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TECHNICAL NOTE

Summary Note for CoRWM on the Physical Disturbances for Deep Geological Disposal, Phased Deep Geological and Deep Borehole Disposal

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ABSTRACT

The UK policy for the long-term management of radioactive wastes is currently undergoing review as part of the Government's Managing Radioactive Waste Safely (MRWS) Programme. The Committee on Radioactive Waste Management (CoRWM), was set up by Government in November 2003 to oversee a public consultation on such long-term management options. CoRWM's key task is to recommend to Government what should be done with wastes for which no long-term management strategy currently exists. CoRWM is due to make their recommendations to Government in July 2006.

Nirex is an independent body responsible for supporting Government policy to develop and advise on safe, environmentally sound and publicly acceptable options for the long-term management of radioactive materials in the UK.

This Summary Note has been prepared by Nirex in response to a request from CoRWM for more information on the physical disturbances caused by the deep geological disposal, phased deep geological disposal and deep borehole disposal options for the long-term management of radioactive materials in the UK.

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TECHNICAL NOTE

Summary Note for CoRWM on the Physical Disturbances for Deep Geological Disposal, Phased Deep Geological Disposal and Deep Borehole Disposal

1 INTRODUCTION

The UK policy for the long-term management of radioactive wastes is currently undergoing review as part of the Government's[1] Managing Radioactive Waste Safely (MRWS) Programme [1]. The MRWS Programme sets out two key decisions to be made. Firstly, a decision to be reached on the option (or combination of options) selected for the long-term management of radioactive wastes in the UK. Secondly, a decision on the approach to implementation is required, which would include site selection strategy and criteria for the long-term management option(s) chosen.

An independent committee, the Committee on Radioactive Waste Management (CoRWM), was set up by Government in November 2003 to oversee a public consultation on such long-term management options. CoRWM's key task is to recommend to Government what should be done with wastes for which no long-term management strategy currently exists – that is high-level waste (HLW), intermediate-level waste (ILW) and some low-level waste (LLW) unsuitable for disposal at Drigg[2]. CoRWM will also consider materials that may be declared as waste in the future, such as spent nuclear fuel and separated stocks of plutonium and uranium. The inventory of wastes and materials that are being considered by CoRWM is described in CoRWM Document [2]. CoRWM is due to make their recommendations to Government in July 2006. A Government decision on implementation is expected around 2007 [3].

CoRWM held a series of 7 Specialist Workshops in June/July 2005 to assist them in the assessment of how the various short-listed waste management options [4] perform against the assessment criteria CoRWM have developed. The aims of the workshops were to develop scoring schemes and identify what information is needed to enable scoring of the short-listed options. A record of the key aspects of the workshops can be found in CoRWM Document 1256.2 [5].

During these specialist workshops several questions or requests for information were raised by the specialist group members to help them understand or clarify issues related to the options. They particularly identified information that would allow them to assess options against key criteria or sub-criteria (as described in Reference [5]). These information needs are summarised in CoRWM Document 1254 [6].

Nirex is an independent body responsible for supporting Government policy to develop and advise on safe, environmentally sound and publicly acceptable options for the long-term management of radioactive materials in the UK. This includes setting specifications and standards based on a phased geological repository concept, and providing advice on how to treat and package radioactive waste through application of the Nirex Letter of Compliance process.

In July 2003 the Secretary of State for the Environment, Margaret Beckett announced that: "*It is very important that Nirex stands ready, along with others, to help CoRWM reach its*

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[1] Department for Environment, Food and Rural Affairs and Devolved Administrations for Scotland, Wales and Northern Ireland.

[2] However, for some ILW and LLW, the Nirex Letter of Compliance system has provided a framework that enables helpful progress to be made on the conditioning and packaging.

view and inform policy decisions. It is important also that the company can do this from a position where it is, and can be seen to be, independent of industry" [7].

Nirex was asked by CoRWM to provide feedback on these information needs, in particular indicating where Nirex could provide information to support the scoring of options (this is described in Reference [8]). Some of the information requested by CoRWM was not available in an easily accessible or up to date format, therefore Nirex offered to provide this information in the form of summary notes.

This Summary Note has been prepared by Nirex in response to a request from CoRWM for more information on the physical disturbances caused by the deep geological disposal, phased deep geological disposal and deep borehole disposal options for the long-term management of radioactive materials in the UK.

1.1 Scope

This Summary Note provides information on the physical disturbance that could be caused from implementing the following options, which have been short-listed by CoRWM, for UK radioactive materials:

- Deep geological disposal;
- Phased deep geological disposal;
- Deep borehole disposal.

