Preferred Concepts for Disposal of the UK Inventory of Depleted, Natural and Low Enriched Uranium – 16382

Daniel Galson *, Fiona Neall *, Liz Harvey *, Lucy Bailey **
* Galson Sciences Ltd, UK
** Radioactive Waste Management, UK

ABSTRACT

Depleted, natural and low enriched uranium (DNLEU) forms a significant quantity of the UK inventory of higher activity radioactive materials. The great majority comprises uranic materials produced from uranium enrichment operations and from reprocessing of spent nuclear fuels. The most recent estimate of the total quantity (stocks plus arisings) of UK-owned DNLEU from civil nuclear operations is 170,000 tU. Current UK Government strategy is for DNLEU to be stored indefinitely in existing or new facilities, as required. However, Government strategy for long-term management of uranic materials is under review and a change could potentially cause this material to be reclassified as a waste.

An Integrated Project Team (IPT) was formed in 2012 with the objective of identifying and addressing the issues associated with the potential need to dispose of DNLEU, in order to inform wider decision-making on the long-term management of UK DNLEU. Key technical issues considered by the IPT relate to the following:

1. The need for an improved understanding of the UK DNLEU inventory.
2. The identification of preferred chemical and physical form(s), and preferred packaging and disposal concepts for DNLEU - the main subject of this paper.
3. The approach to safety assessment of DNLEU disposal.

This paper summarises the disposal concepts under consideration by the IPT, and the rationale for identification of preferred concepts for disposal of DNLEU inventory components. The conclusions will be of interest to other programmes and countries with a requirement to manage large quantities of similar materials.

INTRODUCTION

The most recent estimate of the total quantity (stocks plus arisings) of UK-owned depleted, natural and low enriched uranium (DNLEU) from civil nuclear operations is that reported in the 2013 UK Radioactive Waste Inventory (UKRWI), amounting to 170,000 tU [1]. This is 17% by volume of the UK inventory of higher activity radioactive materials. The great majority comprises uranic materials produced in the UK thermal reactor fuel cycle. The main DNLEU types considered in this study are deconverted depleted uranium (DU) tails from uranium enrichment operations (to be stored in the form of U_3O_8 powder), and Magnox Depleted Uranium (MDU) and Thermal Oxide Reprocessing Plant (THORP) Product Uranium (TPU) from reprocessing of spent nuclear fuels (stored in the form of UO_3 powder). The long-term storage containers for these materials include DV-70 painted mild steel boxes (approximately 3 m^3) for DU tails, 200-litre mild steel drums and 210-litre stainless steel drums for MDU, and 50-litre stainless steel drums for TPU. The DU tails are mainly owned by URENCO UK Limited and the reprocessed uranium is mainly owned by the Nuclear Decommissioning Authority (NDA) and EDF Energy. There is a further small and highly variable portion of the inventory, termed 'miscellaneous DNLEU', which was also considered in lesser detail.

Current UK Government strategy is for DNLEU to be safely and securely stored indefinitely in existing or new facilities, as required. At present, the UK Government considers DNLEU to be a zero-value asset radioactive material, but Government strategy for long-term management of uranic materials is under review and a change could potentially cause this material to be reclassified as a higher activity radioactive waste (HAW). If this were to happen, then DNLEU could require disposal in a geological disposal facility (GDF).

An Integrated Project Team (IPT) comprising Radioactive Waste Management (RWM)[1] staff and members of the contractor base has been formed, with the objective of identifying and addressing the issues associated with the potential need to dispose of DNLEU, in order to inform wider decision-making on the long-term management of UK DNLEU. Key technical issues being considered by the uranium IPT relate to the following:

1. The need for an improved understanding of the UK DNLEU inventory – work is summarised in [2].
2. The identification of preferred chemical and physical form(s), and preferred packaging and disposal concepts for DNLEU – the main subject of this paper.
3. The approach to safety assessment of DNLEU disposal – work is summarised in [3].

APPROACH

Project activities have been subject to an iterative process of procurement, delivery and review, achieved by splitting the programme into four gated stages (Fig. 1). The project plan is illustrated in Fig. 2:

- In Stages 1 and 2, initial assessment and research were undertaken to develop a representative set of credible geological disposal concept options. These are identified in TABLE I.
- Stage 3 focused on assessment activities to inform refinement of these options, including assessments of GDF design and cost, GDF operational and post-closure safety, disposability, and implications for DNLEU owners.
- Stage 4, currently underway, is focused on identification and evaluation of

[1] RWM was established on 1 April 2014 as a wholly owned subsidiary of the NDA. The role of RWM is to implement the UK Government's policy of geological disposal of HAW by delivering a GDF and by providing independent assessment of packaging of HAW such that it is suitable for interim storage and eventual disposal in a GDF. Previously, RWM had been a part of the NDA – the Radioactive Waste Management Directorate.

preferred options for a range of potential future situations, and has included refinement of illustrative designs for the preferred options based on the work in Stage 3.

