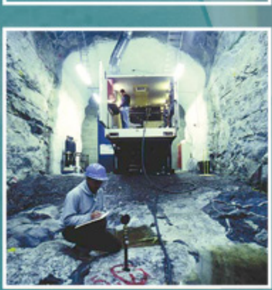
Geological Disposal: Generic Environmental and Sustainability Report for a Geological Disposal Facility

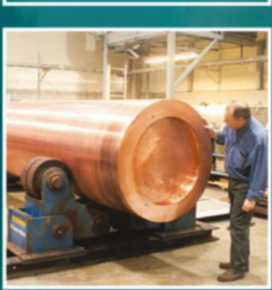
Non Technical Summary

October 2010







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John Dalton
Head of Communications
Nuclear Decommissioning Authority (Radioactive Waste Management Directorate)
Curie Avenue
Harwell campus
Didcot
Oxon
OX11 ORH

Report cover photos: SKB and NDA (2010).

Report for

Dr Mark Gough, Sustainability Assessment Manager
Radioactive Waste Management Directorate
Nuclear Decommissioning Authority
Curie Avenue
Harwell Science and Innovation Campus
Oxfordshire
OX11 0RH

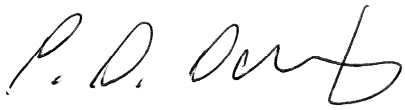
Main Contributors

Pete Davis
Phill Minas
Matthew Keep
Amy Souter
Philip Smith

Issued by

……………………………………………………………
Phill Minas

Approved by



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Pete Davis

Entec UK Limited

17 Angel Gate
City Road
London EC1V 2SH
England
Tel: +44 (0) 207 843 1400
Fax: +44 (0) 207 843 1410

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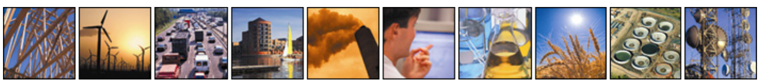

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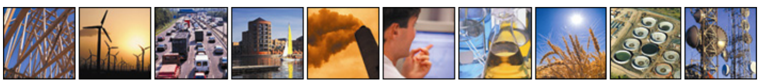


Glossary

AONB — **Area of Outstanding Natural Beauty** – Designated under the National Parks and Access to the Countryside Act 1949 to conserve and enhance beauty, including landscape, biodiversity, geodiversity and cultural heritage.

Backfill — A material used to fill voids in a geological disposal facility. Three types of backfill are recognised:

- **Local backfill**, which is emplaced to fill the free space between and around waste packages;
- **Peripheral backfill**, which is emplaced in disposal modules between waste and local backfill, and the near-field rock or access ways; and
- **Mass backfill,** which is the bulk material used to backfill the excavated volume apart from the disposal areas.

Bentonite — A highly sorbing clay material used as a backfill in certain disposal concepts.

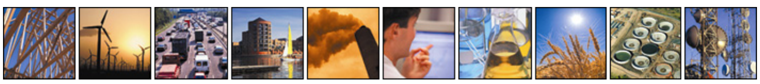
BERR — **Department for Business, Enterprise and Regulatory Reform** (now split between DECC and Department for Business, Innovation and Skills)

Borehole — The generalised term for any cylindrical excavation into the ground made by a drilling device for purposes such as site investigation, testing and monitoring.

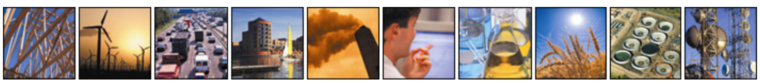
Buffer — Any substance placed around a waste package in a repository to serve as a barrier to restrict the access of groundwater to the waste package and to reduce by sorption and precipitation the rate of eventual migration of radionuclides from the waste.

Climate Change — Long-term change in average weather conditions and/or the frequency and nature of extreme weather events. May reflect natural variation and/or variation due to human activity.

CoRWM — **Committee on Radioactive Waste Management** – An independent body that provides scrutiny and advice to the UK Government on the long-term management of radioactive waste.



CO_2	**Carbon Dioxide –** A naturally occurring gas and also a by-product of burning fossil fuels and biomass, as well as other industrial processes. It is the most significant greenhouse gas.
DECC	**Department of Energy and Climate Change** (formed from elements of BERR and Defra) – the UK Government department responsible for all aspects of UK energy policy, and for tackling global climate change on behalf of the UK.
Defra	**Department for the Environment, Food and Rural Affairs** – the UK Government department responsible for policy and regulations on the environment, food and rural affairs.
Disposal Tunnel	Tunnel in which HLW, SF, Pu and HEU disposal canisters are placed for disposal.
Disposal Vault	Underground opening where ILW or LLW waste packages are emplaced.
Drift	An inclined tunnel, which would provide access to the underground facility.
DU	**Depleted Uranium –** Uranium with a lower concentration of uranium-235 that occurs naturally in uranium ore. It is a by-product of the uranium enrichment process.
EIA	**Environmental Impact Assessment –** A formal, statutory process for identifying the environmental effects (positive and negative) of proposed development projects before development consent is granted. The statutory requirement for Environmental Impact Assessment comes from Directive 85/337/EEC as amended by Directive 97/11/EC and Article 3 of Directive 2003/35/EC. When not strictly required under the terms of the directive and enabling UK legislation, may be undertaken on an informal basis.
Embodied carbon	The carbon emissions associated with embodied energy i.e. the total primary energy consumed during resource extraction, transport, manufacture and fabrication of a product.
Evaporite rock	These would typically comprise anhydrite (anhydrous calcium sulphate), halite (rock salt) or other evaporite rocks that result from the evaporation of water from water bodies containing dissolved salts).



Footprint — Indicates the area of host rock required to accept the inventory which is to be disposed of. As well as the inventory for disposal the footprint will be determined by properties of the host rock and the geometry of the features within it. It will also be influenced if disposal tunnels or vaults are able to be built on different levels.

GDF — **Geological Disposal Facility –** An engineered underground containment facility for disposing of radioactive waste, designed so that natural and man-made barriers work together to minimise the escape of radioactivity.

Geological disposal — Refers to the burial of radioactive waste deep inside a rock formation to ensure that no significant quantities of radioactivity ever reach the surface environment. The term "disposal" implies that there is no intention to retrieve the radioactive waste at some future date.

Geophysical survey — A survey using geophysical methods in order to gain information about the subsurface. Geophysical techniques include ground penetrating radar (radio), electrical resistivity, seismology and remote sensing.

HAW — **Higher Activity Waste –** A term used to describe HLW, ILW and a small fraction of LLW with a concentration of certain specific radionuclides. Also, SF, Pu and U that may be declared as waste in the future.

HEU — **Highly Enriched Uranium** – Uranium containing 20% or more of the isotope U-235.

HGV — **Heavy Goods Vehicle -** A vehicle used for the transport of goods that exceeds 3.5 tonnes.

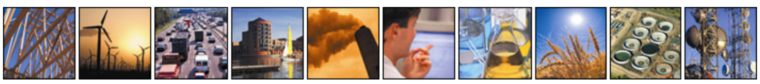
Higher strength rock — These would typically comprise crystalline igneous and metamorphic rocks or geologically older sedimentary rocks where any fluid movement is predominantly through discontinuities.

HLW — **High Level Waste –** Radioactive waste above 4 GBq per tonne of alpha or 12 GBq per tonne of beta/gamma activity which releases heat to the extent that it needs to be considered in the design of storage and disposal facilities.

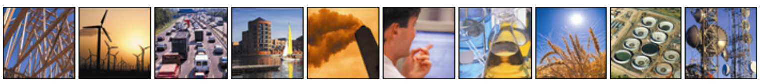
IAEA — **International Atomic Energy Agency** – The IAEA is the world´s center of cooperation in the nuclear field. It was set up as the world´s "Atoms for Peace" organization in 1957 within the United Nations family. The

	Agency works with its Member States and multiple partners worldwide to promote safe, secure and peaceful nuclear technologies.
ILW	**Intermediate Level Waste** – Radioactive waste exceeding the upper activity boundaries for LLW (above 4 GBq per tonne of alpha or 12 GBq per tonne of beta/gamma activity), but which does not generate sufficient levels of heat to require it to be factored into the design of storage and disposal facilities.
LLW	**Low Level Waste –** Radioactive waste having a radioactive content not exceeding 4 GBq per tonne of alpha activity or 12 GBq per tonne of beta/gamma activity.
Lower strength sedimentary rock	These would typically comprise geologically younger sedimentary rocks where any fluid movement is predominantly through the rock matrix.
MgO	**Magnesium Oxide –** Is a chemical compound comprising magnesium and oxygen. Sacks of MgO would be used as buffer material within the evaporite rock ILW/LLW vaults.
Minerals sterilisation	Sterilisation of a minerals resource, or a minerals reserve (where a site is covered by valid planning permissions for the extraction of minerals), occurs when other non-minerals development takes place on, or close to, mineral deposits, rendering them incapable of being extracted.
MRWS	**Managing Radioactive Waste Safely** – The UK Government programme for the long-term management of higher activity radioactive wastes. It is UK Government policy to manage such wastes in the long-term through geological disposal, coupled with safe and secure interim storage and ongoing research and development to support its optimised implementation.
NDA	**Nuclear Decommissioning Authority –** A non-departmental public body, established under the Energy Act 2004. The NDA is responsible for the decommissioning and clean-up of the UK's civil public sector nuclear sites. The NDA's sponsoring Government department is the Department for Energy and Climate Change (DECC). For some aspects of the NDA's functions in Scotland, the NDA is responsible to Scottish Ministers.
NPS	**National Policy Statement** – Policy statements produced by the Department of Energy and Climate Change (DECC), Department for Transport and the Department for Environment Food and Rural Affairs

	(Defra). They include the Government's objectives for the development of nationally significant infrastructure in a particular sector and state and include policies or circumstances that Ministers consider should be taken into account in decisions on infrastructure development. NPSs will also become material planning considerations for Local Planning Authorities (LPAs) when determining planning applications.
NRVB	**Nirex Reference Vault Backfill –** A specified mix of Portland cement, hydrated lime, limestone flour and water. NRVB may be used for backfilling higher strength rock and lower strength sedimentary rock ILW/LLW vaults.
NuLeAF	**Nuclear Legacy Advisory Forum** – An organisation set up to represent Local Government at a national level on issues of national nuclear waste management.
Pu	**Plutonium –** A radioactive element occurring in very small quantities in uranium ores but mainly produced artificially, including for the use in nuclear fuel, by neutron bombardment of uranium.
Ramsar Site	A site of international conservation importance designated under the Ramsar Convention (Convention on Wetlands of International Importance) 1971, to protect wetlands that are of international importance.
RIGS	**Regionally Important Geological Site –** A non-statutory designation for sites of geological or geomorphological importance in a regional / local context. Sites may be designated for educational, cultural, scientific or aesthetic reasons.
SA	**Sustainability Appraisal** – A systematic, iterative and consultative process to appraise the sustainability effects of a strategy, policy, plan or programme. Sustainability appraisal can include the requirements of the Strategic Environmental Assessment Directive.
SEA	**Strategic Environmental Assessment** – A formal, statutory process under the SEA Directive (2001/42/EEC) that incorporates environmental considerations into the development of plans and programmes likely to have significant environmental effects. When not strictly required under the terms of the Directive and enabling UK legislation, SEA may be undertaken on an informal basis.



SF	**Spent Fuel –** Radioactive fuel assemblies removed from a nuclear power reactor and treated either as radioactive waste or, via reprocessing, as a source of further radioactive materials for creating more fuel.
SPA	**Special Protection Area** – Sites classified under the European Community Directive on Wild Birds to protect internationally important bird species. Part of the Natura 2000 Network.
SSSI	**Site of Special Scientific Interest –** A statutory designation (under the Wildlife and Countryside Act, 1981) for the best wildlife and geological sites in the country.
SWMP	**Site Waste Management Plan –** A statutory requirement under the Site Waste Management Plans Regulations 2008, for all new construction projects with a contract value exceeding £300,000. Establishes how construction wastes can be reduced and site-gained materials can be re-used to minimise the amount of waste that has to be disposed of.
TMP	**Traffic Management Plan –** Sets out the details of measures to minimise the effects of changes in vehicle movements resulting from a development. It may include routing arrangements and times when delivery vehicles may access the site.
U	**Uranium –** A heavy, naturally occurring and weakly radioactive element, commercially extracted from uranium ores. Used as a fuel in nuclear reactors.



1. Introduction

This Non-Technical Summary summarises the findings of a generic (i.e. non-site-specific) Strategic Environmental Assessment (SEA) undertaken to inform the continuing development of a range of illustrative geological disposal concepts for higher activity radioactive wastes (HAW)[1].

The purpose of the assessment is to identify, characterise and assess the likely non-radiological environmental, social and economic effects that may arise at a generic level from implementing different illustrative geological disposal concepts in different geological settings (host rock types). Potential measures that could be used to mitigate adverse, or enhance beneficial effects, have been identified and outlined. These measures could be incorporated into future design iterations for a Geological Disposal Facility (GDF), or taken into consideration during future stages of the process for site selection.

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[1] Higher activity radioactive wastes (HAW) consist of certain Low Level Wastes (LLW) that are not suitable for alternative disposal, Intermediate Level Waste (ILW) and High Level Waste (HLW), and materials not currently declared as waste that may require geological disposal in the future, e.g. Plutonium (Pu), Uranium (U) and Spent Fuel (SF).

2. Background

2.1 Managing Radioactive Waste Safely

In 2001 the UK Government and devolved administrations[2] initiated the Managing Radioactive Waste Safely (MRWS) programme with the aim of finding a practicable solution for the UK's HAW that:

- Achieved long-term protection of people and the environment;
- Did this in an open and transparent way that inspired public confidence;
- Was based on sound science; and
- Ensured the effective use of public monies.

In October 2006, following recommendations made by the independent Committee on Radioactive Waste Management (CoRWM) [1], the UK Government and devolved administrations accepted CoRWM's recommendations that geological disposal, preceded by safe and secure interim storage, was the best approach for the long-term management of HAW.

In June 2008, following an extensive consultation process, the Government published a White Paper setting out a framework for implementing geological disposal [2].

2.2 The Managing Radioactive Waste Safely site selection process

The MRWS White Paper [2] sets out a six stage approach for selecting a site and implementing a GDF (**Figure 2.1**). The UK Government is using a voluntarism and partnership approach to implement geological disposal. This is an approach in which communities voluntarily express an interest in taking part in the site selection process that will ultimately provide a site(s) for geological disposal. The White Paper also identifies the Nuclear Decommissioning Authority (NDA) as the implementing organisation responsible for planning and delivering a GDF. The NDA has set up the Radioactive Waste Management Directorate (RWMD) to develop an effective delivery organisation to implement a safe, sustainable and publicly acceptable geological disposal programme.

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[2] UK Government in this context means the Department for Environment, Food and Rural Affairs (Defra) and the Department for Business, Enterprise and Regulatory Reform (BERR). Some elements of Defra and BERR have been brought together in the Department of Energy and Climate Change (DECC). The Devolved Administrations are the Welsh Assembly Government and the Department of the Environment Northern Ireland. The Scottish Government supports long-term, near surface, near site storage and disposal facilities for higher activity radioactive wastes and therefore did not sponsor the MRWS White Paper.

