Pre-application advice and scrutiny of Radioactive Waste Management Limited: Joint regulators' assessment of the 2016 generic Disposal System Safety Case

Issue 1

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We would welcome your feedback on this document.

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Executive summary

Radioactive Waste Management Limited (RWM) is responsible for implementing the management and ultimate disposal of higher activity radioactive waste (HAW) through constructing and operating a geological disposal facility (GDF). In 2017, RWM published a suite of safety case reports for a future GDF based on its understanding of the scientific and engineering principles supporting geological disposal. A site for a GDF has not yet been identified. The safety case is based on assumptions about possible geological settings, GDF concepts and designs, and is referred to as the 2016 generic Disposal System Safety Case (2016 gDSSC).

The Environment Agency and the Office for Nuclear Regulation (ONR) are responsible for ensuring that any future GDF in England meets our high standards for protecting people and the environment and, if it does, for granting the necessary environmental permits and nuclear site licence for our respective regulatory remits of environmental protection, safety, security, radioactive materials transport and safeguards.

We have assessed the 2016 gDSSC at the request of RWM, under the terms of our agreements with RWM to provide scrutiny and advice on parts of its work ahead of any permit or licence application. A generic DSSC is not a regulatory requirement. We recognise that the 2016 gDSSC represents an early stage for RWM in developing its approach for demonstrating the safety of any future geological disposal facility. Our assessment provides advice and comment to RWM on matters within our respective regulatory remits to help ensure that any future applications supporting a GDF take full account of our permitting and licensing requirements; it does not form the basis of any regulatory decision.

Currently, from our assessment of the 2016 gDSSC, we have not identified any fundamental regulatory issues that would prevent RWM developing a safety case in the future to address our regulatory requirements. However, our position is subject to some reservations that we present in this report. We note that there is a significant amount of work for RWM to do to develop a comprehensive, site-specific safety case, and that many aspects can only be fully evaluated when a site is selected and specific designs are produced. We advise RWM to continue the constructive dialogue with us and take steps to address our feedback as it progresses this further work.

Contents

1. Introduction

UK government policy for the long-term management of higher activity radioactive waste (HAW[1]) is described in the 2014 White Paper [1], which sets out the framework for managing HAW in the long-term through geological disposal. Radioactive Waste Management Limited (RWM) is responsible for implementing government policy on geological disposal of HAW.

The Environment Agency and the Office for Nuclear Regulation (ONR) are responsible for ensuring that any future Geological Disposal Facility (GDF) in England meets our high standards for protecting people and the environment and, if it does, for granting the necessary environmental permits and nuclear site licence for our respective regulatory remits of environmental protection, safety, security, radioactive materials transport and safeguards.

In 2017 RWM published a suite of safety case reports for a future GDF[2] based on its understanding of the scientific and engineering principles supporting geological disposal. A specific site for a GDF has not yet been identified. The safety case is based on assumptions about possible geological settings and related GDF concepts and designs, and is referred to as the 2016 generic Disposal System Safety Case (2016 gDSSC). The 2016 gDSSC updates RWM's previous, 2010, gDSSC.

We assessed the 2016 gDSSC under the terms of our agreements with, and at the request of, RWM, as part of our ongoing Pre-application Advice and Scrutiny (PAAS) Programme. Our regulatory assessment brings together the views of specialists in transport and nuclear safety from ONR and specialists in radioactive waste disposal from the Environment Agency. We keep our regulatory partner, Natural Resources Wales, aware of matters arising and important outcomes of our assessment of the 2016 gDSSC from our PAAS Programme.

A generic DSSC is not a regulatory requirement. Our assessment provides advice and comment to RWM on matters within our respective regulatory remits to help ensure that any future applications supporting a GDF take full account of environmental permitting and site licensing requirements; it does not form the basis of any regulatory decision.

2. The generic Disposal System Safety Case

RWM considers that the main purpose of the gDSSC is to give confidence that a GDF can be implemented safely in the UK in a range of host rocks typical of those found in the UK (currently covering illustrative disposal concepts for high heat and low heat generating wastes in higher strength rock, lower strength sedimentary rock and evaporites). It does this by describing and assessing the safety and environmental implications associated with all aspects of geological disposal of HAW [2]. RWM also intends to use the 2016 gDSSC in order to [2]:

- demonstrate it is confident that the UK's radioactive waste can be safely disposed
- invite and support discussions with regulators and others
- provide a basis for assessing the disposability of waste packages and provide advice to waste producers

[1] The term higher activity waste refers to all radioactive material that has no further use that falls into the following categories: High Level Waste (HLW), Intermediate Level Waste (ILW) and the relatively small volume of Low Level Waste (LLW) that is not deemed suitable for disposal at existing near-surface facilities such as the Low Level Waste Repository.

[2] https://www.gov.uk/government/collections/demonstrating-the-safety-of-a-geological-disposal-facility-gdf

- support the siting process for a GDF by providing information to communities interested in hosting a GDF
- inform its Science and Technology Plan (S&T Plan [3]) by identifying research and development needs
- provide a basis for the early assessment of the suitability of potential sites for a GDF, and inform the development of illustrative disposal concepts and designs
- provide a source of information to support the development of site-specific GDF designs and safety cases

The 2016 gDSSC considers conventional, radiological and environmental safety when waste is transported to a GDF (in the generic Transport Safety Case (TSC) [4]), during construction and operation of a GDF (in the generic Operational Safety Case (OSC) [5]), and in the long-term period after closure (in the generic Environmental Safety Case (ESC) [6]).

RWM intends to develop the gDSSC iteratively, updating it as necessary to support continued interaction with the regulators, disposability advice on waste packaging proposals and engagement with stakeholders [2]. When potential sites are identified, RWM will start to develop site-specific safety cases based on specific concepts and designs. RWM intends to develop site-specific safety cases as a separate and parallel work stream from its generic safety case work. RWM considers that this approach will ensure that it has well-understood, benchmark safety cases, whilst developing the site-specific ones up until the point at which it decides that generic safety cases are no longer necessary [2].

3. Purpose and scope of the regulators' assessment

Our aim in assessing the 2016 gDSSC is to help ensure that any future applications for a GDF take full account of our environmental permitting and site licensing requirements. In addressing this aim, we have considered whether:

- the 2016 gDSSC has been developed in-line with regulatory expectations[3] and whether it addresses our previous regulatory comments
- there are any specific areas where RWM needs to improve the gDSSC to provide further confidence in the safety of geological disposal
- the 2016 gDSSC provides an appropriate basis for RWM's disposability assessments to minimise the risk that conditioning and packaging of HAW now results in packages that are incompatible with geological disposal in the future, and is commensurate with safety case assumptions
- there are any fundamental issues that we consider would, or might, prevent RWM from making an adequate safety case for a GDF in the future

Our assessment will also help us to:

- provide visibility of, and confidence in, the role of regulators in the management of HAW
- develop our understanding of the safety cases that could be made for a GDF in a range of geological environments
- inform our regulatory assessment process and planning for an application for a future GDF
- advise RWM on how it may improve its future work plans

We expect a safety case to be supported by evidence provided, or referenced, in it. Therefore, we constrained our assessment to those documents that comprise the suite submitted (and published) by RWM. We did not track all lines of evidence down into supporting documentation, but we did

[3] Noting that we do not require generic safety cases.

check a few selected lines of reasoning. We also requested some supporting documentation from RWM to inform our assessments and to follow lines of inquiry, but we did not assess any claims, arguments or evidence contained within them. We concentrated on aspects of the 2016 gDSSC that could transfer into a site-specific DSSC and new areas included in the 2016 gDSSC.

We did not consider RWM's generic environmental assessments [7, 8, 9] in our assessment because RWM states that "they do not add to the safety arguments" (§1.4.1 of [2]), although they are included in RWM's 2016 suite of gDSSC documents. We provided advice on these documents separately [10]. We will expect RWM to clarify the relationship between its generic environmental assessments and the gDSSC.

Lack of specific comment on any particular aspect of work reported in the 2016 gDSSC and its supporting documents should not be interpreted as tacit acceptance or endorsement of that area of work, or details within it.

4. Overview and general comments

This section provides a summary of our main findings and comments. Further detail on our findings relevant to our individual regulatory vires is provided in Annexes 1 and 2.

4.1. Structure and accessibility of the 2016 gDSSC

RWM has improved the gDSSC documentation from that provided in 2010. The 2016 gDSSC is better structured, more systematic and clearer than the 2010 gDSSC.

The suite of 2016 gDSSC documents comprises an overview report [2] and the 3 main safety cases (TSC, OSC and ESC) [4, 5, 6]. These are underpinned by documents describing the assessments, the 'system information' (the system specification and design documents) and the knowledge base (status reports). This is a logical structure for presenting a safety case for a GDF. Figures showing the links between each safety case and their underpinning documents are useful (§3 of [2]).

Overall, we consider the 2016 gDSSC is better structured and clearer than the 2010 gDSSC, informed by the expansion of RWM's knowledge base and an updated inventory for disposal. RWM has reduced the amount of repetition within and between documents, since 2010, but there are still some areas (notably within the 2016 gTSC) where repetition is apparent.

The overview report [2] provides a good and easily readable summary of the 2016 gDSSC and presents the main reasons why RWM considers that HAW can be disposed safely in a GDF. Separating the common technical background information [11] from the overview report is useful; it makes for a much more readable overview report. However, RWM should improve the cross-referencing between overarching topics in the overview report and where these topics are discussed in more detail in the 2016 gDSSC.

The 2016 gDSSC is clearer with respect to RWM's plans for the future development of the DSSC [2] than in 2010, but it does not explicitly identify those aspects that RWM will take through to a site-specific DSSC. Therefore we have not been able to draw conclusions from our review that would necessarily hold for the duration of the development of the DSSC.

Recommendation 2016 gDSSC_R1: RWM should improve the clarity of the DSSC to demonstrate what learning has been considered, including operational experience from relevant sites, make suitable reference to where detailed assessment has been carried out and highlight clearly its achievements, in particular relating to aspects of the 2016 gDSSC that may be transferrable to a site-specific DSSC.

Although the 2016 gDSSC presents a more balanced consideration of the 3 geological environments, it includes limited discussion on how a safety case for an evaporite host rock may be developed, which is likely to have significant differences with respect to the emphasis of safety analysis and claims compared with higher strength rock and lower strength sedimentary rock. At this generic stage of the GDF programme, RWM needs to make sure that it provides a balanced

analysis for all of its illustrative disposal concepts while clearly indicating the advantages and disadvantages of each.

We note that the 2016 gDSSC is not a safety case in the conventional sense; instead it presents information on how RWM intends to make a safety case once a suitable site has been found. This approach would not be appropriate in a site-specific safety case, and RWM should be clear on this matter when it presents the 2016 gDSSC to a wider audience.

The Technical Background document [11] includes a central glossary to which other documents in the gDSSC refer. This provides a useful reference source, but it does not include a number of important terms, such as: environmental safety assessment or nuclear safety assessment; safety case; period of authorisation; post-closure; ionising radiation; risk; dose; potentially exposed group; human intrusion; disposal gallery; and disposal horizon. Some gDSSC reports have their own glossaries, but where they are included they are not comprehensive.

Recommendation 2016 gDSSC_R2: RWM should develop and include a single, comprehensive glossary in future safety cases, which should be updated, as necessary, as implementation progresses.

RWM's status reports provide a structured review and summary of relevant published scientific literature and discuss its relevance in the UK context. These will serve as a useful source of reference and will assist people with a broad knowledge of geological disposal to better understand the science and technology underpinning geological disposal of UK HAW. These documents, along with RWM's S&T Plan [3], provide a good overview of RWM's generic Research and Development (R&D) programme and its current scientific understanding, but do not give us an understanding of how they contribute towards demonstrating safety of geological disposal. We have provided separate advice to RWM on the Status Reports [12].

RWM has previously informed us that the GDF safety case and design development is linked via the system specification (see Figure 2 of [2]), and the iterative nature of this development will ensure that it has captured cross-cutting matters and it is managing any consequential effects upon other phases and safety cases appropriately. RWM should strengthen the gDSSC to reflect this position and capture matters that affect different phases. We consider this can be done ahead of detailed design by identifying those decisions that will be made in the future that may impact other areas of the safety case.

Through its development of safety arguments, RWM has collated its claims and arguments to support the demonstration of environmental safety of a GDF. However, it has yet to formally collate the supporting evidence. We advise RWM to progress work on designing and implementing tools to present and demonstrate the critical lines of reasoning and evidence supporting the safety cases and we have documented this as a Regulatory Observation (RO) [13] in order to monitor progress. This work should cover both the operational and post-closure periods.

4.2. Transport Safety Case

The content and scope of the 2016 gTSC [4] is generally adequate for the current generic stage of the GDF programme, but RWM could improve any future updates by including more information on the maintenance of reusable transport containers, arrangements for venting of packages during transport, and transport implications with respect to any future need to retrieve waste packages from a GDF.

4.3. Operational Safety Case

We consider that the 2016 gOSC [5] presents a comprehensive update of the 2010 gOSC, produced using safety case methods and processes that are aligned to relevant good practice. The 2016 gOSC draws upon RWM's technical research and knowledge base, taking cognisance of international learning and knowledge relating to geological disposal.

The 2016 gOSC identifies, rationalises and assesses potential hazards for the generic concept designs, identifying potential safety measures, safety functions and required risk reduction factors that may need to be included within the developed design once a site is selected. We consider that progress on the majority of aspects is appropriate for the current generic stage of the GDF

programme, providing confidence that RWM will be able to apply appropriate standards, guidance and relevant good practice to the developing OSC as a detailed design is progressed.

RWM's current approach to fire safety means that the opportunity to reduce risks As Low As Reasonably Practicable (ALARP) through engineering design of the facility may be missed. Furthermore, the lack of a fire protection strategy is a significant shortfall with respect to regulatory expectations for fire safety. Although RWM has identified the need to undertake further work to address fire safety, we have raised a Regulatory Issue (RI) asking RWM to develop a credible fire protection strategy to inform and prioritise fire safety measures, appropriate to the stage of the GDF programme [14].

We consider RWM has adequately robust OSC and Operational Safety Assessment (OSA) processes, and that it is applying appropriate project controls. We also consider RWM has demonstrated a satisfactory understanding of the importance and characteristics of a good safety culture, commensurate with the current generic stage of the GDF programme. RWM has defined Forward Action Plans (FAPs) for the further development of the gOSC and the supporting generic Operational Safety Assessment (gOSA). We will engage with RWM to ensure the FAPs are progressed appropriately.

4.4. Environmental Safety Case

RWM has improved the structure and readability of the 2016 gESC [6] compared with the 2010 gESC. The 2016 gESC has a structured narrative approach to presenting the safety arguments, focussing on identification and substantiation of environmental safety functions. We consider this is appropriate for the current generic stage of the GDF programme.

The 2016 gESC evaluates only post-closure environmental safety. It refers to the generic Operational Environmental Safety Assessment (gOESA) for environmental safety during the operational phase (which includes construction, operation, closure and decommissioning of the GDF). At this generic stage of the GDF programme, we are not opposed to operational and post-closure environmental impacts being documented separately, but, in their present format, we consider that they are not consistent.

The 2016 gESC 'summary and key messages' focusses on evidence to show that geological disposal of HAW can be accomplished in a way that ensures environmental safety at the time of disposal and in the long-term (§11 of [2]). It does not discuss important assumptions or uncertainties that RWM considers are poorly supported or require further work. We expect an ESC for a GDF to present a balanced, unbiased view of the safety of geological disposal.

RWM's safety assessment approach represents an improvement over the 2010 gESC. However, both the gOESA and generic Post-Closure Safety Assessment (gPCSA) contain shortfalls that we will expect to see addressed for a site-specific submission and we have raised 2 Regulatory Issues asking RWM to develop:

- its capability in OESA development to make sure that all potential environmental impacts are considered and that it is consistent with the PCSA, where appropriate [15]
- a comprehensive understanding of the nature and consequences of non-radioactive substances in the inventory for disposal that are hazardous to human health or non-human biota, or are considered hazardous substances or non-hazardous pollutants in terms of groundwater pollution and use this to assess quantitatively their impacts [16]

RWM also needs to develop further its approach to assessing the gas pathway and human intrusion.

4.5. Retrievability

Government policy [1] discusses the concept of retrievability, such that waste packages could be removed from a GDF if there was a compelling reason to do so. RWM states that it will carry out design work in such a way that the option for retrievability is not excluded [11], noting that retrieval may become progressively more difficult (and costly) through the GDF's lifetime. RWM considers retrievability of waste packages within the generic design document [17], but this is not reflected

across the gDSSC. Retrievability is not a regulatory requirement but, given RWM's intent, it should ensure that the implications from, and requirements needed to, facilitate potential retrievability are appropriately considered within the DSSC so that the safety of such activities is adequately demonstrated.

Recommendation 2016 gDSSC_3: RWM should clarify its approach to retrievability, and identify the research that would be needed to underpin it.

RWM's approach to retrievability should demonstrate that the safety consequences of retrieval meet the ALARP principle and are consistent with best available techniques, and that any related provisions included in the design do not adversely affect security, safeguards or operational or post-closure safety [18].

Recommendation 2016 gDSSC_R4: RWM should ensure that the implications from, and requirements needed to facilitate, potential retrievability are encompassed within the OSC so that the safety of such activities can be adequately demonstrated. Implications for security and safeguards should also be considered.

4.6. Inventory for disposal

The inventory for disposal is better defined in the 2016 gDSSC, and the consideration of variant scenarios represents a more systematic approach than that taken in 2010.

RWM has based its inventory for disposal on the 2013 UK Radioactive Waste Inventory (UKRWI), which was the most recent version at the time the 2016 gDSSC was being written. RWM has assessed 12 alternative inventories for the 2016 gDSSC as part of its assessment of disposal inventory uncertainty [19, 20]. This has replaced the upper inventory bound approach, which RWM used in the 2010 gDSSC. We consider this approach an improvement.

Recommendation 2016 gDSSC_R5: RWM should continue to revise and update its inventory for disposal and assess a range of inventory scenarios as it moves forward from the gDSSC to a site-specific DSSC, taking into account new developments (such as, diversion of wastes to other management or disposal options in the future) that could alter RWM's underpinning assumptions regarding volume and activity of waste streams destined for geological disposal.

RWM has analysed the predicted inventory of radioactive waste arisings within the UK from across industry which could be destined for a GDF, including those from civil nuclear sites and Ministry of Defence (MoD) related activities. RWM estimates that arisings from the defence programme will cease in 2060 and arisings from the submarine programme will cease in 2070 [19]. For irradiated fuel arising from the submarine programme, RWM states that the inventory quantities are bound within the sensitivity studies placed on the management of civil reactor irradiated spent fuel and therefore are implicitly considered within the 2016 gDSSC [20]. However, the 2016 gDSSC includes limited evidence to underpin the assumption that the chemical and radiological properties of MoD owned fuel are bound within the sensitivities of civil reactor irradiated spent fuel. Furthermore, it does not adequately underpin the assumptions on the isotopic composition of other forms of MoD-derived uranium and legacy spent fuel, although these are discussed within the alternative inventory scenarios [20].

