processing, nuclear fuel fabrication, and spent nuclear fuel reprocessing, and from the operation and decommissioning of Magnox reactor power stations;
- **United Kingdom Atomic Energy Authority** (UKAEA) – from the decommissioning of reactors, laboratories and other facilities associated with its nuclear research programme;
- **Ministry of Defence** (MoD) – from the manufacture of nuclear weapons and from the operation of nuclear powered submarines;
- **Amersham Plc** – from the production of radioisotopes for use in healthcare, scientific research and industry;
- **Urenco (Capenhurst) Ltd** – from uranium enrichment.

3.17 In addition, waste is produced on a smaller scale at numerous sites that use radioactive materials, such as hospitals, universities and research laboratories.

**Waste Volumes**

3.18 Based on figures provided by the 2001 United Kingdom Radioactive Waste Inventory and the predicted capacity of the existing facility near the village of Drigg, in Cumbria (or replacement near-surface facility) for LLW, a combined ILW and non-near surface disposal LLW volume of 256,000m$^3$ is identified. This comprises 168,000m$^3$ of waste arising to 2090 and 88,000m$^3$ of waste arising post-2090. The volume of 168,000m$^3$ of waste arisings to 2090 has been used as the Reference Case volume for the current series of Generic Documents.

3.19 Alternative waste arising scenarios have been developed by Nirex using different sets of assumptions regarding key decisions on the future operating and decommissioning characteristics of the nuclear industry. A Variant Case is also described in the Generic Documents. This provides for additional commercial reactor decommissioning wastes (88,000m$^3$).
3.20 The Reference Case volume of 168,000 m$^3$ is taken as the basis for the Stage 1 environmental assessment. However, the likely consequences of an increase in this volume to the variant case volume of 256,000 m$^3$ are also considered, where appropriate and where there is sufficient information available.

3.21 The types and volumes of waste associated with each of these scenarios are illustrated in Table 3.2. These volumes have been rounded for the purposes of description and assessment to 168,000 and 256,000 respectively.

<table>
<thead>
<tr>
<th>Conditioned Volume (m$^3$)</th>
<th>Reference Case</th>
<th>Variant Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unshielded ILW (UILW)</td>
<td>151076</td>
<td>152102</td>
</tr>
<tr>
<td>Shielded ILW (SILW)</td>
<td>14291</td>
<td>73957</td>
</tr>
<tr>
<td>Total ILW</td>
<td>165367</td>
<td>226059</td>
</tr>
<tr>
<td>LLW</td>
<td>1897</td>
<td>29547</td>
</tr>
<tr>
<td><strong>Total ILW + LLW</strong></td>
<td><strong>167264</strong></td>
<td><strong>255606</strong></td>
</tr>
</tbody>
</table>

### Geological Environment

3.22 Previous studies undertaken by Nirex have identified a range of geological environments in the UK that could potentially be suitable for hosting a repository. Four basic environments have been identified, namely:

- Hard (strong) fractured rocks from repository level to ground surface;
- Bedded sedimentary rocks from repository level to ground surface;
- Bedded sedimentary rocks overlying hard fractured rocks, with the hard fractured rocks occurring at repository level; and
- ‘special environments’, such as those in which the repository is located in rock salt or in rocks containing dense brines.
4. Site Characterisation Phase

Purpose of Site Characterisation

4.1 Characterisation comprises detailed surface and subsurface investigations and is required to acquire and interpret information on the geological, hydrogeological and environmental conditions at a potential repository site. The site characterisation phase comprises those investigations, surveys and assessments required prior to commencement of construction.

4.2 This information is necessary to:

- Demonstrate that there is a sufficient understanding of the geology, hydrogeology and hydrogeochemistry of the site and the region in which it lies;
- Provide the necessary data for safety assessments of the proposed facility; and
- Provide the necessary data for design purposes;
- Provide an understanding of the socio-economic and environmental conditions in the area.

Main Activities

4.3 The site characterisation phase of the development would include a range of activities from desktop studies and non-intrusive site survey to deep boreholes and monitoring of ground conditions and hydrogeological parameters.

4.4 The investigations required to characterise the geosphere would take place within the overall framework of the siting studies for a repository. The actual process that would be adopted in the UK for selecting sites for characterisation or investigation is outside the scope of the present study. However, in order to identify the key features of the site characterisation phase that would form part of the PGRC, and which could have an environmental effect, key assumptions regarding the nature of this phase have been made and these are described in this chapter.

4.5 It is assumed for the purposes of assessment, and in accordance with the Generic Documents, that sites identified as potentially suitable for a repository facility would be greenfield (sites that have not been previously developed) and predominately flat. However, this assumption does not preclude the use of a brownfield site if appropriate in the future.

4.6 In addition it is assumed that the repository would be capable of being characterised using boreholes drilled from land based sites, and that sites for investigation are ones that have not been investigated previously. For the purposes of assessment it is assumed that the
repository would be approximately 650m deep. Furthermore, it is assumed that the geological environment would comprise one of the host rock types described in Chapter 3.

4.7 The geographical search to identify the sites for detailed investigation is likely to be a high-level desk-based screening process. Therefore it is assumed that no site investigations would be required to identify sites for detailed investigation (i.e. prior to the site characterisation phase).

4.8 For the purposes of assessment, it is assumed that the initial site search process would identify two broad locations for detailed investigation at the site characterisation phase. The detailed investigations would comprise surface based characterisation studies consisting of approximately 20 deep boreholes at each of the two locations. This does not preclude more than two locations being investigated in detail, if appropriate following the site selection stage.

4.9 Following detailed investigation it is assumed that a single clearly preferred location emerges from a site comparison study undertaken on completion of the surface-based characterisation.

4.10 Any underground investigations requiring personnel access at the preferred location are considered to be an integral part of the construction of the repository and are therefore described in Chapter 5 of this report. Similarly, any ongoing investigations required to confirm and monitor performance during the operational phase are considered to be part of the operation as described in Section 7.

Stages of Site Investigation

4.11 The first activities at each of the two locations would be to undertake a series of regional surveys comprising airborne and ground based geophysical surveys, geological mapping and remote sensing studies utilising aerial photographs and satellite imagery. At the end of these investigations, the sites for the first boreholes would be confirmed.

4.12 Main surface activities at each location at the borehole stage would include formation of individual drilling sites, including fencing, site clearance and levelling, installation and operation of investigation borehole rigs and associated infrastructure, such as settlement ponds. In addition, a temporary access road is likely to be required, dependent on the location.

4.13 For the purposes of the Stage 1 environmental assessment, it is assumed that there would be 20 drilling rig sites in total at each location, of which up to three drilling rig sites could be in operation at any one time. Such assumptions will be reviewed at each stage of assessment, as it is possible that several boreholes may be drilled from a single drilling rig and that rigs not drilling deep boreholes may concurrently work on shallow boreholes.

4.14 The key stages of investigation are described in the following text.
Stage 0: Review of Existing Data and Information

4.15 This stage would include:

- Desk studies using existing information;
- Additional processing and interpretation of existing geophysical data.

4.16 This would provide a general understanding of geological succession (rock types present within the geological sequence at the site) and geological structure (thickness of units, geometrical configuration, major deformations such as faults and folds).

4.17 This would inform the selection of sites for characterisation and form the basis for planning a programme of further investigations.

Stage 1.1: Initial Site Investigations – Regional Surveys

4.18 This stage would include non-invasive studies, such as:

- Airborne geophysical surveys;
- Ground geophysics;
- Interpretation of aerial photographs and satellite imagery;
- Surface geological mapping;
- Collection of rock samples from the surface;
- Analysis of rock samples to determine rock types.

4.19 This would provide an improved understanding of the surface geology and, based on interpretation of the data, an improved understanding of the likely geological sequence and structure at depth. An initial assessment of rock mass fractures would be obtained from surface geological mapping. The major output from this stage would be a three dimensional (3D) model of the region around the potential locations showing the geological sequence and structure.

4.20 This information would be used for input to the design of the next stage of investigation. In particular, this information would help in locating the initial deep cored boreholes in Stage 1.2 (Campaign No 1).

Stage 1.2: Initial Site Investigations – Initial Boreholes (Drilling Campaign No 1)

4.21 This stage would include Campaign No 1 of deep cored boreholes (assumed to be approximately seven in number). These multi-purpose holes would provide rock cores, the geological sequence within which would be recorded and which would be used to provide samples for laboratory testing.
4.22 The boreholes would also provide access to the rock mass at depth to permit in situ testing to be carried out to assist in defining the properties of the rocks at depth and determine parameters related to hydrogeology, hydrochemistry, thermal properties, rock mechanics and seismicity.

4.23 The results of the group of boreholes, in conjunction with the Stage 1.1 geophysical surveys would provide a better understanding of the geological framework of the site including the spatial heterogeneity of the materials (i.e. how much they vary across the site investigated). The understanding of the nature of possible fractures in the potential repository host rock would be improved with data becoming available from surface outcrops as well as from deep boreholes.

4.24 Interpretation of the geology of the site would provide a basic understanding of the way in which the rocks have formed and changed during their history. Conclusions could therefore be drawn about the likely processes causing further changes in the rocks.

4.25 This information would be used as the basis for developing a conceptual model of the site that shows the processes likely to affect the performance of a repository at the site to allow an initial qualitative assessment to be made of the likely radiological performance of the site. This model would also form the basis for a review of the feasibility of constructing a repository at the site and act as the basis for an assessment of the likely layout and location of the underground waste vaults.

4.26 This would assist in the determination of whether there is justification for the site to be investigated further and, if so, identifying the requirements for Stage 2.1 investigations and estimating the total amount of characterisation (including the number of deep boreholes) likely to be required to understand the geosphere at the site.

**Stage 2.1: Detailed Site Investigations – Drilling Campaign No 2**

4.27 This stage includes Campaign No 2 of deep boreholes (assumed to be approximately seven in number). These would be multi-purpose boreholes and targeted boreholes. As during Campaign 1, the multi-purpose boreholes would provide rock cores that would be recorded and subject to laboratory testing. Access to the rock mass at depth would permit in situ testing to be carried out to assist in defining the properties of the rocks at depth. Additional data on parameters related to hydrogeology, hydrochemistry, thermal properties, rock mechanics and seismicity would be gathered.

4.28 In addition to the borehole studies, additional surveys and monitoring would be undertaken to allow more detailed assessment of seismic activity throughout the potential repository zone.

4.29 Ground investigations (such as trenches and geophysical surveys) would be carried out in any notable locations identified during Stage 1.1.
4.30 Field mapping of exposed geology, laboratory testing of soil samples obtained and fracture mapping of suitable outcrops would also be undertaken.

4.31 The distribution of deep borehole data would provide greater confidence on subsurface geological conditions and on the spatial heterogeneity. Greater detail on geology throughout the area would be obtained from the field mapping of outcrops.

4.32 In addition, greater confidence would be obtained on the likely long-term changes from monitoring of seismic activity and ground investigations to determine whether there is evidence of notable features (such as fractures).

4.33 The information gained would be used to significantly enhance the descriptive geological model in particular with regard to the level of detail and confidence regarding geological structure, spatial heterogeneity, characterisation of fractures, surface or outcropping geology and long-term change. This added confidence in understanding would feed into the progressive enhancement of the understanding of the performance design issues, thus allowing the remaining uncertainties to be identified and fed back into the design of the third drilling campaign and associated characterisation activities to be undertaken during Stage 2.2.