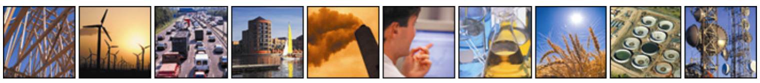
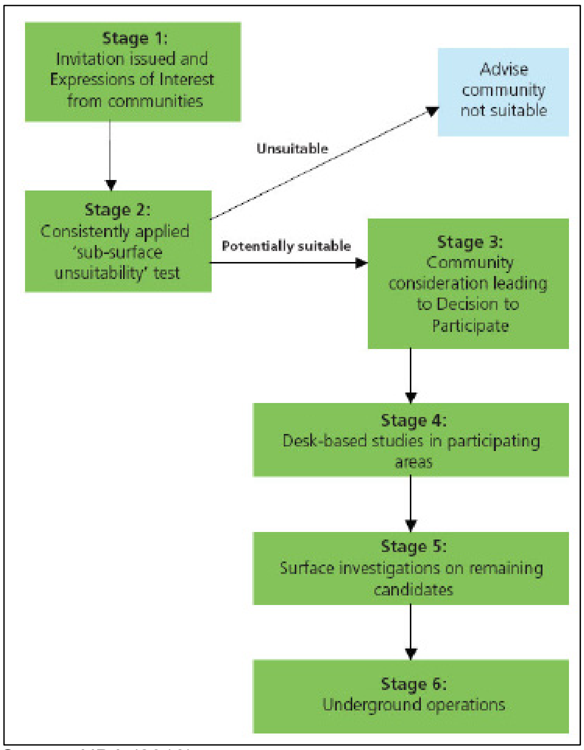


Figure 2.1 Managing Radioactive Waste Safely site selection process



Source: NDA (2010)

During the current Stages 1, 2 and 3 of the MRWS site selection process, the NDA is supporting the UK Government and local communities as they consider expressing an interest and taking a decision to participate in the site selection process. The NDA is also developing illustrative geological disposal concepts that could be suitable for the UK and is assessing their potential effects should they be implemented.

Participating communities whose areas have not been screened out by subsurface criteria and who wish to continue their involvement will be carried forward to Stage 4. The UK Government would then ask the NDA to undertake further investigations in these communities to evaluate their potential suitability for hosting a GDF and to assess the potential impacts of building a GDF in the area.

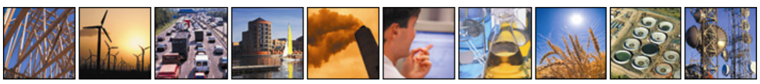
At the end of Stage 4 the local community and decision making bodies would consider whether to proceed to the next stage, and the Government would then make an informed decision on one or more candidate site(s) to take forward to Stage 5.

During Stage 5 of the site selection process the NDA would undertake more detailed studies and assessments of the remaining candidate sites. These would involve surface-based investigations which would include boreholes and regional surveys. At the end of Stage 5 the local community and decision making bodies would consider whether to proceed to the next stage, and the Government would then make an informed decision on a preferred site. The NDA would then apply for planning permission to implement a GDF at the preferred site during Stage 6.

2.3 Illustrative geological disposal concepts

There is a range of geological environments in the UK that could be suitable for constructing a GDF. There is also a range of geological disposal concepts, being studied and developed in the UK and internationally, that could provide safe and secure geological disposal of HAW within this range of geological settings. At this stage the NDA is examining a wide range of potentially suitable geological disposal concepts so that a well informed assessment of options can be carried out at appropriate decision points in the implementation programme. Drawing from this work, illustrative geological disposal concepts for each of three generic geological settings (host rock types) are being developed and used to:

- Further develop understanding of the functional and technical requirements of the disposal system;



- Further develop understanding of the design requirements;
- Support the scoping and assessment of the safety, environmental, social and economic impacts of a GDF;
- Support development and prioritisation of the NDA's research and development programme;
- Underpin analysis of the potential cost of geological disposal; and
- Support assessment of the disposability of waste packages proposed by waste owners.

The NDA is developing illustrative geological disposal concepts solely for these purposes. It is not intended that one of these concepts is necessarily going to be implemented. At this stage, no geological disposal concept has been ruled out.

The three geological settings (or host rock types) are:

- Higher strength rock;
- Lower strength sedimentary rock; and
- Evaporite rock.

In order to develop illustrative geological disposal concepts, a number of assumptions have been made about host rock types, the layout of a GDF and how a GDF programme would be implemented. These assumptions are purely for planning purposes and to enable designs to be developed. They do not pre-empt the outcomes of the MRWS site selection process. The NDA has produced a draft report entitled *'Geological Disposal – Generic disposal facility designs'*, which details illustrative geological disposal concepts for each generic host rock type [3]. The work which has been undertaken by RWMD in relation to site investigation has been published in a number of reports [10] [11] [12] [13] [14].

Geological disposal concept development has also considered a number of waste inventories. The generic SEA has considered the "Derived Inventory Reference Case excluding Pu/U" and the "Derived Inventory Upper Inventory"[3] which have been taken to represent the likely minimum and maximum volumes of waste for disposal, although it is accepted that neither scenario is a bounding case.

Key differences between the assumptions made for different host rock types are: the size of an underground facility footprint; the volume of host rock to be excavated and its subsequent use; the material needed for buffering

[3] The radioactive waste inventories have been derived from radioactive waste stream data in the UK Baseline Inventory detailed in the MRWS White Paper [2] and the 2007 UK Radioactive Waste Inventory [4], to provide packaged volumes to inform GDF design requirements.

emplaced waste containers; and the material needed for backfilling disposal areas. **Table 2.1** provides a summary of the key design specifications for the illustrative geological disposal concepts for each host rock type from the NDA report on Generic disposal facility design [3], which have been used to inform the assessment. Illustrations of these concepts are provided in **Appendix A**.

Table 2.1 Summary description of the illustrative geological disposal concept specifications for each host rock type

Description	Higher strength rock	Lower strength sedimentary rock	Evaporite rock
Assumed host rock type	Crystalline igneous and metamorphic rocks or geologically older sedimentary rocks, overlain by a permeable sedimentary rock	Geologically younger sedimentary rocks with high clay content, overlain by a permeable sedimentary rock	Anhydrite (anhydrous calcium sulphate), halite (rock salt) or other evaporites that result from the evaporation of water from waterbodies containing dissolved salts, overlain by a permeable sedimentary rock
Surface facility footprint	1.1 square kilometres (km^2) for both the Derived Inventory Reference Case excluding Pu/U and Derived Inventory Upper Inventory	1.1km^2 for both the Derived Inventory Reference Case excluding Pu/U and Derived Inventory Upper Inventory	0.5 - 1.1km^2 for both the Derived Inventory Reference Case excluding Pu/U and Derived Inventory Upper Inventory
Underground facility depth	650 metres (m) (assumed to be between 200m and 1000m)	500m (assumed to be between 200m and 1000m)	650m (assumed to be between 200m and 1000m)
Underground facility footprint	4.3km^2 for the Derived Inventory Reference Case excluding Pu/U 9.8km^2 for the Derived Inventory Upper Inventory	7.8km^2 for the Derived Inventory Reference Case excluding Pu/U 19.5km^2 for the Derived Inventory Upper Inventory	6.5km^2 for the Derived Inventory Reference Case excluding Pu/U 18.4km^2 for the Derived Inventory Upper Inventory
Excavation methods	Drill and blast	Combination of tunnel boring machine, road header and drill & blast	Continuous miner and/or road header
Underground accesses	1 drift and 3 shafts	1 drift and 3 shafts	4 shafts
ILW/LLW vault buffer material	Nirex Reference Vault Backfill (NRVB)	NRVB	Sacks of Magnesium Oxide (MgO) to be placed on top of waste as progressively placed
ILW/LLW vault backfill material	NRVB	NRVB	Due to the nature of the host rock no backfill material would be required
HLW/SF buffer material	Bentonite	Bentonite	Crushed rock salt
HLW/SF disposal tunnel backfill material	Crushed rock and bentonite	Bentonite	Crushed rock salt
Waste disposal area backfilling programme	ILW/LLW vaults backfilled once all ILW/LLW is placed in the GDF. HLW/SF disposal tunnels backfilled as each tunnel is filled.	ILW vaults and HLW/SF disposal tunnels backfilled as each vault/tunnel is filled.	Due to the nature of the host rock there would not be a need to backfill ILW/LLW vaults. HLW/SF disposal tunnels backfilled as each tunnel is filled.
Mass backfill material	Crushed rock	Bentonite and sand	Crushed rock salt

Source: NDA (2010) [3]

A summary of the estimated excavated rock arisings (including the use of excavated rock on site) and buffer/backfill requirements for the different host rock types, based on the information provided in the NDA report on Generic disposal facility design [3], is provided in **Table 2.2**.

It should be noted that storage and use of rock excavated from the construction of underground facilities would vary. With the exception of the evaporite rock type, a proportion of the host rock excavated from the construction of underground facilities would be stored on site in surface bunds. For the evaporite rock type, none of the excavated rock would be suitable for surface bunding or for landscaping. However, as excavated evaporite rock would be required for backfilling, a dedicated and appropriately designed storage area would be required somewhere on site.

For the higher strength and evaporite host rock types, the excavated rock would also meet backfilling requirements for HLW/SF disposal tunnels during the operational phase and for the backfilling of the access tunnels (drift and/or shafts) and common service areas during the closure phase, negating the need to import any crushed rock for this purpose. The lower strength sedimentary rock would not be suitable for backfilling and therefore all backfill material would need to be imported.

Box 1 – Assessment assumptions and uncertainties
Some aspects of our generic assessment work are presented quantitatively, in the form of relatively precise figures. However, this precision should not be taken to reflect a high degree of certainty or accuracy. At this very early stage in the geological disposal programme there are inevitably many uncertainties, and as a result we have made many assumptions. As our work progresses more information will become available and in some areas these uncertainties will be resolved. The quantitative information presented in this report should be seen as illustrative. Figures quoted are often the direct output of design and modelling work based on our current assumptions and are therefore presented with a relatively high level of precision. Working in this way allows us to develop a better understanding of geological disposal and to better focus our future work. A discussion of some of the uncertainties inherent in our current work can be found in **Section 3.5**.

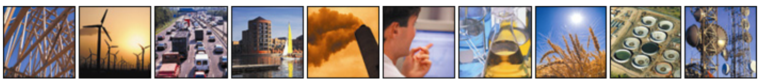


Table 2.2 Summary of excavated rock and buffer/backfill assumptions for the illustrative geological disposal concepts

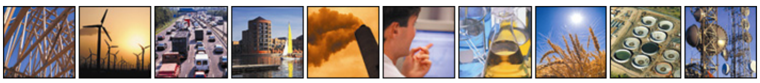
Quantity assumptions (m^3)		Derived Inventory Reference Case excluding Pu/U			Derived Inventory Upper Inventory		
		Higher strength rock	Lower strength sedimentary rock	Evaporite rock	Higher strength rock	Lower strength sedimentary rock	Evaporite rock
Excavated Rock		5,225,000	4,820,000	4,273,000	13,800,000	11,775,000	11,366,000
Stored on site/in bunds (maximum volume)		3,589,000	3,589,000	1,172,121	3,589,000	3,589,000	2,816,121
ILW/LLW vault and HLW/SF disposal tunnel buffer/backfill requirements	Bentonite	714,000	257,000	n/a	1,946,000	731,000	n/a
	NRVB	1,000,000	1,050,000	n/a	2,300,000	2,540,000	n/a
	Excavated crushed rock	1,190,000	n/a	872,000	3,010,000	n/a	2,516,000
	MgO	n/a	n/a	144,000	n/a	n/a	356,000
Underground access (drift and/or shaft) mass backfill requirements	Excavated crushed rock	263,771	n/a	191,314	263,771	n/a	191,314
	Bentonite and sand (30:70) mix	n/a	126,660	n/a	n/a	126,660	n/a
Common services area mass backfill requirements	Excavated crushed rock	296,308	n/a	108,807	296,308	n/a	108,807
	Bentonite and sand (30:70) mix	n/a	73,749	n/a	n/a	73,749	n/a
Surplus excavated rock removal off-site		None*	1,231,000	3,100,879	6,640,921	8,186,000	8,549,879
Material imports (Bentonite, NRVB, MgO, and sand)		2,444,000	1,307,000	144,000	6,246,000	3,271,000	356,000

Please note:

Buffer/backfill materials differ for the different host rock types (refer to the assumptions in **Table 2.1**). It is assumed that crushed rock backfilling requirements for the higher strength rock and evaporite rock types could be met using excavated rock from the construction of the underground facilities and therefore the quantities of crushed rock required are not included in the materials import total.

*For the higher strength rock Derived Inventory Reference Case excluding Pu/U all excavated higher strength rock would be stored on-site, in the form of surface bunds, and used for backfilling. Therefore none of the excavated rock would need to be transported off-site.

Source: NDA (2010)



For the purposes of the assessment it is assumed that any of these illustrative geological disposal concepts would be implemented in four phases as outlined in **Table 2.3**:

Table 2.3 Phases of GDF implementation

Phases of GDF implementation

Surface-based site investigations:

Initially a range of detailed surface and sub-surface investigations would be undertaken to gather information on the environment. This information would assist with the selection of a suitable site and design. For the purposes of this assessment it is assumed that the site investigations works would involve:

- ***Regional surveys*** – airborne and satellite surveys, geophysical surveys and surface mapping over a 1 year period).
- ***Deep borehole construction*** – the construction of 20 deep boreholes (>1,000m) and 50 shallow (<100m) boreholes at two candidate sites (each approximately 50km^2 in size) over an 8 year period;
- ***Post-completion testing*** – testing of boreholes to address any significant remaining uncertainties, over a 4 year period; and
- ***Baseline monitoring*** (the final stage) – groundwater monitoring for a period of 2 years to establish existing (baseline) conditions.

The site investigations would take place over a period of some 10 years (with substantial overlap of the different activities anticipated).

Construction

A GDF would consist of surface buildings and infrastructure, an access road, rail infrastructure, underground accesses (a drift and/or several shafts), underground waste disposal areas (ILW/LLW vaults and HLW/SF disposal tunnels) and underground service area, connected by a network of underground roads.

Initial construction would take some 10 years, during which time the underground accesses would be constructed as well as the first underground waste disposal areas. Thereafter the waste disposal areas would be constructed as required.

Operation

Following initial construction, a GDF would enter the operational phase. The key activities during operation would be the ongoing construction of the waste disposal areas as required, the emplacement of the radioactive waste, and the backfilling of the waste disposal areas.

Depending on the host rock type, some waste disposal areas would be backfilled when they are full of waste, and some would remain open until all of the waste had been received. The emplacement of radioactive waste has been assumed to begin in 2040; ILW/LLW waste disposal would commence from 2040; HLW/SF disposal in 2075; and Pu/U disposal in ~2136.

Two radioactive waste inventories have been considered for disposal in a GDF:

- **The Derived Inventory Reference Case excluding Pu/U** (**396,144m^3** of packaged waste); and
- **The Derived Inventory Upper Inventory** (**970,675m^3** of packaged waste).