Recommendation 2016 gDSSC_R6: The safety functional requirements (SFR) for the emplacement and vault closure operations should have due regard for the radiological, chemical and physical characteristics of the waste. Therefore, RWM should present a clear understanding of the bounding concern for operational safety within the GDF, taking due account of civil and defence derived waste.

RWM's inventory for disposal includes data on 112 radionuclides that Nirex[4] assessed as being relevant to geological disposal [21]. RWM reviewed the applicability of this list and prioritised relevant radionuclides when preparing the inventory for disposal [19]. However, RWM has not provided information on how this exercise was carried out, nor does it reference RWM's ongoing, more comprehensive, review of relevant radionuclides.

RWM has identified some contaminants in its inventory for disposal that are classified as hazardous substances under the Water Framework Directive [22]. However, it has not developed a comprehensive understanding of the nature, concentrations and consequences of non-radioactive substances in the inventory for disposal that are hazardous to human health or considered hazardous substances or non-hazardous pollutants in terms of groundwater pollution. RWM should work with the Nuclear Decommissioning Authority (NDA) and waste producers to make sure that future iterations of the UKRWI include data on all the substances that it needs to support the DSSC, and that waste producers carry out the appropriate waste characterisation to support the development of an assessment model for the non-radiological component of the inventory for disposal. We consider this work is urgent and have communicated its importance to the NDA, RWM and waste producers [16, 23].

Recommendation 2016 gDSSC_R7: RWM should establish a comprehensive inventory of materials associated with GDF construction, operation and closure relevant to the environmental safety assessments, and consider the effects of these materials in future safety cases.

RWM makes no reference to the accuracy of inventory estimates associated with radionuclides that contribute most to the overall impacts from a GDF, for example, chlorine-36 and iodine-129 for the post-closure groundwater pathway. We advise RWM to identify explicitly the necessary further work associated with radionuclides and other substances that contribute most to the overall environmental safety performance of a GDF.

There is a lack of discussion of safeguards and associated requirements in the derived inventory reports [19, 20]. The generic GDF design document [17] states that the level of safeguards provisions will depend upon the nuclear material emplaced within a GDF. RWM should include a discussion on safeguards requirements as it continues to update the inventory for disposal.

As a site-specific safety case develops, we will expect RWM to demonstrate how any changes to the inventory for disposal would impact on decisions on GDF design and capacity.

4.7. Criticality

RWM's proposed approach to ensure criticality safety during the transport and operational phases of a GDF is consistent with relevant good practice. RWM has also carried out detailed research on exploring the mechanisms and potential for criticality events during the post-closure phase of a GDF.

RWM has provided a set of generic package fissile limits for standard low heat generating waste (LHGW) packages to assist waste producers in developing packaging proposals [24]. This information may also be useful to those starting to consider the transport of wastes containing fissile materials and the generic package limits will simplify the process of criticality assessment for some waste producers. The document [24] is outside the scope of the gDSSC and we have not assessed it as part of this work.

We have asked RWM to engage with the UK nuclear industry to identify all waste streams for which criticality safety assessments may be particularly challenging and to develop work programmes to contribute towards the provision of packaging advice for these waste streams. We have also asked RWM to inform regulators whether it would be able to apply its criticality assessment approach to packaging proposals in which the levels of fissile materials may be

[4] Nirex was the predecessor organisation to RWM.

expected to exceed current International Atomic Energy Agency (IAEA) Transport Regulations. This is documented via a Regulatory Observation [25].

RWM claims (for example, [26]) that post-closure criticality is low-likelihood and low-consequence. RWM has assessed the impact of the consequences of a post-closure criticality on the performance of a GDF in a higher strength rock, which is cited in the PCSA [27][5]. The calculations assume a rapid transient criticality occurs at 10,000 years post-closure, which is the earliest assumed failure time for one type of high heat generating waste (HHGW) disposal container. RWM assumes that a quasi-steady state post-closure criticality occurs at 100,000 years post-closure. RWM does not present in the gESC why it considers that an earlier quasi-steady state post-closure criticality could not be initiated, given the potential for much earlier failure of LHGW containers.

Recommendation 2016 gDSSC_R8: RWM should improve the clarity of its claims, arguments and evidence for post-closure criticality safety in an ESC.

4.8. Records

The 2016 gDSSC does not mention operational records in any detail, particularly retention and retrievability of package records over the GDF's lifetime to underpin continued safe operations and long-term environmental safety. There is information relating to waste package records, with focus on what waste packagers need to provide, but there is no specific mention of RWM's approach to managing them for the long-term [28].

Recommendation 2016 gDSSC_R9: RWM should develop and implement a strategy for obtaining and managing (for the long-term) the full range of data and records necessary to underpin continued safe operations and demonstrate compliance with any future nuclear site licence and environmental permits.

4.9. Balance between operational and post-closure impacts

We expect RWM to establish and maintain an appropriate balance between managing operational and post-closure impacts. RWM acknowledges this in the overview report [2], however, we do not consider that this is reflected in all the supporting documents. For example, the safety case objectives summarised in the Safety Case Production and Management document [29] are biased towards the operational period. Similarly, RWM's approach to the role of 'intelligent customer' for the 2016 gDSSC appears biased towards meeting ONR's expectations of a licensee's arrangements for nuclear safety, and does not mention meeting the requirements of an environmental permit and the Environment Agency's guidance relating to geological disposal [30]. We expect RWM's arrangements to reflect all statutory requirements in a coherent manner.

Recommendation 2016 gDSSC_R10: RWM should strengthen the DSSC to give greater confidence that matters which could adversely impact safety or environmental performance during all phases of a GDF lifecycle are identified and resolved satisfactorily in an integrated and optimised manner.

4.10. Use of the 2016 gDSSC to support disposability assessments

RWM uses the gDSSC as the basis for its waste package disposability assessment process. This process is necessarily conservative at this stage, given the large uncertainties and lack of detailed GDF design.

RWM intends to define waste acceptance criteria (WAC) for a GDF once the design, location and model of operation of a GDF have been accepted. The 2016 gDSSC does not explain how RWM proposes to transition from its waste packaging specifications to WAC: it should refer to RWM's ongoing work in this area.

[5] We understand from discussion with RWM that reference should have been made to the 2016 PCSA in the 2016 gDSSC documentation rather than to the 2010 PCSA.

Recommendation 2016 gDSSC_R11: The DSSC should clarify how waste acceptance criteria will be derived from the safety case.

Recommendation 2016 gDSSC_R12: RWM should consider the arrangements to be put in place to minimise the risk of receipt of waste packages that do not meet GDF waste acceptance criteria.

We consider RWM's position that it will not be able to endorse packaging proposals for HHGW with a Letter of Compliance for the foreseeable future to be inconsistent with the high levels of performance claimed for HHGW disposal container designs in the 2016 gESC.

Recommendation 2016 gDSSC_R13: RWM should develop its understanding of the performance of HHGW to enable it to endorse proposals for HHGW on a similar basis to those for LHGW.

5. Recommendations from our review of the 2010 gDSSC

We made 57 recommendations to RWM from our assessment of the 2010 gDSSC [31]. RWM has made reasonable progress against the majority of these. Areas where progress is less advanced are typically related to site-specific matters where RWM is unable to demonstrate significant progress prior to identification of potential sites.

Annex 4 summarises our assessment of RWM's progress to date, as demonstrated in the 2016 gDSSC, and identifies some recommendations for RWM to continue to engage with us to ensure our regulatory expectations are met in any future safety case submission.

6. RWM's forward programme

RWM states that "the output of each safety case supports the identification of research requirements to develop the knowledge base for subsequent safety cases" [2]. We do not consider that the 2016 gESC systematically and explicitly identifies the further work that is required, nor links to RWM's ongoing research as outlined in its S&T Plan [3].

Recommendation 2016 gDSSC_R14: RWM should identify areas of uncertainty in the DSSC, as it develops, for which further research or site-specific information is required to address, and provide links to ongoing research.

RWM has demonstrated awareness of current legislative and regulatory requirements, as summarised in the Disposal System Specification [32]. However, it needs to demonstrate that it has a process in place to identify and address new regulatory requirements or expectations, such as those being considered by the IAEA relating to transport of packages that are intended for both long-term interim storage and subsequent transport to a GDF. This relates to Recommendation R56 from our assessment of the 2010 gDSSC and we expect it to be addressed through that (see Annex 4).

Throughout the development of the 2016 gDSSC, we have maintained an open, transparent and constructive dialogue with RWM. We advise RWM to continue this dialogue in order to further develop its understanding of our regulatory expectations as the GDF development programme progresses.

7. Conclusions

We have assessed the 2016 gDSSC to help ensure that any future applications for a GDF take full account of our environmental permitting and site licencing requirements. Our assessment has also helped us to provide information and advice in relation to our role in regulating geological disposal, as summarised in this report.

The 2016 gDSSC is significantly improved over the 2010 gDSSC, and we are pleased that RWM has taken our earlier advice into account in its preparation. The 2016 gDSSC documentation is generally of high quality. However, the 2016 gDSSC is not strictly a fully scoped safety case; instead it presents information on how RWM intends to make a safety case once a suitable site has been found.

We consider that RWM has generally applied good practice in the development of the 2016 gDSSC. However, as described in this report, we have identified a number of areas where RWM needs to improve the gDSSC to provide further confidence in geological disposal.

We consider that the 2016 gDSSC provides a suitable basis for RWM's waste package disposability assessment process for LHGW. However, we are disappointed that RWM says that it will not be able to use the 2016 gESC to endorse packaging proposals for HHGW for the foreseeable future.

We recognise that the 2016 gDSSC represents an early (but important) stage for RWM in developing its approach for assessing the safety of any future geological disposal facility. Currently, from our assessment of the 2016 gDSSC, we have not identified any fundamental regulatory issues that would prevent RWM developing a safety case in the future to address our regulatory requirements. However, we note that there is a significant amount of work for RWM to do to develop a comprehensive, site-specific safety case, and that many aspects can only be fully evaluated when a site is selected and specific designs are produced. RWM should continue to engage in dialogue with the regulators and take steps to address our feedback as it undertakes this further development work.

As a result of our assessment of the 2016 gDSSC, we have raised new 3 Regulatory Issues and 2 new Regulatory Observations, as follows:

- GDF_RI_013 Characterisation and assessment of the non-radioactive component of waste in the inventory for disposal [16]
- GDF_RI_014 Operational environmental safety assessment [15]
- GDF_RI_015 Approach to fire safety assessment [14]
- GDF_RO_007 Auditable evidence in support of an ESC [13]
- GDF_RO_008 Defining waste package fissile levels [25]

We expect RWM to resolve Regulatory Issues within a specified timescale. We recognise that some matters (termed Regulatory Observations) cannot be fully addressed in the current generic context and might require information that RWM can only obtain at a future stage in the programme once a site has been identified. Nevertheless, we fully expect RWM to progress work to address and resolve ROs at the earliest stage possible in the programme. We monitor progress against RIs and ROs through our PAAS Programme [23].

In addition, we present 38 new recommendations arising from our assessment to assist RWM in developing its DSSC for a GDF. These are listed in Annex 3.

Annex 1: Office for Nuclear Regulation's assessment of the 2016 generic Operational and Transport Safety Cases

Introduction

The 2016 gDSSC is non-site-specific, and as such, detailed designs have not been developed. Therefore ONR's assessment has focussed on consideration of whether the 2016 gOSC [5], the 2016 gTSC [4] and RWM's processes provide sufficient evidence that, at the current generic stage of the GDF programme, RWM would be able to achieve the regulatory expectations as defined in our Safety Assessment Principles (SAPs) [33]. The SAPs do not specifically consider requirements for disposal facilities, however, they do provide a framework for assessing safety cases for nuclear safety and radioactive waste management, and as such will form the basis of our assessment of any future site-specific safety submission related to geological disposal.

In our assessment, we consulted the following range of specialist disciplines:

- fault studies
- mechanical engineering
- civil engineering and external hazards
- internal hazards
- conventional fire safety
- conventional health & safety
- nuclear liabilities regulation
- radiological protection
- criticality
- transport of radioactive materials
- nuclear materials safeguards
- nuclear security
- leadership and management for safety

This range of specialist disciplines reflects the main specialist disciplines that we anticipate will be involved when we assess any future site-specific safety case. This does not preclude other specialist disciplines from being involved in future regulatory engagements with RWM.

Although our assessment of the 2016 gOSC and gTSC is constrained to those documents that comprise the 2016 gDSSC suite, we requested some supporting documentation to inform our assessments and to follow lines of inquiry. However, we have not assessed any claims, arguments or evidence contained within them.

Operational Safety Case

The 2016 gOSC identifies, rationalises and assesses potential hazards for the generic concept designs, identifying potential safety measures, safety functions and required risk reduction factors that may need to be included within the developed design once a site is selected. We consider that progress on the majority of aspects is appropriate for the current stage of the GDF programme, providing confidence that RWM will be able to apply appropriate standards, guidance and relevant good practice to the developing OSC as the detailed design is progressed.

We consider RWM has adequate OSC and OSA processes, and that it is applying suitable project controls. We also consider RWM has demonstrated a satisfactory understanding of the importance

and characteristics of a positive safety culture, commensurate with the current generic stage of the GDF programme.

Forward action plans

RWM identifies FAPs in the gOSC Main Report [5] and each of the supporting gOSA volumes [34, 35, 36, 37]. None of the FAPs place anticipated timescales for delivery of the actions. The Main Report states that RWM is yet to agree the manner in which implementation of the FAPs will be managed and controlled, but that close out will be linked to RWM's S&T Plan [3]. The Main Report notes that all future work associated with development of the gOSC and the gOSAs will be managed as part of RWM's Technical Programme.

Fault studies

We are aware that the design and operating mode of some aspects of a GDF cannot be developed until a site has been selected, so we consider it is reasonable that RWM has not yet developed the OSA for these aspects at the current generic stage of the GDP programme. RWM has identified areas of work relating to these aspects in a FAP, which gives us some assurance that they will be addressed in a timely manner within the developing OSC as the detailed design is progressed.

RWM has developed a preliminary process flow description, which is independent of the site and hence host rock, to facilitate a structured hazard identification process at the current generic stage of the GDP programme. We consider this is an appropriate method of providing structure to the preliminary hazard identification. RWM will have to consider any future changes to the process flow description to determine whether they will affect the hazards that were previously identified and analysed, or whether they could result in new hazards requiring analysis.

We consider RWM has adequately robust OSC and OSA processes, and that it is applying appropriate project controls. RWM has made provision to capture this within the gOSA FAP, requiring the development and implementation of an integrated design and safety process to ensure that a consistent approach is applied.

RWM has applied a structured approach to hazard identification, which we consider appropriate at the current generic stage in the design. RWM has identified an extensive list of faults and rationalised them into fault sequences and fault sequence groups, which we consider is in accordance with good practice.

Where sufficient information is available, RWM has undertaken preliminary safety assessment. The safety assessments consider the rationalised fault sequences and identify the unmitigated consequences and the initiating event frequencies, and use these to undertake Design Basis Analysis (DBA). RWM uses DBA to identify safety functional requirements (SFR), potential candidate safety measures and the required risk reduction factors for these measures. This gives us some assurance that an adequate safety case could be made once a GDF site is selected and the design has been developed.

In determining the bounding case consequences for the primary waste streams, RWM has factored in the quantity of material to be managed (and hence the frequency / risk associated with the waste). Thus, if there is only a very limited quantity of material with the highest consequence with respect to safety but a more significant quantity of material with slightly lower consequences, RWM may consider the latter case to be bounding. We note that this could result in the use of consequences that are not the true bounding case (worst possible), but we consider the approach may be reasonable for some aspects of the fault analysis, provided that RWM can justify why the excluded materials are considered to be 'outliers'.

ONR expects the developed OSC to specify such 'basis of calculation assumptions' as operating limits and conditions, supported by a robust demonstration that they can be reliably enforced within the operating GDF. This would be likely to require that suitably robust, bespoke, arrangements are put in place whenever the excluded materials are processed. Notwithstanding this, we suggest it may be simpler to perform the DBA analysis using true bounding source terms, and to use the 'higher risk' (lower consequence) source term for the probabilistic safety analysis when it is developed.

Recommendation 2016 gDSSC_R15: RWM should demonstrate that the source term utilised to derive the radiological consequences used for DBA is suitably conservative (and unmitigated) as the safety assessment is developed. If some source terms are excluded, appropriate limits, conditions and exclusions should be considered.

Recommendation 2016 gDSSC_R16: RWM should specify limits or conditions within the developed OSC where waste container throughputs are used as part of the fault frequency assessments.

The gOSA volume 3 [36] makes note of exposure distances and exposure times used to calculate unmitigated consequences. We have not assessed the detailed assumptions made within the reference documents supporting the preliminary fault analysis but we advise RWM to ensure that the consequences used for the DBA are conservative and unmitigated.

Mechanical engineering

RWM applied a partial protected approach (claiming passive mitigation) to resolve unmitigated fault consequences in the 2010 gDSSC. ONR considered this could result in the incorrect safety classification of mechanical plant and equipment [31]. In the 2016 gOSC, RWM uses unmitigated doses for the assessment of radiological consequences to workers and members of the public from accident and normal operations [35, 36]. At the current generic stage of the GDF programme, the level of design definition limits the scope of design basis accidents, however, we are content that RWM is now considering unprotected radiological consequence within design basis assessments in the 2016 gOSC.

RWM has addressed possible faults resulting from the discharge of gas through all stages of operations [35, 36]. The gOSA identifies a forward action to define the requirements and develop the ventilation system design. This needs to be delivered to a level which permits hazard and failure identification studies to be undertaken in order to provide a definitive fault set related to ventilation system failures. RWM does not currently have detailed ventilation design proposals, but it has undertaken substantive work to understand the possible gaseous discharges that will need to be managed. In addition, RWM has identified relevant good practice and provided schemes for ventilation system designs to manage ventilation during the construction and emplacement stages of a GDF.

Part B of the Disposal System Specification (DSS) [38] defines temperature limits to ensure the performance of the engineered and natural barriers is not adversely affected, and RWM has developed concept designs to deliver the requirements through, for example, spacing arrangements for high heat generating waste packages. Although this work is only developed to a concept level, RWM has demonstrated suitable consideration of management of heat generation for the current generic stage of the GDF programme.

We believe that RWM is taking into account learning from relevant international programmes regarding high reliability equipment, for example, visiting a full scale demonstration shaft winding unit which has been operating for many years in Germany.

