



Review of LLW Repository Ltd's 2011 environmental safety case: Issue resolution forms

Issue 1, 15 May 2015

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1. Introduction

This report collates all of the Issue Resolution Forms (IRFs) we raised during our review of the 2011 Environmental Safety Case (ESC) submitted to us by LLW Repository Ltd as required by its Environmental Permit (LLW Repository Ltd 2011a to 2011p).

Our review of the 2011 ESC is documented in a series of technical review reports of which this is one (Environment Agency 2015a to 2015i). Each of our technical review reports provides further information on our approach to the review and our assessment of the adequacy of the 2011 ESC against our requirements, which are detailed in our Guidance on Requirements for Authorisation: Near-Surface Disposal Facilities on Land for Solid Radioactive Wastes (the GRA) (Environment Agencies 2009). A high level summary of our review can be found in our Non-technical Summary report (Environment Agency 2015a) and a fuller overview in our Overview report (Environment Agency 2015b). Environment Agency (2015b) provides a fuller explanation of our review process and how these forms were used. This report should be read in conjunction with the originating technical review reports (Environment Agency 2015c to 2015g).

IRFs are detailed records of concerns and queries raised during our review of the 2011 ESC. Each IRF defines one or more actions. We asked LLW Repository Ltd to provide a substantive response to the action(s) specified in the IRF by a specified date(s).

Table 1 describes the IRF classification used for our review of the 2011 ESC. Each Regulatory Issue (RI), Regulatory Observation (RO) and Technical Query (TQ) is reproduced in Appendix 1, 2 and 3 respectively.

Table 1 Issue Resolution Form categories

Issue Resolution Form category	Explanation
Regulatory Issue (RI)	A Regulatory Issue is a deficiency sufficiently serious that, unless or until it is resolved, we will either: (a) not grant a permit; or (b) grant a permit constrained by major limiting conditions (as distinct from information or improvement conditions) defined by us to mitigate the consequences of the RI.
Regulatory Observation (RO)	A Regulatory Observation is a deficiency not sufficiently serious to prevent our issuing a permit but sufficiently serious that, unless or until it is resolved, we will include an improvement or information condition in the permit requiring defined actions on defined timescales to resolve it (or to demonstrate suitable and sufficient progress towards resolving it). Relatively minor but related ROs may be grouped into a single improvement or information requirement. (We may also apply minor limiting conditions in the permit until it has been resolved.) An RO can become an RI if the condition is not met.
Technical Query (TQ)	A Technical Query is a deficiency not sufficiently serious for us to require defined action by LLW Repository Ltd but sufficiently significant for us to request action. An individual TQ is unlikely to become an RO even if not addressed, but a number of unresolved TQs may accumulate into an RO.

The IRFs are linked to our technical review reports using the following form of referencing:

- ESC-XX-SCM-xxx: Safety Case Management (Environment Agency 2015c)
- ESC-XX-INF-xxx: Inventory and Near Field (Environment Agency 2015d) or Optimisation and Engineering (Environment Agency 2015f)

- ESC-XX-SUE-xxx: Site Understanding (Environment Agency 2015e)
- ESC-XX-ASO-xxx: Optimisation and Engineering (Environment Agency 2015f) or Assessments (Environment Agency 2015g)

The IRFs are not sequentially numbered. This is because some IRFs were identified as possible queries but not issued, for example, following further detailed review of information provided in support of the 2011 ESC, or following on from clarifications provided by LLW Repository Ltd.

Issues were closed only when we had determined that the LLW Repository Ltd response adequately addresses the issue. Each IRF records the interactions between us and LLW Repository Ltd. By the completion of our review of the 2011 ESC, all of the IRFs were satisfactorily addressed and closed. Additional information provided by LLW Repository Ltd in response to an IRF is referenced in the form and available at the time of writing on the LLW Repository Ltd website (<http://llwrsite.com/national-repository/key-activities/esc/>).

2. References

- Environment Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2009. Near-Surface Disposal Facilities on Land for Solid Radioactive Wastes: Guidance on Requirements for Authorisation, February 2009.
- Environment Agency, 2015a. Review of LLW Repository Ltd's 2011 Environmental Safety Case: Non-technical Summary. Issue 1.
- Environment Agency, 2015b. Review of LLW Repository Ltd's 2011 Environmental Safety Case: Overview. Issue 1.
- Environment Agency, 2015c. Review of LLW Repository Ltd's 2011 Environmental Safety Case: Safety Case Management. Issue 1.
- Environment Agency, 2015d. Review of LLW Repository Ltd's 2011 Environmental Safety Case: Inventory and Near Field. Issue 1.
- Environment Agency, 2015e. Review of LLW Repository Ltd's 2011 Environmental Safety Case: Site Understanding and Evolution. Issue 1.
- Environment Agency, 2015f. Review of LLW Repository Ltd's 2011 Environmental Safety Case: Optimisation and Engineering. Issue 1.
- Environment Agency, 2015g. Review of LLW Repository Ltd's 2011 Environmental Safety Case: Assessments. Issue 1.
- Environment Agency, 2015h. Review of LLW Repository Ltd's 2011 Environmental Safety Case: Forward Issues. Issue 1.
- Environment Agency, 2015i. Review of LLW Repository Ltd's 2011 Environmental Safety Case: Issue Assessment Forms. Issue 1.
- LLW Repository Ltd, 2011a. The 2011 Environmental Safety Case. Addressing the GRA. Repository Ltd Report LLWR/ESC/R(11)10031.
- LLW Repository Ltd, 2011b. The 2011 Environmental Safety Case. Main Report. LLW Repository Ltd Report LLWR/ESC/R(11)10016.
- LLW Repository Ltd, 2011c. The 2011 Environmental Safety Case. Management and Dialogue. LLW Repository Ltd Report LLWR/ESC/R(11)10017.
- LLW Repository Ltd, 2011d. The 2011 Environmental Safety Case. Inventory. LLW Repository Ltd Report LLWR/ESC/R(11)10019.
- LLW Repository Ltd, 2011e. The 2011 Environmental Safety Case. Near Field. LLW Repository Ltd Report LLWR/ESC/R(11)10021.
- LLW Repository Ltd, 2011f. The 2011 Environmental Safety Case. Optimisation and Development Plan. LLW Repository Ltd Report LLWR/ESC/R(11)10025.
- LLW Repository Ltd, 2011g. The 2011 Environmental Safety Case. Engineering Design. LLW Repository Ltd Report LLWR/ESC/R(11)10020.
- LLW Repository Ltd, 2011h. The 2011 Environmental Safety Case. Hydrogeology. LLW Repository Ltd Report LLWR/ESC/R(11)10022.
- LLW Repository Ltd, 2011i. The 2011 Environmental Safety Case. Site Evolution. LLW Repository Ltd Report LLWR/ESC/R(11)10023.
- LLW Repository Ltd, 2011j. The 2011 Environmental Safety Case. Monitoring. LLW Repository Ltd Report LLWR/ESC/R(11)10024.
- LLW Repository Ltd, 2011k. The 2011 Environmental Safety Case. Environmental Safety during the Period of Authorisation. LLW Repository Ltd Report LLWR/ESC/R(11)10027.
- LLW Repository Ltd, 2011l. The 2011 Environmental Safety Case. Assessment of Long-term Radiological Impacts. LLW Repository Ltd Report LLWR/ESC/R(11)10028.

LLW Repository Ltd, 2011m. The 2011 Environmental Safety Case. Assessment of Non-radiological Impacts. LLW Repository Ltd Report LLWR/ESC/R(11)10029.

LLW Repository Ltd, 2011n. The 2011 Environmental Safety Case. Assessment of Impacts on Non-human Biota. LLW Repository Ltd Report LLWR/ESC/R(11)10030.

LLW Repository Ltd, 2011o. ESC Forward Programme. LLW Repository Ltd Report LLWR/ESC/R(11)10040.

LLW Repository Ltd, 2011p. The 2011 Environmental Safety Case. Waste Acceptance Criteria. LLW Repository Ltd Report LLWR/ESC/R(11)10026.

Appendix 1: Regulatory Issues

IRF Number	Title
ESC-RI-SCM-001b	Maintenance of ESC expertise and knowledge
ESC-RI-SCM-002	Engagement with national stakeholders
ESC-RI-INF-001	Impact of 2010 National Inventory
ESC-RI-INF-002	Impact of grout on leachate composition
ESC-RI-INF-005	Container condition monitoring and sampling programme
ESC-RI-ASO-001	Optimisation of vault sequencing
ESC-RI-ASO-002	Optimisation of vault operational conditions
ESC-RI-ASO-003	Optimisation of disposal system in relation to possible future waste retrieval or facility protection
ESC-RI-ASO-005	Assessment of impacts of C-14 bearing gases
ESC-RI-ASO-006	Very long term impacts if the LLWR does not erode
ESC-RI-ASO-007	Deriving WAC for groundwater pathway
ESC-RI-ASO-010	Inventory heterogeneity and PEGs in coastal erosion dose assessments
ESC-RI-ASO-011	Inventory heterogeneity and events in human intrusion dose assessments
ESC-RI-ASO-012	Marine foodstuffs pathway
ESC-RI-ASO-013	Human intrusion into radioactive sources
ESC-RI-ASO-014	Doses during the period of authorisation

ESC-RI-SCM-001b: Maintenance of ESC expertise and knowledge

Title	Maintenance of ESC expertise and knowledge
Date original IRF raised (ESC-RI-SCM-001)	30/09/2011
Date raised	20/12/2012
Acknowledgment required by	04/01/2013
Response required by	01/02/2013
Related issue numbers	ESC-RI-SCM-001
Originated by	Environment Agency
Current owner	Environment Agency
Review group	SCM
Approved by	Environment Agency

History

Status	Date	Description
Raised	30/09/2011	
Acknowledged	14/10/2011	
LLWR Response	16/12/2011	
Response Assessed	18/12/2012	
Further actions raised	20/12/2012	Further action raised (ESC-RI-SCM-001b.A1)
Acknowledged	20/12/2012	
LLWR Response	27/02/2013	
Response Assessed	10/02/2014	
Transferred	10/02/2014	
Closed	10/02/2014	

Statement of Regulatory Issue

The Environmental Safety Case (ESC) is a large and complex body of work developed over many years by a range of technical experts. The ESC is central to the management of the site and affects how it develops and is operated. It is important that the ESC is maintained and kept up to date in the light of site developments and of advances in understanding and technology, and that it can be effectively interpreted and communicated internally and externally so that the implications for the ESC of changes to the site or its operation can be fully understood before such changes are made.

A key expectation of an organisation disposing of radioactive waste is that it maintains a positive environmental safety culture and a management system and resources to enable it to plan and control work, ensure sound science and engineering are applied, provide information, maintain records and ensure quality management. To achieve this, the organisation must operate with sufficient expert knowledge and ensure adequate knowledge retention and succession planning is in place.

During the early stages of production of the latest ESC, during 2006 to 2007, we raised a number of concerns with the then operators of the site regarding the knowledge and expertise of the team developing the ESC. We believed that insufficient expertise and knowledge was present within the organisation to effectively lead and manage the development of the ESC and to maintain ownership and 'intelligent customer' understanding of it. We believed the operators risked losing control of the ESC development and as importantly a capability to continually manage it once approved.

With the change in management organisation between 2007 and 2008 a largely new team was brought in to manage and deliver the ESC. We considered this team to be sufficient and to provide sufficient defence in depth (numbers) and skills. However, we continued to voice concern that the team largely consisted of contractors and secondees, accepting that key individuals were on long-term contracts and represented a fairly stable team. However, as the ESC production and review comes to an end we have continuing concerns that the ESC team may be largely 'disbanded' and key skills and knowledge will be lost, particularly given that few of the team members are permanent LLWR staff.

We acknowledge that LLW Repository Limited has committed within the ESC to maintain the necessary skills to both operate the site and to maintain the ESC. However, this commitment has not extended to presentation of any specific plans on how expertise and knowledge will be retained, how the team will continue to ensure sound science and engineering are applied and how succession planning will be managed.

The ESC will be a central tool for the management of the LLWR going forward and we expect a fully competent team to be in place to manage and maintain it, one that has been able to retain knowledge from the ESC development. In relation to the ESC we expect there to be a commitment to, and demonstration of how LLW Repository Limited will:

- Maintain knowledge management and ensure knowledge transfer during any transition within the ESC production/maintenance teams
- Remain a capable and forward looking organisation
- Maintain clear roles and responsibilities
- Develop and maintain resources
- Ensure adequate training
- Retain intelligent customer control of the ESC and any contractors supporting it
- Deliver effective succession planning

Regulatory Issue Actions

ESC-RI-SCM-001.A1	LLW Repository Limited shall provide a robust plan of how it will ensure the continual availability to the Site Licence Company of adequate up-to-date expertise and knowledge to maintain, interpret and periodically update the ESC. The plan should address retention of intelligent customer control of the ESC and any contractors and maintenance of knowledge, such as of national and international best practice.
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	14/10/2011
Comment: An appropriate plan will be provided.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	16/12/2011
<p>The LLWR is developing detailed plans to achieve the objectives described above.</p> <p>We are actively considering creating a new combined technical team comprising the environmental and nuclear safety case teams and the monitoring team. The intention would be to create a single overall team capable of developing the environmental and nuclear safety cases and supporting the implementation of the safety cases throughout the site's operations within a single implementation and change control process. Bringing together the ESC and monitoring teams would ensure that there were an integrated team capable of understanding the performance of the facility based on fit-for-purpose monitoring data. This would also provide flexibility in managing workloads between the ESC and monitoring teams. Members of the new overall technical team would perform the Intelligent Customer (IC) roles for the safety cases and monitoring. The intention would be that the team would be of sufficient size and depth to allow individuals to be developed as part of succession planning for IC roles.</p> <p>This new combined technical team would be led by a member of the LLWR's lead team with the necessary experience and expertise, who was either a secondee from the Parent Body Organisation (PBO) (i.e. someone contracted to be on long-term secondment to the LLWR) or, at least in time, a staff member. This would provide the necessary leadership and continuity to the team and provide the assurance that the requirements of the safety cases were being represented at the top management level in the organisation. The intention would also be that the leaders of the safety case and monitoring teams within the overall combined technical team would be staff members, at least in time.</p> <p>Following the formation of the combined team, we would undertake an analysis of the baseline capability required by the team and then, where the required roles could not be filled by existing staff, aim to recruit staff with the necessary skills and experience for the roles, or abilities and aptitudes to develop into the roles, where these are not already filled. Any necessary development of staff would be undertaken as part of our normal staff development processes. In the case of the ESC Project team, we have already recruited one new staff member with the necessary abilities to be a leading member of the team once they have gained sufficient experience. Our intention is to try to recruit further staff to the Project team. Similarly, new staff members have recently been recruited to the nuclear safety case and monitoring teams.</p> <p>We recognise that the transition to the position we wish to achieve in terms of continuity of capability in the ESC area may take some years, particularly recruiting and developing staff. The current ESC Project team comprises mainly a number of highly capable and experienced PBO and contractor staff. There is no reason to think that at least most of these staff will not want and be available to continue to support the LLWR during the period of transition.</p> <p>We recognise that the LLWR is a relatively small organisation compared with those managing many of the other nuclear sites with environmental permits and site licences and there are limits to the 'strength in depth' that can be provided and the succession planning that can be undertaken. Also, the size of the team might need to be increased when major reviews or revisions of the ESC are being undertaken. Our experience also shows that it can be difficult to recruit individuals with the desired skills and experience to West Cumbria. Although it is not our intention to rely on the PBO, it does provide re-assurance that the LLWR will continue to be able to deploy suitably qualified and experienced individuals to support ESC activities. One of our PBO companies has a UK-based department that specialises in the development of ESCs and was closely involved in the development of the 2011 ESC (acting both through the provision of a 'reachback' staff member and as a contractor to the LLWR). This company will continue for the foreseeable future to provide a resource for management of, or for supporting the development and use of, the ESC that could be called upon should the need arise. The other PBO companies also have staff with relevant expertise and experience. This overall experience and expertise played an important</p>		

part in the selection of the PBO, the Nuclear Decommissioning Authority recognising the importance of the ESC to the LLWR.

We are also giving consideration to developing links to universities with courses and research programmes relevant to the ESC and other aspects of company operations. One important aim would be to identify and build relationships with potential recruits.

Our intention is to implement the ESC as a 'live' safety case within our general processes for maintenance of safety cases and formal change control. New procedures will require the ESC to be regularly reviewed. The ESC Project team is also being formally integrated into the processes for development and control of Waste Acceptance Criteria (WAC) and for accepting waste under variations to the WAC. Embedding the ESC into the LLWR's formal processes and procedures will provide an on-going requirement for the existence of staff with the necessary expertise and experience. Clearly, the ESC team needs to be maintained to fulfil the required functions, but the requirement to fulfil these functions will itself help to ensure the ESC team is not allowed to 'fade' away.

The ESC Project team presents on the ESC at national and international conferences. We are involved in international projects, including the IAEA's PRISM Project and the DISPONET initiative, and the BIOPROTA Project. We have also supported the IAEA on the production of their documentation relating to disposal, and have recently been invited to help with one of their training missions. We will continue with these and similar activities. These activities will help to develop further, maintain and keep up to date the knowledge of the ESC Project team of national and international best practice.

All the main contractor companies in the UK specialising in the development of ESCs, including the necessary underpinning technical analyses and impact assessments, were utilised in the development of the 2011 ESC. These companies provide a substantial reservoir of knowledge and expertise on the LLWR's ESC. These companies have all been in existence for many years and there is no reason not to expect that they will continue to be able and will wish to provide support to the LLWR over the coming years. The future programme of work undertaken to further develop and utilise the ESC will continue to require contractor support (albeit at a lower level than has been the case during the development of the 2011 ESC), helping to keep knowledge current within the contracting community.

The above plans give us confidence that, whilst recognising the constraints resulting from the need to draw on a limited pool of expertise in ESCs and the location and size of the LLWR, we will be able to maintain the capability to manage and undertake the development of the ESC and its application to the management of the facility.

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 18/12/2012
Approved by: Environment Agency	Date: 10/01/2013

LLW Repository Ltd has provided a reasonable response to ESC-RI-SCM-001.A1. We believe LLW Repository Ltd has clearly re-iterated a commitment to the development and maintenance of ESC expertise and knowledge in a broad sense and illustrated how they intend to achieve this in practice over the coming years through high level plans.

Since the response was provided to this IRF we have also seen evidence of these high level plans being implemented through:

- Further efforts to recruit technical specialists into the ESC team, including success in recruiting one individual.
- Conversion of the ESC Project Manager from a PBO reachback contractor to a member of permanent staff.
- Further steps being taken to move towards a combined and broadened safety case team.

- Developing and undertaking tendering exercises to secure sufficient contractor support in the areas required, using a tiered approach to ensure the necessary support of specialist contractors.
- Development of lifetime plans taking account of the future needs of the ESC and also requirements resulting from the ESC.

We have also held discussions with LLW Repository Ltd regarding the scale and possible scope of the forward ESC programme to support implementation, but also to address likely 'forward issues' and 'improvements' that the Environment Agency ESC review has and may identify. We believe LLW Repository Ltd recognises this need, but we are yet to see this commitment and associated plans clearly laid down within lifetime plans.

Since this IRF was first responded to we have also seen the transfer of the skills managed by one of the key PBO companies with ESC capabilities to another company outside of the PBO. This has to date been managed with no adverse impacts, however, this illustrates one of the risks presented by reliance upon PBO reachback capabilities. In particular this change does put under threat the continued availability of one key reachback ESC team member.

We are therefore pleased that some further progress has been made, but continue to have some concerns with regards to the LLW Repository Ltd strategy to maintain ESC skills and expertise in the short and long term. We will therefore continue to closely monitor this issue through our routine regulation of the site and also through our interactions on the ESC review. As part of this we would like make the following recommendations:

- LLW Repository Ltd should continue to maintain a live baseline skills understanding and undertake active workforce planning. In particular, LLW Repository Ltd should ensure it has a clear understanding of the range of skills required now and in the longer term to manage, implement, develop and maintain the ESC. This should include the necessary skills to effectively ensure implementation of the ESC at an operational level. This understanding should be documented.
- LLW Repository Ltd should be more proactive in maintaining the necessary contractor support and ensuring that support continues to be available to it. This may for example involve active engagement with contractors on future needs and the timing of that need.
- LLW Repository Ltd should be cautious in its reliance upon PBO reachback support (see Recommendation SCM10). As demonstrated by recent changes this route to access key skills cannot be guaranteed and the PBO could change at any time for a number of reasons. Even if a new PBO could provide similar support there could be a significant loss in the continuity between project team members.

Additionally we believe it is necessary to provide more robust reference to relevant management arrangements that ensure the appropriate management and development of the necessary skills and succession planning.

We therefore raise the following action:

Regulatory Issue Actions

ESC-RI-SCM-001b.A1	<p>Taking account of the further points raised within this IRF, LLWR Ltd should:</p> <ul style="list-style-type: none"> • Provide further details, including reference to relevant procedures (which should also be provided), of how LLW Repository Ltd manage and maintain a live baseline skills understanding and undertake active workforce planning. In particular this should highlight how the necessary skills to manage, implement and maintain the ESC are identified and retained. • LLW Repository Ltd should provide further re-assurance that they are taking appropriate steps to ensure they can maintain access to the necessary contractor skills. • LLW Repository Ltd should provide further re-assurance
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	<p>that they fully understand the risks associated with a change in PBO or the loss of key skills from within the PBO. Also, that they have a robust structure and management system to cope with and manage any such change.</p> <ul style="list-style-type: none"> • Confirm that the ESC and the importance of the skills required to support it are adequately recognised within general site management arrangements, including those skills necessary to ensure effective implementation of the ESC at an operational level. Relevant site procedures should be supplied.
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	20/12/2012
Comment: The further information requested will be provided.		

LLW Repository Ltd Response

LLW Repository Ltd	ESC Project Manager	27/02/2013
<p><i>Provide further details, including reference to relevant procedures (which should also be provided), of how LLW Repository Ltd manage and maintain a live baseline skills understanding and undertake active workforce planning. In particular this should highlight how the necessary skills to manage, implement and maintain the ESC are identified and retained.</i></p> <p>The LLWR has an organisational baseline document along with a corresponding organisational chart, both currently at version 4.22, posted on the company's intranet and available to view by all employees. The baseline lists the key and non-key role holders within the organisation while the organisation chart shows the incumbents to the identified company positions. The baseline and organisation charts are updated approximately monthly to reflect both organisational and appointment changes. The relevant RSP is 11.06.02.</p> <p>The baseline and organisation chart are based on assessments of the technical capability required by individuals, in terms of competence and experience, and the volume of work. These assessments are made by the relevant subject matter experts, taking into account regulatory requirements and work plans.</p> <p>A Strategic Resourcing Committee meets monthly, chaired by the LLWR's MD and attended by the Lead Team (RSM1.0A). This Committee monitors organisational capability, identifying any emerging problems and placing actions to rectify them.</p> <p>At an operational level, the Management of Change process (RSP 11.06) is used to manage organisational changes. It identifies potential resource and capability gaps arising from change and places actions to ensure any deficiencies are addressed.</p> <p>Succession planning is discussed below.</p> <p><i>LLWR Ltd should provide further re-assurance that they are taking appropriate steps to ensure they can maintain access to the necessary contractor skills.</i></p> <p>The LLWR is currently in the process of re-competing its contracts with suppliers for support to the development and application of the ESC. The contracts will cover direct support to the ESC Project team, general technical support, geological and hydrogeological support, and peer review. The contracts will be framework contracts with a duration of four years. The future programme of work to develop and apply the ESC will be undertaken partly utilising these framework contracts. LLWR will be able to maintain access to the necessary contractor skills through these framework contracts.</p> <p><i>LLWR Ltd should provide further re-assurance that they fully understand the risks associated with a change in PBO or the loss of key skills from within the PBO. Also, that they have a</i></p>		

robust structure and management system to cope with and manage any such change.

One of the key duties of the Head of HR and Training is maintaining the Site Licence Company (SLC) capability to be able to fulfil regulatory requirements without non-SLC involvement. This is often difficult given the small size of the organisation and the limited capability in some areas that a small organisation brings.

The company has two succession plans in place. The first is a key role plan that identifies cover for all the organisational roles identified as required to operate within the regulatory framework. The second is a business succession plan that identifies a successor for all the Lead Team, Band 3 and key Band 4 positions within the SLC. Where we are unable to identify an SLC successor in either of these succession plans, the Lead Team will consider the implications at the monthly Strategic Resourcing Committee meeting and set actions to address the shortfall.

Confirm that the ESC and the importance of the skills required to support it are adequately recognised within general site management arrangements, including those skills necessary to ensure effective implementation of the ESC at an operational level. Relevant site procedures should be supplied.

In addition to the replies given above, it is noted that the consideration of the formation of a new technical team, reported in the earlier response, has led to the creation of a new Science and Engineering team. This new team combines the ESC Project team, the monitoring team, the nuclear safety case team, and the Chief Engineer's team. This new team will provide centralised and resourced support to the maintenance and implementation of the site's safety cases, including the ESC.

A formal plan for overall implementation of the ESC has been developed and implementation according to the plan is underway. The formal processes and procedures necessary to implement the ESC will be developed. These new processes and procedures will require formal implementation plans. The formal implementation process will reveal if there are any gaps in resources or capability necessary for the application of the ESC.

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 10/02/2014
Approved by: Environment Agency	Date: 10/02/2014

The above responses provide further re-assurance that LLW Repository Ltd is adequately aware and taking suitable actions to address and maintain adequate expertise and knowledge in relation to the ESC.

We asked how LLW Repository Ltd was maintaining a live baseline skills understanding and undertaking active workforce planning. Evidence has been provided that an organisational baseline is actively and regularly managed and that relevant procedures are in place to help achieve this. Monthly Strategic Resourcing Committee meetings were identified as one mechanisms used to review and maintain adequate skills and to monitor organisational capability. Robust management of change processes are in place to address change and how it may impact upon resource and capability needs. Overall we consider that adequate management arrangements are in place to maintain a live baseline skills understanding.

Having recognised that LLW Repository Ltd has in the past been heavily reliant upon contractor skills and remains so to some extent, we sought re-assurance that steps were being taken to maintain access to these contractor skills in the longer term. LLW Repository Ltd has confirmed that it is re-competing its contracts for support to the ESC for a period of 4 years.

We asked LLW Repository Ltd to indicate how it manages risks associated with the potential loss of skills from a change of PBO. In response LLW Repository Ltd has identified a key responsibility of their Head of HR and Training to maintain SLC capability to achieve regulatory requirements

without non-SLC involvement. Additionally, two succession plans have been identified, along with the use of a Strategic Resourcing Committee to address any identified shortfalls.

To address our queries about the adequacy of LLW Repository Ltd's management arrangements in recognising ESC skills requirements and skills required for operational implementation, reference has been made to the formation of a new Science and Engineering Team and a developing implementation plan. We welcome the formation of the new Science and Engineering Team as a new centralised and more flexible/robust resource to support and help implement the ESC. We are aware of the ESC implementation plan and have been regularly updated on progress with it. We accept that this plan can lead to the identification of any gaps in resources or capability necessary for ESC implementation.

Overall, we believe this response has adequately addressed our comments and provided further re-assurance that the necessary expertise and knowledge can be maintained to support and implement the ESC. This RI has therefore been adequately addressed and can be closed.

However, we recognise that LLW Repository Ltd is a relatively small organisation that cannot reasonably maintain a large pool of ESC skills. Additionally, other challenges LLW Repository Ltd faces are recognised, such as difficulties in recruiting into specialist posts and maintaining capabilities between major ESC reviews. For this reason we recommend that LLW Repository Ltd pays particular attention to the maintenance of skills and capabilities associated with maintenance and implementation of the ESC, ensuring adequate defence in depth and succession planning is in place (Recommendation SCM11 of Environment Agency 2015, Review of LLW Repository Ltd's 2011 Environmental Safety Case: Safety Case Management). Furthermore, we recommend that continuing efforts are made to ensure access to relevant contractor skills and capabilities which may only be required on a periodic basis (Recommendation SCM12 of Environment Agency 2015, Review of LLW Repository Ltd's 2011 Environmental Safety Case: Safety Case Management).

Actions completed, Regulatory Issue resolved and Form closed

Owner: Environment Agency	Date: 10/02/2014
Approved by: Environment Agency	Date: 10/02/2014

ESC-RI-SCM-002: Engagement with national stakeholders

Title	Engagement with national stakeholders
Date raised	30/09/2011
Acknowledgment required by	14/10/2011
Response required by	31/12/2011
Related issue numbers	ESC-TQ-SCM-003
Originated by	Environment Agency
Current owner	Environment Agency
Review group	SCM
Approved by	Environment Agency

History

Status	Date	Description
Raised	30/09/2011	
Acknowledged	14/10/2011	
LLWR Response	16/12/2011	
Response Assessed	16/07/2013	
Transferred	19/11/2013	
Closed	21/11/2013	

Statement of Regulatory Issue

The GRA makes clear that we expect developers of disposal facilities to engage widely in dialogue on their developing ESC. LLW Repository Limited have provided evidence of significant engagement at a number of levels such as with the NDA, PBO, Planning Authority, regulators, local communities, customers and a range of national and international organisations such as NuLeaf, the NDA National Stakeholder Group, Government and international technical bodies.

LLW Repository Limited has demonstrated some good practice in this area, such as organisation of community open days at the LLWR. We also note that LLW Repository Limited have communicated with a wide range of stakeholders regarding the issue of the ESC via a communiqué issued shortly after the ESC was submitted to the Environment Agency. Furthermore, the LLWR web site has been redeveloped to present the ESC openly.

However, one area of engagement we believe warrants additional effort is in relation to local and national NGOs, for example Greenpeace, Friends of the Earth and Radiation Free Lakeland. These are examples of groups that are recognised as having an active interest in the disposal of radioactive waste. The GRA states that engagement should include “other interested parties and the general public”.

We acknowledge that efforts have been made to communicate with these groups. However, given their limited resource and likely interest, we believe further efforts should be made to engage with such groups, along with any broader members of the general public or interest groups who may wish to engage further with LLW Repository Limited’s plans and subsequently our consultation on the anticipated permit application. In particular we would wish to see efforts to engage with such groups openly, inclusively and constructively prior to any permit variation application and as necessary thereafter to ensure effective dialogue.

Regulatory Issue Actions

ESC-RI-SCM-002.A1	LLW Repository Limited shall provide a plan of action to engage in dialogue with a broader set of national and local stakeholders. This plan should cover activities up to and during any permit variation consultation and determination.
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	14/10/2011
Comment: A plan for appropriate engagement will be provided.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	16/12/2011
<p>This response sets out our plans for continuing stakeholder engagement during the period of the Environment Agency's review of the 2011 ESC and our application for a new permit, and the subsequent due process.</p> <p>We will continue with our general engagement with stakeholders, which includes engagement on the 2011 ESC and the related planning application. Stakeholders include our regulators, local politicians, local council officers, members of the public, consignors, contractors and the NDA and other national bodies. Formal fora include, amongst others, the NDA National and West Cumbria Sites Stakeholder Group, the LLWR Site Stakeholder Group and the national LLW Implementation Group.</p> <p>In addition, we will make further attempts to engage with national and local NGOs with an interest in radioactive waste disposal. We will write to these NGO groups inviting them to visit the LLWR site to receive presentations on the LLWR, ESC and the related planning application, and take a tour of the site. We will also offer to visit the groups to make the presentations and discuss any areas of interest or concern.</p> <p>We will also run a one-day 'open day' at a local venue, possibly Drigg Village Hall, to enable interested members of the general public to engage with the ESC Project team on the ESC. We will advertise the open day on our website, the West Cumbria(s) Stakeholder Group website and in the local press, and write to individual local stakeholders informing them of the event.</p> <p>In addition, we plan to produce a leaflet to raise awareness of the ESC. The leaflet will be distributed to the immediate local community (Drigg and Carleton, Seascale and Gosforth Parishes) and made available as part of our literature at meetings, exhibitions and conferences.</p> <p>We plan to complete these additional engagement activities before the summer of 2012.</p> <p>Prior to the submission of our application for a revised permit, we will discuss with the Agency the best way to alert stakeholders to our submission. This may be that LLWR again writes to the same wide range of local, regional, national and international stakeholders as we did at the time the 2011 ESC was submitted to the Agency and made available on our website. Again, we would offer presentations or meetings with the objective of helping stakeholders respond to the Agency's public consultations on the submission and Agency's decision. We will also engage with stakeholders on the submission through our continuing general engagement programme referred to above.</p>		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 16/07/2013
Approved by: Environment Agency	Date: 21/11/2013

This Regulatory Issue (RI) sought a further plan of action from LLW Repository Ltd to ensure local and national stakeholders were made aware of the ESC and permitting process and were able to contribute if they wished.

In response LLW Repository Ltd has detailed a number of actions which addressed our concerns. In particular we note that LLW Repository Ltd wrote to a range of local and national stakeholders to increase their awareness and offer further information and in addition an 'open day' was held in September 2012 to allow questions to be asked around the ESC. The 'open day' was widely advertised.

We believe LLW Repository Ltd has responded adequately to this RI and has demonstrated an enhancement of its ongoing engagement plans. This RI can be closed.

Actions completed, Regulatory Issue resolved and Form closed

Owner: Environment Agency	Date: 21/11/2013
Approved by: Environment Agency	Date: 21/11/2013

ESC-RI-INF-001: Impact of 2010 National Inventory

Title	Impact of 2010 National Inventory
Date raised	05/09/2011
Acknowledgment required by	16/09/2011
Response required by	31/12/2011
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	INF
Approved by	Environment Agency

History

Status	Date	Description
Raised	05/09/2011	
Acknowledged	16/09/2011	
LLWR Response	19/03/2012	
Response Assessed	28/06/2013	
Transferred	03/07/2013	
Closed	03/10/2013	

Statement of Regulatory Issue

The forward inventory assumed for the 2011 ESC derives fundamentally from the 2007 edition of the UK Radioactive Waste Inventory, which was the most recent at the time of LLW Repository Ltd's data freeze in April 2010. The 2010 edition of the Inventory has subsequently been published, and we expect the ESC to be consistent with the inventory projections as reflected in this latest version.

Regulatory Issue Actions

ESC-RI-INF-001.A1	LLW Repository Ltd shall provide an assessment of the implications of the 2010 UK Radioactive Waste Inventory for the ESC and a demonstration that the ESC (as amended if necessary) is consistent with the best available information on future waste arisings.
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	16/09/2011
<p>Comment: We are in the process of procuring contractor support to help us undertake an assessment of the implications of the 2010 UK Radioactive Waste Inventory for the 2011 ESC. We intend to provide this assessment to the Agency. Our intention, in this assessment, is to update our inventory model (PIER) and then use simple scaling calculations and judgements, possibly supported by some more detailed calculations, to reach conclusions about the implications for the overall conclusions drawn in the 2011 ESC. We are not intending to change design data (as would be required for a different volume inventory in the</p>		

Extended Disposal Area repository) and undertake a complete set of revised underpinning and assessment calculations for the 2010 inventory.

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	19/03/2012
A response is provided in report: <i>Updated Assessment Calculations based on the 2010 UK Radioactive Waste Inventory</i> , LLWR/ESC/R(12)10045, Issue 1, March 2012. This report is based on a review of the 2010 Inventory, reported in: <i>A Forward Inventory for LLWR based on the 2010 UKRWI</i> , Issue 3, March 2012. The PIER workbooks have also been updated for the new inventory for the four inventory cases considered in the 2011 ESC.		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 28/06/2013
Approved by: Environment Agency	Date: 24/09/2013

The RI questioned the impact of the 2010 UKRWI inventory on the inventory to be disposed of to the LLWR. We asked LLW Repository Ltd to assess the impacts on the inventory and also what the potential impacts any changes to the inventory would have on the risk via the various assessment pathways within the 2011 ESC.

LLW Repository Ltd has provided an assessment of the impacts of the 2010 UKRWI on the inventory within the ESC. We note the review of the UKRWI has identified no significant changes that will impact on the ESC. Assessment calculations have also been undertaken, and no significant implications on the ESC have been observed.

We note that no review of the non-radiological inventory has been undertaken with regards to the 2010 UKRWI. However, we note that LLW Repository Ltd is liaising with Radioactive Waste Management (RWM) and the Nuclear Decommissioning Authority (NDA) to try to improve reporting of the non-radiological component of the inventory.

We are satisfied at present with LLW Repository Ltd's treatment of this RI. This RI is now closed.

Actions completed, Regulatory Issue resolved and Form closed

Owner: Environment Agency	Date: 30/09/2013
Approved by: Environment Agency	Date: 03/10/2013

ESC-RI-INF-002: Impact of grout on leachate composition

Title	Impact of grout on leachate composition
Date raised	03/04/2012
Acknowledgment required by	30/04/2012
Response required by	10/06/2012
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	INF
Approved by	Environment Agency

History

Status	Date	Description
Raised	03/04/2012	
Acknowledged	04/04/2012	
LLWR Response	18/04/2012	E mail comments received from LLWR Ltd. Modifications to the text and the submission schedule have been made to take account of LLWR Ltd's comments. Re-drafted RI sent to LLWR Ltd 29/04/2012.
Acknowledged	02/05/2012	
Response Assessed	02/07/2012	
Transferred	02/08/2014	
Closed	13/11/2014	

Statement of Regulatory Issue

The LLWR facility utilises a disposal system which places Low Level Wastes in containers, the containers are then filled with a liquid grout with the specific objective of encasing the waste items and forming a solid mass throughout the container. The amount of grout within a container will vary from 10% to 80% with an average of 40% by weight of the total vault contents. The ESC itself utilises an estimated total volume of 631905 m³ of grout in GoldSim model input parameters.

The emplaced grout plays a vital role in the LLWR environmental safety case for the following reasons:

- it physically stabilises the waste reducing settlement as a result of waste degradation
- it provides low permeability containment for waste items and prevents the waste items from becoming saturated prior to the placement of the final cap. This will slow the migration rate of leachates and minimise leachate generation during the pre capping operational period.
- it provides chemical attenuation and containment of radioactive leachate derived from the waste

The grout used in the vaults comprises of a mixture of 3 parts Pulverised Fuel Ash (PFA) to 1 part Ordinary Portland Cement (OPC) together with performance enhancing additives. The two main components of the grout have the potential to produce a number of hazardous¹ and non hazardous compounds as a result of the leaching process which take place in the repository. Of greatest concern would be the PFA component of the grout.

Chemical	Units	PFA	
		Minimum	Maximum
Aluminium	% w/w	24	26
Aluminium	mg/kg		
Aluminium oxide	% w/w		
Antimony	mg/kg	1	325
Arsenic	mg/kg	4	128
Barium	mg/kg	0	36,000
Barium oxide	% w/w		
Beryllium	mg/kg	0.2	9.1
Boron	mg/kg	5	310
Cadmium	mg/kg	<0.1	4
Calcium	% w/w	5.3	5.7
Calcium	mg/kg		
Calcium oxide	% w/w		
Carbon	mg/kg		
Chloride	mg/kg	0	2,990
Chromium	mg/kg	16	220
Cobalt	mg/kg	2	115
Copper	mg/kg	10	474
Fluoride	mg/kg	0	230
Fluorine	mg/kg		
Gold	mg/kg		
Iron	% w/w	7.7	9.5
Iron	mg/kg		
Iron oxide	% w/w		
Lead	mg/kg	<1	976
Magnesium	% w/w	2.1	2.6
Magnesium	mg/kg		
Magnesium oxide	% w/w		
Manganese	mg/kg	0.27	1,600
Manganese oxide	% w/w		
Mercury	mg/kg	<0.01	1.3
Molybdenum	mg/kg	<2	81
Nickel	mg/kg	8.3	583
Phosphorous	mg/kg	262	2,818
Phosphorous	% w/w	0.6	2.1
Phosphorous pentoxide	% w/w		

¹ Please note that we are currently investigating the potential environmental impacts of Chromium VI associated with PFA. As this information becomes available we will make it available to assist with resolving this Regulatory Issue.

Chemical	Units	PFA	
		Minimum	Maximum
Potassium	% w/w	1.9	3.4
Potassium	mg/kg		
Potassium oxide	% w/w		
Selenium	mg/kg	<1	162
Silica	% w/w		
Silicon	% w/w	48	56
Silicon	mg/kg		
Silver	mg/kg	0.126	0.126
Sodium	% w/w	0.7	1.1
Sodium	mg/kg		
Sodium oxide	% w/w		
Sulphur	% w/w	0.9	1.1
Sulphur	mg/kg		
Sulphur trioxide	% w/w		
Thallium	mg/kg	0.374	0.374
Tin	mg/kg	<2	1847
Titanium	% w/w	1	1.1
Titanium	mg/kg		
Titanium dioxide	% w/w		
Total sulphate	mg/kg	1,600	4,240
Uranium	mg/kg	3.65	3.65
Vanadium	mg/kg	44	1,339
Zinc	mg/kg	43.3	919

Table 1 Typical Pulverised Fuel Ash Composition (Reference 1)

Element/species	WQS (mg/l)	Highest experimental leachate concentration (µg/l)	Required dilution
Al	200	58,600	293
As	10	299	30
B	1000	900	-
Ba	1000	33,100	33
Ca	250,000	778,000	3
Cd	5	40	8
Cr	50	549	11
Fe	200	120	-
Hg	1	0.5	-
K	12,000	2640,000	220
Li	25,000	27,600	-
Mg	50,000	250	-
Mn	50	15	-
Mo	70	7000	100
Na	200,000	857,000	4.3
Ni	20	101	5
P	2200	800	-
Pb	25	2070	83
Sb	5	11	2
Se	10	265	26
Sn	25	7	-
Sr	-	74,100	-
V	20	1030	50
Zn	5000	1830	-
Cl ⁻	250,000	3,450,000	13
SO ₄ ²⁻	250,000	213,000	-
NO ₃ ⁻	50,000	10,300	-
pH	10		-

Table 2 Peak ion concentrations in leachate (BRW Report 220192) (Reference 2)

The tables above show typical composition of a PFA product and the derived leachate from a PFA/OPC mixture used for mine stabilisation (Ref.1 & 2). Literature sources state that approximately 2% of PFA is typically soluble in water².

² Linton R W., Williams P, Evans C A Jr and Natusch D F S, 1977 Determination of the surface predominance of toxic elements in airborne particles by ion microprobe mas spectrometry and auger electron spectrometry, Analytical Chemistry, 49 (11), 1514-1521.

We are confident that the presence of significant volumes of grout within the vault will influence the composition of the resultant leachate collected from the vaults and potentially changes the outputs from the presented ESC groundwater assessment. These changes will influence both the composition and chemical characteristics of the vault leachate. Existing experimental work used to support the understanding of near field process, do take account of the presence of and impact of grout. In most cases the experiments consider the impact of the grout on the chemical environment within the waste mass. By widening the characterisation of and quantifying the amount of individual leachable components of the grout it may be possible to gain a greater understanding of the impact of the presence of large volumes of grout on near field and groundwater processes.

In order to provide a realistic future leachate assessment we would expect the output leachate to be realistic and representative of all of the contents of the vaults. Consequently, the leachate assessment needs to take account of the presence of all hazardous and non-hazardous leachable components of the grout.

Useful References

1. Pulverised Fuel Ash and Furnace Bottom Ash; A technical Report on the Manufacture of Products from Pulverised Fuel Ash (PFA) and Furnace Bottom Ash (FBA) Environment Agency & WRAP.
2. Stabilising Mine Workings with PFA Grouts; Environmental Code of Practice: BRE Construction Division, 2006.

Regulatory Issue Actions

ESC-RI-INF-002-A1	LLWR Ltd should supply an up to date material specification sheet for all ingredients of the current PFA formulation. For the PFA element of the grout, the source of the material should be supplied if possible together with any quality information supplied by the manufacturer. (By 10 th June 2012)
ESC-RI-INF-002-A2	Please develop and provide a detailed work programme to derive a representative leachate composition for the Vault disposals The programme should identify the scope and objective of desk and laboratory trials as well as identifying the laboratory methods being used to undertake the work. (By 10 th June 2012) It is accepted that the delivery of this programme may take some time, with desk derived information being available to allow us to appropriately assess the environmental consequences of the authorised disposals.

LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	02/05/2012
<p>Comment: We will aim to give a response on the detailed work programme well before the required date. We anticipate that our programme to address this Issue will include the following elements:</p> <ul style="list-style-type: none"> • Determine composition or range of compositions of PFA used at LLWR in grout. • Review and summarise current position on the effect of grout on bulk vault chemical conditions and leachate composition. • Undertake revised 'non-rad' assessment calculations including components of PFA using standard solubility limitation and equilibrium sorption modelling. • Specify (if required and in association with the Agency) and undertake experimental work on grout leaching using either a standard leaching test or a bespoke approach. • Undertake revised 'non-rad' assessment calculations using experiment leaching data (if 		

required).

Please note that we do not intend to decide on the need for a leaching test and its design until we have assessed the need based on our standard modelling approach, i.e. if calculated releases are deemed unacceptably high, we would go on to try and make our modelling less cautious through the use of the results of a leaching test. This means that our initial work programme will not include detailed proposals for a leaching test; however, we hope to complete the initial review and first set of calculations within a few weeks (depending on the availability of contractors).

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	02/07/2012
Action A1		
LLWR grout comprises OPC, PFA and a plasticiser Sikament 10. For completeness, information available on all ingredients is provided.		
The OPC is supplied by Hanson Cement. Please find attached OPC specific and a general cement data sheets.		
The PFA is supplied by CEMEX and is EN 450-1 fineness category N or S. Data sheets for category N and S are attached along with a general PFA data sheet. The data sheets do not provide detailed chemical compositions. The PFA comes almost exclusively from Drax, but if Drax is in an outage period the PFA is sourced from Cottam or West Burton.		
The plasticiser comes from Sika and is Sikament 10. A data sheet for Sikament 10 is attached (it is dated 2005, but is the most up-to-date version available). This product is not widely used and is being phased out over the next few months. A replacement is being investigated for suitability.		
Action A2		
A work programme is set out in ESC Project Technical Specification: Assessment of the Non-radiological Impacts from Leaching of LLWR Grout, LLWR/ESC/SPE(12)100, which is attached.		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 23/07/2013
Approved by: Environment Agency	Date: 24/09/2013

The 2011 ESC did not take account of leachable hazardous substances and non-hazardous pollutants that will be derived from the presence of the large volumes of grout used in the repository vaults. We sought confirmation of the nature of leachates and the significance of them in the resulting discharges to groundwater.

We requested a staged assessment approach with the use of desk-based information to assess the significance of the leachable components of the grout. A desk-based approach is suitable to provide a short-term assessment, in the longer-term it is reasonable to use site derived leachate information where possible.

With regard to Action ESC-RI-INF-002-A1, LLW Repository Ltd has supplied the relevant data sheets that provide the information requested within the action. It has also provided hazard data sheets for the components of the grout. Thus we assess this action as completed and no further action is required.

With regard to Action ESC-RI-INF-002-A2, LLW Repository Ltd has undertaken a literature review and assessment of the composition the grout, and its likely effect on non-radiological impacts. LLW Repository Ltd has identified relevant experimental leaching data provided by the Building Research Establishment (BRE). BRE undertook both batch and column tests on a number of grout mixtures to assess the components that leach from the grout and has measured the leaching characteristics over a number of bed volumes. LLW Repository Ltd has compared, for each of the leaching elements, how the LLWR grout would compare with the leaching characteristics identified by the BRE.

We note that no experimental work has been performed on LLWR grout to assess whether the leaching data provided by the BRE are appropriate for the LLWR grouts. However, from comparison of the grout compositions, the BRE data appear to provide a reasonable analogue for LLWR grout.

LLW Repository Ltd adapted its non-radiological hydrogeological risk assessment model to use the data provided by BRE to assess the potential impact of the non-radiological components of the grout. The modelling used contaminant concentrations based on the most conservative of the leaching test results, so the modelling results should err on the side of caution. The assessment demonstrated that the relevant Water Quality Standards (WQSs) are not exceeded by any of the contaminants, with only vanadium coming close to its WQS. The results indicate that the main source of non-radioactive contamination from the LLWR is associated with the disposed waste as opposed to the grout material and the PFA therein.

Uncertainty remains over the dominant form of chromium released via leaching from PFA. We note that hexavalent chromium is classified by the Joint Agencies Groundwater Directive Advisory Group (JAGDAG) as an interim hazardous substance. It is therefore important that LLW Repository Ltd maintains awareness of current understanding of chromium leaching as well as the classification of various forms of chromium as hazardous substances.

The quoted output from the hydrogeological risk assessment does not provide an indication as to whether the peak concentrations from the PFA and the disposed inventory coincide or whether they occur at different timescales. The use of timescale graphical outputs would clarify this.

From the presented data we accept that LLW Repository Ltd has demonstrated, using desk based information and the ESC hydrogeological risk assessment model, that the PFA is limited in terms of impact on groundwater. However, we expect LLW Repository Ltd to confirm that the leachability of the LLWR grout is as predicted from the graphs produced by the BRE to ensure that the model data is applicable. LLW Repository Ltd should also monitor the leachate from the vaults to ensure that the leachate data do not indicate any significant difference from the modelled data.

As a result of this Regulatory Issue (RI), we have made a number of recommendations to LLW Repository Ltd:

- We would like to see a future experimental programme consider leaching experiments using site-derived grout samples in order to confirm the appropriateness of the BRE experimental results (see Recommendation INF28 of Environment Agency 2015, Review of LLW Repository Ltd's 2011 environmental safety case: Inventory and near field).
- We expect the leachable constituents of the grout to be included in the vault source term for future updates to the hydrogeological risk assessment to demonstrate the overall impact of the facility on receiving groundwater (see Recommendation ASS36 of Environment Agency 2015, Review of LLW Repository Ltd's 2011 environmental safety case: Assessments).
- The forward environmental monitoring programme should consider continuing regular sampling of leachates derived from the vault areas. Periodic sampling of vault leachate should be carried out up to and following final capping in order to identify any long-term changes in the composition of leachate associated with grout leaching. Analysis should include an appropriate suite of hazardous substances and non-hazardous pollutants, corresponding with substances likely to be in the waste, containers and the grout.
- LLW Repository Ltd should maintain awareness of any changes in the designation of hazardous substances by JAGDAG, including chromium in its various leachable forms (included in ESC-FI-006).

- Due to changes in manufacturing processes the composition of major grout ingredients will change. When this occurs, we would recommend that LLW Repository Ltd confirm that the leachate composition will not significantly change such that it may impacts upon the assessment outcomes (see Recommendation ASS36 of Environment Agency 2015, Review of LLW Repository Ltd's 2011 environmental safety case: Assessments)

In summary, we consider that LLW Repository Ltd's study provides reassurance that hazardous substances and non-hazardous pollutants in the LLWR grout will not cause significant impacts on groundwater. However, the grout will contribute to the concentrations of hazardous substances and non-hazardous pollutants leaching from the repository. Because of the significant quantities of PFA-based grouts being used in the repository, we consider it essential that LLW Repository Ltd maintains an awareness of grout as a potential source of hazardous materials and takes account of its presence in future versions of the hydrogeological risk assessment. LLW Repository Ltd should maintain awareness of any changes in the designation of hazardous substances present in the grout and any wider outcomes from the testing of PFA grouts.

Actions completed, Regulatory Issue resolved and Form closed

Owner: Environment Agency	Date: 03/02/2014
Approved by: Environment Agency	Date: 13/11/2014

ESC-RI-INF-005: Container condition monitoring and sampling programme

Title	Container condition monitoring and sampling programme
Date raised	16/05/2012
Acknowledgment required by	23/05/2012
Response required by	A1 by 01/10/2012 A2 by 31/10/2012
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	INF
Approved by	Environment Agency

History

Status	Date	Description
Raised	15/06/2012	
Acknowledged	29/06/2012	
LLWR Response	20/12/2012	
Response Assessed	01/08/2013	
Transferred	01/08/2013	
Closed	03/10/2013	

Statement of Regulatory Issue

The 2011 ESC utilises the concept of the grouted waste container as providing a number of significant safety functions such as resistance to settlement and limited attenuation of leachates. The whole restoration strategy is dependent on the ability of the grouted waste container to achieve these safety objectives.

In order to deliver these safety functions it is assumed that the grouted waste container retains its functionality over an extended period of time as each vault is filled. Recent visual and intrusive inspections of the Vault 8 containers has shown significant degradation of the container and grouted waste mass. This degradation is thought to have arisen partly as a result of the extended period of storage prior to capping; however, there is currently no evidence to indicate that similar degradation could not occur over shorter time periods consistent with the proposed vault filling strategy.

In order to ensure that the assumptions used in the ESC are realistic we would expect a comprehensive visual inspection and monitoring/sampling programme of the waste containers prior to the placement of the final cap (Vault 8 and subsequent vaults). The objective of the programme would be to ensure that container safety functions are not compromised and the ESC assumptions are validated with appropriate empirical evidence.

The presented ESC monitoring and sampling programme does not include any provision for the formal inspection, monitoring and sampling of the waste containers. Taking into account the learning from the current investigations into the container and grout condition we would expect the ESC to incorporate provision for such an inspection and sampling programme.

Regulatory Issue Actions

ESC-RI-INF-005.A1	We seek demonstration and confirmation that the grouted container performance assumptions utilised in the ESC can be achieved over the whole operational life of the site. We therefore expect a comprehensive review of the grouted waste and container performance assumptions used within the presented ESC, taking account of the output from any inspection, monitoring and sampling programmes. The consequences of any changes in performance assumptions should be assessed against the proposed final cap and restoration strategy.
ESC-RI-INF-005.A2	Taking into account the learning gained from the container condition investigations, an appropriate programme of inspection, monitoring and sampling of container conditions should be presented. Mechanisms to ensure that learning and outputs from the ongoing investigations influence site operational decisions should be linked to this programme.

LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	29/06/2012
Comment: Responses to the actions will be provided.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	20/12/2012
A response to both actions is provided in the following report: LLWR, <i>Vault 8 Containers Issues Project: Position Paper - December 2012</i> , RP/LLWRGR/PROJ/00139/A.		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 03/07/2013
Approved by: Environment Agency	Date: 03/09/2013

This Regulatory Issue (RI) was raised as a result of observations made during an inspection of containers in the north-west corner of Vault 8. Our inspection raised a number of concerns which are highlighted below:

- a) Apparent presence of softened grout within the waste packages.
- b) The presence of significant ullage volume between the underside of the lids of the containers and the top surface of the grout.
- c) The presence of vegetation within the grouted wasteforms.
- d) The presence of non-standardised containers.
- e) The presence of water located on top of the containers.
- f) The condition of some containers, particularly full height ISO-containers.

A container inspection and assessment programme was carried out by LLW Repository Ltd in parallel with our review of the 2011 ESC. This programme acknowledges that the full container condition and assessment programme will not be delivered prior to the completion of our review of the 2011 ESC, with elements of the assessment continuing. Where we believe it remains

necessary for LLW Repository Ltd to provide further information on container condition issues and cap settlement we have raised these within a Forward Issue (ESC-FI-025).

Action ESC-RI-INF-005.A1 requested further demonstration and confirmation that the grouted performance assumptions utilised in the ESC can be achieved, over the whole lifetime of the site. In response, LLW Repository Ltd undertook a series of work packages, as presented in Ref (1). A summary of the outputs and our positions with regards to these is provided below.

Grout softening

LLW Repository Ltd has demonstrated that the softening of the grout within Vault 8 is not a significant or widespread issue within Vault 8. This is supported by data presented within Ref (1), which shows that the maximum depth of softened grout observed was 12 cm. We agree that this is therefore not a significant issue with regards to cap settlement and can be managed through appropriate engineering.

LLW Repository Ltd also undertook a literature survey on grout softening. This indicated that the small amount of softening seen was probably due to weathering of the grout. We conclude that LLW Repository Ltd has adequately addressed the grout softening issue.

We note that LLW Repository Ltd plans to continue to monitor this issue through annual and opportunistic inspection, which we support and expect to see completed and reported. LLW Repository Ltd will be further optimising the container lid design in order to minimise the presence of standing water and infiltration of water into the grouted waste. Furthermore, LLW Repository Ltd has implemented improvements to container grouting which has led to a reduction in the ullage space between the top of the waste and the container lid. This will also reduce the likelihood of future grout softening.

We note that the presence of grout softening was not identified in the 2011 ESC and should therefore be taken account of in assessments of total container settlement potential.

Ullage space

The work documented in Ref (1) indicated that the distribution of the ullage/inaccessible voidage between the top of the grouted waste form and the container lid was a far more significant issue within Vault 8 than anticipated by LLW Repository Ltd. This presented the company with a significant challenge in understanding how the engineered cap will perform. Assessing this report, we requested a further study that presented the underlying data used for determining the potential voidage within stacks and identified whether there were particular regions within Vault 8 which potentially could raise concerns with regards to cap emplacement (Ref 2).

We consider that within Ref (2), the authors have used the best available data to estimate the total voidage within a stack. However, we note that determining the voidage within the containers and within a stack carries a significant degree of uncertainty due to the lack of information within the records. This has resulted in an 'averaging approach' to the voidage being taken, which does not necessarily represent a worst case situation that could arise. We have concluded that the outputs from stack voidage investigations should only be treated as indicative and that care should be applied in using this information for decision making purposes. We question the potential for the higher stacking of containers without further assessment work being completed first to demonstrate safety.

We conclude that it should be possible to mitigate uncertainty in potential settlement by applying appropriate engineering and by employing appropriate emplacement strategies, as quoted within the 2011 ESC. It is likely that additional engineering and the implementation of emplacement measures will be needed to adequately manage some existing containers which have significant void space or settlement potential.

In addition to the information presented within the 2011 ESC, LLW Repository Ltd intends to implement a number of additional control measures to mitigate potential settlement arising from the presence of the ullage void space. These include:

- incorporation of packaging and void space requirements within the WAC
- training waste consignors to better understand BAT and WAC packaging expectations

- increased use of emplacement strategies to take account of containers with settlement potential
- further optimisation of the container design
- localised changes to the final engineered cap design
- potential changes to the maximum stack height presented in the 2011 ESC

This work has not yet been fully completed. The forward work programme will need to assess the suitability of the cap for Vault 8 associated with the degree of higher stacking of containers employed. It is hoped that with the implementation of the above improvements to future disposals, the level of settlement uncertainty can be reduced. Forward Issue ESC-FI-001 seeks continued work and reporting in this area to ensure that the design is substantiated and safety demonstrated before capping commences.

Container condition

Survey and inspection work also identified that the condition of a number of containers is poor, particularly within the north west corner of Vault 8. In some cases through-hole corrosion and bulging sides have been identified. These issues have raised questions as to whether higher stacking can be effectively implemented within Vault 8 without further engineering mitigation and changes to the cap design. LLW Repository Ltd has put in place forward plans to address this issue and we will review the outcome of this work prior to any capping of Vault 8.

Investigation implications

We note that as a result of the issues discussed above, LLW Repository Ltd has identified the potential need for an additional metre of profiling within the cap. This is intended to ensure the cap will be able to cope with the predicted settlement. Information on the extent and nature of the necessary changes to the capping layer has not been presented; we will assess these changes as part of the LLWR Engineering Forward Programme.

Ref (2) gives a good understanding of the voidage present within non-standard disposals and the implications on the cap. The most significant non-standard disposals in terms of potential voidage appear to be Hex cylinders, which were grouted in-situ in Vault 8. Typically many non-standard disposals are grouted internally (where internal spaces exist) and any remaining voidage present within non-standard packages is low and thus should not present a significant issue to the settlement of the cap. Generally, items which are not grouted internally are constructed of high integrity or solid materials and are therefore unlikely to impact significantly on cap performance.

Ref (2) indicates that a number of waste packages have vegetative growth within them. This can be seen by simple inspection of Vault 8 containers. It is, however, stated that the impacts of this are mainly visual and we have no reason to disagree with this conclusion. However, we question the impact such growth may be having on the physical and chemical properties of the grout itself. We note that LLW Repository Ltd plans to remove this vegetation and implement a future program to inhibit growth of vegetation within the grouted waste mass. We support this approach and expect this to be implemented in both Vault 8 and any future vaults.