Closure and post-closure

On completion of waste emplacement, and following a period of maintenance and monitoring, it is assumed that the operators of a GDF, in consultation with the candidate community, would seal and close the underground facility, and decommission the surface facilities and infrastructure. This would take place over a period of some 10 years. The site would then be restored to an agreed end state. It is assumed that the only structures remaining on site would be any surface bunds.

At the time of closure, it is assumed for the purposes of the assessment that the waste disposal areas would have been backfilled and/or sealed and therefore it would be necessary to progressively backfill the remaining underground roadways, facilities (workshops etc), and access tunnels (drift and/or shafts).

Source: NDA (2010)

A range of transport modes and combinations of those modes are being considered by the NDA to transport the materials required to construct a GDF and transport radioactive waste for geological disposal, including rail, road and sea. For the purposes of the assessment, for all host rock types two transport scenarios for the transport of radioactive wastes have been considered; 'Road/Rail' and 'Sea/Road/Rail'. For the Road/Rail scenario, it is assumed that 70% of the radioactive waste would be transported to the site by rail, with the remaining 30% transported by road. For the Sea/Road/Rail scenario, it is assumed that 80% of the radioactive waste would be transported to the site via ship, with the remaining 10% by road and 10% by rail from the port to the site. The transport, and associated carbon assumptions used for the assessment are those used in the carbon footprint report [6], produced alongside the generic SEA.

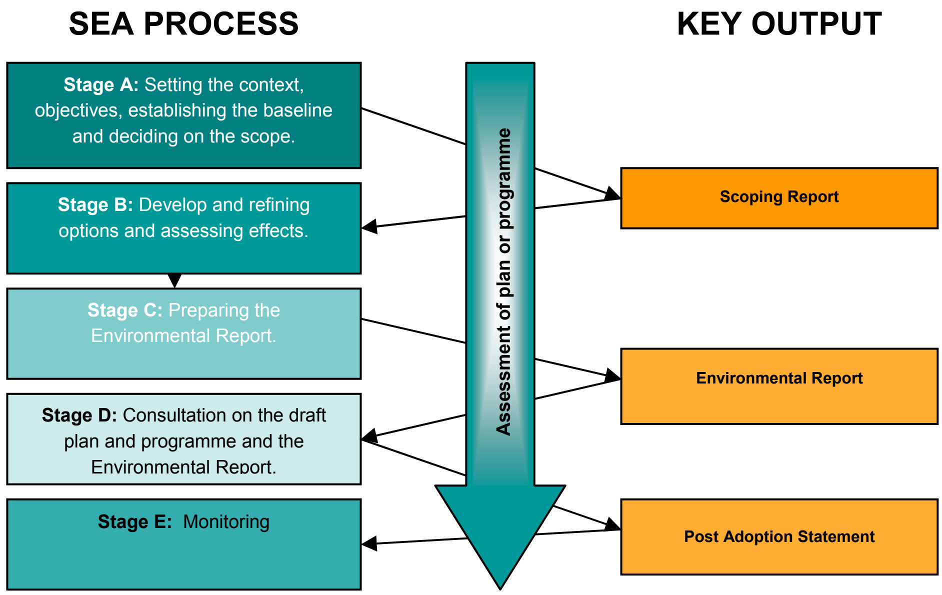
2.4 Strategic Environmental Assessment

SEA became a statutory requirement following the adoption of the European Union's Directive 2001/42/EC on the assessment of the effects of certain plans and programmes on the environment [5]. This was transposed into UK legislation on the 20th July 2004 as *Statutory Instrument No. 1633 – The Environmental Assessment of Plans and Programmes Regulations 2004*. The objective of the SEA Directive is:

> "*to provide for a high level of protection of the environment and to contribute to the integration of environmental considerations into the preparation and adoption of plans and programmes with a view to contributing to sustainable development*."

Throughout the course of the development of a plan or programme, the aim of the SEA is to identify the associated environmental effects of implementing the plan or programme, to propose measures to avoid, manage or mitigate any significant adverse effects and to enhance any beneficial effects. The main stages of the SEA process are highlighted in **Figure 2.2**.

Figure 2.2 Outline of the Strategic Environmental Assessment process



Source: Entec (2010)

The NDA's proposed approach to SEA for the GDF programme is set out in its published *'Strategy for Sustainability Appraisal and Environmental Assessment'* [6]. The Strategy includes a commitment to meet the requirements of the SEA Directive [5] and transposing regulations. It also states that the SEA will cover environmental, social and economic considerations and will be presented in an 'Environmental and Sustainability Report'.

The relationship between the environmental (and socio-economic) assessment process and the site selection process is outlined in **Figure 2.3**.

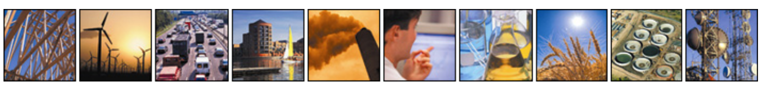
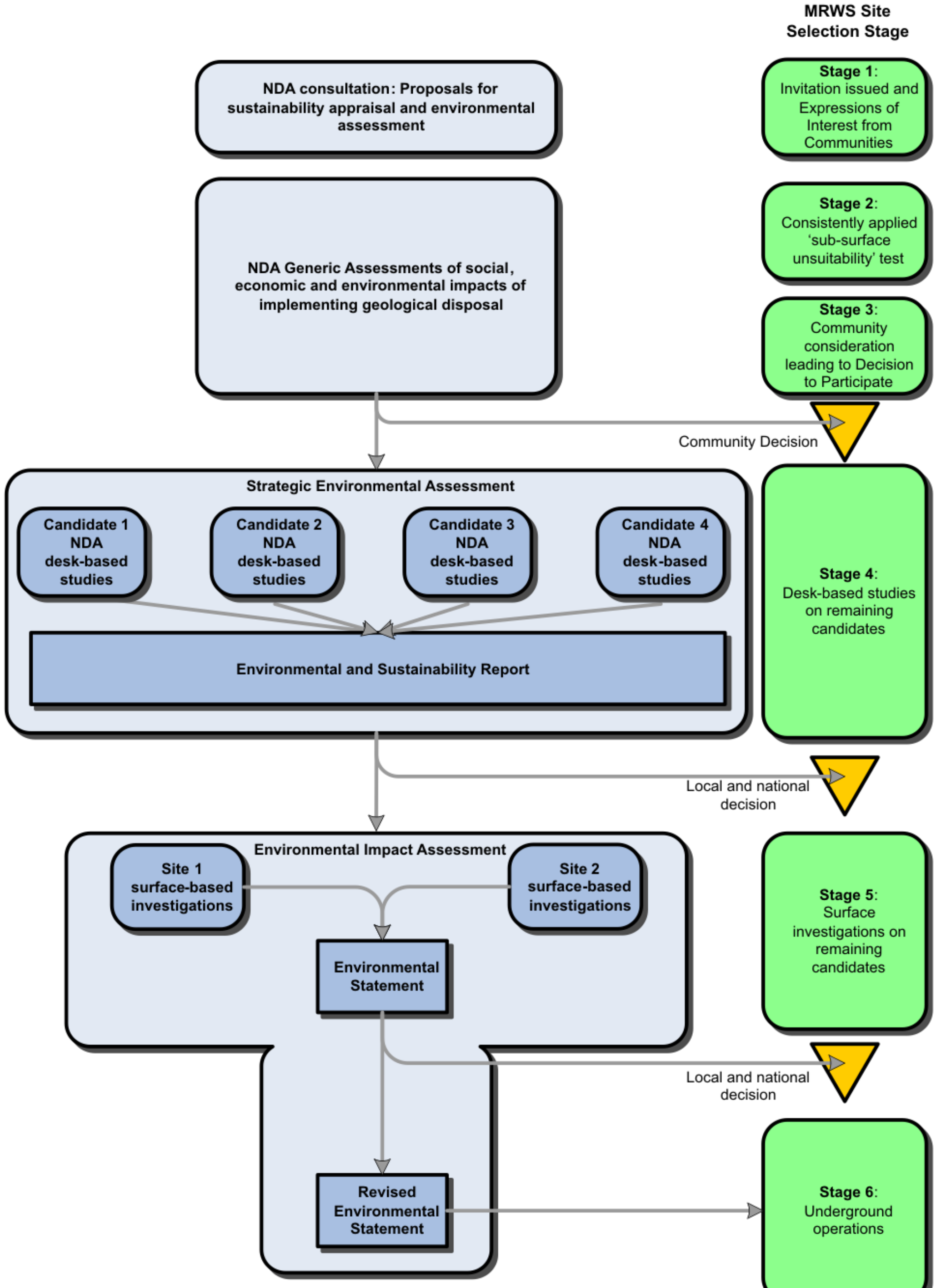


Figure 2.3 Overview of Managing Radioactive Waste Safely assessments



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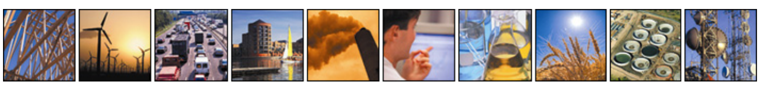
Source: NDA (2010)



The SEA (and subsequent Environmental Impact Assessments) would be developed iteratively with design development for a GDF. The results of the assessments would be fed into the development of the designs to enable any adverse environmental, social and economic impacts to be designed out or mitigated where possible.

2.4.1 Generic Strategic Environmental Assessment of the illustrative geological disposal concepts

At Stage 3 of the MRWS Site Selection Process (refer to **Figure 2.1**) and as outlined in the *'Strategy for Sustainability Appraisal and Environmental Assessment'* [6], the NDA committed to complete a generic (i.e. not site-specific) SEA of the illustrative geological disposal concepts. The generic SEA is the subject of this Non-Technical Summary.

The findings of the generic SEA will be used to influence the development of geological disposal concepts and to provide information on potential non-radiological effects to communities that have expressed an interest (or are considering expressing an interest) in participating in the site selection process and in hosting a GDF.

The generic SEA and this Non-Technical Summary are not part of a formal, statutory assessment process. In consequence, while some aspects of the generic SEA work summarised in this report are in line with the UK SEA Regulations, the work and this Non-Technical Summary do not seek to be fully compliant with statutory requirements.

A formal, statutory SEA will be undertaken following a community decision to participate in the site selection process. It is anticipated that such an assessment would build on the work of the generic SEA, using the potential effects that have been identified and assessed to inform the scope of the work.

The potential radiological effects of implementing a GDF are being considered as part of a Generic Disposal System Safety Case [7] which is being developed for the disposal facility programme. The NDA is in the process of producing a comprehensive suite of documents underpinning the safety case which will describe potential radiological (and associated chemo-toxic) effects associated with the packaging and transport of radioactive waste, the conduct of construction and operations at a GDF (including non-radiological safety), the eventual closure of a disposal facility and the longer-term post-closure phase. The assessments in the generic SEA do not seek to duplicate the safety case work. During future stages of the programme, radiological issues would be incorporated into the environmental and socio-economic assessment work.

3. Methodology

The following subsections set out the information used to provide the context for the assessment and the sustainability objectives that have been used to assess the illustrative geological disposal concepts, and details how the assessment has been undertaken and the effects recorded.

3.1 Review of plans and programmes

As part of the assessment process, a review of 128 international, European, and national and regional plans, programmes, strategies and policies considered relevant to geological disposal has been undertaken.

The plans and programmes follow a hierarchal order with international and European documents providing a more strategic context under which national and regional documents set more specific aims relevant to the spatial area they cover. The majority of plans and programmes relate to nuclear issues (e.g. the International Atomic Energy Agency Convention on the safety of spent fuel management and on the safety of radioactive waste management), the promotion of sustainability (e.g. the United Nations World summit on sustainable development and Defra's Securing the future - the UK Government sustainable development strategy), or specific environmental issues such as climate change, biodiversity, air and water quality, historic environment and waste.

The review highlighted the main aims and objectives of the documents as well as any specifically relevant targets contained within them. The findings of the review informed the development of the assessment framework by ensuring that the issues covered by the plans and programmes were adequately covered within the sustainability objectives and supporting guide questions. As the sustainability objectives have been used to assess the potential effects of the illustrative geological disposal concepts, the relationship with, and effects on, the plans and programmes have also been considered.

3.2 Baseline information

Relevant information on the existing environment (baseline information) has been collected to inform the assessment. As the potential location of a GDF is unknown at present, the amount of baseline information that is relevant and can be meaningfully collected for consideration in the assessment is constrained (i.e. it would be impractical to collect project level information for the whole country at this stage). While a wide range of environmental and socio-economic issues have been considered, due to the activities and scale of works associated with a GDF the key issues are anticipated to be:

- **Landscape and visual –** Many of the UK's nuclear facilities (the sources of HAW to be emplaced in a GDF) are situated in relatively rural locations. There are a number of designated landscape areas (Areas of Outstanding Natural Beauty and National Parks) throughout the UK, some in relatively close proximity to nuclear facilities. The excavation of rock for the underground elements of a GDF would probably affect landscape and visual receptors, as would the construction of surface facilities and infrastructure.

- **Geology and soils –** A GDF would require the excavation of large volumes of rock and would result in the displacement of top-soils associated with the surface facilities and infrastructure.

- **Water –** Some river basin areas have less than good water quality status, both in terms of chemical quality and biological quality. Groundwater resources are also under pressure in some areas. Water resources may be required during the lifetime of the project and water quality may be affected by activities on site, such as through the migration of contaminants.

- **Ecology and nature conservation/biodiversity –** The UK contains a number of internationally important habitats supporting internationally important plant and animal species. Some 3% of the UK land area is designated as Ramsar sites and over 6% is designated as Special Protection Areas (SPA). In addition, there are more than 5,000 Sites of Special Scientific Interest (SSSI). A GDF could have an effect on such ecological receptors.

- **Traffic and transport –** There is an established road and rail infrastructure in the UK that handles 150 billion tonne kilometres and 50 billion tonne kilometres of freight by road and rail respectively. The movement of wastes to and from a GDF during construction and operation (including radioactive wastes for emplacement), construction traffic movements and staff movements may all have an effect on the traffic and transport network.

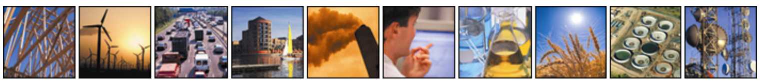
- **Waste –** The NDA is anticipated to generate some $3,000,000m^3$ of waste during decommissioning. The UK Government's policy is that a GDF is the preferred option for long-term management of some of this waste. The construction, operation and closure of a GDF may also generate (non-radioactive) wastes.

3.3 Sustainability themes and assessment objectives

Building on the analysis of plans and programmes and the review of relevant baseline information, sustainability themes, objectives and guide questions have been developed to facilitate the assessment. These are set out in **Table 3.1**.