The gOSA [35, 36] does not specifically address the effects of ageing and degradation, instead setting a requirement that good safety performance should be delivered through life, and that equipment would be replaced based on an inspection, maintenance and testing schedule to be developed as the detailed design develops. RWM demonstrated the feasibility of operating a GDF and associated design elements for 160 years or more [39]. The report examines the potential impacts on GDF operations and safety issues related to the extended operational period. Furthermore, RWM has told us that it is planning work to understand the access requirements for maintenance in a GDF. We are content that RWM is giving due consideration to plant and equipment ageing and degradation, commensurate with the current generic stage of the GDF programme.

The GDF design is not sufficiently developed to enable meaningful assessment of mechanical engineering aspects. However, the 2016 gDSSC gives us some assurance that RWM will apply relevant modern standards and good practice throughout the GDF implementation process [40],

and that a suitable process is in place to identify and address emerging issues as the GDF design develops.

Civil engineering and external hazards

The SFR outlined in Appendix B of the gOSA Volume 3 [36] primarily relate to the handling of waste packages and do not place explicit functions on the engineered civil structures of a GDF, although implicitly they assume that the structures will be operational and maintain their geometry. As the gESC develops and becomes more detailed, RWM needs to more clearly define the safety functions and structural performance applicable to civil engineering structures and related systems, structures and components (SSCs) as per the intent of civil engineering SAP ECE.1 [33].

RWM presents limited information in the 2016 gDSSC on how it intends to characterise external hazards. Although the gDSSC is non-site-specific, it will be valuable at an early stage for RWM to determine what framework, or principles, it has, or will establish, to characterise external hazards. RWM could explore aspects of ONR external and internal hazards SAPs EHA.2 (data sources) and EHA.4 (derivation of design basis) [33] at the current generic stage of the GDF programme, ahead of site selection. Studies for some external hazards, for example: fault rupture; vibratory ground motion; and other geo-hazards, require extensive planning and organisation. Therefore, RWM should develop its understanding relating to how the intent of the external and internal hazards (EHA), civil engineering (ECE) and assurance of validity of data and models (AV) series within the ONR SAPs [33] would be recognised in such studies. This should include the level of verification and validation that will be applied to them.

Recommendation 2016 gDSSC_R17: When applying DBA to the developing design for a GDF, RWM should have particular regard to the classification of SSCs and the requirements that this may place upon the design and operational lifecycle of these SSCs.

In the 2016 gOSC, RWM addresses the main topic areas relating to civil engineering and external hazards with respect to the construction of a GDF, however, much work remains to be done, once a site has been chosen. We consider that RWM could have developed the following topics further at this generic stage of the GDF programme:

- consideration of construction on different levels underground. This is important with respect to assessing risks of a tunnel / underground structure collapsing during construction and the impact on neighbouring structures
- clarity regarding identified construction techniques and anticipated groundwater flows for the 3 generic host rock environments and what operational experience is available to support this
- consideration of the various options available for tunnel linings; RWM mentions the use of shotcrete in the generic Disposal Facility Design document [17], but does not discuss the use of either steel or polypropylene fibres to improve fire resistance
- segregation of construction and waste emplacement ventilation circuits, which should be achieved by segregation underground including the use of isolating structures (for example, blast doors, concrete walls and rock structure)
- consideration of adequate protection for waste emplacement areas from, for example, fire and blasting in the construction areas
- whilst some aspects of the design and orientation of the excavation disturbed zone (EDZ) are discussed [11], discussion of the EDZ size, assumptions and substantiation are not evidently sufficiently developed
- monitoring of a GDF both during construction and the operational phase is discussed in general terms, but further consideration of the monitoring strategy should be apparent in the 2016 gOSC
- the importance of validation and verification, in particular independent peer review, for the GDF programme could be recognised further within the 2016 gOSC by enhancing the visibility of the reviewers / organisations used, the comments and responses that have been raised and how RWM has addressed these

Internal hazards

We agree with RWM that at the current generic stage of the GDF programme, prior to completion of a detailed design, it is not possible to perform a quantitative internal hazards assessment. We are content that the 2016 gOSC recognises the importance of the main internal hazards of fire, toxic and flammable gases, explosion, flooding, collapse and dropped loads. Assessment of fire safety requires further attention in the 2016 gOSC and is discussed in more detail in the following section.

The 2016 gOSC provides good evidence that RWM understands the nuclear safety aspects, however, further evidence could be provided to demonstrate understanding for the underground specific safety aspects. Even at the current generic stage of the GDF programme, the gOSC should make specific reference to legislation and standards relating to underground working. Furthermore, assimilation of operational learning, relating to both nuclear and underground aspects relevant to a GDF, could be enhanced. We are aware, through our engagement with RWM, of its efforts to learn from operational experience, but we consider that RWM could improve its assimilation of operational learning, (relating to both nuclear and underground aspects relevant to a GDF) in the 2016 gOSC.

The 2016 gOSC makes some potentially optimistic assumptions which are not adequately substantiated by appropriate evidence. For example, it assumes there will be no pressurised waste packages accepted into a GDF. We would not expect potential fault sequences to be discounted at the current generic stage of the GDF programme without adequate justification. RWM should ensure all assumptions are adequately underpinned, and provide its assessment of the sensitivity of the safety case to the assumptions; for example, for the assumption that no pressurised waste containers will enter a GDF, RWM should consider the impact of non-conforming / pressurised waste packages within the DSSC.

Recommendation 2016 gDSSC_R18: RWM should ensure assumptions within the OSC are adequately underpinned, and provide assessment of the sensitivity of the OSC to those assumptions.

RWM defines internal hazards as “those hazards to plant and structures that originate within the site boundary and over which the facility operator has control over the initiating event in some form” [41]. This is subtly different to how ONR defines internal hazards in the SAPs [33], which does not refer specifically to control over the initiating event, meaning the operator has control over the fault progression. RWM should adopt the full extent of the ONR definition to ensure the OSC is developed fully in line with ONR’s expectations.

Conventional fire safety

RWM has identified fire and explosion as a significant hazard in the 2016 gOSC, but it has not completed a fault assessment sequence for fire [5]. We accept that at the current generic stage of the GDF programme it is unnecessary for a generic design to contain detailed and specific risk control measures and that a strategic approach adopting high level principles is appropriate.

2016 gOSA volume 1 [34] demonstrates that RWM proposes to follow recognised good practice for mitigating risk to people from fire in an existing structure through the application of the hierarchy of risk control. However, the document makes no reference to engineering for safety by good design at the concept phase; fire safety is normally addressed at concept phase during the design of modern tunnels, particularly where life safety is a priority. We are concerned that RWM’s current approach may result in fire safety being incorporated as an add-on and that the opportunity to reduce risks to ALARP through engineering design of the GDF will be missed.

The theoretical methodology in the 2016 gOSA volume 1 [34] makes no reference to the development of a high level fire protection strategy to inform and prioritise the fire safety measures. Although RWM includes development of a fire hazard management strategy in the FAP in the 2016 gOSA volume 3 [36], it does not reference timescales for anticipated closure of the action.

We are concerned that the lack of a fire protection strategy may place reliance on the use of the hierarchy of control[6] alone to control fire risk in an extensive underground facility, and we consider that this approach is a serious shortfall with respect to regulatory expectations for fire safety. This is being addressed through GDF_RI_015 [14].

RWM should develop a credible fire protection strategy to inform and prioritise fire safety measures, appropriate to the stage of the GDF programme development. The fire protection strategy should incorporate and complement fire protection measures offered by the design, and take into account the remaining fire engineering challenges, and identify alternative measures to mitigate risk and protect people. Extended escape distances, single direction of escape, and smoke control, are just some examples of subject areas which are typical in extensive underground structures and which present significant departures from normal design expectations for fire safety.

An important component underpinning the fire strategy for this type of facility involves an assessment of combustible load. We advise RWM that it needs to evaluate the rate of fire growth, smoke production and hot gas temperature, to inform its choice of fire protective measures. We would not expect exact details and precise location of combustible items, but, at the current generic stage of the GDF programme, RWM should estimate credible worst case fire loading from transport systems, and substantial electrical and hydraulic equipment.

Conventional health and safety

One of RWM's principal safety claims is that "All reasonably practicable steps will have been taken to implement design provisions whose functions are to prevent or minimise the risk of injury due to conventional hazards" [5]. RWM recognises the constraints of the 2016 gOSC, placing its focus on credible and feasible hazard control, underpinning the fundamental claim that a GDF will be safe to operate and construct when a suitable site has been identified.

RWM has identified 12 high level conventional generic fault sequence groups upon which its assessment is based [34]. We consider the selected groups encompass a reasonable topic range upon which a design risk assessment approach can be explored against the fundamental considerations of the 'general principles of prevention' outlined under the Construction (Design and Management) Regulations 2015 (CDM 2015).

In the absence of a site or detailed site conditions and an associated construction methodology, ONR considers that identification of the most potentially harmful conventional fault groups is premature. RWM's Conventional Health and Safety (CHS) study has, however, focussed solely on these 'high hazard' topics and on limited applications. The CHS findings at the current generic stage of the GDF programme should therefore be viewed as a limited, generic sampling approach. In this context, we advise caution by RWM in the wording of overall findings to ensure that CHS compliance is appropriately reconsidered as the detailed design develops.

RWM asserts in the 2016 gOSC Main Report that CDM 2015 covers "the management of health, safety and welfare when carrying out construction projects, including design. These Regulations are not yet applicable to a GDF as the project has neither been notified nor are formal design activities being undertaken" (§2.1 of [5]). We advise RWM that the Health and Safety Executive considers the designer's duties apply as soon as designs which may be used in construction work in the UK are started, including concept design, and requires relevant work to be carried out as part of feasibility studies (see §77 of [42]). We consider the designer requirements of CDM 2015 are relevant to the developed generic design illustrations and the associated CHS assertions presented in the 2016 gOSC. RWM should seek to engage ONR on this topic through the PAAS Programme.

RWM compares CHS practice with other UK and overseas high-hazard industry underground construction projects to take due cognisance of operational intelligence. Recognition of the role

[6] ERICPD: Eliminate, Reduce, Isolate, Control, Personal protective equipment, Discipline.

and value of relevant good practice by reference to wider industry learning, via industry bodies (and other routes) is significant in a CHS context and we welcome RWM's approach.

RWM has sought to address conventional hazards within its wider nuclear safety case approach through its hazard identification and management strategies. RWM's overall approach to CHS, presented in the documentation is very high level, and there is insufficient information to demonstrate a full appreciation of statutory requirements, core compliance standards, and hazard reduction measures. We advise RWM to continue to engage with ONR, through the PAAS Programme, on matters of CHS to ensure it fully understands the regulatory framework.

Nuclear liabilities regulation

RWM intends the GDF to be designed as a 'clean' facility. Therefore, RWM is expecting only minor quantities of external contamination on packages but it recognises that the large number of packages being handled at a GDF may necessitate areas of a GDF to be designated as 'controlled areas' due to the potential for inadvertent contamination arisings [35]. RWM has identified an action within the FAP to determine the radiation and contamination zoning requirements and the controls necessary to minimise exposures and prevent unauthorised contamination transfer. We advise RWM to seek to minimise accumulation, in accordance with the SAPs [33]. In so doing, RWM should consider the inlet operations for all packages and ensure the contamination management strategy is appropriately justified to ensure the risks to operators are ALARP. RWM should consider relevant international practices and developments to inform how these may vary and be managed over the long GDF timeframe.

Recommendation 2016 gDSSC_R19: RWM should consider the inlet operations for all packages and justify the contamination management strategy to ensure the risks to operators are ALARP. RWM should consider relevant international practices and developments to inform how these may vary and be managed over the long GDF timeframe.

RWM discusses solid waste disposals from a GDF, including plastic, paper, clothing, wood and metallic items which will arise from routine monitoring and maintenance activities for inlet activities, which will be disposed of in accordance with best available techniques [34]. However, it is not clear whether RWM has considered operational wastes from the systems in place to support a GDF itself, for example high efficiency particulate air filters within the ventilation system(s), or how it will manage these waste arisings in accordance with the expectations of the relevant SAPs [33]. We advise RWM that it should design facilities and systems to minimise waste arisings and ensure that risks from associated activities (including retrieval, packaging, monitoring and storage) are ALARP.

Recommendation 2016 gDSSC_R20: RWM should ensure that the management of operational waste arising from the supporting functions of a GDF (including solid wastes arising from ventilation and effluent systems) are considered within the design. This should include the control, retrieval and management (storage and disposal) of operational waste arisings, making reference to relevant good practice.

RWM has not adequately addressed in the 2016 gOSC how safety will be maintained and the risks managed from areas that are 'closed' (that is, no longer receiving waste) whilst operations continue elsewhere within the GDF, whether the disposal area is itself backfilled or not. RWM has not clearly justified the proposed backfilling strategies demonstrating that each is the ALARP option for the relevant host rock. RWM states that meaningful consideration of backfilling requires that the means of backfilling be known, which is not anticipated until after site selection and development of more detailed designs. RWM should explore the backfilling strategy and justify its underpinning assumptions more fully during the current generic stage of the GDF programme, which may influence the design and facilitate ALARP solutions. This was subject to a recommendation from our review of the 2010 gDSSC (R16 of [31]).

Recommendation 2016 gDSSC_R21: RWM should develop a detailed understanding of the safety implications of backfilling, disposal area closure and decommissioning operations within a GDF, with the aim to underpin decisions on process sequencing and timing of the activities

ONR expects RWM to monitor the GDF during operations to detect faults that could impact upon operational safety. In the 2016 gOSC, RWM does not identify monitoring requirements other than those associated with routine package acceptance monitoring at the surface receipt facilities. We do not expect RWM to set out its detailed monitoring activities at the current generic stage of the GDF programme, but we do expect RWM to develop its strategy for monitoring, informed by appropriate fault sequences. This in turn will inform the developing design of the GDF. This was subject to a recommendation from our review of the 2010 gDSSC (R42 of [31]).

Recommendation 2016 gDSSC_R22: RWM should develop its monitoring strategy to underpin safe operations, particularly considering the requirements for monitoring of conditions within loaded and partially loaded disposal areas and any monitoring necessary to satisfy safeguards requirements.

Radiological protection

Given the current generic stage of the GDF programme and lack of detailed design, RWM has concentrated effort on assessing the safety implications of the higher radiological consequence tasks in the 2016 gOSC. The focus of the normal operations assessment is on those areas where design provisions, engineered protection or process design and optimisation will be required. It is based on a representation of a GDF as a functional process flow description; a high-level description of activities and the required plant and equipment that could be used to implement the required functions. We consider this is an appropriate method of providing structure to the normal operations safety assessment.

RWM has identified those areas of a GDF (including surface receipt, unloading, underground transfer and emplacement) and the worker groups (including health physicists, task operatives, drivers and banksman) that it considers to be the most significant in terms of doses, enabling calculation of illustrative normal operations doses. We would expect RWM to target, manage, reduce and optimise these doses through the design process.

The dose rates RWM has used in its assessments are unmitigated illustrative values, calculated in the absence of GDF safety measures. These provide a measure of the maximum harm potential. We advise RWM that future dose assessment from normal operations will require the calculation of radiological doses post-mitigation with the inclusion of safety measures claimed in a full safety assessment.

RWM has not calculated operator doses from the inhalation pathway in the 2016 gOSC as it intends to operate a GDF as a 'clean' facility. Air change rates achieved by the ventilation systems will further reduce the potential airborne contamination levels associated with any minor entrained contamination. RWM considers ingestion and injection pathways during fault conditions in the radiological protection assessment. We consider the illustrative operator dose assessments in the 2016 gOSC are appropriate to the current generic stage of the GDF programme.

RWM identifies illustrative safety measures to meet the dose reduction targets in the 2016 gOSA. It does not conclude that those measures are the correct solution as the assessment is not yet supported by development of suitable options, including application of the ‘eliminate, prevent, protect and mitigate’ hierarchy. As such, RWM is correct not to assume that it has met legal requirements in full at the current generic stage of the GDF programme.

RWM considers that, in broad terms, the processes and operations at a GDF will be functionally similar to those currently being undertaken at numerous HAW storage and handling facilities at existing licensed sites, and because safety cases and ALARP arguments for their operation are mature and the engineered systems required to reduce risks are well understood, it will focus its future work on implementing a proven solution within an engineered underground facility. We agree that there is relevant operational experience from the current industry that could be applied to a GDF, however, we advise RWM that it will need to adequately demonstrate ALARP when deploying such systems underground.

The design will need to consider the specific requirements of operating a nuclear facility in the sub-surface environment. This may present certain challenges which are relatively unique but RWM does not expect these will require novel technological solutions. The areas which require further

work to fully underpin the principal claim are largely related to actual design development and the resolution of the FAPs. We consider this approach by RWM is reasonable at the current generic stage of the GDF programme.

RWM acknowledges that the contribution to operator doses from natural radon gas may be significant. RWM has not assessed the implications of radon at the current generic stage of the GDF programme as the emanation rate will depend on the precise nature of the host rock, equilibrium air concentration and the local air change rate provided by the GDF ventilation system. RWM asserts that this can only be assessed at the site-specific stage when there is more design detail available. We accept that the dose contribution from natural radon gas depends on the host rock and the equilibrium airborne concentration, however, RWM should consider undertaking bounding radon dose assessments for the three generic host rocks, and use this to inform the adequacy of future mitigation including installation of suitable underground facility extract ventilation systems designed specifically for a GDF.

Recommendation 2016 gDSSC_R23: RWM should consider including bounding radon dose assessments for a number of host rocks, in any future development of the gDSSC.

Transport of radioactive materials

We consider the 2016 gTSC [4] is adequate in both content and scope for the current generic stage of the GDF programme. However, RWM will need to obtain specific information regarding transport operations, design and oversight as the programme develops. There is little information in the 2016 gTSC on how RWM anticipates that regulatory requirements could be met, but we accept that this may be difficult at the current generic stage of the GDF programme.

There is repetition within the suite of transport documentation, both in the executive summary and body of the documents, such that similar statements appear across a number of documents. This enables the reader to approach each as a stand-alone document and does not detract. However, we advise RWM that, as the level of detail within each document grows in the future, we expect there to be less repetition.

RWM should remain alert to potential changes to regulatory requirements or updated safety standards, such as those being considered by IAEA relating to packages which are intended for both long-term interim storage and subsequent transport to a GDF. RWM needs to fully define and implement the requirements for design, servicing and maintenance of these packages to support package approval safety case submissions.

The Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009 (CDG) are currently under review and the possibility exists that the UK may adopt different requirements, in part, to those under the European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR 2017). Whilst the identity of the consignor, package owner and carrier may be not be defined at the current generic stage of the GDF programme, we consider RWM could address the duties on each arising from CDG 2009, ADR and The Regulation concerning the International Carriage of Dangerous Goods by Rail (RID) within the TSC [4] or the DSS [32].

