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Inventory for geological disposal

Implications of the 2019 IGD for the generic Disposal System Safety Case

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Preface

This report is part of ongoing research by Radioactive Waste Management (RWM) and its contractors into implementing geological disposal for radioactive wastes in the UK.

Geological disposal is the UK Government's policy for the higher-activity radioactive wastes. The principle is isolation of the waste deep inside a suitable rock formation to prevent harmful quantities of radioactivity from reaching the surface. The waste will be placed in an engineered containment facility of tunnels and vaults constructed underground – a geological disposal facility (GDF). The facility will be designed so that multiple natural and man-made barriers work together to minimise the escape of radioactivity. Higher-activity radioactive wastes cover a range of categories including high level waste (HLW), spent nuclear fuel, intermediate level (ILW) and certain low level (LLW) radioactive wastes.

A GDF will be carefully designed and engineered. Typically, ILW and LLW would be encased in a cement grout and packaged in steel or concrete containers, for subsequent placement in the vaults. In time, the vaults would be backfilled with a cement-based material, completely surrounding the waste packages. Engineered barriers would be provided by the cement grout, the containers and the backfill. Natural barriers would be provided by geological formations surrounding the GDF and that lie between it and the accessible human environment. The concept for longer-lived HLW and spent nuclear fuel is slightly different: containers holding these materials would be placed directly into deposition tunnels, further apart from each other, again using engineered and natural barriers.

Executive Summary

The UK Radioactive Waste Inventory (UK RWI) is published every three years by RWM's parent body, the Nuclear Decommissioning Authority (NDA) and Department for Business, Energy and Industrial Strategy (BEIS). Based on a stock-take in 2019, the most recent data was published in 2020, reporting on sources, quantities and properties of radioactive waste and materials across the UK.

RWM has updated its inventory for geological disposal (IGD) to take account of the latest UK RWI. This report assesses the implications of the changes to the IGD, including the alternative inventory scenarios, for the findings of RWM's generic Disposal System Safety Case (DSSC).

The inventory changes are small, and the implications are:

- Minor adjustments to RWM's illustrative generic Geological Disposal Facility (GDF) designs
    - Changes of up to +2% to the GDF footprint (host rock dependent)
    - Slight changes to the operational programme
- the conclusions of RWM's 2016 generic DSSC are unaffected
- no new research needs are introduced by the inventory changes

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1 Introduction

1.1 The generic Disposal System Safety Case

RWM was established as the organisation responsible for delivering a programme for the safe, secure and permanent 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, 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 system of multiple man-made and natural barriers designed to prevent harmful quantities of radioactivity and non-radioactive contaminants from being released to the surface environment.

To identify potentially suitable sites for a GDF, the Government has developed an approach based on consent: working with interested communities that are willing to participate in the siting process [2]. No site has yet been identified for a GDF.

In order to make progress while potential 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 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

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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.*

- 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) that is 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 concepts.

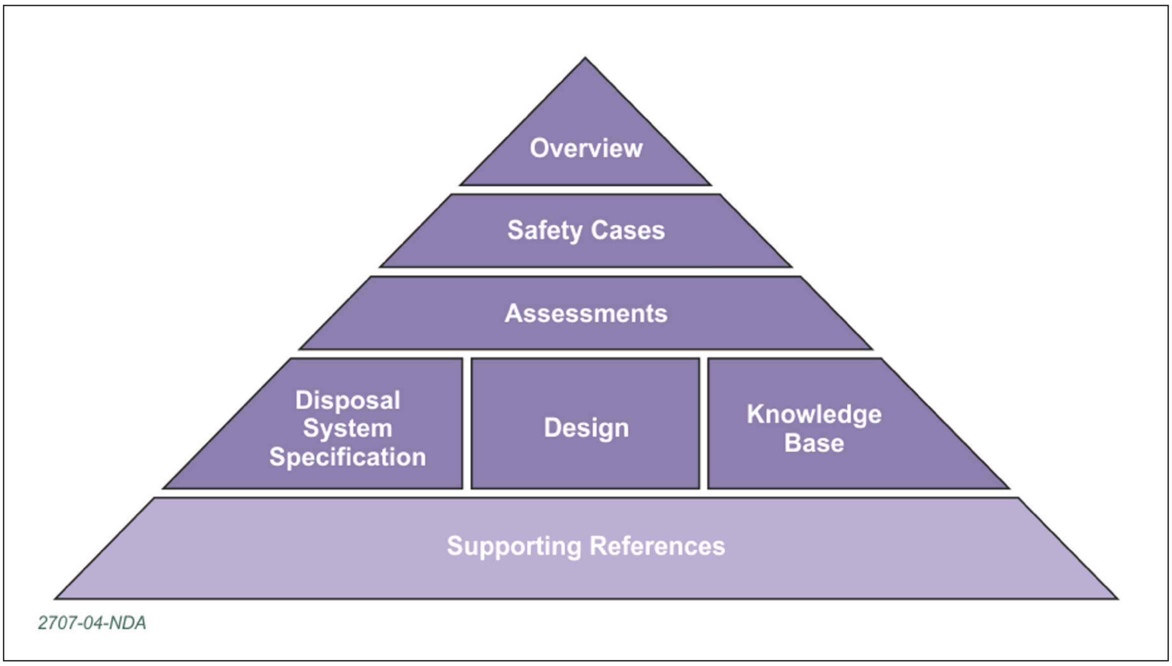
High level information on the inventory for disposal, the illustrative disposal concepts and other aspects of the disposal system is collated in a technical background document (the Technical Background) [3] that supports this generic Disposal System Safety Case.

The generic Disposal System Safety Case (DSSC) plays a key role in the iterative development of a geological disposal system. This 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 demonstrates that geological disposal can be implemented safely, and also forms a benchmark for RWM to provide waste producers with advice on packaging 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 DSSC documents and summarises the safety arguments that support geological disposal. The safety cases present the safety arguments for the transportation of radioactive wastes to the GDF, the operation of the facility and long-term safety following 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. These documents are underpinned by an extensive set of supporting references. A full list of the documents in 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 'Implications Report'

The current version of the generic DSSC was published in 2016 and was based on the 2013 inventory for geological disposal (IGD)[2] [4], which in turn was based on the 2013 UK radioactive waste inventory (RWI) [5]. The UK RWI contains information on the stocks and arisings of legacy wastes; it is updated periodically and, following the production of the UK RWI, RWM updates its IGD. As a result of this process, the 2016 IGD [6] was produced based on the 2016 UK RWI [7]. Production of the IGD involves assumptions and data enhancements, for example in producing the inventories of the spent fuels (SFs); details of how this is done can be found in the method report [8].

The differences between the 2013 and 2016 IGDs were reported [9] and the implications of these differences on the generic DSSC assessed [10]. The 2019 IGD [11] has now been published based on the 2019 UK RWI and the differences between the 2016 and 2019 IGDs have been reported [12] and accepted into the DSSC.

This document is the 'Implications Report' and assesses the implications of changes between 2016 and 2019 inventories for geological disposal on the generic DSSC.

This report replaces the previous implications report [10] within the generic DSSC suite of documents.

1.3 Objective

This report aims to assess the changes to the inventory for geological disposal, set out how they affect the findings of the generic DSSC and identify future research needs required as a result of the changes.

1.4 Scope

This report presents the changes to the IGD and the implications of these changes for the technical documents within the generic DSSC suite.

A consideration of the implications for documents that sit outside of the generic DSSC is excluded from the scope of this report, as is a detailed discussion of the inventory changes (these are presented elsewhere [12]).

1.4.1 Iterative development of the generic DSSC

RWM's safety cases are continually refined and improved through the use of an iterative method for their production (as illustrated in **Figure 2**). The process starts with the key inputs, which include the IGD, and the Disposal System Specification. These inform the illustrative designs of the geological disposal facility, with the assessments and safety cases based on these designs.

As part of the iterative development of the safety cases, RWM operates a 'needs-driven' research programme: the need for additional research is highlighted during the different phases of producing the safety cases and new tasks are added to RWM's Science and Technology Plan [13].