As the UK HAW disposal programme is still at the generic stage (i.e. there is no site yet), consideration has been given to necessary design refinements considering the range of generic host rock environments under consideration by RWM: higher strength rock (HSR), lower strength sedimentary rock (LSSR), and evaporites (EVR).

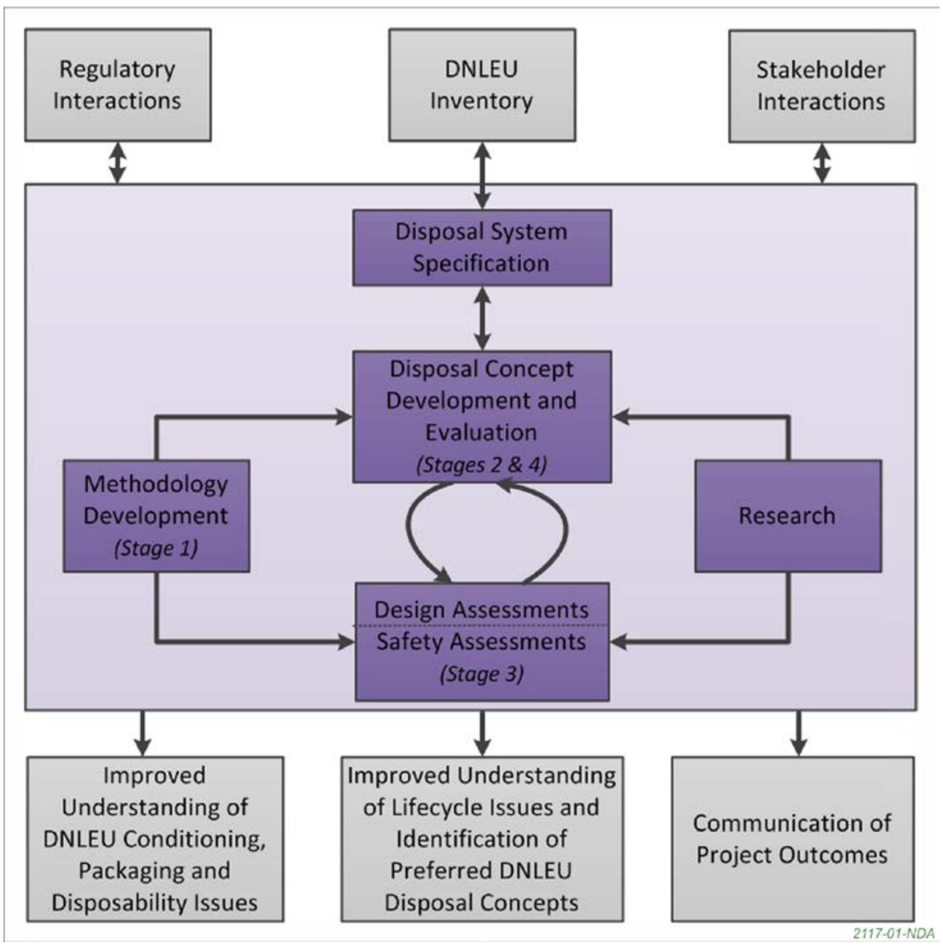

Fig. 1. Illustration of project stages and principal outcomes.

This paper summarises the disposal concepts considered by the uranium IPT and the rationale for identification of preferred concepts for disposal of DNLEU inventory components. Both nearer-surface and geological disposal concept options were evaluated, as well as the possibility of using DNLEU in place of mass backfill in disposal areas for other wastes subject to geological disposal (referred to here as

'GDF use' options[2]). The conclusions will be of interest to other programmes and countries with a requirement to manage large quantities of similar materials.

The results of the Stage 3 assessments are summarised in terms of impacts on GDF disposal concepts in HSR, and by reference to Concept F (Concept F is broadly in line with RWM's current baseline for this material[3]). The next section then identifies the preferred disposal concept options identified in Stage 4, considering a wider range of potential situations that could arise. Work for disposal in other geological environments and at other depths was considered by reference to geological disposal in a HSR. Information gaps and remaining uncertainties pertaining to concept selection are also identified.