As part of our inspection of the containers we had also raised the following concerns with regards to their design and methods of filling with grout:

- Some container types were allowing the collection of significant quantities of water on their lids.
- Some container types had open grout ports allowing water access to the grouted waste mass.
- A grout layer placed on top of many container lids (designed as load spreading material) was degrading and did not appear to be functioning as designed. Additionally the degrading material could present a risk to the drainage system of the vault.

We therefore questioned whether the existing container design and grouting processes fully represented BAT. LLW Repository Ltd has subsequently undertaken several pieces of work to address these issues. Improved grouting processes have already been implemented and a separate work programme is ongoing to examine and as necessary re-design the container to prevent water collection and ingress, with the aim of increasing the life of the containers and protecting the waste further. We will review this work as it is progressed.

We consider that LLW Repository Ltd has either addressed many of the concerns and questions we raised in Action ESC-RI-INF-005.A1 or is addressing them through forward programmes of work. We conclude that:

- a) The issue of grout softening has been addressed within the reported data and we are content with the concluded outcomes. As part of its annual and ad hoc inspection program, LLW Repository Ltd is carrying out measurements of grout softening to ensure that no significant changes occur.
- b) We note that LLW Repository Ltd has presented the data for voidage within Vault 8. However, a significant degree of uncertainty still exists in understanding the voidage present and we expect this to be addressed within chosen options for stack height and cap engineering which are being addressed by forward programmes of work. LLW Repository Ltd has demonstrated that the disposal of non standardised containers does not significantly impact on the cap performance.
- c) Vegetation is growing from a number of waste packages within the vault. This has a visual impact, but may also have an impact on the chemical and physical nature of the grout within the waste packages. LLW Repository Ltd is implementing a programme of work to remove the vegetation and inhibit its growth in the future.
- d) A number of containers within the northwest corner of the vault are corroded or have bulges present on the side. We note as a result of the containers' condition and the voidage identified within this area of the vault LLW Repository Ltd plans to increase the profiling material by 1 m compared with that presented within the ESC. At present we are content with this additional profiling, however, as part of the forward engineering program further work will be undertaken to ensure that this 1 m profiling also addresses the uncertainty within the voidage.
- e) We note that the ISO freight container design is not fully optimised. LLW Repository Ltd has a programme of work in place to review the BAT for container design. We have formalised an expectation for LLW Repository Ltd to complete this work within ESC-FI-025.

We are broadly content that LLW Repository Ltd has addressed Action ESC-RI-INF-005.A2. Where our concerns have not been fully addressed they are captured within future work programmes:

- a) LLW Repository Ltd plans to undertake annual inspections of both the containers and the grout within the containers. This will monitor any future degradation. We expect these inspections to be undertaken to provide us with confidence that no further significant deterioration that could impact on the ESC is occurring. We will monitor this action through our future regulatory program for the LLWR, to ensure that such inspections occur and that the data is reviewed to assess any potential impacts.
- b) LLW Repository Ltd plans to remove all vegetation from Vault 8 and will continue to do so prior to capping. We also note that LLW Repository Ltd will assess the BAT for preventing further vegetation growth within the waste packages prior to capping within Vault 8 and future vaults. We will follow this action through our future regulatory program for the LLWR.
- c) LLW Repository Ltd has not yet presented a case for higher stacking of containers within Vault 8. We will expect this to be addressed within the forward engineering work program and must be provided prior to Vault 8 capping work commencing. Our expectations of this work are captured within ESC-FI-001.
- d) LLW Repository Ltd has presented a case for its present understanding of the voidage within the waste packages. However, we note that a significant degree of uncertainty is present within the calculations. We seek confidence from the forward engineering program that the cap is suitable for the higher stacking present within the ESC and that the voidage present within each stack can be accommodated. This issue will be taken forward via ESC-FI-001.

Container monitoring programme

LLW Repository Ltd has committed to an ongoing monitoring programme to examine the condition of exposed containers, we are satisfied that this programme addresses our expectations. We also expect the impact of container degradation to be incorporated into a wider engineering performance monitoring strategy. Our expectations for this are outlined in ESC-FI-026.

Summary

Overall we are content that this RI has been adequately addressed at this stage of the programme and can therefore be closed. In reaching this conclusion we take account of the presence of a substantial forward work programme designed to address the remaining issues and develop the detail of closure engineering further. We will monitor progress of these forward programmes through our future regulatory programme for the LLWR. We have also raised Forward Issues in relation to key areas of ongoing work, where we believe they are necessary to the demonstration of safety.

References

1. Vault 8 Containers Issues Project: Position Paper December 2012. RP/LLWRGR/PROJ/00139 Issue 1, 20 December 2012.
2. LLWR Waste Emplacement Strategy: Assessment of the Implications of Voidage in Vault 8. Penfold, J., Burrow, J. and Robinson, P. Quintessa Report QRS-1443ZP-1 Version 2.1, May 2013.

Actions completed, Regulatory Issue resolved and Form closed

Owner: Environment Agency	Date: 27/09/2013
Approved by: Environment Agency	Date: 03/10/2013

ESC-RI-ASO-001: Optimisation of vault sequencing

Title	Optimisation of vault sequencing
Date raised	05/09/2011
Acknowledgment required by	16/09/2011
Response required by	30/11/2011
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	ASO
Approved by	Environment Agency

History

Status	Date	Description
Raised	05/09/2011	
Acknowledged	16/09/2011	
LLWR Response	30/11/2011	
Response Assessed	01/07/2013	
Transferred	01/07/2013	
Closed	29/01/2014	

Statement of Regulatory Issue

The 2011 ESC provides assessments of the impacts of disposals of LLW in a reference disposal area (RDA) comprising the existing Trenches 1–7, the existing Vaults 8 and 9 and future Vaults 10–14, and for an extended disposal area (EDA) comprising the RDA plus further future Vaults 15–20. Vaults 8–14 are assumed to be built in sequence from north to south between the trenches and the coast, whereas Vaults 15–20 are assumed to be built after Vault 14 between the southern end of the trenches and the East-West Stream. By way of explaining this approach, it is noted in the ESC that the RDA is essentially the area previously referred to as the ‘consented area’, a term that originally implied an understanding that existing planning permission applied to disposals throughout that area. However, it is further noted that the current planning authority, Cumbria County Council, does not recognise the ‘consented area’ to have any meaning, and therefore that new developments anywhere on the site will require planning permission.

It is also argued in the ESC that the whole LLWR site is expected to be disrupted by coastal erosion within a period of no more than about 5000 years from now. Disruption of the site is projected to begin in a few hundred to a few thousand years, the timing depending largely on the extent of sea level rise, most likely starting with undercutting of Vault 8, the part of the site closest to the eroding coast.

The ESC provides extensive information on the optimisation of the design for Vaults 9–20, of the closure engineering for the site (the RDA or the EDA), and of the location of Vaults 15–20, as well as other arguments supporting the contention that the proposed disposal system is expected, with the current understanding of the disposal system and site, to result in risks to people and the environment that are as low as reasonably achievable, as required by Requirement R8 of the GRA. The ESC does not, however, provide any demonstration that constructing and using the vaults in the sequence implied by their numbering provides optimised protection of people and the environment. There are clearly alternative sequences in which vaults in the proposed locations could be constructed and used, and some of these would have some apparent advantages over

the proposed sequence. For example, if some or all of Vaults 15–20 were to be constructed before Vault 10, and the readily movable waste from Vault 8 transferred to them, the amount of waste in the most vulnerable part of the site would be reduced while it is still movable, pending possible future improvements in projections of erosion and/or means of mitigating its effects. Future improvements in waste management might even make eventual refilling of Vault 8 unnecessary and so at least delay impacts from erosion of the facility. Clearly, the proposed sequence will also have advantages over the alternatives, and we consider analysis of the balance between the advantages and disadvantages of different sequences to be an essential element of satisfying Requirement R8.

Regulatory Issue Actions

ESC-RI-ASO-001.A1	LLW Repository Ltd shall provide an explicit optimisation case for the proposed sequencing of vaults, taking account of the current understanding of the disposal system and of the site and its evolution. This case may draw upon arguments, analyses and evidence already presented in the ESC where appropriate, but should explicitly address the specific optimisation question.
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	16/09/2011
<p>Comment: The approach adopted in the 2011 ESC was to consider a Reference Disposal Area covering the area originally consented for disposal in 1957, and mostly considered for disposal in the past. We also considered disposal in an Extended Disposal Area. We did not explicitly address sequencing of vault construction over the whole extended area. We believe that factors such as the uncertainties associated with the mode, timing and direction of coastal erosion, the weak dependence of calculated peak doses on timing of erosion, and the fact that peak calculated doses result from wastes disposed in the trenches, mean that deciding sequencing based on coastal erosion is of very doubtful value. We will, however, undertake an optimisation study to examine this possibility. This study will consider other factors such as the disadvantages in moving wastes (including directly disposed wastes) from Vault 8.</p>		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	30/11/2011
The optimisation study required is presented in LLWR/ESC/R(11)10042.		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 01/07/2013
Approved by: Environment Agency	Date: 29/01/2014

LLW Repository Ltd carried out an optimisation exercise in response to this Regulatory Issue (RI) (Optimisation of Vault Sequencing, LLWR/ESC/R(11)10042, November 2011). This report addressed the following areas:

- Uncertainty associated with the timing, form and location of repository disruption
- Reduction of dose via vault sequencing changes

- Restoration benefits
- Operational and engineering benefits

Our RI and LLW Repository Ltd's response considered potential opportunities for optimisation of vault sequencing within the reference and extended disposal areas (RDA and EDA).

We acknowledge that the timing, mode and direction of coastal erosion and consequent site disruption are subject to significant uncertainties. The inventories and rates of arising of future waste streams for disposal to the vaults are also subject to considerable uncertainty. We agree that the uncertainties are such that strong arguments cannot reasonably be made regarding more detailed aspects of optimisation, such as the precise implications of different vault sequencing options.

The most important conclusion from the Regulatory Issue response is that the radionuclides that are linked to the most significant projected impacts in the event of coastal erosion are associated with comparatively small volumes of future disposals. LLW Repository Ltd is confident that the emplacement strategies presented within the 2011 ESC are at least equivalent in reducing risks to those which could be achieved with alternative vault sequencing strategies and we agree with this. The emplacement strategies would be used to 'spread out' and place certain wastes deeper within the repository, reducing potential peak exposures. We have commented on the proposed emplacement strategies elsewhere in our ESC review.

We accept that the engineering benefits associated with the separation of vault construction from operations do not deliver any optimisation benefits when compared to the presented strip restoration sequence approach LLW Repository Ltd has adopted. We note that the presence of an operational vault adjacent to a vault under construction may increase operational and design complexity, but could potentially be further optimised without changing the current vault sequence. The presented ESC does not provide detailed design drawings showing the layout of the interface between the operational vault disposal area and the exposed front of the strip restoration. This information will be available as part of the planning application, with further design information presented during the design justification process leading up to construction. As a result of the need to minimise the period of container exposure prior to capping, the size and sequencing of operational vaults will be further optimised; this can be more easily achieved when the operational area is adjacent to the restoration area.

A revision to the sequencing of the EDA and RDA vaults would necessitate changes to the proposed strip capping restoration (Section 5.2.5 of LLW Repository Ltd's Level 2 report on Optimisation and Development Plan). We accept that the proposed strip capping of the vaults within the RDA does offer an advantage over alternative sequencing approaches. Advantages may be gained with regards to material availability and the minimisation of exposure of future vault wastes and existing trench wastes. Because of the uncertainty associated with the long-term performance of the interim trench cap, the size of future vaults and the rate at which these vaults will be filled, it is possible that the presented strip restoration sequence will not be delivered exactly as presented in the 2011 ESC. If future vaults were to be constructed in the footprint of the EDA, then it may be possible to separate the restoration of the trenches from the construction and restoration of future vaults. We have sought clarification and demonstration of an optimised restoration sequence in ESC-FI-025.

Whilst other vault sequencing strategies might offer some operational efficiency benefits over the current proposals, by separating disposal and construction operations, we recognise the significant uncertainties associated with future coastal erosion and also the advantages of the current strip capping approach. We accept that a satisfactory case has been made to address the issues raised within this RI and concur with LLW Repository Ltd's conclusions that alternative vault sequences do not currently offer any clear benefits over the current proposals. We consider this issue closed with regard to the 2011 ESC, but will expect ongoing consideration of potential benefits from any changes to the vault construction and capping sequence.

Actions completed, Regulatory Issue resolved and Form closed

Owner: Environment Agency	Date: 01/07/2013
Approved by: Environment Agency	Date: 29/01/2014

ESC-RI-ASO-002: Optimisation of vault operational conditions

Title	Optimisation of vault operational conditions
Date raised	05/09/2011
Acknowledgment required by	16/09/2011
Response required by	30/11/2011
Related issue numbers	ESC-RI-ASO-003
Originated by	Environment Agency
Current owner	Environment Agency
Review group	ASO
Approved by	Environment Agency

History

Status	Date	Description
Raised	05/09/2011	
Acknowledged	16/09/2011	
LLWR Response	30/11/2011	
Response Assessed	01/09/2013	
Transferred	01/09/2013	
Closed	18/11/2013	

Statement of Regulatory Issue

The 2011 ESC provides assessments of the impacts of disposals of LLW in a reference disposal area (RDA) comprising the existing Trenches 1–7, the existing Vaults 8 and 9 and future Vaults 10–14, and for an extended disposal area (EDA) comprising the RDA plus further future Vaults 15–20. The ESC also provides extensive information on the optimisation of the design for Vaults 9–20, of the closure engineering for the site (the RDA or the EDA), and of the location of Vaults 15–20, as well as other arguments supporting the contention that the proposed disposal system is expected, with the current understanding of the disposal system and site, to result in risks to people and the environment that are as low as reasonably achievable, as required by Requirement R8 of the GRA.

It is argued in the ESC that the optimised design of the vaults and closure engineering – particularly the final cap – will combine to establish and maintain unsaturated conditions in the vaults for several hundred years. In the early part of this period, before and after capping, the waste packages contribute to minimising contact between the waste and any water that is in the vaults, and hence the potential for contaminants to enter leachate. Should it become necessary to move wastes during vault operation (or should a future generation wish to retrieve wastes from the vaults) the ease of the task will depend in part on the integrity of the waste packages. The projected dates for filling and closing vaults indicate that future vaults will be open for periods up to 20 years or more, and future improvements in waste management could extend these periods further.

During its operational period, it is assumed that each vault will be uncovered, but that water will be removed by leachate management systems. The ESC does not, however, explicitly explain why covering the vault with a temporary tent or roof, or otherwise protecting the disposed or stored waste against water, would not be optimal, and this is not self-evident in view of the potential benefits of minimising all inputs of water to the vault. We also note that maintaining dry conditions

during the emplacement of waste is considered best practice at some near surface LLW disposal facilities in other countries.

Regulatory Issue Actions

ESC-RI-ASO-002.A1	LLW Repository Ltd shall provide an explicit optimisation case for the proposed operational configuration of vaults, specifically the absence of measures to minimise contact between incoming water and the waste during vault operation.
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	16/09/2011
<p>Comment: The option of covering the wastes was considered in the optioneering undertaken during the development of the current vault disposal concept, prior to recent work supporting the development of the 2011 ESC. We propose to review the relevant references and provide them to the Agency along with a paper setting out our position.</p> <p>We note that our approach does include measures to minimise contact between incoming water and waste during vault operation, including packaging the waste and vault drainage systems. We also note that the approach adopted in France and Spain, often quoted as examples of roofing, only involves roofing of the waste during emplacement while the waste monoliths are being created. The waste monoliths are uncovered for most of the period up to the time of final capping.</p>		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	30/11/2011
A discussion of the optimisation of vault operational conditions is presented in LLWR/ESC/R(11)10043.		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 01/09/2013
Approved by: Environment Agency	Date: 18/11/2013

In response to the this Regulatory Issue (RI), LLW Repository Ltd provided a report entitled 'Optimisation of Vault Operational Conditions, LLWR/ESC/R(11)10043'.

Since a response was received to this RI, a container inspection programme and subsequent investigation undertaken by LLW Repository Ltd identified a degree of unexpected degradation of Vault 8 containers and the presence of previously unrecognised voidage within certain containers.

Inspection of the stored and disposed containers identified penetrative and non penetrative corrosion of the fabric of some containers (only the exterior top and sides of the containers where inspected). The corrosion is believed to have occurred as a result of prolonged outside storage and exposure to the elements, combined with collection of water on the top surface of some container designs. Some corrosion corresponds to welded container details and areas which had been subject to paint damage.

The identified voidage within certain containers is believed to have occurred as the result of waste settlement following grouting. In some container designs grout ports have remained open following grouting and therefore, in some cases water has collected in the container voidage and

subsequently been discharged. However, activity levels in this water have been monitored and shown to be low. Vegetation has been found on some containers, growing on grout placed to the top of containers and within grout ports.

As a result of the above findings LLW Repository Ltd has already implemented a number of changes, including measures to reduce voidage due to grout settlement and measures to prevent water collection on container tops. Further short-term improvement measures being undertaken include vegetation removal, plugging of some grout ports where waste is visible and implementation of improved container inspection programmes.

We support these shorter term actions, which we believe are necessary to demonstrate optimisation.

LLW Repository Ltd has also identified the need for further optimisation work to minimise the exposure and therefore degradation of waste containers and to minimise operational discharges of radioactivity. This optimisation work will address improved container design and also vault and capping sequencing with the aim of ensuring containers are only exposed, prior to capping, for as long as they can be demonstrated to remain fully intact and robust. LLW Repository Ltd has committed to this work in response to this RI and elsewhere (Shaw 2013). We have also raised a Forward Issue (ESC-FI-025) which seeks to ensure delivery of an effective optimisation programme for the container, vault design, operational procedures and restoration sequence. This work will ensure that LLW Repository Ltd continues to optimise the current design concept as described within the 2011 ESC.

As part of the work LLW Repository Ltd will undertake on vault and capping sequencing, we expect consideration of the period containers can be safely left exposed and mechanisms to provide earlier interim or final protection of the wastes. As part of the container optimisation work, we expect consideration of improved container design and protection to optimise lifetime in line with vault and capping sequencing, and to prevent or minimise operational discharges.

LLW Repository Ltd plans to undertake an optimisation study which will consider if there are short-term actions that should be taken to improve container performance without the need for the relicensing of the container for transport purposes. Over a longer time period, LLW Repository Ltd plans to undertake a more comprehensive review of the container design which will not be constrained by the current container design transport licensing requirements. This constraint is necessary because the relicensing of the container design could take several years to complete. Both studies will seek to understand how long containers can be left before capping in Vault 9 and the future vaults.

LLW Repository Ltd is also considering what (if any) and when action should be taken to provide additional protection to containers or wastes in Vault 8 in advance of the placement of the final engineered cap, this might for example include the potential use of temporary or interim coverage of the stored containers. This final aspect is being considered as part of the closure studies for Vault 8 which forms part of the Engineering Forward Plan (Shaw 2013).

We agree that an optimisation case has been made to address the identified action and therefore this RI is closed. We accept there are severe obstacles to the installation of a roofing system for the as-built vaults. However, roofing systems, temporary or otherwise, should remain an option for future vaults, but we accept that operations would be restricted and the freedom to move and stack containers would be limited.

References

Shaw, N., 2013. Engineering Forward Plan to Support the Environmental Safety Case. LLW Repository Ltd Report RP/LLWRGR/PROJ/00142 Issue A, April 2013.

Actions completed, Regulatory Issue resolved and Form closed

Owner: Environment Agency	Date: 01/07/2013
Approved by: Environment Agency	Date: 18/11/2013

ESC-RI-ASO-003: Optimisation of disposal system in relation to possible future waste retrieval or facility protection

Title	Optimisation of disposal system in relation to possible future waste retrieval or facility protection
Date raised	05/09/2011
Acknowledgment required by	16/09/2011
Response required by	30/11/2011
Related issue numbers	ESC-RI-ASO-002
Originated by	Environment Agency
Current owner	Environment Agency
Review group	ASO
Approved by	Environment Agency

History

Status	Date	Description
Raised	05/09/2011	
Acknowledged	16/09/2011	
LLWR Response	30/11/2011	
Response Assessed	03/09/2013	
Transferred	03/09/2013	
Closed	18/08/2014	

Statement of Regulatory Issue

The 2011 ESC provides assessments of the impacts of disposals of LLW in a reference disposal area (RDA) comprising the existing Trenches 1–7, the existing Vaults 8 and 9 and future Vaults 10–14, and for an extended disposal area (EDA) comprising the RDA plus further future Vaults 15–20. The ESC also provides extensive information on the optimisation of the design for Vaults 9–20, of the closure engineering for the site (the RDA or the EDA), and of the location of Vaults 15–20, as well as other arguments supporting the contention that the proposed disposal system is expected, with the current understanding of the disposal system and site, to result in risks to people and the environment that are as low as reasonably achievable, as required by Requirement R8 of the GRA.

It is also argued in the ESC that the whole LLWR site is expected to be disrupted by coastal erosion within a period of no more than about 5000 years from now. Disruption of the site is projected to begin in a few hundred to a few thousand years, the timing depending largely on the extent of sea level rise, most likely starting with undercutting of Vault 8, the part of the site closest to the eroding coast.

It is argued in the ESC that the proposed engineering is designed and optimised for permanent disposal of the waste, taking account of the expected erosion of the facility, and it is assumed that active measures are not maintained to prevent erosion of the facility. Depending on our overall review of the ESC, we may permit further disposals on this basis, noting our GRA Principle that long term safety should not depend unduly on future human actions. However, future generations may take a different view and decide to intervene by recovering waste from the facility for alternative management or by seeking to protect the facility against erosion over long periods of

time. We would not expect LLW Repository Ltd to make particular provision for such future possibilities, especially if such provision might detract from the long-term safety of the facility as a permanent disposal facility. However, we would not expect LLW Repository Ltd to make such future actions unnecessarily difficult if reasonable allowance could be made without compromising safety. The ESC does not explicitly address such options that may facilitate possible future measures to retrieve waste or enhance its protection from erosion, but which would not compromise the safety of the facility as a permanent disposal facility.

Regulatory Issue Actions

ESC-RI-ASO-003.A1	LLW Repository Ltd shall provide an explicit optimisation case that possible future actions to retrieve waste from the vaults or protect the LLWR against coastal erosion have not been unreasonably hindered or precluded.
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	16/09/2011
Comment: We propose to provide a position paper demonstrating that our approach does not unreasonably hinder or preclude future human actions to retrieve wastes or protect the disposal facility against coastal erosion.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	30/11/2011
A discussion of the optimisation in relation to possible future interventions is presented in LLWR/ESC/R(11)10044.		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 03/09/2013
Approved by: Environment Agency	Date: 18/08/2014

In response to this Regulatory Issue (RI) LLW Repository Ltd provided a report entitled 'Optimisation in relation to possible future interventions, LLWR/ESC/R(11)10044'. The report addresses the identified issues associated with retrievability.

The LLWR has been designed and optimised as a final disposal facility, with no intent to retrieve waste (in line with government policy). Vault 9 and parts of Vault 8 are temporarily operated as a storage facility, although LLW Repository Ltd's intent is for any stored waste to be disposed of once its environmental permit allows this. Therefore, both Vault 8 and 9 have been designed and built as disposal facilities. Similarly, containers have not been designed with retrieval in mind, nor could they reasonably be designed to retain full integrity for many years after disposal. However, they also do not pose any particular issues with regards to potential retrieval in the future.

Our RI sought clarification on whether wastes could be readily retrieved from vaults in the future should future generations consider this necessary. The 2011 ESC notes that retrieval of all trench wastes is within current industrial capability and we sought a similar assurance that current and future development of the LLWR would not preclude the possibility of waste retrievability from the vaults, nor make retrievability unnecessarily difficult for future generations.

LLW Repository Ltd has now provided that assurance and states that there is nothing in the current design or future plans that would hinder or preclude future generations from retrieving

wastes or even developing sea defences adjacent to the site, either as part of a deliberate action in relation to the LLWR or as part of wider plans for coastal management in Cumbria. In a broader context, we note that future generations of decision-makers will make their own decisions about the acceptability of disposals at the LLWR.

Key to any future waste retrieval would be good waste records (waste information and location). Such information is routinely collected and retained by LLW Repository Ltd. However, we have noted elsewhere some limitations in the current waste tracking systems and sought improvements in the future. We understand that LLW Repository Ltd is undertaking a programme of improvements to the tracking system and recommended that consideration be given to ensuring records appropriately consider the potential need for future retrieval of vault wastes (see Environment Agency 2015, Review of LLW Repository Ltd's 2011 Environmental Safety Case: Inventory and Near Field).

LLW Repository Ltd has adequately addressed the issues raised in this RI and it can be closed.

Actions completed, Regulatory Issue resolved and Form closed

Owner: Environment Agency	Date: 03/07/2013
Approved by: Environment Agency	Date: 18/08/2014

ESC-RI-ASO-005: Assessment of impacts of C-14 bearing gases

Title	Assessment of impacts of C-14-bearing gases
Date raised	30/09/2011
Acknowledgment required by	14/10/2011
Response required by	31/12/2011 (A1); 31/08/2012 (A2)
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	ASO
Approved by	Environment Agency

History

Status	Date	Description
Raised	30/09/2011	
Acknowledged	14/10/2011	
LLWR Response	03/02/2012 (A1) 27/09/2013 (A2)	
Response Assessed	07/11/2013	
Transferred	07/11/2013	
Closed	15/11/2013	

Statement of Regulatory Issue

In the ESC, the assessed conditional risks associated with the release from wastes of C-14 bearing gases exceed the GRA risk guidance level, by a factor of up to several tens, at the end of the period of institutional control assumed for other pathways (100 years after closure). LLW Repository Ltd argues in the ESC that:

- these assessed risks can be reduced to below the guidance level by preventing residence and cultivation on the cap
- relatively simple planning measures (such as proscribing these specific land uses and/or establishing others) could reliably prevent such actions for a considerable period of time
- by 300 years after closure, the assessed risks are below the guidance level, even if residence and/or cultivation on the cap area are allowed

LLW Repository Ltd further argues that the assessed risks probably overestimate the risks that could actually occur by a considerable margin, potentially sufficient that the actual risks are likely to be below the guidance level. It cites a number of sources of pessimism, but particularly emphasise two such sources: modelling of the partitioning of C-14 in the near field between gases, solution and solid material and the consequent releases of C-14 from the near field; and modelling the uptake of C-14 from methane gas into soils and the subsequent behaviour of C-14 in the biosphere. It suggests an intention to carry out further work (modelling, and possible experimental work) to support less pessimistic assessment of these risks.

We support LLW Repository Ltd's intention to do further work on this issue. We do not rule out accepting an ESC that depends on the extended period of post-closure control measures suggested by LLW Repository Ltd's current position, but we would require considerable further

assurance that such an approach is reliably achievable and optimal. We agree that the assessment presented in the ESC is probably pessimistic, possibly very pessimistic, and we consider that a less pessimistic assessment, if adequately underpinned, could considerably enhance the overall robustness of the case.

We specify two actions below. **When action A1 has been completed to our satisfaction, this Regulatory Issue will be downgraded to a Regulatory Observation.**

Regulatory Issue Actions

ESC-RI-ASO-005.A1	LLW Repository Ltd shall provide by 31 December 2011 a scoping assessment of the conditional risks from C-14-bearing gases using assumptions that they consider may be demonstrated to be cautiously realistic and set out a programme of further work needed to provide full underpinning of those assumptions.
ESC-RI-ASO-005.A2	LLW Repository Ltd shall complete an adequately underpinned cautiously realistic assessment of the conditional risks from C-14-bearing gases.

LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	14/10/2011
<p>Comment: We have been developing plans to refine our analysis of the estimation of the risks from the C-14 gas pathway, both over the next year in support of our application for a new permit for disposal and over the next few years. We believe that new experimental data may be required for a fully underpinned assessment, hence the expectation of the need for a multi-year programme. We will use our best endeavours to provide a scoping assessment by the 31 December 2011, but it may only be possible to respond adequately after this date. We will provide an improved analysis by the end of August 2012.</p>		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	03/02/2012
<p>A scoping assessment, providing a revised position on the risks from the C-14 labelled gas pathway, is provided in report: <i>Scoping Assessment of Carbon-14 Bearing Gas</i> LLWR/ESC/R(12)10046 Issue 1, February 2012. This response is intended to meet action ESC-RI-ASO-005.A1 above. Further work is planned to meet action ESC-RI-ASO-005.A2 above. This further work and a forward programme of work beyond August 2012 are outlined in the report.</p>		

LLW Repository Ltd	ESC Project Manager	27/09/2013
<p>An underpinned cautiously realistic assessment of the conditional risks from C-14-bearing gases, providing a revised position on the risks from the C-14 labelled gas pathway, is provided in report: <i>Assessment of Carbon-14 Bearing Gas</i>, LLWR/ESC/R(13)10059 Issue 1, September 2013. This response is intended to meet action ESC-RI-ASO-005.A2 above.</p>		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 07/11/2013
Approved by: Environment Agency	Date: 15/11/2013

We agree with LLW Repository Ltd that the 2011 ESC C-14 assessment appears overly cautious in relation to similar assessments undertaken for near-surface repositories overseas. The revised scoping calculations, which were issued to us in February 2012, incorporated revised, more realistic, modelling assumptions and indicated that annual risks would probably remain below the risk guidance level after around 2180. We consider that the scoping assessment, and associated forward programme of work, addresses Action ESC-RI-ASO-005.A1.

LLW Repository Ltd provided us with a full updated assessment of radiological impacts associated with C-14 bearing gas for both the RDA and EDA vaults in September 2013. The results of this assessment supersede the data provided in the 2011 ESC.

Significant updates in this study include:

- Further assessment of the C-14 inventory and associated waste forms, and examination of the effect of alternative waste processing assumptions on the C-14 inventory, its distribution between waste forms, and its location in the repository.
- Work to understand and characterise C-14 release processes at the waste container scale.
- Presentation of a revised model for C-14 bearing gas release from the vaults, representing the largely unsaturated, containerised, heterogeneous conditions in the vaults after completion of closure engineering (capping) over each vault.
- A review of the scientific understanding of the transport of gases through plant canopies and the development of a detailed soil plant model that informed the development of an updated assessment level biosphere model.

We consider that the updated assessment provides a more realistic appraisal of the physical and chemical form of C-14 bearing wastes likely to be consigned in future, revised package- and vault scale representation of C-14 release processes, updated partitioning factors and biosphere factors. These changes have resulted in a reduction in dose of about two orders of magnitude compared with the 2011 ESC dose calculations. Peak annual doses are calculated at around 3 μ Sv to a person representative of the group at greatest risk (an individual that gain all their vegetables, fruit and some animal products from an agricultural smallholding established over the area of the vaults). This corresponds to an annual risk of 1.8 E-7, which is below the risk guidance level. Peak doses are associated with area averaged C-14 fluxes from Vaults 10 and 15-20. Dose associated with the area averaged flux from the trenches is an order of magnitude lower than dose associated with the area averaged flux from the combined vaults. Peak impacts are calculated for 100 years after closure of the last vault (2230 AD).

A range of alternative cases were used to explore uncertainties in the inventory, near field release model and the biosphere model. None of the credible cases yielded doses that are significantly higher than the reference case.

We consider that the information contained within the updated C-14 assessment adequately addresses Action ESC-RI-ASO-005.A2. This Regulatory Issue can therefore be closed.

Actions completed, Regulatory Issue resolved and Form closed

Owner: Environment Agency	Date: 15/11/2013
Approved by: Environment Agency	Date: 15/11/2013

ESC-RI-ASO-006: Very long term impacts if the LLWR does not erode

Title	Very long term impacts if the LLWR does not erode
Date raised	30/09/2011
Acknowledgment required by	14/10/2011
Response required by	31/12/2011
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	ASO
Approved by	Environment Agency

History

Status	Date	Description
Raised	30/09/2011	
Acknowledged	14/10/2011	
LLWR Response	06/02/2012	
Response Assessed	03/09/2013	
Transferred	03/09/2013	
Closed	15/11/2013	

Statement of Regulatory Issue

In our review of LLW Repository Ltd's 2008 Requirement 2 submission we recommended that the ESC include proportionate consideration of the impacts that could arise in the very long-term if the facility were for some unforeseen reason not to erode. In doing so, we noted that the 2002 PCSC had indicated some assessed risks several tens of thousands of years after closure that were significantly higher than those in the first 10,000 years, due to ingrowth of U-234 daughters and the possible discharge of radionuclides in groundwater to a terrestrial biosphere following a significant decrease in sea level associated with glaciation.

Assessments are presented in the ESC for a scenario in which the facility is eroded significantly later than expected, but there is no assessment or discussion of potential impacts in the very long-term if the facility were not to be eroded. There is no discussion of potential transport processes, environmental change or radioactive ingrowth in the very long term (> 10,000 years) to give rise to impacts greater than those assessed for shorter time frames, or of whether impacts in such situations could be of concern.

However strong the current evidence may be for the contention that the facility will be eroded, we note that:

- a) The scientific understanding that underpins this contention is largely of relatively recent vintage, and represents a substantial change from previous paradigms. While it seems unlikely that the current view might ultimately turn out to be fundamentally flawed, it is not inconceivable.
- b) The analysis of erosion is predicated on the assumption that the facility is not effectively protected against erosion. This is consistent with our regulatory guidance that such protection

should not be assumed to occur, but our guidance does not mean that the possibility of such protection may be completely ruled out.

We do not expect detailed assessment of potential impacts in the very long-term, but we do expect for completeness explicit arguments why we should have confidence that such impacts will not be substantially greater than those assessed for shorter timescales.

Regulatory Issue Actions

ESC-RI-ASO-006.A1	LLW Repository Ltd shall provide an explicit case for the acceptability of risks associated with potential very long term impacts if the facility were not to be eroded.
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	14/10/2011
<p>Comment: We will provide the results of calculations for an extended assessment period, beyond that provided already for the delayed coastal erosion scenario, along with a stated position on the acceptability of the estimated risks. The calculations will be for human intrusion and groundwater pathways and will provide results for radiological impacts on humans. Consideration will be given to potential changes that might occur over longer timescales, such as in near-field chemical conditions or the state of the cap.</p>		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	06/02/2012
<p>Report, <i>Assessment of Radiological Impacts in the Very Long Term if the LLWR is not Eroded</i>, LLWR/ESC/R(12)10047 Issue 1, February 2012, sets out a case for the acceptability of risks in the very long term.</p>		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 03/09/2013
Approved by: Environment Agency	Date: 15/11/2013

LLW Repository Ltd provided the report, *Assessment of Radiological Impacts in the Very Long Term if the LLWR is not Eroded*, LLWR/ESC/R(12)10047 Issue 1, February 2012 in response to this Regulatory Issue (RI). The response provided further evaluation of the possibilities by which the site might not be eroded within a few thousand years and an assessment assuming that the site should exist up to 250,000³ years after present (yAP). This scope and approach used for the very long-term assessment is considered appropriate.

This assessment assumed that the LLWR site is not eroded by coastal recession due to a fall in sea level within about 10,000 yAP. The fall in sea level is hypothesised as being due to rapid cessation and control of global CO₂ emissions and of CO₂ levels in the atmosphere, leading to reversion towards a climate evolution near to the natural scenario in the absence of greenhouse gas emissions. This scenario is even less likely than the maintenance of current sea levels. The

³ 250,000 years after present is the timescale for secular equilibrium with U-238 which corresponds with three half-lives of Th-230, which is about 250,000 years.

ESC predicts that if current sea levels are maintained, a local rate of coastal erosion estimated at about 0.2 m per year will occur. If this erosion rate remained constant, then site erosion could be expected to occur in a period from around 2,500 to 5,000 yAP. This illustrates the very low likelihood of the very long-term scenario addressed.

The very long-term assessment assumes that the current site configuration and layout of the Drigg Dunes will be present over extended periods and the nature of long-term radiological hazards present in the wastes will remain intact with coastal erosion not changing the current site geography. This differs from a scenario where human intervention, in the form of the construction of coastal defences, delays the onset of erosion. The 2011 ESC discusses the potential role local coastal defences might temporarily play in delaying coastal erosion; because of the expected continued rise in sea level the defences would have to be maintained, and substantially redesigned and/or repositioned. Thus, the maintenance of the repository over extended periods is not considered as a credible means to prevent erosion of the LLWR site over very long term periods. The GRA does not require LLW Repository Ltd to carry out an assessment for this scenario.

The results of this additional assessment showed that conditional risks from the groundwater pathway are about one order of magnitude above the GRA risk guidance level. Calculated doses from human intrusion events are about one order of magnitude above the lower end of the GRA dose guidance range, for prolonged exposure to radon following human intrusion. In the very long-term scenario, radium in-growth from uranium decay becomes a more important factor.

The significance of the results must take account of the very low likelihood of the scenario being realised and the conservative nature of the source term used for the assessment. Taking into account these factors we can conclude that the assessment meets the objective of the GRA Requirement 6. This RI has been adequately addressed and can be closed.

References

LLW Repository Ltd. The 2011 ESC: Site Evolution, LLWR/ESC/R(11)10023, May 2011.

LLW Repository Ltd. The 2011 ESC: Optimisation and Development Plan, LLWR/ESC/R(11)10025, May 2011.

Actions completed, Regulatory Issue resolved and Form closed

Owner: Environment Agency	Date: 15/11/2013
Approved by: Environment Agency	Date: 15/11/2013

ESC-RI-ASO-007: Deriving WAC for groundwater pathway

Title	Treatment of decay chains in deriving WAC for groundwater pathway
Date raised	04/10/2011
Acknowledgment required by	21/10/2011
Response required by	30/11/2011
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	ASO
Approved by	Environment Agency

History

Status	Date	Description
Raised	04/10/2011	
Acknowledged	28/10/2011	
LLWR Response	31/01/2012	
Response Assessed	03/07/2013	
Transferred	03/07/2013	
Closed	18/11/2013	

Statement of Regulatory Issue

When modelling impacts from multiple radionuclides using a GoldSim model, GoldSim itself does not distinguish between activity of a given radionuclide introduced into the system as an initial condition or from a source term and activity of that radionuclide grown in from radioactive decay of its parent radionuclide(s). For an inventory specified as total initial activities of multiple radionuclides, the total doses/risks calculated to arise from a given radionuclide do not necessarily correspond to the total impact attributable to disposal of the specified initial inventory of that radionuclide. The total doses/risks calculated may include contributions due to ingrowth of the given radionuclide from disposal of its parent radionuclide(s) and may exclude the doses/risks due to ingrowth of daughter radionuclides from the initial inventory of the given radionuclide. If a modeller wants to assess the total dose/risk attributable to the disposal of a given activity of a given radionuclide, then explicit provision has to be made in the model coding or input parameters to give this result.

From inspection of GoldSim model files, the coastal erosion calculations appear to achieve this result by performing multiple runs of the model with different inventories each containing only one radionuclide chain, and in the human intrusion calculations the amount of a given radionuclide present from each source appears to be modelled as a separate contaminant. However, from the GoldSim files we have seen to date, the calculations for the groundwater pathway do not appear to keep the different contributions separate and therefore the calculated risks from, for example, Ra-226 appear to include those from Ra-226 ingrown from disposed Th-230, U-234, etc., and to exclude those from Pb-210 and Po-210 ingrowth from the original Ra-226. The results for unit disposal activities in deterministic cases R23 and R24 (Tables 6.17 and 6.18 of the Level 3 report) appear to support this, the tabulated risks from Pb-210, for example, being significantly higher than those for Ra-226. We would expect the total dose due to disposal of 1 TBq of Ra-226 to be similar to or higher than that due to disposal of 1 TBq of Pb-210, as an activity of Pb-210 approaching 1

TBq would be present by ingrowth not much more than 100 years after disposal of 1 TBq of Ra-226 (i.e. around the time when well pathway risks peak).

This is not a significant concern in relation to calculating the total impacts from the defined inventory cases, as all of the doses/risks are accounted for somewhere. However, it is not a correct basis for the calculation of hypothetical limits on total activity of each radionuclide that could be disposed of as part of the derivation of proposed WAC, as in this case each impact needs to be attributed to the disposal that causes it.

Regulatory Issue Actions

ESC-RI-ASO-007.A1	LLW Repository Ltd shall provide either an explanation of how the groundwater pathway assessment results were correctly used in the derivation of activity limits for the WAC or corrected calculations of the relevant limits.
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	28/10/2011
Comment: The Issue raised will be investigated and either an explanation or correction will be provided.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	31/0/1/2012
<p>Revised results for the capacities calculated from the assessment of the groundwater pathway for the Reference Disposal Area (RDA) repository are presented in report: <i>Radiological Capacities for the RDA and EDA LLWR Repository Designs for the Groundwater Pathway</i>, SERCO/E005758/001, January 2012. The approach used to derive the results is described in the report. These results replace those reported in the Level 3 groundwater assessment report: <i>Radiological Assessment Calculations for the Groundwater Pathway for the LLWR 2011 ESC</i>, SERCO/TAS/E003796/011 Issue 6, April 2011.</p> <p>We have now resolved the anomalies between the capacities calculated from the groundwater pathway assessments for the RDA and Extended Disposal Area (EDA) repositories, noted in the ESC Level 2 <i>Assessment of an Extended Disposal Area</i> report. Report SERCO/E005758/001 also reports the equivalent results for capacities for the EDA repository. The resolution of the anomalies is described in report: <i>Reconciliation of Differences Between the RDA and EDA Calculations in the 2011 ESC for the Groundwater Pathway</i>, SERCO/E005758/002, January 2012.</p> <p>We propose to discuss with the Environment Agency the most appropriate time to submit revised proposals for Waste Acceptance Criteria (from those set out in the Level 2 <i>Waste Acceptance</i> report), given the recognised need for discussions about our proposed approach before submission of our application for a new permit.</p>		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 12/11/2013
Approved by: Environment Agency	Date: 12/11/2013

Two issues were addressed in LLW Repository Ltd's response to this Regulatory Issue (RI).

Firstly, anomalies between the groundwater pathway calculations for the extended disposal area (EDA) and the reference disposal area (RDA) were resolved, as described in 'Reconciliation of Differences Between the RDA and EDA Calculations in the 2011 ESC for the Groundwater Pathway', SERCO/E005758/002, January 2012. The following discrepancies were addressed through updating the EDA model:

A difference in the minimum thickness of the saturated zone permitted in the vault compartments in the RDA and EDA near field model.

A difference in the assumed degree of saturation in the B2 compartments that underlie the trench and vault compartments.

A stochastic element in the EDA assessment model was set up to return the mean value, rather than the most likely value, in deterministic calculations.

The deterministic assessment cases from the 2011 ESC were re-run using the modified EDA assessment model. The results obtained were found to be within 50% of those obtained with the unmodified model. For the well, estuary and marine pathways, the results are within 30% or less of those obtained with the unmodified model.

Secondly, LLW Repository Ltd acknowledged that there was an error in the groundwater pathway radiological capacity calculations relating to the treatment of decay and ingrowth. The radiological capacity for a radionuclide that has radioactive daughters should be related to the sum of the risks associated with that radionuclide and all its radioactive daughters. However, in the 2011 ESC, the effect of daughter risks was not accounted for. Instead, capacities for daughter radionuclides would be based on the sum of the risks from both the disposed and ingrown inventory. This error only affects radionuclides that are part of significant chains.

Updated radiological capacities for the groundwater pathway for both the RDA and EDA were calculated to address this issue, as reported in 'Radiological Capacities for the RDA and EDA LLWR Repository Designs for the Groundwater Pathway', SERCO/E005758/001, January 2012. The updated EDA model was used in these calculations.

Updated capacities were calculated for the well, stream, marine and estuary pathways for the expected natural evolution scenario and the delayed coastal erosion scenario deterministic models. These capacities replace those presented in the 2011 ESC.

We consider that the information contained within the response to this RI addresses Action ESC-RI-ASO-007.A1. This Regulatory Issue can therefore be closed. However, we note that the capacities documented in 'Radiological Capacities for the RDA and EDA LLWR Repository Designs for the Groundwater Pathway', SERCO/E005758/001, January 2012 have subsequently been updated in calculations that take account of the presence of EDTA in the facility (Radiological and Non-radiological Capacities for the LLWR in the Presence of EDTA, AMEC SF6817/001, September 2013).

Actions completed, Regulatory Issue resolved and Form closed

Owner: Environment Agency	Date: 12/11/2013
Approved by: Environment Agency	Date: 18/11/2013

ESC-RI-ASO-010: Inventory heterogeneity and PEGs in coastal erosion dose assessments

Title	Inventory heterogeneity and PEGs in coastal erosion dose assessment
Date raised	16/02/2012
Acknowledgment required by	29/02/2012
Response required by	30/03/2012
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	ASO
Approved by	Environment Agency

History

Status	Date	Description
Raised	24/02/2012	
Acknowledged	15/03/2012	
LLWR Response	04/05/2012	Revised response rec'd in August 2013
Response Assessed	06/09/2013	
Transferred	06/09/2013	
Closed	20/11/2013	

Statement of Regulatory Issue

LLW Repository Ltd has assessed, in the 2011 ESC, a range of potential doses and risks resulting from future coastal erosion of the facility. However, exposure scenarios and pathways involving the inhalation or ingestion of particulate material on the beach with relatively high specific activity have not been assessed to a sufficient degree.

LLW Repository Ltd claims its assessment model represents spatial heterogeneity of the wastes and dispersion through the storm beach and foreshore into the marine environment. This Regulatory Issue relates to the scale at which heterogeneity is represented in the model. LLW Repository Ltd has considered heterogeneity of the waste on a scale of tens of modelling cells. For the coastal erosion scenario, the model homogenises over eight to nine cells that are considered to be in the process of erosion at any one time, such that radioactivity within each of these cells can be assumed to be homogenised with tens of thousands of cubic meters of bulk waste within each cell. LLW Repository Ltd has not presented any evidence to explain how the waste material will be homogenised in such a manner. We consider such a degree of homogenisation unlikely in practice and LLW Repository Ltd's dose assessment is therefore unrepresentative of the range of doses that might reasonably be incurred. In summary, we now require a range of additional 'what if' calculations, exploring the consequences of heterogeneity at a much finer scale together with the consideration of a range of additional exposure pathways and potentially exposure groups.

Recent communication from LLWR⁴ states there is no evidence or reason to suppose the presence of 'hot particles' at the LLWR of the type observed, for example, on beaches near Sellafeld and Dounreay. LLW Repository Ltd also states that the quantities of ultimate interest are 'annual risk' to a person representative of those at greatest risk (citing GRA paragraph 6.3.10) or 'effective dose' to a person during or after an 'intrusion' event (citing GRA 6.3.36).

We do require assessments in support of these GRA paragraphs. We also wish to examine the robustness of the underpinning assumptions and methodologies. The fact that there is a 'risk' element to the calculation supporting GRA 6.3.10, does not necessarily justify the use of risk-based arguments at every stage in the assessment chain. In LLW Repository Ltd's assessment, the 'risk' of inhaling or ingesting a relatively high activity particle is, implicitly, subsumed into the calculation of the average activity in each of the modelling cells.

Risk-based arguments, and use of averaging, can potentially mask huge variability. The GRA has paragraphs warning against the limitations of risk assessment, notably:

6.3.22 In cases where the hazard presented by the waste warrants a detailed assessment of risks, we shall expect a probability distribution of dose to be one of the outputs from each risk assessment that the developer/operator undertakes.

6.3.28 Some scenarios will involve future events so uncertain that it may not be appropriate to undertake numerical risk assessments for comparison with the risk guidance level, as this could distort the overall picture of risks. These scenarios might include a range of "what-if" scenarios. Such scenarios may affect whether or not the environmental safety case overall is judged acceptable and the environment agencies will need to consider them one by one.

7.2.7 To an extent appropriate to the radiological hazard presented by the waste, the environmental safety case should make use of multiple lines of reasoning based on a variety of evidence, leading to complementary environmental safety arguments. The evidence may be both qualitative and quantitative, supported where appropriate by robust numerical analyses. The reasoning and assumptions should be clear and the evidence supporting them traceable.

Although the LLWR is an LLW facility, the absence of localised concentrations of higher (than average) activity waste cannot be demonstrated given the nature of:

- how LLW is defined (activity averaged over a tonne)
- how LLW has historically been consigned (e.g. averaged per consignment)
- the physical nature of much LLW (e.g. contamination on essentially clean materials some of which may be high specific activity particulate material)
- the presence of quantities of long-lived wastes in the vaults and trenches

We believe the hazard presented by certain waste forms during coastal erosion warrants a more detailed exploration of the range of potential doses. LLW Repository Ltd has produced a detailed Level 3 coastal erosion assessment report⁵. However, we consider this assessment report is limited for two main reasons.

1) Limited exploration of the impact of heterogeneously distributed material on the beach

Key defining assumptions in the LLWR Level 3 assessment (Table 7.2) include:

"The waste is treated as homogeneous material that is uniformly eroded and dispersed", and "Radionuclide are homogeneously distributed in the bulk waste within each vault/trench model cell".

Further simplifying assumptions are made on page 53:

"Radionuclide concentrations in storm beach and foreshore materials decrease with increasing distance from the foreshore, as radionuclides are progressively dispersed and diluted".

⁴ Email communication, R. Cummings to D. Brazier 16/01/2012.

⁵ Assessment Calculations for Coastal Erosion for the LLWR 2011 ESC, QRS-1443ZC-R1 Version 3, April 2011.

Although material will generally breakdown with erosion; given the form and inhomogeneous distribution of certain waste types, the specific activity of a lesser proportion of discrete items or particulates may increase, whilst at the same time become more easily available for ingestion or inhalation.

The associated 'development and testing' Level 3 report⁶ (p 39) states:

"The ingested material is likely to be derived from spatially extensive areas, so the use of suitably spatially averaged radionuclide concentrations for the ingested material is considered to be appropriate" and "As the suspended material will originate from a spatially extensive area, it is appropriate to base exposure estimates on spatially averaged activity concentrations."

This might be a reasonable modelling approach when calculating external doses to a dog walker (for example) but, as discussed above, it has the potential to mask huge variability in doses arising from pathways giving rise to internal and contact doses. We wish to see the calculations extended by consideration of a reasonable and representative (realistic worst case) range of 'what if' calculations for exposure to a range of known or foreseeable particulate waste types at the LLWR (e.g. plutonium oxide from the Drigg magazines and AWE, radium sulphate paint, radium needles, other long lived 'low activity sources', higher activity waste items discussed in the RECALL interviews, thorite and monazite sands, uranium, americium from smoke detectors). Appropriate specific activities can be obtained from published literature (e.g. radium concentration in the paint formulas historically used by MoD) or by taking advice from consignors or use of recent HPA guidance (discussed below).

Page 40 of the 'development and testing' Level 3 report gives some discussion of the health impacts with particulates found at Dounreay and Sellafield and concludes with a statement for LLWR-derived alpha particulate that:

"...the particles are too large to be readily inhaled. Therefore, the main consideration would be ingestion. However, the risk of induction of gastrointestinal lesions would be negligible, even if the particles became temporarily lodged at specific locations in the gut. Based on the above considerations, evaluation of doses and risks from particles is not included in the model proposed in this report."

No assessment has been provided by LLWR to back up this claim of negligible risk from ingestion of this form of waste material.

2) Limited exploration of Potentially Exposed Groups (PEGs)

The three main PEGs considered by LLW Repository Ltd (based on the results of a 'habit survey') are:

- a 'dog walker' or beachcomber;
- an inshore fisherman, and
- high-rate consumers of locally caught marine foodstuff.

Other beach users, such as a family playing or having a picnic on the beach are not assessed. This is an important PEG to consider; it is a pastime we can observe on the Drigg beach and there is no reason to believe families in the future will not wish to do the same. Consideration of such exposure scenarios and pathways is standard practice in contaminated land assessment. LLW Repository Ltd has already invoked the use of NRPB W-36⁷ for its assessment of doses to workers from (trench) 'selective retrievals', where the prescribed 'construction scenario' (Appendix D) is used to calculate doses to workers.

NRPB W-36 also has guidance on the assessment of doses for a 'recreational scenario' and a 'housing scenario' which could be adapted for a beach scenario. Children have a higher propensity for ingestion of small objects, whether inadvertently or deliberately (e.g. Pica disorder) and the

⁶ Development and Testing of a Capability for Radiological Assessment of Coastal Erosion, QRS-1443U-R1, May 2011.

⁷ NRPB - W36 Methodology for Estimating the Doses to Members of the Public from the Future Use of Land Previously Contaminated with Radioactivity, W B Oatway and S F Mobbs, March 2003.

consideration of such exposure pathways should not be excluded on the grounds of extreme behaviour. A helpful guide to assessing such exposure pathways may be found in Table 4 (p.17) of the recent HPA consultation draft⁸ on assessing heterogeneously distributed radioactive material. People do not necessarily detect and spit-out hard granular material that may enter their mouth. For example we know of cases where families have taken vacuum flasks onto the beach, dropped the cup in the sand, wiped the cup clean (partially unsuccessfully) then swallow grains of sand with the hot fluid. Other exposure pathways have also been considered in HPA's assessment⁹ of risks from radioactive objects and particles on the beach near Sellafield.

The 'dog walker' example could also be extended to consider the potential for the dog to pick up contamination in its fur/paw and carry it back into the rear of a vehicle and then into the home. Such exposure scenarios and pathways are not unreasonable. They involve ordinary people doing ordinary things. As such, we expect to see an assessment of potential doses, expressed as a series of 'what if' scenarios with supporting calculations (as per GRA 6.3.28).

We accept there are severe problems in trying to quantify the likelihood of such exposures occurring. The scenarios should be credible; we do not require uncorrelated worst case assumptions to be combined. In addition to dose calculations, LLW Repository Ltd could additionally provide a discussion of particle density (for particles above a certain threshold of activity concentration) to accompany each of the new exposure pathways and scenarios.

Regulatory Issue Actions

ESC-RI-ASO-001.A1	LLWR shall carry out additional assessments to explore the impact of waste heterogeneity at the particulate scale for an additional range of potentially exposed groups.
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	15/03/2012
A response will be provided.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	04/05/2012
A response is provided in ESC Project Memo LLWR/ESC/Mem(12)146, 04/05/2012.		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 06/09/2013
Approved by: Environment Agency	Date: 20/11/2013

LLW Repository Ltd has broadly followed our suggestions to adopt HPA (now Public Health England, PHE) guidance, with some modifications to account for the uncertainty about future repository evolution. LLW Repository Ltd presented results for a range of possible or potential

⁸ Guidance on the Assessment of Exposure from Land Contaminated with Heterogeneously Distributed Radioactive Material, W. B. Oatway and S. F. Mobbs, HPA-RPD-000, Draft for Consultation. July 2011.

⁹ Health Risks from Radioactive Objects on Beaches in the Vicinity of the Sellafield Site, J. Brown and G. Etherington, HPA-CRCE-018, April 2011.

wasteforms in a series of 'what if' type assessments for different types of waste that may or may not be present in the LLWR.

In summary, these illustrative assessments suggested it is possible for someone to incur higher doses than assessed in the 2011 ESC, once waste heterogeneity is taken to the particulate scale; although the corresponding likelihood of encountering any 'hot spot' (as opposed to encountering average level contamination or clean sand) is correspondingly much lower. Consequently, the risks are low and consistent with Requirement 6 (Risk Guidance Level) of the GRA. The illustrative assessments showed that significant doses could arise from ingestion of radium sources and alpha-rich particles but that the probability of encountering such items is extremely low given the low numbers of such deposits at the LLWR.

As an illustration, the highest activity alpha-rich object recovered from the Sellafield beach to date is a particle containing 84 kBq Pu-238, 309 kBq Pu-239/240 and 634 kBq Am-241. If such a particle were ingested, it would potentially give rise to a committed effective dose of around 20 mSv to an adult (or twenty times the annual dose limit for a member of the public) and 55 mSv to a 1 year old child⁹. If the same particle were ingested by a three month old infant, the dose could be in the region of 300 mSv. However, caution is required when assessing doses to a 3 month old. Beach occupancy by children of this age is normally very low; direct contact with the beach is probably restricted (e.g. if the child is in a pram or chair) and would not be mobile. Consequently, there would be a much lower likelihood of such an infant encountering a particle than for other age groups considered.

We commissioned HPA (PHE) to independently review LLW Repository Ltd's supplementary assessments (WB Oatway, N Higgins, Review of Assessments of Prospective Exposure to Low Activity Sources or Particulate Material following Coastal Erosion of, and Intrusion into, the LLWR, April 2013). The main conclusion of the review is that the LLW Repository Ltd's assessments generally follow the approach used by the HPA/PHE in their recent work on assessing radiological consequences from the use of beaches contaminated by radioactive objects. The reviewers found that the methodologies used in the assessment generally employ a suitable level of caution and include the most significant exposure scenarios, pathways and groups of people likely to be the most exposed. The reviewers suggested that more detailed information on some aspects of the methodology should be provided, including a discussion of the likely impact of exposure scenarios not considered in detail.

After considering PHE's review, we produced supplementary guidance on the future disposal of discrete items and particles to the LLWR¹⁰. We stated that for future disposals, an optimised approach to waste acceptance is likely to entail restricting disposal of items, individually carrying a significant burden of radioactivity, in view of coastal erosion. Equally, we said an optimised approach is likely to entail preventing any processes within the LLWR, or as a result of coastal erosion, that might lead to the production of high dose particles. We suggested these considerations may require improvements to waste characterisation and segregation as part of an optimised approach. We also stated it is acceptable to use the GRA's risk guidance level as a criterion for random encounters with particles, but that a 'test of significance' should apply to casual curiosity and deliberate searches, which includes the case of 'a particle or multiple particles collected as a result of a deliberate search'. We proposed this 'test of significance' should be the effective dose to any person during and after coastal erosion of the LLWR should not exceed a dose guidance level in the range of around 3 mSv/year to around 20 mSv/year (consistent with the existing guidance for human intrusion as set out under Requirement R7 in the GRA).

LLW Repository Ltd has subsequently re-evaluated its earlier supplementary assessment of potential doses from particle ingestion using more realistic assumptions (Sumerling, T. J., 2013, Assessment of Individual Radioactive Particles and WAC for Active Particles, LLWR/ESC/R(13)10056, August 2013). This report shows that, using International Commission on Radiological Protection (ICRP) Publication 68 dose coefficients (as opposed to ICRP Publication 72), calculated doses for inadvertent ingestion of particles is still the limiting pathway (compared

¹⁰ R. E. Smith, 2013. Advice to Environment Agency Assessors on the Disposal of Discrete Items, Specific to the Low Level Waste Repository, Near Drigg, Cumbria (Version 6a), 1 May 2013.

with external exposure, inhalation and skin contact routes) but are reduced by up to an order of magnitude, compared to the earlier assessment. This is because dose coefficients in ICRP Publication 68 are more appropriate for ingestion of raw, solid particulate radionuclides.

LLW Repository Ltd considers (and PHE agrees) that only particles of size 1 mm or less are capable of being inadvertently ingested and that deliberate ingestion of stone-sized objects (e.g. by children or PICA sufferers) should not be considered when considering WAC for future disposals.

Using more representative assumptions, LLW Repository Ltd found that the only particles that have the capacity to lead to a committed effective dose in the range 3 to 20 mSv are radium paint (to Admiralty specification), the highest alpha-rich Sellafield particle found to date and PWR spent fuel particles. In no case is 20 mSv exceeded, although some doses are within the 3 – 20 mSv range. These calculations are again illustrative of the kinds of particles which cannot be ruled out as absent from the LLWR.