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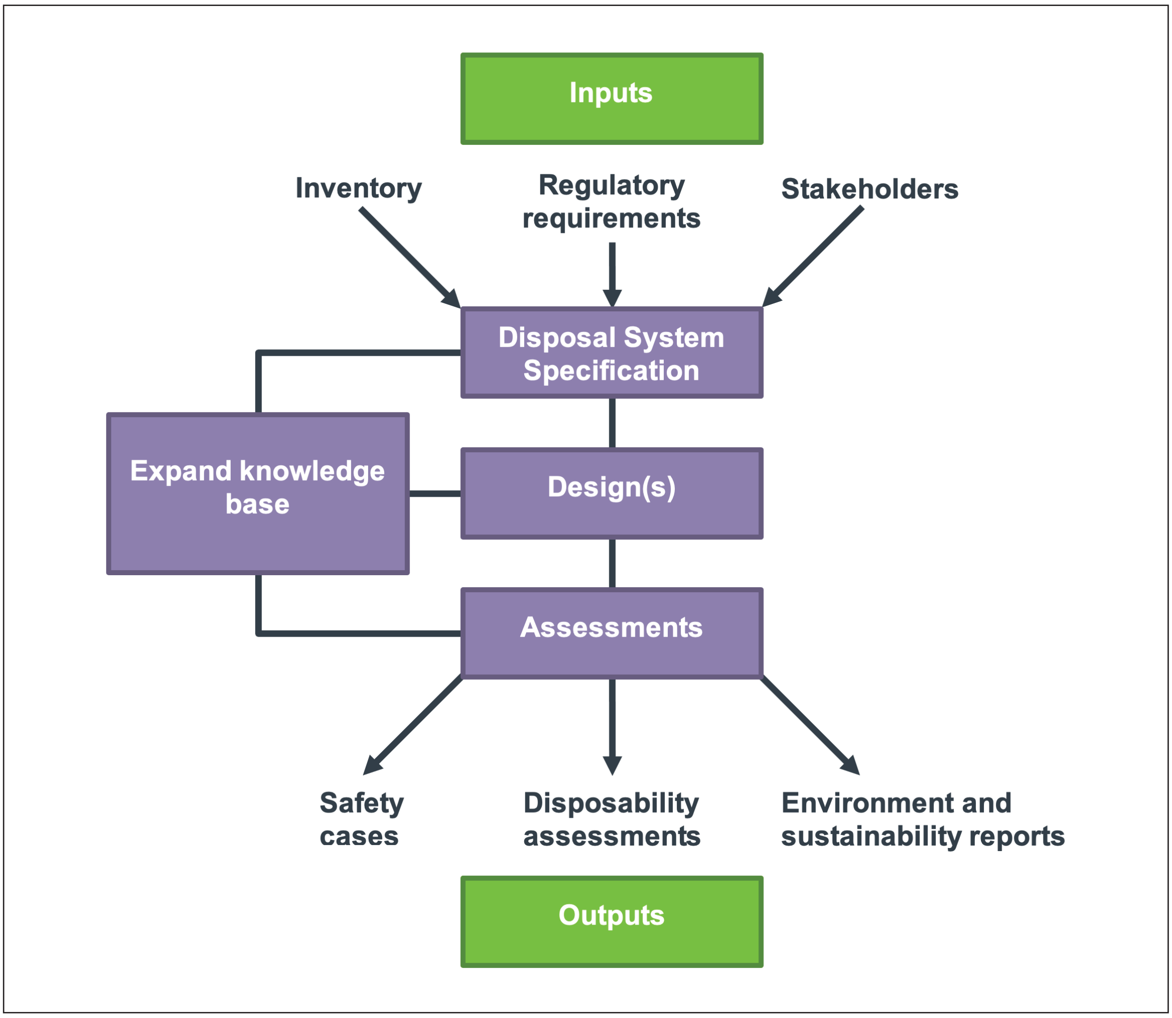
[2] Originally published as the 2013 'Derived Inventory', it is referred to here as the 2013 IGD.

As part of the iterative development, safety cases incorporate learning from:

- the production of the previous iteration of the safety cases
- the needs-driven research programme
- other industries (for example mining)

This document reports a key part of the iterative process: the IGD has been updated following the production of the 2019 UK RWI and the implications for the safety case need to be assessed and any further research that is required as a result of these inventory changes needs to be identified.

Figure 2 - The iterative model for the development of RWM's safety cases



1.4.2 Status of Research

The generic DSSC is supported by eight research status reports that present the scientific and engineering understanding that supports geological disposal in the UK; these reports are summarised in Table 1. RWM's scientific and engineering understanding is not altered by changes to the inventory; however, changes to the inventory could result in additional knowledge being required in order to underpin the production of RWM's safety cases.

This report will identify knowledge gaps when considering the implications of the inventory changes on the generic DSSC. Where necessary, new or updated task sheets will be prepared that detail the additional work required to address the knowledge gaps identified in this report, ready for inclusion in a future update to RWM's Science and Technology Plan.

Table 1 - The status reports and the current state of knowledge that they present

Status report	Current state of knowledge presented
Waste package evolution **[14]**	The evolution of waste packages (wasteforms and waste containers) during storage and after disposal in the GDF
Engineered barrier system (EBS) **[15]**	The evolution processes affecting the EBS from the construction of the GDF until after its closure
Geosphere **[16]**	The role of the geosphere in providing isolation and containment of the waste as part of a multi-barrier system
Biosphere **[17]**	The understanding of the biosphere and RWM's approach to representing it in the generic DSSC
Gas **[18]**	Understanding of gas generation and migration in the context of GDF safety
Behaviour of radionuclides and non-radiological species in groundwater **[19]**	How radionuclides and non-radiological species may behave in a GDF, focussing on the post-closure phase
Waste package accident performance **[20]**	The performance of waste packages under accident conditions (fire and impact) during transport and disposal operations
Criticality safety **[21]**	Studies that support the demonstration of criticality safety in RWM's safety cases

1.5 Report structure

The remainder of this report is structured as follows:

- Section 2: changes to the inventory
- Section 3: implications for the Disposal System Specification
- Section 4: implications for the illustrative GDF designs
- Section 5: implications for the Transport Safety Case
- Section 6: implications for the Operational Safety Case
- Section 7: implications for the Environmental Safety Case
- Section 8: implications for the disposability assessment process
- Section 9: conclusions

2 Changes to the Inventory

Summary of changes to the inventory

The IGD has been updated following the publication of the 2019 UK RWI. The key assumptions are unchanged between the 2016 and 2019 IGDs. The 2019 IGD introduces an estimate of the GDF construction materials; this was not included in the 2016 IGD. Changes to the packaged volume of waste (+4%), activity (<1% at 2200) and number of disposal units (+8%) are small and are associated with changes to the waste producers' plans and improved waste characterisation.

A range of alternative inventory scenarios has been used to explore the uncertainties associated with the IGD; the changes to these alternative scenarios are small.

No new knowledge gaps, and therefore no additional research needs, have been identified.

The IGD scenario represents RWM's best estimate of how the wastes and materials in the IGD will arise; none of the scenario changes are considered significant in terms of their overall effect. However, the quantities of the waste and material types have changed as a result of, for example, improvements to the estimates of waste that will arise from planned operations and decommissioning programmes. The changes between the 2016 and 2019 IGDs have been reported [12] and a summary is presented in the following sub-sections.

2.1 Changes to the quantity of waste

Table 2 shows the percentage changes to the stored quantities of waste in the 2019 IGD relative to the 2016 IGD. The key changes to the quantities of wastes are:

- Legacy LLW (-57%) as Magnox LLW graphite is now destined for the LLW Repository (LLWR)
- Legacy ILW (-16%) largely from re-estimations of waste volumes at Sellafield
- DNLEU (-11%) from changes to the assumed arisings

Table 2 - Changes to the waste and material quantities

Waste type [unit]	2016 IGD	2019 IGD	Difference [%]
Legacy LLW [m^3]	8,880	3,830	-57%
Legacy ILW [m^3]	265,000	221,000	-16%
HLW [WVP cans[3]]	7,650	7,660	<1%
Legacy SFs [tHM]	7,320	7,440	2%
DNLEU [tU]	215,000	192,000	-11%
HEU [tU]	22.9	22.9	
Pu [tHM]	5.75	5.75	0%
New build ILW [m^3]	8,440	8,440	0%
New build SFs [tU]	14,300	14,300	0%
MOX SF[4] [tHM]	1,460	1,460	0%

Changes to the packaged volumes of the wastes in the IGD are presented in **Table 3**. The changes are generally small (of the order of a few percent). The most notable change is to Legacy UILW (+13%) as a result of revised packaging assumptions.