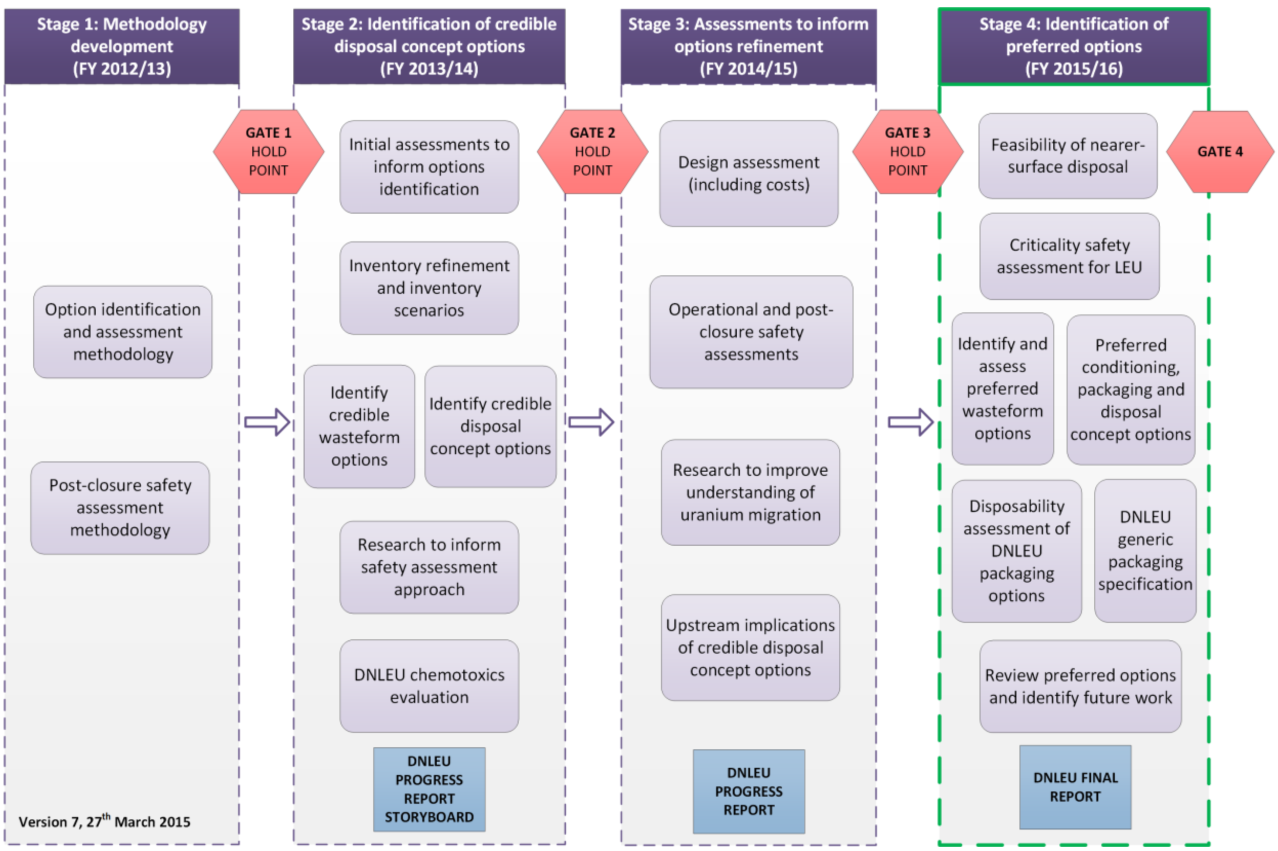

Fig. 2. Project plan showing the four gated stages, and the main tasks within each stage (work in current year is highlighted by dashed green line).

2 UK government policy is that a single GDF would be preferred for the entire range of wastes requiring geological disposal.

3 The reference approach involves grout encapsulation of DNLEU in the form of U_3O_8 into 500-litre drums, transport to a GDF in Type B reusable containers, and disposal as unshielded intermediate-level waste.

TABLE I. Credible geological and nearer-surface disposal concept options for bulk DNLEU, and rationale for consideration. Shading is used to show options that were screened out during the project and are not preferred under any circumstances.

