Radioactive Waste Management

NDA Report no. DSSC/412/01

Geological Disposal

Generic Disposal Facility Design

December 2016

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Preface

Radioactive Waste Management Limited (RWM) has been established as the delivery organisation responsible for the implementation of a safe, sustainable and publicly acceptable programme for the geological disposal of the higher activity radioactive wastes in the UK. As a pioneer of nuclear technology, the UK has accumulated a legacy of higher activity wastes and material from electricity generation, defence activities and other industrial, medical and research activities. Most of this radioactive waste has already arisen and is being stored on an interim basis at nuclear sites across the UK. More will arise in the future from the continued operation and decommissioning of existing facilities and the operation and subsequent decommissioning of future nuclear power stations.

Geological disposal is the UK Government's policy for higher activity radioactive wastes. The principle of geological disposal is to isolate these wastes deep underground inside a suitable rock formation, to ensure that no harmful quantities of radioactivity will reach the surface environment. To achieve this, the wastes will be placed in an engineered underground facility – a geological disposal facility (GDF). The facility design will be based on a multi-barrier concept where natural and man-made barriers work together to isolate and contain the radioactive wastes.

To identify potentially suitable sites where a GDF could be located, the Government has developed a consent-based approach based on working with interested communities that are willing to participate in the siting process. The siting process is on-going and no site has yet been identified for a GDF.

Prior to site identification, RWM is undertaking preparatory studies which consider a number of generic geological host environments and a range of illustrative disposal concepts. As part of this work, RWM maintains a generic Disposal System Safety Case (DSSC). The generic DSSC is an integrated suite of documents which together give confidence that geological disposal can be implemented safely in the UK.

Executive Summary

RWM has been established as the delivery organisation responsible for the implementation of a safe, sustainable and publicly acceptable programme for geological disposal of the UK's higher activity waste. Information on the UK Government's approach to implementing geological disposal, and RWM's role in the process, is included in an overview of the generic Disposal System Safety Case (the Overview).

The geological disposal facility (GDF) will be a highly-engineered facility, located deep underground, where the waste will be isolated within a multi-barrier system of engineered and natural barriers designed to prevent the release of harmful quantities of radioactivity to the surface environment. To identify potentially suitable sites where the GDF could be located, the Government is developing a consent-based approach based on working with interested communities that are willing to participate in the siting process. Development of the siting process is ongoing and no site has yet been identified for the GDF.

In order to progress the programme for geological disposal in the absence of a specific site, RWM has developed generic, illustrative disposal concepts for three host rocks. These host rocks are typical of those being considered in other countries, and have been chosen because they cover the range of issues that may need to be addressed when developing the GDF in the UK. They are:

- higher strength rock, for example, granite
- lower strength sedimentary rock, for example, clay
- evaporite rock, for example, halite

The inventory for disposal is defined in the Government White Paper on implementing geological disposal. The inventory includes the higher activity wastes and other nuclear materials that could, potentially be declared as wastes in the future. For the purposes of developing disposal concepts, these wastes have been classified as follows:

- high heat generating wastes (HHGW), that is: spent fuel (SF) from existing and future power stations and High Level Waste (HLW) from SF reprocessing
- high fissile activity waste, that is: Plutonium (Pu) and highly enriched uranium (HEU)
- low heat generating wastes (LHGW), that is: Intermediate Level Waste (ILW) arising from operating and decommissioning of reactors and other nuclear facilities, together with a small amount of Low Level Waste (LLW) unsuitable for near surface disposal, and stocks of depleted, natural and low-enriched uranium (DNLEU)

This document is the Generic Disposal Facility Designs report and is one of two volumes that make up the Generic Design (the other being the Generic Transport System Designs report [7]). This document has been developed as part of a suite of documents that together form the generic Disposal System Safety Case (generic DSSC), and is intended to provide information to a wide range of interested parties of the work RWM has undertaken on the development of a number of illustrative designs for geological disposal in the UK. It also provides the basis for safety assessments that underpin the generic DSSC.

Developing these illustrative designs, in turn, helps to enhance the understanding of how waste disposal could be carried out in different geological environments; how safety can be addressed in all phases of development; how long it might take to develop; and what it is likely to cost. This cost is affected by many factors, but the most significant are the inventory of waste, the timing of waste arisings, the timing and duration of each phase of implementation, the geological environment at the site of the GDF and the design of the GDF itself. At the current stage of the planning for geological disposal there are inevitable uncertainties about all of these factors.

This update has been prepared in order to quantify the impact of adopting design changes and enhancements within the GDF illustrative designs and the updated inventory, such that up to date designs are available as an input to support the siting process.

The illustrative designs describe the processes of waste emplacement and the design characteristics that a disposal facility will need to include for disposal of LHGW and HHGW. The surface facility design is idealised at this stage and does not address aspects of spatial and topographical detail which would only be possible after an identification of a specific site, or sites. Surface facilities allow for the receipt and transfer of waste and its transfer underground via either an inclined tunnel (drift) or shaft. The surface facilities also include the necessary infrastructure for the support of ongoing construction and the provision of essential services (power, water and ventilation). The illustrative design assumes that the surface site is located directly above the underground disposal area, but recognises that these could be spatially separated and linked by inclined tunnels or drifts.

The illustrative designs assume four separate underground accessways to provide security of access and egress, separation of construction and operational activities and separate ventilation circuits for both construction and operation.

It is assumed that LHGW and HHGW disposal areas will be horizontally separated to ensure any interactions between the two areas do not compromise the key safety functions of the different engineered barrier components, taking account of the potential thermal, mechanical, hydrogeological and chemical interactions.

The underground layouts are idealised, in that vaults and disposal tunnels are constructed with uniform dimensions on a regular grid pattern. To provide some flexibility, they have been arranged in groups/modules (panels) which will be constructed in ‘blocks’ of suitable rock. In practice, at a specific site, vaults and disposal tunnels will be located and sized based on the site-specific hydrogeological and geotechnical conditions. The illustrative designs and layouts have been based on assumed parameters and typical host rock properties; the site-specific designs will depend on the geological characteristics of the chosen site such as the local stress field and the distribution and properties of fault zones.

Some LHGW packages require shielding and will be transported underground to an operational inlet cell, where they will be removed from a reusable shielded transport container and transferred by remote handling to disposal vaults, for emplacement via a remotely operated overhead crane.

Some LHGW in self-shielded packages will not require remote handling, and will be transferred using a free steered stacker truck.

HHGW will be transported underground in a purpose-designed shielded transport container. The disposal containers will then be removed from the transport container and then emplaced within the disposal tunnel.

The process of developing and operating the facility will take many decades. An assessment of the potential impacts of carrying out closure operations will be undertaken to optimise the process, taking account of the outcomes of discussions with the regulators and the local community. The decision on when to close the facility after all of the waste has been placed underground for final disposal will take into consideration the views of the local community. The exact condition of the surface site at the end of closure operations will be agreed through consultation with the UK Government, regulators and the local community. When a decision has been taken to close the facility, a programme of backfilling of underground features will be undertaken. This programme will also include the construction of a series of seals with the final backfilling and sealing of the shaft and drift accesses. This will also include the decommissioning of surface facilities.

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1 Introduction

1.1 The generic Disposal System Safety Case

RWM has been established as the delivery organisation responsible for the implementation of a safe, sustainable and publicly acceptable programme for geological disposal of the UK's higher activity radioactive waste. Information on the approach of the UK Government and devolved administrations of Wales and Northern Ireland[1] to implementing geological disposal, and RWM's role in the process, is included in an overview of the generic Disposal System Safety Case (the Overview) [1].

A geological disposal facility (GDF) will be a highly-engineered facility, located deep underground, where the waste will be isolated within a multi-barrier system of engineered and natural barriers designed to prevent the release of harmful quantities of radioactivity and non-radioactive contaminants to the surface environment. To identify potentially suitable sites where a GDF could be located, the Government is developing a consent-based approach based on working with interested communities that are willing to participate in the siting process [2]. Development of the siting process is ongoing and no site has yet been identified for a GDF.

In order to progress the programme for geological disposal while potential disposal sites are being sought, RWM has developed illustrative disposal concepts for three types of host rock. These host rocks are typical of those being considered in other countries, and have been chosen because they represent the range that may need to be addressed when developing a GDF in the UK. The host rocks considered are:

- higher strength rock, for example, granite
- lower strength sedimentary rock, for example, clay
- evaporite rock, for example, halite

The inventory for disposal in the GDF is defined in the Government White Paper on implementing geological disposal [2]. The inventory includes the higher activity radioactive wastes and nuclear materials that could, potentially, be declared as wastes in the future. For the purposes of developing disposal concepts, these wastes have been grouped as follows:

- High heat generating wastes (HHGW): that is, spent fuel from existing and future power stations and High Level Waste (HLW) from spent fuel reprocessing. High fissile activity wastes, that is, plutonium (Pu) and highly enriched uranium (HEU), are also included in this group. These have similar disposal requirements, even though they don't generate significant amounts of heat.
- Low heat generating wastes (LHGW): that is, Intermediate Level Waste (ILW) arising from the operation and decommissioning of reactors and other nuclear facilities, together with a small amount of Low Level Waste (LLW) unsuitable for near surface disposal, and stocks of depleted, natural and low-enriched uranium (DNLEU).

RWM has developed six illustrative disposal concepts, comprising separate concepts for HHGW and LHGW for each of the three host rock types. Designs and safety assessments for the GDF are based on these illustrative disposal concepts.

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1 Hereafter, references to Government mean the UK Government including the devolved administrations of Wales and Northern Ireland. Scottish Government policy is that the long term management of higher activity radioactive waste should be in near-surface facilities and that these should be located as near as possible to the site where the waste is produced.

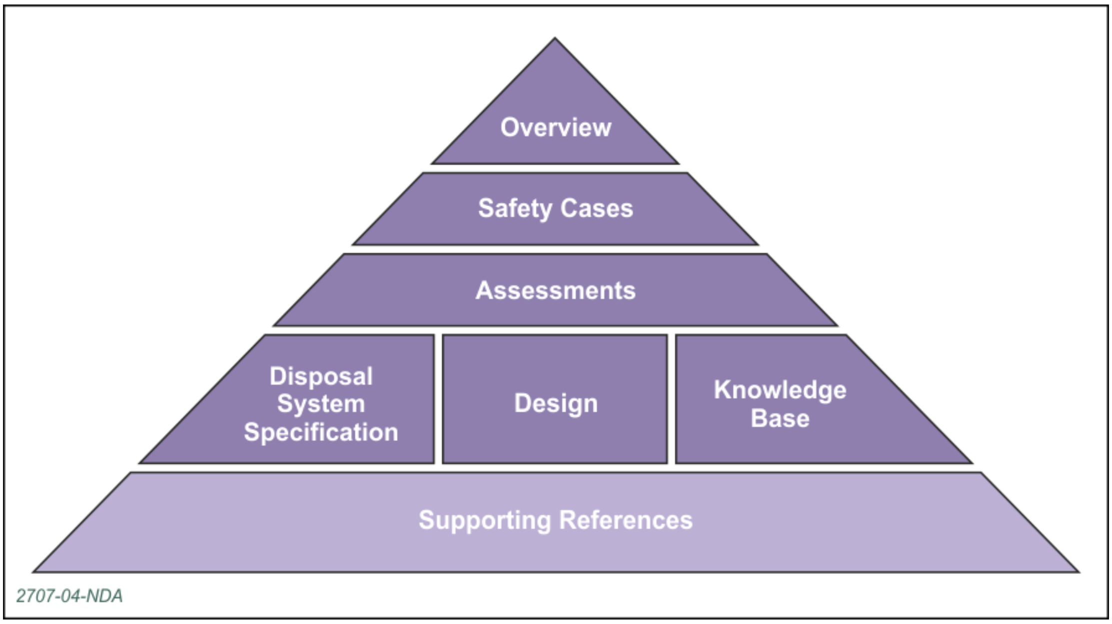
High level information on the inventory for disposal, the illustrative disposal concepts and other aspects of the disposal system is collated in a technical background document (the Technical Background) [3] that supports this generic Disposal System Safety Case.

The generic Disposal System Safety Case (DSSC) plays a key role in the iterative development of a geological disposal system. This iterative development process starts with the identification of the requirements for the disposal system, from which a disposal system specification is developed. Designs, based on the illustrative disposal concepts, are developed to meet these requirements, which are then assessed for safety and environmental impacts. An ongoing programme of research and development informs these activities. Conclusions from the safety and environmental assessments identify where further research is needed, and these advances in understanding feed back into the disposal system specification and facility designs.

The generic DSSC provides a demonstration that geological disposal can be implemented safely. The generic DSSC also forms a benchmark against which RWM provides advice to waste producers on the packaging of wastes for disposal.

Document types that make up the generic DSSC are shown in Figure 1. The Overview provides a point of entry to the suite of DSSC documents and presents an overview of the safety arguments that support geological disposal. The safety cases present the safety arguments for the transportation of radioactive wastes to the GDF, for the operation of the facility, and for long-term safety following facility closure. The assessments support the safety cases and also address non-radiological, health and socio-economic considerations. The disposal system specification, design and knowledge base provide the basis for these assessments. Underpinning these documents is an extensive set of supporting references. A full list of the documents that make up the generic DSSC, together with details of the flow of information between them, is given in the Overview.

Figure 1 Structure of the generic DSSC



1.2 Introduction to the Generic Disposal Facility Designs report

This document is the Generic Disposal Facility Designs report and is one of two volumes that make up the Generic Design (the other being the Generic Transport System Designs report).

The generic DSSC was previously published in 2010. There are now a number of drivers for updating the safety case as an entire suite of documents, most notably the availability of an updated inventory for disposal [4].

This document updates and replaces the 2010 Generic Disposal Facility Designs report, published as part of the 2010 generic DSSC suite. This issue includes the following improvements:

- The generic illustrative GDF designs have been updated to reflect an updated inventory and to incorporate other changes to further improve and enhance the designs.
- Consideration has also been given to addressing comments made by regulators and other organisations that can be addressed at this early stage, while the designs are generic.
- Additionally, reference has been made to a number of documents published prior to and since the 2010 Generic Disposal Facilities Design report [5] that make specific recommendations regarding the designs.
- This update captures these changes to the design as well as changes to the underpinning assumptions, such as inclusion of the 2013 Derived Inventory (herein referred to as the Inventory) which describes the types and numbers of waste packages for disposal in the GDF. The Inventory is summarised in Section 2.5.1 and is described in more detail in the 2013 Derived Inventory [4]. A comparison between the GDF designs for the different inventory scenarios is detailed in the Implications Report [6].

The significant changes to the design since the 2010 generic DSSC are as follows:

- the layout of the surface facilities, in response to a review of security considerations
- the number of disposal vaults and tunnels required in the GDF, in response to the Inventory
- the addition of dedicated Shielded ILW (SILW) vault types to accommodate different waste package types in the Inventory
- disposal vault and tunnel lengths, spacing and orientation based on enhancements to the design

Since publication of the 2010 generic DSSC, a number of design studies have been undertaken in response to identified issues, implementation of a number of change controls (the process for including design changes identified by RWM, regulators and other stakeholders) and in areas where potential design improvements or enhancements were identified. This update captures these changes to the design as well as changes to the underpinning assumptions, such as inclusion of the 2013 Derived Inventory (herein referred to as the Inventory) which describes the types and numbers of waste packages for disposal in the GDF. The Inventory is summarised in Section 2.5.1 and is described in more detail in the 2013 Derived Inventory.

1.3 Objective

The objectives of this report are to:

1) provide information on the work that has been undertaken to develop illustrative designs for geological disposal in the UK
2) enhance the understanding of how waste disposal could be carried out in different geological environments; how safety can be addressed in all phases of development; what the environmental and socio-economic implications of geological disposal might be; how long it might take to develop; and what it is likely to cost

3) quantify the impact of adopting design changes and enhancements within the GDF illustrative designs and the updated inventory, such that up to date designs are available to support the siting process

1.4 Scope

The generic design for the GDF is described in the following two reports:

- **The Generic Transport System Designs (GTSD) report [7] –** describes the operations required commencing at waste producers' sites, to ensure safe and efficient transport of transport packages through the public domain to the GDF. The report describes both the requirements and potential logistics associated with the transport operation based on road, rail and sea scenarios.
- **The Generic Disposal Facility Designs (GDFD) report –** describes the processes of construction, waste package receipt, handling and emplacement and the design characteristics that the disposal facility will need to include for the Inventory. The report provides information on what the facility could look like and identifies the different packaging and disposal processes for different types of waste.

These reports are intended to provide information to a wide range of interested parties on the work undertaken to develop illustrative designs for geological disposal in the UK. The designs have been developed drawing on work done both in the UK and in international programmes in a number of different geological environments and aligned with the requirements specified in the Disposal System Specification.

It is stressed that although illustrative designs have been prepared for each of the three host rocks, this does not mean that any of the illustrative designs developed will necessarily be finally chosen for the selected site, or that any of the designs are favoured more than any other. Until such time as more specific information becomes available, the approach will be to consider a limited number of geological environments, encompassing typical, potentially suitable UK geological environments. This approach has been adopted to provide a manageable number of illustrative designs which can be used in the associated assessments of safety, environmental, social and economic impacts whilst keeping open a broad choice of disposal concept options.

1.5 Document structure

This report describes generic disposal facility illustrative designs and includes the following:

- construction of surface facilities and underground access
- LHGW handling and emplacement
- HHGW handling and emplacement
- underground infrastructure and services
- backfilling
- sealing and closure
- monitoring
- security and safeguards
- retrievability

A summary of each section is as follows:

- Section 2 identifies the Disposal System Specification requirements, design assumptions and primary design elements for the generic illustrative designs. This section includes information on the design process and how RWM integrates safety requirements into the design.

- Section 3 summarises the environmental and sustainability requirements of the GDF
- Section 4 summarises the construction process
- the surface and underground facilities, services and infrastructure are identified in Sections 5 to 11 inclusive
- Section 12 discusses the backfilling, sealing and closure requirements for the GDF
- Section 13 and 14 deal with the monitoring programmes that will be undertaken and matters affecting security and nuclear safeguards
- Section 15 addresses retrievability and how waste could be retrieved from a disposal facility
- the implications of adopting a different inventory scenario on the GDF design are discussed in Section 16
- the report is concluded in Section 17 which describes the way forward and how the design is expected to evolve over time

The drawings are listed at the end of the report.

2 GDF Design Development

2.1 Disposal concepts

At the present generic stage of the programme, the range of geological environments that could be available to host the GDF is wide and diverse and a range of potentially suitable geological disposal concepts are being examined for LHGW [8] and HHGW [9].

A disposal concept is defined by the engineered barrier system and the layout required to deliver the safety functions and requirements defined in the Disposal System Specification (DSS). A disposal concept is specific to a waste category and geological environment.

At this stage in the process, RWM has selected six illustrative geological disposal concept examples as the basis for RWM's current design work and these are listed below in Table 1. These concepts have been developed within specific geological constraints and are supported by extensively documented research and development and have been subject to detailed safety assessment, regulatory scrutiny and international review. However, this does not mean that a disposal concept developed now will necessarily be that used in a particular geological environment; at this stage, no disposal concepts have been ruled out.

Table 1 Sources of illustrative geological disposal concepts for host rocks and classes of waste

Host rock	Illustrative Geological Disposal Concept Examples[d]	
	LHGW	HHGW
Higher strength rocks[a]	UK LHGW Concept *(RWM, UK)*	KBS-3V Concept *(SKB, Sweden)*
Lower strength sedimentary rock[b]	Opalinus Clay Concept *(Nagra, Switzerland)*	Opalinus Clay Concept *(Nagra, Switzerland)*
Evaporites[c]	WIPP Bedded Salt Concept *(US-DOE, USA)*	Gorleben Salt Dome Concept *(DBE-Technology, Germany)*

Notes
a. Higher strength rocks – the UK LHGW concept and KBS-3V concept for spent fuel were selected due to availability of information on these concepts for the UK context.
b. Lower strength sedimentary rocks – the Opalinus Clay concept for disposal of long-lived ILW, HLW and spent fuel was selected because a recent OECD Nuclear Energy Agency review regarded the Nagra (Switzerland) assessment of the concept as state of the art with respect to the level of knowledge available. However, it should be noted that there is similarly extensive information available for a concept that has been developed for implementation in Callovo-Oxfordian Clay by Andra (France), and which has also been accorded strong endorsement from international peer review. Although we will use the Opalinus Clay concept as the basis of the illustrative example, we will also draw on information from the Andra programme. In addition, we will draw on information from the Belgian super container concept, based on disposal of HHGW in Boom Clay.
c. Evaporites – the concept for the disposal of transuranic wastes (TRU) (long-lived ILW) in a bedded salt host rock at the Waste Isolation Pilot Plant (WIPP) in New Mexico was selected because of the wealth of information available from this facility. The concept for disposal of HHGW in a salt dome host rock developed by DBE Technology (Germany) was selected due to the level of concept information available.
d. For planning purposes the illustrative concept for depleted, natural and low enriched uranium is assumed to be same as for ILW/LLW and for plutonium and highly enriched uranium is assumed to the same as for HLW/SF.

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It should be noted that these individual examples are not considered to be the 'best' available or even especially suited to implementation in the UK. Rather they provide a range of options (disposal in tunnels, with or without supporting plinth, in boreholes and in caverns), which covers the range within the catalogue of concepts previously described for

LHGW and HHGW. This approach does not imply any preference over other national concepts or concept options or ones.

Development and the technical understanding of disposal concepts is a continuing process and work to select the most appropriate disposal concepts will continue as the GDF design is refined. Further information about the disposal concepts being considered and their selection is provided in the Technical Background.

2.2 Development of the generic designs

The three illustrative designs presented in this report are based on the six geological disposal concepts identified in Table 1 above (higher strength rock, lower strength sedimentary rock and evaporite rock).

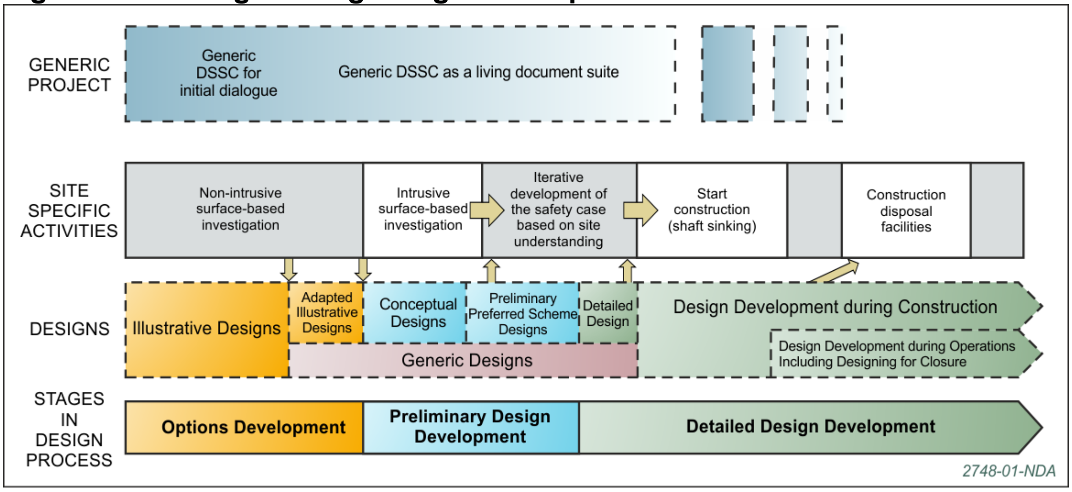
The illustrative designs are currently being used to:

- further develop the understanding of the functional and technical requirements of the disposal system
- further develop the understanding of the design requirements
- support the scoping and assessment of the safety, environmental, social and economic impacts of the GDF
- support development and prioritisation of RWM's R&D programme
- underpin the analysis of the potential cost of geological disposal
- support assessment of the disposability of waste packages proposed by waste owners

At the current stage of the programme, work is focused on analysing and developing generic, illustrative designs. In the future, these illustrative designs will be tailored to the specific boundary conditions of UK geology and the waste inventory, and also constraints resulting from the siting process. It is expected that these illustrative designs will continue to be required and updated as the designs move forward through the process from their current illustrative status through the conceptual and preliminary design stages and until a detailed design for the GDF at a specific site is developed.

Generic illustrative designs will also be maintained in parallel with site-specific designs. The purpose of these generic illustrative designs will be to support generic assessments, to provide information to support the verification of site-specific designs and also support the Disposability Assessment process until a specific site is identified. The process for design development is shown in Figure 2.

Figure 2 Engineering design development



2.3 Iterative design process

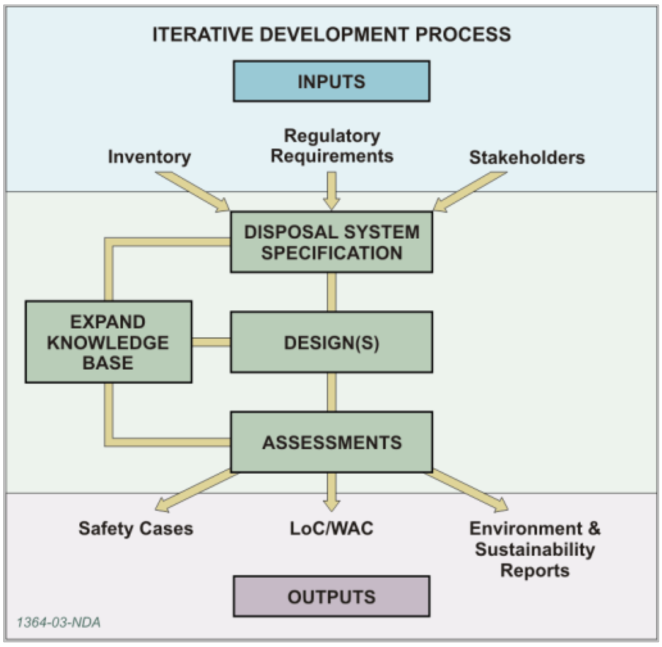
RWM has developed a generic DSS which describes the requirements on the disposal system and provides the starting point for design and assessment work. The DSS comprises two documents:

- **The Disposal System Specification Part A – High Level Requirements (DSS Part A) [10] –** which describes the high-level requirements on the disposal system and is in a form suitable for a wide range of stakeholders
- **The Disposal System Specification Part B – Technical Specification (DSS Part B) [11] –** which describes in more detail the requirements on the disposal systems, together with a justification for each requirement

The illustrative designs have been developed to be consistent with the requirements defined in the DSS Part B. These documents currently describe generic requirements, reflecting the fact that a site and a disposal concept have yet to be selected. They will be periodically updated throughout the implementation of the GDF programme, for example to respond to changes in regulations and to respond to issues identified from undertaking safety assessments. The DSS Part B, in particular, will evolve from generic to site-specific requirements as site-specific information becomes available.

Figure 3 gives an overview of the process by which the DSS incorporates external sources of information to guide the design and assessment processes, which in turn leads to refinements and changes in the DSS. Since this figure represents a high-level illustration of the process, to avoid making the figure over-complicated feedback loops have not been explicitly represented. Nevertheless, this figure clearly identifies the main constraints on and outputs from the design process.

Figure 3 Iterative disposal system development



The use of illustrative designs and safety assessments of these designs allows RWM to challenge and identify potential improvements to these designs and allows appropriate disposal solutions for different waste types to be addressed and identify further research and development tasks.

The iterative process described in Figure 3 will continue as development of the design and safety case continues. There will be hold points throughout this process when regulators will be required to assess the safety case and agree or give consent to commence the next stage (for example, construction, commissioning, operation, decommissioning, closure). Safety Functional Requirements will be used to provide the formal, auditable link between the safety assessment work and the design. Requirements will be developed in terms of design functionality so that designers have the freedom to provide the most appropriate way to implement the required functions. In the future, this will be integrated into a formal requirements management system that is likely to include a constraints set in order to clearly articulate and agree the requirements and enable their delivery.

2.4 Design reports and supporting documents

As described in Section 1, the generic illustrative design for the GDF is described in two reports: the GTSD report and this document, the GDFD report. These reports present an overview of what the facility and the transport system could look like and identifies the different packaging and disposal processes for different types of waste. The data that supports the designs presented in these reports are provided in the Data Report [12]. These reports are supported by a number of other documents:

- **Design Status Report [13] –** This document records the rationale behind the key historical design developments to date and the overview of the engineering design work. This status report will be periodically updated to include design enhancements that are adopted, in order to support any future design development work and to provide reference to the underpinning source information.
- **Engineering Design Manual [14] –** The Engineering Design Manual is the part of the RWM's internal management system which describes the engineering design process that will be followed to establish, maintain and update the engineering designs that will be used for the development, construction, commissioning,

operation, closure and decommissioning of the waste disposal systems for the GDF. This manual provides users of the engineering design process with an overview of the requirements, expectations, steps and tools to work with confidence and compliance, to know how to obtain the detailed operational documentation, and understand how that fits with the wider arrangements.

- **Science and Technology Plan [15]–** In order to prioritise the R&D programme, RWM has developed a Science and Technology Plan which presents a plan to deliver future generic research and development activities. Generic is defined as those activities that can be undertaken without specific knowledge of the eventual host site for the GDF. The plan provides opportunities for dialogue and involvement of interested parties and stakeholders in the development of RWM's knowledge base for the safe geological disposal of radioactive waste. This document identifies areas in the GDF design where additional work is required to expand the RWM knowledge base.

To underpin the design process, it is sensible to take advantage of the work carried out in the area of geological disposal over the last three decades, in the UK and overseas. RWM is continuing to collaborate with other national programmes on research, demonstrations and trials for aspects of geological disposal. These include DOPAS (Demonstration of Plugs and Seals), ESDRED (Engineering Studies and Demonstration of Repository Designs), MoDeRn (Monitoring Developments for Safe Repository Operation and Staged Closure). RWM is also continuing to collaborate with other national programmes on emplacement technologies for LHGW and HHGW and full-scale mock-up trials for the emplacement of HHGW packages have been carried out in underground or surface research facilities in countries such as Germany, Sweden, Switzerland, France and Belgium. These collaborations are discussed in more detail in the Science and Technology Plan.

Since publication of the 2010 generic DSSC, the GDF and transport system designs have been developed to address identified issues and enhance aspects of the designs. One aspect of this work programme has been the adoption of Building Information Modelling (BIM) and the development of GDF designs in a 3D design environment. The use of BIM is part of the *Government Construction Strategy* [16], which requires the whole project lifecycle, including the design, to be conducted in a BIM environment.

This approach is outlined in [17] and sets out the process for RWM to be compliant with the Government's requirement that all public sector construction projects are delivered in a BIM environment by 2016.

Since the first edition of this report and in accordance with the adoption of BIM as described above, three dimensional representations of the illustrative GDF designs have been developed for each geological environment. These 3D representations have been used in the updated illustrative GDF designs presented in this report and will continue to be developed to add further detail and functionality in the future as the process progresses.

2.5 Design assumptions

In order for RWM to develop illustrative designs for the GDF within different host rocks and to allow safety, environmental and socio-economic assessment assessments of these illustrative designs, assumptions have been made regarding the design, construction, operation and closure of the GDF. This section describes the design assumptions used in the current generic designs. The basis for the illustrative designs for the GDF in the UK, including assumptions for the geological environment, radioactive waste inventory, waste package design and disposal concepts are presented in the Technical Background.

2.5.1 Inventory

It is assumed that the GDF will accept all types of LHGW and HHGW as specified in the Inventory, the volumes of which are detailed in Appendix A with the associated quantities of each type of waste package listed in Appendix B. The waste packages include legacy waste arising from the UK nuclear industry since the 1940's and also nuclear new build (NNB) packages that are anticipated to be generated by the planned new fleet of nuclear power stations.

The volume of waste produced by new power stations would depend on factors such as the reactor type, number of new reactors and their operational life. RWM currently makes assumptions regarding these factors in order for us to understand the relationship between the amounts and nature of such wastes and the implications for the size and design of the GDF and for the level of safety and environmental protection provided by the facility. The waste types and the waste package types currently assumed to be disposed of within the GDF are shown in the table below.

Table 2 Radioactive waste categories

<table>
<tr><th>Category</th><th>Sub-division</th><th>Waste Package Types</th></tr>
<tr><td rowspan="4">LHGW</td><td>LLW</td><td>4 metre box
500 litre drum</td></tr>
<tr><td>SILW</td><td>2 metre box
4 metre box
6 cubic metre concrete box
500 litre robust shielded drum
3 cubic metre robust shielded box
1 cubic metre concrete drum
500 litre concrete drum</td></tr>
<tr><td>UILW</td><td>3 cubic metre box
3 cubic metre drum
500 litre drum
Miscellaneous Beta Gamma Waste Store (MBGWS) box</td></tr>
<tr><td>DNLEU[2]</td><td>500 litre drum (Miscellaneous and TPU waste streams, handled as UILW)
Transport and Disposal Container (Depleted UF6 Tails and MDU, handled as SILW)</td></tr>
<tr><td rowspan="5">HHGW</td><td>HLW</td><td rowspan="5">Disposal container</td></tr>
<tr><td>SF[3]</td></tr>
<tr><td>Pu</td></tr>
<tr><td>HEU</td></tr>
<tr><td>Mixed Oxide Fuel (MOX)</td></tr>
</table>

It is currently assumed that no waste packaging or encapsulation will be undertaken at the disposal facility and all waste will arrive packaged in a form that meets the relevant

[2] DNLEU will be packaged in 500 litre drums (UILW) and Transport and Disposal Containers (SILW) depending upon the waste stream

[3] This includes both Legacy spent fuel (Magnox and PFR) and spent fuel arising from a programme of new nuclear power stations

specifications (as detailed in the GTSD report) and therefore, is suitable for emplacement on arrival at the facility.

2.5.2 Surface facilities and underground access

As no host site has yet been identified for the GDF, the surface facilities are currently assumed to be located on a single rectangular-shaped site with level topography.

At this stage, the underground facilities are assumed to be constructed directly below the surface facilities. However, it is possible that the surface site could be horizontally displaced and the accessways (drifts and shafts) linked to the underground disposal areas by service tunnels. There are several factors, many of which are site-specific, that will need to be considered when determining the maximum lateral separation that could be feasible.

2.5.3 Geological environment and depth of the underground facility

For the higher strength rock example, the host geological environment is assumed to be a higher strength rock overlain by a permeable sedimentary rock.

For the lower strength sedimentary rock example, the geological environment is assumed to be a lower strength sedimentary rock overlain by a permeable sedimentary rock.

For the evaporite rock example, the geological environment is assumed to be a bedded evaporite (halite) rock salt overlain by a permeable sedimentary rock

For the purposes of developing the illustrative designs, the following depths below ground level have been assumed for the three host rocks:

- higher strength rock – 650m
- lower strength sedimentary rock – 500m
- evaporite rock – 650m

The location of the disposal horizons will be determined by the site investigations and the safety case, and will also take into account the potential advantages and disadvantages of increased depth.

2.5.4 Underground facilities

The underground facilities are assumed to be arranged in an idealised layout, to be constructed on one level or horizon within a single uniform rock formation containing no structural discontinuities. For each geological environment considered, it is assumed the host rock will be sufficiently extensive vertically and horizontally to accommodate the facility.

The current illustrative disposal facility designs recognise the potential for deleterious interaction between co-located disposal areas of the GDF. To minimise the effects of such interactions, the current planning assumption, irrespective of geological environment, is to observe a minimum 500m separation distance between the LHGW and HHGW disposal areas [18].

2.5.5 Construction, operation and closure

For the purposes of developing the illustrative designs, the initial underground construction phase of the GDF is assumed to take approximately 10 years, during which time underground access will be established and the facility will be constructed to the point where it could accept waste.

At this stage, for the purpose of providing a basis for undertaking safety assessments and environmental assessments, and considering the logistics associated with moving wastes to the facility, assumptions have been made regarding the timings and throughput rates.

Throughput rates have been based on earlier studies (*Generic Repository Designs* [19]) or from information drawn from other national programmes.

The timing of the disposal programme is very important for planning, not only for RWM but also for the organisations having responsibility for the wastes held in interim storage and for communities affected by the management arrangements for the wastes.

RWM assumes as its planning basis that the GDF will be available to receive LHGW in 2040 and HHGW in 2075. It is recognised that the basis for the siting process is consent-based and partnership, and consequently the process is driven in large part by discussions with local communities. Therefore this date, like all other aspects of the current GDF programme, must not be seen as fixed, but rather a reasonable basis for planning based on current assumptions. It is assumed that disposal vaults and tunnels will be constructed on an as required basis throughout the operational period. The operational assumptions are assumed to be consistent across the three illustrative designs.

For the purpose of developing the illustrative design, it is currently assumed that the backfilling, sealing and closure of the LHGW vaults, roadway infrastructure and access ways from the surface will take place over a nominal 10 year period after completion of all emplacement operations. As the HHGW disposal tunnels are backfilled as emplacement progresses, complete backfilling of these tunnels will be completed on commencement of this 10 year closure period. During this period, all equipment would be decommissioned underground and the vaults, tunnels, shafts and drift backfilled and sealed. The surface facilities would be decommissioned and demolished and the site restored to an agreed end state.

2.5.6 Underground construction

It is assumed that construction of the vaults for LHGW and the disposal tunnels for HHGW will take place concurrently with emplacement operations. At the time of first waste emplacement, there will be one unshielded ILW (UILW) vault constructed and operational, one UILW vault undergoing fit-out and one SILW/LLW vault constructed and operational. A vault for Robust Shielded ILW (RSILW) waste packages will also be constructed ready for waste disposal although this would depend upon the schedule of arising RSILW Containers. Construction of one HHGW disposal module comprising 20 disposal tunnels will be completed prior to the arrival of the HHGW containers.

Construction of the vaults for LHGW and the disposal tunnels for HHGW will take place on an as-required basis, with potentially two or three tunnels under construction and fit-out at any one time.

2.5.7 Depth of underground facility

Based on the 2014 White Paper [2], it is assumed that the depth of the GDF will be between 200 and 1000 metres below ground level. The assumed depth is 650 metres below ground level for the higher strength rock and evaporite rock designs, and 500 metres below ground level for the lower strength sedimentary rock design. Additionally, it is assumed that there will be 300 metres of overlying water-bearing strata in all three host rocks considered.

2.5.8 Excavation support

The assumptions for support are currently based on the disposal concepts adopted by sister organisations and assessed in the *Design Assessment for Geological Repositories Report* [20].

In the higher strength rock and lower strength sedimentary rock designs, the excavation support is assumed to comprise a combination of steel mesh, rockbolts and shotcrete. For the lower strength sedimentary rock design, the use of concrete segmental linings has not been discounted. In evaporite rock, the assumption is that rock bolts and mesh will be used for excavation support.

The long-term stability of excavations is an important consideration, bearing in mind the currently assumed operating period of the facility; some features including the shafts, drift, and common services area will be required to be stable and serviceable for up to 160 years. Excavation support, maintenance and associated monitoring considering this extended operating period will be a key area for future design activities to ensure this can be achieved [21].

It is assumed that access to the facility excavations for inspection and maintenance will be available in all but the remotely operated areas, which could be inspected using remote means. Maintenance requirements of the support systems will vary with the rock types, but more reliance will be placed on the support systems rather than the rock itself as rock strength reduces and/or depth increases.

2.6 Integrating safety into the design

Safety, environmental, security and safeguards principles have been defined for the design process [22]. These define the objectives of geological disposal as being to ensure that all disposals of solid radioactive waste are made in a way that protects people and the environment, now and in the future, commands public confidence and is cost-effective.

Concentrating and containing radioactive waste and isolating it from the surface environment is the internationally accepted strategy for the long-term safe management of such materials. The development of the GDF will follow internationally accepted practices with the use of multiple engineered and natural barriers to achieve safety. Radiological protection as outlined in the Radiological Protection Criteria Manual [23] is followed for the generic designs.

The illustrative designs consider the transport of radioactive waste, the construction, operation and closure of the GDF and the safety of the disposal facility in the very long term, after it has been sealed and closed. More detail on the safety of the GDF can be found in the transport, operational and environmental safety cases [24, 25, 26].

RWM has also continually reviewed and updated the illustrative designs based on the outputs from the safety assessment process. This process involved interaction between the designers and safety assessors to ensure that these proposed changes complied with the relevant safety legislation. This interface between design and assessments ensures that the safety cases and design are integrated to one another.

These illustrative designs for geological disposal provide a number of key safety provisions in the packaging, transportation and handling of radioactive wastes within the disposal facility and are discussed in the following sub-sections.

2.6.1 Assessment of waste packages

The quality of the waste packages is essential to operational safety of the GDF. At present, to ensure compliance with the DSS, generic waste package specifications [27] have been developed to specify the requirements for the waste packages. Assessment of a packaging proposal is undertaken as part of the Disposability Assessment process against the requirements of these specifications. This process gives the waste producer confidence that the waste package has been assessed by an independent waste management organisation in accordance with procedures that are scrutinised by the regulators and has been found to be compliant with the concept for geological disposal as presently understood. This does not remove the need for further assessment of the waste package against future waste acceptance criteria but, the provision of a final-stage Disposability Assessment Letter of Compliance is an essential component of the package record. Further information on the Disposability Assessment process is available in *Radioactive Wastes and Assessment of the Disposability of Waste Packages* [28].

2.6.2 Transport packages

The transport system for radioactive waste includes all of the processes, equipment and management arrangements required for the movement of waste packages from a waste-producing site to the GDF including, for example, loading of transport packages onto vehicles, monitoring of transport packages and vehicles during transit as well as changes in transport mode.

The most hazardous materials, including some types of LHGW and all HHGW, are planned to be transported in large reusable transport containers made from high-integrity materials that provide containment of radioactive materials and shielding from radiation even under transport accident conditions (severe impact and fire). At this stage designs have been developed for two re-usable transport containers to transport waste to the GDF. The first is a Standard Waste Transport Container (SWTC) which will be used to transport the majority of LHGW packages. The second is the Disposal Container Transport Container (DCTC) which will be used for the transport of HHGW [7].

RSILW containers will be transported to the GDF using a transport overpack, which is an enclosure for transporting one or more waste packages from the waste site to the GDF.

Less hazardous LHGW is assumed to be packaged in ‘industrial packages’; typically large steel or concrete boxes which are designed to be both a transport and disposal package.

The safety of the packages is provided by a combination of the design and by the regulatory limitation of the quantity and form of the radioactive material that can be carried in the respective transport containers. The adoption of encapsulated wasteform will also help to potentially minimise the likelihood of internal contamination of the transport package although facilities exist to monitor and decontamination the interior of transport packages if necessary. Details of these designs and their assessment of safety are provided in [7].

2.6.3 Receipt and dispatch of transport packages

Under currently established arrangements, prior to any waste packages being dispatched to the GDF, a rigorous system of checking and monitoring of each transport package will be carried out by the consigning organisation (the waste owner or the organisation acting on behalf of the waste owner) as detailed in Transport Package Safety report [29]. This will ensure, in particular, that the specific identification of individual waste packages in terms of the nature and quantity of waste is confirmed and that the package complies with the waste acceptance criteria that will be established for receiving waste at a disposal facility.

Following receipt of packages at the GDF, administrative checks of the consignment, physical inspection of the transport package, and radiological measurements of surface dose and contamination will be carried out. This will confirm that no damage had been sustained in transport and act as a cross-check on the inspection carried out at the point of dispatch.

Should any packages fail to meet acceptable criteria, then facilities will be in place to safely and properly handle these. These facilities are described in more detail in Section 5.

2.6.4 Surface facilities

When considering conventional and radiological safety, it is prudent to physically segregate construction and waste handling operations, with separate controlled access to each area. The waste handling and transfer operation will be classified for radiological protection based on the potential levels of radiation and contamination in each area.

Surface facilities are to be designed to meet all requirements necessary to satisfy the safety case. The buildings and structures, whose failure could affect the safe operation of the facility, will be seismically qualified and designed to cope with factors such as extreme weather conditions. The design of the buildings will also include appropriate security features as required for the waste types.

The layout of the surface facilities has been developed based in part upon a recent assessment of security requirements for the GDF. The results of this assessment have been used to ensure the proposed security measures are robust and include an increase in fencing and barriers, relocation of car parking to outside of the perimeter fence and a reduction in the sections of straight road leading up to the facility.

2.6.5 Transfer underground

The illustrative designs for higher strength rock and lower strength sedimentary rock environments assume that waste packages are transported underground on an inclined drift transport system. This system would be designed to meet ONR's non-prescriptive regulatory framework, building on the safety standards of the Swiss Federal Office of Transport as provided in *The Ordinance on the Construction and Operation of Railways* [30] (which are effectively the world safety standards for rack and pinion operation), and would be similar to those used throughout the world for the safe transport of passengers and freight on steep gradients as detailed in *Drift Rack and Pinion Transport System Specification and Justification* [31]. Where RWM intends to use designs and/or standards for structures, systems and components related to nuclear safety, further work will be required to analyse those designs and/or standards to demonstrate that they meet the ONR's non-prescriptive nuclear safety regulatory regime. This comprises rack and pinion locomotives, which are on a separate rail system to that used for surface rail receipt, to avoid direct connection to the underground access drift. In accordance with standard rack and pinion railway practice, the drift locomotives would always be at the downhill end of the train while in the drift. The locomotives and vehicles would be equipped with multiple failsafe braking systems and two locomotives would be used to ensure safety should there be a failure with one of them. All drift wagons would be specifically designed for rack and pinion operation. They would be equipped with brakes that engage with the fixed rack [31]. A rack and pinion system was chosen as the most appropriate means of transporting large loads (up to 80t) down a steep incline. The incline, up to 1:6, is deemed too steep for conventional locomotive which rely on frictional adhesion. Other forms of transport were considered, such as a cableway and funicular railway, but rack and pinion was selected as the prefered choice for this application [31].

The illustrative design in an evaporite rock environment assumes that the waste packages will be transported underground via a vertical shaft. The operating facility within evaporite deposits at the Waste Isolation Pilot Plant (WIPP) in the USA transports waste via shafts and it was proposed to utilise shaft transport at a proposed repository in the Gorleben salt dome, Germany [32] and also by Posiva at the proposed repository in Finland [33]. In order to comply with UK law, it is necessary to demonstrate the risk for operations to be as low as reasonably practicable. All shaft conveyances would be designed to meet the Mines Regulations 2014 (as relevant good practice) as would be the case for conventional mine equipment. Although shaft transport designs would be based on conventional mine winding systems, which are used extensively and internationally as a means of safely accessing deep underground mines and are high integrity, the waste shaft hoist would be designed and constructed to be of demonstrably very high integrity with substantiation in line with that used for nuclear cranes with any learning from experience from international designs for waste shaft hoists. In addition, it is recognised that to make a safety case for its use, a number of additional safety claims will be necessary. These are likely to include consideration and demonstration of waste package integrity in identified fault scenarios. Any shaft hoist would likely have additional measures such as an additional independent load-path if found to be practicable. Conventional safety systems would be included which protect against over-travel and uncontrolled lowering along with impact absorbers and shaft bottom arrestors. Where required, containment and shield doors could also be incorporated into any design to give additional protection to operators and the public. It is also likely that movement of the shaft conveyance would be done remotely and operator access at delivery of the waste package to the underground environment restricted.

Although there is an assumption that, in Evaporite, access from the surface to the disposal horizon will be by shaft only, in practice, access could be by shaft and/or drift in any of the geological environments which RWM is considering. The preferred solution will be highly dependent on the local geology, and is therefore a site specific issue.

2.6.6 Handling operations

All lift heights will be kept to a minimum so as to limit potential damage to the waste package, in the unlikely event that a waste package is dropped. The UK has experience of handling ILW from the management of a number of waste stores. Transport containers will be monitored to check for integrity at surface in the waste receipt and transfer facility. If the container or package is non-compliant it can be taken 'off-line' to a maintenance facility for further monitoring and testing.

Once underground, UILW waste packages are monitored at the inlet cell prior to removal from the SWTC. In a higher strength rock, transport containers carrying disposal containers would be monitored at the underground transfer hall prior to the container being removed from the transport container and transferred in to the deposition machine. In a lower strength sedimentary rock and evaporite rock the HHGW transport container would be monitored prior to being transferred on to the narrow gauge rail system.

2.6.7 Construction and operation activities

The illustrative designs have been developed assuming that the underground operations associated with construction (such as excavating the underground disposal vaults and tunnels) will be kept separate from the operational activities (such as the emplacement of waste) with the use of separate access routes underground, separate ventilation circuits and a series of mobile seals and bulkheads. These aspects are discussed in more detail in Section 8.

Personnel access and egress will be possible by both the construction and operational sides of the GDF; i.e. there will be two possible routes for access and two for egress.

The spacing between the vaults will be arranged to minimise geotechnical interactions between adjacent vaults, and will take into account the need for concurrent construction and waste emplacement operations.

Tunnelling and underground excavation can be a hazardous activity and construction must be undertaken with robust safety management arrangements and complying with general health and safety, mining and nuclear legislative requirements.

The GDF will be constructed using a combination of techniques such as drilling and blasting methods, tunnel-boring machines, continuous miners and roadheaders, depending on the nature of the host rock and the size and dimensions of the tunnel to be driven. Safety during construction will be provided by working to a well-defined safety management system, and by establishing a strong safety culture.

The Generic Operational Safety Assessment [25] identifies the non-radiological safety assessment during construction and operations at the GDF.

Workers carrying out operational, maintenance, inspection and testing activities at the GDF will be subject to radiation doses. The Operational Safety Case assesses the operations undertaken in relation to waste handling and emplacement to ensure that any radiation doses received by workers are as low as reasonably practicable (ALARP).

2.6.8 Ventilation and drainage systems

In the illustrative designs both the ventilation and drainage for underground construction and waste emplacement areas are designed as separate systems. The design of both systems will allow progressive development of the disposal facility with concurrent construction and waste emplacement. This will be achieved by the installation of bulkheads and seals between two separate circuits, which could be moved periodically to switch the services for each newly constructed disposal vault or disposal tunnel to the waste emplacement circuit.

The ventilation system will control certain aspects of the underground environmental conditions, but importantly it has also been designed to ensure that the construction areas remain at a positive pressure relative to the waste emplacement areas. The waste disposal area ventilation will be kept at a negative pressure, relative to both the surface atmosphere and the construction areas. The ventilation system is described in more detail in the *GDF Ventilation Study report* [46].

2.6.9 Power supply

The illustrative designs provide for two independent power supplies to the construction and operational areas, each with the capacity to meet the demands for maintaining the facility should one of the supplies fail. Back-up generation and emergency winding facilities will also be provided. The illustrative designs provide for systems which are sufficiently robust to remain safe in the event of system failures such as provision for the recovery of remote handling equipment. An assessment of the resilience of the proposed GDF power supply has been undertaken and the findings presented in the *Assessment of the Current GDF to Withstand Loss of Off-site Power* Report [34] and the conclusions of this study have been incorporated into the GDF design. Further detail is described in Section 11.4.

2.6.10 Backfilling and sealing

Backfilling (including emplacement of buffer materials, local and peripheral backfill) and sealing of disposal areas is required as part of the multi-barrier functions for waste disposal.

Buffer or backfill is placed around the waste container to:

- protect the waste container from physical disruption (eg by movement in the bedrock)
- control the rate at which groundwater can move to and around the waste container (eg by preventing flow)
- control the rate at which corrosive chemicals in groundwater can move to the waste container
- condition the chemical characteristics of groundwater and porewater in contact with the container and the wasteform so as to reduce corrosion rate and/or solubility of radionuclides
- control the rate at which dissolved radionuclides can move from the wasteform into the surrounding rock
- control or prevent the movement of radionuclide-containing colloids from the wasteform into the rock
- suppress microbial activity in the vicinity of the waste

- permit the passage of gas from the waste and the corroding container into the host rock

Mass backfill will be placed in all service and transport tunnels and will:

- restore mechanical continuity and stability to the rock and engineered region of a geological disposal facility so that the other engineered barriers are not physically disrupted (eg as a clay buffer takes up water and expands)
- close voids that could otherwise act as groundwater flow pathways within a geological disposal facility

Seals will be constructed to:

- cut off potential fast groundwater flow pathways within a backfilled geological disposal facility (eg at the interface between mass backfill and host rock)
- prevent access of people into a closed geological disposal facility

The designs for plugs and seals are based on a wide range of international designs underpinned by research programmes such as the DOPAS Project in which RWM participated. Lessons learnt from these programmes will be applied to the GDF in the UK.

2.7 Flexibility of the design

At the current stage of the programme, RWM is examining a wide range of potentially suitable 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 designs have been prepared for each of the three host rocks.

RWM does not intend that one of these illustrative designs is necessarily the one that would be used in the relevant geological environment and at this stage no geological disposal concept has been ruled out. Depending on the location of the GDF, there could be a number of additional considerations incorporated into the design.

The following sections describe some of the potential variations that could be incorporated within the GDF design in the future.

2.7.1 Surface facilities

The surface facilities will be the most visible aspect of the disposal system, and minimising adverse effects on local landscape character and visual amenity will be an important design consideration.

If it was not possible to locate all required surface facilities on a single site due to space constraints, then the division into a waste receipt site and a construction site would be a potentially viable option which would not necessarily affect the underground layout. The main constraint would be the location of the underground access points (drift / shafts) relative to the GDF underground facilities in order to make logistics practicable.

Even if the surface facilities were to be located at two or more sites, then, depending upon the siting process, the facility would still operate in the same way as the designs outlined in this report.

2.7.2 Extent of underground facilities

The size of the underground areas of the GDF will be determined by the Inventory, the selected disposal concepts, including such aspects as: the size of excavations and separation distances between emplacement zones, characteristics of the host geological environment, for example the orientation of stress, the presence of major structural discontinuities and the near-field geological environment. Indicative underground layouts have been prepared for a single inventory scenario (the Inventory). These simplified indicative layouts assume that the host rock is sufficiently extensive, vertically and particularly horizontally to accommodate the GDF on a single horizon.

In practice, land ownership, mineral rights, planning boundary issues and the lateral extent of the host rock and the presence of layout-determining structures such as fault zones could limit the area available. The underground facilities have therefore been designed in modules to allow for flexibility and enable the design to be modified, based upon the structural geology of the host site. For example, modules will be positioned to avoid structural features such as faults.

In practice, it may be possible or desirable to build the GDF over a smaller area, either by virtue of the host rock being sufficiently thick or due to the presence of a different, suitable host rock above or below the proposed facility horizon. If such geological conditions prevailed and if the rock mass characteristics were acceptable, then it could be possible to develop the facility on multiple levels, each having a smaller footprint.

If a multi-level facility was constructed, there would be little or no impact on the surface facilities or the underground workings, other than to reduce the horizontal extent of the underground. Where disposal vaults and tunnels are constructed on multiple levels, it is essential to ensure that sufficient separation is maintained to ensure that there is no detrimental interaction between them.

2.7.3 Depth of the underground facilities

The depth at which the GDF will be located is assumed to be between 200m and 1,000m but the exact depth will depend on the site geological environment. For planning purposes, a minimum depth of 200m is specified, to provide a depth of cover greater than the likely maximum extent of surface change in the very long term while the wastes are still hazardous.

The maximum depth of 1.0km is considered appropriate at this time for construction, but in some situations it would be possible to construct at greater depths. As the depth of a disposal facility increases, the range of options available for access, construction, operation and closure reduces. Ambient temperatures rise due to the geothermal gradient and construction and operational requirements increase, subject to the rock mass characteristics. The depth of any potential geological environment will, therefore, be important in determining how the facility will be constructed, the excavation sizes, the support requirements and long-term stability in the underground environment.

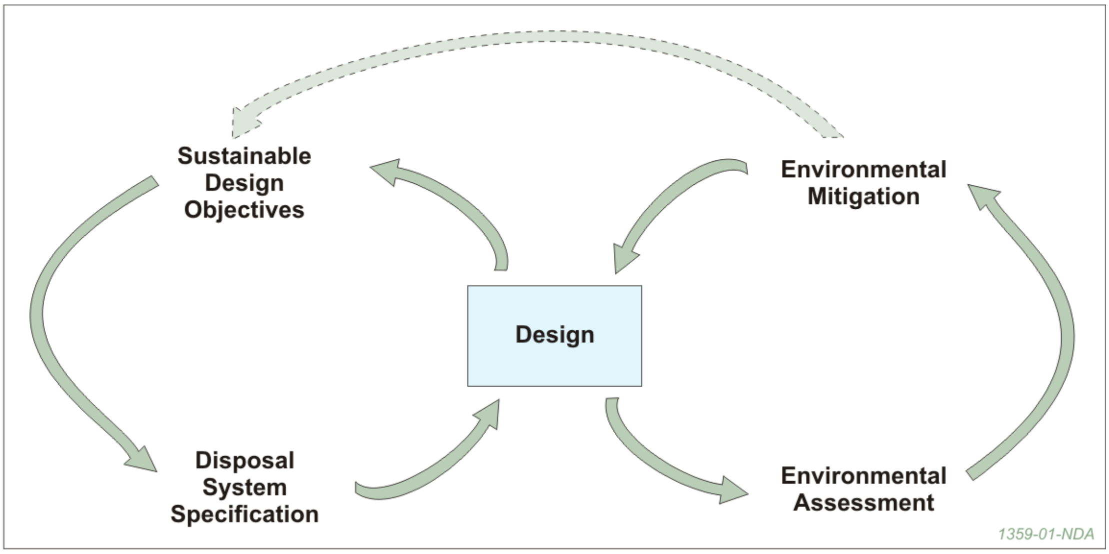
3 Environment and Sustainability

RWM carries out generic environmental, socio-economic and health impact assessments [35, 36, 37], alongside its generic safety case work, to support illustrative design development and to inform the early stages of the siting process for the GDF. Potential mitigation (and enhancement) measures identified by this work are fed back into the design process. Site-specific environmental and sustainability assessments will be carried out to support more detailed stages of design and later stages of the siting process. Ultimately, a detailed Environmental Impact Assessment (EIA) will be prepared to support a development consent application to construct and operate the GDF at the chosen site. Further information on RWM's approach to environmental and sustainability assessment is provided in a technical note [38].

The iterative process of environmental and sustainability assessment feeding back into design development will help to ensure that the environmental performance of the GDF is maximised. However, this process is largely reactive and will not necessarily capture and address all of the environmental and sustainability issues associated with design development – particularly at a detailed level. To provide a more proactive input, RWM has developed sustainable design objectives [39] covering themes such as embodied impact, energy efficiency and use of renewable resources. These feed into the design process through the DSS. RWM's approach to addressing these objectives is described in the Implementation plan and proposed approaches [40].

This "twin track" approach to addressing environmental and sustainability issues in design is illustrated in Figure 4.

Figure 4 Addressing environmental and sustainability issues in the design process



The key environmental and sustainability issues identified from RWM's generic assessment work, and how they are being, or will be, addressed during design development are outlined below.

3.1 Surface spoil management

The generation of spoil from underground excavations has been identified as a key issue in terms of potential environmental effects. For example, the surface storage of spoil will have an effect on landscape character and visual amenity; the transport of large spoil volumes off-site may result in significant noise and air quality effects and it may significantly increase the carbon footprint of the facility. Early consideration of spoil volumes, the phasing of spoil generation, the capacity for surface storage and the need for off-site transport is essential in understanding and assessing such effects. This has been considered in the design of the generic transport system. In principle, the design aims to minimise spoil generation and, where possible, to maximise its retention on site in the form of either temporary or permanent screening bunds.

In some geological environments, excavated spoil will eventually be used as backfill in the underground facility. In such cases, surface storage of spoil rather than disposal off-site further reduces the need for transport movements to import backfill.

Careful consideration will be given to the disposal route and transport mode for any surplus spoil taken off site and to any commercial value, or other use it may have. Appropriate dust control measures will also be implemented during bund construction and during any re-use of spoil for backfill. Appropriate monitoring and spoil management will also be implemented to mitigate leachate problems if required.

Any solid secondary wastes generated during the operation of the facility will be disposed of within the GDF prior to closure of the facility. Provision will also be made for the management of any contaminated wastes arising from decontamination activities at the GDF. The design seeks to minimise the amount of radioactive waste and effluents produced by disposal facility operations.

3.2 Traffic and transport management

Careful attention to the design of the transport system, selection of the most appropriate transport modes, transport routes and sympathetic infrastructure development will all serve to minimise any potential adverse environmental effect and, at the same time, will result in a transport system which can be operated in a safe and efficient manner. The transport operations associated with the GDF include the transportation of radioactive waste, construction materials and equipment, excavated spoil, personnel and visitors.

Rail is assumed to be the primary means for importing bulk construction materials and most radioactive waste packages and for the export of any excess rock spoil. A rail station has also been included in the generic surface layout to allow for the possibility of workers commuting by rail, although the viability of a passenger rail system has yet to be assessed in light of the assumed number of workers regularly travelling to and from the GDF. Further information on the design of the transport system associated with the GDF can be found in the GTSD report.

3.3 Landscape character and visual amenity

The visual appearance and setting of the GDF in the landscape will be influenced by a combination of building design, materials, layout, structure, form and colour, landscape works (both on site and off site) and local landscape character. For a rural site, the approach to the design of the surface facilities would probably be different from that for a site on the edge of an urban development. To reduce and minimise any adverse effects of the surface facilities on landscape character and visual amenity, options that could be considered are:

- minimising the height of buildings and surface structures
- using material from site clearance and excavated spoil to both screen the surface facilities and integrate the site with the local topography

The spoil quantities and spoil management process resulting from site clearance and the underground construction activities will be considered during the design of site screening bunds. The rate and quantity of the spoil produced will determine the quantity of materials available on site for bund construction. A much lower proportion of the construction spoil arising from the evaporite rock design would be retained on site, as the evaporite rock itself would not be suitable for planting and would degrade in the presence of water. In this scenario, the screening bunds would be constructed using materials from site clearance and from the shaft excavations in the soils and rocks covering the evaporite formation. If further screening measures are required, then trees or fencing may be utilised.

In the current illustrative designs for a higher strength rock and lower strength sedimentary rock environment, bund capacity provides the maximum volume of surface storage for excavated spoil within the assumed surface footprint, taking into account the likely effect of the bunds themselves on landscape character and visual amenity (largely in terms of their assumed height). The regular plan and profile of the bunds in the illustrative designs highlights their artificial, engineered nature. In reality, the bunds will be designed, as far as possible, to “fit in” with the local topography and landscape character.

At this stage, it is assumed that the surface facilities will be located directly above the underground disposal facility, but it is recognised that surface facilities could be in a different location to the underground site and linked by access drifts or shafts and service tunnels. Dependent upon site-specific factors, a lateral separation distance of the order of up to 10km between the surface facilities and the underground vaults could be feasible, based on an underground facility located at a depth of 1,000m [2]. In such a scenario there may be a need for some surface facilities to be located directly above the underground facility, perhaps separated from the main surface site by several kilometres.

3.4 Flora and fauna

The construction and operation of a disposal facility and its associated transport infrastructure has the potential to affect local wildlife, both directly within the footprint of surface works and indirectly through disturbance and possible effects on ecosystem function. Adverse effects on biodiversity will be minimised and, where possible, access to nature will be improved. Effects on ecology and biodiversity are site-specific, but the principles remain the same. Planning for changes to the transport infrastructure, and/or surface or sub-surface facilities will be undertaken on a timescale that allows changes to be implemented prior to any need for significant movement of materials associated with the change from or to the site of the GDF.

Advanced planning and ecological assessment will be used to ensure that works on-site have as little adverse effect on local wildlife as possible. To this effect, monitoring will be implemented well in advance of construction and consideration will be given during design development to maximising opportunities to maintain and enhance local biodiversity through appropriate habitat creation and management.

3.5 Drainage and groundwater management

The surface water drainage system will be designed in accordance with good practice at the time of construction, with due consideration for topography and local drainage regime. Potential for an increase in the frequency of extreme weather events and for changes in average annual rainfall will be taken into account when designing the surface water drainage system.

To reduce flood risk and adverse effects on water quality, good working practices will be followed throughout all stages of construction and operation. These measures could include capturing rain water from roof areas and the use of sustainable drainage systems, use of vegetated building roofs and rainwater harvesting to attenuate storm water flows and reduce run off quantity from site, minimising flood risk. Surface water drainage and waste water from surface buildings and effluent from underground will be collected and handled separately.

Design development will take into account the protection of groundwater resources and the potential effects on any groundwater abstractions. This may, for example, involve appropriate treatment of surface site drainage before discharge to soakaways and minimising the area of impermeable surfacing to allow local groundwater recharge.

Regular sampling and analysis will be undertaken to ensure that the water quality meets the required standards before discharge; surface water and waste water will be collected and sampled separately. Treated effluent will be discharged from the site to a suitable drainage network or local watercourse, under permit from the environmental regulator. Assessments of the impacts on groundwater during the operational and post-closure phases are described in more detail in [25 and 26].

3.6 Water supply

A potable water supply will be provided to the GDF to cater for every day needs but it also anticipated that grey water will be used in parts of the facility. The demand for water is likely to be at its highest during backfilling and closure. The quantity of water required will be determined as the design develops and more specific information is gathered.

3.7 Ground vibration

Blast parameters associated with use of explosives for underground excavations will be designed to minimise damage to the geological environment using appropriate charge densities and detonator sequencing. Surface ground vibration controls from underground blasting at the depths assumed for facility construction will be designed to ensure significant environmental effects are not created.

3.8 Noise

Where possible, surface operations will only be undertaken during the day to reduce nuisance noise. However, there are areas that will need to run 24 hours a day such as winding of construction materials from underground areas to the surface. Where practicable, plant systems will be selected which generate minimum noise levels, and noisy plant and equipment will be enclosed in buildings, which could, if necessary, be fitted with acoustic panels. Early consideration of the phasing of spoil generation and minimising the need for off-site transport will be essential in minimising adverse noise effects on the local transport network.

3.9 Light

Particular care will be taken in the specification and siting of all surface lighting in order to minimise light pollution outside of the site without compromising safety and security. A screening bund around the site could be designed to help to minimise light pollution.

3.10 Air quality

Construction and operation of the GDF and associated transport infrastructure is unlikely to result in any breach of *UK Air Quality Objectives* [41]. Local air quality may be affected by dust generation and by exhaust emissions from both traffic movements and static plant. Adverse effects will be minimised by ensuring appropriate management systems and controls are implemented during construction and operation. This will include any exhaust from construction plant or stand-by generators etc which will be selected and properly maintained to ensure minimal pollutant emissions; rail is assumed to be the primary means of transporting bulk materials to and from site as it will reduce exhaust emissions from road haulage.

The main point of release for aerial discharges from the underground facilities will be through the ventilation system and out via discharge stacks. The ventilation system will be designed to protect both workers and the public by filtering out contaminants before they reach the surface, such that any releases to the atmosphere are below regulatory limits.

Potential odour problems from water treatment plant and any composting facilities will be taken into account in designing the surface layout and in the detailed design of such facilities.

3.11 Sustainable design

Sustainable design is essential to help avoid or minimise long-term damage to the natural environment, to make the most of opportunities for environmental improvement, and to support the social and economic fabric of a host community. RWM has developed and published a number of sustainable design objectives [40] under the following themes:

- embodied impact
- energy efficiency
- durability
- waste management
- renewable resources
- environmental protection
- healthy buildings
- social equity

RWM has developed an approach to addressing these objectives that suggests when each objective should be addressed and aligns them with appropriate design stages. In most cases the objectives can only be addressed effectively during later, more detailed stages of the design process. However, the issue of embodied impact can be addressed during early illustrative design work, at least for bulk construction materials, and may influence early decisions on design approaches for key elements of both the underground and surface facilities.

4 Construction

4.1 Initial construction phase

The initial construction phase of the GDF will include the establishment of underground access and the facility will be constructed and commissioned to the point where it can accept the first LHGW.

On commencement of the construction phase, sufficient infrastructure comprising the basic surface facilities will be constructed to enable underground excavation to commence including all necessary security provisions. The first buildings will be the shaft winder houses, spoil bunker, spoil removal infrastructure and associated offices, workshops and stores to enable the shafts and drift construction to commence. In the case of the evaporite rock design, a fourth shaft for waste emplacement will be constructed in place of the drift. Depending on the method of shaft sinking, some of the shaft infrastructure may be temporary initially and subsequently replaced by permanent structures after shaft sinking is completed. Work on all four underground access routes will be undertaken concurrently. The construction intake shaft will be the first to be completed, followed soon thereafter by the construction return shaft. This will allow the construction ventilation circuit to be initiated. The emplacement return shaft will be the next access route to be completed, with the emplacement intake drift or shaft being finished last. This will complete the emplacement ventilation circuit. In the case of the drift in higher strength and lower strength sedimentary rock designs, this will be constructed from surface and from underground.

Data gathered during the site investigation phase, such as shaft centre line boreholes, boreholes drilled along the line of the drift, if a drift is proposed, and other deep boreholes drilled to the facility horizon will all be used for an initial preliminary assessment for the underground design. As the shafts and drift are excavated information on the local geological environment will be logged and geotechnical logging undertaken. Drilling in advance of the heading will provide additional information regarding the geological environment and rock mass characteristics that will be encountered. This advanced drilling will allow support requirements to be identified and materials made available for use. It will also provide information on the groundwater conditions and rock mass characteristics that could be encountered. This will also allow, if required, grouting of the strata to aid groundwater management and improve rock mass characteristics.

Tunnels driven at the facility horizon will be subject to the same procedures as those for excavation and construction of the access routes allowing decisions to be made regarding support, groundwater management and the suitability of strata for the construction of vital structures such as inlet cell, disposal vault or disposal tunnel.

During access route construction, spoil from each individual access route will be brought to the surface and placed in screening bunds, with the exception of the evaporite rock design, where spoil from the evaporite horizon would be removed from site. Once the access routes and initial service tunnels are complete, all spoil will be brought to the surface via the construction return shaft.

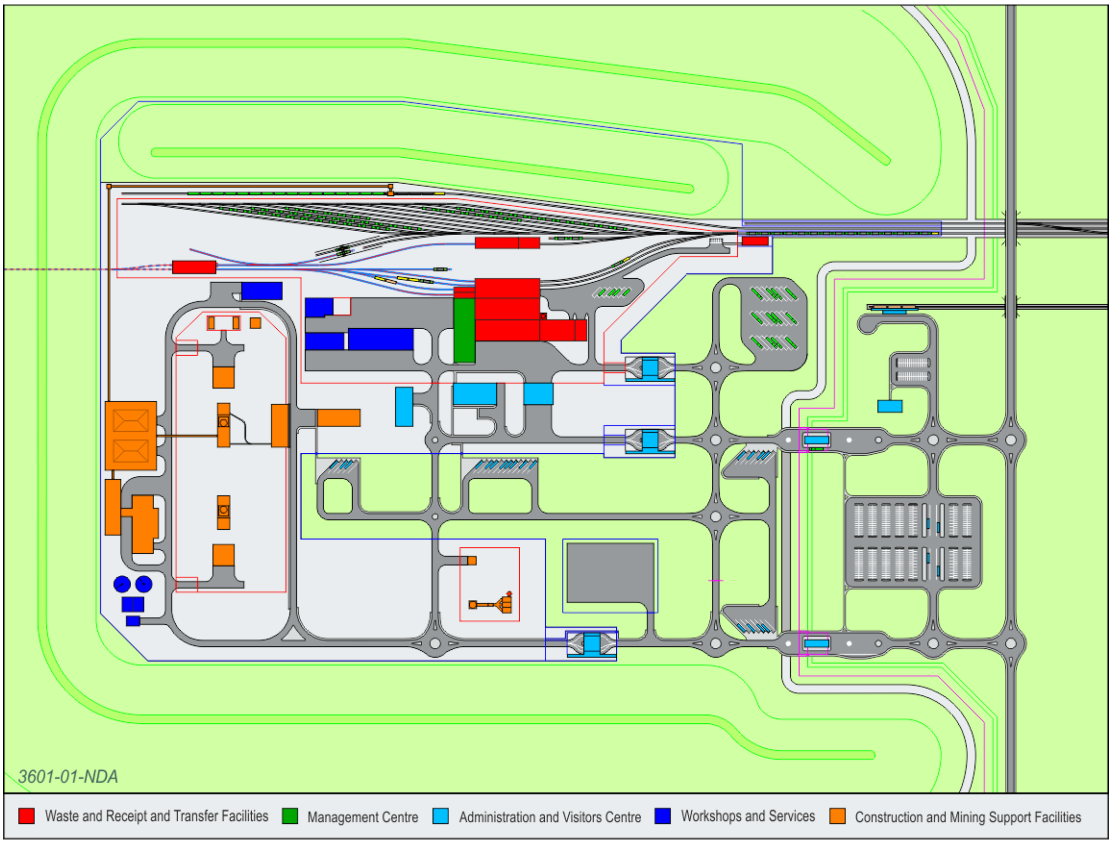
General infrastructure, including the road and rail access onto site, rail sidings, electricity, water and other services will be constructed in parallel with underground access. If required at this stage, a visitor’s centre could also be constructed on the surface. An initial screening bund for the sidings will also be constructed at this time from the surface strip and excavated spoil.

Illustrative volumes of excavated spoil and quantities of construction materials are provided in Appendix D to support environmental and safety assessments.

Following commencement of underground construction via the shafts and drift, the remaining surface facilities will be constructed, including the LHGW waste receipt and handling facilities and associated infrastructure, including the management centre, workshops and stores.

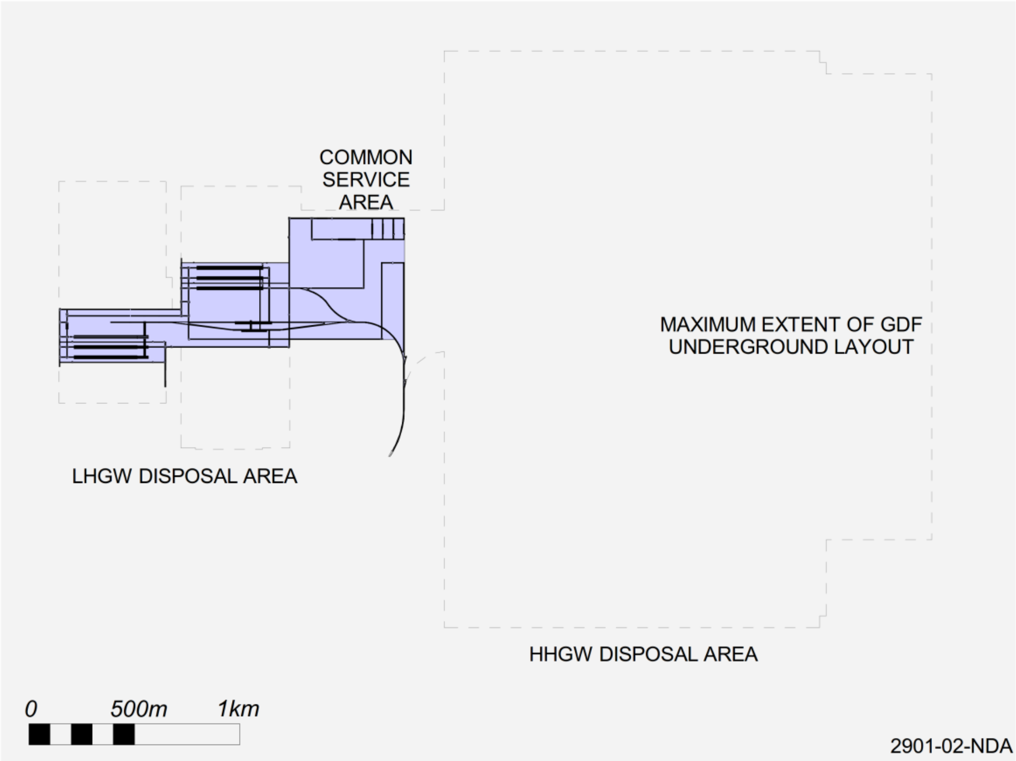
Figure 5 shows the conceptual layout of the surface facilities at the time of first waste emplacement for the higher strength rock design. The figure shows the assumed layout of the GDF including the majority of the construction and administration buildings, with the operational buildings for LHGW packages. A small number of additional buildings and associated infrastructure to enable receipt of HHGW packages and subsequent transfer underground will be constructed prior to 2075.