Table 4 shows the change in the number of disposal units. There is an increase of around 9% in the number of LHGW disposal units, largely because of changes to the assumptions that waste producers have made regarding how the waste will be packaged (in particular the increased use of 500 l drums). The change in the number of HHGW packages is small.

Table 3 - Changes to the packaged volume of each waste group

Waste group	Packaged volume [m^3]		Difference [%]
	2016 IGD	2019 IGD	
Legacy SILW/SLLW	99,300	92,600	-7%
Legacy UILW/ULLW	329,000	372,000	13%
RSCs	2,730	2,610	-4%
DNLEU	191,000	184,000	-4%
New build SILW	18,900	18,900	0%
New build UILW	22,100	22,100	0%
HLW	9,860	9,880	0%
Legacy SF	16,900	17,000	1%
New build SF	39,400	39,400	0%
MOX SF	11,900	11,900	0%
HEU	2,470	2,470	0%
Pu	620	620	0%
Total	744,000	773,000	4%

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[3] *Waste vitrification plant canisters. Three WVP cans are included in each disposal container.*

[4] *Mixed oxide (MOX) fuel is assumed to be manufactured using plutonium from spent fuel reprocessing.*

Table 4 - Changes to the number of LHGW and HHGW disposal units

Waste category	Disposal units [-]		Difference [%]
	2016 IGD	2019 IGD	
LHGW	146,000	159,000	9%
HHGW	19,300	19,300	0.2%
Total	165,000	178,000	8%

2.2 Changes to the activity of the waste

The evolution of the total activity is shown in **Figure 3** as a log-log plot and the total activity of the inventory at 2200 is presented by waste group in **Table 5**. The increase in the total activity of the inventory is small (<1% at 2200) and it can be seen from **Figure 3** that the difference remains small at later times. However, as shown in **Table 5**, there are some significant changes to individual waste groups:

- 186% increase in the activity of the RSC group (the total activity remains low)
- 41% increase in the activity of the legacy SILW / SLLW (the total activity remains low)
- an increase of 22% in the activity of the HLW waste group due to revised estimates

Figure 3 - The evolution of the activity in the 2016 and 2019 IGDs

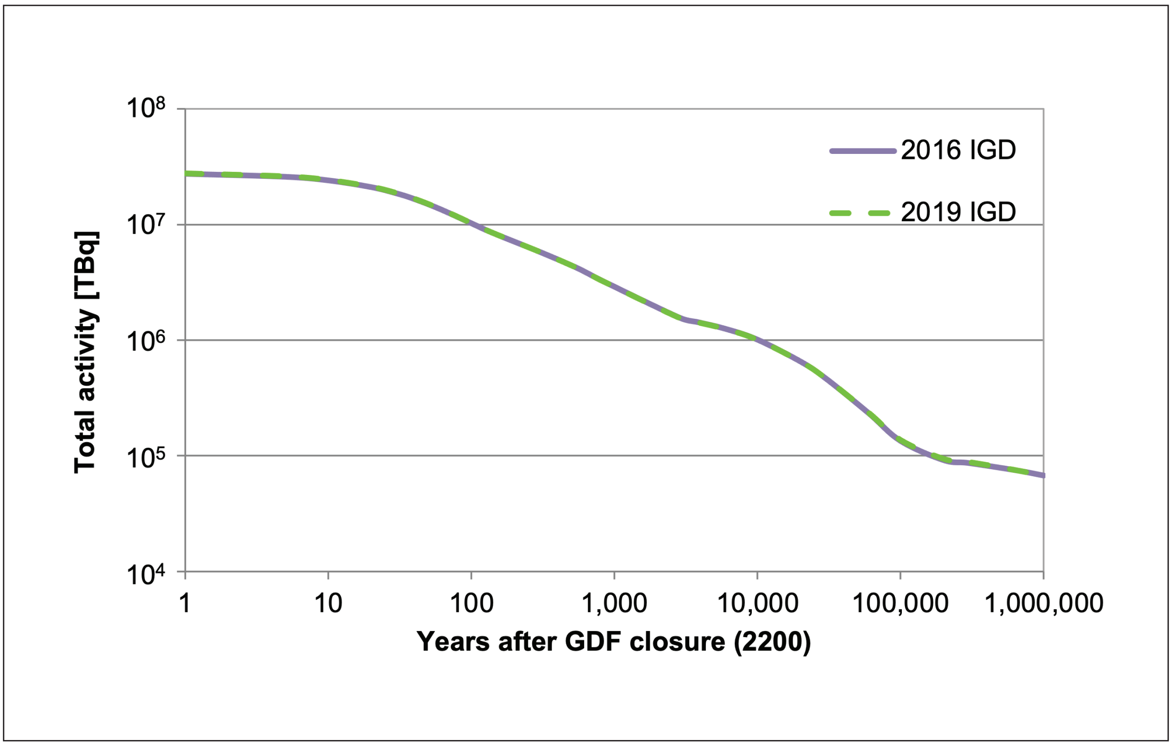

Table 5 - Changes to the waste group activities at 2200

Waste group	Activity at 2200 [TBq]		Difference [%]
	2016 IGD	2019 IGD	
Legacy SILW/SLLW	13,800	19,400	41%
Legacy UILW/ULLW	372,000	398,000	7%
RSCs	1,110	3,180	186%
DNLEU	9,560	9,800	3%
New build SILW	154	154	0%
New build UILW	793,000	793,000	0%
HLW	1,200,000	1,460,000	22%
Legacy SF	2,730,000	2,780,000	2%
New build SF	19,000,000	19,000,000	0%
MOX SF	3,700,000	3,700,000	0%
HEU	54	54	0%
Pu	43,700	43,700	0%
Total	27,900,000	28,200,000	1%

2.3 Changes to the material composition of the waste

The IGD reports the material masses associated with a variety of different waste materials; these materials are grouped into three categories: metals, organics and others. Table 6 presents a summary of the changes to these categories between the 2016 and 2019 IGDs. The increase in 'unspecified' materials is largely a result of the fact that the 2019 IGD is a 'light update' so does not include the full review and enhancement process.

Table 6 - Changes to the waste material masses between the 2016 and 2019 IGDs

Waste group	Material mass [t]		Difference [%]
	2016 IGD	2019 IGD	
Metals	129,000	103,000	-20%
Organics	13,600	10,400	-24%
Others	460,000	422,000	-8%
Unspecified	1,680	2,840	68%
Total	604,000	539,000	-11%

In addition to the materials composition of the wastes, the 2019 IGD introduces, for the first time, an estimate of the GDF construction materials and of operating materials remaining underground after closure. This information is presented on a per disposal vault / disposal tunnel basis and for the shafts, drift and common service areas for the whole GDF. Data are presented for the generic illustrative GDF design in each of three different rock types.

The data are intended to support the establishment of a comprehensive inventory of materials associated with GDF construction, operation and closure relevant to post-closure environmental safety assessments and to enable these to be assessed in future safety cases. This data will be further refined as more GDF design details become available.

2.4 Changes to the alternative scenarios

Alternative scenarios have been used to explore the effects of changes in the assumptions and data uncertainties on the IGD [22]. The scenarios have been reviewed[5] and their impacts assessed for the 2019 IGD [12]. In general, the impacts of the alternative scenarios on the 2019 IGD are the same as or similar to those on the 2016 IGD. The greatest impact continues to be that from uncertainties in the waste radioactivity and volume, which are dominated by a small number of waste streams. The changes to the impacts of those scenarios that have been assessed quantitatively is as follows:

- the impact of the 'less Magnox reprocessing' scenario is decreased compared to 2016 as the mass of Magnox spent fuel not reprocessed is less for the 2019 IGD
- the impact of lifetime extensions for existing reactors is unchanged as the AGR lifetime extensions were included in the 2016 IGD and have not changed
- the overall impact of using UK RWI uncertainty factors has decreased, although the uncertainty associated with I-129 has increased as a result of changes to a waste stream with a high uncertainty factor specified for this radionuclide
- the impact of excluding graphite wastes has reduced as a result of Magnox LLW graphite not being included in the 2019 IGD
- the impact of excluding ILW / LLW boundary wastes has increased in percentage terms as further waste streams have been identified as falling into this category. However, the absolute values are small and the conclusions that this scenario would have a small impact remain valid.