<table>
<tr><th>Concept ID</th><th>Primary goal</th><th>Waste package</th><th>Transport and disposal container</th><th>Vault/tunnel/silo backfill</th></tr>
<tr><td colspan="5">Geological disposal concept options</td></tr>
<tr><td>A</td><td>Use current/planned storage packaging options (also reduces cost and resource use)</td><td>Oxide powders in storage containers</td><td>Industrial Package (IP) reusable transport container</td><td>HSR & LSSR: load-bearing cementitious mortar
EVR: crushed salt</td></tr>
<tr><td>B</td><td>Lowest technological risk</td><td colspan="2">Oxide powders in storage containers with mild steel, combined transport/disposal container (TDC)</td><td>HSR & LSSR: load-bearing cementitious mortar
EVR: crushed salt</td></tr>
<tr><td>C</td><td>Minimise lifecycle cost</td><td colspan="2">Oxide powders in storage containers with soft-sided TDC</td><td>HSR & LSSR: load-bearing cementitious mortar
EVR: crushed salt</td></tr>
<tr><td>D</td><td>Prioritise public acceptability (assumed to be achieved by prioritising retrievability)</td><td colspan="2">Oxide powders in storage containers with stainless steel TDC</td><td>HSR & LSSR: load-bearing cementitious mortar
EVR: crushed salt</td></tr>
<tr><td>E</td><td>Prioritise post-closure safety (long containment)</td><td colspan="2">UO_2 briquettes in long-lived copper containers</td><td>HSR & LSSR: Clay or bentonite
EVR: crushed salt</td></tr>
<tr><td>F</td><td>Based on 2010 generic disposal system safety case (DSSC) disposal concept for DNLEU [4]</td><td>Cement-encapsulated oxide powder in 500-litre drums in stillages</td><td>IP reusable transport container</td><td>HSR: Nirex Reference Vault Backfill (NRVB)
LSSR: cementitious mortar
EVR: none</td></tr>
<tr><td>G(A)</td><td rowspan="2">Reduce GDF footprint by using high heat generating waste (HHGW) access tunnels for DNLEU disposal (in place of mass backfill)</td><td>Oxide powders in storage containers</td><td>IP reusable transport container</td><td>HSR & LSSR: low-pH, load-bearing cementitious mortar
EVR: crushed salt</td></tr>
<tr><td>G(B)</td><td colspan="2">Oxide powders in storage containers with mild steel TDC</td><td>HSR & LSSR: low-pH, load-bearing cementitious mortar
EVR: crushed salt</td></tr>
</table>

Concept ID	Primary goal	Waste package	Transport and disposal container	Vault/tunnel/silo backfill
Nearer-surface disposal concept options				
NS1 (direct-access silo)	Considers feasibility of nearer-surface disposal	As Concept A		HSR & LSSR: cementitious mortar
NS2 (silo 50-200 m depth)		As Concept A		HSR & LSSR: cementitious mortar
NS3 (vault 50-200 m depth		As Concept A or Concept B		HSR & LSSR: load-bearing cementitious mortar

STAGE 3 ASSESSMENTS: GDF IN HIGHER STRENGTH ROCK

GDF Design and Operational Safety

- All options are expected to be able to meet GDF operational safety requirements, with any remaining issues resolvable through design.
- Each option has a different GDF footprint: Concept F requires 6 vaults, whereas the alternatives might need 4 (A), 5 (B/D), 71 (E) and 0 (GDF use options) vaults.
- Scoping calculations suggest that, relative to Concept F, the cost of DNLEU disposal in a GDF might be reduced by ~£240M[4] if Concept A were implemented, and by ~£180M if Concept B or D were implemented. The GDF use options would increase the cost by ~£1,100M, assuming a 20-year extension to the operational period, and option E would increase the cost by ~£3,700M, largely owing to the requirement for a much larger number of vaults[5].
- The GDF operational safety evaluation considered (i) safety during construction and (ii) safety during operations. In terms of (i), ranking reflected the amount of additional construction required, with the GDF use options (least construction) ranked best and Concept E (most construction) worst. In terms of (ii), ranking of vault-based options reflects robustness of the waste packages, with Concept E (most robust packages) best, Concept F second best, and Concept A (least robust) worst. The GDF use options perform poorly because they assume that packages will be transported over long distances and that the ventilation outtake will be routed past workers.
- Overall, Concept E has significant disadvantages in terms of cost and operational safety. The GDF use options have benefits in terms of reduced

[4] All costs quoted in this paper are indicative and undiscounted.

[5] Note that Concept E has not been optimised for footprint. With some modifications to its implementation at a GDF, the number of vaults could possibly be reduced to ~15, but it would still have a larger footprint and be significantly more costly than Concept F.

construction requirements and additional operational flexibility. Their relatively high cost results from scheduling and co-location assumptions that are at present poorly underpinned.

GDF Post-closure Safety

- There are no significant differences in calculated peak risk between options because of the extremely long half-life of the dominant radionuclide in the inventory, U-238, and the inability to demonstrate, particularly at the generic stage, that additional engineering would retain safety functions over these timescales.
- Uncertainties in the behaviour of Ra-226 in the far-field are a significant influence on calculated risk, are the same for all concepts, and can only be assessed on a site-specific basis.
- At a generic stage, only Concept E can be distinguished on the basis of post-closure safety considerations. The bentonite buffer component of Concept E could potentially provide a benefit in reducing groundwater flow and, therefore, radionuclide fluxes to the far-field. However, depending on the site, it may not be possible to take credit for such performance of this barrier on the timescales of interest. The long-lived container in option E delays, but does not reduce, peak radionuclide fluxes to the far-field.
- The post-closure safety benefits of option E are considered to be outweighed by other considerations, such as cost and the difficulty of emplacing bentonite to the required standard.
- Differences in calculated radionuclide flux to the far-field between non-bentonite backfill options (no backfill, crushed rock and NRVB) are not significant, and therefore geomechanical considerations and emplacement practicality should be given more weight in selecting preferred backfill option(s).