Other higher activity particles from other waste materials such as MOX fuels, irradiated highly-enriched uranium (from materials test reactors and naval reactors), plus weapons grade enriched uranium and plutonium was not quantitatively assessed. We will recommend that in future updates of the ESC, LLW Repository Ltd includes these more hazardous wastes types as scoping assessments (see Recommendation ASS23 of Environment Agency 2015. Review of LLW Repository Ltd's 2011 environmental safety case: Assessments).

LLW Repository Ltd will seek to limit, as far as practicable, disposal of particles from any source that (individually) carries an activity sufficient to give rise to a significant assessed effective dose. Its focus will be on placing conditions on waste that has the potential to include significant numbers of specific activity particulate material and waste consigners will be obliged to consider the possibility that a consignment may contain such particles through the following criterion:

'Waste containing or that may contain Active Particles, or that may breakdown to form Active Particles, may be accepted for disposal but only on approval of a Waste Consignment Variation Form by LLW Repository Ltd.'

Active particles will be defined in the glossary of the revised LLWR WAC as follows:

'Active Particle means a particle in the size range of 0.6 to 2.0 millimetres of high-specific activity material such that a single particle could bear of the order of a megabecquerel (1 MBq) or more of alpha-emitting radionuclides or 0.01 megabecquerel (0.01 MBq) or more of radium-226. This implies a fragment of a high-activity material, typically more than about 100 megabecquerel per gram (100 MBq/g) of most alpha-emitting radionuclides or 10 megabecquerel per gram (10 MBq/g) of radium-226. Examples of Active Particles include fragments of Admiralty specification radium-sulphide paint, fragments of irradiated nuclear fuel (especially PWR, MOX or highly enriched uranium fuels) or plutonium.'

Waste containing (or that may contain) such 'active particles' may be accepted for disposal at LLWR but only on approval of a Waste Consignment Variation Form. We will continue to monitor developments in the WAC and its implementation.

The non-radiological aspects of exposure to the intake of particulate waste are not considered in this IRF.

The action raised by this Regulatory Issue has been adequately addressed and is therefore closed.

Actions completed, Regulatory Issue resolved and Form closed

Owner: Environment Agency	Date: 20/11/2013
Approved by: Environment Agency	Date: 20/11/2013

ESC-RI-ASO-011: Inventory heterogeneity and events in human intrusion dose assessments

Title	Inventory heterogeneity and events in Human Intrusion dose assessment
Date raised	24/02/2012
Acknowledgment required by	09/03/2012
Response required by	30/04/2012
Related issue numbers	ESC-RI-ASO-010
Originated by	Environment Agency
Current owner	Environment Agency
Review group	ASO
Approved by	Environment Agency

History

Status	Date	Description
Raised	24/02/2012	
Acknowledged	05/03/2012	
LLWR Response	19/07/2012.	
Response Assessed	06/09/2013	
Transferred	06/09/2013	
Closed	20/11/2013	

Statement of Regulatory Issue

LLW Repository Ltd has assessed, in the ESC, a range of potential doses resulting from possible future human intrusion events. The treatment of spatial variability (heterogeneity) in waste activities is discussed in Section 3 of the Level 3 assessment report¹¹. This Regulatory Issue relates to the scale at which heterogeneity is represented in the dose assessment calculations. This issue is closely related to our Regulatory Issue on heterogeneity in dose calculations for coastal erosion (ESC-RI-ASO-010), noting a similar modelling approach for the inventory is used in both assessment cases.

With the exception of low activity sources / sealed sources, which are considered separately by LLW Repository Ltd¹², the human intrusion assessment does not address the potential impacts of intrusion at the scale of specific waste items or waste forms. LLW Repository Ltd has considered heterogeneity of the waste on a scale of tens of modelling cells (covering the entire projected inventory of the trenches and vaults) such that radioactivity within each of these cells can be assumed to be homogenised with tens of thousands of cubic meters of bulk waste within each cell. LLW Repository Ltd has not presented any evidence to explain how the waste material will be homogenised in such a manner. We consider such a degree of homogenisation unlikely in practice

¹¹ Assessment Calculations for Human Intrusion for the LLWR 2011 ESC, Galson Sciences, 0977-3 Version 2, March 2011.

¹² Assessment of the Disposal of Low-activity Sources at the LLWR, LLWR/ESC/R(11)10037, Version 1, Sumerling, T.J., March 2011.

and LLW Repository Ltd's dose assessment is therefore unrepresentative of the range of doses that might reasonably be incurred.

Section 7 of the Level 3 assessment report states (page 49):

“Comments are given in the report text about any potential for significantly higher doses, but in this case such results should be weighed against the low likelihood of occurrence, e.g., that a number of investigation boreholes should pass through the same small area.”

We wish to examine the scope and extent of 'significantly higher doses' in quantitative terms, together with a separate discussion of likelihood of occurrence. In summary, we now require a range of additional calculations, exploring the consequences of inventory heterogeneity at a much finer scale for the identified human intrusion events.

Although LLWR is an LLW facility, the absence of localised concentrations of higher (than average) activity waste cannot be demonstrated (for reasons given in ESC-RI-ASO-010).

The fact that 'intruders' would be exposed to a wide range of materials (which could include cap materials, 'clean' wastes and bulk waste) does not lessen the impact of ingesting or inhaling one or more relatively high activity particles.

In ESC-RI-ASO-010, we suggested a range of long-lived radioactive particulate material that we considered salient for coastal erosion timescales. For Human Intrusion events (following the withdrawal of management control), the timescales of concern may be different, hence additional radionuclides may need consideration (radioactive decay).

Doses arising from any revised assessments for intake of high activity particulate material may not differ substantially between the different intrusion events that are already considered in the assessment. However, the probability of intake of higher (than average) activity material, in particulate form, may be proportionate to the total volume of material processed or the amount of time spent in the vicinity of the waste material.

Human intrusion events

The following intrusion events have been assessed in the LLWR report (page 7):

B1: Geotechnical investigations;

B3: Housing development;

B7: Smallholding;

C1: Informal scavenging;

C2: Local organised material recovery.

One event not assessed is 'landfill theft' or 'illicit material recovery'. For dose assessment purposes, the event may be similar to 'organised material recovery' but there may be different follow-on consequences to consider, for example handling at a scrap yard. There are many reported cases worldwide of landfill theft, predominantly involving metals. Copper, tin, lead, zinc, aluminium, nickel and other strategically important metals may be much in demand¹³. Legitimate organised recovery may be considered before or after the withdrawal of management control¹⁴, but theft is another possibility after the withdrawal of control. The cap would be a deterrent but not to those who were determined. Information is already in the public domain detailing the amount of metal within the trenches¹⁵. A search on Google today will reveal this information. There is no reason to believe this information will not be as easily available in the future. The fact that

¹³ Strategically Important Metals, House of Commons Science and Technology Committee Report HC 726, 17 May 2011.

¹⁴ We note reports that 100+ tonnes of Malayan monazite sand was 'hand picked' from the trenches in 1960 for resale Ref. Uncertainty in Specific radium and Thorium disposals to the trenches at Drigg, Note for the Record: C. P. Lennon, Dec 2002.

¹⁵ Heterogeneity of Past and Potential Future Disposals at the LLWR, Nexia Solutions (07) 9126, Issue 04, April 2011.

the material is also radioactively contaminated may not be readily apparent or of significant concern to those who are only focused on resale value, which may be significant.

Another event not considered is that of farmers or others making use of the cap materials. Historically, there is anecdotal evidence for collecting aggregate from local beaches in West Cumbria. We are also aware that some farmers currently have rights to collect sand from the Drigg dunes. In future, the cap materials may be seen as a valuable local building resource, in the same way that historical man-made structures and relics have been ransacked for their utility as raw materials. Cap performance may be severely compromised as a result, even if the waste is not directly uncovered. This event should be assessed for potential consequences, not only for human intrusion but also for impacts to the gas pathway and groundwater pathway (introducing oxidising conditions). Any consequences for the subsequent evolution of the LLWR should be assessed against the dose guidance level rather than the risk guidance level.

Other exposure pathways and parameters

It is also possible that an 'intruder' could be exposed as a result of high activity particulate material entering an open wound (sustained during the intrusion event). Other exposures can arise from particulate material trapped under the nails, in clothing or in shoes. These exposure routes should also be considered. Guidance on the assessment of such pathways can be found in HPA's assessment of risks from contact with radioactive objects on the beach near Sellafield¹⁶.

In Section 6.2.7 C1 (Informal Scavenger), the basis for assuming a visit to the site for 1 hour a day, 50 days per year, is not given. Someone keen on this activity could make a hobby of it and spend far more time per year than this. The 'informal scavenger' may be the limiting case of someone ill-equipped with the least level of personal protective equipment when considering open wound exposure.

Regulatory Issue Actions

ESC-RI-ASO-011.A1	LLWR shall carry out additional assessments to explore the impact of waste heterogeneity, intrusion events and exposure pathways and consequences as discussed in the main text.
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Technical Integrator	05/03/2012
A response will be provided.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Technical Specialist	19/07/2012
A response is provided in ESC Project Memo LLWR/ESC/Mem(12)148, 19/07/2012.		

¹⁶ Health Risks from Radioactive Objects on Beaches in the Vicinity of the Sellafield Site, J. Brown and G. Etherington, HPA-CRCE-018, April 2011.

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 06/09/2013
Approved by: Environment Agency	Date: 20/11/2013

LLW Repository Ltd accepts that the potential for exposure to high activity particulate material, following human intrusion into the LLWR, is a significant issue that was not addressed in its May 2011 ESC documentation.

We commissioned the Health Protection Agency (HPA, now Public Health England or PHE) to review the LLW Repository Ltd memo in accordance with HPA's methodology for assessing doses from heterogeneously contaminated land (as employed for HPA's 2011 Sellafield beach particles study). Reference: 'Oatway WB and Higgins NA, Review of Assessments of Prospective Exposure to Sealed Sources or Particulate Material following Coastal Erosion of, and Intrusion into, the LLWR, CRCE-EA-3-2013, April 2013'. In subsequent discussions with HPA and LLW Repository Ltd, there was some discussion around the right way to calculate skin doses, but we are now satisfied the approach LLW Repository Ltd has adopted is cautious, if not realistic (i.e. potential doses have not been underestimated).

No significant non-stochastic health effects are likely at the absorbed doses calculated. Three highly unlikely cases were identified in which the calculated absorbed dose could reach a threshold level for tissue effects after two hours skin contact, but would not lead to severe or irreversible health effects (discussed in GRA paragraph 6.3.40). Deliberate ingestion of certain items, for example medical radium sources or radium contaminated clinker, such as the larger items recovered from Dalgety Bay were they to be disposed at LLWR could lead to deterministic effects but inadvertent ingestion of material greater than about 1 mm in size is not likely.

LLW Repository Ltd has put in place an improved emplacement strategy so that higher activity containers are not placed in the uppermost stack positions or close together (for example in the same or adjacent stacks) in the vaults. Therefore the probability of intercepting one or more higher activity containers becomes lower and the potential for higher doses is reduced. Although this emplacement strategy is primarily aimed at reducing impacts during coastal erosion, it will also reduce impacts associated with intrusion events prior to the onset of erosion.

One of the important assumptions in the assessment is that the number of particles per gram is inversely proportional to the assumed activity on the particle. Hence, assuming a different activity on the particle in the waste leads to a different number of particles per gram of waste, and a different frequency (probability) of encounter of the particle. However, it leads to the same calculated value (expectation value) of annual effective dose.

LLW Repository Ltd's calculation of the number of particles per gram in the waste neglects radioactive decay between filling of individual trenches or vaults and filling of all trenches or vaults. It also assumes that all of the activity is present in the form of particles (1 mm particles for most exposure modes and 10 micron for inhalation) and that these particles are mobilised (that is, not embedded within other materials).

Overall, it is concluded that intrusion into the LLWR (before, during or after coastal erosion) is unlikely to give rise to annual doses above the lower guidance level (3 mSv) even assuming the waste in the LLWR is composed entirely of 1 mm particles and so Requirement 7 of the GRA has been met. We asked LLW Repository Ltd to assess impacts associated with higher activity items and to develop waste acceptance criteria for single items requiring direct control in IRF ESC-RO-ASO-006.

The only particle that is likely to be present at the time of the earliest intrusion event that could give rise to an absorbed dose above the threshold for deterministic effects in skin in

about 2 hours is a fuel fragment containing Sr-90 or Cs-137, similar to those found at Dounreay, that is excavated from the last vault to be closed (Vault 14), that is, the vault with the minimum decay time before the intrusion event. However, the number of fuel fragments containing Sr-90 or Cs-137 disposed of in the LLWR is expected to be very small. In addition, Intrusion at a date later

than 2210, or into the trenches or other vaults would not give rise to deterministic effects in skin. Thus we consider that that dose thresholds for severe deterministic injury to individual body tissues are unlikely to be exceeded as a result of human intrusion into the facility in accordance with Requirement 7 of the GRA.

The action raised within this Regulatory Issue has been adequately addressed and is therefore closed.

Actions completed, Regulatory Issue resolved and Form closed

Owner: Environment Agency	Date: 20/11/2013
Approved by: Environment Agency	Date: 20/11/2013

ESC-RI-ASO-012: Marine foodstuffs pathway

Title	Dose calculations from marine foodstuff during coastal erosion
Date raised	04/04/2012
Acknowledgment required by	13/04/2012
Response required by	18/05/2012
Related issue numbers	ESC-RI-ASO-010
Originated by	Environment Agency
Current owner	Environment Agency
Review group	ASO
Approved by	Environment Agency

History

Status	Date	Description
Raised	04/04/2012	
Acknowledged	04/04/2012	
LLWR Response	04/05/2012	
Response Assessed	03/07/2013	
Transferred	03/07/2013	
Closed	15/11/2013	

Statement of Regulatory Issue

LLW Repository Ltd has calculated potential doses from the ingestion of marine foods following coastal erosion¹⁷. The assessment considers a range of marine foodstuffs including crustaceans and molluscs. However, the potential for 'filter feeders' to trap higher activity particulate material in their gut does not appear to have been considered or assessed.

LLW Repository Ltd should now re-assess this exposure pathway. In ESC-RI-ASO-010, we suggested a range of long-lived radioactive particulate material that we considered salient for coastal erosion timescales. Mussel farmers in the coastal region already have plans to dredge sections of the seabed for young mussels. Such particulate material will be readily available for uptake by 'filter feeders' and some of this material may be entrained in the gut. For assessment purposes, CEFAS recommend that particles sizes up to 1mm should be taken into account¹⁸.

LLW Repository Ltd should separately consider the number of such higher activity particles that may be available for human consumption via this marine foodstuffs pathway and therefore the likelihood of individuals receiving elevated doses.

¹⁷ Assessment Calculations for Coastal Erosion for the LLWR 2011 ESC, QRS-1443ZC-R1 Version 3, April 2011.

¹⁸ Literature Review on Particle Assimilation by Molluscs and Crustaceans, Cefas Environment Report RL 10/08, April 2008.

Regulatory Issue Actions

ESC-RI-ASO-011.A1	LLWR shall carry out additional dose assessments to explore the potential human impact of higher activity particulate material via the marine foodstuffs pathway.
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	04/04/2012
An appropriate assessment will be provided in response.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	04/05/2012
A response is provided in ESC Project Memo LLWR/ESC/Mem(12)146, 04/05/2012.		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 03/07/2013
Approved by: Environment Agency	Date: 15/11/2013

The LLW Repository Ltd memo addresses the identified request. The company has calculated ingestion doses from seafood to a range of particles using the methodology applied by the Health Protection Agency (HPA, now Public Health England or PHE) to assess radiological impacts of radioactive particles found on beaches in the vicinity of Sellafield.

The highest calculated annual dose is for ingestion of particulates in shellfish by a high rate consumer gaining their entire annual intake from the Drigg shore, and assuming complete dissolution of the particles in the human gastrointestinal tract. This case is based on the ingestion of sand particles retained by shellfish (mainly in the gut parts) and a calculated intake of about 30 thorium bearing particles in 36 kg of shellfish consumed per year, which leads to a calculated annual dose of 20 microSv and annual risk of 1×10^{-6} . We note that naturally occurring thorium in coastal sediments in Cumbrian waters is far in excess of any future contribution from the destruction of the LLWR.

Ingestion (via shellfish) of an alpha-rich particle such as those found on Sellafield beaches could give rise to a dose above 100 mSv if standard International Commission on Radiological Protection (ICRP) f1 values are used. The doses calculated using the HPA measured dissolution (f1) factors are below 100 mSv and the overall risk to health is below 10^{-6} per year.

Since this memo was provided, LLW Repository Ltd has re-evaluated risks from particle ingestion in another memo (LLWR/ESC/R(13)10056, August 2013). This later assessment employs dose coefficients from ICRP Publication 68 (rather than Publication 72) because the factors are more relevant to intake of raw waste. ICRP Publication 72 is relevant to soluble radioactivity absorbed into plants and is not appropriate for ingestion of raw waste. We agree with this position and the issue is closed.

Actions completed, Regulatory Issue resolved and Form closed

Owner: Environment Agency	Date: 03/07/2013
Approved by: Environment Agency	Date: 15/11/2013

ESC-RI-ASO-013: Human intrusion into radioactive sources

Title	Dose calculations for human intrusion into radioactive sources
Date raised	30/04/2012
Acknowledgment required by	22/06/2012
Response required by	06/07/2012
Related issue numbers	ESC-RI-ASO-010; ESC-RI-ASO-011
Originated by	Environment Agency
Current owner	Environment Agency
Review group	ASO
Approved by	Environment Agency

History

Status	Date	Description
Raised	15/06/2012	
Acknowledged	15/06/2012	
LLWR Response	28/09/2012	
Response Assessed	03/07/2013	
Transferred	03/07/2013	
Closed	15/11/2013	

Statement of Regulatory Issue

LLW Repository Ltd's assessment calculations for Human Intrusion¹⁹ (HI) do not assess the consequences of intrusion into sealed or 'low activity' radioactive sources, which are known to be present in the trenches and vault 8. Page 6 states, "*The inadvertent recovery and handling of sealed sources involves specific exposure and limitation considerations, and is addressed by Sumerling (2010c).*" There is no listing of 'Sumerling (2010c)' in the references, though we believe the report in question is, Sumerling, T.J., 2011. Assessment of the Disposal of Low-activity Sources at the LLWR. LLWR/ESC/R(11)10037, Version 1, March 2011.

Section 3.3 of the main HI assessment states "*Exposure to individual containers or individual sources extracted or broken out from the containers is being considered in separate assessment calculations, considering both human intrusion and the finding of such items on the beach following erosion of the facility (Sumerling, 2011).*" However, 'Sumerling 2011' does not contain any assessment of standard HI type events into radioactive sources and instead, states on page 3:

"We consider that the limiting assessment cases: – will occur after the facility has been impacted by coastal erosion, source containers have been distributed with other waste on the beach and may be broken open by wave action on the cobble storm beach;

– involve a beach user, e.g. walker or beachcomber, either interacting with a single source container or finding and taking away one or a small number of individual sources."

¹⁹ Hicks, T.W. and Baldwin, T.D., Assessment Calculations for Human Intrusion for the LLWR 2011 ESC, Galson Sciences Report 0977-3 Version 2, March 2011.

An argument for the ‘coastal erosion’ scenario being the ‘limiting case’ is presented on page 14, *“In both cases, the important exposure modes are similar – external dose due to inspection, carrying away or proximity to a container, or exposure to an individual source (skin dose) if the container is broken open either naturally or during a human intrusion.”*

We do not agree that the ‘important exposure modes are similar’ for human intrusion scenarios before and after coastal erosion. Unlike the main HI assessment, there is no assessment in ‘Sumerling 2011’ of typical HI scenarios such as the geotechnical worker and lab analyst, the housing developer or a smallholding (for example). In the absence of a comparative assessment, there is no basis for assuming that HI events following coastal erosion represent the limiting case for the assessment of exposure to radioactive sources. HI events have the potential to generate dust from drilling into sources and the dust inhalation pathway could be more severe than external or skin contact dose. We note here the safety assessment performed by AEAT in 2001 for the Hungarian near surface repository²⁰. In that assessment, the limiting exposure pathway for HI into radioactive sources was for inhalation of dust from alpha-bearing sources during excavation (assuming the area being excavated was enclosed - not open to atmosphere), resulting in significant worker doses and a consequent decision on intervention and retrieval (as acknowledged in the LLWR Optimisation and Development Plan).

GRA paragraph 6.3.41 discusses three classes of human intrusion. The third class is an *“archaeological investigation carried out without knowing about or understanding radioactivity, but recognising that there has been human activity at the site in the past”*. We consider this scenario similar to the ‘excavation worker’ scenario addressed in the AEAT report.

LLW Repository Ltd should now re-assess the human intrusion exposure pathway, taking account of a range of specific source disposal consignments at their specific locations for exposure pathways including dust inhalation. A list of known source consignments is presented in Appendix 1 (Table A1 and A2) of ‘Sumerling 2011’. In addition, we know of a consignment (following a warehouse fire) of 275,000 smoke detector sources (each containing 33.3 kBq of Am-241) that we also believe should be assessed against HI scenarios.

The significance of assessing intrusion into specific wastes derives from Requirement 7 (para 6.3.40) of the GRA, *“The developer/operator will need to show that dose thresholds for severe deterministic injury to individual body tissues are unlikely to be exceeded as a result of human intrusion into a near-surface disposal facility”*

In addition, without a thorough assessment of intrusion into known waste deposits containing significant quantities of localised radioactivity, it cannot be demonstrated that this near-surface facility and its wastes have been properly optimised for radiological protection.

Regulatory Issue Actions

ESC-RI-ASO-013.A1	LLW Repository Limited shall carry out additional human intrusion assessments for a range of known deposits of radioactive sources at LLWR.
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	15/06/2012
We plan to provide a response to this IRF combined with that of IRF ESC-RI-ASO-011. We will undertake the calculations requested, noting how reasonable we believe the different cases to be, with appropriate justification.		

²⁰ Baker, A.J., Berci, K., Chambers, A.V., Csige, I., Elekes, Z., Jackson, C.P., Jefferies, N.L., Juhasz, L., Kelly, M., Mészáros, S., Sumner, P.J., Svingor, É., Thorne, M.C., Watson, S.P., Wells, D., Safety Analysis of the Püspökszilágy Radioactive Waste Treatment and Disposal Facility: An Assessment of Post-Closure Safety, Phare Project 990167, European Commission, March 2001.

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	28/09/2012
A response is provided in LLWR ESC Project memo LLWR/ESC/Mem(12)165 28/09/2012.		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 03/07/2013
Approved by: Environment Agency	Date: 15/11/2013

This RI asked LLW Repository Ltd to carry out additional assessments for human intrusion into a range of known disposals of radioactive sources at the LLWR.

In response, LLW Repository Ltd presented results from a number of additional human intrusion scenarios that involved interception of the following wastes²¹:

- low activity sources disposed according to the conditions agreed with the Environment Agency in 2005
- sources disposed before 2005, especially the potential impacts from source disposals in 2001/2 that were not consistent with the conditions that were later agreed
- debris waste from a warehouse fire containing Am-241 sources

Assessments were made of:

- absorbed dose from intact sources and source fragments
- absorbed dose from a volume of sources where this is appropriate
- effective dose from handling of source containers
- effective dose due to borehole drilling directly into a source container or source bearing waste
- effective dose if a sources or source bearing waste are dispersed over land that is subsequently used for housing development or by a smallholder

Doses calculated for intrusion into these sources are no more than a few micro sieverts. All values are small fractions of the 20 mSv per year dose guidance value for exposures that are of short duration. Many of the assessed cases also have a low probability even if the assumed intrusion event occurs, i.e. the probability that the assumed intrusion event intercepts consignments of sources is low.

The highest calculated effective dose that is found is in the case that a site development excavation intercepts a source container loaded with Ra-226 sources and this activity is dispersed over land on which a dwelling is constructed. For this case, an annual effective dose of 0.2 mSv is calculated, due mainly to radon progeny. This has to be added to the calculated effective dose from other wastes present, which for the average concentration of radionuclides in Vault 8 has been calculated in the 2011 ESC as 2.6 mSv for the site occupier event and 4.0 mSv for the smallholder event. The conditional chance of excavating such a source container is estimated at about 1 in 80. In practice, the location of the containers is known and, consistent with the emplacement strategy developed in the 2011 ESC, higher activity radium-bearing wastes would not be placed within 5 m of the projected cap surface.

No cases were found in which the calculated absorbed dose could approach the threshold level for tissue effects and thus no tissue effects would occur.

²¹ Sumerling, T. and Jackson, D. Response to IRF ESC-RI-ASO-013: Dose calculations for human intrusion into radioactive sources. LLW Repository Ltd memo LLWR/ESC/Mem(12)165.

We consider that the information contained within the updated calculations adequately addresses Action ESC-RI-ASO-013.A1. Resultant doses will be below the relevant dose guidance level. This Regulatory Issue can therefore be closed.

Actions completed, Regulatory Issue resolved and Form closed

Owner: Environment Agency	Date: 15/11/2013
Approved by: Environment Agency	Date: 15/11/2013

ESC-RI-ASO-014: Doses during the period of authorisation

Title	Total doses to representative person from LLWR during the Period of Authorisation
Date raised	25/05/2012
Acknowledgment required by	07/06/2012
Response required by	29/06/2012
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	ASO
Approved by	Environment Agency

History

Status	Date	Description
Raised	30/05/2012	
Acknowledged	01/06/2012	
LLWR Response	08/02/2013	
Response Assessed	06/09/2013	
Transferred	06/09/2013	
Closed	15/11/2013	

Statement of Regulatory Issue

The LLWR will remain under institutional control for another 180 years. The documentation suggest that during this time there will be varying degrees of offsite exposure of members of the public from direct radiation, liquid discharges, groundwater migration, emissions of dust, and emissions of gases, including radon-222 and carbon-14. A series of assessments of offsite exposure from each of these exposures have been made to discrete groups. However there is no clear indication of whether these exposures could be additive and in what combinations. Statements in the Level 1 and Level 2 reports state that Period of Authorisation (PoA) doses 'can be summed' but we request that LLW Repository Ltd carry out the dose summation at suitable time intervals throughout the PoA. For example a group exposed to direct radiation could also be exposed to radon gas emanation. Radon gas emanation is indicated to give rise to doses of up to 50 micro Sv /y. Doses from direct radiation from the various proposed vaults are also expected to range up to several tens of micro Sv/y. The implication is that doses of 100 micro Sv/y or more could be realised by addition of doses via these pathways.

The National Dose Assessment Working Group (NDAWG) has provided advice²² on the assessment of doses to the critical group (representative person) for prospective dose assessments and retrospective dose assessments. This covers various approaches to applying site specific and generic habits data to form realistic candidate critical groups across a range of exposure pathways. Although solid waste disposal facilities are outside the scope of NDAWG's

²² See <http://www.ndawg.org/NDAWGpapers.htm> and the jointly badged guidance, Authorisation of Discharges of Radioactive Waste to the Environment; Principles for the Assessment of Prospective Public Doses at <http://publications.environment-agency.gov.uk/dispay.php?name=GEHO1202BKLH-E-E>

work; during the PoA, the dose assessment process has similarities with assessments carried out for other nuclear sites. Therefore it would seem appropriate to consider the guidance for relevance against the PoA part of the LLWR assessment.

During the institutional control period, a dose constraint of up to 300 micro Sv/y applies from all related pathways on the site. Once the period of institutional control expires an overall risk guidance level of 1 in 10⁶ applies, which equates to a dose of ~20 micro Sv/y for pathways that are likely to occur.

Given that during the period of institutional control (PoA) doses of 50 micro Sv/y or higher are possible, it is necessary to understand the time trend in doses out to the end period of institutional control (~180 years). This will show what offsite doses are to be expected at the transition from the end of the PoA into the early post closure phase. There is currently no indication in the assessment of whether predicted doses decline to <20 micro Sv/y by the start of the post-closure phase.

The LLWR should identify whether there are candidate critical groups who may be exposed to more than one exposure pathway and identify which age groups are being considered and why. These groups should be described, including consideration of whether or how the composition of these groups might change over the 180 years of the PoA.

The Level 1 reports states (p78) that, "future annual doses depend on assumed future habits and locations, but are unlikely to be significantly higher." We request that LLWR Repository Ltd expand upon those 'unlikely' situations where doses could potentially be significantly higher.

Regulatory Issue Actions

ESC-RI-ASO-014.A1	For the dose assessment covering the PoA the LLW Repository Ltd should consider the NDAWG and related guidance on acquisition and use of habits data for prospective dose assessments. LLW Repository Ltd should identify whether there are candidate critical groups who may be exposed to more than one exposure pathway and identify which age groups are being considered and why. These groups should be described, including consideration of how the composition of these groups might change over the 180 years of the PoA. The implication of the changes on to the group composition with time on exposure and doses should be considered. Doses to these groups should be presented to show the time trend in doses up to and including the end of the PoA and the dose to the critical group at each stage identified.
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	01/06/2012
A response will be provided.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	08/02/2013
A response is provided in LLWR/ESC/Mem(12)177.		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 06/09/2013
Approved by: Environment Agency	Date: 15/11/2013

We have reviewed LLW Repository Ltd's findings and observe that LLW Repository Ltd has examined the joint environment agencies and NDAWG guidance and sees nothing in the guidance documents, in as much as they could apply to our assessment of the PoA, that is at odds with its general approach to using habit data to define characteristics of potentially exposed groups, nor the allocation of habits to critical groups, with the exception that arguments should have been set out as to why groups other than adults were not assessed.

With regard to the second part of our action, requesting a reasonable estimate of prospective doses to critical groups, and the breakdown and evolution of that dose, LLW Repository Ltd provided a more explicit and quantitative consideration to the location and make up of potentially exposed groups, and to the site development and performance of the engineered barriers during the PoA. The supplementary memo set out a more realistic representation of exposed groups, expected site development and engineering performance. The findings showed that:

- The most exposed critical group for the present day can be considered as the population dwelling to the northeast of the disposal area. The exposure of this group is primarily from inhalation of radon daughters, assumed consumption of local foodstuffs (mainly milk and milk products), and direct radiation (workers at the coal yard and site perimeter walkers); other pathways make trivial additions.
- The reasonably estimated annual effective dose to adults in this group is about 70 μSv . Children and infants could receive higher doses than adults via consumption of milk and milk products (plus 20% and times 3 respectively), but their exposure via direct radiation will be much lower, so that children and infants are unlikely to receive a total annual dose greater than the adults considered.
- To assess the evolution of doses over the PoA, LLW Repository Ltd considered two potentially exposed groups: the northeast resident group (see above) plus a hypothetical group that does not exist at present, making use of a drinking water well to the southwest of the disposal area and also exposed through other pathways. The calculated total annual dose to both groups decreases to about 1 μSv at the assumed end of active control of the site (end of the PoA). That is comfortably below the value of 20 $\mu\text{Sv y}^{-1}$, which corresponds to the post-closure risk guidance level for a situation that is assumed to occur.
- The largest contribution to calculated annual dose for both groups is from radon. This decreases as capping proceeds.
- The dose from the groundwater pathway remains below the 20 $\mu\text{Sv y}^{-1}$ constraint at all times, when considered separately.
- There is no evidence that tritiated groundwater releases are causing any harm at the moment. Furthermore, the land between the disposal area and the coast is currently a site of special scientific interest and a special area of conservation, so that there is unlikely to be any development that would include a water abstraction well that might intersect tritium contaminated groundwater. Nevertheless, the possibility that tritium contaminated groundwater could be abstracted from an offsite borehole (assumed to be located between the site and the coast) has been examined. Potential annual doses from tritium (via the well abstraction pathway) are estimated to be 3 $\mu\text{Sv y}^{-1}$ in 2011, falling by more than an order of magnitude by 2050.

We have reviewed the assessments and agree with the assumptions and conclusions. However, we also stress the need for continued environmental monitoring to confirm findings remain as expected, as discussed in Environment Agency 2015, Review of LLW Repository Ltd's 2011 Environmental Safety Case: Site understanding. This Regulatory Issue can therefore be closed.

Actions completed, Regulatory Issue resolved and Form closed

Owner: Environment Agency	Date: 15/11/2013
Approved by: Environment Agency	Date: 15/11/2013

Appendix 2: Regulatory Observations

IRF Number	Title
ESC-RO-SCM-001	Change control for the ESC
ESC-RO-SCM-002	Ensuring continuing consistency between bulk waste properties and ESC assumptions
ESC-RO-SCM-003	Internal scrutiny of ESC project
ESC-RO-SCM-004	Long term management of ESC related records
ESC-RO-SCM-005	Forward work programme on the ESC
ESC-RO-INF-002	Authorised disposals, storage and forward inventory of Vault 8
ESC-RO-INF-003	Non-standard disposals to Vault 8
ESC-RO-INF-003b	Non-standard disposals to Vault 8
ESC-RO-SUE-001	Final capping of the trenches
ESC-RO-SUE-007	The use of future monitoring to reduce uncertainties in the ESC
ESC-RO-SUE-008	Development of environmental monitoring strategy
ESC-RO-SUE-009	Consolidation and resolution of engineering uncertainty
ESC-RO-ASO-001	Impacts to non-human biota during the period of authorisation
ESC-RO-ASO-002	Post-closure impacts to non-human biota
ESC-RO-ASO-003	Non Human biota assessment of human intrusion scenarios
ESC-RO-ASO-004	Management of Uncertainty
ESC-RO-ASO-005	Safety functions
ESC-RO-ASO-006	Linkage between ESC and single item limits
ESC-RO-ASO-007	ESC assessment code documentation and quality assurance

ESC-RO-SCM-001: Change control for the ESC

Title	Change control for the ESC
Date raised	30/09/2011
Acknowledgment required by	14/10/2011
Response required by	01/12/2011 (A1); 31/12/2013 (A2)
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	SCM
Approved by	Environment Agency

History

Status	Date	Description
Raised	30/09/2011	
Acknowledged	14/10/2011	
LLWR Response	20/12/2012 (A1) 04/10/2013 (A2)	
Response Assessed	10/11/2013	
Transferred	13/02/2014	
Closed	13/02/2014	

Statement of Regulatory Observation

To date the LLWR has not operated with an Environmental Safety Case (ESC) fully approved by the regulators, and as such has not operated any formal change control processes in relation to it.

Now that LLW Repository Limited have developed an updated ESC that they hope will be sufficient to gain a permit for further disposal of radioactive waste, and intends to maintain and use as a management tool, we expect to see in place robust change control processes for the ongoing management of the ESC and its relationship to site operations.

All work that supports the ESC needs to be properly planned and controlled. Any changes need to be made within a well-defined change control process, described in the written management arrangements, that assures quality and includes decision-making, doing the work and recording what has been done.

We expect this change control process to:

- Facilitate effective update of the ESC in relation to availability of new information, knowledge or standards.
- Drive LLW Repository Limited to determine the need for change.
- Effectively manage information related to changes.
- Define review periods and review strategy.

We recognise that this is an issue LLW Repository Limited has already identified as necessary to progress. We consider this issue as vital to the ongoing effectiveness of the ESC and would therefore like to work with LLW Repository Limited as they develop these processes.

Regulatory Observation Actions

ESC-RO-SCM-001.A1	LLW Repository Limited shall provide a programme detailing how they will develop and achieve a robust change control process for the ongoing management of the ESC and its relationship to site operations. The programme should incorporate discussions with the Environment Agency. The programme should detail how change control will be managed effectively prior to delivery of a fully implemented system.
ESC-RO-SCM-001.A2	LLW Repository Limited shall demonstrate delivery of a robust change control process for the ongoing management of the ESC and its relationship to site operations. This process should be captured within written management arrangements and quality processes. Roles and responsibilities should be clearly defined.

LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	14/10/2011
<p>Comment: A programme for implementing the 2011 ESC is under development. The programme includes the development of an approach to formal change control for the ESC and then implementation of the approach. We will present and provide this plan to the Agency by the required date. We will then implement the programme taking into account any feedback from the Agency. The programme will include discussions with the Agency on the details of the implementation.</p>		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	14/10/2011 and 04/10/2013
<p>Action A1: A response to the first action comprises the presentation relating made to the Agency at the 12th September 2012 Monthly Liaison Meeting and a plan for implementing the 2011 ESC, set out in: R Cummings and A Huntington, <i>2011 ESC Implementation Plan</i>, LLWR/ESC/R(12)10049, December 2012.</p> <p>The plan includes consultation with the Agency (activities '13: ESC Process Development' and '18: Implement ESC RSP Process' under work stream 'Repository Site Procedure').</p> <p>The plan lays out a staged approach to implementation, covering initial implementation under work stream 'Initial ESC Implementation', and final implementation after the revised permit is received, in work stream 'Implementation of Revised Permit'.</p> <p>Action A2: Robust arrangements have now been implemented to integrate the management of the ESC into the LLWR's formal change control processes. The development and subsequent review phases of the 2011 ESC were managed as a project and controlled through a Project Execution Plan (PXP). This PXP has now been withdrawn and replaced with a new Repository Site Procedure: RSP 2.25, <i>Development and Application of the LLWR's Environmental Safety Case</i>, Issue 1, September 2013. The approach used to integrate the ESC into the LLWR's change control processes has been based on the approach used for the LLWR's nuclear safety cases, and in particular uses the existing Plant Modification Process (RSP 1.27, <i>Modification to or Experiment on Existing Plan</i>, Issue 5, April 2013). RSP 2.25 was discussed with the Environment Agency during the development of the Procedure. It covers the various aspects mentioned in the Statement of Regulatory Observation, including update of the ESC, consideration of change stemming from new information or proposals, management of information, and review. It also defines roles and responsibilities. In line with the approach taken to 'owning' and managing the LLWR's nuclear safety cases, LLWR's MD has taken on the responsibility of being the 'ESC Owner'.</p>		

A new Repository Role of 'ESC Manager' has been defined (RR 0150).

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 13/02/2014
Approved by: Environment Agency	Date: 13/02/2014

In response to Action A1 of this Regulatory Observation (RO), LLW Repository Ltd provided an Implementation Plan²³ in October 2011 and this was supported by a presentation made to us in September 2012 at one of our regular Monthly ESC Liaison meetings with LLW Repository Ltd.

The plan provides an adequately detailed presentation of the steps LLW Repository Ltd proposed to take to develop a robust change control process for the ESC. A key step proposed to achieve this was the development of a process owner as well as a new site procedure. The site procedure will adequately address the issues we have raised in this RO such as the need to facilitate the update and management of the ESC into the future as changes are necessary. The plan also incorporates consultation with the Environment Agency at key points.

The plan explains how a staged approach will be taken to implementation, covering 'initial implementation' before any revised permit is issued and then 'final implementation' addressing any revised permit that may be issued. We are satisfied that this approach suitably addresses immediate needs to ensure the updated ESC is implemented where it can, but also addresses further changes that are likely to need consideration.

The Implementation Plan went further than requested within our RO and addressed wider issues such as:

- implementation of revised Waste Acceptance Criteria (WAC)
- development of an Environmental Clearance Certificate
- development of waste acceptance procedures
- training
- software and tracking system development
- engagement with consignors on change

We support these changes being planned and changes already put in place to support implementation of the ESC both now and following any revised permit. We are content that the plan adequately demonstrates LLW Repository Ltd's commitment to effective use of the ESC as a 'live' management tool.

Following work against the Implementation Plan referred to above and in response to Action A2 of this RO, in October 2013 LLW Repository Ltd provided a new procedure for the management of the ESC (RSP 2.25, Development and Application of the LLWR's Environmental Safety Case, Issue 1, September 2013). This Procedure forms part of LLW Repository Ltd's Integrated Management System and is the main document for the development and control of the ESC. LLW Repository Ltd indicates that the purpose of the document is to ensure that the 'ESC is developed and applied in such a way that the relevant requirements set out in the LLWR's Permit from the Environment Agency are met'. It is explained that the document will help to ensure that the facility is designed, operated and closed in accordance with the assumptions made within the most recent ESC, unless otherwise agreed in writing with the Environment Agency.

The document addresses the appointment of an ESC Manager, development and review of the ESC, how changes to the ESC will be affected and the update of tools and records associated with

²³ R. Cummings and A. Huntington, 2011 ESC Implementation Plan, LLWR/ESC/R(12)10049, December 2012.

the ESC. Roles and responsibilities within the procedure are clearly defined and supported where necessary by SQEP (Suitably Qualified and Experienced Person) role assessment specifications. We welcome the fact that the LLWR Managing Director has been appointed as ESC Owner.

We are satisfied that relevant considerations with regards to change control and management of the ESC are addressed within the procedure. For example, it addresses issues that must be considered and addressed in updating the ESC, what new information may need to be assessed, the need for development of assumptions, analyses and assessments and ongoing peer review. With regards to effecting changes the procedure addresses the assessment of significance, notification of the Environment Agency, changing the ESC and recording changes along with the update of associated documentation such as WAC and the Environmental Clearance Certificate. Update of tools (for example, an Issues Register) and records are also addressed.

We note that the processes being adopted are largely based upon LLWR's nuclear safety case processes and also the associated Plant Modification Process (RSP 1.27, Modification to or Experiment on Existing Plan, Issue 5, April 2013). We believe this is appropriate as it will call upon established practices and facilitate wider common understanding.

Importantly the procedure also defines reviews of the ESC which will be annual, periodic (approximately every three years) and major (approximately every ten years), with agreement on timing from the Environment Agency. These reviews will be used to identify significant changes to the ESC or affecting the ESC, the need for significant review and update of the ESC and then to complete such major updates where required.

Overall, we are satisfied that LLW Repository Ltd has demonstrated development of a robust change control process for the ongoing management of the ESC and its relationship to site operations. This process has been documented within LLW Repository Ltd's Integrated Management System and roles and responsibilities have been defined. This RO can therefore be closed.

Actions completed, Regulatory Observation resolved and Form closed

Owner: Environment Agency	Date: 13/02/2014
Approved by: Environment Agency	Date: 13/02/2014

ESC-RO-SCM-002: Ensuring continuing consistency between bulk waste properties and ESC assumptions

Title	Ensuring continuing consistency between bulk waste properties and ESC assumptions
Date raised	30/09/2011
Acknowledgment required by	14/10/2011
Response required by	30/06/2012
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	SCM
Approved by	Environment Agency

History

Status	Date	Description
Raised	30/09/2011	
Acknowledged	14/10/2011	
LLWR Response	16/07/2012	
Response Assessed	10/02/2014	
Transferred	10/02/2014	
Closed	10/02/2014	

Statement of Regulatory Observation

The Environmental Safety Case (ESC) has been prepared during a period of rapid change in waste management practice, where increasingly materials are being treated before disposal and waste management practices are generally becoming better. This has significant benefits in terms of minimisation of waste disposal volumes, but at the same time will lead to changes in the form of wastes being disposed. Such changes could include significantly better packing fractions or changes in the average chemical or physical form of the waste (e.g. disposal of more residues as opposed to raw materials).

To cope with such expected changes we are aware that LLW Repository Limited, within the ESC, has assumed a certain degree of change over the coming years. Change control processes and periodic reviews are also proposed. It is also recognised that individual unusual consignments would individually be assessed before disposal. However, we believe that the cumulative effects of possible changes in disposed waste composition could potentially challenge some of the assumptions made within the ESC (e.g. quantities of grout added). Although change control and reviews may identify such trends or changes, we see no reason why a more robust set of 'triggers' could not be established to flag changes in waste disposal behaviour that could potentially threaten assumptions made within the ESC. Such 'triggers' could provide early warning of any necessary re-assessment in relation to the ESC and remove the necessity for reviews to spot potentially significant changes that could threaten assumptions made within the ESC.

Regulatory Observation Actions

ESC-RO-SCM-002.A1	LLW Repository Limited shall consider establishing quantitative trigger levels to flag changes in bulk properties of waste being disposed of at the LLWR that could potentially lead to waste masses with characteristics inconsistent with ESC assumptions. Where such triggers are identified a programme should be presented to implement robust systems to identify key changes and to trigger an assessment of the issue.
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	14/10/2011
Comment: We have committed in the 2011 ESC to introducing an annual review of the ESC. One objective is to review trends in waste accepted for disposal to ensure that the assumptions of the ESC remain valid. In developing our approach to this review process, we will give further consideration to the use of quantitative trigger levels and how these might be applied. Our conclusions will be discussed with the Agency.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Technical Integrator	16/07/2012
A response is provided in ESC Project Memo LLWR/ESC/MeM(12)157, 16/07/2012.		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 10/02/2014
Approved by: Environment Agency	Date: 10/02/2014

LLW Repository Ltd, in its memo LLWR/ESC/MeM(12)157, 16 July 2012, concludes that establishing quantitative trigger levels with regards to bulk properties of waste would not be the most efficient way of identifying changes that may influence the ESC and provide their justification for this. The memo identifies a range of properties that may be of relevance.

LLW Repository Ltd argues that its proposals for a systematic and recorded annual review that addresses the bulk properties of wastes will be more effective and flexible. It is proposed that these reviews will identify and quantify trends in bulk waste properties on an annual basis and then identify the significance of any changes. Proportionate assessment of any identified changes in trends would be undertaken.

It is argued that establishing a range of 'triggers' to identify significant changes in bulk properties would be complex and unlikely to be comprehensive. For example, establishing triggers would need to consider a wide range of changes that might occur, some of which may be hard to anticipate. Additionally, changes in bulk properties could also have significant spatial variability associated with them which must be taken into account. Simple triggers may not do this effectively. Furthermore, reliance on triggers may mask potentially significant changes in bulk waste properties if they are not adequately conceived and implemented.

Having reviewed LLW Repository Ltd's justification for its current position of adopting annual reviews to identify changing trends in bulk properties of wastes, we agree with its conclusions. We agree with LLW Repository Ltd's proposals to undertake systematic and recorded annual reviews that will examine trends in bulk properties and assess these in comparison with assumptions made

within the ESC. We agree that development of trigger levels is likely to prove complex and that potential issues that could arise may be too broad for triggers to be of benefit.

This RO has been adequately addressed and can be closed.

Actions completed, Regulatory Observation resolved and Form closed

Owner: Environment Agency	Date: 10/02/2014
Approved by: Environment Agency	Date: 10/02/2014

ESC-RO-SCM-003: Internal scrutiny of ESC project

Title	Internal scrutiny of ESC project
Date raised	30/09/2011
Acknowledgment required by	14/10/2011
Response required by	30/06/2012
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	SCM
Approved by	Environment Agency

History

Status	Date	Description
Raised	30/09/2011	
Acknowledged	14/10/2011	
LLWR Response	02/07/2012	
Response Assessed	13/02/2014	
Transferred	13/02/2014	
Closed	13/02/2014	

Statement of Regulatory Observation

The Environmental Safety Case (ESC) has and continues to be a key project for the LLWR, which is central to all operations and the environmental safety of the site. Given the significance of the ESC we would expect the project to be subject to a full range of audits, both internal and external.

We are aware that:

- LLW Repository Limited holds appropriate environmental and quality certification and is audited accordingly.
- The ESC Project has been extensively audited by external bodies with regards to delivery and financial matters.
- LLW Repository Limited operates quality management systems which include internal auditing of processes and independent inspector auditing by topic area.
- The ESC Project Team have undertaken a number of audits of contractors.
- Peer review work has been undertaken.

However, we are aware that no specific arrangements have been put in place to audit the ESC project arrangements, nor the outputs. We do not believe any independent inspections have explicitly examined the ESC project arrangements throughout its production. Given the significance of the project to date and going forward we would expect to see a greater level of internal independent oversight of the project.

Regulatory Observation Actions

ESC-RO-SCM-003.A1	LLW Repository Limited shall review their current internal auditing arrangements taking into account the significance of the ESC as a site management tool. A plan should be presented which demonstrates how LLW Repository Limited plan to ensure that their future internal audit arrangements take due account of the ESC.
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	14/10/2011
Comment: Our internal audit plan is currently being revised and will include audits of the ESC Project. We will ensure that our ongoing internal audit plan takes account of the implementation of the ESC as this occurs and that this plan is presented to the Agency.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	02/07/2012
<p>The assurance arrangements at LLWR have recently been reviewed and proposals made for improvement. The review and the resulting proposals were documented in a paper¹ and associated appendices^{2,3} presented in December 2011 to the LLWR Environment Health and Safety (EHS) Committee (the LLWR's Nuclear Safety Committee). The proposals are now being implemented.</p> <p>The revised assurance arrangements include a formal requirement for the LLWR's Independent Site Inspector to audit projects (including the ESC Project) on a rolling basis. A 'deep slice' audit of the ESC was undertaken in March 2012 and a report is in preparation. This type of audit is planned for the ESC Project every two years.</p> <p>In addition to the requirement to audit the ESC as a project, the new assurance arrangements also place requirements on Process Owners to carry out regular audits of their procedures. Once the ESC is implemented through a Repository Site Procedure, the revised arrangements will require the Process Owner for the ESC to undertake regular self-audits, in addition to those of the LLWR's Independent Site Inspector. These self-audits will be required every one or two years, the frequency to be determined during the implementation. In addition, the new assurance arrangements require Key Legislation Owners to present a two-yearly Assurance Review at the EHS Committee. Further oversight will therefore be achieved by the requirement for the Environmental Manager to bring an assurance review of environmental legislation and permitting compliance to the EHS Committee.</p> <p>In addition, the Internal Audit Programme undertaken by the Quality Team will continue. An audit of record keeping by the ESC Project was undertaken in November 2011⁴. The future audit programme includes an annual review of the ESC implementation plan, once it is produced. Once the implementation plan is produced, the scope of future internal audits will be reviewed and appropriate audits included in the audit programme. (The detailed Internal Audit Programme spreadsheet can be provided on request.)</p> <p>References</p> <ol style="list-style-type: none"> 1. <i>Review of EHS&Q Assurance Arrangements</i>, 13 December 2011, LLWRRNSC(11)23. 2. <i>Appendix 1: Review of Internal and Site Inspection Audit Programmes at LLWR</i>. 3. <i>Appendix 2: Streamlining of Site Inspection Programme, Following Increased Auditing of Key Legislation Conditions by Process Owners</i>. 4. <i>Low Level Waste repository Inspection/Audit Report, Environmental Safety Case Records, QA.11.012, 16 November 2011</i>. 		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 13/02/2014
Approved by: Environment Agency	Date: 13/02/2014

This Regulatory Observation (RO) sought a review of LLW Repository Ltd's internal auditing arrangements to ensure it took adequate account of the significance of the ESC to the site's operations. A plan was sought addressing how improvements would be made. In response LLW Repository Ltd has provided evidence that it has reviewed its assurance arrangements associated with the ESC and more generally.

In particular the evidence provided demonstrates that a significant review of assurance arrangements and their scope has been carried out and considered at an appropriate level within LLW Repository Ltd. A number of enhancements to the internal auditing arrangements have been made as a result of the review including:

- A rolling programme of project reviews (including the ESC) by the Independent Site Inspector. Evidence of a 'deep slice' audit undertaken in 2011 was provided in LLW Repository Ltd's response.
- New arrangements for process owners (for example, ESC Process Owner) to carry out regular audits or procedures.
- There will be a requirement on the ESC Process Owner to complete self-audits against relevant Repository Site Procedures for the ESC once implemented.
- Key Legislation Owners will be required to present a two-yearly assurance review on relevant legislation (including environmental) to the Environmental Health and Safety Committee.

Assurance was also given that Quality Team internal audits will also continue and an example of a recent audit on records was provided.

We are satisfied that LLW Repository Ltd has carried out a sufficient review of its internal audit arrangements and identified improvements that will ensure the ESC and the work to deliver and develop it is adequately considered. We will expect LLW Repository Ltd to continue to keep the adequacy of the internal audit programme under review. We consider that this RO can be closed.

Actions completed, Regulatory Observation resolved and Form closed

Owner: Environment Agency	Date: 13/02/2014
Approved by: Environment Agency	Date: 13/02/2014

ESC-RO-SCM-004: Long term management of ESC related records

Title	Long term management of ESC related records
Date raised	30/09/2011
Acknowledgment required by	14/10/2011
Response required by	31/01/2012
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	SCM
Approved by	Environment Agency

History

Status	Date	Description
Raised	30/09/2011	
Acknowledged	14/10/2011	
LLWR Response	30/01/2012	
Response Assessed	30/02/2012	
Transferred	13/02/2014	
Closed	13/02/2014	

Statement of Regulatory Observation

The ESC contains a general description of records management processes applied at the LLWR. We are informed that the ESC Project applies the same records management procedures to their records, which is appropriate. However, the ESC is particularly important to the management of the site and we note that very large volumes of data and information have been generated over the years to support the ESC. Much of this data has been generated externally by contractors and is not necessarily, at this point, actively and directly managed by LLW Repository Limited.

We expect to see evidence that all records and data associated with the ESC are, and will be, actively managed in an appropriate manner. This includes data generated by contractors. We wish to see a plan addressing the scope of records to be managed, timescales for collating and managing these records and details of how the records will be actively managed in accordance with LLWR procedures and the environmental permit. Records management should be consistent with expectations detailed within the GRA.

Regulatory Observation Actions

ESC-RO-SCM-004.A1	LLW Repository Limited shall prepare a plan of how they intend to apply records management procedures to all ESC records so as to comply with LLWR procedures and environmental permit requirements. This should address the scope of records considered, details of how the records will be actively managed and the timescales over which this will be achieved.
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	14/10/2011
Comment: Collection of records relating to the development of the 2011 ESC is underway. A retention schedule for ESC Project records has been produced. Our detailed arrangements for ESC record management will be presented to the Agency, noting that arrangements for long-term retention of LLWR records will need to be consistent with those being developed by the NDA.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	30/01/2012
A response setting out our current approach to records management and our plans for the future retention of records is given in ESC Project Memorandum LLWR/ESC/MeM(12)142, <i>Management of ESC Records</i> , January 2012.		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 13/02/2014
Approved by: Environment Agency	Date: 13/02/2014

Through this Regulatory Observation (RO) we sought a clear plan of how LLW Repository Ltd planned to apply its records management procedures to ESC records, including ESC generated reports, contractor generated materials and other relevant records as detailed within our GRA.

The response (ESC Project Memorandum LLWR/ESC/MeM(12)142, *Management of ESC Records*, January 2012) provided details of how ESC records are and will be managed in the future, with reference to general LLWR procedures (for example, RSP 5.01). The memo details the scope of records to be considered and how they will be actively managed. The memo also details a number of areas of work ongoing or to be completed at a later date, which we will address through our ongoing regulation of the site. Actions are identified within the memo to ensure relevant contractor reports and data are captured within LLW Repository Ltd's own systems.

We welcome the fact that LLW Repository Ltd has identified a number of drivers for the retention of ESC records and recognises the need to keep records 'live' and not archived until after the next major ESC update. We note that, in compliance with the permit for the LLWR, all relevant ESC records will be retained indefinitely unless otherwise agreed by the Environment Agency, and that records will be kept in duplicate in diverse forms (paper and electronic), ensuring future access and management.

With regards to the long-term management of records LLW Repository Ltd refers to an ongoing Nuclear Decommissioning Authority (NDA) project to look at national options for the long-term management and archiving of records from the nuclear industry, including those from the LLWR. We support the fact that LLW Repository Ltd is engaged with this project and has committed to ensure that its records management procedures are consistent with the outcome. We consider it important that the differences in nature and use of records generated from a disposal facility are recognised when compared to other NDA decommissioning sites. We note that after the end of the period of authorisation of the site we will expect LLWR records to be included in the 'public archive'.

The response provided adequately addresses our requests and this RO can therefore be closed.

Actions completed, Regulatory Observation resolved and Form closed

Owner: Environment Agency	Date: 13/02/2014
Approved by: Environment Agency	Date: 13/02/2014

ESC-RO-SCM-005: Forward work programme on the ESC

Title	Forward work programme on the ESC
Date raised	30/09/2011
Acknowledgment required by	14/10/2011
Response required by	30/11/2011
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	SCM
Approved by	Environment Agency

History

Status	Date	Description
Raised	30/09/2011	
Acknowledged	14/10/2011	
LLWR Response	15/11/2011	
Response Assessed	03/02/2014	
Transferred	21/02/2014	
Closed	26/02/2014	

Statement of Regulatory Observation

LLW Repository Limited has already identified in the 2011 ESC and elsewhere areas of the Environmental Safety Case (ESC) in which it recognises further work will be needed, and further such areas are likely to be identified through our review of the ESC and LLW Repository Limited's developing view of the future of the LLWR. We also expect LLW Repository Limited to maintain awareness of scientific developments, both within and outside the UK that may have a bearing on the ESC for the facility. We therefore expect LLW Repository Limited to develop a future work programme to support maintenance and development of the ESC through to site closure. This programme should address both issues currently known to require further development or monitoring and the ability to identify new issues that may be of relevance (for example via involvement in international programmes). There should be a focus on long term development of understanding.

Currently the ESC only outlines possible areas for future work and in limited detail. We expect to see further detail captured in a forward plan, which will demonstrate how LLW Repository Limited will deliver both known and anticipated requirements for forward work and also maintain awareness of scientific developments with a bearing on the ESC. We are aware that LLW Repository Ltd is already working on such a plan, which is expected to be available in the autumn of 2011.

Regulatory Observation Actions

ESC-RO-SCM-005.A1	LLW Repository Ltd shall provide a future work programme addressing scientific work that will be undertaken to support the developing ESC through to site closure.
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	14/10/2011
Comment: A future work programme for the development of the ESC up to the next major iteration of the ESC is being formulated and will be presented to and discussed with the Agency.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	15/11/2011
The future work programme for the development of the ESC has been developed and is reported in: R Cummings, <i>ESC Forward Programme</i> , LLWR/ESC/R(11)10040, October 2011.		
This work programme was presented to, and discussed at, the monthly Liaison Meeting between the Environment Agency and the LLWR ESC Project held on the 26 th October 2011.		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 03/02/2014
Approved by: Environment Agency	Date: 21/02/2014

In response to this Regulatory Observation (RO) LLW Repository Ltd provided a more detailed and developed forward programme of work (R Cummings, *ESC Forward Programme*, LLWR/ESC/R(11)10040, October 2011) which includes a schedule of work over the next five years, with indications of areas for further development. We accept that it would not be possible, or a worthwhile exercise, to specify in detail the nature of the future work programme over the longer term, which should be informed by work in the short to medium term. However, we would expect regular updating of the forward programme to take account of new information, priorities or opportunities.

LLW Repository Ltd explains that the forward programme of work has been influenced by its own findings, input from the Peer Review Group and the Environment Agency, along with experience gained from participation in international programmes. We believe this is appropriate. It is also explained that the programme will be developed further based upon a number of inputs including the Environment Agency review of the 2011 ESC, the Environmental Permit, future input from the Peer Review Group, experience gained from international programmes, the findings of ongoing work and developments related to the LLWR, for example significant changes in the nature of waste disposals.

The forward programme presented by LLW Repository Ltd addresses all the key technical areas we would expect to see such as optimisation, inventory, near field, site characterisation and assessments. We are pleased to see certain key areas of work specified, such as support to future work on the detailed design of vaults and closure engineering and further development of the approach to non-radiological assessment.

In the programme LLW Repository Ltd recognises the importance of maintaining a 'live' and up to date ESC using the forward programme to support this and to prepare for the next major update, which is assumed to take place at 10 years. The availability of suitably qualified and experienced staff to support and maintain the ESC is recognised, as is the value of a forward programme in helping to maintain and develop these skills and to keep them 'live' through to and beyond subsequent major reviews.

The forward programme indicates that the work is not yet costed in detail. We are, however, aware that further work has since been completed on this as part LLW Repository Ltd's next Lifetime Plan in support of its bid for the next management contract period with the NDA, which was successful.

We consider that this RO has been adequately addressed by LLW Repository Ltd in that a future work programme has been provided addressing scientific work that will be undertaken to support the developing ESC through to site closure. We are satisfied that the programme is presented at an appropriate level of detail at this point in time and addresses the areas we would expect to see covered by it. This RO can therefore be closed.