**Stage 2.2: Detailed Site Investigations – Drilling Campaign No 3**

4.34 This third stage of deep drilling would include a third campaign (Campaign No 3) of deep drilling (assumed to be approximately six boreholes in number). This is expected to complete the programme of deep drilling at the site. The deep boreholes are likely to be more targeted in terms of both their location in relation to specific geological features and in terms of the range of data obtained to reflect any uncertainties remaining from Stage 2.1. Laboratory testing of selected samples of soil and rock would be carried out to resolve any uncertainties in their characteristics.

4.35 Shallow boreholes, trial pits and geophysical surveys would also be used to characterise the Quaternary deposits below the surface. In addition, monitoring of the seismic activity would continue utilising the monitoring network installed during the previous stage.

4.36 On completion of these investigations there would be a high level of confidence regarding the geological succession and geological structure of the site including the soil cover, cover rocks and repository host rocks. Some issues regarding the geological structure at depth may require further investigation using cross-hole surveys that could only be carried out in Stage 2.3 when the network of deep boreholes is complete.

4.37 It is expected that the overall level of confidence in the geology of the site would be such that no significant changes to this understanding in relation to the performance assessment or engineering design would arise from further surface based characterisation even though such characterisation would yield some additional data.
4.38 The descriptive geology model would address all the key issues and uncertainties that have previously been identified from the performance assessment and engineering design studies.

4.39 The understanding of the geology at this stage would be sufficient to form the framework in which the models of hydrogeology, hydrochemistry, rock mechanics, transport properties and thermal properties can be built. It would be possible to construct predictive models of the site that could adequately reproduce the characteristics of the site as revealed by surface based characterisation that can be tested in the programme of cross-hole testing to be undertaken in Stage 2.3 and in the subsequent phase of underground investigations.

**Stage 2.3: Post-completion Testing**

4.40 This stage includes:

- Cross-hole testing utilising the completed network of deep holes to address any significant remaining uncertainties regarding the geological structure at depth. The need for such surveys, if any, would be assessed as part of the evaluation of the Stage 2.2 characterisation activities.
- Ongoing monitoring of seismic activity.

4.41 On completion of this stage, the geology of the site would have been described in sufficient detail to provide a high degree of confidence in the geoscientific understanding of the site and to have provided an adequate framework for the performance assessment and engineering design studies.

**Stage 2.4: Establish Baseline Conditions**

4.42 This stage of the characterisation programme is set aside for establishing baseline groundwater pressures and hydrochemistry. No further geological studies would be carried out.

**Site Investigation Techniques**

4.43 The techniques applied in the site investigation phase would depend on the best practice and state of the art technologies available at the time. Work is ongoing within Nirex to review the possible techniques available and to develop different approaches to the drilling, coring and testing of boreholes from those used previously at Sellafield and Dounreay, in order to give increased flexibility, to reduce the cost per borehole and minimise the environmental impact.
Approaches to Drilling Deep Boreholes

4.44 It is considered necessary to drill boreholes to a depth of approximately 1.5 times the depth of the waste vaults as it is necessary to characterise the entire succession of geological strata and not only the materials within which vaults are to be constructed. For the purposes of assessment it is assumed that the repository would include waste vaults at a depth of 650m and therefore it is assumed that boreholes may be required to a depth of up to approximately 1000m.

4.45 The preferred approach to drilling would be deep boreholes drilled with a minimum diameter of 76mm continuously cored and for the drilling to be carried out using small mobile rigs. It is considered that this would be the optimum method for drilling in an environment comprising hard crystalline rocks to the surface. However, the probable range of geological environments that could be suitable for a repository include those with at least several hundred metres of sedimentary rocks either as a cover sequence over a hard basement formation or with sedimentary rocks extending to repository depth.

4.46 There are no known precedents for the adoption of small (76mm) diameter boreholes of this type in geological environments containing substantial sequences of sedimentary rocks. Therefore the ability to achieve the required depth, information and data quality is uncertain. Nirex therefore propose to design and test an approach to deep drilling using 76mm boreholes drilled with small mobile drilling rigs at a test facility in the UK.

4.47 The precedent practice in the UK is to use large diameter boreholes (approximately 159mm diameter at target depth). Therefore, given the uncertainty at this time, the maximum borehole size for the purposes of this assessment has been assumed to be 159mm with appropriately sized drilling rigs.

4.48 It is proposed that the deep boreholes would be formed primarily by rotary coring methods in order to reduce the overall quantity of cuttings, produce fine-grained cuttings and to form a smooth borehole for testing and instrumentation purposes.

Site Drainage

4.49 It is likely that a water supply would be required for the borehole investigations. Each borehole site would generate several sources of water requiring discharge, including groundwater present/encountered within the excavated borehole, surface runoff from the site and any effluent arising from water use on site.

4.50 Water from borehole operations would be treated through the use of attenuation and/or treatment features appropriate to the local hydrology prior to discharge to the existing surface/groundwater system. This could include the use of balancing/settlement ponds. Should any such water (e.g. that containing certain drilling fluids) contain contaminants that
could not be treated on site to a standard appropriate for discharge, this would be processed off site and disposed of in line with best practice and legislative requirements.

4.51 Individual drilling sites would be located to minimise the effect on local hydrology as far as possible.

**Borehole Remediation**

4.52 On completion of the investigation, any boreholes that are not to be retained for long-term monitoring will need to be sealed and remediated in accordance with the guidance defined by the Environment Agency (Decommissioning Redundant Boreholes and Wells, National Groundwater and Contaminated Land Aftercare, undated report). This will include:

- Boreholes capped and sealed at the surface. Boreholes that are located at the selected repository site and are no longer required for monitoring purposes will need to be sealed to a higher standard to ensure that they do not jeopardise the performance of the repository;
- Any freshwater aquifer physically isolated from any deeper, more saline water.

4.53 The designs for the boreholes will assume that they will subsequently need to be closed. The following principles related to remediation will be made:

- Any casings that are installed in a borehole will either be designed to be of a quality that can remain in the borehole as part of the remediation design and will be fully cemented into the borehole, or they will be designed to be removed as part of the remediation;
- Any instrumentation installed into the boreholes will be designed to be capable of being removed from the boreholes prior to closure;
- Designs and method statements for the final remediation of the borehole will form part of the designs for drilling the boreholes.

**Land Management**

4.54 A strategy for land management will be developed to ensure that all aspects of land management are addressed, including:

- Arrangements for entry to land for the purpose of undertaking investigations and surveys, including provision of accesses;
- Arrangements for obtaining permissions from owners/occupiers of and owners of mineral rights for entry to the land for undertaking investigations and surveys, including provision of accesses;
- Arrangements for agreeing and managing payment of compensation to owners/occupiers for utilisation of land;
- Developing and agreeing arrangements for restoration of land on completion of characterisation activities, including arrangements for aftercare of restored land; and
4.55 It is assumed that five years aftercare will be required following completion of site restoration.

Area of Investigation

4.56 In order to adequately characterise an area to determine its suitability to host a deep repository facility it is necessary to examine a relatively wide area. For the purpose of defining a characterisation programme, the following areas are defined.

Site Area

4.57 The Site Area is likely to cover approximately 50km² within which it is anticipated that a suitable target area can be identified. The Site Area is likely to be identified from a desk-based study of existing information and from the results of non-invasive surveys such as geophysical surveys, surface geological mapping and interpretation of aerial photographs and satellite imagery. The target area would be identified on the basis of these non-invasive surveys together with the drilling of some initial deep boreholes.

Target Area

4.58 The Target Area covers approximately 10km² within which the waste disposal vaults and associated underground facilities will be constructed.

District Area

4.59 In order to define the geological framework of the Site Area and to develop suitable groundwater flow models it is anticipated that at any location within the UK it is likely to be necessary to extend investigations out into a wider area. Such investigations are likely to include geophysical surveys, geological mapping and the establishment of the near-surface hydrogeology and surface hydrology. The investigations in this wider area are unlikely to require the drilling of deep boreholes. It is assumed that this District Area will have dimensions of approximately 20-30km by 20-30km and will contain the surface water and groundwater catchment area for the target area.

Region Area

4.60 Some features that may have relevance to the potential repository may occur at greater distance from the target area. For example, some major geological features may be of relevance and it is likely that monitoring of seismic activity will extend over a wider area. This Region Area is likely to be approximately 60km by 60km centred in the target area within which relevant information will be collected, largely from detailed review of existing information supplemented as necessary by regional monitoring.
Individual Drilling Sites

4.61 Within the Site Area, it is assumed that individual drilling rig sites would occupy an area of approximately 120m x 120m (excluding the temporary access road, if required).

Programme

4.62 It is assumed that a period of 2.5 years would be required for the geographical search and identification of potentially suitable repository sites for detailed investigation.

4.63 The detailed investigation is likely to take a minimum of 8 years in total. This period includes the tasks identified in Figure 4.1 overleaf. It is recognised that if more than two sites were to be investigated, the programme may be extended.

4.64 It is considered that deep investigation boreholes would take approximately 5-6 months each to drill and test. During this time, drilling is likely to be undertaken 24 hours per day, 7 days per week.

4.65 For any borehole sites not forming part of the selected location for construction of the facility, it is assumed that five years aftercare will be required following completion of site restoration.

Employment

4.66 Estimated personnel required for the detailed site investigation of two sites would be in the range of 180 - 415 people per year. The majority of these would be professional (approximately 95 – 180) with a higher proportion of support staff during the initial two years of site investigations. A number of semi-professional staff would also be required.
Figure 4.1: Indicative Programme for Site Investigation Works

<table>
<thead>
<tr>
<th>ID</th>
<th>Task Name</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Regional Surveys</td>
<td>10 mons</td>
</tr>
<tr>
<td>2</td>
<td>Regional Hydrogeological Surveys</td>
<td>21 mons</td>
</tr>
<tr>
<td>3</td>
<td>Drilling Campaign No 1</td>
<td>21 mons</td>
</tr>
<tr>
<td>4</td>
<td>3D Seismic Survey</td>
<td>20 mons</td>
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<tr>
<td>5</td>
<td>Quaternary Studies</td>
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<td>6</td>
<td>Seismic Monitoring Network</td>
<td>11 mons</td>
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<td>7</td>
<td>Drilling Campaign No 2</td>
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<td>8</td>
<td>Drilling Campaign No 3</td>
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<td>9</td>
<td>Design and Installation of Instrumentation Network</td>
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<td>10</td>
<td>Post-completion Testing</td>
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<td>11</td>
<td>Baseline Hydrogeology and Hydrochemistry</td>
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</tr>
<tr>
<td>12</td>
<td>Interpretation, Modelling Design and Safety Assessment</td>
<td>72 mons</td>
</tr>
</tbody>
</table>
5. **Construction**

**Main Activities**

**Rock Characterisation Facility**

5.1 Following completion of the site investigations described in Chapter 4 and public endorsement of a preferred location, the selected location would be subject to further detailed investigation through the construction of a Rock Characterisation Facility (RCF). It is envisaged that a RCF would be designed as an integral part of an underground repository facility and would be clearly identified as the final phase of site investigation and the first phase of construction of the facility.

5.2 It is assumed for the purposes of assessment that a single RCF would be constructed at the selected repository location. Following the detailed site investigations, there would be a high level of confidence in the long-term safety of the prospective repository to justify proceeding to underground investigations. Construction of an RCF provides an opportunity for obtaining information over a large volume of rock mass and at *in situ* conditions that is not available from surface-based boreholes. It is assumed that the scientific programme associated with the RCF would provide the information required to consolidate a decision on whether to continue with the development of a repository at the site.