RWM could improve future updates to the TSC by inclusion of more information on the following:

- maintenance of reusable transport containers
- arrangements for venting of packages during transport
- transport implications with respect to any future need to retrieve waste packages from a GDF

Recommendation 2016 gDSSC_R24: RWM should include, in the TSC, more information on the maintenance of reusable transport containers, arrangements for venting of packages during transport, and transport implications with respect to any future need to retrieve waste packages from a GDF.

Nuclear materials safeguards

Arrangements for safeguarding of nuclear materials are important to a future GDF given the inventory anticipated for disposal. The current IAEA requirements for terminating safeguards [43]

are unlikely to be met for many potential waste streams, therefore RWM will need to adequately integrate safeguards requirements into the developing GDF design to ensure all regulatory expectations are appropriately considered.

ONR has engaged with RWM through the PAAS Programme to ensure that its safeguards arrangements are suitable for the current generic stage of the GDF programme, noting that this engagement is far in advance of application of any formal safeguards requirements. We consider RWM has demonstrated commitment to ensuring that management of safeguards will be included in its systems and arrangements.

We note a lack of discussion of safeguards and associated requirements in the derived inventory reports [19, 20], which is surprising given the main focus of safeguards is the nuclear materials inventory. As RWM continues to update the inventory for disposal, it should include a discussion on safeguards requirements, especially given that the generic design document [17] states that the level of safeguards provisions will depend upon the nuclear material emplaced within a GDF.

The DSS Part A [32] and Part B [38] define high level requirements with regards to safeguards, which are appropriate to the current generic stage of the GDF programme. However, RWM could give further consideration to the influence the retrievability of emplaced waste could have on the safeguards approach, particularly for materials of greater potential significance from a safeguards perspective.

RWM should develop the monitoring requirements to deliver any safeguards requirements in conjunction with the wider GDF monitoring strategy to ensure that safeguards is adequately integrated within the developing GDF design. As such, RWM should develop its monitoring strategy and requirements ahead of detailed site-specific GDF design development.

The generic GDF design document [17] focusses on safeguards requirements derived from IAEA requirements, whereas other documents in the 2016 gDSSC focus on those from Euratom. RWM should be consistent in its regard to safeguards requirements across all its systems and documentation. This is, however, of low significance given the UK's impending exit from the Euratom Treaty. We expect RWM to update its references to safeguards requirements appropriately, following implementation of a new UK safeguards regime.

Nuclear security

Nuclear security was not explicitly included within the scope of our assessment because the primary document associated with security, RWM's Conceptual Security Arrangements (CSA) [44], is not part the 2016 gDSSC documentation. Nevertheless, we consider the CSA is a comprehensive and detailed document which addresses all of the main security issues which we would expect to see at the current generic stage of the GDF programme at a sufficient level of detail to provide a holistic overview of RWM's proposals for generic security arrangements for a GDF.

As the GDF programme develops, we expect RWM to develop detailed security requirements and proposals for measures to mitigate any potential vulnerabilities. We expect future iterations of RWM's security arrangements to adhere to the principles set out in the Security Assessment Principles (SyAPs) [45].

Leadership and management for safety

We consider RWM has demonstrated a satisfactory understanding of the importance and characteristics of a positive safety culture, commensurate with the current generic stage of the GDF programme. However, we expect to continue to engage with RWM and advise RWM that, based on our learning and experience relating to nuclear new build, a significant challenge will be to develop its safety culture in a way which is meaningful throughout each phase of the programme for different groups of workers with different backgrounds, while maintaining consideration of nuclear safety as the overriding priority.

RWM has demonstrated an adequate understanding of the role of the intelligent customer and design authority with respect to the gOSC for a GDF. However, we expect RWM to assure us it will

continue to implement these functions effectively, for all outsourced work, as RWM develops its commercial strategy for a GDF and use of the supply chain grows in scale and complexity.

Although RWM considers it is approximately 15-20 years away from applying for a nuclear site licence, RWM is already operating as a prospective licensee, meaning that it embodies the culture and demonstrates the competences of a company that is fit to hold a nuclear site licence. The evidence to support this includes RWM's early adoption of a number of arrangements characteristic of a nuclear site licensee, such as:

- development and implementation of a nuclear baseline
- development and implementation of a process for management of organisational change
- implementation of an integrated management system

RWM has also established an internal regulator under its Health, Safety, Security, Environment and Quality (HSSEQ) Directorate, which provides an audit and review function independent of executive decision-making. The objective of the internal regulation function is to provide assurance to senior managers that RWM complies with all relevant safety legislation and that important safety related decisions are subject to review and challenge. This is consistent with our expectations [46]. Based on our experience relating to nuclear new build, the future development of RWM's internal regulation function is important and we will want to be assured that RWM has the necessary resources and competence at each stage of the programme lifecycle as part of a robust overall assurance framework.

The 2016 gOSC identifies some of the important steps on RWM's path to becoming a nuclear site licensee. These include:

- development and implementation of arrangements for compliance with the nuclear site licence conditions, recognising that this will be needed well in advance of a licence being granted
- demonstration of the adequacy of RWM's organisational structure and resourcing, including intelligent customer and design authority capability
- further development of RWM's management system as a coherent framework linking legal requirements through to detailed processes and procedures

The 2016 gOSC claims that "lessons learned from relevant incidents and recent major projects have been identified and assessed in order to ensure a continuous learning from experience approach is implemented" (Table 5 of [5]). The evidence supporting this includes a review undertaken by RWM of the lessons learned from a range of applicable projects and incidents which feeds into a GDF design (§4 of [5]), a process that will continue, and RWM's learning from the events at the US DOE Waste Isolation Pilot Plant (WIPP) in 2014 [47].

The main lesson RWM draws from these sources is the fundamental importance of developing and maintaining a strong safety culture, alongside an effective management system. Specific lessons include the need for:

- effective processes for risk management, monitoring and assurance
- a clear understanding of the safe operating envelope of the GDF
- effective communications and worker involvement
- adequate independent oversight and challenge

We are satisfied that RWM understands the importance of learning from experience, and has satisfactorily addressed this in the 2016 gOSC.

RWM's programme phase definitions do not mention its project management arrangements. Based on our experience relating to nuclear new build projects, we consider this is important. We advise RWM that as it gets closer to the start of construction of a GDF, its project delivery arrangements will become more important. We will want to be assured that these adequately address nuclear safety requirements and allow for the exercise of important functions such as intelligent customer, design authority and internal assurance.

Conclusions

We are satisfied that the 2016 gOSC and gTSC further developed and improved upon the 2010 gOSC and gTSC, and have been produced using safety case methods and processes which are better aligned to relevant good practice.

The inventory for disposal is better defined in the 2016 gDSSC, with consideration of variant scenarios which we consider is a more robust approach than that taken in 2010. The 2016 gDSSC draws upon RWM's technical research and knowledge base, taking cognisance of international learning and knowledge relating to geological disposal.

The 2016 gOSC identifies, rationalises and assesses potential hazards for the generic concept designs, identifying potential safety measures, safety functions and required risk reduction factors that may need to be included in any site-specific design.

However, RWM's current approach to fire safety creates the possibility that the opportunity to reduce risks to ALARP through engineering design of the GDF will be missed. The lack of a fire protection strategy is a serious shortfall with respect to regulatory expectations for fire safety.

RWM has made suitable progress against a large proportion of the recommendations raised during our assessment of the 2010 gDSSC. Areas where progress is less advanced are typically related to site-specific matters that RWM is unable to demonstrate significant progress with prior to site selection. There are, however, some recommendations which we advise RWM to continue to engage with ONR through the PAAS Programme to ensure our regulatory expectations are met in any future safety case submission. In addition, we have raised a number of recommendations to RWM resulting from our assessment of the 2016 gOSC and gTSC. They are provided to help RWM develop the gDSSC in the future and make progress towards producing an acceptable site-specific safety case for a GDF. These recommendations are listed in Annex 3.

Annex 2: Environment Agency's assessment of the 2016 generic Environmental Safety Case

Introduction

In our regulatory guidance, the Guidance on Requirements for Authorisation (GRA) [30], we do not specify a need for a generic Environmental Safety Case (gESC). Furthermore, not all parts of the GRA are applicable at this stage, and those parts that are applicable need to be interpreted in a generic context. Therefore, the scope of our assessment of the 2016 gESC is different from that for a site-specific submission. In our assessment we have looked for evidence that RWM understands the requirements of the GRA, and has interpreted them in a way that is appropriate in the generic context and that supports RWM's disposability assessment process, so that, when a site is proposed, RWM is capable of developing an ESC and waste acceptance criteria to meet our regulatory expectations.

We expect the claims and arguments in an ESC to be supported by readily traceable evidence (§7.2 of [2]). We constrained our assessment of the 2016 gESC to relevant documents in the 2016 gDSSC. We did not track all lines of evidence through the supporting documentation, but we did check a few selected lines of reasoning.

Our assessment of the gESC is based around answering 5 questions:

- Are the scope, format and content of the 2016 gDSSC appropriate for an ESC for a GDF at this stage?
- Does the 2016 gDSSC provide an appropriate basis for the assessment of future disposability and endorsements through the disposability assessment process?
- Does the 2016 gDSSC methodology provide a suitable basis to develop a future site-specific safety case?
- Does the 2016 gDSSC confirm or modify our recommendations and conclusions from our assessment of the 2010 gDSSC?
- Do the forward plans in the 2016 gDSSC set out a reasonable course towards developing a full site-specific safety case?

Scope, format and content of the 2016 gESC

Introduction

The GRA describes our expectations for a site-specific ESC. We have advised RWM on its development of the gESC through our PAAS Programme [23].

The 2016 gESC is summarised in a main report [6] and is supported by documents describing the environmental safety assessment and the 'system information', which comprises the system specification and design documents, and the underpinning knowledge base (the status reports). Figure 7 (§3 of [2]) provides a useful illustration of the links between the gESC and its supporting documents.

The 2016 gESC uses safety arguments to demonstrate that disposal could be achieved safely. It does not explicitly aim to demonstrate meeting the principles and requirements of the GRA, however, it does include a table summarising where information supporting each requirement of the GRA may be found in the safety case, referring to the 2010 gESC for more information [6]. This is appropriate for this generic stage of the GDF programme. However, we will expect a site-specific ESC to be a stand-alone suite of documents with respect to demonstrating meeting regulatory requirements.

The 2016 gESC evaluates only post-closure environmental safety (§2.6 of [6]). It refers to the Operational Environmental Safety Assessment (OESA) for consideration of environmental safety during the operational phase (which includes construction, operation, closure and decommissioning of the GDF). At this generic stage of the GDF programme, we are not opposed to operational and post-closure environmental impacts being documented separately, but, in their present format, we consider that they are not consistent. An ESC supporting an application for an environmental permit will need to meet the requirements of the GRA for both operational and post-closure environmental safety. We do not consider that RWM has considered fully all relevant operational impacts (see below).

Accessibility of the 2016 gESC

The 2016 gESC is generally coherent and largely self-contained. RWM provides section numbers, where possible, where reference is made to supporting information. This has led to an improved gESC which has helped our assessment, and we encourage RWM to continue to improve its referencing in this respect for future submissions.

RWM has improved the structure and readability of the 2016 gESC compared with the 2010 gESC. It is shorter and focusses on identification and substantiation of environmental safety functions, RWM's evaluation strategy and evaluation of 'environmental safety states'. We consider RWM's structured narrative approach to presenting the safety arguments in the gESC (§3 to §9 of [6]) is appropriate in a generic context. However, separate summaries for 6 generic disposal concepts (HHGW and LHGW in higher strength rock, lower strength sedimentary rock and evaporites) has led to fragmentation and repetition of safety claims, which is probably unavoidable until there is greater clarity on the host geology.

We understand that RWM's baseline assumes a co-located (LHGW and HHGW) GDF. RWM presents the ESC as if disposal of HHGW and LHGW are sited at separate locations, which we consider is inappropriate and we advise RWM to rectify this. We advise RWM to collate the safety claims and arguments for each geological environment into the same section, in order to achieve a clearer and more efficient presentation.

RWM considers its primary audience for the 2016 gDSSC is regulators and other stakeholders such as members of the Committee on Radioactive Waste Management (CoRWM) that have a scientific and technical background. We note that RWM's list of stakeholder requirements [32] (which is focussed around NDA and Government requirements for RWM to show efficiency, expediency and cost effectiveness), is unlikely to be representative of the interests of potential host communities. RWM needs to consider how it can meet the requirements and interests of potential host communities and other people to instil confidence in geological disposal.

Evidence base

RWM has constructed the 2016 gESC around environmental safety functions. It has also screened the Nuclear Energy Agency (NEA) generic list of features, events and processes (FEPs) [48] to inform the scope of the PCSA. We consider this combination of a 'top down' (safety function) and 'bottom up' (FEP) approach to the development of the ESC is suitable but we cannot judge its implementation at this stage. We suggest RWM could further improve its approach by highlighting FEPs, or combinations of FEPs, that could cause failure of one or more safety functions. This would help identify potential vulnerabilities of the disposal system. RWM generally makes it clear that choices relating to design, barriers and materials are currently undecided and that the 2016 gDSSC presents examples for illustrative purposes only. In a site-specific submission, we will expect RWM to align the FEP analysis with the conceptual model of the geological environment.

We welcome RWM's increased emphasis on the role of environmental safety functions in the 2016 gESC. We consider the environmental safety function approach should help RWM develop and demonstrate a comprehensive environmental safety analysis, provided RWM implements it appropriately within its work programmes.

RWM is continuing to develop its environmental safety functions approach [2]. We advise RWM to clarify how it intends to specify and document design requirements at a concept-specific and site-specific stage. RWM discusses the potential adoption of a requirements management system such

as that developed and used by Posiva Oy (VAHA system) [49]. We advise RWM to progress work to design and implement a requirements management system as a matter of priority.

We expect evidence supporting important safety claims in the ESC to be readily traceable. We have checked the audit trail for selected claims in the 2016 gESC and found examples where the supporting evidence simply reiterates the statement in the higher level document, and statements that are unsupported by evidence or links to evidence. "[We] expect the pre-operational environmental safety case to provide a sound scientific and technical basis…" (paragraph 5.4.18 of [30]). We have advised RWM to develop a system to document the claims, arguments and evidence underpinning its ESC and use it to ensure that important claims in the ESC are supported by evidence which is readily auditable[7] [13].

Important safety arguments are not readily apparent from the gESC [6]. For example, the PCSA [27] states, "most of the radionuclides in the inventory for disposal will decay within the waste containers, so that the activity of any radionuclides released from degraded waste packages will be low.…The total activity of the waste will change little in the period beyond 100,000 years… processes such as sorption, diffusion and dispersion will act to limit the concentrations of any radionuclides that might migrate to the biosphere" (§4.3.1 of [27]). This safety argument is not carried through to the 2016 gESC. We expect RWM to identify the important safety arguments on which the ESC is founded using its system to document the claims, arguments and evidence underpinning its ESC [13].

Disposal system specification

RWM separates its disposal system requirements into high level requirements such as legislation and guidance (Part A [32]) and technical requirements that can be developed as implementation progresses (Part B [38]). We consider this separation useful. However, we note that there is poor linkage between the 2 sets of requirements, even on a thematic level. It is difficult to determine how or whether the high level requirements in Part A will be underpinned in RWM's forward work plan.

RWM should make it clear that, while it documents the main overarching nuclear and environmental legislative requirements, it does not discuss all relevant legislation that a GDF developer/operator will need to comply with.

Currently, RWM's technical requirements reflect assumptions and, at this generic stage of the GDF programme, RWM is not able to define a meaningful or actionable technical specification.

Recommendation 2016 gDSSC_R25: RWM should determine how the safety functions will be met through its disposal system design and specification to support development of its technical specification in the site-specific state.

We are pleased that RWM recognises the importance of optimisation in making design decisions at the generic stage of the GDF programme, coupled with an "iterative design optimisation process followed in a site-specific ESC to ensure that any radiological exposures from a GDF are ALARA" (as low as reasonably achievable) (§2.3 of [6]). RWM recognises the importance of maintaining a range of options to be considered in future site-specific optimisation decisions. This will help make sure that its packaging advice is robust to a range of future outcomes. This is consistent with our advice to RWM [23, 31].

We advise RWM to provide evidence to substantiate the depths chosen for its illustrative disposal concepts for the 3 geologies and to explain why it has chosen different depths for the higher strength rock and evaporite geologies compared with lower strength sedimentary rock. We also advise RWM to explain why the depths differ from those concepts in similar geologies internationally, which RWM used as the basis of its disposal concepts [11].

[7] RWM has informed us that it is developing a 'post-closure safety tool' to document the claims, arguments and evidence underpinning its safety assessment. It may wish to further develop this tool to meet the action in [13].

Management of uncertainties

The 2016 gESC identifies 4 main areas of uncertainty (uncertainty over the future state of the disposal system, data uncertainty, model uncertainty and uncertainty about human behaviour). The gESC addresses this uncertainty through the use of alternative conceptual models and scenarios. We consider this approach to the treatment of uncertainties is appropriate for a gESC and is in accordance with the GRA.

The 2016 gESC does not clearly identify the main uncertainties for the 6 disposal concepts nor assess the significance of these uncertainties. The GRA requires the developer/operator of a GDF to take adequate account of all uncertainties that have a significant effect on the ESC. This should include establishing "a clear forward strategy for managing each significant uncertainty, based on considering, for example, whether the uncertainty can be avoided, mitigated or reduced, and how reliably it can be quantified" (§7.3.10 of [30]). In the 2016 gESC, RWM demonstrates how it intends to manage the uncertainties relevant to the safety assessment [6], but it does not explicitly identify those uncertainties it considers are the most significant.

RWM should link the important uncertainties within the safety case to its management strategy. We advise RWM to ensure that the research being carried out under the S&T Plan [3] is traceable to relevant parts of the gDSSC; we suggest this could be done by a relatively simple modification to the task sheets within the S&T Plan. Identification of the main uncertainties that have a significant effect on the ESC would help RWM prioritise the S&T Plan by focussing efforts on uncertainties that have the greatest impact in the gDSSC.

Recommendation 2016 gDSSC_R26: RWM should progress efforts to identify the uncertainties that have a significant effect on the ESC and establish a forward strategy for their management.

Quality assurance

We consider RWM's quality assurance, with respect to the 2016 gESC documents, could be improved. We have identified a number of typos, potentially contradictory statements, inconsistent use of terms and erroneous referencing. For example, the Overview Report states that the total volume of packaged waste in a GDF will be 650,000 m^3 (§1.2 of [6]) while other documents in the 2016 gDSSC suite state 750,000 m^3. Such simple errors lead us to question RWM's quality control procedures and may undermine confidence in a safety case.