Figure 5 Surface facilities (higher strength rock) at time of first waste emplacement (circa 2040).



For the underground facilities, the construction will commence with the initial underground access roadways and drift extension, the UILW inlet cell, disposal support facilities and LHGW disposal vaults; one vault be made ready for emplacement, one undergoing fit-out/commissioning and another undergoing construction and other necessary support facilities for vault operations. This will allow the commencement of waste disposal, with further construction of the remaining vaults taking place on an as-required basis. During initial underground construction, underground evacuation and self-supporting safe havens will be considered. Alternative means of egress will be planned in case of emergencies. The layout of the underground facilities at the time of first waste emplacement in a higher strength rock is shown in Figure 6.

Figure 6 Underground facilities (higher strength rock) at time of first waste emplacement (circa 2040).



For the lower strength sedimentary rock and evaporite rock designs, a similar amount of underground infrastructure and number of vaults would be constructed to enable first waste emplacement.

Following construction of the facilities and prior to commencement of operations, there will be a period of commissioning. The surface facilities will be commissioned on a building by building basis as and when they are complete. The surface infrastructure will require commissioning to enable and support the below ground access emplacement and construction activities.

Those facilities required for waste acceptance handling and transfer will be commissioned in the same manner as the other surface facilities and the underground access methods.

The underground facilities will require the most complex commissioning due to the utilities, infrastructure, waste package handling, operational systems and equipment required for emplacement of the waste packages. Once all the individual facilities have been commissioned there will be periods of pre, inactive and active commissioning of the whole system prior to approval been given for operations to commence. Similar requirements will be required as each new underground facility is constructed prior to its operation.

4.1.1 Underground ventilation

The purpose of the underground ventilation systems will be to provide adequate ventilation for both construction and waste emplacement activities throughout the life of the facility. The standards used for the design of the ventilation system must necessarily be a combination of good practice in the nuclear, mining and tunnelling industries.

Segregation of the construction and waste emplacement ventilation circuits will be an important feature of the design. It ensures that, in the event of an accident, any airborne contamination from the waste emplacement areas will not be drawn into the construction areas, and that dust and fumes generated by the blasting and excavation work will not be drawn into the emplacement areas where they could affect operational equipment and personnel.

4.2 Concurrent construction and operation

The illustrative underground layouts have been configured to limit the amount of construction work required up to first waste emplacement. This approach will allow the disposal facility to be developed using continuously improving systems and equipment over time.

The underground infrastructure and support facilities have been designed to allow the disposal of waste to take place at the same time as ongoing construction, by providing segregation between these activities. This will be facilitated by utilising airlocks and seals between different zones and areas underground and by the provision of independent ventilation circuits.

It is currently assumed that the HHGW waste receipt and handling facilities will be constructed at a later date allowing sufficient time for commissioning prior to waste acceptance at the facility. Provision will be made in the surface design for this facility to be constructed without interfering with ongoing LHGW emplacement activities. No additional rail sidings will be necessary, as the throughputs of HHGW will be significantly lower than LHGW.

The LHGW vaults will be constructed in modules, ie banks of vaults. This will offer the advantages of repeatability while also providing a degree of flexibility in positioning and orientation to account for variations in geological environment and geotechnical characteristics. Strict control will be maintained on the levels of excavation damage caused to the surrounding rock by controlling the blast design (where applicable) and by careful management of the excavation operations.

To support these construction principles, a blasting study has been undertaken [42] to assess the vibration and air overpressure effects from blasting operations in a higher strength rock. The study assessed the vibration and air pressure in disposal vaults at distances of 50m and 100m from blast operations, which correspond to the distances for disposal vaults undergoing fit-out and emplacement operations adopted in the higher strength rock illustrative design. The sequence of UILW vault construction and disposal will mean that there will be at least one constructed but non-operational vault separating these activities. This separation, by pillars of rock coupled with the design of blast patterns, where required, will be sufficient to ensure that blast vibration will not affect the waste emplacement operations.

The blasting study concludes that by application of controlled blasting (such as electronic delay detonation) and implementation of a vibration control and monitoring strategy, blasting operations can be safely carried out whilst safeguarding disposal vaults undergoing fit-out, waste emplacement operations and previously emplaced disposal vaults.

It is recognised that alternative construction techniques to drill and blast, such as tunnel boring machines or roadheaders, could be used for construction in higher strength rock. In lower strength sedimentary and evaporite host rocks, it is envisaged the majority of excavation could be carried out by mechanical excavation techniques using roadheaders or continuous mining machines. Such construction techniques have much lower impact in terms of vibration than drill and blast methods.

After a period of operation, disposing of LHGW, the disposal facility will be further developed to the point where it can accept HHGW, as shown in Figure 7, below. The underground areas for HHGW disposal will be physically segregated from the ongoing LHGW disposal operations. However, these construction and disposal activities will be supported by the same shafts and drift access provided for LHGW operations. This will allow the commencement of waste disposal, with further construction of the remaining tunnels taking place on an as-required basis.

The extent of any excavation disturbed zone (EDZ) around an excavation will depend on a number of factors, including hydrogeological and mechanical properties of the strata, the state of the in-situ stress, the size and geometry of the opening and the excavation method.

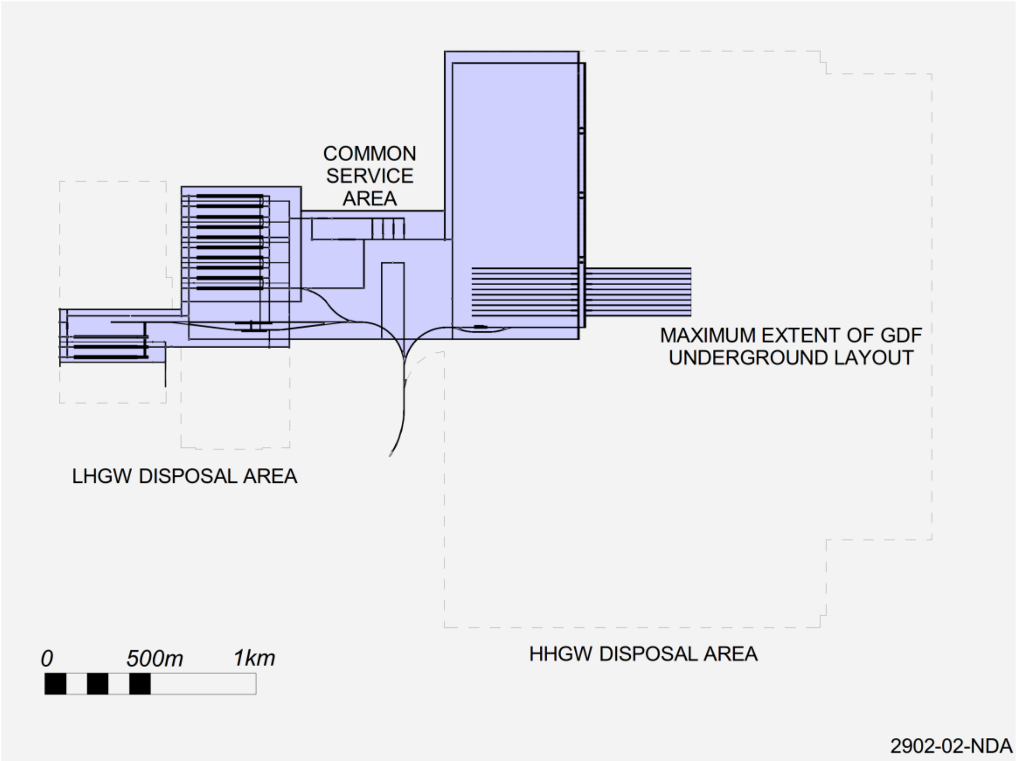
Ground movement around an excavation can be controlled by the application of appropriate rock support, excavation dimensions and extraction ratios determined prior to excavation and then refined through ongoing geotechnical mapping and testing.

The development of the EDZ will also be dependent on the timing and rigidity of the support emplacement. The inclusion of early, rigid support (precast concrete or cast in-situ linings) will result in a restriction of EDZ development, provided the support remains stable. More-efficient support may be offered by using a less-rigid support (for instance, shotcrete and rock bolts) followed by a supplementary support installed sometime later, although this will not be achievable in certain areas of the facility, for example, an operational or fully completed UILW vault.

Mechanical excavation methods impart less damage to the surrounding rock, ie the EDZ than drill and blast. However, the EDZ can be minimised by careful design of blast drill-hole patterns and use of blast initiation delays (smooth-wall or pre-split blasting methods and by the use of electronic detonation systems).

These are site-specific issues, and will be addressed in more detail at a later stage in the design process.

Figure 7 Illustrative underground layout at time of first HHGW waste emplacement (approx. 2075) in a higher strength rock



4.3 Excavation profiles and rock support

Developing illustrative designs allows a representation of typical excavation, rock support, and designs of disposal vaults or tunnels in a particular host rock. The excavation profiles for the underground configuration of the GDF (disposal vaults, disposal tunnels, service tunnels etc.) are detailed in the following sections. These profiles are based on the concepts for similar rock types as described in Section 2.1 of this report.

Excavation profiles and dimensions will be determined based on the prevailing geotechnical characteristics of the host rock and the in-situ stress regime, and will be sufficient to provide adequate long-term stability for the duration of the construction, operation and closure phases.

Excavation profiles and design of rock support systems have been taken from sister waste management organisations and international precedent in mining and tunnelling and tailored to the waste package types in the UK Inventory and are summarised in the *Design Assessment for Geological Repositories* report [20]. The excavation profiles have been reviewed and rock pillar spacing has been calculated for each geological environment and these are detailed in the design enhancements report [48].

The long-term stability of excavations is an important consideration, bearing in mind the currently assumed operating period of the facility; some features including the shaft, drifts, and common services area will be required to be stable and serviceable for up to 160 years. Excavation support, maintenance and associated monitoring considering this extended operating period will be a key area for future design activities to ensure this can be achieved.

A system of ground monitoring will be established to enable decisions to be made regarding the need for maintenance to the excavations as required. The excavation design will be undertaken in such a manner to ensure, as far as is reasonably practicable, that the excavations require little or no maintenance.

It is assumed that access to the facility excavations for inspection and maintenance will be available in all but the remotely operated areas, which could be inspected using remote means. Maintenance requirements of the support systems will vary with the rock types, but more reliance will be placed on the support systems rather than the rock itself as rock strength reduces and/or depth increases.

The excavation profiles are described in the following sections and all dimensions shown are as excavated. Rock support in the form of rockbolts and shotcrete are also indicated.

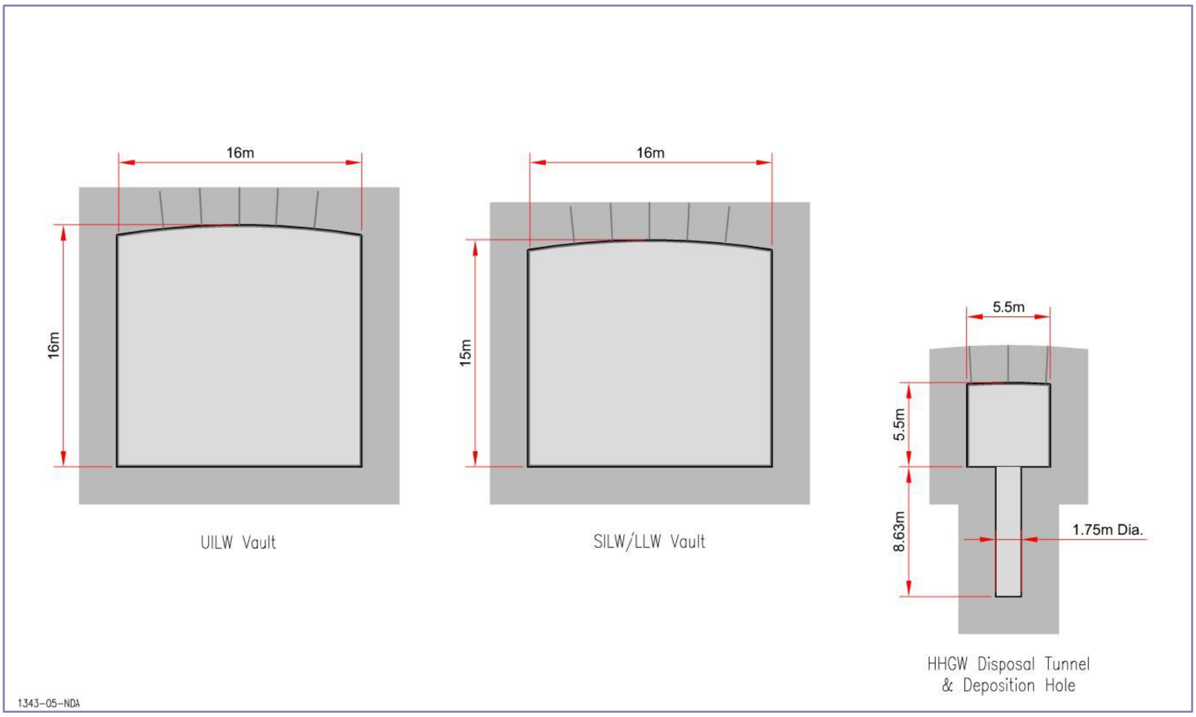
4.3.1 Higher strength rock

All vertical access shafts in higher strength rock would have a finished internal diameter of 8.0m and would be excavated using well established technology. Permanent shaft support would be provided by a mechanical lining (concrete) and hydrostatic lining installed where necessary to prevent the ingress of water and ensure safety. The drift would be 5.5m in diameter for 1.8km (300m depth of overlying sediments) through the hydrostatically lined section and then 'D' shaped (5.5m high by 5.0m wide) to the facility horizon.

General underground tunnel support is assumed to be by rock bolt, mesh and shotcrete. Rockbolts are currently assumed to be 2.5m long and located at 2.5m intervals, corresponding to a coverage of 20% of the excavation surface area (excluding floor). Mesh and shotcrete will be 200mm thick in disposal vaults and 50mm in other excavations.

The underground excavations would be of varying cross-sections, and generally be 'D' shaped. The excavation cross-sections and profiles of the disposal vaults and tunnels are shown in Figure 8 and all excavation profiles in a higher strength rock are shown on Drawing E/DRG/0041038.

Figure 8 Excavation profiles for higher strength rock



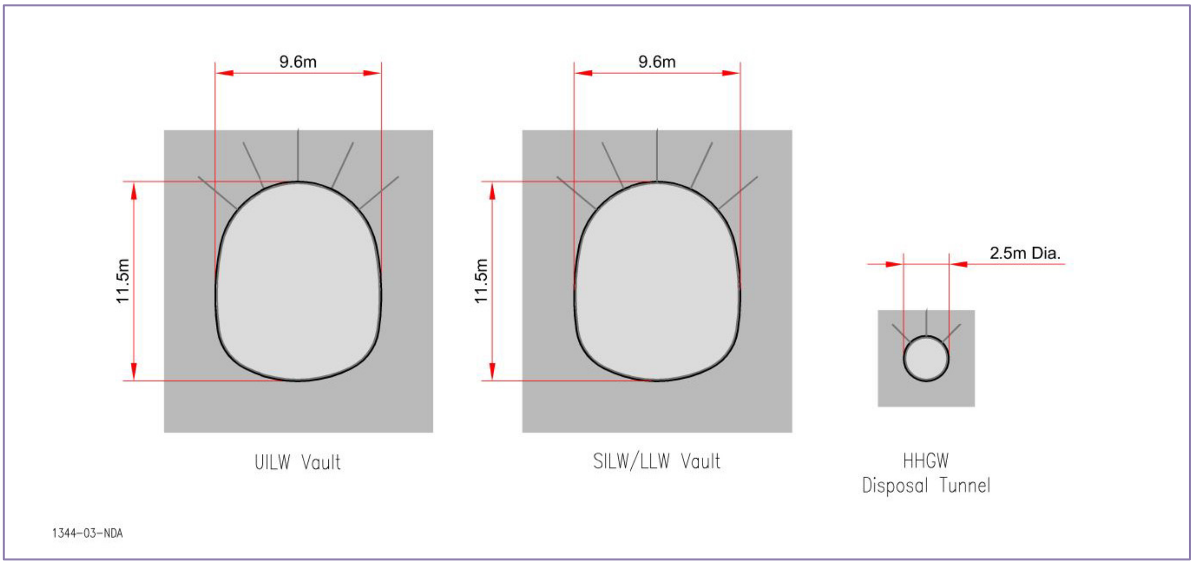
4.3.2 Lower strength sedimentary rock

All vertical access shafts would be constructed in a similar manner to higher strength host rock, described above. The drift would be 5.5m in diameter for its full length to the facility horizon, with a hydrostatic lining in the top 1.8km (300m depth).

Tunnel support would be by rock bolt, mesh and shotcrete. The use of concrete segmental linings or in-situ concrete linings has not been discounted for use in supporting some of the facilities. Rockbolts are currently assumed to be 3m long and located on a grid pattern in the crown and walls at 2m intervals, except in the disposal tunnels where 1.5m long rockbolts will be installed at 1.5m intervals. This corresponds to a coverage of 40% of the excavation surface area (excluding floor). Mesh reinforced shotcrete is assumed to be 300mm thick in all underground excavations.

The underground excavations would be of varying cross-sections, and a mix of elliptical and circular profiles would be used. The excavation cross-sections and profiles of the disposal vaults and tunnels are shown in Figure 9 and all excavation profiles in a lower strength sedimentary rock (based on the Nagra concept) are shown on Drawing E/DRG/0041088.

Figure 9 Excavation profiles for lower strength sedimentary rock



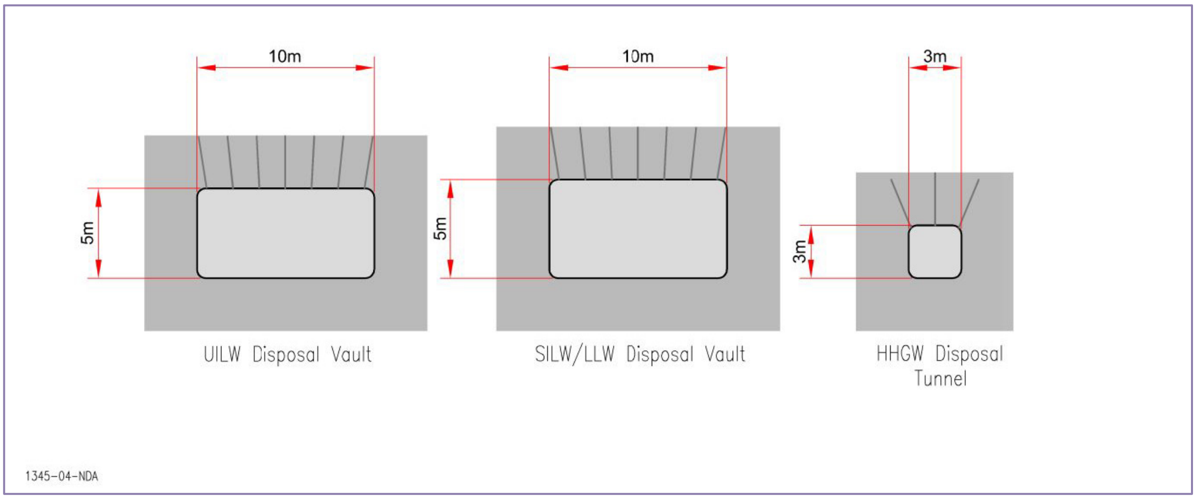
4.3.3 Evaporite rock

All vertical access shafts would have a finished diameter of 8.0m, with the exception of the Emplacement Air Intake shaft, which would be 9m to accommodate the transfer underground of waste packages. Permanent shaft support would be provided by a mechanical lining (concrete) and hydrostatic linings installed where necessary to prevent the ingress of water and ensure safety. The bottom section of the shafts would have a concrete lining to give long-term integrity with minimal maintenance. Conventionally, excavation in evaporite rocks is carried out either by drill and blast or mechanical, roadheader or continuous mining machines. Many mining applications in bedded evaporite deposits utilise continuous miners, which are well suited to forming wide but relatively low (3.0–6.0m high) excavations.

Tunnel support would be by rock bolt and mesh. Rockbolts are currently assumed to be 3m long and located at 1.5m intervals. This corresponds to a coverage of 50% of the excavation surface area (excluding floor). Shotcrete will not be used in evaporite rock.

The underground excavations proposed would be of varying cross-sections, but would generally be rectangular in shape. The excavation cross-sections and profiles of the disposal vaults and tunnels are shown on Figure 10 and all excavation profiles are shown on Drawing E/DRG/0041138.

Figure 10 Excavation profiles for evaporite rock



Evaporite rocks and some sedimentary rocks are prone to time-dependent deformation, known as 'creep'. The creep rates in evaporite rock would govern the length of time an excavation would remain open for disposal without the need for refurbishment. The rate of closure of the excavations would vary with depth, type of deposit and excavation profile and amount of ground support installed. The creep rate could be extremely low, typically of the order of a few millimetres per year, and in such situations the excavations could remain viable for many years with little or no maintenance. As creep rates increase, then excavations would need to be maintained by scaling of the walls of the excavation and where appropriate, the re-installation of supports. Creep rates in evaporite deposits are known to increase with increased temperature. In disposal areas, where the temperature rises due to the waste emplaced, this is likely to accelerate creep rates which will close up the disposal vaults and tunnels more rapidly.

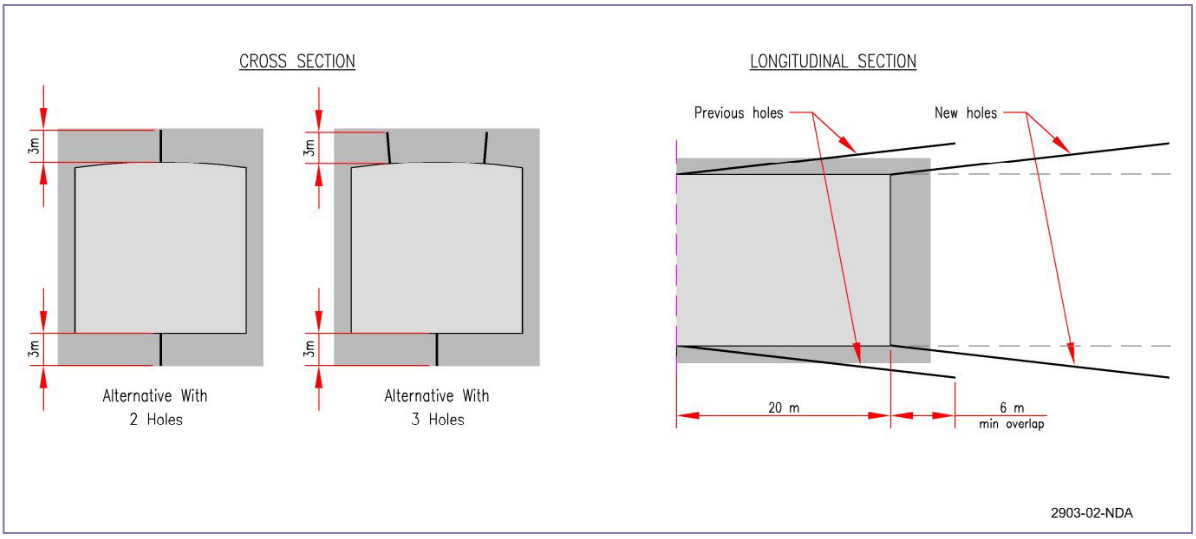
While it would be possible to undertake maintenance work in some accessible areas of the facility, remotely operated areas will require remote maintenance, where feasible or would require the removal of waste packages to allow maintenance to occur. For this illustrative design, disposal vault and tunnel dimensions are considered to be suitable to allow waste disposal within the life span of the excavations with minimal maintenance.

Monitoring of strata movement and assessment of the prevailing creep rate would be undertaken once excavations are made at the depth of the disposal facility. This data would assist in ensuring that appropriately sized vaults and tunnels would be excavated to provide longevity of excavations with minimum maintenance. This is of particular importance given the long operational period of the facility of up to 160 years.

4.4 Groundwater management during construction

Prior to the design of underground facilities and supporting services, such as drainage and ventilation, detailed hydrogeological characterisation of the host rock will be required. Even if the host rocks have low permeability, access must be constructed through overlying sediments which could include permeable formations or fracture-dominated rock. Design and operational procedures for construction of both tunnels and shafts will be based on detailed data provided by exploratory boreholes in order to tailor counter-measures (grouting, freezing, lining, etc.) to local conditions. Figure 11 shows a potential method for construction of an service tunnel using probe drilling. Drilling ahead of the excavation could be used to employ grouting or ground freezing in order to control groundwater. This would aim to ensure safety during construction, minimise risks of any accidental inflow during the long operational period and reduce any impacts on the local hydrogeochemical environment.

Figure 11 Construction of service tunnel



In terms of reducing accidental inflow, the design will take into consideration the location of all boreholes drilled for site characterisation. Boreholes will be plugged and sealed before construction, to ensure they do not act as preferential pathways in accordance with best current practice during normal exploration and characterisation works. It is recognised that some of the boreholes, those that do not compromise safety for the underground environment, will remain open to allow continuous monitoring, if required. For evaporite rock rigorous assurance of achieving negligible inflow is critical as lower salinity waters can cause rock dissolution leading to potentially major perturbations. This needs to be considered even during the exploration phase to account for the possibility of boreholes being drilled through bedded salt into underlying formations (which could contain artesian aquifers in some settings).

Higher strength and lower strength sedimentary rocks suitable as host rocks would have low fluxes of groundwater under natural conditions, but flows into open excavations at depths of 500m or more could be significant due to a high hydraulic gradient. Design of engineering countermeasures needs to consider maximum potential inflows that may be encountered – which are likely to be associated with specific structures (faults, fractures, sand channels, etc.). Depending on their frequency, either local (eg grouting) or general (high performance liners) solutions would be implemented. Even then some small scale groundwater penetration into underground openings is likely, especially when these will be open for decades. This would be managed by appropriate drainage infrastructure plus a monitoring programme to detect any deterioration in hydraulic sealing and allow early remediation.

In some cases, disturbance zones may need to be traversed, which could have high transmissivity. In case this is necessary, appropriate technology for groundwater control would be applied.

Even in an evaporite formation it cannot be precluded that brine pockets would not be encountered during excavation or that brine seepages would occur during operation. The potential for these would be determined during site characterisation and again appropriate ventilation, drainage or sealing measures implemented.

5 Waste Transport, Receipt and Transfer

The surface operations and infrastructure currently cater for receipt of waste packages at the surface and their transfer to the drift (or shaft) for transport underground. These operations are described in the following sub-sections. RWM recognise that the detailed design and configuration of the surface facilities will be developed as the project advances and will need to include consideration of alternative systems at appropriate stages of development so that an optimised system can be developed.

The surface site boundary fence will not encompass the entire footprint of the underground workings. The land above the GDF could be subject to constraints on its use (both before and after GDF closure), but these, and any required markings to indicate the extent of the underground footprint will be developed at the detailed design stage.

5.1 Waste transport

The transport system considers the use of rail, road and sea, with a preference for the use of rail transport where possible. The surface facilities will be configured to handle package arrivals by these modes. The use of sea transport has been allowed for and will be site location dependent.

The transport systems described in the GTSD report would be sufficient to enable transport of the waste packages to the disposal facility in order to meet the anticipated rate of waste arisings and the currently assumed emplacement rate profile for the GDF (Section 8.2). All transport packages, whether arriving by road or rail, would be transported to the site on appropriately covered vehicles. The sections below describe the transport of waste packages within the GDF site, following arrival at the site entrances.

A schematic arrangement of surface facilities is shown on Drawing Number E/DRG/004023. It is currently assumed that the surface facilities cover approximately 1.5km^2 however the layout of the surface facilities will be tailored to the site/or sites, once they have been identified.

5.1.1 Rail transport

The capacity of the rail receipt system has been designed with sufficient redundancy to accommodate all transport packages arriving by rail in consignments, if required.

On-site rail sidings have been provided to enable trains carrying LHGW to be separated into smaller numbers of wagons which will be marshalled ready for shunting to the LHGW waste package receipt and transfer facility for onward transfer to the drift (or shaft in the evaporite design). On-site rail arrival sidings will be provided to enable these operations to be carried out safely and effectively.

For the illustrative designs, the arrival sidings have been designed to meet the following requirements:

- to accommodate a main-line train, currently assumed to consist of up to 12 wagons
- to handle the expected peak daily arrival rate of approximately 10 waste packages per day
- In conjunction with the dispatch sidings, to act as temporary short-term storage so that in the event of unplanned interruption to the disposal operations (assumed to be a maximum of 1 week in duration) all transport packages already in transit could complete their journey to the facility. In that event, further dispatches from waste producers' sites would be postponed until the backlog is cleared.

- DCTCs will not be stored in the sidings but placed into the HHGW waste transfer building temporary storage area
- in conjunction with the arrival sidings, the dispatch sidings provide sufficient storage for the entire facility fleet of rail wagons and sufficient space to marshal these wagons

These requirements for the arrival sidings will be met by four straight and parallel tracks, each 240m long, giving a capacity of 48 wagons.

For the illustrative designs, the dispatch sidings have been designed to:

- permit the shunting of wagons carrying empty SWTCs and DCTCs, into trains of up to 12 wagons in length, prior to delivery to the main-line sidings for collection by a main-line locomotive
- handle the expected peak daily dispatch rate
- in conjunction with the arrival sidings, provide the storage capacity stated above

These requirements for the dispatch sidings will be met by a further four straight and parallel tracks, each 240m long, giving an overall site capacity of 96 wagons.

By making the layout of the arrivals and dispatch sidings the same and by grouping them together on the site, a degree of operational flexibility will be provided.

5.1.2 Road transport

The current planning assumption for the illustrative designs is based on an average rate of approximately two road vehicles carrying transport packages arriving per day.

A lay-by will be provided at the site entrance to permit up to two heavy goods vehicles (HGVs) to park at any time while documentation is being checked at the security centre gatehouse. A turning area will be provided outside the security centre to turn back unauthorised vehicles, before they enter the site.

Within the site, a parking area will be provided for up to 24 HGV trailers, to accommodate both arrivals and dispatches. On-site electric tractor units will be used to collect the trailers from the parking area and transfer them to the waste package transfer facility.

To reach the waste package transfer facility the on-site tractor unit, once it has collected the trailer with transport package, will need to pass through a further security gatehouse. This will be on a just-in-time basis meaning the majority of transport packages will be delivered immediately to the waste package transfer facility, for transfer underground. However, a small number of parking spaces will be provided adjacent to the facility for temporary storage of transport packages.

HGVs departing to a waste producer's site will, if possible, be loaded with an empty reusable transport container at the waste package transfer facility, depending on the scheduled requirements of the waste producer. No special facilities will be provided, other than an area for departing vehicles to wait while dispatch documentation is being checked at the transport management centre.

5.2 Waste receipt and transfer

5.2.1 Transport package receipt and transfer facilities

The process will begin with the road or rail transportation of the waste packages from the waste-packaging and interim storage sites to the GDF. A system for checking, monitoring and verifying the contents of each waste package will be carried out by the consignor before leaving the waste producer's site.

To eliminate the hazards associated with unauthorised trains inadvertently entering the designated nuclear-licensed site boundary area, it is currently proposed that two off-site rail sidings parallel to the main line will be provided to receive the consignments of rail wagons carrying transport packages. The rail wagons will be met at the off-site rail siding and transferred onto site by a dedicated shunting engine. To reduce the potential consequences of an impact incident, its speed will be restricted. Empty wagons carrying reusable transport containers will be transferred to the off-site rail siding for return to the main-line sidings.

Upon arrival of the train the consignment documentation will first be checked and processed at the gatehouse and transport management centre before the transport packages are allowed on site. The shunter will then transfer the wagons to the on-site rail sidings, which form a temporary holding area. The shunter will transfer individual wagons as required to either of the waste package transfer facilities for onward transfer underground on a just-in-time basis.

Road arrivals will be directed through the security centre gatehouse, where documentation will be checked. Unauthorised vehicles will be turned around before entering the site. The trailers will be parked in a secure parking area within the site boundary. An on-site electric tractor unit will collect the trailer with transport package and will pass through a further security gatehouse to transfer it to the waste package transfer facility for onward transfer underground.

The primary facilities for transferring transport packages from road or rail arrivals to the underground transport system will be grouped together (Figure 12). The LHGW receipt and dispatch facilities will be capable of handling transport packages arriving by any combination of rail and road. The HHGW receipt and dispatch facilities are currently designed for handling transport packages arriving by rail only. It is currently assumed that these facilities will be modified (as necessary) at a later date to accommodate arrivals of Pu and HEU in the HHGW facility.

Figure 12 Low heat generating waste receipt, transfer and dispatch facilities

The LHGW package transfer facility will allow the unloading of rail and road vehicles. If necessary, manual decontamination of the transport package and or road vehicle will be undertaken. Once accepted, the transport package will be released from the trailer and transferred within the same building to a drift wagon using an overhead travelling crane (safe working load, SWL, 80t). Throughout the facility, lift heights will be minimised and package movement rates controlled. The layout of this and other facilities will seek to restrict the ability to lift transport packages over one another, to avoid the possibility of collisions and one or more packages becoming damaged due to dropped loads.

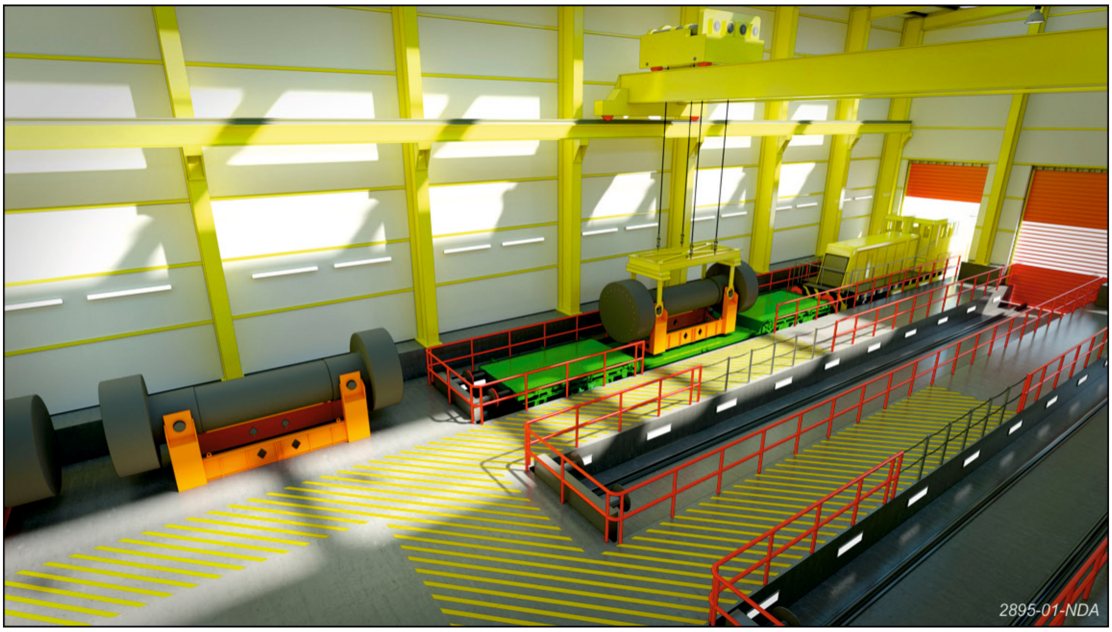
As well as having fail-to-safe systems, the crane will incorporate a retrieval system so that in the event of a total electrical failure it could be mechanically operated to safely lower the transport package to floor level.

LHGW transport packages arriving by rail will be handled in a similar way. The main-line rail wagon will be shunted into one of two bays, where the cover will be removed to permit monitoring and inspection. There will be provision for manual decontamination of the transport package and or rail wagon if necessary. Normal procedures will then be a direct transfer by overhead travelling crane from the main-line wagon to the drift wagon.

In the unlikely event of damage to a transport package or any other non-conformance, it may be undesirable or not possible to return the package to the consignor. In such instances there would be a facility to transfer non-conforming transport packages to the shielded transport container maintenance facility for further rectification work. Very simple repairs could be undertaken in the temporary set-down area.

HHGW transport packages arriving by rail will be handled in a similar way to the LHGW packages but in a separate adjacent facility (Figure 13). Main-line rail wagons will be shunted into one of three bays, each of which will accommodate two rail wagons. This will enable a week's worth of deliveries to be temporarily stored within the facility, based on an arrival rate of 200 packages per year. The covers will be removed to permit monitoring and inspection. There will be provision for manual decontamination of the transport package and/or rail wagon if necessary. Normal procedures will then involve direct transfer by overhead travelling crane from the main-line wagon to the drift wagon (or shaft transfer system in the evaporite rock illustrative design). Two pairs of trunnions are attached to the DCTC body. Each trunnion sits within a recess in the cast steel cylinder and is connected to the body by bolts. All four trunnions will be used as tie down points during transportation. The pair of trunnions at the top end of the container can also be used as lifting points. The pair of trunnions at the bottom end of the container can be used as pivots on the transport frame when rotating the container from a vertical orientation to a horizontal orientation and vice versa. This will be done during installation onto the transport frame in preparation for transport and vice versa during removal of the transport frame on completion of a transport operation.

Figure 13 High heat generating waste receipt, transfer and dispatch – surface facilities



Empty reusable transport containers will be returned to the surface and into the relevant transfer facility for routine contamination monitoring prior to dispatch. Six testing stations will be provided in the LHGW transfer facility, and a single test station will be provided in the HHGW transfer facility. These will be provided with facilities to allow rectification of containers failing the tests.

Following clearance for re-use, empty ILW transport containers will normally be stored either in the small temporary storage area adjacent to the testing stations or they will be transferred to the main covered store for transport containers, adjacent to the transport container maintenance facility.

DCTCs cleared for re-use will normally be stored in the transfer facility, in a temporary storage area adjacent to the test facility.

Empty road trailers or rail wagons will remain in the reception bay of the relevant package transfer building, awaiting loading with an empty reusable transport container by the overhead travelling crane from the temporary storage area. The trailer or rail wagon will then be transferred as described previously.

The disposal routes for radioactive wastes at the GDF are detailed on the flow diagrams included in the Drawings section of this report.

5.2.2 Transport container maintenance and storage facilities

It is currently assumed that there will be separate maintenance and storage facilities for the LHGW and HHGW transport containers.

When an LHGW transport container (for example, the SWTC) requires more extensive maintenance than minor turn-round inspection, a bogie will transfer it from the transport package transfer facility to the transport container maintenance and storage facility. In the case of a DCTC for HHGW, the transport container will be delivered to the HHGW transport container maintenance area which is a segregated area within the HHGW waste package transfer facility.

The maintenance and storage facilities will enable:

- repair of containers that had failed the turn-round inspection in the transport package transfer facility
- scheduled annual inspection and maintenance of all containers
- scheduled periodic inspection and maintenance of all containers (more extensive than annual maintenance)
- recovery and rectification of non-conforming transport containers and/or waste packages, as described earlier

Every transport container entering the maintenance facility will pass through an inspection and monitoring area and then into an interlocked containment booth for opening and, if necessary, decontamination.

The containment booth will contain a shielded and filtered cell with purpose-designed remote handling equipment for opening transport containers and removing any waste package(s), even under difficult circumstances involving damaged or other non-compliant items. The remainder of the containment booth will be unshielded, but equipped for decontamination operations, and will be large enough to accommodate a transport container and its lid in separate lay-down areas.

Even for routine scheduled maintenance, the following operations will be carried out remotely until it had been confirmed that the container was empty and has no major internal contamination:

- lid removal
- transfer of the lid and container body from the shielded cell to other parts of the containment booth for decontamination
- any decontamination removal found to be necessary
- transfer of decontaminated items out of the containment booth to other parts of the maintenance facility for further treatment

The maintenance facility will provide the capability for all scheduled maintenance and limited mechanical repairs of the transport container. Other areas will include the lifting equipment store, the pressure testing station, the leak testing station and facilities for checking the dimensional tolerances of repaired containers.

In addition, this facility will be able to receive any transport packages that might fail acceptance tests, and will have the equipment to take the necessary remedial actions.

The main covered storage area for reusable transport containers will be adjacent to the maintenance facility.

6 Surface Support Facilities and Infrastructure

6.1 Construction support facilities

There will be a number of facilities located on the GDF surface site to support the ongoing underground construction activities. The primary construction support facilities are described in the following sub-sections, however this is not intended to be an exhaustive list of all facilities and the need for some of these facilities will be dependent upon the geological environment of the site. In addition, there will be a requirement for a number of other buildings such as a laboratory and a drilling core store.

6.1.1 Rock crushing facility

The rock-crushing facility will be divided into two sections: an excavated rock store that will contain a supply of suitable rock ready for crushing that has previously been removed from the disposal facility and the crushing plant. Rock from the surface stockpiles will be moved to the rock store in the rock-crushing facility. A mechanical front-end loader would place this rock in a hopper that feeds the rock-crushing facility. Multiple crushing processes will be required to get the required size fractions. The crushed rock will then be fed into the holding silos in the buffer materials handling plant, to be incorporated as backfill directly (evaporite) or blended with bentonite (for the higher strength rock illustrative design).

Surplus rock spoil, not used for backfill or able to be accommodated within the surface screening bunds, will be taken via a conveyor from the rock-crushing facility through to the rail system to be taken off site.

6.1.2 Surface stockpile for excavated rock

With the exception of the illustrative design in an evaporite rock, it is assumed that at least some of the rock excavated from the underground workings will be retained on site by the creation of a screening bund around the site of the works, although this will depend upon the nature of the host rock. The bund will be progressively constructed and landscaped throughout the lifetime of the GDF. A screening bund might be formed between the perimeter fence and the rail receipt sidings at an early stage of construction and before commencement of disposal operations. This would provide isolation and visual screening of transport packages in the rail sidings during GDF operations.

Although rock excavated from the underground development of roadways, vaults, disposal tunnels, etc., could be brought up the construction return shaft at any time, it is assumed that the surface operation to place the rock in the perimeter screening bund will be constrained to daytime hours. Therefore, in order to allow rock to be removed from underground as expeditiously as possible, a stockpile will be required at the surface. The stockpile will be enclosed in a building in order to control noise and potential release of dust. The rock will be taken by an enclosed belt conveyor from the construction return shaft to the top of the covered building and discharged into either of two bunkers. The material will then be loaded by a front-loading shovel into articulated dump trucks during daytime working hours for use in the construction of the screening bund around the site.

If a situation arises where it is not possible to store all of the excavated rock on site, arrangements will be put in place to transport surplus excavated rock off site. These arrangements will consist of a conveyor to transport the spoil from the bunkers to the rail sidings, to be removed from site.

The arisings from underground construction in the evaporite rock illustrative design are assumed to be unsuitable to be used in bunds around the site. When stored on the surface, they would be exposed to rainwater meaning that there would be a potential for leaching and consequent pollution. The evaporite rock may also degrade over time resulting in loss of volume, particularly over the timescales involved with the construction and operation of the GDF. As a consequence of these risks, it is very likely that surface storage of such a material will require an environmental permit and extensive pollution prevention and control measures. Therefore, it is planned to export the excavated evaporite arisings from site via the rail system. In this scenario, screening bunds can be formed from site clearance material and any spoil generated from initial shaft excavation through overlying (non-evaporite) materials. Additional screening using vegetation and fencing may be considered, dependent upon site location and planning conditions.

6.1.3 Buffer materials handling plant

A buffer materials handling plant will be required in the higher strength rock and lower strength sedimentary rock illustrative designs; in the evaporite rock design, the rock crushing plant serves this purpose for salt.

In the higher strength rock illustrative design, buffer material will be formed into pre-compacted blocks and rings, packaged appropriately to prevent degradation, and transferred to the drift for onward movement underground. To produce the pre-compacted blocks, bentonite will be withdrawn from storage bins and transferred, blended and weighed, and the moisture content of the mix will be adjusted to the required level. The bentonite will then be transferred to one of a number of block compaction machines. Completed blocks will then be conveyed from the compaction machine to the block-loading bay, where blocks would be inspected, sorted and placed on suitable rail wagons. Blocks will be grouped logically on wagons to provide the desired combination for the deposition hole or disposal tunnel being filled.

The buffer materials handling plant will also be required to produce crushed rock spoil and bentonite, to be used as mass backfill for common services area and roadway infrastructure.

In the illustrative design for a lower strength sedimentary rock, the buffer materials handling plant will be required to produce blocks of bentonite and granulate.

6.1.4 Construction offices

The office block will provide facilities, including construction personnel changing facilities, a control room linked to the main GDF control room and a lamp room.

6.1.5 Construction workshops, stores and marshalling area

Workshops and stores will be provided to service the construction works. The workshops will be equipped with both mechanical and electrical plant servicing areas and will have an overhead travelling crane. The stores will have a racking system for smaller parts and an open area with an overhead travelling crane for the larger items of stored equipment. These will be located adjacent to a laydown area for the storage of construction materials and also linked to the construction return shaft via rails to enable maintenance of spoil skips.

6.1.6 Fire and rescue station

A fire and rescue station will be provided on the surface site. This will serve both the surface and underground in the event of an emergency. The station will be a combination of a conventional fire station and a rescue station, and will be staffed by trained fire and rescue personnel, and provide a permanently available service.

Facilities will follow best practice adopted in the mining and nuclear industries and will include fire engine(s), self-contained breathing apparatus, protective clothing (for example, fire suits and full body suits), a lamp room, active change rooms and showers, whole-body radiological monitoring, an ambulance and a first aid room.

6.1.7 Explosives store

Subject to the properties of the host rock, explosives might need to be used as part of the underground excavation operations. An explosives store will be provided on site to ensure that explosives will be held securely and will be available as and when required. The store will be sited in the construction area and explosives delivery, storage, transportation and use will be subject to strict controls and statutory requirements.

Depending on the nature and quantities of explosives involved, storage of explosives on the site would require a licence to have been granted by ONR under the Explosives Regulations 2014. Such a licence would include conditions relating to the type and maximum quantities of explosives that may be stored, separation distances from certain other buildings, and, if appropriate, the construction, siting or orientation of the store (including any protective works around the building), the activities that may be carried on within the store (or particular rooms or other structures within the store). In addition to complying with the conditions of the licence, the licence holder must also comply with directly applicable provisions of the 2014 Regulations relating to safety and security of explosives (e.g. preventing/controlling fires and explosions, preventing unauthorised access to explosives, reporting losses).

6.2 Waste emplacement support facilities

The following principal surface facilities will be provided to support the ongoing waste emplacement activities at the GDF.

6.2.1 Ventilation facilities

A number of different ventilation systems will be necessary for the GDF. These will include systems for the ventilation of the nuclear facilities on the surface, and the normal provisions for ventilation and air conditioning of modern buildings. Where feasible, passive ventilation and heating/cooling systems will be used for the surface facilities.

A fan house will be located adjacent to the emplacement return shaft and will be connected to the shaft by a fan drift. This fan house will contain the fans to draw air through and out of the emplacement side of the GDF.

All discharges from the ventilation system will be led to the atmosphere through a stack located at the side of the ventilation fan house. Equipment will be in place to monitor quantities of dust, aerial contaminants, gases and radionuclides prior to release to atmosphere. High Efficiency Particulate Arrestors (HEPA) will be used to filter the air discharged to atmosphere to minimise the release of particulate material.

6.2.2 Active effluent treatment plant

An active liquid effluent treatment facility will be provided to treat all radioactive liquid effluent arising from the surface and underground operations during the operational period.

Any active liquid effluent, collected from underground operations, will be brought to the surface via the emplacement intake drift or shaft (in evaporite rock) using a bowser and will be shunted into a covered unloading station. A flexible coupling will then be connected to the tanker, and the contents pumped to receipt tanks at the active effluent treatment plant.

6.2.3 Management centre

The management centre will provide the following facilities:

- in conjunction with the transport management centre, round-the-clock operational control and monitoring of all transport package arrivals and dispatches

- processing and recording of all quality assurance documentation, including maintenance records
- changing room facilities for workers involved in active operations on the surface and underground
- welfare facilities
- health physics monitoring and records service
- office accommodation for management, operations and support staff
- offices for use by the various regulators, including the Health and Safety Executive, Environment Agency and the European Atomic Energy Community (Euratom), who will periodically visit the facility

6.2.4 Transport management centre

The transport management centre will be located close to the road and rail arrivals and dispatch areas. Its primary function will be to check and process documentation relating to arriving transport packages and departing reusable transport containers. The primary control will be through inventory tracking procedures. The transport management centre will be closely linked to the main control room, which will have overall responsibility for the co-ordination and control of vehicle movements both on and off site.

6.2.5 Drift and shaft transport vehicle maintenance facility

In the GDF, where waste packages are transported underground using a drift transport system, a facility will be provided for the maintenance of the drift locomotives and rolling stock. A rack and pinion rail track running the full length of the facility will provide maintenance bays for up to three drift locomotives or wagons. In the GDF, where waste would be emplaced using a shaft transport system, the maintenance facility would be integrated into the waste package transfer buildings. It would be accessible by rail track to the emplacement shaft transport system. Both of the facilities will have a monitoring and decontamination area, inspection pit, machine and welding shop, and will be served by an overhead travelling crane with an appropriate SWL.

A control room that will be the focal point for monitoring and controlling the disposal facility will be located above this facility. This control room will address both surface and underground facilities, during normal operations and also during emergencies (during site emergencies the control room will also function as part of the emergency control centre). The location of the control room has been chosen so that control room staff will have good direct visibility of the main operations within the rail sidings and the transport package receipt and transfer facilities, as well as the usual alarm and CCTV monitoring, and back-up systems.

6.2.6 Shunting engine and main-line wagon maintenance facility

A separate maintenance facility will be provided, adjacent to the drift wagon and locomotive facility, for the shunting engines and the fleet of main-line rail wagons. The facility will not be used for routine maintenance, only essential repairs. This facility will have an inspection pit and a machine and welding shop, and will be served by an overhead travelling crane with a suitable SWL.

6.2.7 Laboratories

The laboratories will share the same building as the active laundry (within the active area). Their role will be to analyse active or potentially active liquid and gaseous samples taken from various operational processes on the site. This will also include sampling and analysis of liquid and airborne discharges to ensure that compliance with regulatory limits was maintained. In addition, analysis of environmental samples (eg air, water) will be carried out to monitor and record any of the disposal facility. The relatively small liquid effluent arisings will be transported to the active effluent treatment receipt tanks for processing.

6.2.8 Active laundry

It is assumed that an active laundry will be provided on site. This will be a separate facility within the active area to handle the laundering of clothing used in the active operations area. It will be similar to any normal industrial laundry, with washers and drying systems, but in addition will have an active change area and radiological controls and monitoring. The laundry will also wash protective clothing and respirators for re-use. The active liquid effluent will be pumped to the active effluent treatment plant receipt tanks for processing. All other work clothing worn outside the active area will be exported from site to a commercial laundry.

6.2.9 Mechanical and electrical workshops and stores

The mechanical and electrical workshops and stores will serve both surface and underground operational requirements for the supply and maintenance of equipment. The workshops will be equipped with both mechanical and electrical plant servicing areas and will have an overhead travelling crane (SWL approximately 20t). The stores will have a racking system for small parts and an open area with an overhead crane for any larger items of equipment requiring storage.

6.2.10 Administration and reception

The administration and reception building will provide the following:

- offices for staff engaged in managing the disposal facility, including senior managers, finance and accounts, IT, safety and environmental, training and corporate communications services
- welfare facilities
- conference and meeting rooms
- training facilities

6.2.11 Visitor centre

A separate visitor centre will be provided outside the fenced site boundary. Facilities might typically include a reception area with a static exhibition and computer simulation of the disposal facility operation, conference facilities, meeting rooms and demonstration facilities.

6.3 Surface infrastructure

6.3.1 Personnel access

A car park and bus terminal will be located outside of the GDF boundary fence. Personnel will gain access to the site via the security turnstiles and will proceed on foot to the on-site shuttle bus park for access to the facilities.

A railway station has been included in the illustrative designs, located outside of the GDF perimeter fence. However, the viability of a rail service for workers has yet to be assessed in light of the numbers regularly commuting to and from the site. Shuttle buses will operate to move personnel to and from the railway station.

Shuttle bus parking areas will be located within the boundary fence, close to the main facilities to allow for dropping off and picking up of personnel during shift changes.

6.3.2 Security fencing and vehicle access control points

The perimeter of the GDF will be controlled to prevent unauthorised access. These boundary fences will be designed to meet the appropriate regulatory expectations for a licensed nuclear site and are planned to have three access points, two road vehicle control points for admission of personnel, waste packages and construction vehicles, and a gatehouse to control rail movements. Other areas within the GDF such as the waste receipt area and construction areas will also be fenced separately. Further control points will be positioned within the GDF to control movements to individual areas of the site, ie the waste receipt area, the management area and the construction area.

6.3.3 Electrical sub-station and compound

Two independent supplies will be taken from the distribution network to feed two surface sub-stations, one sub-station located within the operational area and a second sub-station within the construction area. The surface sub-stations will supply power to both the surface and underground facilities. The surface sub-station design will be based on duplication of in-feeds, transformers and distribution boards at each sub-station, with the capability to cross-connect sub-stations in order to supply power to the entire GDF in the event of loss of supply at either surface sub-station. Additionally, each of the surface sub-stations will include mobile backup diesel generators, to maintain the GDF essential load in the event of total loss of the distribution network supply, as described in Section 11.4.

Further detail of the design of the proposed electrical system at the GDF is described in Section 11.4.

6.3.4 Exterior lighting

There will be three types of exterior lighting on the site: operational, amenity and security.

- Operational lighting will be required so that operations will be carried out in a safe manner. For example, the stockyards will have a relatively high level of lighting to illuminate working areas.
- Amenity lighting will be provided for access roads and car parks. Footpaths will also be illuminated at low level by lighting bollards.
- For security reasons, the fence around the operational area will be illuminated. Other sensitive areas will also be illuminated.

Particular care will be taken in the specification and siting of all surface lighting in order to minimise light pollution outside of the site without compromising safety and security. A screening bund around the site could be designed to help to minimise light pollution.

6.3.5 Water supply

There will be a requirement for water to be used for construction, operation and closure activities. A drinking water supply and on-site storage piped distribution system will be installed to the site. Water will be needed during construction and backfilling operations as well as used to clean during and after construction activities and process water will be used for decontamination activities. Water will also be necessary for fire suppression systems and firefighting provision. The source of supply could be from an existing local utility water supply network, assuming the water pressure and quantity required were acceptable. Alternatively, it may be necessary to upgrade an existing system in order to provide an adequate supply to the site.

A storage tank will be provided on site, of sufficient capacity to ensure emergency supply in the event of a failure in the normal supply.

6.3.6 Water treatment and drainage

A wastewater treatment plant will be constructed on the site for all non-active drainage pumped from underground. This will be located close to the construction area of the site and will be designed to provide appropriate wastewater treatment for all site facilities. Foul water from the washing and changing facilities, toilets etc., will be collected by a system of pipes and, then routed to the on-site wastewater treatment plant. Surface water run-off will be passed through multi-bay settlement tanks, oil interceptors and storage tanks, with arrangements for chemical conditioning should this be necessary.

The surface water drainage system will be designed in accordance with best practice, with due consideration for topography and the local drainage regime. To cater for extreme rainfall events, the site roads will be laid with the appropriate falls or spillways provided so that surface water run-off will be discharged to either existing water courses or to lower lying land, to prevent the site from flooding. Shaft accesses will be covered and laid to fall from the shaft collars, to avoid the inundation risk in storm conditions. For non-active surface areas, a sustainable drainage system (SUDS) will be designed, with due consideration of topography and the local drainage regime.

Regular sampling and monitoring will be undertaken to ensure that the quality and quantity of the water complies with the discharge consent. Should a non-compliance be recorded for certain agreed parameters the discharge would be diverted to a non-compliance holding tank where the water would be stored until the situation was rectified. The water would then either be treated appropriately on site before being discharged or if necessary, taken off site by road or rail tanker for specialist treatment.

The treated water will be discharged from the site to a suitable drainage network or local watercourse, under permit from the environmental regulator. Discharges to local watercourses will be limited to a permitted run-off rate. If necessary, suitable balancing facilities will be constructed to ensure that this requirement can be met.

7 Surface to Underground Waste Transport and Facilities

The facilities that are required to enable the transfer and emplacement of waste packages underground are described in the following sub-sections. It is recognised that the detailed design and configuration of these facilities will require development as the project advances. At appropriate stages of development, the design will be reviewed as part of the iterative process for disposal system development.

Access to the underground facilities will be via a combination of shafts and a drift or shafts only, depending upon the geological environment. For the illustrative designs in a higher strength rock and lower strength sedimentary rock, access underground is assumed to be via a drift and three shafts. For evaporite rocks, access is assumed to be via four shafts. The final design will be based on the information acquired during the site investigation phase. Designs for underground access will take account of amongst other matters, safety, the environmental impacts of operations, the package throughput, the depth of the disposal horizon and the characteristics of the overlying geological sequence.

A lateral separation distance of up to 10km between the surface facilities and the underground disposal facilities disposal areas is considered feasible. However, in theory, the lateral separation could be greater or less than 10km, depending on the site(s) available. A number of factors will need to be considered when determining the lateral separation, such as the impact on operational safety. This distance could impact the arrangement of the underground accessways and may impact on access and egress, for example, some shafts may be replaced by drifts.

There will be many site-specific factors that will influence the separation distance, which could either reduce that distance, or in certain circumstances allow it to be increased as detailed in the *Statement on Separation Distance Limit between a Surface Facility and Underground Vaults* [43].

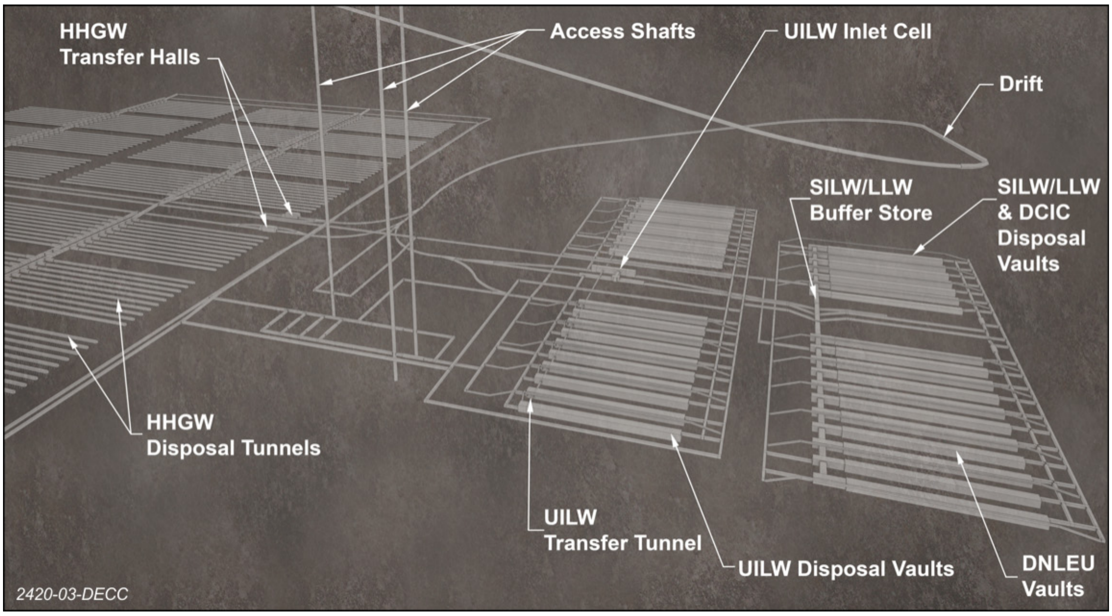
7.1 Drift

The entrance to the drift will be covered by a drift top building, which would provide a weatherproof structure for drift trains and operational personnel awaiting final clearance to go underground. The building will be equipped with doors and other protection measures to allow only authorised trains (drift/wagons and locomotives) to enter the drift.

The drift top building will also be the point where operational personnel passing into and out of the underground areas via the drift will be recorded. Combined with similar records for construction personnel from the construction intake shaft, this would provide an accurate record of the number of personnel underground at all times.

The drift is assumed to be constructed at an average gradient of 1:6, and will connect the surface waste transfer facilities with the underground disposal facilities. The drift will have a spiral configuration, as shown in Figure 14.

Figure 14 Drift configuration



The drift will be the principal means of access from the surface to the underground disposal facilities. Its primary functions would be:

- transport of waste packages and containers
- transport of large components
- transport of operational personnel
- export of liquid effluents
- a route for services
- the air intake for disposal ventilation (the emplacement intake)

Based on the assumed depth of the underground facilities, the approximate length of the drift would be 4.0km in the higher strength rock design and 3.0km in the lower strength sedimentary rock design. This is subject to the location of the underground disposal facilities in relation to the location of the surface facilities, allowing for changes in gradient at the start and finish.

The upper section of the drift is assumed to pass through high-permeability sedimentary strata, which will require pre-treatment to control groundwater inflows during construction. Groundwater control in the upper 10m or so of strata will be achieved by de-watering. Thereafter, treatment by grouting from the surface will be carried out to the maximum practicable depth of about 130m below ground level. Groundwater control for the drift at depths in excess of this will be by conventional cover grouting techniques from within the drift, and will form part of the excavation cycle. There are a number of alternate methods that can be adopted such as ground freezing, concrete lining or dewatering. These will be considered based on site-specific characteristics.

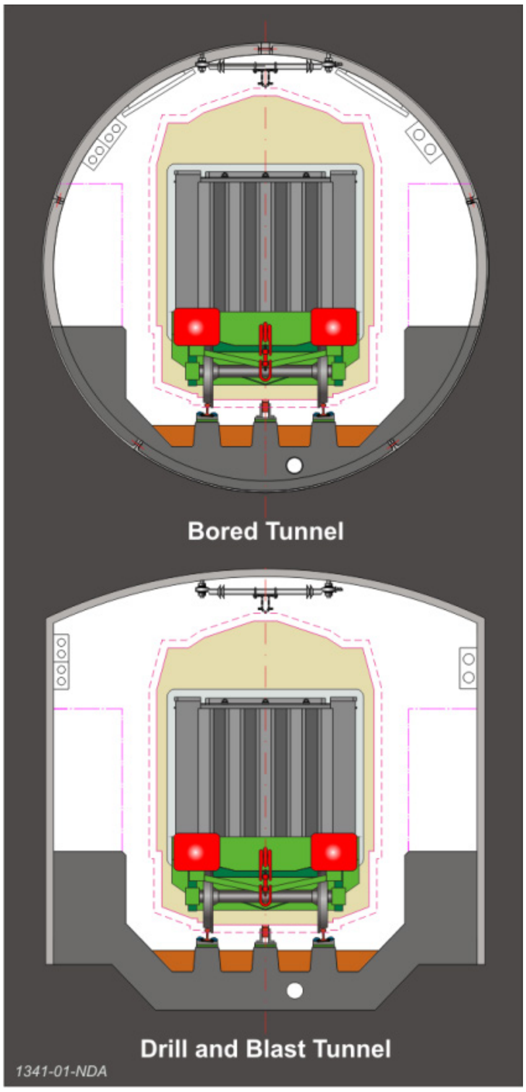
Starting from the surface, the first 60m length of the drift (10m depth) will likely be constructed by cut-and-cover methods with a drift portal at the surface. A number of construction techniques are available for excavating the remainder of the drift including tunnel boring machine (TBM), road header and drill and blast techniques. The upper section of drift will be formed by TBM and would be circular in cross-section, with an assumed concrete hydrostatic pressure-resistant lining of 5.5m internal diameter.

Beyond 300m depth in the drift, it is assumed there will not be a requirement for a hydrostatic pressure-resistant lining and that this lower section will require support in the form of rock bolts, mesh and shotcrete. It is assumed that this section of the drift can be driven upwards from underground to meet the tunnel from the surface. Access to construct this lower section of the drift will initially be via a shaft and that this section will require only minimal ground support. The tunnel here will be either circular or a 'D' cross-section, 5.5m wide by 5.0m high, depending upon the method of excavation adopted.

Due to the length of the drift, there may be a requirement to provide for evacuation of personnel below ground by reducing travel distance to a place of relative safety such as a safe haven or a protected corridor.

An electrical sub-station and pumping station will be constructed about halfway down the drift, to collect and remove any residual groundwater from the upper section. The design will also incorporate an additional pumping station at the bottom of the drift and a sump to provide additional drainage storage capacity. The drift floor will be in-filled with a concrete invert to support the rack-and-pinion rail system, and will incorporate a gravity drain. The drift would carry a number of services, including a 100mm diameter water main, 11kV power cables and a 100mm diameter pumping main for discharging groundwater and process water arising from the ongoing construction activities. Indicative cross-sections through the upper and lower drift sections are shown in Figure 15.

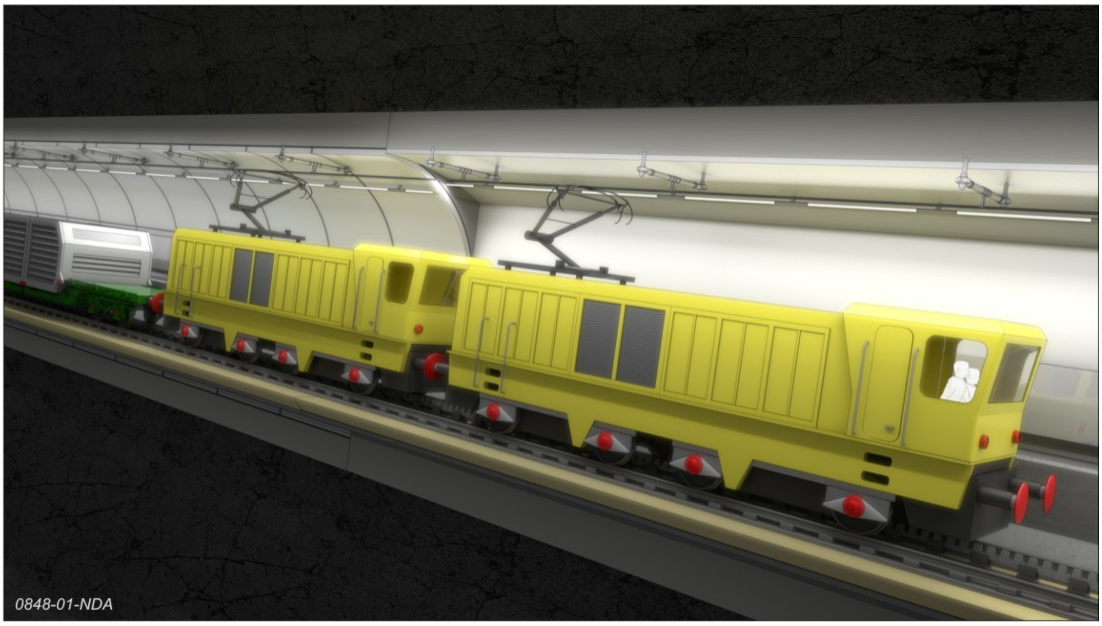
Figure 15 Cross-sections through the upper and lower sections of the access drift



Once excavation, lining and support are complete, a rack and pinion rail system will be installed, capable of transporting loads of up to 80t.

The drift locomotives can be powered electrically from overhead cables via a pantograph, and are currently assumed to be restricted to a maximum speed of 20km/h (Figure 16). A separate carriage will be provided for the transport of personnel. Personnel and waste transport packages would be carried on different trains at different times.

Figure 16 Rack and pinion drift transport system



There would be four basic types of drift wagon:

- wagon for transport packages only
- general-purpose wagon for plant, equipment and materials
- effluent bowser
- carriage for personnel

Prior to first waste emplacement, the drift rail system will be used for the transportation of large, long and heavy mechanical plant and equipment for the inlet cell and disposal facilities.

Following the commencement of disposal, the drift will be designated a radiologically controlled area, with restricted use and access and special safety precautions.

7.2 Shafts

All vertical access shafts will have a finished internal diameter of 8.0m, with the exception of the emplacement intake shaft in evaporite rock. This waste emplacement shaft will be constructed with an internal diameter of 9.0m to accommodate a DCTC used for HHGW, as described in the *Vertical Shaft Transportation* report [44].

The shafts will be excavated using proven and well established techniques. Drilling and grouting and/or ground freezing could be employed to advance the shafts through water-bearing strata. Permanent shaft support will be provided by a concrete lining, which will include an additional hydrostatic lining where necessary to prevent the ingress of water. These design elements (and those for the different host rocks) will be tailored to individual site properties and the required waste emplacement throughput rates.

The primary functions of the three shafts common to the illustrative designs in all three host rocks will be to:

- transport plant and materials
- provide ventilation to the construction and operational areas underground
- provide an export route for excavated rock

The three shafts common to all host rocks considered are currently assumed to have a finished internal diameter of 8.0 metres. This size of shaft will allow for the flexibility for the transport of plant, materials and people if required.

The construction intake shaft will be the principal means of access underground for construction personnel and materials and act as the construction ventilation intake.

During construction, the construction return shaft will chiefly serve as the export route for excavated rock and also act as an air return for the construction ventilation system. The shaft will be equipped with a high-performance winding system to maximise its rock removal capacity.

The emplacement return shaft (the third ventilation shaft) in conjunction with the drift will enable separate ventilation of the waste disposal operations from the construction operations.

All shafts will be constructed with sumps for the installation of safety equipment (eg shaft bottom arrestors) and have a water storage capacity with pumps and pipe columns to the surface.

Where the shafts pass through high-permeability sedimentary cover strata, they will be lined with a hydrostatic pressure-resisting concrete lining. The bottom section of the shafts may not need a hydrostatic lining, but will have a suitable concrete lining.

The design and appearance of the winding systems within the shafts and the shaft-top buildings and structures will be similar to those used at deep mines around the world, but as discussed in Section 2.6.5, the design will need to satisfy ONR's regulatory system.

The headgear will be erected over the shafts, from which the shaft conveyances (cages or skips) will be suspended from wire ropes. Emergency back-up generators will be provided for shaft winding in case of loss of power and the need to evacuate personnel from underground. An emergency mobile winder will also be available for use in case of an incident where access to the shaft is required. The shaft systems will be based on relevant good practice and incorporate up-to-date control, monitoring and safety equipment to reduce the risk of and mitigate accident situations.

7.3 Emplacement shaft (evaporite rock)

Shaft-only access is currently assumed in the illustrative design for evaporite rock. Thus, the waste for disposal will be transported underground via a fourth shaft, which will be constructed instead of the drift described above (Figure 17). This shaft will have an increased diameter of 9m in comparison to the other shaft in order to accommodate some of the waste packages. The entrance to this dedicated waste emplacement shaft (referred to as the emplacement intake shaft) will be within the coverage of the waste package transfer facilities, which will provide a weatherproof environment. The transport container will be transferred onto a shaft bogie which will then be delivered on to a cage in the emplacement intake shaft.

The emplacement intake shaft top building will also be the point where emplacement operational personnel passing into and out of the underground areas via the shaft will be recorded. This will provide an accurate record of the number of personnel underground at all times, when combined with similar records from the other underground accesses.

Figure 17 Surface access to the emplacement shaft

7.4 Access and egress for personnel

Personnel access to and egress from the underground facility will be provided for personnel working on the construction or operational activities. In a higher strength rock and lower strength sedimentary rock environments access arrangements would be via:

- drift (operation intake)
  - primarily to transport operational personnel
  - and to provide a means of egress from underground
- shafts (construction intake)
  - primarily to transport construction personnel
  - and to provide a means of egress from undergorund

There is currently no drift in the evaporite design so access and egress for both the construction and operational phases will be via the shafts. The operation intake is currently assumed to provide access for operations personnel however this will likely need reconsideration in the future with operational safety input. The construction intake will provide access for construction personnel.

In the event that there is a problem in either the construction or operations side of the facility it will be possible for personnel to gain access to the un-affected side and allow a means of additional egress.

7.5 Underground transport

In the illustrative designs, which are assumed to be constructed on a single horizontal level using an idealised layout, the underground emplacement rail system will split in two directions at the disposal facility level, with one branch going to the LHGW disposal area and the other serving the HHGW disposal area.

In the higher strength and lower strength sedimentary rock illustrative designs, operational personnel will be transported down the drift in a dedicated personnel carriage to the emplacement support facilities in a carriage hauled by two locomotives. Personnel will disembark at a platform at the opposite side of the inlet cell from waste arrivals. The personnel platform will also provide access to the main underground control room. Trains carrying waste packages will not be permitted in the drift when trains are transporting personnel.

8 Illustrative Underground Layouts and Operations

8.1 Illustrative underground layouts

The illustrative layouts of the GDF are based on construction of the disposal facility on a single level horizontal underground. RWM recognise that this is only an assumption used for the purpose of developing illustrative designs and any detailed site-specific designs could result in an alternative layout that could influence the size of the required facility footprint.

The vaults and tunnels have been arranged in a modular layout to provide flexibility when tailoring the design to a specific site; these modules can then be arranged in accordance with the structure of the host geological environment. This flexibility of the layout could also be adapted to include construction of modules at different levels within the geological formation.

The generic layouts have been based on distances between the packages within the disposal vaults taking into consideration geotechnical parameters and thermal considerations for the HHGW. Site-specific data could allow the disposal containers to be placed closer together or the rock pillars between vaults and tunnels could be decreased (geotechnical). If so, there would be a corresponding decrease in the overall GDF footprint.

Once a host site for the GDF is identified, the site-specific host rock properties, including rock strength, structure, hydrogeological properties and other factors will be considered and evaluated to determine its suitability to host the GDF. These properties will influence the design of the underground facilities and may result in changes such as the implementation of a multi-horizon layout or the use of different disposal concepts, selected and tailored to site conditions.

Based on geotechnical considerations, all disposal vaults and tunnels will most likely be aligned parallel with the direction of the assumed maximum principle stress. Aligning the disposal vaults and tunnels with the maximum horizontal stress would result in the minimum horizontal stress acting across the excavation roof. This orientation will improve stability, assist with excavation rates and contribute towards the most cost effective support. If the alignment was perpendicular to the maximum horizontal stress then roof conditions will deteriorate resulting in increased instability, lower excavation rates and increased support costs.

Underground, the disposal facility will be split into two disposal areas, separated by a common services area. An LHGW disposal area for the disposal of LLW, SILW, UILW and DNLEU, and an HHGW disposal area for HLW, SF, Pu and HEU.