Table 3.1 Sustainability themes, objectives and guide questions

Sustainability theme and objective	Guide questions
1. Policies and Planning: Fulfil Government policy and meet the requirements of applicable international and national legislation.	▪ Will the activities contribute towards fulfilling Government policies on sustainable development? ▪ Will the activities follow guidance set out in the national policy framework for development (i.e. Planning Policy Statement series)? ▪ Will the activities achieve the necessary requirements set out in international legislation and policy (i.e. EU directive)?
2. Landscape and Visual: Maintain and enhance the quality and character of the landscape and townscape, and minimise visual effects and light pollution.	▪ How extensive will the land take requirements be? ▪ Will there be an introduction of new landscape and visual features or elements?
3. Cultural Heritage: Minimise detrimental effects on heritage assets and seek to enhance the recording, conservation and preservation of assets and their settings.	▪ Will there be the potential to affect sub-surface archaeology? ▪ Will there be the potential to affect surface archaeology? ▪ Will there be the potential to affect the setting of listed buildings? ▪ Will there be the potential to affect traditional activities?
4. Geology and Soils: Reduce contamination and safeguard soil quality and quantity. Where land is affected by contamination, remediate to a condition suitable for use.	▪ Will there be a loss of soil reserves? ▪ Will there be a deterioration of soil quality? ▪ Will there be a change in the soil erosion regime? ▪ Will there be a change in the geological erosion regime?
5. Water: Maintain and enhance water quality, minimise abstraction to conserve resources at sustainable levels. Reduce the risk of flooding.	▪ Will there be an increase/decrease in water abstraction? ▪ Will there be a change in the quality of surface water or ground water? ▪ Will there be a potential to increase the levels of flood risk?
6. Ecology and Nature Conservation / Biodiversity: Protect, enhance and promote natural biodiversity and habitats and avoid their fragmentation.	▪ Will the activities have an effect on wildlife or habitats? ▪ Will the need for additional infrastructure lead to a fragmentation of habitats or affect wildlife?
7. Traffic and Transport: Reduce the need to travel, particularly by car or lorry, and reduce the levels of road congestion maintaining and improving, where appropriate, travel facilities and choices.	▪ Will there be a change in the sources, levels and types or road traffic generated? ▪ Will there be a change in the sources, levels and types of rail traffic? ▪ Will there be a change in the sources, levels and types of maritime traffic? ▪ Will there be any effects on the national transport network? ▪ Will there be any affects from additional transport infrastructure?
8. Air Quality: Minimise the emission of pollutants and enhance air quality to exceed statutory levels where possible.	▪ Will there be a change in the key types of and sources of pollutants emitted? ▪ Will there be a change in the key sources of dust generated?
9. Climate Change: Minimise greenhouse gas emission, encourage adaptability to climate change and encourage the use of low carbon technology. Increase the proportion of energy generated from renewable sources.	▪ Will there be a change in emissions of greenhouse gases? ▪ To what extent will the potential consequences of climate change be mitigated against? ▪ Will there be a change in the levels of energy consumed? ▪ Will energy be supplied from renewable sources?
10. Noise and Vibration: Minimise noise pollution and the effects of vibration.	▪ Will there be a change in the sources and levels of noise generated? ▪ Will there be a change in the sources and levels of vibration generated?

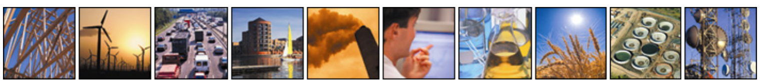


Sustainability theme and objective	Guide questions
11. Land Use: Minimise consumption of, and reduce damage to, undeveloped land and agricultural holdings through re-use of previously developed land and existing buildings.	▪ Will land be required? ▪ Will there be a change in existing land use patterns?
12. Socio-economics: Maximise access for all to opportunities for rewarding employment, education and skills training. Encourage a strong, diverse and stable economy.	▪ Will there be a change in employment opportunities? ▪ Will there be a change in the employment profile? ▪ Will there be a change in the demographic profile? ▪ Will there be a change in the demand for housing? ▪ Will there be a change in the level of qualifications and skills available in the area? ▪ Will there be a change in the use of recreational facilities? ▪ Will there be a change in the quality of life? ▪ Will there be a change in the levels of deprivation? ▪ Will there be a change in the demand for General Practitioners, dentists and schools etc?
13. Health and Well-being: Protect and promote human health and well-being through healthy lifestyles and healthcare provision. Create conditions to improve health and reduce health inequalities.	▪ Will there be a change in the levels of health of the population? ▪ Will there be a change in the levels of health of workers or contractors? ▪ Will there be a change in the levels of crime? ▪ Will there be a change in the fear of crime? ▪ Will there be a change in well-being and health inequalities?
14. Safety: Promote safe working practices that minimise the risk of accidents or hazards to workers, contractors or the local community.	▪ Will there be a change in the types of hazards associated with the activities? ▪ Will there be a change in the accident rates on site? ▪ Will there be a change in the risk to workers or contractors? ▪ Will there be a change in the transport accidents rates? ▪ Will there be a change in the risk to the local population?
15. Waste: Minimise the generation of waste and promote the application and adherence to the waste management hierarchy.	▪ Will there be a change in the amount of sewage to be disposed? ▪ Will there be a change in the type and levels of waste generated? ▪ Will waste be managed in accordance with the waste hierarchy (reduction, re-use, recycling and compositing, recovery of energy, and disposal)?
16. Resource Use, Utilities and Services: Encourage and promote the efficient use of resources (materials, aggregates, metal).	▪ Will materials/equipment be sourced locally? ▪ Will there be a change in the quantities of resource use? ▪ Will materials be required for additional infrastructure?

3.4 Assessing effects

The assessment considers the extent to which implementation of the illustrative geological disposal concepts would contribute towards the achievement of the objectives, relative to the baseline situation, as listed in **Table 3.1**. It considers each phase of implementation and the different host rock types and waste inventories as outlined above.

The completion of the assessment against the sustainability objectives is also supported by the use of the 'guide questions' that ensure that full consideration is given to specific issues and the various factors that can influence an objective. Guide questions help provide the detailed assessment framework. As 'guide questions', it is not



intended that they are answered individually or consistently, rather they serve as a guide to the types of issues that may need to be considered to ensure a comprehensive assessment of the potential effects is made. For example, the guide questions for sustainability theme 3 (Cultural Heritage), prompt consideration of surface and subsurface archaeology, listed buildings and traditional activities.

A six point qualitative scoring system has been used to assess the effects of the illustrative geological disposal concepts which provides an indication of the magnitude of the effects predicted (**Table 3.2**).

Table 3.2 Qualitative scoring system

Score	Description	Symbol
Major positive effect	The illustrative geological disposal concept contributes significantly to the achievement of the objective,	++
Minor positive effect	The illustrative geological disposal concept contributes to the achievement of the objective but not significantly.	+
Neutral / negligible	The illustrative geological disposal concept does not have any positive or negative effects on the achievement of the objective.	0
Minor negative effect	The illustrative geological disposal concept detracts from the achievement of the objective but not significantly	-
Major negative effect	The illustrative geological disposal concept detracts significantly from the achievement of the objective.	- -
Uncertain	The illustrative geological disposal concept has an uncertain relationship with the objective or the relationship is dependant on the way in which the aspect is managed. In addition, insufficient information may be available to enable an assessment to be made.	?

The assessment has then been recorded in an assessment matrix, structured according to the sustainability themes that cover each objective.

3.5 Uncertainties

At this stage there are inevitable uncertainties about the location, siting and design of a GDF. The following site dependant uncertainties have been identified prior to completing the assessment of the illustrative geological disposal concepts for the different host rock types as they are dependent on site location and more detailed design information, which is not known at this stage:

- The cultural heritage value of the site and its surrounds.
- The location of the site in relation to water, floodplains and flood sensitive areas.
- The biodiversity value of the site and its surrounds.

- The proposed transport method for construction materials, machinery and any construction wastes.
- The location of the site in relation to strategic and local road networks, and sensitive receptors such as houses and schools.
- The local air quality of the site and its surrounds.
- The land use value of the site and its surrounds.
- The nature of the local economy and employment.
- The nature, duration and value of any community benefits package agreed as part of the implementation of a GDF.
- The quantities of waste arising and proposed waste management methods (e.g. the extent of re-use and recycling).
- The quantities of backfill material required for backfilling the remaining underground roadways and facilities are not available at this stage. Estimates are provided for certain areas. Consequently it is unknown whether crushed rock backfill requirements for this purpose could be met on site using the excavated rock from the construction of the underground facilities.
- The quantities of resources, utilities and services required are not available at this stage.
- The potential effects of climate change on the environment (particularly in relation to water resources and quality, flooding, erosion, biodiversity and socio-economics) are uncertain at this stage.

Due to these uncertainties, it has not been possible to assess the illustrative geological disposal concepts against all of the relevant guide questions at this stage, since there is not enough information to make a meaningful assessment. Where guide questions have not been addressed, or the effect is uncertain due to the lack of site-specific information, these will be the subject of further study during Stage 4 of the MRWS site selection process and future assessments of geological disposal concepts. Taking this into account, it should be noted that clarification of the uncertainties is likely to have an effect on the final outcome of the assessment.

The uncertainties regarding the location of a GDF also make considering the cumulative effects of implementation, in conjunction with other nationally or regionally significant infrastructure plans or programmes, difficult. A range of nationally significant infrastructure schemes is anticipated in the draft National Policy Statements (NPSs) being developed for energy, waste, transport and water infrastructure; however, many of the draft NPSs are non-locational and generic in nature. Exceptions to this include the new nuclear power generation NPS [8], which identifies 11 potential sites that could be suitable for the construction of new nuclear power stations by the end of 2025. The combination of a GDF in proximity to a new nuclear power station may give rise to a number of cumulative effects, such as increases in traffic movements, disturbance to biodiversity and fragmentation of habitats, changes to the landscape as well as changes to noise, air quality and water quality. However, the magnitude and significance of these cumulative effects would be dependent on the location of receptors and the projects, the design and scale of the proposals, and the timing of works.

4. Assessment of effects

4.1 Summary of potential effects

The full assessment is presented in the *Generic Environmental and Sustainability Report* [9]. **Tables 4.2** to **4.5** summarise the key effects of the illustrative geological disposal concepts for each host rock type against each sustainability theme across the four implementation phases. Broadly, the nature of the effects would be very similar for each host rock type, although the scale and significance of the effect for the different host rock types would vary.

As outlined in **Table 3.2, Section 3.4**, a six point colour coded scoring system has been used to assess the effects of the illustrative geological disposal concepts, which provides a graphical indication of the magnitude of the effects predicted.

In addition, for the purposes of comparing the different host rock types and the different waste inventories, shading and symbols have been used in **Tables 4.2 to Table 4.5** to highlight where the potential effects could be greater, as outlined in the key below.

Table 4.1 Key to Tables 4.2 to 4.5

>	**Comparison of the different host rock types** Where the box has a greater than symbol, the potential effect of the indicated host rock type could be *greater* when compared to the other host rock types. Where there are no boxes with a greater than symbol against a sustainability theme, there would probably not be any potential significant difference in effect between the different host rock types. Refer to the commentary within **Tables 4.2** to **Table 4.5** for details.
*	**Comparison of the different waste inventories (Derived Inventory Reference Case excluding Pu/U and the Derived Inventory Upper Inventory)** Where a * symbol is shown, the potential effect of the indicated waste inventory could be greater when compared to the other waste inventory. Where there are no * symbols against a sustainability theme, there would probably not be any significant difference in effect between the different waste inventories. Refer to the commentary within **Tables 4.2** to **Table 4.5** for details.

Table 4.2 Summary of effects for the surface-based site investigations phase (for both the Derived Inventory Reference Case excluding Pu/U and Derived Inventory Upper Inventory)

Site investigation phase						
Sustainability Theme	Higher strength rock		Lower strength sedimentary rock		Evaporite rock	
	Reference Case	Upper Inventory	Reference Case	Upper Inventory	Reference Case	Upper Inventory
1. Policies and Planning	+	+	+	+	+	+
2. Landscape and Visual	-	-	-	-	-	-
3. Cultural Heritage	?	?	?	?	?	?
4. Geology and Soils	-	-	-	-	-	-
5. Water	-	-	-	-	-	-
6. Biodiversity, Flora and Fauna	?	?	?	?	?	?
7. Traffic and Transport	-	-	-	-	-	-
8. Air Quality	-	-	-	-	-	-
9. Climate Change	-	-	-	-	-	-
10. Noise and Vibration	?	?	?	?	?	?
11. Land Use	-	-	-	-	-	-
12. Socio-economics	+	+	+	+	+	+
	?	?	?	?	?	?
13. Health and Well-being	?	?	?	?	?	?
14. Safety	-	-	-	-	-	-
15. Waste	-	-	-	-	-	-
16. Resource Use, Utilities and Services	-	-	-	-	-	-

Summary of the key effects

Potential positive effects

The site investigations would help to ensure the selection of an appropriate site for the development of a GDF, thus contributing positively towards fulfilling policy and legislative commitments for the safe long-term management of radioactive wastes.

Employee opportunities could be generated, a proportion of which may be available to local people, and could benefit the local economy (e.g. through increased use of garages, shops and accommodation). However, whilst positive, any benefits are unlikely to be significant due to the scale and temporary nature of employment created and the specialist nature of the works.

Potential negative effects

Drilling campaigns could have a negative effect on resources (soil, water, energy and materials), would generate wastes, and could also have a negative visual effect.

In addition, there would be an increase in traffic, with associated air quality and climate change effects. Depending on the site, there may also be negative effects on cultural heritage, biodiversity, the local community and businesses.

There is the potential for borehole drilling campaigns to affect sites of recognised importance for their geological value (e.g. SSSI or RIGS). Such effects would be site specific and therefore are uncertain.

In the case of the higher strength rock and evaporite rock types, drilling campaigns may result in the temporary sterilisation of mineral resources/reserves. This would be unlikely in the case of the lower strength sedimentary rock type as its commercial value would be low.

Comparison of different waste inventories

There would probably not be any difference in effects between the different waste inventories, as the site investigation works would be of a similar scale in each case.

Comparison of different host rock types

With the exception of potential effects on minerals, there would no discernable differences between the different host rock types as the site investigations would be similar for each host rock type.

The effects identified for the site investigation works would probably be an order of magnitude less than the effects for the other programme phases. They would be of a relatively small scale and spread over a number of years, with the main effects at any one borehole site being felt for a few months only.

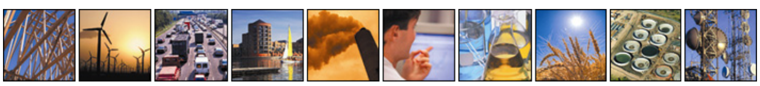


Table 4.3 Summary of effects for the construction phase (for both the Derived Inventory Reference Case excluding Pu/U and Derived Inventory Upper Inventory)

Construction phase						
Sustainability theme	Higher strength rock		Lower strength sedimentary rock		Evaporite rock	
	Reference Case	Upper Inventory	Reference Case	Upper Inventory	Reference Case	Upper Inventory
1. Policies and Planning	+	+	+	+	+	+
2. Landscape and Visual	> -	> -	> -	> -	-	-
3. Cultural Heritage	> ?	> ?	> ?	> ?	?	?
4. Geology and Soils	-	-*	-	-*	-	-*
	?	?	?	?	?	?
5. Water	-	-*	> -	> -*	-	-*
6. Biodiversity, Flora and Fauna	> ?	> ?	> ?	> ?	?	?
7. Traffic and Transport	> - -	> - -*	- -	- -*	- -	- -*
8. Air Quality	> -	> -*	-	-*	-	-*

Summary of the key effects

Potential positive effects

The construction of a GDF would fulfil policy and legislative commitments for the long-term management of radioactive wastes. However, it could be associated with a significant carbon footprint, which if not offset by corresponding reductions elsewhere in the UK economy could detract from the UK meeting its obligations under the Climate Change Act 2008.