Through our regulatory inspection of RWM's management of data and models underpinning the 2016 gDSSC, we concluded that RWM has improved its procedures for data management and model development significantly and that its current system ensures good traceability of data and controlled use of data and models. We expect RWM to have a systematic programme of work aimed at building confidence in the modelling and we identified a number of areas where RWM should further improve its processes in order to address this [23]. Guidance on the content of a validation package for models used in a safety case can be found in ONR's Technical Assessment Guide (paragraph 5.8 of [50]). We have asked RWM to provide us with a document that sets out how it intends to address the regulatory requirement aimed at building confidence in its modelling [13]. We expect RWM to consider the quality of existing data and models when identifying areas for further research and development (R&D), site investigation and assessment, and to identify important uncertainties and have a plan to address them.

Operational environmental safety assessment

The gOESA [51] provides a semi-quantitative assessment of dose to the public and non-human biota as a result of emission of radioactive gases during most (but not all) of the operational period. It considers potential impacts via other pathways qualitatively or excludes them entirely from the scope of the assessment (either because insufficient information is available or because they are considered elsewhere).

An OESA should include all potential impacts to the environment during the operational phase (including impacts associated with construction, operation, closure, and decommissioning). The 2016 gOESA does not give us confidence that all operational dose limits and environmental discharge limits could be met. We consider there are significant gaps in RWM's assessment

including, for example: quantitative assessment of the impacts of the non-radioactive component of the waste; impact of construction activities such as water abstraction and effluent management; and potential releases from emplaced waste in the period between final sealing and closure. In addition, RWM provides no information on its approach to the treatment of alternative geological environments during the operational phase other than for peak gaseous releases; we would like to understand what it considers the main differences could be.

The 2016 gOESA does not include all the information that we would expect at this stage in a generic OESA. We advise RWM to widen the scope of its quantitative assessments, to ensure a single coherent assessment of environmental safety for the operational phase. We also advise RWM to make the operational environmental assessment consistent with the post-closure assessment, as far as possible. RWM should also develop its internal capability in this area commensurate with that associated with post-closure performance. We have raised a Regulatory Issue to cover these requirements (actions 1-4 of [15]). We have also advised RWM to develop a programme, process and methodology to systematically document the claims, arguments and evidence underpinning its ESC covering both the operational and post-closure periods (action 1 of [15]).

The 2016 gDSSC does not clearly describe the links between the gOESA and the gOSC and gESC. Figures 4, 5, 6 and 7 in the Overview Report [2] need to be consistent with each other and show the links correctly and consistently to avoid confusing messages as to whether the OESA feeds in to the OSC or the ESC (or both) (noting that the text in the introduction of the gOESA, states that the gOESA supports both the gESC and the gOSC).

Post-closure radiological safety assessment

RWM describes its approach to the development of the post-closure radiological safety assessment in the gESC report (§2.4 of [6]). The description of the assessment strategy is not as robust and transparent as we would expect. RWM could also improve the presentation of its safety assessment methodology within its safety case documentation, for example by providing a flow diagram.

RWM does not present conceptual models that summarise the current level of understanding of components of the disposal facility in the 2016 gESC. The PCSA [27] describes the approach to model development that RWM will carry out in a site-specific assessment rather than the approach that has been undertaken within the 2016 gESC and it refers to relevant status reports for more detail [52, 53, 54, 55]. We understand that uncertainties will exist at this generic stage, but we note that a more detailed understanding is already possible for those wastes that are already packaged. RWM does not present conceptual models at a package scale for different waste-container combinations, even though it has information to begin developing an understanding at this level of detail for packaged wastes. Therefore, it is not clear how RWM has implemented safety functions related to wastes, wasteforms and containers in its quantitative assessments.

Recommendation 2016 gDSSC_R27: RWM should explain the linkages between the near-field conceptual models and the package-scale understanding being developed from its ongoing work, to support the packaging and storage of wastes ahead of geological disposal.

RWM recognises the need for differing levels of modelling in order to reflect GDF processes appropriately in relation to post-closure safety. However, we advise RWM to improve the transparency by including a figure showing the model hierarchy and the links between different model types and processes to demonstrate consistency between models and their underlying assumptions. We consider RWM's use of base and variant scenarios for each illustrative geological environment is appropriate. RWM's data management system helps ensure consistency between its models [56].

The PCSA concentrates on impacts via the groundwater pathway post-closure [27]. There is considerably less information relating to impacts associated with the gas pathway, human intrusion and to non-human biota during the post-closure phase. A more comprehensive assessment will be required to meet the requirements of the GRA.

The PCSA concentrates on higher strength and lower strength sedimentary rocks. For a GDF in an evaporite environment, RWM assumes that there will be little or no water to act as a groundwater flow pathway in evaporites or for gas generation. We advise RWM that it would need to justify this assumption in an ESC for a GDF in an evaporite host rock.

The 2016 gDSSC does not include groundwater pathway calculations for HHGW disposal in the higher strength rock base case scenario because RWM anticipates that the expected lifetime of the copper containers used in this illustrative concept will be in excess of 100,000 to 300,000 years. Instead, RWM includes a variant scenario which assumes the early failure of a single copper container after between 50,000 and 500,000 years and states that impacts from multiple failures could be calculated in a proportionate manner.

The mechanism that caused one container to fail could also cause similar containers to fail. We do not consider the scaling factor approach used in the 2016 PCSA represents this uncertainty sufficiently. RWM should present a reasonable range of scenarios for container failure, underpinned by information on likelihood of failure and number and position of containers that could be affected.

RWM should also substantiate the use of a scaling approach, for example, whether the likelihood of failure could be influenced by failure of an adjacent container? We advise RWM to assess the results of multiple container failures that takes into account the likelihood of multiple releases. In this work, RWM should consider the effects of mechanical shear and copper creep as possible failure mechanisms; it regards the latter as “one of the only processes whereby ‘common-cause’ failure of many containers could occur, possibly at much earlier times than container failures due to corrosion” [53].

Recommendation 2016 gDSSC_R28: RWM should assess the results of multiple container failures that takes into account the likelihood of multiple releases and considers an appropriate range of possible failure mechanisms.

For lower strength sedimentary rock, illustrative calculations for the groundwater pathway assess that total risks for the base scenario for all waste types are significantly below the risk guidance level. For higher strength rock, illustrative mean risks for all waste types are assessed to be in excess of the risk guidance level for the well pathway from about 60,000 years in calculations in which diffusion and sorption are not accounted for. This highlights the importance of processes such as rock matrix diffusion and sorption in the geosphere in maintaining risk below the guidance level for the well pathway. In making a future site-specific ESC, RWM should provide evidence that these processes will retard radionuclide migration sufficiently if they are relied on to demonstrate safety in accordance with regulatory limits and guidance levels.

The 2016 gESC presents illustrative calculations of gas generation and migration for the different disposal concepts, but does not present the risk associated with human exposure. Instead, RWM references a research report containing illustrative calculations of carbon-14 generation from LHGW, which showed that in some scenarios the calculated risk from carbon-14 generation is in excess of the risk guidance level [57]. RWM states that it does not intend to carry out assessment modelling for this pathway until the site-specific stage. We acknowledge that developing quantitative models to assess gas transport through the geosphere without site-specific data is challenging, however, we consider that work to develop a quantitative understanding of gas generation within the near-field is possible at a generic stage. Without further assessment, RWM cannot demonstrate full understanding of this pathway and the circumstances under which it could potentially become limiting in the gDSSC. We advise RWM to develop its understanding of risk for the gas pathway at this generic stage of the GDF programme, and to work with waste producers to ensure that its assumptions relating to gas generation from specific packages are appropriate. We also note that information on gas generation in an evaporite environment is sparse. While we agree that there is likely to be little free water in the host rock, we expect RWM to substantiate its assumption that the water content of the waste packages will constrain gas generation. RWM should carry out further work at this stage.

Recommendation 2016 gDSSC_R29: RWM should develop its understanding of risk for the gas pathway at this generic stage of the GDF programme, and work with waste producers

to ensure that its assumptions relating to gas generation from specific packages are appropriate.

RWM has used insight models for the groundwater pathway to help understand the relationship between the wastes and the environmental safety functions provided by the engineered and natural barriers between the wastes and the surface environment. We consider this represents good practice.

Recommendation 2016 gDSSC_R30: RWM should develop its insight modelling to cover all the main exposure pathways in so far as it is possible and reasonable in the current (generic) context.

The 2016 PCSA does not include human intrusion calculations. RWM considers that, at this stage in the process, there is little benefit in presenting even stylised calculations, as they could only be based on illustrative scenarios and would have no relevance to optimisation. Instead RWM discusses strategies that it could employ to prevent or reduce the likelihood of intrusion. We consider that at this stage in the siting process, the development of specific preventative strategies is appropriate.

Recommendation 2016 gDSSC_R31: RWM should start to develop outline human intrusion scenarios and use these as a basis for optimisation of the generic design and preventative strategies.

The 2016 gESC includes an assessment of radiological impacts to non-human biota [27, 55]. This assessment was carried out in 2008 and was also cited in the 2010 Biosphere Status Report [58]. The assessment does not reflect the latest research on non-human biota assessment, including updates to the ERICA model and outputs from international research programmes (§5.4 of [55]). RWM should update this assessment or substantiate why it considers that an update is not required.

Post-closure non-radioactive contaminant assessment

The 2013 inventory for disposal does not quantify hazardous substances or non-hazardous pollutants because the 2013 UKRWI contains insufficient information on them. Thus the 2016 gDSSC does not include a quantitative assessment of the impact of the non-radioactive component of the inventory. Instead, RWM identifies what it considers are important hazardous substances that may be present in the inventory and calculates a maximum allowable inventory that it considers could be safely disposed of in a GDF [27]. We consider this approach is appropriate given the lack of available information, but stress that the 2016 PCSA is strictly a radiological PCSA as non-radiological species are only briefly covered. We have raised a Regulatory Issue asking RWM to work with waste producers to obtain sufficient data to enable it to carry out a quantitative assessment of the impacts of hazardous substances and non-hazardous pollutants and develop appropriate WAC [16]. We consider this is a matter of high priority given the lead time in producing the UKRWI and to minimise the risk that vital information is not obtained before wastes are packaged.

RWM assumes that groundwater immediately outside a GDF is the receptor in terms of meeting the ‘prevent’ requirement of Schedule 22 of the Environmental Permitting Regulations 2016 in its calculations. We consider this interpretation of ‘prevent’ is very conservative. In practice, we would take a more risk-based approach to interpreting ‘prevent’, as set out in the government guidance on groundwater activities [59]. Discernible concentrations of hazardous substances in the groundwater down-gradient of the discharge zone are allowed if a number of conditions are met (including putting in place all necessary and reasonable measures to avoid the entry of hazardous substances to groundwater [59]). These conditions allow us to take a more pragmatic, risk-based, approach when regulating discharges of hazardous substances to groundwater in the context of a GDF.

Presentation of results

RWM presents illustrative probabilistic calculations for the groundwater pathway up to 300,000 years post-closure, which it compares with the risk guidance level. RWM uses alternative

reasoning, together with deterministic 'what if' calculations and comparison with natural analogues, to establish confidence over longer timescales. We consider this approach is in accordance with our expectations for presentation of risk over very long timescales (§7.3.6 of [30]). However, while RWM understands that it cannot rely on numerical model outputs alone to demonstrate post-closure safety, it does not present a clear rationale for choosing to truncate its total system model at 300,000 years post-closure. At 300,000 years post-closure the total radioactivity of separated uranium is increasing, therefore it may be premature to truncate the calculations at this point. For a site-specific safety case, we expect RWM to justify the timescales it uses for its assessments and to demonstrate it has addressed the point of greatest risk appropriately.

RWM also calculates mean activity fluxes through various components of the disposal system. We advise RWM to compare these interim model outputs with other environmental safety indicators to strengthen the ESC (§7.3.7 of [30]).

RWM uses the expectation value of risk (which it also refers to as the 'mean calculated risk') for comparison with the risk guidance level. RWM says that it could use other statistical measures to present the results of probabilistic calculations, and that it will consider appropriate measures when more information about a specific site is available. We advise RWM to use its terminology consistently and to consider how best to assess the outputs from probabilistic models in future assessments, for example looking at uncertainty bands and probability distributions. We suggest the expectation value of risk may not be appropriate for comparison with the risk guidance level in the case of a highly skewed distribution of results, as seen in some of the illustrative calculations.

Underpinning for the disposability assessment process

Appropriateness of the 2016 PCSA as a basis for disposability assessment

Through its process of disposability assessment, RWM assesses waste packager's packaging proposals against its packaging specifications that are derived from its safety cases, such as the gESC. However, environmental safety in the 2016 gESC is presented as a set of high level claims as to how an ESC could be made in a given geological environment. The detailed arguments and site-specific evidence to support these claims will only begin to be substantiated once RWM has identified a site to develop a GDF, characterised it and finalised the GDF design. Until the point at which a site-specific ESC is accepted by the appropriate environment agency, important features of the geological environment which have a strong bearing on RWM's waste packaging specifications remain uncertain. Therefore we consider that the 2016 gESC provides a generic framework for waste packaging advice rather than the quantitative underpinning that would be necessary in the future to derive WAC.

Recommendation 2016 gDSSC_R32: RWM should clarify whether it should place more emphasis on the use of the engineering and scientific principles that underlie the packaging specifications when undertaking disposability assessment, rather than using the gESC in its current state of development.

It is not clear to us how RWM has taken account of the safety functions related to wastes, wasteforms and containers in its 2016 gDSSC assessments because conceptual models at a package scale for different waste-container combinations are not presented [27]. Although the waste package evolution status report [52] discusses the individual components of a waste package and their evolution, it does not provide sufficient linkage to the safety assessment due to the disaggregated nature of the presentation. We recognise that uncertainties will exist at this current generic stage of the GDF programme, but presentation of a more detailed understanding should be possible for wastes that are already packaged.

RWM indicates that it will support its understanding of wasteform and barrier behaviour by "insight models and simple, deterministic calculations" (Figure 5 of [6]). We expect that a site-specific ESC and the WAC resulting from it would be the result of a rigorous and comprehensive demonstration of environmental safety which would require the development of a thorough and detailed analysis of disposal system behaviour and evolution.

As we note earlier, the total radioactivity of separated uranium is increasing at the time the post-closure assessment calculations are truncated. RWM does not present the methodology for, or

examples of, far-future modelling of GDF in the gDSSC. Therefore, it is not clear to us how RWM will configure and use such calculations in a future ESC, whether they will be suitable to address regulatory requirements and whether consequences resulting from them need to be considered when making decisions on waste packaging operations.

Recommendation 2016 gDSSC_R33: RWM should clarify how it intends to use alternative reasoning (such as deterministic 'what if' calculations and comparison with natural analogues) when assessing the implications of impacts in the very long-term on GDF design, and the implications on packaging advice.

RWM only presents the outputs from its radiological assessments according to waste type and important radionuclides. We advise RWM to also analyse and present the results by contribution to GDF performance according to the stage in the waste's lifecycle (for example, packaged under a final stage Letter of Compliance, endorsed under a conceptual or interim stage Letter of Compliance or packaging proposal not yet assessed). This would have several advantages:

- identifying wastes and/or waste management options which may strongly influence the overall impacts from a GDF and opportunities where alternative waste packaging options may improve environmental safety
- helping identify optimal decisions before wastes are packaged (noting that there is more flexibility for deriving an optimised GDF if a waste has not yet been packaged)
- highlighting to RWM any wastes already packaged which may require specific or additional EBS features as part of optimisation or may be sensitive to differing host rock and/or disposal concept.

Recommendation 2016 gDSSC_R34: RWM should analyse and present the results of its assessment according to the stage in the waste's lifecycle (for example, packaged under a final stage Letter of Compliance, endorsed under a conceptual or interim stage Letter of Compliance or a packaging proposal not yet assessed) as well as according to waste type and important radionuclides.

Use of the 2016 gDSSC in underpinning advice to waste producers

RWM has identified 14 'packaging criteria' in its packaging specifications. These are properties of a waste package that indicate the extent to which a safety function is fulfilled. RWM uses them as the basis for defining generic high level packaging requirements (that is, acting as preliminary WAC). As RWM aligns its provision of packaging advice to the 2016 gDSSC using post-closure performance assessments, we will look for evidence that environmental safety functions are prominent in RWM's disposability assessments.

RWM's case for using the 2016 gDSSC to underpin its advice to waste producers is affected by the complexity arising from the variety of waste packages included in the generic packaging specifications and the envelope of proposals it receives from waste producers. For example, RWM currently recognises 11 'standardised containers' for LHGW. We note that different waste packaging options associated with several of these containers (for example, unconditioned wastes in robust containers, pucked wastes entombed in thin-walled containers and vitrified wastes) could result in the need for additional, different conceptual models of waste package evolution and radionuclide release. We have asked RWM to assess the impacts of complexity arising from the receipt, handling and emplacement of populations of different waste packages [60]. However, RWM does not mention in the 2016 gESC whether there are any issues relating to the assessment of post-closure impacts arising from this complexity that require resolution, and it remains to be demonstrated that such a flexible approach to waste packaging can achieve an optimised GDF design.

RWM's base case anticipates that the expected lifetime of its copper containers will be in excess of 100,000 to 300,000 years.

Recommendation 2016 gDSSC_R35: RWM should substantiate its assumption that the design of the disposal container (whether copper or another material), the quality control of its manufacture, and the handling procedures to load, transport and emplace it, are such that no weaknesses or defects would lead to earlier container failure.

RWM will not finalise the design of its disposal containers for HHGW until a site has been selected. Therefore RWM considers it will not be able to endorse HHGW for the foreseeable future. RWM should clarify why its apparent confidence in the performance of the HHGW disposal container designs under consideration cannot translate into performance characteristics in packaging specifications such that it could endorse packaging proposals for HHGW on an equal basis as those for LHGW.

Waste producers regularly put forward proposals for new packaging concepts to RWM to consider. We recognise that safety cases cannot easily adapt to changes in real time, but RWM should clarify in the gDSSC how safety cases will be updated to take into account new waste packaging approaches which may arise as GDF implementation progresses. Furthermore, we note that RWM does not explicitly recognise changes in packaging proposals as an initiating action in its iterative safety case development process (Figure 3 of [6]).

Recommendation 2016 gDSSC_R36: RWM should clarify how it will feed significant changes in waste packaging into generic disposal inventories, designs, assessments and safety cases.

RWM intends to define WAC for a GDF once the design, location and model of operation of a GDF have been accepted. The 2016 gDSSC should explain how RWM proposes to transition from its waste packaging specifications to WAC and should refer to RWM's ongoing work in this area [61].

Support to the development of a future site-specific ESC

Support to the siting process

We have no regulatory role in the decision-making process for selecting potential sites for a GDF. However, we will provide advice and comment on matters within our regulatory remit to inform that decision-making process.