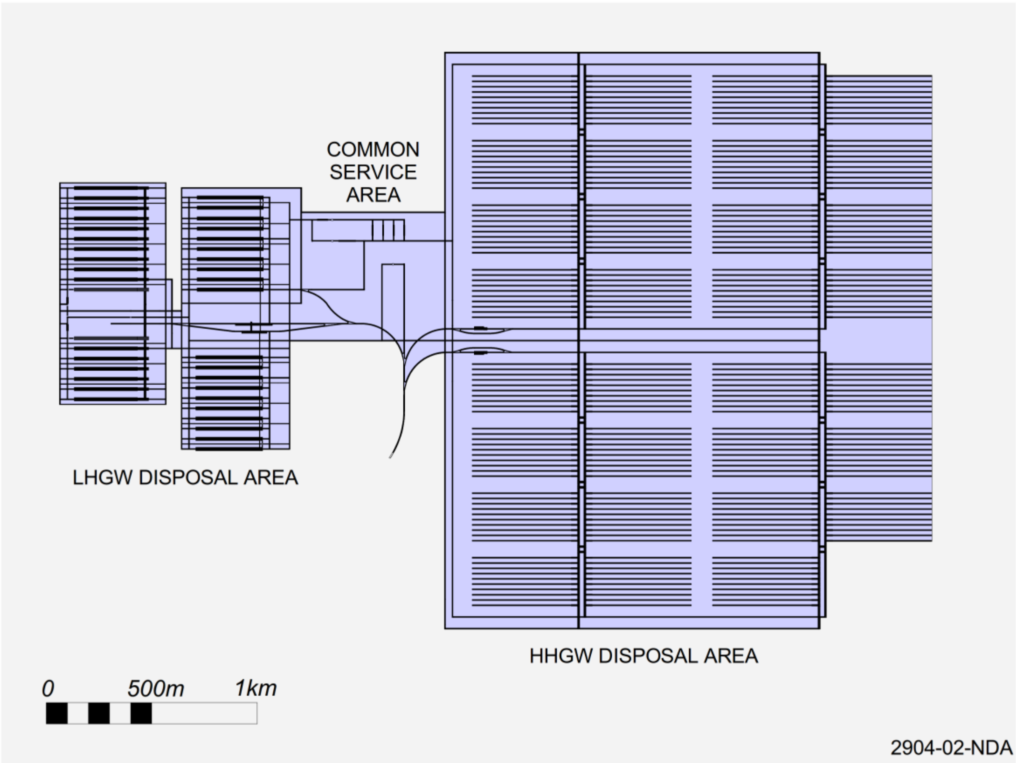
As a general principle, the temperature in the LHGW disposal vaults for the current illustrative designs will be minimised as far as is reasonably practicable. For the UILW disposal vaults, the design aim for the operational phase (including backfilling) is to provide an environment in which the temperature of the waste packages remains within targets specified in the DSS Part B [11]. This target is defined as 50°C with excursions up to 80°C for up to 5 years, and an air temperature within a disposal vault limited to 50°C (required for effective operation of equipment eg emplacement cranes).

The designs for LHGW vault operation will be established to ensure, so far as possible by passive means, that the temperatures can be kept below this level. Therefore, effects of co-location with HHGW could have an impact on the temperature in the LHGW disposal vaults. The operational temperatures for the LHGW disposal vaults have been calculated and modelled previously, as detailed in the *Nirex Vault Environment Feasibility Study*

Summary Report [45].The ventilation system for the GDF has been analysed and is described in more detail in [46].

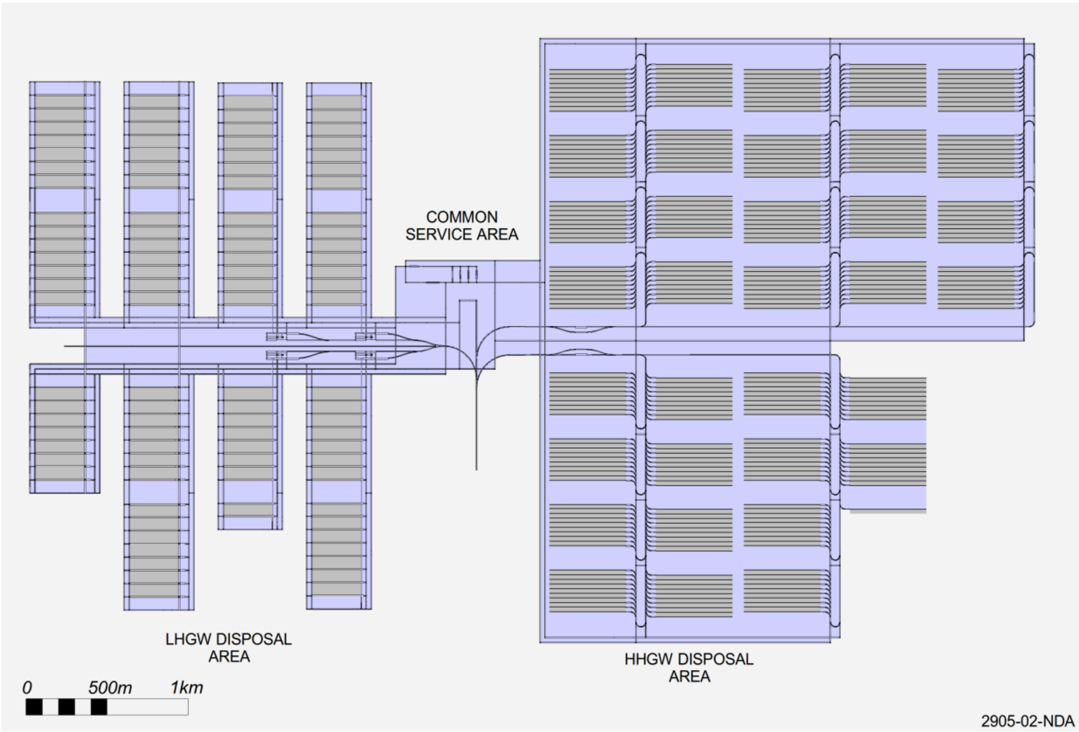
The illustrative layouts for each host rock, having regard to orientation and pillar size, considered are shown in Figures 18 to 20. A layout for each host rock has been prepared showing the maximum extent of the GDF and the total number of anticipated disposal vaults and tunnels.

Figure 18 Final illustrative underground layout in a higher strength rock



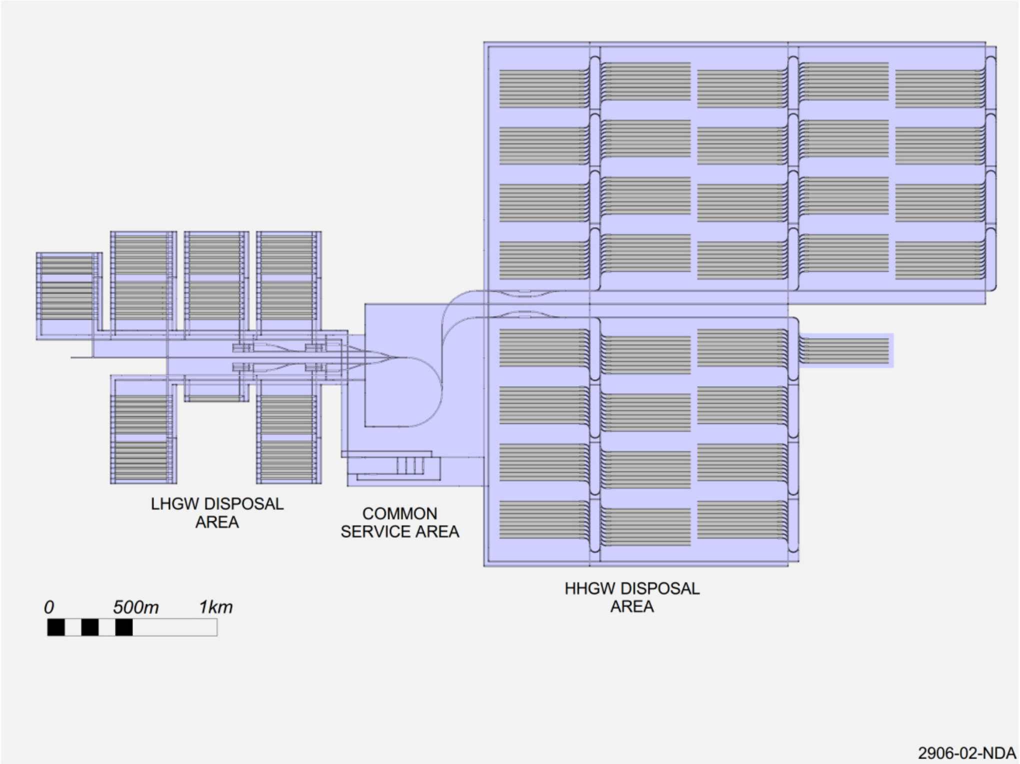
For the higher strength rock, the footprint for the 2013 Derived Inventory will be approximately 7.6 km^2 (Figure 18).

Figure 19 Final illustrative underground layout in a lower strength sedimentary rock



For the lower strength sedimentary rock illustrative design, the footprint for the 2013 Derived Inventory will be approximately 15.3 km^2 (Figure 19).

Figure 20 Final illustrative underground layout in an evaporite rock



For the evaporite rock illustrative design, the footprint for the 2013 Derived Inventory will be approximately 10.3 km^2 (Figure 20).

A more detailed analysis of the illustrative design footprints for the different host rocks and the inventory scenarios is provided in Appendix E.

8.2 Operational programme

Construction of the vaults for LHGW and the disposal tunnels for HHGW will take place concurrently with emplacement operations. At the time of first waste emplacement, there will be one UILW vault constructed and operational, one UILW vault undergoing fit-out and one SILW/LLW vault constructed and operational. A vault for RSILW waste packages will also be constructed ready for waste disposal although this will depend upon the schedule of arising RSILW Containers. Construction of one HHGW disposal module comprising 20 disposal tunnels will be completed prior to the arrival of the HHGW containers.

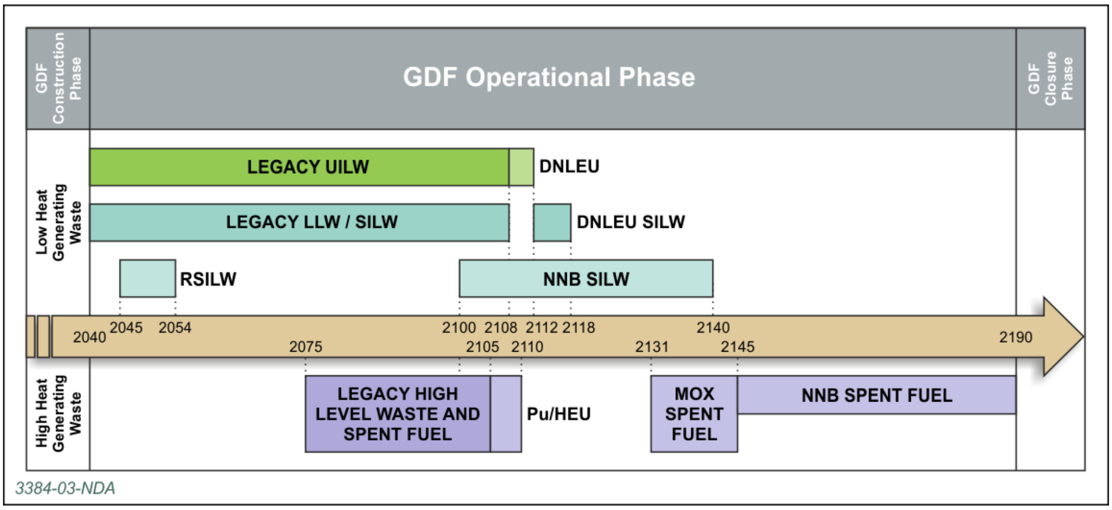
Construction of the vaults for LHGW and the disposal tunnels for HHGW will take place on an as-required basis, with potentially two or three tunnels under construction and fit-out at any one time.

At this stage, for the purpose of providing a basis for undertaking safety assessments and environmental assessments, and considering the logistics associated with moving wastes to the facility, assumptions have been made regarding the timings and throughput rates. The rate of handling and emplacing these waste packages is within the maximum tolerances of the throughput levels currently assumed for the GDF and the facility will have the flexibility to dispose of smaller or larger number of total waste packages per year. Throughput rates have been based on earlier studies (*Generic Repository Designs* [19]) or from information drawn from other national programmes.

For the Inventory, the throughput for LHGW will average approximately 2,300 disposal units per year from 2040 to 2063. Between 2063 and 2108 the throughput will reduce to an average 1,500 disposal units per year. DNLEU packaged in 500 litre drums (UILW) will be emplaced at a similar rate (1,500 disposal units per year) once the legacy UILW has been emplaced and would take approximately four years, until 2112. DNLEU packaged within TDCs will be emplaced following the completion of emplacement of DNLEU packaged in 500 litre drums. The rate of disposal is assumed to be similar, resulting in the emplacement of these packages over a six year period, by 2118. NNB ILW will be emplaced in parallel with the end of legacy ILW/LLW and DNLEU from 2100 to 2140.

The disposal of legacy HHGW will commence in 2075 and continue until 2105 at a throughput rate of 200 disposal containers per year, based on the *Outline Design for a Reference Repository Concept for UK High Level Waste/Spent Fuel* [47]. Disposal of residual Pu and HEU will be scheduled to follow the disposal of legacy HLW and SF, from 2105 to 2110. MOX will be available for emplacement at 2131 based on the rate of cooling, and will take approximately 14 years to emplace. Subsequently, spent fuel from the 16GW(e) new nuclear power stations programme will take 45 years to dispose of up until 2190. The phasing over time for the Inventory is shown graphically in Figure 21.It would be possible to reschedule consignments should the need arise, for example, due to problems with packaging of a particular waste type or disruption of transport networks.

Figure 21 GDF waste emplacement timings



Following emplacement of all waste in a higher strength rock, the LHGW vaults will be backfilled and sealed in a single campaign. This differs for a lower strength sedimentary rock, where it is assumed that the LHGW vaults will be backfilled and sealed once each vault has been filled with waste packages.

For the purpose of developing the illustrative design in evaporite rock, the LHGW disposal vaults will not be backfilled as the strata will be allowed to creep[4] naturally and close the excavations over time. Each vault will be sealed once filled with waste packages.

The backfilling of disposal tunnels for HHGW will be carried out progressively as disposal containers are emplaced.

The development of the operational programme is based on a number of assumptions. For LHGW these assumptions are typically practical in nature; such as the timing of waste

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[4] Creep: the nature of some evaporite rocks to move over time, which can cause the closure of underground openings.

arisings. For HHGW, the disposal schedule is more related to managing the impacts of the thermal output of the wastes.

The dates for disposal of HHGW are based on a number of parameters including; the radionuclide inventory of the HHGW, properties of the geological environment and the disposal concept and associated temperature targets for the backfill and buffer materials. At this generic stage many of these parameter values are assumptions and this will result in uncertainty in the disposal dates that are presented in the operational programme. For example, should the design chosen for a site be different to those assumed for the illustrative designs then a substantially different emplacement schedule could result.

The approach adopted in the illustrative designs is to present a time efficient programme, whereby the emplacement period is minimised and other parameters within the GDF are adjusted accordingly. For the illustrative designs this means that the thermal target of the disposal concept is met by increasing disposal container separation distances, where necessary, rather than by adjusting the emplacement date to allow for more decay.

9 LHGW Handling and Emplacement

The LHGW disposal area comprises a series of disposal vaults connected by access/transfer tunnels. There will be five types of disposal vault within the LHGW disposal area:

- UILW vaults to accommodate legacy UILW (including DNLEU packaged in 500 litre drums)
- SILW/LLW vaults to accommodate legacy SILW and LLW waste packages
- dedicated vaults to accommodate DNLEU in TDCs;
- dedicated vaults to accommodate NNB SILW concrete drums from new nuclear power stations which will have specific handling requirements
- dedicated RSILW vaults to accommodate RSILW containers which have specific handling requirements

The disposal vaults are constructed to allow through flowing ventilation and the waste packages are placed on a concrete floor of sufficient strength to support the stacks of waste packages.

When considering the inventory of radioactive waste for disposal, there are a number of different types of waste package that are non-standard and various features will require special consideration prior to emplacement. Details of these packages and their requirements are provided in Appendix G.

9.1 UILW handling

The legacy UILW packages will be transported to the inlet cell directly by rail via the drift. In the evaporite rock, the packages will be transported to the inlet cell by rail from the base of the emplacement shaft. Following arrival at the inlet cell, the packages will be remotely removed from their transport containers and transported to the disposal vault via a designated transfer tunnel. The inlet cell is where each UILW disposal unit will be removed from its reusable SWTC and transferred to a designated vault for emplacement. A schematic of the inlet cell suite is shown in section in Figure 22. The UILW will be delivered in a range of package types, including stillages holding four 500 litre drums, and individual 3 cubic metre drums, 3 cubic metre boxes and Miscellaneous Beta Gamma Waste Store (MBGWS) boxes. These UILW waste packages will be transported from the inlet cell to the vaults via a common transfer tunnel.

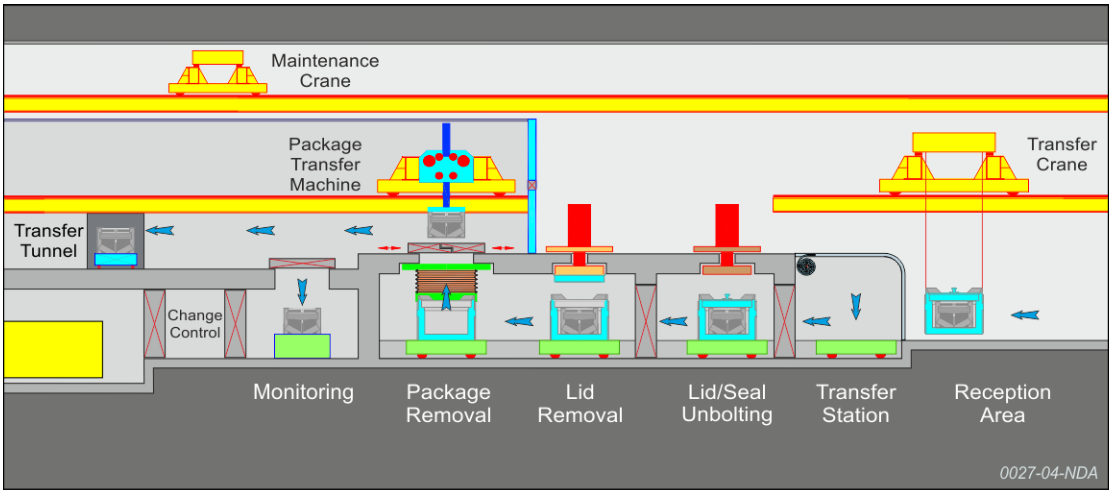
The size of the excavation to accommodate the inlet cell design will be different for each of the generic geological environments due to assumed geological parameters and the support requirements for each. However, the process for removing the containers from their SWTC and transferring to the vault is similar in all generic geological environments. Therefore the structures for undertaking this will be similar in all three generic designs and sufficient space to accommodate these structures is included.

The inlet cell will be located underground to enable the waste packages to be transported in their reusable SWTC as close as possible to the point of disposal. The inlet cell will be shielded and will provide containment of radioactive material in the unlikely event of an incident. In addition to the in-built redundancy that will be incorporated into the inlet cell systems, a retrieval system will be provided so that the cranes could be manually operated in the event of total electrical failure. Shielded viewing windows and CCTV will allow visual monitoring of all stages of the operations within the inlet cell.

Following transfer underground via the drift or emplacement shaft, wagons containing UILW packages will arrive at the end of the container transfer line for offloading. The container transfer line would have an 80t SWL overhead travelling crane for lifting and moving packages.

Figure 22 follows the waste package as it arrives at the reception area (right hand side) in its SWTC to delivery to the transfer tunnel (left hand side) prior to subsequent emplacement in the vault.

Figure 22 Schematic UILW inlet cell



Once the UILW package has been removed from the SWTC, at the package removal station, the SWTC will be returned to the surface. Appropriate monitoring, and where required decontamination, of the SWTC will be undertaken. Prior to the relidding of the SWTC, a number of checks may be undertaken to prevent the relidding of an SWTC which still has a package present. Engineering measures will be used to prevent this from happening, through the use of laser scanning, to ensure that the SWTC is empty, prior to relidding. This could also be supported by an operator visual check, via CCTV.

In order to ensure that the location of each package within the GDF is known, at all times, a package configuration management system will be used. This would be in addition to any independently operated nuclear material safeguards assurance system.

9.2 UILW emplacement

9.2.1 Higher strength rock

The UILW disposal vaults will have a cross-section of approximately 16.0m × 16.0m (Figure 23) and a length of 317m with an effective length for disposal of 295m. A total of 20 disposal vaults will be built to accommodate UILW packages based on the Inventory.

Figure 23 Schematic cross-section through an UILW vault – higher strength rock

Disposal would start from the far end of the vault, and work back towards the transfer tunnel access hatch. The basic stack arrays in the vaults will be as follows:

- stillages of four 500 litre drums would be stacked in arrays seven wide and seven tall
- 3 cubic metre boxes and 3 cubic metre drums will be stacked six wide and seven tall
- MBGWS boxes will be stacked six wide and six tall

Emplacement within the vaults would be by an overhead travelling 20t SWL crane running the full length of the vault, as shown on Drawing Number E/DRG/0041029.

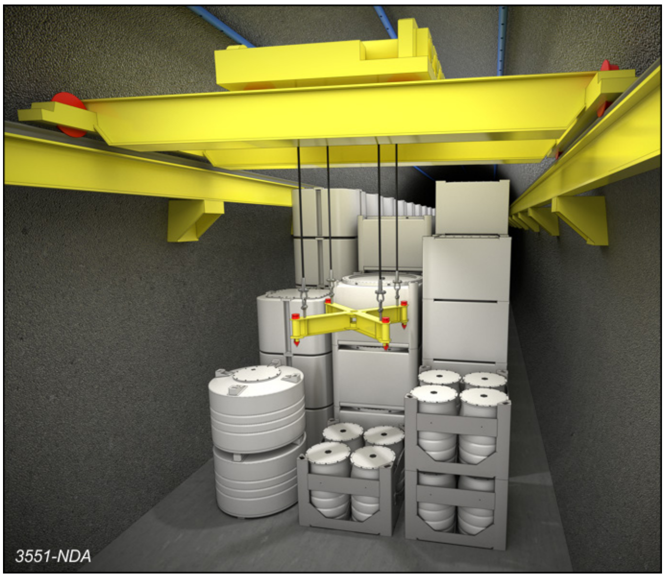
The placing of the disposal units in the vault will be controlled such that units can be positioned about a common reference point. Laser control of crane movements is a proven system that could be employed.

At the front of each UILW disposal vault there will be a crane maintenance area that will be shielded from the waste packages by a shield door. This will enable the emplacement crane to be maintained and/or repaired in a safe environment. Reliability of the emplacement crane will be essential to vault operation, and the design will incorporate redundancy and mechanical back-up. To deal with the unlikely event of a total crane system failure, a retrieval system will also be provided to enable the crane to be pulled back to the crane maintenance area. In case the crane failure occurred whilst a package is hoisted, after the crane has been retrieved to a position adjacent to the shield door, facilities will be provided to enable direct operation of the lowering mechanisms and disengagement of the waste package before safe retrieval of the crane into the crane maintenance area.

9.2.2 Lower strength sedimentary rock

The UILW disposal vaults will have a cross-section of approximately 9.6m wide × 11.5m high (Figure 24) and a length of approximately 317m with an effective length for disposal of 295m (Drawing Number E/DRG/0041080). A total of 58 disposal vaults will be built to accommodate UILW packages, based on the Inventory.

Figure 24 Schematic cross-section through an UILW vault – lower strength sedimentary rock



Disposal will start from the far end of the vault, and work back towards the access hatch, as shown on Drawing Number E/DRG/004080. The basic stack arrays in the vaults will be as follows:

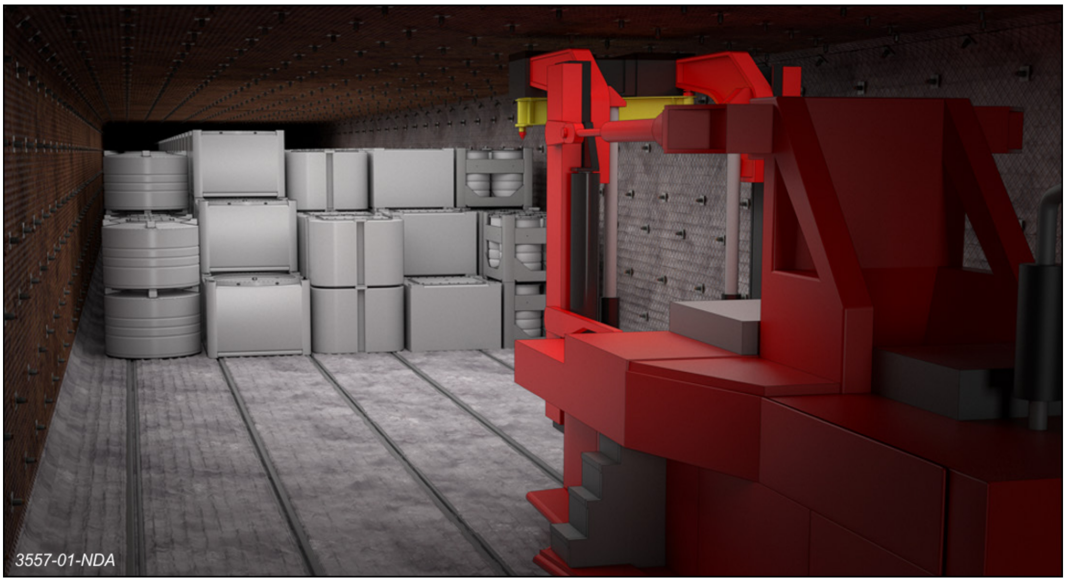
- stillages of four 500 litre drums will be stacked in arrays three wide and five tall
- 3 cubic metre boxes and 3 cubic metre drums will be stacked three wide and five tall (as illustrated in Figure 24)
- MBGWS boxes will be stacked two wide and five tall

The emplacement operation and the crane facilities will be similar to those described for UILW in the illustrative design for higher strength rock.

9.2.3 Evaporite rock

The UILW disposal vaults will have a cross-section of approximately 10.0m wide × 5.0m high (Figure 25). The length of the vault will be approximately 317m with an effective length for disposal of 295m. A total of 49 vaults will be built to accommodate packages from the Inventory.

Figure 25 Schematic cross-section through an UILW vault – evaporite rock



Each disposal vault will be sealed at the exit, ventilation outlet end and the shield door at the entry to the disposal vault will provide containment at the other end of the disposal vault. Disposal will start from the far end of the vault, and work back towards the front of the disposal vault utilising a remotely operated stacker truck, as shown on Drawing Number E/DRG/0041130. The basic stack arrays in the vaults will be as follows:

- stillages of four 500 litre drums will be stacked in arrays five wide and three tall (as illustrated in Figure 25)
- 3 cubic metre boxes and 3 cubic metre drums will be stacked five wide and three tall
- MBGWS boxes will be stacked five wide and three tall

9.3 SILW and LLW handling

The SILW and LLW packages will be transported by rail to a temporary storage area, located off the drift extension. They will then be taken by stacker truck to their respective disposal vaults via service tunnels. DNLEU in TDCs, as described in the Inventory Report, will also be handled in this manner but will be emplaced in their own dedicated vaults. In the future, DNLEU may need to be separated, based on post-closure implications and at the current time the DNLEU TDC disposal vaults have been placed adjacent to the SILW vaults as handling and emplacement procedures are similar RSILW containers will be routed to the vault reception area where they are removed from their transport container and emplaced within the dedicated RSILW vault. NNB SILW concrete drums will be routed to their own dedicated vault in a similar manner.

SILW will be delivered in a range of packages, and comprise 4 metre boxes, 2 metre boxes, 6 cubic metre concrete boxes. LLW is currently assumed to be packaged in 4 metre boxes. The majority of DNLEU is currently assumed to arrive in TDCs. SILW and LLW packages will be delivered underground to the SILW/LLW reception area. They will be unloaded by an 80t SWL overhead travelling crane into the SILW/LLW temporary storage area, ready for disposal in the vaults. On account of the lower arrival rate of arrival of SILW and LLW packages, waste packages will be temporarily stored in dedicated storage areas to allow emplacement to take place in campaigns.

SILW and LLW package handling will be by an 80t capacity remotely operated stacker truck in all geological environments, which will transport the packages along the vault and stack them at the disposal face. There will be appropriate segregation between the SILW and LLW vaults and the service tunnels (e.g. through the use of a roller shutter door), to limit access to the vaults. The method of segregation will likely be controlled by an interlock, to ensure that access is only granted to the remotely operated stacker truck, during normal operations.

DNLEU packages will be handled and emplaced in the same fashion, albeit in dedicated disposal vaults.

The vault garage will house the stacker truck used for SILW, LLW, DNLEU, NNB SILW and RSILW disposal. To allow maintenance of this truck, a garage area will be integrated into the common services area. This will include all the necessary workshop facilities to undertake maintenance, including a crane, workbenches, stores, etc. It is proposed to use a battery-powered or electrically powered stacker truck in the vault.

9.4 SILW and LLW emplacement

9.4.1 Higher strength rock

An SILW/LLW disposal vault of cross-section about 16.0m wide × 15.0m high (Figures 26 and 27) will be constructed. Each vault will be 300m long (Drawing E/DRG/0041031). Due to the stacker truck manoeuvring, the vault will have an effective length for disposal of 265m. Based on the 2013 Derived Inventory, there is a requirement for five vaults to dispose of legacy SILW/LLW.

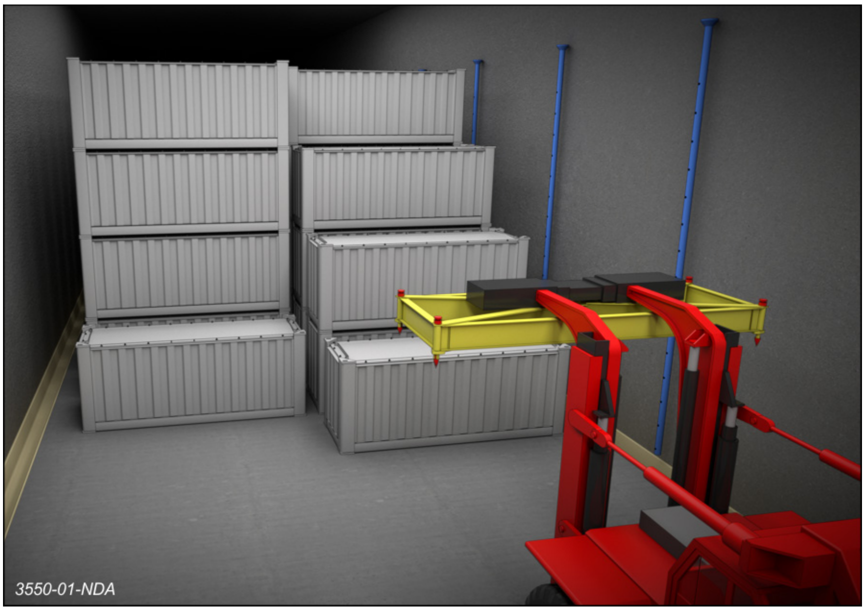
Dedicated disposal vaults for DNLEU packaged in TDCs are assumed to have the same excavation profile as SILW/LLW disposal vaults. A total of 11 vaults are required to dispose of DNLEU.

The SILW/LLW/DNLEU packaged in TDCs disposal vaults will be filled in a similar manner to the UILW disposal vaults, in arrays across the vault cross-section, starting from the far end. The basic stack arrays in the vaults will be as follows:

- 6 cubic metre concrete boxes will be stacked in arrays four wide and five tall
- 4 metre boxes will be stacked three wide and five tall
- 2 metre boxes will be stacked five wide and five tall
- TDCs will be stacked two wide and four tall

Figure 26 Schematic cross-section through a SILW and LLW vault – higher strength rock

Figure 27 Schematic cross-section through an SILW vault for DNLEU – higher strength rock



9.4.2 Lower strength sedimentary rock

A SILW/LLW disposal vault will have a cross-section 9.6m wide × 11.5m high (Figures 28 and 29), each of which will be 300m long (Drawing E/DRG/0041081) with an effective length for disposal of 295m. Based on the 2013 Derived Inventory, there is a requirement for 18 vaults to dispose of legacy SILW/LLW and 30 vaults to dispose of DNLEU packaged in TDCs.

Disposal would start from the far end of the vault, and work back towards the entrance. The basic stack arrays in the vaults will be as follows:

- 6 cubic metre concrete boxes will be stacked in arrays two wide and three tall

- 4 metre boxes will be stacked one wide and three tall
- 2 metre boxes will be stacked two wide and three tall
- TDCs will be stacked either one wide and two tall or one wide and three tall

Figure 28 Schematic cross-section through an SILW and LLW vault – lower strength sedimentary rock

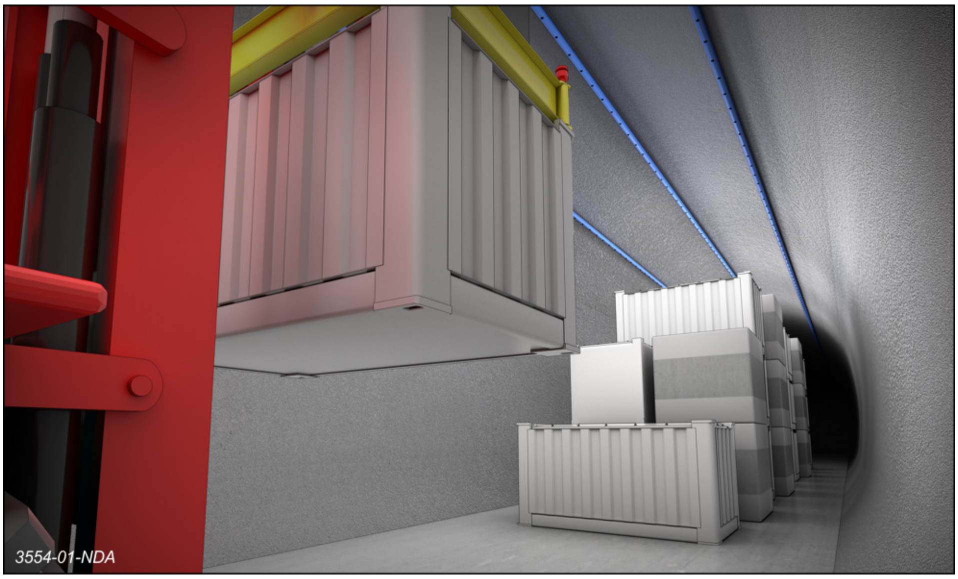
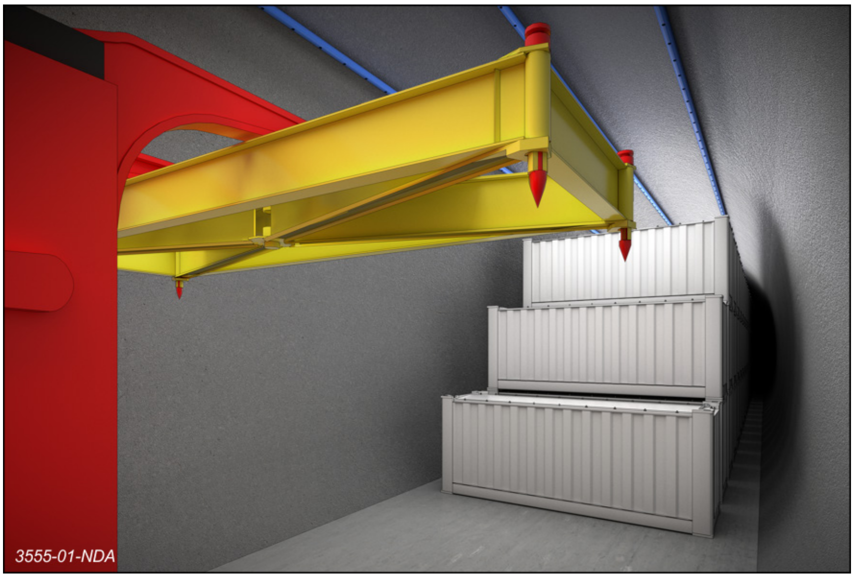


Figure 29 Schematic cross-section through an SILW vault for DNLEU – lower strength sedimentary rock



9.4.3 Evaporite rock

A SILW/LLW vault will be 10.0m wide × 5.5m high (Drawing E/DRG/0041131 and Figure 30), each of which will be 300m long with an effective length for disposal of 295m. Dedicated vaults to accommodate DNLEU packaged in TDCs will have the same length, however these vaults are assumed to be 8.0m wide × 5.5m high (Drawing E/DRG/0041139 and Figure 31).

Based on the 2013 Derived Inventory, there is a requirement for 10 vaults to dispose of legacy SILW/LLW and 27 vaults to dispose of DNLEU packaged in TDCs.

Disposal will start from the far end of the vault and work back towards the entrance utilising a remotely operated stacker truck. The basic stack arrays in the vaults will be as follows:

- 6 cubic metre concrete boxes will be stacked in arrays four wide and two tall
- 4 metre boxes will be stacked two wide and two tall
- 2 metre boxes will be stacked four wide and two tall
- TDCs will be stacked one wide and two tall

Figure 30 Schematic cross-section through a SILW and LLW vault – evaporite rock

Figure 31 Schematic cross-section through an SILW vault for DNLEU – evaporite rock

9.5 NNB SILW concrete drum waste package handling

The Inventory includes two variants of NNB SILW concrete containers that will be delivered to the GDF, as follows:

- 1 cubic metre concrete drums
- 500 litre concrete drums

The transport overpack containing NNB SILW concrete drum waste packages will be routed to the SILW/LLW package reception area for potential temporary storage and transfer to a dedicated vault as follows:

- the drift or shaft transfer wagon terminates at the SILW/LLW package reception area
- the transport overpack is lifted from the drift wagon by the SILW/LLW reception area crane (SWL 80 t)
- the transport overpack containing NNB SILW concrete drums is placed in an adjacent temporary storage area
- The transport overpack is lifted, by an 80t remotely operated stacker truck, and transferred to a dedicated vault. Note that the capacity of the stacker truck can be reduced but it is suggested that it is maintained so that the stacker truck could be utilised for all SILW packages.

For unloading operations of NNB SILW concrete drums in a dedicated vault, it is assumed that an 80t, remotely operated stacker will place the transport overpack onto an unloading station located at the front of the vault; this area is known as the vault reception area. The vault reception area will be enclosed by a containment screen and the stacker truck would enter through a roller shutter door. The unloading station will be separated from the stacks of emplaced NNB SILW concrete drums by a full package stack height shield wall and door.

The transport overpack will be remotely opened in the vault reception area and a robotic arm will be used to undertake the operations necessary to allow unloading of NNB SILW concrete drums from the transport overpack. To provide the necessary positional accuracy for the operation of the robotic arm, the unloading station will incorporate location features to accurately position the transport overpack. Direct vision of all of the unloading operations will be provided.

These are illustrated in Drawing Numbers E/DRG/0041034, E/DRG/0041084 and E/DRG/0041134.

9.6 NNB SILW concrete drum emplacement

9.6.1 Higher strength rock and lower strength sedimentary rock

A dedicated SILW disposal vault of cross-section of 16.2m wide × 16.0m high will be constructed for NNB SILW concrete drums in higher strength rock. Each vault will be 300m long. Due to the stacker truck manoeuvring, the vault will have an effective length for disposal of 277m. There will be a requirement for a single dedicated SILW vault to dispose of the NNB SILW concrete drums included in the Inventory. Whilst the disposal vault dimensions are the same for the NNB SILW packages, there is a requirement to remove the packages from the transport overpack by remote handling. This activity will be undertaken at the vault reception area at the entrance at each disposal vault. The packages are emplaced at the designated location by remotely operated crane. As a result, a dedicated vault is required for these packages. Emplacement of packages will start from the far end of the vault and work back towards the vault reception area.

For the lower strength sedimentary rock illustrative design, a dedicated SILW disposal vault of cross-section 9.6m wide × 11.5m high will be constructed for NNB SILW concrete drums.

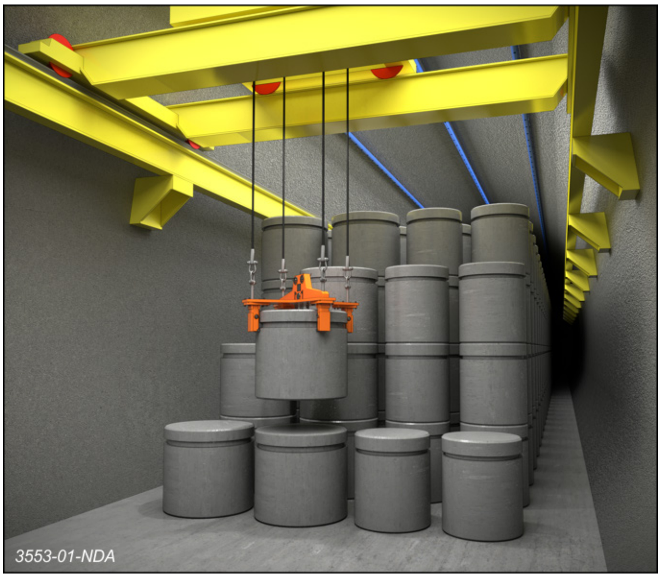
Each vault would be 300m long. Due to the stacker truck manoeuvring, the vault would have an effective length for disposal of 277m. There will be a requirement for five dedicated SILW vaults to dispose of the NNB SILW concrete drums included in the Inventory.

The NNB SILW concrete drums will be handled using a crane within the vault reception area and the emplacement vault. A crane maintenance area is required to be above the vault reception area and incorporation of a walkway in this area to provide access for crane maintenance.

The unloading station will be located beneath the operating area of the crane as shown on Drawing Numbers E/DRG/0041034 and E/DRG/0041084. It is possible that both 1 cubic metre concrete drums and 500 litre concrete drums will be emplaced in the same vaults, however, they will be emplaced in dedicated package arrays. The package arrays for the NNB SILW concrete drums in their dedicated vaults in the higher strength rock and lower strength sedimentary rock designs are illustrated in Figures 32 and 33.

Figure 32 1 cubic metre concrete drums and 500 litre drums stacked in a dedicated vault in a higher strength rock

Figure 33 1 cubic metre concrete drums and 500 litre drums stacked in a dedicated vault in a lower strength sedimentary rock



9.6.2 Evaporite rock

A dedicated SILW disposal vault of cross-section about 10.0m wide × 5.0m high will be constructed for NNB SILW concrete drums in evaporite rock. Each vault will be 300m long. Due to the stacker truck manoeuvring, the vault will have an effective length for disposal of 270m. There will be a requirement for five dedicated SILW vaults to dispose of the NNB SILW concrete drums included in the Inventory.

For the evaporite rock design, NNB SILW concrete drum handling within the vault reception area and vault will utilise a rail mounted stacker truck, the robotic arm will be positioned above the NNB SILW concrete drum removal station to allow access for both the remotely operated 80t rail mounted stacker truck which brings the transport overpack into the vault reception area and the remotely operated rail mounted stacker truck used to emplace the packages in the vault.

A traversable turntable between the unloading station and the shield door enables the rail mounted stacker truck to be positioned facing the unloading station for extracting waste packages from the transport overpack and then turn through 180 degrees to face the vault for emplacement. The turntable can also traverse across the width of the vault reception area so that it can align with the rails set in channels in the floor that are spaced to align with the rows of packages in the vault.

An area for maintaining the rail mounted stacker truck will also be provided.

The package arrays for the NNB SILW concrete drums in their dedicated vaults in the evaporite rock design are illustrated in Figure 34.

Figure 34 1 cubic metre concrete drums and 500 litre drums stacked in an illustrative dedicated vault in an evaporite rock

9.7 RSILW container handling

The Inventory includes two variants of RSILW containers that will be delivered to the GDF, as follows:

- 500 litre robust shielded drum;
- 3 cubic metre robust shielded box.

These packages will be emplaced in a dedicated RSILW container vault. Similar to the SILW/LLW wastes described earlier in this report, the rate of receipt of these packages at the GDF will be low, therefore, they will be temporarily stored in a dedicated storage area to allow emplacement to take place in campaigns.

The transport overpack containing RSILW containers will be routed to the SILW/LLW package reception area for potential temporary storage and transfer to the dedicated RSILW container vault as follows:

- drift or shaft transfer wagon terminates at SILW/LLW package reception area
- lift transport overpack from drift wagon using top ISO corner fittings and SILW/LLW reception area crane (SWL 80t)
- place transport overpack containing RSILW containers in adjacent temporary storage area
- lift transport overpack, using top ISO corner fittings and dedicated 80t manually-operated stacker truck, and transfer to a dedicated RSILW container vault

Both variants of RSILW container will be emplaced in the same vaults, however the arrays of the packages will be configured such that a 3 cubic metre robust shielded box is not lifted over a 500 litre Robust Shielded Drum, to avoid potential incidents resulting from dropping a heavier package onto the lighter variant.

The handling equipment used to emplace the packages in the vaults would be different in the three host rocks; an overhead travelling crane is planned to be used in higher strength rock and lower strength sedimentary rock and a rail mounted stacker is intended to be used in evaporite rock. However, there are a number of similar handling technologies and operations that are employed in all geological environments and these are described below.

For unloading operations of RSILW containers in a dedicated vault, it is assumed that a dedicated 80t remotely operated stacker will place the transport overpack onto an unloading station located at the front of the dedicated vault, known as the Vault Reception Area. The Vault Reception Area will be enclosed by a containment screen and the stacker truck will enter through a roller shutter door. The unloading station will be located beneath the operating area of the dedicated RSILW vault crane, and the area separated from the stacks of emplaced RSILW containers by a full package stack height shield wall with a shield door above.

The transport overpack will be opened remotely in the vault reception area and a robotic arm used to undertake the operations necessary to allow unloading of RSILW containers from the transport overpack. To provide the necessary positional accuracy for the operation of the robotic arm, the unloading station will incorporate location features to accurately position the transport overpack. 500 litre robust shielded drums will be unloaded from the transport frame, whilst still attached to the transport overpack. For 3 cubic metre robust shielded boxes, the robotic arm will be used to unlock tie-down twistlocks. RSILW container handling will utilise the vault crane and direct vision of all of the unloading operations will be provided through appropriate thickness shielding windows.

It is necessary to install an interlock system in the dedicated RSILW vault comprising two containment barriers to reduce worker doses in worst case accidents in the vault reception area and in the vault itself. These are illustrated on Drawing Numbers E/DRG/0041033, E/DRG/0041083 and E/DRG/0041133, described as ‘Containment Screen & Roller Shutter Door’ and ‘Shield Door’, respectively. The intention is to restrict person access in the vault reception area during unloading and emplacement of both variants of RSILW container. The shield door is intended to provide protection during maintenance operations in the vault reception area.

The interlock system will ensure that the shield door remains closed, except for when a package has been delivered to the vault reception area, the stacker truck has been removed and the roller shutter door is closed. The shield door will remain open until all RSILW containers in the vault reception area have been emplaced and the crane/rail mounted stacker truck has returned to the vault reception area after which time it is then closed again.

The roller shutter door will be interlocked to ensure it can only be opened when the shield door is closed to allow access for the stacker truck carrying RSILW containers into the vault reception area and during maintenance and other routine operations.

An alternative route for receipt of a 500 litre robust shielded drum is in a SWTC. The means of unloading a 500 litre robust shielded drum from an SWTC and delivering it to the RSILW vault are not specified. This could be achieved by unpacking the SWTC in the UILW inlet cell and transfer to the RSILW vault via an additional or extended transfer tunnel. Alternatively an SWTC could be transferred to the Vault Reception Area by the same route as an overpack, using suitable lifting frames, and the Vault Reception Area modified to provide a means of unpacking of the SWTC.

9.8 Emplacement of RSILW containers

9.8.1 Higher strength rock and lower strength sedimentary rock

A dedicated SILW disposal vault of cross-section about 16m wide × 12m high will be constructed for RSILW containers in higher strength rock. Each vault will be 300m long. Due to the stacker truck manoeuvring, the vault will have an effective length for disposal of

277m. There would be a requirement for a single dedicated SILW vault to dispose of the RSILW containers included in the Inventory.

A dedicated SILW disposal vault of cross-section 9.6m wide × 11.5m high will be constructed for RSILW containers in the lower strength sedimentary rock design. Each vault will be 300m long (Drawing E/DRG41085). Due to the stacker truck manoeuvring, the vault will have an effective length for disposal of 277m. There will be a requirement for three dedicated SILW vaults to dispose of the RSILW containers included in the Inventory in a lower strength sedimentary rock.

RSILW container handling within the vault reception area and vault will utilise a crane and direct vision of all of the unloading operations will be provided through appropriate thickness shielding windows.

The crane maintenance area is required to be above the vault reception area and incorporation of a walkway in this area to provide access for crane maintenance.

The unloading station will be located beneath the operating area of the crane as shown in Drawing Number E/DRG/0041033.

It is assumed that to facilitate automated handling, a ‘stillage-type’ transport frame will be used, incorporating a restraint mechanism to limit vertical movement. Drawing Numbers E/DRG/0041033 and E/DRG/0041083 provide illustrations of the automated handling arrangements to be provided at the vault reception area for removal of 500 litre robust shielded drums in Type IP-2 configuration.

For 500 litre robust shielded drums in their Type B configuration, ie with shock absorbers as shown in Drawing Numbers E/DRG/0041033 and E/DRG/0041083, will utilise the same automated handling arrangements provided at the dedicated vault entrance for emplacement in the Type IP-2 configuration.

To minimise tool change operations for the main RSILW vault crane, it is envisaged that the lifting frames will be configured to mimic the bottom lifting feature of the RSILW container and will be capable of lifting both the top shock absorber and the RSILW containers.

The stack configurations, ie stack orientations and respective stack heights, considered in the 3-high stack vault design for higher strength rock and lower strength sedimentary rock designs are shown in Figures 35 and 36.

Figure 35 500 litre robust shielded drums and 3 cubic metre robust shielded boxes stacked in a higher strength rock dedicated vault

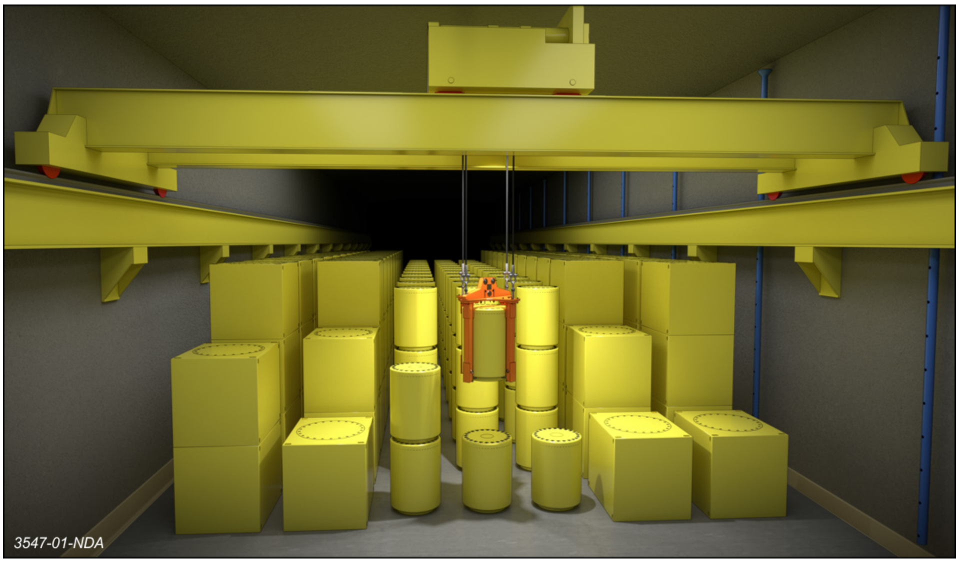
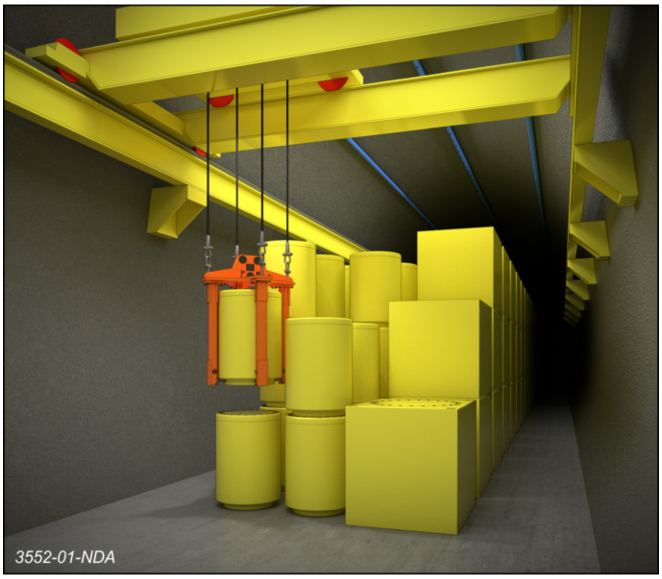


Figure 36 500 litre robust shielded drums and 3 cubic metre robust shielded boxes stacked in a lower strength sedimentary rock dedicated vault



9.8.2 Evaporite rock

A dedicated RSILW disposal vault of cross-section about 10.0m wide × 5.0m high will be constructed for RSILW containers in evaporite rock. Each vault will be 300m long. Due to the stacker truck manoeuvring, the vault will have an effective length for disposal of 270m. There will be a requirement for two dedicated SILW vaults to dispose of the RSILW containers included in the Inventory.

For the evaporite rock design, RSILW container handling within the vault reception area and vault will utilise a rail mounted stacker truck. The robotic manipulator will be positioned above the RSILW container removal station to allow access for both the remotely operated

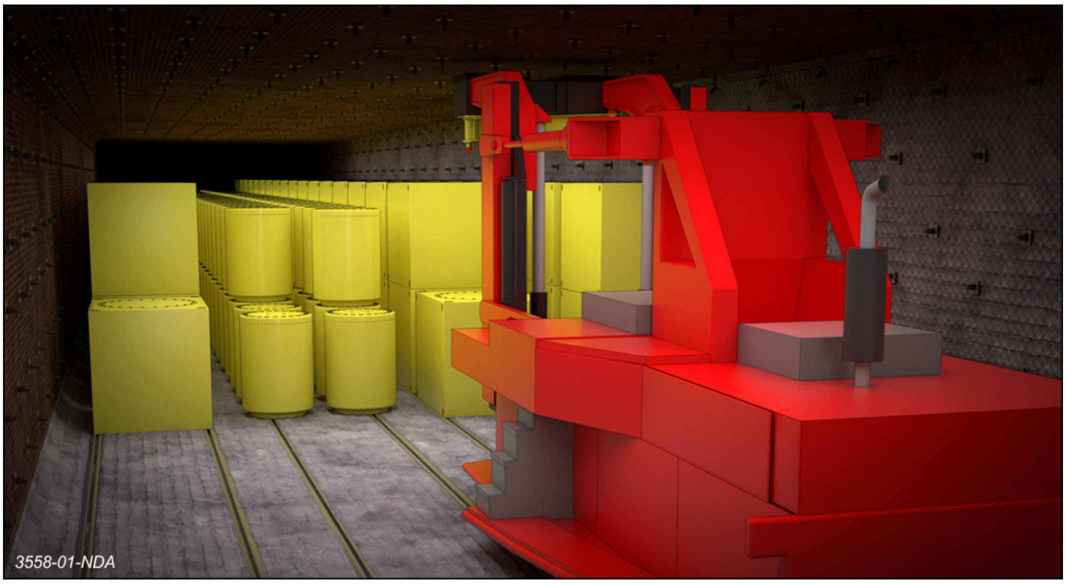
80t stacker truck and the remotely operated rail mounted stacker truck used to emplace the packages in the vault. Direct vision of all of the unloading operations will be provided through appropriate thickness shielding windows.

A traversable turntable between the unloading station and the shield door enables the remotely operated rail mounted stacker truck to be positioned facing the unloading station for extracting packages from the transport overpack and then turn through 180 degrees to face the vault for emplacement. The turntable can also traverse along the width of the vault reception area so that it can align with the rails set in channels in the floor that are spaced to align with the rows of packages in the vault.

An area for maintaining the rail mounted stacker truck is also provided.

The stack configurations, ie stack orientations and respective stack heights, considered in the 2-high stack vault design for evaporite rock design are shown in Figures 37.

Figure 37 500 litre robust shielded drums and 3 cubic metre robust shielded boxes stacked in an evaporite rock dedicated vault



10 HHGW Handling and Emplacement

The HHGW disposal area is currently assumed to consist of a series of disposal tunnels connected by service tunnels for the disposal of HLW, Legacy SF, Pu, HEU, MOX and NNB SF. The assumed method of excavation, dimensions and shape of the disposal tunnels in each geological environment is different. The handling of HHGW packages varies, dependent upon the host rock, as described in the sections below.

The characteristics of the host rock will determine the exact separation distance and the length and size of the disposal tunnels. The spacing between disposal tunnels (rock pillar size) has been determined by both geotechnical calculations [48] and thermal assessment. The minimum pillar size in conjunction with the disposal container spacing was calculated using empirical formulae and assumed rock characteristics and the thermal calculations were then used to model the thermal characteristics of bounding case scenarios to ensure that temperatures were within thermal targets; 100°C for higher strength rock, 125°C for lower strength sedimentary rock, and 200°C for evaporite rock.

It should be emphasised that the description of the HHGW handling and emplacement is deliberately high level at this stage and associated drawings are simplified. The aim is to focus on the layout as, according to the existing programme, emplacement of HHGW would not begin until 2075, by which point extensive experience of waste emplacement processes should have been gained from other national programmes that are further advanced with their facilities.

It is currently assumed that HHGW will be disposed of in cylindrical disposal containers. For higher strength rock it is assumed that disposal containers will have a copper outer shell (Variant 1). In lower strength sedimentary rock and evaporite rock, carbon steel (variant 2) disposal containers will be used.

10.1 HHGW handling

10.1.1 Higher strength rock

In operation, disposal containers will be transported underground in a DCTC [7] to the transfer hall where the shock absorbers would be removed from the DCTC.

The DCTC will be rotated to the vertical orientation using the trunnions on the body of the DCTC and lowered into a cell in the transfer hall floor using the overhead crane (SWL 80t). The lid will then be unbolted but not removed. The deposition machine will be located above the cell, and the gamma gate tilted so that the shielded tube was orientated in a vertical direction. The shielded tube will be lowered to a position where the bottom is slightly above the DCTC, and the lid of the DCTC will be removed onto a rolling table. The hoist on the deposition machine will be moved over the tube, and the hoist tool and the docking device lowered and connected to the grapple unit of the disposal container. The grapple unit will be disengaged from its recess inside the tube, and lowered through the shielded tube, and the disposal container lifted from the DCTC into the shielded tube. The shielded tube will then be elevated and tilted to the horizontal orientation. The operations will be supervised with a CCTV camera inside the cell. The camera will also be used for inspection of the disposal container and observation of possible damage. The empty DCTC will be inspected internally for damage, and the lid re-fitted. The lid bolts will be inserted and tightened, and the transport container lifted up from the cell, rotated back to horizontal and located back onto the tie-down frame. The DCTC would be further inspected for contamination, with inspection of the bolts, trunnions and general outer surfaces. The shock absorbers would then be fitted, and the DCTC placed on a drift wagon for return to the surface.

A maintenance area will be required in the HHGW side of the facility to allow routine maintenance and repair of the deposition machine.

10.1.2 Lower strength sedimentary rock

In the lower strength sedimentary rock generic design, the DCTC will be taken to a transfer hall, where the shock absorbers will be removed and the DCTC transferred to a rail mounted transfer wagon.

From here, the transfer wagon will be moved using a locomotive into the disposal tunnel reception area. Two interlocking shield doors will be provided at the disposal tunnel reception area, one at the entrance to the reception area and one at the entrance to the disposal tunnel. With the inner door closed, the outer shield door will be opened, and the emplacement trolley and its power unit will enter the reception area and be aligned with the disposal tunnel. The locomotive and transfer wagon will enter the reception area on a parallel track to that accommodating the emplacement trolley. Personnel will leave the area and the outer shield door will be closed ready for the emplacement operation. The process of transferring the disposal container from the transfer wagon onto the bentonite blocks will then be undertaken. For this operation, the disposal container will be moved out of its shielding, on the transfer wagon, horizontally onto the support bed, which will be fitted with a side transfer capability to allow the disposal container to be moved onto the bentonite support blocks located on the emplacement trolley. During this operation, cameras mounted on the support bed will be used for identification of the disposal container and observation of possible damage. The transfer of the container in the disposal tunnel reception area is illustrated on Drawing Number E/DRG/0041089.

10.1.3 Evaporite rock

On arrival underground, the DCTC will be placed onto a rail vehicle at the base of the emplacement shaft and taken to the transfer hall, where the shock absorbers will be removed and the shielded container removed from the DCTC and transferred to a deposition machine. From here, the deposition transfer machine will be moved into the disposal tunnel reception area, on a parallel track to that accommodating the emplacement trolley. Two interlocking shield doors will be provided at the reception area of the disposal tunnels, one at the entrance to the reception area and one at the entrance to the tunnel. With the inner door closed, the outer gate will be opened, and the disposal trolley and its power unit will enter the reception area and be aligned with the disposal tunnel.

The process of transferring the container from its shielding directly onto the emplacement trolley will then be undertaken. For this operation, the disposal container will be moved out of its shielding, on the deposition transfer machine, horizontally onto the support bed, which will be fitted with a side transfer capability to allow the disposal container to be moved onto the emplacement trolley. During this operation, cameras mounted on the support bed will be used for identification of the disposal container and observation of possible damage. The transfer of the container in the disposal tunnel reception area will be similar to that for the lower strength sedimentary rock design. The container will then be ready for emplacement.

10.2 HHGW emplacement

10.2.1 Higher strength rock

The HHGW disposal area will consist of disposal tunnels designed for in-tunnel vertical emplacement of individual disposal containers within deposition holes (Figure 38). Each disposal tunnel is assumed to be single entry, and will be nominally 500m long and have dimensions of 5.5m wide × 5.5m high [47]. There will be a 150mm thick concrete floor to create a uniform base. Ten disposal tunnels will be grouped together to form a disposal area and it is currently assumed, based on the output of the thermal assessment, that a 19.5m wide rock pillar will separate the disposal tunnels.

The layout of the disposal tunnels together with their service tunnels will be rectangular in shape. A series of deposition holes will be drilled along the line of each disposal tunnel. These deposition holes will not be lined with concrete.

The service tunnels would have a 'D'-shaped cross-section with an arched roof, and will vary in cross-section from 5.5m wide x 5.5m high to 7.0m wide x 7.0m high.

Disposal containers will be emplaced in deposition holes spaced at 6.5m centres along the disposal tunnels, with the exception of MOX containers which will be spaced at 9.5m centres to manage the anticipated heat output. An 8% additional allowance of deposition hole numbers is included at this stage to account for potential out of specification holes. This may be reduced by better rock characterisation in the future.

A total of 310 disposal tunnels will be required to dispose of the Inventory of HHGW. These are shown on Drawing Number E/DRG/0041026.

The deposition machine (Figure 38) will transport the disposal container directly to the disposal tunnel. It will then be located in the correct position over the selected deposition hole, which will be pre-loaded with bentonite blocks and rings before emplacement of the disposal container (Figure 39).

Shielding would be lowered to the tunnel floor, and the disposal container will be tilted to the vertical and lowered into the deposition hole. The disposal container will then be lowered into the deposition hole lined with bentonite rings. A further three bentonite blocks will be retained within the deposition machine for placement on top of the disposal container. The deposition machine then returns to the transfer hall. After all of the deposition holes in a disposal tunnel are filled, the disposal tunnels will be backfilled with bentonite blocks. Bentonite pellet backfill will be used to fill all void space and a tunnel seal will be constructed.

Figure 38 Deposition machine - higher strength rock

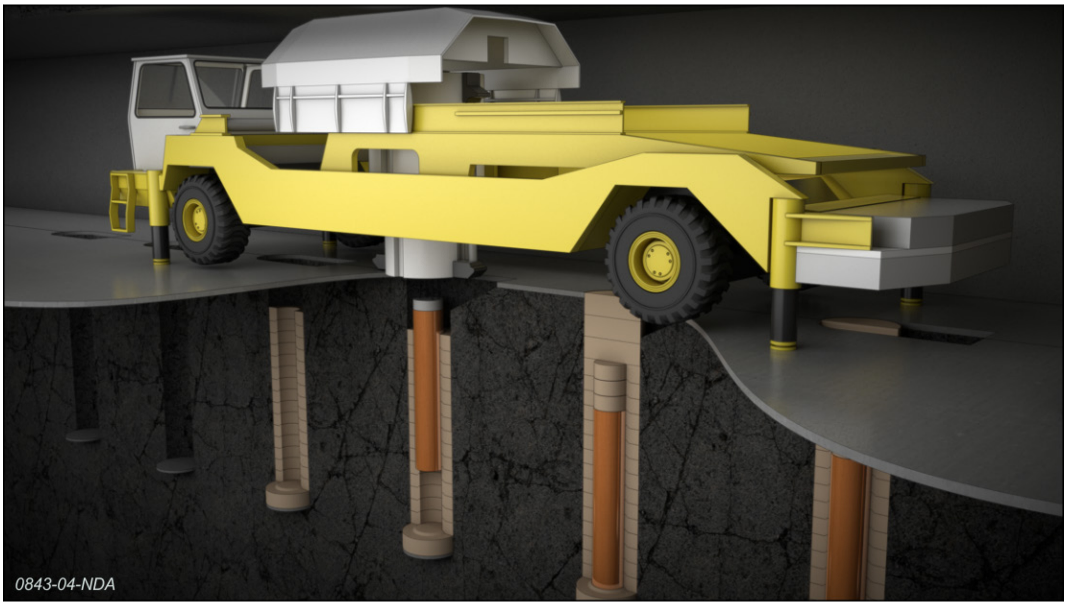
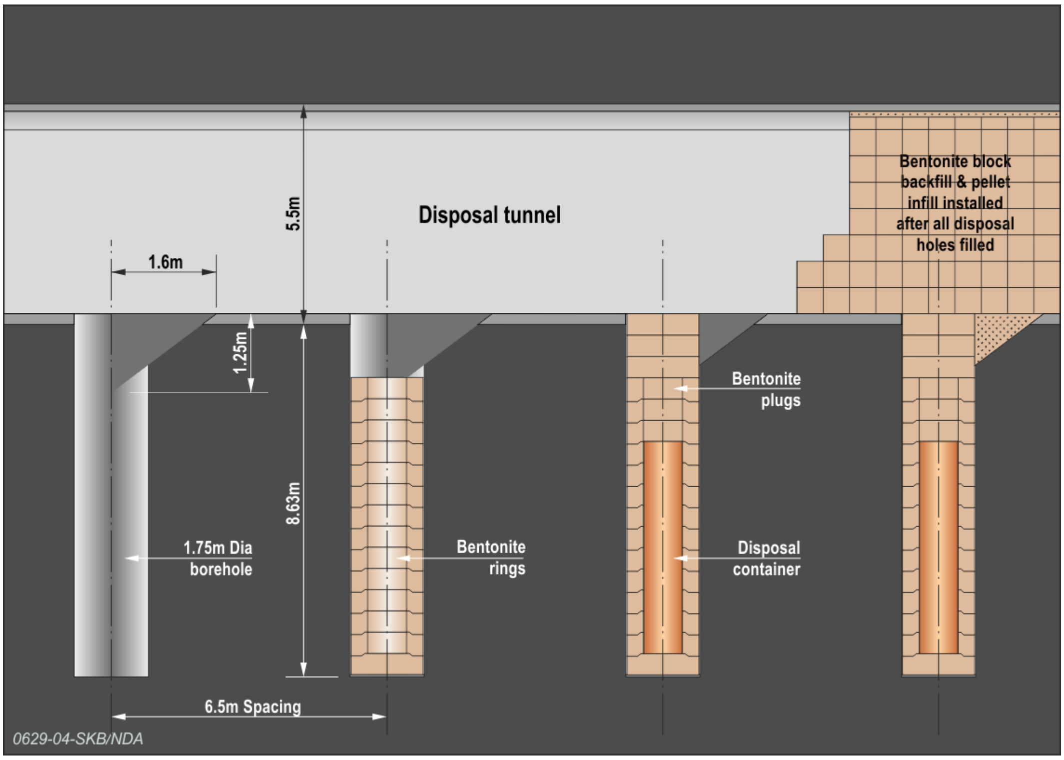


Figure 39 HHGW disposal tunnel: longitudinal section through the tunnel – higher strength rock



10.3 Lower strength sedimentary rock

The HHGW disposal area will consist of a series of disposal tunnels connected by service tunnels from the drift for the disposal of HHGW containers. In the lower strength sedimentary rock design, these disposal tunnels will be designed for the horizontal disposal of individual disposal containers, placed on a layer of bentonite blocks (Figure 40). It is currently assumed that each disposal tunnel will be nominally 500m long and 2.5m in diameter. However, the entrance to the disposal tunnel (first 30m) will be considerably larger, 5.6m wide × 3.8m high, to allow for the transfer of the disposal container from the DCTC onto bentonite blocks that will have been pre-placed onto an emplacement trolley. There will be a concrete floor to provide a uniform base. The disposal tunnels will be separated by rock pillars of 26m width.

A total of 341 disposal tunnels will be required to dispose of the Inventory of HHGW. The underground layout is shown on Drawing Number E/DRG/0041076.

Following transfer to the emplacement trolley, the shield door to the disposal tunnel will be opened and the emplacement trolley will transfer the disposal container and support blocks to the required location in the disposal tunnel using a haulage system. The disposal container and supporting bentonite blocks will be lowered as a unit to the floor of the disposal tunnel and released from the trolley. The emplacement trolley will be withdrawn back to the reception area, and the inner shield door closed. The empty DCTC will be inspected internally for damage, before being returned to the transfer hall using the transfer wagon and subsequent transfer to the drift wagon and delivery to the surface.

A mobile bentonite hopper will be delivered into the reception area; all personnel will leave the reception area, and the outer gate will be closed. The inner door will be opened, and the hopper will enter the tunnel, straddle the container and proceed to emplace pre-compacted bentonite pellets around the previously emplaced disposal container on its bentonite plinth. Once complete, the hopper will be removed from the tunnel. The process will be repeated after each disposal container, to provide progressive backfilling of the disposal tunnel.

The disposal container placement cycle will be repeated until the disposal tunnel is filled with disposal containers. It is assumed that each disposal container will be placed 3m apart from the previous container.

Figure 40 Schematic of a HHGW disposal tunnel – lower strength sedimentary rock

10.4 Evaporite rock

The HHGW disposal area will consist of a series of disposal tunnels suitably connected by service tunnels from the waste emplacement shaft for the disposal of HLW, SF, Pu and HEU. These disposal tunnels will be designed for horizontal disposal of individual disposal containers on the floor of the disposal tunnel. Each disposal tunnel is assumed to be nominally 500m long × 3m wide × 3m high. However, the entrance to the disposal tunnel (first 30m) will be larger (6.0m wide × 5.5m high), to accommodate the transfer of the disposal container from the DCTC onto the disposal trolley. Each disposal tunnel will be separated by a rock pillar of approximately 20m.

A total of 327 disposal tunnels will be required to dispose of the Inventory of HHGW. These are shown on Drawing Number E/DRG/0041126.

Following transfer to the emplacement trolley in the disposal tunnel reception area, the shield door to the disposal tunnel will be opened, and the emplacement trolley will transfer the disposal container to the required location in the disposal tunnel using a haulage system. The disposal container will be lowered to the floor of the disposal tunnel and released from the trolley (Figure 41). The emplacement trolley will be withdrawn back to the reception area, and the inner shield door closed. The empty shielding will be inspected internally for damage, before being returned to the transfer hall by the deposition transfer machine and subsequent transfer to the rail wagon and delivery to the surface via the shaft.

The area of the disposal tunnel around the disposal container will be filled with crushed evaporite host rock, (from the surface rock crushing plant), immediately after placement of the disposal container. The crushed rock will be transferred to a mobile hopper. The mobile hopper with a locomotive attached will be transferred to the reception area of the disposal tunnel, and the outer shield door closed remotely.

The inner shield door will be opened and the mobile hopper detached from the locomotive and moved to the far end of the disposal tunnel, over the disposal container that had just been emplaced. The crushed evaporite rock will be discharged, to fill the area beyond the disposal container, and will then be gradually withdrawn to fill the area all around the disposal container.

The mobile hopper will then be withdrawn to the reception area, the inner shield door closed and the hopper connected to the locomotive.

The outer shield door will then be opened, the locomotive and mobile hopper will be moved and the next disposal container brought in to the reception area.

The above cycle will be repeated until the disposal tunnel is filled with disposal containers, and crushed host rock fills the remaining voids. It is assumed that disposal containers will be placed 3.0m from the previous container. Once all of the disposal containers have been placed within a disposal tunnel, a tunnel seal will be constructed.

Figure 41 Schematic of a HHGW disposal tunnel – evaporite rock

11 Underground Facilities, Infrastructure and Services

In developing illustrative designs it is necessary to consider the infrastructure and services required to support underground operations at the GDF. The following sub-sections detail the provisions currently envisaged for the underground facilities in each geological environment.

11.1 Underground facilities

11.1.1 Common services area

The underground facilities that will support the construction activities of the facility as well as the disposal operations will be located in an area termed the 'common services area'. They will consist of a number of facilities, which are identified below.

11.1.2 Active area support facility

There will be a number of additional support facilities in the LHGW Active Area Support Facility. A sampling laboratory will house equipment to allow necessary checks to be made, such as radioactive concentrations within any collected groundwater. This will sample the effluent contained in the Active Liquid Effluent Receipt and Dispatch Area prior to its dispatch to the surface.

11.1.3 Active liquid effluent receipt and dispatch area

The Active Liquid Effluent Receipt and Dispatch Area will contain the collection tanks for liquid effluents arising within the active areas, and the pumps and valves needed to circulate and export the liquid to the bowser filling station located adjacent to the inlet cell complex.

11.1.4 Workshops and storage

Workshops will provide an area where vehicle repair and maintenance could be undertaken. This facility will be required for all phases of construction, operation and closure. Workshops will also include a place for storage of materials and vehicle/plant spares.

It is currently assumed that large construction items will be transported underground via the drift (or waste emplacement shaft in the evaporite rock illustrative design). An area at the base of the drift or shaft will be used to store these materials until required. Facilities will be provided to check for any potential contamination of the transfer wagon and contents before they enter the construction area.

11.1.5 Spoil bunker and crushing plant

A rock bunker facility will be constructed near the construction return shaft. This will act as temporary surge storage for excavated rock, to regulate the feed to the shaft. The bunker will also permit shaft downtime to be accommodated without the necessity to stop vault and tunnel construction activities.

11.1.6 Personnel facilities

The personnel hall provides a rest area for construction staff during the shift, and will be required for the duration of construction works. It will also provide a safe area with additional refuge facilities in case of an emergency. The facility will require an electrical supply, sanitary facilities, environmental monitoring equipment and an airlock. This facility will be located off the primary service tunnel and close to the workshops/storage hall and electrical sub-station. Separate facilities are provided for operational staff in the Active Area Support Facility.