However, the forward programme is still at a relatively high level and we find it difficult in places to correlate commitments made elsewhere in the ESC with specific items in the forward programme. These include a commitment to review the correlations between elicited parameters to identify, for example, where poor performance of one property leads to lower performance of another and work on gaining improved understanding of the uncertainties associated with water flow and radionuclide release under partially-saturated conditions. Similarly, the FEP and uncertainty tracking system contains a number of entries detailing areas for further work under 'uncertainty management' but with no specific link to the forward programme. LLW Repository Ltd should ensure that all such commitments are systematically captured so that they are included in the forward programme.

Furthermore, we recognise LLW Repository Ltd's commitment to update the forward programme further following completion of our technical review of the ESC and when any varied Environmental Permit is issued, such that it can take account of our recommendations, any Forward issues (FIs) raised and any specific permit requirements. It should also take account of any final comments received from the Peer Review Group.

We will therefore require LLW Repository Ltd to provide a more detailed forward programme following issue of the new Environmental Permit (ESC-FI-004).

Actions completed, Regulatory Observation resolved and Form closed

Owner: Environment Agency	Date: 26/02/2014
Approved by: Environment Agency	Date: 26/02/2014

ESC-RO-INF-002: Authorised disposals, storage and forward inventory of Vault 8

Title	Authorised disposals, storage and forward inventory of Vault 8
Date raised	31/05/2012
Acknowledgment required by	08/06/2012
Response required by	06/07/2012
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	INF
Approved by	Environment Agency

History

Status	Date	Description
Raised	15/06/2012	
Acknowledged	15/06/2012	
LLWR Response	16/07/2013	
Response Assessed	07/08/2013	
Transferred	07/08/2013	
Closed	25/09/2013	

Statement of Regulatory Observation

In order to determine whether waste currently stored in Vault 8 under the terms of the current Environmental Permit, can be considered disposed we need a clear understanding of what the Vault 8 inventory used in the 2011 ESC includes. In particular we need assurance that LLW Repository Limited's calculations are based on an assumed total Vault 8 inventory (i.e. when it is full) that includes all disposals to 4-high stacking plus all stored containers stacked above 4-high.

Ref [1] refers throughout to disposals to Vault 8, no mention appears to be made to stored wastes in Vault 8. Inventory of Vault 8 to 31st March 2008 (From ref [2] Table 5.2) and Reference Case A forward inventory of Vault 8 (From ref [2] Table 5.3) – it isn't clear from the text whether the inventory to 31st March 2008 is the original planned capacity (to height of 4 half-height ISO containers), and the forward inventory represents the waste that is stacked higher and which is currently 'stored' under the terms of the current licence (see [2] page 4-5), plus waste yet to be consigned (Ref [2] page 4 "*the vault is now almost full to this original [height of 4 half-height ISO containers] design capacity*").

The distinction between the inventory of authorised disposals to Vault 8 and inventory of stored waste in Vault 8 and future disposals to Vault 8 is particularly unclear when we consider relevant text in underpinning Level 3 reports, for example:

- "The date of 31st March 2008 to separate past and future disposals was selected on the basis of the start of the data in the UKRWI" [1] (section 3.2).
- Reference to "emplaced V8 and Forward V8 – 14" (ref [3] Figure 93).
- "disposals made to Vault 8 in the period to 31 March 2008; disposals to the vaults from 1 April 2008 (the 'forward inventory')." [4] (Executive Summary).

- “In this study, a similar division of the inventory components has been made between the trenches, disposals to Vault 8 up to 31 March 2008 and future arisings (post 2008) to Vault 8 and future vaults.” [4] (section 2.2).
- “Disposals²⁴ continuing through temporary stacking on top of the original 4-high stacks [in Vault 8]. When the next disposal vault, Vault 9, becomes available it has been assumed that the higher stacked containers will be retrieved and disposed to the new vault.” [5] (section 4.1 page 33). From this can we infer that the Vault 8 inventory figures in [5] Table 22 do not include ‘stored’ wastes stacked at greater than 4-high?
- [4] section 4.3 page 21, identifies 3 components of the radionuclide inventory for Vault 8 being:
 - “8402 containers disposed at 31 March 2007 for which a detailed radionuclide inventory was already available
 - 449 containers disposed to stacks of up to 4 containers between 1 April 2007 and 31 March 2008, and
 - 497 containers stored in higher stack locations to 31 March 2008.” [i.e. those containers stored under the terms of the current licence]

The lack of a clear distinction between authorised disposals and stored wastes, and confusion caused by inconsistent use of terminology, as highlighted in the discussion above, has made statements made within the ESC unclear, and has the potential to reduce confidence in the safety case.

References

- 1 The 2011 ESC _ Inventory_LLWR/ESC/(R11)10019.
- 2 The ESC Non-technical Summary_LLWR/ESC/R(11)10034.
- 3 Harper A, ESC 2011: The Disposed and Forward Inventory, Serco Report Serco/E003756/12 Issue 2, April 2011.
- 4 Baston G M N, Magalhaes S, Schneider S & Swanton S W. LLWR Environmental safety Case: Improvements to the Radionuclide Inventory of the LLWR. Serco Report SERCO/E003756/010 Issue 1 April 2011.
- 5 Wareing AS, Eden L, Jones A and Ball M. LLWR Environmental Safety Case: The Inventory of Past and Potential Future Disposals at the LLWR, Nexia Solutions Report 9124 Issue 04, April 2011.

Regulatory Observation Actions

ESC-RO-INF-002-A1	Please confirm whether or not LLW Repository Limited’s calculations are based on an assumed total Vault 8 inventory (i.e. when it is full) that includes all disposals to 4-high stacking plus all stored containers stacked above 4-high.
ESC-RO-INF-002-A2	Please provide clarification regarding the range of different terminology used to describe the Vault 8 inventory, as discussed in the above Issue Resolution Form.

²⁴ This is a good example of how confusion can arise from alternative application of nomenclature. “Disposal” here means the temporary stacking of containers on top of the 4-high stacks – these are not authorised disposals (in regulatory sense) they are currently stored. In this context would be better described as “Waste transfers to vault 8 are continuing through....”.

LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	15/06/2012
Comment: The requested confirmation and clarification will be provided.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Technical Specialist	16/07/2012
ESC-RO-INF-002-A1 Please confirm whether or not LLW Repository Limited's calculations are based on an assumed total Vault 8 inventory (i.e. when it is full) that includes all disposals to 4-high stacking plus all stored containers stacked above 4-high. We confirm that the calculations presented in the 2011 ESC are based on an assumed total Vault 8 inventory as described in ESC-RO-INF-002-A1.		
ESC-RO-INF-002-A2 Please provide clarification regarding the range of different terminology used to describe the Vault 8 inventory, as discussed in the above Issue Resolution Form. The inventory assumed for Vault 8 is composed of: <ul style="list-style-type: none">• Material placed in the Vault to 31 March 2008. This comprises of, as stated in Section 4.3 page 21 of Reference [1]:<ul style="list-style-type: none">○ 8402 containers disposed at 31 March 2007 for which a detailed radionuclide inventory was already available○ 449 containers disposed to stacks of up to 4 containers between 1 April 2007 and 31 March 2008, and○ 497 containers stored in higher stack locations to 31 March 2008.• Material arising after 31 March 2008 which could be accommodated within Vault 8 under the assumptions of total available volume made in the 2011 ESC. <p>We note that some confusion has arisen over the significance of information given by Swanton <i>et al.</i> (2011) and Harper (2011), and that given by Wareing <i>et al.</i> References Baston <i>et al.</i> 2011 and Harper (2011) are the most recent assessment of inventory data for the 2011 ESC and represent the definitive statement of the inventory derived for this purpose. Wareing <i>et al.</i> 2011 provides some useful information upon which References Basto <i>et al.</i> 2011 and Harper 2011 draw, but should not be taken as providing a definitive statement of the inventory.</p> REFERENCES <ul style="list-style-type: none">ⁱ Baston G M N, Magalhaes S, Schneider S & Swanton S W. <i>LLWR Environmental safety Case: Improvements to the Radionuclide Inventory of the LLWR</i>. Serco Report SERCO/E003756/010 Issue 1 April 2011.ⁱⁱ Harper A, ESC 2011: <i>The Disposed and Forward Inventory of LLWR</i>, Serco Report Serco/E003756/12 Issue 2, April 2011.ⁱⁱⁱ Wareing AS, Eden L, Jones A and Ball M. <i>LLWR Environmental Safety Case: The Inventory of Past and Potential Future Disposals at the LLWR</i>, Nexia Solutions Report 9124 Issue 04, April 2011.		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 07/08/2013
Approved by: Environment Agency	Date: 03/09/2013

LLW Repository Ltd has clarified that the total Vault 8 inventory is used in the assessment calculations, thereby addressing Action ESC-RO-INF-002.A1.

LLW Repository Ltd has clarified the terminology used for the disposals to Vault 8, thereby addressing Action ESC-RO-INF-002.A2. We note that the terminology used can prove confusing and the company should ensure that clarity is maintained in future reports.

LLW Repository Ltd's response satisfies our concerns with regards to this RO, which can be closed.

Actions completed, Regulatory Observation resolved and Form closed

Owner: Environment Agency	Date: 03/09/2013
Approved by: Environment Agency	Date: 25/09/2013

ESC-RO-INF-003: Non-standard disposals to Vault 8

Title	Non-standard disposals to Vault 8
Date raised	21/06/2012
Acknowledgment required by	29/06/2012
Response required by	31/07/2012
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	INF
Approved by	Environment Agency

History

Status	Date	Description
Raised	21/06/2012	
Acknowledged	29/06/2012	
LLWR Response	22/10/2012	
Response Assessed	30/11/2012	
Transferred	07/12/2012	
Closed	15/11/2013	

Statement of Regulatory Observation

We are aware that many non-standard disposals (use of containers other than those specified, such as WAGR boxes, and uncontainerised disposals, such as fuel flasks and reactor heat exchangers, that are grouted in-situ) have occurred in Vault 8. LLW Repository Ltd will need to have approved such non-standard disposals, and in order to do so we assume they have carried out assessments of the potential effects of such disposals on the disposal system and on the safety case, particularly with respect to their impact on waste settlement. This will require further, more detailed, information on non-standard disposals, that is not evident from the ESC or its supporting information.

LLW Repository Limited should be able to demonstrate traceable information and evidence pertaining to its decisions with respect to approving such disposals, including any assessments of how specific non-standard disposals may impact on the safety case, in order to make those decisions.

References

1. The 2011 ESC. Non-technical Summary, LLWR/ESC/R(11)10034.
2. The 2011 ESC. Waste Acceptance, LLWR/ESC/(R11)10026.

Regulatory Observation Actions

ESC-RO-INF-003-A1	To present a fuller picture of disposals in Vault 8, LLW Repository Limited should provide a list of non-standard disposals that have been made to Vault 8.
ESC-RO-INF-003-A2	LLW Repository Limited should provide a description of its non-standard disposal process, including the factors and

	<p>issues that are considered in deciding whether to approve non-standard items for disposal. Reference should be made to relevant procedures in place.</p> <p>Additionally, where practices have changed over the lifetime of Vault 8, description should be provided of previous processes under which non-standard disposals were made and assessed.</p>
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	29/06/2012
Comment: Responses to the actions will be provided.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	22/10/2012
<p>ESC-RO-INF-003-A1</p> <p>To present a fuller picture of disposals in Vault 8, LLW Repository Limited should provide a list of non-standard disposals that have been made to Vault 8.</p> <p>Please see attached list of non-standard disposals in Vault 8.</p> <p>(Several erroneous skip records are omitted from the list. Some full waste skips were given tracking numbers before being sent to WAMAC. Once at WAMAC they were emptied, reused and the next consignment given a new tracking number. The compacted waste was then sent to LLWR with a separate tracking number. The skip records are omitted from the list of non-containerised waste in Vault 8).</p> <p>ESC-RO-INF-003-A2</p> <p>LLW Repository Limited should provide a description of its non-standard disposal process, including the factors and issues that are considered in deciding whether to approve non-standard items for disposal. Reference should be made to relevant procedures in place.</p> <p>Additionally, where practices have changed over the lifetime of Vault 8, description should be provided of previous processes under which non-standard disposals were made and assessed.</p> <p>Current practice is as follows.</p> <p>Non-standard item disposal requests would normally be assessed in the first instance through the standard enquiry process (managed under RSP3.05.02). The waste enquiry process is where the consigning of a specific volume of waste is considered. The assessment would normally be managed by the specific consignor's single point of contact within the Delivery team in Waste Services. For a non-standard item, the Delivery team would seek advice from the Waste Acceptance team, also in Waste Services, who would consult with other LLWR teams to establish a position on the acceptability of disposal.</p> <p>At the waste consignment stage, a non-standard item would be treated as a variation to the WAC. A request for a variation by a consignor would be submitted through the Customer team email inbox and managed through the variation process (under RSP 3.04.02). This procedure guides the Waste Acceptance team through the variation process, ensuring that the necessary LLWR teams have had the opportunity to assess the proposal. The results of the process are recorded on the Waste Consignment Variation Management Form (RSF3.04.01).</p> <p>As part of the variation process, the consignor is expected to identify the WAC for which they are requesting a variation, which would include a request to dispose of a non-standard item,</p>		

where the item would not be packaged in a standard container. A suitable justification for each variation to a WAC is required, normally in the form of a BAT assessment with any necessary supporting information.

The following are required to assess a proposed variation:

- Waste Acceptance Specialist
- Responsible Engineer (Safety Case)
- LLWR Operations/Supply Chain Operations
- Commercial
- Waste Services Manager (sources only).
- ESC Project Manager
- Waste Acceptance Manger
- Independent Person (sources only).

All must agree to the variation. All comments, concerns or assessments are either included on the Waste Consignment Variation Management Form or referenced from there. The outcome of the review is that a request for further information is generated, or LLWR approve or reject the variation request.

All supplied information, correspondence, requests and the management form are uploaded onto the LLW Waste Control Variation Database.

The need to manage non-containerised items as a variation became an explicit requirement in the 2002 version of the WAC (then called the CFA). The formal requirement for assessment in the way described above (along with the rest of the waste acceptance process) was included in the LLWR's Repository Site procedures in 2011.

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 07/12/2012
Approved by: Environment Agency	Date: 15/11/2013

LLW Repository Ltd has provided a response to both actions ESC-RO-INF-003-A1 and ESC-RO-INF-003-A2.

We consider that LLW Repository Ltd has addressed Action A1 and thus this action has been closed.

However, we still have concerns with regard to Action A2. LLW Repository Ltd has provided a description of the procedures in place for dealing with non-standard disposals at present (2011 onwards). However, the same information has not been provided for non-standard disposals made between 2002 and 2011. It is not clear pre-2002 what procedures, if any, were in place to control non-standard disposals to Vault 8. In addition, we note that LLW Repository Ltd states that between 2002-2011 non-standard disposals were controlled and assessed through the 2002 version of the CFA. However, from this statement it is not clear how this control was achieved.

We therefore seek greater clarity of what processes were used prior to 2011 to identify and assess non-standard disposals. We expect a detailed description of processes in place throughout the lifetime of the vaults that were used to assess and identify non-standard disposals, including how these were implemented, for example through procedures or other requirements. As part of this description we expect an indication of the information that is available now relating to disposals of non-standard items back to the start of vault disposals. For example, what level of assessment was completed with regards to voidage.

As part of this response LLW Repository Ltd should provide a number of representative examples of non-standard consignment assessments undertaken for vault disposals prior to 2011. Through these, we are seeking increased confidence that procedures in place were effectively implemented

and also that relevant information is available to support understanding of Vault 8 settlement properties.

This RO has been superseded by ESC-RO-INF-003B which addresses the outstanding action below.

Regulatory Observation Actions

ESC-RO-INF-003-A1	Closed.
ESC-RO-INF-003-A2	As described above, LLW Repository Ltd to provide further detail on their procedures in place pre-2002 and between 2002-2011 for accepting non-standard disposals, and how these were controlled and assessed. For both cases provide examples of how these procedures were followed.

Actions completed, Regulatory Observation resolved and Form closed

Owner: Environment Agency	Date: 15/11/2013
Approved by: Environment Agency	Date: 15/11/2013

ESC-RO-INF-003b: Non-standard disposals to Vault 8

Title	Non-standard disposals to Vault 8
Date original IRF raised (ESC-RO-INF-003)	21/06/2012
Date further actions raised	19/12/2012
Acknowledgment required by	21/12/2012
Response required by	22/01/2013
Related issue numbers	ESC-RO-INF-003
Originated by	Environment Agency
Current owner	Environment Agency
Review group	INF
Approved by	Environment Agency

History

Status	Date	Description
Raised	21/06/2012	
Acknowledged	29/06/2012	
LLWR Response	22/10/2012	
Response Assessed	30/11/2012	
Further actions raised	19/12/2012	Further action raised (IRF-RO-INF-003b)
Acknowledged	19/12/2012	
LLWR Response	24/05/2013	
Response Assessed	26/07/2013	
Transferred	26/07/2013	
Closed	27/09/2013	

Statement of Regulatory Observation

We are aware that many non-standard disposals (use of containers other than those specified, such as WAGR boxes, and uncontainerised disposals, such as fuel flasks and reactor heat exchangers, that are grouted in-situ) have occurred in Vault 8. LLW Repository Ltd will need to have approved such non-standard disposals, and in order to do so we assume they have carried out assessments of the potential effects of such disposals on the disposal system and on the safety case, particularly with respect to their impact on waste settlement. This will require further, more detailed, information on non-standard disposals, that is not evident from the ESC or its supporting information.

LLW Repository Limited should be able to demonstrate traceable information and evidence pertaining to its decisions with respect to approving such disposals, including any assessments of how specific non-standard disposals may impact on the safety case, in order to make those decisions.

Regulatory Observation Actions

ESC-RO-INF-003-A1	To present a fuller picture of disposals in Vault 8, LLW Repository Limited should provide a list of non-standard disposals that have been made to Vault 8.
ESC-RO-INF-003-A2	<p>LLW Repository Limited should provide a description of its non-standard disposal process, including the factors and issues that are considered in deciding whether to approve non-standard items for disposal. Reference should be made to relevant procedures in place.</p> <p>Additionally, where practices have changed over the lifetime of Vault 8, description should be provided of previous processes under which non-standard disposals were made and assessed.</p>

LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	29/06/2012
Comment: Responses to the actions will be provided.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	22/10/2012
<p>ESC-RO-INF-003-A1</p> <p>To present a fuller picture of disposals in Vault 8, LLW Repository Limited should provide a list of non-standard disposals that have been made to Vault 8.</p> <p>Please see attached list of non-standard disposals in Vault 8.</p> <p>(Several erroneous skip records are omitted from the list. Some full waste skips were given tracking numbers before being sent to WAMAC. Once at WAMAC they were emptied, reused and the next consignment given a new tracking number. The compacted waste was then sent to LLWR with a separate tracking number. The skip records are omitted from the list of non-containerised waste in Vault 8).</p> <p>ESC-RO-INF-003-A2</p> <p>LLW Repository Limited should provide a description of its non-standard disposal process, including the factors and issues that are considered in deciding whether to approve non-standard items for disposal. Reference should be made to relevant procedures in place.</p> <p>Additionally, where practices have changed over the lifetime of Vault 8, description should be provided of previous processes under which non-standard disposals were made and assessed.</p> <p>Current practice is as follows.</p> <p>Non-standard item disposal requests would normally be assessed in the first instance through the standard enquiry process (managed under RSP3.05.02). The waste enquiry process is where the consigning of a specific volume of waste is considered. The assessment would normally be managed by the specific consignor's single point of contact within the Delivery team in Waste Services. For a non-standard item, the Delivery team would seek advice from the Waste Acceptance team, also in Waste Services, who would consult with other LLWR teams to establish a position on the acceptability of disposal.</p> <p>At the waste consignment stage, a non-standard item would be treated as a variation to the WAC. A request for a variation by a consignor would be submitted through the Customer</p>		

team email inbox and managed through the variation process (under RSP 3.04.02). This procedure guides the Waste Acceptance team through the variation process, ensuring that the necessary LLWR teams have had the opportunity to assess the proposal. The results of the process are recorded on the Waste Consignment Variation Management Form (RSF3.04.01).

As part of the variation process, the consignor is expected to identify the WAC for which they are requesting a variation, which would include a request to dispose of a non-standard item, where the item would not be packaged in a standard container. A suitable justification for each variation to a WAC is required, normally in the form of a BAT assessment with any necessary supporting information.

The following are required to assess a proposed variation:

- Waste Acceptance Specialist
- Responsible Engineer (Safety Case)
- LLWR Operations/Supply Chain Operations
- Commercial
- Waste Services Manager (sources only).
- ESC Project Manager
- Waste Acceptance Manger
- Independent Person (sources only).

All must agree to the variation. All comments, concerns or assessments are either included on the Waste Consignment Variation Management Form or referenced from there. The outcome of the review is that a request for further information is generated, or LLWR approve or reject the variation request.

All supplied information, correspondence, requests and the management form are uploaded onto the LLW Waste Control Variation Database.

The need to manage non-containerised items as a variation became an explicit requirement in the 2002 version of the WAC (then called the CFA). The formal requirement for assessment in the way described above (along with the rest of the waste acceptance process) was included in the LLWR's Repository Site procedures in 2011.

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 07/12/2012
Approved by: Environment Agency	Date: 17/12/2012

LLW Repository Ltd has provided a response to both actions ESC-RO-INF-003-A1 and ESC-RO-INF-003-A2.

We consider that LLW Repository Ltd has addressed Action A1 and thus this action has been closed.

However, we still have concerns with regard to Action A2. LLW Repository Ltd has provided a description of the procedures in place for dealing with non-standard disposals at present (2011 onwards). However, the same information has not been provided for non-standard disposals made between 2002 and 2011. It is not clear pre-2002 what procedures, if any, were in place to control non-standard disposals to Vault 8. In addition, we note that LLW Repository Ltd states that between 2002-2011 non-standard disposals were controlled and assessed through the 2002 version of the CFA. However, from this statement it is not clear how this control was achieved.

We therefore seek greater clarity of what processes were used prior to 2011 to identify and assess non-standard disposals. We expect a detailed description of processes in place throughout the lifetime of the vaults that were used to assess and identify non-standard disposals, including how

these were implemented, for example through procedures or other requirements. As part of this description we expect an indication of the information that is available now relating to disposals of non-standard items back to the start of vault disposals. For example, what level of assessment was completed with regards to voidage.

As part of this response LLW Repository Ltd should provide a number of representative examples of non-standard consignment assessments undertaken for vault disposals prior to 2011. Through these, we are seeking increased confidence that procedures in place were effectively implemented and also that relevant information is available to support understanding of Vault 8 settlement properties.

Regulatory Observation Actions

ESC-RO-INF-003-A1	Closed.
ESC-RO-INF-003-A2b	As described above, LLW Repository Ltd to provide further detail on their procedures in place pre-2002 and between 2002-2011 for accepting non-standard disposals, and how these were controlled and assessed. For both cases provide examples of how these procedures were followed.

LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	19/12/2012
We will provide further clarification of our initial response and supporting evidence.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	24/05/2013
<p>From 2002</p> <p>The need to manage non-containerised items as a variation became an explicit requirement in the 2002 version of the WAC (then called the CfA). A variation form (historically called a D5) would be submitted to Waste Services, requesting disposal of an item outside the WAC (CfA). This request would then be assessed by the appropriate people, for example there would be (at least) a technical review and a commercial review. If the variation met the WAC in all other respects (i.e. radiological and inaccessible voidage) then it would be approved for disposal.</p> <p>Due to the nature of the majority of the non-standard items a key consideration was the compliance with the 10% inaccessible voidage criteria. If the non-standard item was deemed not to meet this criteria, or there was a question about whether it would meet this criteria, the variation would be elevated to the Engineering department for approval. This would result in a consideration of the voidage to be either acceptable (i.e. within an acceptable range) or that any potential voidage would be managed by detailed design of the cap in specific areas.</p> <p>An example of a disposal where this Engineering consideration of voidage occurred relates to the disposal of redundant hex cylinders in 2009. An Engineering assessment was undertaken to consider the implications in terms of voidage and resultant cap stability. The Engineering team provided advice about where the items should be located in the vault if they were to be accepted. Placing the items on the shelf area of the vault meant there was in most cases no waste below the items and that there was greater flexibility in that area for cap detailing if required. The proposal to dispose of the cylinders and accommodate the potential voidage by detailing the cap above them to accommodate the expected settlement was referred to the Agency at the time of disposal. Another non-standard disposal that was discussed with the Agency was the disposal of aluminium ingots from Capenhurst in 2002. It was agreed with the regulator that these would be disposed in several discrete locations in</p>		

Vault 8 to minimise the risk of potential future retrievals.

For the disposal of non-standard items that required in vault encapsulation, a Plant Modification Proposal (PMP) would need to be produced and approved. A PMP is a formal process of assessment to allow a change to normal practice to occur (i.e. in vault encapsulation) or to transport and move a large item (i.e. using a mobile crane brought to site). The PMP form contains a consideration of many aspects of safety related to the disposal of large items, such as risk assessments and dose assessments.

As an example of the linkage between a variation for a non-standard item and its related PMP, attached is a variation (D5) form – reference 2583 and the associated PMP – LLWR/PMP/2007/181. The PMP provided covers the receipt of two heat exchangers, a sliding top module, a fixed base module and base module. The description of the proposal includes the requirement to fill the internal voids with grout to minimise voidage to reduce settlement of the cap demonstrating that this was a key consideration. Further examples could be provided if requested.

Before 2002

Non-standard items were not a variation before 2002 and so were accepted as part of the usual disposal process, in that if they met all the requirements of the CfA, there was no requirement for assessment as they were 'compliant' disposals.

We believe, however, that non-standard disposals would have been dealt with under the PMP process due to their nature and the requirement to undertake work outside the normal operations to emplace them. We have located two examples of PMPs for non-standard items disposed prior to 2002, these are:

- PMP 88/8, from 1988, concerning the disposal of redundant stainless steel tanks to Trench 7. The PMP includes a safety assessment covering six aspects; radiological, fixing of contamination, presence of water, transporting, clearing of redundant area and criticality.
- PMP 95/30D, from the 1995 campaign to in-vault grout various items. The description of the proposal explicitly includes the need to grout the internal voidage where this has not been done previously and then external encapsulation of the items in concrete.

The latter PMP demonstrates that minimising voidage was a consideration in the approval for acceptance of these items into Vault 8 prior to the requirement for non-standard items to be considered as a variation. Paperwork for the above examples is attached.

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 26/07/2013
Approved by: Environment Agency	Date: 27/09/2013

LLW Repository Ltd has provided a list of the non-standard disposals that are currently within Vault 8. Thus Action ESC-RO-INF-003.A1 has been addressed to the satisfaction of the Environment Agency.

Action ESC-RO-INF-003.A2 requested that LLW Repository Ltd provides the relevant processes used for managing non-standard disposals. LLW Repository Ltd's initial response outlined the procedures that it currently has in place for managing non-standard disposals at the LLWR. However, this it did not address past practices, particularly those prior to 2002. Thus we raised a subsequent action to receive this information.

LLW Repository Ltd has since provided us with a description of the relevant processes that were in place covering the periods before 2002 and also from 2002 to 2011. LLW Repository Ltd has provided us with examples of relevant forms used as part of these processes (D5s and PMPs) as evidence of these processes being implemented.

This evidence has provided the Environment Agency with confidence that processes were in place to control the disposal of non-standard disposals and that these have been implemented. However, we note that for the period prior to 2002 it is less clear whether the PMP process was implemented fully due to the fact that non-standard disposals were treated as 'routine disposals'.

A key issue of interest to us with regards to non-standard disposals is their voidage, which was specified as being limited at 10% and required to be uniformly distributed. As part of a separate work package, LLW Repository Ltd has demonstrated that the voidage present within non-standard containers will have little impact on the settlement of the cap (Ref 1). This is based upon evidence of the voidage within disposals, the nature of the disposed items and their locations. This addresses one of our key concerns with regards to non-standard disposals.

Overall, we conclude that LLW Repository Ltd has addressed our concerns identified within this RO and has provided details of procedures and processes by which non-standard disposals have and continue to be controlled. We note that prior to 2002 routine disposals and non-standard disposals were treated similarly and thus it may be the case that non-standard disposals were not as well controlled as those after 2002. However, a separate assessment of the impact of non-standard containers on the settlement of the cap has alleviated our concerns about a possible lack of controlling process prior to 2002. This issue is now closed.

References

1. Jefferies N.; Vaults 8 Containers Issue Project: Position Paper December 2012, RP/LLWRGR/PROJ/00139 Issue 1, 20th December 2012.

Actions completed, Regulatory Observation resolved and Form closed

Owner: Environment Agency	Date: 27/09/2013
Approved by: Environment Agency	Date: 27/09/2013

ESC-RO-SUE-001 Final capping of the trenches

Title	Final capping of the trenches
Date raised	05/09/2011
Acknowledgment required by	16/09/2011
Response required by	30/04/2012
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	SUE
Approved by	Environment Agency

History

Status	Date	Description
Raised	05/09/2011	
Acknowledged	16/09/2011	
LLWR Response	26/11/2012	
Response Assessed	31/07/2013	
Transferred	14/11/2014	
Closed	14/11/2014	

Statement of Regulatory Observation

Schedule 9 Requirement 7 of the LLWR authorisation issued in 2006 requires LLW Repository Ltd to report annually on the performance of the interim cap over the trenches. The next such report is due by 1 May 2012, and we expect this report to provide a significantly better and complete analysis of the cap's performance than previous reports, taking account of results from recently upgraded monitoring systems.

In the ESC, LLW Repository Ltd states an intention to construct the final cap in sections, capping each vault and the adjacent section of the trenches when the vault has been filled. Capping of the trenches will therefore, according to this plan with the current predicted waste inputs, not be completed until about 2080, long after the specified design life of the interim cap. We need to be assured that the trenches will, at all times, have a cap whose performance is consistent with that assumed in the ESC and BAT equivalency. The obvious way to achieve this would be to cap the whole trenches area immediately or in the near future, but if LLW Repository Ltd can demonstrate that this is not necessary then it will need to provide an alternative scheme that can be relied upon to provide for an adequately performing interim cap on any given area of the trenches throughout the period until that area is finally capped.

In due course, we will expect LLW Repository Ltd to demonstrate that its proposed capping scheme is optimal, taking account of the performance of the interim cap over periods for which it is the only capping over the trenches. That demonstration will need to take full account of the conclusions of the 2012 Requirement 7 report and so cannot be provided yet. In the mean time, we need further assurance that immediate (or near future) capping of the trenches is unnecessary.

Regulatory Observation Actions

ESC-RO-SUE-001.A1	LLW Repository Ltd shall demonstrate that the interim trench cap, with any necessary maintenance, renovation or replacement, can reasonably be made to perform, with a high degree of confidence, sufficiently well to ensure consistency with the assumptions in the ESC until completion of the last stage of the final capping.
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	16/09/2011
<p>Comment: As noted above, the approach of capping of the trenches in strips as the adjacent vaults are progressively capped is set out in the 2011 ESC and associated planning application to the local planning authority, Cumbria County Council. We have also set out in the ESC that we will undertake future assessments at appropriate intervals, or as warranted by new information such as from our continuing monitoring programme, to understand if this approach continues to be optimal. The performance of the interim cap as it ages will be a key input to these assessments. If the approach of capping in strips ceased to become the optimal approach, for example because of deterioration in the performance of the interim cap, an alternative approach, such as replacement of the interim cap or final capping of the remaining cap area, would be adopted. We believe that is not possible to predict with certainty the change in performance of the cap over time. Each decision on the optimal approach would be based on the situation and information available at the time. It is acknowledged in the 2011 ESC that we have not yet fully demonstrated that the approach of capping in strips is optimal. We are intending to undertake an optimisation study for the capping of the trenches once sufficient monitoring data are available from the recently upgraded monitoring systems. It would be desirable to base this optimisation study on a full year's data, which will not be available until after April 2012. In the interim, we suggest that it may be helpful to set out our approach and supporting arguments in a position paper. We would also like to agree with the Agency when would be the best time to undertake the full optimisation study.</p>		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	26/11/2012
<p>A response is provided in ESC Project memo <i>Response to Issue Resolution Form ESC-RO-SUE-001 (Final Capping of the Trenches)</i>, LLWR/ESC/Mem(12)147, supported by the report of the optimisation of the management of trench leachate, <i>LLWR Trench Hydrogeological Management BAT: Final Report</i> Quintessa report QRS-1442ZN-R3, Version 1, November 2012, already provided to the Agency.</p>		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 31/07/2013
Approved by: Environment Agency	Date: 14/11/2014

For the period prior to the construction of the final cap over the trenches, LLW Repository Ltd needs to demonstrate that the performance of the interim trench cap remains sufficient and consistent with application of Best Available Techniques (BAT). The 2011 ESC recognised that consideration was required as to whether the current interim trench cap represented use of BAT and was optimised.

In response to this RO, LLW Repository Ltd developed a strategy for the improvement of the interim trench cap, which comprised re-sealing and repairing all the trench probe perforations using modern construction quality assurance (CQA) approaches, together with re-profiling of depressions in the cap surface (Quintessa 2012). A campaign of opportunistic excavation and geophysics surveys was also planned with a view to repairing other potential weaknesses in the trench cap, for example the join in the membrane between Trenches 6 and 7. In addition, 0.5 m depth land drains were to be constructed to drain areas of standing water and improve cap drainage. At the end of the investigation programme, LLW Repository Ltd planned to measure the performance of the repaired cap and re-assess its effectiveness and whether the repairs represented application of BAT.

LLW Repository Ltd commenced the programme of trench cap repairs in the autumn of 2013. The company successfully repaired the trench probes and installed 'top hat features' designed to reduce leakage around the probe. During the excavation of the probes and trial trenches LLW Repository Ltd identified a number of faults in the trench membrane. These faults were seen to extend over distances of up to 50 m, with the membrane missing over areas in excess of 10 m². The majority of faults were thought to be the result of poor installation and the placement of cover material over the membrane.

The extent of the faults meant that the repairs to the trench probes were not likely to achieve the required reduction in infiltration. LLW Repository Ltd therefore abandoned the planned programme of work and focussed on further targeted investigations to gain improved data on the extent of membrane failures. At the time of writing, LLW Repository Ltd is reviewing and updating the BAT strategy, informed by these further investigations. The company is intending to determine what actions are required to further enhance the trench cap, up to the point of final capping, taking into account wider programmes of capping and engineering work being undertaken on the site.

We will continue to expect LLW Repository Ltd to apply BAT and will review any approach they adopt. We require the company to demonstrate that the strip restoration sequence is optimised in ESC-FI-025 and ESC-FI-026.

We are satisfied that this RO has been adequately addressed and that a suitable programme of work is in place to ensure that BAT are applied to the interim trench cap. This RO can therefore be closed.

References

Quintessa, 2012. LLWR Trench Hydrogeological Management BAT: Final Report Quintessa report QRS-1442ZN-R3, Version 1, November 2012.

Actions completed, Regulatory Observation resolved and Form closed

Owner: Environment Agency	Date: 14/11/2014
Approved by: Environment Agency	Date: 14/11/2014

ESC-RO-SUE-007: The use of future monitoring to reduce uncertainties in the ESC

Title	The use of future monitoring to reduce uncertainties in the ESC
Date raised	29/06/2012
Acknowledgment required by	06/07/2012
Response required by	10/08/2012
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	SUE
Approved by	Environment Agency

History

Status	Date	Description
Raised	29/06/2012	
Acknowledged	29/06/2012	
LLWR Response	19/10/2012	
Response Assessed	11/04/2013	
Transferred	11/04/2013	
Closed	10/10/2013	

Statement of Regulatory Observation

A robust and comprehensive environmental sampling and monitoring programme will be required to both support the forward development of the ESC and to address the inherent uncertainties associated with a model based ESC.

The 2011 ESC main report (LLWR/ESC/(R11)10016) contains a commitment to keep the LLWR's programme of monitoring under review. This will take the form of an annual review, based on the outcome of the programme for the previous year and phased developments and, in 2011-12, considering all the findings and implications of the ESC. The current forward monitoring programme is outlined in the Level 2 Monitoring report (LLWR/ESC/(R11)10024).

We consider that the presented forward monitoring programme appears focussed on the provision of performance assurance rather than the systematic reduction of the inherent environmental uncertainties. The presented ESC forward programme does not specifically address how the key uncertainties identified in the 2011 ESC can be reduced in order to produce a more realistic assessment.

We would expect key uncertainties to be systematically addressed over the Period of Authorisation (PoA) with targeted monitoring and sampling programmes and where appropriate site based experimental programmes. This is particularly relevant to the vault disposals where site derived information is not yet available. It is likely that a well designed monitoring programme can achieve both performance assessment and uncertainty reduction objectives using common information.

As the LLWR ESC is maintained and updated, we would expect identified uncertainties to be assessed and systematically reduced in order to ensure that the ESC continues to be an

applicable tool for making decisions about the regulation, operations, management and development of the site.

In particular, the forward monitoring programme would be expected to contain elements designed to consider the following key uncertainties identified in the Level 2 assessment of long-term radiological impacts (LLWR/ESC/(R11)10028):

- “the time at which the facility will be eroded by the sea, sea level at the time of erosion and rate of release of radionuclides from eroded material into marine waters;
- the primary release rate of C-14 from key wasteforms, the degradation rate of cellulose and the assumption of uniform biogeochemical conditions in the GRM model;
- the effective dilution factor of water entering the Regional Groundwater from the repository, linked to the degradation of the engineered features; uncertainties related to the heterogeneous nature of the quaternary sediments and consequent flow path characteristics and dilution”.

Other significant uncertainties that are identified within the future programme (LLWR/ESC/(R11)10016) which future monitoring would help to consider include:

- Near field - release of contaminants from the near-field and unsaturated zone behaviour.
- Evolution of the engineered barriers – monitoring the performance of the existing cut-off wall as well as future engineered features.
- Geology and hydrogeology – further consideration of the elevated groundwater levels immediately to the west of the site, analyse the implications of new geological data on the location of discharges, analyse head data collected in order to monitor the effects of the construction of Vault 9 and (potentially) use long-term tracer tests to build confidence in the understanding of contaminant transport.

The settlement behaviour of grouted waste containers and the capping system would also benefit from the empirically derived monitoring information.

We wish to see evidence of how the forward monitoring programme will be tailored to specifically provide robust site derived data that can be used to reduce uncertainties in the conceptual site model and to independently help determine the accuracy of near field and contaminant transport models to address these uncertainties. We also wish to understand how such monitoring data are envisaged to be used to enhance the ESC going forward. Such a forward programme should, at an appropriate level of detail, cover the whole of the operational period of the facility and can consist of specific monitoring proposals for shorter term and longer term objective based environmental monitoring and sampling activities.

Regulatory Observation Actions

ESC-RO-SUE-007.A1	<p>Please provide evidence of how the forward monitoring programme will be developed throughout the PoA and linked to the ESC in order to reduce key uncertainties in the ESC.</p> <p>We wish to understand how the ESC will be used to help drive the scope and content of the forward monitoring programme.</p>
ESC-RO-SUE-007.A2	<p>Please clarify the systems in place to ensure that linkages between the ESC team and the monitoring team will be maintained going forward and that, where appropriate, site-derived information is fed into the ESC on a regular basis, interpreted and utilised to review and refine the monitoring programmes.</p> <p>We wish to understand how a feedback loop will be established between the monitoring programme(s) and review and upkeep of the ESC.</p>

LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	29/06/2012
Comment: Responses to the actions will be provided.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	19/10/2012
A response is provided in ESC Project Memo LLWR/ESC/Mem(12)176.		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 06/11/2012
Approved by: Environment Agency	Date: 10/10/2013

LLW Repository Ltd memo LLWR/ESC/Mem(12)176 states that 'we have identified the main uncertainties that bear on the 2011 ESC and will continue to keep these uncertainties under review and to manage them'. However, the 2011 ESC as submitted does not clearly identify these key uncertainties (see ESC-RO-ASO-004).

Table 2 of the memo outlines the approach to addressing uncertainties identified by us in this RO. We find it difficult to link these 'key uncertainties' presented with entries in the features, events and processes (FEPs) and uncertainty tracking system²⁵, which we received after memo LLWR/ESC/Mem(12)176, as the majority of uncertainties listed do not directly map onto FEPs (uncertainties may be covered by one or more FEP). In addition, the examples provided in this RO are not intended to provide a comprehensive list of key uncertainties that could be reduced through future monitoring.

We wish to see a systematic identification of key uncertainties followed by an assessment of if (and, if relevant, how) future monitoring could be used to reduce these uncertainties. These key uncertainties, which we would define as an uncertainty that has, or could have, a significant effect on the ESC, should be clearly mapped to entries in the FEP and uncertainty tracking system to maintain the audit trail.

Nevertheless, we welcome the examples of the key uses of monitoring data in the ESC and the potential approaches to addressing some of the key uncertainties in the ESC. The suggestions in Table 2 seem broadly reasonable, but the table does not include all the uncertainties identified by LLW Repository Ltd as having a significant effect on the ESC. We also note that, whilst the memo references Entec's Long Term Environmental Monitoring Strategy report to illustrate its proposed approach, we are not clear at this point in time to what extent its recommendations will be taken forward.

With respect to the potential approaches that offer the best potential to reduce some of the key uncertainties (Table 2 of LLWR/ESC/Mem(12)176), LLW Repository Ltd states that 'It is not a commitment to undertake particular pieces of work as in a number of cases we envisage further studies and decision points before commissioning detailed research'. We would wish to have further information about what further studies are proposed and the process to be followed, key decision points, decision makers and timeframes.

²⁵ LLW Repository Ltd, 2013. 2011 Low Level Waste Repository Environmental Safety Case: Features, Events and Processes and Uncertainty Tracking System. Excel spreadsheet reference MASTER 2011 FEP List_LLWR04127061103_0_2 - ajb7 macro Jan 2013.

We therefore consider that the Action ESC-RO-SUE-007.A1 could be further addressed in the future; however, the response has provided sufficient information for the purpose of completing our review of the ESC. We also accept that there may be limited opportunities to reduce uncertainties in assessment model parameters through monitoring, as opposed to conceptual model uncertainties or for general confidence building²⁶. We will close this action on the grounds that there is no immediate need for the information that is outstanding. However, a Forward Issue has been raised to request more information about how LLW Repository Ltd intends to develop the forward monitoring programme to address key uncertainties in the ESC (ESC-FI-005).

We welcome the organisational change at the LLWR referred to within the response and consider that the bringing together of the ESC and Monitoring teams, along with the procedures that are now in place, allows us to close Action ESC-RO-SUE-007.A2.

In addition we have two further detailed comments on statements within the response:

From Table 1:

<p>'Surface water monitoring of contaminant concentrations'</p>	<p>'Such monitoring is relevant to the radiological impacts that arose as the result of past discharges from authorised disposals. The monitoring will not be a good test of current ESC models. The data do confirm that the system is performing as expected.'</p>
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If, as stated, the data from surface water monitoring of contaminant concentrations confirm that the system is performing as expected, this must surely provide at least an indirect test of ESC models.

From Section 5:

'Experimental work may often be the preferred approach and we consider such work to be outside the conventional monitoring programme.' We would expect full integration between monitoring and experimental studies that are designed to address the same uncertainties.

Overall, we are satisfied that this IRF can be closed, but again note that we have raised a FI (ESC-FI-005).

Actions completed, Regulatory Observation resolved and Form closed

<p>Owner: Environment Agency</p>	<p>Date: 10/10/2013</p>
<p>Approved by: Environment Agency</p>	<p>Date: 10/10/2013</p>

²⁶ More broadly we would expect a systematic review of uncertainties to determine which should be addressed by monitoring, experiment, modelling or other approaches.

ESC-RO-SUE-008: Development of environmental monitoring strategy

Title	Development of a Long Term Monitoring Strategy to Support the Environmental Safety Case
Date raised	14/01/2013
Acknowledgment required by	21/01/2013
Response required by	15/03/ 2013
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	SUE
Approved by	Environment Agency

History

Status	Date	Description
Raised	14/01/2013	
Acknowledged	15/01/2013	
LLWR Response	10/04/2013	
Response Assessed	11/04/2013	
Transferred	11/04/2013	
Closed	10/10/2013	

Statement of Regulatory Observation

In line with Requirement R14 of the Guidance on Requirements for Authorisation (GRA), we would expect the Environmental Safety Case (ESC) to include a robust programme of monitoring and sampling specifically designed to monitor for changes caused by construction, operation and closure of the facility. In order to deliver this objective it is important that an overarching strategy is developed to identify the specific sampling and monitoring objectives. The strategy should be high level in approach and suitably long term, so as to cover the entire period of authorisation.

We consider it critical that an overarching long term monitoring strategy is in place covering the relationship between monitoring activities and ESC objectives.

For example IAEA (2004) states “*The design of the surveillance and monitoring programme therefore needs to be based on the assumptions, modelling and findings of the safety assessment.*”²⁷

Such a programme would need to address short term monitoring objectives (which have been addressed in the ESC) and longer term objectives corresponding to the ongoing development, operation and optimisation of the site throughout the period of authorisation.

²⁷ Surveillance and monitoring of near surface disposal facilities for radioactive waste. Vienna: International Atomic Energy Agency. 2004.

The presented ESC incorporates a Level 3 document that reviews the LLWR long term monitoring requirements (Long Term Environmental Monitoring Strategy, Entec 2011²⁸). We consider that the main body of the presented ESC has not appropriately integrated and taken account of the Level 3 recommended long term monitoring strategy.

The Level 2 Monitoring submission specifically states "We do not think it is appropriate to set out at this stage detailed proposals for monitoring over the whole period of institutional control. Rather, our approach is to demonstrate an understanding of the issue".

This contrasts with the Level 3 Long Term Environmental Strategy report whose stated objective is to set out the basis for forming the long term environmental monitoring strategy for LLWR. The Long Term Environmental Strategy then goes on to present International and Environment Agency expectations for long term monitoring strategies.

We think it is appropriate and in line with best practice to present a set of high level monitoring objectives which covers the entire period of authorisation. These objectives do not need to be detailed, instead they should identify what media will be part of the monitoring and programme and how it will support the ongoing development of the ESC.

Integration between the presented long term monitoring strategy and the presented ESC monitoring submission.

The presented Level 2 monitoring document (LLWR/ESC/R(11)/10024) describes the environmental monitoring programme and recent underpinning sampling. We consider that it does not effectively address the longer term monitoring strategy as presented in 'Long Term Environmental Monitoring Strategy' (Entec, April 2011²⁹). This Level 3 document presents a number of longer term monitoring recommendations for all of the main environmental media and pathways. These recommendations have not been assessed or implemented into the main ESC and as a consequence do not form part of the forward monitoring programme.

In its current form we do not consider the Level 2 ESC documentation presents an appropriate comprehensive monitoring strategy which is able to appropriately support the presented ESC. It is therefore important that the presented Level 2 monitoring document is updated and amended to fully incorporate the strategic elements set out in the Level 3 Long term strategy review. The revision would take account of the key finding of the ESC in terms of the maximum future risks and the assertions and assumptions underpinning the analysis that leads to the risk calculations.

Regulatory Observation Actions

ESC-RO-SUE-008.A1	<p>Please describe LLWR's approach to and mechanism for the identification of long-term monitoring objectives and the incorporation of these objectives into the ESC.</p> <p>A set of high level monitoring objectives should be presented which will support monitoring programmes going forward. The objectives should cover all of the main environmental pathways identified in the ESC. Where appropriate the objectives should identify the ESC driver. Monitoring objectives should cover the entire authorised life of the site.</p>
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²⁸ Hayes P, Keep M, Fretwell B and Smith G, *Long Term Environmental Monitoring Strategy*, Entec report 27280 Issue 4, April 2011.

²⁹ Hayes P, Keep M, Fretwell B and Smith G, *Long Term Environmental Monitoring Strategy*, Entec report 27280 Issue 4, April 2011.

LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	15/01/2013
Comment: A response will be provided.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	10/04/2013
A response is provided in LLWR ESC Project Memo LLWR/ESC/Mem(13)210.		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 11/04/2013
Approved by: Environment Agency	Date: 10/10/2013

In line with the requirements of this RO, LLW Repository Ltd has defined 4 high level monitoring objectives that are applicable throughout the period of authorisation. These should be used to develop the framework for a site environmental monitoring strategy that should cover the entire period of authorisation and look at how requirements will change as the facility is further developed.

We welcome LLW Repository Ltd's commitment to undertake a programme of work to reach a view on the framework and approach for long-term monitoring. We request that this programme considers how monitoring requirements and priorities will change during the period of authorisation, ensuring that no actions are carried out (for example, site engineering) that would unnecessarily jeopardise future monitoring opportunities³⁰ (see Recommendation SUE55 of Environment Agency 2015, Review of LLW Repository Ltd's 2011 Environmental Safety Case: Site understanding).

During the development of this RO, we reviewed LLW Repository Ltd's post-2011 ESC review of the monitoring programme, which was informed by a series of workshops that took place in November 2011³¹. This timing is significant in that the review was not able to take into account feedback on our review of the 2011 ESC. This should be considered within the company's review of long-term monitoring. We also note that the post-2011 ESC review of the monitoring programme was focussed on monitoring requirements that could reduce uncertainties in the key models used in the 2011 ESC, looking separately at the near field/engineering, geosphere and wider environment. LLW Repository Ltd should ensure that this process includes consideration of all significant uncertainties of relevance to the overall ESC. Specific linkage to significant uncertainties identified in the FEPs and uncertainty tracking system would aid clarity (see ESC-FI-023).

The future monitoring programme should also document how LLW Repository Ltd envisages that it will continue to be reviewed and modified throughout the period of authorisation (see Recommendation SUE55 of Environment Agency 2015, Review of LLW Repository Ltd's 2011 Environmental Safety Case: Site understanding). We should be kept fully informed of progress on this programme of work.

³⁰ We recognise that the need to maintain future monitoring capability must be balanced against other factors such as the need to achieve long-term environmental performance.

³¹ LLW Repository Ltd, 2012. *ESC Review of the Monitoring Programme: Post 2011 ESC*, LLWR/ESC/R(12)10048, November 2012.

On the basis of the response received from LLW Repository Ltd, we consider that this RO can be closed; however, the recommendations outlined above should be taken into consideration in the forward work programme.

Actions completed, Regulatory Observation resolved and Form closed

Owner: Environment Agency	Date: 11/04/2013
Approved by: Environment Agency	Date: 10/10/2013

ESC-RO-SUE-009: Consolidation and resolution of engineering uncertainty

Title	Consolidation and resolution of engineering uncertainty
Date raised	21/01/2013
Acknowledgment required by	22/01/2013
Response required by	31/03/2013
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	SUE
Approved by	Environment Agency

History

Status	Date	Description
Raised	21/01/2013	
Acknowledged	05/02/2013	
LLWR Response	10/04/2013	
Response Assessed	20/07/2013	
Transferred	14/11/2014	
Closed	14/11/2014	

Statement of Regulatory Observation

The presented 2011 ESC includes an engineering design and associated safety justification for the design. The design incorporates many different and novel design aspects, many of which could be described as being at a conceptual stage³². We broadly concur that the presented engineering design concept can meet high level regulatory expectations.

Because of the extended life of site operations and restoration it is unrealistic to expect the engineering design of the facility presented within the ESC to be fully complete and to correspond fully with the as built design. As a result the majority of the engineering systems could be considered as conceptual in nature.

Our review has identified a number of areas where we have outstanding questions relating to the demonstration of appropriate safety performance and the ability of the design to achieve this. These questions will need to be fully addressed prior to construction. These questions include:

- Demonstration of the long term robustness and performance of the final capping design
- Performance and functionality of the vault and leachate management infrastructure

³² Conceptual means that the ESC has provided evidence that allows assessment of a realistic performance which could be constructed, however the actual as built design will need further assessment and optimisation design justification prior to final regulatory acceptance.

- Engineering aspects of overtopping mitigation measures both within and below the containment system
- Appropriate justification of novel and unique design concepts

In order to remove and address these outstanding questions and to provide confidence in the developing site engineering we consider it appropriate that a high level, but comprehensive engineering work programme is established addressing these questions and other aspects of engineering that require further development. The output of the engineering work programme will feed into the ongoing evolution and optimisation of the engineering design and inform long term engineering studies. The programme is likely to extend beyond our current review of the ESC and permit application and will inform the design of future capping and vault development.

A forward plan might comprise of the following activities:

- Identification and agreement of outstanding engineering issues, areas of concern, areas requiring further development and uncertainties
- Workshop with the specific objective of communicating areas of regulatory concern and outstanding questions Addressing issues which can be easily resolved and issues requiring further work
- Development of a forward engineering work programme, incorporating outputs of the engineering workshop with current LLWR plans and engineering understanding

The forward engineering programme should, at a high level, seek to deliver:

- Clarity around the timescales for the development of more detailed engineering designs and underpinning work, along with regulatory interactions
- Improvements to information provision on specific aspects of the design to remove regulatory uncertainty
- Demonstration of long term engineering performance using site and desk based investigations and studies
- Commitment to appropriate optimisation and improvement of the existing engineering design prior to the detailed design stage and further construction

Regulatory Observation Actions

ESC-RO-SUE-009.A1	Please present an outline (strategic level) engineering improvement programme incorporating the outcome of the forthcoming engineering workshop (currently planned for January/February 2013), as discussed in this RO.
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	05/02/2013
Comment: A plan will be provided.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	Senior Consultant	10/04/2013
Please refer to RP/LLWRGR/PROJ/000142_A.		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 20/07/2013
Approved by: Environment Agency	Date: 14/11/2014

We are satisfied with the engineering design presented within the 2011 ESC and consider it addresses the requirements of the GRA. However, we recognise that considerable further development of the engineering design is required prior to construction.

This Regulatory Observation (RO) was generated as the result of the identification of a large number of queries relating to the engineering design during our review of the 2011 ESC. The objective was to collate our observations on the engineering design and to seek a high level engineering programme describing what steps LLW Repository Ltd proposes to take to develop the engineering design further and to address our queries. These queries included clarification of how LLW Repository Ltd would substantiate and validate its designs and ensure they remain fully consistent with the ESC and are adequately documented within it.

Our assessment of LLW Repository Ltd's response to this RO reflects information gained through our review of the 2011 ESC, the company's forward engineering programme and further discussions held with the company at regular ESC Liaison meetings and a workshop.

The forward engineering programme (Shaw 2013) sets out the necessary steps and work areas needed to both address the questions raised in our review of the 2011 ESC and the subsequent engineering workshop. The forward engineering programme also describes the wider stages of engineering programme development needed to allow the construction of the engineering systems and restoration of the repository. The engineering forward programme is designed to provide answers to a number of defined questions which LLW Repository Ltd needs to answer prior to construction. It uses a combination of investigations, design processes and desk studies. We note that this programme of work must aim to achieve the best environmental solution whilst remaining flexible and accounting for design evolution and changes throughout the process.

Alongside the forward engineering programme, LLW Repository Ltd identified a number of potential regulatory 'hold points' where regulatory interaction is required to scrutinise design elements. We have reviewed these hold points and have informed the company that we consider its proposals are sufficient to facilitate our regulatory interactions as the design evolves (Fairhurst 2013).

We consider that the forward engineering programme is an appropriate mechanism to achieve an optimised engineering design.

We have raised 6 Forward Issues (FI) designed to make sure that LLW Repository Ltd's forward engineering programme takes account of our expectations, as informed by our review of the 2011 ESC (see Table 1 below). The FIs seek the production of plans and work scopes against which we can monitor and measure performance during our regulatory interactions. This RO has been adequately addressed and can be closed.

Table 1: Forward Issues relating to the implementation of the engineering forward programme

Forward Issue	Title
ESC-FI-001	Cap settlement issues
ESC-FI-023	Leachate management strategy
ESC-FI-024	Gas management strategy
ESC-FI-025	Protection of waste prior to final capping
ESC-FI-026	Engineering delivery
ESC-FI-027	Cap performance assessment

References

- Fairhurst, A., 2013. Engineering Assessment Framework. Environment Agency Letter 29th July 2013, ref LLWR/13/009/0.
- Shaw, N., 2013. Engineering Forward Plan to Support the Environmental Safety Case. LLW Repository Ltd Report RP/LLWRGR/PROJ/00142 Issue A, April 2013.

Actions completed, Regulatory Observation resolved and Form closed

Owner: Environment Agency	Date: 14/11/2014
Approved by: Environment Agency	Date: 14/11/2014

ESC-RO-ASO-001: Impacts to non-human biota during the period of authorisation

Title	Impacts to non-human biota during the period of authorisation
Date raised	28/06/2012
Acknowledgment required by	29/07/2012
Response required by	12/09/2012
Related issue numbers	ESC-RO-ASO-002 & ESC-RO-ASO-003
Originated by	Environment Agency
Current owner	Environment Agency
Review group	ASO
Approved by	Environment Agency

History

Status	Date	Description
Raised	03/08/2012	
Acknowledged	03/08/2012	
LLWR Response	25/03/2013	
Response Assessed	27/03/2013	
Transferred	27/03/2013	
Closed	10/10/2013	

Statement of Regulatory Observation

The Guidance on Requirements for Authorisation Requirement R9 on Environmental Radioactivity requires site operators to investigate the radiological effects of a disposal facility on the accessible environment during both the operational and post-closure periods to show that all aspects of the accessible environment are adequately protected. To address this requirement, an assessment of impacts to non-human biota as a result of exposures to ionising radiation is presented in the 2011 ESC. This Regulatory Observation (RO) relates to the assessment of impacts to non-human biota during the period of authorisation (POA); two separate regulatory observations (ESC-RO-ASO-002 & ESC-RO-ASO-003) address post-closure impacts.

The assessment of the current ecological status of the LLWR and its environs presented in SERCO/TCS/004354/01 and summarised in LLWR/ESC/R(11)10030, including details of protected sites and protected species, draws heavily from the analysis presented by Eden and Barber in 2007. We agree with the conclusion that there is one protected site, the Drigg Coast Site of Special Scientific Interest (SSSI) and marine Special Area of Conservation (SAC) that could be impacted by discharges of radionuclides (and non-radioactive contaminants) from the LLWR at the present day and at times in the future.

Information on the site ecology was drawn from Eden and Barber (2007)³³ and the Vault 9 planning application ecological impact assessment by Wilkinson (2007)³⁴. The surveys on which the

³³ Eden, L. and Barber, N., 2007, Assessment of the Impact of Radioactive Disposals and Discharges at the LLWR on the Ecosystem, Nexia Solutions (07) 8310: Issue 3, April 2007.

assessments were based date from approximately 2001 to 2006. There is no map showing habitats on the site, therefore it is difficult to visualise the locations of key habitats compared with the disposal area and thus assess the likelihood of discharges impacting them. No attempt has been made in the 2011 ESC to provide an update on the ecological status of the site or its environs. In particular, there is no reference to potential changes in site habitats resulting from the 2005 replanting programme and other recent site works such as the Vault 9 construction works. Furthermore, there is no reference to the most recent phase of ecological assessment that has been undertaken on the site. This should be done to confirm present day habitats on the site and occurrence of protected species.

Data on current discharges from the LLWR and details of environmental monitoring given in SERCO/TCS/004354/01 are taken from Eden and Barber (2007), which details monitoring and discharge data from 2004. It is not clear why these data have not been updated with more recent monitoring data. With reference to the assessment made by Eden and Barber in 2007, it is stated that present day impacts to the environment are managed by sampling and monitoring and are very low. However, no evidence is provided to justify this statement.

Reference is also made to the field sampling undertaken as part of the Drigg Dunes SSSI ERICA case study (Wood *et al.*, 2008³⁵). However, the relevance of the Wood *et al.* (2008) field sampling campaign to the ESC is not made clear. Sample locations are not specified in the ESC documentation, and no justification is provided to indicate either the relevance of these data to the ESC nor that full coverage of all relevant habitats and ecosystems that could be impacted by the facility have been considered.