5.3 However, there must be confidence that the RCF will not disturb to an unacceptable degree the site conditions that it is intended to investigate and that its location and the methods used in its construction will not compromise the long-term safety of a repository at the same location.

5.4 The RCF is assumed to comprise two shafts. The main shaft would be 8m finished diameter and the secondary shaft 5m diameter. The two vertical shafts are assumed to be developed to 650m below ground level.

5.5 The main shaft would be used for normal access/egress with the secondary shaft as the second means of egress. The main shaft would be the ventilation intake, the secondary shaft would be the exhaust.

5.6 Following works undertaken in the RCF, it is assumed that construction of the repository itself would be undertaken at the same location (as described below). Although this would complete works to characterise the site prior to construction of the repository, there would be ongoing investigations and monitoring undertaken throughout subsequent phases of the project to confirm and monitor performance as described in paragraph 4.10.
The Repository

5.7 The Reference Design for the repository is illustrated in Figure 5.1.

Figure 5.1: Reference Repository Design

5.8 Construction can be divided into two parts. The first part would comprise construction of the waste vaults and associated repository facilities in preparation for waste emplacement. Following completion of the initial vaults and facilities, the second part of the construction phase comprises the continued construction of additional vaults concurrently with waste emplacement to completed vaults.

5.9 The first phase of the repository construction is described below.

Initial Repository Construction Phase

Below Ground Structures

5.10 The construction phase up to first waste emplacement includes access via the two shafts previously developed as an RCF and a new access drift (inclined tunnel linking surface to underground) for handling the waste packages. The drift would be approximately 5.5 metre diameter and some 4km long.

5.11 Two vaults (one for UILW and one for SILW/LLW) would be constructed and equipped prior to commencement of emplacement of waste in the vaults. A further UILW vault would also be excavated prior to commencing waste emplacement, ready for equipping during the next
phase. Each vault is assumed to be 16m wide by 16m high and 300m long. An inlet cell and transfer tunnel would be required to receive waste and transfer it to the vaults.

5.12 In addition, links between the underground facilities and ventilation roadways would be required, together with waste receipt and transfer areas.

Above Ground Structures

5.13 The requirements for onsite infrastructure are based on the Generic Repository Surface Layout. These are likely to include:

- Diversion of existing services or access routes, if present;
- Earthworks;
- Construction of haul routes and spoil tip preparation;
- Surface Buildings;
- Bridges;
- Roads and hardstanding;
- Railways and associated equipment;
- Drainage;
- Service ducts;
- Landscaping;
- Security.

5.14 Disposal of the spoil is assumed to be on site, in landscaped mounds that would provide screening of surface facilities and would be developed progressively with ongoing repository construction. However, it is likely that some of the spoil produced would be used during the construction of surface features, including areas of hardstanding and roads.

5.15 An access road and rail link form part of the Reference Case Design. The Reference Case Design surface layout for the repository has been designed to accommodate most of the waste arriving by rail. In the case of a repository constructed on an off-shore island a local transport link to port facilities would need to be considered.

5.16 On-site rail infrastructure required includes rail links to provide an interface with the off-site system and on-site running rails for main-line and on-site vehicles. Sidings would be required for train arrival/departure and package receipt.

5.17 Off site works may be required to provide links between the newly constructed on-site facilities and the existing road and rail network.
Road Transport

5.18 On-site road infrastructure would be designed to accommodate Category 3 vehicles. Provision would be made for parking, including light goods vehicle parking and staff car parking.

Phase 2: Repository Construction After First Waste Emplacement

5.19 The development phase after the first waste emplacement would include the excavation and fit-out of the remaining vaults. The works to be carried out would be mainly underground, although there would be further landscaping on the surface as the spoil mounds become extended. Works would include:

- Landscaping
- Construction and fit-out of the remaining vaults
- Provision of ventilation, power and other services
- Testing and commissioning of vaults

5.20 The facility would be laid out to enable the emplacement of waste (operational activities) and the construction of the new vaults to be progressed concurrently but with the processes segregated. This would enable vaults to be constructed in a timely manner over the operating life of the repository.

5.21 At completion of construction, the repository would comprise 11 vaults for unshielded intermediate level waste and 2 vaults for shielded intermediate level waste and low level waste. Each vault is assumed to be 16m wide by 16m high and 300m long.

Construction Area

5.22 For the purposes of assessment it is assumed that the RCF would require an above ground area of approximately 400m x 200m, excluding the site access road. During construction of the repository itself, an above ground area of approximately 1200m x 1200m has been assumed.

Construction Techniques

5.23 The main activities associated with construction of the RCF would include formation of the facility, including fencing, site clearance and levelling, installation and operation of man-access underground facilities and associated infrastructure, buildings and discharge control mechanisms. In addition, the RCF would require construction of an access road and site services.

5.24 The shafts for the RCF are likely to be constructed from the surface down using traditional blasting and drilling methods. Blasted rock would be returned to the surface using a hoist
mechanism for sorting and storage. One or more sublevels may be excavated in the shaft to ascertain the properties of the bedrock before progressing to the depth of final disposal.

5.25 Construction of the repository itself would require further site clearance and levelling, earth movement and rock placement. In addition, construction of the site infrastructure, including building, road and rail links and the main security fence would be required.

5.26 The repository would require construction of the main access drift and the equipping of the drift with permanent trackwork, power and control systems, locomotives and rolling stock to provide a rack-and-pinion rail system. In addition, one of the RCF shafts would be converted to a ventilation role only by replacing the winding system and head-gear with a system suitable for shaft maintenance work and emergency egress and installation of the ventilation systems.

5.27 The drift would have three main areas:

- A surface portal that would be constructed using civil engineering techniques and which would provide the transition area for the installation of tunnelling equipment and for the establishment of a rockhead for start of tunnelling;
- An upper section where the drift would be expected to pass through water bearing strata and which would be constructed with a concrete hydrostatic lining for water exclusion and rock support. This section would be machine mined;
- A lower section in non-water bearing, self-supporting strata where it would be unlined but supported as necessary with rockbolts, mesh, sprayed concrete (shotcrete) or a combination of these methods. This section would be excavated using drilling and blasting techniques.

5.28 The access drift would be driven concurrently from the surface and from the underground facilities. The overall drift construction is programmed to take four years – three years for excavation and support of the tunnel and one year for fitting out with permanent transport systems.

5.29 Drift advance rates are assumed to be an average of 20m per week in the upper, lined sections of the drift and 30m per week in the lower, unlined sections.

5.30 Underground mining works would be employed using proven techniques. The majority of the roadways are assumed to be relatively small (approximately 5m x 5m) in cross section and driven by conventional drill and blast methods in good strata, requiring limited support (in the form of rockbolts, mesh and sprayed concrete if required). The excavation advance rate is assumed to be approximately 4m per day, based on a three shift per day operation.
5.31 During the initial stages of construction, the main shaft would chiefly serve as the export route for excavated rock and also act as an air intake for the construction ventilation system. Initially the secondary shaft would be the principal means of access underground for personnel and materials; but following the commissioning of the drift and prior to the first waste emplacement, it would be converted to serve as a ventilation shaft and as a means of egress from underground in an emergency. The headframe would be removed from this shaft and a smaller shaft building (assumed to be approximately 10m high) would be constructed and equipped with emergency winding systems. From this time, the main shaft would provide the normal access/egress for construction personnel and the drift would be used for the operational activities (emplacement of waste and transport of operational personnel).

5.32 Major excavations for vaults at 16m x 16m cross section would be carried out by driving an initial top heading at 5m x 5m and then excavating the general area by benching techniques. The time allowed for the excavation of the approximately 300m length of vault and crane maintenance cells (after completion of the pilot heading) is 62 weeks, which represents an overall advance of approximately 5m per week.

5.33 Construction engineering works, and the installation of water and sewage, ventilation and electricity systems would be carried out at the same time as the final repository is built. Construction engineering works include building the walls, floor and sublevels of the surface buildings. Construction of the road and rail facilities associated with the facility may require earthworks, piling and bridge construction.

**Spoil**

5.34 For the Reference Case Design, the total volume of rock spoil generated throughout the construction period would be approximately 1.5 million m$^3$.

**Landscape**

5.35 Consideration would be given to early planting to establish the landscaping and provide a visual screen before commencement of construction work on site. As discussed above, spoil is proposed to be used to form landscaped mounds that would provide screening of surface facilities and would be developed progressively with ongoing repository construction.

**Fencing**

5.36 The construction site boundary would be fenced to deter the intrusion of humans and minimise the risk to wildlife from site operations. The fenced area would include the landscape screen mounding areas which would be formed from the material excavated during construction. Due to the duration of this phase, the site boundary fence is expected to be in the form of a permanent fence.
Lighting

5.37 Lighting would be required on site to enable construction to be carried out safely, including security lighting and CCTV. This is likely to include security lighting of the main construction fence. However, lighting poles would be reduced to a practicable minimum and directional shields would be used to control light spillage.

Liquid Effluents

5.38 Water from construction areas, which is known to be free from radioactive contamination, would be diverted to a central underground collection area and pumped up the drift to the water despatch facility for treatment prior to being pumped to a suitable licensed discharge point. Treatment and discharge control would include attenuation and pollution control measures such as settlement ponds and would be designed to be appropriate to the local hydrological requirements. Water from the shaft area would be collected in the sumps and pumped to the surface and discharged under the same regime.

5.39 Runoff from the landscape screen mounds around the site would also be treated prior to discharge. Rock excavated from depth within the landscape mounds could include minerals and chemicals unsuitable for surface water discharge. Such runoff would be treated appropriately prior to discharge or contained as appropriate.

Ventilation

5.40 Ventilation for the construction activities would be provided by an underground, intake forcing system so that the whole construction area would be at positive pressure to the surface atmosphere. The exhaust construction air would return to the surface via the 5m secondary shaft. Further ventilation equipment would be installed in vaults prior to emplacement (operation) commencing. Ventilation systems provided during operation are described in Section 7.

Noise and Vibration Control

5.41 Potential sources of noise could include:

- Site clearance and surface-level excavation;
- Underground construction activities, including use of explosives;
- Earth movement and rock placement;
- Construction of site infrastructure, such as roads, car parks, marshalling yard, buildings, drainage, fencing and services;
- Construction of on site infrastructure, including new rail link and highway access as required;
• Vehicle movements both on-site and off-site.

5.42 Where practicable, plant systems would be selected which generate minimum noise levels. Noisy plant and equipment would be enclosed in buildings, which could, if necessary, be fitted with acoustic panels. Chutes discharging rock would be lined with rubber. Where practicable, reversing alarms on vehicles would be replaced by ‘quiet’ alarms and operating hours of large surface vehicles would be restricted. The visual screening banks around the site would also help to reduce off-site noise.

5.43 Using site-specific information on ground conditions, it would be possible to calculate the appropriate amount of explosive to be used and the detonation sequence, in order to control vibration levels.

**Dust Control**

5.44 Appropriate dust control measures would be taken during soil stripping excavation and in the movement of rock and soil to construct screening mounds. Typical measures include:

- damping down of unsealed surfaces and stockpiles;
- minimising the height and volume of stockpiles;
- wheel washing of mobile plant and HGVs before they leave the site including where necessary, mechanical wheel spinning and settlement tanks;
- provision of hardstanding areas for vehicles accessing construction sites;
- controlled handling of spoil during transfer activities;
- drainage control;
- adequate sheeting of loads;
- road sweeping facilities;
- enclosure of potential sources of dust (e.g. spoil loading areas); and use of solid hoardings.