Considerations for DNLEU Owners

- A schedule has been derived for each option, based on the assumed disposal window at a GDF for the option, and options have been compared in terms of cost, operational safety and environmental impact. Scheduling, technology readiness, transport and socio-economic issues have also been considered.
- Concepts E and F perform significantly worse than all other options in terms of cost, operational safety and environmental impact, owing to the need for construction, operation and decommissioning of additional packaging and treatment plants. In particular, scoping cost calculations suggest that ~£1200M of treatment and packaging costs could be saved by implementing any of Concepts A/B/D in place of Concept F; Concept E would cost ~£1600M more to implement than Concept F. The GDF use options are expensive relative to Concepts A/B/D, because they assume a longer period of storage prior to disposal and a longer period during which the stores require an

export capacity. However, as noted above, GDF scheduling assumptions for DNLEU disposal are still poorly underpinned.

STAGE 4 IDENTIFICATION OF PREFERRED DISPOSAL CONCEPT OPTIONS

Conclusions of Stage 4 Work

The situations considered and the preferred disposal concept options for each are summarised in TABLE II, along with a summary of the reasons for a preference.

TABLE II. Summary of the situations for which preferred disposal concept options have been identified and the preferred option(s). Concepts in **bold** text are preferred, with other concepts given as alternatives that could be favoured in some host rocks or sites, or for other specific reasons. The key reasons for the preference(s) are also summarised.

Situation	Preferred disposal concept option(s)	Reason
Site with HSR host rock	**A, B, D**	GDF vault concepts minimise resource use and number of vaults. A or B: choice may depend on operational safety and preference for smaller number of handling operations. D if retrievability is required.
Site with LSSR host rock	**A** NS3(A)	A: small waste packages, efficient emplacement. NS3(A): could significantly reduce number of vaults required compared to GDF vaults in LSSR or evaporite.
Site with evaporite host rock	**A, B** G(A), G(B)	A: small waste packages, efficient emplacement. B: would require redesign of vaults to allow efficient disposal of TDCs. G: fewer concerns about backfill in evaporite and would reduce footprint by 18 vaults compared to Concept F. G(B) would reduce emplacement operations compared to G(A).
Small footprint for a single GDF for all HAW	**A** G(A), G(B) NS3, NS2	Depends on host rock and site as to best way to reduce GDF footprint.
Retrievability required	**D** F	Use of stainless steel containers improves retrievability. D would be less costly, and would require fewer resources than F.
Changes in inventory	No preference	All concepts scale to the inventory.
Accelerating emplacement	**NS3** NS2	Nearer-surface options can be implemented independently of a GDF, thus more amenable to significant changes in scheduling.

Situation	Preferred disposal concept option(s)	Reason
Disposal of miscellaneous DNLEU required	**A, F**	Miscellaneous DNLEU is a tiny fraction of DNLEU inventory. Disposal route may depend on chemical form or enrichment. A: might allow disposal of this material to be more easily 'diluted' in the rest of the DNLEU. F: may provide a passively safe wasteform.
Episodic disposal	**A, B** Not F, G	F: stopping and starting an encapsulation plant and extending its operational lifetime would be costly. G: unlikely that tunnels could be partly filled and then emplacement stopped. Vault-based concepts: all acceptable.
Sequential backfilling	**A, B** NS3, NS2	Sequential backfilling could be advantageous for A and B; allows backfill to be emplaced in 'layers', potentially allowing 'dry' (non-flowing) materials to be used.
Requirement to reduce voidage	F, A, B	Depending on the requirement to reduce voidage: Minimising voidage would require F. If porosity was acceptable, storage containers could be 'topped up' with incompressible material (e.g. sand) and TDCs could be infilled. Overpacked MDU drums could be treated with an annular grout infill or be repackaged.