2.5 Knowledge gaps and future research needs

No new knowledge gaps, and therefore no new research needs, have been identified.

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[5] *The scenario definitions remain unchanged; however, the baseline for the scenario may have changed as a result of new data becoming available (eg updated data from the UK RWI).*

3 Implications for the Disposal System Specification

Summary of implications for the Disposal System Specification

The Disposal System Specification (DSS) has been developed to describe the requirements on the disposal system and is core to RWM's generic design and assessments work. The waste and material types that would comprise the inventory for geological disposal are defined in the Implementing Geological Disposal White Paper and have not changed. The DSS does not impose any requirement that is dependent on the quantities of the wastes and materials. As a result, the DSS is robust to a range of changes in the inventory.

No new knowledge gaps, and therefore no additional research needs, have been identified.

The DSS has been developed to describe the requirements on the disposal system and is core to RWM's generic design and assessments work. The primary objective of the DSS is to provide the designers of the disposal system with the requirements that must be satisfied and thereby define the scope and bounds of the engineering design work. Two documents form the DSS:

- Disposal System Specification Part A – High Level Requirements [23], which documents the high-level external requirements on the disposal system that derive from the inventory of waste for disposal, legislative and regulatory requirements, and the stakeholder requirements. Part A includes requirements related to the activities required to transport, receive and emplace waste packages in a GDF
- Disposal System Specification Part B – Technical Requirements [24], which captures the technical requirements defined by RWM to frame the development of a disposal solution to meet the requirements of Part A. This enables RWM's work programme to develop in line with the functional needs of a GDF. It is envisaged that Part B will be updated when site specific information becomes available, allowing the designs to be refined to meet site specific requirements

The DSS requires that the IGD includes the waste and material types that would comprise the inventory for disposal in a GDF [2]; these waste and material types have not changed. The DSS does not impose any requirement that is dependent on the quantities of the wastes and materials and so is robust to changes in the size of the inventory.

The DSS requires that the disposal system designs and assessments:

- use the IGD as the source of waste package information
- take account of inventory scenarios in order to understand the impacts of inventory uncertainties

Although the DSS remains robust, the requirements highlight a number of areas in which the implications of the inventory changes on the disposal system designs and assessments need to be checked; this is done in the remainder of this document.

The changes to the inventory do not result in any new research needs in order to ensure that the DSS remains robust.

4 Implications for the generic illustrative designs

Summary of implications for the generic illustrative designs

Generic illustrative designs for the GDF have been produced for each of three types of host rock. The changes to the IGD would have the following impact on these designs:

- no impact on the transport system design
- small changes to the number of disposal vaults and disposal tunnels
- overall changes to the GDF footprint in the range +1.0% to +2.0%
- no significant impact on the operational programme

No new knowledge gaps or research needs have been identified

4.1 Generic Transport System Design

The generic Transport System Designs report [25] describes the operations required, commencing at waste producers' sites, to ensure safe and efficient carriage 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. As there are no new sites and no new waste package or transport container types, the inventory changes have no implications for the generic Transport System Design.

4.2 Disposal Facility Design

Generic illustrative designs for a GDF in each of three types of host rock are described in the Generic Disposal Facility Design report [26], which describes the processes of construction, waste package receipt, handling and emplacement, and the design characteristics that the GDF will need to include for the inventory.

Developing the illustrative designs allows an understanding of the aspects of constructing a GDF such as the underground layout, the disposal schedule and the likely cost. These aspects are affected by many factors, one of the most significant being the inventory (both quantity and timing of waste arisings). The impact of the inventory changes on the generic illustrative designs is reported below.

The implications of the inventory changes on the generic illustrative designs are set out in terms of the estimated number of disposal vaults and tunnels, the estimated GDF footprint and the assumed operational programme and throughput rates. In order to assess the implications of the inventory changes, a number of assumptions have been made. These assumptions and the subsequent design philosophy have remained the same as those which underpinned the designs based on the 2016 IGD as set down in the Generic Disposal Facility Design report [26].

4.2.1 Number of disposal vaults and tunnels and footprint

In the generic illustrative designs for all three host rocks, LHGW is disposed of in disposal vaults, while the HHGW is disposed of in disposal tunnels[6]. Due to the variation in the size of the disposal vaults and tunnels, the impact varies for each host rock. A summary of the changes is presented in **Table 7**. The key points are:

- the increase in the number of LHGW disposal units, results in a small increase (2.8% to 4.7%) in the number of disposal vaults
- the increase in the number of HHGW disposal units results in a small increase in the number of disposal tunnels in lower strength sedimentary and evaporite rock illustrative designs (0.3%) and no change in a higher strength rock illustrative design
- the overall increase to the estimated underground areas, or 'footprints', required to accommodate the IGD is minimal (+1.0% to +2.0%)

Table 7 - Impact of changes between the 2016 and 2019 IGDs on the footprint and numbers of disposal vaults and disposal tunnels in the different host rock types[7]

	Parameter [unit]	IGD		Difference [%]
		2016	2019	
HSR	No. LHGW disposal vaults [-]	36	37	2.8%
	No. HHGW disposal tunnels [-]	321	321	0.0%
	GDF footprint [km²]	7.7	7.8	1.3%
LSSR	No. LHGW disposal vaults [-]	107	112	4.7%
	No. HHGW disposal tunnels [-]	352	353	0.3%
	GDF footprint [km²]	15.2	15.5	2.0%
Evap.	No. LHGW disposal vaults [-]	90	94	4.4%
	No. HHGW disposal tunnels [-]	338	339	0.3%
	GDF footprint [km²]	10.4	10.5	1.0%

4.2.2 Operational programme

The overall programme assumed for the 2019 IGD is consistent with that for the 2016 IGD; the start of waste emplacement (2040) and end of operations (2190) remain the same, with any changes accommodated within this period.

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[6] *It is noted, however, that the disposal concepts differ in each of the host rocks.*

[7] *Higher strength rock (HSR), lower strength sedimentary rock (LSSR) and evaporite (Evap.).*

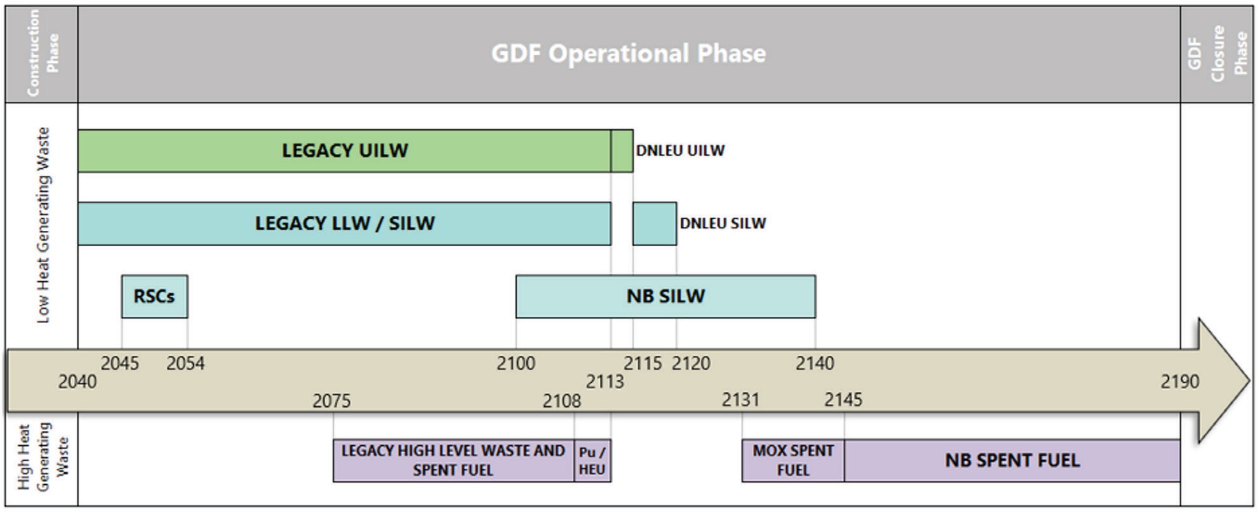
The main difference between the 2016 and 2019 inventories is an increase in the total number of LHGW disposal units. Assuming similar throughput rates, the legacy ILW/LLW will take up to five years longer to emplace. However, a reduction in DNLEU (UILW) disposal units reduces the time to emplace these packages by three years. Overall, legacy LHGW emplacement (excluding new build ILW) will take two years longer compared to the 2016 IGD.