CoRWM is considering implementing these options for different radioactive materials. It is assumed that each option would be implemented as a single, centralised facility for all the materials that CoRWM has identified it could be used for:

a) Deep and Phased Deep Geological Disposal for high-level waste (HLW) and spent fuel (SF), plutonium (Pu), uranium (U), intermediate-level waste (ILW), and low-level waste (LLW) unsuitable for shallow disposal. For the purposes of clarity in this Summary Note the potential impacts are outlined for a separate HLW/SF type repository and an ILW/LLW type repository, and for co-location on a single site.

b) Deep Borehole Disposal for HLW, SF, Pu and U.

The range of radioactive materials that can be addressed has implications for the size of the facilities, and the overall environmental impacts. Where possible, issues are identified for each of the stages of facility development that are largely common to all options. Variations between options are then identified and qualified.

The phases of development of each option, and the key activities, are identified in Section 2.2.

Information is provided on the physical disturbance resulting from each key activity during the lifetime of an option, in terms of the impact on:

- Earthworks;
- Fragmentation of Habitat;
- Potential for injury to fauna;
- Hydrological Disturbance;
- Light;
- Noise;
- Vibration;
- Heat.

1.2 Description of the Information Need

This Summary Note has been prepared by Nirex at CoRWM's request to support CoRWM in their assessment of waste management options against sub-criterion 10 'Physical Disturbance'. The following options that have been short-listed by CoRWM are considered in this Summary Note:

- CoRWM Option 7 - Deep geological disposal;
- CoRWM Option 8 - Deep borehole disposal;
- CoRWM Option 9 - Phased deep geological disposal.

1.3 CoRWM Assumptions

For the purposes of assessing the short listed options against criteria CoRWM has made a number of assumptions [4]. For the deep geological disposal and phased deep geological disposal option CoRWM has assumed that ILW, LLW not suitable for Drigg and depleted uranium would be disposed of in a Nirex type ILW repository and HLW, spent fuel (SF) and plutonium would be disposed of in a KBS-3V type concept[3]. For the deep borehole option CoRWM has assumed that HLW, SF, plutonium and uranium would be disposed of in boreholes based on the very deep hole concept investigated by SKB [9].

1.4 Approach

The physical disturbances described in this Summary Note have been identified by using information from a systematic non-radiological environmental assessment methodology that was developed for radioactive waste management concepts [10].

Nirex has developed a staged approach to non-radiological assessment and has previewed the methodology with stakeholder groups as part of ongoing dialogue on the application of Strategic Environmental Assessment (SEA) and Environmental Impact Assessment (EIA) to develop a repository concept [11]. The objective behind the staged approach is to have appropriate environmental impact assessment information readily and openly available throughout concept development.

At this stage, where generic concepts only are being considered, the focus is on the main environmental impacts. Impacts that are influenced by the particular site where the option would be implemented cannot be evaluated at this stage of the process, when particular sites for implementing options are not being considered. The range of radioactive materials to be managed in the facility will affect its size and the overall environmental impacts.

Nirex studies and stakeholder dialogue have indicated that there is very little that can be realistically identified for a non site-specific concept against some of the headings listed. The approach commonly used in these circumstances is to address issues through the use of indicators as a basis for assessment.

The proposed indicators are set out in Table 1.

[3] The KBS-3V concept has been developed for the long-term management of spent nuclear fuel in Sweden. Nirex has recently collaborated with SKB to develop a Reference Repository Concept for UK HLW/SF (that is based on the KBS-3V concept) in order to demonstrate the viability of this option.

Table 1 Aspect of Physical Disturbance and Proposed Indicators

Aspect	Indicator
Earthworks	Approximate surface site area
Fragmentation of habitat	Main surface activities
Potential for injury to fauna	Use of fencing
Hydrological disturbance	Changes to broad patterns of surface water distribution and flow, and Key sources of discharge to surface water
Light	Sources of light, noise and vibration during all phases
Noise	
Vibration	
Heat	None available (see below)

A review of Environmental Statements for other HLW management and disposal facilities [12, 13] has indicated that the heat output from a repository to the atmosphere is not expected to be a significant environmental issue.

This issue will need to be considered further during the development of a waste management option. However, information is not available at this stage to support a detailed assessment, and it is not thought to be a discriminating issue between the options.

The physical disturbances described in this Summary Note are based on the concept descriptions set out by CoRWM [4] and draw on information from the Nirex Phased Geological Repository Concept [14], the UK Reference HLW/SF Concept [15], the SKB work on deep boreholes [9] and an outline of a deep borehole concept for UK wastes [16].

For clarity the impacts are considered for separate repositories for HLW/SF and ILW/LLW. Any differences in impacts from co-locating these facilities at one site are noted in the tables.

2 DESIGN ASSUMPTIONS AND DESCRIPTION OF PHASES

This section outlines the key assumptions that have been made about the site that will be used for the waste management options being considered in this Summary Note.