A separate rescue room will contain a fire station and rescue facility as well as a safe haven, if required.

11.1.7 Vehicle hall and garage

Vehicles used during the construction phase will be housed in a dedicated hall when not in use. This hall will be located close to the drift or the waste emplacement shaft in the case of the evaporite rock illustrative design, and will require a power supply for maintenance work, a crane, lighting, vehicle recharging and workbenches.

This facility provides for free steered vehicle maintenance and repair. Typical requirements will be electrical and mechanical workshops, cranes and jacking apparatus, vehicle-washing bays and controlled collection of water run-off, and battery-charging area.

11.2 Ventilation systems

A summary of the ventilation design, and its requirements for the different disposal areas, is provided below. More detailed information on the ventilation system for the GDF generic designs is provided in [25]. The system must:

- ensure that the manned operational areas have an acceptable working environment, commensurate with both nuclear and mining/construction requirements
- Segregate the emplacement ventilation circuit from the construction ventilation circuit. This will include air lock/security doors between the two areas.
- Achieve suitable environmental conditions in the vaults and tunnels to maintain the integrity of the waste packages for as long as necessary until they are backfilled. As part of this, the ventilation system must also prevent the build-up of explosive gases (such as hydrogen and methane) and radioactive gases (such as carbon-14, tritium and radon).
- provide adequate ventilation flows for the activities, including the control of dust and fumes that are generated
- provide suitable filtration
- ensure ventilation moves from areas of low potential for contamination to areas of higher potential for contamination – the cascade principle

The segregation of the two underground ventilation circuits will be achieved by using all four underground access routes (the drift and three shafts, or four shafts in evaporite rock) as ventilation routes. In addition, the location of the construction and emplacement intakes (the drift and emplacement intake shaft in evaporite rock) and construction and emplacement return shafts will further ensure that intake air should not be contaminated from exhaust sources. Prevailing wind factors and the location of potential fire sources will be taken into consideration during positioning of the construction and emplacement air intakes.

Intake fans are currently assumed to be installed in a ventilation hall close to the base of the construction intake shaft, to draw air down the shaft and force the air into the construction areas and to ensure that the construction areas remain at a positive pressure relative to the waste emplacement areas. However in practice these fans may be located on the surface. The waste disposal area ventilation will be supplied solely by the exhaust fans at the top of the emplacement return shaft, keeping the whole area at a negative pressure, relative to both the surface atmosphere and more importantly, the construction areas. The pressure differential between the construction and emplacement ventilation circuits plays an important role in maintaining segregation of air streams. It will also ensure that under fan fault conditions the system will fail to safe, and that emplacement air could not enter the construction side of the operations.

The ventilation will play an important role in controlling the propagation of fires underground. The ventilation design is based on good practice, and segregates the flows to the construction and disposal sides of the facility. However, the effects of fires may change the ventilation flow patterns, or may invoke an intended change to control an incident.

11.2.1 Ventilation – LHGW disposal area

The air to ventilate the waste disposal areas will enter via the emplacement intake drift (or via the shaft in the evaporite rock illustrative design) and flow through the manned areas and into the vaults via ducted, filtered and damped systems, to allow control and monitoring of the flows. The ventilation route into the UILW vaults will be via the transfer tunnel and through the vault end wall below the crane maintenance area. This arrangement will enable air flow velocities to be controlled in the transfer tunnel during emplacement operations.

During disposal of UILW the majority of the air flow will enter the vault via a shielded ventilation duct located at the end of the vault beneath the crane maintenance area. Following completion of waste emplacement and fitting of the shielded roof plug in the hatch, ventilation of the vault will be controlled completely by adjustable dampers within the shielded ventilation duct. The air will be drawn out of the far end of each vault via shielded ducting and through two sets of HEPA filters to remove any contaminated particles from the air. This will make the exhaust air suitable for discharge along the disposal area return roadways, ultimately, up the emplacement return shaft.

The SILW/LLW vault ventilation filters will be located in a common filter room and will be permanently on-line. The filter room will be sited close to the far end of the module of SILW/LLW vaults. The air will be drawn out of the far end of each vault, and along an active ventilation duct to the filter room. It will then pass through two sets of HEPA filters, to remove any contaminated particles from the air and to make the exhaust air suitable for discharge to the surface. This air will enter the common disposal return roadways before being drawn under negative pressure via the emplacement return shaft to the exhaust point on the surface.

For the RSILW and NNB concrete drum SILW vaults, ventilation flow will remain directionally the same as for all other LHGW vaults. Air that ventilates these vaults will enter via the emplacement intake and flow into the vault reception area, via a filtered duct located adjacent to the roller shutter door. The same ventilation ducting will be used to control and condition the air entering the disposal area of the vault, located behind the shield wall. In operation air will be drawn out of the far end of the vault(s), and along an active ventilation duct within the roadway to the filter room. It will then pass through two sets of HEPA filters, to remove any contaminated particles from the air and to make the exhaust air suitable for discharge to the surface. Such a design ensures preferential air flow within the GDF, with the direction of flow always towards areas of potentially greater radiological risk (cascade principle).

The design of the ventilation system will allow progressive development of the disposal facility with concurrent construction and waste disposal. Isolation will be achieved by bulkheads or stoppings between the two separate ventilation circuits, which could be moved to switch the ventilation of each newly commissioned vault to the waste emplacement area circuit. The construction intake fans will allow the total flow to be varied as necessary, but suitable regulation will be required to ensure that adequate flow will be directed to the vault under excavation.

11.2.2 Waste temperature – LHGW temperature

Long-term increases in waste package temperature beyond the established target of 50°C [11] can affect package corrosion and gas generation and equipment reliability. Therefore, the designs for operation will be established to ensure that the temperatures can be kept below this level, so far as possible by passive means. As a general principle, temperature will be minimised. This will also be included during the backfilling process, although short-term excursions above 50°C would be acceptable during this period.

11.2.3 Ventilation – HHGW disposal area

The disposal tunnels that will be used for the disposal of HHGW will be single entry and ventilated using auxiliary methods. The use of auxiliary ventilation systems, where air is forced into or exhausted from a single entry excavation, requires that a full ventilation circuit is maintained at all times. It should be noted that auxiliary ventilation will be required during both construction and operation of the disposal tunnels. Once the disposal tunnel has been backfilled, there is no further need for ventilation.

11.2.4 Waste temperature – HHGW temperature

A maximum target temperature is defined for HHGW engineered barrier systems (EBSs) to prevent excessive temperature from damaging the EBS materials. In particular, bentonite can potentially suffer alteration and lose its swelling properties if subjected to high temperatures over prolonged periods. Thermal convection (or water refluxing) resulting in mineral dissolution and re-precipitation can also degrade buffer performance, especially if it occurs before the buffer has re-saturated fully.

The temperature predicted in HHGW disposal tunnels has been assessed using rock parameters, waste temperatures and rock pillar spacings to predict a likely temperature in the waste and the engineered barrier system. The outputs were used to ensure that the rock pillar spacing was suitable to ensure that the maximum target temperature for the EBS were appropriate for each geological environment.

For a higher strength rock, based on the Swedish KBS-3V concept and taking into consideration appropriate cooling periods, deposition hole spacing of 6.5m (centre to centre) and disposal tunnels with rock pillar separation of 19.5m would enable temperatures at the buffer interface with the waste package to be maintained below a 100°C target [11]. Due to the heat generated by MOX SF, these containers will be placed in deposition holes at intervals of 9.5m centre to centre.

For a lower strength sedimentary rock, a temperature limit mid-way through the buffer within the disposal tunnels of 125°C has been adopted, based on the Nagra concept, as described in the *Summary Overview* [49]. The tunnel rock pillar spacing of 26.0m has been adopted in the design based on the geotechnical assessment and thermal assessment confirming that this maximum target temperature will not be exceeded using this rock pillar spacing.

The target temperature for the evaporite rock illustrative design was based on the Gorleben, German concept. In the case of the design that is proposed, the backfill will comprise crushed host rock, which, under pressure and assisted by heat generated by the waste, will help the backfill material creep over time, with similar properties to the surrounding, undisturbed rock. The spacing between the disposal tunnels will be approximately 20m, based on the geotechnical assessment work [48] with the thermal assessment confirming that this interval would result in the maximum target temperature limit for the HHGW waste of 200°C being achieved.

11.3 Underground groundwater management during operation

The design of drainage systems for the underground areas will allow progressive development of the disposal facility with concurrent construction and waste emplacement. As the underground facility is developed the disposal areas (vaults and disposal tunnels) will progressively be transferred from the construction drainage circuit to the active effluent drainage circuit, by appropriate diversion and sealing. Liquid effluent from the active effluent drainage circuit, which will include all of the underground radiologically controlled areas (including the operational vaults and disposal tunnels), will be collected from various locations throughout the underground facility, including sumps located at disposal vault and tunnel entrances. This effluent will be transferred to the active liquid effluent receipt and dispatch area within the underground UILW emplacement support facilities. From there, it will be brought to the surface by bowser for treatment in the active liquid effluent treatment facility.

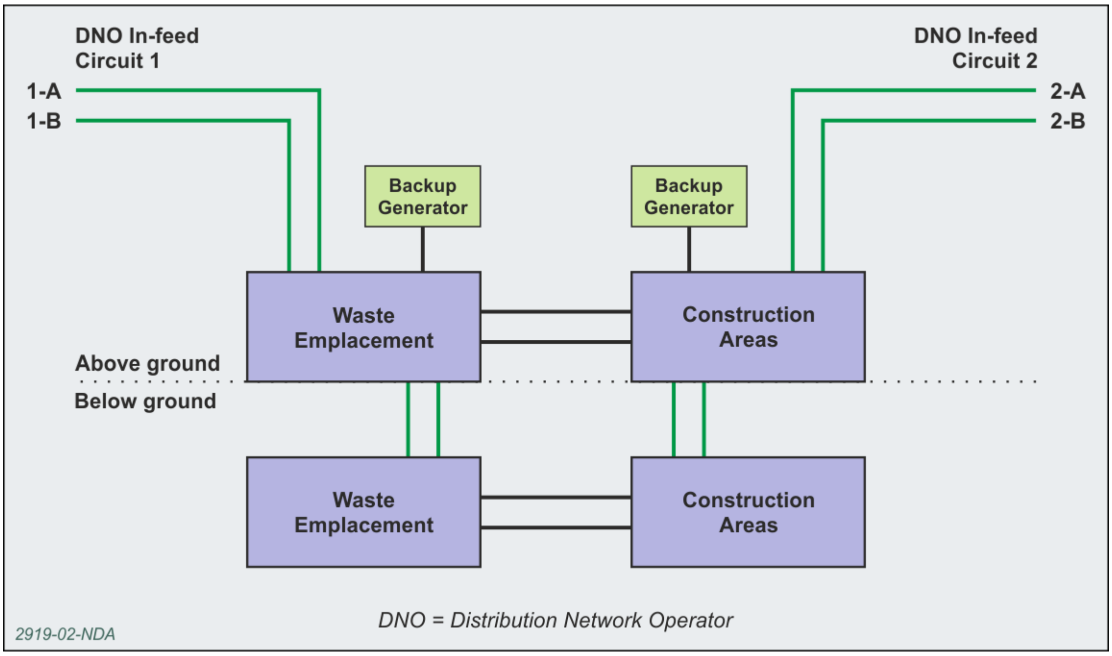
Water from the construction activities or from entering the facility via the drift or shafts will be collected at the base of those facilities in a sump. The water collected here will be pumped via the construction intake shaft to the water dispatch facility at the surface. It is unlikely that the GDF will be constructed in a geological formation likely to result in inflow of significant quantities of groundwater such to cause a concern to construction and operation activities. However, in a higher strength rock, some groundwater should be expected with minimal groundwater anticipated in a lower strength sedimentary rock environment. It is reasonable to assume that groundwater would not be present in significant quantities within an evaporite rock formation.

11.4 Electrical power supplies

A secure electrical power supply and distribution system will be essential for the GDF in order to maintain continuity of operational activities while ensuring plant and personnel safety and security.

To achieve the required level of supply security and redundancy, the design principal implemented focuses on the duplication of both the electrical substation equipment and of the power cabling. This principle will be implemented throughout the site, from the distribution network operator (DNO) in-feed to the site through to the individual load points within the GDF, wherever possible. In this manner, each item classed as an essential load will be provided with two separate normal supplies, constituting a firm supply as shown in Figure 42.

Figure 42 Electrical infrastructure



In addition to the duplication of equipment, the security of supply will be further supported by utilising duplication and separation of the power cabling. Wherever possible, each supply cable will follow a physically different route, so that in the event of an incident those results in the damage of one supply cable it would be unlikely to affect the other supply. Where physical separation is not possible, then alternative methods such as fire barriers and cable protection systems would be utilised.

The general basis of design is that the GDF will be considered as two distinct working areas, these being the waste emplacement and construction areas. In this way, the electrical power systems for each facility will be of a similar design and also allow cross-connection to further support the required supply reliability and availability.

Two independent firm supplies will be taken from the DNO network as the in-feeds to the GDF. Each of these supplies will be capable on its own of providing all the electrical power required by the entire GDF.

These firm supplies will feed two surface substations, one substation located within the operational area and a second substation within the construction area. Each of the surface substations will include dedicated diesel generators, suitably sized to maintain the GDF essential load in the event of total loss of the DNO supply. In the event of the failure of both the on-site dedicated generators, either generators stored on site or generators supplied by a third party and stored off-site will be used. The *Assessment of the Current GDF to Withstand Loss of Off-Site Power* study [34] recommended that the GDF design incorporates an on-site back-up generator supply of up to 12 generator sets and associated fuel tanks. The two surface substations will supply power to two underground substations, one in the emplacement area and the second in the construction area. Two independent and physically separated cables from the surface substations will feed each of the underground substations. These cables will be routed via the emplacement intake and emplacement return shaft for the waste operational activities and via the construction intake and return shafts for the construction activities.

The underground substations will also have the capability to cross-connect in the event of loss of supply from one of the surface substations. Other local underground substations consisting of transformers and motor control centres will be established for major load items, such as pumping and ventilation/dehumidification plants, in addition to those for disposal and construction activities.

A separate substation will be established approximately halfway along the drift. This will consist of transformers and switchboards for general power associated with drift construction/maintenance activities and general supplies.

It is estimated that the total power demand for the GDF will be in the region of 20MVA at full operational load. The essential load, as supported by the dedicated diesel generators, is estimated to be in the region of 5.5MVA.

This design of duplication of the power supply mitigates against the consequences from loss of power over a range of timescales and demonstrates the resilience of the GDF to prolonged loss of power incidents.

11.5 Fire prevention, detection and suppression

11.5.1 Fire prevention

In order to minimise the risk of fire, it is necessary to ensure that the specifications for the facilities and equipment include, as appropriate, the requirements for fire-resistant or non-flammable materials to be included in their construction. Where this is not practicable, then the materials used would need to be assessed in terms of flammability, location of use, generation of noxious or toxic fumes in combustion, and the quantity and accumulation of these materials. This assessment would include consideration of the potential impact of the use of flammable liquids such as diesel fuel, oils used in hydraulic systems and lubricants.

Every effort will be made to use non-flammable or limited flammability materials which will also ensure compliance with the ONR Safety Assessment Principles. As part of the detailed design process, reduction of the potential for fire severity and duration within the GDF by adoption of fire prevention measures in design will be considered in detail, including the selection of flame-resistant materials, minimisation of combustibles and control of ignition sources where possible. Control will be exercised over the use and volume of flammable materials throughout the disposal facility, including careful segregation of flammable materials from waste-handling and transfer routes.

11.5.2 Fire detection

Fire detection options for the operational facility have been reviewed in detail in the *GDF Fire Suppression and Consequence Management Study* [50] and advice provided regarding technologies that may be available for the construction areas. The prime candidate detection technology to be used for general coverage of the operational areas is considered to be video imaging detection. Although the existing design standards are limited, UK suppliers have a track record for its use in road tunnel protection. It is anticipated that this will be a mature technology by the time the GDF detailed design and construction commences. Other specific detection technologies will be adopted for specific hazards in areas, for example, where flammable materials or electrical equipment are located.

With respect to the construction areas of the GDF, detection using Metal Oxide Sensors (MOS) and neural networks to discriminate between fire and diesel fumes are currently being trialled and again are likely to be a candidate technology by the time of GDF construction. Air sampling systems using dust filters are also proven for use in mines and may be used in construction areas.

The precise nature of the fire detection technologies to be adopted in both construction and operational areas of the GDF will be developed as the detailed design progresses.

11.5.3 Fire suppression

Fire suppression options for the operational facility have been reviewed in detail in the GDF Fire Suppression and Consequence Management Study. Whilst it will be possible in many instances to reduce the potential for fire spread and severity by selection of materials, this alone does not achieve defence in depth or reduce the risk of fire to as low as reasonably practicable (ALARP) and there is always the potential for unforeseen fires originating from materials or equipment. Any fires in tunnels and vaults are expected to be primarily of electrical origin, vehicles, cables, crane festoons etc., which may still produce significant amounts of smoke even if selected to have reduced fire propagation characteristics. Currently the largest foreseeable scenario is a fire involving tyres on large loading vehicles for which measures will require to be taken to mitigate the risk, eg by the use of flame retardant tyre materials.

General area coverage of the facility will be provided as well as suppression coverage of specific fire hazards. For general area coverage, a water based system is the principal candidate using pre-action sprinklers. Due to the high ventilation flow rates a high velocity sprinkler or water spray system is proposed that is zoned and manually activated on confirmation of fire through fire imaging technology such as video imaging detection. In an evaporite rock, it may be possible to use a water mist fire suppression system, which would introduce less water to the rock and reduce the risk of dissolution. For specific hazards hypoxic systems, water mist and gaseous suppression agents are likely candidates. Onboard suppression systems for vehicles and specific higher hazard plant items will be adopted.

The likelihood of fires developing from smaller fires could be reduced by consideration of component layout. A fundamental design objective for the GDF is to minimise the potential for fire to occur and if it does to limit the fire size and duration. The fire performance of materials involved in the construction of the facility including vehicles and equipment used within it can have a significant effect upon the nature of the fire hazard. The selection of materials should be undertaken considering such criteria as the inherent combustibility of the materials of construction, susceptibility to rapid spread of flame, and toxicity of combustion products.

The feasibility of providing fire compartmentation underground in the GDF has been investigated and it is considered to be possible both within the operational side and parts of the construction side where there are to be fixed facilities. The recommended fire resistance periods for the various areas of the GDF have been based as a minimum on a 60 minute fire resistance period with some areas designed to have greater periods of fire resistance. The periods of fire resistance proposed are initial recommended values and are expected to be confirmed or adjusted as the design progresses.

The design of the shaft and other high priority infrastructure such as the sub-stations and pumping stations will include fire compartmentation as recommended in the fire suppression study [50] to ensure an increased fire resistance of this essential infrastructure and personnel safety.

The ventilation system will play an important role in controlling the propagation of fires underground. It is also recognised that a fire may disrupt the normal ventilation flows. The ventilation system for construction and disposal areas will be segregated and provided by two discrete systems, and a fire affecting one system should not disrupt the other.

Other facilities and precautions to manage fire safety will include the following:

- surface, fire and rescue station – serving both the surface and underground facilities, this will be a combination of a civilian fire station and a mines rescue station
- underground fire-fighting stations – two such facilities will be provided, one serving the construction area and the other the disposal area
- Fire-fighting system – the fire water supply to the GDF will comprise duplicate, pressurised water mains with an emergency storage supply at the surface. Fire ranges will be sited in the ventilation intake roadways at suitable intervals and other locations of greatest fire risk.
- portable or equipment-mounted fire extinguishers – these will be a combination of dry powder, carbon dioxide, foam or water sited at strategic locations, eg electrical substations and plant rooms
- fire-fighting and rescue plan – this will be prepared to show the position of all ranges, hydrants, valves, fire stations and fire points

11.6 Emergency preparedness

The evacuation of the underground facilities may be required in the event of emergency situations, such as:

- fire
- inrush
- significant rockfall

A fire compartmentation scheme has been proposed that will aid the safe evacuation of personnel below ground by reducing travel distance to a place of relative safety such as a safe haven or a protected corridor. It is recognised that travel distances below ground in the GDF can be large and therefore it may be necessary for personnel to make progressive escape to finally reach the surface or in some cases, although not preferable, to remain in a place of relative safety until a rescue team arrives. In order to fulfil both of these requirements, the location of sealed self-supporting safe havens will be developed in conjunction with the provision of compartmentation fire suppression and suitable ventilation and smoke control as well as the supply to all personnel of self-rescue sets has been proposed.

Compartmentation, fire suppression and smoke control options will be designed to work together to provide overall satisfactory fire protection arrangements within the GDF.

Response plans including firefighting will be developed with the local emergency services and regular, joint exercises will be held to test the efficiency of these plans.

It is possible that an inrush (a sudden, unexpected inflow into the GDF having the potential to expose persons to danger) could occur in the facility. An inrush can be associated with gas, water or a material that is likely to flow when wet. The potential for such an inrush to occur is likely to be greatest during the construction phase, particularly in the early stages of drift and shaft construction. Best practice is to adequately research the geological environment through which excavations will be made and past mining history. In addition to those researches, it is usual to drill in advance of the heading, taking appropriate precautions such as blowout prevention and injecting grout to reduce flow and assist with groundwater management. This best practice will be adopted throughout the construction process for the purposes of advancing all excavations.

It is also possible that a rockfall may occur in the facility, particularly during construction, or if there is a failure of the installed support. It is assumed that procedures will have been developed to reduce injury as far as reasonably practical, in the event that a rockfall occurred during construction. Should a rockfall occur in a part of the facility where rock support has failed, there is a potential for access to be restricted or blocked entirely. If this occurs in a service tunnel, there would be an alternative means of egress. If a rockfall blocks a single entry excavation, there will be emergency procedures in place to affect a safe recovery of those personnel trapped by the rockfall.

Separate evacuation plans will be required for both the construction and emplacement areas of the GDF. However, both evacuation plans will need to be complementary as it should be possible to escape from the construction area to the emplacement area and vice versa.

11.7 Control systems

Systems will provide for the control of systems and equipment performing operations throughout the GDF. They will allow local and remote control of equipment, monitoring of plant status, and acquisition of data from various instrument systems, and will provide records of operational performance.

The long-term aim will be to enable all the main disposal activities to be controlled and monitored from the central control room on the surface. However, more complex operations such as those within the inlet cells will be likely at times to require local operation, with direct operator viewing through windows to identify and rectify problems and help in maintenance work. Also, the operations will be controlled locally during commissioning and during initial operation until confidence in remote operation is gained. These system requirements will be reflected in the philosophy to provide the options to control underground operations from local control stations, the underground control room or the surface central control room. To support this approach, appropriate standards of lighting will be provided throughout the GDF to ensure all necessary operational, maintenance, inspection and testing activities can be safely undertaken.

The control system will include a number of safety circuits. These must be independent of normal control circuits. As these safety circuits and also other elements of the control system will be classified ‘essential’ for the safety of the plant, the entire control system will be powered from a battery-back-up electrical system.

The control system will interface with a number of other systems. One such system, the inventory tracking system, will pass information to and receive information from the control system, to ensure correct disposal records for every single waste package. The control system will also interface with other essential systems such as ventilation and fire detection, providing the necessary indication of status and alarms. The electronic control systems will be commensurate with established nuclear industry standards.

12 Backfilling, Sealing, Closure and Decommissioning

The key activities to be considered during the closure phase are:

- backfilling and sealing of disposal areas
- backfilling and sealing of access tunnels, shafts and boreholes
- removal and decommissioning of surface buildings and installations and site restoration
- institutional control

The decision on when to close the facility after all of the waste has been placed underground for final disposal will take the views of the local community into consideration. This will allow the local community to have an input into whether the facility may stay open for an additional period or the nature of the end state of the site. An assessment of the potential impacts of carrying out closure operations will be undertaken to optimise the process, taking account of the outcomes of discussions with the regulators and the local community. The exact condition of the surface site at the end of closure operations will also need to be agreed through consultation with Government, regulators and the local community.

The backfill materials will comprise Nirex Reference Vault Backfill (NRVB), cementitious grout, bentonite and crushed host rock to provide a post-closure safety function and will be selected based on the host geological environment. Quality control of backfill materials will be undertaken at source and again on site, prior to being taken underground. Most designs envisage this occurring in a stepwise manner with disposal tunnels/vaults being backfilled and sealed as soon as they are full, then emplacement modules will be sealed as they are filled and finally the entire disposal facility sealed when all waste has been emplaced. However due to the properties of the different geological environments, the underpinning disposal concept and waste type (LHGW or HHGW), backfilling could occur at different stages in the programme ie either during the operational phase whilst waste is being emplaced in other disposal vaults and tunnels or during the closure phase. Such a process focuses on minimisation of potential degradation of both engineered barriers and the host rock due to the rock-mechanical, hydrogeological and geochemical perturbations caused by openings at depth. This approach aims to reduce risks to operators associated with upkeep and monitoring, and also environmental impacts associated with spoil management and potential long-term drainage. However, early backfilling could cause potential conflicts with the desire to maintain ease of retrieval. There are significant benefits associated with prompt backfilling of disposal areas, when compared with deferred backfilling. The main advantages associated with prompt backfilling are; more predictability in the disposal system, less likelihood of a fault occurring, lower dose implications for operators and potentially lower cost. There are potential issues associated with prompt backfilling including increased temperature caused by curing of cementitious backfill materials and associated gas generation, which due to earlier backfilling will have increased activity and could cause potential conflicts with the desire to maintain ease of retrieval. Such trade-offs can only be sensibly assessed on a site-specific basis and in full consultation with all stakeholders.

12.1 Disposal vault and tunnel backfilling during operational phase

12.1.1 LHGW disposal vaults - Lower strength sedimentary rock

It is currently assumed that in the illustrative design in a lower strength sedimentary rock, the disposal vaults would be backfilled and sealed using cementitious grout, in two elements:

- local backfill, to fill the space around and in the immediate vicinity of the packages
- peripheral backfill, to fill the void between the waste stacks and the disposal vault walls and ends

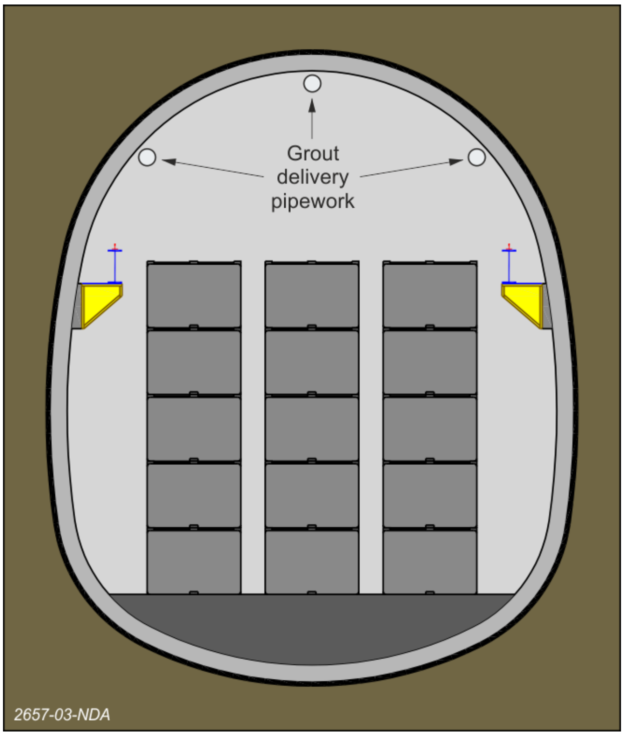
A designated underground area (central batching and mixing area) would be required for the wet mixing of the cementitious grout from first waste disposal, as each LHGW disposal vault would be backfilled on completion of waste emplacement. The dry backfill materials would be delivered to the site and temporarily held in silos on the surface. These materials would then be pneumatically transferred via the construction intake shaft, as required, to the central batching and mixing area. The backfill batching area would be sited on the operational side of the disposal facility, and would comprise a series of silos for the storage of the dry backfill components. The components would be blended in this area and then transferred to a mixing area located closer to the disposal vaults. A grout-mixing area would be available, servicing each module.

Quality control would be exercised on the production of the backfill, and if any material were deemed unsuitable it would be collected by a mobile silo in the construction return roadway for recovery and removal. This could be carried out underground or, alternatively, the material could be recovered and dealt with at the surface.

It is assumed that a backfill ratio[5] of approximately 1:1 is achieved to meet the requirements of the DSS. It is also assumed that the crown space above the waste is backfilled. It is assumed that backfilling would take place progressively on completion of waste emplacement in each vault, using grout injected through pre-installed pipes suspended from the disposal vault roof and sidewalls (Figure 43).

[5] The backfill ratio is the volume of backfill to the volume of conditioned waste.

Figure 43 Disposal vault backfill arrangements for lower strength sedimentary rock



12.1.2 LHGW disposal vaults - Evaporite rock

Chemical conditioning of the waste packages is currently envisaged. This is undertaken by placing bags of magnesium oxide (MgO) on top of each stack of waste packages. These will be placed on top of waste packages as each array is placed. The MgO buffer will be stored at the surface and transported underground via the construction intake in campaigns. An underground temporary store will be required to store the MgO buffer prior to it being taken into the disposal vaults.

In the illustrative design for evaporite rock, it is currently proposed that no backfilling will be required within the disposal vaults. Following emplacement of the waste packages, the vaults would be sealed, as described in Section 12.3. The illustrative design is based on natural creep eventually closing the excavations over time. However, in the case of thinner evaporite formations, crushed salt may be used to minimise the local perturbations resulting from such creep.

12.1.3 HHGW disposal tunnels

When all the deposition holes in a disposal tunnel have been filled, the disposal tunnels would be backfilled with pre-compacted bentonite blocks. The remaining space between the stack of bentonite blocks and the vault walls would be backfilled with bentonite pellets. These pellets would be air blown into the remaining gaps in stages as the backfilling progresses along the tunnel, based on the Swedish Nuclear Fuel and Waste Management Company (SKB) concept described in [51].

Disposal tunnels will be progressively backfilled as part of the disposal process with pre-compacted bentonite pellets in the lower strength sedimentary rock illustrative design.

Disposal tunnels will be progressively backfilled as part of the disposal process with crushed host rock in the evaporite rock illustrative design.

12.2 Disposal vault and tunnel backfilling during closure phase

12.2.1 LHGW disposal vaults - higher strength rock

Following emplacement of waste within a LHGW disposal vault, it will be backfilled and sealed using Nirex reference vault backfill (NRVB), a cement-based material. Although there is only one backfill type to be used, there are two elements:

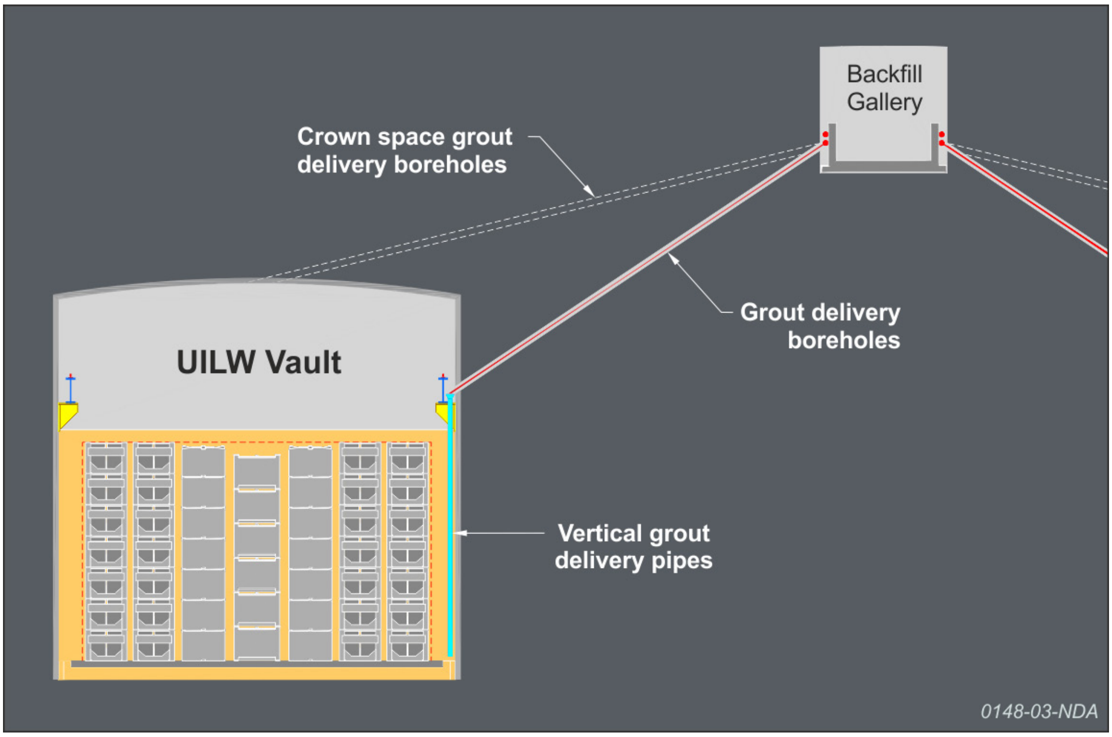
- local backfill, to fill the space around and in the immediate vicinity of the packages
- peripheral backfill, to fill the void between the waste stacks and walls and ends of the disposal vaults

Some initial peripheral backfill, manufactured using temporary facilities, will be placed during vault construction (eg a layer beneath the load-bearing floor). The dry backfill materials will be delivered to the surface site, as required, and temporarily held in silos on the surface. The separate materials would be transferred underground to a central batching and mixing area. This backfill batching area will be sited on the emplacement side of the disposal facility, and will comprise a series of silos for the storage of the dry backfill components. The components will be blended in this area and then transferred to the mixers within the backfill galleries.

Backfill galleries will be sited above the vaults, and one gallery will be used for backfilling two vaults (Figure 44). Backfill galleries will be 3.0m wide × 3.0m high and contain the mixers and boreholes connected to grout hoppers located on the disposal vault walls that will direct the grout into the vault via vertical perforated pipes along the vault walls. This process will be undertaken once all the waste has been emplaced.

It is assumed that a backfill ratio of approximately 1:1 is achieved. The backfill provides a post-closure safety function as outlined in the Technical Background and the ratio is derived based on the waste inventory to be emplaced. It is also assumed that the crown space above the waste is backfilled. Backfilling would take place in a single campaign after final waste emplacement.

Figure 44 Disposal vault backfill galleries cross-section



12.3 Sealing strategy

The sealing strategy for the GDF is described in the sections below. Work is continuing on the European Commission (EC) DOPAS project in which RWM are active participants. The project aims to assess the feasibility of constructing repository plugs and seals using industrial scale trials. It aims to measure and analyse their characteristics and assess how their performance might change over time in repository conditions - particularly their hydraulic performance with respect to safety objectives.

Seals would be constructed at specific locations throughout the GDF. Each LHGW disposal vault would be sealed at each end and each HHGW disposal tunnel would be sealed at its entrance. Seals would be constructed at specific locations in service tunnels that provide access to the disposal vaults and tunnels eg to isolate modules as well as having regard to locations where strata of higher permeability has been intersected. Care would be taken in relation to the excavation of those areas where seals were planned, in order to optimise seal construction and performance. Seals would be constructed where the shafts and drift intersect the facility horizon with additional seals constructed at locations in each access route between the facility horizon and surface. Each access route would be sealed at surface and the location marked and recorded. Mass backfill material placed between the seals would be geological environment specific.

12.3.1 Higher strength rock

In addition to being placed at each end of disposal vaults and entrance to disposal tunnels, low-permeability seals consisting of compacted bentonite retained by a concrete structure would be constructed to isolate vault modules, disposal areas, shafts and the drift. To optimise the efficiency of sealing, the cross-sectional area of entrances / exits would be kept to the minimum practicable for construction, ventilation and operation.

Sufficient space would be provided to enable construction of each low-permeability seal, in areas of the host rock which have been characterised as having a low permeability. Seals would be constructed to a standard to maintain a permeability performance at least as low as the host rock in which the seal is constructed to minimise radionuclide movement through the EDZ.

12.3.2 Lower strength sedimentary rock

The disposal facility is expected to be constructed in a low-permeability environment. However, each HHGW disposal tunnel would be sealed at one end with highly compacted bentonite and a concrete bulkhead. A shield door would provide a seal at the tunnel entrance. A seal would be constructed across the end of the disposal tunnel reception area and the intervening area in-filled.

Seals would retain backfill materials within the disposal vaults and tunnels and also minimise the potential for radionuclide migration in the long term. To optimise efficiency of sealing, the exact location of the seals would be tailored to each vault / tunnel and the cross-sectional area of entrances/exits would be kept to the minimum practicable for construction, ventilation and operation.

Each SILW/LLW disposal vault would be sealed at each end, and similar seals would be placed in the tunnels that provide access to each LHGW disposal module. This type of seal would also be constructed at the exit end of a UILW vault. The seal at the UILW vault entrance would be provided by the existing shield door.

Additionally, low-permeability seals (a 40m length of highly compacted bentonite retained by a concrete structure) would be placed in the main disposal facility accesses (shafts and drift) at the facility horizon. Backfill material would then be placed to fill any void space. The final design of the sealing system would take account of the layout and geological environment, and the provision of additional seals would be considered where, for example, the access intersects a higher-permeability stratum. Seals would be constructed to a standard to maintain a permeability performance at least as low as the host rock in which the seal is constructed and to also minimise radionuclide transmission through the EDZ.

12.3.3 Evaporite rock

Other than in the LHGW disposal vaults, all other underground excavations, including HHGW disposal tunnels would be backfilled with crushed host rock between seals and then sealed off by construction of a rigid concrete wall. There would be a rigid concrete wall with contact grouting around the concrete component as required. The disposal tunnel reception area and service tunnels associated with the disposal of HHGW would be in-filled with crushed rock salt, with periodic placement of tunnel seals. A tunnel seal is likely to comprise 0.5–1.0m of formwork, 15-30m apart, and in-filled with concrete.

To optimise the efficiency of sealing, the cross-sectional area of entrances and exits would be kept to a minimum practicable for construction, ventilation and operation. Seals are installed to isolate and prevent access to vaults. They also minimise the potential for radionuclide migration for some long term scenarios (eg brine displacement by generated gas).

The shafts would be in-filled in one of two ways. One option, as proposed at the WIPP facility in the USA, is to construct a seal at the base of each shaft using salt-saturated concrete, with the monolith being sufficiently large enough to fill the shaft inset. The remainder of the fill would be various layers of compacted clay, crushed salt and asphalt water stops with concrete plugs above and below. The top 160m would be compacted rock fill. A second option would be to in-fill the shafts using multi-component seals comprising salt concrete and bitumen, as at Gorleben in Germany. The final design of the sealing system would take account of the layout and geological environment, and additional seals may need to be provided.

12.4 Closure and decommissioning

At the time of closure, the disposal vaults and tunnels will already have been sealed and backfilled, and it will only be necessary to progressively backfill the remaining tunnels, facilities (workshops, etc.), shafts and drift. A full breakdown of the backfill quantities is given in Appendix F.

The remaining underground facilities will be backfilled with mass backfill, which will vary according the host rock in order to as far as reasonably practicable, restore the natural conditions of the host rock. In the higher strength rock, the mass backfill would comprise crushed rock, whereas in a lower strength sedimentary rock mass backfill would comprise sand (70%) and bentonite (30%). In the evaporite rock design, the mass backfill would comprise crushed evaporite rock which has been imported to site.

The closure operations will be undertaken in such a way as to provide the necessary post-closure safety functions. The environment that exists within the GDF upon closure (the initial state) will provide the basis for modelling of the GDF's evolution in the post-closure phase.

The surface facilities will be decommissioned, stripped of engineering equipment and demolished. The surface environment will be remediated and landscaped to the end state agreed with the Government, regulators and the local community. Monitoring of the closure operation and the environment will continue throughout the closure phase. For planning purposes, a notional period of 10 years has been included, during which time backfilling, sealing and closure will be implemented.

Monitoring of the closure operation and the environment will continue throughout the closure phase (see Section 13). Records from the GDF will be placed in a national archive for use as required by future generations. Any physical marking of the site that might be required by the Government, regulators or in an agreement with the local community will be undertaken.

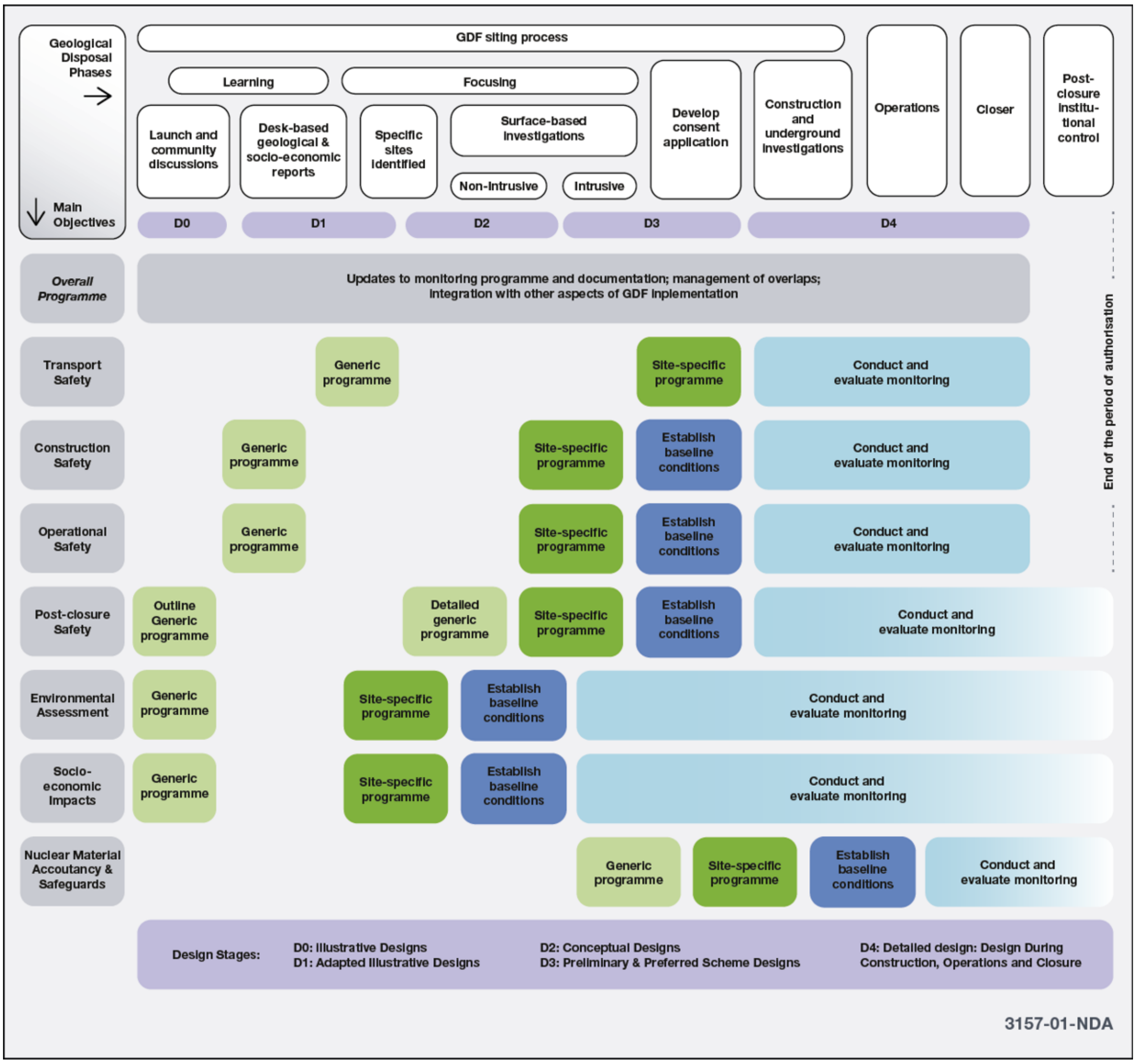
Following closure, the facility will be the responsibility of the authority charged with institutional control. A period of post-closure monitoring could be undertaken by that authority.

13 Monitoring

At each stage in GDF development a wide range of parameters could be monitored to track performance of the disposal facility and its effects on the surrounding environment. Monitoring could: be used to support the development of safety cases by contributing to the understanding of system behaviour; provide assurance of safety by checking implementation conforms to safety case arguments and assumptions; and be used to demonstrate compliance with regulatory requirements and conditions. In this way, monitoring can support decision making, help to build confidence in geological disposal and contribute to enhancement of the disposal system.

In the UK, options for monitoring have been considered previously [52] and the context for monitoring has been established [53]. However, monitoring specifications have only been developed for specific parts of a disposal system, such as radiological monitoring [54], monitoring of ILW and LLW vaults during operations [55], and post-closure monitoring [56,57]. Further development of the monitoring programme will need to respond to engagement with regulators and local public stakeholders once potential geological disposal facility sites have been identified A framework for addressing outstanding gaps is provided by a monitoring programme specification [58], which outlines a strategy for developing a detailed monitoring programme and identifies the current understanding of monitoring requirements, parameters and techniques based on a series of monitoring sub-programmes (Figure 45).

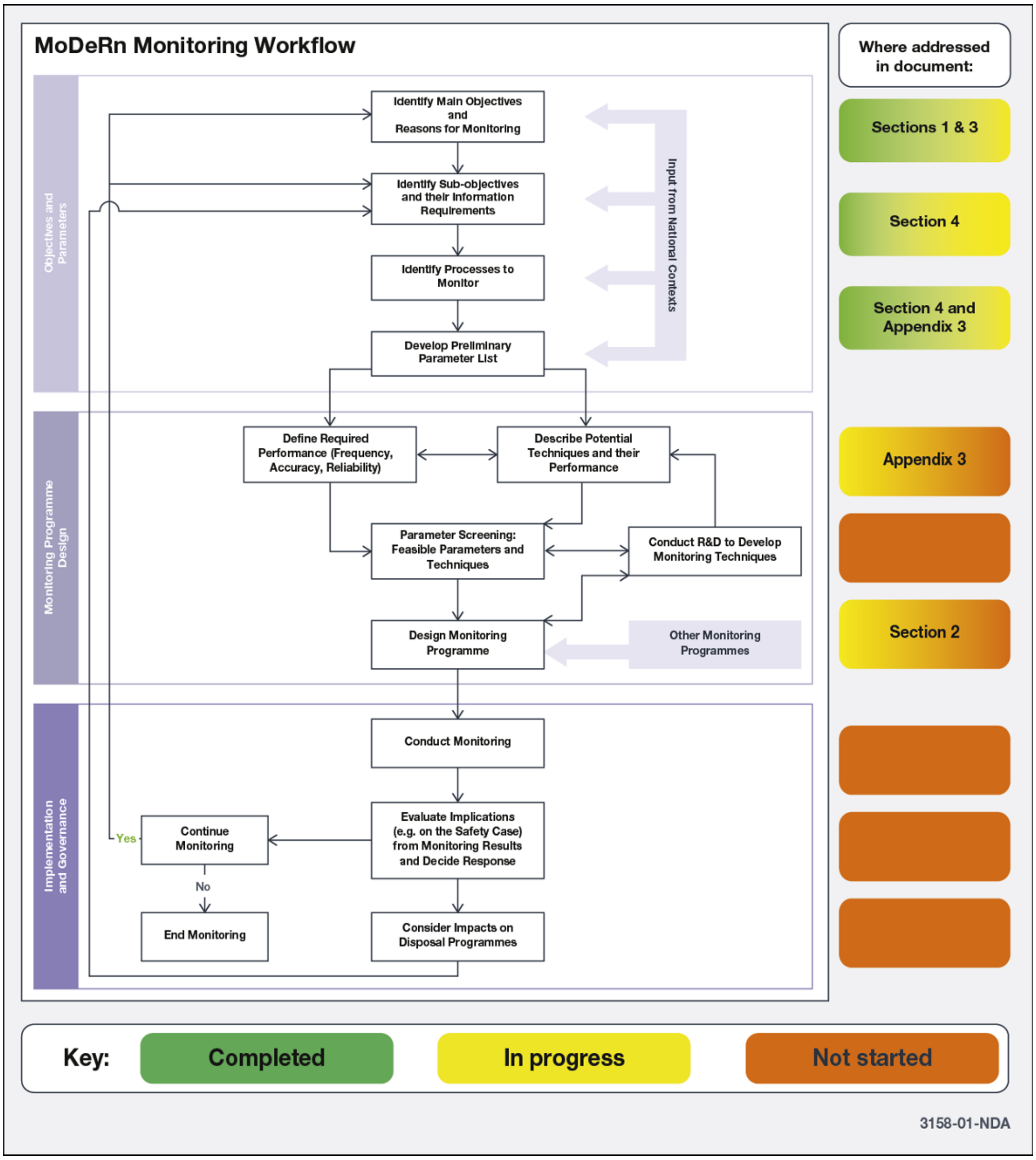
Figure 45 The framework for addressing further development of RWM's monitoring programme.



In parallel with UK work, international collaborative projects have established the principles and objectives of monitoring. These include the publication of an International Atomic Energy Agency (IAEA) technical document on monitoring of GDFs [59], and a European Thematic Network (ETN) that considered the role of monitoring in a phased approach to geological disposal of radioactive waste [60]. The IAEA recognises the importance of monitoring within the life cycle of the GDF, and emphasises the importance of baseline monitoring and contingency plans to address unexpected or abnormal system behaviour. The guidance also includes the principle that the GDF should be designed to be intrinsically and passively safe during the post-closure period, with no further actions required from future generations, and in particular, that long-term safety should not rely on monitoring.

In terms of disposal system performance, development of the RWM monitoring programme will build on lessons learned from the EC MoDeRn Project, in which RWM was a partner and the on-going Modern2020, in which RWM is also a partner. The structured approach developed in the MoDeRn project (the MoDeRn Monitoring Workflow) and an understanding of technical feasibility and stakeholder involvement, have been used in developing the monitoring programme specification, as illustrated in Figure 46.

Figure 46 The MoDeRn monitoring workflow and an analysis of the current progress in defining the RWM monitoring programme



In terms of environmental monitoring, RWM is collaborating with other European waste management organisations to establish a reference framework for long-term environmental monitoring and testing at potential geological disposal sites. This work is being carried out under the auspices of the European 'Implementing Geological Disposal – Technology Platform' (IGD-TP).

As can be seen from Figure 46, the monitoring programme will commence with the collection of data and information to support the establishment of baseline conditions. The monitoring programme will then evolve as monitoring is conducted during construction and throughout on-going construction, operation and closure activities. Any extension of the monitoring programme into the post-closure period will depend on decisions taken by future generations. A summary of the activities during each stage is provided below, focusing on monitoring associated with disposal system performance.

13.1 Baseline monitoring

Prior to constructing the GDF, the monitoring programme will commence with the collection of baseline monitoring information. This will provide a baseline against which future change can be measured. Many of the monitoring systems established during this period are likely to run throughout the remaining duration of the project, to track geological, hydrogeological and environmental change and to help assess the performance of mitigation and enhancement measures developed as part of project implementation. Geological and hydrogeological parameters might include ground elevation and groundwater pressure, amongst many other parameters. Environmental monitoring might cover issues such as air quality, surface and ground water quality, biodiversity, and background radiation levels.

13.2 Construction monitoring

During the construction phase, monitoring of surface and sub-surface parameters will be undertaken to develop further understanding of the effects that construction, operation and closure of the facility will have on the performance of the site relevant to the safety case. This work could include, for example:

- monitoring of ground movement to determine expected behaviour, and to support the development of geotechnical models to establish confidence in rock support designs
- monitoring to confirm that the site is being developed in a manner that is compliant with any discharge consents
- monitoring of parameters such as groundwater inflow and groundwater chemistry to support development of the safety case and the geological disposal facility design

During construction, monitoring will support detailed iterations of the geological disposal facility design.

13.3 Monitoring during on-going operation and closure

During the operational period, protection of the public and the environment will be provided through passive measures, ie measures that do not depend on human intervention or on any active engineered system, and through active measures that rely on people and systems. The aim will be to provide protection as far as reasonably practicable through passive measures. Monitoring activities during operations shall verify that operational safety goals are being met. The illustrative designs include provision for:

- package monitoring – records at dispatch, monitoring and checking on receipt, selective monitoring of waste packages to confirm package origin and content, performance and integrity
- planned preventative maintenance and routine condition monitoring of plant and equipment
- the monitoring requirements during the operational period will also include ongoing construction monitoring due to these activities running concurrently.

As progress is made towards closure of the facility, it is expected that emplacement of the engineered barrier system will be undertaken progressively. A progressive and planned shift from partial reliance on active safety measures and monitoring towards full reliance on passive safety measures is anticipated.

13.4 Post-closure monitoring

The environment agencies guidance documents on requirements for authorisation (GRA) [61] advises that: “unreasonable reliance shall not be placed on human action to protect people and the environment and that assurance of environmental safety must not depend on monitoring or surveillance after the declared end of the period of authorisation". However society will have to decide on the level at which the geological disposal facility is monitored following closure. The period over which this geological disposal facility monitoring might continue will depend on decisions taken by future generations, in the light of guidance provided by the current generation, information from the monitoring system and other factors. Therefore, monitoring following closure is not ruled out, provided it does not produce an unacceptable impact on the environmental safety case.

14 Security and Safeguards

As the GDF will be a civil nuclear site, capable of accepting Category I to III nuclear material for disposal, a security plan must be approved by the Office for Nuclear Regulation (ONR) Civil Nuclear Security (CNS) under the *Nuclear Industries Security Regulations 2013* [62].

14.1 Security

In accordance with the ONR CNS guidance document [63] which provides guidance on avoiding the disclosure of information that could assist a person or group planning theft or sabotage, this report does not contain detailed information on the physical security arrangements assumed or planned in order for the GDF to protect nuclear and other radioactive materials and its related factors. This detail will be contained within the GDF security plan. This will detail the security regime for the protection of the GDF, nuclear and other radioactive material and sensitive nuclear information on the site. It is assumed that the GDF will be designed and constructed to provide appropriate physical security features to operate as a Category I facility from the outset, although it will operate initially as a Category III facility from first receipt of ILW and LLW. This future-proofing will ensure sufficient surface area and infrastructure is available and minimise unnecessary disruption to GDF services and operations to prepare for subsequent upward re-categorisation when Category I and II nuclear materials are introduced.

It is also assumed that prior to the receipt of Category II materials, the GDF will be re-categorised. In advance of the disposal of significant quantities of Pu and HEU, it is assumed that the GDF will be re-categorised to a Category I civil licensed nuclear site. Each re-categorisation will involve increased control on access to all areas, incorporate sufficient detection and surveillance systems to identify malicious activity and provide an adequate armed response to prevent theft and deny sabotage attempts. If necessary, this re-categorisation could be undertaken earlier in the programme, however this would have manpower and cost implications.

The waste emplacement area will be categorised as a Designated Area, which includes the surface waste receipt and handling buildings. The full extent of this area is shown in Drawing E/DRG/0041023. All these facilities will be grouped near to the waste emplacement entrance (either drift or shaft), rail arrivals and dispatch sidings, to establish a single area.

Transport of nuclear material to and within the GDF site will have to be described in a transport security statement and an associated transport security plan, also approved by ONR CNS.

14.2 Safeguards

The UK is a signatory of the Nuclear Non-Proliferation Treaty, and is committed to use nuclear materials from its civil nuclear programmes for peaceful uses. The verification of Treaty compliance is carried out by inspectors from the IAEA, under its safeguards agreements with member states [64]. Safeguards are technical and political measures that deter and ultimately detect the diversion of certain materials from civilian use to non-peaceful uses.

The emplacement of any nuclear material subject to safeguards in the GDF will require safeguards verification of the underground and surface facilities. This verification is to provide independent assurance that nuclear material is not being diverted from its declared disposal. It is preferable that the foundation for this verification system is established during the design and construction phases of the facility, via so-called “safeguards by design”. This requires very early consultation with safeguards inspectorates of the

European Commission and the IAEA. While the verification system will be modelled on a generic approach to safeguarding the GDF, it will later be tailored to a site-specific GDF design, host rock, and the type and form of nuclear materials emplaced. The design will have to incorporate sufficient safeguards measures to give assurance on the absence of diversion of nuclear materials. An effective, operator-provided, nuclear material accountancy and control system will be an essential aspect of safeguards. This system may be independently verified by the IAEA and/or European Commission inspectors using a variety of technical measures (eg containment and surveillance systems) and by tracking and monitoring material.

The level of safeguards provisions at the GDF will depend on the nuclear material emplaced, its accessibility, the complexity of design, the ability to track nuclear material through to emplacement and ease of retrievability. The European Commission and IAEA will verify GDF construction activity against submitted designs and may also verify emplacement of nuclear material during the operational phase.

As the GDF design may initially allow for easy waste retrieval, safeguards verification is expected to continue until sealing and closure. The measures to safeguard nuclear material can only be terminated if the nuclear material is practicably irretrievable as described in [65] although this will conflict with any potential requirement for long-term retrieval.

More detail about the application of safeguards to the GDF can be found in *The Application of Nuclear Safeguards to a UK geological disposal facility* [66].

15 Retrievability

15.1 Context

15.1.1 UK definitions

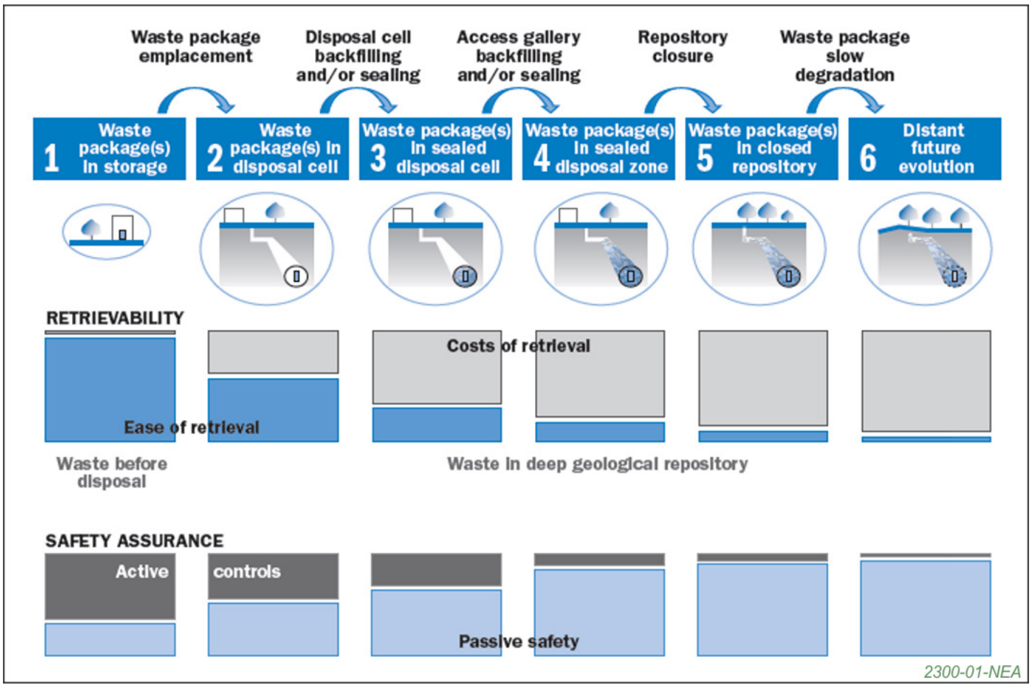
The term 'retrievability' is used as an overarching term to refer to a number of different approaches to removal of radioactive waste from the GDF after it has been emplaced. The following terms were first proposed by CoRWM in their recommendations to Government [67] and have been subsequently adopted by RWM:

- **Reversibility –** A term used in the UK to describe retrieval by reversing the original emplacement process (eg removal of emplaced ILW packages using the vault emplacement crane, similar to the process used for removal of waste packages from an interim store). In this context, reversibility is only possible before any form of backfilling or sealing has taken place and is dependent on the continued integrity of the waste packages, disposal vaults and tunnels, and emplacement equipment. In some other countries, the term 'reversibility' is used to denote an ability to reverse decisions as part of a phased decision-making process.
- **Retrievability –** The term is used where it is possible to withdraw the waste from the GDF by building in a methodology that would allow access to the waste even after vaults and tunnels had been backfilled. This could be achieved, for example, by keeping service tunnels open for a period after emplacement and vault/tunnel backfilling, and by ensuring that any backfill materials could be readily removed.
- **Recoverability –** A term developed by CoRWM to define situations when removal of waste from a closed GDF by mining or similar intrusive methods. Once service tunnels have been backfilled and/or the GDF has been sealed, intrusive re-excavation operations would be required to recover the waste. These would be likely to pose greater technical challenges and be more expensive than other forms of retrievability.

15.1.2 The Nuclear Energy Agency retrievability scale

The Nuclear Energy Agency (NEA) reversibility and retrievability project was carried out in several phases between 2007 and 2011. RWM staff participated in the project. The project included the development of a generic Retrievability Scale [68] which illustrates the lifecycle stages of waste packages, the relationship between ease of retrieval and cost throughout this lifecycle, and how safety assurance changes from predominantly active controls to passive safety with each stage (Figure 47). The NEA Retrievability Scale is generic and can be applied to any geological disposal facility.

Figure 47 NEA retrievability scale



The NEA scale can be broadly aligned with the current terminology described by CoRWM related to the UK GDF and for the different phases of the GDF lifecycle, and this is shown in Table 3.

Table 3 The NEA retrievability scale in relation to CoRWM's retrievability terminology

<table>
<tr><th>NEA Retrievability Scale</th><th>Description of Stage</th><th>CoRWM Terminology</th><th>GDF Phase</th></tr>
<tr><td>Stage 1</td><td>Waste Package(s) in storage</td><td rowspan="2">Reversibility</td><td>Pre-construction/ Construction Phase</td></tr>
<tr><td>Stage 2</td><td>Waste Package(s) in disposal cell</td><td rowspan="2">Operational Phase</td></tr>
<tr><td>Stage 3</td><td>Waste Package(s) in sealed disposal cell</td><td rowspan="2">Retrievability</td></tr>
<tr><td>Stage 4</td><td>Waste Package(s) in sealed disposal zone</td><td>Closure Phase</td></tr>
<tr><td>Stage 5</td><td>Waste Package(s) in a closed repository</td><td rowspan="2">Recoverability</td><td rowspan="2">Post-Closure Phase</td></tr>
<tr><td>Stage 6</td><td>Distant future evolution</td></tr>
</table>

15.1.3 Current approach to retrievability

The degree to which wastes are 'retrievable', and the type of retrieval approach required, depends on a range of factors, including:

- the type of waste

- the disposal concept
- the time elapsed after emplacement
- the extent to which the GDF has been closed
- the nature of the surrounding geological environment

Future decision-making regarding retrievability will need to take account of relevant site-specific characteristics. RWM recognises the Government's view that a decision on whether or not to keep the GDF (or vaults and tunnels within it) open once facility waste operations cease can be made at a later date, although RWM recognise that some geological disposal concepts have limitations with respect to delaying the emplacement of some types of backfill. As the siting process progresses, decisions with respect to retrievability will be made in discussion with the independent regulators and local communities. The final design will then reflect the decisions made in the light of those discussions.

In the meantime, in line with Government policy as set out in the Implementing Geological Disposal White Paper, design development is carried out in such a way that the option for retrievability is not excluded. The policy and requirements of retrievability are detailed in the DSS Part B. The remainder of this section considers how retrievability has been addressed in the different illustrative designs.

15.2 Retrievability of LHGW packages

For the illustrative designs in a higher strength rock and lower strength sedimentary rock, the process of emplacement for ILW and LLW would be similar, in principle, to that applied to surface storage. The design of stable vaults will allow ILW/LLW disposal vaults to remain open until all the waste has been emplaced, when a decision to backfill all vaults could be taken. Assuming appropriate control of environmental conditions to ensure package integrity, reversal of the emplacement process would only require re-use of the remote handling systems in the UILW and RSILW vaults, and re-use of a stacker truck in the SILW/LLW disposal vaults. However, it is recognised that removal of packages using an overhead crane would be more selective than a stacker truck in the SILW vault, which would operate on a first-in last-out philosophy

Leaving filled vaults open introduces risks associated with unexpected mechanical failure of the rock, water inflow, build-up of explosive gasses and accelerated degradation of the waste packages as well as significantly increasing the overall ventilation quantity requirements. It also introduces potential risks to workers associated with extensive monitoring and maintenance of the structures. Backfilling each disposal vault immediately following emplacement reduces these risks and provides physical protection for the waste packages.

Once vaults are backfilled the waste packages would be more difficult to retrieve, and a programme of backfill removal would be required. Studies have been undertaken to demonstrate retrievability of LHGW packages. In particular, Nirex demonstrated the feasibility of using high-pressure water jets to retrieve ILW packages from disposal tunnels backfilled with NRVB [69].

As the backfilling and sealing of the GDF progresses, it would become progressively more difficult to recover waste from the facility. After closure, this would require a programme of re-mining, which should be feasible with existing technology. However the risks of harm to health and adverse environmental impacts would increase.

For the illustrative design in an evaporite rock, the process of disposal for ILW and LLW would be similar in principle to that applied to surface storage, allowing individual or batches of waste packages to be retrieved while the vault is still operational. The issue of retrievability from these vaults would therefore only require the re-use of the stacker trucks.

However, depending on the creep rate of the host rock, packages will be more difficult to retrieve through time. After extended periods, a programme of re-excavation would be the only way to recover the waste packages.

15.3 Retrievability of HHGW packages

15.3.1 Higher strength rock

The programme for the illustrative design in higher strength rock assumes that a buffer is emplaced in each disposal hole at the same time as emplacement of the disposal container. Disposal tunnels would be backfilled as soon as all the disposal holes within it are filled. Therefore, the potential for reversal of the emplacement process is limited to a short period.

Retrieval of waste packages from a disposal hole would first require removal of the bentonite buffer. SKB has demonstrated that a saturated bentonite buffer can be removed from a disposal hole by slurrying it with a saline solution [70].

Should a decision be taken to retrieve disposal containers once backfilling of the disposal tunnel has taken place, retrieval would require dismantling of the disposal tunnel plug and re-mining of the bentonite backfill placed in the disposal tunnel. SKB have tested the dismantling of disposal tunnel plugs, deposition tunnel backfill and disposal hole buffer as part of the Prototype Repository Project [71]. Recovery of the disposed spent fuel following closure would also require re-mining of the mass backfill emplaced in the access tunnels.

15.3.2 Lower strength sedimentary rock

The programme for the illustrative design in a lower strength sedimentary rock currently assumes that each disposal tunnel would be backfilled progressively with a dry granulated bentonite buffer as the disposal containers are emplaced within it. Emplacement of the buffer is currently envisaged to be undertaken using a system of augers to achieve the required backfill density. This system is not readily reversed, but it is technically feasible to remove the disposal container from the tunnel prior to sealing of the main access tunnels by retrieval incorporating a method for dismantling of the disposal tunnel plug and removal of the bentonite. Should the requirement arise to recover the disposal containers, once backfilling of the main access ways had taken place, then this would become a re-excavation process.

15.3.3 Evaporite rock

The programme for the illustrative design in evaporite rock assumes that each disposal tunnel is backfilled progressively as the disposal containers are emplaced within it.

Once backfilling has taken place, then, should the requirement arise to recover the disposal containers, this would become a re-excavation process.

16 Implications of a Change in Inventory

16.1 Introduction

The designs presented in this report are based on the Inventory [4]. However, there are sources of uncertainty in the eventual inventory requiring geological disposal that are also covered by RWM's work programme. These include uncertainties in the volumes and radionuclide contents of the currently identified wastes and materials in the Inventory and uncertainties in scenarios for the future operation of nuclear plants and other facilities that produce these wastes and materials.

A range of scenarios have been developed for the inventory of wastes that may require geological disposal in order to evaluate the implications of these uncertainties for the geological disposal programme [72]. RWM wants to be able to demonstrate that the GDF can be developed to deal with an inventory safely and securely. These scenarios also provide visibility to local communities of what might be involved in hosting the GDF and allow the implications of the uncertainties on geological disposal to be assessed. In particular, the relationship between a change in waste type, decrease or increase in waste package numbers and the implications for the size and design of the GDF and for the safety and environmental protection provided by the facility can be understood.

A total of 12 sensitivity scenarios have been defined that represent the potential changes that could occur to the UK Radioactive Waste Inventory (UKRWI). These scenarios are as follows:

- **Scenario 1: More reprocessing of oxide fuel –** Reprocessing of fuel used in legacy Pressurised Water Reactor (PWR) and Advanced Gas Cooled Reactor (AGR) reactors would lead to an increased inventory of HLW, separated Pu and HEU but would reduce the inventory of SF. The likelihood of this scenario occurring is very low as there are no plans to reprocess these fuels.
- **Scenario 2: Less reprocessing of Magnox fuel –** The current assumption is that all Magnox SF will be reprocessed. However, this scenario considers the consequences of the Magnox reprocessing plant not completing fuel reprocessing. Magnox SF would require disposal in the GDF. There would be a reduction in the amounts of HLW, ILW, DNLEU and Pu, as well as a reduction in the amount of MOX SF.
- **Scenario 3: Increased lifetime of operating legacy reactors –** Some of the currently operating reactors could be granted an operational lifetime extension. This scenario explores the additional wastes that would be created by these reactors operating for longer.
- **Scenario 4: Recognition of UKRWI uncertainty estimates –** The data submissions that waste producers make for the Recognition of UKRWI contain an estimate of the volume uncertainty, both upper (4a) and lower (4b). This scenario explores the impact of using the uncertainty volumes of the UKRWI waste streams.
- **Scenario 5: Separated Pu not disposed of as MOX SF –** Preferred policy for the long term management of civil Pu is to reuse as MOX fuel. This scenario considers a change to this policy, meaning Pu stocks would need to be disposed of in another form within the GDF.
- **Scenario 6: LLW from the Low Level Waste Repository –** It might be necessary to excavate some of the waste at the Low Level Waste Repository (LLWR) for disposal in the GDF. However, at present the volume cannot be quantified, although the low level of radioactivity in the waste would have a very small impact on the GDF.

- **Scenario 7: Depleted Uranium Increases –** Uranium enrichment in the UK is assumed to continue to 2023. Additional U-enrichment in the UK would lead to an increase in the inventory of DNLEU. This scenario considers the effects of additional DNLEU on the GDF.
- **Scenario 8: New Build Programme: additional reactors –** The current stated industry ambition for new nuclear development is 16 GW(e). This is not a Government target and the Government is supportive of industry bringing forward plans for further development in future. In line with the stated industry ambition, the 2013 Derived Inventory includes a 16 GW(e) NNB programme, assumed to be comprised of six European Pressurised Reactors (EPR) and six AP1000 reactors. To explore the impact of additional (or fewer) reactors being built, the inventory associated with a single EPR and a single AP1000 reactor are given.
- **Scenario 9: Foreign wastes and material are included –** UK Government policy is that radioactive waste should not be imported to, or exported from the UK except in specifically defined and limited circumstances. For example spent sealed sources manufactured in the UK being returned from overseas for treatment and disposal. In such circumstances, waste materials could be added to UK stocks and, if an agreement to do so exists, a radiologically equivalent (or substitute) waste material would be returned to the country of origin.
- **Scenario 10: Alternative Packaging Assumptions –** Alternative packaging assumptions for wastes, including the use of new or alternative packages would affect the 2013 Derived Inventory packaged volume and the numbers of waste packages and disposal units. This scenario considers the impact of these alternative assumptions.
- **Scenario 11: Graphite wastes do not require geological disposal –** The baseline strategy for reactor decommissioning graphite is geological disposal. Management of graphite waste by geological disposal provides a robust baseline strategy suitable for planning purposes. The extended period of quiescence that reactors are scheduled to be in means that there is sufficient time for alternative options to develop such that any future decisions on the management of radioactive graphite waste will be appropriately informed. In addition the NDA has identified factors that would drive a review of this strategic position. To account for the possibility of a change in the NDA's strategic position, this scenario explores the implications of graphite not being disposed of to the GDF.
- **Scenario 12: More short-lived intermediate level was declared as suitable for management by the LLWR –** The 2013 UK Radioactive Waste Inventory includes 42 ILW streams that waste producers expect to manage as LLW through near-surface disposal by using radioactive decay storage and/or decontamination processes. Some combustible wastes are expected to be incinerated and some metal wastes are expected to be recycled. However, only those ILW streams where there is an established decontamination or incineration process have been excluded from the 2013 Derived Inventory. This scenario explores the impact of these streams not being disposed of to the GDF.

The potential implications of these scenarios are discussed in the following sub-sections. Of the twelve scenarios identified six have been assessed quantitatively, namely Scenarios 2, 3, 4, 8, 11 and 12. A summary of the anticipated changes in vault and tunnel numbers, and underground footprint is tabulated in Appendix H.

16.1.1 Impact on GDF surface facilities

It is considered that the surface facilities for the GDF would remain the same for the different inventory sensitivity scenarios. Waste receipt and transfer buildings and construction support buildings will still be required whatever the inventory scenario. The major implications for the design would be the impact on the underground footprint and operations. However, due to the change in number of disposal vaults and tunnels required, there would be a change in the volume of excavated material that might cause a change to the volume of material being stored on the surface or that needs to be transported off site.

At present, it is assumed that the Inventory and scheduling only require that a single underground waste emplacement route is available.

16.1.2 Impact on package and handling complexity

The waste package types that will be handled and disposed of in the GDF are discussed in the Technical Background. Some of the inventory sensitivity scenarios identified above require disposal of different waste package designs within the GDF to those already assumed in the Inventory. The inclusion of these additional waste package types would require the GDF handling systems to be adapted to be able to lift and emplace these packages. Depending upon the number of these additional package types, the changes to the lifting mechanisms may have an impact on the emplacement rate and therefore the operational programme. The addition of some waste package types may also require dedicated infrastructure and disposal vaults for these wastes, such as the inclusion of additional shielded areas where the packages could be removed from their shielded transport containers. The addition of some wastes, such as ILW that has been thermally treated would also require disposal within dedicated vaults separate to other waste types. This could create a requirement for additional vaults and their associated infrastructure and changes to the GDF underground footprint.

16.1.3 Impact on GDF footprint

The illustrative designs and layouts have been based on assumed parameters and typical host rock properties, and the site-specific design would obviously depend on the characteristics of the chosen site such as the local stress field and fault zones.

The current footprint for the GDF for the Inventory in a higher strength rock is 7.6km^2. A change in numbers of waste packages would cause a change in disposal vault and tunnel numbers, which would also result in a change to the overall GDF underground footprint. For the inventory sensitivity scenarios assessed quantitatively the footprint would range from 6.8km^2 to 9.5km^2 in a higher strength rock. This equates to a potential variation in footprint from a reduction of 11% to an increase of 25%.

The current footprint for the GDF for the Inventory in a lower strength sedimentary rock is 15.3km^2. For those inventory sensitivity scenarios quantitatively assessed, the footprint would range from 14.4km^2 to 21.5km^2. This equates to a potential variation in footprint from a reduction of 6% to an increase of 41%.