The number of HLW and AGR SF disposal units has increased slightly and, adopting the same throughput rate as for the 2016 IGD (200 disposal units / year) and assuming the emplacement starts in the same year (2075), the emplacement of these wastes will continue until 2108, which is similar to the 2016 IGD. The HEU and Pu will continue for 5 years after this until 2113.

The updated IGD has no impact on the operational programme for NB SILW, MOX Spent Fuel and NB Spent Fuel. The emplacement dates and durations for the NB wastes are the same as the assumptions for the 2016 IGD for 16 GW(e) of new build power stations. However, it must be noted that a number of new build projects have since either been delayed or cancelled. The completion date of the GDF waste emplacement programme, which is currently controlled by the new build spent fuels, will be re-evaluated as new information becomes available.

The inventory changes do not introduce any significant changes to the operational programme and an updated schematic of the operational programme is shown in Figure 4.

Figure 4 - The operational programme for the 2019 IGD



4.3 Alternative inventory scenarios

There are uncertainties in the inventory for geological disposal and the alternative inventory scenarios explore the sources of these and their potential impact. The 2019 IGD has an increase in the uncertainty on the number of LHGW disposal units and volume and a reduction in the uncertainty in HHGW compared to the 2016 IGD.

Whilst there would be no change to the surface facilities, a change in the number of disposal units would have an impact on the number of disposal vaults and tunnels required which would have implications on the underground GDF footprint, the volume of construction materials required and the excavated spoil generated and result in changes to the GDF programme and cost. However, these changes would not affect the overall conclusions in the generic Disposal System Safety Case.

4.4 Knowledge gaps and future research needs

4.4.1 Spent fuel packaging

The 2019 IGD provides additional detail on the “other fuels” at Sellafield: small quantities of WAGR, SGHWR and miscellaneous LWR spent fuels are now identified separately. Recognising that SF packages have yet to be manufactured and decisions about their ultimate design have not yet been made, it has been necessary to make assumptions regarding the form of conditioning and packaging for the purposes of these illustrative designs. Whilst it is currently assumed that existing designs of spent fuel disposal containers will be used for these fuels, additional work will be needed to develop container designs for these fuels. This is covered in an existing S&T plan [13] task (Task 420.001: Develop and Maintain the Disposal Container Designs).

5 Implications for the generic Transport Safety Case

Summary of implications for the generic Transport Safety Case

The generic transport safety case (TSC) demonstrates the confidence that safe transport will be provided to move all the waste from the various storage sites to the GDF. Because there are no new package types or increases to bounding package inventories introduced in the 2019 IGD, there are no implications for the transport package safety (TPS) report. The bounding assessment in the transport safety assessment (TSA) will not change as the number of disposal units is roughly constant. The best estimate assessment will be affected by the inventory changes; however, the inventory changes are small and do not affect the conclusions of the TSA. Therefore, the inventory changes would not significantly impact the generic TSC.

The generic Transport Safety Case (TSC) demonstrates the confidence that safe transport will be provided to move all the waste from the various storage sites to the GDF. The generic TSC covers radioactive waste and materials transport only and not conventional transport associated with construction or operations. The generic TSC main report [27] draws together the main safety arguments and evidence from two supporting reports:

- the Transport Package Safety (TPS) report [28] which describes the means by which safe transport of waste to the GDF will be provided, by describing the procedures, assessments and approvals that are, or will be, in place. The TPS therefore presents a qualitative safety assessment, principally through demonstrating that compliance with the IAEA transport regulations can be achieved

- the Transport Safety Assessment (TSA) [29] which provides an assessment of the dose to operators from the transport operation as a whole

The implications of the 2019 IGD on the TPS and TSA are presented in **Sections 5.1** and **5.2** respectively. As the TSC main report summarises the safety arguments of the TPS report and TSA, the implications for the TSC main report are the same as those described in **Sections 5.1** and **5.2**.

5.1 Transport package safety

The TSC is underpinned by the description of the radioactive waste transport system presented in the generic Transport System Design (TSD) report [25]. As discussed in Section 4.1, there are no implications for the TSD as a result of the differences between the 2016 and 2019 IGDs. As such there are no implications for the qualitative safety assessment presented in the TPS report.

5.2 Transport safety assessment

The TSA presents an illustrative dose assessment for operators from routine operations with both bounding and best estimate assumptions and compares these results to the targets and limits in the RWM Radiological Protection Criteria Manual (RPCM) [30]. The assessment calculates the dose to operators for moving the wastes in the IGD from the sites at which they are stored to a GDF. As a site for a GDF is yet to be identified, the TSA assesses seven notional locations distributed throughout England and Wales.

The quantitative safety assessment presented in the TSA is also sensitive to changes in the number of transport packages and activities of the waste. The total number of disposal units has increased by approximately 8% between the 2016 and 2019 IGDs, resulting in an increase in the number of transport packages by 6.4%; the proportion of Type B (unshielded waste streams) to IP (Industrial standard (shielded) package) waste streams has also increased by 2.2%.

Any inventory changes will impact on the external dose rates of the transport packages. To assess the impact of the inventory changes on the TSA, the dose rate from each package has been summed at set distances from each of the transport packages for both the 2016 and 2019 IGDs. The results of the comparison are presented in Table 8. The highest increase in dose rate can be seen at 2 m from the surface of the package (0.3%), as shown in Table 8. Taking a pessimistic approach and applying this increase to the maximum dose rates to transport operators from the best estimate case will not affect the conclusions of the TSA: all transport operator groups remain below RWM's Basic Safety Objective (BSO) (1 mSv/yr) for normal operational exposure of employees working with ionising radiation, as set out in Table 1 of RWM's RPCM.

Table 8 - Change in the summed dose rates at different distances from the transport package

Distance from Transport package	Change
0 m (surface)	-0.6%
1 m	-1.5%
2 m	0.3%

The bounding assessment will not change because the maximum dose rate of a package is constrained by the Carriage of Dangerous Goods Regulations [31], which implement the IAEA transport regulations in the UK. The analysis simplistically assumes that all packages have the maximum permissible external dose rate as specified by the regulations and takes no account of the package contents.

Consequently, there is no significant impact to the generic TSC caused by the differences between the 2016 and 2019 IGDs.

5.3 Alternative inventory scenarios

The uncertainties in the inventory are explored in a series of alternative inventory scenarios. The alternative scenarios would not challenge the bounding scenario of the TSA as the scenario is set at the maximum dose rate allowed by the transport regulations. Therefore, the alternative inventory scenario would not challenge the TSC.

5.4 Knowledge gaps and future research needs

A number of exotic fuels have been separately identified in the inventory including; WAGR, SGHWR and a variety of LWR fuels. The effects of separately identifying these fuel types in the inventory should be investigated in terms of defining their transport packages. This is covered in an existing S&T plan [13] task (Task 420.001: Develop and Maintain the Disposal Container Designs).

6 Implications for the generic Operational Safety Case

Summary of implications for the generic Operational Safety Case

The generic OSC radiological hazard analysis is based on a bounding source term methodology which is insensitive to small changes in the IGD. The changes introduced by the 2016 IGD do not affect the validity of the extant bounding source terms or the conclusions of the generic OSC.

The changes to the inventory do not result in any knowledge gaps or necessitate any additional research.

6.1 Structure of the generic Operational Safety Case

The generic OSC main report [32] is supported by 4 detailed volumes:

- Volume 1: non-radiological and construction safety assessment, [33]
- Volume 2: normal operations safety assessment, [34]
- Volume 3: accident safety assessment, [35]
- Volume 4: criticality safety assessment, [36]

The non-radiological and construction safety assessment covers conventional safety and will be unaffected by changes to the IGD. The implications on the radiological aspects are discussed below.

6.2 Radiological safety

In the current phase of the GDF programme, conceptual designs are neither available nor appropriate. The generic OSC is therefore based on a Process Flow Description which represents emplacement operations functionally without assuming specific design solutions or technologies. The generic OSC radiological hazard analysis identifies a bounding source term for each emplacement route and each principal hazard type (external dose, internal dose and off-site discharge). These source terms are used in the radiological consequence assessments for the design basis faults, to determine requirements for engineered safety measures[8]. This approach does not identify worst case packages but instead develops a source term that bounds all waste streams with respect to risk. The bounding source term methodology accounts for inventory uncertainties and variability within waste streams and can efficiently accommodate small changes to the IGD.