2.1 Key Design Assumptions

The following design assumptions, that were used in the development of the Generic Repository Design for the Nirex Phased Geological Repository Concept (PGRC) [17], have been used for all options considered in this Summary Note in order to provide a consistent basis for identifying physical disturbances:

- The facility would be developed from a green-field site. It would be developed as a stand-alone facility with no opportunities for sharing services (e.g. with any neighbouring nuclear sites).
- The site would be predominantly flat, i.e. no major surface excavation or filling operations would be required, and there would be no topographical constraints on site layout and construction.
- No other geographical or land ownership issues would influence the area or shape of the site required.
- The existing main road and rail infrastructure off-site would be capable of supporting the development and operation of the facility without the need for improvement, i.e. only a new access road and rail link spur to the site would be required.
- No topographical features would rule out the new rail link to the site.
- Screening of the construction and operation activities would be provided by a landscaped screening mound, formed around the site, using material excavated from underground. Screening mounds would be provided at an early stage alongside the rail receipt sidings.

The assumption of a green-field site is used as a basis for identifying physical disturbances, as it is considered to be the most conservative assumption. A preferable option may be to use an existing brown-field site. However this should be addressed as part of site selection, and is outside the scope of this Summary Note.

It is also assumed that the centralised facility for the deep geological and phased deep geological options will be a single site. The potential exists for these two options to have the Waste Container Receipt and Handling Area at a separate location to the Construction and Mining Support Area. However, this would not be expected to occur unless significant environmental benefits were identified during site selection and is outside the scope of this Summary Note.

2.2 Phases and Activity Descriptions

In considering the environmental effects of a waste management option, it is necessary to identify impacts associated with each phase of CoRWM Options 7, 8 and 9, for each environmental topic.

The phases, and the activities in each phase that are largely applicable for all options, are set out in Table 2.

Table 2 Phases and Activity Descriptions

Main Phase	Activity Description
Site Characterisation	Surface-based surveys and investigation boreholes.
Construction	(i) Underground research (site confirmation) and, (ii) Construction of the disposal facility. This will include movement of construction personnel and construction materials.
Transport	Issues associated with the transportation of the waste packages to the facility. The impacts associated with the transport system design will be considered as far as possible.
Operation	(i) Main operational stage of the disposal facility, and (ii) Care and maintenance (for the phased disposal option only). This will include the transport requirements associated with the facility operations.
Closure	(i) Backfilling, sealing and closure of the repository [4], the decommissioning and dismantling of the surface facilities and closure of the site, and (ii) A period of post-closure monitoring.

For purposes of identifying the physical disturbances for CoRWM Options 7, 8 and 9, indicative durations for each phase have been estimated. These are set out in Table 3.

The durations and timings for transportation of waste packages to the facility and waste emplacement operations are concurrent for all options, and addressed in a single table. The periods for construction of a disposal facility and waste emplacement operations overlap by varying amounts depending on the option considered. When these activities are carried out at the same time the impacts identified will be cumulative.

The durations estimated for construction of CoRWM Options 7, 8 and 9 are the total durations over which the activities are expected to extend. Activity levels may vary during these periods, for example deep borehole construction activities may be in a series of campaigns rather than continuously throughout the indicated duration.

[4] For the Deep Borehole Disposal Option (CoRWM Option 8), sealing of the boreholes is expected to run concurrently with Transport and Waste Emplacement. However all other aspects of the repository infrastructure; for example receipt facilities, marshalling yards etc; are assumed to remain until the Closure Phase.

Table 3 Indicative Durations for Phases and Activities

Phase	Activity	Duration	Summary Table (see Section 3)
Site Characterisation	Surface-based Investigation	10 years	4
Construction	Underground Research	13 years	5
	Construction of: HLW/SF Repository ILW/LLW Repository Deep Boreholes	(See Footnote[5]) 51 years 15 years 50-100 years	6
Transport	Transportation of Waste Packages to Facility	50 years	7
Operations	Waste Emplacement	50 years	
	Care and Maintenance	50 years (where applicable)	8
Closure	Backfilling, Sealing and Closure Repository Deep Boreholes	 10 years 3 years [6]	9
	Post-closure Monitoring (nominal 100 year duration)	100 years	10

[5] These are the total durations over which these activities are expected to occur. The activities may not be continuous throughout these periods, for example deep boreholes are expected to be constructed as required, rather than continuously throughout the period. The drilling of over 30 disposal boreholes at three years per borehole (to drill and fill) would take about 100 years, but with a doubling of the drilling and emplacement equipment then this period could be reduced to 50 years.

[6] Period for closure and removal of the repository infrastructure; for example receipt facilities, marshalling yards, site access roads and car parks.