The main conclusions of the Stage 4 work are:

- The preferred wasteform is powdered uranium oxide in the chemical form favoured for long-term storage: U_3O_8 (DU tails) and UO_3 (MDU and TPU). Disposal of the powdered oxide wasteform would avoid the penalties in operational safety, resources and cost associated with processing to any other wasteform, e.g. compacted oxide pellets or cement encapsulation of oxide powders. While this represents a change from RWM's current illustrative disposal concept (Concept F, cement encapsulation of DNLEU), it is expected that a GDF operational safety case could be made for this wasteform, based on precedent experience for existing uranium oxide stores. However, there is a need for RWM to develop methodologies and safety case arguments specific to the disposal of an unimmobilised uranium oxide powder (see below).
- As noted in the previous section, post-closure safety does not significantly discriminate between any of the geological disposal concept options, in large part because of the very long half-life of U-238 and the inability to demonstrate that additional engineering would retain safety functions over these timescales.
- Concept A offers potential advantages in terms of reduced resource use and cost saving in upstream lifecycle activities, and is the most flexible disposal option with respect to emplacement. The small disposal units, based on the

existing and planned storage containers, mean that emplacement efficiency is high in all vault designs in all host rocks. This benefit extends to the use of this packaging option in the nearer-surface disposal concepts considered: NS2 (silos) and NS3 (vaults). There are uncertainties about the design of a stillage that would be required to allow both efficient handling of the small storage containers, such as the 50-litre and 210-litre drums, and stacking to the required heights in vaults in HSR.

- Concept B potentially brings benefits in terms of improved operational safety and efficiency by the use of TDCs. The TDC provides a more robust waste package than the storage containers alone (or in stillages) while also reducing the number of handling and emplacement operations. The illustrative design of the TDCs, based on a bespoke 6 m container, has been refined to take account of concerns about voidage. However, the designs may still be considered sub-optimal in terms of underground handling by stacker truck, because of their size and gross mass. Further optimisation of the package design could potentially address these issues.
- Concept C was found to have no significant advantages over other concepts, but introduced additional uncertainties (e.g. duration of integrity of the waste packages; introduction of additional organic materials), so was screened out as not being preferred in any conceivable circumstances.
- Concept D has the same benefits as Concept B, but with the added benefit of longer-term retrievability, should this be required.
- Concept E was found to have the potential to delay peak doses, but not actually to reduce them, so it does not meet its primary goal and was not considered to be preferred in any conceivable situation.
- Concept F is not favoured for the disposal of the bulk of the DNLEU inventory because of its high upstream costs and resource use. However, it might offer a potential disposal route for those miscellaneous DNLEU materials that are not suitable for disposal in their current form. A cement-encapsulated wasteform would be robust and passively safe for operations. This could be in a dedicated disposal area for DNLEU, or in the low heat generating waste (LHGW) disposal module.
- Concept G is technically complex with several significant open questions about its implementation in HSR and LSSR. It may be more practical and less challenging to implement in evaporite, where backfill is less of an issue owing to the expected properties of the host rock. The costs associated with extended storage of the DNLEU are a significant disadvantage of this option and more than outweigh the cost savings arising from reduced underground construction. The storage costs, however, depend on assumptions regarding the schedule for emplacement and, therefore, on the location of emplacement. For example, if tunnels used for the ventilation circuit around the HHGW disposal module are used, this would require the GDF schedule to be extended to allow the DNLEU to be emplaced after all other wastes (i.e. after 2190). Other disposal locations might allow episodic emplacement through the GDF schedule, as capacity becomes available, and provide

significant cost savings from reduced refurbishment and replacement of stores and repackaging of storage containers.

- Nearer-surface concepts, particularly the NS3 vault facility, appear to offer benefits if early emplacement of DNLEU is desired or a restricted host rock volume limits disposal at GDF depth. With respect to potential cost savings from nearer-surface disposal, the most significant (up to £700M) arise from advancing the DNLEU disposal schedule, thus avoiding the costs associated with storage. Cost reductions at a GDF from implementation of nearer-surface disposal are predicated on replacing large numbers of GDF vaults, for example in LSSR or evaporite, with fewer, larger disposal spaces at shallower depth. However, the provision of duplicate facilities and services, such as reception areas and ventilation, and requirements for independent evacuation routes, add costs for a shallower facility. The balance of costs is uncertain at this time, and would need to be determined on a site-specific basis.
- The only disposal concept considered in the evaluation that was not identified as a preferred option in any situation is the nearer-surface direct-access silo concept NS1. This was because of the difficulty foreseen in making a robust post-closure safety case. The greater depth and isolation offered by the other nearer-surface concepts, and the potential to locate them under the seabed (but accessed from land)[6], suggests that a post-closure safety case could be made for these options. A nearer-surface underground vault facility (NS3) is likely to be preferred over an underground silo facility (NS2) as the former offers a potentially simpler operational process, more closely aligned to the LHGW vaults in a GDF.
- The cost of storage of the DNLEU has been identified as a significant differentiator between disposal options that have different emplacement schedules. For most cases, a fixed emplacement period for all DNLEU of 30 years has been assumed. However, a potential benefit for options using the TDCs makes use of the low hazard associated with storage of the TDCs. In principle they could be ‘stockpiled’ at a surface buffer store to allow emplacement whenever there was spare throughput capacity. If storage containers were packaged in the TDCs rather than repackaged at the stores, or the contents of stores due for refurbishment or replacement were prioritised, there are potential benefits to be achieved.
- Criticality safety for the small part of the inventory comprising LEU may require alternative transport and disposal concepts that make use of smaller packages with reduced fissile content. It may also be necessary to immobilise the material and the primary containers in the TDC in order to satisfy criticality safety requirements. Although the proportion of the DNLEU inventory of concern with respect to criticality safety is so small that it should not influence the choice of disposal concept for the bulk of the material, a suitable disposal concept for it does need to be identified taking account of