In terms of hazard and risk potential, no changes have been identified that would invalidate arguments supporting the published safety case. The areas of interest are:

- Normal operational dose exposure and the illustrative hazard management arrangements (Isolate)
- Accident scenarios and risk of inadvertent exposure (direct or indirect)

This information is the basis of screening criteria applied in the operational safety assessment [37] that is part of the disposability assessment process.

6.3 Knowledge gaps and future research needs

The changes to the inventory have not resulted in any new knowledge gaps that would necessitate future research.

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[8] *Design basis faults are the accident scenarios which cannot be precluded by design and therefore require the provision of engineered safety measures to make the associated risk as low as reasonably practicable; they are identified as per the Nuclear Operational Safety Manual (RWM14-31).*

7 Implications for the generic Environmental Safety Case

Summary of implications for the generic Environmental Safety Case

The implications of the inventory changes on the generic Environmental Safety Case, which summarises the findings of the generic Operational Environmental Safety Assessment (OESA) and the generic Post-Closure Safety Assessment (PCSA), have been considered. No implications have been identified for either the OESA or the PCSA.

The changes to the inventory do not result in any knowledge gaps or necessitate any additional research.

The generic Environmental Safety Case (ESC) [38] considers the environmental safety of the illustrative GDF designs at the time of disposal and after GDF closure. The generic ESC is supported by the generic Operational Environmental Safety Assessment (OESA) [39], which addresses environmental safety during the operational phase of the GDF, and the generic Post-Closure Safety Assessment (PCSA) [40], which includes a quantitative analysis of how radionuclides could be released from waste packages and migrate through the engineered and geological barrier system in the long-term after GDF closure.

The implications of the 2019 IGD on the OESA and PCSA are described in Sections 7.1 and 7.2 respectively. The generic ESC main report is not considered separately as it summarises the safety arguments of the OESA and PCSA; the implications on the generic ESC main report are therefore covered in Sections 7.1 and 7.2.

7.1 Operational environmental safety assessment

The 2016 generic OESA presents an assessment of operational discharges associated with all wastes and materials covered by the 2013 Derived Inventory. The scope of the 2016 generic OESA includes consideration of the impacts of offsite radioactive and non-radioactive releases on the public and to non-human biota. Qualitative arguments are presented for:

- solid, liquid and gaseous non-radioactive releases,
- solid and liquid radioactive releases.

These arguments will also apply to the 2019 IGD and it is recognised that, in the future, the OESA will need to address these in a quantified fashion. At this stage the generic OESA focuses on the dose from aerially discharged gaseous radionuclides (H-3, C-14 and Rn-222, which is the short-lived progeny of Ra-226). The calculated doses are sensitive to changes including to: the IGD; the host rock, GDF design and operational philosophy, the GDF site's geography, prevailing metrology and the arrangements for the ventilation system or the discharge stack; and the host rock's natural background radiation. **Table 9** shows the change in the maximum activity of the key gaseous radionuclides in LHGW during the operational period for the 2019 and 2016 IGDs. Comparison with the 2013 inventory data does not significantly alter the results of the comparison.

Table 9 - The change in the maximum activity of the key gaseous radionuclides in LHGW between 2040 and 2200 in the 2016 and 2019 IGDs

Date	Activity [TBq]		Difference [%]
	2016 IGD	2019 IGD	
H-3	33,100	33,100	<0.1%
C-14	14,400	14,600	1.7%
Ra-226	9.42	9.55	1.3%

The expected impact of these changes is:

- Dose rates from gaseous emissions for all organisms reported in the 2016 OESA were at least an order of magnitude below both the ERICA[9] screening dose rate value of 10 µGy per hour for a terrestrial ecosystem, which reflects predicted no-effect dose rate (PNEDR) values derived as part of the ERICA project, and ICRP derived consideration reference levels (DCRLs) for relevant reference animals and plants (RAPs). The expected impact of the changes in inventory would be an increase in dose to terrestrial reference organisms; however, these increases are anticipated to be small, with the doses remaining well below the screening values.
- The dose to members of the public presented in the OESA is dominated by Rn-222 and, to a lesser extent, C-14-bearing carbon monoxide, with H-3 providing only a minor contribution. The expected impact of the changes in inventory would be an increase in dose. This will depend on how the waste streams are packaged. For example, dose associated with DNLEU will depend on whether it is encapsulated (assumed in the 2016 OESA gas calculations) or unencapsulated (since assumed for DNLEU that is less than 1% enriched in uranium)[10]; calculations on the impact of this change in assumptions have not been carried out yet. Dose rates to members of the public from gaseous emissions reported in the 2016 OESA were below the legal dose limit for members of the public of 1 mSv per year but above the source-related dose constraint of 0.15 mSv per year and the BSO of 0.02 mSv per year. Increases in dose associated with the changes described above are not expected to change this conclusion.

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[9] *Environmental Risk from Ionising Contaminants: Assessment and Management (ERICA) was a EURATOM-funded project whose major outputs were the ERICA Integrated Approach and the ERICA Assessment Tool. The Integrated Approach seeks to combine exposure/dose/ effect assessment with risk characterisation and managerial considerations; it is applied by the ERICA Assessment Tool, which is a software programme that guides the user through the various steps. The ERICA Assessment tool is used as part of RWM's biosphere assessment.*

[10] *DNLEU is one of the primary waste groups contributing to Radon-222 generation. Since calculation of the gas generation rates, RWM has improved its assumptions on the packaging of DNLEU. Since the assessment reported in the 2016 OESA, it is now assumed that DNLEU that is less than 1% enriched in U-235 (i.e. depleted uranium tails from enrichment and depleted uranium arising from reprocessing of Magnox fuel) will be packaged as powder within its existing container, which will be grouted within transport and disposal containers. It was determined that the emanation factor for unencapsulated wastes would be a more appropriate cautious approximation for these wastes and this is expected to result in an increase in Rn-222 release as the emanation coefficient for the affected waste streams increases from 0.14 to 1 (i.e. by a factor of ~7).*

- HHGW is assumed to be packaged in durable containers that will retain any gaseous radionuclides throughout the operational phase. As a result, HHGW is excluded from further consideration

At this generic stage, the changes to the IGD have no implications for findings of the OESA.

7.2 Post-closure safety assessment

7.2.1 Groundwater pathway

The Post-closure Safety Assessment (PCSA) [40], which supports RWM's generic Environmental Safety Case (ESC) [38], assesses the long-term impacts of the GDF for many thousands of years after the facility has closed. The PCSA includes illustrative calculations of post-closure radiological risk[11], associated with disposal of the IGD, as part of this assessment. It is noted that these quantitative assessments used the 2013 IGD as a basis for inventory data, whilst inventory comparisons discussed here refer to comparisons with the 2016 IGD. The implications of the update from the 2013 to 2016 IGD were assessed in [10] and found not to significantly alter the calculations and assessments presented in the PCSA.

The PCSA treatment of the groundwater pathway provides illustrative numerical assessments of risk, in the generic higher strength rock (HSR) and lower strength sedimentary rock (LSSR) environments. Numerical assessments are not conducted for the evaporite, as the base case is not expected to include a groundwater pathway. These assessments are conducted for each of the waste groups found in the inventory. In the higher strength rock concept, a few of the waste groups are found to have calculated risk close to the regulatory risk guidance level (RGL) of 10^{-6} per year, these are: UILW, SILW and DNLEU. For LHGW, changes to calculated risk would, in the worst case, be proportional to the inventory change and would be less if the radionuclide is subject to effects such as solubility limitation in groundwater. The effects of the new IGD on the assessments for on the LHGW waste groups are:

- The UILW group includes some modest increases in key radionuclide quantities in this IGD update, such as Tc-99 (12.5%), I-129 (13%), Cs-135 (11.9%), U-235 (9.7%), U-238 (13.6%), Np-237 (10.9%). The most significant of these is I-129, which is important in the groundwater pathway in both the HSR and LSSR concepts. Other key radionuclides either exhibit declines, such as Cl-36 (-58.7%), or are largely unchanged. Such changes would at most result in minimal changes to the illustrative risk curves shown in the PCSA.