3 IDENTIFICATION OF PHYSICAL DISTURBANCES

This Summary Note indicates the physical disturbances for each activity in the following ways:

1. Earthworks, Habitat and Fauna - Description of approximate surface site area, main surface activities and use of fencing.
2. Hydrological Disturbance - Changes to broad patterns of surface water distribution and flow, and key sources of discharge to surface water.
3. Light, Noise and Vibration - Sources of light, noise and vibration.

Summaries of the physical disturbances identified for each of the options are set out in Tables 4 to 10 as follows:

Table 4 Site characterisation;

Table 5 Construction and operation of an underground research facility;

Table 6 Construction of repository, or deep boreholes, including centralised receipt facilities;

Table 7 Transportation of waste packages, and waste emplacement operations;

Table 8 Care and maintenance of the emplaced waste (where applicable);

Table 9 Backfilling, sealing and closure;

Table 10 Monitoring post-closure.

4 INDIRECT AND CUMULATIVE IMPACTS

Inter-relationships between impacts can arise, which can lead to further environmental effects. For example, changes in traffic flows may lead to changes in local air quality and noise, which in turn have 'knock-on' implications for community health and quality of life for local people. Where possible, these should be identified and addressed. However, these issues would be influenced by features of the location where the facility was developed, and are outside of the scope of this Summary Note.

5 SUMMARY

This Summary Note has been prepared by Nirex in response to a request from CoRWM for more information on the physical disturbances caused by the deep geological disposal, phased deep geological disposal and deep borehole disposal options for the long-term management of radioactive materials in the UK.

The physical disturbances described in this Summary Note have been estimated from Nirex's work on its Phased Geological Repository Concept, its Reference HLW/SF Concept and through a high-level review of the information currently available with regard to deep borehole disposal.

Information was requested on the physical disturbance during each key activity during the lifetime of an option in terms of the impact on:

- Earthworks;
- Fragmentation of Habitat;
- Potential for injury to fauna;
- Hydrological Disturbance;
- Light;
- Noise;
- Vibration;
- Heat.

As information is not available for some of the issue headings for non site-specific concepts, suitable indicators have been identified for use in assessing environmental impacts. This approach is commonly used during the early stages of environmental assessment of options, and is consistent with the staged approach to non-radiological environmental assessment of a repository concept that has been developed by Nirex and previewed with stakeholders.

For Earthworks, Fragmentation of Habitat, and Potential for injury to fauna, the indicators used are:

- Approximate Surface Site Area;
- Main Surface Activities;
- Use of Fencing.

For Hydrological Disturbance the indicators used are:

- Changes to broad patterns of surface water distribution and flow;
- Key sources of discharge to surface water.

For Light, Noise and Vibration the indicators are:

- Principle sources of light, noise and vibration during all phases of repository development.

Heat output from a repository to the atmosphere is not expected to be a significant environmental issue. It is not thought to be a discriminating issue between the options.

The information is presented by phase and activity to support the development of a ‘timeline’ of impacts for each option.

Table 4 Summary of Impacts During Site Characterisation Phase
Nominal Duration - 10 Years

Option	Earthworks, Habitat & Fauna	Hydrological Disturbance	Light, Noise & Vibration
Deep Geological Disposal **Phased Deep Geological Disposal** **Deep Borehole Disposal** Note: Site characterisation requirements are expected to be similar for deep geological disposal, phased deep geological disposal [18] and deep borehole disposal.	**Approximate Survey Area** 50 km^2. **Approximate Site Area for individual drilling rigs** 120 x 120 metres (plus a temporary access road, subject to location). **Main Surface Activities** Formation of individual drilling sites, including fencing, site clearance and levelling, installation and operation of investigation borehole rigs and associated infrastructure, including settlement ponds. Deep investigation borehole drilling operations. Up to 3 sites at any time, 20 sites total, in the survey area of 50 km^2. **Use of Fencing** Individual drilling sites will be fenced to deter intrusion of humans, and risk to wildlife from site operations. ***Possible Mitigation Measures:*** *Individual drilling sites will be located to minimise impact on habitat and local fauna.*	**Changes to surface water distribution** None. **Key sources of discharge** Discharge from investigation borehole operations to existing surface water system (through settlement ponds). ***Possible Mitigation Measures:*** *Individual drilling sites will be located to minimise impact on local hydrogeology.*	**Sources of Light, Noise & Vibration** Detailed Site Investigation; comprising deep investigation boreholes and regional surveys. Approximately 20 deep investigation boreholes on identified site, plus shallow investigation boreholes and other survey work. Deep investigation boreholes would take approximately 5-6 months to drill and test. Drilling equipment would be sound proofed to limit noise and vibration, but drilling likely to be undertaken 24 hours a day, 7 days a week. Site and drilling rig lighting required for 24 hour operations. Regional surveys - Large area short duration surveys, for example seismic surveys. (These may involve use of explosives as an 'energy' source leading to noise and vibration.) ***Possible Mitigation Measures:*** *Individual drilling sites will be operated in compliance with noise regulation requirements.*