The current footprint for the GDF for the Inventory in an evaporite rock is 10.3km^2. A change in numbers of waste packages would cause a change in disposal vault and tunnel numbers that would also result in a change to the overall GDF underground footprint. For the inventory sensitivity scenarios identified above, the footprint would change in a range from 10.0km^2 to 11.9km^2. This equates to a potential variation in footprint from a reduction of 3% to an increase of 16%.

A tabulated summary of the change to the GDF underground footprints associated with the different sensitivity scenarios is provided in Appendix H.

16.1.4 Impact on operational programme

The current operational programme for the Inventory is detailed in Section 8.2. The operational programme is based on the date of waste arisings and assumed throughput rates for disposal with different numbers of waste packages being handled and disposed of at the GDF over time. The general throughput of waste packages is seen to be the highest number in the initial period with packages numbers generally decreasing over the lifetime of the GDF. The current assumed numbers of waste packages are well within the maximum throughput rates currently assumed for the GDF and so the current design has the flexibility to handle and receive an increase number of packages per year if required. In the current programme wastes are disposed of over a 150 year period between 2040 and 2190, with GDF closure in 2200.

If the inventory scenario were to change then this could result in a change to the GDF programme. Of the eight sensitivity scenarios assessed quantitatively the two that have been calculated to have the most significant impact on the operational programme are; scenario 4a – upper volume uncertainty and scenario 4b – lower volume uncertainty.

In Scenario 4a, despite the increased volume of waste for disposal there is no change to the overall operating timeframe with wastes still disposed of between 2040 and 2190. However, the increased number of UILW packages means that the throughput rate through the inlet cell has to increase to 2,500 packages per annum and continues at a higher rate for longer, meaning three-shift working is required, which would increase operational costs. Even considering this higher rate of disposal, the legacy wastes would be disposed of between 2040 and 2129; this is 24 years longer than the currently accepted programme (2040-2105). This also means that disposal of DNLEU occurs later, between 2129-2139.

The increased number of legacy SILW/LLW and RSILW containers means that there will be additional tranches of waste arrivals that will need disposal. This will result in a need to increase the rate of vault construction and emplacement operations to ensure that these wastes are disposed of before the arrival of ILW associated with a NNB programme.

Scenario 4a also envisages an increased number of vitrified HLW disposal containers (+3,241), which as legacy waste, will arrive from 2075 onwards. The additional containers mean that the disposal of legacy HLW/SF runs from 2075 to 2121, 16 years longer than the original programme. This means that disposal of Pu/HEU wastes will commence in 2121 until 2126. The additional legacy disposal containers has the effect of filling part of the operational dormant period between disposal of Pu/HEU and the arrival of MOX SF, but means that Pu/HEU wastes will need to be stored at interim facilities for longer.

For Scenario 4b, despite there being a decrease in volume of waste for disposal there is no overall change to the operating timeframe with wastes being disposed of between 2040-2190. The decreased number of UILW packages means that the initial throughput rate through the inlet cell can be reduced to 2000 packages per annum from 2300 packages from 2040-2051. In 2051 the rate is reduced to 1500 packages per annum, which could also result in a change to two-shift working, therefore reducing operational costs. The lower rate means that less emplacement operations are required to dispose of the wastes. The timeframe for disposal would be shorter than currently accepted, finishing in 2094 rather than the currently assumed completion of 2105. This means that DNLEU can be disposed of between 2094-2105.

The decreased number of legacy SILW/LLW and RSILW containers means that there are fewer tranches of waste requiring disposal. This means that the rate of vault construction and emplacement operations can be reduced, however, vaults will remain open for longer before being filled with waste.

Scenario 4b also has a decreased number of vitrified HLW disposal containers. These fewer disposal containers mean that the disposal of legacy HLW/SF runs from 2075 to 2106, equivalent to three years less than the reference case scenario. The disposal of Pu/HEU wastes will commence in 2102 until 2104. This increases the operational hiatus between disposal of Pu/HEU and the arrival of MOX SF by 22 years.

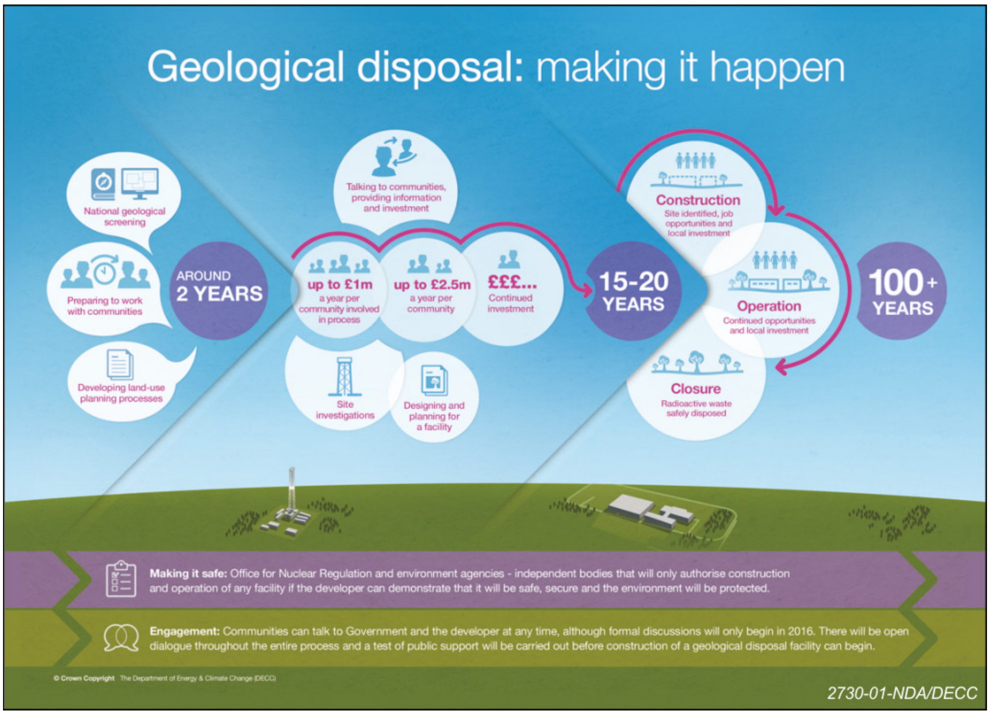
17 The Way Forward

This report summarises the generic designs that have been prepared for the GDF in the UK. It describes the processes of waste emplacement and the design characteristics that the disposal facility will need to include for disposal of LHGW and HHGW.

The illustrative designs described in this report have also been prepared to allow RWM to undertake the associated assessments of safety, environmental, social and economic impacts and assessments of the costs to develop the facility. This update has been prepared in order to quantify the impact of adopting design changes and enhancements within the GDF illustrative designs and the updated inventory, such that up to date designs are available as an input to support the siting process. It is stressed that while these illustrative designs have been developed for three host rocks (a higher strength rock, a lower strength sedimentary rock and an evaporite rock), it does not mean that these settings are in any way preferred, that any of the illustrative designs will necessarily be adopted for a selected site, or that any of the concepts are favoured more than any other.

The framework for implementing Geological Disposal is described in [2] and the process is shown in the Figure 48.

Figure 48 Diagram showing process moving forward



As the process above progresses, details of a geological environment and site-specific characteristics will become available. Until such time as more specific information becomes available, the approach that will continue to be taken is to define a number of generic geological disposal concepts applied to typical, potentially suitable UK geological environments. The generic DSSC documents will initially describe generic requirements, reflecting the fact that a site and a disposal concept have yet to be identified. They will be periodically updated, for example to respond to changes in regulations and to respond to learning from undertaking assessments and further research. The DSS Part B, in particular, will evolve from generic to site-specific requirements as site-specific information becomes available at the more detailed level and as issues that are recognised today are resolved. Some issues are of a general nature and faced by other countries in implementing geological disposal, and some are UK-specific.

As the process progresses, there will also be a requirement to maintain and periodically update the generic illustrative designs and this report to take account of future requirements and to support both wider stakeholder engagement and the waste packaging assessment process. It is expected that these illustrative designs will continue to be required and updated as the designs move forward through the process from their current illustrative status through the conceptual and preliminary design stages and until a detailed design for the GDF at a specific site is developed.

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Glossary

A glossary of terms specific to the generic DSSC can be found in the Technical Background.

Appendix A – Waste Volumes for Disposal

The waste volumes used in the generic designs have been provided in the DSS Part B.

Waste category	Waste type	2013 Derived Inventory	
		Volume of packaged waste (m^3)	Conditioned waste volume (m^3)
LHGW	Legacy LLW	11,800	11,100
	Legacy ILW	415,000	327,600
	DNLEU UILW	13,600	11,200
	DNLEU SILW	203,800	149,200
	NNB ILW	41,000	25,000
HHGW	Legacy HLW	9,300	1,400
	Legacy SF	14,800	3,400
	Pu/HEU	3,100	869
	MOX SF	11,900	594
	NNB SF	39,400	5,900
	TOTAL	763,700	536,263

Appendix B – Waste Package Numbers

This section describes the various waste package types, their dimensions and the number of packages for each waste type that have been derived from the Inventory. There is also information on the characteristics of each of the package types. Note that the number of disposal units is given to three significant figures.

LHGW (Unshielded ILW) Waste Packages

Waste package type	Total number of disposal units[6]
Legacy waste packages	
Stillages of 500 litre drums	22,900
Stillages of enhanced 500 litre drums (precast)	224
Stillages of enhanced 500 litre drums (basket)	6,530
Total disposal stillages of 4 500 litre drums	**29,700**
3 cubic metre drums	563
3 cubic metre box (side lifting)	4770
3 cubic metre box (corner lifting)	403
3 cubic metre Sellafield box (i.e. single skinned)	54,300
3 cubic metre Enhanced Sellafield box (i.e. double skinned)	16,300
MBGWS	1,500
NNB waste packages	
3 cubic metre box (round corners)	960
3 cubic metre drums	7,270
Total UILW	**116,000**

6 A UILW disposal unit consists of either one 3 cubic metre box, one 3 cubic metre drum or four 500 litre drums contained in a stillage.

LHGW (SILW) Waste Packages

Waste package type	Total number of disposal units
Legacy waste packages	
6 cubic metre boxes	426
4 metre boxes (no liner)	2,180
4 metre boxes (100mm concrete liner)	1,190
4 metre boxes (200mm concrete liner)	399
2 metre boxes (100mm concrete liner)	75
500 litre robust shielded drum	1,240
3 cubic metre robust shielded box	1,040
NNB waste packages	
4 metre boxes (100mm concrete liner)	60
1 cubic metre concrete drum	6,840
500 litre concrete drum	3,240
Total SILW	**16,700**

LHGW (LLW) Waste Packages

Waste package type	Total number of disposal units
4 metre boxes (no liner)	584
Stillages of 500 litre drums	54
Total LLW	**638**

HHGW package types and numbers

Waste type	Total number of disposal units
HLW	2,400
AGR SF	2,190
PWR SF	572
Magnox	836
PFR	19
MOX	2,700
NNB SF	8,940
Total HHGW	**17,700**

Number of plutonium and uranium disposal units

Waste type	Waste package type	Total number of disposal units
Pu	Disposal container (similar to HLW/SF)	196
HEU	Disposal container (similar to HLW/SF)	780
DNLEU	Disposal stillages of 500 litre drums	5,940
	Transport and Disposal Containers 2.4m Height	2,890
	Transport and Disposal Containers 2.3m Height	3,780
	Transport and Disposal Containers 2.1m Height	581

Total number of disposal units

Inventory	Total number of disposal units
2013 Derived Inventory	164,900

Appendix C – Summary of the Illustrative Designs

This table contains a high level summary of the illustrative design. Further information can be found in Sections 5 to 11 inclusive.

Element	Host rock		
	Higher strength rock	Lower strength sedimentary rock	Evaporite rock
Surface facilities	Bentonite buffer store	Bentonite buffer store	-
	Store for crushed rock and imported sand/cement	Store for crushed rock and imported sand/cement	Store for crushed evaporite rock and imported sand/cement
Underground access	3 shafts and 1 drift	3 shaft and 1 drift	4 shafts
Assumed depth for facility horizon (based on selected concept)	650m depth	500m depth	650m depth
Waste package transfer underground	Via drift	Via drift	Via shaft
Underground rock support	Rock bolts and mesh with shotcrete	Rock bolts and mesh with shotcrete. Concrete segments not discounted	Rock bolts and mesh
Inlet cell requirements	1 inlet cell required	4 inlet cells required	4 inlet cells required
SILW/LLW disposal vault dimensions	Arch roof profile 16.0m × 15.0m and 300m long. 32.0m rock pillar spacing between vaults.	Horse shoe shape 9.6m × 11.5m and 300m long. 72.0m rock pillar spacing between vaults.	Rectangular shape 10.0m × 5.5m and 300m long. 21.0m rock pillar spacing between vaults.
DNLEU disposal vault dimensions	Arch roof profile 16.0m × 15.0m and 300m long. 32.0m rock pillar spacing between vaults.	Horse shoe shape 9.6m × 11.5m and 300m long. 72.0m rock pillar spacing between vaults.	Rectangular shape 8.0m × 5.5m and 300m long. 23.0m rock pillar spacing between vaults
RSILW disposal vault dimensions	Arch roof profile 16.0m × 12.0m and 300m long. 32.0m rock pillar spacing	Horse shoe shape 9.6m × 11.5m and 300m long. 72.0m rock pillar spacing	Rectangular shape 10.0m × 5.0m and 300m long. 21.0m rock pillar spacing

Element	Host rock		
	Higher strength rock	Lower strength sedimentary rock	Evaporite rock
	between vaults.	between vaults.	between vaults.
New Build SILW (concrete drum) disposal vault dimensions	Arch roof profile 16.2m × 16.0m and 300m long. 32.0 rock pillar spacing between vaults.	Horse shoe shape 9.6m × 11.5m and 300m long. 72.0m rock pillar spacing between vaults.	Rectangular shape 10.0m × 5.0m and 300m long. 21.0m rock pillar spacing between vaults.
UILW disposal vault dimensions	Arch roof profile 16.2m × 16.0m and 317m long. 32.0m rock pillar spacing between vaults.	Horse shoe shape 9.6m × 11.5m and 317m long. 72.0m rock pillar spacing between vaults.	Rectangular shape 10.0m × 5.0m and 317m long. 21.0m rock pillar spacing between vaults.
HHGW disposal tunnel dimensions	Arch roof profile 5.5m × 5.5m and 500m long. 19.5 rock pillar spacing between tunnels.	Circular shape 2.5m diameter and 500m long. 26.0m rock pillar spacing between tunnels.	Rectangular shape 3.0m × 3.0m and 500m long. 20.0m rock pillar spacing between tunnels.
Disposal of SILW/LLW	Remotely operated stacker truck	Remotely operated stacker truck	Remotely operated stacker truck
Disposal of UILW	Remotely using an overhead crane	Remotely using an overhead crane	Remotely using a rail mounted stacker truck
Disposal of HHGW	Vertical boreholes drilled along base of disposal tunnel surrounded with bentonite rings	Horizontally in disposal tunnels on pre-stacked bentonite blocks and surrounded with bentonite pellets	Horizontally in disposal tunnels and surrounded with crushed host rock
Underground transport of HHGW	By locomotive to the transfer hall and then transported to the disposal tunnel in a free steered vehicle	By locomotive to the transfer hall and then transported to the disposal tunnel reception area by locomotive	By locomotive to the transfer hall and then transported to the disposal tunnel reception area by locomotive
Idealised surface footprint	Approximately 1km^2	Approximately 1km^2	Approximately 1km^2
Underground footprint	Approximately 7.6km^2	Approximately 15.3km^2	Approximately 10.3km^2
Indicative underground dimensions	Approximately 4.1km x 2.7km	Approximately 6.2km x 3.7km	Approximately 5.7km x 3.1km

Element	Host rock		
	Higher strength rock	Lower strength sedimentary rock	Evaporite rock
Volume of excavated material	Approximately 10,800,000m^3	Approximately 8,830,000m^3	Approximately 6,520,000m^3
UILW disposal vaults numbers	20	58	49
SILW/LLW disposal vaults numbers	5	18	10
SILW DNLEU disposal vaults numbers	11	30	27
RSILW disposal vaults numbers	1	3	2
NNB SILW concrete drum disposal vaults numbers	1	5	5
HHGW disposal tunnels numbers	310	341	327
Backfilling – LHGW disposal vaults	NRVB injected into vaults prior to closure.	Cementitious grout injected into vault once each vault is filled.	No backfill, sacks of MgO placed on top to absorb moisture and carbon dioxide
Backfilling – HHGW disposal tunnels	Backfilled once all boreholes in a disposal tunnel are filled. Backfill would be blocks of bentonite and bentonite pellets.	Backfilled progressively as the disposal containers are placed. Backfill would be bentonite pellets.	Backfilled progressively as the disposal containers are placed. Backfill would be crushed evaporite rock.
Backfilling – plugs and seals	Compacted bentonite retained by a concrete structure.	Compacted bentonite retained by a concrete structure.	Rigid concrete wall with contact grouting.
Backfilling – mass backfill to remaining tunnels and underground facility areas.	Crushed host rock.	Bentonite and sand mix (30:70 ratio).	Backfilled with crushed evaporite rock.

Appendix D – Construction Materials and Volumes

The volumes of excavated materials and construction materials have been calculated using the 3D models for each host rock and associated supporting spreadsheets.

Volumes of excavated materials

Inventory scenario	Higher strength rock	Lower strength sedimentary rock	Evaporite rock
2013 Derived Inventory	10,800,000m^3	8,830,000m^3	6,520,000m^3

Volume of construction materials

Concrete

It is anticipated that the volume of concrete required to construct the underground facilities including concrete floors, operating plugs, seals and the shafts and drift will be as follows:

Inventory scenario	Higher strength rock	Lower strength sedimentary rock	Evaporite rock
2013 Derived Inventory	456,000m^3	888,000m^3	360,000m^3

Shotcrete

It is anticipated that the volume of shotcrete required to construct the underground facilities, including the shafts and drift, will be as follows:

Inventory scenario	Higher strength rock	Lower strength sedimentary rock	Evaporite rock
2013 Derived Inventory	301,000m^3	1,190,000m^3	532m^3

Steel reinforcement

The mass of steel reinforcement associated with the seals and plugs, the reinforcement in the drifts and shafts, wire mesh supports and arches in the drift is expected to be:

Inventory scenario	Higher strength rock	Lower strength sedimentary rock	Evaporite rock
2013 Derived Inventory	4,050t	5,500t	5,010t

Rock Bolts

The coverage and number of rock bolts to support the underground openings is expected to be:

Inventory scenario	Higher strength rock[7]	Lower strength sedimentary rock[8]	Evaporite rock[9]
2013 Derived Inventory	180,000	785,000	831,000

[7] Based on 20% coverage.

[8] Based on 40% coverage.

[9] Based on 50% coverage.

Appendix E – GDF Footprint

Footprint for the higher strength rock illustrative design

Underground feature	Area
UILW vaults	270,000m^2
SILW, LLW/RSILW, DNLEU (Packaged in TDCs) and NNB SILW concrete drum vaults	241,000m^2
HHGW disposal tunnels	3,360,000m^2
Roadways and support area	3,750,000m^2
Total footprint	**Approximately 7.6km^2**

Footprint for the lower strength sedimentary rock illustrative design

Underground feature	Area
UILW vaults	1,320,000m^2
SILW, LLW, RSILW, DNLEU (Packaged in TDCs) and NNB SILW concrete drum vaults	1,220,000m^2
HHGW disposal tunnels	4,150,000m^2
Roadways and support area	8,600,000m^2
Total footprint	**Approximately 15.3km^2**

Footprint for evaporite rock illustrative design

Underground feature	Area
UILW vaults	435,000m^2
SILW, LLW, RSILW, DNLEU SILW (Packaged in TDCs) and NNB SILW concrete drum vaults	389,000m^2
HHGW disposal tunnels	3,360,000m^2
Roadways and support area	6,110,000m^2
Total footprint	**Approximately 10.3km^2**

Appendix F – Backfill Materials and Volumes

Required buffer and backfill materials for higher strength rock illustrative design

Material	Volume
LHGW – NRVB[10]	1,740,000m^3
HHGW bentonite buffer	275,000m^3
HHGW disposal tunnel backfill[11]	4,150,000m^3

Required buffer and backfill materials for lower strength sedimentary rock illustrative design

Material	Volume
LHGW – cementitious grout[12]	1,850,000m^3
HHGW bentonite buffer blocks and backfill[13]	656,000m^3

Required buffer and backfill materials for evaporite rock illustrative design

Material	Volume
LHGW – MgO	6,930m^3
HHGW crushed host rock in disposal tunnel backfill	1,270,000m^3

---

10 All these quantities assume that the crown space of the SILW/LLW and UILW vaults would be filled during backfilling operations. A backfill ratio of 1:1 is assumed.

11 Comprising 100% bentonite.

12 All these quantities assume that the crown space of the LHGW vaults would be filled during backfilling operations. A backfill ratio of 1:1 is assumed.

13 Bentonite is used as blocks for the disposal container to rest on. The disposal tunnel backfill is assumed to be pre-compacted bentonite pellets.

Appendix G – Packages Requiring Special Emplacement

When considering the inventory for disposal, there are a number of different types of waste package that are non-standard and various features will require special consideration prior to emplacement. The following table provides details of these packages and their requirements.

<table>
<tr><th colspan="3">Package description</th><th rowspan="2">Number of packages</th><th colspan="2">Emplacement caveat</th><th colspan="2">Endorsement</th></tr>
<tr><th>Container</th><th>Waste</th><th>Waste owner</th><th>Challenge</th><th>Emplacement requirement</th><th>File</th><th>Status</th></tr>
<tr><td>500 litre drum</td><td>Harwell RHILW</td><td>RSRL</td><td>10</td><td>Initial batch of drums manufactured using super-plasticiser in grout annulus.</td><td>Potential requirement to isolate from packages with significant actinide burden.</td><td>TPC 10 067</td><td>Final (packing of waste into drums)
Interim (final disposal package)
Waste has been packed</td></tr>
<tr><td>500 litre drum</td><td>PFR raffinate</td><td>DSRL</td><td>743</td><td>Maximum heat output at 2090 exceeds limit of 25W (based on criteria applicable at the time of assessment).</td><td>Distribution of packages to manage heat burden within vault(s).
Requirement potentially restricted to sub-set of packages.</td><td>TPC 10 501</td><td>Interim</td></tr>
</table>

Package description			Number of packages	Emplacement caveat		Endorsement	
Container	Waste	Waste owner		Challenge	Emplacement requirement	File	Status
500 litre drum	Dragon fuel	RSRL / SL	251	Significant fissile loading. Stack collapse scenario for post-closure criticality imposes unreasonably restrictive Safe Fissile Mass (SFM).	Restrictions on fissile loading (50g Pu and <1kg graphite) for other disposal units within the same stack as a single Dragon fuel disposal unit.	TPC 15 711	Conceptual
3 cubic metre drum	Trawsfynydd sludge	Magnox	28	Non-standard lifting features. Shallow twistlock pockets due to shallow slope of drum shoulders.	Potential requirement for special handling arrangements (such as dedicated lifting frame)	TPC 20 035	Final Packages manufactured
3 cubic metre drum	Trawsfynydd mixed sludge (including RV1 residues and PNV sludge)	Magnox	9	Non-standard lifting features. Shallow twistlock pockets due to shallow slope of drum shoulders.	Potential requirement for special handling arrangements (such as dedicated lifting frame)	TPC 20 540	Final Packages not yet manufactured

Package description			Number of packages	Emplacement caveat		Endorsement	
Container	Waste	Waste owner		Challenge	Emplacement requirement	File	Status
3 cubic metre drum	Trawsfynydd remaining sludge and RV3 residues	Magnox	tbc	Non-standard lifting features. Shallow twistlock pockets due to shallow slope of drum shoulders.	Potential requirement for special handling arrangements (such as dedicated lifting frame)	tbc	Planned submission based on existing endorsements
3 cubic metre box (side lifting, non-standard)	Trawsfynydd FED and skips	Magnox	3	Performance of packages in seven-high stack has not been demonstrated. Super-plasticiser used in manufacture of encapsulation grout.	Limitation on stack height (cannot be emplaced at base of stack). Potential requirement to isolate from packages with significant actinide burden.	TPC 20 059	Final Packages manufactured
3 cubic metre box (side lifting)	Harwell RIPPLE X and large sources	RSRL	4	Package identifier will be based on Berkeley (Magnox) prefix due to reallocation of boxes for use at Harwell.	Package number recognition will need to accommodate incorrect identifier prefix.	TPC 12 111	Final Packages not yet manufactured

Package description			Number of packages	Emplacement caveat		Endorsement	
Container	Waste	Waste owner		Challenge	Emplacement requirement	File	Status
3 cubic metre box (side lifting)	Hunterston A solid ILW	Magnox	300+	Package identifier will be based on Berkeley (Magnox) prefix due to reallocation of boxes for use at Hunterston A. Not all boxes will be re-allocated Berkeley boxes and remaining 600-700 boxes will carry Hunterston A prefixes.	Package number recognition will need to accommodate incorrect identifier prefix.	TPC 20 125	Interim
6 cubic metre concrete box	WAGR decommissioning ILW (various streams)	SL	112	Super-plasticiser used in manufacture of concrete box. Also used sealant in manufacture of many boxes.	Potential requirement to isolate from packages with significant actinide burden.	TPC 17 100	Final Packages manufactured (further packages may be manufactured using current stock of boxes)

Appendix H – Implications of a Change in Inventory

The following table summarises the anticipated changes in vault and tunnel numbers, and underground footprint resulting from various potential changes of inventory that have been considered in Section 16.

Geology	Vault/ Tunnel	Scenarios								
		Reference	2	3	4a	4b	8a	8b	11	12
		2013 Derived Inventory	Scenario 2 - No more Magnox reprocessing	Scenario 3 - Life time extensions	Derived Inventory Upper Volume Uncertainty	Derived Inventory Lower Volume Uncertainty	Single NNB Reactor - EPR	Single NNB Reactor - AP1000	Scenario 11 - Graphite wastes not included	Scenario 12 - Boundary wastes not included
Higher Strength Rock	UILW	20	20	20	38	16	1	1	19	20
	SILW/LLW	5	5	5	9	3	1	-	2	5
	RSILW	1	1	1	1	1	-	-	1	1
	NNB SILW	1	1	1	1	1	1	-	1	1
	DNLEU SILW	11	10	11	11	11	-	-	11	11
	HLW/SF tunnel	310	358	328	361	302	14	10	310	310
	Area km2	7.6	8.5	8.6	9.5	6.8	-	-	7.5	7.6
Lower Strength Sedimentary Rock	UILW	58	57	58	151	47	1	1	54	57
	SILW/LLW	18	18	18	24	12	1	-	5	18
	RSILW	3	3	3	3	2	-	-	3	2
	NNB SILW	5	5	5	5	5	1	-	5	5
	DNLEU SILW	30	29	30	30	30	-	-	30	30
	HLW/SF tunnel	341	394	362	395	331	17	12	341	341
	Area km2	15.3	17.0	15.7	21.5	14.4	-	-	14.7	

Geology	Vault/ Tunnel	Scenarios

		Reference	2	3	4a	4b	8a	8b	11	12
		2013 Derived Inventory	Scenario 2 - No more Magnox reprocessing	Scenario 3 - Life time extensions	Derived Inventory Upper Volume Uncertainty	Derived Inventory Lower Volume Uncertainty	Single NNB Reactor - EPR	Single NNB Reactor - AP1000	Scenario 11 - Graphite wastes not included	Scenario 12 - Boundary wastes not included
Evaporite Rock	UILW	49	48	49	89	40	1	1	45	48
	SILW/LLW	10	10	11	14	7	1	-	3	10
	RSILW	2	2	2	2	2	-	-	2	2
	NNB SILW	5	5	5	5	5	1	-	5	5
	DNLEU SILW	27	26	27	27	27	-	-	27	27
	HLW/SF tunnel	327	379	347	379	318	16	12	327	327
	Area km^2	10.3	11.1	10.7	11.9	10.0	0	0	10.1	

Appendix I - Waste Disposal Route Diagrams

NDA - 1584-04	Waste Disposal Routes for Higher Strength Rock
NDA - 1585-04	Waste Disposal Routes for Lower Strength Sedimentary Rock
NDA - 1586-04	Waste Disposal Routes for Evaporite Rock

Disposal Routes for Radioactive Wastes in Higher Strength Rock

HHGW

HLW/SF/Pu/HEU

1. Disposal Canister Transport Container (DCTC) arrives on site via rail network and waits in dedicated siding before being transferred by an on-site shunter to the HHGW Waste Receipt & Transfer Facility (WRTF)
2. DCTC unloaded from mainline rail wagon by Overhead Travelling Crane (OHTC) and transferred onto drift wagon

LHGW

UILW

1. Shielded Waste Transport Container (SWTC) arrives on site via road or rail network and waits either in the HGV parking area or dedicated siding before being transferred by an on-site shunter to the LHGW Waste Receipt & Transfer Facility (WRTF)

SILW/LLW/RSILW/NNB SILW/TDC

1. Industrial Package 2 (IP2)/Transport Overpack (TOP) arrives on site via road or rail network and waits either in the HGV parking area or dedicated siding before being transferred by an on-site tractor unit/shunter to the LHGW Waste Receipt & Transfer Facility (WRTF)

UILW and SILW/LLW/RSILW/NNB SILW/TDC

SWTC/IP2/TOP unloaded from HGV or rail wagon by Overhead Travelling Crane (OHTC) and transferred onto drift wagon

All routes

Tandem drift locos on the rack & pinion rail system haul loaded drift wagon from WRTF into Drift Top Building and descend underground via inclined drift

HLW/SF/Pu/HEU

1. Drift train arrives at the Underground HHGW Transfer Hall (TH) and the DCTC is unloaded by an OHTC and the shock absorbers are removed
2. The DCTC is then rotated to the vertical and lowered into transfer pit. The Disposal Container (DC) is then transferred vertically into the Deposition Machine (DM). The shielded section of the DM is then rotated to the horizontal
3. DM drives to Disposal Tunnel (DT) and is positioned directly over a Deposition Hole (DH). The shielded section of the DM is rotated to the vertical, the gamma gate opened and the DC is lowered into the bentonite lined DH
4. Finally the DM lowers bentonite plugs to cap the DH and retreats from the DT back to TH

UILW

1. Drift train arrives at the Underground UILW Container & Stillage Reception Area
2. SWTC unloaded by OHTC from drift wagon and transferred onto Inlet Cell Bogie (ICB) within Transfer Station
3. Roller shutter door closes, inner shield door opens and the ICB moves to the Lid Seal/Unbolting Station within Inlet Cell
4. With the seal released and bolts removed, ICB moves to the Lid Removal Station. With the lid removed ICB moves to the Package Removal Station.
5. Once on station, the containment shroud descends, the overhead hatch opens and the Package Transfer Machine lifting mechanism descends to engage on the Disposal Unit (DU)
6. The DU is removed from the SWTC, raised into the Package Transfer Area and moved horizontally to be placed on the Transfer Tunnel Bogie (TTB)
7. TTB moves along the Transfer Tunnel to directly below the UILW Vault access hatch. Vault Emplacement Crane (VEC) lifting mechanism descends and engages with DU and then ascends back into the vault to be secured within the VEC traverser
8. VEC moves to designated position, lowers DU to vault floor or stack position, releases DU and retreats back to Crane Maintenance Area

SILW/LLW/RSILW/NNB SILW/TDC

1. Drift train arrives at the Underground SILW/LLW/RSILW/NNB SILW/TDC Container Reception Area
2. IP2/TOP unloaded by OHTC from drift wagon and transferred to SILW/LLW/RSILW/NNB SILW/TDC Temporary Storage Area (TSA)

IP2 route

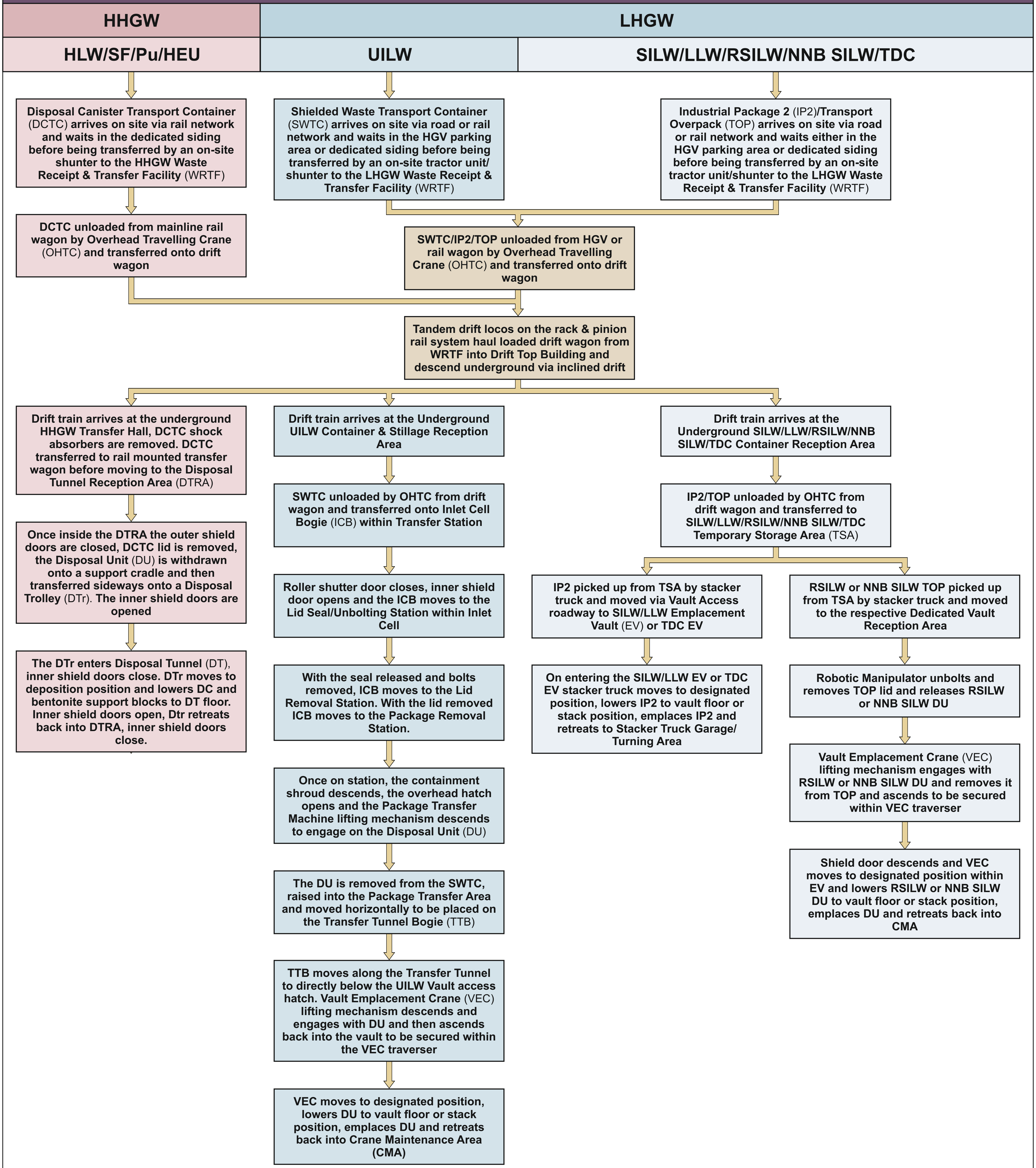
1. IP2 picked up from TSA by stacker truck and moved via Vault Access roadway to SILW/LLW Emplacement Vault (EV) or TDC (EV)
2. On entering the SILW/LLW EV or TDC EV stacker truck moves to design-ated position, lowers IP2 to vault floor or stack position, emplaces IP2 and retreats to Stacker Truck Garage/Turning Area

TOP route

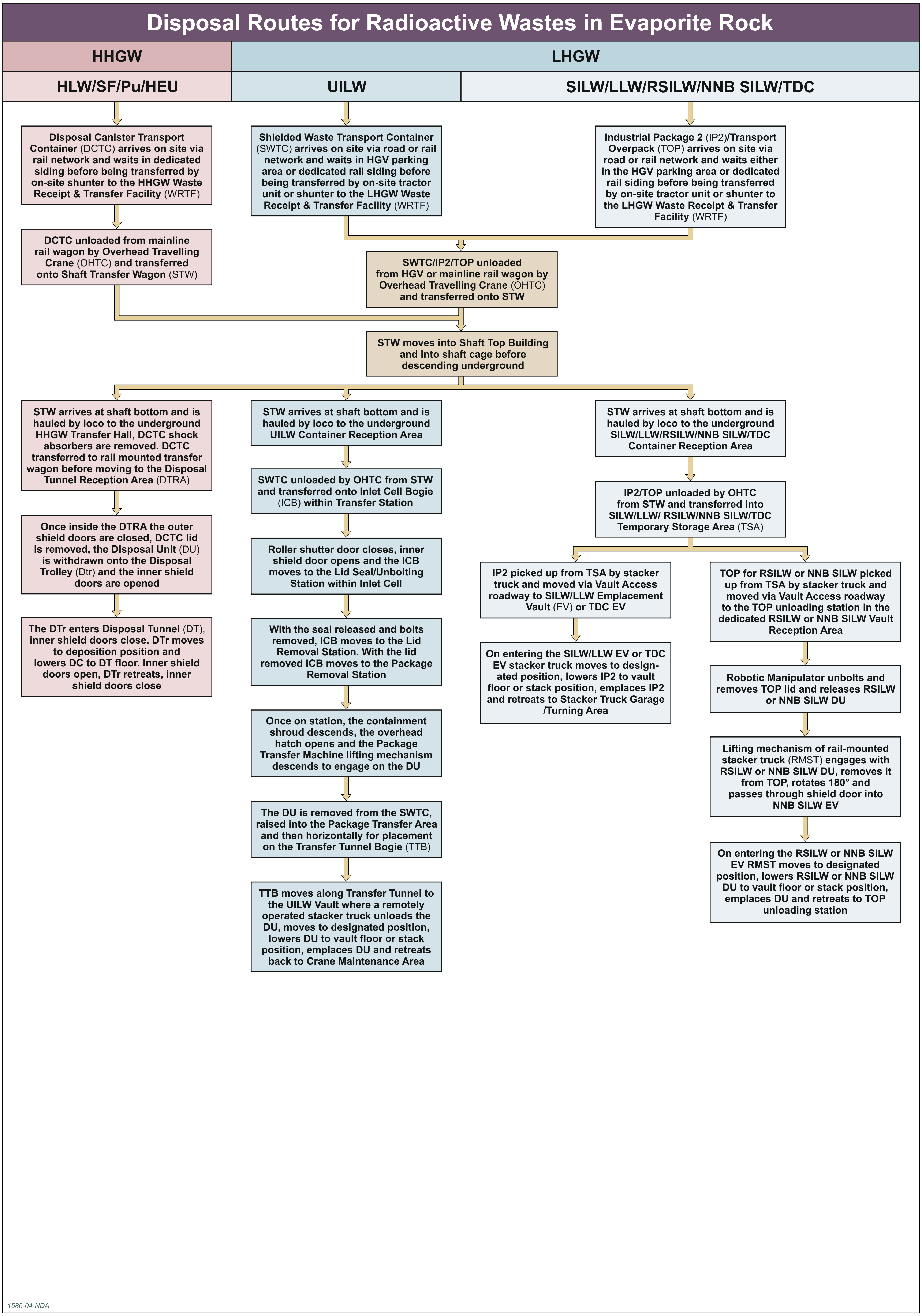
1. RSILW or NNB SILW TOP picked up from TSA by stacker truck and moved to the respective Dedicated Vault Reception Area (DVRA)
2. On entering the DVRA, stacker truck moves to designated position, lowers TOP onto removal station, and retreats to STG/TA.
3. With the DVRA roller-shutter containment door closed, the Robotic Manipulator unbolts and removes TOP lid and releases RSILW or NNB SILW DU
4. Vault Emplacement Crane (VEC) lifting mechanism engages with RSILW or NNB SILW DU and removes it from TOP and ascends to be secured within VEC traverser
5. Shied door descends and VEC moves to designated position within EV and lowers RSILW or NNB SILW DU to vault floor or stack position, emplaces DU and retreats back into CMA

1584-04-NDA

Disposal Routes for Radioactive Wastes in Lower Strength Sedimentary Rock



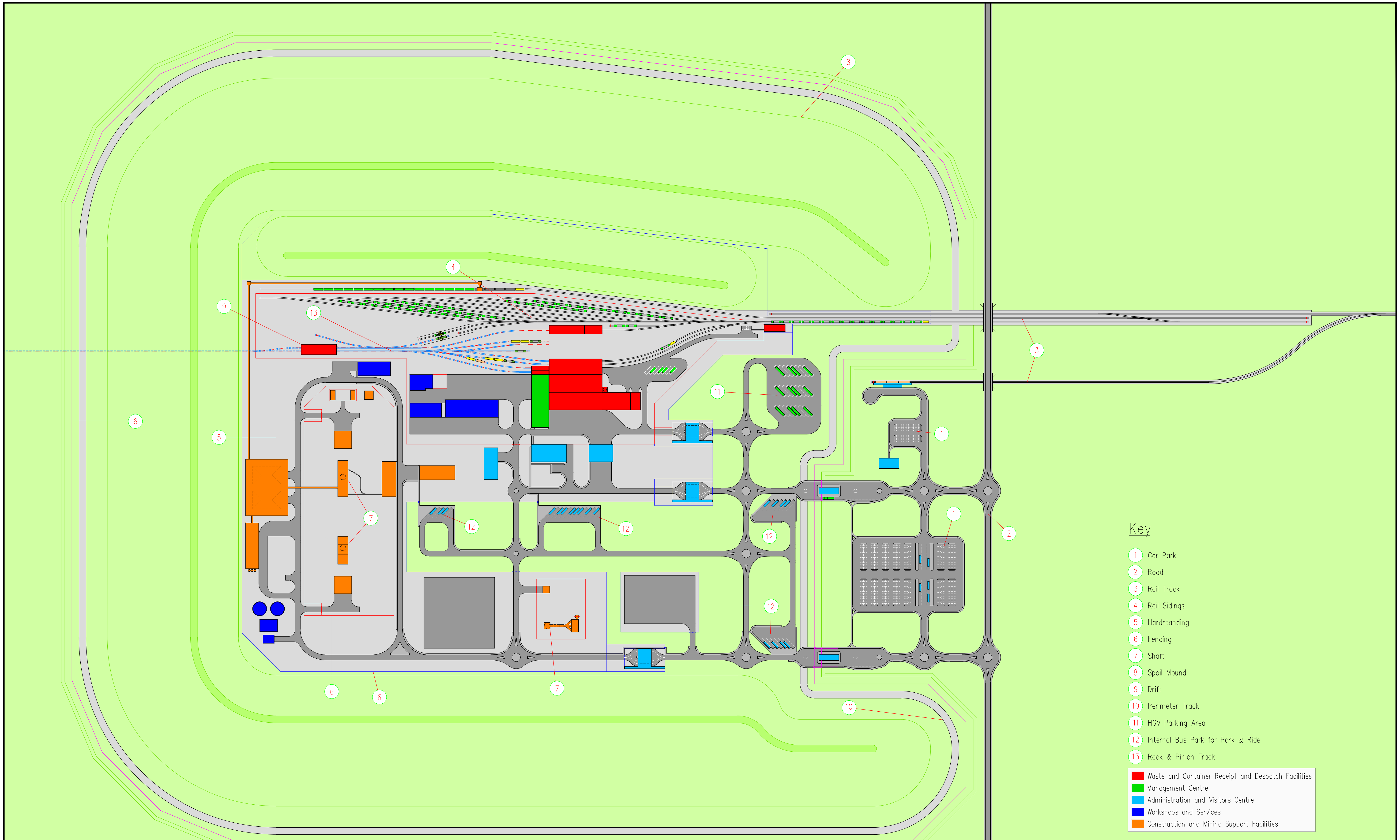
1585-04-NDA


Disposal Routes for Radioactive Wastes in Evaporite Rock
HHGW
LHGW
HLW/SF/Pu/HEU
UILW
SILW/LLW/RSILW/NNB SILW/TDC
Disposal Canister Transport Container (DCTC) arrives on site via rail network and waits in dedicated siding before being transferred by on-site shunter to the HHGW Waste Receipt & Transfer Facility (WRTF)
DCTC unloaded from mainline rail wagon by Overhead Travelling Crane (OHTC) and transferred onto Shaft Transfer Wagon (STW)
Shielded Waste Transport Container (SWTC) arrives on site via road or rail network and waits in HGV parking area or dedicated rail siding before being transferred by on-site tractor unit or shunter to the LHGW Waste Receipt & Transfer Facility (WRTF)
Industrial Package 2 (IP2)/Transport Overpack (TOP) arrives on site via road or rail network and waits either in the HGV parking area or dedicated rail siding before being transferred by on-site tractor unit or shunter to the LHGW Waste Receipt & Transfer Facility (WRTF)
SWTC/IP2/TOP unloaded from HGV or mainline rail wagon by Overhead Travelling Crane (OHTC) and transferred onto STW
STW moves into Shaft Top Building and into shaft cage before descending underground
STW arrives at shaft bottom and is hauled by loco to the underground HHGW Transfer Hall, DCTC shock absorbers are removed. DCTC transferred to rail mounted transfer wagon before moving to the Disposal Tunnel Reception Area (DTRA)
Once inside the DTRA the outer shield doors are closed, DCTC lid is removed, the Disposal Unit (DU) is withdrawn onto the Disposal Trolley (Dtr) and the inner shield doors are opened
The DTr enters Disposal Tunnel (DT), inner shield doors close. DTr moves to deposition position and lowers DC to DT floor. Inner shield doors open, DTr retreats, inner shield doors close
STW arrives at shaft bottom and is hauled by loco to the underground UILW Container Reception Area
SWTC unloaded by OHTC from STW and transferred onto Inlet Cell Bogie (ICB) within Transfer Station
Roller shutter door closes, inner shield door opens and the ICB moves to the Lid Seal/Unbolting Station within Inlet Cell
With the seal released and bolts removed, ICB moves to the Lid Removal Station. With the lid removed ICB moves to the Package Removal Station
Once on station, the containment shroud descends, the overhead hatch opens and the Package Transfer Machine lifting mechanism descends to engage on the DU
The DU is removed from the SWTC, raised into the Package Transfer Area and then horizontally for placement on the Transfer Tunnel Bogie (TTB)
TTB moves along Transfer Tunnel to the UILW Vault where a remotely operated stacker truck unloads the DU, moves to designated position, lowers DU to vault floor or stack position, emplaces DU and retreats back to Crane Maintenance Area
STW arrives at shaft bottom and is hauled by loco to the underground SILW/LLW/RSILW/NNB SILW/TDC Container Reception Area
IP2/TOP unloaded by OHTC from STW and transferred into SILW/LLW/ RSILW/NNB SILW/TDC Temporary Storage Area (TSA)
IP2 picked up from TSA by stacker truck and moved via Vault Access roadway to SILW/LLW Emplacement Vault (EV) or TDC EV
On entering the SILW/LLW EV or TDC EV stacker truck moves to design-ated position, lowers IP2 to vault floor or stack position, emplaces IP2 and retreats to Stacker Truck Garage /Turning Area
TOP for RSILW or NNB SILW picked up from TSA by stacker truck and moved via Vault Access roadway to the TOP unloading station in the dedicated RSILW or NNB SILW Vault Reception Area
Robotic Manipulator unbolts and removes TOP lid and releases RSILW or NNB SILW DU
Lifting mechanism of rail-mounted stacker truck (RMST) engages with RSILW or NNB SILW DU, removes it from TOP, rotates 180° and passes through shield door into NNB SILW EV
On entering the RSILW or NNB SILW EV RMST moves to designated position, lowers RSILW or NNB SILW DU to vault floor or stack position, emplaces DU and retreats to TOP unloading station
1586-04-NDA

Drawings

Higher strength rock illustrative design drawings

E/DRG/0041021	Overall Surface Layout - First Emplacement of LHGW
E/DRG/0041023	Overall Surface Layout - End of Construction
E/DRG/0041026	2013 Derived Inventory – Underground Layout – End of Operational Phase
E/DRG/0041027	2013 Derived Inventory – Underground Layout – Waste Categories
E/DRG/0041028	2013 Derived Inventory – UILW Underground Emplacement Support Facilities – High and Low Level Layouts
E/DRG/0041029	2013 Derived Inventory – UILW Underground Emplacement Support Facilities – Longitudinal Section
E/DRG/0041030	2013 Derived Inventory – UILW Disposal Vault Transfer and Emplacement – Longitudinal Section
E/DRG/0041031	2013 Derived Inventory – SILW/LLW Disposal Vault Transfer and Emplacement – Longitudinal Section
E/DRG/0041032	2013 Derived Inventory – UILW & SILW/LLW Disposal Vault Transfer and Emplacement – Cross sections
E/DRG/0041033	2013 Derived Inventory – RSILW Container Disposal Vault Transfer and Emplacement – Layout and Longitudinal Section
E/DRG/0041034	2013 Derived Inventory – NNB SILW Concrete Drum Disposal Vault Transfer and Emplacement – Layout and Longitudinal Section
E/DRG/0041035	2013 Derived Inventory – RSILW Container & NNB SILW Concrete Drum Vault Transfer and Emplacement – Cross-Sections
E/DRG/0041036	2013 Derived Inventory – HHGW Transfer Hall - Layout & Sections
E/DRG/0041037	2013 Derived Inventory – HHGW Disposal Tunnel and Deposition Holes – Cross & Longitudinal Sections
E/DRG/0041038	LHGW, HHGW & Common Services Area – Excavation Profiles
E/DRG/0041039	SILW/DNLEU Disposal Vault Transfer and Emplacement Cross-Section



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STAT/REV	APPROVED BY	AUTHORISED BY RWM	DESCRIPTION	DRAWN	CHECKED	DATE
P–05	S.LESSER	I.PHIMISTER	REVISION DETAILS ADDED	T.WARING	D.WILLIS	NOV 16
P0–4	S.LESSER	I.PHIMISTER	REVISED ANNOTATION TO MEET SECURITY REQUIREMENTS	T.WARING	S.LESSER	APRIL 2016
P03	S.LESSER	M.JOHNSON	FIRST REVISION OF SURFACE LAYOUT. DRAWING NUMBER PREVIOUSLY USED FOR UNDERGROUND LAYOUT. RENUMBERED AND RETITLED.	A.UBHOO	P.GASKELL	DEC 14

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DATE	DEC 14

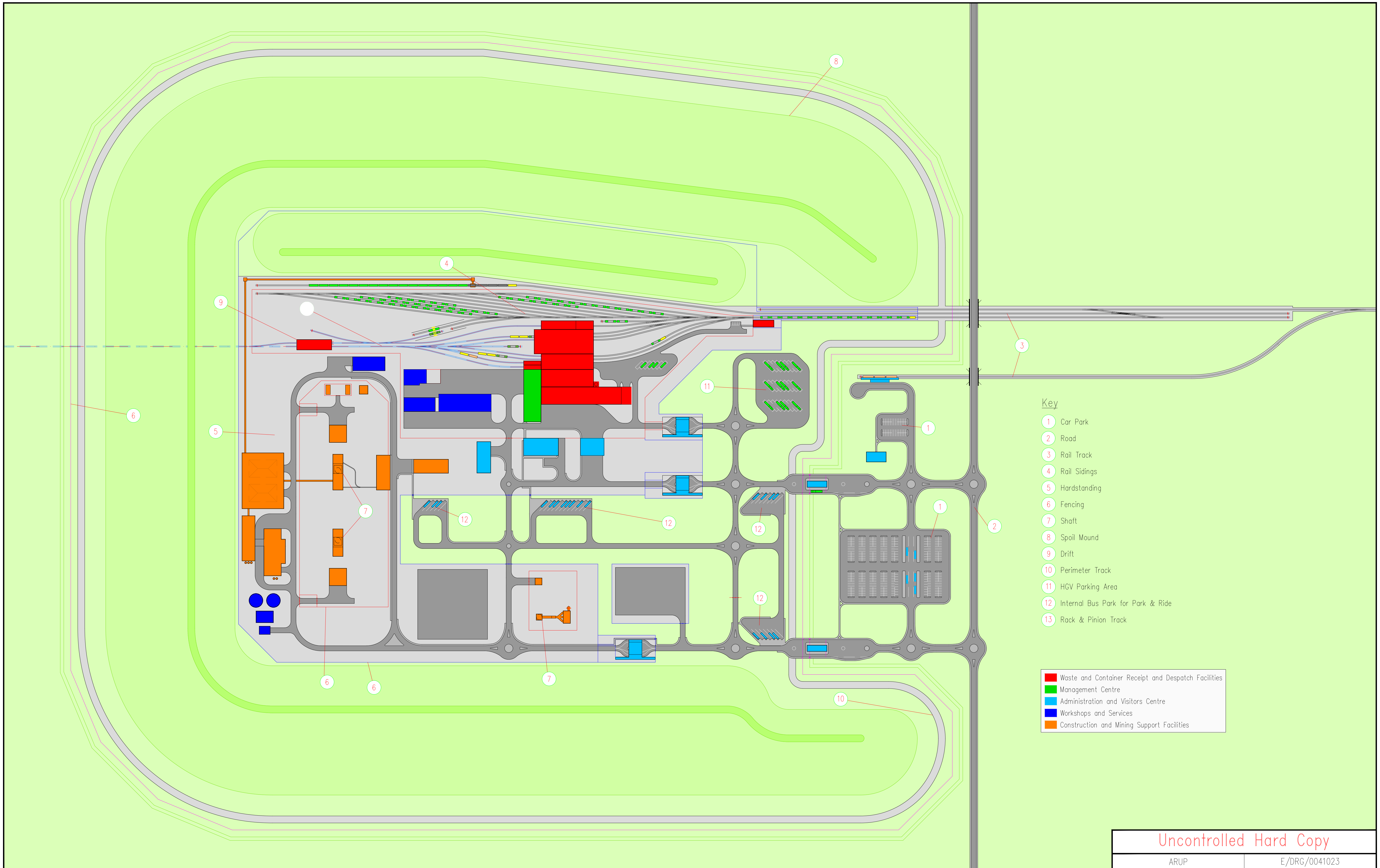
Radioactive Waste Management

W.B.S.	50003.11.03
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:5000

GEOLOGICAL DISPOSAL FACILITY

2013 INVENTORY FOR DISPOSAL
HIGHER STRENGTH ROCK
Overall Surface Layout
First Emplacement of LHGW

A3 SIZE | DRG. No. E/DRG/0041021 | P–05 STAT/REV



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P-04	S.LESSER	I.PHIMISTER	REVISION DETAILS ADDED.	T.WARING	D.WILLIS	NOV 16
P-03	S.LESSER	I.PHIMISTER	REVISED ANNOTATIONS TO MEET SECURITY REQUIREMENTS DRAWING NUMBER PREVIOUSLY USED FOR UNDERGROUND LAYOUT. RENUMBERED AND RETITLED.			
P-02	S.LESSER	M.JOHNSON	ISSUED AS SURFACE LAYOUT DRAWING. DRAWING NUMBER PREVIOUSLY USED FOR UNDERGROUND LAYOUT. RENUMBERED AND RETITLED.	A.UBHOO	P.GASKELL	DEC 14

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APPROVED	S.LESSER
AUTHORISED BY RWM	M.JOHNSON
DATE	DEC 2014

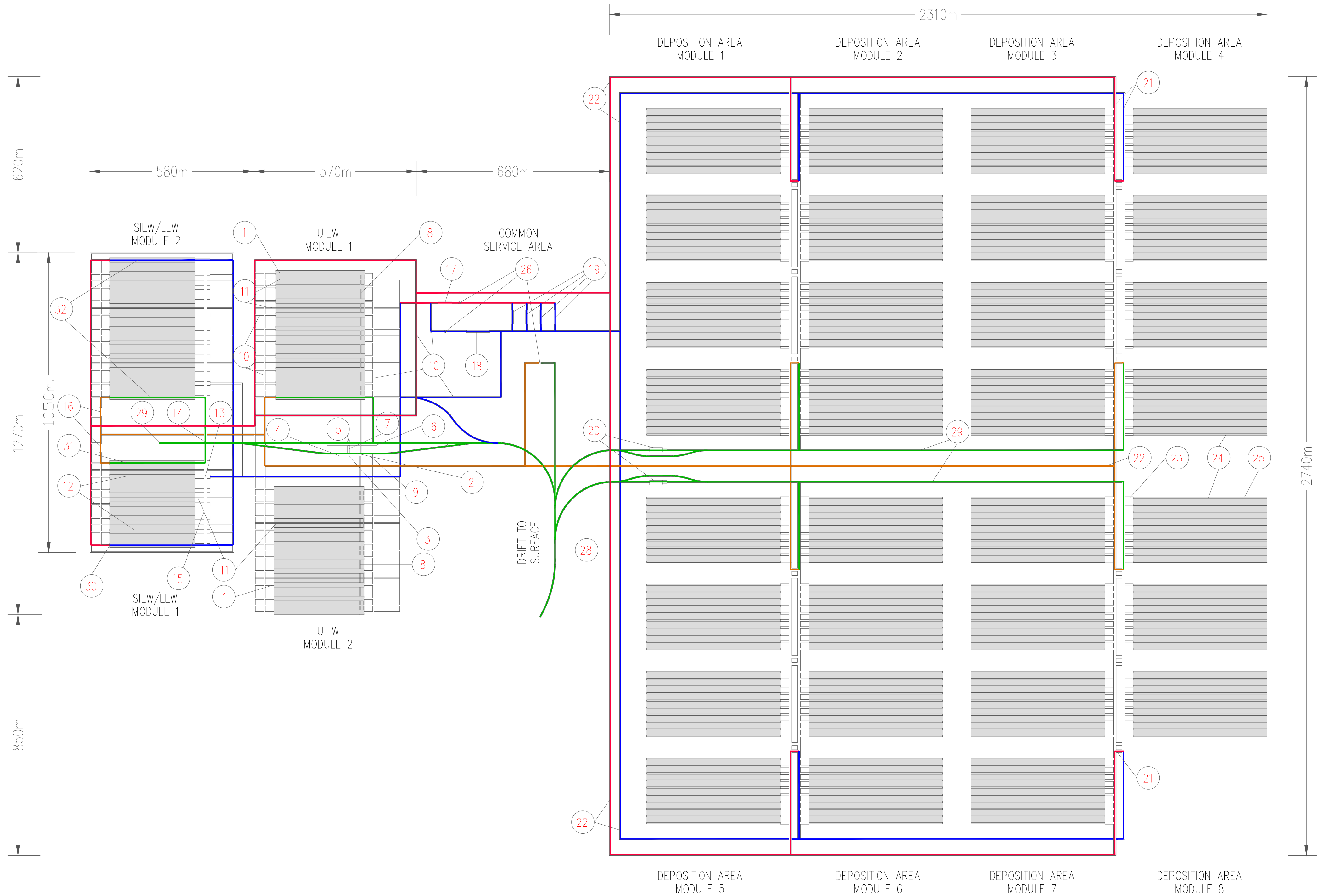
Radioactive Waste Management

W.B.S.	50003.11.03
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:5000

GEOLOGICAL DISPOSAL FACILITY

2013 INVENTORY FOR DISPOSAL
HIGHER STRENGTH ROCK
Overall Surface Layout
End of Construction

A3 SIZE | DRG. No. E/DRG/0041023 | P-04 STAT/REV



1 UILW DISPOSAL VAULT
2 UILW INLET CELL
3 UILW PACKAGE TRANSFER
4 UILW TRANSPORT CONTAINER TRANSFER LINE
5 UILW RECEPTION/MARSHALLING AREA (HIGH)
6 UILW RECEPTION/MARSHALLING AREA (LOW)
7 UILW ACTIVE AREA SUPPORT FACILITY
8 UILW TRANSFER TUNNEL
9 LHGW EFFLUENT RECEPTION/DESPATCH
10 LHGW SERVICE TUNNELS
11 LHGW BACKFILL GALLERY
12 SILW/LLW DISPOSAL VAULT
13 SILW/LLW FORKLIFT GARAGE/TURNING AREA
14 SILW/LLW TEMPORARY STORE
15 SILW/LLW VAULT ACCESS
16 SILW/LLW HEPA FILTERS
17 HHGW/LHGW SPOIL BUNKER
18 HHGW/LHGW VENTILATION HALL
19 HHGW/LHGW SUPPORT HALLS
20 HHGW TRANSFER HALL
21 HHGW TRANSPORT TUNNEL
22 HHGW SERVICE TUNNEL
23 HHGW DISPOSAL TUNNEL ENTRANCE
24 HHGW DISPOSAL TUNNEL
25 HHGW DEPOSITION HOLE
26 ACCESS SHAFTS
27 BORED DRIFT
28 DRILL & BLAST DRIFT
29 DRIFT EXTENSION
30 RSILW CONTAINER DISPOSAL VAULT
31 NNB SILW CONCRETE DRUM DISPOSAL VAULT
32 DNLEU VAULTS

LEGEND

- CONSTRUCTION INTAKE
- CONSTRUCTION RETURN
- EMPLACEMENT INTAKE
- EMPLACEMENT RETURN

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STAT/REV	APPROVED BY	AUTHORISED BY RWM
P02	S.LESSER	I.PHIMISTER

UPDATED FOLLOWING IMPLEMENTATION OF CR54 REVISED NUMBER OF VAULTS TO 20 AND 11 NEW VAULTS ADDED FOR DNLEU PACKED IN TDC'S

DRAWN	CHECKED	DATE
N.ROBERTSON	P.GASKELL	JULY 2016

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for RADIOACTIVE WASTE MANAGEMENT LTD UNDER CONTRACT INSTRUCTION No. 007927

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CHECKED	P.GASKELL
APPROVED	S.MILWARD
AUTHORISED BY RWM	M.JOHNSON
DATE	MARCH 2015

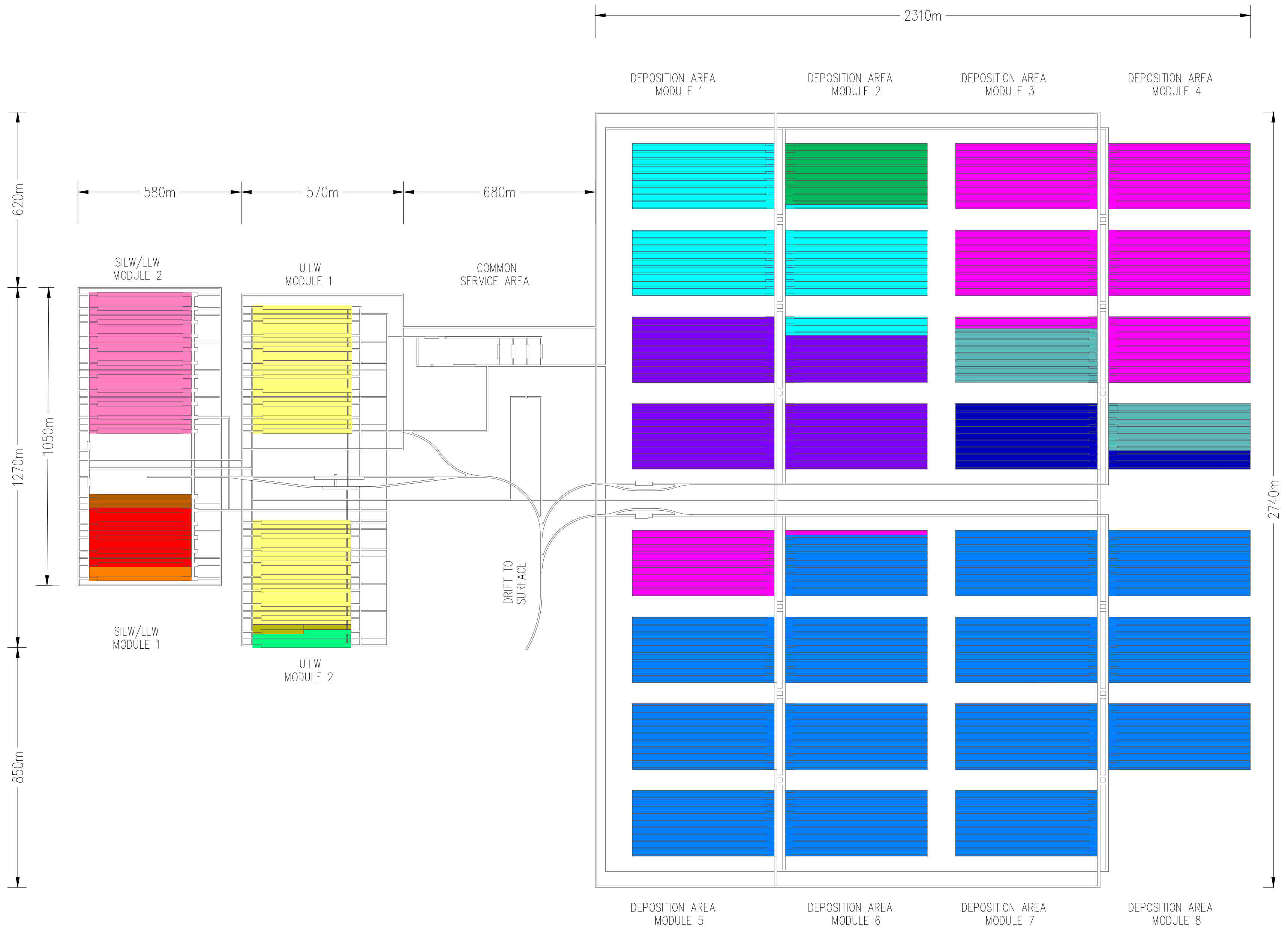
Radioactive Waste Management

W.B.S.	50003.11.03
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:10000

GEOLOGICAL DISPOSAL FACILITY

2013 INVENTORY FOR DISPOSAL
HIGHER STRENGTH ROCK
UNDERGROUND LAYOUT
END OF OPERATIONAL PHASE

A3 SIZE | DRG. No. E/DRG/0041026 | P/02 STAT/REV



LHGW	NUMBER OF DISPOSAL VAULTS
LEGACY SILW/LLW	5.0
NNB SILW	1.0
RSILW	1.0
DNLEU (SILW)	11.0
LEGACY UILW	18.0
DNLEU (UILW)	0.5
NNB UILW	1.5
TOTAL LHGW	38.0

HHGW	NUMBER OF DISPOSAL TUNNELS
LEGACY HLW	37.3
LEGACY AGR SF	33.9
LEGACY PWR SF	8.9
LEGACY MAGNOX/PFR SF	13.3
PU/HEU	15.1
MOX SF	62.6
NNB SF	138.8
TOTAL HHGW	310.0

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ARUP E/DRG/0041027

STAT/REV	APPROVED BY	AUTHORISED BY RWM
P02	S.LESSER	I.PHIMISTER

UPDATED FOLLOWING IMPLEMENTATION OF CR54 REVISED NUMBER OF VAULTS TO 20 AND 11 NEW VAULTS ADDED FOR DNLEU PACKAGED IN TDC'S

DRAWN	CHECKED	DATE
N.ROBERTSON	P.GASKELL	JULY 2016

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CHECKED	P.GASKELL
APPROVED	S.MILWARD
AUTHORISED BY RWM	M.JOHNSON
DATE	MARCH 2015

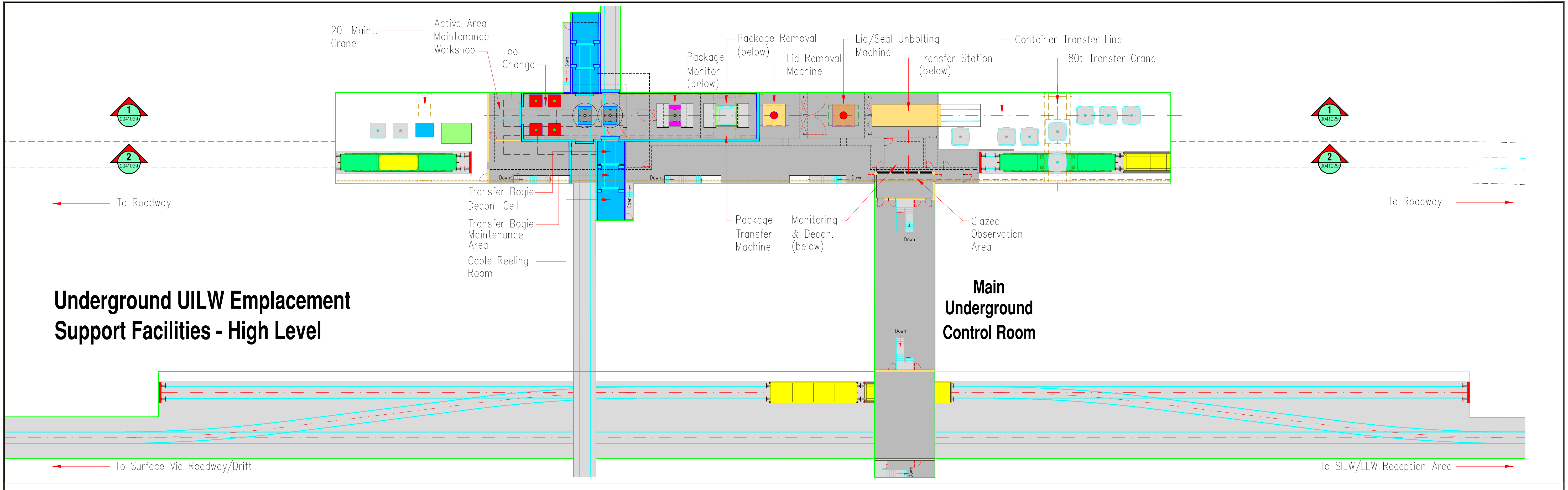
Radioactive Waste Management

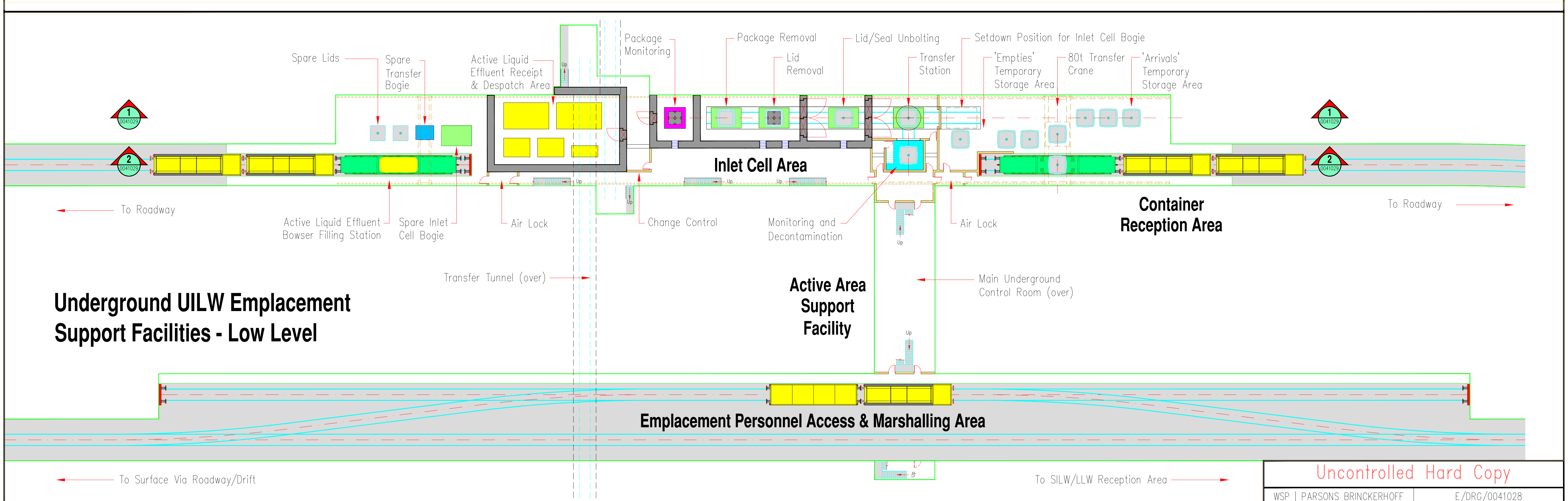
W.B.S.	50003.11.03
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:10000

GEOLOGICAL DISPOSAL FACILITY

2013 INVENTORY FOR DISPOSAL
HIGHER STRENGTH ROCK
UNDERGROUND LAYOUT
WASTE CATEGORIES

A3 SIZE | DRG. No. E/DRG/0041027 | P/02 STAT/REV





STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	DRAWN	CHECKED	DATE	Description
P–03	S. MAJHU	I.PHIMISTER	M. PADLEY	P. GASKELL	MARCH 2017	REVISED IN LINE WITH CLIENT COMMENTS MARCH 2017
P–02	S.MAJHU	I.PHIMISTER	R.SINGLETON	P.GASKELL	JULY 2016	REVISED TO RWM COMMENTS

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INSTRUCTION No. RWM 007927

SECURITY CLASS
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DRAWN	R.STACEY
CHECKED	P.GASKELL
APPROVED	S. MILWARD
AUTHORISED BY RWM	M.JOHNSON
DATE	DEC 2014

Radioactive Waste Management

W.B.S.	
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	NTS

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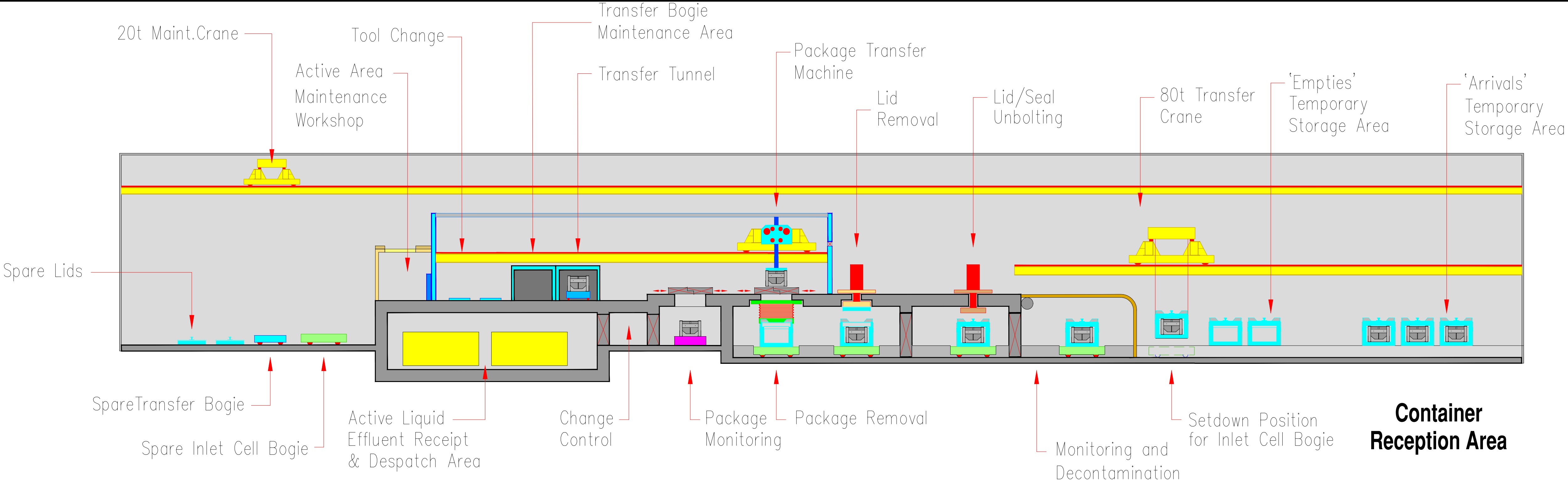
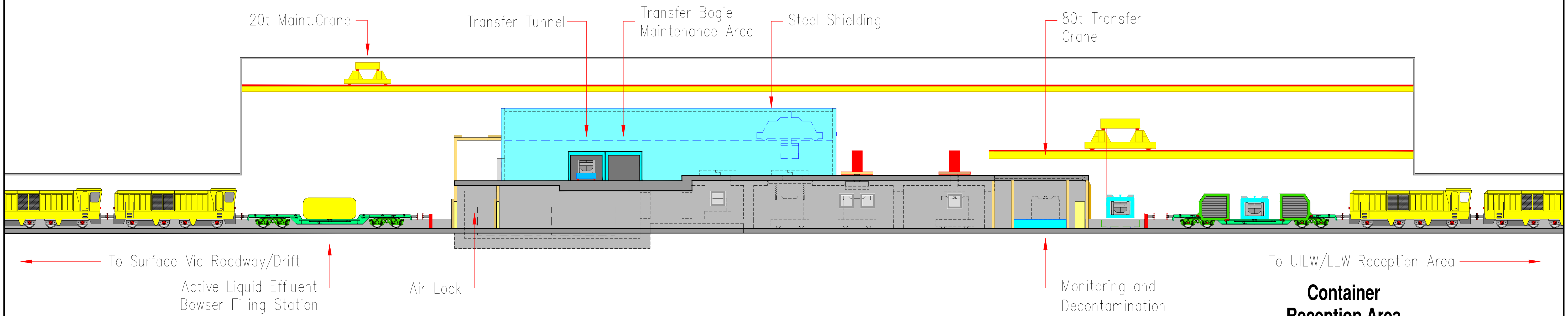
GEOLOGICAL DISPOSAL FACILITY