Construction would generate significant employment, a proportion of which may be available to local people, and could benefit the local economy (e.g. through increased use of garages, shops, accommodation etc). A community benefits package would also have a positive effect.

Potential negative effects

There would probably be a number of detrimental effects, arising particularly from the construction of the surface facilities and infrastructure, and from the excavation and storage of rock from the construction of underground facilities. All of the host rock types score negatively in relation to transport, climate change, waste and resource use, due to the significant volumes of excavated rock and other wastes which would be exported from the site, and/or construction material that would be imported to the site.

Construction of the surface facilities and infrastructure, and the storage of excavated rock could also have a negative effect on land uses due to the land take required, and could have a negative landscape and visual effect. In addition, depending on the location of the site, surface activities may negatively affect cultural heritage, biodiversity and the local community.

Comparison of different waste inventories

For all host rock types, in the majority of cases, the effect of the Derived Inventory Upper Inventory could be greater, due to the increased size of underground facility, with an associated increase in timescales, volume of rock affected, materials required, waste generated, and surplus excavated rock to be removed off-site.

Comparison of different host rock types

Construction of a GDF within the higher and lower strength sedimentary rock types may have a greater effect on environmental assets (landscape, cultural heritage, biodiversity and land use) depending on the level of surface disturbance. Although the surface site area is assumed to be 1.1km^2 for each of the host rock types, given that a smaller volume of excavated rock would be stored on site in the case of the evaporite rock type, surface disturbance could be less. However, the potential difference in effect on such assets would probably not be significant.

Construction phase

Sustainability theme	Higher strength rock		Lower strength sedimentary rock		Evaporite rock		Summary of the key effects
	Reference Case	Upper Inventory	Reference Case	Upper Inventory	Reference Case	Upper Inventory	
9. Climate Change	- -	- -*	- -	- -*	- -	- -*	(see below)
10. Noise and Vibration	?	?	?	?	?	?	
11. Land Use	> -	> -*	> -	> -*	-	-*	
12. Socio-economics	++	++*	++	++*	++	++*	
	?	?*	?	?*	?	?*	
13. Health and Well-being	?	?*	?	?*	?	?*	
14. Safety	-	-*	-	-*	-	-*	
15. Waste	- -	- -*	> - -	> - -*	- -	- -*	
16. Resource Use, Utilities and Services	> - -	> - -*	- -	- -*	- -	- -*	

Summary of the key effects

__Comparison of different host rock types *(continued)*__

The construction of a GDF could affect sites of recognised importance for their geological value (e.g. SSSI or RIGS). In the case of the higher strength rock and evaporite rock types, construction of a GDF may also result in the sterilisation of mineral resources/reserves, a GDF within evaporite rock potentially having the greatest effect when compared to higher strength rock due to it having a larger underground facility footprint. However, for both host rock types a proportion of the excavated rock would be used for backfilling the vaults. This would negate the need to import any crushed rock for backfilling, which could otherwise affect mineral resources supply elsewhere. The potential also exists for the beneficial use of the remainder of excavated rock to be removed off-site. Although the underground facility within lower strength sedimentary rock would have the greatest underground facility footprint of all of the host rock types, it is unlikely to have a direct effect on mineral resources/ reserves due to its low commercial value.

Due to the increased size of the lower strength sedimentary rock underground facility footprint when compared to the other host rock types, its construction could have a greater effect on groundwater. In the case of lower strength sedimentary rock and evaporite rock (depending upon its type), there would also be the potential for excavated rock to negatively affect water quality. Lower strength sedimentary rock may contain sufficient sulphide to cause acid generating reactions, and the evaporite rock type halite is highly soluble in fresh water. The evaporite rock anhydrite, however, is less soluble.

The lower strength sedimentary rock type could have the greatest effect in relation to waste arisings, as opportunities for the beneficial re-use of any surplus excavated rock could be limited due to its low commercial value. In the case of lower strength sedimentary rock greater volumes of waste excavated rock could therefore be generated.

Construction of a GDF within higher strength rock may give rise to more significant effects on traffic and air quality when compared to the other host rock types due to the need to import greater quantities of construction materials to the site via road (taking account of the transport of materials for the construction of the surface-based facilities, underground accesses, common services area and ILW/LLW vaults and HLW/SF disposal tunnels).

CO_2 emissions associated with the transport of construction materials to site by road are estimated to be greatest for higher strength rock, due to the greater volumes of construction materials required compared to the other host rock types.

With respect to embodied carbon (associated with the surface based facilities, and underground waste disposal areas and common services area), the higher strength rock type could potentially have a more significant effect when compared to the other host rock types.

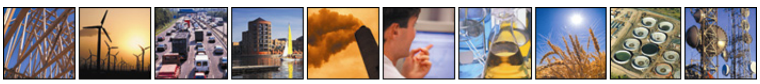


Table 4.4 Summary of effects for the operation phase (for both the Derived Inventory Reference Case excluding Pu/U and Derived Inventory Upper Inventory)

Operation phase

Sustainability theme	Higher strength rock		Lower strength sedimentary rock		Evaporite rock	
	Reference Case	Upper Inventory	Reference Case	Upper Inventory	Reference Case	Upper Inventory
1. Policies and Planning	+	+	+	+	+	+
2. Landscape and Visual	> -	> -	> -	> -	-	-
3. Cultural Heritage	?	?	?	?	?	?
4. Geology and Soils	-	-*	-	-*	-	-*
5. Water	-	-*	> -	> -*	-	-*
6. Biodiversity, Flora and Fauna	> ?	> ?	> ?	> ?	?	?
7. Traffic and Transport	> - -	> - -*	- -	- -*	- -	- -*
8. Air Quality	> -	> -*	-	-*	-	-*

Summary of key effects

<u>Potential positive effects</u>

As per construction, the operation of a GDF would fulfil policy and legislative commitments for the long-term management of radioactive wastes. However, it could be associated with a significant carbon footprint, which if not offset by corresponding reductions elsewhere in the UK economy could detract from the UK meeting its obligations under the Climate Change Act 2008.

The operation of a GDF would generate employment and continue to support local services. A community benefits package would also continue to have a positive effect. However, there would be a reduction in employment from the construction phase.

<u>Potential negative effects</u>

Once a GDF becomes operational, the construction of the surface facilities and infrastructure would have been completed, so there would probably not be any further significant landscape and visual, cultural heritage and biodiversity effects. However, any visual effect of the surface facilities and infrastructure, and effects on land uses would remain and there may be continued disturbance to biodiversity (flora and fauna) in the site and surrounds.

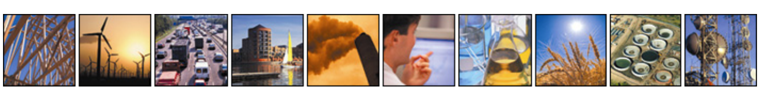
Construction of the waste disposal areas would be ongoing throughout the operational phase, excavated as required for waste emplacement. There would be continued negative effects in relation to geology, transport, climate change, waste and resource use, due to the significant volumes of surplus excavated rock and other wastes to be removed off-site, and construction, and buffer/backfill material to be imported to site.

<u>Comparison of different waste inventories</u>

For all host rock types the potential effect of the Derived Inventory Upper Inventory could be greater than that of the Derived Inventory Reference Case excluding Pu/U, due to the increased size of the facility, with an associated increase in timescales, volume of rock affected, construction, and buffer/backfill materials required, waste generated, and increase in excavated rock to be removed off-site.

<u>Comparison of different host rock types</u>

A GDF within the higher strength rock and evaporite rock types could result in the sterilisation of mineral resources/reserves, with the evaporite rock type potentially having the greatest effect due to its larger underground facility footprint compared to higher strength rock. However, for both host rock types a proportion of the excavated rock would be used for backfilling. This would negate the need to import crushed rock for this purpose, which could otherwise affect minerals supply elsewhere. The potential also exists for the beneficial use of the remainder of excavated rock removed off-site.



Operation phase

Sustainability theme	Higher strength rock		Lower strength sedimentary rock		Evaporite rock	
	Reference Case	Upper Inventory	Reference Case	Upper Inventory	Reference Case	Upper Inventory
9. Climate Change	- -	- -*	- -	> - -*	> - -	- -*
10. Noise and Vibration	?	?	?	?	?	?
11. Land Use	> -	> -*	> -	> -*	-	-*
12. Socio-economics	+	+*	+	+*	+	+*
	?	?*	?	?*	?	?*
13. Health and Well-being	?	?*	?	?*	?	?*
14. Safety	-	-*	-	-*	-	-*
15. Waste	- -	- -*	> - -	> - -*	- -	- -*
16. Resource Use, Utilities and Services	> - -	> - -*	- -	- -*	- -	- -*

Summary of key effects

Although the underground facility for the lower strength sedimentary rock type would have the greatest footprint, this would probably not have a direct effect on mineral resources or mineral reserves due to its low commercial value. However, during the operational phase in the case of the higher strength and lower strength sedimentary rock types, significant quantities of bentonite would need to be imported for backfilling, which could have an effect on minerals resources and reserves elsewhere. The potential effect associated with the import of bentonite could be greater for the higher strength rock type than that of lower strength sedimentary rock, as a greater quantity of bentonite would be required for this purpose.

As noted in the construction phase, due to the increased size of the lower strength sedimentary rock underground facility footprint compared to the other host rock types, its construction could result in a greater effect on groundwater. In addition, in the case of lower strength sedimentary rock and evaporite rock (depending upon its type), there would also be the potential excavated rock to negatively affect water quality if it came into contact with water.

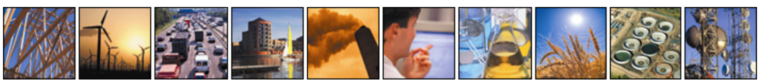
The lower strength sedimentary rock type would continue to have the greatest effect in relation to waste arisings during the operational phase, due to there being fewer potential opportunities for re-use of any surplus excavated rock arising from the continued construction of the waste disposal areas.

During operation the higher strength rock type could have a more significant effect on traffic and air quality when compared to the other host rock types due to the need to import greater quantities of buffer/backfill materials to the site via road.

There would not be any difference in effects associated with the transport of radioactive waste between the different host rock types, as all would be designed to accept the same volumes. However, the CO_2 emissions associated with the transport of radioactive waste by rail (the Road/Rail scenario, which assumes a 70:30 rail and road split) are estimated to be greater than if radioactive waste is transported predominantly by sea (the Sea/Road/Rail scenario, which assumes a 80:10:10 sea, rail and road split).

Overall for the construction and operational phase, based on CO_2 emissions estimates for the Derived Inventory Reference Case the evaporite rock type would probably generate the greatest amount of transport related CO_2 emissions, as although fewer construction and buffer/backfill materials would be required when compared to the other host rock types, a significantly greater volume of surplus excavated rock would need to be removed off-site.

For the Derived Inventory Upper Inventory the lower strength sedimentary rock type could generate the greatest amount of transport related CO_2 emissions, due to the volume of surplus excavated rock to be removed off-site and construction materials and buffer/backfill materials to be transported to the site.



Operation phase							
Sustainability theme	Higher strength rock		Lower strength sedimentary rock		Evaporite rock		**Summary of key effects**
	Reference Case	Upper Inventory	Reference Case	Upper Inventory	Reference Case	Upper Inventory	
16. Resource Use, Utilities and Services	> - -	> - -*	- -	- -*	- -	- -*	During operation, resource use could be greater for the higher strength rock type, due to the need to import greater volumes of buffer/backfill material when compared to the other host rock types. It is noted in the case of the higher strength rock and lower strength sedimentary rock types that bentonite, required for buffer/backfilling, is not widely available in the UK and therefore may need to be shipped from abroad.

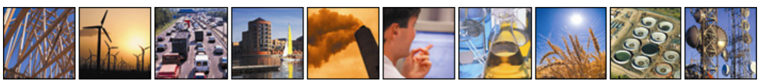
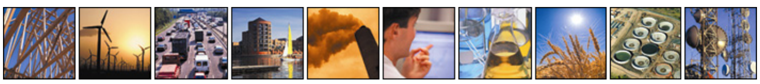


Table 4.5 Summary of effects for the closure and post-closure phase (for both the Derived Inventory Reference Case excluding Pu/U and Derived Inventory Upper Inventory)

Closure and post-closure phase							
Sustainability theme	Higher strength rock		Lower strength sedimentary rock		Evaporite rock		**Summary of key effects**
	Reference Case	Upper Inventory	Reference Case	Upper Inventory	Reference Case	Upper Inventory	
1. Policies and Planning	?	?	?	?	?	?	By the closure and post-closure stage, given the timescales involved and that a site location is not known at this stage, many of the potential effects have been identified as uncertain, although the potential for both adverse and beneficial effects has been noted. At closure and post-closure, it is anticipated that, in general terms, the magnitude and significance of effects, where identified, would decrease in most cases when compared to the construction and operational phases. **Potential positive effects** Given the substantial time period that would have passed by the time a decision is reached to close a GDF, the potential effect of this phase in relation to policies and planning is uncertain. Closure and post-closure activities would generate employment opportunities. However, the scale of employment would be much lower (a reduction of an estimated 249 posts) than that during the operational phase, with the potential for job losses of both operational staff and closure staff when they are no longer required. **Potential negative effects** Employment would continue to decrease as decommissioning progressed. Following completion of the site restoration, the majority of staff employed at a GDF, with the exception of those professional staff involved in post site restoration maintenance, would no longer be employed. Compared to the previous stages of GDF development, this could have a significant negative effect on employment in the local area, with significant effects on the local economy due to the loss of income and GDF expenditure. During backfilling, sealing and closure of the underground facility and the decommissioning of surface facilities and infrastructure, the works could continue to affect environmental assets and local communities (e.g. residents). The potential effects of site restoration on the landscape, cultural heritage, biodiversity and land uses are uncertain. The nature of the effects would depend on the site restoration works undertaken, i.e. whether the site were restored to its previous land use, whether opportunities for enhancements were pursued and whether the site became available for other uses. The closure and post-closure activities would probably continue to have a negative effect in relation to traffic, waste and resource use, due to the import of significant volumes of backfill material to the site and the removal of waste from the site, with associated air quality and climate change effects.
2. Landscape and Visual	> ?	> ?	> ?	> ?	?	?	
3. Cultural Heritage	> ?	> ?	> ?	> ?	?	?	
4. Geology and Soils	-	-	> -	> -	> -	> -	
5. Water	> -*	> -	> -	> -*	-	-	
6. Biodiversity, Flora and Fauna	> ?	> ?	> ?	> ?	?	?	
7. Traffic and Transport	-	-*	> -	> -*	-	-*	
8. Air Quality	-	-*	> -	> -*	-	-*	



Closure and post-closure phase

Sustainability theme	Higher strength rock		Lower strength sedimentary rock		Evaporite rock	
	Reference Case	Upper Inventory	Reference Case	Upper Inventory	Reference Case	Upper Inventory
9. Climate Change	-	-*	> -	> -*	-	-*
10. Noise and Vibration	?	?	?	?	?	?
11. Land Use	> ?	> ?*	> ?	> ?*	?	?*
12. Socio-economics	+	+	+	+	+	+
	?	?*	?	?*	?	?*
13. Health and Well-being	?	?	?	?	?	?
14. Safety	-	-*	-	-*	-	-*
15. Waste	-	-*	-	-*	-	-*
16. Resource Use, Utilities and Services	-	-*	> -	> -*	-	-*

Summary of key effects

For the higher and lower strength sedimentary rock types, there would be potential for NRVB to create a plume of high pH alkaline groundwater over time due to its lime content. The potential long-term effect on groundwater associated with the use of NRVB could be greater for the higher strength rock type when compared to lower strength sedimentary rock, as a greater volume of NRVB would be used. In the case of the evaporite rock type, the crushed rock backfill material would not have any long-term effects on groundwater, due to it being the same as the host rock.