RWM's stated purpose of the 2016 gDSSC includes: providing "a basis for the early assessment of the suitability of potential sites; informing the development of illustrative disposal concepts and designs as part of the iterative development process"; and "a source of information to support future development of site-specific designs and safety cases" (Executive Summary of [2]). It also is intended to "support the siting process by providing information to communities interested in hosting the GDF" (Executive Summary of [2]).

Due to its level of technical detail and, by necessity, repetitive nature, RWM will need to make considerable effort to present information from the 2016 gDSSC in a way that will inform discussions with potential host communities. We advise RWM to explore with other stakeholders what information from the 2016 gDSSC is useful for them and how it would be best presented.

Suitability of the gESC for different geological environments

RWM has taken a more balanced consideration of disposal concepts in different geological environments than in the 2010 gDSSC. This will help the 2016 gDSSC support the siting process for a wider range of potential host rock geologies. However, the latest gDSSC only discusses the evaporite geology qualitatively, and the associated underpinning knowledge base is much less developed than that for other candidate geologies. By analogy with the safety analysis for WIPP, we consider that an ESC for an evaporite geological environment would be significantly different to those for higher strength rock or lower strength sedimentary rock. For example, an ESC for an evaporite host rock would probably be more focussed on future human actions that could impact on a GDF, for example by disturbing the disposal system and establishing flow within the brine or adjacent groundwater systems or creating a means of direct exposure to waste. The 2016 gDSSC does not demonstrate that RWM has fully considered the differences in developing an ESC for an evaporite host rock compared with other potential geological environments.

Recommendation 2016 gDSSC_R37: RWM should enhance its knowledge base on evaporites at this generic stage of the GDF programme if it is to be considered further as a potential host rock.

The geological environment will contribute to long-term safety by isolating the waste, protecting the engineered barriers and limiting the transport of contaminants to the surface environment. The

2016 gDSSC illustrates how safety arguments may be made for each of the illustrative disposal concepts. This could inform the development of a future site-specific safety case. These illustrative disposal concepts do not represent actual geological environments in the UK, but include very specific features that may be encountered. RWM states that it seeks to draw "a balance between representing a 'realistic' setting for a GDF and correlating the setting with rock types for which the data required in numerical modelling are available. Although the illustrative geological environment is not representative of any particular location in the UK, it has hydrological and geochemical features that could in practice be found in the UK" (§10.3 of [27]). We recognise that calculations can be based on broad scenarios with the potential to exist in England and Wales, but, given the specific nature of some features, RWM should emphasise that these are not intended to represent any existing locations or pre-suppose that a GDF will be located at a specific location in future engagement.

Development of the gESC and future site-specific DSSCs

RWM does not say when it intends to update the gDSSC in the future. If RWM intends maintaining a gDSSC we advise it to set out a timetable and/or define triggers for updates. Such triggers may, for example, relate to significant changes to the generic assumptions, such as changes to waste packaging or progress with siting.

When a potential site has been identified, RWM will develop the site-specific ESC in parallel with the generic ESC "until there is sufficient confidence in the site-specific ESC that the generic ESC is judged no longer to be required" (§2.1 of [6]). RWM says it will make this decision as the surface-based investigations near completion [2]. We support the fact that this strategy allows for the possibility of new sites being put forward for consideration and allows RWM to continue to carry out disposability assessments that encompass more than one potential disposal concept. However, we advise RWM to define the basis for making the decision that there is sufficient confidence in the site-specific ESC and to justify selection of its preferred site. RWM also needs to determine and explain how site-specific ESCs will support decision-making if more than one site is put forward.

We query whether there will be a time when RWM considers that it has taken the generic concept as far as it is reasonably necessary to progress. A more detailed timeline than that presented in Figure 1 of the Overview Report [2], even if appropriately caveated, would help clarify RWM's planning for the development of important documents and regulatory submissions.

Table 2 of the ESC Report [6] provides a good summary of the "objectives of ESCs produced throughout the GDF development programme". However, we note that the Initial Site Evaluation and Preliminary Environmental Safety Evaluation are not ESCs, although they are regulatory submissions. We require an initial site-specific ESC for regulatory review when an application is made for a permit to commence a second stage of underground operations in which the focus of activity shifts from investigating the suitability of the potential host geology to a substantially increased phase of underground activities leading to construction of, for example, access tunnels, disposal areas and associated support systems required to implement the planned design of a GDF [30]. We expect RWM to maintain its capability in safety case development throughout all stages of GDF development, operation and closure, for example supported by its work on a GDF Technical Programme.

Recommendation 2016 gDSSC_R38: RWM should clarify the requirements of the other regulatory submissions produced throughout the GDF development programme and the permitting stages.

For a site-specific safety case, we will expect the developer to have in place clear waste package separation and emplacement strategies and associated procedures to control final emplacement of waste packages within a GDF.

RWM informed us that aspects of its current safety assessment methodology will also be applicable to a site-specific case [62], including:

- the requirements of the disposal system specification
- aspects of the PCSA methodology, including: introduction of 'safety states'; and the method for presentation of assessment outputs, including presenting probabilistic risk calculations up to

300,000 years and use of alternative reasoning, including deterministic 'what if' calculations and comparisons with natural analogues to give confidence of continued safety over very distant timescales

- the approach to management of data and models

The 2016 gDSSC does not discuss these enduring aspects, and what outputs of the 2016 gDSSC, such as methodologies, approaches and data, that may be transferrable to a site-specific DSSC. We consider this is a missed opportunity that would have added transparency to the outcomes of the 2016 gDSSC.

Use of the gESC to support future site investigation work

RWM summarises the existing knowledge base relating to its illustrative geological environments, including rock types, structures and groundwater, together with those natural processes which may have impacts on a UK GDF, in the Geosphere Status Report [54]. This information will be useful in supporting the development of a future site-specific safety case. However, RWM provides no information on what characterisation or research would be required to move from the generic to site-specific ESC. It does not identify the knowledge gaps, nor the research to address them, even though there are relevant tasks in the S&T Plan [3], such as ongoing watching briefs on data acquisition methods and interpretation and modelling techniques.

The 2016 gDSSC references the 2010 Site Characterisation Status Report [63] for information on site characterisation techniques and data acquisition. However, we are aware that RWM has developed its understanding in this area considerably since 2010. RWM has, for example:

- defined generic information requirements and parameters that will underpin its design, safety case and environmental assessment [64, 65, 66]
- assessed the techniques available to measure these parameters and the interpretation and modelling approaches that will be used to develop the necessary conceptual understanding
- developed a preliminary generic programme on site characterisation

None of this work is referred to in the 2016 gDSSC. Without this information, the 2016 gDSSC does not demonstrate that RWM fully understands the issues that it needs to consider in order to successfully characterise a potential site for a GDF or that it has identified R&D to address any gaps.

Use of the gESC to support development of a monitoring programme

RWM discusses its requirements for monitoring in the Design Report (§13 of [17]). Monitoring is vital to demonstrate that all components of the disposal system are performing as required, that they will meet their safety function requirements during the post-closure phase and that the operator can comply with the terms of its environmental permit. Separately, RWM has set out a strategy for developing a detailed monitoring programme and its current understanding of monitoring requirements [67]. The strategy is not part of the 2016 gDSSC, therefore we have not assessed it and cannot comment on its adequacy.

RWM intends to develop the monitoring programme in response to stakeholder and regulator engagement once potential sites have been identified. We expect a site-specific ESC to set out clear plans for monitoring, in accordance with Requirement 14 of the GRA [30]. In the meantime, we advise RWM to maintain a watching brief on developments in monitoring techniques and analysis, and to identify gaps and explore opportunities through its ongoing R&D programme. We also advise RWM to capture knowledge from the current operation of stores with regards to inspection and monitoring of package condition and associated technologies, including remote detection, to identify best practise and areas for development.

Whether the 2016 gESC confirms or modifies the conclusions from our assessment of the 2010 gESC

Addressing our feedback

RWM identifies feedback from the regulators, CoRWM and issues from other stakeholders as important drivers of the iterative development process. We would have liked to have seen a high

level discussion of those important matters relevant to the safety case on which third parties (including CoRWM and regulators) have expressed concerns in the past, and what RWM has done to address them.

We made 57 recommendations to RWM when we assessed the 2010 gDSSC [31]. We summarise our opinion on RWM's progress towards addressing these in Annex 3.

RWM competence and skill

During the development of the 2016 gESC, RWM maintained a satisfactory balance between in-house development of the gESC together with collaboration with, and learning from, others, such as the NEA, IAEA, European Commission (EC), other waste management organisations and consultants in the UK and overseas, to maintain and build on its in-house capability. We encourage its learning from national and international sources.

RWM submits its safety case work to external scrutiny and publishes papers at scientific conferences and in peer-reviewed journals. This is good practice and helps to build confidence in RWM's scientific and technical capability and credibility.

We have asked RWM to provide us with a formal workforce capability plan that sets out how it intends to meet and maintain, at a sustainable level, the competences listed in its Competence Register [23].

Evidence of forward thinking

In 2011 (§A3-69 of [31]) we advised RWM to provide more evidence of its forward thinking, particularly with respect to moving from a generic to a site-specific ESC. We consider RWM has made progress in this matter, however, we think RWM could have taken the opportunity to identify explicitly a comprehensive list (in so far as is reasonably achievable in the generic context) of matters that it considers are important to address in order to progress implementation of geological disposal without undue delay, and to link its S&T plan with the gDSSC more closely.

Confidence in RWM's ability to make an acceptable environmental safety case

Our assessment of the 2016 gESC provides pointers to areas for further improvement and identifies some matters that, if not addressed, would prevent RWM making an acceptable ESC. Notwithstanding this, it is clear that RWM is committed to engaging with us via our ongoing PAAS Programme and taking our advice into account as it progresses its work, such that it can understand fully, and be capable of addressing, our requirements of an acceptable ESC in support of any future application for an environmental permit. We note that, under the staged approach to regulation within the Environmental Permitting Regulations 2016, the first environmental permits that the developer of a GDF would require are for site characterisation. These permit applications do not require an ESC which is of the same scope as one that would be required for disposal operations, but they do provide further opportunities for RWM to progressively develop its approach to demonstrating environmental safety for a specific site.

RWM's forward work plan

Development of information underpinning a site-specific safety case

RWM states that "the output of each safety case supports the identification of research requirements to develop the knowledge base for subsequent safety cases" (§2.2 of [6]). This is in accordance with RWM's S&T Plan, which lists the DSSC as being one of 7 high-level drivers for RWM's research plan [3]. The 2016 gESC does not systematically and explicitly identify the further work that is required. RWM should clarify how it intends to feed understanding from the gESC back into developing its forward programme, and how supporting the DSSC ranks among the other high level drivers for R&D.

It is not clear from the 2016 gESC how RWM will manage its R&D going forward from the generic stage to the site-specific stage of the GDF programme. RWM should clarify how it will manage the links between generic and site-specific research, for example whether it will manage separate

generic and site-specific S&T Plans and status reports in parallel until such a time when a site is selected and the gDSSC is 'frozen'.

Forward research programme

Throughout the 2016 gESC, RWM mentions areas where further work or data are required, but, generally, RWM tends to only provide examples of data needed or lists relating to specific topic areas. Only the groundwater impact section of the ESC Main Report makes explicit reference to forward research tasks (§10.8.1 of [6]). If RWM had done this consistently throughout the ESC Main Report where future or ongoing R&D is implied, or where the need for ongoing/further research is alluded to, we would be more confident that RWM's S&T Plan focuses on all areas that it currently identifies as important to demonstrating environmental safety. A high level summary of future work priorities is included in the 2016 gESC (research on the effects of voidage, gas generation, non-radioactive contaminants, migration of radionuclides through low permeability fractured rock and natural processes), however, we do not consider this is a comprehensive list.

RWM is carrying out many research projects in collaboration with other organisations, either nationally or internationally, for example via the Natural Environment Research Council, NEA, IAEA, EC and BIOPROTA. Given the generic status of RWM's research programme, we consider that this collaborative approach is appropriate and will allow a good balance between value for money and targeted research on areas of specific interest. We note particularly good examples where RWM collaborates nationally and internationally to investigate areas of common interest, such as, the effects of climate change, fate and transport of important radionuclides in the environment, carbon-14 behaviour, and assessment of impacts to non-human biota. If RWM intends to continue to participate in EC projects it will need to consider and plan for how it will participate post-Brexit.

RWM needs to develop a better understanding of how wastes and barriers will evolve and interact within the disposal areas and between disposal areas, taking into account the requirements of specific waste packages.

We comment earlier on the less developed knowledge base on the evaporite disposal concepts compared with those associated with the other potential host rocks. We advise RWM to expand its knowledge on developing and operating a GDF in an evaporite geology commensurate with that of a GDF in higher strength rock and lower strength sedimentary rock or justify why, at this (generic) stage, it considers that it has done enough.

Conclusions

We consider the 2016 gESC to be improved over the 2010 gESC, noting it is not a safety case in the conventional sense; instead it presents information on how RWM intends to make a safety case once a suitable site has been found. It is not intended to support an application for an environmental permit, and it would not be an acceptable safety case in this situation. We will expect any site-specific ESC to be a stand-alone document with respect to demonstrating meeting/addressing regulatory requirements, and with the main lines of evidence readily auditable.

The 2016 gESC 'summary and key messages' focusses on evidence to show that geological disposal of HAW can be accomplished in a way that ensures environmental safety at the time of disposal and in the long-term [§11 of [6]). It does not discuss important assumptions or uncertainties that RWM considers are poorly supported or require further work. We expect an ESC for a GDF to present a balanced unbiased view of the safety of geological disposal. RWM should be open with respect to identifying where there is the potential for things to not go as planned, or to not perform as expected. Furthermore, we would expect it to have in place procedures to help it respond in the case of unplanned and unforeseen features, events, and processes.

RWM's safety assessment approach represents an improvement since the 2010 gDSSC. However, both the OESA and PCSA contain shortfalls that we will expect to see addressed for a site-specific submission. RWM needs to develop its capability in OESA to make sure that all potential environmental impacts are considered and that it is consistent with the PCSA, where appropriate. RWM also needs to develop further its approach to its assessment of the gas

pathway, human intrusion and impacts from non-radioactive hazardous substances and non-hazardous pollutants.

We are pleased to note that RWM has addressed our recommendation “to consider more uniformly the range of geological settings in developing its assessment approach, until such time as the geological setting is defined” [§A3-26 of [31]). However, RWM needs to be careful how it presents its arguments with regard to developing a GDF in the 3 geologies in the gDSSC. A significant gap in the 2016 gDSSC is the lack of a discussion on how a safety case for an evaporite host rock may be developed, and this is likely to have significant differences in the emphasis of safety analysis and claims compared with higher strength rock and lower strength sedimentary rock. At this generic stage of the GDF programme, RWM needs to make sure that it provides a balanced argument for each of the cases, focussing on making the safety case for all the geologies while clearly indicating the advantages and disadvantages of each.

The 2016 gDSSC does not fully support assessment of the disposability of HHGW packages. RWM says that it will not be able to endorse packaging proposals for HHGW with a Letter of Compliance for the foreseeable future despite the high level of performance claimed for HHGW disposal container designs in the gESC.

Through its development of safety arguments, RWM has collated its claims and arguments to support the demonstration of environmental safety of a GDF. However, it has yet to formally collate the supporting evidence. We support the development of a requirements management system and post-closure safety tool to support the safety arguments upon which future safety cases are constructed and thus demonstrate why it believes that geological disposal can be achieved safely.

We consider that the presentation of the 2016 gESC would be improved by including a clear description of how far RWM has come and how far it has yet to go with respect to demonstrating confidence in the safety of geological disposal (at least in a generic sense). We advise RWM to consider how best it could present what it needs to do to improve the gESC and areas for further work.

We have raised a number of recommendations to RWM resulting from our assessment of the 2016 gESC. They are provided to help RWM develop the gDSSC in the future and make progress towards producing an acceptable site-specific safety case for a GDF. These recommendations are listed in Annex 4.

Throughout the development of the gESC, we have maintained an open, transparent and constructive dialogue with RWM. We advise RWM to continue this dialogue via our PAAS Programme in order to further develop its understanding of our regulatory expectations as the GDF development programme develops.

Annex 3: Recommendations from our assessment of the 2016 generic Disposal System Safety Case

We have made the following recommendations to RWM from our assessment of the 2016 gDSSC to help RWM develop the gDSSC in the future and make progress towards producing an acceptable site-specific safety case. They are not in any order of priority.

General recommendations

2016 gDSSC_R1	RWM should improve the clarity of the DSSC to demonstrate what learning has been considered, including operational experience from relevant sites, make suitable reference to where detailed assessment has been carried out and highlight clearly its achievements, in particular relating to aspects of the 2016 gDSSC that may be transferrable to a site-specific DSSC.
2016 gDSSC_R2	RWM should develop and include a single, comprehensive glossary in future safety cases, which should be updated, as necessary, as implementation progresses.
2016 gDSSC_R3	RWM should clarify its approach to retrievability, and identify the research that would be needed to underpin it.
2016 gDSSC_R4	RWM should ensure that the implications from, and requirements required to facilitate, potential retrievability are encompassed within the OSC so that the safety of such activities can be adequately demonstrated. Implications for security and safeguards should also be considered.
2016 gDSSC_R5	RWM should continue to revise and update its inventory for disposal and assess a range of inventory scenarios as it moves forward from the gDSSC to a site-specific DSSC, taking into account new developments (such as, diversion of wastes to other management or disposal options in the future) that could alter RWM's underpinning assumptions regarding volume and activity of waste streams destined for geological disposal.
2016 gDSSC_R6	The safety functional requirements (SFR) for the emplacement and vault closure operations should have due regard for the radiological, chemical and physical characteristics of the waste. Therefore, RWM should present a clear understanding of the bounding concern for operational safety within the GDF, taking due account of civil and defence derived waste.
2016 gDSSC_R7	RWM should establish a comprehensive inventory of materials associated with GDF construction, operation and closure relevant to the environmental safety assessments, and consider the effects of these materials in future safety cases.
2016 gDSSC_R8	RWM should improve the clarity of its claims, arguments and evidence for post-closure criticality safety in an ESC.
2016 gDSSC_R9	RWM should develop and implement a strategy for obtaining and managing (for the long-term) the full range of data and records necessary to underpin continued safe operations and demonstrate compliance with any future nuclear site licence and environmental permits.
2016 gDSSC_R10	RWM should strengthen the DSSC to give greater confidence that matters which could adversely impact safety or environmental performance during all

	phases of a GDF lifecycle are identified and resolved satisfactorily in an integrated and optimised manner.
2016 gDSSC_R11	The DSSC should clarify how waste acceptance criteria will be derived from the safety case.
2016 gDSSC_R12	RWM should consider the arrangements to be put in place to minimise the risk of receipt of waste packages that do not meet GDF waste acceptance criteria.
2016 gDSSC_R13	RWM should develop its understanding of the performance of HHGW to enable it to endorse proposals for HHGW on a similar basis to those for LHGW.
2016 gDSSC_R14	RWM should identify areas of uncertainty in the DSSC, as it develops, for which further research or site-specific information is required to address, and provide links to ongoing research.