**Use of Materials**

5.45 Construction of the surface facilities, including operational centre, waste receipt facility and decontamination building is assumed to require approximately 16,000 tonnes of concrete and 1,900 tonnes of stainless steel (BNFL 1992).

5.46 Quantities of materials required for constructing the underground vaults, inlet cells, reinforcement and tunnels of the repository are currently being evaluated.
5.47 The quantity of explosives to be used during construction of the repository is estimated to be approximately 3750 tonnes.

5.48 It is anticipated that approximately 24,000 tonnes of stainless steel would be used for waste containers to provide encapsulation of the waste (Nirex 2005g).

Programme

5.49 The overall programme for construction of the RCF, including consultation, is assumed to take 9 years.

5.50 The programme for construction of the first stage of the repository includes a period for obtaining planning permission to permit the development of an underground storage/disposal facility, which is assumed to take 3 years to complete. During this period, the design for the repository would be developed both to support the planning approval process and in preparation for construction to commence. The initial construction phase up to first waste emplacement is assumed to take 7 years.

5.51 The main features of the construction programme are as follows:

- As discussed above, the access drift construction is programmed to take four years – three years for excavation and support of the tunnel and one year for fitting out with permanent transport systems.
- Drift advance rates are assumed to be an average of 20m per week in the upper sections of the drift and 30m per week in the lower sections. In addition to this allowances have been made for groundwater stabilisation works by grouting or other means in the upper sections.
- The development of the main underground roadways for access and ventilation is programmed to start immediately on receipt of planning approval and an advance rate of 25m per week has been assumed.
- The underground infrastructure and the first vault would be excavated in year four.
- Civil, mechanical and electrical fit-out of the first vault is programmed to take about 18 months and be completed by the end of year five.
- The drift bottom infrastructure and the inlet cells would be excavated concurrently with the main underground roadways and the first vaults. The inlet cell is programmed to be available for civil engineering works early in year four, with the inlet cell ready to receive mechanical equipment by the end of that year. This coincides with the completion of the drift fit out which enables the equipment to be transported via drift train rather than through the shafts.
The mechanical and electrical fit-out of the inlet cells would be carried out during year five.

Year six would be given over to system commissioning, certification and approval and year seven to active commissioning, leading to the repository having full approval by the end of year seven.

Following this initial period of construction, construction of additional vaults is assumed to be ongoing throughout the operational period of waste emplacement (for a period of 50 years).

**Employment**

During construction a range of professional (e.g. site management; civil, mining and electrical engineers; geologists; safety advisors), semi-professional (e.g. tunnelling engineers, welders, mechanical fitters) and support (e.g. plant operators, crane drivers, security) staff would be required.

Estimated personnel required would be in the range of 70 – 370 people per year for the initial construction period. The majority of these would be professional or semi-professional but with a significant proportion of support staff required. Figures for the ongoing construction, which is concurrent with the operational period are provided in Section 7.

**Traffic**

The predicted levels of traffic associated with construction are summarised in Table 5.1 below. Construction materials are estimated to require in the region of 70 lorries per week for 9 years and 20 lorries per week for a further 50 years. An additional 1600 cars and 10 buses per week are estimated to be generated by construction personnel.

<table>
<thead>
<tr>
<th>Table 5.1: Construction Traffic Volumes (168,000m³ Reference Case)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Initial Repository Construction Phase</strong></td>
</tr>
<tr>
<td>Spoil</td>
</tr>
<tr>
<td>Construction materials</td>
</tr>
<tr>
<td>Personnel: Cars</td>
</tr>
<tr>
<td>Personnel: Buses</td>
</tr>
<tr>
<td><strong>Construction/Operation Following First Waste Emplacement</strong></td>
</tr>
<tr>
<td>Spoil</td>
</tr>
<tr>
<td>Construction materials</td>
</tr>
<tr>
<td>Personnel: Cars</td>
</tr>
<tr>
<td>Personnel: Buses</td>
</tr>
<tr>
<td>Source: Table 3.6 Nirex Report N/078 Volume 1</td>
</tr>
</tbody>
</table>

Source: Table 3.6 Nirex Report N/078 Volume 1
5.56 Estimated construction traffic journey distances are assumed to be as set out in Table 5.2 below.

Table 5.2: Construction Traffic Journey Distances

<table>
<thead>
<tr>
<th>Construction Materials</th>
<th>One-way Journey Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>52.0km(^{(1)})</td>
</tr>
<tr>
<td>Commuting</td>
<td>15.8km(^{(2)})</td>
</tr>
<tr>
<td>Buses</td>
<td>8.5km(^{(3)})</td>
</tr>
</tbody>
</table>

\(^{(2)}\) Source: National Travel Survey 2003-2004 (DfT)
\(^{(3)}\) Source: National Travel Survey 2003-2004 (DfT)

5.57 The application of the above journey distances to the predicted numbers of journeys gives the following total and annual transport distances:

Table 5.3: Construction Transport (Total Distances)

<table>
<thead>
<tr>
<th>Mode</th>
<th>Total Distance (mill. km)</th>
<th>Initial Stage (9 years)</th>
<th>Following First Waste Emplacement (50 years)</th>
<th>Total (59 years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HGV's</td>
<td>3.41</td>
<td>5.41</td>
<td>8.82</td>
<td></td>
</tr>
<tr>
<td>Cars</td>
<td>23.66</td>
<td>115.02</td>
<td>138.68</td>
<td></td>
</tr>
<tr>
<td>Buses</td>
<td>0.08</td>
<td>0.44</td>
<td>0.52</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>27.15</td>
<td>120.88</td>
<td>148.02</td>
<td></td>
</tr>
</tbody>
</table>

Table 5.4: Construction Transport (Average Annual Distances)

<table>
<thead>
<tr>
<th>Mode</th>
<th>Average Annual Distance (mill. km)</th>
<th>Initial Stage</th>
<th>After First Waste Emplacement</th>
</tr>
</thead>
<tbody>
<tr>
<td>HGV's</td>
<td>0.38</td>
<td>0.11</td>
<td></td>
</tr>
<tr>
<td>Cars</td>
<td>2.63</td>
<td>2.30</td>
<td></td>
</tr>
<tr>
<td>Buses</td>
<td>0.01</td>
<td>0.01</td>
<td></td>
</tr>
</tbody>
</table>

5.58 The transport associated with the construction of the repository does not include transport associated with construction of any additional transport infrastructure such as upgraded or new roads or the extension of rail lines to link the site to the mainland rail system.
Other Construction Projects

5.59 Box 5.1 provides examples of other major construction projects proposed or undertaken in the UK.

**Box 5.1: Example Construction Projects**

**Heathrow Terminal 5**

**Project:** Construction of new airport terminal accommodating 30 million passengers per year.

**Comprising:** Includes new main terminal building, satellite building, control tower, hotel, 6km site roads, 13.5km bored tunnel (road, rail links and storm water outfall tunnel), 4000 space multi-storey car park.

**Duration:** Construction Phase 1: 5 ½ years. Phase 1 opening 2008, Phase 2 in 2011.

**Area of T5 site:** 260 hectares

**Height:** Control tower 87m high, tallest in UK.

**Methods:** Tunnel boring for rail infrastructure. Terminal building includes 18,500 tonne roof of 22 steel box section rafters supported by 11 pairs supporting abutments.

**Excavation:** 6.5 million cubic metres earth moved. A proportion used to create embankments for M25 spur road, remainder used on site.

**Materials:** 1.5 million cubic metres concrete, 150,000 tonnes steel reinforcement, 80,000 tonnes structural steel

**Deliveries:** Restricted to agreed hours with specific routes allocated for heavy traffic. Bulk deliveries brought in by rail.

**Employment:** Up to 6,000 construction workers during the most intensive periods of work. Approximately 60,000 over the duration of construction project.

**Working hours:** Contractors working within agreed times. Exceptions are planned and agreed in advance.

**Mitigation:** Code of construction practice including: 24-hour emergency response team, Specialist team to monitor impacts such as construction noise, air quality, dust, Community liaison manager, planting of 450 native semi-mature trees, 2,000 native semi-mature shrubs and over 100,000 evergreen ground cover shrubs. Archaeological excavation.
## Crossrail

**Project:** New rail line through central London and extending into outer London and parts of Berkshire and Essex. To provide additional mainline rail capacity into central London from the west, north east and south east.

**Comprising:** 65km of surface track, 23km of underground track, 26 vent shafts, 100 main construction sites.

**Duration:** 6 years construction

**Starting:** 2008

**Length of tunnel:** 46km

**Depth:** Up to 50m below surface

**Initial works:** Boreholes have been driven to establish ground conditions for tunnelling and shaft construction

**Methods:** Tunnel boring, including sections of twin bore tunnels within central London, new underground stations. Tunnel shafts to be built to connect the tunnels to surface. Up to 13 tunnel boring machines required at any one time.

**Excavations:** Approximately 8 million cubic metres of material, primarily clay with significant quantities of granular material and chalk.

**Waste:** Excavated material to be reused or recycle where practical e.g. as part of landscape scheme or in other construction projects. Where this is not possible, material would be used in restoration of landfill sites. Some material arising is likely to be contaminated. This material would be handled, managed and disposed of in accordance with relevant statutory procedures.

**Materials:** 1 million tonnes concrete, 140,000 tonnes structural steel, 140km new rails

**Employment:** Up to 15,000 construction workers during the most intensive periods of work

**Working hours:** 24 hour working, seven days per week for tunnel construction and building of new underground stations. Above ground works would be undertaken between 7am and 7pm on weekdays and between 7am and 2pm on Saturdays. Work on or close to existing railways may need to take place during possessions, when normal train services are suspended.

**Mitigation:** Includes use of low-noise plant, local noise screens, barriers and enclosures, enclosure of major, noisy items of plant
6. Transport

Introduction

6.1 Transport associated with the PGRC would comprise four components:

- Movements associated with the transport of waste materials from the locations where the waste arises to the disposal facility;
- Movements of materials and personnel associated with the construction of the facility, including construction of new or enhanced transport facilities at the site;
- Movements associated with the operation of the facility (e.g. personnel); and
- Movements associated with the operational, care and maintenance and backfilling/closure phases.

6.2 This section deals with the first component of transport; transport of waste packages. Information about the transport associated with construction, both of the repository facility and any transport infrastructure associated with it is included in the previous Section 5 dealing with construction.

Packaging of Waste

6.3 Packaging of wastes to Nirex standards and specifications, in accordance with Government strategy to render wastes 'passively safe' is already being carried out. Wastes are immobilised and packaged to form waste packages. The steel and concrete waste packages provide physical containment, which enables safe waste storage, transport, handling and disposal and facilitates retrievability.

6.4 The Nirex standard waste containers can be divided into two categories:

- Unshielded packages, which owing to radiation levels or containment requirements require remote handling and must be transported in a shielded transport container. These packages are all ILW and are known as unshielded or UILW;
- Shielded packages, which have built-in shielding (if needed) and/or contain low-activity materials so that packages can be handled using conventional techniques and are transport packages in their own right. LLW containers require no shielding. Some ILW containers have any necessary shielding built in and are thus known as shielded or SILW.
6.5 A transport system has been planned and designed to facilitate the movement of packaged wastes to the repository facility and is described in this section. Further information is provided in the Generic Transport System Design (GTSD).