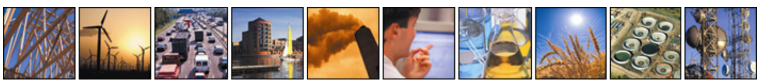
Comparison of different waste inventories

For all host rock types, in the majority of cases, the potential effect of the Derived Inventory Upper Inventory could be greater than that of the Derived Inventory Reference Case excluding Pu/U, due to the increased size of the underground facility, with an associated increase in timescales, backfill materials required and waste generated.

Comparison of different host rock types

Based on current known backfill estimates, the lower strength sedimentary rock type could give rise to more significant effects during the closure and post-closure phase, due to the need to import all backfill material. For both the higher strength rock and evaporite rock types, excavated rock could meet crushed rock drift and/or shafts and common services area backfill requirements, negating the need to import crushed rock for backfilling of these areas. For the higher strength rock and evaporite rock types, it is unknown whether crushed rock requirements for backfilling the remaining underground roadways and facilities could be met using surplus excavated rock from the construction of the underground facility. However, surplus excavated rock would remain on site in surface bunds and some or all of the excavated rock could be used for this purpose. In the case of the lower strength sedimentary rock type, as all backfill material would need to be imported to the site this could result in a greater number of transport movements, with associated secondary effects on air quality and climate change, resource use and markets/supply chains. It is also noted that bentonite, which would be used for mass backfilling for the lower strength sedimentary rock type, is not widely available in the UK and therefore bentonite may need to be shipped from abroad.

Following decommissioning and site restoration, the scale of any residual effects at surface could differ between the different host rock types. Assuming that a dedicated storage area for excavated rock would be demolished as part of decommissioning, any potential residual landscape and visual and land use effect could be less for the evaporite rock type as only the surface screening bunds would remain on site. These could be of a smaller volume than the surface bunds for the higher strength and lower strength sedimentary rock types, which are assumed to comprise up to 3,589,000m^3 of excavated rock.



4.2 Key mitigation and enhancement measures

Measures have been identified in the assessment that could be used to address the potential adverse effects identified or to enhance the potential positive effects associated with GDF implementation. These could be incorporated into future design iterations for a GDF and/or be taken into consideration during the site selection process. A summary of the key mitigation measures/enhancements identified is set out in **Table 4.6**. A full list of possible mitigation and enhancement measures is provided in the Generic Environmental and Sustainability Report [9].

Table 4.6 Key mitigation and enhancement measures

Key mitigation and enhancement measures to address significant adverse effects
Geology and Soils:
Opportunities for the beneficial re-use of surplus excavated rock to be removed off-site should be explored. For example, excess excavated rock could be exported via a railhead for use as aggregates/construction materials. The transport implications of exporting excavated rock off-site would need to be considered carefully. Where possible, the disposal of excavated rock to landfill should be avoided. The available options should be subject to assessment.
Traffic and Transport:
Where practicable, provision should be made for the transport of any plant, materials and wastes to and from the site via rail or sea. Other alternatives to road transport could be the use of conveyors (such as those used in quarrying and mining) as a means of transport to rail or port facilities. Consideration should be given to the potential longer-term use of any new infrastructure provided: whether a dedicated transport link for a GDF is provided or whether there are opportunities for wider industrial/commercial use of any new transport infrastructure. All available transport options should be subject to environmental assessment to determine their effect.
To minimise the movement of construction materials, locally sourced construction materials should be used where practicable and, where possible, any construction waste should be retained and used on site.
A Traffic Management Plan (TMP) should be prepared and adopted. The TMP is likely to include details on car parking, temporary road signage and construction traffic routing and timing. Similarly, a Green Travel Plan should be developed and implemented, outlining measures to reduce private vehicle use such as the promotion of car sharing, the provision of services for construction workers to the site (i.e. buses) and the provision of public transport passes where the site is accessible by public transport.
Routing strategies should be implemented in order to avoid, as far as possible, sensitive receptors and congestion effects. Deliveries should be co-ordinated by a logistics manager to prevent queuing of vehicles. Arrivals of materials should also be scheduled outside of peak hours to minimise any disruption to the existing highway network.
Climate Change:
Where possible, materials with lower embodied energies should be utilised. When considering the detail of design and within engineering appraisal, the carbon associated with construction materials should be considered, for example it's source, distance to be transported, method of transport and volume. Where reasonable lower carbon alternatives are available they should be considered.
Construction waste generation on site should be minimised (where transport off-site would be required) in order to limit carbon emissions associated with this additional transport requirement.
Development should not be considered within areas at risk of flooding from rivers or the sea unless the development can be protected to an appropriate degree. Drainage on site should be sufficient to manage surface water flows and minimise risk of site flood during heavy rainfall. All infrastructure key to the running of the facility, such as power supply and computer systems should be designed to be fully resilient to flooding such that in the event of localised flooding the facility can remain fully safe and secure.

Key mitigation and enhancement measures to address significant adverse effects

Climate Change:

Where possible, the use of mains electricity to power equipment and plant would be preferential to diesel or petrol powered generators. The potential for renewable energy generation (e.g. solar panels, dedicated wind turbines, ground source heat pumps or biomass boilers) to meet energy needs on site should be considered.

All buildings on site should be designed to the highest standards of energy efficiency, meeting or exceeding future Building Standards requirements, and should be well adapted to future climate. Designing in low carbon energy provision and energy efficiency is more cost effective than retrofitting solutions at a later date and is therefore recommended. Similarly, limiting the need to artificially cool buildings, through good design is recommended.

Waste:

Best practice waste minimisation and management practices should be implemented, with a focus on materials resource efficiency (using less and re-using more), in accordance with WRAP guidance, *Delivering Effective Waste Minimisation* and *Delivering Good Practice Waste Management*.

Materials usage and waste should be considered early in the design process, and opportunities to 'design out waste' should be considered. This could involve: design with existing resources (taking account of resources available on site or close by); standardisation of building form, layout and materials; design for easy demolition, re-construction and adaptability; designing to material dimensions; use of made-to-measure materials; and the use of modern methods of construction (that eliminate or reduce the requirement for site cutting and handling of materials). This should involve early discussions between the client, designers, contractors and sub-contractors to identify potential waste streams and their quantities. Further guidance on waste minimisation through design is provided in the WRAP document, *Achieving Effective Waste Minimisation through Design: Guidance on designing out waste for construction clients, design teams and contractors.*

Where there is the potential for long-term use of buildings on the site(s) (e.g. offices), a high level of design quality and flexibility should be adopted to allow for future use.

The potential for materials wastage should be reduced through effective procurement: producing accurate estimates of materials required; ordering the correct amount of materials at the correct time; developing partnerships with suppliers who can implement waste minimisation at source; and setting up schemes with suppliers to take back surplus materials.

Best practice procedures for the protection, storage and handling of materials should be followed. A robust logistics plan should be developed, identifying how materials are to be moved to, from and on site, and how they are stored. This could include just-in-time delivery or the use of consolidation centres to help reduce damage to materials and products by minimising the amount of time stored on site, and take back schemes for surplus material.

Provision should be made for the segregation of wastes to enable a high level of recycling. Options for re-use of materials on site should be identified. Where re-use and recycling is not possible, options for disposal should be investigated to minimise environmental effects.

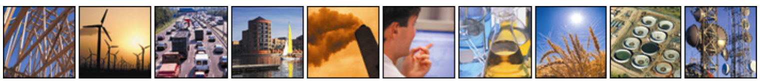
A waste minimisation strategy should be implemented as part of the Site Waste Management Plan (SWMP) for the works. As a minimum, the SWMP should contain detailed measures to comply with relevant waste legislation, but should also include good practice guidance and objectives in order to maximise the reduction, reuse and recovery of waste, with disposal to landfill as the least preferred option.

Resource Use:

All buildings on site should be designed to the highest standards of energy and water efficiency, incorporating features such as energy efficient insulation materials, lighting and heating systems and appliances (e.g. double glazing, energy efficient bulbs, 'A' rated white goods and dual low flush toilets), and systems for the collection and recycling of water (e.g. rain water and grey water recycling systems).

The potential for materials wastage should be reduced through effective procurement, providing accurate estimates of materials required, ordering the correct amount of materials at the correct time, and using supplies that take back surplus material.

The use of products and materials with good practice levels of recycled content and inherently lower embedded carbon (relative to other products meeting the same specification), or those with low environmental impact (e.g. those that are A-rated in the Green Guide specification) should be specified. AggRegain, the free sustainable aggregates information service provided by the WRAP Aggregates Programme (http://www.aggregain.org.uk/), provides a lot of useful information and advice on sourcing sustainable aggregates.



5. Conclusions

This Non-Technical Summary summarises the findings of the generic SEA of the potential environmental and wider sustainability effects of illustrative geological disposal concepts for three different host rock types (higher strength rock, lower strength sedimentary rock and evaporite rock), as assessed against 16 sustainability themes and objectives. It has been undertaken to inform the continuing development of a range of disposal facility concepts for HAW and to provide information to communities that have expressed an interest (or are considering expressing an interest) in participating in the site selection process and in hosting a disposal facility.

5.1 What would be the significant effects?

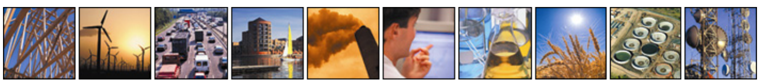
The assessment has identified several potentially significant positive and negative effects that would be associated with one or more phases of GDF implementation (irrespective of host rock type or waste inventory considered). These are:

- **Potentially significant positive effects:**
  - Compliance with UK Government policy on managing HAW in the long-term through geological disposal.
  - Socio-economic effects associated with the investment and employment created during construction, operation and closure of a GDF.
- **Potentially significant negative effects:**
  - During construction and operation, potentially significant negative effects associated with geology and soils, transport and traffic, climate change, waste and resource use.

The differences between potential effects associated with the different illustrative geological disposal concepts are largely affected by two factors. Firstly, the volume of rock that would have to be excavated, which would be dependant on the volume of waste to be emplaced and, secondly, the host rock type, which would dictate the design of underground facilities and construction material requirements. Together, these two factors would dictate how the excavated rock could be used and managed, with consequent effects on traffic and transport movements that in turn would give rise to a number of related effects (e.g. on local air quality, climate change, waste arisings and resource use).

5.2 What would be the effects of different waste inventories?

It has been assumed that the scale of surface development for a GDF and the maximum rate of waste package delivery would be the same for the different waste inventories. Consequently, in the case of the Derived Inventory Upper Inventory (which consists of greater volumes of waste) radioactive waste would be delivered over a longer



period. In terms of the surface facilities there would not, therefore, be any significant differences in potential effects on landscape character and visual amenity, cultural heritage and archaeology, soils, surface water quality and flood risk, biodiversity and land use (environmental aspects that would be affected by the scale of surface development) between the different waste inventories. Some effects might be evident over a longer time period in the case of the Derived Inventory Upper Inventory, but given the overall scale of operations and the time periods involved, such differences would probably not be significant.

However, in order to accommodate different volumes of radioactive wastes, the footprint of the underground facility would vary for the different waste inventories. Due to the increased size of the underground facility, and the associated increase in timescales with the emplacement of greater volumes of radioactive wastes, the potential effect of constructing a GDF to dispose of the Derived Inventory Upper Inventory radioactive waste volumes on geology, groundwater, traffic and transport, air quality, climate change, waste and resource use, utilities and services could be greater than that of the Derived Inventory Reference Case excluding Pu/U. This would be due to the increase in the volume of host rock affected, with the potential for greater effects on geology and groundwater flows; an increase in materials required to be imported to the site (with an associated increase in embodied carbon); and an increase in waste generated, particularly surplus excavated rock to be removed off-site, with greater transport, air quality and climate change effects.

5.3 What would be the effects of different host rock types?

Although the scope of the surface-based site investigations would be broadly similar for each of the three host rock types, there may be differences in the implementation of surface-based site investigations, as follows:

- For the higher strength rock type, if the host rock extends to surface it may be appropriate to use relatively small mobile drilling rigs as such boreholes can be drilled at a relatively small diameter with less steel casing required. Compared with the larger drilling rigs which would be required for all other host rock types, such small rigs require fewer drilling crew, a smaller footprint, less supporting infrastructure and can be operated during daylight hours (compared with 24/7 working for larger drilling rigs). As such there is the potential for reduced environmental impacts when using such equipment.

- Site investigations for lower strength sedimentary rock, by nature of their relatively homogeneous (uniform) structure and composition, may require fewer deep boreholes to be constructed (in comparison to site investigations for higher strength rock), with a greater reliance on geophysical surveys. As such there is the potential for reduced local impacts by nature of the reduced number of borehole locations.

Similarly, it is assumed that the surface facilities and infrastructure would be of a similar scale for the different host rock types. However, the underground facility footprint would vary, with the lower strength sedimentary rock type having the largest underground footprint, and the higher strength rock type having the smallest.

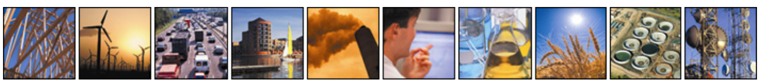
Due to the increased size of underground facility footprint, there would be the potential for a GDF within lower strength sedimentary rock to have a greater effect on groundwater. In addition, the potential effect of the lower strength sedimentary rock type on surface water quality could be greater, as this rock type may contain sufficient sulphide to cause acid generating reactions on exposure to air and water, giving rise to the potential for contamination of water when stored in surface bunds. Similarly, the evaporite rock type halite is highly soluble in fresh water and therefore if excavated halite rock were to come in contact with water whilst stored within the surface facilities the potential would exist for contamination of surface water courses with high chloride waters. The evaporite rock anhydrite, however, is less soluble, and therefore the pollution risk would be less than halite. Notwithstanding this, the evaporite rock would be stored within a suitably designed area and therefore adverse effects would be unlikely.