SERCO/TCS/004354/01 states that activity that may arise from the LLWR site is masked by that from the Sellafield site, with the exception of the groundwater under the site and adjacent land and surface water on site and on adjacent land. However, elsewhere in the reports (e.g. LLWR/ESC/R(11)10030 page 43) there is a conclusion that at the present day the Sellafield discharges contribute significantly to the dose rates observed in the Drigg stream. However, the tidal reach is not given in any of the reports and so it is not clear whether the radionuclides from Sellafield can be 'washed' into the Drigg stream. This is a) an example of lack of detail in the report and b) needs to be addressed to show how the Sellafield radionuclides might influence the assessment outputs. Section 4.2.2 in SERCO/TCS/004354/01 indicates that the radioactivity may arise from LLWR so this would be a good reason to show where the tidal limit is to help better understand which radionuclide source is important in the different scenarios.

No new assessment of impacts to non-human biota has been undertaken for the POA in the 2011 ESC. Instead, reference is made to the results of the assessments undertaken by Eden and Barber (2007) and Wood *et al.* (2008). We query this decision for the following reasons:

- Eden and Barber (2007) used environmental concentrations measured in 2003-2004 to calculate dose rates to the Drigg stream ecosystem. These were based on data for a limited number of radionuclides. Reference is needed to more recent sampling data and trends in environmental concentrations to justify statements to the effect that future environmental concentrations will be lower than today (e.g. "*discharges are managed and radionuclide concentrations in the local environment due to the LLWR will be expected to decline*".) More recent monitoring data may also be available for a wider range of radionuclides.
- Eden and Barber (2007) used a prototype version of the ERICA tool in their assessment. This prototype had more limited functionality than later versions (e.g. there was no functionality for adding new radionuclides to the database). Subsequent updates to the ERICA tool have also incorporated updated reference data from the scientific literature.

³⁴ Wilkinson, J, 2007, *Construction of Vault 9 at LLWR, Drigg, Cumbria: Ecological Impact Assessment*, Wilkinson Associates Environmental Consultants, Prepared for British Nuclear Group, April 2007.

³⁵ Wood, M D, Marshall, W A, Beresford, N A, Jones, S R, Howard, B J, Coplestone, D and Leah, R T, 2008, *Application of the ERICA Integrated Approach to the Drigg coastal sand dunes*, J. Environ. Radioact., **99**, 1484-1495.

- The objectives of the Wood *et al.* (2008) study were very different to those of the 2011 ESC, and it was not designed to be a specific assessment that could be used to confirm or demonstrate environmental protection.
- The relevance of the study by Wood *et al.* (2008) on the Drigg Coast SSSI to the ESC is unclear given that it is stated that discharges of radioactivity from the LLWR site are very small compared with those from the Sellafield site as marine and aerial activity is able to travel from the Sellafield site, at least as far as the Drigg site. It is noted that “*the only exception to this is the groundwater under the site and adjacent land and surface water on site and on adjacent land (not including tidal waters)*” (SERC/TCS/004354/01 page 29).

A number of Agency comments on Eden and Barber (2007) have not been addressed in the 2011 ESC:

- The assessment lacks explicit uncertainty or sensitivity analysis and there appears to be an assumption that the assessment is conservative. There should be a systematic justification made for the implied claim of conservatism.
- Opportunities should be taken to ensure that relevant biota monitoring is undertaken, or data obtained, with a view to verifying the assessment tool predictions in terms of predicted activity concentrations. It is recognised that protected and feature species cannot be sampled, however opportunistic samples may often be taken (e.g. road kill for bird species and biota washed up on shore) which would provide real data on interest species. Such ad hoc monitoring would allow a picture of typical concentrations in biota to be built up to verify predicted activity concentrations.
- Given that there is air kerma measurement data available around the site, there may be value in comparing these results with the predicted external dose rates for the biota. It may provide additional confidence if these numbers were comparable.

It is considered that the 2011 ESC fails to demonstrate a sufficient understanding of the nature of impacts to non-human biota during the POA and fails to provide adequate assurance that impacts to non-human biota in all relevant ecosystems during this period will be low. A more thorough assessment of impacts for the POA should be presented, considering the key radionuclides of concern during this period. This should include consideration of all ecosystems of relevance, including fresh and coastal waters, beach/estuarine environments and terrestrial environments.

The assessment could be further enhanced by comparison with results from monitoring programme. Dose rates are available for some of the sites of interest (e.g. the Drigg Stream). But these data are not compared with the external (or even total) dose predictions made with the ERICA tool – this would be a useful check recognising that the dose rates will include a contribution from natural background. Similarly, dose rates for fish and shellfish are quoted (not specified whether wholebody or edible fractions). These data could be used to compare the outputs of an ERICA assessment activity concentration predictions (whilst recognising that it may not be possible to distinguish between LLWR and Sellafield contributions).

Regulatory Observation Actions

ESC-RO-ASO-001.A1	With reference to the LLWR environmental monitoring programme, provide an LLWR-specific assessment of impacts to all relevant ecosystems of interest resulting from releases of radionuclides into the environment during the period of authorisation.
ESC-RO-ASO-001.A2	Please address the various omissions and queries set out in this Regulatory Observation. This can be either a re-issue of the original ESC document or an addendum to the existing report.

LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	03/08/2012
Comment: Responses to the actions will be provided.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	25/03/2013
A response is provided in ESC Project memo LLWR/ESC/Mem(13)202, 22/03/2013.		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 27/03/2013
Approved by: Environment Agency	Date: 10/10/2013

This RO addressed the issue that we felt that the non-human biota assessment for the PoA did not adequately make use of the most recent monitoring data and survey data to perform an assessment of impacts to the observed biota / habitats on the site and in the adjacent SAC. Instead, the information presented was drawn from a previous 2007 assessment and the ERICA Drigg Dunes case study that was undertaken for a very different purpose.

LLW Repository Ltd provided maps of outputs from the most recent ecological surveys and links to more detailed sources of information in memo LLWR/ESC/Mem(13)202. In future updates to the ESC, the company should use this information to demonstrate that the generic reference species and habitats present in the ERICA assessment tool (or alternative model) are suitable for assessment of the environment local to the LLWR.

LLWR/ESC/Mem(13)202 presents monitoring data from discharges, leachate and the Drigg Stream to indicate that the 2003/4 data used in the PoA assessment are conservative. This point is accepted, however, there is no reference as to whether there are any additional radionuclide specific data available to support the assessment.

Environmental activity concentrations in the vicinity of the LLWR are likely to be dominated by discharges from Sellafield, however, the magnitude of this effect is difficult to determine. Marine discharges will be dominated by Sellafield and this will dominate sea-to-land transfers to the Drigg Coast SAC. Wood et al. 2008 indicate that overall impacts to biota in the SAC are below dose rates of concern; however, the sampling locations are not published in their study. There also appears a potential for activity sourced from Sellafield to be washed up the Drigg Stream as far as the site boundary, however, we would expect activity in the stream to be dominated by historic discharges from the LLWR. Environmental monitoring data presented by LLW Repository Ltd indicate that present day impacts to biota in the stream are below levels of concern.

The 2011 ESC did not include a specific assessment of impacts to the SAC from LLWR discharges during the PoA. Although impacts are likely to be low, there may be some pathways that need attention, for example, impacts to biota near the south western site boundary via external dose. We queried this issue through a Further Information Notice in support of the planning application for disposal of stored waste in Vault 8, the construction and operation of future vaults and closure of the facility. In response, LLW Repository Ltd provided further information about potential impacts and we concluded that the LLWR will present no adverse impacts to the integrity of the Drigg Dunes SAC throughout the period of authorisation (see Environment Agency, 2014. Form HR02: Proforma for Stage 3 Appropriate Assessment, Drigg Low Level Waste Repository, Environmental Permit Variation EPR/YP3293SA/V002).

The points raised with regard to the problematic nature of opportunistic sampling of biota are accepted. However, we would urge LLW Repository Ltd to make best use of relevant survey data, e.g. grass samples from the annual monitoring of radioactivity in the annual RIFE surveys.

In summary, we accept that present day impacts to biota from the LLWR are at levels below concern and that impacts are unlikely to significantly increase during the PoA. We have therefore closed this RO. However, we would expect a future PoA non-human biota assessment to make greater use of the latest (radionuclide-specific where possible) discharge and monitoring data (see Recommendation ASS29 of Environment Agency 2015, Review of LLW Repository Ltd's 2011 Environmental Safety Case: Assessments).

Actions completed, Regulatory Observation resolved and Form closed

Owner: Environment Agency	Date: 28/03/2013
Approved by: Environment Agency	Date: 10/10/2013

ESC-RO-ASO-002: Post-closure impacts to non-human biota

Title	Post-closure impacts to non-human biota
Date raised	04/05/2012
Acknowledgment required by	29/07/2012
Response required by	12/09/2012
Related issue numbers	ESC-RO-ASO-001 and ESC-RO-ASO-003
Originated by	Environment Agency
Current owner	Environment Agency
Review group	ASO
Approved by	Environment Agency

History

Status	Date	Description
Raised	04/05/2012	
Acknowledged	03/08/2012	
LLWR Response	25/03/2013	
Response Assessed	27/03/2013	
Transferred	27/03/2013	
Closed	10/10/2013	

Statement of Regulatory Observation

The following Regulatory Observation (RO) is the summarised output from our review of the post-closure assessment of the Level 2 Non-Human Biota Assessment report. The assessment was carried out against relevant non-human biota assessment best practice and assessment tools.

The Guidance on Requirements for Authorisation Requirement R9 on Environmental Radioactivity requires site operators to investigate the radiological effects of a disposal facility on the accessible environment during both the operational and post-closure periods to show that all aspects of the accessible environment are adequately protected. To address this requirement, an assessment of impacts to non-human biota as a result of exposures to ionising radiation is presented in the 2011 ESC.

This RO addresses the assessment of impacts post-closure, which used the ERICA integrated approach to the assessment and management of environmental risks from ionising radiation. A separate RO addresses impacts to non-human biota during the period of authorisation.

From our review of the post-closure non-human biota assessment, we can conclude from our review that the way the ERICA software tool has been used, the general approach taken to the assessment and the predicted dose rates to different wildlife provide some confidence that the LLWR releases from the facility during the post-closure period are likely, on the whole, to be low and generally not going to impact on the wildlife/environment.

Our review did identify a number of issues that should be addressed to ensure the assessment meets current best practice requirements. This RO sets out these issues.

General Comments.

A common theme within the non-human biota assessment is the lack of detail and full justification/statements of the work undertaken within the assessment, which otherwise appears thorough and could potentially demonstrate that the wildlife and the environment around the LLWR

are adequately protected. We would, where applicable, expect the assessment to explicitly state all the input values used in a clear manner to enable others to replicate the calculations. There are a number of statements made which need to have evidence to support the points being made using, for example, evidence from the scientific literature. Of particular note is the identification of some relatively high dose rates being calculated for certain species; the reasons for their dismissal need to be more fully justified.

In order to be able to verify the dose rate calculations that have been undertaken, there needs to be clear referencing to input parameters. However, there are a number of occasions for which this has not been undertaken.

For example, the ERICA model calculates dose rates to wildlife based on input concentrations. In this case, the LLWR ESC predications of future arisings from a number of scenarios (current and extended areas) are used as the input. LLWR/ESC/R(11)10030 states that "*For both the groundwater and surface-water transport pathways, radionuclide concentrations in the relevant environmental media are given in the Level 3 documentation for the human impact assessment, so they are not reproduced herein.*" It is considered that there needs to be better cross referencing between reports where this is the case and the LLWR should give thought to the fact that individual reports may be read by people in isolation so there should be sufficient justification/evidence to support conclusions made in each report.

Biosphere concentration data from the groundwater pathway assessments do not appear to have been documented in any of the supporting ESC documentation. Furthermore, it is not evident what concentrations were selected (e.g. whether maximum or mean concentrations were selected, and at what times during the period of assessment). Therefore, it has not been possible to validate the input concentrations for the groundwater pathway calculations for either the reference case or the EDA.

We therefore request that LLWR document input data for the ERICA groundwater pathway assessment and justify the selection of the data.

We note that input data (maximum concentrations in biosphere compartments and times of maxima) for the coastal erosion pathway reference case at 1,000 years after present (AP) are appended to the Level 3 reports. However, the coastal recession models presented in the 2011 ESC predict that the receding coastline is likely to reach the site boundary in the period between 300 and several thousand years AP. Therefore, use of the 1,000 year reference case for the timing of coastal erosion in the calculation of dose rates to non-human biota cannot be described as conservative.

Given that calculated impacts at 1,000 years AP for the coastal erosion pathway exceed the $10 \mu\text{Gy h}^{-1}$ screening level, we would expect an assessment of the implications on dose rates to non-human biota as a result of coastal erosion taking place before 1,000 years AP. This would be consistent with coastal erosion assessment for human potentially exposed groups (PEGs) for which an early erosion case of 300 years AP was considered. It is noted that peak impacts to PEGs from the vault disposals in particular are sensitive to the timing of erosion, with higher impacts being calculated for the case of early erosion.

LLWR should therefore explore and present the effects of early coastal erosion on dose rates to non-human biota.

According to LLWR/ESC/R(11)10030, default parameters have been used in the ERICA tool wherever possible (with a few minor variations largely to address C-14). However, it is obvious that other changes have been made, for example, according to section E5 in SERCO/TCS/004354/01, a value of 20 was used for the radiation weighting factor for alpha activity whereas in ERICA the default is 10.

There needs to be a clear statement of any changes to the default parameters used in the ERICA tool for each scenario being assessed by the LLWR to enable others to verify the dose rate calculations that have been undertaken. The version of the ERICA tool used in the assessment should also be specified; the software is periodically updated, incorporating updated reference data such as wildlife concentration factors.

We therefore require appropriate documentation and justification for all changes to default parameters in the ERICA tool.

The ERICA assessment only includes consideration of a subset of the radionuclides included in the LLWR inventory. However, there are sufficient data in the ERICA tool to allow for the inclusion of most of the omitted nuclides, for example Ac-227, Am-242m, Am-243, Cm-245, Cm-246, Cm-248, Nb-93m, Pu-244, Th-229, U-233, U-236 and Zr-93. There are already isotopes of these elements included in ERICA which means that there are default transfer parameters available within the ERICA tool. Each of these nuclides could also be added via the add radioisotope function within the ERICA tool. It therefore seems reasonable to include these nuclides in the assessment.

LLWR should justify the selection of radionuclides in ERICA assessment and confirm that omission of additional species does not lead to significantly increased impacts.

Although it is good to see that the habitats around the LLWR are identified and that an attempt has been made to identify and link the species of interest (as designated in the legislation) to these sites, one thing that is missing is an indication of the confidence we can place on the feature species adequately representing the reference organism. For example, an explanation of why the amphibian geometry can adequately represent the Natterjack Toad. LLWR need to identify how the reference organisms present in the ERICA assessment tool can be matched to the feature species that have been identified within the LLWR work.

LLWR should show how the reference organisms present in the ERICA assessment tool can be matched to the feature species that have been identified within the LLWR work.

Throughout the document there are a number of unsubstantiated statements relating to the relative importance or sensitivity of species receiving the highest doses. For example:

- Firstly, for the coastal erosion pathway, the highest dose rates are predicted to be 80-100 μGyh^{-1} depending upon the organism type. These doses are significantly in excess of the 10 μGyh^{-1} screening level, but are dismissed as not being important without appropriate evidence within the report(s).
- The report does not define the spatial extent receiving impacts, for example what proportion of the Drigg sand dunes site is potentially impacted?
- The assessment does not provide evidence from the literature (e.g. critical biological effects data and concentration ratio data) to support the statement that invertebrates and insects are relatively insensitive to radiation. All statements such as these need to be supported by appropriate scientific evidence.

Similarly, we do not believe that there is adequate justification for the dismissal of some species from further consideration for which relatively high dose rates may be calculated. For example:

- Grasses and herbs receive the highest dose rates resulting from migration of radionuclides in groundwater. We disagree that they are not of ecological importance, firstly because they are primary producers and secondly because the sand dune system for which the LLWR site is, in part, designated is only possible because of the stabilising nature of the grasses and herbs. Examining the point about the spatial extent of their coverage on the beach – it may be true that there is a small spatial extent but nowhere in the report has the actual extent been discussed to put this into context. This is further justification for the need to map the current extent of the habitats within the adjacent Drigg Coast protected site as pointed out in other Regulatory Observations.
- The discounting of the presence of sea anemones on the beach (storm beach during coastal erosion) may be reasonable but if there are rock pools or areas of standing water when the tide is out then we suspect that sea anemones will have colonised them. In addition, could the potential change in sea temperatures with climate change increase the likelihood of their presence in this environment? Biotope mapping of the current extent and distribution of marine habitats and key species would help here.
- Dose rates to birds eggs are discounted because “*it is debatable whether birds would nest on the storm beach*”. However, looking at the dose contribution it is clear that the bulk of the dose rate comes from internally incorporated radionuclides which must arise from the parent. Thus the dose is derived not from the birds nesting on the storm beach (and similarly the cliff) but whether they feed on the storm beach. This is considered much more likely.

- Invertebrates and insects permanently residing on the cliff and beach could receive absorbed dose rates of up to about $100 \mu\text{Gy h}^{-1}$, however, the significance of these doses is discounted as “*such organisms are relatively insensitive to radiation*”. We point out elsewhere that these species may form part of a human food chain. Although we acknowledge that these organisms are relatively insensitive to radiation, nowhere is it justified that the predicted dose rates are acceptable.
- How likely is it that a wading bird would be found in the offshore environment?

We therefore seek justification, with reference to target organisms / spatial scale and the biological effects literature, statements to support the case that those organisms exhibiting the highest dose rate predictions are more radio-insensitive, and hence that dose rates that are significantly above the chosen screening level are not considered important. Statements dismissing the presence or importance of potential biota from further consideration need to be justified.

We understand why C-14 is modelled differently but, especially given the $9 \mu\text{Gy h}^{-1}$ value quoted, we query why it is dealt with in isolation from the contribution of other radionuclides.

Please justify reasons for treatment of dose rates associated with C-14 separately from contributions from other radionuclides.

No formal assessment of uncertainty is presented in the non-human biota assessment. With regards to doses to biota inhabiting the storm beach during the period of coastal erosion, it is stated that if a factor of three to five is applied to account for uncertainty then the results could be “somewhat” above the $10 \mu\text{Gy h}^{-1}$ but then the report(s) do not discuss this any further. The uncertainty should be formally assessed and justified.

It should be reasonably easy to account for some of the uncertainty through, for example, the conservatism built in the assessment, and with reference to the usage of the ERICA model but this is not done (and cannot be done by the reader because of the lack of information contained in the report).

It is noted that the cliff and beach are transient environments with continual turnover, migration and movement of organisms between the potentially contaminated area adjacent to the LLWR, other areas of beach and further afield. Thus, even if there is potential for radiological detriment to individual organisms, there is no potential for significant harm to local populations, or at local colony levels. Thus it is assumed that the waste source is averaged and homogenous and exposure/ingestion would be of the averaged waste mass. However, calculated dose rates depend on the activity of the wastes exposed and it would seem reasonable to consider the situation in which variability of the distribution of waste items and activity is considered (for example as is done in the human intrusion assessment).

Please present an assessment of uncertainties in the ERICA assessment, incorporating alternative scenarios and consideration of known uncertainties.

In addition, a general point is made that, throughout the ESC submission, there are a number of minor issues that reduce confidence in the overall assessment of impacts to non-human biota. For example, there is confusion over the value and use of the numeric dose criteria applied ($10 \mu\text{Gy h}^{-1}$) with different terms being employed (e.g. screening threshold, threshold screening level and an implication that the $10 \mu\text{Gy h}^{-1}$ is more restrictive than “*the previous value used in the UK of $40 \mu\text{Gy h}^{-1}$* ” (LLWR/ESC/R(11)10030, page 5)). The terms and numbers are used incorrectly throughout the relevant documents. $10 \mu\text{Gy h}^{-1}$ is not a threshold. It is a generic screening level for use in identifying when further effort/resources need to be expended to fully demonstrate that the environment/wildlife are adequately protected from the impacts of authorised releases of radionuclides. The $40 \mu\text{Gy h}^{-1}$ value was a “regulatory action level”; i.e. if the dose rates predicted to wildlife inhabiting a particular site exceed the $40 \mu\text{Gy h}^{-1}$ then the regulators need to consider possible action which may include reducing permits etc. In the case of the LLWR, given that some of the predictions for future radionuclide releases will take place beyond periods of institutional control it is prudent to use the generic screening level for comparison to determine the likely risk and effort needed in the assessment.

Although these issues do not affect the overall conclusions from the assessment, it does instil a lack of confidence in the overall understanding of the field of environmental radioactivity assessment.

It should be noted that ongoing dialogue is being undertaken relating to the assessment of higher activity particles from the erosion of the waste. At the end of this dialogue we may require the post-closure impacts on non-human biota to be checked to ensure that they remain appropriate.

Regulatory Observation Actions

ESC-RO-ASO-002.A1	A number of improvements to the presented Non-Human Biota ESC report (in italics) are set out above, we seek a response to address these issues. We believe a revision of the relevant ESC reports would be the best mechanism to present this further information to ensure a clear audit trail is maintained.
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	03/08/2012
Comment: A responses to the action will be provided. Consideration will be given as to the best form of response.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	25/03/2013
A response is provided in ESC Project memo LLWR/ESC/Mem(13)203, 22 March 2013.		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 27/03/2013
Approved by: Environment Agency	Date: 10/10/2013

We welcome the inclusion of the modelled environmental concentrations that were input to the ERICA tool and clarification that these concentrations are the peak concentrations during the assessment period. Although a discussion is provided regarding the timings of the peaks related to key radionuclides, the times of each peak for each radionuclide for each compartment should also have been provided to enhance clarity and it is recommended that such data is presented in future assessments (see Recommendation ASS31 of Environment Agency 2015, Review of LLW Repository Ltd's 2011 Environmental Safety Case: Assessments).

A separate assessment of impacts to non-human biota due to coastal erosion at 300 years AP has not been presented. Instead, arguments are provided that indicate that impacts could be up to 26% greater than presented in the reference case at 1000 years AP. Maximum doses to some species are predicted to exceed the screening level of $10 \mu\text{Gy h}^{-1}$, however, we accept that there is evidence to suggest that plants and invertebrates can be subject to dose rates higher than this level without deleterious effect. As the highest dose rates are calculated for invertebrates, it is likely that doses slightly in excess of $100 \mu\text{Gy h}^{-1}$, which could occur to invertebrates and plants inhabiting the storm beach during the onset of early erosion, will not cause harm.

We accept from the arguments presented in memo LLWR/ESC/Mem(13)203 that omission of some of the radionuclides in the LLWR inventory from the assessment does not appear to be significant in terms of overall risk. We recommend that future non-human biota assessments should include all relevant radionuclides, using surrogate data as required, or substantiate the reasons for, and significance of, their omission (see Recommendation ASS31 of Environment Agency 2015, Review of LLW Repository Ltd's 2011 Environmental Safety Case: Assessments).

As discussed in IRF ESC-RO-ASO-001, we still consider that there is insufficient mapping of default habitats/biota to that which is observed on and around the LLWR. We accept that there does not need to be a one to one mapping of reference biota to identified species, however, there is a need to demonstrate that reference species are suitable. It is appreciated that future environmental changes will affect the size and distributions of populations of many species. However, the extent of such changes is difficult to predict. Without specific evidence on the effect of future climate and topographical change on the habitats (for example, it is debatable as to whether the dunes will disappear or migrate inland as a result of coastal erosion), we expect the assessment to concentrate on those species that are observed today and assume that similar populations will exist in the future. In future updates of the ESC, LLW Repository Ltd should demonstrate that the generic reference species and organisms present in the ERICA assessment tool (or alternative model) can be matched to the feature species that have been identified in the environment local to the LLWR. We expect the next review of the ESC to include an assessment that concentrates on those species that are observed today and which assumes that similar populations will exist in the future (see Recommendation ASS33 of Environment Agency 2015, Review of LLW Repository Ltd's 2011 Environmental Safety Case: Assessments).

The effect of uncertainties in the dose rate modelling is clearly explained in memo LLWR/ESC/Mem(13)203. However, missing from this discussion are the implications of uncertainties relating to definition of scenarios and conceptual models and the estimation of environmental concentrations for input to the ERICA model. We recommend that such uncertainties are explored in a future assessment (see Recommendation ASS32 of Environment Agency 2015, Review of LLW Repository Ltd's 2011 Environmental Safety Case: Assessments).

The discussion on the treatment of C-14 doses via the gas pathway and the implications of post-2011 updates in the C-14 model are accepted.

An assessment of the implications of higher activity particles on the beach to non-human biota is not presented in memo LLWR/ESC/Mem(13)203. Given that the focus of protection is at a population level, we do not consider this a significant omission, given that exposure to particles and/or discrete items will only impact upon a few individuals.

Several minor errors in the ESC documentation have been noted in memo LLWR/ESC/Mem(13)203, which wrongly indicated that default ERICA data had been changed. Although these errors are not significant in terms of the results of the assessment, it indicates a failure of QA procedures and led to reduced clarity in the nature of the non-human biota calculations supporting the ESC.

We note that much of the information contained within memo LLWR/ESC/Mem(13)203 is taken from a contractor study responding to the specific issues and queries³⁶. We have not seen this study, thus our comments above are solely based on the information provided in the project memo.

Overall we consider the response to this RO adequately addresses our comments, subject to the recommendations raised above being addressed in the future by LLW Repository Ltd. This RO can therefore be closed.

Actions completed, Regulatory Observation resolved and Form closed

Owner: Environment Agency	Date: 03/04/2013
Approved by: Environment Agency	Date: 10/10/2013

³⁶ Thorne, M.C. and Kelly, M., 2012. Technical Note Addressing Technical Queries on the 2011 ESC Non-Human Biota Assessment. AMEC Report D000082 / SF0006326 Issue 1.

ESC-RO-ASO-003: Non Human biota assessment of human intrusion scenarios

Title	Assessment of non-human biota impacts associated with intrusion into waste materials
Date raised	17/05/2012
Acknowledgment required by	29/07/2012
Response required by	12/09/2012
Related issue numbers	ESC-ASO-RO-002 and ESC-ASO-RO-001
Originated by	Environment Agency
Current owner	Environment Agency
Review group	ASO
Approved by	Environment Agency

History

Status	Date	Description
Raised	17/05/2013	
Acknowledged	03/08/2012	
LLWR Response	25/03/2013	
Response Assessed	03/04/2013	
Transferred	03/04/2013	
Closed	10/10/2013	

Statement of Regulatory Observation

The Guidance on Requirements for Authorisation (GRA) requires that the assessment of effects on the accessible environment should include an assessment of effects after intrusion into the facility. In response to this, it is stated in the Environmental Safety Case (ESC) that possible whole body dose rates to non-human biota following intrusion into the facility will be of a similar magnitude to those for non-human biota arising from the cliff erosion pathway³⁷.

We consider this to be a reasonable assumption, however, in the non-human biota assessment it is considered that small mammals and birds do not fully reside in the exposed waste environment. *“Doses to small mammals and birds using the cliff and beach area were first identified as a concern, but fall below the screening level when their habits and sources of sustenance are factored in. That is, mammals and birds will tend to spend time on, and gain their sustenance mainly from, the foreshore or inland heath”*¹. However, in an extensive cliff environment, we think that it is reasonable that birds and mammal populations will occupy the cliffs for extended periods of time. During the period of erosion of the facility, we consider that such biota could be exposed to *undiluted* waste. For example, small mammals could burrow into the trench and degraded vault wastes.

³⁷ Thorne, M.C. and Schneider, S. Assessment of the impacts on non-human biota for the 2011 LLWR ESC. Serco TAS report 004354/01 Issue 2, 2011.

Further justification for the approach to assessment of non-human biota intrusion into the facility is given by analogy to the dose rates associated with a human scavenging while the wastes are being exposed by coastal erosion³⁸. In these calculations it was assumed that a scavenger visits the site and is exposed to radioactivity as a result of inhalation of contaminated dust, ingestion of contaminated soil and external irradiation. The scavenger is assumed to visit the site for 1 hour per day for 50 days per year. The annual effective dose to such a scavenger was assessed to be 2.5 mSv. This is a dose rate of 50 $\mu\text{Sv h}^{-1}$, a value very similar to dose rates calculated for non-human biota exposed via the coastal erosion pathway. However, the analogy of non-human biota exposure to a scavenger as defined above during an intrusion event is not considered appropriate, as some species may spend a significantly longer period of time in/on the cliff environment (e.g. small mammals and birds), potentially receiving a high proportion of their sustenance from the cliff environment.

We also note that the non-human biota assessment does not consider exposure to undiluted wastes in the cliffs. Instead, as described on p32 of the coastal erosion assessment report³⁹, radionuclide concentrations in the cliffs are calculated taking into account dilution by the underlying geology.

Additional calculations assessing impacts to biota permanently residing in the cliff environment, including consideration of exposure to undiluted waste, are required. Occupancy rates for biota inhabiting the cliff should be carefully considered and justified to ensure the likely behaviours of significant species are assessed.

Regulatory Observation Actions

ESC-RO-ASO-003.A1	Please re-assess dose rates to non-human biota following intrusion into the facility during coastal erosion. To include consideration of exposures to undiluted waste materials to biota both making transitory use of the cliffs and biota permanently residing in the cliff environment.
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	03/08/2012
Comment: A responses to the action will be provided.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	25/03/2013
A response is provided in ESC Project memo LLWR/ESC/Mem(13)204, 22 March 2013.		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 03/04/2013
Approved by: Environment Agency	Date: 10/10/2013

³⁸ Hicks, T W and Baldwin, T D, 2011, Radiological Assessment of the Potential Impacts of Human Intrusion at the LLWR, Galson Sciences Ltd, Report 0977-3, Version 2, April 2011.

³⁹ Towler, G., Penfold, J., Limer, L. and Paulley, A. Assessment calculations for coastal erosion for the LLWR 2011 ESC. Quintessa report QRS-1443ZC-R1, 2011.

Memo LLWR/ESC/Mem(13)204 makes reference to the effects of biota inhabiting burrows in undiluted waste, noting, in comparison with intrusion into diluted waste, that while external dose rates will be increased, internal dose rates are likely to be unchanged as feeding locations will be unchanged and more widely distributed. It is stated that this could lead to an increase in total dose rate to a rat burrowing into the waste materials from 5.88 to 12.8 $\mu\text{Gy h}^{-1}$. This calculation is taken from a contractor study responding to the specific issues and queries⁴⁰. We have not seen this study thus we are unable to comment on the assessment assumptions.

There is thus a potential for doses to small mammals burrowing into the waste material during coastal erosion to receive dose rates in excess of the 10 $\mu\text{Gy h}^{-1}$ screening level. Vertebrates are more radiosensitive than either invertebrates or plants. The European Union PROTECT project proposes a generic screening value of 10 $\mu\text{Gy h}^{-1}$ that should protect 95% of all species, noting that, due to differences in radiosensitivity, not all organism groups will be offered this level of protection⁴¹. A vertebrate screening value (illustrative or order of magnitude) of 2 $\mu\text{Gy h}^{-1}$ is also put forward, which should protect 95% of all vertebrate species; it is estimated that 85% of vertebrate species will be protected at 10 $\mu\text{Gy h}^{-1}$. Similarly, the International Commission on Radiological Protection (ICRP) has specified a Derived Consideration Reference Level for a rat of 4 – 40 $\mu\text{Gy h}^{-1}$, defined as ‘a band of dose rate within which there is likely to be some chance of deleterious effects of ionising radiation occurring to individuals of that type of RAP⁴² (derived from a knowledge of expected biological effects for that type of organism) that, when considered together with other relevant information, can be used as a point of reference to optimise the level of effort expended on environmental protection, dependent upon the overall management objectives and the relevant exposure situation.’⁴³

These results indicate that there is a potential for a small number of mammals to receive doses that could possibly result in deleterious effects through burrowing into waste materials during coastal erosion. However, the likelihood of a number of individual mammals receiving these doses needs to be balanced against the requirement to protect the population as a whole. These arguments are not fully developed by LLW Repository Ltd, however, we consider that, given the likely small number of individuals considered, that the intrusion doses calculated for small mammals are acceptable. Overall we consider this RO has been adequately addressed and can be closed.

Actions completed, Regulatory Observation resolved and Form closed

Owner: Environment Agency	Date: 03/04/2013
Approved by: Environment Agency	Date: 10/10/2013

⁴⁰ Thorne, M.C. and Kelly, M., 2012. Technical Note Addressing Technical Queries on the 2011 ESC Non-Human Biota Assessment. AMEC Report D000082 / SF0006326 Issue 1.

⁴¹ Andersson, P., Beaugelin-Seiller, K., Beresford, N. A., Copplestone, D., Della Vedova, C., Garnier-Laplace, J., Howard, B. J., Howe, P., Oughton, D.H., Wells, C. and Whitehouse, P., 2008. PROTECT Deliverable 5. Numerical benchmarks for protecting biota from radiation in the environment: proposed levels, underlying reasoning and recommendations.

⁴² Reference Animal and Plant.

⁴³ ICRP, 2009. Environmental Protection: Transfer Parameters for Reference Animals and Plants ICRP Publication 114, Ann. ICRP 39 (6), 2009.

ESC-RO-ASO-004: Management of Uncertainty

Title	Management of uncertainty
Date raised	11/06/2012
Acknowledgment required by	18/06/2012
Response required by	17/08/2012
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	ASO
Approved by	Environment Agency

History

Status	Date	Description
Raised	15/06/2012	
Acknowledged	15/06/2012	
LLWR Response	22/10/2012	
Response Assessed	06/09/2013	
Transferred	06/09/2013	
Closed	12/11/2013	

Statement of Regulatory Observation

GRA Reference

GRA para 7.3.10 states “*The developer/operator will need to demonstrate that the environmental safety case, for both the period of authorisation and afterwards, takes adequate account of all uncertainties that have a significant effect on the environmental safety case. This will mean establishing and maintaining:*

- *a register of significant uncertainties;*
- *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.”*

Headline Observation

We consider there to be significant shortcomings in LLWR’s approach to uncertainties as documented in the 2011 ESC reports. In particular, there seems to be no evidence to show that uncertainties have been managed across the ESC as a complete assessment. See more detailed comments in the sections below.

Key Uncertainties

Level 2 report LLWR/ESC/R(11)10028

The Level 2 report LLWR/ESC/R(11)10028, *Assessment of Long-term Radiological Impacts*, provides in Section 10.3 (p.239) a list of five ‘key uncertainties’, stating the following:

“*Key uncertainties include the following:*

- the time at which the facility will be eroded by the sea, sea level at the time of erosion and rate of release of radionuclides from eroded material into marine waters;

- the primary release rate of C-14 from key wasteforms, the degradation rate of cellulose and the assumption of uniform biogeochemical conditions in the GRM model;
- the effective dilution factor of water entering the Regional Groundwater from the repository, linked to the degradation of the engineered features;
- uncertainties related to the heterogeneous nature of the Quaternary sediments and consequent flow path characteristics and dilution;
- assumptions on future human activities on the site, especially those giving rise to exposure to radon in buildings constructed on the site or excavated waste.”

While we accept that these may indeed be important uncertainties, we remain unconvinced that this is a comprehensive list of the key uncertainties inherent in the modelling projections of the ESC. Section 10.3 is very short (one side of A4) and lacks any discussion about how the list was compiled or about what steps were taken to ensure that it is comprehensive. It also provides no discussion of the implications of the five uncertainties identified or of how they have been taken into account in the assessment.

More examples of key or significant uncertainties are cited in the various ESC reports which are not listed in 10.3, for example:

- in Section 2.4.1 of the same report, “There are, however, significant uncertainties in many physical and chemical processes. These include uncertainties in the modes of radionuclide release from wastes of uncertain characteristics, sorption and retardation processes, and resuspension/deposition of sediments, that we only approximate by our models”;
- fifteen key near-field uncertainties listed in Table 8.1 of the Level 2 Near Field report;
- seven key assumptions & uncertainties cited in Table 4.2 of the Level 2 Site Evolution report;
- the assumption of ‘continuity of strata’ as a key uncertainty in the Level 3 report on “Alternative Hydrogeological Models for LLWR”; and
- “the development of fractures, and their extent and connectivity”, as a key uncertainty in relation to radionuclide release from compacted wasteforms, in the Level 3 report on “Physical and Chemical Heterogeneity on the Container Scale”.

Numerous other uncertainties are listed in the various ESC documents (not necessarily stated as key or significant) and many more modelling assumptions and simplifications are made (each with an inherent level of uncertainty). The overall approach to the management of these explicit and implicit uncertainties is not evident to us from the presented ESC. There are several paragraphs written on the ‘treatment of uncertainty’ in the Level 3 report by Baker et al., “*Technical Approach to the 2011 Environmental Safety Case*”. This report from November 2008 sets out a reasonable ‘proposed approach’ to this important topic, but in this Regulatory Observation we are interested in what was actually done, in practice.

Section 5.4.6 of Baker et al. 2008, states, “...a register of significant uncertainties will be established and maintained, which indicates how significant uncertainties have been addressed and the extent to which further data gathering, calculations or decisions are needed.” Section 10.3 (also Section 2.3.6) of the Level 2 report on long term radiological impacts states that LLW Repository Ltd has established an ‘FEP and Uncertainty Tracking system’ but, to date, we have not seen a copy of the supporting database that underpins this system. Section 2.3.2 of the Level 2 report, *Uncertainty and its Treatment*, says (p.28):

“We adopt the classification of uncertainties that is conventional in radioactive waste disposal assessment, focusing on their mode of treatment in the safety assessment, thus:

- Scenario uncertainty – definition of a scenario, or scenarios, sufficiently broad to represent the possible evolutions of the disposal facility and its environment;
- Model uncertainty – models, including alternative model assumptions, that adequately represent the features, events and processes (FEPs) that are important to radionuclide release, transport and exposure to humans;
- Parameter uncertainty – variation of model parameter values within their realistic or possible ranges.”

The five 'key uncertainties' listed in the Level 2 long term radiological impact report are not classified against this system. In addition, we have not identified the "*priorities for further work by which key uncertainties might be reduced*", discussed in Section 2.3.2 (p.28) of that report. Section 2.3 also states under the subheading *Sources of uncertainty* (p.27), "*The treatment of uncertainty may, however, be constrained by limited data and the models that are available.*" Implicit in this statement are examples of unquantifiable uncertainties ('limited data' and 'model availability'). If either or both of these constrain the reliability of the assessments to a significant degree, they should be given discussion and consideration as potential key uncertainties.

Model Uncertainty and Related Issues

The cited approach to classifying uncertainties (scenario, model, parameter) is standard practice within safety case and repository performance assessments. More recently, model uncertainty (conceptual and mathematical) is recognised from benchmarking exercises as a significant source of uncertainty in the sense that different model constructions or codes can produce radically different outputs, all else being equal. Of all types of model uncertainty, we agree with Baker et al. 2008 that, "*uncertainty in the conceptual model is usually the most important.*" However, we have found little discussion in the ESC documents that recognises the limitations of the conceptual model (its completeness, representativeness or simplifications) or any recognition that the key assumptions defining the various conceptual models in use may themselves qualify as key uncertainties. In relation to model uncertainty, although the intention (in Baker et al. 2008) is to present evidence that models used are, "appropriate and cautious" there is little discussion we can find in the ESC reports demonstrating why a particular chosen model is considered more evidence-based or scientifically underpinned than alternative conceptual models.

Model quality is a closely related topic that is partly addressed in the Level 2 report on Long-term Radiological Impacts, Section 2.3.5 (*Assessment models*), which contains a brief paragraph on conceptual model quality (p. 31), "*Development of conceptual models may be iterative and generally includes stages of discussion and review. Scoping calculations and results from model testing may also reveal where attention should be focused to improve a model, and focus it to the assessment in hand.*" We note generic references to 'may be iterative' and 'may also reveal'. This statement is insufficient because it does not explain or reference what was done to assess or improve conceptual model quality for the various models in use.

We are not convinced that 'modelling objectives' (see GRA paragraph 7.3.22) are addressed in the ESC, despite the claim (in the Level 3 report LLWR/ESC/R(11)10031, *Addressing the GRA*) that they are addressed. We have found no explicit statement on modelling objectives for any of the models in use.

Data Availability and Choice of Models

Availability of data is recognised (Section 2.3.2 of Level 2 report on long term radiological impact) as a limitation when treating uncertainties but there is no discussion of whether availability of data influenced the choice of models in practice. More generally, other than a statement describing the adoption of a reduced complexity FEP list (from ~1400 in 2002 to ~300 in 2011), we have found no discussion of the advantages and disadvantages of using simple or complex models or whether this debate took place and influenced decisions on choice of models in use (see GRA paragraph 7.3.22).

Use of Models

LLWR/ESC/R(11)10028, Section 2.3.5, *Program quality and implementation*, states (p.32): "*When judging the suitability of a program (code) for use in a safety assessment, it must be demonstrated that the program is suitable for its purpose, has been used properly, the code development process has followed appropriate procedures, and that the program produces accurate results.*"

The pedigree of Goldsim (and to a lesser extent, CONNECTFLOW and GRM) is acknowledged. What is equally important is how the modellers have applied these tools to the assessment problem at hand.

Testing of Model Implementations

LLWR/ESC/R(11)10028, Section 2.3.5 (p.32) states: "*Each contractor developing a GoldSim model implementation (or using any other program) follows a rigorous process of specification of the mathematical model, implementation and testing. GoldSim implementations are generally*

developed in stepwise fashion with testing of component elements, arithmetic and sense checks to verify that the model is behaving as expected. The final model implementation is subjected to comprehensive verification checks to systematically verify the implementation of the specified mathematical model.”

No references are provided to back up the claims of rigorous testing of elements, arithmetic and sense checks or comprehensive verification checks. Given this is the ESC, we would expect to see such references listed. Within such references we would expect to see evidence that data input choices and decisions made by modellers have been documented and checked.

Quality Assurance and Code Verification and Validation

LLWR/ESC/R(11)10028, Section 2.3.5 (p.32) also states, *“Quality assurance procedures are in place to ensure traceable and transparent selection of data in the model based on reliable data sources, or where based on modeller judgment to explicitly record that judgement.”*

No references are provided for any of these claimed QA procedures. Relevant GRA paragraphs here include 7.2.9.

Page 33 states, *“The GRM program [49] has been verified and validated against a comprehensive set of test cases”* Reference 49 is the program user guide and a later reference (made in Figure 5.2) points to a GRM program verification report. The meaning of words “verified” and “validated” are not defined in the ESC or its glossary. LLW Repository Ltd should explain what it means by verification and validation. It should be more explicit about the measures taken to establish confidence in model reliability. In future, it should explicitly list the key model limitations and simplifications so that the reader is aware of the caveats to predictive accuracy when evaluating model outputs.

Elicitation of Parameter Uncertainties

The Level 3 Report SERCO/E.003796/010 Issue 2, *Elicitation of Uncertainties for LLWR*, concerns the elicitation of parameter uncertainties for use in the 2011 ESC by especially convened panels of experts. The report covers a large amount of work and appears pivotal in terms of data for the LLWR 2011 ESC.

Elicitation of uncertainties in this manner is presented in the report as being a standard and routine approach. We recognise that data elicitation approaches of this nature have been widely used in the radioactive waste management field both in the UK and in the USA over several decades.

Established use, however, does not in itself validate an approach. More specifically, it may indicate that nobody has thought of a better approach, but it does not thereby follow that the approach is good enough for the intended purpose. We can agree that use of a structured approach such as this is likely to be superior in terms of the results it gives to an unstructured approach, and also that use of a panel of experts is likely to be superior to reliance on a single expert.

The report states that *“The probabilities are subjective probabilities or ‘degrees of belief’.”* The idea of ‘degrees of belief’ corresponds to a Bayesian type of approach, in which a person has an initial belief, by definition unsubstantiated, and then progressively modifies this belief in the light of relevant factual evidence presented to him/her. Given sufficient relevant factual evidence, all rational and suitably knowledgeable people will converge on the same eventual belief, regardless of their initial beliefs.

In the various data elicitation exercises described in this report a problem, or potential problem, lies with the provision of sufficient relevant factual evidence to the experts involved in the exercises. At best “data out” can only be as good as “data in”. In other words, the judgment of experts can only be as good and as relevant as the source material (evidence) on which they base their judgments. Only very limited information is given in the report about “data in”. We regard this as a crucial omission. In the absence of relevant factual evidence, initial beliefs are no better than, literally, anybody’s guess. (Section 2.2, Methodology, 8th para. (p.13), recognises this, saying: *“It is important that as much available material relating to the parameter/issues of interest and to related parameters/issues as practicable is collated. It is also desirable that graphical summaries of the information are prepared. The briefing material should be distributed to the experts in advance of the meeting to help them prepare for the meeting. The briefing material can also provide a very useful reference during the discussions at the meeting.”*)

Equally, the report is uninformative about the specific uses to which the “data out” are being put. In particular, it presents little or no information about the sensitivity of the results of risk calculations to the data provided through the processes described in this report. In the Executive Summary (p.3) and also in Section 1, Introduction (p.8), the parameters that were the subject of data elicitation are, however, described as “key parameters of the system”.

Each data elicitation exercise described, moreover, is full of assumptions, some transparent and others less so. It is often not clear who has made these assumptions, the panel of experts concerned or others, or indeed when the assumptions were made. A profusion of assumptions tends further to debase the results of the process.

We are not convinced that if a blind repeat of these data elicitation exercises were undertaken using different panels of experts, based on the descriptions given in this report but not including the particular assumptions identified, the results would be the same or similar. In other words, we are unconvinced about the repeatability of the data elicitation exercises given a blind test.

Regulatory Observation Actions

ESC-RO-ASO-004.A1	LLWR Repository Ltd shall respond to each of the observations in this Regulatory Observations and produce evidence to show how the various uncertainties in the ESC were managed to elicit the five ‘key uncertainties’ presented at the end of the Level 2 report on long term radiological impact.
ESC-RO-ASO-004.A2	LLWR Repository Ltd shall explain what arrangements are in place to address key or significant uncertainties in future work programmes or ESC updates and describe what measures will be undertaken to evaluate and improve confidence in the modelling projections.

LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	15/06/2012
Comment: Responses to the actions will be provided.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	22/10/2012
A response is provided in ESC Project Memo LLWR/ESC/Mem(12)174, 20 October 2012.		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 06/09/2013
Approved by: Environment Agency	Date: 15/11/2013

We have assessed the supplementary memo provided in response to this Regulatory Observation (RO) (Response to Issue Resolution Form, ESC-RO-ASO-004: Management of Uncertainty ESC Project Memo LLWR/ESC/Mem(12)174, 20 October 2012). LLW Repository Ltd states that the list of the five ‘key uncertainties’ presented at the end of the Level 2 report on long-term radiological impact should not be taken to be a comprehensive list of key uncertainties and that it had been identified using the author’s judgement rather than using a systematic formal process. The response does not address the question why the claimed approach to managing uncertainties (in ‘Technical Approach to the 2011 Environmental Safety Case’) was not implemented in practice.

Instead, LLW Repository Ltd points to the register of uncertainties in which a comprehensive list of key uncertainties is presented. The register of uncertainties is included in the FEPs and uncertainties tracking system. This system shows how each identified FEP has been considered within the 2011 ESC and allows the tracking of the key FEPs associated with each pathway and model. The system also provides a means by which significant uncertainties can be identified, rated according to expert judgement on the importance to sub-system performance and record how the uncertainty is treated in the ESC.

LLW Repository Ltd states that the most important aspect of its approach to meeting the needs of the GRA with regards to uncertainties is the careful consideration and exploration of uncertainties applied to each conceptual and numerical model used in the production of the ESC. The register of uncertainties in the 'FEPs and uncertainty tracking system' is an important aspect of LLW Repository Ltd's overall approach for the management of uncertainties as it is designed to identify and assess all significant uncertainties within the ESC. However, the initial version of the system recorded a technical position that pre-dated the 2011 ESC and was not included in the 2011 ESC submission. Thus the presented ESC did not provide evidence to demonstrate that uncertainties had been managed across the ESC in a systematic manner.

An updated version of the FEPs and uncertainty tracking system, consistent with the position presented in the ESC, was issued to us in early 2013. We consider that this system provides a starting point for a register of significant uncertainties and that LLW Repository Ltd is to be commended for this. However, the classification system employed within this tracking system is not sufficiently explained in the ESC documentation. We acknowledge the role that 'expert judgment' plays in identifying and classifying uncertainties, but it appears there is little guidance issued to contributing authors to help ensure some level of consistency between topic area experts. There is no common uncertainty classification system in use that pertains to the various ESC assessments.

The supplementary memo provided in response to this RO appropriately addresses the identified issues. However, in order to deliver a wider range of improvements to the ESC, we have raised a Forward Issue (FI) requesting an improved evaluation and communication of uncertainty (ESC-FI-008). Within this FI we will be seeking a better linkage between the FEPs and uncertainty tracking system (or suitable alternative) and the assessment of uncertainty associated with key assumptions on engineering performance, conceptual uncertainty in assessments and model uncertainty (inherent in the choice of one particular model over alternatives), which are not captured in the database in its current form. Good understanding and communication of significant uncertainties in the performance of LLWR is integral to maintaining confidence in the ESC.

Overall, subject to the FI referred to above, we consider the response to this RO is adequate and it will therefore be closed.

Actions completed, Regulatory Observation resolved and Form closed

Owner: Environment Agency	Date: 12/11/2013
Approved by: Environment Agency	Date: 12/11/2013

ESC-RO-ASO-005: Safety functions

Title	Safety Functions
Date raised	30/10/2012
Acknowledgment required by	09/11/2012
Response required by	14/12/2012
Related issue numbers	ESC-RO-ASO-004
Originated by	Environment Agency
Current owner	Environment Agency
Review group	ASO
Approved by	Environment Agency

History

Status	Date	Description
Raised	30/10/2012	
Acknowledged	30/10/2012	
LLWR Response	18/03/2013	
Response Assessed	06/09/2013	
Transferred	06/09/2013	
Closed	20/11/2013	

Statement of Regulatory Observation

Introduction

The following Regulatory Observation highlights our concerns about the lack of clarity and developed thinking in the 2011 ESC in respect of defining safety functions. We consider that the (top-down) safety function approach could make a useful contribution to building confidence in disposal facility safety, which would complement the (bottom-up) FEP approach to demonstrating acceptable risk. We consider that such an approach is an important component of best practice and would help significantly to meet the requirements set out in the GRA. In particular:

GRA 7.3.3(a) *"The environmental safety case should include an explanation of, and substantiation for, the environmental safety functions provided by each part of the system. It should also identify which radionuclides each function is relevant to and the expected time period over which the function is effective"*.

GRA 7.3.4 *"explore the contribution that each environmental safety function makes to the environmental safety case (for example, by sensitivity analyses)" and "explore the circumstances where more than one function is impaired"*.

GRA 7.3.2 *"The disposal system will consist of multiple components or barriers. There is a distinction between these components and the environmental safety functions they provide. A given component may contribute to the environmental safety case in a number of ways, and these safety functions may be wholly or partly separate from one another."*

We consider that some aspects of the 2011 ESC as presented do not represent current best practice, nor do they meet the above GRA requirements for the reasons set out below.

International Peer Review comments

The International Peer Review report of 2010⁴⁴ states that “*safety functions have been shown to be a valuable tool in safety assessment in many national programmes (e.g. Belgium, France, Sweden and Finland) and have the potential of being useful for the ESC as well*”. The report makes a clear recommendation to LLW Repository Ltd about the benefits of the safety function approach:

“A safety function methodology may very well be used for the LLWR. The key benefits would be:

1. That the description of the repository evolution can be focussed on the issues that are important for the performance
2. Scenarios can be selected in a systematic/structured way. Most likely the same scenarios will be identified, but the selection process will be transparent”.

We agree with the international peer review team on the benefits of a safety function approach. In its response to the international peer review⁴⁵, LLW Repository Ltd states:

“We are familiar with the safety function methodology, and indeed use the language and methodology of ‘safety functions’ in our ‘Main Report’ and ‘Optimisation’ report. However, we have not chosen to give that approach as much emphasis as is the case in some other waste management programmes.

“More importantly, and as our document hierarchy demonstrates, our approach to the safety case has been to identify important safety-relevant features, events and processes in the system. These are discussed in the ‘Main Report’, safety arguments are made and scenarios developed. A FEP⁴⁶ database has been produced, against which our scenarios can be referenced. The FEP database also includes a register of uncertainties, which indicates how uncertainties have been addressed. This fulfils the regulatory requirement to address uncertainty management.”

Other than its use as a non-technical, communication tool in the main Level 1 report, LLW Repository Ltd has not made use of the ‘safety function’ methodological approach in its assessment, in favour of a FEP approach. LLW Repository Ltd is not obliged to adopt a safety functional approach to demonstrating safety; however, we wish to see evidence of why further development of the approach was considered unnecessary.

FEPs and safety functions

In rejecting further development of the safety function approach, LLW Repository Ltd states that an alternative approach had been used to identify the safety relevant FEP. However, we consider that a safety function approach is complementary, as opposed to alternative, to a FEP approach. This is identified in a recent report from the OECD/Nuclear Energy Agency⁴⁷:

“...each way, if seen in isolation, has advantages and limitations ... and the limitations of each way could or should be compensated by the advantages of the other”.

This NEA MeSA report postdates the 2011 ESC. However, OECD/NEA reports are intended to disseminate good practice. We regard best practice in environmental safety cases for solid radioactive waste disposal facilities as a topic area that continues to develop. We consider the safety function approach has good potential to aid the task of assessing and managing for safety. This approach has been recognised for a number of years as discussed in Section 2.1 of the PAMINA workshop report⁴⁸. In summary, a FEP analysis is a bottom-up way of demonstrating acceptable risk through identifying features, events and processes. A safety function approach is a

⁴⁴ International Peer Review of the Approach and Preparations for the Environmental Safety Case Project, SKB report, March 2010.

⁴⁵ Jefferies, N., Response to the International Peer Review of the Approach and Preparations for the Environmental Safety Case project. LLW Repository Ltd report LLWR/ESC/R(11)10039 ISSUE 1, April 2011.

⁴⁶ Features, events and processes.

⁴⁷ Methods for Safety Assessment of Geological Disposal Facilities for Radioactive Waste. Outcomes of the MeSA initiative. NEA 2012.

⁴⁸ see <http://www.ip-pamina.eu/downloads/pamina1.1.1.pdf>

top-down structured assessment (in increasing levels of detail) of what safety depends on. It can help:

- define scenarios and demonstrate that the disposal system is well understood and is sufficiently robust;
- serve as a confirmatory tool for the FEP approach by providing a check on the comprehensiveness of FEP combinations and a link between FEP and safety functions (as SKB has done for KBS-3 / SR-Site);
- define associated functional requirements to raise awareness of the role and importance of particular barriers during the period of authorisation or institutional control period;
- provide a bridge between the ESC and operational practice in terms of engineering design, quality assurance, maintenance and monitoring programmes;
- set out the expected performance requirement for each engineering element; and
- flag when a particular barrier or system is approaching 'failure' i.e. can no longer deliver one or more of its identified safety functions (accepting that there may be no sharp 'cliff edge' between acceptable performance and a failed system or component).

In its response to the International Peer review recommendation about the benefits of the safety function approach, LLW Repository Ltd makes mention of the use of a FEP database which forms the basis of scenario development. A final version of this database has not been made available for our review, so we are unable to comment on the appropriateness of the FEP-based approach used for scenario development.

LLWR's response to the international peer review states that, "*The FEP database also includes a register of uncertainties, which indicates how uncertainties have been addressed. This fulfils the regulatory requirement to address uncertainty management*". We cannot comment on this statement as we have not seen the FEP database nor the associated register of uncertainties. Without these documents we cannot form a view either (a) on whether the 2011 ESC has considered an adequate range of scenarios, or (b) on whether the GRA guidance on managing uncertainties has been adequately addressed.

Furthermore, we have found no clear description of the safety concept for the facility as a whole. In this context, the safety concept is the understanding of why the disposal system is safe, irrespective of identified uncertainties and detrimental phenomena; i.e. why it is expected to be robust. The Main Report presents some elements of the safety concept such as the safety strategy and a list of safety arguments but these are focussed on management arrangements. The safety concept should include a description of the roles of the natural and engineered barriers and the safety functions that these are expected to provide in different time frames - in summary - why the disposal system is expected to be safe.

Summary

We are unconvinced that the safety function approach is unnecessary for the ESC. On the contrary, we suggest a safety function approach would materially help provide clarity on the roles and performance requirements of the various components of the disposal system and their relative contributions to overall safety of the facility.

Annex – Further detailed comments

Mixed messages in L1, L2 and L3 documents

Overall, the ESC gives mixed messages about the role and purpose of safety functions in the ESC. Baker *et al* 2008⁴⁹ states (p 17):

“The ESC will also present a high level integration of the arguments and evidence for safety. This will include a qualitative analysis of the safety functions of the facility and the features or controls that satisfy or enhance each function.”

And (p 18):

“We will illustrate a thorough understanding of the performance of the existing and planned disposal facilities in terms of safety functions, e.g. isolation of the waste, containment of radionuclides and attenuation of releases, and the features and processes that promote or potentially reduce those functions.”

We see that the term ‘safety functions’ has been adopted as a communication tool in the Main Report, stating (p 28) that: *“An important aspect of developing, comparing and selecting a set of control measures has been developing a clear understanding of the safety functions of the different control measures and the qualitative or quantitative effects that they might have on environmental impact”* Subsequently, the Main report states (p48): *“The near field provides a number of important safety functions limiting the release of contamination via the groundwater and gas pathways”*.

Similarly, there is reference to safety functions in the Level 2 report on addressing the GRA, for example *“The contribution to performance or safety functions by individual barriers is explored in our Level 3 ESC assessment reports”* on p74. This report references the Level 2 Engineering Design, Optimisation and Development Plan and Near Field reports for the supporting evidence on the contribution to safety functions of the components of the disposal system. However none of these reports mention or identify safety functions. Elsewhere in the ESC, there is no structured identification or development of the various safety functions at a more detailed level and no demonstration of *“a clear understanding of the safety functions of the different control measures”*, as indicated on page 28 of the Main Report.

Approach to safety functions in the ESC Main Report

A first pass at identifying high-level safety functions has been presented in the ESC Main Report (isolation of the waste, containment of contaminants and attenuation of releases). However, we are looking for a clear, *“explanation of, and substantiation for, the environmental safety functions provided by each part of the system”*. We have not managed to establish a clear link between safety functions and the presented evidence and arguments elsewhere in the ESC. The cited references in response to GRA paragraphs 7.3.2, 7.3.3 and 7.3.4 in the L3 ‘Addressing the GRA’⁵⁰, purport to address the relevant GRA requirements but contain little if any discussion on safety functions. This makes our task of assessing the robustness of the LLWR difficult.

Although the Main Report and supporting Level 2 and 3 documents do provide a description of the various physical components of the disposal system, there is no linkage back to the Main Report describing the environmental safety functions they provide or whether these safety functions are provided individually or in conjunction with other component(s).

There is a summary list of control measures and functions in Table 3.1 of the Main Report but there is no hierarchy, dependency or prioritisation of the listed functions and it contains no supporting reference to the other ESC reports where a *“clear understanding of the safety function”* may be found.

Specifically, we consider the table has the following deficiencies:

⁴⁹ Baker, A., Cummings, R., Shevelan, J. and Sumerling, T. Technical Approach to the 2011 ESC, LLW Repository Ltd., November 2008 (LLWR/ESCR(08)10010).

⁵⁰ Addressing the GRA. LLWR/ESC/R(11)10031. May 2011.

- it does not fully describe or reflect the full range of control measure and functions presented within the main body of the ESC;
- it does not reflect the changing functions of control measures over the whole life of the facility; and
- it does not provide the reader with a linkage to presented evidence in the ESC.