Table 5 Summary of Impacts During Construction Phase - Underground Research Activity Nominal Duration - 13 Years

Option	Earthworks, Habitat & Fauna	Hydrological Disturbance	Light, Noise & Vibration
Deep Geological Disposal **Phased Deep Geological Disposal** **Deep Borehole Disposal**	**Approximate Surface Site Area on each repository site (HLW/SF, ILW/LLW or co-located)** 400 by 200 metres, with site access. **Main Surface Activities** Formation of underground research facility, including fencing, site clearance and levelling, installation and operation of man-access underground facility and associated infrastructure, buildings, settlement ponds and discharge control mechanisms. Construction of access road and site services. **Use of Fencing** The research facility site will be fenced to deter intrusion of humans, and risk to wildlife from site operations. ***Possible Mitigation Measures:*** *Animal fencing and wildlife crossing tunnels to be considered during design of site access routes.*	**Changes to surface water distribution on each repository site (HLW/SF, ILW/LLW or co-located)** Diversion of any existing water courses around surface site area. **Key sources of discharge** Discharge from underground operations to existing surface water system through settlement ponds. ***Possible Mitigation Measures:*** *Discharges will pass through pollution control and discharge control mechanisms to suit local hydrological requirements.*	**Sources of Light, Noise & Vibration (per site)** Construction activities in preparation for underground research activity, including: • Site clearance and preparation; • Initial infrastructure requirements; • Erection of headframes and mining equipment. Man-access underground investigation, including possible use of explosives (see Table 7). ***Possible Mitigation Measures:*** *The underground research facility will be operated in compliance with noise regulation requirements.*

Table 6 Summary of Impacts During Construction Phase - Construction of Repository (or Deep Boreholes) Nominal Duration between 15 and 51 Years depending on option

Option	Earthworks, Habitat & Fauna	Hydrological Disturbance	Light, Noise & Vibration
Deep Geological Disposal **Phased Deep Geological Disposal**	**Approximate Surface Site Area - (HLW/SF or ILW/LLW)** Construction site area including landscape screening mounds. 1,200 x 1,200 metres per repository. 1,600 x 1,200 metres if repositories are co-located. (A co-located facility is estimated to require approximately 40% less land than two separate sites [19].) **Main Surface Activities** Site clearance and levelling, earth movement and rock placement. Construction of the entire site infrastructure, including building, road and rail links and the main security fence. **Use of Fencing** The construction site boundary will be fenced to deter intrusion of humans, and risk to wildlife from site operations. Wildlife will be excluded from the construction site area. This includes the landscape screen mounding areas which will be formed from the material excavated during vault construction. Because of the duration of this phase	**Changes to surface water distribution on each repository site (HLW/SF, ILW/LLW or co-located)** Diversion of any existing water courses around surface site area. **Key sources of discharge** Discharge from underground operations to existing surface water system through settlement ponds, pollution control and discharge control mechanisms to suit local hydrological requirements. This will include the run off from the landscape screen mounds around the site. Rock excavated from depth may contain minerals and chemicals unsuitable for surface water discharge. ***Possible Mitigation Measures:*** *Diverted water courses will be kept outside of the construction site boundary, and managed to allow re-population by indigenous wildlife.*	**Sources of Light (per site)** Lighting for construction activities, including headframes to shafts. (Two 35 metre height headframes - approx. 600 metres from the main public highway.) Security lighting of main construction fence. **Sources of Noise & Vibration (per site)** Initial surface construction activities, including: • Site clearance and surface-level excavation; • Earth movement and rock placement; • Site infrastructure requirements; - Roads and car parks; - Marshalling yard; - Buildings; - Drainage, fencing and services; • Off-site infrastructure; - New rail link; - New highway access. Initial noise and vibrations arising from blasting at shallow depth during the initial stages of repository development [19]. (Approx. 10,000 tonnes for HLW/SF repository and 3,500 tonnes for ILW/LLW repository.) Vehicle movements both off-site and on-site, including loading and unloading.