- For SILW, risk calculations are dominated by Cl-36, which sees only a 0.15% increase in the new IGD. Other radionuclides, Ni-59 (47.6%) and I-129 (27.6%) experience modest increases. Such increases will not significantly change the PCSA results.

- For DNLEU, the inventory changes produce large increases in Tc-99 (46 times) and Np-237 (145 times). The PCSA calculated risk is dominated by U-234 and U-238 and would not be substantially altered by such increases. Modest changes in other radionuclides also occur, most notably U-234 (22.4%); such increases will not significantly alter the illustrative risk curves shown in the PCSA.

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[11] *These calculations are probabilistic in nature, in order to represent uncertainty within the system, and in discussions that follow it is the mean risk that is referred to.*

- For the RSC group, I-129 increases significantly (844%) in the new IGD, while Cl-36 (164.2%), Ni-59 (186.8%) and Tc-99 (163.8 %) also show increases. However, the PCSA [40] calculations used the 2013 IGD, and the 2016 IGD featured a substantial reduction in RSC inventory. Comparing the 2013 and 2019 IGD sees more modest increases, such as I-129 (5%), Cl-36 (50.5%), Ni-59(158%) and Tc-99 (9.9%). These levels would not substantially alter the calculated risk in the PCSA which, for the RSC waste group, is not close to the RGL.

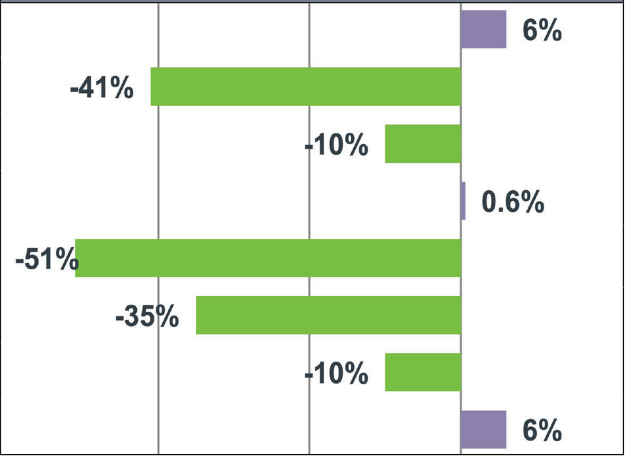
For HHGW, the inventory changes are summarised as follows:

- HLW has only some modest inventory increases in key radionuclides, with increases in Cl-36 (21.1%), Se-79 (19.8%) and Cs-135 (20.8%).
- MOX, HEU, Pu and the new build groups, don't change in the inventory update.

Calculated risk in the PCSA, for HHGW in a HSR is based on a single container failure scenario. Therefore, activity per container, rather than total activity is the parameter of interest; it is not expected this would change significantly as a result of the new IGD. For the LSSR and evaporite concepts, calculated risk is many orders of magnitude below the RGL and would remain so given inventory changes of this nature. Consequently, illustrative calculations of risk would not be expected to change for HHGW.

The transport of radionuclides in the groundwater pathway is also affected by organic complexants; which can bind with radionuclides and enhance their solubility and mobility. The presence of complexants is assessed in the PCSA, mostly in the form of cellulose degradation products. In the inventory update the quantity of cellulosics has decreased (see **Table 10**), although there is some increase in 'Other Organic Complexants', which is dominated by cellulosics in terms of inventory. Overall, these changes would likely reduce the potential for radionuclide transport via complexants.

Table 10 - Total Masses of key Metals and Organics in 2016 and 2019 IGD

Waste group	Material mass [t]		Difference [%]
	2016 IGD	2019 IGD	
Magnox/magnesium	6,300	6,670	 6%
Aluminium (& alloys)	1,730	1,030	-41%
Stainless steel	40,200	36,300	-10%
Zircaloy/zirconium	6,290	6,330	0.6%
Cellulose	2,170	1,070	-51%
Other ferrous metals	71,000	46,100	-35%
Graphite	78,400	70,700	-10%
Uranium	1,720	1,820	6%

7.2.2 Gas pathway

The key radionuclides in gases that contribute to post-closure radiological risk are C-14 and Rn-222 [40]. Tritiated gases (those containing H-3) are not significant in the post-closure phase due to the short half-life of tritium, meaning it would decay to negligible quantities before it could be released and travel to the biosphere after closure.

The inventory of C-14 has increased modestly in a few waste groups, such as RSC (56.2%), UILW (19.4%) and Legacy SF (1.01%) in the inventory update; with the total C-14 inventory increasing slightly by around 2%. The illustrative calculations of risk from C-14 [41] are strongly dependent upon the fraction of C-14 released into the gas phase and the potential release area. In the generic stage, the uncertainties surrounding this fraction are large and would dominate inventory changes of this order. The release of C-14 is also likely to be affected by the material in which it is present; reactive metals such as Magnox and aluminium are likely to have more significant release fractions [41]. The IGD update has seen such materials either decrease (e.g. aluminium) or see small increases.

The radiological risk associated with Rn-222 is the result of its place in the U-238 decay chain; as disposed, Rn-222 would not pose a risk due to its short half, but it can experience in-growth due to the decay of U-238. If U-238 migrates to the biosphere, via groundwater, then Rn-222 can contribute significantly to radiological risk. The U-238 inventory experiences moderate increases in some waste groups (e.g. UILW 13.6%), but in total the U-238 decreases slightly in the inventory update. There may be slight increases or decreases in radiological risk as a result of inventory changes, but U-238 migration is expected to be solubility limited, and as a result modest inventory changes are not likely to significantly change the potential risk due to the ingrowth of Rn-222.

7.2.3 Bulk gases

The generation of bulk gases in a GDF may be important, as they can influence the safety functions of the disposal system, for example, via over pressurisation. Also, bulk gases can act as carriers for radiological gases, such as C-14, in the gas pathway. The bulk gas produced is likely to be dominated by hydrogen, with carbon dioxide and methane also generated. The inventory materials that will have the biggest impact on gas generation rates are likely to be metals and organic materials. In the inventory update these materials see modest or moderate changes in their inventory, as shown in Table 10, with key materials such as stainless-steel and aluminium showing decreases. Gas generation will also occur as a result of processes which will be very dependent on the site and concept chosen for the GDF, such as radiolysis of water.

Gas generation rates are dependent on non-inventory factors, such as the site and concept chosen for the GDF as well as wate packaging decisions. This means that there are large uncertainties on gas generation at the current, generic stage. Therefore, the effects of the inventory changes, which are modest for the relevant materials, will be dominated by such uncertainty.

7.2.4 Human intrusion

Human intrusion calculations were not included in the generic PCSA. The generic ESC was instead concerned with strategies that may be employed to ensure that inadvertent human intrusion into a GDF will be extremely unlikely. The inventory has no impact on such considerations.

7.2.5 Non-radiological pollutants

RWM is currently undertaking work on non-radiological pollutants to inform the safety assessments of such hazards for future safety cases. Scoping studies on hazardous substances were presented in the PCSA for the specific purpose of informing future inventory data requests. In this inventory update, only some of the identified non-radiological hazardous materials have been recorded. For some of the non-radiological species, this is the first time that data have been requested; the data for these species in the 2019 UK RWI (and therefore the 2019 IGD) are limited. However, it is anticipated that more data will be available in future iterations of the UK RWI. The process of incorporating data on non-radiological hazards into the IGD is an important step in RWM's programme of work in this area.

7.2.6 Criticality safety

There are no inventory changes that would affect criticality safety for LHGW; however, the inclusion of new spent fuel streams requires consideration for HHGW. RWM's criticality safety research programme has identified the preferred solutions for demonstrating the criticality safety of spent fuel transport and disposal, setting out the components of scoping level criticality safety assessments for each phase of spent fuel management and disposal [42]. This work has been based on assumptions set out in the 2013 Derived Inventory and more recent work [43] has built upon some of the research gaps identified in the options study. The inclusion of the new fuel types will have minimal implications on the overall generic criticality safety case, as they are largely bounded by the assumptions made for other types of fuel in terms of fuel material (oxide fuel), initial uranium enrichment and burn-up, i.e. they are not significantly different from those previously studied. The burn-up values are slightly lower than those assumed in the recent work; however, the criticality safety research programme still needs to undertake a significant amount of work to build upon the scoping calculations performed to date and build these into detailed and optimised calculations as site-specific data becomes available and designs are developed. Work to include these new fuels, and others that were not originally considered (such as experimental reactor fuel), in the knowledge base is planned through a series of Science and Technology Plan Task Sheets from the 2020 Science and Technology Plan [13] (including 20.4.001, 20.4.004 and 20.4.005) and wider work developing the criticality safety demonstration of spent fuel disposal more generally is the focus of other science and technology tasks.