6.6 Waste containers are described in the following table:

**Table 6.1: Nirex Waste Containers**

<table>
<thead>
<tr>
<th>Nirex Standard Containers</th>
<th>Waste Container</th>
<th>Transport Package</th>
<th>Package Type</th>
<th>External dimensions (m)</th>
<th>Maximum weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ILW</td>
<td>500 litre drum</td>
<td>No</td>
<td>Unshielded</td>
<td>0.8 dia x 1.2 high</td>
<td>2000</td>
</tr>
<tr>
<td></td>
<td>3m³ box</td>
<td>No</td>
<td>Unshielded</td>
<td>1.72 x 1.72 plan, 1.225 high</td>
<td>12000</td>
</tr>
<tr>
<td></td>
<td>3m³ drum</td>
<td>No</td>
<td>Unshielded</td>
<td>1.72 dia x 1.225 high</td>
<td>12000</td>
</tr>
<tr>
<td></td>
<td>4 metre ILW box</td>
<td>Yes</td>
<td>Shielded</td>
<td>4.013 x 2.438 plan, 2.2 high</td>
<td>65000</td>
</tr>
<tr>
<td>LLW</td>
<td>4 metre LLW box</td>
<td>Yes</td>
<td>Shielded</td>
<td>4.013 x 2.438 plan, 2.2 high</td>
<td>30000</td>
</tr>
<tr>
<td></td>
<td>2m LLW box</td>
<td>Yes</td>
<td>Shielded</td>
<td>1.969 x 2.438 plan, 2.2 high</td>
<td>30000</td>
</tr>
<tr>
<td>Non-standard containers</td>
<td>Shielded 500 litre drum</td>
<td>No</td>
<td>Unshielded⁴</td>
<td>0.8 dia x 1.2 high</td>
<td>4000</td>
</tr>
<tr>
<td></td>
<td>MBGWS box</td>
<td>No</td>
<td>Unshielded</td>
<td>1.85 x 1.85 plan, 1.37 high</td>
<td>11000</td>
</tr>
<tr>
<td></td>
<td>WAGR box</td>
<td>Yes</td>
<td>Shielded</td>
<td>2.21 x 2.438 plan, 2.2 high</td>
<td>50000</td>
</tr>
<tr>
<td></td>
<td>3m³ drum²</td>
<td>No</td>
<td>Unshielded</td>
<td>1.72 x 1.72 plan, 1.225 high</td>
<td>12000</td>
</tr>
</tbody>
</table>

Source: Table 3.1 of Nirex Report N/077 Volume 1

⁴ Although shielded, classified as unshielded as can be handled in same manner as unshielded drums.
² Special lifting arrangements required.
Transport Packages

6.7 Some waste packages (defined as the wasteform and the waste container) are suitable for transport in their own right, as such they are a transport package. Other waste packages must be transported in a reusable shielded transport container to meet the necessary safety requirements for transport. The requirements for safe transport of radioactive waste, which all transport packages are required to meet, are set out in the IAEA Regulations 2002. The following table summarises the eight types of transport package:

Table 6.2: Nirex Transport Packages

<table>
<thead>
<tr>
<th>Package Type</th>
<th>Dimensions (m)</th>
<th>Max. Payload (kg)</th>
<th>Max. Gross Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 RSTC-70</td>
<td>2.23 x 2.23 x2.025</td>
<td>12,000</td>
<td>28,000</td>
</tr>
<tr>
<td>2 RSTC-285</td>
<td>2.45 x 2.45 x 2.36</td>
<td>12,000</td>
<td>64,000</td>
</tr>
<tr>
<td>3 4 metre ILW box</td>
<td>4.013 x 2.438 x 2.2</td>
<td>43,000³</td>
<td>65,000</td>
</tr>
<tr>
<td>4 4 metre LLW box</td>
<td>4.013 x 2.438 x 2.2</td>
<td>27,000</td>
<td>30,000</td>
</tr>
<tr>
<td>5 2 metre LLW box</td>
<td>1.969 x 2.438 x 2.2</td>
<td>28,000</td>
<td>30,000</td>
</tr>
<tr>
<td>6 SWTC-70</td>
<td>2.2 x 2.2 x 1.954</td>
<td>12,000</td>
<td>28,000</td>
</tr>
<tr>
<td>7 SWTC-150</td>
<td>2.39 x 2.39 x 2.13</td>
<td>12,000</td>
<td>40,000</td>
</tr>
<tr>
<td>8 SWTC-285</td>
<td>2.45 x 2.45 x 2.32</td>
<td>12,000</td>
<td>65,000</td>
</tr>
</tbody>
</table>

Adapted from Table 3.1 Nirex Report N/076

Storage

6.8 Following packaging, waste is stored in surface facilities, generally at its site of origin or site of packaging.

Scenarios and Means of Transport

6.9 Four scenarios are considered resulting from two assumptions about the amount of waste to be disposed of, and two assumptions about how this waste is transported. In terms of the amount of waste, the Reference Case involves 168,000m³ of waste and the Variant Case involves 256,000m³ of waste. In terms of the modes of transport used, the ROADRAIL scenario assumes that all waste packages that can be transported by HGV are transported by road and the remainder are transported by rail. The MAXRAIL scenario assumes that all packages are transported by rail albeit with some short road transport from production sites to the nearest railheads when these are located off-site.

³ The maximum payload weight could vary with the amount of shielding.
Table 6.3: Transport of Waste Scenarios

<table>
<thead>
<tr>
<th>Transport Option</th>
<th>Reference Case 168,000m³</th>
<th>Variant Case 256,000m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAXRAIL</td>
<td>Scenario 1</td>
<td>Scenario 2</td>
</tr>
<tr>
<td>ROADRAIL</td>
<td>Scenario 3</td>
<td>Scenario 4</td>
</tr>
</tbody>
</table>

6.10 Existing information produced by Nirex from their LOGCOST model quantifies the amount of transport associated with waste transport for the four scenarios.

6.11 If the facility is at an off-shore location, waste will generally be transported by road or rail to a port, before completing its journey by ship.

Transport Vehicles

6.12 Main-line rail wagons designed for the purpose would carry any of the above transport packages. More details of the design of these rail wagons are provided in Section 4 of Nirex Report N/076.

6.13 The Road Vehicles (Construction and Use) Regulations 1986, as amended, (known as the C&U Regulations) impose limits on certain goods vehicle loads for road vehicles. The transport of the above packages by road requires a vehicle that exceeds the 2.55m width limit that means that vehicles are defined as Special Type Category 1 Road Vehicles. However, it is understood that the vehicles would have special Department for Transport dispensation to operate as a normal C&U or authorised weight (AW) rules vehicle. This means that they would not be subject to operating restrictions as long as they were loaded within the C&U and AW axle and gross vehicle weight limitations. In practice this means that packages with a maximum gross weight of 26,000kg could be transported by road without being subject to special regulations.

6.14 For the larger packages (over 26,000kg) there would be a requirement for a Special Type Category 3 Road Vehicle. This is subject to a number of operating restrictions. Details of Category 1 and Category 3 road vehicles are provided in Section 4 of Nirex Report N/076.

Transport Arrival and Scheduling

6.15 Waste package deliveries to the repository shall be scheduled to ensure that the required emplacement throughput can be maintained.

6.16 The repository design would include a small amount of buffer storage for waste that has been unloaded from its transport conveyance. This would prevent unduly detailed constraints on the timing of delivery of individual packages via the transport system from the waste packaging sites.
6.17 Trains carrying packages may arrive at any time but normal arrivals and departures would be scheduled within the hours of 06.00 to 22.00 on weekdays and 06.00 to 18.00 on Saturdays. If possible, most trains would be scheduled to arrive and depart between 08.00 and 17.00.

6.18 One or a small number of preferred road routes would be identified for HGVs from the national motorway and trunk road network. These would be routes that offer the best available combination of safety, ease of access and low environmental impact.

6.19 HGVs of all types would use only the designated routes under normal circumstances and would use the same routes for departure. Different routes would not be used without the prior agreement of Nirex and would not be approved without strong justification.

6.20 Road vehicles carrying packages may arrive at any time but normal arrivals and departures of HGVs of all types would be scheduled within the hours of 06.00 to 22.00 on weekdays and 06.00 to 18.00 on Saturdays.

6.21 Consistent with the Generic Disposal System Specification, a nominal 50-year emplacement period is assumed for both the Reference Case and the Variant Case, with the aim of considering the highest anticipated constant emplacement rate.

**Number of Transport Packages**

6.22 Waste is produced throughout the UK. For the purposes of the generic assessment the UK has been divided into 10 zones of roughly equal size and it is assumed that the waste facility would be located in one of these 10. The amount of transport associated with the disposal of waste is therefore a product of the relative locations of the producing sites and the location of the possible repository site.

6.23 The following table summarises the annual number of transport packages transported by road and rail for the four waste transport scenarios.

*Table 6.4: Annual Number of Transport Packages Transported*

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Description</th>
<th>By Road</th>
<th>By Rail</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Reference Case/MAXRAIL</td>
<td>-</td>
<td>1456</td>
</tr>
<tr>
<td></td>
<td>2040-2089</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Variant Case/MAXRAIL</td>
<td>-</td>
<td>1614</td>
</tr>
<tr>
<td></td>
<td>2040-2084</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Variant Case/MAXRAIL</td>
<td>-</td>
<td>1500</td>
</tr>
<tr>
<td></td>
<td>2085-2089</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Reference Case/ROADRAIL</td>
<td>777</td>
<td>679</td>
</tr>
<tr>
<td></td>
<td>2040-2089</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Scenario Description

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Description</th>
<th>By Road</th>
<th>By Rail</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Variant Case/ROADRAIL 2040-2084</td>
<td>860</td>
<td>754</td>
</tr>
<tr>
<td></td>
<td>Variant Case/ROADRAIL 2084-2089</td>
<td>405</td>
<td>1095</td>
</tr>
</tbody>
</table>

Adapted from Tables 6.2a and b and 6.3a and b, Nirex Report N/076 (based on ‘Average of 10 zones’)

#### 6.24

The following table expresses the package arrival rate in terms of road and rail vehicles:

**Table 6.5: Annual Vehicle Arrival Rates (1-way Movements)**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Description</th>
<th>HGV's</th>
<th>Wagons (Trains)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Reference Case/MAXRAIL 2040-2089</td>
<td>-</td>
<td>1,068 (123)</td>
</tr>
<tr>
<td>2</td>
<td>Variant Case/MAXRAIL 2040-2084</td>
<td>-</td>
<td>1,185 (137)</td>
</tr>
<tr>
<td></td>
<td>Variant Case/MAXRAIL 2085-2089</td>
<td>-</td>
<td>1,298 (223)</td>
</tr>
<tr>
<td>3</td>
<td>Reference Case/ROADRAIL 2040-2089</td>
<td>777</td>
<td>679 (82)</td>
</tr>
<tr>
<td>4</td>
<td>Variant Case/ROADRAIL 2040-2084</td>
<td>860</td>
<td>754 (91)</td>
</tr>
<tr>
<td></td>
<td>Variant Case/ROADRAIL 2085-2089</td>
<td>405</td>
<td>1095 (196)</td>
</tr>
</tbody>
</table>

Adapted from Tables 6.2a and b and 6.3a and b, Nirex Report N/076 (based on ‘Average of 10 zones’)

#### 6.25

The above table shows that in ROADRAIL scenarios there are expected to be 777 HGV arrivals per year for the Reference Case or 15 arrivals per week equating to 30 HGV movements per week. It can be seen that the expected maximum number of trains associated with waste transport equates to some 4 trains per week.