	this site boundary fence is expected to be in the form of a permanent fence. ***Possible Mitigation Measures:*** *Early identification and managed relocations of wildlife habitats to minimise impacts at the start of the construction phase.* *Animal fencing and wildlife crossing tunnels to be considered during design of site access routes.*		Ventilation system for underground vault construction operations. ***Possible Mitigation Measures:*** *Use of 'high cut-off' lighting to minimise light pollution.* *Use of earth mounding as visual and noise screening.* *Blasting design to control noise and vibration.* *Location of critical activities within the site.* *Construction activities will be carried out in compliance with noise regulation requirements.* *Consideration of noise control measures at design stage.*
Deep Borehole Disposal	**Approximate Surface Site Area** 1,000 x 1,000 metres for the centralised receipt facility. 7.0 km^2 (nominally 2,800 x 2,300 metres) for the deep borehole locations. **Main Surface Activities** As for Deep Geological Disposal. **Use of Fencing** Similar to Deep Geological Disposal, however fencing of the 7.0 km^2 may principally be for demarcation purposes, with robust fencing of the individual active borehole locations and access routes.	**Changes to surface water distribution** Similar to Deep Geological Disposal, with diversion of any existing water courses around centralised receipt facility. **Key sources of discharge** Significant quantities of fluid will be required to assist with the drilling of the deep boreholes, and separately with the stabilisation of the boreholes once drilled. Discharges from all construction operations to existing surface water system will be through settlement ponds, pollution control and discharge control mechanisms to suit local hydrological requirements.	**Sources of Light** Lighting for construction activities, including deep borehole drilling rigs. (60 metre height - 34 locations - 3 maximum at any time.) Security lighting of main construction fence. **Sources of Noise and Vibration** Similar to Deep Geological Disposal, but with surface based deep borehole drilling rather than underground construction activities. Total activity levels will be lower as deep borehole disposal would be used for HLW, SF, Pu and HEU. However, surface-based construction activities will continue throughout the waste emplacement period associated with the construction of each deep borehole.

Table 7 Summary of Impacts During Transportation and Emplacement of Waste Nominal Duration - 50 Years

Option	Earthworks, Habitat & Fauna	Hydrological Disturbance	Light, Noise & Vibration
Deep Geological Disposal **Phased Deep Geological Disposal**	**Approximate Surface Site Area - (HLW/SF or ILW/LLW)** 1,000 x 1,000 metres per repository. 1,200 x 1,000 metres if repositories are co-located. (Area excludes landscape screening mounds, which are outside of the main security fence.) If the deposition tunnels for the HLW/SF repository are to remain open throughout the waste emplacement period (Options 7 & 9), an additional site area will be required for storage of 2.3 million m^3 of spoil which will need to be brought to the surface. (This additional site area is not required if deposition tunnels are backfilled after waste emplacement.) **Main Surface Activities** Facility operations. Vehicle movements to and from facility. **Use of Fencing** The main security fence will exclude wildlife from the operational site area. ***Possible Mitigation Measures:*** *Following removal of the construction*	**Changes to surface water distribution on each repository site (HLW/SF, ILW/LLW or co-located)** No changes during this period. Diversion of any existing water courses around surface site area will have been implemented during the construction phase. **Key sources of discharge** Discharge from site infrastructure (i.e. buildings, roads and car parks) and underground operations to existing surface water system through settlement ponds, pollution control and discharge control mechanisms to suit local hydrological requirements. This will include the run off from the landscape screen mounds around the site. The material previously excavated from depth could potentially contain minerals and chemicals unsuitable for surface water discharge. ***Possible Mitigation Measures:*** *The diverted water courses will continue to be managed to allow re-population by indigenous wildlife.*	**Sources of Light (per site)** Waste transport road and rail vehicle movements. Lighting for: - Site access roads, and entrances; - Vehicle parks; - Marshalling yards. **Sources of Noise & Vibration (per site)** Waste transport road vehicle movements (HGV): - On public highway; - Entering and leaving facility; - Movements within facility. Waste transport rail vehicle movements (Dedicated trains): - On main rail link; - Entering and leaving facility; - Movements within marshalling area. Unloading of waste transport containers from offsite road and rail vehicles, and loading reusable containers. Operation of access shafts and drift rail system. Ventilation system for underground vault operations. Facility and staff vehicle movements on and off site. Building and infrastructure maintenance. Alarm (including testing).