2013 DERIVED INVENTORY
HIGHER STRENGTH ROCK
UNDERGROUND UILW EMPLACEMENT SUPPORT FACILITIES
HIGH & LOW LEVEL LAYOUTS

A3 SIZE | DRG. No. E/DRG/0041028 | P–03 STAT/REV



Underground UILW Emplacement Support Facilities - Longitudinal Section 1-1



Underground UILW Emplacement Support Facilities - Longitudinal Section 2-2

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STAT/REV	APPROVED BY PB	AUTHORISED BY RWM
P-03	S. MAJHU	I.PHIMISTER
REVISED IN LINE WITH CLIENT COMMENTS MARCH 2017		
DRAWN	CHECKED	DATE
M. PADLEY	P. GASKELL	MARCH 2017
P-02	S.MAJHU	I.PHIMISTER
REMOVAL OF SUPERFLUOUS ANNOTATIONS.		
DRAWN	CHECKED	DATE
T.PRATT	P.GASKELL	OCT 2016

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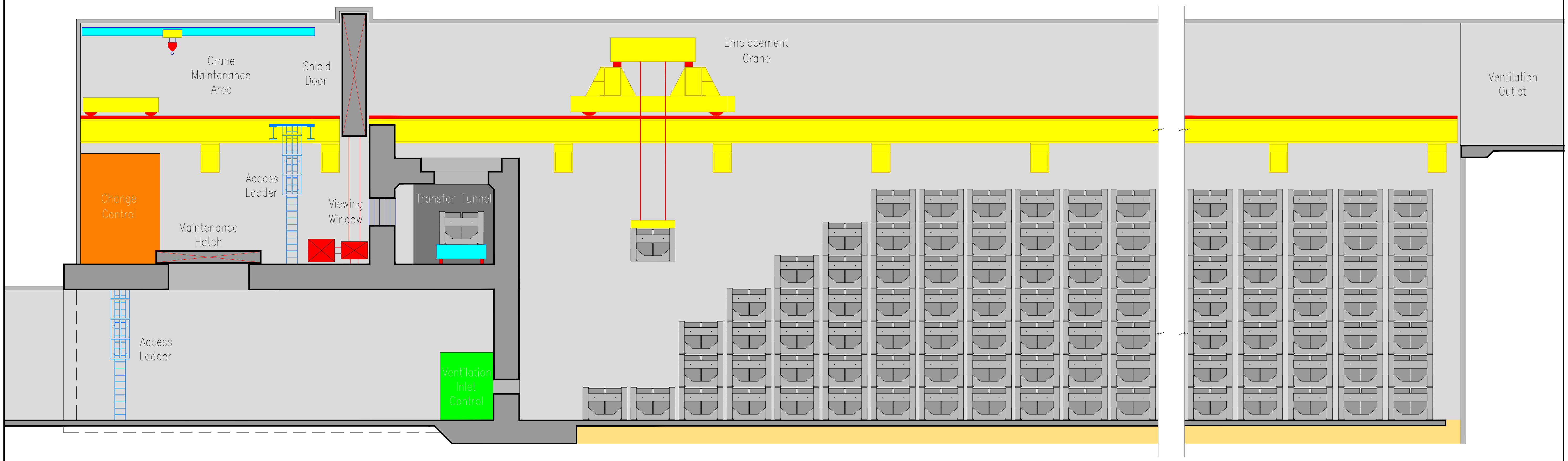
APPROVED	S. MILWARD
AUTHORISED BY RWM	M.JOHNSON
DATE	DEC 2014

Radioactive Waste Management

W.B.S.	
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:375

GEOLOGICAL DISPOSAL FACILITY
2013 DERIVED INVENTORY
HIGHER STRENGTH ROCK
UNDERGROUND UILW EMPLACEMENT SUPPORT FACILITIES
LONGITUDINAL SECTIONS

A3 SIZE | DRG. No. E/DRG/0041029 | P-03 STAT/REV



STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM
DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE

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AUTHORISED BY RWM	M.JOHNSON
DATE	DEC 2014

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W.B.S.	
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:150

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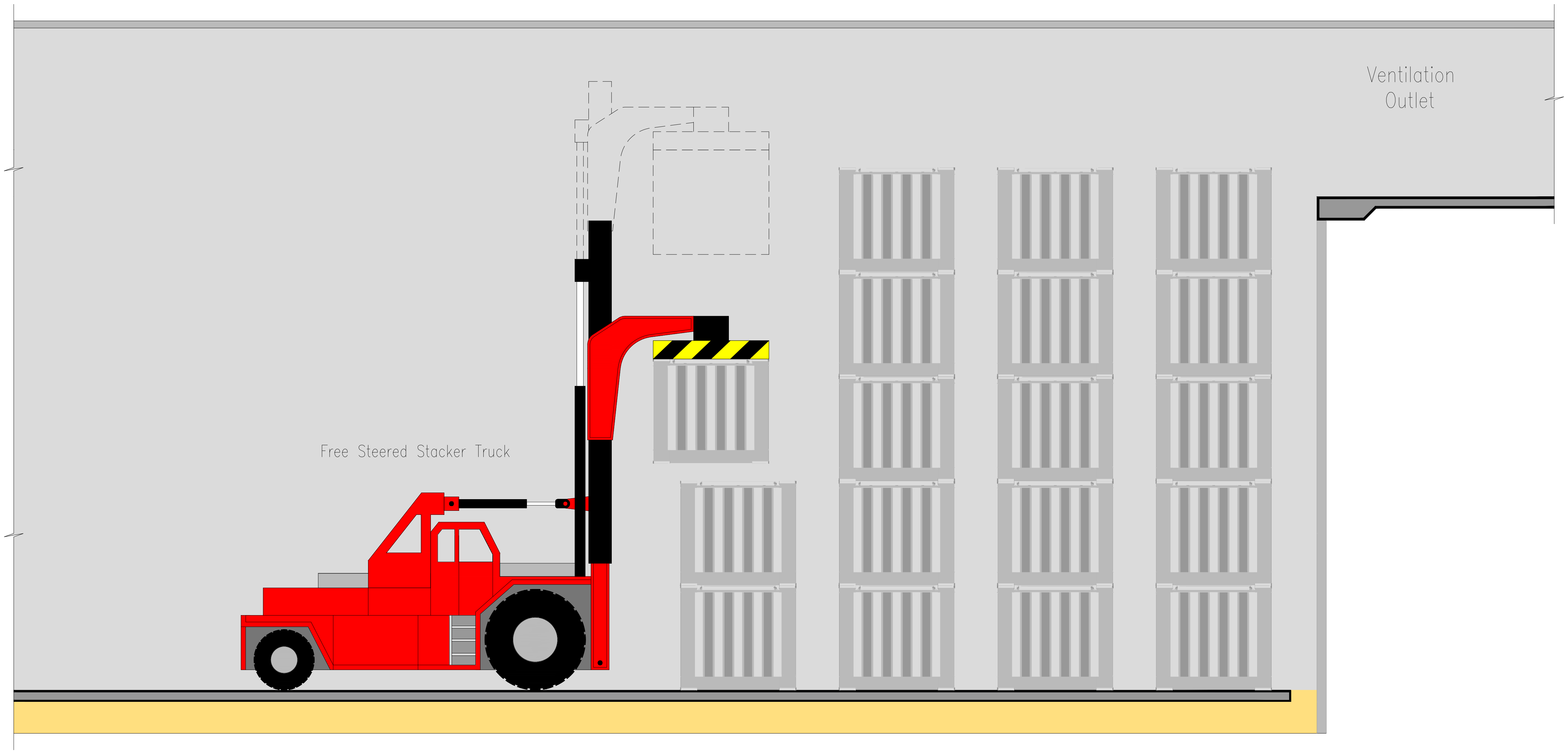
GEOLOGICAL DISPOSAL FACILITY

2013 DERIVED INVENTORY
HIGHER STRENGTH ROCK
UILW DISPOSAL VAULT TRANSFER AND EMPLACEMENT
LONGITUDINAL SECTION

A3 SIZE | DRG. No. E/DRG/0041030 | P-01 STAT/REV



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STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	DESCRIPTION	DRAWN	CHECKED	DATE
P-03	S. MAJHU	I.PHIMISTER	REVISED IN LINE WITH CLIENT COMMENTS MARCH 2017	M. PADLEY	P. GASKELL	MARCH 2017
P-02	S.MAJHU	I.PHIMISTER	REVISED STACKER TRUCK TO REMOVE EXHAUST AND AMENDED ANNOTATION.	R.SIINGLETON	P.GASKELL	JULY 2016

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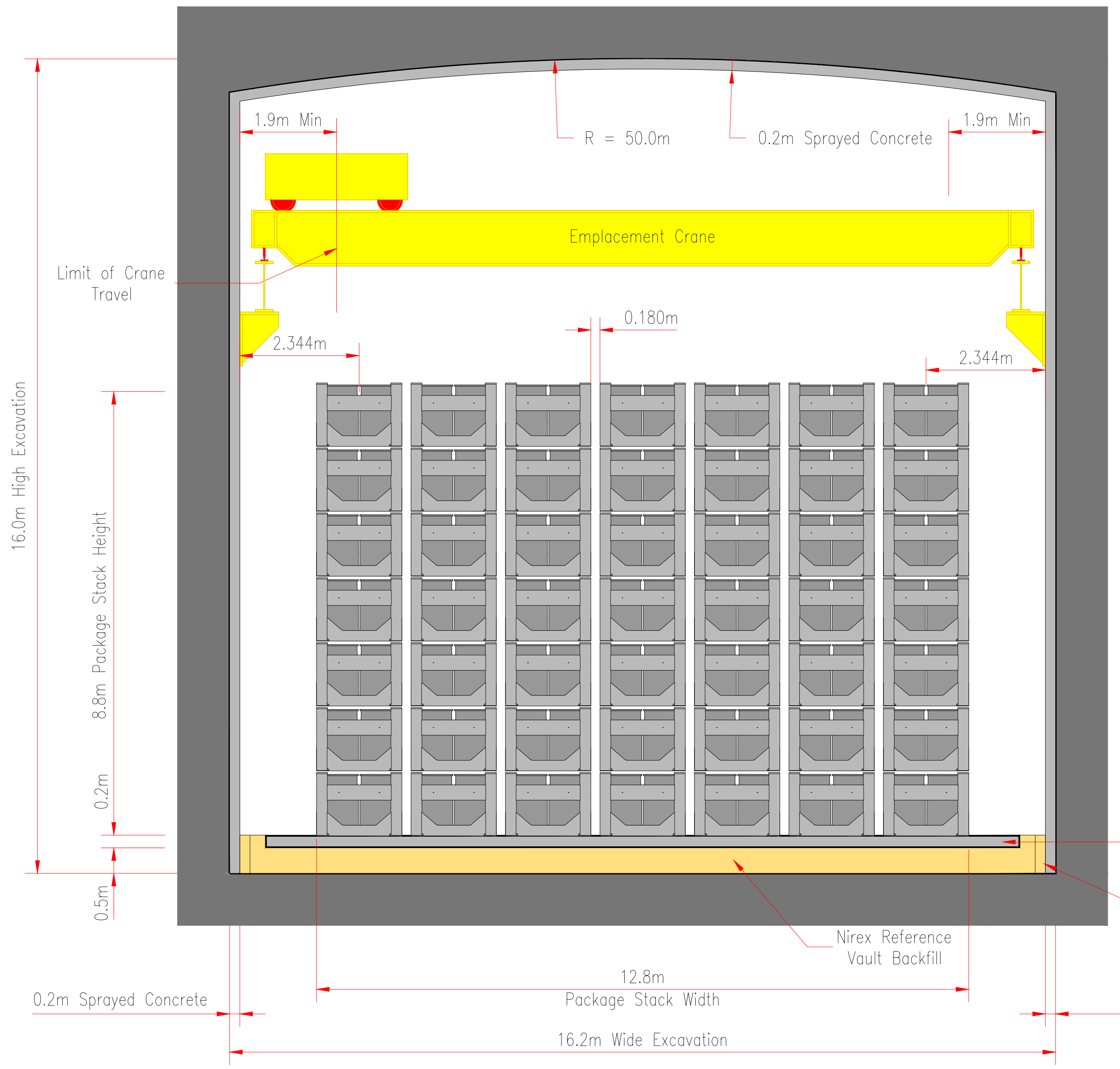
CHECKED	
APPROVED	
AUTHORISED BY RWM	M.JOHNSON
DATE	DEC 2014

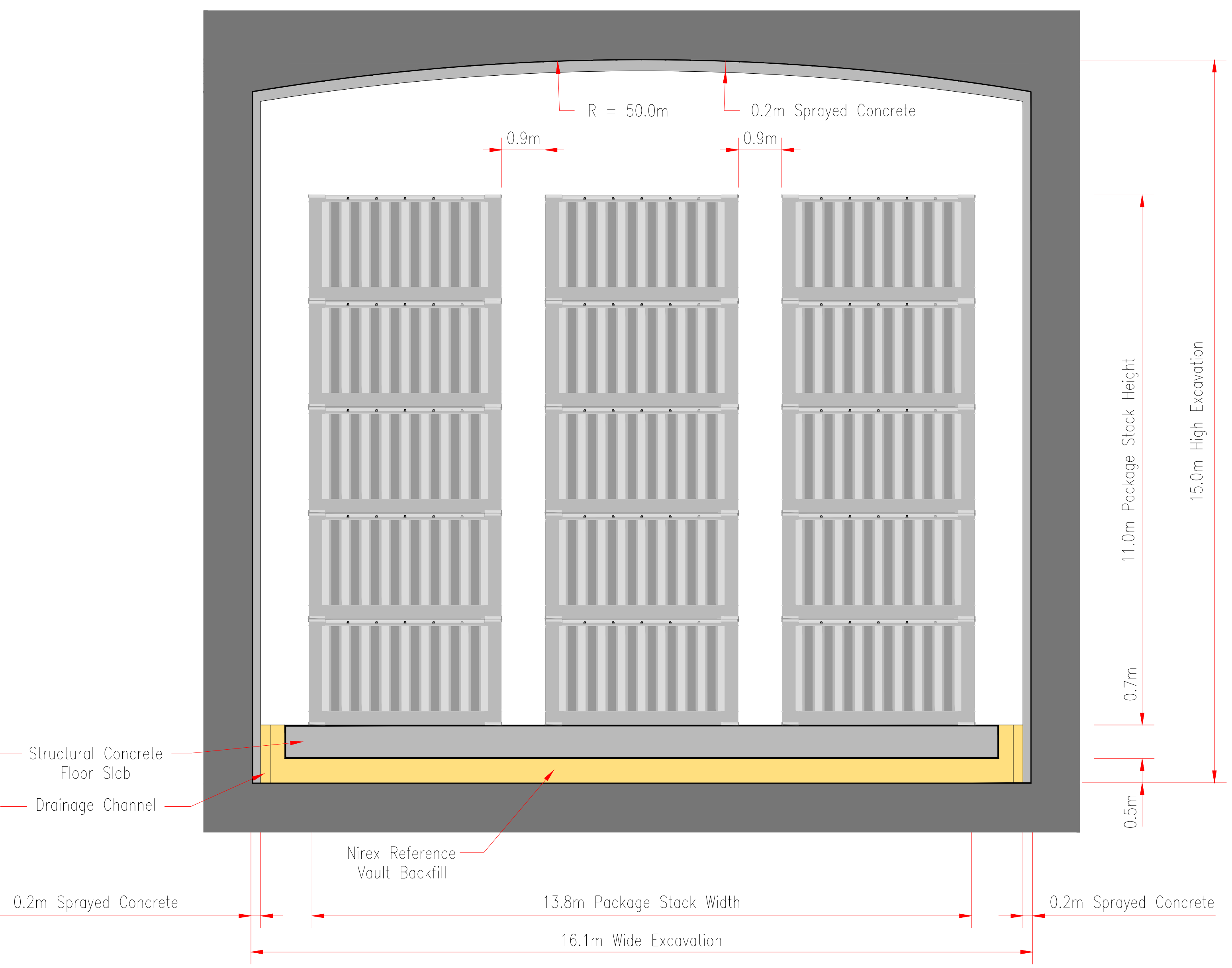
W.B.S.	
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:100

GEOLOGICAL DISPOSAL FACILITY
2013 DERIVED INVENTORY
HIGHER STRENGTH ROCK
SILW/LLW DISPOSAL VAULT TRANSFER AND EMPLACEMENT
LONGITUDINAL SECTION

SIZE	DRG. No.	STAT/REV
A3	E/DRG/0041031	P-03



UILW Vault



SILW/LLW Vault

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STAT/REV	APPROVED BY PB	AUTHORISED BY RWM
P-02	S.MAJHU	I.PHIMISTER

UPDATED THE PACKAGE SPACING DIMENSIONS BASED ON THE VAULT & TUNNEL CALCULATOR FOR HIGHER STRENGTH ROCK, UPDATED TO IMPLEMENT CR54. ALSO AMENDED ANNOTATIONS

DRAWN	CHECKED	DATE
R.SINGLETON	P.GASKELL	OCT 2016

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DRAWN	R.STACEY
CHECKED	P.GASKELL
APPROVED	S.MILWARD
AUTHORISED BY RWM	M.JOHNSON
DATE	DEC 2014

Radioactive Waste Management

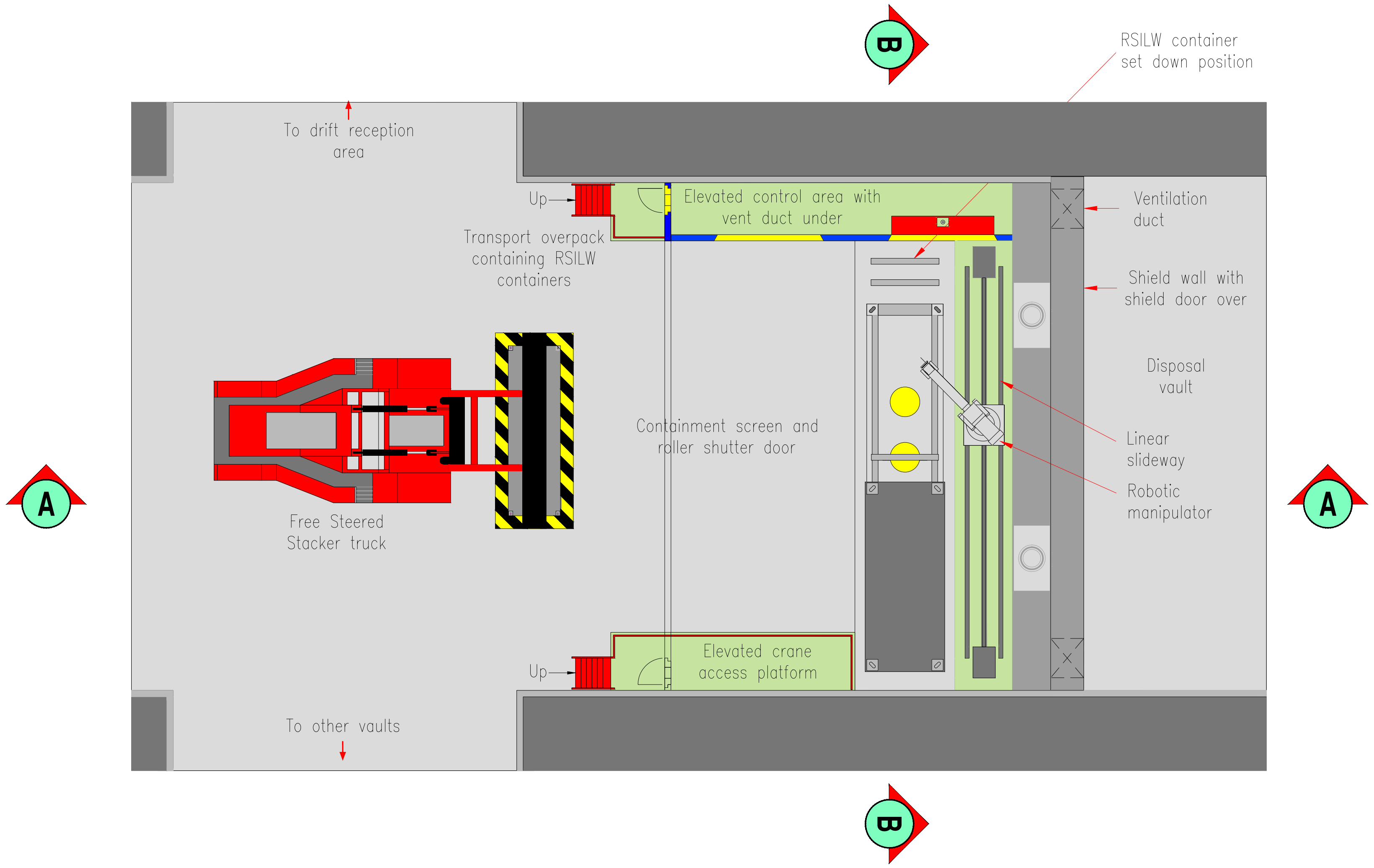
W.B.S.	
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:125

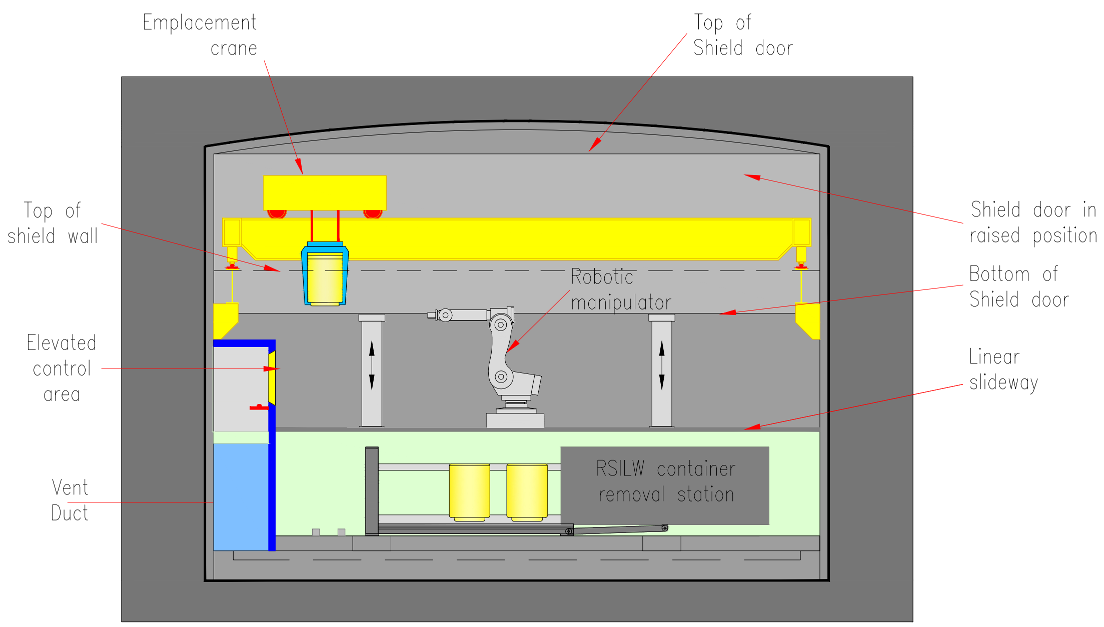
GEOLOGICAL DISPOSAL FACILITY

2013 DERIVED INVENTORY
HIGHER STRENGTH ROCK

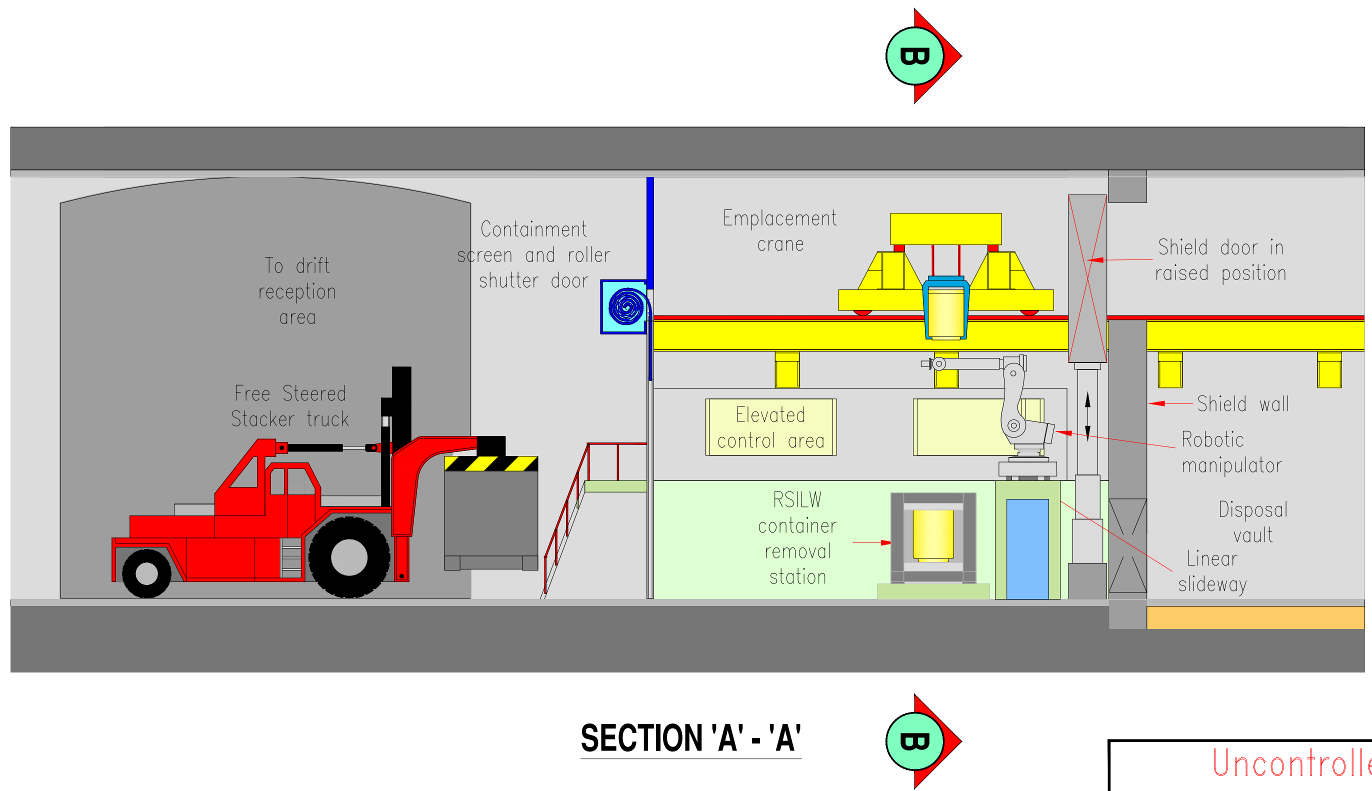
UILW & SILW/LLW DISPOSAL VAULT TRANSFER AND EMPLACEMENT CROSS-SECTIONS

SIZE	DRG. No.	STAT/REV
A3	E/DRG/0041032	P-02





SECTION 'B' - 'B'



SECTION 'A' - 'A'

STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM
									P-03	S. MAJHU	I.PHIMISTER	P-02	S.MAJHU	I.PHIMISTER
									REVISED IN LINE WITH CLIENT COMMENTS MARCH 2017			REVISED SHIELD DOOR ANNOTATION TO STATE OPEN TO RAISED POSITION.		
DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE
R.STACEY									M. PADLEY	P. GASKELL	MARCH 2017	T.PRATT	P.GASKELL	OCT 2016

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DRAWN	R.STACEY
CHECKED	P.GASKELL
APPROVED	S.MILWARD
AUTHORISED BY RWM	M.JOHNSON
DATE	JAN 2015

Radioactive Waste Management

W.B.S.	
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:200

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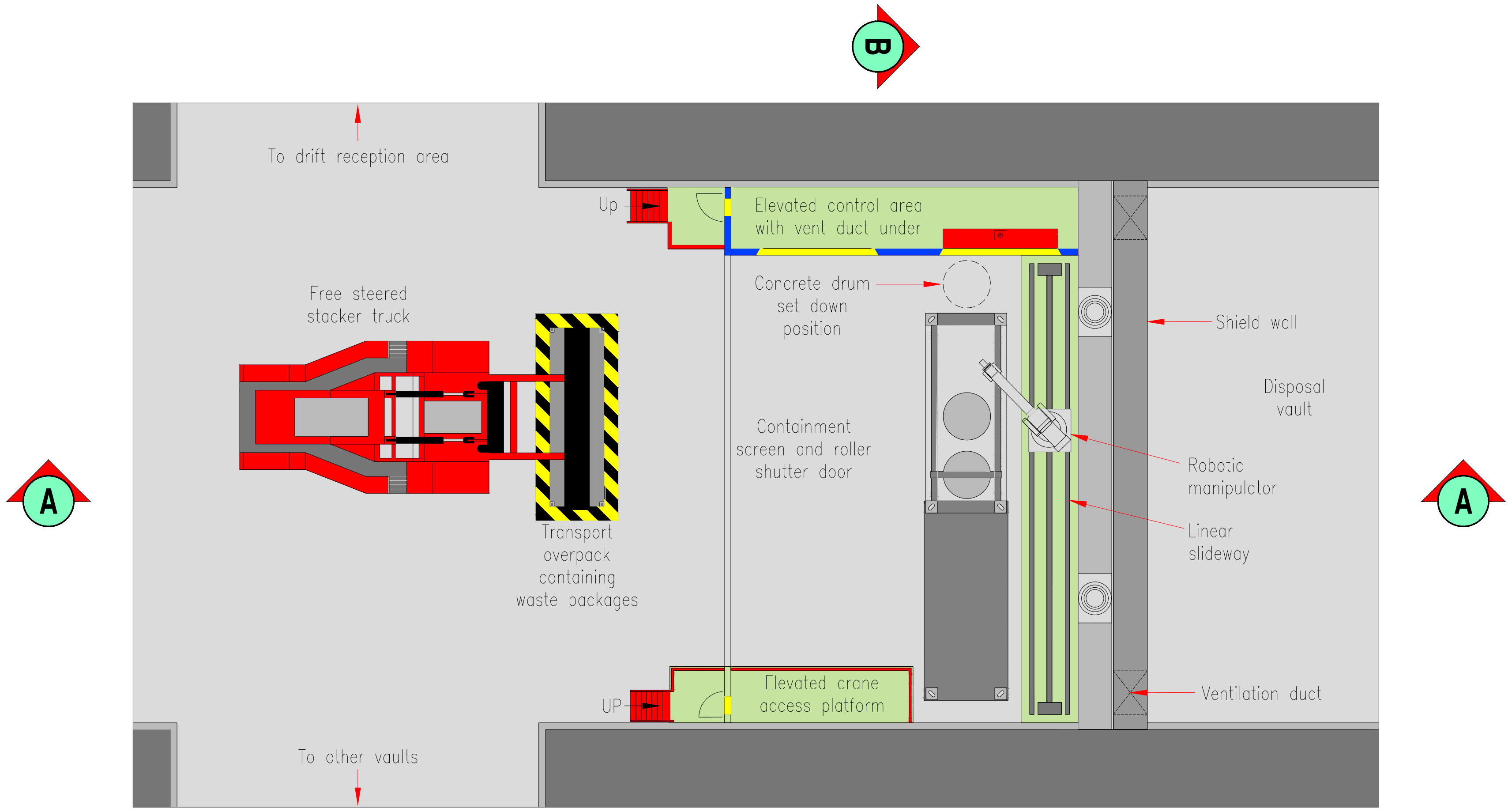
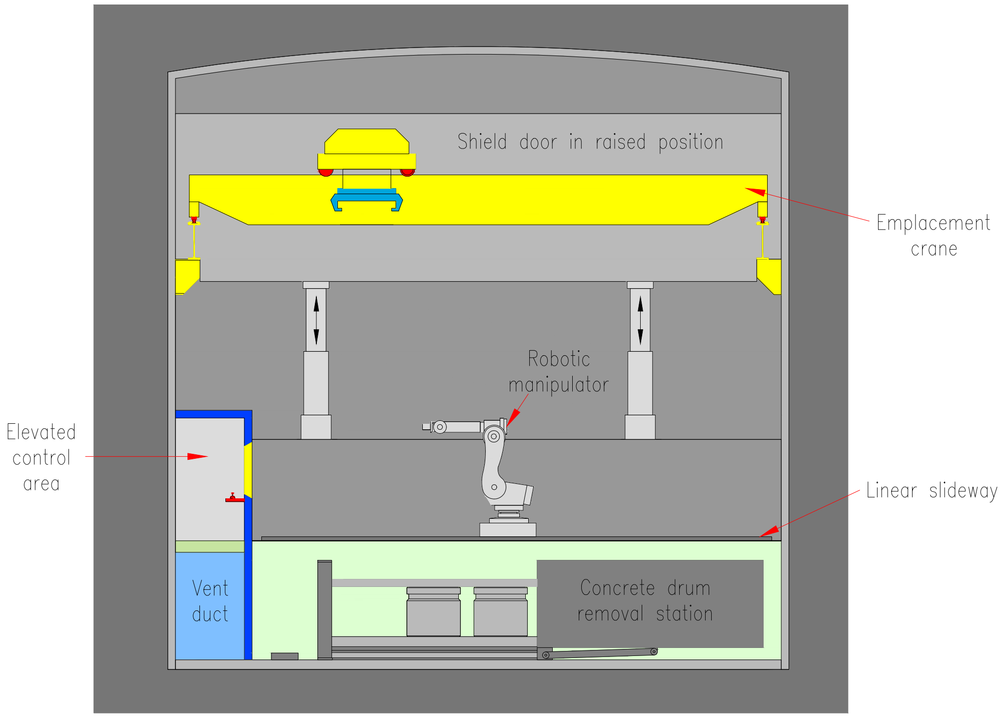
GEOLOGICAL DISPOSAL FACILITY

2013 DERIVED INVENTORY
HIGHER STRENGTH ROCK

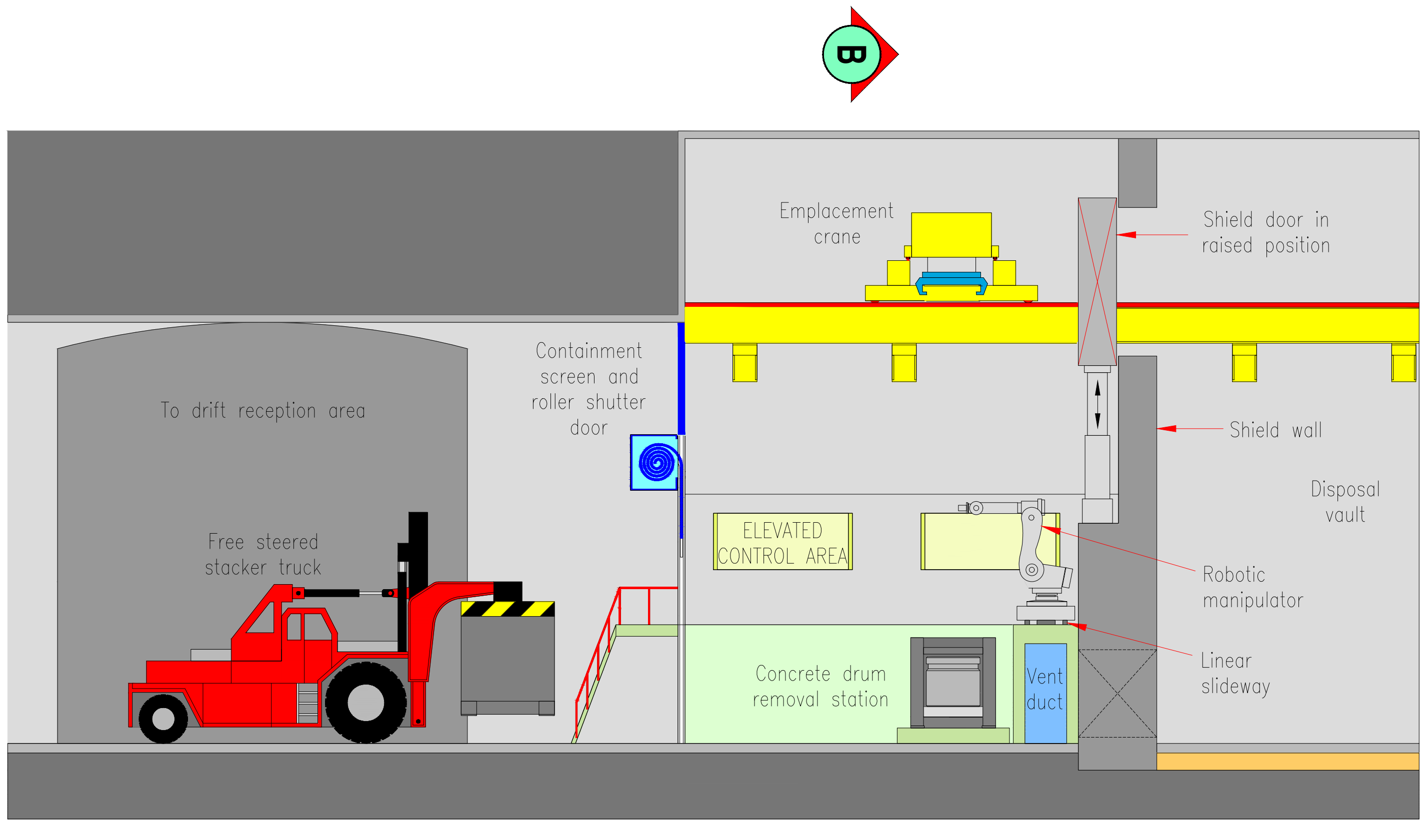
RSILW CONTAINER DISPOSAL VAULT TRANSFER AND EMPLACEMENT
LAYOUT & LONGITUDAL SECTION

SIZE	DRG. No.	STAT/REV
A3	E/DRG/0041033	P-03





SECTION 'B' - 'B'



SECTION 'A' - 'A'

B

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STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY NUVIA	AUTHORISED BY RWM
									P-03	S. MAJHU	I.PHIMISTER	P-02	C.EDWARDS	M.JOHNSON
									REVISED IN LINE WITH CLIENT COMMENTS MARCH 2017			MINOR AMENDMENTS BASED ON RWM FEEDBACK.		
DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE
									M. PADLEY	P. GASKELL	MARCH 2017	S.WILLIAMS-CONDOR	K.MOSS	MARCH 2015

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CHECKED	K.MOSS
APPROVED	C.EDWARDS
AUTHORISED BY RWM	M.JOHNSON
DATE	MARCH 2015

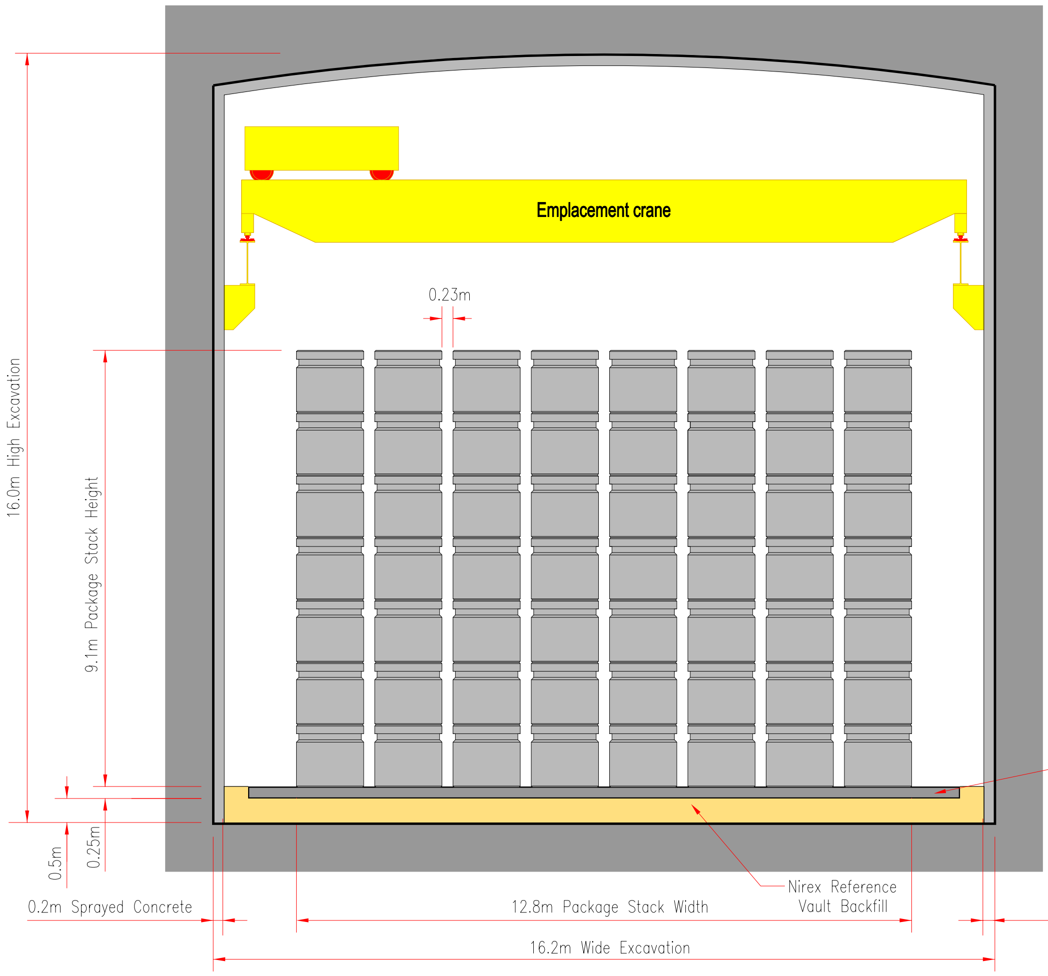
Radioactive Waste Management

W.B.S.	
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:500

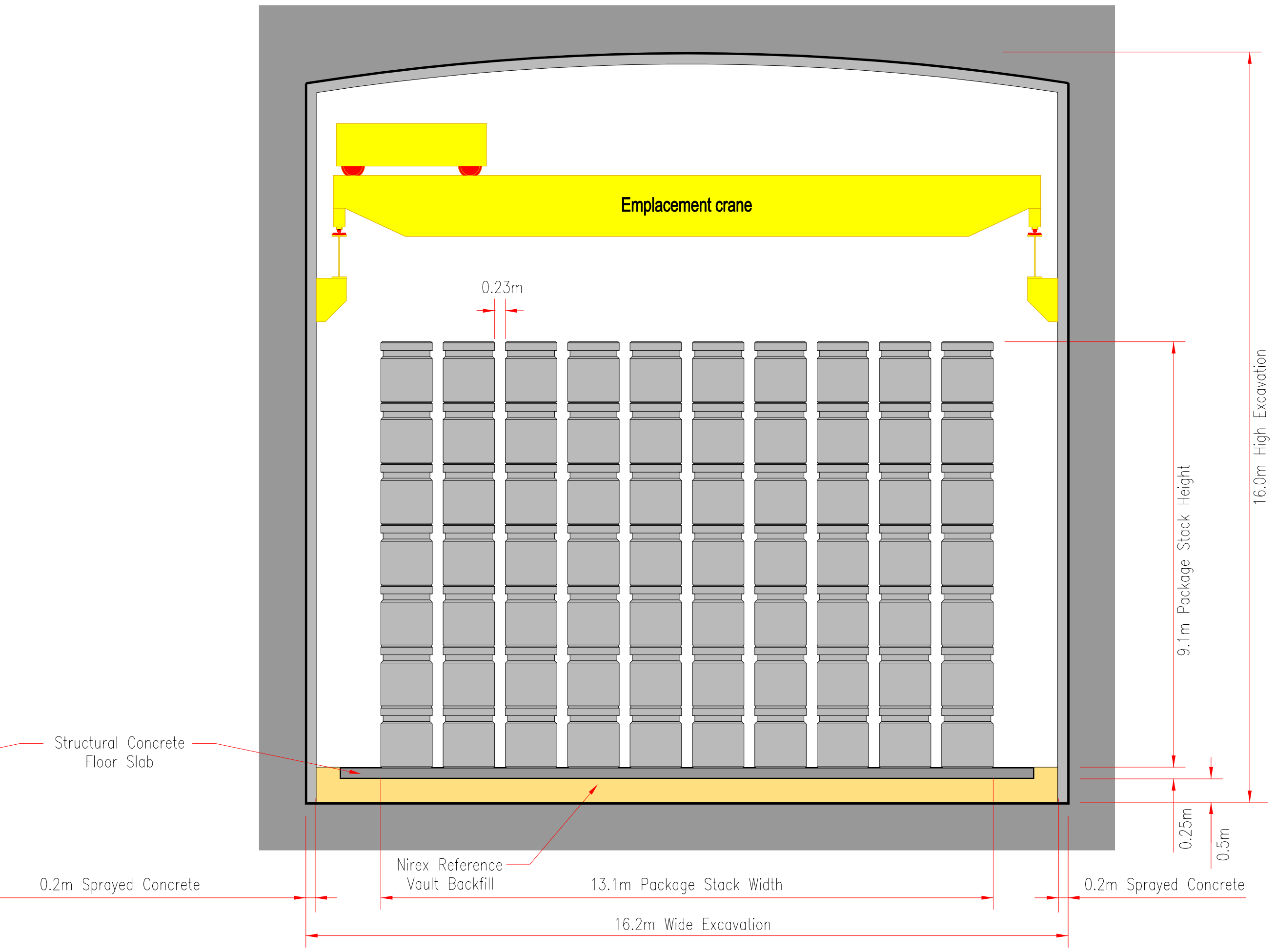
NUVIA LIMITED | E/DRG/0041034

GEOLOGICAL DISPOSAL FACILITY
2013 DERIVED INVENTORY
HIGHER STRENGTH ROCK
CONCRETE DRUM DISPOSAL VAULT TRANSFER AND EMPLACEMENT
LAYOUT & LONGITUDINAL SECTION

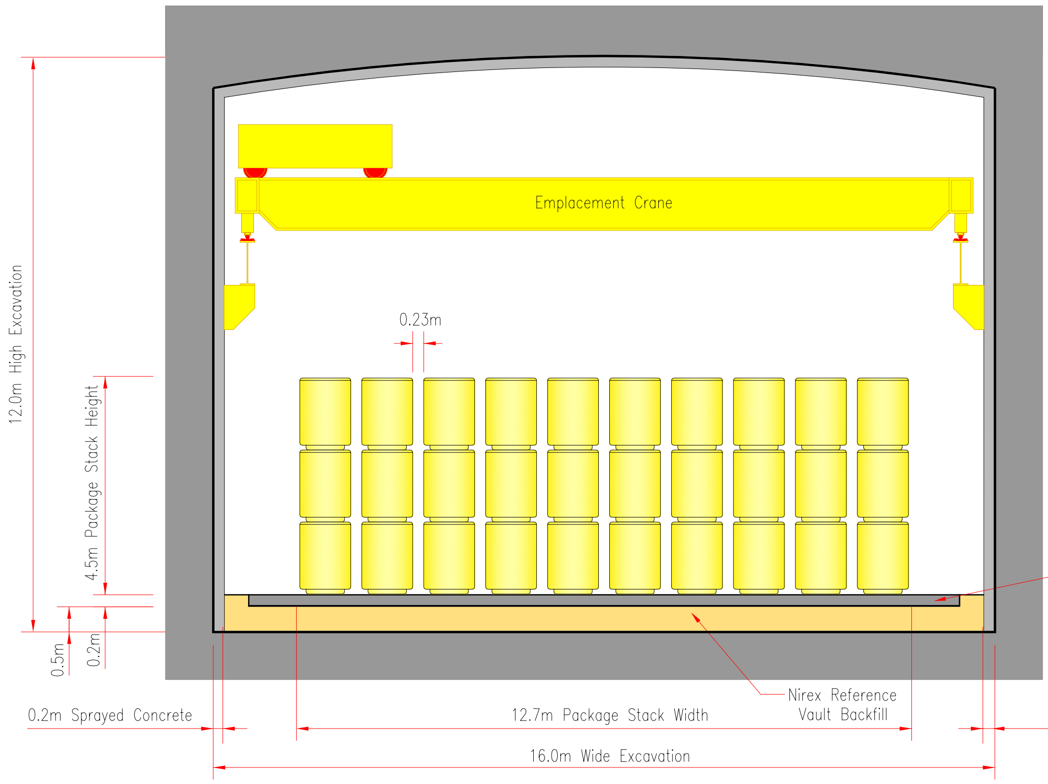
A3 SIZE	DRG. No.	E/DRG/0041034	P-03 STAT/REV



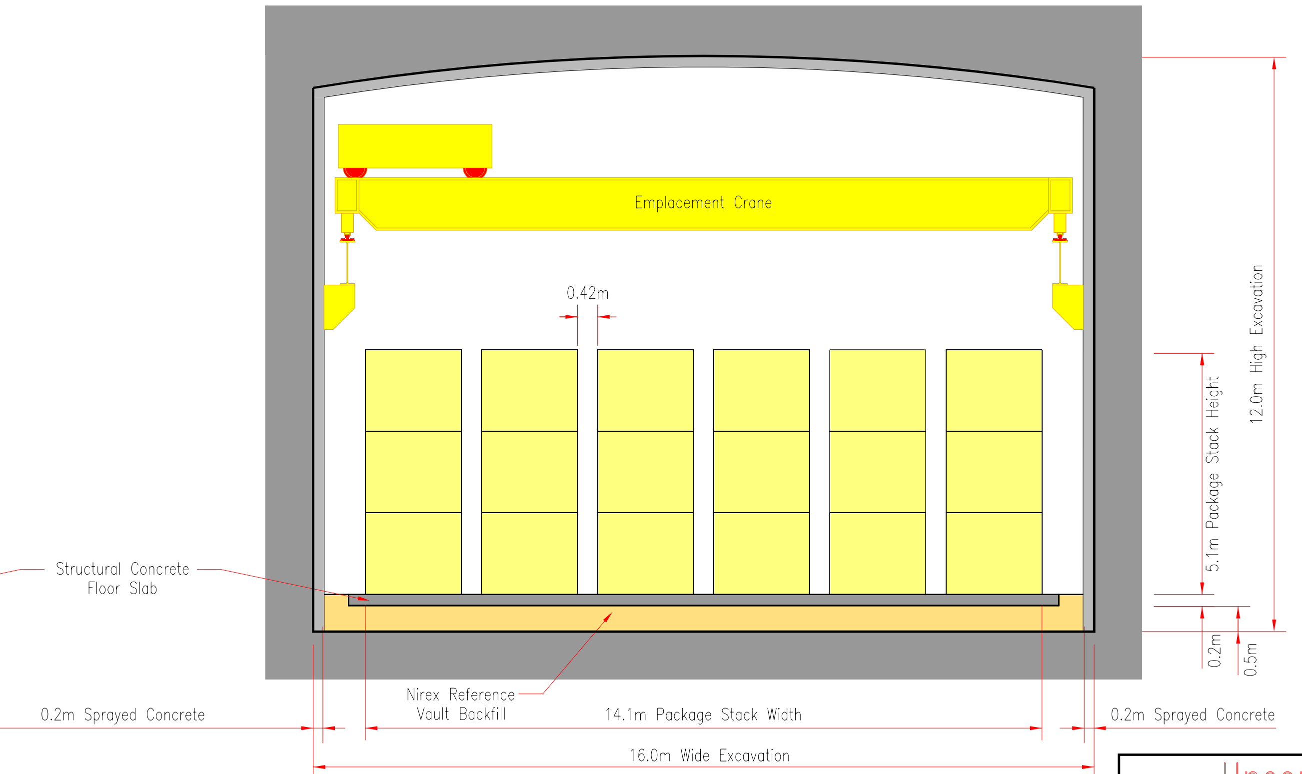
Section through NNB SILW Vault 1m³ Concrete Drums



Section through NNB SILW Vault 500l Concrete Drums



Section through RSILW Vault 500l Drums



Section through RSILW Vault 3m³ Boxes

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STAT/REV	APPROVED BY	AUTHORISED BY RWM	DESCRIPTION	DRAWN	CHECKED	DATE
	BY PB					
	BY PB					
P-04	S. MAJHU (BY PB)	I.PHIMISTER	REVISED IN LINE WITH CLIENT COMMENTS MARCH 2017	M. PADLEY	P. GASKELL	MARCH 2017
P-03	S.MAJHU (BY PB)	I.PHIMISTER	ADDED VAULT CROSS SECTIONS FOR RSILW PACKAGES.	R.SINGLETON	P.GASKELL	JULY 2016
P-02	C.EDWARDS (BY NUVIA)	M.JOHNSON	MINOR AMENDMENTS BASED ON RWM FEEDBACK.	S.WILLIAMS-CONDOR	K.MOSS	MARCH 2015

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CHECKED	K.MOSS
APPROVED	C.EDWARDS
AUTHORISED BY RWM	M.JOHNSON
DATE	MARCH 2015

Radioactive Waste Management

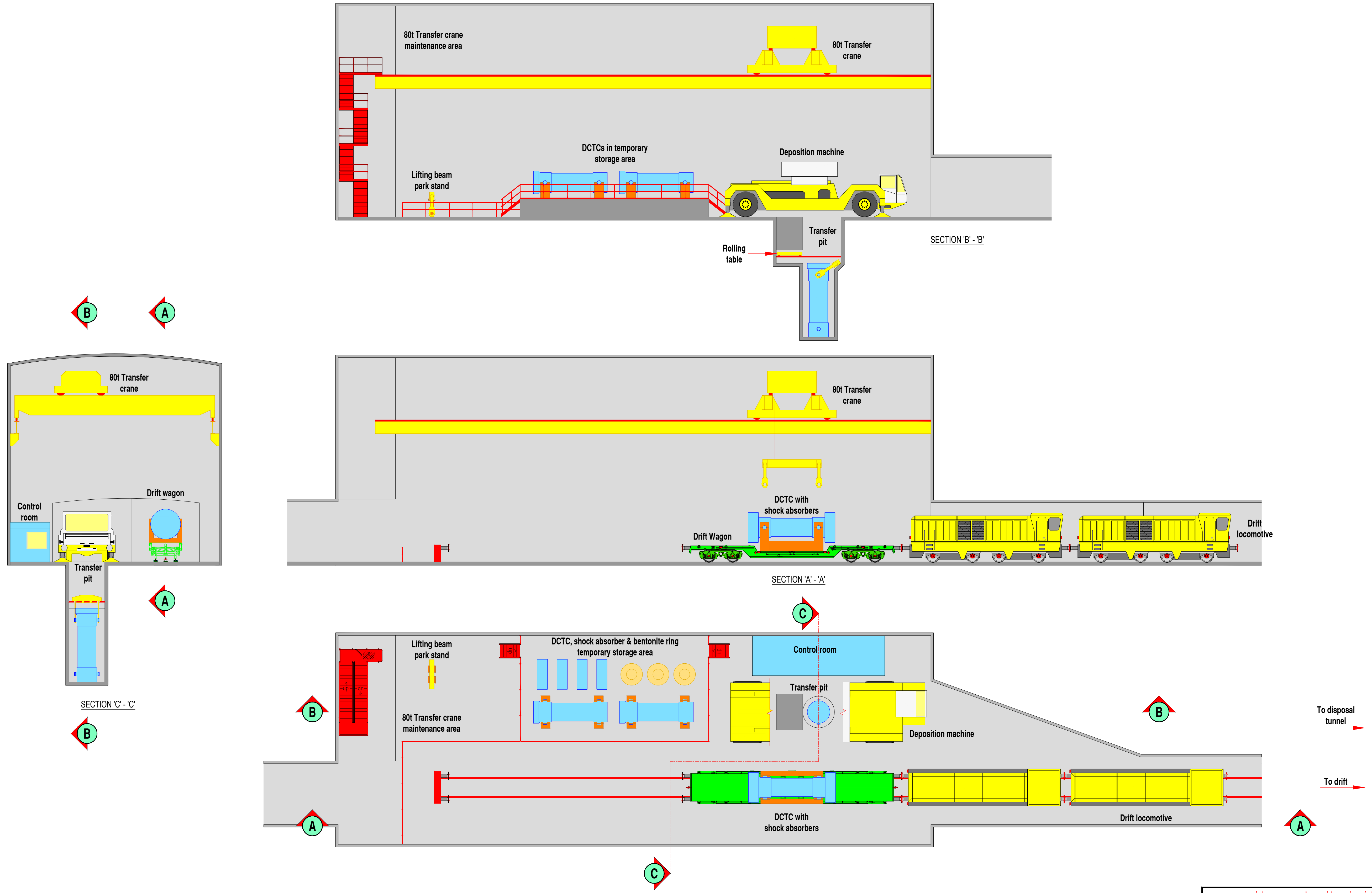
W.B.S.	
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:250

NUVIA LIMITED | E/DRG/0041035

GEOLOGICAL DISPOSAL FACILITY

2013 DERIVED INVENTORY
HIGHER STRENGTH ROCK
RSILW & CONCRETE DRUM DISPOSAL VAULT TRANSFER AND EMPLACEMENT CROSS SECTIONS

A3 SIZE | DRG. No. E/DRG/0041035 | P-04 STAT/REV



STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM
									P–03	S. MAJHU	I. PHIMISTER	P–02	S.MAJHU	I. PHIMISTER
									REVISED IN LINE WITH CLIENT COMMENTS MARCH 2017			UPDATED SECTION C–C TO SHOW PROFILES EXCAVATION.		
DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE
									M. PADLEY	P. GASKELL	MAY 2017	R.SINGLETON	P.GASKELL	JULY 2016

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CHECKED	K.MOSS
APPROVED	C.EDWARDS
AUTHORISED BY RWM	M.JOHNSON
DATE	FEB 2015

Radioactive Waste Management

W.B.S.	
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	NTS

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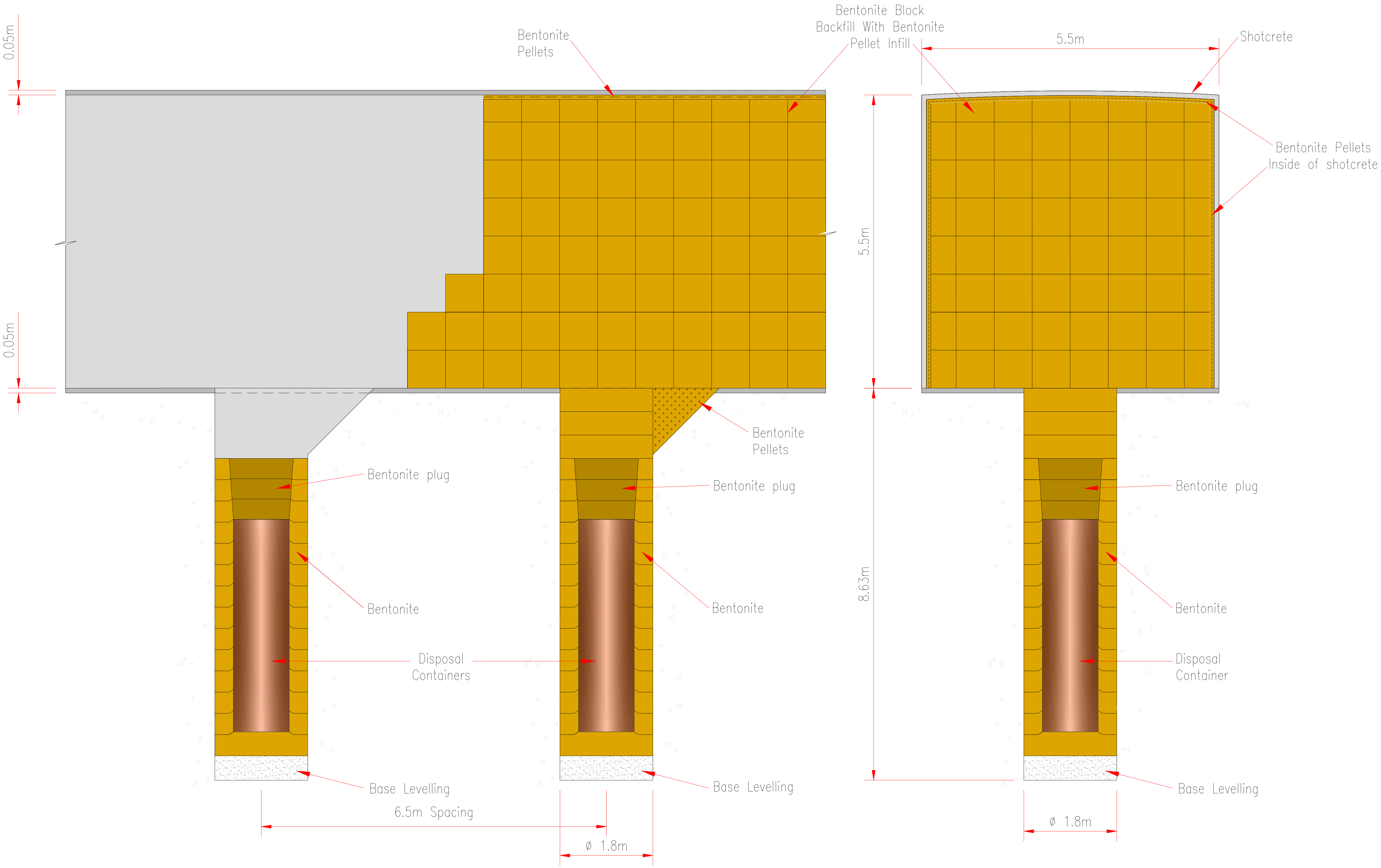
GEOLOGICAL DISPOSAL FACILITY

2013 DERIVED INVENTORY
HIGHER STRENGTH ROCK
HHGW TRANSFER HALL
LAYOUT & SECTIONS

SIZE	DRG. No.		STAT/REV
A3		E/DRG/0041036	P–03



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STAT/REV	APPROVED BY PB	AUTHORISED BY RWM
P–02	S. MAJHU	I. PHIMISTER
REVISED IN LINE WITH CLIENT COMMENTS MARCH 2017		
DRAWN	CHECKED	DATE
M. PADLEY	P. GASKELL	APRIL 2017

STAT/REV	APPROVED BY PB	AUTHORISED BY RWM
DRAWN	CHECKED	DATE

STAT/REV	APPROVED BY PB	AUTHORISED BY RWM
DRAWN	CHECKED	DATE

STAT/REV	APPROVED BY PB	AUTHORISED BY RWM
DRAWN	CHECKED	DATE

STAT/REV	APPROVED BY PB	AUTHORISED BY RWM
DRAWN	CHECKED	DATE

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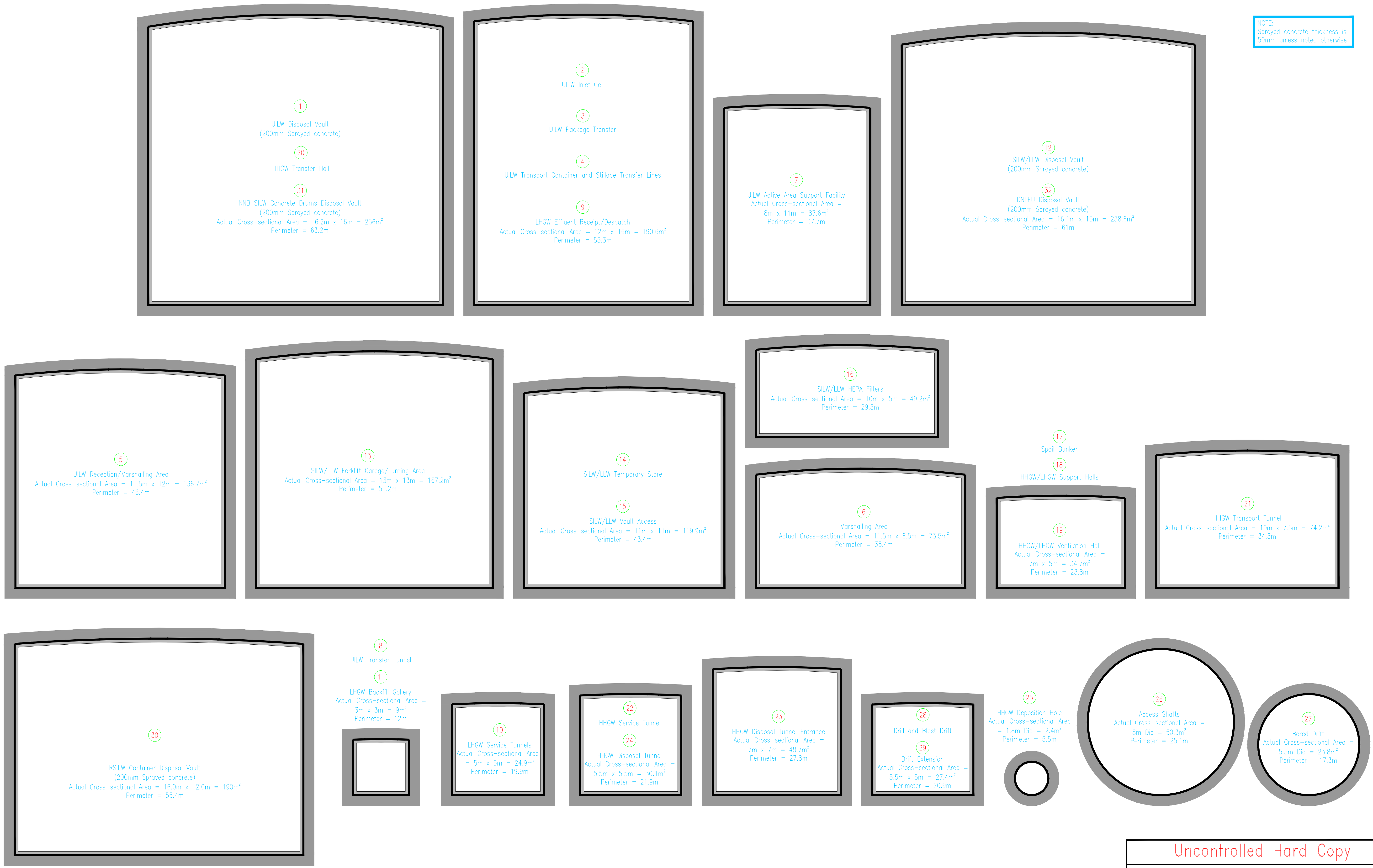
DRAWN	R.STACEY
CHECKED	P.GASKELL
APPROVED	S.MILWARD
AUTHORISED BY RWM	M.JOHNSON
DATE	DEC 2014

Radioactive Waste Management

W.B.S.	
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:75

GEOLOGICAL DISPOSAL FACILITY
2013 DERIVED INVENTORY
HIGHER STRENGH ROCK
HHGW DISPOSAL TUNNEL & DEPOSITION HOLES
CROSS & LONGITUDINAL SECTIONS

A3 SIZE	DRG. No.	E/DRG/0041037	P–02 STAT/REV



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STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	DESCRIPTION	DRAWN	CHECKED	DATE
P-03	S. MAJHU	I. PHIMISTER	REVISED IN LINE WITH CLIENT COMMENTS MARCH 2017	M. PADLEY	P. GASKELL	MAY 2017
P-02	S.MAJHU	I.PHIMISTER	UPDATED FOLLOWING IMPLEMENTATION OF CR54. ADDED EXCAVATION PROFILE FOR DNLEU DISPOSAL VAULT AND ADDED SHOTCRETE THICKNESS INFORMATION.	R.SINGLETON	P.GASKELL	JULY 2016

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for
RADIOACTIVE WASTE MANAGEMENT LTD
UNDER CONTRACT
INSTRUCTION No. RWM 007927

SECURITY CLASS
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CHECKED	
APPROVED	
AUTHORISED BY RWM	M.JOHNSON
DATE	DEC 2014

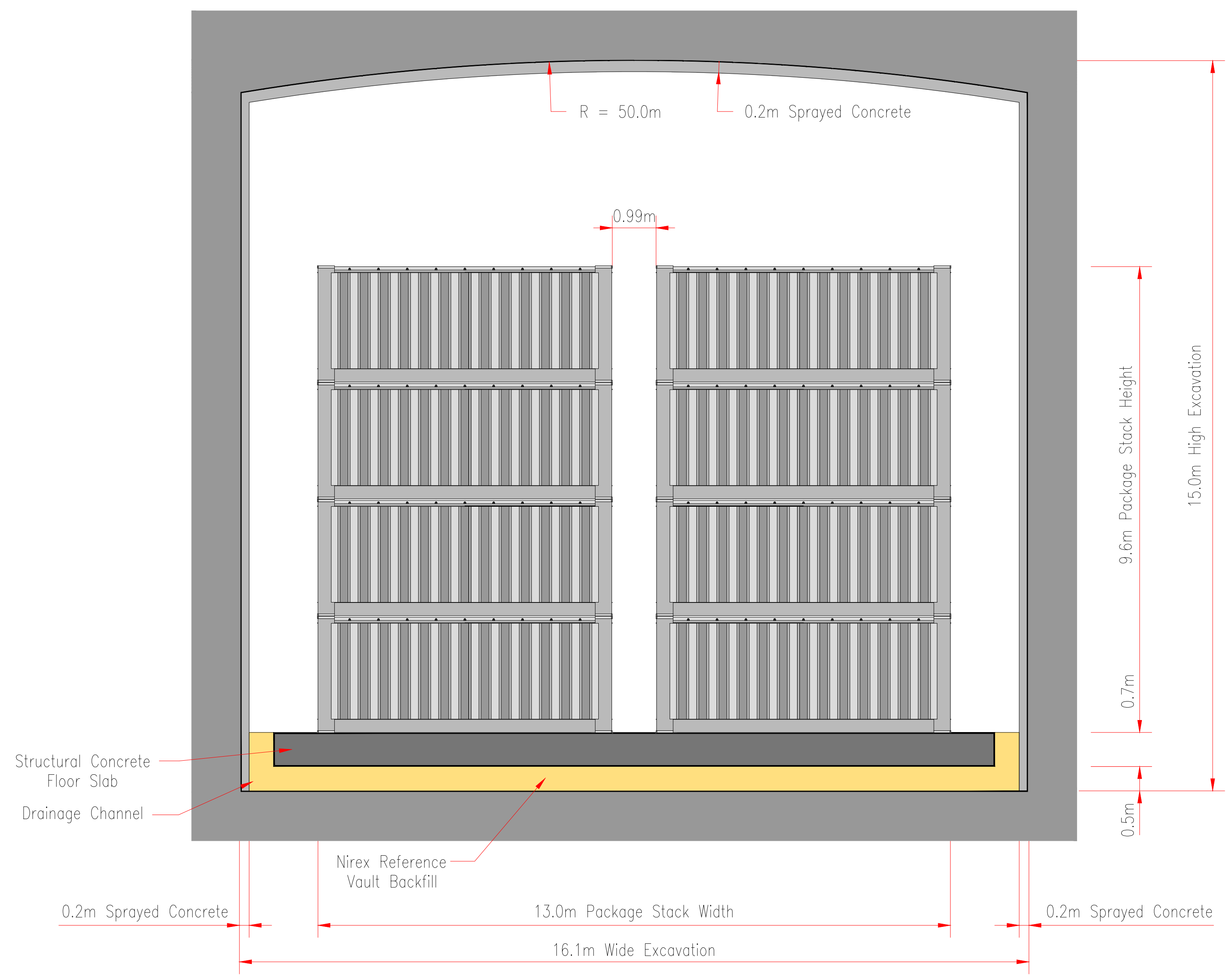
Radioactive Waste Management

W.B.S.	
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:200

GEOLOGICAL DISPOSAL FACILITY

2013 DERIVED INVENTORY
HIGHER STRENGTH ROCK
LHGW, HHGW & COMMON SERVICE AREAS
EXCAVATION PROFILES

SIZE	DRG. No.	STAT/REV
A3	E/DRG/0041038	P-03



DNLEU Vault

STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM
DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE

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CHECKED	P.GASKELL
APPROVED	S. MAJHU
AUTHORISED BY RWM	I. PHIMISTER
DATE	JULY 2016