#### 6.26

There are no HGV movements shown for the MAXRAIL scenario. In reality there would be a number of short trips between production sites and off-site railheads. At the present time arising sites at Sellafield, Trawsfynydd, Hartlepool, Heysham, Winfrith and Rosyth have their own railheads and waste need not be transported by HGV to off-site rail facilities. It has been calculated that the total number of off-site package transfers from road to rail, over the operation of the waste repository is 16,423, equivalent to 328 per year over a 50 year operational period (Appendix 1, Nirex Report N/078).

### Travel Distances

#### 6.27

Table 6.6 summarises the packages that would be transported by road arising from existing waste storage/production sites around the United Kingdom in a ROADRAIL scenario. It is
possible that the numbers may be less for a MAXRAIL scenario, depending on the facilities made available at each waste producing/storage site for transfer to the rail network.

Table 6.6: Road Transport Packages Arising

<table>
<thead>
<tr>
<th>Location</th>
<th>Reference Case Road Transport Packages</th>
<th>Variant Case Road Transport Packages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amersham</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>AWE Aldermaston</td>
<td>1703</td>
<td>1703</td>
</tr>
<tr>
<td>Berkeley</td>
<td>436</td>
<td>631</td>
</tr>
<tr>
<td>Bradwell</td>
<td>262</td>
<td>339</td>
</tr>
<tr>
<td>Calder Hall</td>
<td>1</td>
<td>97</td>
</tr>
<tr>
<td>Capenhurst</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Cardiff</td>
<td>640</td>
<td>640</td>
</tr>
<tr>
<td>Chapelcross</td>
<td>15</td>
<td>145</td>
</tr>
<tr>
<td>Culham</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Dounreay</td>
<td>1,526</td>
<td>1,526</td>
</tr>
<tr>
<td>DSDC(N) Donnington and Stafford</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>DSTL for Halstead</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Dungeness</td>
<td>150</td>
<td>224</td>
</tr>
<tr>
<td>Hartlepool</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Harwell</td>
<td>658</td>
<td>658</td>
</tr>
<tr>
<td>Heysham</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Hinkley Point</td>
<td>399</td>
<td>487</td>
</tr>
<tr>
<td>HMNB Clyde</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>HMNB Devonport</td>
<td>92</td>
<td>92</td>
</tr>
<tr>
<td>HMNB Portsmouth</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Hunterston</td>
<td>1,003</td>
<td>1,101</td>
</tr>
<tr>
<td>Oldbury</td>
<td>269</td>
<td>452</td>
</tr>
<tr>
<td>Rosyth and Devonport (submarines)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Rosyth Royal Dockyard</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sellafield</td>
<td>28,788</td>
<td>29,166</td>
</tr>
<tr>
<td>Sizewell</td>
<td>1,832</td>
<td>1,918</td>
</tr>
<tr>
<td>Springfields</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Tomess</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Trawsfynydd</td>
<td>291</td>
<td>503</td>
</tr>
<tr>
<td>Windscale</td>
<td>244</td>
<td>244</td>
</tr>
<tr>
<td>Winfrith</td>
<td>348</td>
<td>348</td>
</tr>
<tr>
<td>Wylfa</td>
<td>38</td>
<td>318</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>38,826</strong></td>
<td><strong>40,724</strong></td>
</tr>
</tbody>
</table>
6.28 Although no potential sites have been identified for a repository at this stage, Nirex has calculated the amount of travel associated with waste transport from arising sites to each of ten zones within the UK.

6.29 Generally, waste transport is predicted to account for between 0.4 million network km and 1.2 million network km. These network-km would be on specified routes between the arising sites and the repository, the majority of which would be on motorways and trunk roads. A relatively small proportion of this travel will be on more minor roads that link the arising sites and disposal facilities with the strategic road network.

Facilities Required

6.30 The receipt and despatch facilities would be capable of handling transport packages arriving by any combination of rail and road, ranging from all packages arriving by rail to a combination of road and rail arrivals. As discussed in Chapter 4, in the case of a repository constructed on an off-shore island a local transport link to port facilities would need to be considered.

Rail Transport

6.31 It is assumed that transport packages would arrive in trains up to 12 wagons long. This, together with a main-line locomotive and brake van, would give an overall train length of approximately 240 metres.

Road Transport

6.32 On-site road infrastructure would be designed to accommodate Category 3 vehicles. Provision would be made for parking, including light goods vehicle parking and staff car parking.
7. Operation

Introduction

7.1 On receipt at the repository, transport containers would be unloaded and the waste packages would be emplaced in underground vaults. The emplacement phase would provide a barrier in the form of geological isolation but would not yet provide long-term geological containment (which would occur following backfilling and closure – see Section 8).

Characteristics of Waste Received

7.2 On arrival at the repository packaged wasteforms include:

- Immobilised sludges, liquids and slurries – this wasteform consists of fine particles dispersed in a solid cement matrix;
- Encapsulated solid wastes – this wasteform consists of solid items (metal, concrete, graphite etc.) in a solid cement matrix;
- Annular grouted wasteform – in this case the waste is contained within the central region of the waste container, surrounded by a layer of cement grout.

7.3 In addition there may be a small number of solid wastes that can be shown to be passively safe without the need for the immobilisation step.

7.4 The waste contains a range of materials including metals and organic materials whose long-term degradation can impact on the design of the repository concept and its performance. The corrosion of metals in the waste, as well as the metal waste containers, would generate gas, almost wholly hydrogen. Organic materials in the waste can also be expected to be degraded by microbes, generating gases such as carbon dioxide and methane.

7.5 The degradation of organic material can also produce a range of complex organic molecules that have the potential, once they have passed into solution in water, to influence solubility and sorption of some radionuclides in the waste.

Main Activities

7.6 The key activity throughout the operational phase of the development is the emplacement of waste into the excavated vaults and activities associated with site operation.
Waste Emplacement

Rate of Emplacement

7.7 UILW packages would be processed in a single line inlet cell facility before emplacement in the vaults. A constant rate of throughput is assumed over the 50 year operating period with the inlet cell averaging just over 1420 disposal packages/year, with the capability to process up to 2500 per year (based on the maximum throughput of a single inlet cell).

7.8 SILW and LLW packages would be emplaced within 2 vaults. The 300m length of these two vaults includes a 35m front section to allow for the manoeuvring of a large capacity stacker truck used to emplace these relatively low dose packages.

7.9 SILW/LLW packages would be buffer stored outside the vaults to allow emplacement in campaigns. Assuming a constant rate of throughput, approximately 35 disposal packages would be emplaced each year over the 50 year operational period.

UILW Package Handling

7.10 Remote handling facilities would be provided for the movement underground and unloading of reusable transport containers containing unshielded waste packages.

7.11 The rack-and-pinion railway sited in the drift would be used to convey the transport packages to the repository horizon. The UILW packages would be transferred from the drift wagon directly onto an inlet cell bogie in its transport container using an overhead travelling crane. On occasion, UILW packages would be transferred to a small buffer store in the underground reception area.

7.12 Within the inlet cell, the UILW packages would be removed from the reusable transport container and located on a transfer bogie. Once the transfer bogie is loaded with a waste package, it would be moved through dedicated waste transfer tunnels that would pass beneath one end of each UILW vault. The transfer bogie would stop beneath the open hatch of the operational UILW vault. The vault emplacement crane would lift the waste package up through the hatch and traverse along the vault to emplace the package in its designated position within the waste stack. Emplacement would start from the far end of the vault and work back towards the transfer tunnel at the front of the vault. The maximum stacking array across the vault cross-section would be seven packages wide and seven high.

7.13 Each vault would be closed after it had been filled, but not immediately backfilled. The ventilation system would be kept operating to maintain an acceptable environment for the waste packages.

7.14 The empty transport container would retrace its incoming route before the next container could be processed. Within the inlet cell facility, the transport container would have its lid replaced and secured, be checked for contamination and decontaminated if required. The
empty container would then leave the facility and be transported back up the drift to the test and despatch facility located within the transport package transfer facility on the surface.

**SILW/LLW Package Handling**

7.15 SILW and LLW packages require no additional containers for transport and handling. Such packages would be emplaced by conventional mechanical handling with operators in attendance.

7.16 SILW/LLW packages would be taken to the SILW/LLW reception area at the terminus of the drift system and unloaded by overhead travelling crane into the SILW/LLW buffer store, ready for direct emplacement into vaults. Because the rate of arrival of SILW and LLW would be relatively low (35 packages per year), these would be stored until sufficient packages were placed underground to allow emplacement to take place in campaigns.

7.17 Handling of the SILW/LLW packages from the buffer store would be a 65t capacity manually-operated stacker truck which would transport the packages along the vault and stack them at the emplacement face.

**Measurement of Contamination Levels**

7.18 An underground location would be identified within which surface contamination checks and other monitoring of unshielded ILW packages could be performed. This location would provide the necessary shielding, containment and access provisions. A minimum shielded enclosure plan of 5m x 5m would be provided.

**Reusable Transport Containers**

7.19 The external surfaces of the empty reusable transport containers would be monitored after they are returned to the surface facilities. It is assumed that one in ten containers would be monitored as a matter of routine. If required, decontamination would be undertaken prior to the containers leaving the site.

**Summary of Built Development**

7.20 The Reference Case design is based on a stand-alone development on a single surface site constructed in the range 300m to 1000m below ground level (assumed for the purposes of assessment to be 650m). The repository would be serviced by underground access in the form of one inclined drift (tunnel) and two vertical shafts developed to 650m below ground level. The drift would be approximately 5.5 metre diameter and some 4000m long.

7.21 The repository would comprise 11 vaults for UILW and 2 vaults for SILW and LLW. Each vault is assumed to be 16m wide by 16m high and 300m long. An inlet cell would be required to receive waste and transfer it to the vaults.
7.22 The approximate surface land take required for the design is approximately 930,000m$^2$. The estimated area of underground facilities (including drift) is approximately 1,900,000. The Reference Case Design is illustrated in Figure 5.1. More detailed indicative layouts for the Reference Design (surface and underground) are provided at Appendix 2. These illustrate the proposed scheme together with an indication of the likely scale of the proposed development. The highest structures on the site are likely to be the headframes over the shafts, which are likely to be up to 35m above ground.

**Surface Facilities**

*Main Features*

7.23 The main surface buildings for transport package and transport container handling would comprise a transport package transfer facility and a transport container maintenance facility. Within the transfer facility, packages would be transferred by overhead travelling crane from the delivery unit to a rack-and-pinion drift wagon for transportation underground.

7.24 The transport container maintenance facility provides for the major repair of any empty reusable shielded transport containers that might fail the routine ‘turn-around’ inspection that each empty container would receive before being returned to a waste packaging site. This maintenance building would also provide facilities for rectification of any transport packages that might fail acceptance tests at the repository.

7.25 Alongside the transfer and maintenance buildings would be facilities for treatment of any radioactive liquid effluents arising from both surface and underground operations.

7.26 Surface operations would be controlled from a management centre and control room. The control room would provide round-the-clock surveillance and also function as an emergency control centre.

7.27 A main operational control room on the surface would be provided from which all operations can be managed, and the real-time safety, environmental and operational status of all areas of the repository continually monitored.

7.28 A second control room would be established underground, from which all underground operations can be controlled and managed. Readings from local instrumentation shall also be relayed to the surface operational control room.