	fence wildlife may populate the landscape screening mounds that surround the site. Some control may be required to avoid possible conflict with the site security arrangements. *Animal fencing and wildlife crossing tunnels to be considered during design of site access routes.*		***Possible Mitigation Measures:*** *Vehicle movement activities will be carried out in compliance with noise regulation requirements.* *Location of critical activities on the site, including use of enclosures and building.* *Use of earth mounding as noise screening.* *Adherence to permissible noise levels, durations and timings.* *Consideration of noise control measures at design stage.*
Deep Borehole Disposal	**Approximate Surface Site Area** 1,000 x 1,000 metres for the centralised receipt facility. 7.0 km^2 (nominally 2,800 x 2,300 metres) for the deep borehole locations. **Main Surface Activities** As for Deep Geological Disposal. **Use of Fencing** Similar to Deep Geological Disposal, however fencing of the 7.0 km^2 may principally be for demarcation purposes, with robust fencing of the individual active borehole locations and access routes.	**Changes to surface water distribution** Similar to Deep Geological Disposal, with diversion of any existing water courses around centralised receipt facility. **Key sources of discharge** Significant quantities of fluid will be required to assist with the stabilisation of the boreholes prior to backfilling sealing and closure. Discharges from backfilling sealing and closure operations to existing surface water system will be through settlement ponds, pollution control and discharge control mechanisms to suit local hydrological requirements.	**Sources of Light** As for Deep Geological Disposal, with additional requirement of lighting of access routes from centralised receipt facility to individual active boreholes. Lighting required for deep borehole drilling rigs. (Addressed in Table 7.) **Sources of Noise and Vibration** Similar to Deep Geological Disposal. Additional surface activity will support the backfilling and sealing of boreholes after waste emplacement including construction and operation of backfill materials handling facilities. Activity levels may be lower because the volume of material for disposal will be less, but surface-based borehole drilling, waste emplacement and backfilling activities will continue throughout the waste emplacement period.

Table 8 Summary of Impacts During Operations Phase - Care and Maintenance Activity Nominal Duration - 50 Years (Phased Deep Disposal Option only)

Option	Earthworks, Habitat & Fauna	Hydrological Disturbance	Light, Noise & Vibration
Deep Geological Disposal	Not applicable	Not applicable	Not applicable
Phased Deep Geological Disposal	**Approximate Surface Site Area - (HLW/SF or ILW/LLW)** 1,000 x 1,000 metres per repository. 1,200 x 1,000 metres if repositories are co-located. (Area excludes landscape screening mounds, which are outside of the main security fence.) If the deposition tunnels for the HLW/SF repository are to remain open throughout the care and maintenance period (Option 9), an additional site area will be required for storage of 2.3 million m^3 of spoil which will need to be brought to the surface. (This additional site area is not required if deposition tunnels are backfilled after waste emplacement.) **Main Surface Activities** Care and maintenance operations. This may involve removal of redundant buildings and car parking areas. **Use of Fencing** The main security fence will exclude wildlife from the operational site area. ***Possible Mitigation Measures:***	**Changes to surface water distribution on each repository site (HLW/SF, ILW/LLW or co-located)** No changes during this period. Diversion of any existing water courses around surface site area will have been implemented during the construction phase. **Key sources of discharge** Discharge from site infrastructure (i.e. buildings, roads and car parks) and underground operations to existing surface water system through settlement ponds, pollution control and discharge control mechanisms to suit local hydrological requirements. This will include the run off from the landscape screen mounds around the site. The material previously excavated from depth could potentially contain minerals and chemicals unsuitable for surface water discharge. ***Possible Mitigation Measures:*** *The diverted water courses will continue to be managed to allow re-population by indigenous wildlife.*	**Sources of Light (per site)** Lighting for: - Site access roads, and entrances; - Vehicle parks. **Sources of Noise & Vibration (per site)** Ventilation system for underground vault operations. Operation of access shaft (not full-time). Facility and staff vehicle movements on and off site. Building and infrastructure maintenance. Alarm (including testing). ***Possible Mitigation Measures:*** *Location of critical activities on the site, including use of enclosures and buildings.* *Use of earth mounding as noise screening.* *Adherence to permissible noise levels, durations and timings.* *Consideration of noise control measures at design stage.*

	Wildlife may continue to populate the landscape screening mounds that surround the site. Some control may be required to avoid possible conflict with the site security arrangements.		
Deep Borehole Disposal	Not applicable	Not applicable	Not applicable

Table 9 Summary of Impacts During Closure Phase - Sealing and Closure Activity Nominal Duration - 10 Years (3 Years for Deep Borehole Option)