Radioactive Waste Management

W.B.S.	
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:125

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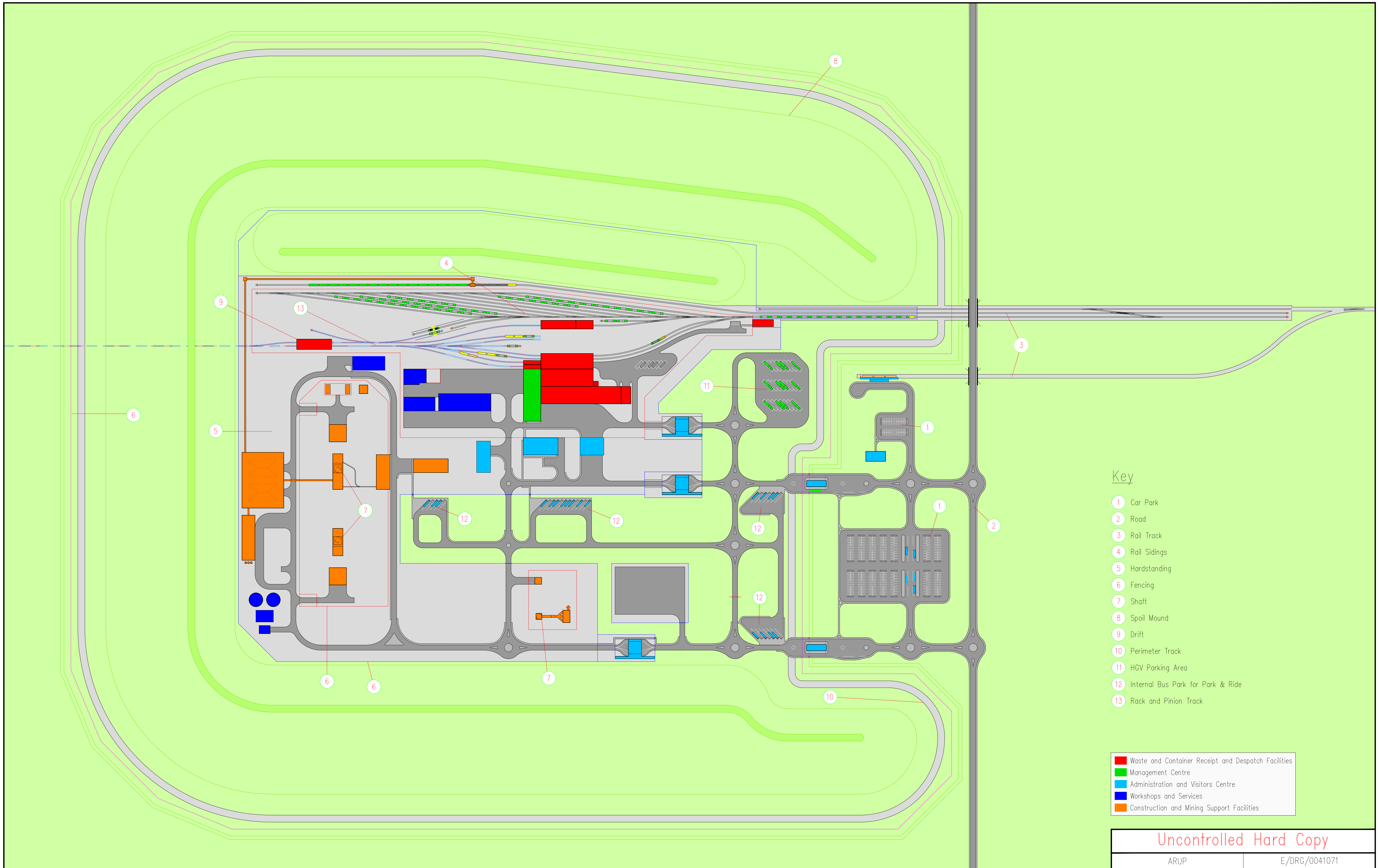
GEOLOGICAL DISPOSAL FACILITY
2013 DERIVED INVENTORY
HIGHER STRENGTH ROCK
DNLEU TRANSPORT & DISPOSAL CONTAINER
DISPOSAL VAULT CROSS-SECTION

A3 SIZE | DRG. No. E/DRG/0041039 | P-01 STAT/REV

Lower strength sedimentary rock illustrative design drawings

E/DRG/0041071	Overall Surface Layout - First Emplacement of LHGW
E/DRG/0041073	Overall Surface Layout - End of Construction
E/DRG/0041076	2013 Derived Inventory – Underground Layout – End of Operational Phase
E/DRG/0041077	2013 Derived Inventory – Underground Layout – Waste Categories
E/DRG/0041080	2013 Derived Inventory – UILW Disposal Vault Transfer and Emplacement – Longitudinal Section
E/DRG/0041081	2013 Derived Inventory – SILW/LLW Disposal Vault Transfer and Emplacement – Longitudinal Section
E/DRG/0041082	2013 Derived Inventory – UILW & SILW/LLW Disposal Vault Transfer and Emplacement – Cross sections
E/DRG/0041083	2013 Derived Inventory – RSILW Container Disposal Vault Transfer and Emplacement – Layout and Longitudinal Section
E/DRG/0041084	2013 Derived Inventory – NNB SILW Concrete Drum Vault Transfer and Emplacement – Layout and Longitudinal Section
E/DRG/0041085	2013 Derived Inventory – RSILW Container & NNB SILW Concrete Drum Disposal Vault Transfer and Emplacement – Cross-Section
E/DRG/0041087	2013 Derived Inventory – HHGW Disposal Tunnel – Cross & Longitudinal Section
E/DRG/0041088	LHGW, HHGW & Common Services Area – Excavation Profiles
E/DRG/0041089	Disposal Tunnel Reception Area – Layout & Sections
E/DRG/0041090	SILW/DNLEU Disposal Vault Transfer and Emplacement Cross-Section



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ARUP	E/DRG/0041071

STAT/REV	APPROVED BY	AUTHORISED BY RWM	DESCRIPTION	DRAWN	CHECKED	DATE
P–07	S.LESSER	I.PHIMISTER	REVISION DETAILS ADDED.	T.WARING	D.WILLIS	NOV 16
P–06	S.LESSER	I.PHIMISTER	REVISED ANNOTATION TO MEET SECURITY REQUIREMENTS.	T.WARING	S.LESSER	JULY 16
P–05	S.LESSER	M.JOHNSON	FIRST REVISION OF SURFACE LAYOUT. DRAWING NUMBER PREVIOUSLY USED FOR UNDERGROUND LAYOUT. RENUMBERED AND RETITLED.	A.UBHOO	P.GASKELL	DEC 14

DRAWING PRODUCED BY:
ARUP

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for
RADIOACTIVE WASTE MANAGEMENT LTD
UNDER CONTRACT
INSTRUCTION No. RWMD05040

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DRAWN	A.UBHOO
CHECKED	P.GASKELL
APPROVED	S.LESSER
AUTHORISED BY RWM	M.JOHNSON
DATE	DEC 2014

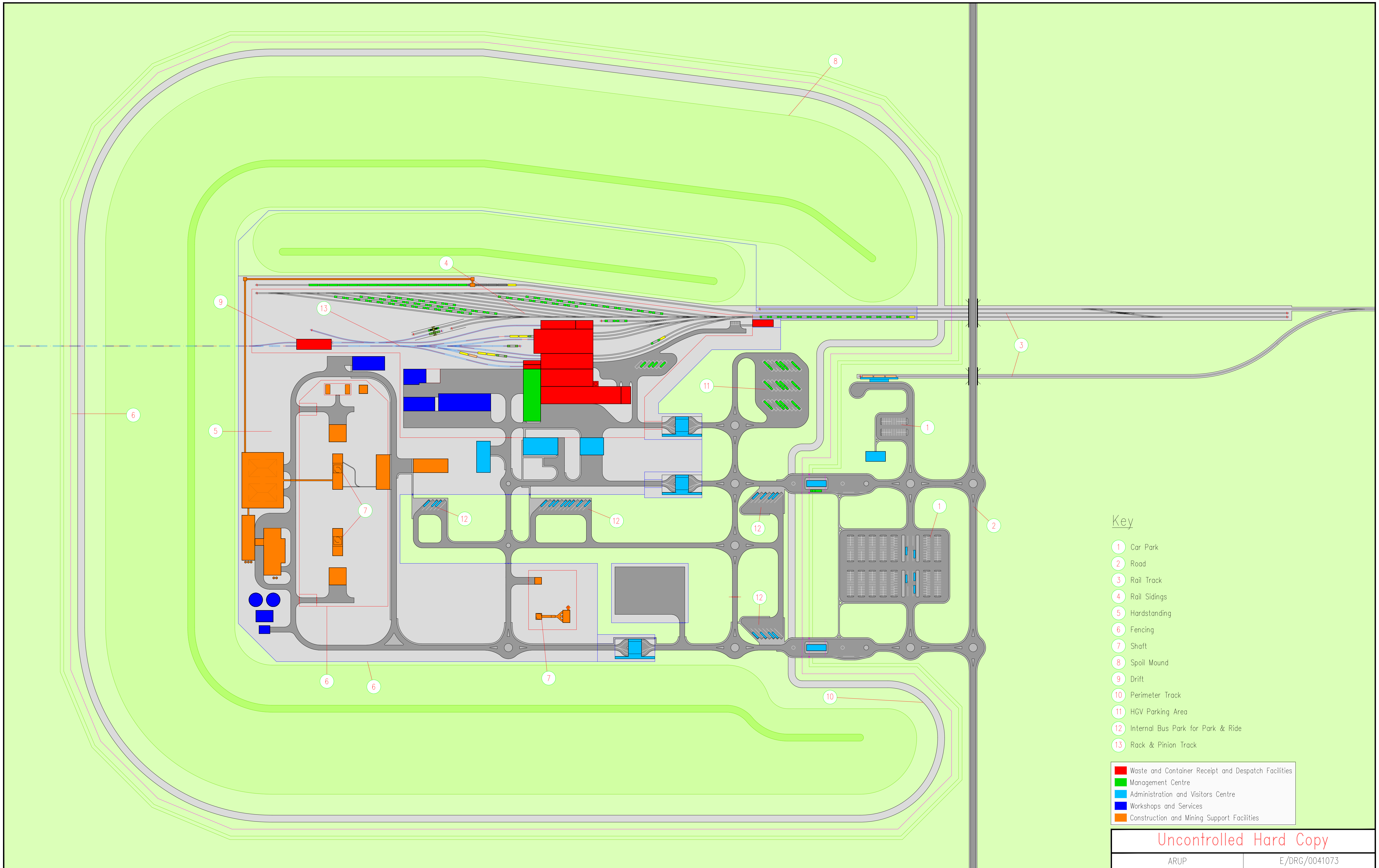
Radioactive Waste Management

W.B.S.	50003.11.03
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:5000

GEOLOGICAL DISPOSAL FACILITY

2013 INVENTORY FOR DISPOSAL
LOWER STRENGTH SEDIMENTARY ROCK
Overall Surface Layout
First Emplacement of LHGW

A3 SIZE	DRG. No.	E/DRG/0041071	P–07 STAT/REV



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ARUP | E/DRG/0041073

STAT/REV	APPROVED BY	AUTHORISED BY RWM	DESCRIPTION	DRAWN	CHECKED	DATE
P-04	S.LESSER	I.PHIMISTER	REVISION DETAILS ADDED.	T.WARING	D.WILLIS	NOV 16
P-03	S.LESSER	I.PHIMISTER	REVISED ANNOTATIONS TO MEET SECURITY REQUIREMENTS.	T.WARING	S.LESSER	APRIL 2016
P-02	S.LESSER	M.JOHNSON	FIRST REVISION OF SURFACE LAYOUT. DRAWING NUMBER PREVIOUSLY USED FOR UNDERGROUND LAYOUT. RENUMBERED AND RENAMED.	A.UBHOO	P.GASKELL	DEC 14

DRAWING PRODUCED BY:
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UNDER CONTRACT
INSTRUCTION No. RWMD05040

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DRAWN	A.UBHOO
CHECKED	P.GASKELL
APPROVED	S.LESSER
AUTHORISED BY RWM	M.JOHNSON
DATE	DEC 2014

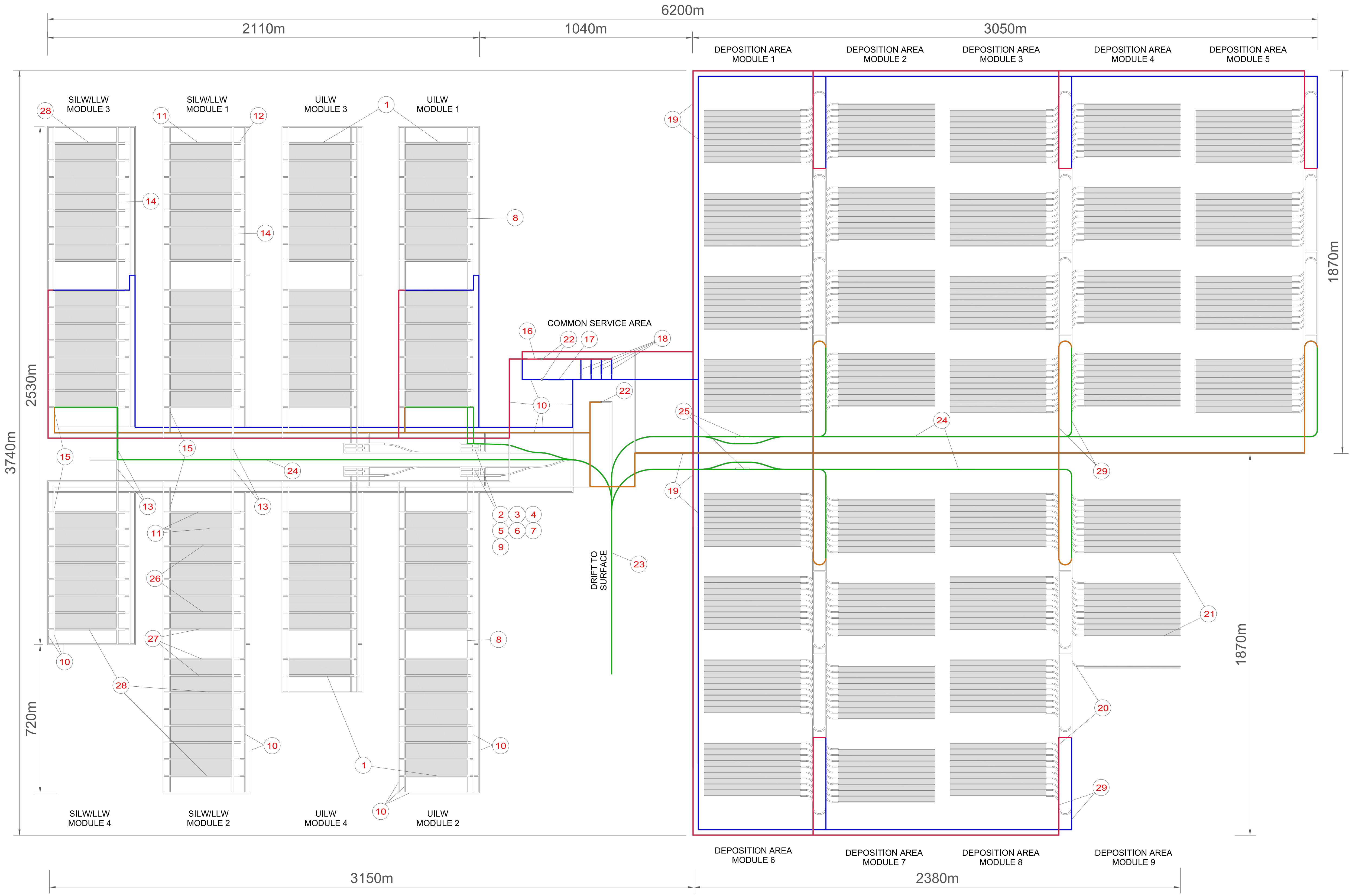
Radioactive Waste Management

W.B.S.	50003.11.03
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:5000

GEOLOGICAL DISPOSAL FACILITY

2013 INVENTORY FOR DISPOSAL
LOWER STRENGTH SEDIMENTARY ROCK
Overall Surface Layout
End of Construction

A3 SIZE | DRG. No. E/DRG/0041073 | P-04 STAT/REV



1. UILW DISPOSAL VAULT
2. UILW INLET CELL
3. UILW PACKAGE TRANSFER
4. UILW TRANSPORT CONTAINER & STILLAGE TRANSFER LINES
5. UILW RECEPTION/MARSHALLING AREA (HIGH)
6. UILW RECEPTION/MARSHALLING AREA (LOW)
7. UILW ACTIVE AREA SUPPORT FACILITY
8. UILW TRANSFER TUNNEL
9. LHGW EFFLUENT RECEIPT/DESPATCH
10. LHGW SERVICE TUNNELS
11. SILW/LLW DISPOSAL VAULT
12. SILW/LLW FORKLIFT GARAGE/TURNING AREA
13. SILW/LLW TEMPORARY STORE
14. SILW/LLW VAULT ACCESS
15. SILW/LLW HEPA FILTERS
16. HHGW/LHGW SPOIL BUNKER
17. HHGW/LHGW VENTILATION HALL
18. HHGW/LHGW SUPPORT HALLS
19. HHGW SERVICE TUNNEL
20. HHGW DISPOSAL TUNNEL ENTRANCE
21. HHGW DISPOSAL TUNNEL
22. ACCESS SHAFTS
23. BORED DRIFT
24. DRIFT EXTENSION
25. HHGW TRANSFER HALL
26. NNB SILW CONCRETE DRUM DISPOSAL VAULT
27. RSILW CONTAINER DISPOSAL VAULT
28. DNLEU SILW DISPOSAL VAULT
29. HHGW TRANSPORT TUNNEL

LEGEND

- CONSTRUCTION INTAKE
- CONSTRUCTION RETURN
- EMPLACEMENT INTAKE
- EMPLACEMENT RETURN

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STAT/REV	APPROVED BY	AUTHORISED BY RWM	DESCRIPTION	DRAWN	CHECKED	DATE
P-03	S. MAJHU	I.PHIMISTER	REVISED IN LINE WITH CLIENT COMMENTS MARCH 2017	M. PADLEY	P. GASKELL	MARCH 2017
P02	S. MAJHU	I. PHIMISTER	UPDATED FOLLOWING IMPLEMENTATION OF CR54 UILW DISPOSAL VAULTS REDUCED BY 18 AND 30 NEW ADDED DNLEU. NUMBER OF DISPOSAL TUNNELS INCREASED BY 5	S. BRITTON	P. GASKELL	JULY 2016

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SECURITY CLASS: Not Protectively Marked

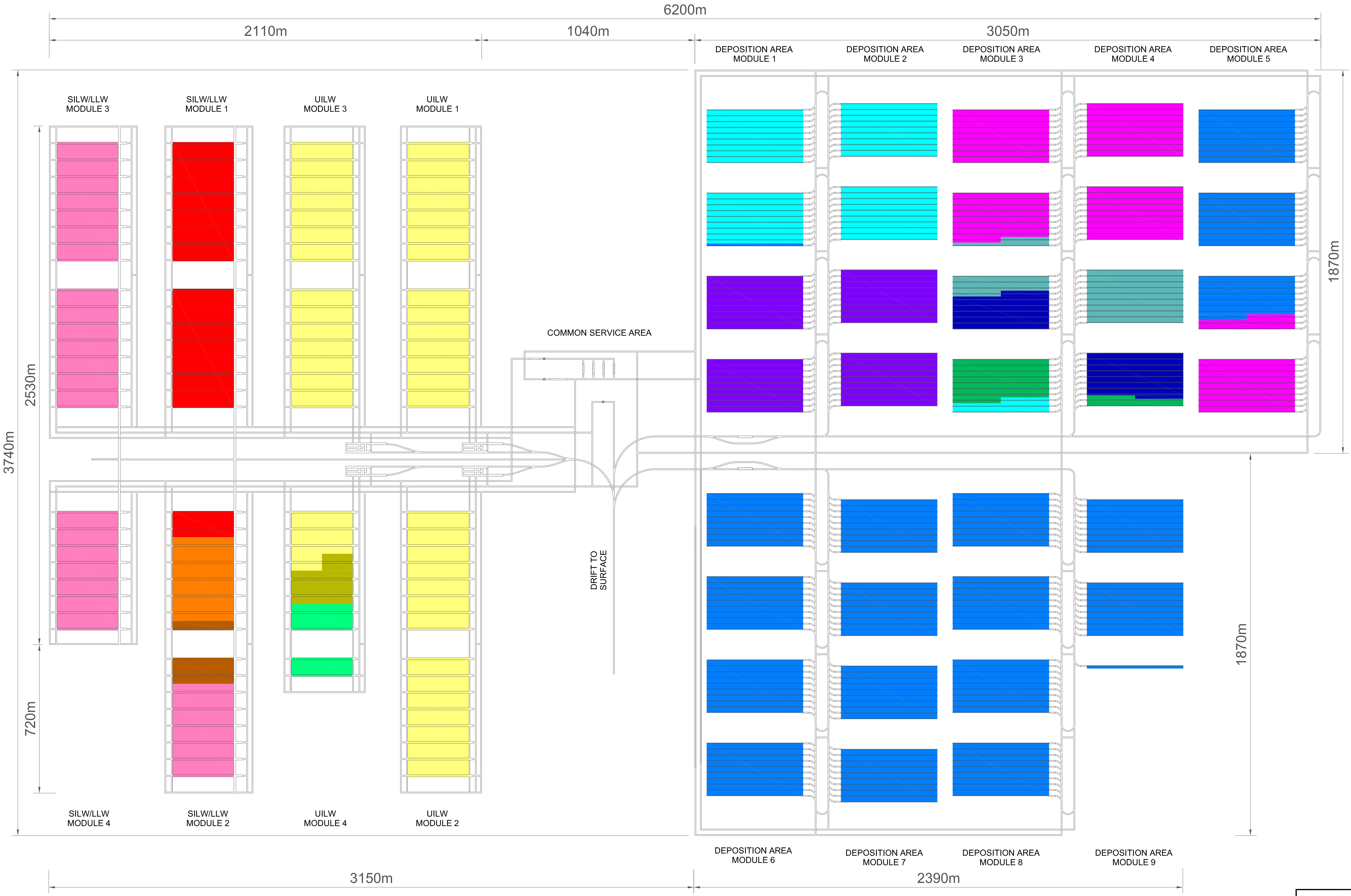
DRAWN	R. STACEY
CHECKED	P. GASKELL
APPROVED	S. MILWARD
AUTHORISED BY RWM	M. JOHNSON
DATE	MARCH 2015

Radioactive Waste Management

W.B.S.	50003.11.03
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:20000

GEOLOGICAL DISPOSAL FACILITY
2013 INVENTORY FOR DISPOSAL
LOWER STRENGTH SEDIMENTARY ROCK
UNDERGROUND LAYOUT
END OF OPERATIONAL PHASE

A3 SIZE | DRG. No. E/DRG/0041076 | P-03 STAT/REV



LHGW	NUMBER OF DISPOSAL VAULTS
LEGACY SILW/LLW	18.0
NNB SILW	5.0
RSILW	3.0
DNLEU SILW	30.0
LEGACY UILW	51.5
DNLEU UILW	2.5
NNB UILW	4.0
TOTAL LHGW	114.0

HHGW	NUMBER OF DISPOSAL TUNNELS
LEGACY HLW	41.0
LEGACY AGR SF	40.5
LEGACY PWR SF	10.0
LEGACY MAGNOX/PFR SF	15.0
PU/HEU	15.0
MOX SF	51.0
NNB SF	168.5
TOTAL HHGW	341.0

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STAT/REV	APPROVED BY	AUTHORISED BY RWM	DESCRIPTION	DRAWN	CHECKED	DATE
P-03	S. MAJHU	I.PHIMISTER	REVISED IN LINE WITH CLIENT COMMENTS MARCH 2017	M.PADLEY	P. GASKELL	MARCH 2017
P02	S. MAJHU	I. PHIMISTER	UPDATED FOLLOWING IMPLEMENTATION OF CR54 UILW DISPOSAL VAULTS REDUCED BY 18 AND 30 NEW ADDED DNLEU. NUMBER OF DISPOSAL TUNNELS INCREASED BY 5	S. BRITTON	P. GASKELL	JULY 2016

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UNDER CONTRACT
INSTRUCTION No. 007927

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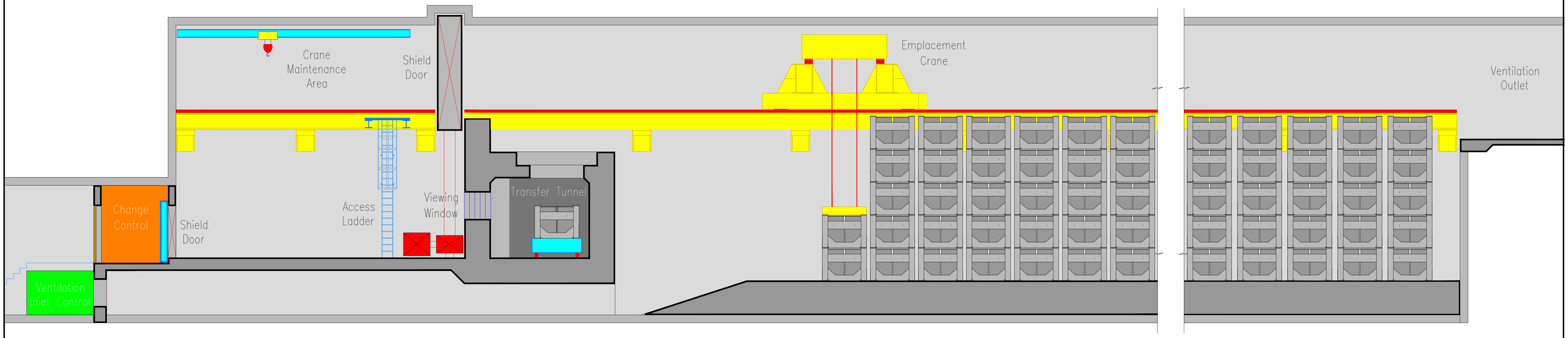
CHECKED	P. GASKELL
APPROVED	S. MILWARD
AUTHORISED BY RWM	M. JOHNSON
DATE	MARCH 2015

Radioactive Waste Management

W.B.S.	50003.11.03
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:20000

GEOLOGICAL DISPOSAL FACILITY
2013 INVENTORY FOR DISPOSAL
LOWER STRENGTH SEDIMENTARY ROCK
UNDERGROUND LAYOUT
WASTE CATEGORIES

A3 SIZE | DRG. No. E/DRG/0041077 | P-03 STAT/REV



STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM
DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE

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APPROVED	S.MILWARD
AUTHORISED BY RWM	M.JOHNSON
DATE	DEC 2014

Radioactive Waste Management

W.B.S.	
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:150

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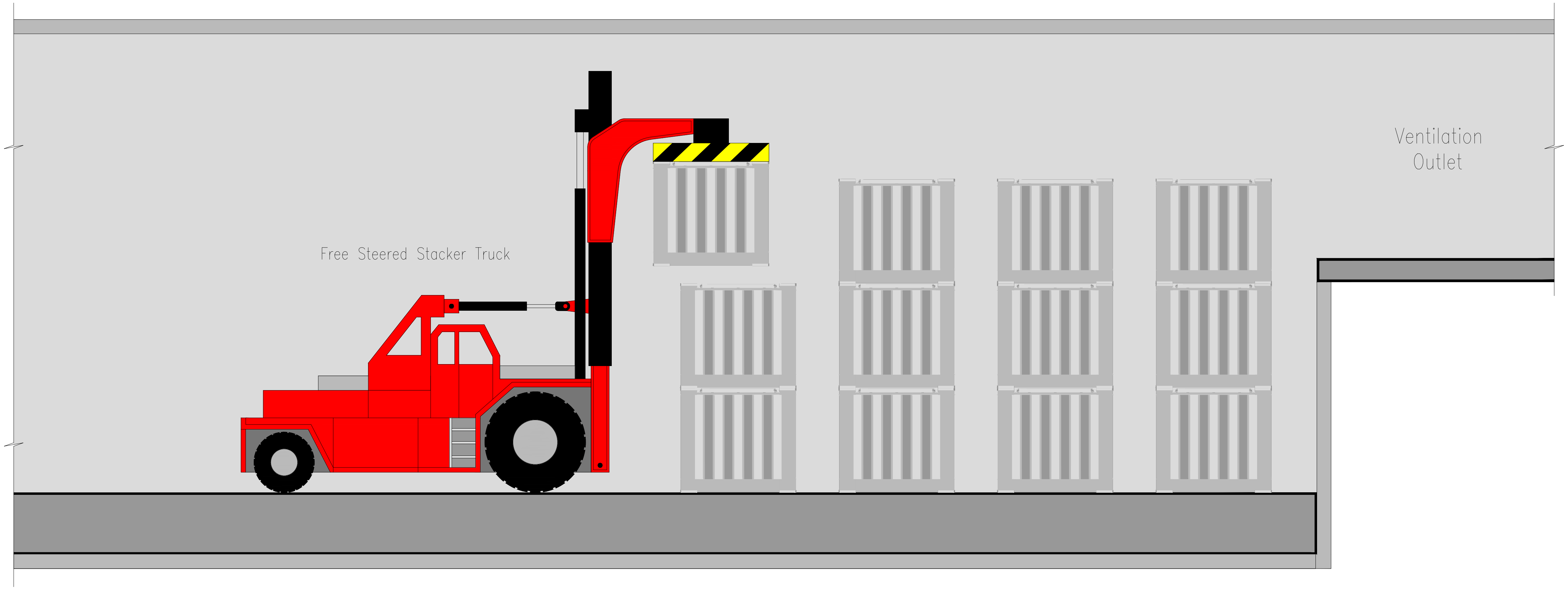
GEOLOGICAL DISPOSAL FACILITY

2013 DERIVED INVENTORY
LOWER STRENGTH SEDIMENTARY ROCK
UILW DISPOSAL VAULT TRANSFER AND EMPLACEMENT
LONGITUDINAL SECTION

A3 SIZE | DRG. No. E/DRG/0041080 | P-01 STAT/REV



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GEOLOGICAL DISPOSAL FACILITY

2013 DERIVED INVENTORY
LOWER STRENGTH SEDIMENTARY ROCK
SILW/LLW DISPOSAL VAULT TRANSFER AND EMPLACEMENT
LONGITUDINAL SECTION

STAT/REV	APPROVED BY PB	AUTHORISED BY RWM
P-02	S.MAJHU	I.PHIMISTER
REVISED ANNOTATION BASED ON RWM FEEDBACK.		
DRAWN	CHECKED	DATE
T.PRATT	P.GASKELL	JULY 2016

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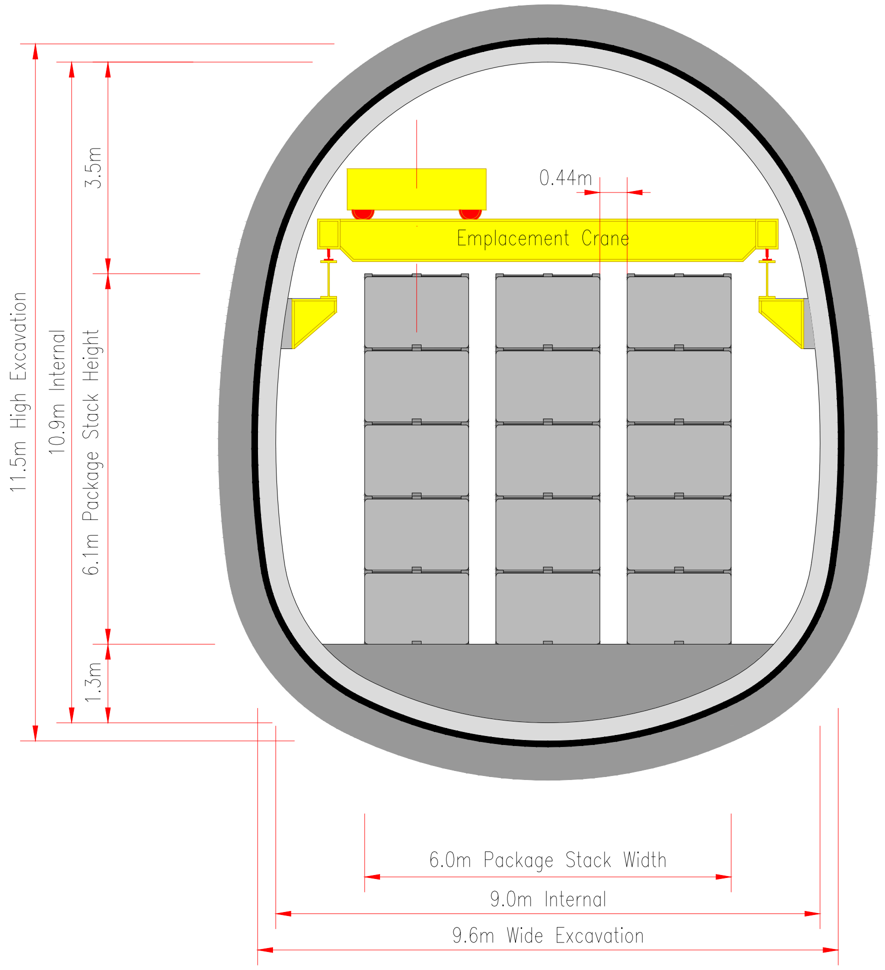
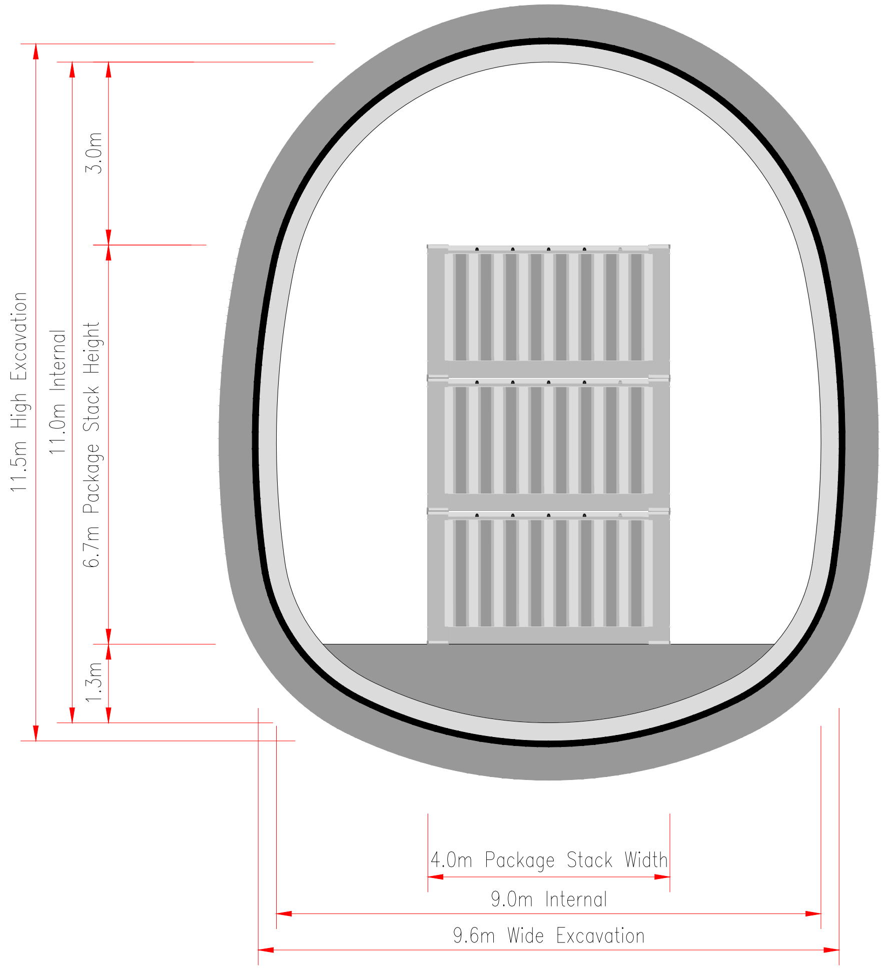
APPROVED	S.MILWARD
AUTHORISED BY RWM	M.JOHNSON
DATE	DEC 2014

W.B.S.	
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:100

SIZE	DRG. No.	STAT/REV
A3	E/DRG/0041081	P-02



UILW Vault



SILW/LLW Vault

STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	DESCRIPTION	DRAWN	CHECKED	DATE
P-03	S. MAJHU	I PHIMISTER	REVISED IN LINE WITH CLIENT COMMENTS MARCH 2017	M. PADLEY	P. GASKELL	MAY 2017
P-02	S.MAJHU	I.PHIMISTER	UPDATED PACKAGE SPACING BASED ON VAULT & TUNNEL CALCULATORS AND AMENDED ANNOTATIONS.	R.SINGLETON	P.GASKELL	JULY 2016

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UNDER CONTRACT
INSTRUCTION No. RWM 007927

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DRAWN	R. STACEY
CHECKED	P. GASKELL
APPROVED	S. MILWARD
AUTHORISED BY RWM	M.JOHNSON
DATE	DEC 2014

Radioactive Waste Management

W.B.S.	
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:125

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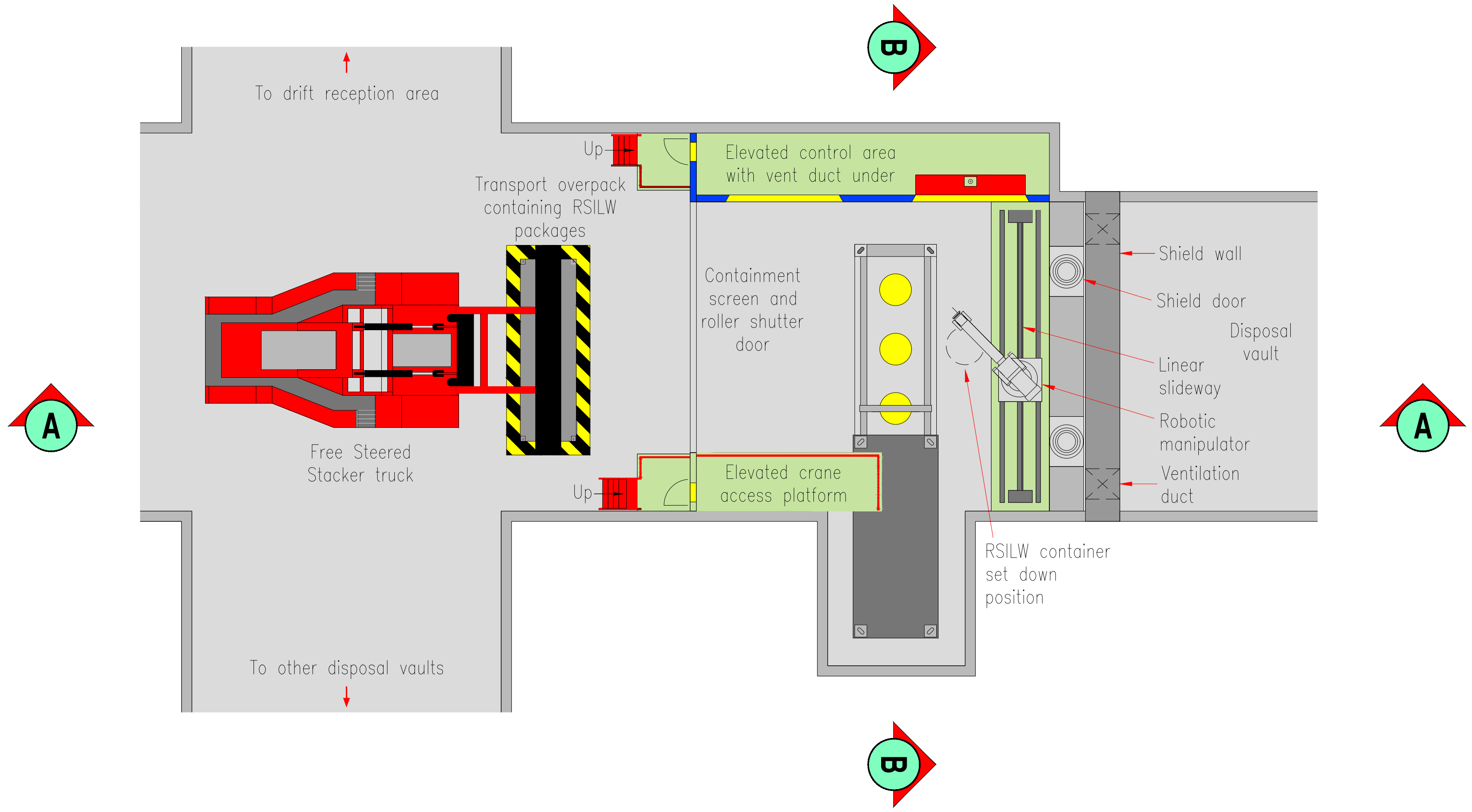
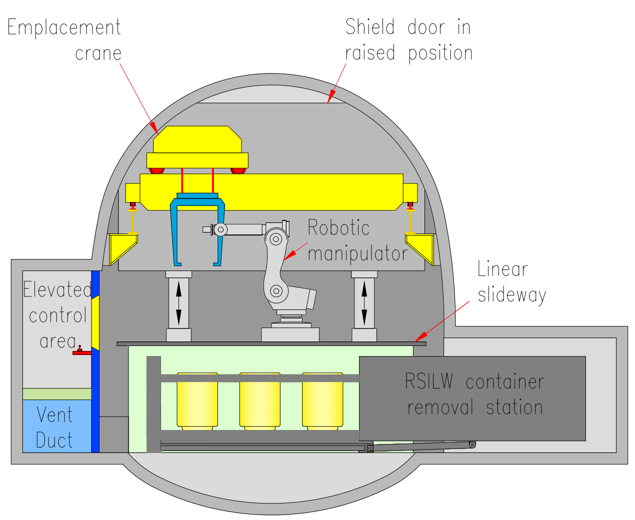
GEOLOGICAL DISPOSAL FACILITY

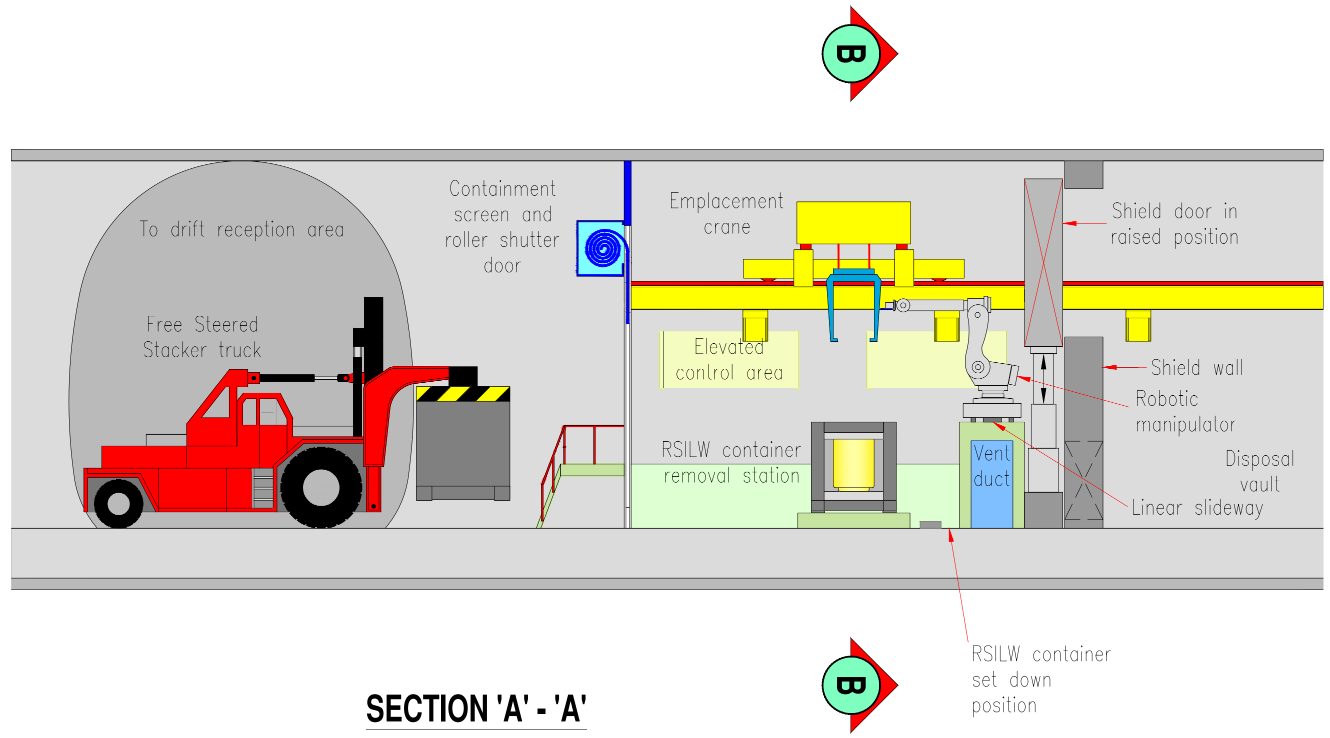
2013 DERIVED INVENTORY
LOWER STRENGTH SEDIMENTARY ROCK
UILW & SILW/LLW DISPOSAL VAULT TRANSFER AND EMPLACEMENT CROSS-SECTIONS

A3 SIZE | DRG. No. E/DRG/0041082 | P-03 STAT/REV





SECTION 'B' - 'B'



SECTION 'A' - 'A'

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NUVIA LIMITED	E/DRG/0041083

STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	DESCRIPTION	DRAWN	CHECKED	DATE
P-03	S MAJHU	I.PHIMISTER	REVISED IN LINE WITH CLIENT COMMENTS MARCH 2017	M. PADLEY	P. GASKELL	MARCH 2017
P-02	C.EDWARDS	M.JOHNSON	MINOR AMENDMENTS BASED ON RWM FEEDBACK	S.WILLIAMS-CONDOR	K.MOSS	MARCH 205

DRAWING PRODUCED BY: NUVIA

NUVIA for RADIOACTIVE WASTE MANAGEMENT LTD UNDER CONTRACT INSTRUCTION No. RWM 007927

SECURITY CLASS

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DRAWN	S.WILLIAMS-CONDOR
CHECKED	K.MOSS
APPROVED	C.EDWARDS
AUTHORISED BY RWM	M.JOHNSON
DATE	MARCH 2015

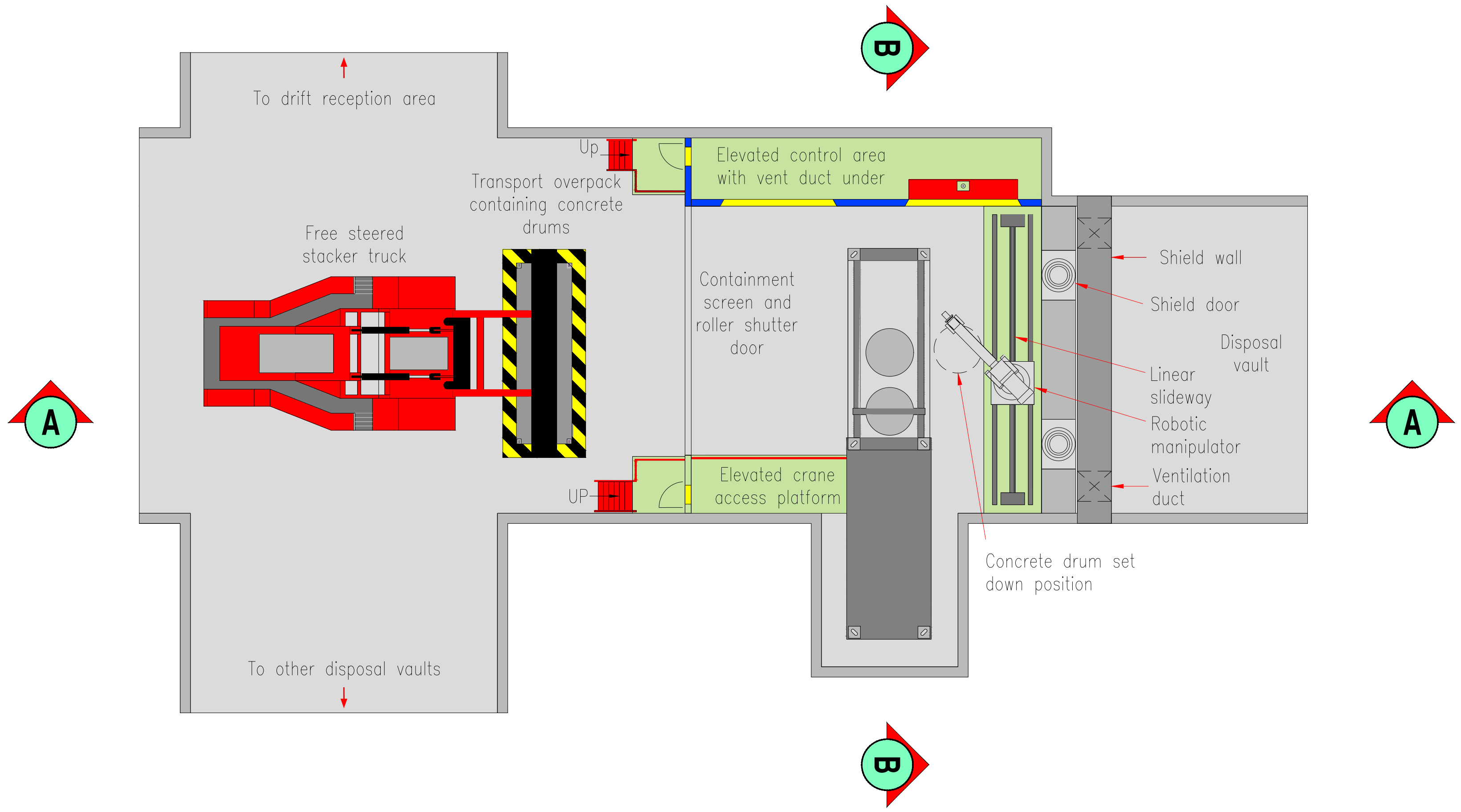
Radioactive Waste Management

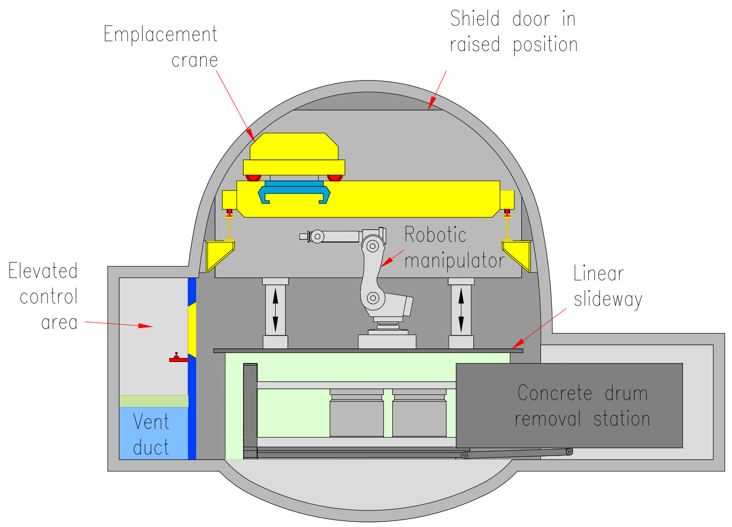
W.B.S.	
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:500

GEOLOGICAL DISPOSAL FACILITY

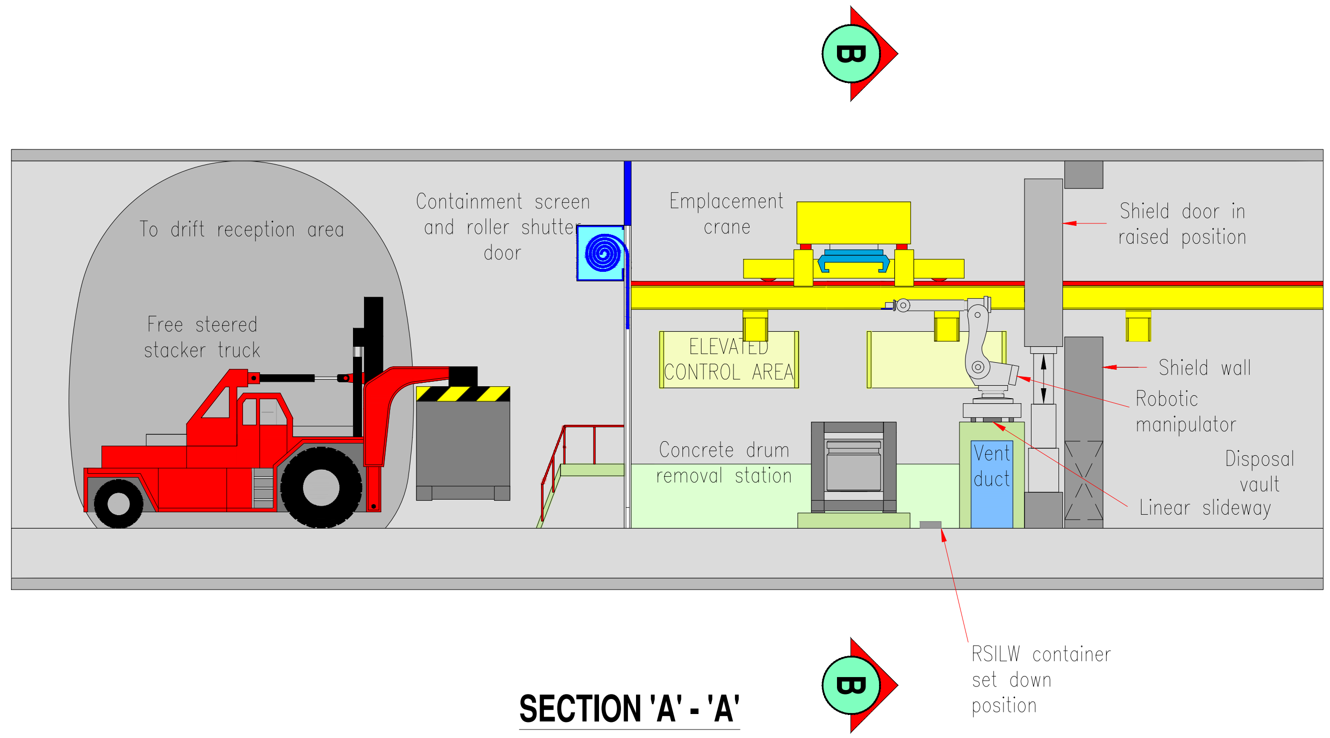
2013 DERIVED INVENTORY
LOWER STRENGTH SEDIMENTARY ROCK
RSILW CONTAINER DISPOSAL VAULT TRANSFER AND EMPLACEMENT
LAYOUT & LONGITUDINAL SECTION

SIZE	DRG. No.	STAT/REV
A3	E/DRG/0041083	P-03





SECTION 'B' - 'B'



SECTION 'A' - 'A'

Uncontrolled Hard Copy

STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	DRAWN	CHECKED	DATE	DESCRIPTION
P-03	S. MAJHU	I PHIMISTER	M. PADLEY	P. GASKELL	APRIL 2017	REVISED IN LINE WITH CLIENT COMMENTS MARCH 2017
P-02	C.EDWARDS	M.JOHNSON	S.WILLIAMS-CONDOR	K.MOSS	MARCH 2015	MINOR AMENDMENTS BASED ON RWM FEEDBACK.

DRAWING PRODUCED BY: NUVIA

NUVIA for RADIOACTIVE WASTE MANAGEMENT LTD UNDER CONTRACT INSTRUCTION No. RWM 007927

SECURITY CLASS: Not Protectively Marked

DRAWN	S.WILLIAMS-CONDOR
CHECKED	K.MOSS
APPROVED	C.EDWARDS
AUTHORISED BY RWM	M.JOHNSON
DATE	MARCH 2015

Radioactive Waste Management

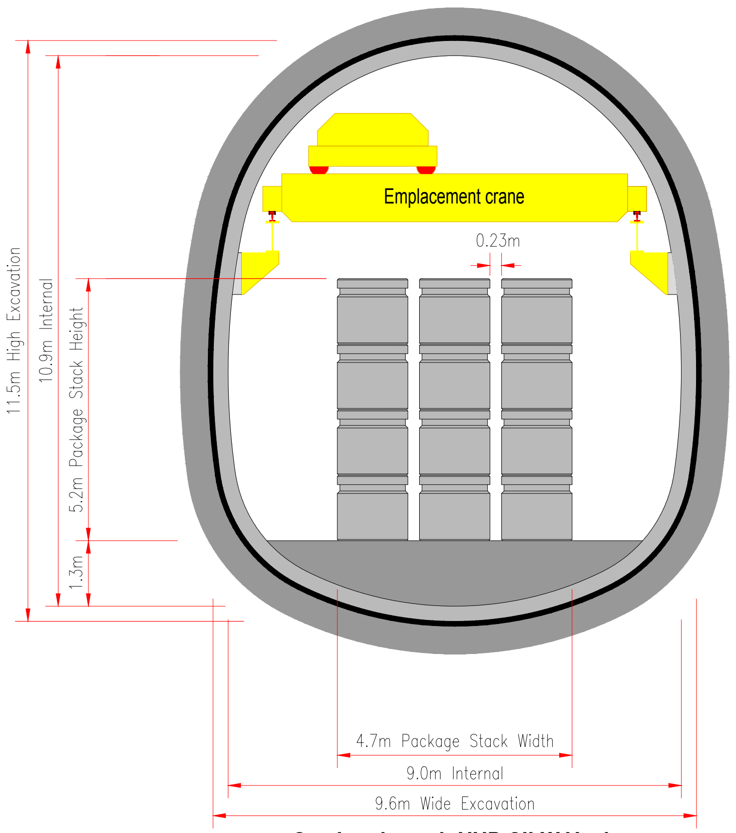
W.B.S.	
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:500

NUVIA LIMITED — E/DRG/0041084

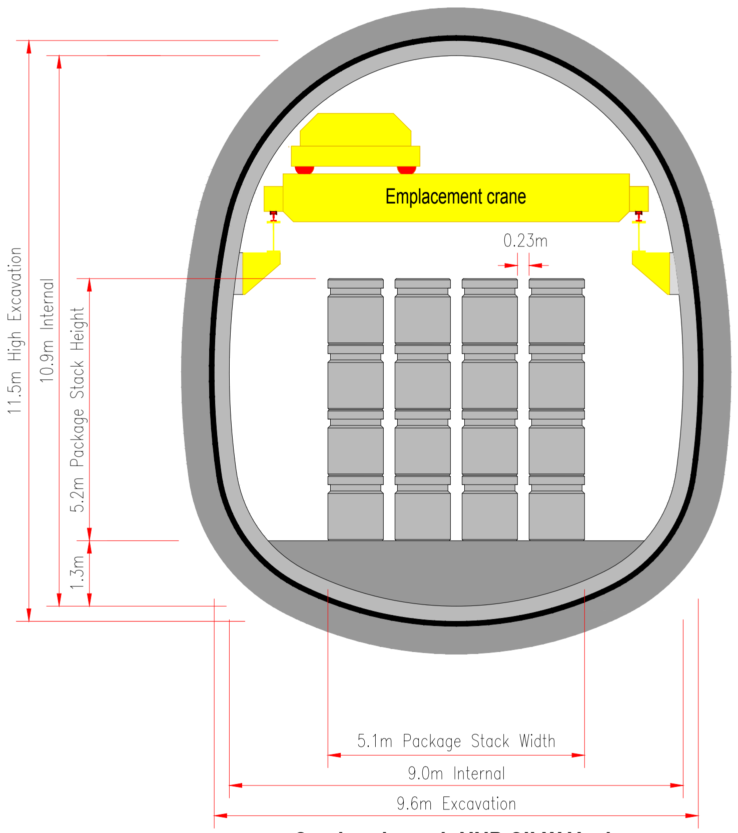
GEOLOGICAL DISPOSAL FACILITY

2013 DERIVED INVENTORY
LOWER STRENGTH SEDIMENTARY ROCK
CONCRETE DRUM DISPOSAL VAULT TRANSFER AND EMPLACEMENT
LAYOUT & LONGITUDINAL SECTION

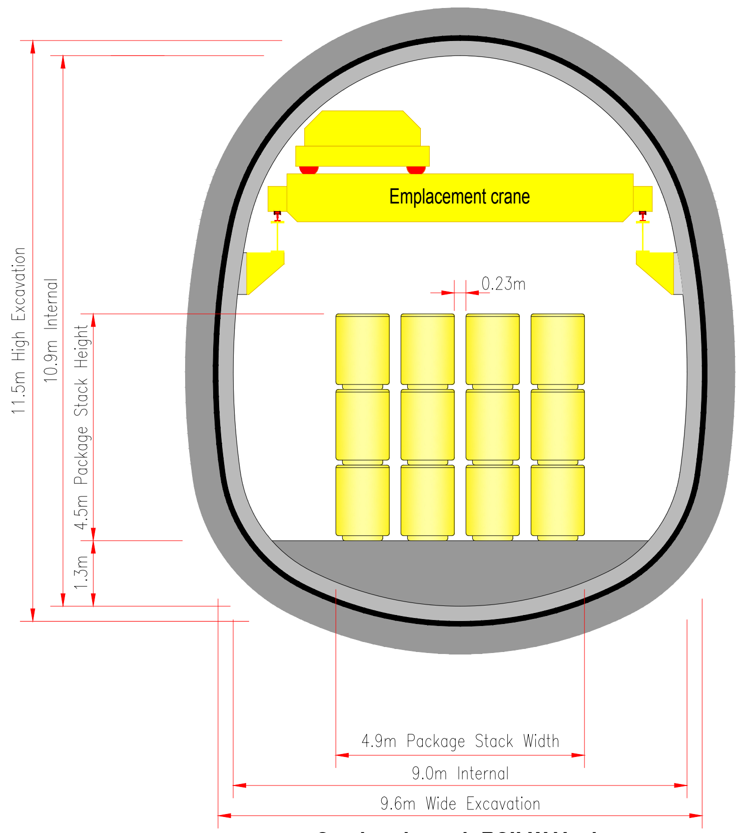
A3 SIZE | DRG. No. E/DRG/0041084 | P-03 STAT/REV



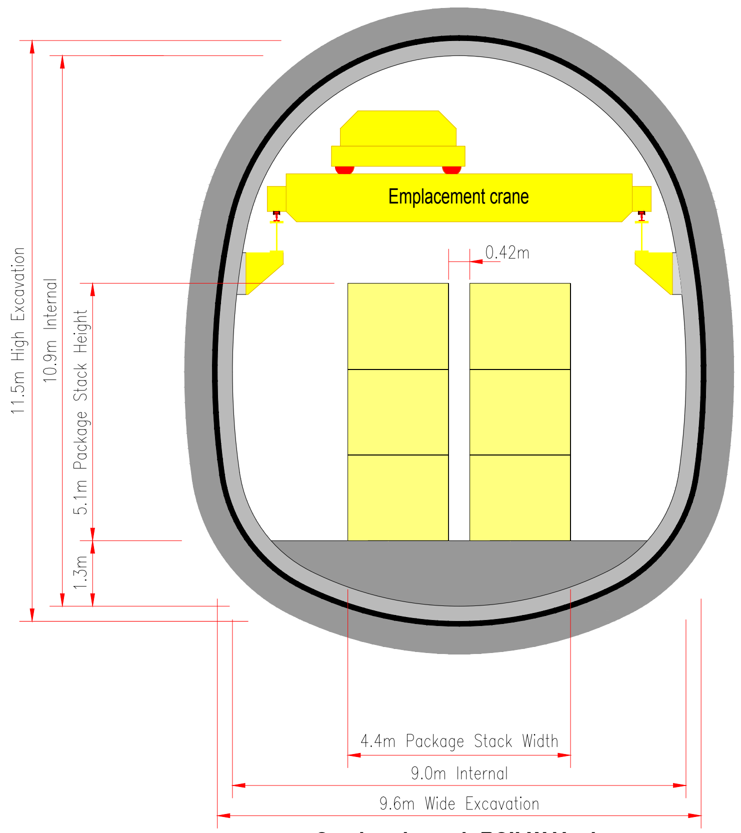
Section through NNB SILW Vault
1m³ Concrete Drums



Section through NNB SILW Vault
500l Concrete Drums



Section through RSILW Vault
500l Drums



Section through RSILW Vault
3m³ Boxes

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STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	DESCRIPTION	DRAWN	CHECKED	DATE
				?	?	
P-04	S. MAJHU	I.PHIMISTER	DETAIL MISSING FROM CRANES	M. PADLEY	P. GASKELL	MARCH 2017
P-03	S.MAJHU	I.PHIMISTER	ADDED 'METRE' TO DIMENSONS.	R.SINGLETON	P.GASKELL	JULY 2016
P-02	C.EDWARDS	M.JOHNSON	MINOR AMENDEMENTS BASED ON RWM FEEDBACK.	S.WILLIAMS-CONDOR	K.MOSS	MARCH 2015

DRAWING PRODUCED BY: NUVIA

NUVIA for RADIOACTIVE WASTE MANAGEMENT LTD UNDER CONTRACT INSTRUCTION No. RWM 007927

SECURITY CLASS: Not Protectively Marked

DRAWN	S.WILLIAMS-CONDOR
CHECKED	K.MOSS
APPROVED	C.EDWARDS
AUTHORISED BY RWM	M.JOHNSON
DATE	MARCH 2015

Radioactive Waste Management

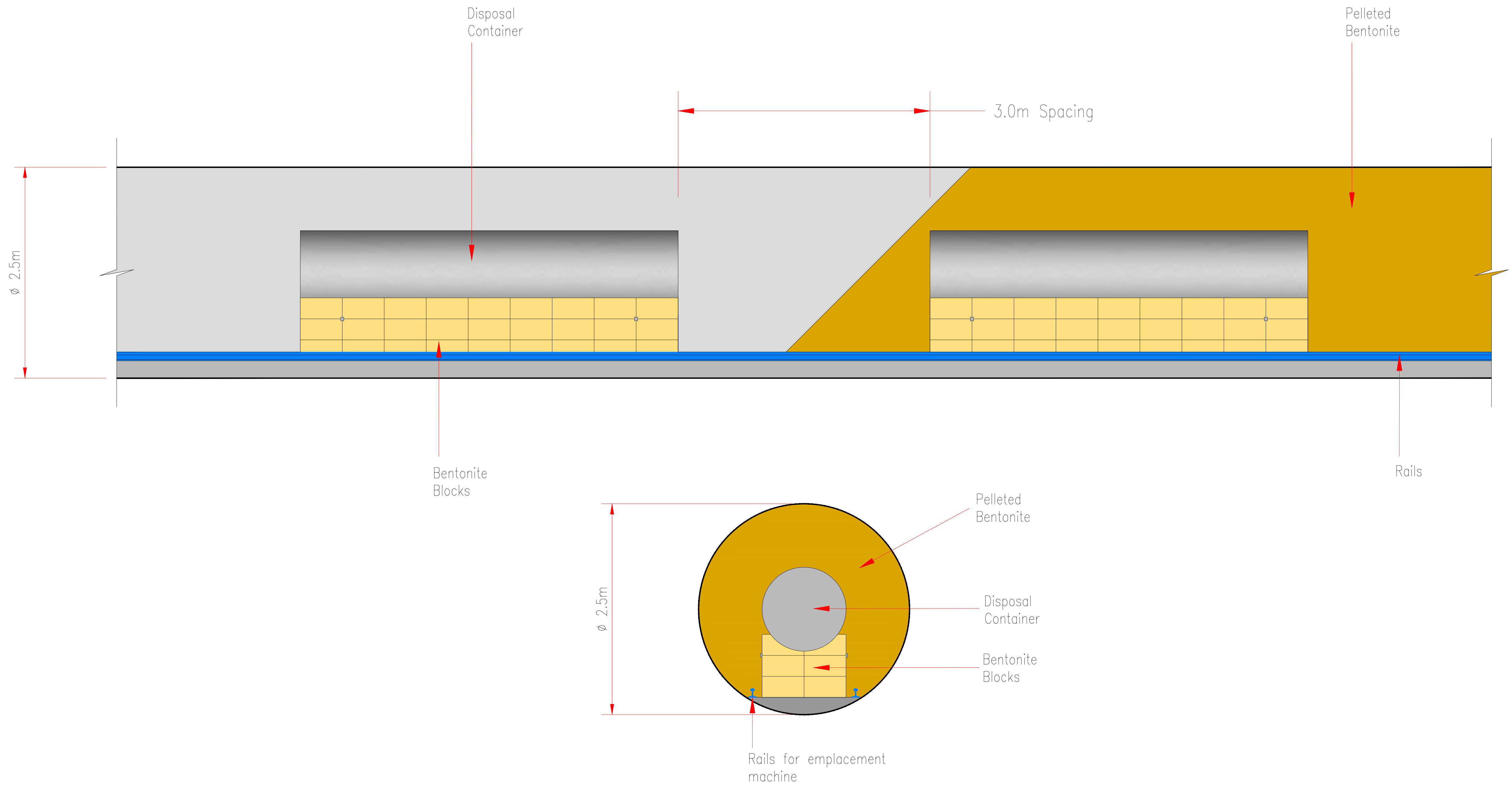
W.B.S.	
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:150

NUVIA LIMITED — E/DRG/0041085

GEOLOGICAL DISPOSAL FACILITY

2013 DERIVED INVENTORY
LOWER STRENGTH SEDIMENTARY ROCK
RSILW & CONCRETE DRUM DISPOSAL VAULT
TRANSFER AND EMPLACEMENT CROSS SECTIONS

SIZE	DRG. No.	STAT/REV
A3	E/DRG/0041085	P-04



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STAT/REV	APPROVED BY PB	AUTHORISED BY RWM
P-02	S.MAJHU	I. PHIMISTER

ADDED ANNOTATIONS TO SECTIONS.