The ESC main report describes the engineering features of the disposal system and the site development plan and management arrangements. What is not considered is the linkage between the components of the disposal system and the safety functions they provide. Two examples where we have struggled to identify the safety functions and anticipated performance of proposed engineering are:

- The ‘gas collection layer’ (incorporated below the base of the capping system). The safety function of this layer is presumably to collect and discharge gases generated from the waste in a controlled manner. Ideally we would like to compare the required engineering performance of the collection layer against the predicted gas flow rate.
- Measures to avoid ‘bath-tubbing’ (with respect to the previous high vault wall design). The Main Report and the L2 Engineering Design report describe the current design concept to direct any overtopped leachate into groundwater rather than allowing it to ‘bathtub’ into surface waters. We have not identified any safety functions for this system. It is stated in the L2 Engineering Design report that, *"Optimisation studies [10] concluded that the risks associated with bathtubbing outweighed the benefits."* The reference to the L3 Optimisation study states, *"bath-tubbing concepts are substantially more likely to lead to discharges to surface or upper ground water systems. The principle was also agreed that such discharges are more likely to lead to impacts to receptors than discharges to deeper water systems"⁵¹*. As with the gas collection layer system, we expect to see a description of the safety functions and the anticipated performance requirements.

Safety functions evolve with time and this is recognised in the GRA. An ESC approach based on safety functions should describe this. For example, we know that the safety functions provided by certain barriers will change, such as the role of the E-W vault retaining walls, cap performance and ultimately the expectation that the whole facility will almost certainly be destroyed by coastal erosion. If any of these aspects were contributing reasons for not adopting the safety function methodology, then this should be discussed.

The information clarifying the safety functions of the disposal system requested above should take account of the changing role of the safety function during the assessment period. The updated table on control measures should similarly take account of changing functions with time.

We therefore request information clarifying the changing roles of various design measures over the life of the site regarding the safety functions they provide.

We consider that a systematic identification of, and referencing to, safety functions throughout the ESC documents would aid the clarity of the overall submission and contribute significantly to building confidence in the ESC.

Regulatory Observation Actions

ESC-RO-ASO-005.A1	Explain why the recommendation of the international peer reviewers to adopt a safety functional methodology was rejected paying particular attention to the points raised in this Regulatory Observation. We wish to see further evidence why the approach was deemed unnecessary.
ESC-RO-ASO-005.A2	To increase clarify around safety functions, describe the safety

⁵¹ Models results supporting this statement are provided in the groundwater assessment, however, since the specific model runs were referred to as the ‘stream pathway’ (making no link to bathtubbing or overtopping) the audit trail is unclear.

	concept for the LLWR and provide further information to extend and enhance the existing list of safety functions in Table 3.1, together with an indication of the timeframes over which they are expected to perform.
ESC-RO-ASO-005.A3	Provide the final version of the FEP database including the register of uncertainties.

LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	30/10/2012
Comment: Responses to the actions will be provided.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	18/03/2013
A response is provided in ESC Project memo LLWR/ESC/Mem(13)201.		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 06/09/2013
Approved by: Environment Agency	Date: 20/11/2013

LLW Repository Ltd has explained its approach in responding to the actions above in their supplementary memo (ESC Project memo LLWR/ESC/Mem(13)201). It notes that, although a formal safety function approach had not been presented in the ESC, nor an analysis of the performance of each barrier in turn, the requirements of the GRA had been met in that they had:

- developed conceptual models and understanding that cover the performance and evolution of each barrier in detail
- characterised the evolution of the properties of the barriers as a function of time
- understood the role of each barrier in controlling the performance of the overall system

We would agree that these are important inputs to analysis of safety functions and addressing the requirements of the GRA. However, we consider that a formal safety function approach would have taken this analysis further in terms of specifically assigning safety functions to components of the disposal system and adding clarity to the arguments presented. The IPRG also recommended a safety function approach for assessing the future functions of the repository and to aid in deriving a comprehensive set of scenarios.

A high-level description of the safety concept is presented in the Level 1 ESC Main Report: 'the function of the LLWR ... is to contain the emplaced wastes and associated hazardous materials'. LLW Repository Ltd states that, given that wastes cannot be contained indefinitely, this statement could be modified to say that 'the objective is to contain the wastes, but where this is not possible the objective is that the system should act in a way that ensures that impacts to people and the environment are acceptable'. Further information is then provided on the barriers in place with reference to timescales of operation and their performance, and linking to sources of further information.

We consider that this analysis presents an improvement over the summary of control measures and functions provided in the 2011 ESC, but still fails to capture certain key aspects of the safety concept. In particular, clarity is not provided on the role of the final engineered cap; LLW Repository Ltd views the cap as providing important control on performance through restriction of infiltration, isolation of the waste and restricting the release of gas. Other important engineered

barriers which impact upon environmental performance include the basal drainage layer and cut-off wall (they provide further defence in depth should the cap fail). LLW Repository Ltd does not present minimum timescales over which it expects the barriers to fulfil their functional role in the 2011 ESC as presented, nor do we consider it discusses potential failure mechanisms on specific parts of the system in as great a depth as would be beneficial to understanding the system. This is a discrepancy that is discussed further in our review of the site engineering (Environment Agency 2015, Review of LLW Repository Ltd's 2011 Environmental Safety Case: Optimisation and Engineering).

We believe that the proportionate use of a safety function approach would have provided clarity on the roles and performance requirements of the various components of the near-surface disposal system and their relative contributions to overall safety of the facility and recommend that such an approach is used in future updates to the ESC. This could include a timeframes / nested timeframes approach to illustrating barrier performance. Such approaches are common with HLW/SF geological disposal facility safety cases overseas, and are considered good practice by NEA. We recognise that the LLWR is a near-surface repository with a significantly shorter lifespan than typical geological disposals, but note the presence of long-lived radionuclides at the LLWR may merit the proportionate application of a safety function approach.

We consider that this issue has been adequately addressed at present and is now closed. However, we recommend that LLW Repository Ltd considers the use of a safety function approach in future updates to the ESC in our review of the 2011 ESC safety case management (see Recommendation SCM22 of Environment Agency 2015, Review of LLW Repository Ltd's 2011 Environmental Safety Case: Safety case management).

Actions completed, Regulatory Observation resolved and Form closed

Owner: Environment Agency	Date: 03/07/2013
Approved by: Environment Agency	Date: 20/11/2013

ESC-RO-ASO-006: Linkage between ESC and single item limits

Title	Effective Linkage between the Environmental Safety Case and single item limits within the Waste Acceptance Criteria
Date raised	20/12/2012
Acknowledgment required by	04/01/2013
Response required by	31/01/2013
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	ASO
Approved by	Environment Agency

History

Status	Date	Description
Raised	20/12/2012	
Acknowledged	20/12/2012	
LLWR Response	07/08/2013	
Response Assessed	18/12/2013	
Transferred	27/01/2014	
Closed	29/01/2014	

Statement of Regulatory Observation

Other than for sources, the 2011 ESC does not include an assessment of the potential environmental consequences of the presence of single items disposed legally within the constraints of the WAC, where those items could challenge assumptions made within the ESC due to high specific activity or otherwise. However, it is noted that the ESC does recognise the issue of 'single items' and a commitment is made within the ESC to address the issue.

The objective of this Regulatory Observation is to scope the nature and extent of single items requiring direct control and to carry out an appropriate assessment of impacts associated with their disposal. We anticipate the output of this Regulatory Observation will be an assessment that defines a set of controls and conditions for disposals of single items, similar to that proposed for low activity sources (Waste Acceptance LLWR/ESC/R(11)10026, May 2011). We are aware that LLW Repository Limited has already commissioned work in this area.

Scoping of the Nature and Extent of Single Items

In the first instance we seek clarification of the scope and nature of single items requiring direct control within the Waste Acceptance Criteria (WAC) to ensure that assumptions made within the ESC are met. These items may be those that could present a significant or unacceptable risk in the future following coastal erosion of the site or human intrusion into it, for example by virtue of high dose rates from that specific item, the likelihood of them being picked up or used, the nature of the contamination or otherwise. Such items may have been deliberately disposed into the LLWR, or may have been disposed of inadvertently with other bulk heterogeneous wastes.

Items could include for example (but should not be limited to):

- High specific activity items with a short decay period.

- Robust discrete items which are environmentally persistent such as activated metals.
- Less durable discrete items where contamination is not environmentally persistent (surface contamination, coatings and soluble contamination).
- Inaccessible contamination and sealed items (excluding sources).
- Discrete items within a heterogeneous consignment which cannot readily be separated from a low activity matrix.
- Variations of the same waste stream within agreed confidence levels.
- Areas of contamination on a single item which cannot be readily separated.
- High value or attractive items (in terms of future human intrusion).

Some consideration should also be given to the scale and scope of possible historic disposals of these types, although we recognise that there is likely to be very limited information, such as the RECALL interviews, available to support such an understanding⁵². For this reason, at this stage we would only expect a broad discussion of this issue.

Incorporation of Single Items into the Environmental Safety Case

For the vault disposals the assessment should specifically address all potential environmental impacts associated with these disposals. This could for example include:

- Direct exposure during the Period of Authorisation (POA) (direct and scattered radiation from items disposed in containers or grouted into the vaults)
- Exposure to the waste on the shoreline as a result of coastal erosion (e.g. direct irradiation, handling or taking the item away).
- Exposure through human intrusion.

The assessment should take into account the likely frequency of such future disposals and the distribution of the items within the waste. The assessment should consider the optimisation of such disposals.

Additionally, the assessment should also consider historic disposals, referring to any bounding assessments that may already be present within the ESC. Broad consideration should be given to the significance of any past disposals of this nature and any additional optimisation of the repository design that could be required as a result.

Incorporation of Single Items into the Waste Acceptance Criteria

Using the outcomes of the above assessment proposed WAC should be developed and presented in relation to single item limits. These WAC should be underpinned and supported by the assessment and wider ESC, in addition to ensuring legal compliance.

Regulatory Observation Actions

ESC-RO-ASO-006.A1	<p>In line with the comments made within this RO:</p> <ul style="list-style-type: none"> • scope the nature and extent of single items requiring direct control within the WAC • complete an assessment of the environmental impacts associated with the disposal of such single items • using the assessment, propose appropriate WAC • consider historic disposals of this nature, assess the possible implications and identify any resulting action required
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⁵² A number of interviewees who took part in the RECALL exercise mention discrete high specific activity disposals.

LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	20/12/2012
Comment: An assessment and proposed WAC will be provided.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	07/08/2013
A response is provided in ESC report: LLWR ESC(13)10055, Assessment of Discrete Items and Basis for WAC.		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 18/12/2013
Approved by: Environment Agency	Date: 29/01/2014

In response to this Regulatory Observation (RO), LLW Repository Ltd produced the following technical report 'Assessment of Discrete Items and Basis for WAC, LLWR ESC(13)10055'. This report presents an assessment of the potential radiation doses to persons who encounter discrete items of radioactive waste disposed in the LLWR. This may occur, in the long-term, due to their deposition on the beach following coastal erosion of the facility or excavation during human intrusion. LLW Repository Ltd's approach to the assessment of discrete items and the incorporation of the results of the assessment into the WAC is summarised below:

LLW Repository Ltd defines a 'Discrete Item' as: 'a distinct item of waste that, by its characteristics, is recognisable as unusual or not of natural origin and could be a focus of interest, out of curiosity or potential for recovery and recycling/re-use of materials should the waste item be exposed after Repository closure.'

LLW Repository Ltd presents an approach to assessing discrete items, and to determining discrete item limits, which is based on a dose-rate guide value of $20 \mu\text{Sv h}^{-1}$. LLW Repository Ltd uses a model that represents discrete items based on spheres of equivalent mass.

Effective doses from Potentially Exposed Group (PEG) encounters with discrete items are calculated taking account of external radiation and also inadvertent ingestion of loose contamination from the surfaces of the model sphere. Surface and volume-contaminated spheres are considered and LLW Repository Ltd argues that the range between these two cases provides a cautious illustration of the effective dose from contaminated items on which the pattern of contamination is undefined. Data are derived and calculations made for model spheres with mass between 10 g and 10 tonnes covering all reasonable waste forms.

Effective dose rates from encounter with model items bearing unit activity (1 GBq) of given radionuclides are then calculated and, inversely, the item activities that will lead to the chosen guide value. This leads to the grouping of radionuclides that present broadly similar potential for radiological impact if present on a discrete item.

Quantitative limits and radionuclide groups for low-activity sources are considered consistent with those derived for discrete items, so a single radionuclide group system is used for both discrete items and low-activity sources.

LLW Repository Ltd's Developments Report⁵³ presents controls for discrete items based on the above criteria. A number of example wastes that could be classified as discrete items are listed, these include:

- hand tools, engineered items and equipment of durable materials
- grouted drums of waste
- large metal items, for example, steel beams and plates, pipe work, shielding, heavy equipment and flasks (but not general scrap metal)

The reporting of radionuclide activity on discrete items is an additional reporting requirement for consignors and forms part of the latest version of the WAC⁵⁴.

LLW Repository Ltd has stated that information and training will be provided to consignors to help them to characterise and assess discrete items in accordance with the WAC requirements. We consider it essential that the consignor is fully aware of the nature and characterisation of discrete items required. It is also considered important that operational experience of the identification and control of discrete items is used to inform the WAC in the future (see Recommendation SCM31 of Environment Agency 2015, Review of LLW Repository Ltd's 2011 Environmental Safety Case: Safety case management).

We have reviewed the relevant outputs of this work and the changes to the WAC to manage discrete items and consider the measures to be reasonable.

The final action of the RO required LLW Repository Ltd to consider historic disposals of this nature, assess the possible implications and identify any resulting action required. LLW Repository Ltd has not carried out any assessment of historic disposals (or currently stored wastes). We have raised a Forward Issue (FI) to address this outstanding response (ESC-FI-013). We will require LLW Repository Ltd to address this issue before the commencement of capping.

We therefore consider that the actions in this RO have either been adequately addressed or can be addressed prior to capping of the wastes commencing, and it can therefore be closed.

Actions completed, Regulatory Observation resolved and Form closed

Owner: Environment Agency	Date: 29/01/2014
Approved by: Environment Agency	Date: 29/01/2014

⁵³ LLW Repository Ltd, 2013. Developments Since 2011 ESC. LLWR/ESC/R(13)10058).

⁵⁴ LLW Repository Ltd, 2014. Waste Services Contract. Waste Acceptance Criteria - Low Level Waste Disposal. LLW Repository Ltd Report WSC-WAC-LOW - Version 4.0 - March 2014.

ESC-RO-ASO-007: ESC assessment code documentation and quality assurance

Title	Environmental Safety Case assessment code documentation and quality assurance
Date raised	20/12/2012
Acknowledgment required by	04/01/2013
Response required by	31/01/ 2013
Related issue numbers	ESC-RO-ASO-004
Originated by	Environment Agency
Current owner	Environment Agency
Review group	ASO
Approved by	Environment Agency

History

Status	Date	Description
Raised	20/12/2012	
Acknowledged	20/12/2012	
LLWR Response	18/03/2012	
Response Assessed	06/09/2013	
Transferred	06/09/2013	
Closed	15/11/2013	

Statement of Regulatory Observation

The 2011 Environmental Safety Case (ESC) makes use of a substantial number of conceptual and mathematical models, implemented via computer codes, to assess the performance of the repository. Post-closure performance in particular, is increasingly dependent on the use of models as, acknowledged by LLW Repository Ltd, "There will be increased reliance on the use of models and their outputs as a measure of acceptable performance"⁵⁵

We previously raised a Regulatory Observation on the management of uncertainty. Closely related to uncertainty is the issue of quality. While the ESC reports as a whole are certified under a quality assurance (QA) scheme, the extent to which quality assurance procedures have been applied to the modelling work is less clear.

The 2002 Post-Closure Safety Case (PCSC) suite included a series of reports documenting model descriptions and justifications for models-in-use in near field, geosphere and biosphere assessments⁵⁶. The objective of these reports was to provide a robust QA framework for the development and verification of models used in the 2002 PCSC, including presentation of such tools as an assessment model flowchart to aid transparency.

⁵⁵ LLW Repository Ltd, 2008, Technical Approach to the 2011 Environmental Safety Case, LLWR/ESC/R(08)10010 Issue 1.

⁵⁶ DTP/98 Model description and justification for the near-field; DTP/97 Model description and justification for the geosphere, DTP/114 Model description and justification for the biosphere.

The Environment Agency's Assessment Codes Review Group, who checked and assessed the use of assessment codes in the 2002 PCSC, judged this work to be of a high standard⁵⁷.

Our review of the 2011 ESC has not identified an equivalent standard of model or code QA documentation. There is brief discussion in the Level 2 report on the Assessment of Long-term Radiological Impacts (Section 2.3.5 – Assessment Models) which contains various claims but little referencing to underpinning reports. Some of the references point to program user guides and others to unspecified sections in Level 2 reports. The 2008 report on the Technical Approach to the 2011 Environmental Safety Case, discusses the treatment of uncertainty in models (Section 5 – Assessment Approach) but not the broader issue of the management of model quality.

We note that the ESC submission does not include a complete list of all the software codes and models used. Without a high level summary of the use of codes and models in the ESC, we do not find it easy to understand how the various models interact and how model output is transferred between different models. Use of an Assessment Model Flowchart, such as those provided in the 2002 PCSC (and by SKB in the 2010 SR-Site safety assessment⁵⁸), would in our view represent best practice.

There appears to be no systematic treatment or discussion of model quality across the ESC. For example, the Generalised Repository Model (GRM) used for the assessment of a number of near field behaviours has a substantial amount of documentation and is considered to meet current best practice criteria. In contrast, other models used in the ESC such as CONNECTFLOW, CFM, PHAST, QPAC, ERICA Tool, SCAPE and the coastal recession empirical model have little or no supporting documentation⁵⁹. There is also a lack of clarity regarding version control of certain models, for example, there are numerous iterations of the groundwater flow model and the geological model and at times it is not clear which version supported what part of the ESC.

The level of detail provided in the ESC to demonstrate the validity of each of the codes in use appears, to a degree, dependent on the preferences of the various contractor organisations. It may be that suitable model documentation and verification rests within the various contractor organisations but the ESC does not present evidence to show that LLW Repository Ltd:

- specified any QA standards for model use or development;
- can justify code selection; or
- can readily identify the strengths and limitations of each model and code.

The evidence submitted does not meet our expectations (Guidance on Requirements for Authorisation paragraph 7.3.23) on confidence building in code development, which should include *“rigorous quality assurance of all modelling activities and associated data handling, including controls over changes to models and data and a detailed audit trail”*

The importance of documenting model quality is to help build confidence in the robustness of the model outputs, the suitability of the chosen codes and the reliability of model projections. This importance of model quality applies regardless of whether models are designed to be 'cautious' or 'realistic'. Information on model quality would also assist in the effective communication of model uncertainty and the quantification of cumulative uncertainties where more information is derived from the output of more than one model such as the groundwater pathway.

We require LLW Repository Ltd to provide a list of the key models and codes employed in the 2011 ESC and to summarise the interaction and flow of information between models. An Assessment Model Flowchart or similar may assist with this task.

⁵⁷ Galson Sciences, 2004. Review of BNFL's 2002 Drigg Post-Closure Safety Case. Report of the Assessment Codes Review Group. 01333-10 Issue 1.

⁵⁸ SKB, 2010. Model Summary Report for the Safety Assessment SR-Site. Technical Report TR-10-51.

⁵⁹ A number of these models are commercially available 'off the shelf' packages. Here we expect QA documentation to support any model or code modification, the development of the conceptual model, the choice of initial and boundary conditions and other key framing assumptions made.

We require evidence to show that the various codes and models are fit for purpose; that is, they perform as intended and have been properly used. This latter point is particularly relevant for modelling platforms such as GoldSim, which has been used to construct assessment models for a variety of environmental pathways and scenarios.

We also require evidence to tell us how LLW Repository Ltd determined that model construction and parameterisation in GoldSim (for each unique application) and Perl scripts⁶⁰ was fit for purpose and the standards and criteria that were applied to any auditing of model development by contractors.

In a future ESC, we would wish LLW Repository Ltd to provide comprehensive accompanying documentation of model selection, usage and QA (for example along the lines of the 2002 model description and justification reports which we previously considered high quality).

Regulatory Observation Actions

ESC-RO-ASO-007.A1	Please provide a list of the key models and codes employed in the 2011 ESC and summarise how the different models interact and how information is transferred between different models and codes.
ESC-RO-ASO-007.A2	Please provide details of the measures taken for each code or model to establish its fitness for purpose, its ability to produce accurate results and how LLW Repository Ltd determined that model construction and parameterisation in GoldSim (for each unique application) and Perl scripts was fit for purpose, and the standards and criteria that were applied to any auditing of model development by contractors.

LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	20/12/2012
The additional information requested will be provided.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	18/03/2012
A response is provided in ESC Project memo LLWR/ESC/MeM(13)194, <i>Assessment Code Documentation and Quality Assurance</i> .		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 06/09/2013
Approved by: Environment Agency	Date: 15/11/2013

In response to this Regulatory Observation (RO) LLW Repository Ltd provided ESC Project memo 'LLWR/ESC/MeM(13)194, Assessment Code Documentation and Quality Assurance'. The

⁶⁰ Perl scripts are used to generate the finite element grid for the 3-D groundwater flow model.

following comments are based on this memo with reference to a later groundwater audit carried out after this RO was issued⁶¹.

- Action ESC-RO-ASO-007.A1. The presented memo effectively outlines and illustrates the key assessment models and codes used in the ESC and a summary of model assurance measures, collated from other parts of the ESC. The response improves the clarity of the presented ESC.
- Action ESC-RO-ASO-007.A2. The presented memo describes the main audit actions undertaken by LLW Repository Ltd during the preparation and development of ESC data. As part of our audit of the groundwater pathway modelling process we inspected and checked a number of the quality processes and documents described. The aim of the audit was to gain confidence that the calculations were undertaken under a suitable quality assurance regime and that relevant procedures were adhered to. We concluded that the contractor organisations have well-established quality management systems that staff were knowledgeable of and actively used during the production of ESC materials. We have made separate comments on the outcome of our groundwater pathway audit outside of the scope of this RO (as discussed in Environment Agency 2015, Review of LLW Repository Ltd's 2011 Environmental Safety Case: Safety case management).

We see the information presented in ESC Project memo LLWR/ESC/MeM(13)194, Assessment Code Documentation and Quality Assurance as a starting point for the next ESC to build upon. Elsewhere in our review of the ESC we recommend improved attention to the identification of models and quality systems within the ESC (see Recommendation SCM17 of Environment Agency 2015, Review of LLW Repository Ltd's 2011 Environmental Safety Case: Safety case management).

LLW Repository Ltd should consider incorporating the descriptions of the models presented in response to this RO in future versions of the ESC. Good practice would include provision of an assessment model flow chart, or similar, to illustrate the linkages and flow of information between the various models (see Recommendation ASS27 of Environment Agency 2015, Review of LLW Repository Ltd's 2011 Environmental Safety Case: Assessments).

In conclusion, we consider that documenting model quality is a key mechanism to help build confidence in the robustness of the model outputs, the suitability of the chosen codes and the reliability of model projections. Documentation on model quality would also assist in the effective communication of model output in higher level documents. We consider this RO adequately addresses the queries we have raised and this RO can be closed.

Actions completed, Regulatory Issue resolved and Form closed

Owner: Environment Agency	Date: 03/07/2013
Approved by: Environment Agency	Date: 15/11/2013

⁶¹ Fairhurst, A., 2013. Audit of 2011 ESC Groundwater Pathway Calculations. Letter from A. Fairhurst of the Environment Agency to R. Cummings of LLW Repository Ltd, reference LLWR/13/015/O. 8 November 2013.

Appendix 3: Technical Queries

IRF Number	Title
ESC-TQ-SCM-001	Board involvement in promoting environmental safety
ESC-TQ-SCM-002	Risk of tsunami affecting the LLWR
ESC-TQ-SCM-003	Establishing the scope of the 'local community'
ESC-TQ-INF-003	Radionuclide forward inventory data
ESC-TQ-INF-004	Analysis of RECALL interviews
ESC-TQ-INF-005	MoD waste streams
ESC-TQ-INF-005a	Response to MoD waste streams
ESC-TQ-INF-006	Ratio of waste to grout infill
ESC-TQ-INF-007	Understanding and optimisation of surcharge requirements and final cap placement timing
ESC-TQ-INF-018	Trench cap leakage
ESC-TQ-INF-020	Future inventory - combined cases
ESC-TQ-INF-021	Key radionuclides: Am-241 contribution to vault 8 and overall inventory
ESC-TQ-INF-024	Uncertainty in isotopic Pu ratios within the trench inventory
ESC-TQ-INF-026	Uranium behaviour
ESC-TQ-INF-032	Containers located within vault 8 and waste tracking
ESC-TQ-INF-035	Impacts on the radon gas pathway
ESC-TQ-SUE-010	Isostasy monitoring
ESC-TQ-SUE-011	Slope stability
ESC-TQ-SUE-019	Extreme events
ESC-TQ-SUE-022	Understanding the role of the dune system
ESC-TQ-SUE-023	Cap slope stability assessment request
ESC-TQ-SUE-024	Concrete slab performance
ESC-TQ-SUE-025	Coastal erosion
ESC-TQ-SUE-026	Seismic assessment
ESC-TQ-SUE-030	Development and assessment of waste fire scenarios during the post operational period
ESC-TQ-ASO-001	Implementation of emplacement strategies within vault 8
ESC-TQ-ASO-003	Coastal and marine biosphere and PEG definitions
ESC-TQ-ASO-004	Incorporation of sea level change in the CONNECTFLOW model
ESC-TQ-ASO-005	Aircraft impact (human intrusion)
ESC-TQ-ASO-006	Radiological impacts - close contact to exposed undiluted wastes
ESC-TQ-ASO-007	Selective retrievals study: GDF disposal costs
ESC-TQ-ASO-008	Integration between the PoA and reference case assessment

IRF Number	Title
ESC-TQ-ASO-009	Well calculations
ESC-TQ-ASO-009a	Well calculations further information
ESC-TQ-ASO-010	Human intrusion into sources

ESC-TQ-SCM-001: Board involvement in promoting environmental safety

Title	Board involvement in promoting environmental safety
Date raised	30/09/2011
Acknowledgment required by	14/10/2011
Response required by	30/11/2011
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	SCM
Approved by	Environment Agency

History

Status	Date	Description
Raised	30/09/2011	
Acknowledged	14/10/2011	
LLWR Response	30/11/2011	
Response Assessed	16/07/2013	
Transferred	19/11/2013	
Closed	21/11/2013	

Statement of Technical Query

The LLW Repository Limited Board, along with its managers, should provide strong leadership to achieve and sustain high standards of environmental safety. They should also provide reassurance that the organisation can be trusted to dispose of radioactive waste in an environmentally safe way. In particular, environmental safety messages must be seen to come from the top of the organisation and be embedded throughout its management levels.

The Environmental Safety Case (ESC) makes reference to the Board approving the EHS&Q policy and environmental messages coming 'from the top'. It also refers to the Head of Safety, Regulatory Liaison and Governance sitting on the LLW Repository Limited Board. However limited evidence is provided as to how the Board are practically involved in promoting safety and environmental performance and ensuring it is achieved.

We would like to see further evidence provided of how the LLWR Board drives a positive environmental culture, promotes environmental performance and monitors achievement of positive outcomes. What activities are undertaken and where are expectations documented?

Technical Query Actions

ESC-TQ-SCM-001.A1	LLW Repository Limited shall provide further evidence of the LLW Repository Limited Board actively driving a positive environmental culture, promoting environmental performance and monitoring outcomes. Reference should be made to any
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	written expectations of the Board.
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	14/10/2011
Comment: Further explanation of the Board's active involvement in promoting environmental performance and monitoring outcomes will be provided.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	LLWR EH&S Director	30/11/2011
<p>The importance placed on environment, health and security (EH&S) by the LLWR SLC Board is indicated by the makeup of the Board, which includes both an Executive EH&S Director and a highly experienced non-executive 'Independent Safety Director' (ISD). In addition to the standard duties of all Board members, the ISD has a defined role in supporting the Board to meet its EH&S responsibilities (role description attached as an appendix).</p> <p>All new Board Members are given specific training both in the role of the Board, through Institute of Directors training, and in LLWR-specific aspects of EH&S, and its Nuclear Site Licence and Environmental Permit, by the EH&S Director.</p> <p>EH&S is the first substantive agenda item at each and every Board meeting, where the Board gets an update on EH&S performance and improvements since the last meeting from the EH&S Director. In addition to this standard agenda item, there is a calendar of papers covering many aspects of EH&S, and this includes:</p> <ul style="list-style-type: none"> • A more detailed quarterly EH&S performance report, which covers all aspects of EH&S performance, events, inspections and high-level key performance indicators. • Annual involvement in the development of the EH&S Improvement Plan and final endorsement of the Plan. • Annual review and approval of the EH&S Policy statement. • An annual report from the ISD on his assurance activities (see below). • An annual report from the Independent Site Inspector (see below). <p>Additionally, the Board requests specific briefs and updates on areas of interest, such as the ESC, and will ask for periodic updates of progress.</p> <p>The ISD carries out a number of activities that increase the visibility of the Board and inform his reporting to the Board, including:</p> <ul style="list-style-type: none"> • Attendance at meetings of the LLWR EH&S Committee, including attendance at the committees that approved the ESC prior to submission to the EA. • Periodic attendance at other safety meetings, such as the Management of EHS Committee (MEHSC) and the Safety Forum. • Private discussions with the Environment Agency, the Nuclear Installations Inspectorate and the Nuclear Decommissioning Authority. • Private discussions with LLWR Safety Representatives, including site tours. • Observation of interactions with relevant stakeholders, in particular the regulators, planning authority and the local community. • General discussions with various company management personnel. <p>These activities allow the ISD to independently confirm to the Board that the information that they are acting on is complete and correct. The annual report from the ISD routinely includes recommendations on how the effectiveness of the Board can be improved, and these reports are discussed with external regulators.</p> <p>In addition to the ISD, the Site has an Independent Site Inspector, who carries out an</p>		

independent, risk-based programme of inspections covering all aspects of EH&S performance. This programme includes key Environmental Legislation and Environmental Permit compliance activities. The Board receives a quarterly summary of the key findings of the Site Inspection Programme as part of the EH&S report and also takes an annual summary report from the Site Inspector.

In addition to the routine activities identified above, the Board will often follow up particular events and ask for a presentation of findings of investigations, such as on the recent maintenance problems, where the board have considered the investigation report and corrective action plan and have been instrumental in developing and communicating the wider action plan. In a recent example of an event involving contaminated items in a non-active waste skip, one of the Non-executive Directors chaired the investigation into the event, to reinforce the seriousness with which the Board viewed such events.

The LLWR is a small organisation and benefits from the fact that the Managing Director can carry out direct, face-to-face briefings of all employees. This is typically done on a quarterly basis and allows the Boards strategic direction to be directly communicated to the workforce. Additionally, the EH&S Director is a regular attendee at the LLWR Safety Forum, which is the primary forum for communication and discussion with workforce representatives on EH&S matters. Individual executive Board members provide environmental leadership through their management roles on a day-to-day basis.

New executive committees are being created at the LLWR, one of which, the Waste Management Strategy Committee, will have responsibility for decision making on waste acceptance and hence limiting the environmental impact of the site through controlling the source term. The Board will maintain oversight of this committee through annual review.

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 16/07/2013
Approved by: Environment Agency	Date: 21/11/2013

This Technical Query (TQ) sought additional evidence that the LLW Repository Ltd Board was providing strong and appropriate environmental leadership.

LLW Repository Ltd has referred to the make-up of the Board which includes an Independent Safety Director (ISD), with documented environmental responsibilities. Evidence has been provided that the Board are made aware of environmental issues, responsibilities and the environmental permit. Evidence has also been provided that the Board are actively involved in reviewing and contributing to environmental matters on a routine basis. In particular the ISD has a role in testing and challenging environmental performance. The Managing Director provides direct leadership through face to face briefings which include environmental matters.

This TQ has been adequately addressed and can be closed.

Actions completed, Technical Query resolved and Form closed

Owner: Environment Agency	Date: 21/11/2013
Approved by: Environment Agency	Date: 21/11/2013

APPENDIX 1: LLWR Independent Safety Director Charter

The Role of the 'Independent Safety Director'

By Roger Coates

The LLWR Ltd Board has chosen to appoint one of its Non-Executive Directors as an 'Independent Safety Director' (ISD). The objective of this note is to define and agree the expectation for this role, which is additional to the standard collegiate responsibilities common to all Board members. This note has been prepared following discussions with NII and the Environment Agency, and takes account of written guidance published by HSE.

Three specific aims for the role can be identified as follows:

- To prompt, encourage and support the Board to ensure that it properly addresses its responsibilities for leadership and delivery of environment, health and safety (EH&S) performance. The Board's responsibilities include the establishment of EH&S policy and strategy, the monitoring of executive action to deliver these, and ensuring compliance with relevant UK legislation.
- To provide assurance to the Board that the information it receives on EH&S matters presents a realistic and representative picture of the state of the company.
- To provide a conduit for two-way communication between the Board and its stakeholders concerned with EH&S matters, and in particular with the workforce and the regulators.

The methods to be used in achieving these aims are envisaged as follows:

- Close contact and discussion with the executive EH&S Director and the Managing Director to encourage the provision of relevant and appropriate EH&S information to the Board, and to ensure the ISD's familiarity and understanding of EH&S processes and issues within the company.
- Through the above discussions, and through discussions with other managers and employees and the observation of activities on the site, to underpin the validity of the EH&S reporting to the Board.
- To meet on a periodic basis with the EH&S stakeholders, particularly the workforce and the regulators, both to communicate the Board's emphasis and focus on EH&S, and to receive views and comment.
- Attendance as an observer at the Nuclear Safety Committee (NSC).

The ISD shall provide specialist input as appropriate at all Board meetings, and shall provide the Board with an annual report of activities and findings.

The ISD shall take whatever time is necessary to deliver the above programme, and it is envisaged that this will require of the order of 10 days per year in addition to NSC and Board meetings.

ESC-TQ-SCM-002: Risk of tsunami affecting the LLWR

Title	Risk of tsunami affecting the LLWR
Date raised	30/09/2011
Acknowledgment required by	14/10/2011
Response required by	30/11/2011
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	SCM
Approved by	Environment Agency

History

Status	Date	Description
Raised	30/09/2011	
Acknowledged	14/10/2011	
LLWR Response	29/11/2011	
Response Assessed	16/07/2013	
Transferred	19/11/2013	
Closed	21/11/2013	

Statement of Technical Query

Following the tsunami in Japan in March 2011, the possibility of a similar event in the UK is unsurprisingly of interest to members of the public and regulators. We recognise that the Environmental Safety Case (ESC) was essentially completed before the tsunami occurred, and that such an event in the UK is not considered probable. Consequently, the ESC does not address the question of tsunamis, nor provide any evidence.

For reassurance and clarity, we believe it is appropriate for a clear position to be stated regarding the possibility and scale of any tsunami impacting the LLWR over its lifetime, referring to any appropriate references for evidence. The potential impacts of any such event should be considered.

Technical Query Actions

ESC-TQ-SCM-002.A1	LLW Repository Limited shall provide a clear and substantiated statement of their position with regard to the possibility and likely scale of any tsunami impacting the LLWR over the site's lifetime.
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	14/10/2011
Comment: A statement will be provided.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Technical Specialist	29/11/2011
<p>A detailed study was undertaken by Defra in 2005 to evaluate risks from a tsunami to the UK (Defra 2005). The conclusion was that the maximum tsunami height around the UK would be a 1 to 2m increase in sea level, with local 'run-up' effects potentially up to a height of 4m. The elevations of the various waste storage and disposal facilities at the LLWR range from +12.5m to +20m AOD. The land to the west of the site (Drigg Dunes SSSI) rises to a height of about 24m AOD before dropping back to the beach, forming a natural barrier to inundation from the coast. Comparing these heights, it is clear that a tsunami is very unlikely to have an impact on the waste currently stored or disposed at the site.</p> <p>LLWR has produced a paper on the application of the EU Fukushima stress test (LLWR 2011a). which considered the site's resilience to extreme external events. The paper concluded that the existing safety measures at LLWR are adequate. LLW that is being processed or stored may be damaged by extreme external events. If this happens, containers, buildings, vaults and trenches would continue to offer some degree of containment. Releases to the environment would be below criteria for significance and public safety would not be threatened. Once damage had occurred, the situation would have no further potential for deterioration as seen at Fukushima.</p> <p>The ONR report on the implications of events at Fukushima for the UK nuclear industry (ONR 2011) states that:</p> <p><i>"Tsunami risk at LLWR is extremely low as a result of its distance from driving mechanisms. Given the clear margin available between the maximum predicted flood heights and the dune protection, flooding impacts are considered to be minimal."</i></p> <p>The ONR statement is based on the understanding of the elevations given above. The ONR report states that:</p> <p><i>"Modelling for a 1 in 50 year storm surge indicates that a 2m increase in sea level is probable and if such an increase was included, the maximum sea level with extreme tide could reach +10.9m AOD."</i></p> <p>Even allowing for ingress from the Ravenglass Estuary, such a surge might only cause flooding of the southern part of the site, and would not be high enough to affect the trenches or vaults.</p> <p>We do not consider tsunami in the 2011 ESC on the basis of their low probability and consequences. The 2011 ESC does consider the effects of coastal erosion over the lifetime of the site (LLWR (2011b & c).</p> <p>We do not take credit for coastal defences because we cannot assume that they will be maintained beyond the period of institutional control or retain their capabilities in the long term. The potential for a tsunami-like event to impinge on the site increases as sea level rises and coastal recession occurs. It is considered, however, that once the facility is capped, there could be no significant impact from such events beyond some limited erosion of the site restoration layers of the cap. If the event occurred after erosion of the disposed waste has commenced, the effect would be similar to that of a major storm event causing some immediate erosion and dispersal of wastes onto the shore and marine environment. Such processes and their effects are considered in the long-term assessment calculations (LLWR 2011c).</p>		

References

Defra, 2005. *The Threat Posed by Tsunami to the UK.*

Low Level Waste Repository Ltd, 2011a. *Fukushima Stress Test*, LLWR EHSC Committee (NSC Committee) LLWRNSC(11)23, October 2011.

Office for Nuclear Regulation, 2011. *Japanese Earthquake and Tsunami: Implications for the UK Nuclear Industry*, Final Report HM Chief Inspector of Nuclear Installations September 2011.

Low Level Waste Repository Ltd, 2011b. The 2011 ESC: Site Evolution, LLWR/ESC/R(11)10023, May 2011.

Low Level Waste Repository Ltd, 2011c, *The 2011 ESC: Assessment of Long-term Radiological Impacts*, LLWR/ESC/R(11)10028, May 2011.

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 16/07/2013
Approved by: Environment Agency	Date: 21/11/2013

This Technical Query (TQ) sought a clear position on the possibility and significance of a tsunami impacting upon the LLWR.

LLW Repository Ltd has provided data indicating the low likelihood of such an event and also the low significance given the elevation of the LLWR, its location and adjacent geography. Office for Nuclear Regulation (ONR) reports agree with this assessment. We also note that the risk from a tsunami in the longer-term, post-capping is reduced further by the protection offered by the cap. Should a tsunami occur after coastal erosion of the site has commenced the likely impacts are bounded by current assessments.

This TQ has been adequately responded to and can be closed.

Actions completed, Technical Query resolved and Form closed

Owner: Environment Agency	Date: 21/11/2013
Approved by: Environment Agency	Date: 21/11/2013

ESC-TQ-SCM-003: Establishing the scope of the 'local community'

Title	Establishing the scope of the 'local community'
Date raised	30/09/2011
Acknowledgment required by	14/10/2011
Response required by	31/11/2011
Related issue numbers	ESC-RI-SCM-002
Originated by	Environment Agency
Current owner	Environment Agency
Review group	SCM
Approved by	Environment Agency

History

Status	Date	Description
Raised	30/09/2011	
Acknowledged	14/10/2011	
LLWR Response	29/11/2011	
Response Assessed	02/07/2011	
Transferred	19/11/2013	
Closed	21/11/2013	

Statement of Technical Query

The Environmental Safety Case (ESC) describes the range of stakeholders LLW Repository Limited have engaged with or identified. However, it does not explain how the range of stakeholders were identified.

In relation to dialogue with local communities the GRA indicates that 'The developer will need to consider, in discussion with the relevant local authorities, how to define "local community" for any specific proposal, taking into account the nature, size and location of the proposed facility'.

We expect to see evidence of how the list of stakeholders has been arrived at, for example through dialogue with the local authority, so as to provide confidence that a full and appropriate range of stakeholders have, or will be engaged.

Technical Query Actions

ESC-TQ-SCM-003.A1	LLW Repository Limited shall provide a description of how their stakeholder list was developed and demonstrate that it is appropriate to the scale and scope of the development being proposed.
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	14/10/2011
Comment: A description of how our stakeholder list was developed and discussion that it is appropriate will be provided.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	29/11/2011
<p>The LLWR has operated for more than 50 years and we are well integrated into our local and regional community. We pursue an active stakeholder engagement programme, making use where appropriate of the mechanisms set up by the NDA to consult with stakeholders. Our staff live as well as work in the area and participate in local and regional organisations. Our Stakeholder Manager was until recently an Executive Member of Copeland Borough Council and is a Parish Councillor. All this has allowed us to develop and maintain a good working understanding of our local and regional stakeholders and hence engage appropriate individuals and organisations on the development of the ESC and other issues.</p> <p>During the development of the ESC we have, as far as is practicable, tried to engage with an appropriate wider range of stakeholders mainly through making use of the NDA fora set up expressly for the purpose of national stakeholder engagement, including their National Stakeholder Group and LLW Strategy Group. These national groups, along with the West Cumbria Sites Stakeholder Group and its LLW Sub Committee, have an appropriate combination of regulatory, industry, local authority, political and community representation.</p> <p>We drew attention to the publication of the 2011 ESC by writing to a wide range of stakeholders, local, regional, national and international. To ensure we contacted an appropriate range of stakeholders, we used our knowledge of local and regional stakeholders, reviewed the list of respondents to the Environment Agency's consultation on the 2002 Safety Cases, and consulted with the Environment Agency and the membership of the LLWR Joint Regulatory Liaison Group, which comprises representation from the NDA, Cumbria County Council, Copeland Borough Council, Environment Agency and Office of Nuclear Regulation.</p>		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 02/07/2013
Approved by: Environment Agency	Date: 21/11/2013

This Technical Query (TQ) asked LLW Repository Ltd to identify how it established its stakeholder engagement list for the purposes of this ESC and to justify its scope.

LLW Repository Ltd has provided an explanation of its ability to define a suitable stakeholder list, making use of its extensive experience and engagement within the local and regional community. LLW Repository Ltd has also explained how it supplemented this experience with input from the Environment Agency, consultation experience from the previous authorisation review and dialogue with the LLWR Joint Regulatory Liaison Group. This dialogue has included regular communication with local authorities, as expected in the GRA.

We conclude that this TQ has been adequately addressed and can be closed.

Actions completed, Technical Query resolved and Form closed

Owner: Environment Agency	Date: 21/11/2013
Approved by: Environment Agency	Date: 21/11/2013

ESC-TQ-INF-003: Radionuclide forward inventory data

Title	Radionuclide forward inventory data
Date raised	14/05/2012
Acknowledgment required by	16/05/2012
Response required by	31/05/2012
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	INF
Approved by	Environment Agency

History

Status	Date	Description
Raised	14/05/2012	
Acknowledged	16/05/2012	
LLWR Response	30/07/2012	
Response Assessed	02/08/2013	
Transferred	02/08/2013	
Closed	07/11/2013	

Statement of Technical Query

Within the Inventory area of the 2011 LLWR ESC, LLW Repository Ltd provides details of the predicted future inventory of key radionuclides which is used to predict the future volume and radionuclide content for disposals in to the LLWR facility over its operational lifetime. The future inventories are also used within the ESC to assess the risk associated with key radionuclides through significant environmental pathways presented within the 2011 ESC as well as for predicting the contents of the vaults.

As part of our assessment of the ESC we wish to see that the link between the forward inventory data for key radionuclides presented in the Level 1 and 2 documents and the source data, for example the UKRWI 2007 and the WIDRAM09 database, is clearly demonstrated.

It is not clear from the Level 3 documents whether all contaminated land waste streams have been included in the forward inventory: we require clarification of which contaminated land and other waste streams have been excluded (and included) in the Reference Case A. Two examples where there is lack of clarity in this area are:

- Table 7 (*LLW streams excluded from future vaults inventory calculation*) in document (07)9124 does not list the Springfields waste streams that are designated for disposal at Clifton Marsh (streams 2E90, 2E91 and 2E191);
- Table 3 in document NNL (08)10241 does not list waste stream 7S01 Defence Estates Contaminated Soil, Ash & Rubble.

It is stated in paragraph 6.4.5 and 6.5.4 of document SERCO/E003756/12 that there are uncertainties in the data held in WIDRAM09 for C-14 and CI-36 in Wylfa waste streams because of data entry errors. We therefore require details of the quality assurance arrangements that were applied in correcting the identified errors for C-14 and CI-36 in the Wylfa waste streams.

The ESC recognises uncertainties in the future CI-36 inventory arising from gas cooled reactor waste streams. Although the outcome of current studies appears inconclusive, LLW Repository Limited should provide details of future intended work for the refinement of estimates of CI-36 in the forward inventory and an indication of any change to the emplacement strategy for these wastes that may result.

Technical Query Actions

A1 and A2 refer to data presented in document SERCO/E003756/12 Issue 2.	
ESC-TQ-INF-003.A1	Identify the waste stream CL01 referred to in document SERCO/E003756/12 Issue 2; CL01 is not listed in UKRWI 2007.
ESC-TQ-INF-003.A2	Clarify the statements and volume estimate in paragraph 6.1.4 of document SERCO/E003756/12 Issue 2 relating to the discounting of contaminated land waste from Springfields; neither of waste streams 2E90, 2E191 (waste for Clifton Marsh) equates to 8E+04 m ³ that is referred to in the submission.
A3 refers to Table 7 in document (07)9124 of the Level 3 submission which lists LLW waste streams excluded from future vaults inventory calculation.	
ESC-TQ-INF-003.A3	<p>Confirm whether or not the following waste streams are included in the Reference Case and demonstrate the link to data presented in Level 2 submission:</p> <p>2E90 General Waste for Clifton Marsh Disposal</p> <p>2E91 Process Wastes for Clifton Marsh</p> <p>2E191 Decommissioning Wastes for Clifton Marsh Disposal</p> <p>5C300 Harwell High Volume Low Activity Waste from Decommissioning and Site Remediation</p> <p>2Y57 Sellafield Excavated Soil and Putrescible Waste</p> <p>2X05 Sellafield site clearance LLW</p> <p>7S01 Defence Estates Contaminated Soil, Ash & Rubble</p> <p>5F300 Windscale contaminated land</p> <p>5G300 Winfrith contaminated land</p> <p>7A33 AWE Aldermaston contaminated land</p>
ESC-TQ-INF-003.A4	Provide a statement of proposals for the refinement of the future inventory estimate of CI-36 in gas cooled reactor wastes.
ESC-TQ-INF-003.A5	Provide details of the quality assurance arrangements that were applied in correcting data entry errors for C-14 and CI-36 in Wylfa waste streams 9H104 <i>et seq</i> .

LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	16/05/2012
Comment: Responses to the queries will be provided		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	30/07/2012
ESC-TQ-INF-003.A1 Identify the waste stream CL01 referred to in document SERCO/E003756/12 Issue 2; CL01 is not listed in UKRWI 2007. Waste stream CL01 (Contaminated land from Springfields) is identified as a waste stream in WIDRAM09. Whilst the UKRWI is updated only every three years, NDA sites produce re-estimates of forward waste arisings (Waste Accountancy Templates) every year in support of their lifetime plans. These re-estimates are captured by the WIDRAM database to produce a more up-to-date dataset than that represented by the UKRWI. It was the then current version of the WIDRAM database which was used as the basis for the forward inventory calculation.		
ESC-TQ-INF-003.A2 Clarify the statements and volume estimate in paragraph 6.1.4 of document SERCO/E003756/12 Issue 2 relating to the discounting of contaminated land waste from Springfields; neither of waste streams 2E90, 2E191 (waste for Clifton Marsh) equates to 8E+04 m³ that is referred to in the submission. Both 2E90 and 2E91 were identified as waste streams to be routed to Clifton Marsh. On this basis neither stream was included in any case for the forward inventory. Waste stream CL01, however, was not clearly routed to a facility other than LLWR and was included in the Reference Case, but excluded from the case examining the rerouting of contaminated land. The volume associated with stream CL01 is 80,102 m ³ .		
ESC-TQ-INF-003.A3 Confirm whether or not the following waste streams are included in the Reference Case and demonstrate the link to data presented in Level 2 submission: 2E90 General Waste for Clifton Marsh Disposal 2E91 Process Wastes for Clifton Marsh 2E191 Decommissioning Wastes for Clifton Marsh Disposal 5C300 Harwell High Volume Low Activity Waste from Decommissioning and Site Remediation 2Y57 Sellafield Excavated Soil and Putrescible Waste 2X05 Sellafield site clearance LLW 7S01 Defence Estates Contaminated Soil, Ash & Rubble 5F300 Windscale contaminated land 5G300 Winfrith contaminated land 7A33 AWE Aldermaston contaminated land The principles upon which waste streams were included in or excluded from the Reference Case are described in Reference [1]. The table below indicates which of the streams noted in the query were not included in the Reference Case used in all assessment calculations and gives the rationale for their exclusion:		

Stream ID	Included in Reference Case?	Reason for exclusion
2E90	No	Routed to Clifton Marsh in Widram09
2E91	No	Routed to Clifton Marsh in Widram09
2E191	No	Routed to Clifton Marsh in Widram09
5C300	No	Very low activity stream, assumed routed away from LLWR
2Y57	No	Very low activity stream, assumed routed away from LLWR
2X05	Yes	-
7S01	Yes	-
5F300	Yes	-
5G300	No	Not present in WIDRAM09 (the basis for the forward inventory in the 2011 ESC).
7A33	Yes	-

ESC-TQ-INF-003.A4

Provide a statement of proposals for the refinement of the future inventory estimate of CI-36 in gas cooled reactor wastes.

In the current inventory, the majority of CI-36 arises as an activation product in reactor concretes, but a significant proportion is also present in reactor graphites. Uncertainties in the CI-36 inventory in LLW graphite arise in the calculations used to estimate activations because of uncertainties in precursor concentrations. There is also uncertainty about the extent to which CI-36 will have been mobilised in the reactor circuits, which means that activity currently assumed to be present in ILW graphite wastes may have ended up in LLW.

The LLWR is working collaboratively with the NDA's Inventory Manager and RWMD to improve inventory data generally in the UKRWI. We also intend to focus on key radionuclides and wastestreams, including those containing CI-36, by identifying these streams to consignors and discussing with them how significant uncertainties can be reduced. It should be noted, however, that CI-36 mainly arises in final stage decommissioning wastes and hence under current plans these wastes will not be consigned for a number of decades. It is possible that consignors will not consider it a priority to improve data for these wastes.

Separately, the NDA are also undertaking characterisation work on graphite wastes as part of their consideration of the management of these wastes. We intend to review and make use of these data if appropriate.

ESC-TQ-INF-003.A5

Provide details of the quality assurance arrangements that were applied in correcting data entry errors for C-14 and CI-36 in Wylfa waste streams 9H104 et seq.

Data queries were discussed with the waste producer (in this case Magnox). Where the waste producer agreed that a change in the data was appropriate they provided written confirmation of what the revised data should be. This confirmation was retained for record purposes. Only when this confirmation was received were the underlying data in PIER modified to reflect the change. The implementation of changes to data in PIER was independently verified.

REFERENCES

1. A Harper, Forward inventory cases for the 2011 ESC for LLWR, SERCO/TAS/003756/009 Issue 2, April 2011.

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 02/08/2013
Approved by: Environment Agency	Date: 07/11/2013

This Technical Query (TQ) raised a number of queries in relation to the forward inventory, seeking clarification on a number of statements presented within the 2011 ESC.

Action ESC-TQ-INF-003.A1 queried the identity of waste stream CL01. This has been satisfactorily addressed by LLW Repository Ltd.

Action ESC-TQ-INF-003.A2 queried the statements and volume estimates relating to the discounting of contaminated land waste from Springfields. This has been satisfactorily addressed by LLW Repository Ltd.

In Action ESC-TQ-INF-003.A3 we questioned whether or not a number of waste streams had been included within the reference case and asked LLW Repository Ltd to demonstrate the link with the data presented within the Level 2 inventory report of the 2011 ESC. LLW Repository Ltd has satisfactorily addressed our concerns.

In Action ESC-TQ-INF-003.A4 we questioned LLW Repository Ltd's proposed plans for reducing the uncertainty associated with CI-36 within the forward inventory. We note and agree with LLW Repository Ltd that CI-36 is predominantly associated with waste that will not be disposed to the repository for several decades. LLW Repository Ltd indicates that uncertainty around the CI-36 inventory is primarily associated with the release of CI-36 from graphite and its circulation within the reactor coolant circuit. We note that LLW Repository Ltd plans to work with the NDA to improve both the forward inventory as a whole, but also in relation to CI-36. We also note that the company plans to gain a better understanding of the release of CI-36 from graphite as part of the NDA ongoing graphite work. We recommend that LLW Repository Ltd does engage with these development programmes and that the data obtained is used within the ESC to reduce uncertainty within the CI-36 inventory. We expect future iterations of the ESC to include updates of the CI-36 forward inventory and how the data obtained from these studies is being used to reduce uncertainty. We have raised a Forward Issue on this topic (ESC-FI-010).

Action ESC-TQ-INF-003.A5 queried the quality arrangements applied in correcting data entry errors for C-14 and CI-36 for waste stream 9H104. LLW Repository Ltd has addressed this query satisfactorily.

Overall we are satisfied with LLW Repository Ltd's responses to this TQ, subject to the Forward Issue raised above. This TQ can therefore be closed.

Actions completed, Technical Query resolved and Form closed

Owner: Environment Agency	Date: 07/11/2013
Approved by: Environment Agency	Date: 07/11/2013

ESC-TQ-INF-004: Analysis of RECALL interviews

Title	Analysis of RECALL interviews
Date raised	11/01/2012
Acknowledgment required by	03/02/2012
Response required by	29/02/2012
Related issue numbers	ESC-RI-INF-004
Originated by	Environment Agency
Current owner	Environment Agency
Review group	INF
Approved by	Environment Agency

History

Status	Date	Description
Raised	11/01/2012	
Acknowledged	30/01/2012	
LLWR Response	23/02/2012	
Response Assessed	02/08/2013	
Transferred	07/10/2013	
Closed	07/11/2013	

Statement of Technical Query

These Technical Queries (TQs) relate to the analysis of the RECALL Interviews (Serco report TCS/003756/007 Issue 2, 12 April 2011) and associated oral evidence from former Sellafield and LLWR employees documented in Serco report TAS/003756.01/002 Issue 2, 12 April 2011. A number of discrete TQs all relating to RECALL interviews are listed below.

TQ1

Serco staff appear to have drawn conclusions and judgements about historical waste management practices at Sellafield and LLWR. In particular, the report authors make judgements about the likelihood and extent of poor practice in relation to some of the claims by ex-workers (the interviewees). We question whether the report authors have the knowledge and experience of historical custom and practice to make such judgements.

We believe it would have proved useful to seek interviewees' comments on the assessors' reasoning and arguments, or been shown sight of a copy of the analysis report. This would have yielded further useful information to test the credibility of assessors' assumptions and suppositions about historical practices

We note in the analysis that for many of the reported issues the attempts made by the assessors to trace relevant records proved unsuccessful though we are not told how much effort went into the archival research.

Can LLW Repository Ltd explain:

- **why it believes Serco consultants were competent to make judgements about historical waste management practice at Sellafield?**
- **what measures and effort were put into tracing historical records?**

- what plans are in place to elicit interviewees' feedback on the arguments and conclusions drawn by the assessors?

We cannot see evidence that independent (of the LLWR or PBO) scrutiny of the analysis of the RECALL interviews has been undertaken. Can LLW Repository Ltd confirm whether the RECALL analysis has been offered to the Independent Peer Review Group?

TQ2

In addition to the enhancing the knowledge of possible disposals to the trenches we agree that the RECALL exercise provides a valuable oral history⁶² of the site and we are interested to know how this oral history will be preserved or made use of in future.

TQ3

Issue 4 Disposal of wastes arising from clean-up in alpha plants, and

Issue 5: The disposal of lead sandwiches, painter handbags and other methods used to provide a level of shielding for higher activity wastes into building skips.

These issues were raised by a number of interviewees. The report states on page 33: *"there have been long-standing procedures in place for separating highly active and low-level wastes arising from within alpha plants. For example, in the 1980 Health and Safety Regulations [1], the instruction for the disposal of waste arising from cleaning up spillages within alpha plants was that it should be treated as highly active waste unless it has been decontaminated or monitoring has shown that the level of contamination is below the defining limit for higher activity wastes."*

Page 34: *"All waste was segregated at source according to the levels of activity and each plant was aware of the expected activity levels of their wastes and would have had a suitable disposal route identified. Therefore, it is unlikely that there would be many occasions on which an unexpected higher activity waste would be generated."*

Assuming other 'disposal' (read 'accumulation') routes for higher activity wastes were readily available at the time, it doesn't necessarily follow that such routes were enacted. If it was quicker and easier to manage such waste as LLW (for example, less paperwork to fill in) then it is reasonable to assume (given the evidence provided by interviewees in the round) that workers under time pressures or instruction to minimise on-site accumulations, may have routinely used such techniques to dispose of higher activity waste.

We question the extent to which waste management procedures were complied with in the 1960's-80's. Many of the conclusions drawn by the assessors lack of underpinning evidence and are based on speculation and supposition about what they believe should have happened at the time. For issues relating to claimed disposal of HAW (such as Issue 38), the assessors counter the various interviewee claims by stating that staff would have complied with all procedures and that Health Physics monitoring would have detected any abnormalities prior to despatch to LLWR. There is naivety in this supposition. There are currently waste embargos in place on Sellafield Operating Units who have failed to comply with current CfA for LLW treatment and disposal. Consequently, even if the records can be found which indicate low levels of non-compliance, we are not convinced that this would necessarily prove high confidence that non-compliances were rare events (as argued by the report assessors). The limitations of Sellafield's assurance processes have been key regulatory themes arising from our solid waste inspection programme over the last ten years.

We would like to see more evidence for why, historically, as with many contemporary nuclear industry practices the LLWR was not routinely used as the default 'easy option' for disposing of higher activity waste. This could include examples of practical and procedural measures used historically at Sellafield to ensure appropriate waste consignment. This could for example include locking of waste receptacles and training of personnel.

⁶² For example, the 'Sellafield Stories' oral history exhibition recently toured west Cumbria <http://www.whitehavennews.co.uk/news/sellafield-s-history-is-brought-back-to-life-1.869113?referrerPath=news>

TQ4

Issue 3 Disposal of waste into another building's skip without the knowledge of the building

This issue was raised by a number of interviewees. The analysis report states (page 32), *"Disposing of wastes in this way would be a clear breach of waste management procedures for the Sellafield site, with potentially serious consequences for the individual involved. It therefore seems most unlikely that this practice would have occurred with any regularity"* Similar claims are made by the assessors response to Issue 5)"

"...any disposal [into locked skips] by unauthorised personnel would have been a deliberate act on this basis is not likely to have occurred very often since the risk of being discovered was greater"

"it is likely only a very small proportion of the workforce were ever involved in such practices".

Can LLW Repository Ltd provide evidence that 'serious consequences' were ever brought to bear on individuals for breaching waste management procedures at Sellafield or LLWR?

What evidence have the assessors used for assuming this practice was not more widespread, as interviewees suggest?

Has LLW Repository Ltd engaged with Sellafield Ltd HP&S about their records to gauge the frequency and significance of breaches of the CfA?

TQ6

Issue 5: The disposal of lead sandwiches, painter handbags and other methods used to provide a level of shielding for higher activity wastes into building skips.