Given the footprint of the underground facility and the volume of rock excavated, there would be the potential for the construction of a GDF to affect sites of recognised importance for their geological value (e.g. SSSI or RIGS), although the designation is typically determined by the surface geology rather than the deeper stratigraphy. Such effects would be site specific and therefore is uncertain at this stage. However, taking account of scale there is the potential for the lower strength sedimentary rock type to have a greater impact when compared to the other host rock types due to the increased size in underground facility footprint.

Similarly, in the case of the higher strength rock and evaporite rock types, the construction of a GDF could also result in the sterilisation of mineral resources/reserves (rendering them incapable of being extracted), with the potential for the evaporite rock type to have the greatest effect due to the increased size of the underground facility footprint. Any effects on minerals resources/reserves would be permanent. The construction of a GDF within lower strength sedimentary rock would be unlikely to have a direct effect on mineral resources/reserves due to its low commercial value.

The quantity of host rock excavated from the construction of underground facilities would vary for the different host rock types, with the higher strength rock type resulting in the excavation of the greatest quantity of host rock, and the evaporite rock type the least. However, the illustrative geological disposal concept for the evaporite rock type would potentially generate the greatest quantities of surplus excavated rock to be removed off-site when compared to the other host rock types, due to the differences in excavated rock usage on site. In the case of the higher strength and lower strength sedimentary rock types, a significant volume of the excavated rock would be stored on site in surface bunds, and a proportion used for backfilling. In the case of the evaporite rock type, none of the excavated rock would be used for surface bunding or landscaping as it is not suitable for this use. Any surface bunds required to screen the site would therefore need to be constructed using spoil from the construction works (e.g. from top-soil stripping), or material may need to be imported for this purpose. Excavated evaporite rock that would be required for backfilling during the operational and closure phases would require a dedicated storage area on site.

Due to the storage of greater quantities of excavated rock on site, the higher and lower strength sedimentary rock types could have a greater effect on landscape character and visual amenity, cultural heritage and archaeology, soils, surface water quality and flood risk, biodiversity and land use (environmental aspects that would be affected by the scale of surface development). Given that a smaller volume of excavated rock would be stored on site in the case of the evaporite rock type when compared to the other host rock types, surface disturbance could be less.



Notwithstanding this, as a greater quantity of surplus excavated rock would need to be taken off-site, carbon dioxide emissions associated with the transport of surplus rock off-site could be greater for the evaporite rock type when compared to the other host rock types.

The surplus excavated rock generated from the construction of an underground facility would result in a significant waste stream. Although the construction of a GDF within lower strength sedimentary rock would not result in the largest quantities of surplus excavated rock to be removed off-site, it could have the greatest effect in relation to waste arisings, as opportunities for the beneficial re-use of any surplus excavated rock could be limited by its low commercial value. Higher strength rock and evaporite rock in comparison are of commercial value, particularly the evaporite rock halite, which is used widely for de-icing roads, for chlorine production, for food seasoning and for medicinal purposes.

For all of the host rock types, surplus excavated rock is assumed to be transported off-site via rail and therefore no significant effects on the road network are anticipated. For the higher strength rock Derived Inventory Reference Case excluding Pu/U, no excavated rock would need to be transported off-site.

The import of construction and buffer/backfill materials to the site, which is assumed to be transported by road, could potentially have the greatest effect on the road network. In the case of the higher strength rock and evaporite rock types, the excavated rock from the construction of the underground facilities would meet requirements for backfilling of the waste disposal areas during the operational phase, negating the need to import any crushed rock for this purpose. The lower strength sedimentary rock, however, would not be suitable for backfilling, and therefore all backfill material would need to be imported to the site.

During the construction and operational phase, although a significant proportion of excavated rock would be retained on site for the higher strength rock type, there would be a requirement for greater quantities of both construction materials and buffer/backfill material for the higher strength rock type when compared to the other host rock types, with the evaporite rock type requiring the least. Consequently, a GDF within higher strength rock may give rise to more significant effects on traffic and air quality during the construction and operational phase. Similarly, with respect to resource use and embodied carbon, construction of a GDF within higher strength rock may have a more significant effect when compared to the other host rock types.

Overall, however, for the construction and operation phase[4], for the Derived Inventory Reference Case the evaporite rock type would probably generate the greatest amount of transport related CO_2 emissions, as although fewer construction and buffer/backfill materials would be required when compared to the other host rock types, a significantly greater volume of surplus excavated rock would need to be removed off-site.

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[4] Total transport related CO_2 emissions for the construction and operation phase takes account of the CO_2 emissions estimates for the transport of surplus excavated rock off-site, for the transport of ILW/LLW vault, HLW/SF disposal tunnel, underground accesses (drift and/or shafts) and common service area construction materials, and ILW/LLW vault and HLW/SF buffer/backfill material.

For the Derived Inventory Upper Inventory the lower strength sedimentary rock type would probably generate the greatest amount of transport related CO_2 emissions, due to the volume of surplus excavated rock to be removed off-site and the volume of construction materials and buffer/backfill materials to be transported to the site.

During the closure and post-closure phase, the lower strength sedimentary rock type could give rise to more significant effects, due to the need to import all mass backfill material. For both the higher strength rock and evaporite rock types, excavated rock stored on site could meet crushed rock drift and/or shafts and common services area backfill requirements, negating the need to import crushed rock for backfilling of these areas. In the case of lower strength sedimentary rock, all mass backfill material would need to be imported to the site, resulting in a significant number of transport movements, with associated effects on air quality and climate change, and resource use and markets/supply chains.

In the case of the higher strength rock and evaporite rock types, it is unknown whether crushed rock backfill requirements for backfilling the underground roadways and facilities could be met using excavated rock from the construction of the underground facility. There would be surplus excavated rock (currently assumed to be transported off-site) which could possibly be used for this purpose if this surplus was retained on site.

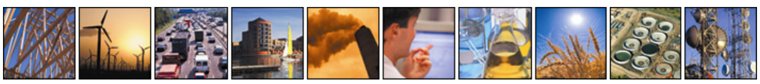
It is noted in the case of the higher strength and lower strength sedimentary rock types that bentonite, required for buffer/backfilling, is not widely available in the UK and therefore may need to be shipped from abroad. In addition, the import of bentonite could also have an effect on minerals resources/reserves elsewhere, with the potential for a GDF within lower strength sedimentary rock to have the greatest effect due to the requirement for greater quantities of bentonite over the duration of the project.

Following decommissioning and site restoration, the scale of any residual effects at surface could differ between the different host rock types. Assuming that the dedicated storage area for excavated rock would be demolished as part of decommissioning for the evaporite rock type, any potential residual effects on landscape character and visual amenity, and on land uses could be less for the evaporite rock type as only the smaller surface screening bunds would remain on site.

For all host rock types, a GDF would fulfil a number of policy and legislative commitments for the long-term management of radioactive wastes in accordance with the MRWS Programme. However, the construction and operation of a GDF could be associated with a significant carbon footprint, which if not matched by corresponding reductions elsewhere in the UK economy could detract from the UK meeting its obligations under the Climate Change Act 2008.

Employment opportunities would be generated, particularly during construction and operation, a proportion of which may be available to local people, and could benefit the local economy (e.g. through the increased use of garages, shops and accommodation). There may be detrimental effects on local communities, due to disturbance from construction and operational activities generating nuisance dust and noise.

The community benefits package would result in investment in the area around a GDF to support the enhancement of opportunities for the local population, help address locally identified needs and issues, and enable subsequent



generations to benefit throughout the lifespan of a GDF and beyond post-closure. The community benefits package would probably not be affected significantly by the host rock type, but may help to ensure that when there are employment spikes at the facility (during construction and operational activities) there are opportunities for subsequent generations of the local community to take advantage of such opportunities through training and skills development.

5.4 What would be the effects of different transport scenarios?

There would probably not be any difference in potential effects associated with the transport of radioactive waste between the different host rock types, as all would be designed to accept the same volumes of radioactive wastes. However, the carbon emissions associated with the transport of radioactive waste by rail (the Road/Rail scenario, which assumes a 70:30 rail and road split) are estimated to be greater than if radioactive waste is transported predominantly by sea (the Sea/Road/Rail scenario, which assumes a 80:10:10 sea, rail and road split).

5.5 What would be the effects during the different implementation phases?

The effects associated with a site investigation phase would probably be an order of magnitude less than the effects for the other phases. This would be due to the relatively small scale of the works and the fact that they would be spread over a number of years, with significant effects at any one borehole site being apparent for only a few months.

The magnitude of effects would be at its greatest during the construction and operation phases, with employment effects expected to be greatest during construction.

By the closure and post-closure stage, given the timescales involved and that a site location is not known at this stage, many of the potential effects have been identified as uncertain, although the potential for both adverse and beneficial effects has been noted. At closure and post-closure, it is anticipated that, in general terms, the magnitude and significance of effects, where identified, would decrease in most cases when compared to the construction and operation phases.

5.6 What are the effects of uncertainty on the assessment?

At this stage there are uncertainties about the location, siting and design of a GDF. This has particularly affected the assessment of significance for those effects where locational factors are key, namely:

- Cultural heritage and archaeological value.
- Water resources, floodplains and flood sensitive areas.

- Biodiversity.
- Air quality.
- The location of the site in relation to strategic and local road networks, and sensitive receptors such as houses and schools.
- Land use.
- The socio-economic composition of the receiving community where a GDF could be located.

In consequence, whilst the assessment has been able to identify and characterise the potential effects associated with the above, it has not been able to conclude whether such effects would be neutral, adverse or significantly adverse. At Stage 4 of the MRWS site selection process many of these uncertain effects would be resolved following further study and more detailed assessment. As these uncertainties become clearer, further assessment would identify more potentially negative effects than are reflected in this report. However, with clarity on candidate sites would come the opportunity to review potentially negative effects, resolve the use of mitigating measures and identify opportunities for enhancement.

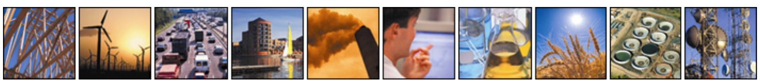
5.7 Next steps

The Generic Environmental and Sustainability Report [9] identifies, characterises and assesses the likely non-radiological environmental, social and economic effects that may arise at a generic (i.e. non-site-specific) level from implementing different illustrative geological disposal concepts in different geological settings (host rock types). The report also outlines potential measures that could be used to mitigate adverse, or enhance beneficial effects, that have been identified. These measures could be incorporated into future design iterations for a GDF, or taken into consideration during future stages of the process for site selection

The report provides information for communities that have expressed an interest (or are considering expressing an interest) in participating in the site selection process and in hosting a GDF.

At the end of Stage 3 of the MRWS site selection process, those communities that have taken a decision to participate in the next stage and have not been screened out for obvious geological reasons would progress to Stage 4. The UK Government would then ask the NDA to undertake further investigations in these communities to evaluate their potential suitability for hosting a GDF and to assess the potential effects of building and operating a disposal facility in the area.

A formal SEA of the NDA's proposals for how a GDF would be implemented in each candidate community, including the proposals for surface-based investigations in each of those communities, would then be undertaken. The NDA would lead and consult on an inclusive SEA process that would consider:



- The proposed scope of the SEA (including, for example, the level of detail of the assessment, the potential effects to be considered, geological disposal concepts and options to be assessed and the proposed form and content of the Environmental and Sustainability Report); and
- The subsequent findings of the assessment.

The approach and findings of the generic assessment presented in this report would be considered during both scoping and assessment for the Stage 4 SEA. For example, as more detailed regional and site-specific information became available the generic effects identified in this assessment for Stage 3 may be quantified or more specifically identified.

5.8 References

[1] Committee on Radioactive Waste Management, *Managing Radioactive Waste Safely – CoRWM's Recommendations to Government,* CoRWM Document 700, July 2006.

[2] HM Government, Welsh Assembly Government and Department for the Environment Northern Ireland, *Managing Radioactive Waste Safely: A Framework for Implementing Geological Disposal,* Cm7386, ISBN 0101738625, June 2008.

[3] NDA-RWMD, *Geological Disposal – Generic disposal facility designs*, NDA Report no. NDA/RWMD/048, ISBN 978840294323, 2010.

[4] NDA-RWMD and Department for Environment, Food and Rural Affairs (Defra), *The 2007 UK Radioactive Waste Inventory - Main Report*, Defra Report Defra/RAS/08.002, NDA-RWMD Report NDA/RWMD/004, May 2008.

[5] European Commission, *Directive 2001/42/EC on the assessment of the effects of certain plans and programmes on the environment,* June 2001.

[6] NDA-RWMD, *Geological Disposal: A Strategy for Sustainability Appraisal and Environmental Assessment*, NDA Report no. NDA/RWMD/014, July 2009.

[7] NDA-RWMD, *Geological Disposal: An overview of the generic Disposal System Safety Case*, NDA Report no. NDA/RWMD/010, ISBN 9781840293944, 2010.

[8] Department of Energy and Climate Change, *Draft National Policy Statement for Nuclear Power Generation (EN-6])*, November 2009.

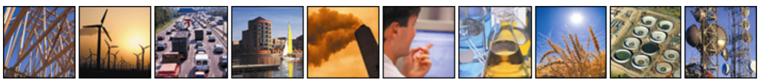
[9] Entec UK Limited, *Geological Disposal: Generic Environmental and Sustainability Report for a Geological Disposal Facility – Assessment Report*, Doc Reg No. 26069-02, September 2010.

[10] Nirex Ltd, *Geosphere Characterisation Project: Status Report: March 2005*. Nirex Report No. N/123, 2006.

[11] Nirex Ltd, G*eosphere Characterisation Project: Status Report: October 2006*. Nirex Report No. N/136, 2007.

[12] NDA-RWMD, *Geosphere Characterisation Project: Status Report: October 2007*. NDA Report No. NDA/RWMD/009, 2008.

[13] NDA-RWMD, *Approaches to Characterising Mudrock Sequences*, NDA Technical Note No. 8102722, 2008.



[14] A. Parkes, *An approach to Characterising a Site for a Co-located Geological Disposal Facility*, Jacobs Engineering Report to NDA-RWMD, March 2009.