Option	Earthworks, Habitat & Fauna	Hydrological Disturbance	Light, Noise & Vibration
Deep Geological Disposal **Phased Deep Geological Disposal**	**Approximate Surface Site Area - (HLW/SF or ILW/LLW)** 1,200 x 1,200 metres per repository. 1,600 x 1,200 metres if repositories are co-located. (Main construction site area including landscape screening mounds.) **Main Surface Activities** Surface activities associated with backfilling, sealing and closure of the underground facilities. Rock retrieval from main landscape screening mound and crushing for use as backfill. Demolition and removal of the site infrastructure, including buildings, road and rail links, car parks and marshalling yards and the main security fence. Final landscaping of site and site clearance. **Use of Fencing** The site boundary will be fenced to deter intrusion of humans, and risk to wildlife from rock recovery from the landscape screening mounds, and from site operations. Wildlife will be excluded from the site area. ***Possible Mitigation Measures:***	**Changes to surface water distribution on each repository site (HLW/SF, ILW/LLW or co-located)** No changes during this period. Diversion of any existing water courses around surface site area will have been implemented during the construction phase. **Key sources of discharge** Discharge from site infrastructure through settlement ponds, pollution control and discharge control mechanisms to suit local hydrological requirements as previously. The site infrastructure, ponds and control equipment will be removed towards the end of this phase leaving a 'soft' landscaped site. ***Possible Mitigation Measures:*** *Diverted watercourses will be retained, subject to the results of consultation. These will be approximately 60 years old and would be expected to be providing a mature wildlife habitat.* *New watercourses may be introduced as part of the landscaping of the old site area, to enhance the surface water distribution and to assist with drainage.* *Any remaining material previously*	**Sources of Light (per site)** Lighting for: - Site access roads, and entrances; - Vehicle parks; - Marshalling yards. **Sources of Noise & Vibration (per site)** Surface construction activities, including: • construction and operation of concrete batching facilities; • construction materials handling. Rock retrieval from main landscape screening mound and crushing for use as backfill. Surface demolition activities, including: • Site clearance; • Building Demolition; • Removal of surface infrastructure; - Roads and car park; - Marshalling yard; - Drainage, fencing and services. Vehicle movements both off-site and on-site, including loading and unloading. Ventilation system for underground vault construction operations.

	Wildlife may have populated the landscape screening mounds that surround the site. Care will be taken in the removal of these new habitats to avoid injury to wildlife. *Restoration of the site will be to the satisfaction of the local planning authority. This should include the creation of diverse and attractive landscapes, which are in keeping with the surroundings, including water areas and woodland to enhance nature conservation, public access and recreation.* *A restoration strategy, including woodland planting and other landscaping, should be formulated for consultation with local stakeholders.*	*excavated from depth that could potentially cause pollution of the surface or ground water will be removed from site.*	***Possible Mitigation Measures:*** *Location of critical activities.* *Use of earth mounding as noise screening.* *Adherence to permissible noise levels, durations and timings.* *Consideration of noise control measures at design stage.*
Deep Borehole Disposal	**Approximate Surface Site Area** 1,200 x 1,200 metres for the centralised receipt facility. 7.0 km^2 (nominally 2,800 x 2,300 metres) for the deep borehole locations. **Main Surface Activities** Drilling rigs for large diameter boreholes will be removed at the start of this phase. Demolition and removal of the site infrastructure, including buildings, road and rail links, car parks and marshalling yards and the main security fence. Final landscaping of site and site clearance. Drilling rigs for large diameter boreholes for waste emplacement. These will be	**Changes to surface water distribution** As for Deep Geological Disposal. **Key sources of discharge** As for Deep Geological Disposal.	**Sources of Light** These are similar to Deep Geological Disposal for a period of three years. Drilling rigs for large diameter boreholes will be removed at the start of this phase, removing the requirement for lighting of these features. **Sources of Noise and Vibration** These are similar to Deep Geological Disposal, however for the Deep Borehole Option, backfilling and sealing of the boreholes themselves is expected to run concurrently with Waste Emplacement. This (three year) period is for closure and removal of the centralised receipt facility

	removed at the start of this phase. **Use of Fencing** As for a single Deep Geological Disposal repository site, the centralised repository facility site boundary will be fenced to deter intrusion of humans, and risk to wildlife from rock recovery from the landscape screening mounds, and from site operations.		infrastructure; for example receipt facilities, marshalling yards, site access roads and car parks.

Table 10 Summary of Impacts During Closure Phase - Post-closure Monitoring Activity Nominal Duration - 10 Years

Option	Earthworks, Habitat & Fauna	Hydrological Disturbance	Light, Noise & Vibration
Deep Geological Disposal **Phased Deep Geological Disposal**	**Approximate Surface Site Area on each repository site (HLW/SF, ILW/LLW or co-located)** 800 x 600 metres. **Main Surface Activities** None. **Use of Fencing** Boundary fence to original licensed site area to deter intrusion of humans and wildlife during the first hundred years of post-closure monitoring activities.	**Changes to surface water distribution on each repository site (HLW/SF, ILW/LLW or co-located)** No changes anticipated during this period. Diversion of any existing water courses around surface site area will have been implemented during the construction phase. (See Possible Mitigation Measures during Sealing and Closure Activities - Table 10.) **Key sources of discharge:** None.	**Sources of Light (per site)** None. **Sources of Noise & Vibration (per site)** None.
Deep Borehole Disposal	**Approximate Surface Site Area** 800 x 600 metres for the centralised receipt facility. 7.0 km^2 (nominally 2,800 x 2,300 metres) for the deep borehole locations.	**Changes to surface water distribution** As for Deep Geological Disposal. **Key sources of discharge** None.	**Sources of Noise and Vibration** None.

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