7.29 The main operational control room would also carry out the functions of an emergency control room.

7.30 Additional support facilities within the active area would include drift locomotive and wagon maintenance, active laundry and laboratories. Changing rooms, welfare facilities and office accommodation would also be provided for management, operations and support staff.
Buildings outside the active area would include an administration and reception building, a visitors centre, mechanical and electrical workshops and stores, and a fire and rescue station serving both surface and underground. Change control facilities would be provided between all active and non-active areas.

### Access Underground

It is envisaged that three access ways would be needed to connect surface facilities to the underground areas. The number required is determined by the need to provide separate access routes for personnel and waste arrivals, to segregate the construction and nuclear operations, to provide services such as power and ventilation and to provide two means of egress for personnel.

The drift would be used for the transfer of packages underground and the return of empty transport containers to the surface. In an emergency it could also provide a second means of egress for construction workers. The drift would be equipped with a rack-and-pinion railway. The length of the drift would allow it to reach the operating depth at a suitable gradient. The system would be similar to those used throughout the world for freight and passenger transport in hilly or mountainous terrain.

Underground repository workers would be transported separately from waste packages and would not be in the drift at the same time. There would be regular monitoring of the drift and, if necessary, actions would be taken to prevent the build-up of radioactive contamination.

The main shaft and associated buildings and structures would be similar to those found at many deep mines in the UK, with cage or skip winding systems and a surface level winder house. The headframe or tower supporting the shaft winding systems would be the tallest structures on the site and would be typically up to 35m in height. The main shaft would provide a second means of egress for operational personnel. A smaller shaft building (assumed to be approximately 10m high and equipped with emergency winding facilities) would be associated with the secondary shaft.

### Inlet Cell

The Inlet Cell is a shielded facility where reusable shielded transport containers would be opened and the waste packages removed and checked prior to transfer to vaults. The cell would have thick concrete walls to provide radiation shielding to protect the workforce. Empty transport containers would undergo monitoring and decontamination, as necessary, before being returned to the surface.
Ventilation Systems

7.37 Ventilation for emplacement activities and the vaults would use exhaust fans located on the surface, placing the emplacement side at negative pressure with respect to surface atmosphere. Ventilation air would be directed through the facility via independent roadway networks by air locks and moveable bulkheads.

7.38 In addition, each UILW vault would have its own filters sited close to the exhaust point where the air from the vault is discharged into the main emplacement return roadway. The SILW/LLW vaults would have a common bank of filters sited close to the vaults, also discharging into the main emplacement return.

7.39 Exhaust air would return to the fans at the surface via a duct inside the 5m secondary shaft and would be discharged at the surface via a stack. This would conform to the site-specific requirements for efficient dilution and dispersal. The discharge stack would be located at least 200m from any underground ventilation intake.

Liquid Effluents

Underground Effluents

7.40 During the operation of the repository there would be various sources of liquid effluents underground. These would arise from groundwater inflow, de-humidification operations and decontamination processes. Water from each of these sources would be collected separately and analysed and only mixed with other streams if radiologically and chemically justifiable. Water arising from designated active underground areas would be stored at the effluent receipt and despatch cell until it could be transported up the drift in dedicated tankers for further testing and processing by the active effluent plant.

7.41 Water from general underground roadways and the drift, where it is known to be free from radioactive contamination, would be diverted to a central underground collection area, transferred up the drift to the water despatch facility for treatment prior to being pumped to a suitable licensed discharge point.

Surface Drainage

7.42 A surface drainage system for the collection of rainwater shall be provided. All surface drainage shall be designed to prevent liquid effluents and runoff from entering the underground part of the repository.

Analysis

7.43 All liquid effluents would be analysed for pollutants, including:

- Radioactivity characterisation and measurement
- Particulate determination
• Physical property determinations (e.g. temperature, pH, alkalinity)
• Non-radioactive effluent measurements or anions and cations.

7.44 Following collection, sampling and analysis of liquid effluent streams, treatment facility would be provided to ensure that concentrations of contaminants conform to authorisation before the effluent is discharged.

7.45 In addition all liquid effluents would be monitored for flow, to determine the quantities treated and discharged.

Water Supply

7.46 A supply of process water shall be made available for washdown, fire systems, backfill mixing etc. A reliable and adequate water storage and distribution system shall be provided for firefighting. Wherever possible within the above constraints, water shall be recycled.

Noise Control

7.47 Where practicable, plant systems would be selected which generate minimum noise levels. Noisy plant and equipment would be enclosed in buildings, which could, if necessary, be fitted with acoustic panels. Where practicable, reversing alarms on vehicles would be replaced by ‘quiet’ alarms and operating hours of large surface vehicles would be restricted. The visual screening banks around the site would also help to reduce off-site noise.

Architecture

7.48 It is anticipated that the larger buildings on site would be of functional appearance, which is likely to include typical industrial steel-framed units with brickwork/blockwork walls at low level and clad with colour-coated profiled aluminium or steel sheeting at higher level (including the roof). Exceptions to this would be the airlock building over the ventilation exhaust shaft and the fan house, which have to be designed to withstand internal suction pressures and so are likely to be steel sheet, reinforced concrete or brick construction clad with profiled sheeting if appropriate.

7.49 The size of the buildings would be kept to a practical minimum. Some would have basements, such as the winder houses, to minimise the building height. However, the height of some buildings cannot be reduced by lowering them into the ground due to safety considerations, particularly the headframes over the shafts.

7.50 Where practicable, colours and styles would be chosen to suit the local surroundings.

Landscape

7.51 In general the landscape design objectives are:
To screen views of some buildings from outside the site – this would be achieved by progressive formation of a screening mound;

To mound and plant on a scale that would conform with the existing topography and vegetation so that, in time, the new landscape would merge with the old;

For some sites, to retain as much as possible of the original vegetation and to create conservation areas to encourage flora and fauna.

**Lighting**

7.52 Lighting would be required on site to enable operations to be carried out safely, including security lighting and CCTV. However, lighting poles would be reduced to a practicable minimum and directional shields would be used to control light spillage.

**Safety**

7.53 Provision shall be made, so far as is practicable, for a personnel exit to the surface from all underground areas to be available for use and, as far as reasonably practicable, for at least two separate personnel exits to be available.

7.54 Provision shall be made for emergency vehicle access throughout the surface site.

7.55 Provision shall be made for mine rescue access to underground areas. An emergency plan shall be made to cover all potential incidents.

**Summary of Key Parameters**

7.56 The operational development for the Reference Case is summarised in Table 7.1 below:

<table>
<thead>
<tr>
<th></th>
<th>Reference Case Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste volume</td>
<td>168,000m$^3$</td>
</tr>
<tr>
<td>Number of surface sites</td>
<td>1</td>
</tr>
<tr>
<td>Rock disposal</td>
<td>On site</td>
</tr>
<tr>
<td>Annual throughput total</td>
<td></td>
</tr>
<tr>
<td>UILW</td>
<td>1455</td>
</tr>
<tr>
<td>SILW/LLW</td>
<td>1420</td>
</tr>
<tr>
<td>35</td>
<td></td>
</tr>
<tr>
<td>Number of UILW vaults</td>
<td>11</td>
</tr>
<tr>
<td>Number of SILW/LLW vaults</td>
<td>2</td>
</tr>
<tr>
<td>Number of drifts</td>
<td>1</td>
</tr>
<tr>
<td>Number of shafts</td>
<td>2</td>
</tr>
<tr>
<td>Approx vault dimensions</td>
<td>16m x 16m</td>
</tr>
<tr>
<td>Excavated volumes</td>
<td>1.5 million m$^3$</td>
</tr>
</tbody>
</table>
Programme

7.57 The duration of the waste emplacement phase would be dependent on a number of technical and economic factors, such as the lifetime of interim surface stores and their rate of emptying, and factors such as the decommissioning strategies for nuclear power stations. For the purposes of the Stage 1 environmental assessment, a reference period of 50 years is assumed for both the Reference Case and the Variant Case. This may need to be revisited throughout future stages of environmental assessment as more information becomes available, for example if wastes associated with the Variant Case are predicted to arise outside the 50 year period.

Operational Capacity

7.58 The repository shall be capable of operating for 365 days per year on a three shifts per day basis.

7.59 The target availability of the repository for emplacement operations, excluding scheduled stoppages, would be 90%. Scheduled stoppages are assumed to be a two-week period for a close-down holiday (nominally the Christmas and New Year period), plus an additional six-week period every two years for major maintenance, inspections and refurbishment.

Employment

7.60 During operation, a range of professional (e.g. operational, plant, engineering and environmental management, safety advisors), semi-professional staff (e.g. shift supervisors, engineering support for nuclear, civils and mechanical operations, drivers) and support staff (e.g. operational staff for receipt and transfer of wastes, security, reception and administration) would be required.

7.61 Estimated personnel required would be in the range of 85 - 500 people per year (including concurrent ongoing construction).

Operational Traffic

7.62 It is estimated that approximately 1400 cars and 10 buses per week may be required for 50 years during operation for personnel transport. Depending on the availability of public transport, a significant proportion of personnel may travel by public transport.

Other Repository Projects

7.63 Box 7.1 provides details of repository projects proposed outside the UK.
### Box 7.1: Other Repository Projects Outside the UK

<table>
<thead>
<tr>
<th>Project</th>
<th>Details</th>
</tr>
</thead>
</table>
| **WIPP, USA** | Waste Isolation Pilot Plant  
Type: Deep disposal  
Location: New Mexico  
Depth: 2150 feet in salt formation  
Waste: Transuranic radioactive waste (similar to ILW).  
Volume: 7550 cubic metres of waste in 2003  
Transport: Waste packaged and transport by road on interstate highway system  
Status: Began operations 1999 |
| **Yucca Mountain, USA** |  
Type: Deep disposal  
Location: 200m below surface and 160m above water table in Nye, Nevada.  
Area: 600 km2 to be permanently withdrawn from public access for repository use.  
Waste: heavy metal, spent nuclear fuel and HLW.  
Volume: 11,000 – 17,000 waste packages (70,000 metric tons) of  
Construction: Approx 5 years  
Emplacement: 24 years  
Status: Awaiting license from Nuclear Regulatory Commission. |
| **Centre de la Manche, France** |  
Type: Near surface facility  
Waste: LLW and ILW  
Volume: 527,214m³ (over 25 years)  
Status: Entered 10 year monitoring phase in 2003 |
| **El Cabril, Spain** |  
Type: Near surface facility  
Location: Cordoba, Spain  
Waste: LLW and ILW  
Volume: 2000m³ per year  
Status: Accepting waste since 2001 |

**Other Projects**  
**Aspo, Sweden:** International Underground Rock Laboratory project. Investigating two sites for possible disposal facility. Trial disposal could begin in 2012.  
**Forsmark, Sweden:** Existing repository at the Forsmark nuclear site disposing of LLW and short-lived ILW in mined facility.  
**Belgium:** Researching HLW disposal in clay at Mol Underground Research Laboratory.
8. Closure and Post-Closure

8.1 Following cessation of emplacement operations, the options would be to backfill, seal and close the facility or to keep it open for a period of care and maintenance with the packages in a readily retrievable state. The provision of a care and maintenance period retains the option for future generations to monitor wastes and the repository system directly and to retrieve waste if decided appropriate.

8.2 At some stage it is assumed that the facility operators, in consultation with society, would close the facility. This would involve backfilling emplacement vaults with cementitious backfill, sealing the underground openings and backfilling access ways. This may be undertaken in stages, with monitoring of each stage, if considered appropriate at the time.