---

[6] Locating the whole GDF sub-seabed (but accessed from land) may also be possible in some coastal sites.

its specific requirements. This may mean accepting a reduced emplacement efficiency for this component (e.g. more infill material around fewer TPU drums in a TDC, or smaller packages for TPU drums) in order to emplace it with the DU, or 'diluting' low enriched TPU with DU[7] (e.g. by selecting drums for emplacement in a TDC based on their enrichment to reduce the TDC average enrichment, or by selectively emplacing TPU containers in the DNLEU vaults).

Remaining Concept-Specific Questions and Uncertainties

There are several remaining questions and uncertainties associated with many or all of the disposal concept options. The issue of voidage in the waste packages is common to all of the options except Concept F and arises partly because of the powdered wasteform – a certain amount of porosity is associated with this material – and partly because, without encapsulation, there is at least some ullage in all of the storage containers. In the case of the older MDU drums, there is also significant voidage associated with partially filled and overpacked drums. At the current generic stage of the UK HAW disposal programme, the amount of voidage in DNLEU waste packages that could be problematic in the disposal vaults is not defined. There are actions that could be taken to reduce this voidage without going as far as cement-encapsulation of the DNLEU inventory. Similarly, for the voidage in the TDCs, designing bespoke containers to reduce the void space and infilling the remainder with suitable material would be an option.

Closely tied to the question of voidage is the uncertainty about the requirements on any backfill material. If voidage in the waste packages must be low in order to avoid coalescence of the open space at the top of the vault resulting in an unsupported roof, then the backfill would need to fulfil a similar function in supporting the overlying rock mass, and perhaps in mitigating the effect of voids in the waste packages. However, collapse of the roof of a vault is unlikely to affect the long-term safety of the DNLEU significantly, although it could cause changes to the host rock that would impact disposal areas for other wastes in a GDF. A dedicated DNLEU disposal area would allow site-specific separation distances from disposal areas for other wastes to be determined based on this factor, as well as other factors (such as chemical interactions arising from organic degradation products or use of cementitious materials). For nearer-surface disposal of DNLEU, however, voidage may be a more consequential issue if, for example, host rock damage from vault collapse were to intersect near-surface aquifers, leading to significantly enhanced groundwater flow through the near field. Thus, for these disposal concepts, in some sites, the allowable voidage in the waste packages may be restrictive or require mitigation.

[7] Some of the DU inventory could also be used to 'dilute' other materials having higher enrichment levels, such as plutonium and highly enriched uranium, were such materials to require disposal

The requirements for backfill are particularly pertinent to Concept G, since the DNLEU would be in relatively close proximity to the HHGW disposal area. However, there are several open questions for Concept G related to implementation in all host rocks. For example, managing the provision of ventilation and other services in tunnels during waste emplacement and sequential backfilling, and safety issues associated with operations in tunnels closed off at one end by backfill emplacement. Furthermore, the circumstances under which this disposal option would be preferred over vault-based concepts will depend heavily on the characteristics of a particular site and the scheduling of DNLEU disposal with regard to HHGW disposal. It is therefore suggested that Concept G is considered a low priority for any future work, unless a site-specific need to re-consider the concept arises.

OVERALL PROJECT CONCLUSIONS

RWM's reference approach for packaging, transport and disposal of DNLEU – as set out in the 2010 generic DSSC – involves grout encapsulation of DNLEU in the form of U_3O_8 into 500-litre drums, transport to a GDF in Type B reusable containers, and disposal as unshielded intermediate-level waste (ILW). The 2010 generic DSSC was the first attempt at an integrated consideration of disposal of DNLEU in the UK, and elements of the approach were recognised to be non-optimal. However, the 2010 DSSC formed the starting point and benchmark for the work carried out by the uranium IPT.

The uranium IPT has adopted an innovative, holistic approach to development and optimisation of disposal concept options and designs. This has involved taking into consideration existing and planned storage practices, requirements for transport, existing disposal options, and new options based on the characteristics of the waste, and has emphasised keeping options open where appropriate. In addition, the uranium IPT approach has been integrated across RWM functions and performed in collaboration with contractors, DNLEU owners and other stakeholders (e.g. regulators). This has allowed for efficient progress and for modifications to proposed packaging approaches and disposal concepts on a timescale that is expected to be helpful to both RWM and DNLEU owners.