7.3 Alternative inventory scenarios

Most of the alternative inventory scenarios considered in the ESC do not change between the 2016 and 2019 IGD. For those scenarios that do change, the following consider reductions in the amounts of UILW and SILW:

- Scenario 11, in which graphite wastes are excluded from the IGD
- Scenario 12, in which LLW/ILW boundary wastes, are excluded from the IGD

Whilst the reductions in UILW and SILW inventory are subject to changes in the new IGD, the assessment of these scenarios is bounded by the baseline inventory scenario. Scenario 2, which considers less Magnox reprocessing occurring, has less impact in the new IGD and consequently will have a reduced effect on the ESC.

The inventory upper and lower uncertainty bands of the IGD (Scenario 4) also change in the new IGD. Overall, the activity for the upper uncertainty band has decreased in the update, but there is a significant increase in I-129, particularly in UILW. I-129 is a significant contributor to calculated risk, via the groundwater pathway. There are also smaller increases in the upper uncertainty of other key radionuclides: Se-79, U-235, U-238 and Tc-99. As is noted in the ESC [38], higher activities of I-129 associated with the upper uncertainty could result in the mean calculated risk exceeding the risk guidance level for the well pathway. This is, however, dependent on radionuclide behaviour in the host rock and aquifer, which in the ESC are based on expectations for an illustrative, generic environment.

7.4 Knowledge gaps and future research needs

The changes to the inventory have not resulted in any new knowledge gaps that would necessitate future research to support the ESC.

8 Implications for the Disposability Assessment process

Summary of implications for the Disposability Assessment process

The Disposability Assessment process supports waste packagers that plan to dispose of higher activity wastes in a GDF. The Disposability Assessment process follows established RWM procedures. These have not been affected by the differences between the 2016 and 2019 IGDs.

No new knowledge gaps, and therefore no additional research needs, have been identified.

The RWM Disposability Assessment process exists to support waste packagers that plan to condition and package higher activity wastes (and nuclear materials) in a form that is compatible with emplacement in a GDF. The 'Waste packages and assessment of their disposability' report [44] provides a description of the methods by which RWM ensure that packaged radioactive waste and nuclear materials

- Have the characteristics necessary for safe transport to, and disposal in, a GDF
- Are compliant with the assumptions made in the generic DSSC

If a disposability assessment concludes that the implementation of the packaging proposal would result in disposable waste packages which *'are assessed to be compliant with published RWM packaging specifications',* the Assessment Report can be accompanied by a 'Letter of Compliance' endorsing the packaging proposal [45]. Because the changes to the IGD do not affect the Disposal System Specification (see **Section 3**), there are no implications for RWM's waste package specifications.

The Disposability Assessment process plays an important role in underpinning the generic DSSC as it provides confidence that the safety cases, which are based on generic assumptions regarding the wastes and the form of packaging, encompass 'real' waste packages being developed by industry.

The continued validity of RWM's existing packaging endorsements is maintained through Periodic Review, which provides active management of the status of the endorsements to ensure that they remain consistent with the current safety case (DSSC) and basis for disposability assessment.

There is a continuing trend for waste packagers to develop innovative packaging proposals[12]. The system of analysis and evaluation of these innovative proposals is based on formal RWM procedures for the assessment of innovative proposals and disposal system change management [46, 47]. Such proposals add complexity to the disposability assessment process. The range of package types that RWM is aware of includes all those that are used in the 2019 IGD. Further innovative packaging proposals will be carefully monitored for any implications.

The changes to the IGD do not result in any new research needs in order to ensure that the Disposability Assessment process remains robust.

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[12] *Innovative packaging proposals do not comply with an existing Part D (detailed) waste packaging specification. Innovative packaging proposals should be compliant with the Part C waste packaging specification, which defines the envelope in which to develop a waste package.*

9 Conclusions

Summary of Conclusions

The objective of this report is to assess the implications of the changes to RWM's inventory for geological disposal on the findings of the generic DSSC. It has been found that the inventory changes do not affect the conclusions of the generic DSSC.

No new research needs have been identified as a result of the changes to the IGD.

9.1 Implications of inventory changes on the findings of the generic DSSC

The purpose of this report is to assess the implications of the changes to the IGD, including the alternative inventory scenarios, on the findings of the generic DSSC [1]. The inventory changes have been assessed [12] and found to be small. The implications of these small changes in the inventory result in the following:

- No impact on RWM's Disposal System Specification as the scope of the inventory has not changed
- Small changes to RWM's illustrative generic GDF designs
  - Changes of 1% to 2% to the GDF footprint (host rock dependent)
  - Small changes to the numbers of vaults (up to 4.7%) and tunnels (up to 0.3%)
  - Slight changes to the operational programme
- No change to the conclusions of RWM's generic Transport Safety Case as the changes to the inventory are small
- No change to the conclusions of RWM's generic Operational Safety Case, which is based on bounding source terms that are unaffected by the inventory changes
- No change to the conclusions of RWM's generic Environmental Safety Case as the changes to the inventory are small
- No change to the disposability assessment process as there are no significant changes to the findings of the generic DSSC

Overall, the inventory changes do not affect the conclusions of RWM's generic DSSC.

9.2 New research needs

A key objective of this report was to identify any new research needs arising as a result of the changes to the IGD. The changes to the inventory have not resulted in any new knowledge gaps that would necessitate future research.

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Glossary

Term	Definition
AGR	Advanced gas-cooled reactor
BSO	Basic safety objective: A numerical target that marks the start of the “broadly acceptable” region of the Health and Safety Executive framework for risk management described in Reducing Risks Protecting People, 1991, and that the Office for Nuclear Regulation expects its inspectors to use in determining whether a licensee is controlling radiological hazards adequately and reducing risks as low as reasonably practicable (ALARP).
Conditioned volume	The conditioned waste volume is the volume of the wasteform (waste plus immobilising medium) within the container
Disposal unit	A waste package, or group of waste packages, which is handled as a single unit for the purposes of transport and/or disposal.
DNLEU	Depleted, natural and low enriched uranium
DSSC	Disposal system safety case
Depleted uranium tails	Depleted uranium left over from enrichment operations
EBS	Engineered barrier system
ESC	Environmental Safety Case
GDF	Geological disposal facility
GW(e)	Gigawatts electrical
HEU	Highly enriched uranium
HHGW	High heat generating waste
HLW	High level waste
HSR	Higher strength rock
IAEA	International Atomic Energy Agency
IGD	Inventory for geological disposal
ILW	Intermediate level waste
IP	Industrial package
Legacy waste	Radioactive waste which already exists or whose arising is committed in future by the operation of an existing facility
LHGW	Low heat generating waste. Some wastes have negligible heat output; these are included in this category

Term	Definition
LLW	Low level waste
LLWR	Low Level Waste Repository
LSSR	Lower strength sedimentary rock
LWR	Light water reactor
MOX	Mixed oxide fuel
NB	New build
OESA	Operational environmental safety assessment
OSC	Operational safety case
Packaged volume	Volume occupied by waste package when waste has been packaged
PCSA	Post-closure safety assessment
Pu	Plutonium
RGL	Risk guidance level
RPCM	Radiological protection criteria manual
RSC	Robust shielded container
SF(s)	Spent fuel(s): nuclear fuel removed from a reactor following irradiation that is no longer usable in its present form because of depletion of fissile material, poison build-up or radiation damage.
SGHWR	Steam generating heavy water reactor
SILW	Shielded ILW
SLLW	Shielded LLW
tHM	Tonnes of heavy metal (1 tonne = 1,000 kg)
TPS	Transport package safety
TSC	Transport safety case
TSD	Transport system design
tU	Tonnes of uranium (1 tonne = 1,000 kg)
UILW	Unshielded ILW
UK RWI	UK radioactive waste inventory (also referred to as UK RWMI- UK radioactive waste and materials inventory)
ULLW	Unshielded LLW
WAGR	Windscale AGR
WVP	Waste vitrification plant

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