DRAWN	CHECKED	DATE
R.SINGLETON	P.GASKELL	JULY 2016

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INSTRUCTION No. RWM 007927

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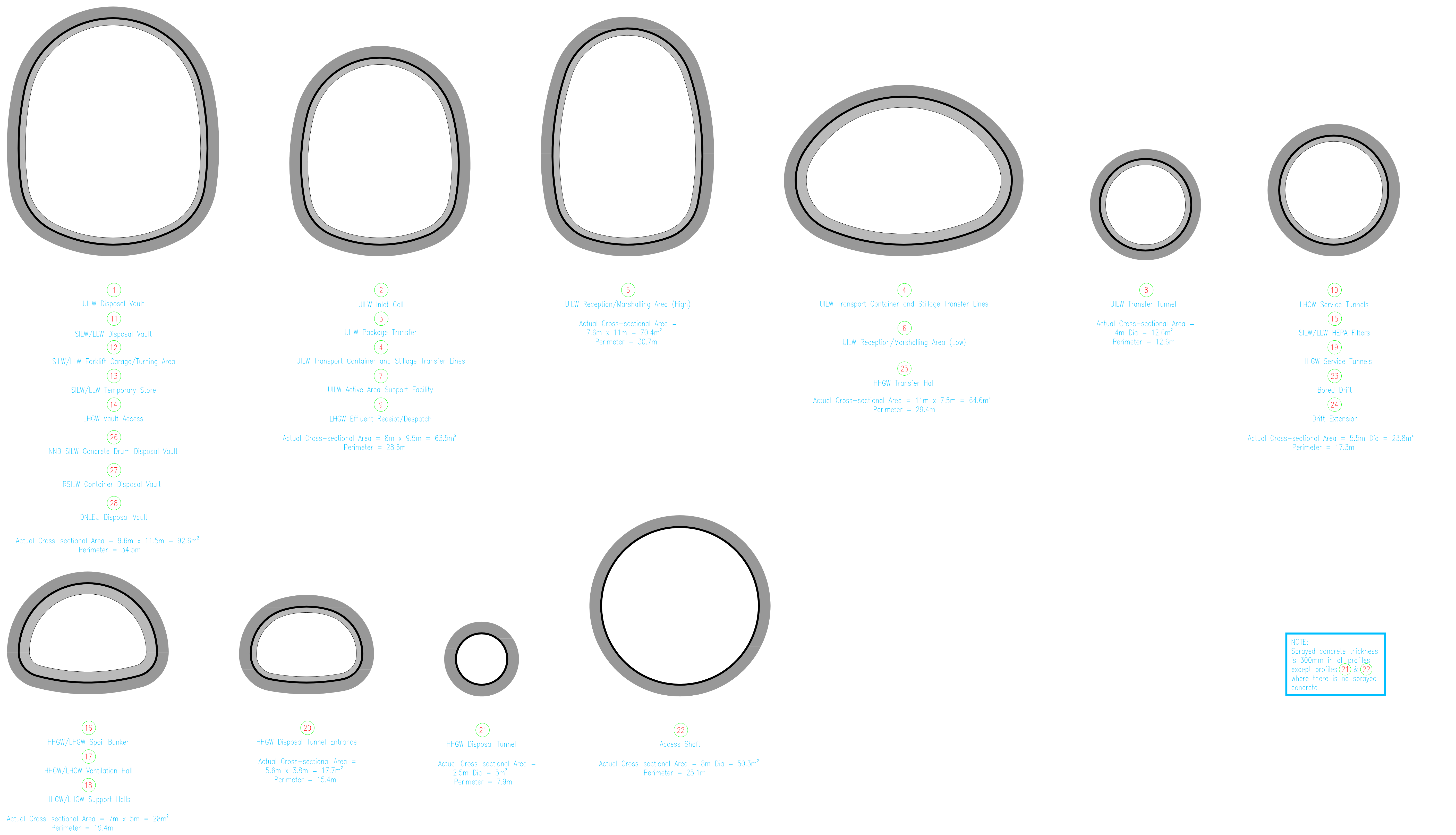
DRAWN	R.STACEY
CHECKED	P.GASKELL
APPROVED	S.MILWARD
AUTHORISED BY RWM	M.JOHNSON
DATE	DEC 2014

Radioactive Waste Management

W.B.S.	
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:50

GEOLOGICAL DISPOSAL FACILITY
2013 DERIVED INVENTORY
LOWER STRENGTH SEDIMENTARY ROCK
HHGW DISPOSAL TUNNEL
CROSS & LONGITUDINAL SECTIONS

A3 SIZE | DRG. No. E/DRG/0041087 | P-02 STAT/REV



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STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	DESCRIPTION	DRAWN	CHECKED	DATE
P–03	S. MAJHU	I PHIMISTER	REVISED IN LINE WITH CLIENT COMMENTS MARCH 2017	M. PADLEY	P. GASKELL	MAY 2017
P–02	S.MAJHU	I.PHIMISTER	ADDED DNLEU VAULT EXCAVATION PROFILE & SHOTCRETE THICKNESS	R.SINGLTON	P.GASKELL	JULY 2016

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CHECKED	P.GASKELL
APPROVED	S.MILWARD
AUTHORISED BY RWM	M.JOHNSON
DATE	DEC 2014

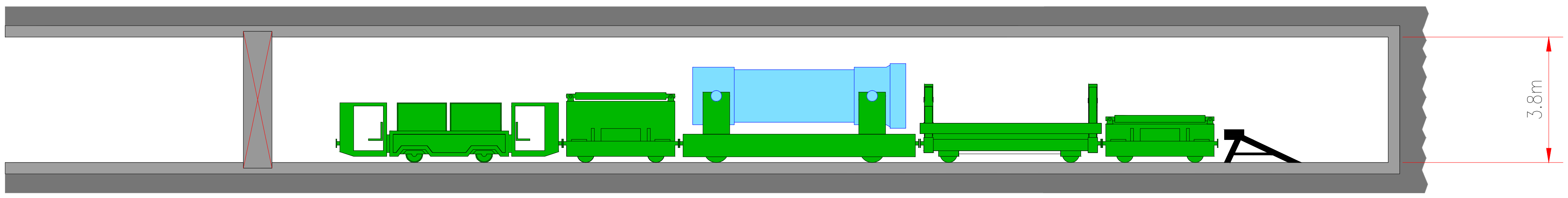
Radioactive Waste Management

W.B.S.	
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:200

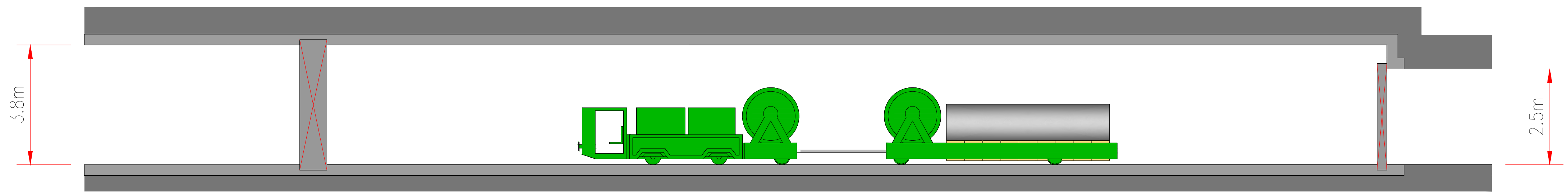
GEOLOGICAL DISPOSAL FACILITY

2013 DERIVED INVENTORY
LOWER STRENGTH SEDIMENTARY ROCK
LHGW, HHGW & COMMON SERVICE AREAS
EXCAVATION PROFILES

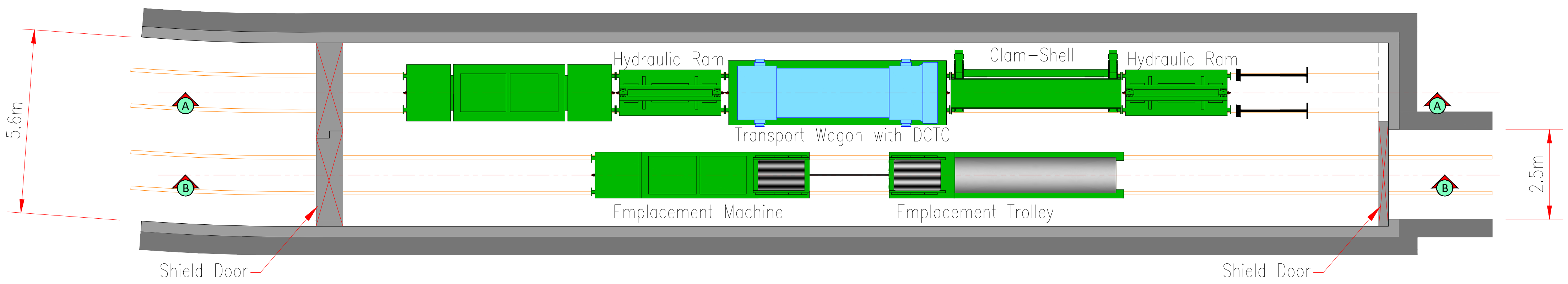
A3 SIZE | DRG. No. E/DRG/0041088 | P–03 STAT/REV



SECTION 'B' - 'B'



SECTION 'A' - 'A'



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STAT/REV	APPROVED BY PB	AUTHORISED BY RWM
		M. JOHNSON
DRAWN	CHECKED	DATE

STAT/REV	APPROVED BY PB	AUTHORISED BY RWM
DRAWN	CHECKED	DATE

STAT/REV	APPROVED BY PB	AUTHORISED BY RWM
DRAWN	CHECKED	DATE

STAT/REV	APPROVED BY PB	AUTHORISED BY RWM
P-03	S. MAJHU	I. PHIMISTER
REVISED IN LINE WITH CLIENT COMMENTS MARCH 2017		
DRAWN	CHECKED	DATE
M. PADLEY	P. GASKELL	MAY 2017

STAT/REV	APPROVED BY PB	AUTHORISED BY RWM
P-02	S.MAJHU	I.PHIMISTER
MINOR AMENDMENT BASED ON RWM FEEDBACK.		
DRAWN	CHECKED	DATE
R.SINGLETON	P.GASKELL	JULY 2016

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UNDER CONTRACT
INSTRUCTION No. RWM 007927

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CHECKED	P.GASKELL
APPROVED	S.MILWARD
AUTHORISED BY RWM	M.JOHNSON
DATE	DEC 2014

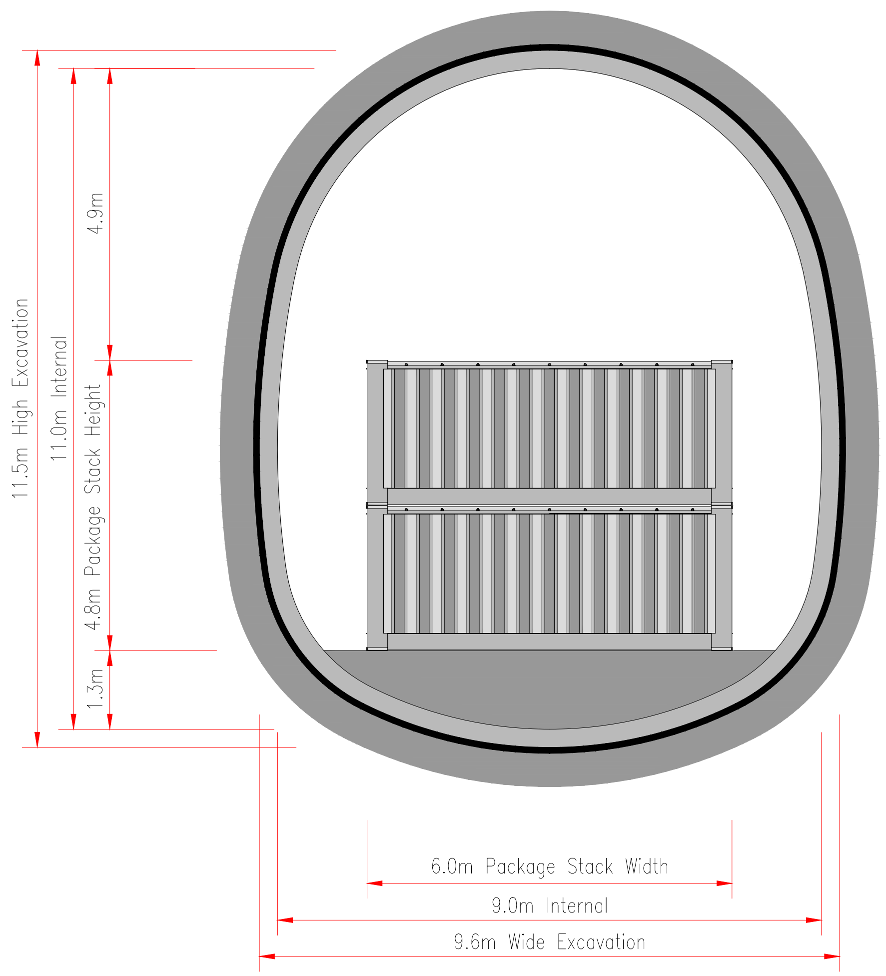
Radioactive Waste Management

W.B.S.	50003.11.03
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:150

GEOLOGICAL DISPOSAL FACILITY

2013 DERIVED INVENTORY
LOWER STRENGTH SEDIMEMENTARY ROCK
DISPOSAL TUNNEL RECEPTION AREA
LAYOUTS & SECTIONS

A3 SIZE	DRG. No.	E/DRG/0041089	P-03 STAT/REV



DNLEU Vault

STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM
DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE

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CHECKED	P.GASKELL
APPROVED	S. MAJHU
AUTHORISED BY RWM	I. PHIMISTER
DATE	JULY 2016

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W.B.S.	
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:125

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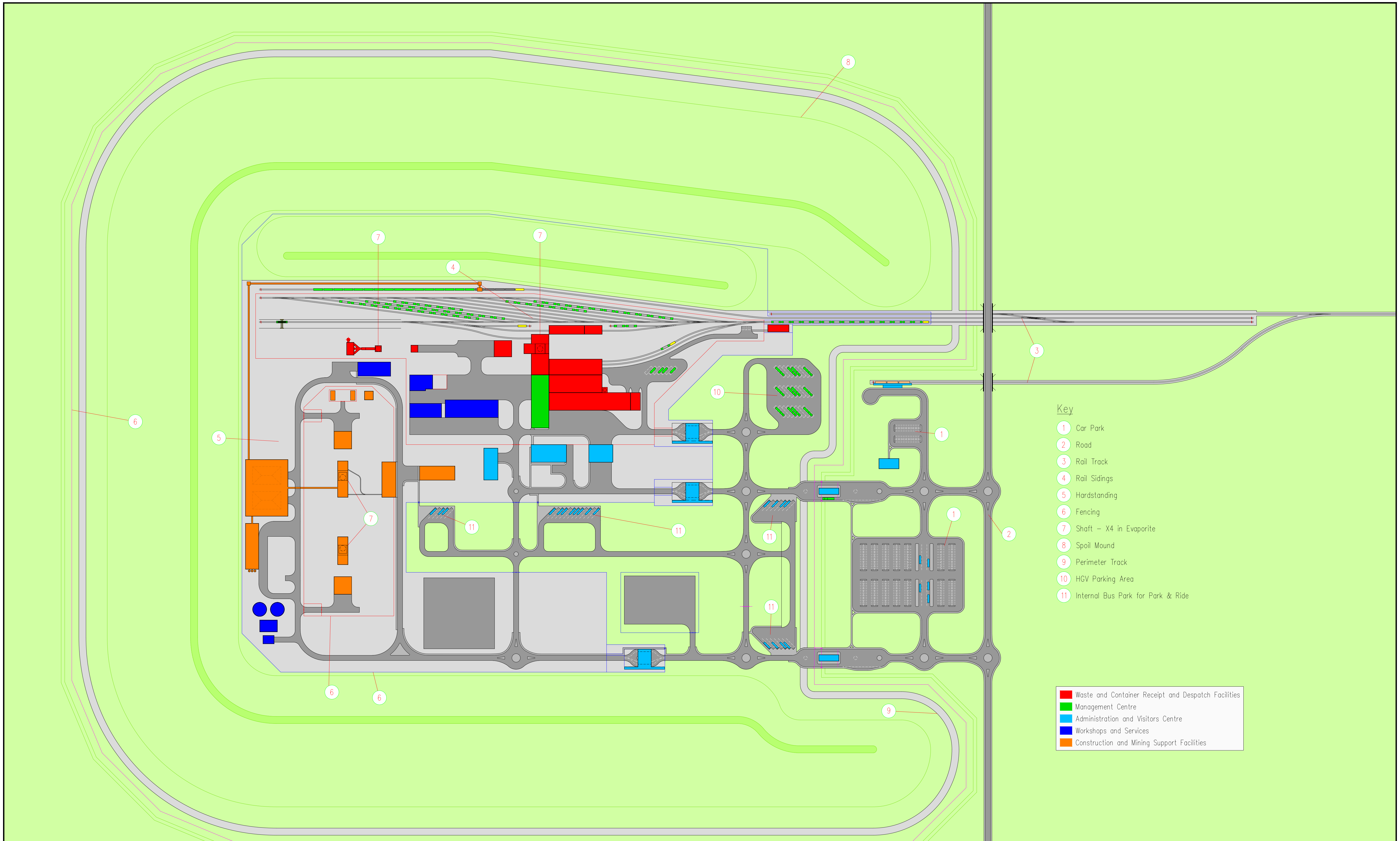
GEOLOGICAL DISPOSAL FACILITY

2013 DERIVED INVENTORY
LOWER STRENGTH SEDIMENTARY ROCK
DNLEU DISPOSAL VAULT TRANSFER AND EMPLACEMENT
CROSS-SECTIONS

A3 SIZE	DRG. No.	E/DRG/0041090	P-01 STAT/REV

Evaporite rock illustrative design drawings

E/DRG/0041121	Overall Surface Layout - First Emplacement of LHGW
E/DRG/0041123	Overall Surface Layout - End of Construction
E/DRG/0041126	2013 Derived Inventory – Underground Layout – End of Operational Phase
E/DRG/0041127	2013 Derived Inventory – Underground Layout – Waste Categories
E/DRG/0041130	2013 Derived Inventory – UILW Disposal Vault Transfer and Emplacement – Longitudinal Section
E/DRG/0041131	2013 Derived Inventory – SILW/LLW Disposal Vault Transfer and Emplacement – Longitudinal Section
E/DRG/0041132	2013 Derived Inventory – UILW & SILW/LLW Disposal Vault Transfer and Emplacement – Cross sections
E/DRG/0041133	2013 Derived Inventory – RSILW Container Disposal Vault Transfer and Emplacement – Layout and Longitudinal Section
E/DRG/0041134	2013 Derived Inventory – NNB Concrete Drum Disposal Vault Transfer and Emplacement – Layout and Longitudinal Sections
E/DRG/0041135	2013 Derived Inventory – RSILW Container & NNB SILW Concrete Drum Disposal Vault Transfer and Emplacement – Cross-Sections
E/DRG/0041137	2013 Derived Inventory – HHGW Disposal Tunnel – Cross & Longitudinal Sections
E/DRG/0041138	LHGW, HHGW & Common Services Area – Excavation Profiles
E/DRG/0041139	SILW/DNLEU Disposal Vault Transfer and Emplacement Cross-Section



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ARUP E/DRG/0041121

STAT/REV	APPROVED BY	AUTHORISED BY RWM	DRAWN	CHECKED	DATE	Description
P–06	S.LESSER	I.PHIMISTER	T,WARING	D.WILLIS	NOV 16	REVISION DETAILS ADDED.
P–05	S.LESSER	I.PHIMISTER	T.WARING	S.LESSER	APRIL 16	REVISED ANNOTATION TO MEET SECURITY REQUIREMENTS.
P–04	S.LESSER	M.JOHNSON	A.UBHOO	P.GASKELL	DEC 14	FIRST REVISION OF SURFACE LAYOUT. DRAWING NUMBER PREVIOUSLY USED FOR UNDERGROUND LAYOUT, RENUMBERED AND RENAMED.

DRAWING PRODUCED BY:
ARUP

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for
RADIOACTIVE WASTE MANAGEMENT LTD
UNDER CONTRACT
INSTRUCTION No. RWMD05040

SECURITY CLASS
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DRAWN	A.UBHOO
CHECKED	P.GASKELL
APPROVED	S.LESSER
AUTHORISED BY RWM	M.JOHNSON
DATE	DEC 14

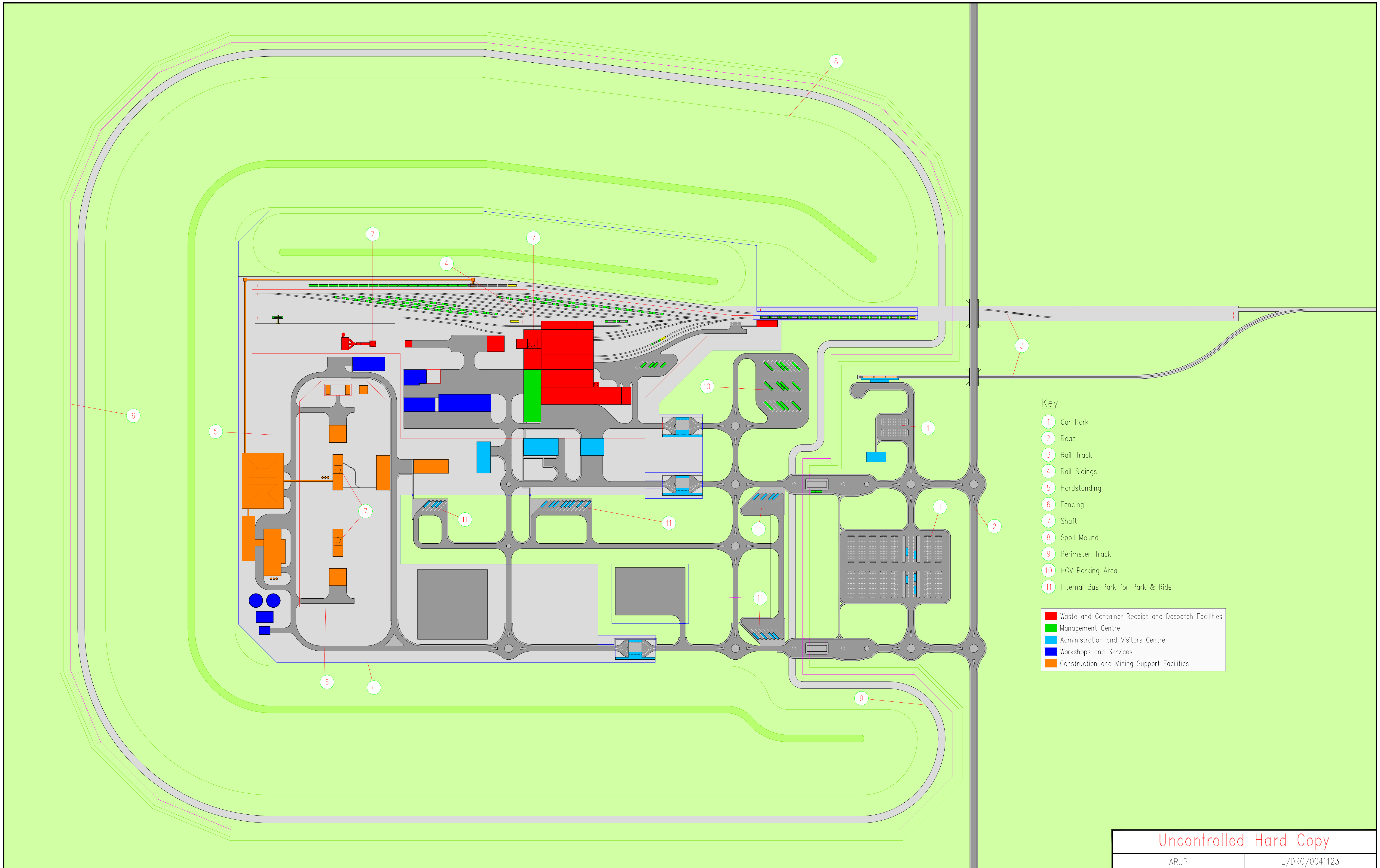
Radioactive Waste Management

W.B.S.	50003.11.03
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:5000

GEOLOGICAL DISPOSAL FACILITY

2013 INVENTORY FOR DISPOSAL
EVAPORATE ROCK
Overall Surface Layout
First Emplacement of LHGW

A3 SIZE	DRG. No.	E/DRG/0041121	P–06 STAT/REV



STAT/REV	APPROVED BY	AUTHORISED BY RWM	DESCRIPTION	DRAWN	CHECKED	DATE
P-04	S.LESSER	I.PHIMISTER	REVISION DETAILS ADDED.	T.WARING	D.WILLIS	NOV 16
P-03	S,LESSER	I.PHIMISTER	REVISED ANNOTATIONS TO MEET SECURITY REQUIREMENTS.	T.WARING	S.LESSER	APRIL 2016
P-02	S.LESSER	M.JOHNSON	FIRST ISSUE OF SURFACE LAYOUT. DRAWING NUMBER PREVIOUSLY USED FOR UNDERGROUND LAYOUT. RENUMBERED AND RETITLED.	A.UBHOO	P.GASKELL	DEC 14

DRAWING PRODUCED BY:
ARUP

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for
RADIOACTIVE WASTE MANAGEMENT LTD
UNDER CONTRACT
INSTRUCTION No. RWND05040

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DRAWN	A.UBHOO
CHECKED	P.GASKELL
APPROVED	S.LESSER
AUTHORISED BY RWM	M.JOHNSON
DATE	DEC 2014

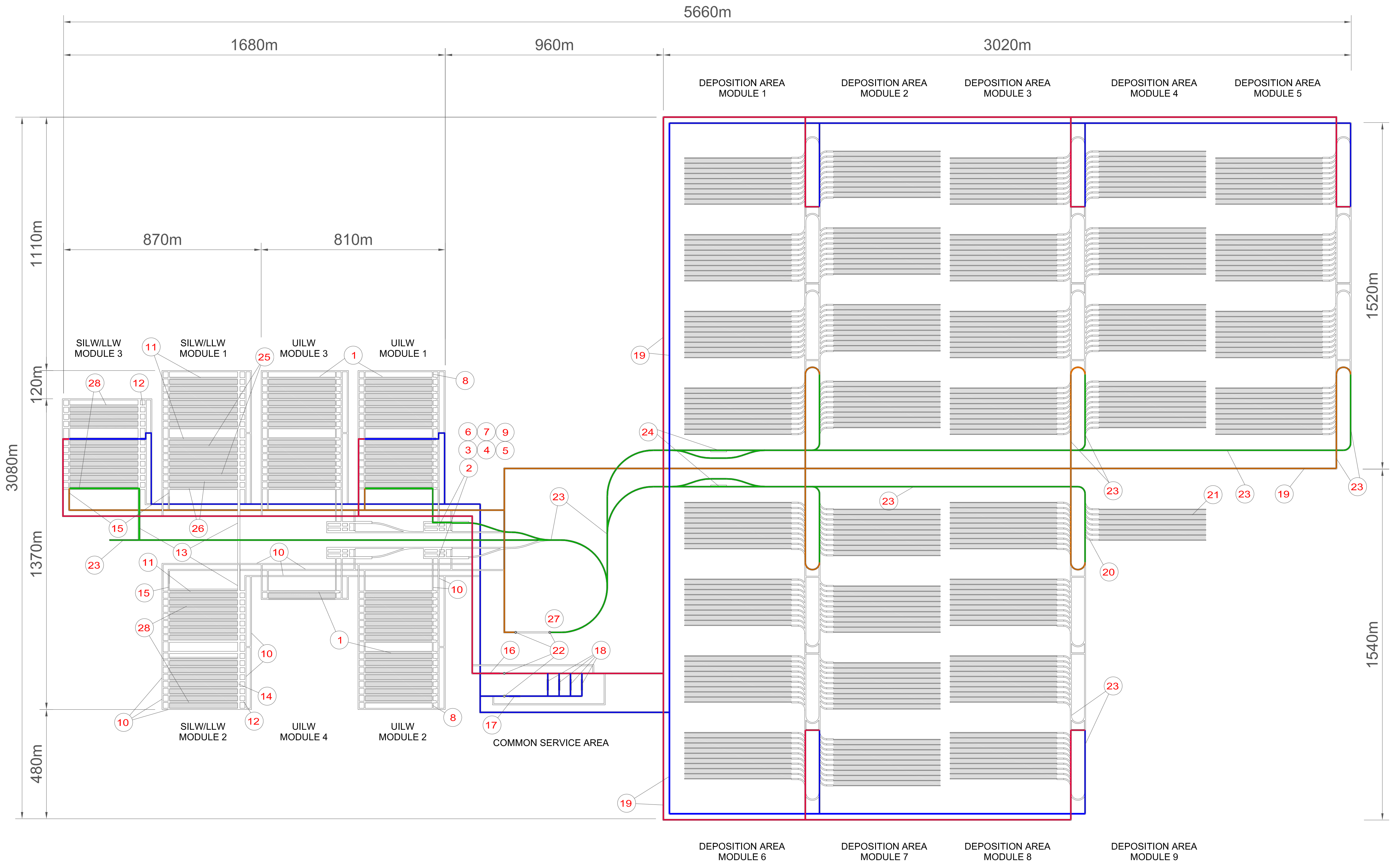
Radioactive Waste Management

W.B.S.	50003.11.03
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:5000

GEOLOGICAL DISPOSAL FACILITY

2013 INVENTORY FOR DISPOSAL
EVAPORITE ROCK
Overall Surface Layout
End of Construction

A3 SIZE | DRG. No. E/DRG/0041123 | P-04 STAT/REV



1. UILW DISPOSAL VAULT
2. UILW INLET CELL
3. UILW PACKAGE TRANSFER
4. UILW TRANSPORT CONTAINER TRANSFER LINES
5. UILW RECEPTION/MARSHALLING AREA (HIGH)
6. UILW RECEPTION/MARSHALLING AREA (LOW)
7. UILW ACTIVE AREA SUPPORT FACILITY
8. UILW TRANSFER TUNNEL
9. LHGW EFFLUENT RECEIPT/DISPATCH
10. LHGW SERVICE TUNNELS
11. SILW/LLW DISPOSAL VAULT
12. SILW/LLW FORKLIFT GARAGE/TURNING AREA
13. SILW/LLW TEMPORARY STORE
14. SILW/LLW VAULT ACCESS
15. SILW/LLW HEPA FILTERS
16. HHGW/LHGW SPOIL BUNKER
17. HHGW/LHGW VENTILATION HALL
18. HHGW/LHGW SUPPORT HALLS
19. HHGW SERVICE TUNNEL
20. HHGW DISPOSAL TUNNEL ENTRANCE
21. HHGW DISPOSAL TUNNEL
22. ACCESS SHAFTS
23. HHGW TRANSPORT TUNNELS
24. HHGW TRANSFER HALL
25. NNB SILW CONCRETE DRUM DISPOSAL VAULT
26. RSILW CONTAINER DISPOSAL VAULT
27. EMPLACEMENT SHAFT
28. DNLEU SILW DISPOSAL VAULT

LEGEND

- CONSTRUCTION INTAKE
- CONSTRUCTION RETURN
- EMPLACEMENT INTAKE
- EMPLACEMENT RETURN

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STAT/REV	APPROVED BY	AUTHORISED BY RWM	DESCRIPTION	DRAWN	CHECKED	DATE
P-03	S. MAJHU	I.PHIMISTER	REVISED IN LINE WITH CLIENT COMMENTS MARCH 2017	M. PADLEY	P.GASKELL	MARCH 2017
P02	S. MAJHU	I. PHIMISTER	UPDATED FOLLOWING IMPLEMENTATION OF CR54 UILW DISPOSAL VAULTS REDUCED BY 18 AND 30 NEW ADDED DNLEU. NUMBER OF DISPOSAL TUNNELS INCREASED BY 5	S. BRITTON	P. GASKELL	JULY 2016

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for RADIOACTIVE WASTE MANAGEMENT LTD UNDER CONTRACT INSTRUCTION No. 007927

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DRAWN	R. STACEY
CHECKED	P. GASKELL
APPROVED	S. MILWARD
AUTHORISED BY RWM	M. JOHNSON
DATE	MARCH 2015

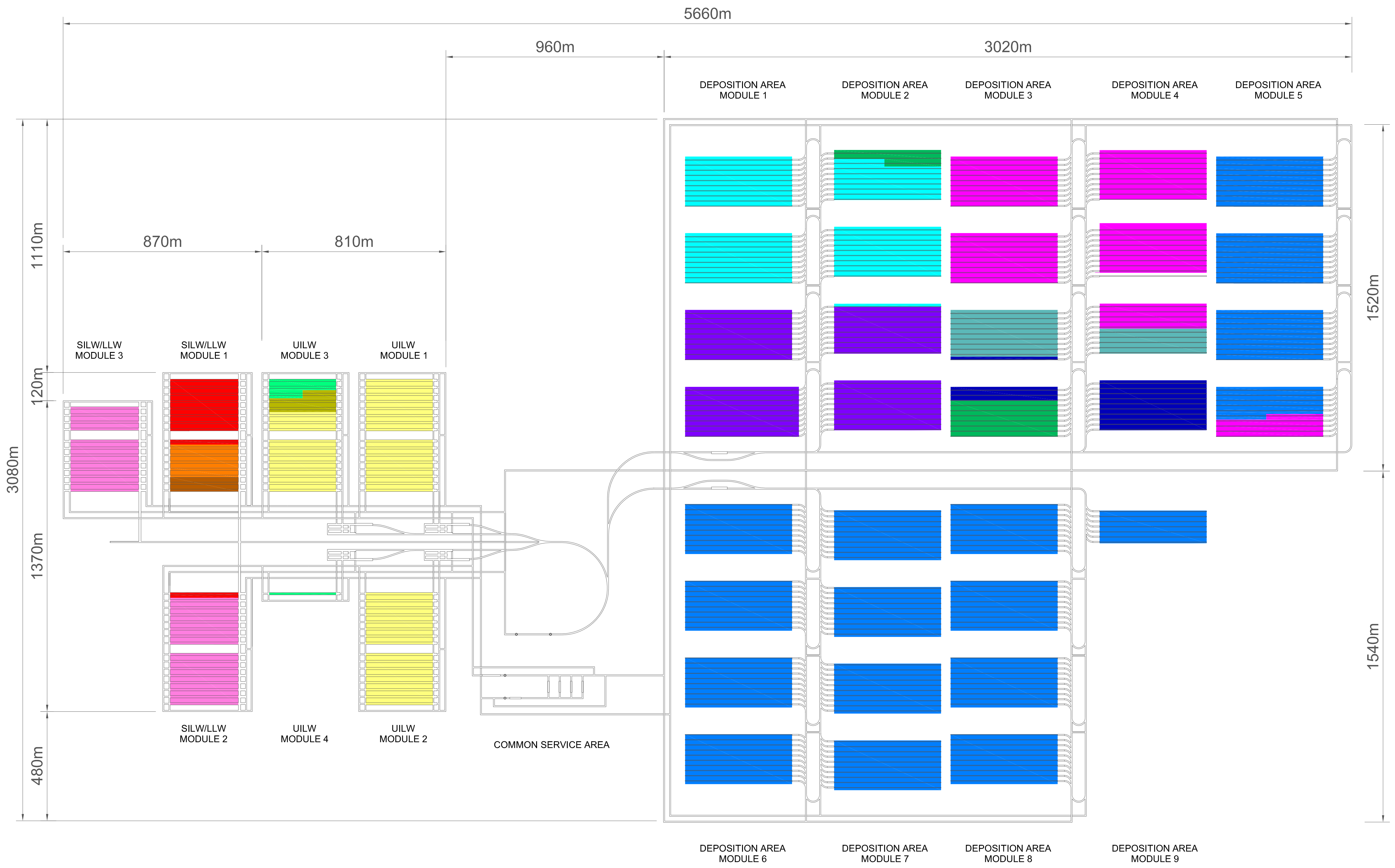
Radioactive Waste Management

W.B.S.	50003.11.03
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:20000

GEOLOGICAL DISPOSAL FACILITY

2013 INVENTORY FOR DISPOSAL
EVAPORITE ROCK
UNDERGROUND LAYOUT
END OF OPERATIONAL PHASE

A3 SIZE | DRG. No. E/DRG/0041126 | P-03 STAT/REV



LHGW	NUMBER OF DISPOSAL VAULTS
LEGACY SILW/LLW	10.0
NNB SILW	5.0
RSILW	2.0
DNLEU SILW	27.0
LEGACY UILW	43.0
DNLEU UILW	2.5
NNB UILW	3.5
TOTAL LHGW	93.0

HHGW	NUMBER OF DISPOSAL TUNNELS
LEGACY HLW	38.8
LEGACY AGR SF	38.4
LEGACY PWR SF	9.6
LEGACY MAGNOX/PFR SF	14.3
PU/HEU	14.0
MOX SF	49.3
NNB SF	162.6
TOTAL HHGW	327.0

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STAT/REV	APPROVED BY	AUTHORISED BY RWM	DESCRIPTION	DRAWN	CHECKED	DATE
P-03	S. MAJHU	I.PHIMISTER	REVISED IN LINE WITH CLIENT COMMENTS MARCH 2017	M. PADLEY	P. GASKELL	MARCH 2017
P-02	S. MAJHU	I. PHIMISTER	UPDATED FOLLOWING IMPLEMENTATION OF CR54 UILW DISPOSAL VAULTS REDUCED BY 18 AND 30 NEW ADDED DNLEU. NUMBER OF DISPOSAL TUNNELS INCREASED BY 5	S. BRITTON	P. GASKELL	JULY 2016

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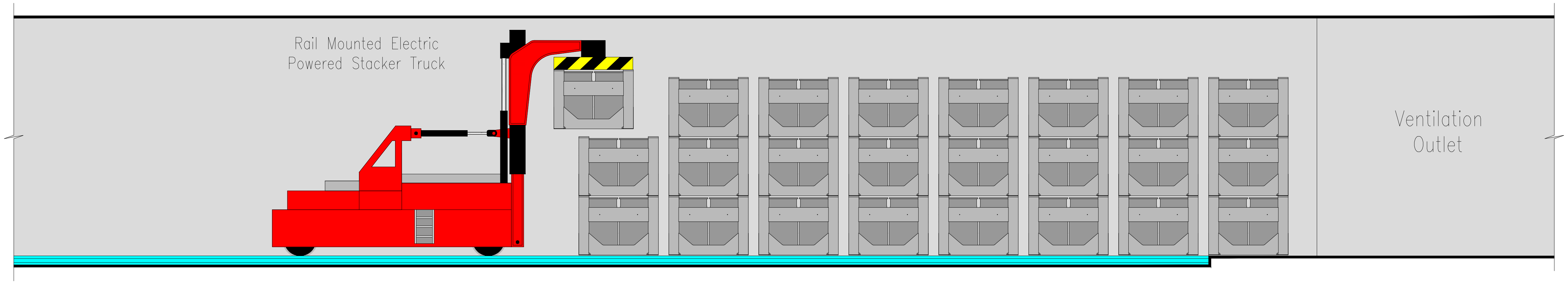
DRAWN	R. STACEY
CHECKED	P. GASKELL
APPROVED	S. MILWARD
AUTHORISED BY RWM	M. JOHNSON
DATE	MARCH 2015

Radioactive Waste Management

W.B.S.	50003.11.03
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:20000

GEOLOGICAL DISPOSAL FACILITY
2013 INVENTORY FOR DISPOSAL
EVAPORITE ROCK
UNDERGROUND LAYOUT
WASTE CATEGORIES

A3 SIZE — DRG. No. E/DRG/0041127 — P-03 STAT/REV



STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM
DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE

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UNDER CONTRACT
INSTRUCTION No. RWM 007927

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DRAWN	R.STACEY
CHECKED	P.GASKELL
APPROVED	S. MILWARD
AUTHORISED BY RWM	M.JOHNSON
DATE	DEC 2014

Radioactive Waste Management

W.B.S.	
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:100

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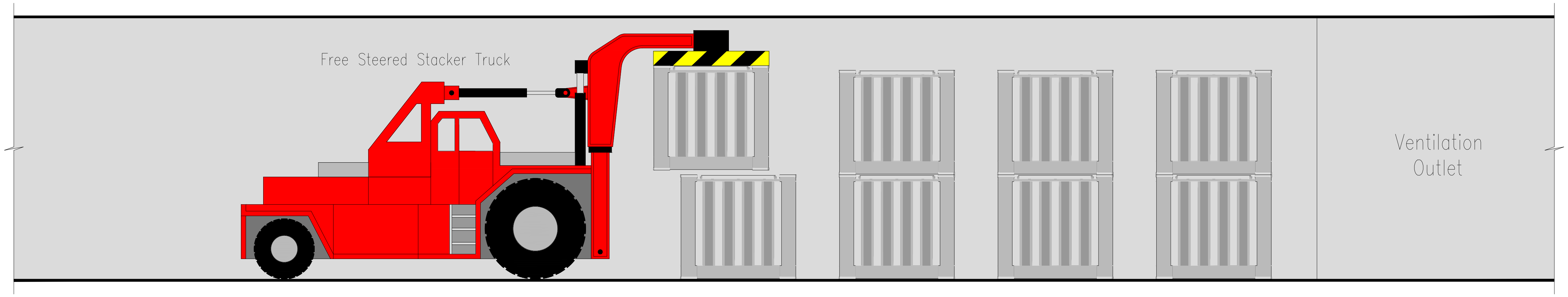
GEOLOGICAL DISPOSAL FACILITY

2013 DERIVED INVENTORY
EVAPORITE ROCK
UILW DISPOSAL VAULT TRANSFER AND EMPLACEMENT
LONGITUDINAL SECTION

A3 SIZE | DRG. No. E/DRG/0041130 | P-01 STAT/REV



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STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM
									P–03	S.MAJHU	I.PHIMISTER	P–02	S.MAJHU	I.PHIMISTER
									REVISED IN LINE WITH CLIENT COMMENTS MARCH 2017			AMENDED ANNOTATIONS BASED ON RWM FEEDBACK		
DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE
									M. PADLEY	P. GASKELL	MAY 2017	T.PRATT	P.GASKELL	JULY 2016

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for
RADIOACTIVE WASTE MANAGEMENT LTD
UNDER CONTRACT
INSTRUCTION No. RWM 007927

SECURITY CLASS
Not Protectively Marked

DRAWN	R.STACEY
CHECKED	P.GASKELL
APPROVED	S. MILWARD
AUTHORISED BY RWM	M.JOHNSON
DATE	DEC 2014

Radioactive Waste Management

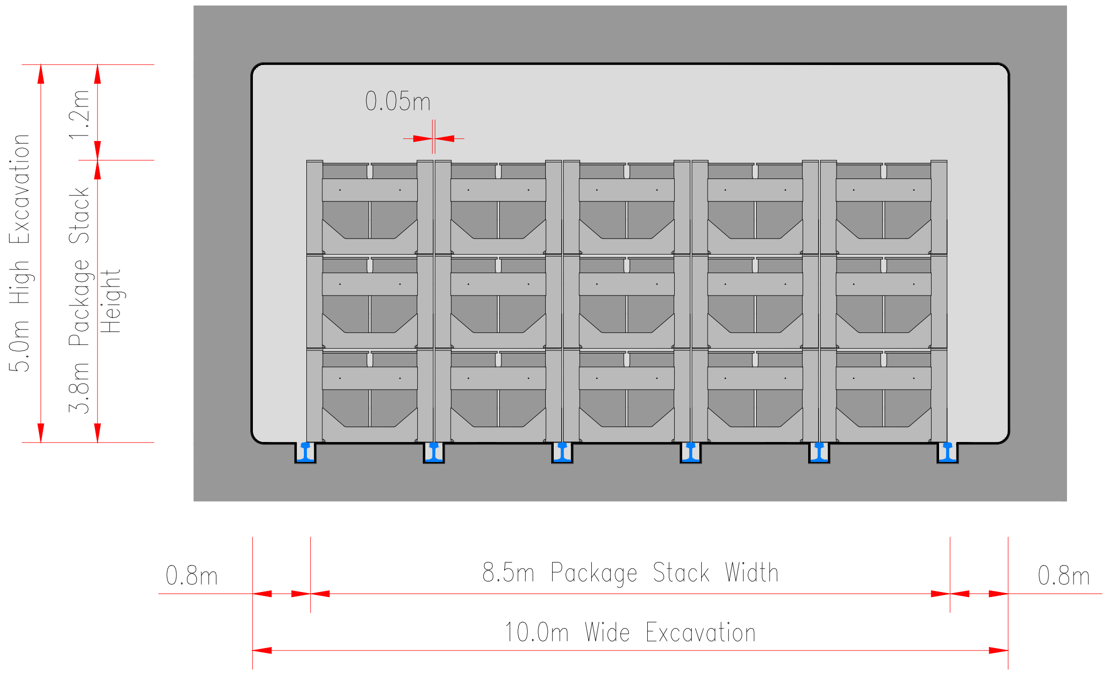
W.B.S.	
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:100

GEOLOGICAL DISPOSAL FACILITY

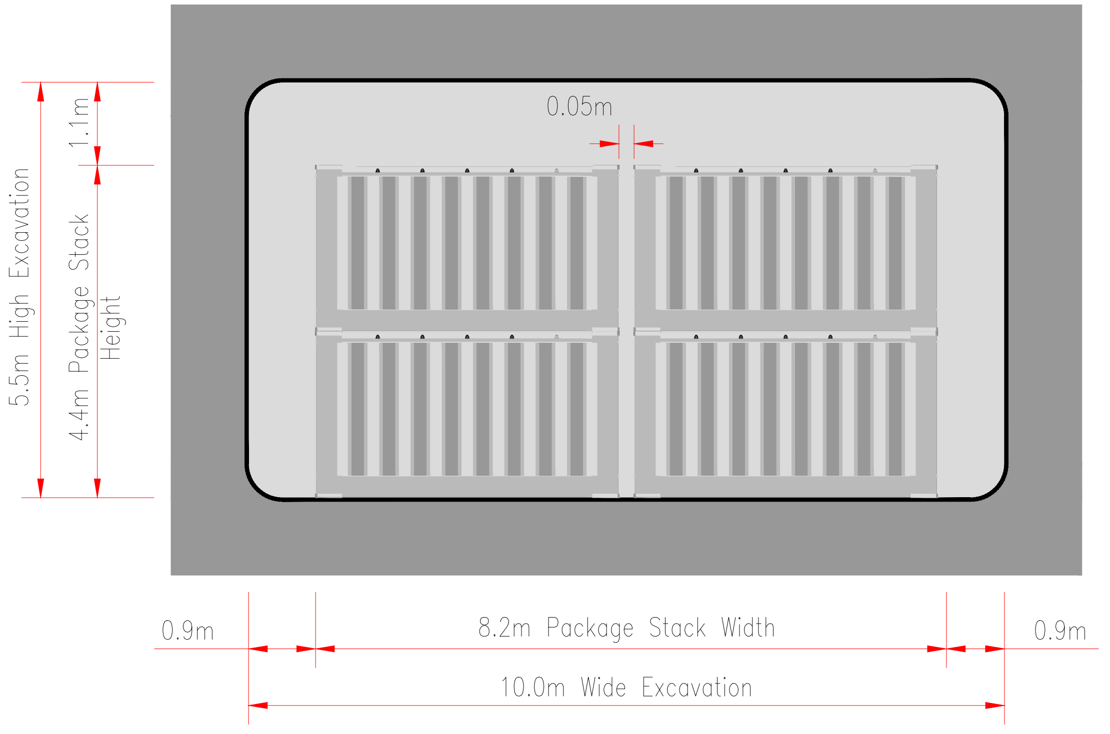
2013 DERIVED INVENTORY
EVAPORITE ROCK

SILW/LLW DISPOSAL VAULT TRANSFER AND EMPLACEMENT
LONGITUDINAL SECTION

A3 SIZE	DRG. No.	E/DRG/0041131	P–03 STAT/REV



UILW Vault



SILW/LLW Vault

STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	Description	DRAWN	CHECKED	DATE
P-03	S.MAJHU	I. PHIMISTER	REVISED IN LINE WITH CLIENT COMMENTS MARCH 2017	M. PADLEY	P. GASKELL	MAY 2017
P-02	M.MAJHU	I.PHIMISTER	UPDATED ANNOTATIONS TO INCLUDE METRES & INCLUDE REVISED SPACING OF 0.05M BETWEEN PACKAGES.	T.PRATT	P.GASKELL	OCTOBER 2016

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INSTRUCTION No. RWM 007927

SECURITY CLASS
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DRAWN	R.STACEY
CHECKED	P.GASKELL
APPROVED	S. MILWARD
AUTHORISED BY RWM	M.JOHNSON
DATE	DEC 2014

Radioactive Waste Management

W.B.S.	
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:100

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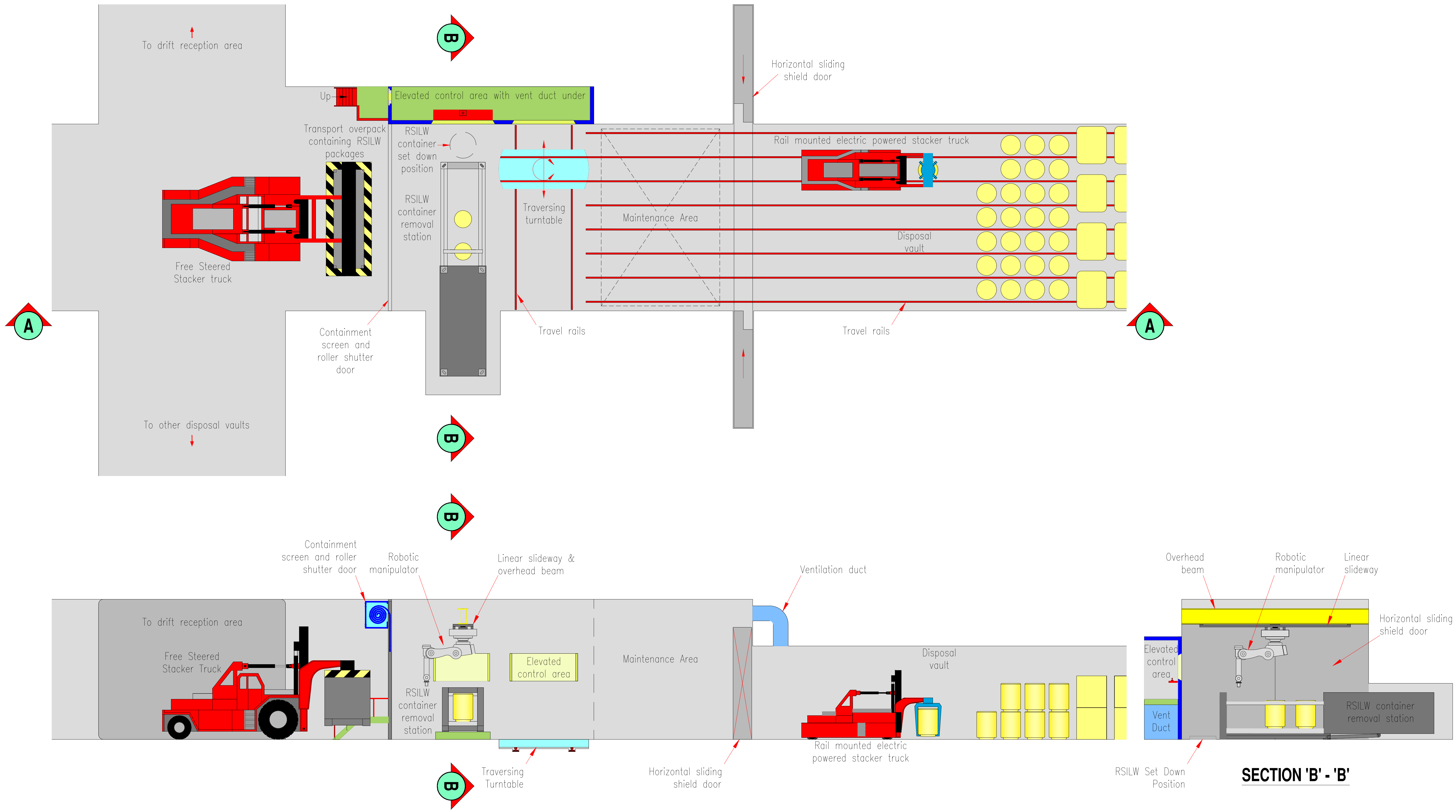
GEOLOGICAL DISPOSAL FACILITY

2013 DERIVED INVENTORY
EVAPORITE ROCK
UILW & SILW/LLW DISPOSAL VAULT TRANSFER AND EMPLACEMENT CROSS-SECTIONS

A3 SIZE | DRG. No. E/DRG/0041132 | P-03 STAT/REV



SECTION 'A' - 'A'

SECTION 'B' - 'B'

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STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM
									P-03	S. MAJHU	I.PHIMISTER	P-02	C.EDWARDS	M.JOHNSON
									REVISED IN LINE WITH CLIENT COMMENTS MARCH 2017			MINOR REVISIONS BASED ON RWM FEEDBACK.		
DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE
									M. PADLEY	P. GASKELL	MARCH 2017	S.WILLIAMS-CONDOR	K.MOSS	MARCH 2015

DRAWING PRODUCED BY: NUVIA

NUVIA for RADIOACTIVE WASTE MANAGEMENT LTD UNDER CONTRACT INSTRUCTION No. RWM 007927

SECURITY CLASS
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DRAWN	S.WILLIAMS-CONDOR
CHECKED	K.MOSS
APPROVED	C.EDWARDS
AUTHORISED BY RWM	M.JOHNSON
DATE	MARCH 2015

Radioactive Waste Management

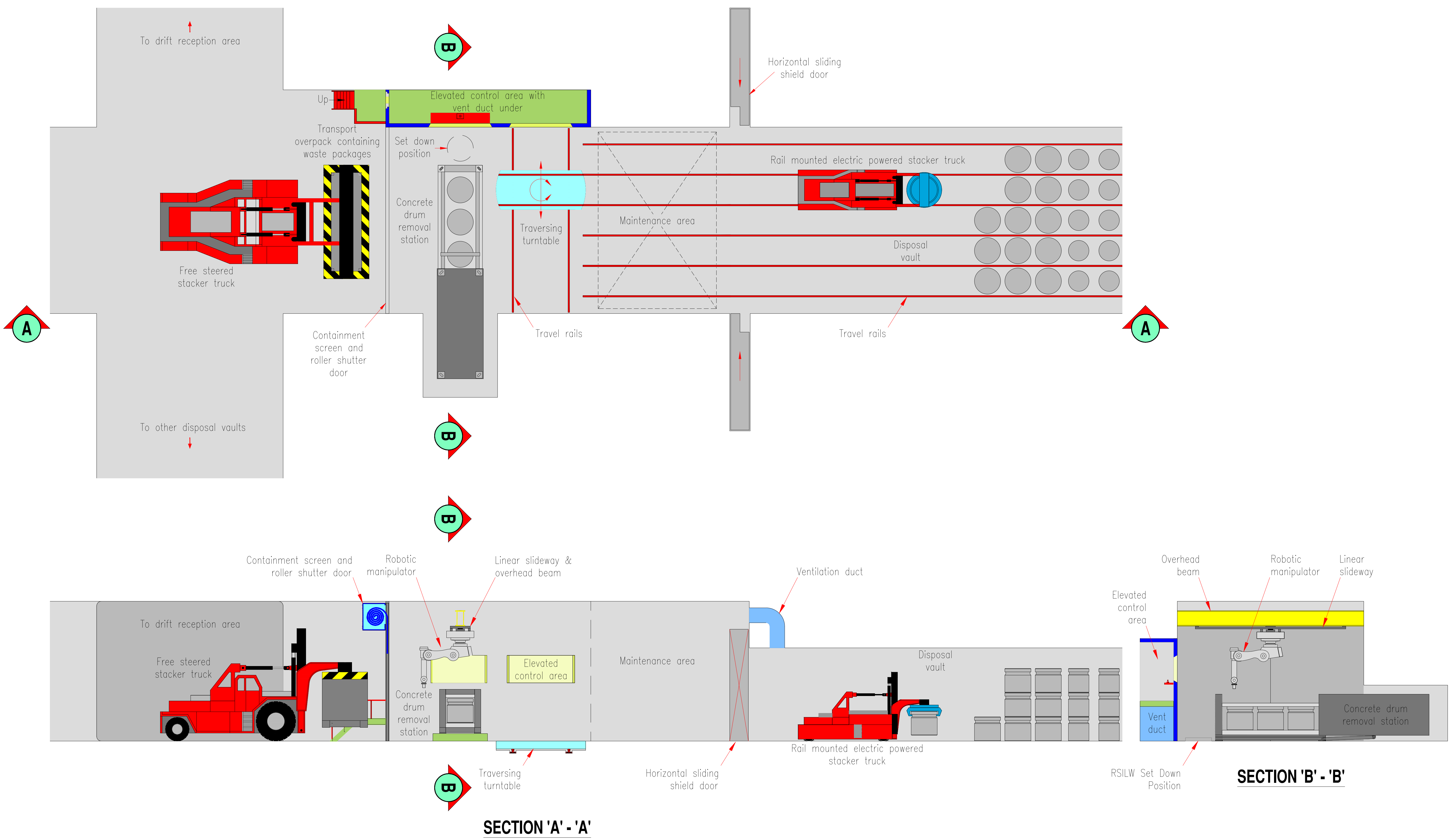
W.B.S.	
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:500

NUVIA LIMITED | E/DRG/0041133

GEOLOGICAL DISPOSAL FACILITY

2013 DERIVED INVENTORY
EVAPORITE ROCK
RSILW CONTAINER DISPOSAL VAULT TRANSFER AND EMPLACEMENT
LAYOUT & LONGITUDINAL SECTION

A3 SIZE | DRG. No. E/DRG/0041133 | P-03 STAT/REV



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NUVIA LIMITED E/DRG/0041134

STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	DRAWN	CHECKED	DATE
P-03	S. MAJHU	I.PHIMISTER	M. PADLEY	P. GASKELL	MARCH 2017
P-02	C.EDWARDS	M.JOHNSON	S.WILLIAMS-CONDOR	K.MOSS	MARCH 2015

P-03: REVISED IN LINE WITH CLIENT COMMENTS MARCH 2017

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UNDER CONTRACT
INSTRUCTION No. RWM 007927

SECURITY CLASS
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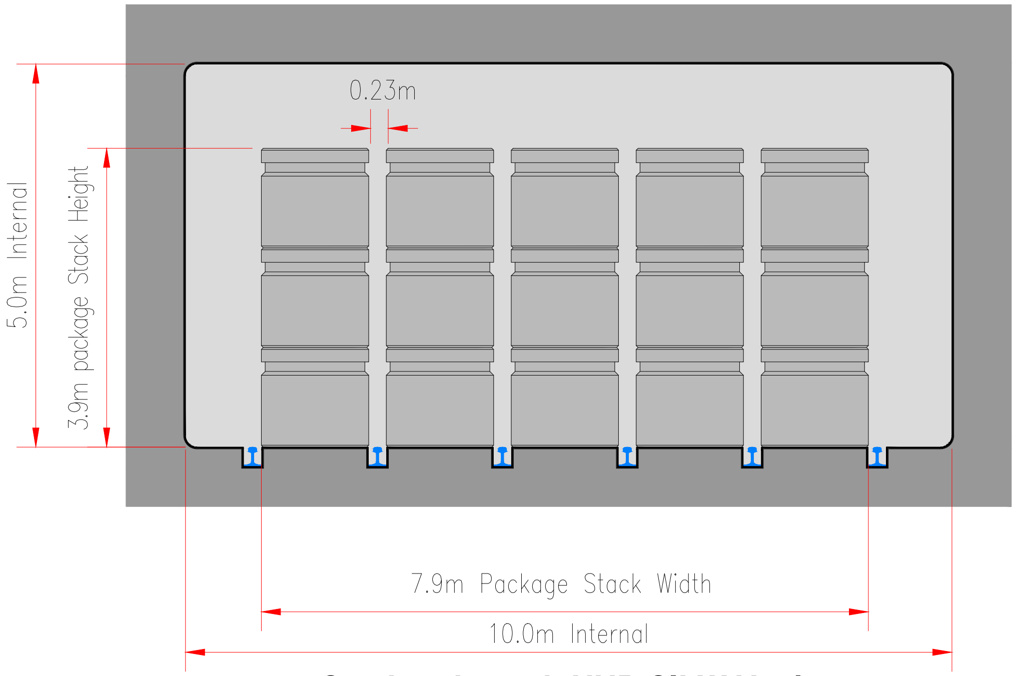
DRAWN	S.WILLIAMS-CONDOR
CHECKED	K.MOSS
APPROVED	C.EDWARDS
AUTHORISED BY RWM	M.JOHNSON
DATE	MARCH 2015

Radioactive Waste Management

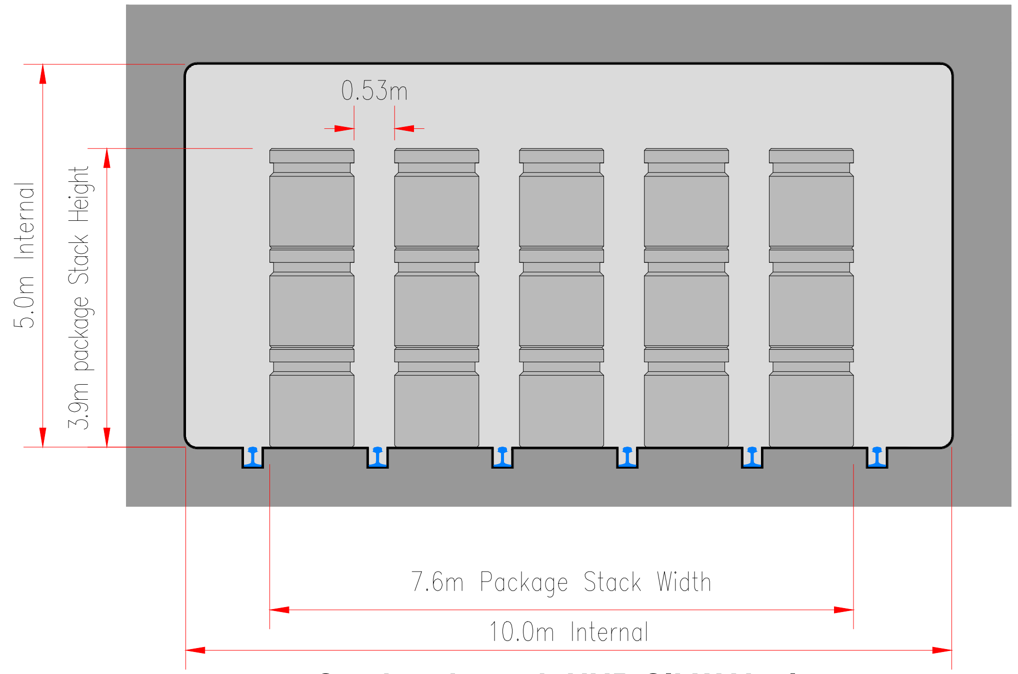
W.B.S.	
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:500

GEOLOGICAL DISPOSAL FACILITY
2013 DERIVED INVENTORY
EVAPORITE ROCK
CONCRETE DRUM DISPOSAL VAULT TRANSFER AND EMPLACEMENT
LAYOUT & LONGITUDINAL SECTION

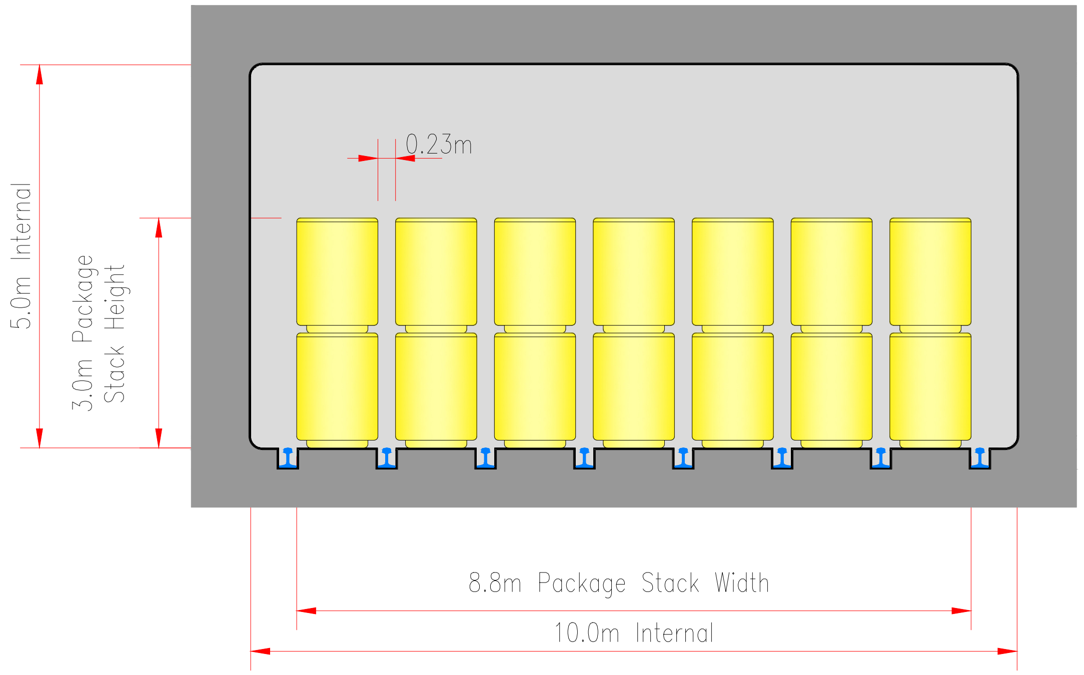
A3 SIZE | DRG. No. E/DRG/0041134 | P-03 STAT/REV



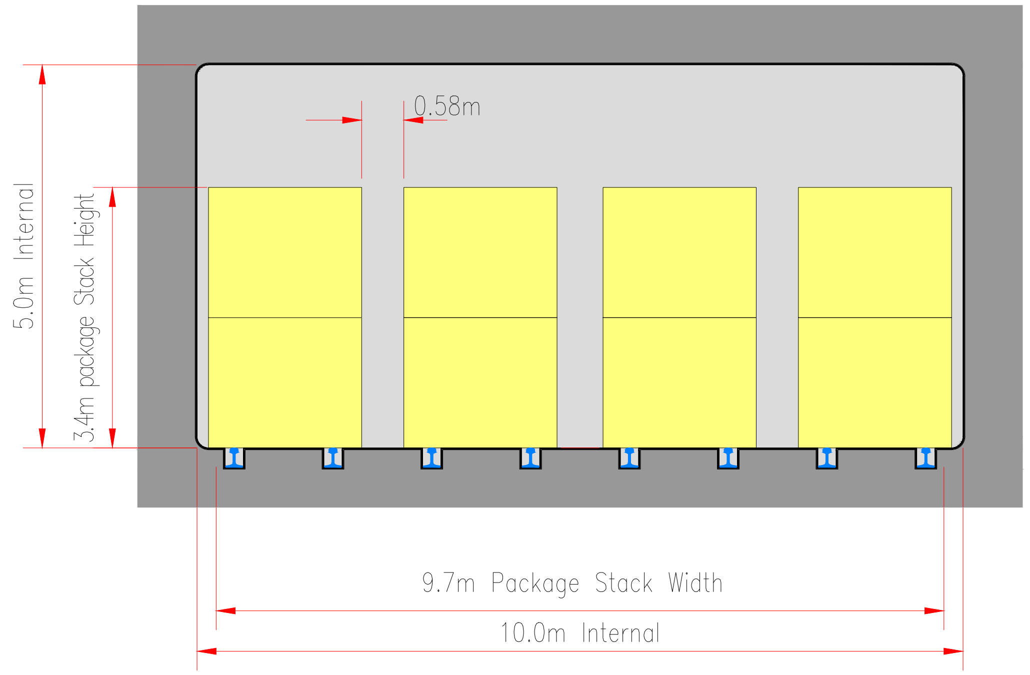
Section through NNB SILW Vault
1m³ Concrete Drums



Section through NNB SILW Vault
500l Concrete Drums



Section through RSILW Vault
500l Drums



Section through RSILW Vault
3m³ Boxes

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STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	DESCRIPTION	DRAWN	CHECKED	DATE
P–04	S. MAJHU	I PHIMISTER	REVISED TO CLIENT COMMENTS MARCH 2017	M. PADLEY	P. GASKELL	MARCH 2017
P–03	S.MAJHU	I.PHIMISTER	REVISED ANNOTATIONS TO INCLUDE METRES & TO REMOVE NUMBER OF DECIMAL PLACES.	R.SINGLETON	P.GASKELL	JULY 2016
P–02	C.EDWARDS	M.JOHNSON	MINOR AMENDMENTS BASED ON RWM FEEDBACK.	S.WILLIAMS–CONDOR	K.MOSS	MARCH 2015

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DRAWN	S.WILLIAMS–CONDOR
CHECKED	K.MOSS
APPROVED	C.EDWARDS
AUTHORISED BY RWM	M.JOHNSON
DATE	MARCH 2015

Radioactive Waste Management

W.B.S.	
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:250

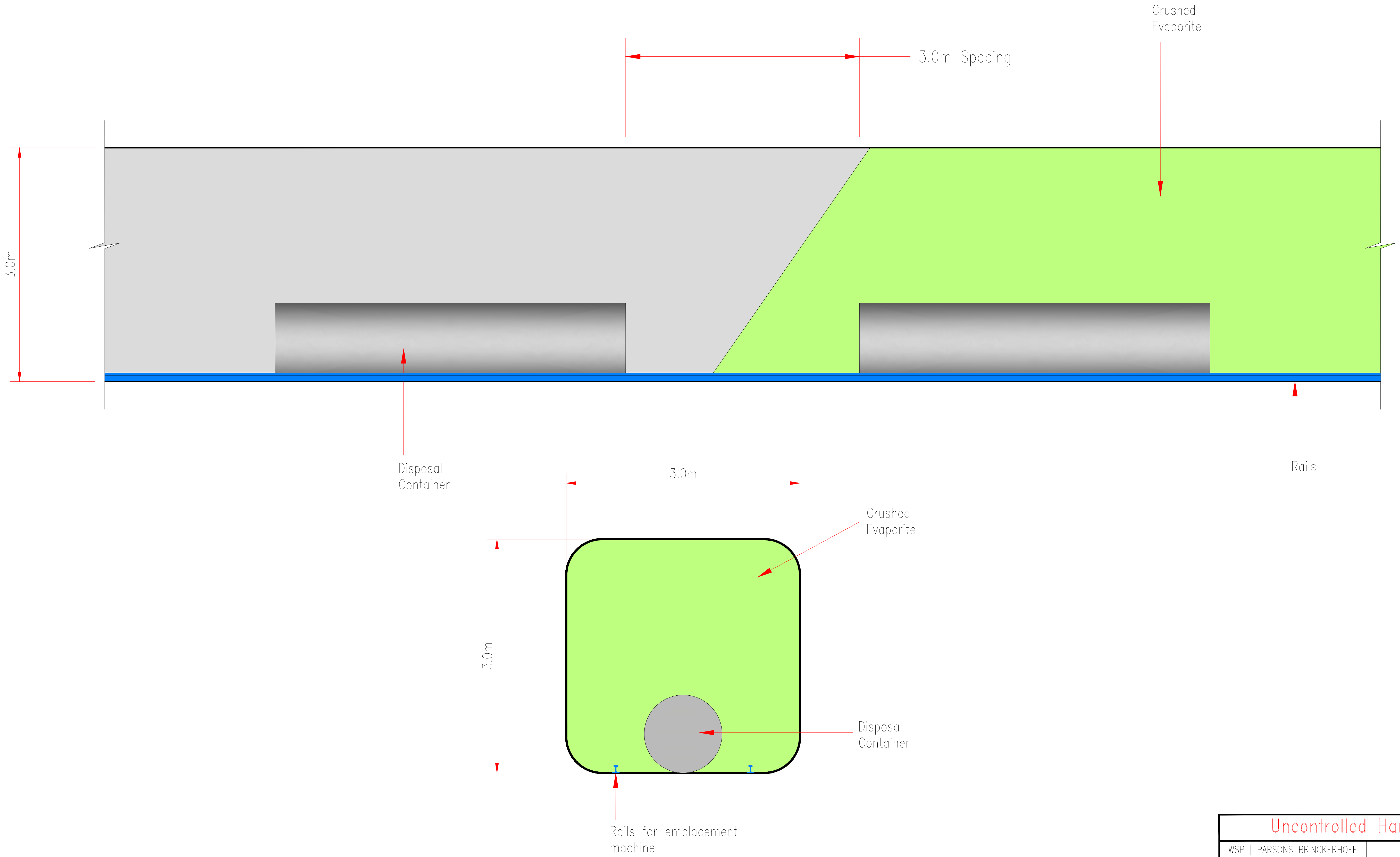
NUVIA LIMITED — E/DRG/0041135

GEOLOGICAL DISPOSAL FACILITY

2013 DERIVED INVENTORY
EVAPORITE ROCK

RSILW & CONCRETE DRUMS DISPOSAL VAULT
TRANSFER AND EMPLACEMENT CROSS SECTIONS

A3 SIZE | DRG. No. E/DRG/0041135 | P–04 STAT/REV



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STAT/REV	APPROVED BY PB	AUTHORISED BY RWM
P–02	S.MAJHU	I.PHIMISTER
ADDED ANNOTATIONS AND AMENDED COLOUR OF BUFFER MATERIAL.		
DRAWN	CHECKED	DATE
R.SINGLETON	P.GASKELL	JULY 2016

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UNDER CONTRACT
INSTRUCTION No. RWM 007927

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DRAWN	R.STACEY
CHECKED	P.GASKELL
APPROVED	S. MILWARD
AUTHORISED BY RWM	M.JOHNSON
DATE	DEC 2014

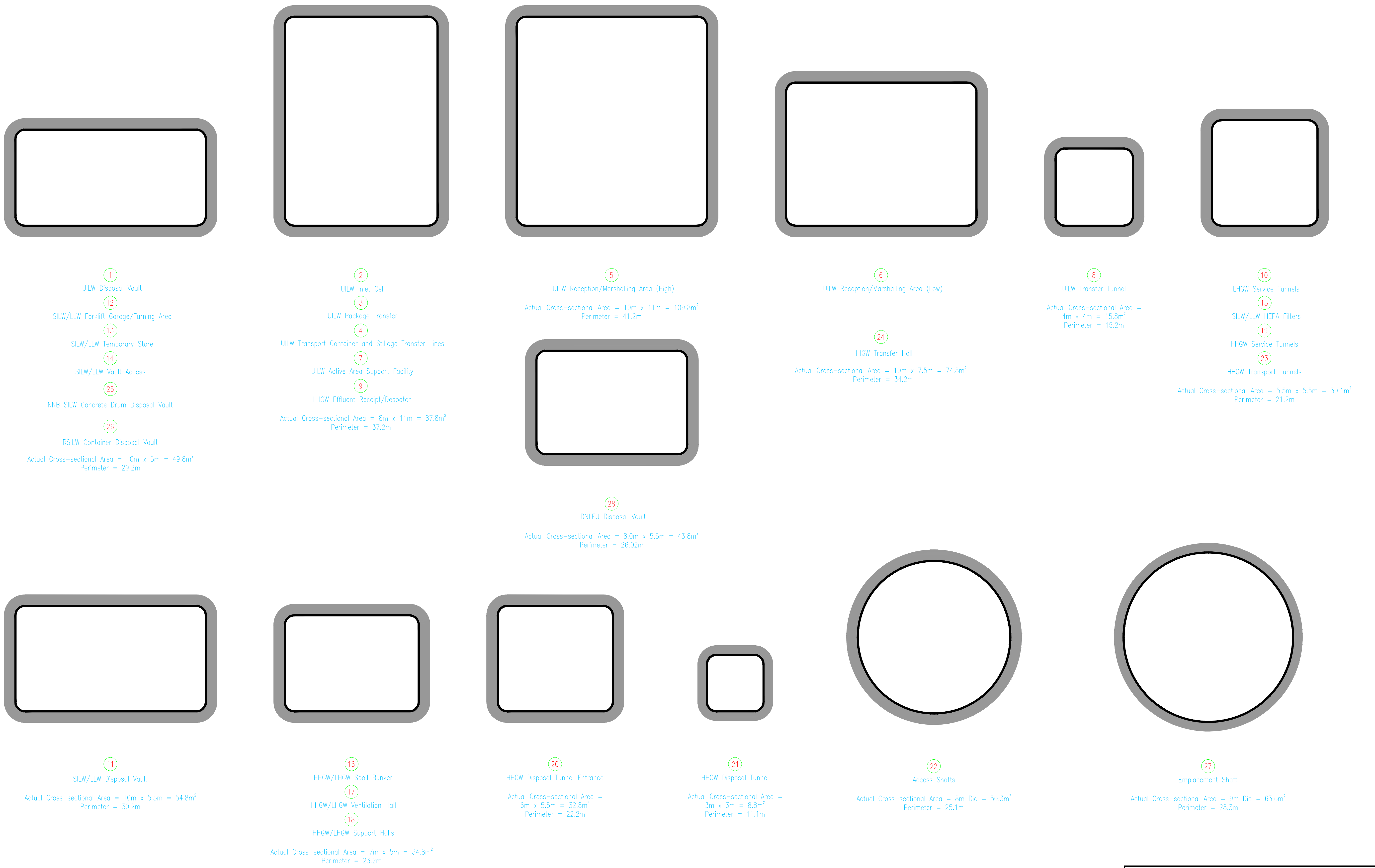
Radioactive Waste Management

W.B.S.	
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:50

GEOLOGICAL DISPOSAL FACILITY

2013 DERIVED INVENTORY
EVAPORITE ROCK
HHGW DISPOSAL TUNNEL
CROSS & LONGITUDINAL SECTIONS

A3 SIZE | DRG. No. E/DRG/0041137 | P–02 STAT/REV



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STAT/REV	APPROVED BY PB	AUTHORISED BY RWM
P–02	S.MAJHU	I.PHIMISTER

UPDATE FOLLOWING IMPLEMENTATION OF CR54.
ADDED DNLEU DISPOSAL VAULT.

DRAWN	CHECKED	DATE
R.SINGLETON	P.GASKELL	JULY 2016

(Four further revision blocks, each: STAT/REV | APPROVED BY PB | AUTHORISED BY RWM; DRAWN | CHECKED | DATE — blank)

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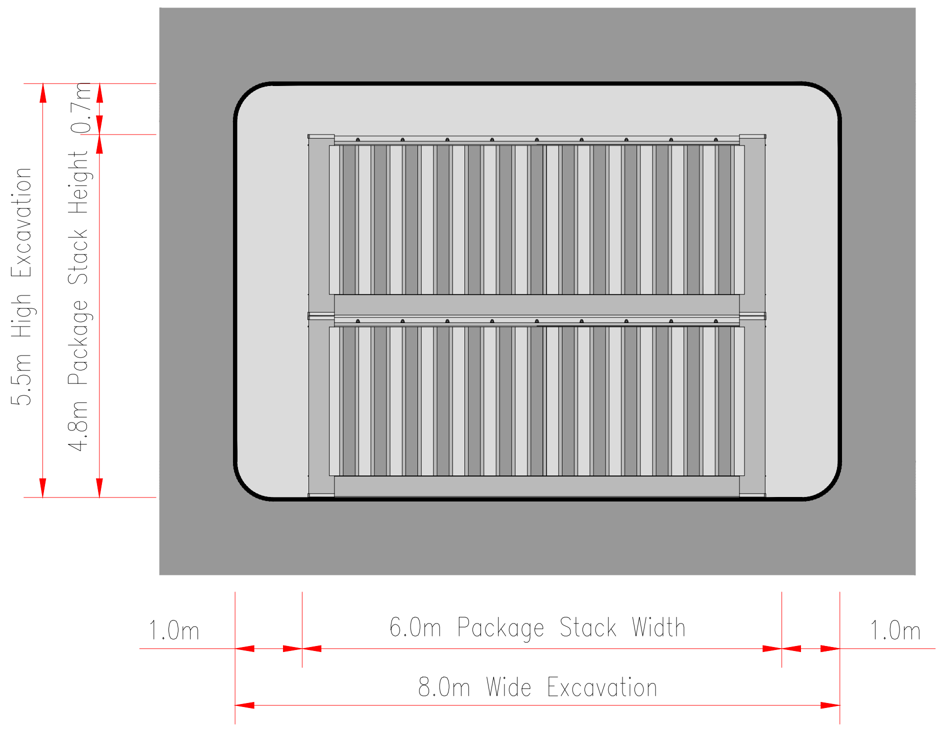
DRAWN	R.STACEY
CHECKED	P.GASKELL
APPROVED	S. MILWARD
AUTHORISED BY RWM	M.JOHNSON
DATE	MAR 2015

Radioactive Waste Management

W.B.S.	
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:200

GEOLOGICAL DISPOSAL FACILITY
2013 DERIVED INVENTORY
EVAPORITE ROCK
LHGW, HHGW & COMMON SERVICE AREAS
EXCAVATION PROFILES

A3 SIZE	DRG. No.	E/DRG/0041138	P–02 STAT/REV



DNLEU Vault

STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM	STAT/REV	APPROVED BY PB	AUTHORISED BY RWM
DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE	DRAWN	CHECKED	DATE

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DRAWN	R.SINGLETON
CHECKED	P.GASKELL
APPROVED	S. MAJHU
AUTHORISED BY RWM	I. PHIMISTER
DATE	JULY 2016

W.B.S.	
SYSTEM	KSF
SUB SYSTEM	LY
UNITS	METRES
SCALE	1:100

GEOLOGICAL DISPOSAL FACILITY

2013 DERIVED INVENTORY
EVAPORITE ROCK
DNLEU DISPOSAL VAULT TRANSFER AND EMPLACEMENT
CROSS–SECTIONS

A3 SIZE | DRG. No. E/DRG/0041139 | P–01 STAT/REV

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001
Certificate No LRQ 4008580

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