The uranium IPT set out to answer a number of questions about the disposal of DNLEU should it be declared as a waste. These questions covered issues of inventory, disposal concepts and post-closure safety, amongst others. Of the main questions posed for Phase 2 of the uranium IPT programme, those relating specifically to disposal concept options are:

1. Would it be feasible to transport and dispose of DNLEU in the same form and packaging used for long-term storage?
2. What are the preferred conditioning, packaging and disposal concept options? What work would be needed to address any remaining concerns relating to these concepts?

3. Would disposal in a nearer-surface facility be feasible for any part of the inventory?
4. What are the upstream implications of the preferred concepts?

It is clear from the identification of the preferred disposal concept options, which are mainly based on the disposal of the DNLEU as an oxide powder in long-term storage containers, that the first question has been answered strongly in the affirmative. The second and third questions have been answered with the identification of a set of representative preferred disposal concept options that include consideration of nearer-surface disposal options, as discussed in this paper. The innovative and integrated consideration of GDF disposal concept options, together with nearer-surface disposal concept options, has allowed the relative strengths and weaknesses of different concepts to be articulated at a level of detail appropriate to the generic stage. The work has also examined the future situations in which one or another option might be preferred. Involvement of DNLEU owners in the work programme has allowed full lifecycle evaluation of the disposal concept options, such that implications for DNLEU owners and for RWM have been addressed in an integrated fashion in identifying preferred concepts (fourth question).

As part of questioning previous RWM assumptions concerning the disposal of DNLEU, the uranium IPT has addressed the question: “how does a particular management approach or barrier contribute to transport, operational or post-closure safety (if at all)?” This has led to recognition that engineered barriers serve a different role for the bulk components of DNLEU compared to other higher activity wastes. It is further recognised that it will be important to communicate clearly the differences in approach to the disposal of DNLEU compared to disposal concepts for ILW and HHGW.

As a consequence of questioning the function of backfill in disposal concepts for DNLEU, the potential issue of voidage has been highlighted. Understanding of the concerns has allowed some options to be identified for addressing this issue, including both appropriate ways for adapting management plans, and mitigation measures engineered into the disposal system that could be implemented if required at a specific site.

In summary, the main conclusions of the work on disposal concept options are:

- There would be many benefits to be gained from RWM moving away from Concept F as its reference illustrative disposal concept. Concept D is the best-performing option of the A/B/D family in terms of accident performance and meeting retrievability requirements, and also represents significant cost savings compared to Concept F. However, any one of Concepts A, B and D provide benefits over Concept F, and certain concepts (e.g. A and B) could potentially be combined, depending on whether DNLEU storage containers were considered transportable in their own right at the time of disposal. Concept F could still be used for minor parts of the DNLEU inventory, e.g.

miscellaneous wastes, assuming that existing grouting plants could be used in such cases.
- The GDF use options provide flexibility and other potential benefits (e.g. in terms of reduced construction requirements at a GDF). However, the evaluation of these is significantly affected by assumptions regarding the feasibility of co-disposal with other wastes and implications for scheduling and costs. The GDF use options could also be combined with vault-based disposal options.

RWM is investigating the possibility of incorporating a change in the reference illustrative concept into the next (2016) update of the generic DSSC. Other work to be reported this year by the uranium IPT includes the following:
- Development of a Generic Specification for packaging DNLEU, considering the preferred conditioning, packaging and disposal concept options.
- Understanding the extent to which disposal concept options that focus on the bulk of the inventory are transferable to LEU, for which criticality safety needs to be considered.
- Identification of the work needed to address any remaining concerns relating to the disposability of DNLEU.

REFERENCES

1 DEPARTMENT OF ENERGY AND CLIMATE CHANGE and NUCLEAR DECOMMISSIONING AUTHORITY, Radioactive Wastes and Materials Not Reported in the 2013 UK Radioactive Waste Inventory. DECC Report URN 14D043 and NDA Report NDA/ST/STY(14)0013 (February 2014).

2 RADIOACTIVE WASTE MANAGEMENT LTD, Geological Disposal: Investigating the Implications of Managing Depleted, Natural And Low Enriched Uranium through Geological Disposal: Progress Report, Report RWM/123 (July 2015).

3 R.D. WILMOT, Integrated Project Team on Uranium: Phase 2 [Task ASS-4]: Post-closure Safety of DNLEU Disposal. Galson Sciences Ltd Report 1207-ASS-4.6 Version 2 for RWM (October 2015).

4 NUCLEAR DECOMMISSIONING AUTHORITY, Geological Disposal: Generic Disposal System Technical Specification. NDA Report NDA/RWMD/044 (December 2010).

ACKNOWLEDGEMENTS

This work was funded by RWM.