Recommendations from assessment of the 2016 gOSC and gTSC

2016 gDSSC_R15	RWM should demonstrate that the source term utilised to derive the radiological consequences used for DBA is suitably conservative (and unmitigated) as the safety assessment is developed. If some source terms are excluded, appropriate limits, conditions and exclusions should be considered.
2016 gDSSC_R16	RWM should specify limits or conditions within the developed OSC where waste container throughputs are used as part of the fault frequency assessments.
2016 gDSSC_R17	When applying DBA to the developing design for a GDF, RWM should have particular regard to the classification of SSCs and the requirements that this may place upon the design and operational lifecycle of these SSCs.
2016 gDSSC_R18	RWM should ensure assumptions within the OSC are adequately underpinned, and provide assessment of the sensitivity of the OSC to those assumptions.
2016 gDSSC_R19	RWM should consider the inlet operations for all packages and justify the contamination management strategy to ensure the risks to operators are ALARP. RWM should consider relevant international practices and developments to inform how these may vary and be managed over the long GDF timeframe.
2016 gDSSC_R20	RWM should ensure that the management of operational waste arising from the supporting functions of a GDF (including solid wastes arising from ventilation and effluent systems) are considered within the design. This should include the control, retrieval and management (storage and disposal) of operational waste arisings, making reference to relevant good practice.
2016 gDSSC_R21	RWM should develop a detailed understanding of the safety implications of backfilling, disposal area closure and decommissioning operations within a GDF, with the aim to underpin decisions on process sequencing and timing of the activities.
2016 gDSSC_R22	RWM should develop its monitoring strategy to underpin safe operations, particularly considering the requirements for monitoring of conditions within loaded and partially loaded disposal areas and any monitoring necessary to satisfy safeguards requirements.
2016 gDSSC_R23	RWM should consider including bounding radon dose assessments for a number of host rocks, in any future development of the gDSSC.

2016 gDSSC_R24 RWM should include, in the TSC, more information on the maintenance of reusable transport containers, arrangements for venting of packages during transport, and transport implications with respect to any future need to retrieve waste packages from a GDF.

Recommendations from assessment of the 2016 gESC

2016 gDSSC_R25 RWM should determine how the safety functions will be met through its disposal system design and specification to support development of its technical specification in the site-specific state.

2016 gDSSC_R26 RWM should progress efforts to identify the uncertainties that have a significant effect on the ESC and establish a forward strategy for their management.

2016 gDSSC_R27 RWM should explain the linkages between the near-field conceptual models and the package-scale understanding being developed from its ongoing work, to support the packaging and storage of wastes ahead of geological disposal.

2016 gDSSC_R28 RWM should assess the results of multiple container failures that takes into account the likelihood of multiple releases and considers an appropriate range of possible failure mechanisms.

2016 gDSSC_R29 RWM should develop its understanding of risk for the gas pathway at this generic stage of the GDF programme, and work with waste producers to ensure that its assumptions relating to gas generation from specific packages are appropriate.

2016 gDSSC_R30 RWM should develop its insight modelling to cover all the main exposure pathways in so far as it is possible and reasonable in the current (generic) context.

2016 gDSSC_R31 RWM should start to develop outline human intrusion scenarios and use these as a basis for optimisation of the generic design and preventative strategies.

2016 gDSSC_R32 RWM should clarify whether it should place more emphasis on the use of the engineering and scientific principles that underlie the packaging specifications when undertaking disposability assessment, rather than using the gESC in its current state of development.

2016 gDSSC_R33 RWM should clarify how it intends to use alternative reasoning (such as deterministic ‘what if’ calculations and comparison with natural analogues) when assessing the implications of impacts in the very long-term on GDF design, and the implications on packaging advice.

2016 gDSSC_R34 RWM should analyse and present the results of its assessment according to the stage in the waste’s lifecycle (for example, packaged under a final stage Letter of Compliance, endorsed under a conceptual or interim stage Letter of Compliance or a packaging proposal not yet assessed) as well as according to waste type and important radionuclides.

2016 gDSSC_R35 RWM should substantiate its assumption that the design of the disposal container (whether copper or another material), the quality control of its manufacture, and the handling procedures to load, transport and emplace it, are such that no weaknesses or defects would lead to earlier container failure.

2016 gDSSC_R36 RWM should clarify how it will feed significant changes in waste packaging into generic disposal inventories, designs, assessments and safety cases.

2016 gDSSC_R37	RWM should enhance its knowledge base on evaporites at this generic stage of the GDF programme if it is to be considered further as a potential host rock.
2016 gDSSC_R38	RWM should clarify the requirements of the other regulatory submissions produced throughout the GDF development programme and the permitting stages.

Annex 4: Progress against recommendations from our assessment of the 2010 generic Disposal System Safety Case

We made 57 recommendations to RWM from our assessment of the 2010 gDSSC [31] and RWM has worked to address them.

	Total
Suitable progress made	23
Suitable progress made but further engagement is	15
Further engagement is needed to fully address	19

Number		Regulators' assessment of progress against the recommendations made from our
R1	[RWM] should explain the future role of the gDSSC and develop a clear route	The 2016 gDSSC explains how RWM intends to develop the DSSC, maintaining separate and
R2	There is much repetition and overlap between documents in the gDSSC. [RWM] should aim to strike a better balance that will address the needs of different audiences, and help to produce a stable and enduring suite of safety case documents.	RWM has significantly reduced the degree of repetition between the documents comprising the

Number	Recommendation	Regulators' assessment of progress against the recommendations made from our assessment of the 2010 gDSSC
		changes to improve the presentation of its safety case, as implementation progresses. We will maintain oversight of this as the safety case develops through the PAAS Programme. ONR and the Environment Agency consider RWM has made suitable progress against this recommendation.
R3	[RWM] should continue to work towards making the gDSSC reasonably accessible to a wide audience.	The 2016 gDSSC is aimed at the regulatory audience. Whilst this is understandable given the current generic stage of the GDF programme, RWM should ensure that the safety case is intended to demonstrate safety to all stakeholders, technical and non-technical. The 2016 gDSSC goes some way to facilitate this by separating the Technical Background [11] from the Overview document [2], and pictorial representations of the gDSSC structure and development, but more should be done by RWM to ensure the safety case is accessible to all stakeholders. However, RWM has taken sufficient steps to improve the presentation of the gDSSC and we are confident RWM will continue to improve in this regard. We will maintain oversight of progress as the safety case develops through the PAAS Programme. ONR and the Environment Agency consider RWM has made suitable progress against this recommendation.
R4	[RWM] should clarify how it will apply change control to the suite of documents and the statements it contains.	The Safety Case Production and Management Report [29] outlines RWM's configuration and change management as applied to the gDSSC and references its specific change management procedure. We have not assessed this procedure as it does not form part of the 2016 gDSSC, but consider this adequate for the current generic stage of the GDF programme. We will maintain oversight of RWM's change control procedures as the safety case develops through the PAAS Programme. ONR and the Environment Agency consider RWM has made suitable progress against this recommendation.
R5	[RWM] should include a wider exploration of waste inventory uncertainty in future revisions of the gDSSC.	The 2016 gDSSC [20] considers 12 alternative inventory scenarios which present a more comprehensive consideration of the uncertainties and assumptions associated with the inventory for disposal than the approach utilised in the 2010 gDSSC. ONR and the Environment Agency consider RWM has made suitable progress against this recommendation.

Transport Safety Case		
R6	[RWM] should clearly define strategic principles and ambitions in the transport strategy, aimed at minimising the number of shipments and the duration of delivery schedules whilst complying with the regulatory requirements that assure safety.	ONR is content that RWM is making adequate progress against this recommendation but considers that there is scope for further improvement. ONR will continue to engage with RWM on this matter through the PAAS Programme.
R7	[RWM] should demonstrate a strategic approach to goal and ambition setting and explain how it will manage the key components of the waste generation and transport aspects over a timescale of decades, recognising the intergenerational issues to be overcome.	ONR is content that RWM is making adequate progress against this recommendation but considers that there is scope for further improvement. ONR will continue to engage with RWM on this matter through the PAAS Programme.
R8	[RWM] should include a diagram in the generic Transport Safety Case (gTSC) Tier 1 document to act as a road map/index for the report structure, enabling the reader to visualise the scope of issues and topics that [RWM] considers necessary to control at a strategic level in a GDF project.	Figure 5 of the gDSSC Overview Report [2] gives an adequate explanatory overview of the transport document hierarchy. ONR considers RWM has made suitable progress against this recommendation.
R9	Since transport radiological safety is provided by compliance with the transport regulations, [RWM] should focus the gTSC on logistics and infrastructure and address strategic issues such as: number of shipments; delivery schedules, modes and infrastructure needs; conventional safety; nuisance; environmental impacts (non-nuclear) of transport; and	ONR considers there is insufficient evidence within the 2016 gDSSC to support adequate judgement of progress. ONR will continue to engage with RWM on this matter through the PAAS Programme.

	dose uptake on nuclear sites and at the GDF.	
R10	[RWM] should present contingency plans to ensure that stored waste can be retrieved and transported beyond the scheduled date for delivery to a GDF. [RWM] should also present plans setting out the actions and programmes required to enable the waste to be retrieved and transported earlier.	ONR considers there is insufficient evidence within the 2016 gDSSC to support adequate judgement of progress. ONR will continue to engage with RWM on this matter through the PAAS Programme.
R11	[RWM] should present plans to manage knowledge and records so as to ensure that package inspection and despatch testing are carried out in compliance with appropriate transport regulations.	ONR considers there is insufficient evidence within the 2016 gDSSC to support adequate judgement of progress. ONR will continue to engage with RWM on this matter through the PAAS Programme.
Operational Safety Case		
R12	Provide a simple waste route diagram that shows the various routes for the different waste streams within a GDF.	RWM has produced a number of standalone disposal route diagrams describing the inlet processes, dependent upon the host rock and waste group (HHGW or LHGW). The flow diagrams are considered appropriately detailed for the current generic stage of the GDF programme. ONR considers RWM has made suitable progress against this recommendation.
R13	Provide a summary document that pulls together various components from the suite of gDSSC documents and presents a coherent safety case to a technical audience.	The gOSC Main Report [5] summarises the findings of the generic safety assessments and coherently presents the safety claims and arguments and supporting evidence, derived in each of the generic safety assessments. The evidence summarised in the main report is not clearly referenced which hinders the reader's ability to follow the golden thread from a claim to the detailed evidence supporting a safety justification. However, RWM has taken sufficient steps to improve the presentation of the gDSSC and ONR is confident RWM will continue to improve in this regard. We will maintain oversight of progress as the safety case develops through the PAAS Programme. ONR considers RWM has made suitable progress against this recommendation.
R14	Provide a Safety Case Manual and a quality assured documentation procedure for the development and	The Safety Case Production and Management Report [29] describes RWM's arrangements for the production and management of the gDSSC, and also summarises the 3 safety case manuals developed for nuclear operations, transport and environment. The manuals themselves have not

	management of a safety case for a GDF.	been explicitly assessed as they were defined by RWM as outside of the scope of the gDSSC, although we have previously provided comment on the Environmental Safety Manual [68]. However, separate to the assessment of the gDSSC, RWM made adequate progress against GDF_RI_003 on control and assurance [69], culminating in regulators considering RWM's quality assurance procedures sufficiently developed and part of normal business to close the RI in March 2017. ONR considers RWM has made suitable progress against this recommendation.
R15	Ensure that [RWM]'s "management of change process" is progressively adapted to be fit for purpose for future stages of the programme so that all the different components of [RWM]'s work progress in parallel.	RWM has already adopted of a number of arrangements characteristic of a nuclear site licensee, including development and implementation of a process for management of organisational change. RWM's forward plans for development of its organisational arrangements identify development of an effective nuclear baseline and management of change arrangements, and ONR will continue to engage with RWM on these matters through the PAAS Programme. ONR considers RWM has made suitable progress against this recommendation.
R16	Develop a more detailed understanding of the safety implications of operations such as backfilling, closure and decommissioning of a GDF, to substantiate the claim that they only make a small contribution to the risk from operations of a GDF.	RWM states that meaningful consideration of backfilling and decommissioning requires the decommissioning strategy to be available and the means of backfilling to be specified. RWM continues that the decommissioning strategy is site-specific and considers that actions to address this recommendation cannot be completed ahead of site selection. ONR considers that RWM should develop the backfilling strategy as part of design development as decisions on backfilling and decommissioning will need to be appropriately integrated to GDF design decisions. To facilitate this, RWM should set out how it will justify such decisions during the current generic stage of the GDF programme. ONR will continue to engage with RWM on these matters through the PAAS Programme.
R17	Take into account the most up to date inventory considerations in the future development of the gDSSC.	RWM has reviewed the inventory since the 2010 gDSSC for the 2016 gDSSC. RWM is committed to regularly updating the inventory for disposal to ensure the safety case remains relevant and valid. ONR considers RWM has made suitable progress against this recommendation.
R18	Consider the impact of construction methods with regard to vibration.	Aspects are highlighted within the 2016 gDSSC documentation, however, a detailed description of the specific site layout, design, operational activities and associated tasks is not available and therefore a detailed consideration of these aspects is not yet possible. Naturally, further detail will be required on this and many other topics but this is dependent on a site being chosen and the commencement of site-specific studies. ONR considers RWM has made suitable progress against this recommendation.

R19	Consider the impact of construction methods on sequencing and emplacement of waste packages.	Aspects are highlighted within the 2016 gDSSC documentation, however, a detailed description of the specific site layout, design, operational activities and associated tasks is not available and therefore a detailed consideration of these aspects is not yet possible. Naturally, further detail will be required on this and many other topics but this is dependent on a site being chosen and the commencement of site-specific studies. ONR considers RWM has made suitable progress against this recommendation.
R20	Consider the requirement for design reviews and regulatory expectations with regard to change management to ensure that the validity of the design is maintained as it develops.	The Safety Case Production and Management Report [29] discusses configuration and change control, referencing out to RWM's change management procedure, which is out of scope and has not been assessed. The report also refers to ONR's guidance on safety cases (SAPs, Technical Assessment Guides and Technical Inspection Guides), which reflect IAEA requirements. The report provides some evidence that RWM has considered regulatory expectations regarding production and management of safety cases but does not explicitly state its arrangements for review of the safety case and management of change following any such review. RWM's response refers to development of its Requirements Management System (RMS) to track and manage evolution of the safety case and ensure this is appropriately linked to the system specification. RWM is continuing to develop its RMS and ONR will engage with RWM on this when appropriate. ONR considers RWM has made suitable progress against this recommendation, and will continue to engage with RWM on this matter through the PAAS Programme.
R21	Consider regulatory expectations, as described in the [ONR] Safety Assessment Principles (SAPs), with respect to examination, inspection, maintenance and testing (EIMT), asset management, longevity and ageing/degradation.	The gOSA Volume 3 [36] does not specifically address the effects of ageing and degradation. It does, however, set a requirement that the safety performance needed should be delivered through life to maintain safety. Furthermore, RWM stated that equipment would be replaced based on an inspection, maintenance and testing schedule to be developed when the design becomes more detailed. At the current generic stage of the GDF programme, RWM has undertaken a study to demonstrate the feasibility of operating a GDF and associated design elements for 160 years or more. The report examines the potential impacts on GDF operations and safety issues related to the extended operational period. RWM commented that following on from this study, there is a package of work planned in 2018 to identify areas within a GDF where access for maintenance would be required. ONR considers RWM has made suitable progress against this recommendation.
R22	Consider unprotected radiological fault consequences within the design basis.	RWM has reported in the gOSA Volume 3 [36] that unmitigated consequences have been conservatively derived, taking no credit for a reduction in the release fraction as a result of waste

		immobilisation (for example, grouting), or for any decontamination factor provided by the waste package. The concept of 'partially protected faults' has been removed[8]. RWM recognises that for high level waste and spent fuel, the package is likely to have a "high safety class (probably class 1)" and will require robust substantiation. The Fault Studies inspector considered the consequence model separately within the main body of their assessment and a new recommendation (R15) has been made relating to source term / inventory as opposed to the consequence modelling. ONR is content that RWM is now considering unprotected radiological consequence within design basis assessments, in a manner appropriate to the current generic stage of the GDF programme ONR considers RWM has made suitable progress against this recommendation.
R23	Consider the lessons learnt from the Fukushima disaster with respect to the assessment of external hazards for UK nuclear facilities and if necessary, modify the standards used to assess external hazards from those currently quoted in the SAPs.	The framework for characterising the specific external hazards is not apparent within the 2016 gDSSC. ONR considers that RWM could provide information regarding how such studies will be setup and the level of verification and validation that will be applied to them. Particular attention could be given to the more onerous external hazards, that is: fault rupture / creep, vibratory ground motion and other, mining related geo-hazards. ONR will continue to engage with RWM on these matters through the PAAS Programme.
R24	Consider further the need for engineered systems to prevent inadvertent exposure of a maintenance worker to a bare unshielded ILW[9] package in a standard waste transfer container which was believed to be empty and returned the surface.	RWM states that the current GDF design is illustrative and only includes safety systems typically found in similar types of facility. At the current generic stage of the GDF programme, no attempt has been made to optimise the design or its safety systems. ONR will continue to engage with RWM on these matters through the PAAS Programme.
R25	Consider fire suppression systems in the ILW underground vaults which would be able to extinguish safely and	RWM has excluded fire safety assessment at the current generic stage of the GDF programme. The FAP within the gOSA volume 3 [36] identifies the need to develop a fire hazard management strategy and a preliminary fire safety assessment.