Appendix A
Illustrations of geological disposal concepts

Figure A1 **Illustrative aerial view of surface facilities for a Geological Disposal Facility (Nuclear Decommissioning Authority, UK)**

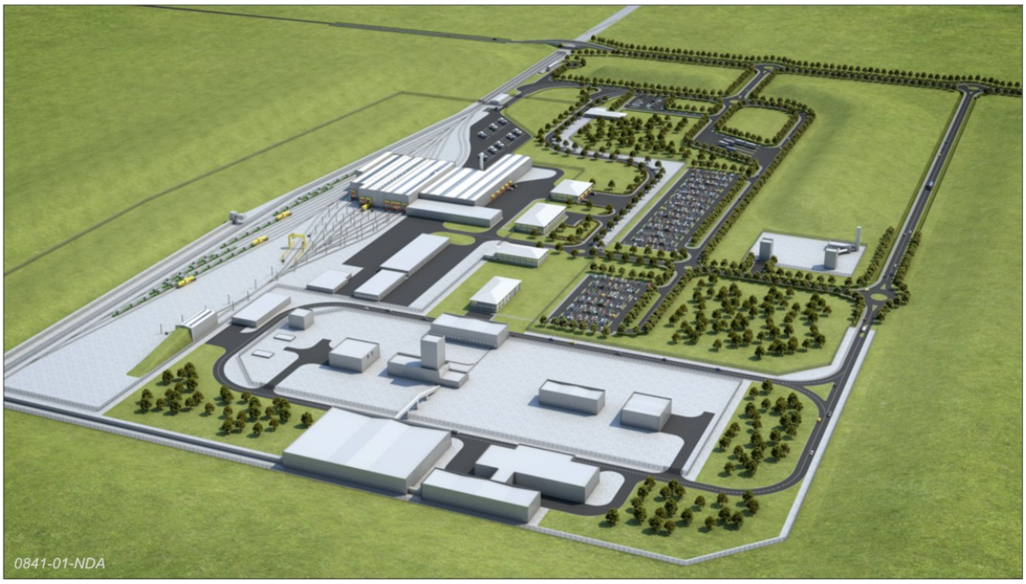
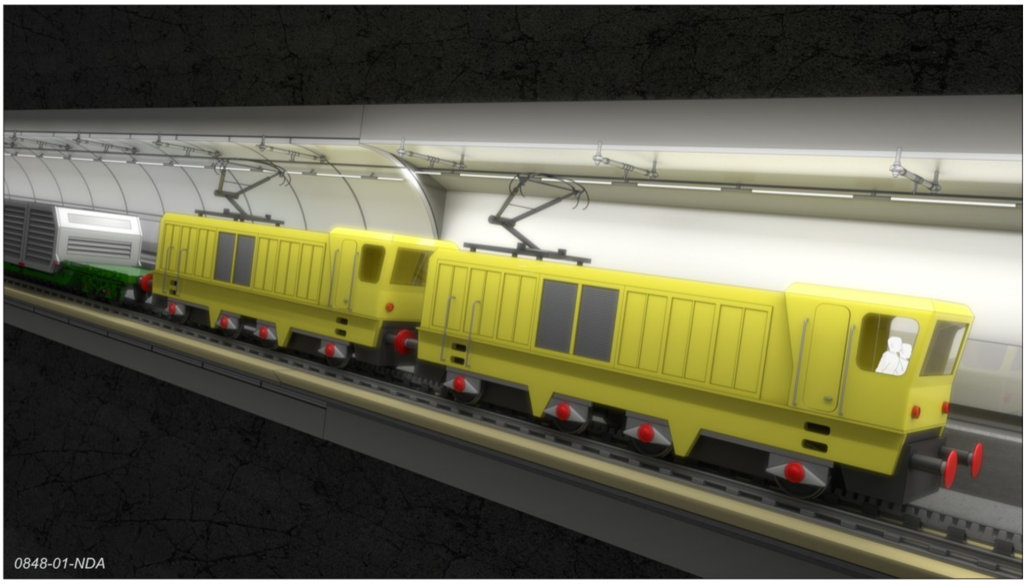


Figure A2 **Indicative illustration of a Geological Disposal Facility drift (Nuclear Decommissioning Authority, UK)**



Source: NDA (2010)

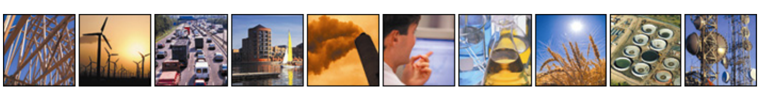


Figure A3 **Illustration of a Geological Disposal Facility surface receipt and transfer facility for Intermediate Level Waste/Low Level Waste (Nuclear Decommissioning Authority, UK)**

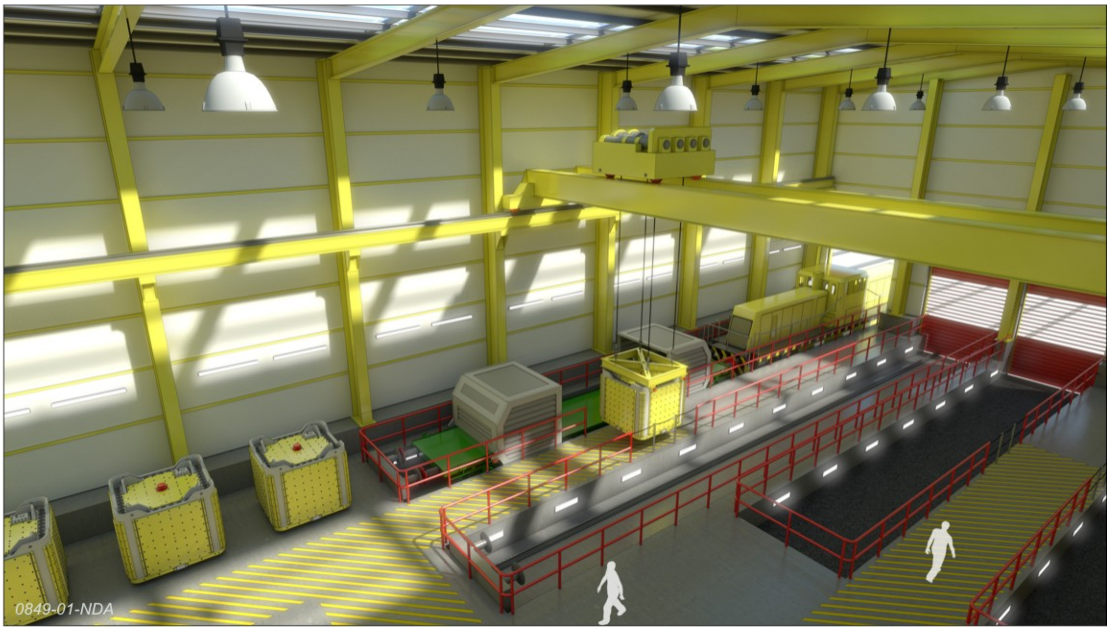
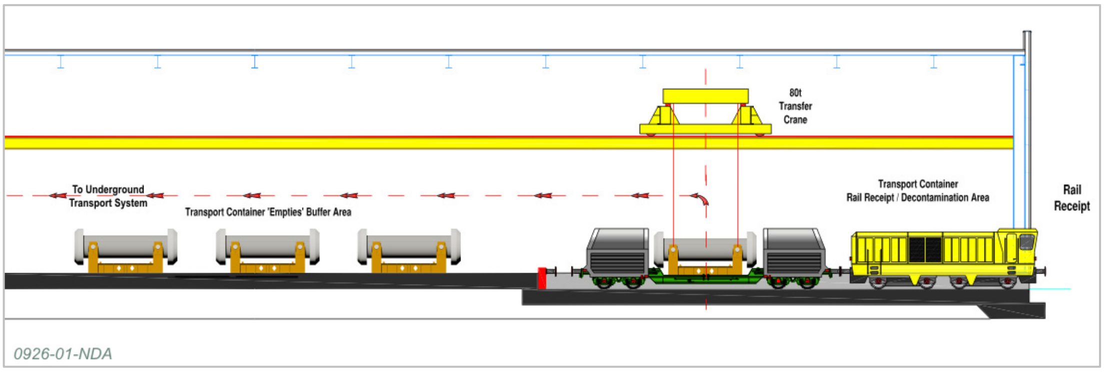


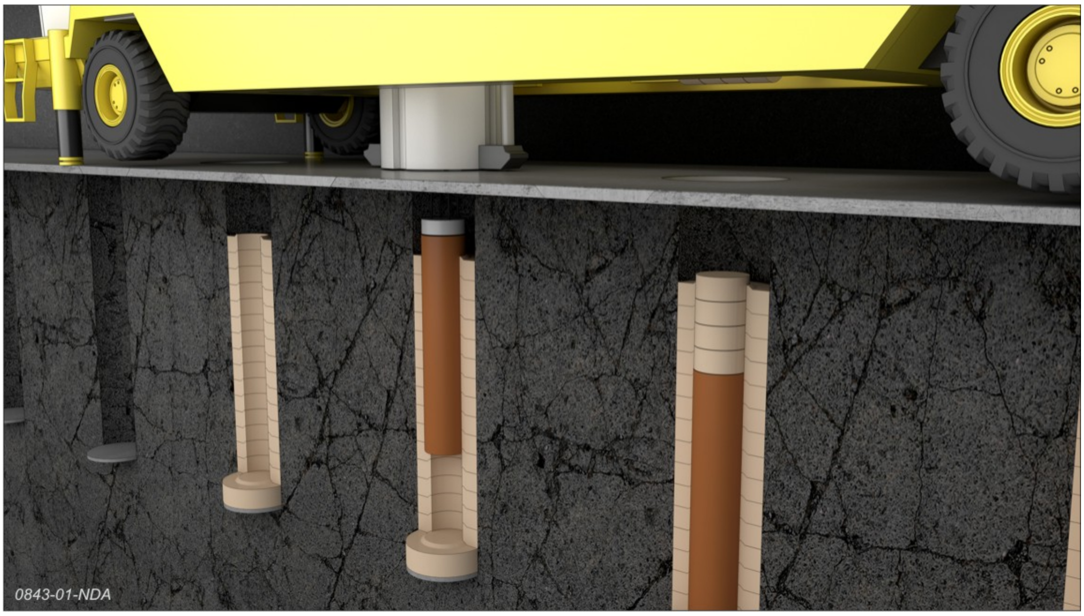
Figure A4 **Illustration of a Geological Disposal Facility surface receipt and transfer facility for High Level Waste/Spent Fuel (Nuclear Decommissioning Authority, UK)**



Source: NDA (2010)

Figure A5 Illustration of a Geological Disposal Facility unshielded Intermediate Level Waste vault in higher strength rock (Nuclear Decommissioning Authority, UK)

Figure A6 Illustration of a Geological Disposal Facility High Level Waste disposal tunnel in higher strength rock (Nuclear Decommissioning Authority, UK)



Source: NDA (2010)

Figure A7 Illustration of a Geological Disposal Facility unshielded Intermediate Level Waste vault in lower strength sedimentary rock (Nuclear Decommissioning Authority, UK)

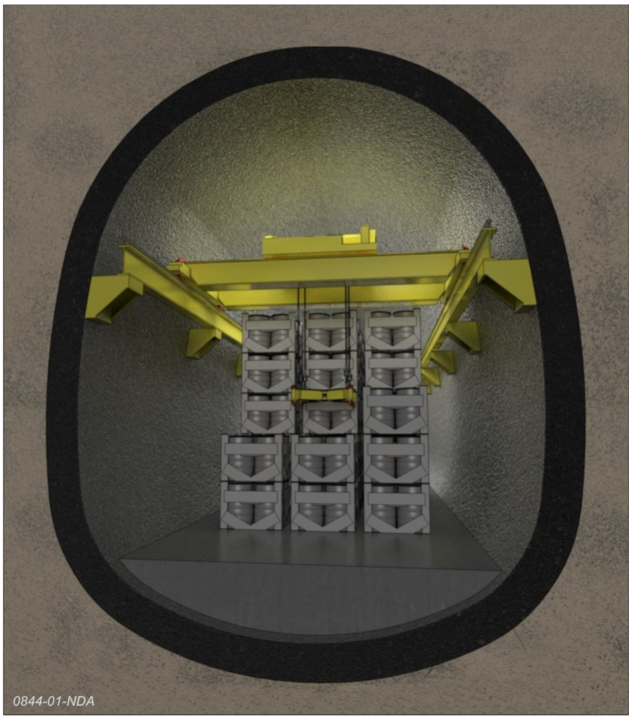
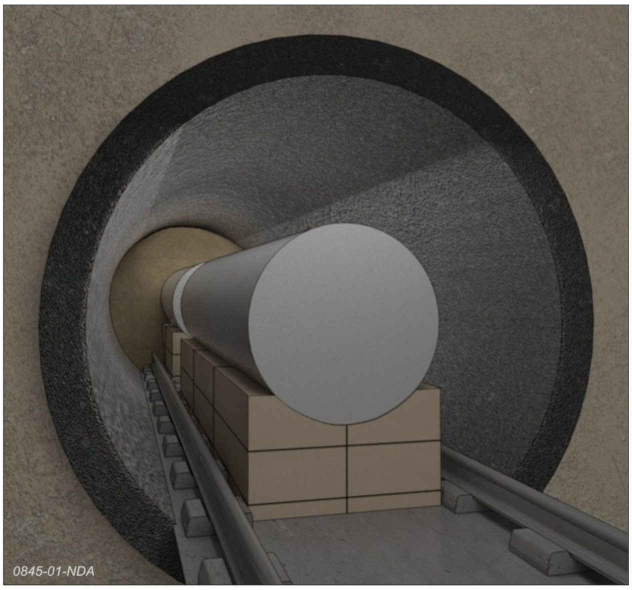


Figure A8 Illustration of a Geological Disposal Facility High Level Waste disposal tunnel in lower strength sedimentary rock (Nuclear Decommissioning Authority, UK)



Source: NDA (2010)

Figure A9 Illustration of a Geological Disposal Facility unshielded Intermediate Level Waste vault in evaporite rock (Nuclear Decommissioning Authority, UK)

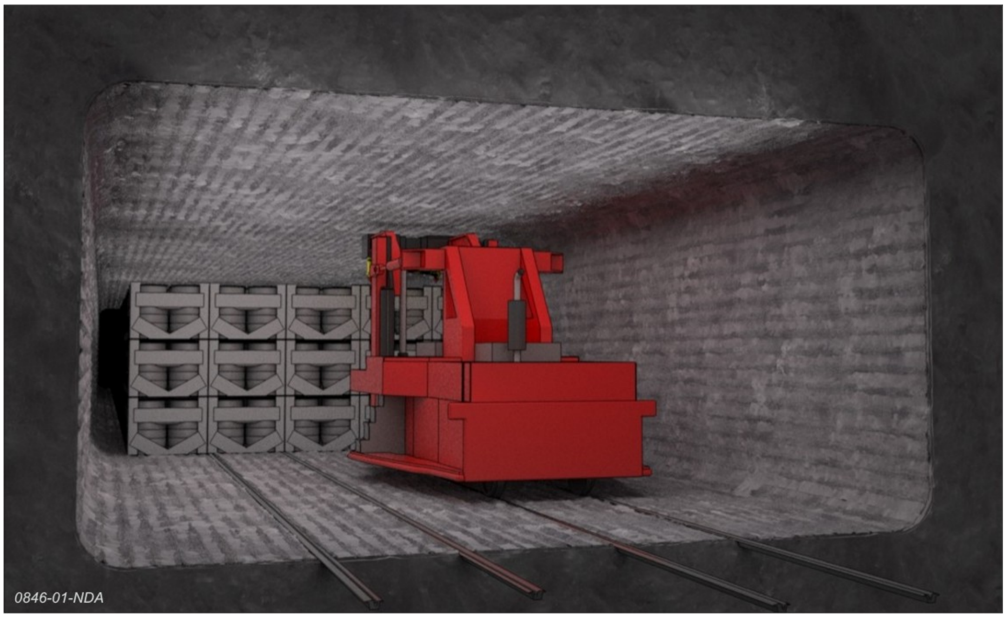


Figure A10 Illustration of a Geological Disposal Facility High Level Waste disposal tunnel in evaporite rock (Nuclear Decommissioning Authority, UK)

Source: NDA (2010)