The analysis states, *"Health Physics routine monitoring did sometimes identify disposals in breach of the CfA (see Issue 42) so this would have served as a deterrent if the disposal practice described here were unauthorised."*

This one example of effective Health Physics monitoring at LLWR (raised by one former employee under Issue 42) is used to suggest that the prospect of Health Physics monitoring was a widespread effective deterrent. It is explicitly used to counter claims regarding issues 3, 5 and 35. This is an example of the tendency to place more confidence in a single piece of information, that is considered representative of a process, than in a larger body of more generalised information (the bias of 'representativeness'). The analysis does not apply the same rules for judging the extent of bad practice even when reported by multiple interviewees. Instead, the assessors argue that such events were untypical rather than the norm.

Can LLW Repository Ltd justify why widespread credit is claimed for small pieces of 'good news' (such as this one example of the deterrent effect of Health Physics monitoring) against the wider body of claims given by interviewees pointing to lax oversight?

Has LLW Repository Ltd engaged with Sellafield HP&S to provide additional evidence of the number and significance of such potential breaches?

The analysis states that *"some, but not all, of the packing materials would have afforded shielding of the tins' activity content; however, the paint tins were used for both LLW and higher activity wastes, including alpha bearing materials"*. The analysis focuses on shielded beta/gamma waste even though the interviewee states that alpha bearing wastes were also disposed by this method.

Why does the analysis of Issue 5 focus on the beta/gamma activity and not comment on the claim that alpha species may also be packaged this way?

TQ7

Issue 6 Disposal of plutonium and americium fused salts and/or plutonium and americium bearing liquids into Trench 2 (30 x 2.5 l Winchester flasks wrapped in lead from B229 laboratories pre-1971).

Within the scoping calculations for this waste stream the 5% scoping value has been used. However it is noted that within the report that this value is used for waste streams that are:

For waste streams already in the inventory of the trenches, does the scoping assessment suggest a change in the assessed content of any key radionuclide, in either direction, in excess of 5% of the total inventory of that radionuclide in the trenches?

From the report it is stated that the waste stream has no clear evidence that it actually existed and that only on the basis of timings has this waste stream been considered as being disposed. However it states clearly:

“Some of the Trench 2 and Trench 3 inventories, because of the timings, could possibly account for the fused salts although they are not mentioned as a key waste-stream [1, 2] and it was not possible to identify the particular disposals in the Inventory.”

What evidence does LLW Repository Ltd have that this waste stream is existent and thus the 5% scoping calculation is appropriate and not the 1% for a new waste streams?

TQ8

Issue 27: All building skips were locked with padlocks, but there were problems associated with missing padlocks and the use of a single key to open all padlocks. This could have led to unrecorded disposals in the skips.

Page 64: *“...it would be highly unlikely that disposing of higher activity items in another building’s skip would occur with any regularity,]*

We suggest that the decision at Sellafield to introduce lockable skips would not have been taken if illicit ‘fly-tipping’ was not proving to be a significant problem. Can LLW Repository Ltd back up this conclusion with any further evidence?

“HP continued monitoring the waste/skips to ensure transport regulations were met and then skips were monitored again at the LLWR site itself. If HP detected any waste above limits, they would instigate a full investigation as to the origin of the waste.”

Can LLW Repository Ltd provide any evidence that Heath Physics detected non-compliant waste and conducted a full investigation for such non-compliances (for the years in question)?

TQ9

Issue 38: Generation and disposal of high activity materials from buildings known to contain a lot of activity e.g. B30.

Page 77, *“Conclusions: It seems highly probable that interviewees were referring to disposals within the limits and as such the activity would have been accounted for under the building’s fingerprint and would be therefore be included in the ‘routine consignment’ fraction of the trenches inventory.”*

The assessors appear to cast doubt on the reliability of the interviewees’ claims. However, the statement from the interviewee is quite clear:

“The Interviewee I-14 knows that some waste from B30 was sent to LLWR that should not have been, and this was done under the instruction of the building supervisors. The building operators would never have sent it to LLWR by themselves. As long as the activity was not higher than allowed by the transport regulations, which might require shielding in lead, then it was considered acceptable to send it to LLWR. I-14 indicated that this was what happened in B30, but suspects it may also have happened in other buildings. “

Can LLW Repository Ltd provide further justification for why it believes the interviewee is mistaken in his recollection?

TQ10

Use of scoping calculations and the 1% and 5% Inventory scales

Within the analysis scoping calculations are used to identify streams which may require further investigation and could have an impact on the inventory of the key radionuclides. The two bands used are for differing classes of waste streams, the first is 1% and this is used for waste streams which have not been included within the inventory but could have an impact on the inventory. The second band is 5% and this scoping value has been used to assess those streams which have

been recorded within the Inventory, but may alter as a result of information obtained from the analysis of interviews.

We agree this is an appropriate method for gauging whether a waste stream has a significant impact on the inventory of the trenches for soluble species but not for insoluble species in the context of coastal erosion and human intrusion scenarios, where concentrations of localised activity (rather than total activity) is the health concern.

We note that each issue (and associated waste stream) is individually analysed and the question arises about the impact on the inventory from several waste streams which together may result in a change in the inventory >1%. For example several interviewees have mentioned potential anomalies with Pu and alpha species, and when assessed separately, these streams do not contribute >1% of the total amount of the radionuclide in question. However, if all the Pu issues were assessed together what would the impact be on the Pu key radionuclide inventory?

We would like to know why LLW Repository Ltd has not assessed the cumulative impact of multiple issues on the inventory for key radionuclides using the same scoping calculations?

Technical Query Actions

ESC-TQ-SCM-003-A1	LLWR to provide answers for all of the technical queries above related to RECALL interviews. Where an answer cannot be provided within the agreed timescale a plan should be developed and agreed with us for the production of a response.
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	30/01/2012
Responses to the questions raised will be provided.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	23/02/2012
<p>TQ1: Can LLW Repository Ltd explain:</p> <ul style="list-style-type: none"> • <i>Why they believe Serco consultants were competent to make judgements about historical waste management practice at Sellafield?</i> • <i>What measures and effort were put into tracing historical records?</i> • <i>What plans are in place to elicit interviewees' feedback on the arguments and conclusions drawn by the assessors?</i> <p><i>We cannot see evidence that independent (of the LLWR or PBO) scrutiny of the analysis of the RECALL interviews has been undertaken. Can LLWR confirm whether the RECALL analysis has been offered to the Independent Peer Review Group?</i></p> <p>The Recall analyses formed part of the inventory improvement project, and were undertaken by SQEP staff under the direct and close supervision of the Serco Project Manager. The work was completed as required by our framework contracts and contracting rules. The Project Manager for the work has over thirty year's experience of the nuclear industry in the UK and Europe. In the early stages of his career, he had extensive experience of undertaking and supervising practical work with radioactive materials. For over a decade he played a leading role in safety and environmental management at the main Radiochemical facility at Harwell, first as Chairman of the Safety Committee, and latterly as principal safety consultant for the building. In these roles he was responsible for the scrutiny of safety cases and for the maintenance of the building's safety management system. For the last 15 years</p>		

he has specialised in issues related to radioactive waste management, and has experience of working with all the nuclear operators in the UK. Using experienced Serco staff had the advantage of ensuring independence in making judgements.

Relevant historical records were sought through direct contact with relevant staff at LLWR and at Sellafield. Where they were unable to source documents directly, they provided advice into obtaining material from archived Sellafield material, although searches for documents known to exist were not always successful. For earlier information, searches were made of material held by the National Archives, and project staff visited Kew to view potentially relevant material. A total of about eight person-weeks were expended on these searches over a period of about four months. Archive searches were not brought to a halt for lack of resource; rather, it was concluded that the expenditure of further effort would be highly unlikely to uncover further useful information.

The reports on the work have been provided to those that participated in the interviews, along with a covering letter, giving them the opportunity to respond. Plans are in place to discuss the results with a small number of those who raised some of the issues highlighted in this IRF.

The contractor reports were reviewed and approved under the ESC Project's procedures, as set out in the Project Execution Plan (which the Environment Agency has). The reports were reviewed by the ESC Task Manager (also the ESC PM in this case) and the ESC Technical Integrator. The evidence is provided by the LLWR sign-off sheets appended to the front of the reports. The detailed Level 3 reports on the RECALL exercise were not passed to the Peer Review Group for review at the time the ESC was being prepared. They have recently been sent to the PRG for review following this TQ.

TQ2

In addition to the enhancing the knowledge of possible disposals to the trenches we agree that the RECALL exercise provides a valuable oral history of the site and we are interested to know how this oral history will be preserved or made use of in future.

The reports and electronic records will be preserved as with the other ESC records – see response to IRF ESC-RO-SCM-004.

TQ3

Issue 4 Disposal of wastes arising from clean-up in alpha plants, and

Issue 5: The disposal of lead sandwiches, painter handbags and other methods used to provide a level of shielding for higher activity wastes into building skips.

We would like to see more evidence for why, historically, as with many contemporary nuclear industry practices the LLWR was not routinely used as the default 'easy option' for disposing of higher activity waste. This could include examples of practical and procedural measures used historically at Sellafield to ensure appropriate waste consignment. This could for example include locking of waste receptacles and training of personnel.

Whilst there is ample evidence of procedural control of LLW waste management at Sellafield, documented in the issues analyses, the point at issue is not whether procedures were ever breached (deliberately or inadvertently). Rather, the question is whether it is credible that such breaches could have been sufficiently extensive to modify the inventory of LLWR materially and thus impact on analyses undertaken as part of the 2011 ESC. The evidence from the assessments is that the inventory of the trenches would have to be substantially modified to materially affect the conclusions drawn in the 2011 ESC. For the reasons outlined in the analyses reported as part of the Recall work, we do not believe such large changes to be credible.

TQ4

Issue 3 Disposal of waste into another building's skip without the knowledge of the building

What evidence have the assessors used for assuming this practice was not more

widespread, as interviewees suggest?

Has LLW Repository Ltd engaged with Sellafield Ltd HP&S about their records to gauge the frequency and significance of breaches of the CfA?

In the context of the LLWR's ESC, the issue here is not whether the practice occurred at all, but whether the practice could have had a material effect on the assessed inventory of the LLWR trenches. For this to be the case, the practice would have had to be not only widespread, but also habitually used to dispose of materials with significant radionuclide inventories.

Examination of the interviewee's comments, as recorded in the report, casts doubt on any assertion that this practice was widespread. Furthermore, there is only a limited suggestion that the practice was used to conceal material unsuitable for disposal at LLWR. Of the six interviewees who raised this issue, two refer to it only as a possibility and two say that it occurred, but suggest that the material so disposed was not in breach of any authorisation. The remaining two interviewees are clear that the practice occurred, but only one of the two makes the suggestion that it was used to conceal material which should not have been consigned to LLWR.

On the basis of the evidence from the interviews, it seems probable that some degree of 'fly tipping' took place. However, the evidence does not suggest that fly tipping was used as a route for the extensive disposal of material which significantly breached the CfA. These considerations, coupled with the comments in the original analysis of Issue 3, indicate that the probability of these practices having a significant effect on the assessed inventory of LLWR is extremely small.

We have engaged with Sellafield on their response to breaches of the CfA, and have established that in a number of significant cases (for example C-14 and H-3 disposals) a full investigation and assessment of consequences took place. Attempts to obtain copies of incident or investigation reports for these and other events raised by interviewees were unsuccessful.

TQ6

Issue 5: The disposal of lead sandwiches, painter handbags and other methods used to provide a level of shielding for higher activity wastes into building skips.

Can LLW Repository Ltd justify why widespread credit is claimed for small pieces of 'good news' (such as this one example of the deterrent effect of Health Physics monitoring) against the wider body of claims given by interviewees pointing to lax oversight?

Has LLW Repository Ltd engaged with Sellafield HP&S to provide additional evidence of the number and significance of such potential breaches?

Why does the analysis of Issue 5 focus on the beta/gamma activity and not comment on the claim that alpha species may also be packaged this way?

Health Physics monitoring does not represent 'a small piece of good news'. Rather, it forms part of a substantial and routine assurance activity aimed at detecting and rectifying inappropriate disposals which may have been made as a result of simple error or oversight or, in exceptional circumstances, as a result of a deliberate attempt to circumvent the CfA for LLWR. This part of the assurance process may occasionally have failed, as all assurance arrangements can, and allowed inappropriate disposals to be made to LLWR. Nevertheless, there is no reason to believe that the arrangements were not generally effective, acting both as a means of intercepting accidental mis-disposals and as a deterrent to any deliberate attempt to flout the rules.

See above in relation to breaches of the CfA.

The only reason for packaging in lead is to provide beta-gamma shielding. It would have been entirely unnecessary for alpha only materials, where the thin walls of a paint can would provide massively more shielding than is required. This suggests the presence of trace quantities of irradiated fuels, which would have beta/gamma emitting fission products associated with them. Under these circumstances, the principal alpha emitter would be

uranium, which is already known to be associated with the trenches in significant quantities.

TQ7

Issue 6 Disposal of plutonium and americium fused salts and/or plutonium and americium bearing liquids into Trench 2 (30 x 2.5 l Winchester flasks wrapped in lead from B229 laboratories pre-1971).

What evidence does LLW Repository Ltd have that this waste stream is existent and thus the 5% scoping calculation is appropriate and not the 1% for a new waste streams?

There is no direct evidence that this waste stream existed. A search of the disposal records over the relevant time frame failed to locate any disposal records which could be matched to a waste stream of this sort. Although the trench inventory is known to contain some Am, which would have been disposed over the relevant timeframe, there is no reason to believe that it arose from the disposal of Am/Pu fused salts.

The choice of 1% and 5% significance levels resulted from a need to meet two distinct requirements. A 5% level was chosen for the scoping calculation on the grounds that any change in inventory smaller than this could have no material impact on any assessments made for the ESC. The 1% level, which applies to *future waste disposals* rather than *new waste streams*, was chosen on the basis that if the waste streams contributing more than this fraction of key radionuclides were assessed in detail, then the nature and quantity of materials in the forward inventory would be well understood.

TQ8

Issue 27: All building skips were locked with padlocks, but there were problems associated with missing padlocks and the use of a single key to open all padlocks. This could have led to unrecorded disposals in the skips.

We suggest that the decision at Sellafield to introduce lockable skips would not have been taken if illicit 'fly-tipping' was not proving to be a significant problem. Can LLW Repository Ltd back up this conclusion with any further evidence?

Can LLW Repository Ltd provide any evidence that Heath Physics detected non-compliant waste and conducted a full investigation for such non-compliances (for the years in question)?

The response to this question is closely linked to that to TQ4. There is no evidence that 'fly tipping' of this sort was a material issue for Sellafield skips. Nevertheless, some measure of control over material introduced to skips (or indeed of material removed from skips) would form part of any effective assurance arrangement, and simply represents the implementation of good practice.

See above in relation to investigating non-compliances.

TQ9

Issue 38: Generation and disposal of high activity materials from buildings known to contain a lot of activity e.g. B30.

Can LLW Repository Ltd provide further justification for why it believes the interviewee is mistaken in his recollection?

As noted in the analysis of Issue 38, the limit given in the authorisation was 20 mCi m^{-3} of waste averaged over one day's tipping, which was given effect by an operational control of $10^{-4} \mu\text{Ci m}^{-2}$ of waste disposed. It is acknowledged that the operational limit was occasionally overridden, provided that a justification could be produced that the limit given in the authorisation would be complied with.

Operational staff will have equated 'Drigg limits' with the operational limits that they were charged with enforcing. However, as noted above, breach of these operational limits did not, if appropriately justified, constitute a breach in the authorisation. We believe that this is likely to be the origin of statements to the effect that 'Drigg limits' were regularly breached at the behest of management.

It should also be remembered that, in the present context, even breaches of the authorisation limits would be of significance for the ESC only if they modified the inventory of LLWR in a way which materially affected safety arguments. As already noted, it is highly improbable, given the circumstances, that this could be the case.

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 02/08/2013
Approved by: Environment Agency	Date: 07/11/2013

This Technical Query (TQ) addresses a number of queries with regards to the RECALL interviews undertaken by LLW Repository Ltd. In particular the information presented within the Level 3 reports (Refs 1,2), which cover the actual interviews and an analysis of the responses.

TQ1 has been addressed by LLW Repository Ltd highlighting the SQEPness (Suitably Qualified and Experienced Persons) of the project manager, who was leading the task for Serco. It has also highlighted the man hours spent targeting specific information to aid with the RECALL exercise and LLW Repository Ltd's interaction with personnel from Sellafield Ltd. We note that the Independent Peer Review Group did not review these documents and thus no independent scrutiny had been applied to the process before submission of the 2011 ESC. We raised our concerns about this and note the documents were subsequently provided to the Peer Review Group for assessment. We are content LLW Repository Ltd has addressed our queries within this action.

TQ2 has been adequately addressed and we are content with the response. We noted the importance of such an exercise and thus sought assurance from LLW Repository Ltd that the relevant records would be maintained for future use. We note that the company plans to maintain the interviews as records for future reference.

TQ3 and TQ4 are queries based around the practice of 'fly tipping' of higher active items into skips and the shielding of such items to facilitate their disposal via the LLW route. We note that for both questions LLW Repository Ltd accepts that such practises may have occurred, but states that there is limited evidence that these practices were at all widespread and thus would not significantly impact on the overall inventory and assessment of the safety of the LLWR. We are content that LLW Repository Ltd has adequately addressed our query, but note that these issues may have wider implications as a result of coastal erosion and/or human intrusion into the site in the future, which could bring such 'higher active items' to the surface⁶³. This TQ focuses on the impact of the findings noted within the RECALL exercise on the overall inventory. Issues associated with the wider implications of such disposals on impacts associated with coastal erosion and human intrusion scenarios are addressed in our technical assessment report (see Ref 4).

TQ6 has partly been addressed within our response to TQ3 and TQ4. We believe the overall response by LLW Repository Ltd adequately addresses our queries. We note and agree with LLW Repository Ltd that Health Physics monitoring acts as an important assurance process contributing towards ensuring inappropriate disposals are not made. As with any assurance process they can

⁶³ Current waste disposal practices may also lead to some 'higher activity items' within the waste. Within the current disposal permit waste must meet the LLW activity limits when averaged over a consignment. Other guidance exists that seeks to ensure that higher activity items are not deliberately 'diluted' within lower activity wastes as a means of disposal unless justified. None the less, it is accepted that some individual items of waste within disposals may exceed LLW activity limits themselves. However, LLW Repository Ltd has included new controls on higher activity particles and discrete items in the latest version of its waste acceptance criteria (Ref 3).

at times fail, leading to the risk that higher activity items are present in the disposed waste – this issue was addressed in the response to TQ3 and TQ4.

LLW Repository Ltd states that the shielding of waste via this approach would only be undertaken for gamma emitters. We do not dispute this, however, we note that within the RECALL exercise, it is stated that alpha emitters can be shielded using the same methods. We note that this could be the result of alpha emitting waste being associated with beta/gamma emitting waste.

TQ7 has been adequately responded to by LLW Repository Ltd. It is noted that there is no record of the disposal of Pu/Am salts referred to; however, it remains a possibility that such disposals were made and not reported in contravention of WAC. The potential issues associated with such disposals are primarily covered by our statements within TQs 3, 4 and 6, that these are unlikely to affect the overall inventory, but will be present a potential risk if the repository is subject to coastal erosion.

TQ8 has been adequately responded to by LLW Repository Ltd. We note that there is no evidence that 'fly tipping' was a material issue at Sellafield and that the locking of skips represents good practice as part of effective waste management arrangements. However, we do note that this issue was identified in the RECALL interviews by several interviewees and thus there is the potential that items will have been disposed via this route. Our response to TQ3 and 4 also covers this query.

TQ9 has been adequately responded to by LLW Repository Ltd who provides its reasons for believing a mistaken recollection is reported. LLW Repository Ltd argues that whether or not ESC limits or operational limits were breached on occasion, this would only be of significance to the ESC if they modified the inventory of LLWR in a way that materially affected the arguments. In many cases it may be true that there would be no overall influence on the case, however, there is a possibility that disposals above the limits could have been due to higher activity single items, which could potentially have a material effect on the current ESC following coastal erosion or human intrusion into the site. These issues will be discussed further within our technical review reports.

TQ10 was not answered by LLW Repository Ltd. However, we do not at this stage expect this query to have a significant impact on the overall trench inventory. We will seek reassurance, going forward, that this will indeed be the case. Thus we recommend that LLW Repository Ltd assesses the impact of combined key radionuclide waste streams (for example, Pu waste streams) and their potential to impact on the overall inventory, as outlined in our query (see Recommendation INF4 of Ref 5).

LLW Repository Ltd has satisfactorily addressed the majority of our questions raised within this TQ. The RECALL exercise has been able to identify a number of areas where the actual trench inventory may not be fully aligned with that recorded. However, it is also evident that it would not be easy to begin to quantify these differences, pointing to the need for these uncertainties to be adequately addressed within the assessments of impacts. We have addressed these issues within our wider assessment of the 2011 ESC and will discuss them within our technical review reports. We also note that the further work undertaken by LLW Repository Ltd on particles and discrete items gives us a degree of confidence that the risk associated with such disposals has been appropriately characterised (see Ref 4). However, we expect LLW Repository Ltd to use all knowledge available to it to assess the potential impacts of higher activity discrete items, potentially located within the historical disposals to the trenches. This Technical Query can be closed, noting that it raises a number of related issues that must be considered elsewhere within the ESC assessment.

References

1. Hickford G. and Smith V., RECALL Interviews, Serco Report SERCO/TAS/003756.01/002 Issue 2, April 2011.
2. Dickinson M and Smith V., Analysis of Issues Raised in RECALL Interviews; Serco Report SERCO/TCS/003756/007 Issue 2, April 2011.
3. LLW Repository Ltd., 2014. Waste Services Contract. Waste Acceptance Criteria - Low Level Waste Disposal. LLW Repository Ltd Report WSC-WAC-LOW - Version 4.0 - March 2014.
4. Environment Agency, 2015. Review of LLW Repository Ltd's 2011 Environmental Safety Case: Assessments.

5. Environment Agency, 2015. Review of LLW Repository Ltd's 2011 Environmental Safety Case: Inventory and near field.

Actions completed, Technical Query resolved and Form closed

Owner: Environment Agency	Date: 07/11/2013
Approved by: Environment Agency	Date: 07/11/2013

ESC-TQ-INF-005: MoD waste streams

Title	MoD waste streams
Date raised	03/02/2012
Acknowledgment required by	10/02/2012
Response required by	02/03/2012
Related issue numbers	ESC-RI-INF-005
Originated by	Environment Agency
Current owner	Environment Agency
Review group	INF
Approved by	Environment Agency

History

Status	Date	Description
Raised	26/01/2012	
Acknowledged	06/02/2012	
LLWR Response	16/03/2012	
Response Assessed	30/05/2012	
Transferred	07/11/2013	
Closed	12/11/2013	

Statement of Technical Query

There are uncertainties surrounding how LLW Repository Ltd has taken account of certain MoD waste streams reported in the National Inventory. During the liaison meeting of 19 January 2012 we queried why stocks and volumes for 7S01 are much reduced in the 2010 Inventory (stocks of ~38.7 m³) compared with the 2007 Inventory (stocks of ~241 m³). LLW Repository Ltd suggested this may be due to a reassessment by MoD/Defence Estates. We also queried whether waste from the clean-up of Dalgety Bay was included in 7S01.

Information presented in Serco report 'Improvements to the radionuclide inventory of LLWR' (SERCO/TAS/003756/010 Issue 1, April 2011) discusses waste stream 7S01 and quotes the revised 2010 Inventory figure of 38.7 m³. Section 5.4.14 states, "*recent information received from Defence Estates [47] indicates that wastes from this stream have been disposed to LLWR since 2007.*" This statement seems to suggest the difference in reported volumes between 2007 and 2010 (~202 m³) may have been consigned to Vault 8. However, information we received from the Inventory contractor Pöyry Energy Limited (attached) implies this reduction may have more to do with the MoD sale of RAF Quedgley (effectively contributing 177 m³ to 7S01 but now removed from the inventory of this stream).

TQ 1 LLW Repository Ltd to report on the amount (volumes and activities) of 7S01-origin wastes (including numbers of ISOs) consigned to LLWR (in particular, since 1.4.2007) and also describe what consideration is made in the forward LLWR inventory for remediation of radium contaminated sites formerly owned by MoD, such as RAF Quedgley.

RWMAC's June 2000 report to Ministers on MoD's contaminated land describes a number of former MoD sites which either were, or were in the process of, being remediated. These include:

- RAF Carlisle
- Ditton Park Compass Observatory

- Army Base Repair Organisation (ABRO) Stirling Forthside
- Eaglecliffe Royal Navy Supply Depot
- ABRO Aldershot and Royal Electrical and Mechanical Engineers (REME) Aldershot

LLWR (Drigg) is cited by RWMAC as the disposal route for a number of these sites with various volumes or tonnages reported. Additional resources in the public domain are also available. For example, “*Remediation of Radium Contaminated Land at a Former Admiralty Research Centre*”, Nukem Ltd, WM’04 Conference, February 29-March 4, 2004, Tucson⁶⁴, which states 100 tonnes of waste from Ditton Park was consigned to LLWR.

Various ESC Inventory documents discuss the significance of the presence of Ra-226 in the trenches (principally from Thorium Ltd) but there is no discussion of the source or significance of any Ra-226 contaminated land consignments to Vault 8.

TQ2: LLW Repository Ltd to report on what records it holds (on volumes and activities) relating to disposal consignments from former MoD sites in the RWMAC study (listed above).

In relation to 7S01, the Serco report also states (5.4.14):

“Current stocks are estimated to be just 38.7 m³ and the level of contamination of wastes consigned to LLWR is typically 10-30 Bq/g. Given a revised density of 1.88 te/m³, this specific activity corresponds to 19-56 MBq/m³, two orders of magnitude lower than the 2007 RWI figure. Based on these figures, a revised estimate for future arisings would be 0.7-2.2 GBq. However, it is also understood that there are no plans to change the specific activity figure for the 2010 RWI. Whether this represents a cautious upper estimate or the presence of higher activity items that are segregated from the bulk soil prior to its disposal as LLW, is unclear.”...“Overall, it appears that the future Ra-226 arisings from 7S01 have been over-estimated”...“it seems possible that total Ra-226 arisings from 7S01 may be reduced by two to three orders of magnitude compared to the best estimate value”

We question the robustness of this analysis. Firstly, there are no reported future arisings for 7S01 wastes in the 2010 Inventory (unlike the 2007 Inventory). L LLW Repository Ltd appears to have taken this statement at face value without examination of the caveats in the ‘commentary on volumes’ for the 2010 WSDS, where Defence Estates state they are, “*not in a position to predict either future arisings or the rate of production with certainty*”. This does not mean there will be no future arisings, just that they have not been estimated.

Secondly, Defence Estates’ Ra-226 activity concentrations are based on an “assumed average 20 Bq/g”. The activity range quoted above (10 - 30 Bq/g) corresponds to the “AA” uncertainty band recorded in both the 2007 and 2010 Inventories (+/- 50%). The Inventory Code for 7S01 is “2” - a ‘derived activity’ best estimate - not a measured activity. Given that average specific activity appears to have fallen from 8E-3 TBq/m³ in 2007 to 4.9E-5 TBq/m³ in 2010, the 2007 assignment of uncertainty bands AA appears overconfident (in hindsight). The revised activity concentration has fallen by over 150%, suggesting an uncertainty band between D and E (a factor of 100 - 1000) would have been more appropriate in 2007. Consequently, we question the confidence that can be attached to bands AA in the 2010 estimate.

Thirdly, 7S01 includes Dalegty Bay. The reliability of Defence Estates’ activity concentration estimates can be assessed by looking at calculations presented to Poyry for Dalgety Bay. The assumed “20 Bq/g” activity concentration has been used by Defence Estates to estimate the total activity at Dalgety Bay at some 14.4 MBq. Yet we know from SEPA’s monitoring results that individual items recovered from the foreshore exceed or are comparable with this estimated total for the site (for example, the 76 MBq single item recovered in November 2011 and a 13 MBq item recovered in October 2011). A proportion of this measured activity can be attributed to Ra-226 (with the rest to its progeny) but it suggests that Defence Estates’ assumed activity concentrations may be substantially underestimated and this has implications for the other MoD contaminated land sites.

⁶⁴ <http://www.wmsym.org/archives/2004/pdfs/4471.pdf>

The Serco reports states (5.4.14), “there are clearly uncertainties concerning the stock activity, the effectiveness of segregation processes, and the potential for future arisings from sites yet to be located. Therefore, further clarification on the position with this stream is required from Defence Estates to enable a more comprehensive assessment.”

TQ3 LLW Repository Ltd to comment on the observations above and update us on the outcome of LLWR engagement with Defence Estates.

7N03 Defence Storage and Distribution Agency Donnington Miscellaneous LLW

The 2007 Inventory WSDS for this MoD stream gives a figure for future arisings of 23 m³ (note 2010 Inventory, stocks are given as 20 m³ with future arisings of 80 m³) for wastes described as “scrap luminised dials, gauges, compasses, signs, mostly luminised with radium 226 or tritium. Thoriated engine parts and thoriated optical lenses”. However, no activity estimates are provided (recorded as Not Estimated) yet the WSDS indicates the waste is destined for disposal at LLWR.

TQ4 LLW Repository Ltd to clarify how waste stream 7N03 arisings (volumes and activities) have been addressed in the ESC and how much (if any) has already been disposed to LLWR.

7J25 – Low Level Luminised Waste sent to LLWR

The 2007 Inventory WSDS for this MoD stream gives a stocks figure of 6 m³ and future arisings of 17.4 m³ (note 2010 Inventory - stocks are 8.4 m³ and future arisings 15 m³) for wastes described as “Luminised scrap/unserviceable MOD stores items and other radioactive items from the de-equipping of ships, together with smaller quantities (annually <1m³) from the MOD Institute of Naval Medicine Alverstoke.”. Activity estimates are provided.

TQ5 LLW Repository Ltd to clarify how waste stream 7J25 arisings (volumes and activities) have been addressed in the ESC and how much (if any) has already been disposed to LLWR.

Technical Query Actions

ESC-TQ-SCM-00X-A1	LLWR to provide responses to TQ1 -5 detailed above. Where an answer cannot be provided within the agreed timescale a plan should be developed and agreed with us for the production of a response.
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	06/02/2012
Responses will be provided on the queries raised.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	16/03/2012
<p>TQ 1 LLW Repository Ltd to report on the amount (volumes and activities) of 7S01-origin wastes (including numbers of ISOs) consigned to LLWR (in particular, since 1.4.2007) and also describe what consideration is made in the forward LLWR inventory for remediation of radium contaminated sites <u>formerly</u> owned by MoD, such as RAF Quedgley.</p> <p>The advice we received from the MoD in July 2010 at the time we were finalising the inventory for the 2011 ESC was that the waste volume and activity in waste stream 7S01 had significantly decreased in the 2010 UKRWI from the 2007 UKRWI. We were told that: ‘The 2010 inventory ... reflects a combination of the result of contaminated soil previously identified in the 2007 inventory having been consigned to the LLWR and the refinement of volume estimates based on the most recent survey results for sites where Radium-226 has</p>		

been identified. We believed that the main source of the decrease was the 'refinement', rather than the disposal. We were not told that much of the reduction was due to a site changing ownership. We were also asked not to directly reference the information provided until the 2010 UKRWI was published. There are no explicit records of wastes from 7S01 being disposed to the LLWR since April 2007.

Waste from formally owned sites should in principle be accounted for in the 'Minor Users' wastestream. This waste stream is estimated based on previous disposals and not on returns from waste consignors. The waste stream should also include radium wastes from sites other than former MoD sites. The Minor Users waste stream is not intended to include large volumes of NORM from, for example, the oil industry and this source is excluded from consideration in the 2011 ESC.

Our conclusion, based on a consideration of 7S01 and Minor Users waste streams, is that the future inventory of Ra-226 is uncertain and improving estimates would be difficult, hence the focus should be on deriving robust Waste Acceptance Criteria and total radiological capacity limits and applying these controls.

TQ2: LLW Repository Ltd to report on what records it holds (on volumes and activities) relating to disposal consignments from former MoD sites in the RWMAC study (listed above).

LLWR holds consignment information forms for wastes from:

- RAF Carlisle – consignor Cumbria Contracting Services
- Ditton Park – consignor Rainbow Cottage
- ABRO – consignor Forthside Depot (MoD)
- Eaglecliffe Royal Navy Supply Depot

The forms contain the volumetric, weight, activity and material composition data for the disposals. For the first three sites, the forms state that the disposals are complete and that 14.6 m³ of waste in total was disposed containing 142 MBq Ra-226. The LLWR also has received four consignments of waste from the Eaglecliffe Royal Navy Supply Depot, but the relevant consignment forms are in archive.

LLWR has not received any waste attributed to the ABRO Aldershot site.

TQ3 LLW Repository Ltd to comment on the observations above and update us on the outcome of LLWR engagement with Defence Estates.

In relation to the uncertainties, see response to TQ1 above. The information published in the 2010 UKRWI was consistent with that provided by MoD while the inventory for the 2011 ESC was being prepared and we have had no further engagement with MoD.

TQ4 LLWR to clarify how waste stream 7N03 arisings (volumes and activities) have been addressed in the ESC and how much (if any) has already been disposed to LLWR.

LLWR have received no consignments of this waste stream to date. This waste stream is included in the future inventory as an orphan waste stream, which would suggest no disposal route is identified.

The inventory for the 2011 ESC included all (but one) orphan LLW streams and hence 7N03 was included and accounted for in the assessment calculations, however, no activity is associated with this waste stream in the UKRWI. The stream comprises 22m³ of mixed waste. Arisings are nominally assumed to be: 1m³ each year between 2008 (no stock reported) and 2019, 0.5m³ a year between 2020 and 2029, and 0.25m³ a year between 2030 and 2049.

TQ5 LLW Repository Ltd to clarify how waste stream 7J25 arisings (volumes and activities) have been addressed in the ESC and how much (if any) has already been disposed to LLWR.

LLWR have received one consignment of 7J25 waste, in 2001, which contained 81.7% (by weight) of the waste stream and had a volume of 18m³. The consignment form shows 209

MBq of Ra-226 disposed.

In the future inventory, 7J25 has a volume of 22.6m³. There is 6.0m³ recorded as 'stock' and arisings recorded as 0.8m³ a year to be disposed between 2008 and 2019, 0.3m³ a year to be disposed between 2020 and 2029, 0.2m³ year to be disposed between 2030 and 2039 and 0.1m³ a year to be disposed between 2040 and 2059. It contains 226 MBq of Ra-226.

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 30/05/2012
Approved by: Environment Agency	Date: 30/05/2012

We consider that TQ3, 4 and 5 have been adequately addressed by LLW Repository Ltd and can be closed. However, we believe further points relating to TQ1 and 2 need to be addressed. These are included in a further Technical Query (TQ), ESC-TQ-INF-005A. Our full response is recorded within that TQ.

Actions completed, Technical Query resolved and Form closed

Owner: Environment Agency	Date: 12/11/2013
Approved by: Environment Agency	Date: 12/11/2013

ESC-TQ-INF-005a: Response to MoD waste streams

Content

Title	Reply to LLWR's response to ESC-TQ-INF-005 MoD waste streams
Date raised	30/05/2012
Acknowledgment required by	07/06/2012
Response required by	29/06/2012
Related issue numbers	ESC-TQ-INF-005
Originated by	Environment Agency
Current owner	Environment Agency
Review group	INF
Approved by	Environment Agency

History

Status	Date	Description
Raised	30/05/2012	
Acknowledged	01/06/2012	
LLWR Response	26/10/2012	
Response Assessed	10/09/2013	
Transferred	12/09/2013	
Closed	12/11/2013	

Statement of Technical Query

This TQ specifically relates to our response to and interpretation of information submitted by LLWR to ESC-TQ-INF-005. This TQ should be read in conjunction with ESC-TQ-INF-005. It is presented as a discrete TQ for clarity. For quality assurance purposes, this should be considered as one TQ.

Original Technical Query

TQ 1 LLW Repository Ltd to report on the amount (volumes and activities) of 7S01-origin wastes (including numbers of ISOs) consigned to LLWR (in particular, since 1.4.2007) and also describe what consideration is made in the forward LLWR inventory for remediation of radium contaminated sites formerly owned by MoD, such as RAF Quedgley.

LLW Repository Ltd's response to TQ 1

The advice we received from the MoD in July 2010 at the time we were finalising the inventory for the 2011 ESC was that the waste volume and activity in waste stream 7S01 had significantly decreased in the 2010 UKRWI from the 2007 UKRWI. We were told that: '*The 2010 inventory ... reflects a combination of the result of contaminated soil previously identified in the 2007 inventory having been consigned to the LLWR and the refinement of volume estimates based on the most recent survey results for sites where Radium-226 has been identified.*' We believed that the main source of the decrease was the 'refinement', rather than the disposal. We were not told that much of the reduction was due to a site changing ownership. We were also asked not to directly reference the information provided until the 2010 UKRWI was published. There are no explicit records of wastes from 7S01 being disposed to the LLWR since April 2007.

Waste from formally owned sites should in principle be accounted for in the 'Minor Users' waste stream. This waste stream is estimated based on previous disposals and not on returns from

waste consignors. The waste stream should also include radium wastes from sites other than former MoD sites. The Minor Users waste stream is not intended to include large volumes of NORM from, for example, the oil industry and this source is excluded from consideration in the 2011 ESC.

Our conclusion, based on a consideration of 7S01 and Minor Users waste streams, is that the future inventory of Ra-226 is uncertain and improving estimates would be difficult, hence the focus should be on deriving robust Waste Acceptance Criteria and total radiological capacity limits and applying these controls.

TQ2: LLW Repository Ltd to report on what records it holds (on volumes and activities) relating to disposal consignments from former MoD sites in the RWMAC study (listed above).

LLW Repository Ltd's response to TQ 2

LLWR holds consignment information forms for wastes from:

- RAF Carlisle – consignor Cumbria Contracting Services
- Ditton Park – consignor Rainbow Cottage
- ABRO – consignor Forthside Depot (MoD)
- Eaglecliffe Royal Navy Supply Depot

The forms contain the volumetric, weight, activity and material composition data for the disposals. For the first three sites, the forms state that the disposals are complete and that 14.6 m³ of waste in total was disposed containing 142 MBq Ra-226. The LLWR also has received four consignments of waste from the Eaglecliffe Royal Navy Supply Depot, but the relevant consignment forms are in archive.

LLWR has not received any waste attributed to the ABRO Aldershot site.

Environment Agency Assessment of LLW Repository Ltd Response

Because of the potential significance of these waste streams in the ESC, we also wish to assure ourselves that LLWR can account for what is already in Vault 8. Waste stream 7S01 is an example of a waste stream which has is likely to contain discrete high activity particles, we therefore chose to explore it in this TQ.

We still seek clarification to our original TQ 1. In the first instance we would like to understand the approximate number of ISO containers in Vault 8 that relate to consignments from all historical MoD sites covered under waste stream 7S01.

If possible for the three former MoD sites with consignments totalling 14.6m³ (from RAF Carlisle, Ditton Park and ABRO Forthside) we request a breakdown of waste volumes derived from each site and the number of ISO containers which have these waste stream in them.

Because of the potential presence of large numbers of burnt humanised aircraft dials (according to the 2000 RWMAC study⁶⁵), we also seek clarification of waste volumes, activities and number of ISO containers attributable to consignments from the Eaglecliff Royal Navy Supply Depot . We recognise that some of this information may be archived and therefore can extend our deadlines accordingly.

We would like to understand the contradiction between a claim that is made that, “*LLWR has not received any waste attributed to the ABRO Aldershot site*” and information from the RWMAC study states that some 60 m³ of waste was disposed to Drigg from the adjacent Royal Engineer (REME) site at Aldershot. Please can you clarify if these waste streams are the same?

⁶⁵ Advice to Ministers on The Ministry of Defence's Arrangements for Dealing with Radioactively Contaminated Land, RWMAC 14 June 2000.

Technical Query Actions

ESC-TQ-SCM-005A-A1	Please address the outputs of our assessment of your response to ESC-TQ-INF-005.
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	01/06/2012
A response will be submitted that provides further information on the disposal of MoD wastes into Vault 8.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	26/10/2012						
<p>We still seek clarification to our original TQ 1. In the first instance we would like to understand the approximate number of ISO containers in Vault 8 that relate to consignments from all historical MoD sites covered under waste stream 7S01.</p> <p>As noted in our response to the original TQ, we have no records of any waste being consigned to the LLWR under waste stream 7S01. It seems that this waste stream is used to record wastes that may arise in the future (the materials are labelled as 'stocks', but it is clear that at least some of this waste is still in the form of unremediated contaminated land).</p> <p>In order to answer this TQ we have taken an alternative approach to that for the original TQ to identifying disposals from MOD or ex-MOD sites. Rather than look for data using specific site names, we interrogated the WTS to output all consignments, both directly consigned to LLWR and also through WAMAC, that had a radium content. From this list we then excluded consignments from Sellafield, Magnox, RSRL, Springfields and GE Healthcare, to leave a list of MOD consignments and 'others'. Data on these remaining disposals are provided below, broken down into disposals made directly to LLWR and via WAMAC.</p> <p><u>Direct disposals</u></p> <p>We identified 11 consignors that we are sure are MOD or former MOD sites.</p> <ul style="list-style-type: none"> • AWE ALDERMASTON • DITTON MANOR PARK (MOD) • FORTHSIDE DEPOT (MOD) • HM NAVAL BASE : PORTSMOUTH • INGLIS BARRACKS MILL HILL ex MoD • LEA REME WOOLWICH • LOGISTIC EXECUTIVE (ARMY) • RAF CARLISLE • REME & ABRO ALDERSHOT • RNSD EAGLESCLIFFE • ROWCROFT BARRACKS (MOD) <p>These 11 sites have sent a total of 53 consignments direct to the repository, containing a total of 14.2 GBq of Ra-226. The following table shows the number of consignments and the total Ra-226 activity by site.</p> <table border="1"> <thead> <tr> <th>Site</th> <th># Consignments</th> <th>Total Ra-226 Activity (MBq)</th> </tr> </thead> <tbody> <tr> <td>AWE Aldermaston</td> <td>8</td> <td>16.403</td> </tr> </tbody> </table>			Site	# Consignments	Total Ra-226 Activity (MBq)	AWE Aldermaston	8	16.403
Site	# Consignments	Total Ra-226 Activity (MBq)						
AWE Aldermaston	8	16.403						

Ditton Manor Park	3	1800.00
Forthside Depot	2	200.946
HM Naval Base: Portsmouth	1	208.840
Inglis Barracks Mill Hill	1	120.240
LEA REME Woolwich	1	267.00
Logistics Executive	6	1359.900
RAF Carlisle	25	8713.734
REME&ABRO Aldershot	1	163.293
RNSD Eaglescliffe	4	1148.190
Rowcroft Barracks	1	196.920

Some consignments have a waste description recorded on the consignment form. These descriptions suggest that some of these consignments do not originate from contaminated land clean up as they are described as metal or wood or have a 0% soil component, although redundant buildings producing non-soil wastes might also be a source of radium particulate.

There were 88 other consignments, containing a total of 15.3 GBq of Ra-226. Many of these are very likely not to be from former MOD or related sites, for example, consignors included BP International and Brent Spar, where the wastes are likely to be NORM from the oil industry. On the other hand, Smith Aerospace Land Remediation (one consignment containing 440 MBq Ra-226, described as predominantly soil and concrete and also containing Pb-210 and Po-210) may well have consigned contaminated land from a MOD site or a related manufacturing site.

Disposals via WAMAC.

We have identified 14 consignors to WAMAC that we believe are MOD or ex-MOD sites or who consigned wastes from such sites. These consignors sent a total of 17 consignments through WAMAC to LLWR. These disposals have a total activity of 695MBq of Ra-226. Information on the sites' consignments is given in the table below. Given the timing of the consignments, it is likely that the individual consignments were sent to the LLWR in separate ISOs.

Site	# Consignments	Container type	Gross weight	Total Ra-226 Activity (MBq)
MoD ex RAF Llanbedr	1	Loose drums	320	5.3
AWE Aldermaston	2	2912	15578	5.879
OSU Burscough	1	Loose drums	260	3.34
Ditton Manor Park	3	2044 and loose drums	16783	554.84
LEA REME Woolwich	1	2912	1025	13.5
Inglis Barracks Mill Hill	1	Loose drums	1645	14.5
Priddy's Hard	1	Loose drums	3701	17.65

RAF Quedgeley	1	Loose drums	1043	7.99
RAF Carlisle	1	2896	6990	33.18
Rainbow Cottage	1	Loose drums	1960	14.97
Albacom Ltd via RWE Nukem	1	Loose drums	2370	19.0
Cumbria Contracting Services	1	Loose drums	120	2.005
RAF Kinloss (EntecUK)	1	Loose drums	93.5	1.62
<i>Vertase FLI (MoD ex Llanbedr)</i>	<i>1</i>	<i>Loose drums</i>	<i>102.8</i>	<i>0.82</i>

There were 28 'other' consignments to WAMAC, containing 2.5 GBq of Ra-226.

If possible for the three former MoD sites with consignments totalling 14.6m³ (from RAF Carlisle, Ditton Park and ABRO Forthside) we request a breakdown of waste volumes derived from each site and the number of ISO containers which have these waste stream in them. We also seek clarification of waste volumes, activities and number of ISO containers attributable to consignments from the Eaglecliff Royal Navy Supply Depot.

Using the approach discussed above of starting with all the Ra-226 disposals and filtering, we have identified some additional consignments that the original search query did not. The following tables give the numbers of consignments and total activities from each of the four sites, either sent directly or via WAMAC.

Direct Disposals

Site	# Consignments	Total Ra-226 Activity (MBq)
RAF Carlisle	25	8713.734
Ditton Manor Park	3	1800.00
ABRO (Forthside Depot)	2	200.946
<i>RNSD Eaglecliff</i>	<i>4</i>	<i>1148.190</i>

WAMAC disposals.

Site	# Consignments	Total Ra-226 Activity (MBq)
RAF Carlisle	2	35.19
Ditton Manor Park	4	569.81
ABRO (Forthside Depot)	-	-
<i>RNSD Eaglecliff</i>	<i>-</i>	<i>-</i>

As reported in the reply to the original TQ, wastes from two of the MOD sites were sent to LLWR by other consignors. Cumbria Contracting Services consigned waste from RAF Carlisle and Rainbow Cottage consigned waste that originated at Ditton Park. The data given in the above table includes both sources of consignments.

Again, the waste descriptions suggest not all the consignments recorded in the above tables were contaminated land.

We would like to understand the contradiction between a claim that is made that, “LLWR has not received any waste attributed to the ABRO Aldershot site” and information from the RWMAC study states that some 60 m³ of waste was disposed to Drigg from the adjacent Royal Engineer (REME) site at Aldershot. Please can you clarify if these waste streams are the same?

We believe that the Royal Engineer (REME) site is a separate site to the ABRO site at Aldershot. LLWR have not received any consignments recorded to be only from the ABRO site. We have identified a consignment from the MOD originating from “REME & ABRO Aldershot”. This was made in March 2002, after the 2000 RWMAC report suggests waste had been consigned. The consignment is recorded to have contained “soil contaminated with radium and progeny from the incineration of luminising waste”, with an activity of Ra-226 of 163.3MBq. That the waste came in a single consignment suggests that the volume was less than 60 m³. The RWMAC report and the WTS records produced by the interrogation are inconsistent, unless the waste identified in the RWMAC report was sent by one of the ‘other’ consignors; however, none of the dates and waste volumes for consignments from the other consignors appear consistent with the information in the RWMAC report. This suggests that if the RWMAC report is accurate and the wastes were consigned to the LLWR, they must be recorded in the WTS not using the site name or listed as containing Ra-226.

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 12/09/2013
Approved by: Environment Agency	Date: 12/11/2013

We raised this Technical Query (TQ) as result of our review and interrogation of waste streams containing radium (Ra). Our review of the 2011 ESC identified that waste streams containing Ra may generate long lived particulate materials which may present a risk following coastal erosion or human intrusion into the waste. It is therefore important the nature and significance of these waste streams are fully understood both in support of the ESC and for forward implementation.

TQ ESC-TQ-INF-005 was not fully addressed by LLW Repository Ltd, in particular in relation to the volumes and activity of the MoD radium containing waste streams disposed to Vault 8. This resulted in a further TQ, ESC-TQ-INF-005A, being raised, asking LLW Repository Ltd to provide us with this detailed information.

LLW Repository Ltd has satisfactorily addressed our queries within its response to ESC-TQ-INF-005A. However, we note that generally there appears to be difficulties in abstracting precise information about certain disposals. For example, the identification of ABRO Aldershot wastes disposed to the vault and the conflicting numbers of consignments disposed from RAF Carlisle. Neither will impact on the ESC, however, we note that there is potential room for improvement in the capability to abstract information from the Waste Tracking System Database for defined disposals from specific sites. We expect that, as part of its forward program, LLW Repository Ltd continues to develop the capabilities of its waste tracking/database systems to facilitate improved information management and accessibility (see Forward Issue ESC-FI-020).

We consider both ESC-TQ-INF-005 and ESC-TQ-INF-005A have been adequately addressed and therefore can be closed.

Actions completed, Technical Query resolved and Form closed

Owner: Environment Agency	Date: 12/11/2013
Approved by: Environment Agency	Date: 12/11/2013

ESC-TQ-INF-006: Ratio of waste to grout infill

Title	Ratio of waste to grout infill
Date raised	30/05/2012
Acknowledgment required by	07/06/2012
Response required by	28/09/2012
Related issue numbers	ESC-RI-INF-003
Originated by	Environment Agency
Current owner	Environment Agency
Review group	INF
Approved by	Environment Agency

History

Status	Date	Description
Raised	30/05/2012	
Acknowledged	01/06/2012	
LLWR Response	24/05/2013	
Response Assessed	07/09/2013	
Transferred	11/09/2013	
Closed	04/10/2013	

Statement of Technical Query

This Technical Query relates specifically to the as placed grout ratio and not the observed degradation of certain Vault 8 containers. We seek clarification specifically relating to the grout to waste ratio, but any answer should incorporate appropriate learning from the ongoing container degradation investigations anticipated, at the point of issue, to be completed by September 2012.

Introduction

The ESC assumes that a number of environmental safety benefits can be delivered from the presence of grout within the containerised waste form. A safety benefit is derived from the structural robustness the presence of the grout matrix is able to provide to contents of the containers after the failure of the container structure. The ESC describes vault wastes as having '*substantial structure*' [Ref.1]. This allows the ESC to conclude in the short term: '*no significant load-related settlement pre-capping or immediately post capping*' [Ref.1].

Prior to the failure of the structural integrity of the ISOs, and other containers, the frame of the container would take any vertical loading imparted as a result of stacking or restoration. Once the containers structural frame fails it is likely that the transfer of load to the grouted waste mass will result in settlement. This is likely to occur relatively shortly after the placement of the restoration layer. The timing of the container structural failure after loading will be determined by the condition of the container at the time of loading and the magnitude of the loading.

The ESC includes a volume which takes account of settlement which will result from voidage already present in the waste container which will not be filled with grout. In the short term assessment a figure of 4%, comprising of packing voids and inaccessible areas is presented. These voids are assumed to be present within the structure of the container with a fraction within the waste.

We seek clarification of the potential for the compression⁶⁶ of the grouted waste after failure of the container structure, so as to understand the potential impact upon cap settlement and stability. The amount of potential compression will be determined by the structural integrity of the grout matrix itself, but also the compressibility of the grouted waste.

The safety case utilises an average grout content of 40% by weight of the total waste package.⁶⁷ At these grout to waste ratios the ESC assumes that containers will not undergo settlement until additional voids are formed by waste degradation over extended timeframes.

The level 3 ESC document *Physical and Chemical Heterogeneity on a container scale NNL 09 (10694)* [Ref.2] seeks to characterise the nature and quantity of wastes placed in the Vault 8 containers. This report presents a normal distribution of grout to waste ratio with a significant number of containers in Vault 8 which, according to calculations, have less than 40% by volume of grout (Figure 1).

The report also discusses the nature and variability of the wastes within the containers. From the presented graphs (Figure 2) it is possible to conclude that a significant number of containers have both grout contents less than 40% and compactable waste types (for example wood, plastics, organics and a proportion of unknowns).

Figure 1 shows a wide distribution of directly consigned and WAMAC consigned containers, with approximately 2500 consignments (or 35% of consignments) with grout contents of less than 40% by volume. This distribution could mean that a substantial number of consignments could exhibit different structural characteristics to those assumed in the settlement assessment.

At 40% grout or above, the ESC assumes that the grouted container will effectively mitigate settlement by restricting the amount of waste induced compression and allowing the transfer of vertical load from the container to the grouted waste mass after the failure of the metal container as a result of corrosion and loading. This is considered a valid assumption, but with reducing grout content the structural stability of the grout will reduce to a point where minimal structural advantage will be gained and the contents of the container are no longer acting as a grouted monolith.

For metallic and well compacted pucks it is reasonable to assume that the waste will provide a sufficient structural integrity to prevent significant⁶⁸ settlement, while compressible organic materials (prior to degradation) or some un-compacted materials may not have equivalent structural strength. From Figure 2 it is possible to estimate that approximately 1200 of the ISOs within Vault 8 which contain grout contents of less than 40% also contain soft organics, and a similar number contain wood.

As can be seen from Figure 1, the majority of low grout content containers relate to directly consigned containers, however, a small number of containers consigned from WAMAC have lower grout ratios.

⁶⁶ Compression is used to describe the reduction in waste volume as a result of vertical loading which may or may not result in settlement of the profiling and capping layers.

⁶⁷ The ESC utilises two indirect methodologies to calculate the grout ratios based on density calculations and item packaging. These methods provide a bulk value, but do not provide any information on the distribution of the grout throughout the waste mass.

⁶⁸ For the purpose of this TQ 'significant' is defined as being greater settlement than predicted in the ESC.

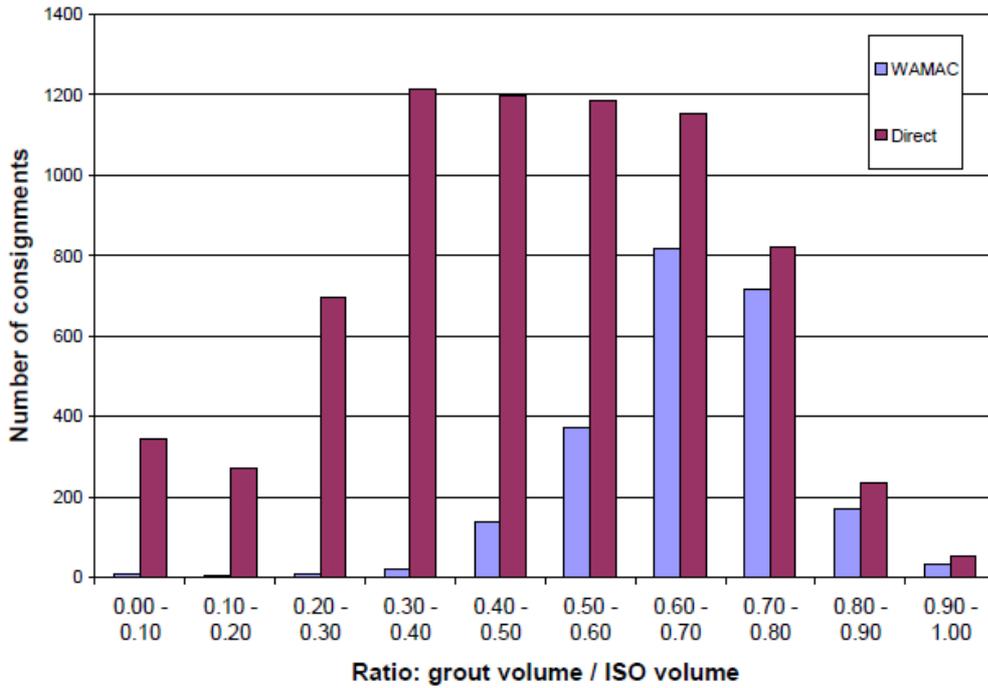


Figure 1: Distribution of grout content of direct consigned and compacted (WAMAC) wastes to Vault 8 (Ref. *Physical and Chemical Heterogeneity on a container scale NNL 09 (10694)*)

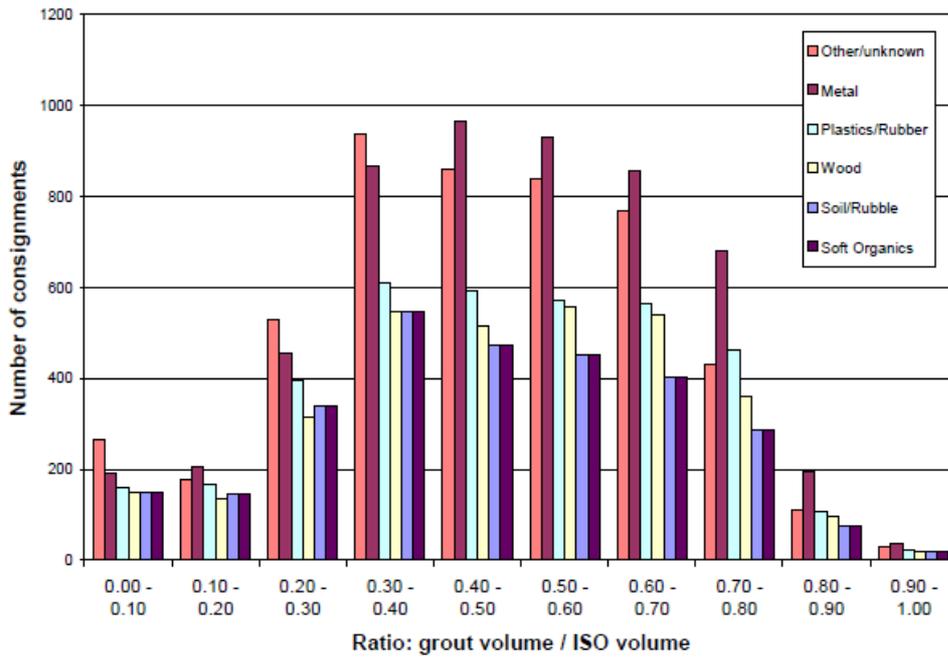


Figure 2 Distribution of grout contents of direct consignments containing specific waste material types (*Physical and Chemical Heterogeneity on a container scale NNL 09 (10694)*)

The main objective of this TQ is to seek confirmation that the presented ESC has identified a realistic settlement worst case against which the performance of the capping system can be compared.

Please develop and assess the implications of a worst case scenario for the settlement of container stacks which have low grout content together with a compressible waste content. The worst case settlement should be located adjacent to a stack or vault wall which does not undergo settlement. The worst case scenario should cover all the main container types present in Vault 8.

In order to provide reassurance that the presented grout ratios are realistic, please provide a recent typical, as placed density, of a typical LLWR grout using a sample from the LLWR grout plant.

Depending on the significance of the worst case we may ask for further investigation of the nature and significance of lower grout contents on potential settlement.

We anticipate that this TQ will be addressed as part of the wider LLWR investigations ongoing into ISO condition and cap stability, due to report around September 2012. A response to this TQ may be incorporated into that wider response and references out from this form.