[8] The fault studies assessment excluded consideration of the long term integrity of the package and a GDF, which are considered within the gESC and are hence outside the scope of the Fault Studies assessment.
[9] Intermediate Level Waste

	rapidly any fire hazards envisaged in the design of a GDF.	ONR considers that the current approach to fire safety is a serious shortfall with respect to regulatory expectations and we have raised an RI to cover this matter [14]. ONR will continue to engage with RWM on these matters through the PAAS Programme.
R26	Provide more detail to justify the long-term chemical stability of cement encapsulated Magnox and uranium in ILW containers, for the long operational period of a GDF prior to its backfilling and closure.	RWM has stated that this is an ongoing area of work that is recorded within the Waste Package Evolution Status Report [52], which is recognised by ONR as a detailed report that includes cementitious waste forms and their temporal evolution. RWM have made provision to capture this in a FAP set out within the gOSA Volume 3, which requires the undertaking of studies to evaluate “in-package processes with the potential to challenge package integrity”. On this basis ONR is confident that this area will be given due consideration as the RWM design progresses. ONR will continue to engage with RWM on these matters through the PAAS Programme.
R27	Consider how the potential fault of a HLW or spent fuel disposal canister being stuck in a steel disposal canister transport container, as a result of a fire, would be managed.	ONR notes RWM specifies that the transport containers will be made of high integrity materials that provide containment and shielding under transport accident conditions (severe impact and fire), in accordance with IAEA Transport Regulations for Type B packages. The Disposal Container Transport Container (DCTC) will be used for HHGW. At the current generic stage of the GDF programme, no decision has been made regarding the final packaging concept for HHGW. There are two high level options that have been considered; copper for use in a higher strength rock environment and carbon steel for use in other rock environments, but other options may be possible. It is indicated that based upon the regulatory transport conditions for the transport container (30 minutes at 800°C, with a 2kW heat load within the container), “the inner container is unlikely to be significantly higher than its steady state temperature”. RWM have made provision to capture this in a FAP set out within the gOSA Volume 3 [36], which requires studies to consider failure modes for the DCTC, but does not specifically identify this potential issue due to fire. Recognising that the design has not been finalised and that the thermal assessment is only preliminary, ONR considers that further work on this may be required in future. ONR will continue to engage with RWM on these matters through the PAAS Programme.
R28	Provide more information on the integrity of packages dropped on to sharp protrusions, angular edges and so on, rather than simple flat surfaces, and consider the ALARP measures that could be used to reduce the dispersion of any particulates produced by the impact.	ONR notes the Waste Package Accident Performance Status Report [73] includes the requirement to include “aggressive targets [primarily the corner of the most rigid package]”. The report also notes that a GDF design will strike a balance between the safety that is inherent within the package design and the safety provided by external engineered and passive safety measures, for example a filtered ventilation extract. RWM has made provision to capture this in a FAP set out within the gOSA Volume 3, which requires that a study is undertaken to review factors related to package performance during accidents.

		ONR considers RWM has made suitable progress against this recommendation, and will continue to engage with RWM on this matter through the PAAS Programme.
R29	Consider in more detail the requirements for radiological and hazardous gas management.	Although RWM does not currently have detailed ventilation design proposals, ONR considers that RWM has undertaken substantive work to understand the possible gaseous discharges that will need to be managed. In addition, the ventilation studies considered by the Mechanical Engineering specialist inspector have identified relevant good practice and provided schemes for ventilation system designs to manage the ventilation of both radioactive and gaseous discharges during the construction and emplacement stages of a GDF. ONR is content that RWM is considering radiological and hazardous gas management in a manner appropriate to the current generic stage of the GDF programme and has identified the need for further detailed studies. ONR considers RWM has made suitable progress against this recommendation, and will continue to engage with RWM on this matter through the PAAS Programme.
R30	Consider in more detail the requirements for managing the removal of heat from a GDF.	Operational temperature limits are considered within the DSS Part B [38] and are derived from the international illustrative concepts underpinning RWM's generic concepts. RWM will need to adequately underpin its assumptions based on site-specific data, when available, and integrate this to the development of the ventilation system design. ONR will continue to engage with RWM on these matters through the PAAS Programme.
R31	Consider regulatory expectations with respect to claims of high reliability.	ONR recognises that reliability is being considered and evidenced through seeking appropriate operating experience from international disposal programmes. The 2016 gDSSC specifies that safety measures will be categorised according to their relative importance in delivery of a safety function. This safety classification, in turn, will define the design requirements including the performance requirements (in terms of functional reliability or availability). This will require an appropriate level of quality assurance. For the specific case of engineered safety measures and their constituent SSCs, the design (including any associated analysis), fabrication, manufacture, assembly, inspection, installation, commissioning, operation and maintenance will be subject to a level of quality assurance commensurate with their safety importance. ONR is content that the reliability claims, in-service testing, inspection and other maintenance procedures are appropriately being considered by RWM in the 2016 gDSSC are appropriate for the current generic stage of the GDF programme.

		ONR considers RWM has made suitable progress against this recommendation, and will continue to engage with RWM on this matter through the PAAS Programme.
R32	Consider in more detail limits on voidage in packages and the effect of partially filled packages on the facility and operator doses.	ONR is content that RWM is making adequate progress against this recommendation, noting its research on voidage, but considers that there is scope for further improvement to underpin assessment of the effect of voidage on operator doses. ONR will continue to engage with RWM on this matter through the PAAS Programme.
R33	Consider in more detail work on maintenance activities in terms of extended operations and the impact of increased dose to workers.	RWM recognises that maintenance and activities as a result of extended operations are not covered in the normal operations assessment. RWM intends to address this as the design is developed. ONR will continue to engage with RWM on this matter through the PAAS Programme.
R34	Provide more detail on how the Conditions for Acceptance (CfA) will be implemented for unshielded ILW packages after they have been removed from the transport containers.	RWM is yet to provide sufficient detail on CfA for unshielded ILW packages and it remains unclear as to what checks will be made on unshielded ILW packages when they are removed from their transport containers or what actions would be undertaken if they were found to be contaminated. ONR will continue to engage with RWM on this matter through the PAAS Programme.
R35	Strengthen the ALARP arguments presented in the gDSSC, when there is more detailed dose and discharge information to work with, and demonstrate how these are made across the documents that make up the gDSSC.	RWM will need to strengthen the ALARP arguments when moving forward from a generic DSSC towards safety cases focused on specific sites. ONR will continue to engage with RWM on this matter through the PAAS Programme.
R36	Identify the requirement for detailed records to demonstrate that the irradiation of the fuel is at least at high as that claimed to support the burn up credit (BUC) in the criticality safety case.	RWM is clearly considering the options regarding transport; the decision to use burn-up credit or multiple water barriers is not a simple one because it involves a large number of factors. Should RWM use a multiple water barrier for transport, burn-up records would not be important. ONR considers RWM has made suitable progress against this recommendation.
R37	Consider either the use of an irradiation monitor to give confidence in the BUC arguments for disposal of fuel or provision of fixed neutron poisons to reduce the reactivity of the spent fuel.	RWM are clearly considering the options regarding transport; the decision to use burn-up credit or multiple water barriers is not a simple one because it involves a large number of factors. ONR considers RWM has made suitable progress against this recommendation.

R38	Consider the use of a criticality warning system or provide an ALARP case for its exclusion.	ONR considers, on the basis of the limited information available at this time, that a criticality warning system is unlikely to be necessary for the operational plant. ONR considers RWM has made suitable progress against this recommendation.
R39	Consider in more detail radiolysis of water in contact with the surface of waste containers and its impact on the corrosion rate.	The Waste Package Evolution Status Report [52] references a single study on radiolytically induced corrosion from 1999. RWM considers it has sufficient understanding of the process for the current generic stage of the GDF programme derived from overseas research programmes, and recognises its understanding will need to be developed as site-specific information is obtained. ONR considers RWM has made suitable progress against this recommendation, and will continue to engage with RWM on this matter through the PAAS Programme.
R40	Consider what further information is required to demonstrate the longevity of ILW/LLW waste packages over the proposed timescales required for a GDF (500 years) and how [RWM] will acquire it.	The Waste Package Evolution Status Report [52] includes evidence to support the longevity of a variety of package designs and waste forms. However, the longevity is dependent on a number of factors, and will require re-evaluation once a site is selected. RWM has also stated that any activities associated with retrieving and remediating degraded packages have not been developed as these are dependent on the host rock and backfilling operations which it claims are site-specific. ONR considers RWM has made suitable progress against this recommendation, and will continue to engage with RWM on this matter through the PAAS Programme.
R41	Consider the impact that defining the environmental conditions to store the waste packages in a GDF will have on: • minimising gas generation • enabling any gases produced to be sufficiently ventilated to minimise doses to the operators • preventing an unacceptable build-up of gas pressure within the repository that may cause damage to the engineered barrier system or the host geology.	RWM considerations have focused on minimisation of corrosion of packages under storage conditions. Ongoing research includes carbon-14 and hydrogen generation from waste forms in the pre-closure environment and post closure environment, uranium behaviour in a disposal environment and the build-up of radon gases and its subsequent release rates. ONR considers RWM has made suitable progress against this recommendation, and will continue to engage with RWM on this matter through the PAAS Programme.

R42	Develop and define a regime to monitor the integrity of waste packages during the operational phase of a GDF.	ONR has identified no evidence with the 2016 gDSSC that RWM has developed and defined a regime to monitor the integrity of waste packages during operational phase of a GDF. ONR will continue to engage with RWM on this matter through the PAAS Programme.
Environmental Safety Case		
R43	RWMD should include a clear statement about the purpose and limitations of post-closure safety assessments presented at the generic stage, in any future update of the gESC documents.	RWM has addressed this recommendation for the 2016 gDSSC by stating that the purpose of the 2016 PCSA is to demonstrate how a post-closure safety case would be carried out when a site is identified and to provide illustrative examples showing how it can use calculations to support demonstration of environmental safety post-closure. RWM should make sure that it does not over-interpret the outputs from generic calculations, or present them in such a way that could allow others to do so. The Environment Agency considers RWM has made suitable progress against this recommendation.
R44	RWMD should ensure that changes to the gESC, as it develops, are appropriately linked (through the Letter of Compliance disposability assessment process) to advice given to waste producers and owners on waste packaging arrangements.	We are aware that RWM is updating its waste package specifications to reflect the 2016 gDSSC, which gives us some confidence that RWM is using the gDSSC to trigger necessary changes in its disposability advice. However, it is somewhat disappointing that RWM has not taken the opportunity to identify emerging trends in waste packaging in the 2016 gDSSC and discuss how and when these may be factored into the developing safety cases. The Environment Agency considers RWM has made suitable progress against this recommendation, and will continue to engage with RWM on this matter through the PAAS Programme.
R45	RWMD should develop generic restrictions on chemotoxic and hazardous substances, in accordance with statutory requirements for groundwater protection.	We have engaged with RWM since 2011 to expand on this recommendation and provide additional guidance. RWM has ongoing work to identify likely hazardous substances and non-hazardous pollutants in its inventory for disposal. This work will support the development of restrictions. We are confident that RWM will continue to engage with waste packagers to ensure appropriate information is obtained on the radionuclide and material inventory for all waste packages destined for geological disposal, and we will continue to maintain oversight of that [16]. The Environment Agency considers RWM has made suitable progress against this recommendation, and will continue to engage with RWM on this matter through the PAAS Programme.
R46	RWMD should provide a list of the generic qualitative constraints on waste packaging, together with an explanation	RWM documents generic qualitative constraints on waste packaging in its waste packaging specifications. We are aware that RWM is updating the waste package specifications, to reflect the 2016 gDSSC.

	in each case of how the constraint arises.	The Environment Agency considers RWM has made suitable progress against this recommendation.
R47	At closure of a GDF, we would expect the ESC to be based on the inventory as disposed of. RWMD should explain how it will progress from using the published UKRWI as the basis for the ESC to using waste package information.	RWM has informed us that it is developing proposals for a process by which waste package data are recorded and incorporated into future safety case updates [70]. We do not see evidence of this in the 2016 gDSSC. We will be interested to engage with RWM on this as the process develops. We will continue to engage with RWM on this matter through the PAAS Programme.
R48	RWMD should improve the detailed description of post-closure safety case methodology, including the description of the conceptual, mathematical and numerical models, in future revisions of the gESC and gPCSA, and consider producing simple descriptions, accessible to all readers.	The 2016 gDSSC includes a description of the PCSA methodology. However, we have identified a number of deficiencies which are documented in Annex 2, for example, the description of the assessment strategy is not as clear or robust as we would expect. We suggest RWM could improve the audit trail by including a chart showing model hierarchy and the links between different model types and processes. The Environment Agency considers RWM has made suitable progress against this recommendation, and will continue to engage with RWM on this matter through the PAAS Programme.
R49	RWMD should clarify whether and, if so, how the approach used in its illustrative quantitative assessments will inform the siting process. We will expect RWMD to clarify this matter in further submissions under our scrutiny programme.	RWM has developed geological screening criteria for the siting programme that include geological attributes relevant to meeting the safety requirements. We are not clear how RWM will use these geological screening criteria or the 2016 gESC to support the siting process. The Environment Agency considers RWM has made suitable progress against this recommendation, and will continue to engage with RWM on this matter through the PAAS Programme.
R50	RWMD should clarify and map out how it might develop any future site-specific ESC. A site-specific ESC should be coherent and largely self-contained, and should integrate the evidence from R&D with claims, arguments and analysis in the ESC.	RWM has clarified that it plans to maintain its generic safety case alongside any developing site-specific safety cases “until there is sufficient confidence in the site-specific ESC that the generic ESC is judged no longer to be required” [6]. RWM needs to explain that “sufficient confidence in the site-specific ESC" will be its (not the regulators’) judgement at this stage and should define how it will make this decision. The Environment Agency considers RWM has made suitable progress against this recommendation.
R51	RWMD needs to develop and present an effective and transparent system for prioritising R&D to ensure it delivers an	The S&T Plan [3] provides an overall view of RWM’s R&D over the next 10 years and includes information on how the programme could be prioritised, if needed. However, the S&T Plan does not provide the reasons for some changes to current version (for example, the addition and

	R&D programme to meet the R&D objectives effectively.	removal of some tasks). We will continue to maintain oversight of RWM's R&D process and programme. The Environment Agency considers RWM has made suitable progress against this recommendation, and will continue to engage with RWM on this matter through the PAAS Programme.
R52	RWMD should describe how it will consider new information from R&D (both its own and other R&D nationally and internationally) and assimilate it into the existing body of knowledge and information relating to the ESC.	RWM is engaged in a number of international and national programmes to develop its knowledge base. RWM outlines this work in the S&T Plan [3] and summarises the results in the status reports [26, 52, 53, 54, 55, 71, 72, 73]. We encourage RWM to continue to participate in relevant national and international programmes as geological disposal progresses. RWM's S&T Plan explains RWM's iterative process for identifying and prioritising the necessary R&D. We will continue to maintain oversight of RWM's R&D programme. The Environment Agency considers RWM has made suitable progress against this recommendation, and will continue to engage with RWM on this matter through the PAAS Programme.
R53	RWMD should describe the process by which the gDSSC (and iterations of any site-specific DSSC in the future) will be used to identify key gaps and uncertainties in safety arguments that R&D might address.	RWM does not clearly identify the main uncertainties in the 2016 gESC nor does it consistently or comprehensively reference the work that it is undertaking to reduce these uncertainties. Inclusion of references in the gESC to specific research tasks in the S&T Plan [3] would provide us with greater confidence that the S&T Plan focuses on all areas that RWM currently identifies as being important to demonstrating environmental safety. We will continue to engage with RWM as it develops its strategy for identifying and prioritising research needs in a site-specific context. The Environment Agency will continue to engage with RWM on this matter through the PAAS Programme.
R54	We would encourage RWMD to produce a shorter, crisper gESC main report, when it updates the gDSSC. This would make it more accessible to a wider audience.	RWM has improved the accessibility of the 2016 gESC main report compared with the 2010 gESC. We are satisfied that RWM will continue to identify and implement changes to improve the presentation of its safety case as implementation progresses. The Environment Agency considers RWM has made suitable progress against this recommendation.
R55	We do not agree with RWMD that "it is premature to be considering optimisation until much later in a GDF implementation programme." We would encourage RWMD to consider optimisation in the early stages. This avoids premature foreclosure of options	The claim that it is premature to be considering optimisation until much later in a GDF implementation programme does not feature in the 2016 gDSSC. RWM states that, at the generic stage, its approach to providing waste packaging advice is robust to a range of future outcomes (§2.3 of [6]), thus allowing waste packagers to make decisions as part of their responsibilities for optimisation as duty holders. Furthermore, from our ongoing dialogue with

	and leads, for example, to a portfolio approach in setting R&D priorities.	RWM [74] we are satisfied that RWM fully understands the regulatory requirements with respect to optimisation. The Environment Agency considers RWM has made suitable progress against this recommendation.
R56	RWMD should describe how it will identify, consider and assimilate any new statutory requirements into the existing body of information.	Part A of the DSS [32] includes a 'structured review' of a selection of national and international standards, directives and requirements to elicit a list of RWM's high level requirements. However, we can find no reference in the 2016 gDSSC to RWM guidance or procedures relating to identifying and assimilating new statutory requirements or changes to existing requirements into the existing body of information. RWM should demonstrate that it has a robust approach for identifying and addressing new legislative requirements and expectations. The Environment Agency will continue to engage with RWM on this matter through the PAAS Programme.
R57	We expect RWMD to continue with and further develop its active and visible approach to dialogue with communities and others, as implementation progresses.	This recommendation is not directly linked to the 2016 gDSSC. The Environment Agency will continue to engage with RWM on this matter through the PAAS Programme.

List of abbreviations

ADR	European Agreement concerning the International Carriage of Dangerous Goods by Road
ALARP	As Low As Reasonably Practicable
ALARA	As Low As Reasonably Achievable
CDG	Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations
CDM	Construction (Design and Management) Regulations
CfA	Conditions for Acceptance
CHS	Conventional Health & Safety
CoRWM	Committee on Radioactive Waste Management
CSA	Conceptual Security Arrangements
DBA	Design Basis Analysis
DCTC	Disposal Container Transport Container
DSS	Disposal System Specification
EC	European Commission
EDZ	Excavation Disturbed Zone
FAP	Forward Action Plan
FEPs	Features, Events and Processes
GDF	Geological Disposal Facility
gDSSC	generic Disposal System Safety Case
gESC	generic Environmental Safety Assessment
gOSA	generic Operational Safety Assessment
gOSC	generic Operational Safety Case
GRA	Guidance on Requirements for Authorisation
gTSC	generic Transport Safety Case
HAW	Higher Activity Radioactive Waste
HLW	High Level Waste
HHGW	High Heat Generating Waste
HSSEQ	Health, Safety, Security, Environment & Quality
IAEA	International Atomic Energy Agency
ILW	Intermediate Level Waste
LHGW	Low Heat Generating Waste
LLW	Low Level Waste
NDA	Nuclear Decommissioning Authority
NEA	Nuclear Energy Agency
OESA	Operational Environmental Safety Assessment

ONR	Office for Nuclear Regulation
PAAS	Pre-Application Advice & Scrutiny (Programme)
PCSA	Post-Closure Safety Assessment
R&D	Research and Development
RI	Regulatory Issue (PAAS)
RID	The Regulation concerning the International Carriage of Dangerous Goods by Rail
RMS	Requirements Management System
RO	Regulatory Observation (PAAS)
RWM	Radioactive Waste Management Ltd
SAP	Safety Assessment Principle(s)
S&T	Science and Technology (Plan)
SFR	Safety Functional Requirement
SSCs	Structures, Systems and Components
SyAP	Security Assessment Principle(s)
UKRWI	UK Radioactive Waste Inventory
US DOE	United States Department of Energy
WAC	Waste Acceptance Criteria
WIPP	Waste Isolation Pilot Plant (US DOE)

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