8.3 After backfilling, sealing and closure the repository would enter the post-closure phase.

Main Activities

Care and Maintenance

8.4 During this period the overall system would be maintained, thereby retaining the capacity and flexibility to respond to changes in requirements for the waste if these are required, including removal of waste to the surface. The emplacement/retrieval equipment could be withdrawn into the crane maintenance area at the end of the vault.

8.5 During this phase, the waste containers would be kept dry. If there was a requirement to keep the repository open for longer than 50 years it would be necessary to take steps such as removal of the waste from each vault to allow access for maintenance/replacement of crane nails, rock support or groundwater management systems.

Backfilling, Sealing and Closure

Backfilling

8.6 When a decision has been taken to backfill the repository, the vaults would be backfilled.

8.7 It is assumed, as described in the Generic Documents, that the space between and around waste packages would be filled with a purpose-designed cement-based material. This is described as local backfill material or Nirex Reference Vault Backfill (NRVB). This material would be designed to provide an effective barrier against the movement of radioactive materials into groundwater. This would be achieved through increasing the alkalinity of the groundwater (chemical conditioning) and providing a large surface area onto which many radionuclides attach.
8.8 In addition to the spaces between waste packages, the NRVB would be used to provide a layer of backfill material in the space between waste packages and the walls and the end of the vaults and above and below stacks of waste packages.

8.9 After this backfilling is complete, prior to sealing and closure, the backfill will be maintained in a 'saturated' condition (i.e. with a high proportion of water contained within it).

8.10 The quantity of local backfill required to provide the appropriate near-field chemistry is defined in terms of the ratio of the volume of NRVB local backfill to the volume of conditioned waste. The requirement, based on the Reference Case volume, is assumed to be a ratio of 1:1 for all waste types to ensure pH buffering.

Sealing and Closure

8.11 After backfilling all disposal vaults, a programme of sealing work would be carried out progressing from the sealing of individual vault entrances and exits through a programme of filling all underground openings. This would include the use of specifically designed low-permeability seals at key location, such as:

- Vault entrances and exits;
- Drifts and/or shafts;
- The intersection of the repository excavations with any underground laboratory excavations;
- Exploratory boreholes, drilled from the surface or underground, that have hydrogeological significance.

8.12 This aims to minimise the potential void space within the repository. Additional seals may be required in tunnels, roadways and other access route.

8.13 The permeability of the sealing material would be equivalent to the effective permeability of the host rock or, if this is not achievable, as low as reasonably practicable.

8.14 The bulk material used to backfill excavated spaces between the seals is known as mass backfill. This material may comprise reclaimed spoil arising from excavation of the repository.

8.15 Prior to this stage it is anticipated that equipment and materials within the underground areas would be removed.

8.16 Following completion of sealing, the repository could be closed. At such a time the multiple barriers that form the basis of the PGRC would be complete and would provide long-term containment of the radioactivity in the repository.

Use of Materials

8.17 The quantities of materials estimated to be required during the emplacement of waste as a buffer material and backfill are outlined in Table 8.1 below.
### Table 8.1: Quantity of Materials Assumed to be Required for Backfill of the Repository (Nirex 2005g)

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total mass of crushed rock for high permeability seals</td>
<td>1,000,000 tonnes</td>
</tr>
<tr>
<td>Total volume of concrete for permanent plugs</td>
<td>29,770 m³</td>
</tr>
<tr>
<td>Total mass of reinforcement for permanent plugs</td>
<td>60 tonnes</td>
</tr>
<tr>
<td>Vault backfill material:</td>
<td></td>
</tr>
<tr>
<td>Portland cement</td>
<td>149,370 tonnes</td>
</tr>
<tr>
<td>Hydrated lime aggregate</td>
<td>56,430 tonnes</td>
</tr>
<tr>
<td>Limestone flour</td>
<td>164,300 tonnes</td>
</tr>
</tbody>
</table>

### Monitoring

8.18 Provisions for monitoring would be available from the earliest stages of site characterisation, through repository operation and up to the post-closure period of institutional control.

8.19 Potential monitoring activities are summarised in Table 8.2:

### Table 8.2: Potential Monitoring Activities

<table>
<thead>
<tr>
<th>Phase</th>
<th>Potential Monitoring Requirements</th>
</tr>
</thead>
</table>
| Care and Maintenance | Waste Characteristics  
|                      | Package Integrity                                                     |
|                      | Near Field  
|                      | Geotechnical response to excavations                                  |
|                      | Groundwater flow and chemistry                                        |
|                      | Thermal effects and gas generation                                    |
|                      | Backfill condition                                                    |
|                      | Sealing systems                                                       |
|                      | Far Field  
|                      | Hydrogeological parameters (e.g. groundwater pressures, permeability/porosity, flow patterns) |
|                      | Geochemical parameters (e.g. pH, Eh, rock-water interaction, radioactivity, gas generation) |
|                      | Seismic and tectonic activity                                          |
|                      | Rock support systems, groundwater management, vault environment particularly during any extended care and maintenance period |
Phase | Potential Monitoring Requirements
--- | ---
**Surface Environment**
Water (aquifers, rivers, lake, sea)
Soil and sediments
Air sampling
Dosimetry around the site

**Groundwater**
Hydrogeological conditions

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**Post-Closure Monitoring**

**Surface Environment**
Radiation, contamination, climatic conditions, gas, surface water, flora, fauna.

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8.20 Decommissioning of the operational surface facilities would include decontamination activities, if required, and facility dismantlement and removal. Facility dismantlement is unlikely to be undertaken until the facility is closed. At this stage, equipment and materials would be salvaged, recycled or reused if possible.

8.21 It is assumed for the purposes of this assessment that following completion of closure, the site would be restored to as near to its preconstruction condition as practicable. This would include the recontouring of disturbed surface areas, a programme of soil aftercare, site revegetation and erosion control.

**Programme**

8.22 The design of the facility allows for a period of care and maintenance of the facility prior to backfilling of up to several hundred years. For the purposes of this assessment, and consistent with the Generic Documents, a care and maintenance phase of 50 years prior to closure has been assumed. However, it is recognised that this period may vary according to the length of time considered appropriate at that time and that, in fact, the decision may be taken not to close the facility.

8.23 For the purposes of this assessment, a period of ten years has been assumed for the closure of the facility.

8.24 Post-closure monitoring would continue as long as considered suitable. However, for the purposes of assessment a period of 100 years has been assumed.
Employment

8.25 During the care and maintenance phase employment would include professional staff (such as site, operational and security management), semi-professional staff (including sampling technicians, data interpretation and maintenance personnel) and support staff such as security. During backfilling and closure, staff with similar skills to those used during construction would be required.

8.26 Estimated personnel required would approximately 120 people per year during backfilling, sealing and closure. The majority of these would be professional or semi-professional but with a significant proportion of support staff required.

Traffic

8.27 Table 8.3 summarises the predicted levels of traffic associated with this phase of the development. This comprises transport of materials and of personnel.

Table 8.3: Predicted Traffic Generation During Care/Maintenance, Backfilling, Sealing and Closure

<table>
<thead>
<tr>
<th></th>
<th>Care and Maintenance Phase</th>
<th>Backfilling Sealing and Closure Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance materials</td>
<td>10 lorries per week for 50 years</td>
<td>400 lorries per week for 10 years</td>
</tr>
<tr>
<td>Personnel: Cars</td>
<td>400 cars per week for 50 years</td>
<td>400 cars per week for 10 years</td>
</tr>
<tr>
<td></td>
<td>5 buses per week for 50 years</td>
<td>5 buses per week for 10 years</td>
</tr>
</tbody>
</table>
9. Summary

9.1 Key parameters of each phase of the PGRC are summarised in Table 9.1.

Table 9.1: Summary of Key PGRC Phases

<table>
<thead>
<tr>
<th>Phase</th>
<th>Activity</th>
<th>Land Take</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site Characterisation</td>
<td>Geographical search and identification of sites for detailed investigation</td>
<td>No intrusive works.</td>
<td>2.5 years</td>
</tr>
<tr>
<td></td>
<td>Detailed investigation (regional surveys and boreholes)</td>
<td>120x120m (14,400m²), excluding access road per borehole site. Total for all boreholes sites: 576,000m².</td>
<td>5-6 months per borehole site. Total for all boreholes: 8 years</td>
</tr>
<tr>
<td>Construction</td>
<td>RCF construction</td>
<td>400m x 200m (80,000m²)</td>
<td>9 years</td>
</tr>
<tr>
<td></td>
<td>Initial phase of repository construction prior to waste emplacement</td>
<td>1200m x 1200m (1,440,000m²). Likely to include RCF construction site.</td>
<td>7 years</td>
</tr>
<tr>
<td></td>
<td>Ongoing construction concurrent with operational phase</td>
<td>No additional land take (site area remains as above)</td>
<td>50 years (concurrent with operational phase)</td>
</tr>
<tr>
<td>Transport</td>
<td>Transport of waste packages to repository site by road, rail or sea.</td>
<td>No additional land take (on site road and rail infrastructure included in construction figure above)</td>
<td>50 years (concurrent with operational phase)</td>
</tr>
<tr>
<td>Operation</td>
<td>Emplacement of waste into excavated vaults.</td>
<td>No additional above ground land take, operational surface land take 930,000m² (approx). Estimated area of underground facilities 1,900,000m² (approx).</td>
<td>50 years</td>
</tr>
<tr>
<td>Phase</td>
<td>Activity</td>
<td>Land Take</td>
<td>Duration</td>
</tr>
<tr>
<td>--------------------------</td>
<td>-------------------------</td>
<td>---------------------------------------------------------------------------</td>
<td>----------</td>
</tr>
<tr>
<td>Closure and Post-Closure</td>
<td>Care and maintenance.</td>
<td>No additional land take</td>
<td>50 years</td>
</tr>
<tr>
<td></td>
<td>Backfilling and closure</td>
<td>No additional land take.</td>
<td>10 years</td>
</tr>
<tr>
<td></td>
<td>Post-closure monitoring</td>
<td>Site potentially restored, resulting in reduction in land occupied and possible use for other purposes.</td>
<td>100 years</td>
</tr>
</tbody>
</table>
Bibliography


Nirex (2005f) *Context Note 2.5: Role and Functions of a Rock Characterisation Facility (RCF).* Nirex Technical Note. United Kingdom Nirex Limited.


Appendix 1: List of Generic Documents

Nirex Phased Geological Repository Concept Generic Documents

N074 Nirex Phased Disposal Concept
N075 Nirex Generic Disposal System Specification Volume 1
N075 Generic Disposal System Specification Volume 2
N076 Generic Transport System Design
N077 Generic Repository Design Volume 1
N077 Generic Repository Design Volume 2
N078 Generic Transport Safety Assessment Volume 1
N078 Generic Transport Safety Assessment Volume 1
N079 Generic Operational Safety Assessment Contents
N079 Generic Operational Safety Assessment Part 1
N079 Generic Operational Safety Assessment Part 2
N079 Generic Operational Safety Assessment Part 3
N079 Generic Operational Safety Assessment Part 4
N079 Generic Operational Safety Assessment Part 5
N079 Generic Operational Safety Assessment Part 6
N079 Generic Operational Safety Assessment Part 7
N079 Generic Operational Safety Assessment Part 8
N080 Generic Post Closure Performance Assessment
Appendix 2: Reference Case Layout Drawings