References

1. Cap Settlement, LLWR/ESC/R(10)10036.
Physical and Chemical Heterogeneity on a container scale NNL 09 (10694).

Technical Query Actions

ESC-TQ-INF-006-A1	<p>Please develop and assess the implications of a worst case scenario for the settlement of container stacks which have a low grout content together with a compressible waste content. The worst case settlement should be located adjacent to a stack or vault wall which does not undergo settlement. The worst case scenario should cover all the main container types present in Vault 8.</p> <p>In order to provide reassurance that the presented grout ratios are realistic, please provide a recent typical, as placed density, of a typical LLWR grout using a sample from the LLWR grout plant.</p>
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	01/06/2012
<p>Comment: A response will be provided through the programme of work being undertaken in response to the results of the recent survey of containers in Vault 8. This work will need to establish the distribution of potential voidage in Vault 8 as part of the substantiation of the final cap and any further higher stacking in Vault 8. Hence, the 'worst case' will be established by default.</p>		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	24/05/2013
<p>i). As part of the programme of work undertaken in response to the Vault 8 container surveys a report was produced that considered the implications of voidage in Vault 8, see reference [1]. The aim of this work was to calculate potential voidage across Vault 8 by considering each stack of containers. This work both substantiates previous work considering the stability of the cap, see references [2,3] and also informs the overall study of voidage in Vault 8, see reference [4].</p> <p>The work reported in reference [1] used two methods (direct estimate and void fraction) to derive the settlement that may occur in each stack due to the waste composition and assumed voidage within the containers. This work should be considered as an alternative to those approaches referenced in previous work, see references [2] and [3]. The work concluded that 75% of the stacks in Vault 8 show settlement of less than 1m, which supports previous work concerning cap settlement and stability. Using the void fraction approach, the</p>		

maximum settlement in a stack has been calculated as 2.25m, see reference [1] for more detail.

A waste stack settlement of 2.25m is approximately equivalent to the height of two half-height ISOs. (Due to the bridging effect of container stacks, a settlement of 2.25m in a stack would not be expressed as 2.25m settlement of the cap.)

Although this method of calculation of settlement is a valid approach, it is a statistical method based on assumptions derived from information in the waste tracking system. Due to waste definitions and approximations used to categorise the waste on the consignment forms, further refinement, although possible in a limited number of consignments, will not significantly alter the conclusions of this study.

Specific consideration will be given to the cap design over any specific areas of the vault, such as close to the edge by the vault wall, where detailing can help mitigate potential future settlement. This work will be further examined in the forward engineering plans, see reference [5]. One of the key decisions to be made is the extent to which higher stacking on Vault 8 will be implemented. The results of the voidage assessments will be used to inform and substantiate this decision.

In Vault 9 potential waste voidage will be dealt with during emplacement and managed via an emplacement strategy to control settlement within waste stacks.

ii). Grout density was measured in the early operational stages at DGF, a typical value being 1,750 kg/m³, see reference [5]. There was a slight change in specification (due to a change of PFA supplier) in 2005, however, the mix design is essentially constant. Based on this, reference [6] concluded (in terms of continued density tests) '*there is no valid reason why the test should be continued as the results do not need to be utilised in either of the operational quality control processes*'. Therefore, there is no reason to consider the original measurements unrepresentative of current grout mixes.

References

- ¹ Quintessa, *LLWR Waste Emplacement Strategy: Assessment of the Implications of Voidage in Vault 8*, Quintessa Report QRS 1443ZP-1, Version 2.1, May 2013.
- ² LLWR, *Cap Settlement*, ESC Level 3 Report LLWR/ESR/R(10)10036, Version 3, April 2011, 2011.
- ³ Coffey Geotechnics, *Cap Performance Briefing Note for review Meeting 12 November 2012*, November 2012.
- ⁴ LLWR, *Vault 8 Containers Issues Project: Position Paper*, RP/LLWRGR/PROJ/00139, Issue 1, December 2012.
- ⁵ LLWR, *Engineering Forward Plan to Support the Environmental Safety Case*, RP/LLWRGR/PROJ/00142, Issue A, April 2013.
- ⁶ Westlakes Engineering, *Review of Grouting Procedures*, Westlakes Engineering Report RP/533/02 Issue 1, September 2012.

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 11/09/2013
Approved by: Environment Agency	Date: 03/10/2013

This Technical Query (TQ) was raised as result of our concerns with regards to the potentially low ratio of grout to waste observed within Figures 1 and 2 within Ref (1). This report indicates that about 35% of the containers have a grout to waste ratio of less than 40% for directly consigned packages. Our concern was that the low grout to waste ratio in some consignments could have a significant impact on the settlement of the engineered cap.

In this TQ we asked LLW Repository Ltd to present a worst case scenario with regards to cap settlement for low grout to waste ratios. However, this request was made prior to us fully understanding the voidage distribution across Vault 8, as a result of ongoing container inspection work and assessments that LLW Repository Ltd was undertaking. Within our TQ we stated that the grout, once the containers have corroded, will be subjected to the same vertical force as that of the containers and thus will be required to be an integral part of the engineering. However, LLW Repository Ltd has clarified that this is not the case and that the grout offers no structural purpose to the integrity of the cap.

No distribution maps of the waste within Vault 8 were provided in the 2011 ESC. However, LLW Repository Ltd's subsequent report on the Assessment of Voidage within Vault 8 (Ref 2) has addressed this and presents an overall indicative picture of the voidage distribution across Vault 8. This has taken into account the waste to grout ratios within the containers and the settlement predicted within the stacks. Therefore, this work has covered the potential impact on settlement that low grout to waste ratio consignments could have. The derivation of the voidage by LLW Repository Ltd has utilised the best available data with regards to the records for deriving the voidage map for Vault 8. This report addresses part of our concerns raised within this TQ.

Within the TQ we also asked LLW Repository Ltd to demonstrate a worst case scenario for each of the container types. We consider that this has not been fully addressed. However, the distribution maps within Ref (2) provide an indication of the areas where differential settlement will potentially be a concern. LLW Repository Ltd has indicated that it is considering a potential modification to the cap around the edges of the north-western sides of the vault to compensate for the additional settlement identified. We question whether this necessarily addresses the worst case scenario, due to the uncertainty associated with the waste materials within the consignments and the lack of detailed records for the consignments to Vault 8 in terms of voidage. However LLW Repository Ltd has a forward engineering work program in place to fully assess the construction and performance of the cap and that this will take into account the potential for cap settlement. Additionally, this forward programme will examine whether and to what degree higher stacking in Vault 8 will be possible given the known extent of voidage within containers. As part of this work we will expect LLW Repository Ltd to demonstrate that the engineered cap can accommodate a reasonable worst case scenario with regards to waste settlement. Our expectations for the forward work programme are set out in Forward Issue ESC-FI-001.

LLW Repository Ltd has provided a response to our query on grout density. This addresses our query and assures us that the grout produced today is not significantly different from that produced in the past, and thus the density figures applied at that time will be relevant to those applied today.

We are satisfied that LLW Repository Ltd has addressed our concerns within this TQ, particularly by providing a better understanding of the voidage present within Vault 8. This TQ can therefore be closed. However, we note that a significant degree of uncertainty still exists with regards to the spatial variability and extent of voidage, and therefore the potential impact on cap settlement. We expect LLW Repository Ltd to demonstrate that the engineered cap can accommodate a reasonable worst case in terms of settlement in its engineering forward programme.

References

1. Small, J.S., Randall, M. and Lennon, C., 2011. Physical and Chemical Heterogeneity on the Container Scale. NNL Report (09)10694 Issue 3.
2. Penfold, J., Burrow, J. and Robinson, P., 2013. LLWR Waste Emplacement Strategy: Assessment of the Implications of Voidage in Vault 8. Quintessa Report QRS-1443ZP-1, Version 2.1.

Actions completed, Technical Query resolved and Form closed

Owner: Environment Agency	Date: 04/10/2013
Approved by: Environment Agency	Date: 04/10/2013

ESC-TQ-INF-007: Understanding and optimisation of surcharge requirements and final cap placement timing

Title	Understanding and Optimisation of Surcharge Requirements and Final Cap Placement Timing
Date raised	26/09/2012
Acknowledgment required by	28/09/2012
Response required by	29/10/2012
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	INF
Approved by	Environment Agency

History

Status	Date	Description
Raised	26/09/2012	
Acknowledged	26/09/2012	
LLWR Response	13/02/2012	
Response Assessed	23/07/2013	
Transferred	23/07/2013	
Closed	14/08/2014	

Statement of Technical Query

The amount and timing of settlement on the integrity and functioning of the final capping system is a very important aspect of the presented Environmental Safety Case. In its current form the presented Environmental Safety Case does not clearly demonstrate how the final capping systems can meet the necessary and assumed settlement performance requirements.

The following Technical Query is divided into two discrete elements, namely the role and management of surcharging as a means of reducing total final cap settlement and the timing of the final capping layer as a means of optimising the amount of settlement incurred by the final capping system.

The Role of Surcharging

The Environmental Safety Case and the site restoration scheme planning application incorporate the requirement for the placement of a profiling layer above the vault and trench waste in order to provide the appropriate restoration form for the placement of the final cap. This restoration layer may comprise of clean engineering soils or suitable VLLW wastes or a combination of the two.⁶⁹

As well as forming an appropriate shape for restoration, the placement of profiling material may have beneficial effects on the integrity of the final cap by pre loading the wastes prior to the

⁶⁹ The use of VLLW as profiling materials is not part of the ESC review.

placement of the final cap and facilitating short term settlement prior to the construction of the cap. This is especially important for the trenches where short term consolidation settlement could occur immediately after the placement of the profiling material, but may also induce some settlement in the Vaults. This short term settlement may be the most significant element of residual settlement and plays an important role in the long term integrity and functionality of the capping system.⁷⁰

The restoration planning application shows a sequence of profile material placement followed by the placement of a strip of the final capping. The sequence of placement of the profiling material is determined by the infill rate of the vault and restoration material availability. It is understood that the profiling material will remain in place for a period of time amounting to a number of years prior to the placement of the final capping and restoration materials.

Taking these assumptions, the restoration scheme planning application shows a programme of profiling and capping specifically designed to minimise settlement after the placement of the final cap. We consider the objective to minimise the residual settlement to be part of the ESC and is not backed up with estimates of surcharge material quantities and the timing needed to achieve the required settlement objectives. In order to ensure post capping settlement is minimised, it is essential that the amount of surcharge material required and length of time required to achieve the required effects is fully understood. It is essential that we understand the required timing and depth of profiling so that we can advise the planning authority on the timing of capping and the need for profiling material. It is accepted that for latter stages of the restoration these calculations may not be practicable, but for the first capping stages of Vault 8 and the adjacent trenches it is considered reasonable to produce these calculations. For the latter vaults settlement objectives can be used.

As part of the ESC we would expect that the strategy for the timing of the surcharge material and final capping will have been optimised to take account of the required functionality of the capping system.

Timing of the Final Capping Layer as a Means of Optimising the Amount of Settlement Incurred by the Final Capping System.

The placement of an interim cap as a means of reducing the impact of settlement on the final capping system has been discussed in a number of Level 3 Environmental Safety Case (ESC) documents (*Section 7 Interim Vs Final Cap, LLWR Modular Vault Projects: Capping Justification Report BNGPS/LLWR/MV/2.3/062/1*). Within this document an environment safety argument is discussed whereby the placement of a final cap is significantly delayed so as to allow as much settlement to occur while an interim cap is in place.

As discussed above, the ESC and planning application proposes a staged approach to the placement of profiling material and final capping. This involves the placement of the final capping layer at a point just after the completion of each vault, typically 2-3 years, but driven by material supply and the construction progress.

The 2011 ESC assumes that the majority of settlement has occurred prior to the placement of the final cap and the final cap would only be placed once the amount of residual settlement would not adversely affect its performance. (*Cap Settlement LLWR/ESC/R(10)10036 Section 2.4 Control of Settlements, For the trenches, the majority of load related settlements will occur shortly after (within 2 years of) placement of the final cap and can be controlled by the construction sequence and pre loading the trenches. As this can be controlled, it is not a primary concern*)

This statement implies that during the first 2 years after the placement of the final cap, the majority of settlement will occur, it is not clear if this period is after the placement of the final cap or the profiling material. We would also expect a statement like this to be backed up with geotechnical data.

In contrast, the LLWR Modular Vaults Project: Capping Justification Report quotes the 2002 Post Closure Safety Case '*The PCSC assumes that much of the settlement of the waste should have occurred prior to the placement of the final cap and the final cap would only be placed once the amount of settlement that remains would not adversely effect its performance. It is anticipated that*

⁷⁰ This does not take account of the outputs from the ongoing container investigations.

this would be around the year 2100. This would allow a minimum of around 50 years for the settlement of wastes.'

We cannot identify within the 2011 ESC and supporting optimisation documents a justified environmental safety reason for the change in approach between the two reports, even taking account of the change of design from gull wing to a single dome design.

Technical Query Actions

ESC-TQ-INF-007.A1	Please set out the expected and required settlement for both the trenches and vaults that can be expected to occur in the short term after the placement of the profiling material and final capping layer. These values should be compared against the expected settlement tolerance of the final cap and associated engineering systems. Taking into account the variable nature of settlement how will the profiling be managed?
ESC-TQ-INF-007.A2	Please provide appropriate calculations or supporting evidence which demonstrates the required surcharge objectives can be met within the timing and placement volumes associated with the proposed restoration scheme. We would be interested to understand the minimum period of time required between the placement of the profiling material and the final capping layer to achieve the required settlement objectives.
ESC-TQ-INF-007.A3	Please present evidence that the timing of placement of the surcharge and final capping system has been subject to an optimisation process and that the chosen capping sequence represents the optimal strategy.
ESC-TQ-INF-007.A4	In order to demonstrate the required settlement has occurred, it will be necessary to monitor total settlement and settlement rate. Please outline proposals to carry out this monitoring and determine when an appropriate amount of surcharge settlement has occurred.
ESC-TQ-INF-007.A5	Please provide an environmental safety justification for the change in the timing of the placement of the final cap from that presented in the previous 2002 PCSC. We seek specific confirmation that the majority of settlement will have taken place prior to the placement of the final cap.
ESC-TQ-INF-007.A6	Please provide a short single statement based on the outcomes from the above actions which clearly presents in a single location, the safety arguments and optimisation measures used to ensure that the placement of surcharging and final capping systems can meet the necessary and assumed performance requirements.

LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	26/09/2012
Comment: Responses to the actions requesting the information on surcharging will be provided.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	Chief Engineer	13/02/2013
A1.	<p>In the short term, vault settlement is considered to be negligible due to the structure of HHISO containers (4.1, LLWR/ESC/R(10)/10036), whereas in respect of the trenches (3.10, LLWR/ESC/R(10)/10036) settlement could be significant (up to 1m in places) and variable.</p> <p>These settlements are to be managed by placement of profile and excess profiling material (surcharge) to a level equivalent to the final cap level (this will ensure that the load applied is similar to that of the final cap). The excess profiling material will be removed, thus removing surface inequalities, and replaced by the final cap following adequate settlement. This will be a minimum of two years post-placement of profiling; the current implementation schedule leaves this excess profiling in place for approximately 10 years. Having undertaken surcharging of the profiling and underlying waste, minimal load settlement is anticipated as the final capping load will be similar to that of the surcharge load. Due to the nature of the waste it is difficult to accurately predict the amount of load settlement that will occur, hence this will be monitored. The loading of the trenches will reduce the voidage that exists within the waste and will result in the expulsion of water from the system. We believe the control of this water to be a key issue in the planning and execution of the work and engineering schemes will be required to demonstrate that the management of this water utilises BAT.</p>	
A2.	<p>Load induced settlement of the trenches is expected to occur within two years after loading (3.2, LLWR/ESC/R(10)/10036), based on engineering judgement. Actual settlement is difficult to predict, hence surcharging using excess profile material to impose a load similar to that of the final cap is proposed. The key element to monitor is the rate of this settlement and criteria need to be set. Given that the time the excess profiling (surcharge) material is currently planned to remain in place is around 10 years, removal of the load related settlement over the trenches is not believed to be an issue. Removal of load induced settlement of the vaults is not possible prior to placement of the final cap, due to the structure and integrity of the containers and the presence of the grout.</p>	
A3.	<p>The additional profiling material (surcharge) is to be placed during the profiling operation of the trenches to a level equivalent to the finished final cap level. Suitable monitoring shall be undertaken to determine the rate and amount of settlement taking place. Following evaluation against expected settlement rates and values the excess profile is to be replaced with the final cap. This allows LLWR (and stakeholders) to gain confidence that settlement of the final cap is within acceptable criteria. Additional material may be added to the surcharge material dependant on any revealed settlement. The sequence of placement of profiling and surcharge material was selected primarily on the following:</p> <ul style="list-style-type: none">➤ Protection of the final cap by removal of load related settlement prior to placement of the “engineered” final cap➤ Coincide with the vault development programme (ESC-RI-ASO-001)➤ Ability to demonstrate completion of load settlement➤ Material management and availability (e.g. re- application of the surcharge material)➤ Potential storage of engineered material	
A4.	<p>Final design of the monitoring scheme is to be undertaken later, however, it will include establishment of a series of robust survey stations with periodic surveys undertaken. The data will then be reviewed to determine the amount and rate of settlement occurring following placement of profile and surcharge load. Due to the nature of the waste it will be the rate of settlement that will be the key factor and the</p>	

amount of settlement will be managed by application of more material if required. This settlement data is vital to determine when the final cap can be installed with confidence, but as stated above the 10 year (approximate) surcharge cycle should allow all load related settlement to be realised. Impact of this surcharge/capping operation on the adjacent areas of the trench cap will also be monitored and assessed during the phased implementation of the proposed works.

- A5. Review of calculated trench settlements (3.10, LLWR/ESC/R(10)/10036) indicates that the majority of load related settlement occurs within a period of around two years post-loading, however degradation settlements could take place over a period of 100s of years with the potential for a significant amount of settlement to have taken place to date. Both load and degradation components are expected to decrease in rate and amount over time.

It is not feasible to remove load related settlement from the vault waste with any certainty, although this settlement is expected to be small due to the presence of the grout. Degradation of the HHISO is likely to be the controlling factor (4.8, LLWR/ESC/R(10)/10036) regarding settlement, with this process taking place up to 1000s of years (central value of 300 years) after final capping.

The 2002 PCSC indicated that final cap placement could occur in about 2100 (9.4.1, 2002f, Drigg Post Closure Safety Case : Site Development Plan). It is considered that this approach provides no allowance for the load related settlement to be removed from the system, prior to installation of the final cap. Due to the uncertainty associated with this settlement within the trenches it is difficult to assure ourselves that a final cap over the trenches would satisfy the performance assumed within the ESC. Placement of profiling material and surcharge material on the trenches could be implemented as one phase and this was considered but was dismissed because of the amount of material required and interfaces with the vault development programme. By implementing earlier phased capping of vaults and adjacent trench areas, LLWR are seeking to reduce infiltration to the waste and therefore delay release and reduce leachate volume in addition to providing evidence through monitoring that the system is performing as intended.

- A6. To ensure the performance of the final capping layers there is a requirement to remove load related settlement that could potentially occur within the trenches. It is acknowledged that schemes do have to be developed to control the water expelled from the trenches as part of this operation and this is one of the key issues to be resolved. This removal of the water from the system does not however impact on the assessments of engineering performance within the ESC documentation.

The settlement induced through the installation and post installation will be adequately monitored in terms of rates and magnitude, the water levels and expulsion of water will also be monitored to ensure and demonstrate that any potential adverse consequence are effectively managed.

It is believed that the load induced settlement will be removed within two years of surcharge placement and under the timings in the current implementation plan this is not considered to be an issue.

Implementation of the surcharging and subsequent final capping in this way provides additional control of the potential impact of loading from the final cap through the removal of load related settlement prior to installation. This will enable the final capping to be placed to meet required performance criteria.

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 23/07/2013
Approved by: Environment Agency	Date: 14/08/2014

The minimisation of short-term settlement in the trenches by surcharging will ensure that the final restoration cap is not subjected to unnecessary settlement and its capacity to mitigate long-term settlement is optimised.

We recognise that the sequence of cap construction and surcharging needed to facilitate site restoration is complex and subject to a variable timeframes, but we consider it important that the underlying safety objectives of surcharging and the optimal placement of cap layers are presented within the ESC.

We have assessed LLW Repository Ltd's response to this Technical Query (TQ) against the safety requirements and capping system performance objectives. The timing of implementation of the surcharging and final restoration will be controlled by the planning permission, although we seek optimisation of the facility by capping as soon as can reasonably be achieved. We have therefore not commented on the timing and sequence of restoration within this TQ. During the planning application consultation we will advise Cumbria Country Council, the relevant Planning Authority, on whether the surcharging and cap design more generally meets safety objectives and on its necessity.

Since this TQ was raised, LLW Repository Ltd has significantly progressed investigations into the condition of containers in Vault 8. The company has investigated voidage within the containers and assessed the potential for settlement once capping commences (LLW Repository Ltd 2012, 2013a).

LLW Repository Ltd's response to this TQ assumes that there will be minimal settlement of the vault wastes once profiling material is put in place. We question this assumption in light of the evidence provided by the Vault 8 container investigations, which show some container degradation, some unexpected voidage within grouted containers and highly variable grout contents and mixing within the containers. These factors could give rise to limited settlement occurring shortly after the placement of the profiling and final capping system. However, LLW Repository Ltd has undertaken significant assessment work to demonstrate that, even with these uncertainties, settlement can be accommodated by the design of the final vault capping system when combined with selective container emplacement (LLW Repository Ltd 2012, 2013a). We are content with this demonstration, but note that further work is required as part of LLW Repository Ltd's forward engineering programme to establish the details of these designs (LLW Repository Ltd 2013b). We will review this further detailed demonstration before commencement of works.

At the end of our review there remain a number of uncertainties relating to maximum stack height and the engineering measures needed to place the proofing materials. We set out our requirements for the development and implementation of an optimised cap design and waste stack heights in Forward Issue ESC-FI-001. Prior to the commencement of the placement of the surcharge materials and the layers of the final cap, LLW Repository Ltd will be required to demonstrate that the surcharging can meet the required performance objectives.

We provide comments against each of the actions of this TQ below:

A1. LLW Repository Ltd's response provides sufficient information to address this action and clarify our understanding of the role of surcharging. The company has estimated both the extent and rates of potential settlement. It will use monitoring to measure settlement during surcharging. The company does not provide details of the cap settlement monitoring, however, the engineering forward programme sets out high level objectives for this monitoring. We are confident that the company can carry out the monitoring appropriately. We will review the outcome of the engineering forward programme prior to the commencement of the placement of surcharge materials.

A2. LLW Repository Ltd's response provides sufficient information to address this action and clarify our understanding of the role of surcharging.

A3. LLW Repository Ltd's response provides sufficient information to this action. The company has appropriately describes the optimisation applied to the design and implementation of surcharging and restoration. We expect the company to apply the stated optimisation objectives when developing detailed restoration sequences.

Because of the ongoing engineering optimisation programme (for example, addressing container and vault/capping sequencing) it is likely that the timing and extent of restoration and vault closure

will change. We expect LLW Repository Ltd to take surcharging into account in the optimisation of the restoration design.

A4. LLW Repository Ltd has provided sufficient information to address this action. In its forward engineering programme, the company will develop and implement an appropriate monitoring capability to measure the rate and quantity of settlement of surcharged materials.

A5. LLW Repository Ltd has described its approach to optimising the timing and role of surcharge and final restoration. The response appropriately describes the evolution of the optimised cap design from that presented in the 2002 PCSC.

A6. LLW Repository Ltd's response to this action provides an appropriate overview of the safety objectives and the reasoning for the cap restoration sequencing and the use of profiling and surcharge materials.

Conclusions

The information presented by LLW Repository Ltd in response to this TQ has clarified the safety assumptions and approach used in the development of the sequence of cap construction and surcharging. We consider that the company has adequately addressed the actions in this TQ and that it can be closed.

At the end of our review there remains uncertainty in the timing and extent of the repository restoration sequence. LLW Repository Ltd will be required to demonstrate the necessary surcharging can be delivered within the adopted restoration sequence. We are confident that the company will be able to deliver the safety benefits derived from surcharging within the chosen capping and restoration sequence.

We note that LLW Repository Ltd will need to provide a surcharging and restoration programme within their planning permission submission. We will advise the planning authority on the nature and requirements for surcharging as part of the restoration sequence.

References

LLWR 2012, *Vault 8 Containers Issues Project: Position Paper: December 2012*, RP/LLWRGR/PROJ/00139 ISSUE A, December 2012.

LLWR 2013a, *Vault 8 Containers Issues Project: Action Plan*, RP/LLWRGR/PROJ/00141 ISSUE A, March 2013.

LLWR 2013b, *Engineering Forward Plan to Support the Environmental Safety Case*, RP/LLWR/PROJ/00142, April 2013

Owner: Environment Agency	Date: 14/08/2014
Approved by: Environment Agency	Date: 14/08/2014

ESC-TQ-INF-018: Trench cap leakage

Title	Trench Cap Leakage
Date raised	26/04/2012
Acknowledgment required by	05/05/2012
Response required by	05/06/2012
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	INF
Approved by	Environment Agency

History

Status	Date	Description
Raised	27/04/2012	
Acknowledged	01/05/2012	
LLWR Response	09/07/2012	
Response Assessed	15/04/2013	
Transferred	29/07/2013	
Closed	04/10/2013	

Statement of Technical Query

The initial outputs from the ongoing investigations into establishing the water balance of the Trench caps were verbally presented at the recent ESC Liaison meeting during April. The initial findings (which could be subject to future change) indicated that up to 50% of the effective infiltration was entering the waste mass.

Assuming that this value remains valid, please can you amend the Trench cap infiltration values used in the presented ESC so as to reflect the measured leakage rate. The impacts and significance of the changes should be assessed.

Technical Query Actions

ESC-TQ-INF-018.A1	<p>Amend the trench cap infiltration values used in the ESC to represent the latest available data and so as to reflect the best available measured leakage rate.</p> <p>The significance of the changes should be presented for the following aspects of the ESC:</p> <ul style="list-style-type: none"> • Ability of the Trench drainage system to maintain the predicted leachate levels and saturation states prior to the placement of the final cap. • The impact of the increased infiltration on the near field and hydrogeological model outputs. • Any other potential environmental safety implications associated with the increased infiltration. <p>In the first instance the impacts can be presented as expert</p>
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	opinion utilising simple calculations as necessary. If the impact of the increased cap infiltration is considered significant then the ESC hydrogeological and near field models should be appropriately modified and assessed.
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	LLWR Safety Case Manager	01/05/2012
Comment: LLWR accepted the TQ and stated that the work was already being addressed via the Trench Cap BAT workload and can be delivered within the identified period.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Technical Integrator/Specialist	09/07/2012
A response is provided in ESC Project Memo LLWR/ESC/Mem(12)153, 09/07/2012.		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 15/04/2013
Approved by: Environment Agency	Date: 29/07/2013

Performance of the interim trench cap

LLW Repository Ltd has been carrying out an investigation into the performance of the interim trench cap system in response to Requirement 7 of Schedule 9 of its Environmental Permit. The investigation sought to quantify the leakage and performance of the interim cap by adopting a water balance approach. While our review of the 2011 ESC was being carried out, the company received additional performance information on the trench cap for the period between 2006 and 2012. The water balance results indicated that up to 50% of the hydrological effective rainfall (HER) was unaccounted for in the measured trench cap run-off. This value was higher than the value used as a basis for the ESC assessment calculations for release to groundwater during the Period of Authorisation (PoA). We therefore requested that LLW Repository Ltd revise its assessment to take account of the apparent cap leakage rate.

ESC Project Memo LLWR/ESC/Mem(12)153 presents updated impact calculations for the PoA using an interim trench cap infiltration rate of 300 mm/year. This infiltration rate appears a reasonable estimate based on the latest trench water balance studies and is significantly higher than the 50 mm/year assumed in the 2011 ESC.

The updated calculations result in peak radiological risks during the PoA that are increased by approximately a factor of 2 compared with risks presented in the 2011 ESC. Key radionuclides and timing of peak risks are similar. In both sets of calculations, peak risks are calculated for the well pathway, with peak risks in 1992 associated with the ingestion of H-3 from well water, exceeding the risk guidance level. By the present day, calculated risks for both sets of calculations are below the risk guidance level.

The memo notes that, although environmental concentrations of H-3 are decreasing with time, current concentrations measured in groundwater are locally higher than modelled concentrations. This is attributed as a consequence of the simple H-3 source term used. Although consumption of water containing peak measured concentrations of H-3 abstracted from a well located between the LLWR and the coast could lead to risks in excess of the risk guidance levels, no such abstractions exist, or are likely to exist during the PoA.

The updated calculations also result in peak concentrations of non-radioactive contaminants in the B3 groundwater underlying the LLWR increasing compared with risks presented in the 2011 ESC. In some cases these increases are relatively significant (by up to 3 orders of magnitude). In the 50 mm/year infiltration rate calculation, concentrations of only benzene and vinyl chloride in groundwater under the trenches were predicted to exceed the LLWR assessment standard (LLWRAS). These exceedances are predicted to have occurred historically. In the case where 300 mm/year infiltration is assumed, LLWRAS exceedances in groundwater underlying the trenches are also predicted for chromium, lead, iron, molybdenum, nickel and zinc. All these metals with the exception of chromium⁷¹ are non-hazardous pollutants; modelled concentrations at the groundwater monitoring boreholes at the LLWR site boundary, the recommended compliance point for non-hazardous pollutants, are not provided. The times of these exceedances are not provided, however, plots provided in a later LLWR memo⁷² indicate that concentrations of these metals are increasing at the end of the PoA, and in some cases are higher than peak concentrations calculated in the post-closure assessment. We set out our requirements for an updated non-radioactive contaminant groundwater assessment in Forward Issue ESC-FI-006, which include better integration of the PoA and post-closure period.

Post-closure impacts for both radionuclides and non-radioactive contaminants are calculated separately to PoA impacts. These calculations start from 2080 and assume completion of the final cap over the trenches and are thus unaffected by this issue. The 2011 ESC assumes that the vault leachate management system is 100% effective during the PoA, hence the impacts discussed above only relate to the trenches.

Given that discharges from the trenches during the PoA are likely to be greater than presented in the 2011 ESC, and that exceedances of LLWRAS are predicted in groundwater, we would expect LLW Repository Ltd to apply Best Available Techniques (BAT) in order to minimise these discharges.

LLW Repository Ltd carried out a BAT assessment which sought to identify remedial options for the interim trench cap until the placement of a final engineered capping layer. The results of this assessment are presented in Paulley et al. (2012)⁷³. The approach to reduce infiltration comprised the re-sealing and repairing of all the trench probe perforations using modern construction quality assurance (CQA) approaches, together with the re-profiling of depressions in the cap surface.

LLW Repository Ltd initiated these works in winter 2013 and encountered significant faults in the trench membrane. As a result, after the survey and repair of the trench probe penetrations was completed, work was stopped. Further investigative work is planned to take account of the observed membrane conditions. LLW Repository Ltd has stated that it will maintain a BAT approach until the installation of the final engineered cap. However, at the time of writing, LLW Repository Ltd has not developed a BAT strategy for the hydrogeological management of the interim trench cap that aligns with the proposed repository restoration sequence.

We will monitor and assess the developing trench cap BAT strategy and its consistency with an optimised repository restoration sequence. LLW Repository Ltd will be required to demonstrate the application of BAT for the period of authorisation and optimisation on a repository scale⁷⁴.

Ongoing assessment issues

We recognise that the level of uncertainty in the measured performance of the interim trench cap is significant as a result of the difficulty in undertaking accurate field measurements of cap

⁷¹ Chromium VI is classified by the Joint Agencies Groundwater Directive Advisory Group as an interim hazardous substance; no valency data are available to determine the proportion of chromium likely to be in this form.

⁷² Baker, A., 2013. Response to Issue Resolution Form ESC-TQ-ASO-008: Integration Between the Period of Authorisation and Reference Case Assessments. ESC Technical Memo LLWR/ESC/Mem(13)198.

⁷³ Paulley, A., Garrard, G. and Nutting, M., 2012. LLWR Trench Hydrogeological Management BAT: Final Report. QRS14435 S ZN RS November 2012.

⁷⁴ Environment Agency, 2015. Review of LLW Repository Ltd's 2011 Environmental Safety Case: Optimisation and Engineering.

performance. These uncertainties, together with real differences in annual cap performances, make it very difficult to calculate a consistent and accurate trench water balance. Previous estimates have indicated a wide range of annual cap efficiencies, ranging from 21% to 82%⁷⁵. These uncertainties partly reflect ongoing changes to the monitoring infrastructure and partly reflect uncertainties in the measurement technique. However, we consider that the infiltration rate of 300 mm/year assumed in the response to this Technical Query (TQ) is more representative of the actual performance of the interim trench cap than the infiltration rate of 50 mm/year presented with the 2011 ESC.

In order to better characterise the performance of the interim cap, we consider it appropriate that LLW Repository Ltd continue to measure the trench cap water balance and to report the results in a similar format to that currently used for reporting against Schedule 9 Requirement 7 of the current environmental permit. A condition to this effect will be included in any revised permit.

We consider it essential that work continues to characterise and improve understanding of the trench water and leachate balance. This should include water entering the trenches via the cap and from shallow groundwater and leachate, the outputs of leachate into groundwater and the collection system and any cap infiltration which does not enter the waste mass (see Recommendation SUE48⁷⁶).

We consider that the actions within this TQ have been adequately addressed and that it can be closed.

Actions completed, Technical Query resolved and Form closed

Owner: Environment Agency	Date: 04/10/2013
Approved by: Environment Agency	Date: 04/10/2013

⁷⁵ Baker, A., 2012. Gas Generation Rate Plots from GRM Calculations. LLW Repository Ltd Technical Memo LLWR06488/06/10/01. Baker, A. and Shevelan, J., 2012. Response to IRF ESC-TQ-INF-018: Trench Cap Leakage. LLW Repository Ltd Technical Memo LLWR/ESC/Mem(12)153.

⁷⁶ From Environment Agency, 2015. Review of LLW Repository Ltd's 2011 Environmental Safety Case: Site understanding.

ESC-TQ-INF-020: Future inventory - combined cases

Title	Future Inventory - Combination of Case B, C and D.
Date raised	14/05/2012
Acknowledgment required by	16/05/2012
Response required by	15/06/2012
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	INF
Approved by	Environment Agency

History

Status	Date	Description
Raised	14/05/2012	
Acknowledged	16/05/2012	
LLWR Response	18/03/2013	
Response Assessed	02/09/2013	
Transferred	12/09/2013	
Closed	18/12/2013	

Statement of Technical Query

Within the Inventory area of the 2011 LLWR ESC, LLW Repository Ltd provides a number of potential future inventory scenarios which are used to predict the future volume and radionuclide content for disposals to the LLWR facility over its operational lifetime. The future inventories are also used where required within the ESC to assess the risk associated with key radionuclides through the relevant exposure pathways presented within the 2011 ESC as well as for predicting the contents of the vaults.

The cases utilised within the 2011 ESC are as follows:

Reference Case (Inventory Case A): includes material from WIDRAM and excludes all non-active waste streams, exclude all waste comprising of VLLW radioactive wastes.

Inventory Case B: Same as reference but includes LLW from New Build.

Inventory Case C: Alternate arising's taking into account changes to volumes of wastes: LLW to VLLW route and also uncertainties in parameters used in calculating the effect of waste processing on disposed volumes.

Inventory Case D: Alternative strategies for the management of contaminated land.

For each of these cases LLW Repository Limited has calculated the fill dates and the volumes and activity that will be disposed to the relevant vaults. These are presented within Table 4.1 Level 2 Inventory Document of the ESC. Each of these cases are presented separately and it appears, to us, that there is the potential for the actual inventory disposed to the LLWR facility to be the result of a combination of these inventory cases. Thus we believe that there is a fifth potential future inventory case possible, which could have implications on the ESC. We would like LLW Repository Limited to provide information on the fill rates and dates for a fifth case which will involve a

combination of Cases B, C and D. LLW Repository Limited should also assess whether this future scenario will have an impact on the ESC.

As well as providing information to support the ESC, the inventory cases are utilised in the planning application to support the planned infill and restoration timescales. We believe that the fifth case could present a further case which gives potentially different future fill dates for the vaults and thus could affect further restoration timescales. We therefore request that any changes in the rate of infill and restoration timescales produced by the fifth case are also presented.

Technical Query Actions

ESC-TQ-INF-020.A1	Provide fill dates for the combined future inventory scenario (Cases B, C and D) and assess implications of the combined scenario and its impact on the ESC. Present any implications for restoration timescales.
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	16/05/2012
The requested information and assessment will be provided. The approach to the assessment will be to use simple scaling arguments, similar to those used in response to ESC-RI-INF-001 relating to the 2010 UKRWI.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	18/03/2013
A response is provided in ESC Project memo LLWR/ESC/Mem(12)178.		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 12/09/2013
Approved by: Environment Agency	Date: 18/12/2013

LLW Repository Ltd presented 4 inventory cases in the 2011 ESC: a reference case and 3 alternatives. The company assumes that the alternatives have similar probabilities of occurring as the reference case. We questioned what impact this may have on the periods before capping each vault. This was of interest to us as we believe it is not an optimal solution to allow waste containers to be exposed for extended periods prior to vault capping (strip-capping), which is currently only planned to occur once each vault is full.

In response to this Technical Query (TQ), LLW Repository Ltd has presented the postulated closing dates of vaults for a combined case, case E (which is a combination of cases B, C and D). For case E the vaults will be open for longer and the actual number of vaults required for the EDA will be fewer. Under this combined case, the vaults will be open for longer, therefore LLW Repository Ltd needs to take appropriate action to protect the wastes. To this end LLW Repository Ltd has instigated a forward engineering programme which will examine the protection of waste, timescales for capping of Vault 8 and the size and sequencing of future vaults to ensure waste exposure is minimised. With regards to this specific TQ, we consider that the company has provided the relevant information on vault closure timing.

In response to our query LLW Repository Ltd has also considered the impacts of a case E on the various risk pathways. We note that C-14, Cl-36, Mo-93 and Co-60 are the main radionuclides for which the activity increases for the RDA vaults as a result of case E, whilst for Ra-226 the activity

with the RDA is reduced. We note for the EDA the main impacts are on Ra-226 and C-14. However, we also note that in all cases and for all risk pathways, the impact does not challenge the risk guidance level of $1 \times 10^{-6} \text{ y}^{-1}$.

We note that LLW Repository Ltd has since updated calculations for the groundwater pathway and the C-14 gas pathway, as documented in the Developments document (LLW Repository Ltd., 2013. Developments since the 2011 ESC. LLW Repository Ltd Report LLWR/ESC/R(13)10058 Issue 1). These updates do not include case E. However, projected risks from these updated calculations are similar to (in the case of the groundwater pathway) or significantly lower than (in the case of the C-14 gas pathway) results calculated in 2011 (Cummings, R 2013. Letter: EA LLWR 13 0198 03 Permit Application Clarification Cases 12 11 13). We would therefore expect updated risks associated with case E for these pathways not to challenge the risk guidance level.

We are satisfied that the data presented in response to this TQ satisfactorily addresses our query, which can be closed. We will expect LLW Repository Ltd to continue to monitor changes to anticipated inventory and any resulting impact upon vault fill times, instigating appropriate optimised management controls to protect the waste or provide for early capping. We are aware that LLW Repository Ltd is addressing these issues within the forward engineering programme, as required under Forward Issue (ESC-FI-025).

Actions completed, Technical Query resolved and Form closed

Owner: Environment Agency	Date: 18/12/2013
Approved by: Environment Agency	Date: 18/12/2013

ESC-TQ-INF-021: Key radionuclides: Am-241 contribution to vault 8 and overall inventory

Title	Key Radionuclides: Am-241 contribution to Vault 8 and overall inventory
Date raised	14/05/2012
Acknowledgment required by	16/05/2012
Response required by	31/05/2012
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	INF
Approved by	Environment Agency

History

Status	Date	Description
Raised	14/05/2012	
Acknowledged	16/05/2012	
LLWR Response	16/07/2013	
Response Assessed	02/09/2013	
Transferred	12/09/2013	
Closed	03/10/2013	

Statement of Technical Query

Within the Level 2 documents relating to the inventory it states that the key radionuclides to the assessment are C-14, Cl-36, Tc-99, I-129, U-234, U-238, Pu-239, Pu-240, Pu-241, Am-241, Ra-226, Th-232. LLW Repository Ltd has determined these are the key radionuclides for the groundwater assessment [1] and have been identified via the PCSC 2002 [2] and the Requirement 2 submission [3].

Ref [1] identifies one of the key radionuclides as Am-241 which contributes 3.67TBq to the total inventory and indicates that the majority of the Am-241 (62%) is associated with the forward inventory. Ref [1] states that, *“Accounting for the material already disposed within Vault 8 indicates that 83% of the Am-241 inventory of LLWR is associated with the vaults, with Vault 8 and 9 accounting for most of the vault inventory. It should be noted that the inventories of Am-241 are those estimated for the wastes at the time of disposal. Ingrowth of Am-241 from decay of relatively short-lived Pu-241 could increase inventories.”* However, elsewhere it appears that Vault 8 is not seen as a significant contributor to the Am-241 inventory. Ref [4], section 4.1, states that Vault 8 *“contributes substantially to the facility inventory for Cl-36 (39%) and Tc-99 (18%) and C-14....only these three key radionuclides are considered in detail here”*, it does not mention Am-241 which, according to ref [1] p24 contributes 22% of the facility inventory for Am-241.

LLW Repository Limited should clarify this apparent contradiction.

More generally we note that reference to a set of key radionuclides is inconsistent in the safety case supporting documentation. Ref [5] (Executive Summary) identifies **12** *“key nuclides, ...:C-14, Cl-36, Tc-99, I-129, Ra-226, Th-232, U-234, U-238, Pu-239, Pu-240, Pu-241 and Am-241”*. This correlates with the 12 *“radionuclides of potential importance to the ESC”*, listed in ref [1] page 6 (Executive Summary). Whereas Ref [4] (section 4.1) recognises **11** key radionuclides, *“the key*

radionuclides disposed of to LLWR (C-14, Cl-36, Tc-99, I-129, Ra-226, U-234 and U-238, Pu-239, Pu-240, Pu-241 and Am-241)". We recognise that mention on Th-232 may have been omitted in [4] (section 4.1) on the basis that most of the Th-232 is in the trenches, but we note that simple definitive statements of "the key radionuclides disposed of to LLWR" should be consistent to avoid undermining confidence in the safety case..

References

3. The 2011 ESC _ Inventory_LLWR/ESC/(R11)10019.
4. Drigg Post Closure Safety Case: Inventory of Past & Potential Future Disposals BNFL: Sept 2002.
5. LLWR Lifetime Plan Inventory and Near Field: LLWR LTP Volume 3 Issue 1 April 2008.
6. Harper, A., ESC 2011: The Disposed and Forward Inventory, Serco Report Serco/E003756/12 Issue 2, April 2011.
7. Baston, G. M. N., Magalhaes, S., Schneider, S. and Swanton, S.W. LLWR Environmental safety Case: Improvements to the Radionuclide Inventory of the LLWR. Serco Report SERCO/E003756/010 Issue 1 April 2011.

Technical Query Actions

ESC-TQ-INF-021.A1	To clarify the position with respect to the contribution of Am-241 associated with Vault 8 to the overall inventory.
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	16/05/2012
A clarification will be provided		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Technical Specialist	16/07/2012
<p>Figure 1 shows the distribution of Am-241 within LLWR, differentiating between material disposed at 31 March 2008, and the forward inventories based on the Reference Case [ii]. Of the 3.67 TBq of Am-241 in the total inventory, 1.26 TBq is associated with the disposed and forward inventory of Vault 8. Vault 8 is therefore predicted to contain, in total, 34% of the Am-241 inventory of LLWR, with waste emplaced in Vault 8 up to 31 March 2008 contributing 22% to the total inventory.</p> <p>It should be noted that these figures do not account for ingrowth of Am-241 from Pu-241, which is accounted for as part of the assessment calculations.</p>		

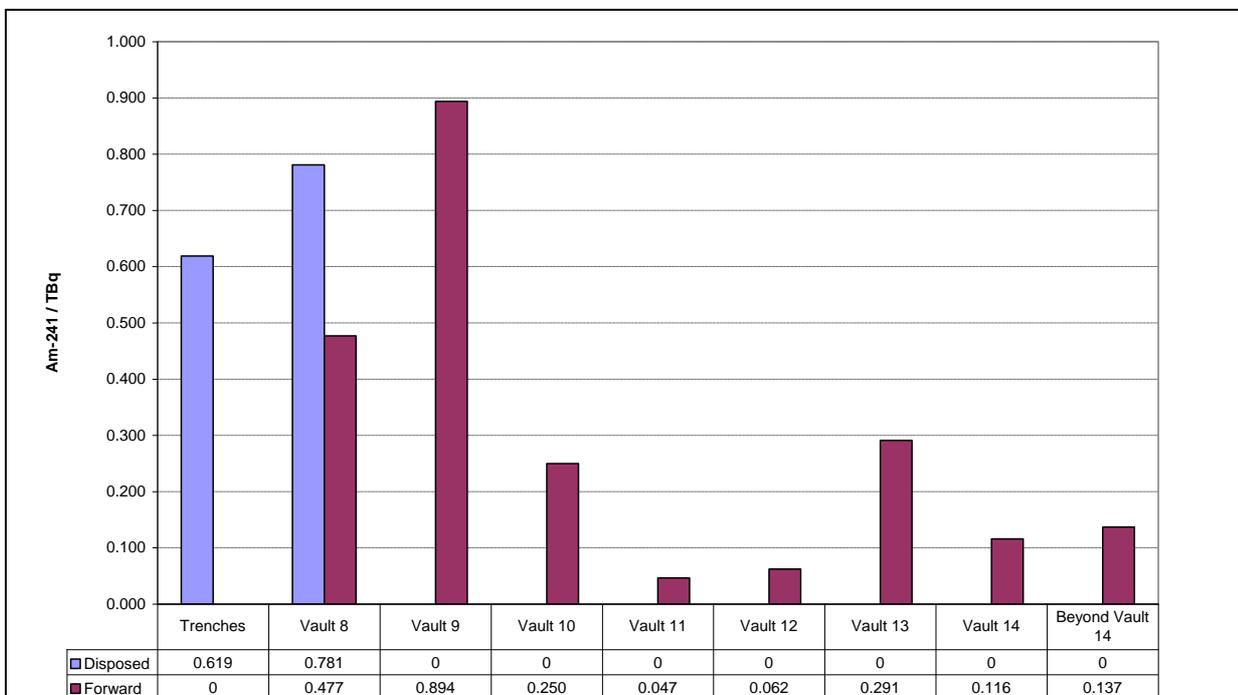


Figure 1: Disposed and predicted Am-241 inventories at LLWR

We acknowledge that there are two typographic errors in section 4.1 of Reference [i]:

- Vault 8 should have been identified as a substantial contributor to the total Am-241 inventory.
- Th-232 should have been identified as a key radionuclide.

As mentioned in the IRF, the Th-232 inventory is predominantly in the trenches with the vault disposals contributing only about 20% to the total inventory.

REFERENCES

ⁱ A Harper, *The disposed and forward inventory of LLWR*, SERCO/E003756/12 Issue 2, April 2011.

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 12/09/2013
Approved by: Environment Agency	Date: 24/09/2013

We raised this Technical Query (TQ) to clarify information relating to the Am-241 contribution from Vault 8 to the overall activity within the repository. LLW Repository Ltd has clarified the issue to our satisfaction and this TQ can be closed.

Actions completed, Technical Query resolved and Form closed

Owner: Environment Agency	Date: 30/09/2013
Approved by: Environment Agency	Date: 03/10/2013

ESC-TQ-INF-024: Uncertainty in isotopic Pu ratios within the trench inventory

Title	Uncertainty in Isotopic Plutonium Ratios within the Trench Inventory
Date raised	01/06/2012
Acknowledgment required by	13/06/2012
Response required by	20/07/2012
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	INF
Approved by	Environment Agency

History

Status	Date	Description
Raised	15/06/2012	
Acknowledged	15/06/2012	
LLWR Response	16/07/2013	
Response Assessed	10/09/2013	
Transferred	12/09/2013	
Closed	03/10/2013	

Statement of Technical Query

For radioactive disposals to the LLWR facility the 2011 ESC has focussed on those radionuclides that will present the most risk to Potentially Exposed Groups (PEG), via the relevant exposure pathways. These radionuclides have been termed key radionuclides. The key radionuclides are C-14, Th-232, Cl-36, Tc-99, I-129, Ra-226, U-234 and 238, Pu 239, 240 and 241 and Am-241. For the trench disposals the inventories of the key radionuclides are composed from key disposals and routine disposals to the relevant trench. Plutonium (Pu) is one of the key radionuclides present within the trenches and the isotopes of Pu present within the trenches are:

- Pu-239 Half life 24,200 years and is a alpha emitter
- Pu-240 Half life 6,563 years and is an alpha emitter
- Pu-241 Half life 14 years and is a beta emitter

As mentioned previously, disposals of Pu will be composed of both key and routine disposals. A key disposal of Pu originated from Magazine 3 at the LLWR and consisted of a number of drums of surface contaminated Pu material. The disposal of this waste occurred in 1968 and then 1971 and was primarily to Trench 2. The origin of the waste (prior to storage in Magazine 3) is not known, however the records have been interrogated to determine the quantity of Pu present. The isotopic ratio of the waste was determined using FISPIN (this is a computer code which calculates changes in numbers of atoms of the nuclides of various species, as a nuclear fuel is subjected to periods of irradiation and cooling). However, two major assumptions have been utilised in determining the isotopic ratio. These are:

- a) The activity composition of Pu has been calculated assuming that the materials arose from Magnox fuel of burn up 1000MWd t^{-1} [Ref 1].

b) The cooling period was typically 2 years [Ref 1].

The above values chosen in (a) and (b) are those which most closely match the processes undertaken at the Sellafield site when the waste was disposed to LLWR in the 1960's. However Ref 1 also states that the main uncertainty associated with determining the isotopic ratio of Pu originates from the values chosen for burn-up and cooling periods chosen within (a) and (b). It also states within the reference that for the Pu inventory, that an order of magnitude seems reasonable. Thus from the above it is not clear within the ESC that if the burn up or cooling periods were to be different, how this will impact on the Pu inventory.

We expect LLW Repository Limited to demonstrate how potential realistic variations in burn up and cooling times could potentially affect the isotopic distribution of Pu within the trenches and also provide confidence to the agency that such changes will have negligible impact on the ESC. In addition, the assessment of burn-up and cooling times should also provide confidence that the order of magnitude assigned to the uncertainty is appropriate.

References

- 1 ESC 2011: The Disposed and Forward Inventory of LLWR, Serco/E003756/12 Issue 2 April 2011.

Technical Query Actions

ESC-TQ-INF-024.A1	LLW Repository Limited should demonstrate that any potential realistic changes in burn-up and cooling times will have limited impact on the isotopic distribution of Pu and subsequently on the ESC assessment.
ESC-TQ-INF-0024.A2	LLW Repository Limited should demonstrate that any potential realistic changes to the burn-up rate and cooling time will fit within the order of magnitude uncertainty stated within the ESC for Pu.

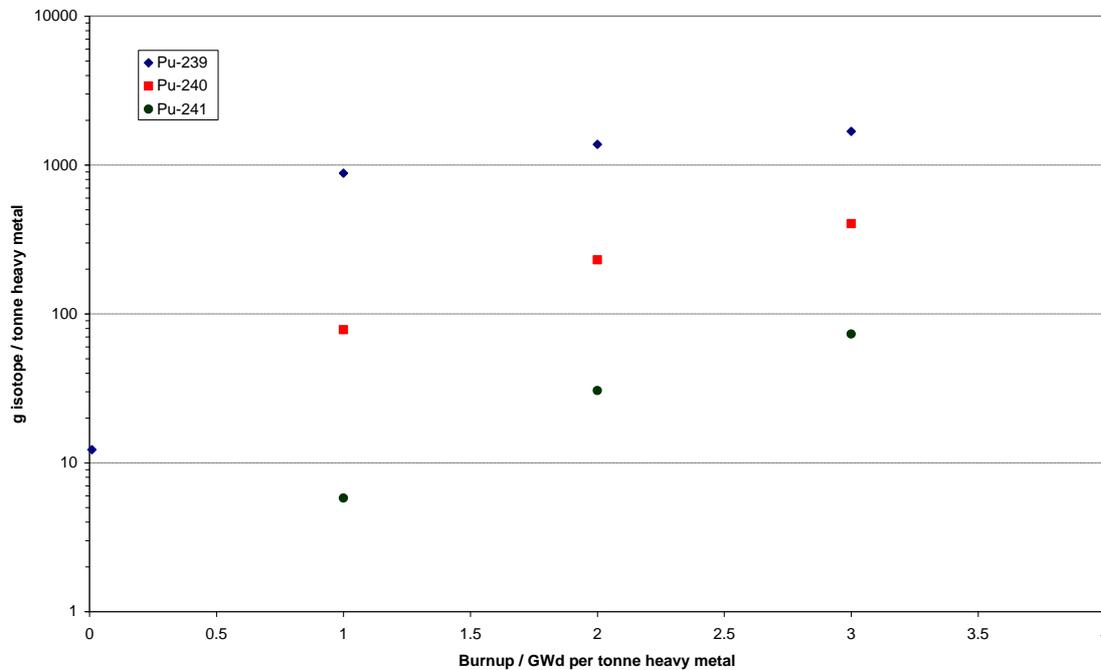
LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	15/06/2012
Comment: The effects of burn-up will be investigated and described.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Technical Specialist	16/07/2012
<p>Pu-239, Pu-240 and Pu-241 are generated in irradiated fuel as a result of the activation/decay sequence given below.</p> <pre> graph LR U238[U-238] -- "n,γ" --> U239[U-239] U239 -- "β" --> Np239[Np-239] Np239 -- "β" --> Pu239[Pu-239] Pu239 -- "n,γ" --> Pu240[Pu-240] Pu240 -- "n,γ" --> Pu241[Pu-241] </pre> <p>The absolute quantities of Pu-239, Pu-240 and Pu-241 at discharge increase with increasing burn-up, and approach a steady-state value. Similarly the amount of Pu-240 and Pu-241 relative to Pu-239 increase with increasing burn-up. This is illustrated in the Figure below, which shows calculations for Magnox fuel at low burn-ups.</p>		



The variation in Pu composition at discharge with burn-up for magnox fuel [77]

Only an increase in average burn-up could increase the quantities of Pu-240 and Pu-241; decreases in burn-up will reduce the quantities of Pu present and thus reduce the impact of Pu from disposals to LLWR. The burn-up of discharged fuel is well understood, and an increase of a factor of two should certainly bound the uncertainty in average burn-up for the material in question. It is clear from the figure that the effects of such a change in burn-up would fit within the order of magnitude uncertainty assumed.

In-growth of Pu-239, Pu-240 and Pu-241 effectively ceases when the fuel is discharged from the reactor. Cooling time therefore affects the quantities of these isotopes only through radioactive decay. The period between discharge of the fuel in the 1960's and the present day is very much greater than the two years assumed in the original calculation. Any uncertainty in the cooling time is therefore small compared with the decay allowed for in the assessment calculations and can have no material effect.

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 10/09/2013
Approved by: Environment Agency	Date: 24/09/2013

In this Technical Query (TQ), we questioned the uncertainty associated with the composition of Pu associated with the burn up of nuclear fuel, and asked whether this could impact on the inventory associated with Pu. We asked for evidence as to why LLW Repository Ltd considered that an uncertainty value of 2 was sufficient with regards to the burn up.

⁷⁷ Nuclear Fuel Simulation System VISTA, IAEA-TECDOC-1535, IAEA, Vienna, February 2007.

The data presented by LLW Repository Ltd in response to this TQ has provided us with confidence that the trench inventory, in which an order of magnitude has been applied to the uncertainty, will cover any uncertainty in the amount of Pu associated with fuel burn up. We note that even a doubling in the burn up will not increase the mass of Pu derived by an order of magnitude. This gives us confidence that the uncertainty bounding applied by LLW Repository Ltd should cover any uncertainty associated with the burn up. The cooling decay applied to the Pu inventory is significantly less than in reality and thus a cautious approach has been applied.

We are satisfied that this TQ has been addressed and it can therefore be closed.

Actions completed, Technical Query resolved and Form closed

Owner: Environment Agency	Date: 30/09/2013
Approved by: Environment Agency	Date: 03/10/2013

ESC-TQ-INF-026: Uranium behaviour

Title	Understanding and modelling the behaviour of disposed uranium
Date raised	29/06/2012
Acknowledgment required by	06/07/2012
Response required by	17/08/2012
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	INF
Approved by	Environment Agency

History

Status	Date	Description
Raised	29/06/2012	
Acknowledged	29/06/2012	
LLWR Response	08/02/2013	
Response Assessed	28/10/2013	
Transferred	28/10/2013	
Closed	12/11/2013	

Statement of Technical Query

We have reviewed how the behaviour of disposed uranium is represented in the 2011 LLWR ESC and how the related uncertainty has been managed. Our comments relate specifically to representation of uranium in the near field in the assessment modelling approach and the associated risk projections to the groundwater pathway.

We conclude the following:

- The near-field solubility and sorption ranges for uranium that have been elicited for the 2011 ESC may not appropriately encompass the associated uncertainties. The assessment approach as presented to date is unlikely to appropriately represent the potential presence and effects of mobility enhancing species that may be present.
- Linked to the above, the assessment cases that consider, independently, unlimited solubility and zero sorption of uranium may not fully encompass the associated uncertainty.

We feel that the case as currently presented may not fully explore the source term uncertainty for the groundwater pathway. The basis of these conclusions is provided below and we place a number of actions to address the concerns that we have raised. We do not expect the results of any further analysis to radically alter the conclusions of the Environmental Safety Case. However, as outlined below, it is not obvious how a revised analysis would affect the projected release to groundwater and how it would compare with the assessments presented to date.

Concerns relating to the representation of uranium behaviour and the treatment of related uncertainty

(1) Basis of the elicited data ranges for uranium solubility and sorption

We note that in eliciting the solubility and sorption ranges (for uranium and other elements) it is stated in the data elicitation report [1] that:

"For both the trenches and the vaults, it is assumed that no complexants other than carbonate are present. It should be noted that the organic complexants in the LLWR differ from those in the proposed NDA-RWMD repository, and it is thought that the former would not have a large effect."

We question the assumption of "no complexants other than carbonate" given the following:

- Reduced Fe(II) colloids have been identified in the trenches and the latter are thought to present a transport vector for uranium. Earlier work [2] has observed that, *"The enhanced levels of colloids measured in the reduced trench environment have the potential to enhance the mobility of alpha emitting radionuclides, which may include uranium and plutonium radioisotopes within the near-field trenches."*
- Complexing agents (e.g. tributyl phosphate, TBP) are declared/known disposals. TBP has been detected in groundwaters in the site monitoring programme.
- The inventory work [e.g. Nexia Solutions (07) 9124] variously refers to "complexants", "unknown organics" and "unknown inorganics". Conceivably some (or all) of these materials may have mobility enhancing properties. Given this uncertainty (and what follows in the next bullet point) we question the robustness of the statement that *"that the organic complexants in the LLWR differ from those in the proposed NDA-RWMD repository"*.
- We are aware of LLWR's concerns at an apparent lack of waste consignor knowledge in relation to "complexants" and (by inference) concerns that such materials may be consigned in ignorance (or may have been consigned to date).
- The solubility enhancing and sorption reducing effects of the degradation products of disposed cellulose (a major inventory component) are not considered directly in the LLWR case. Such effects were considered significant enough as to require representation by others (e.g. the Nirex 97 case) (see below).

Without accounting for the effects of potential mobility enhancing species⁷⁸ it is not clear how the assessment to date has bounded the related uncertainty. As is noted below, it is unclear whether the unlimited sorption and unlimited solubility cases appropriately bound the issues (see (3) below).

We further observe that the assumed pH range within the vault environment (pH 9-11) may not appropriately encompass the range of conditions that may develop therein. Detailed arguments presented to LLWR have suggested that lower pH environments may develop locally within the vault system [3]. Given these uncertainties we would have expected to see some consideration of lower pH vault environments, at least in a variant assessment case.

The move to an elicitation approach in the 2011 ESC is welcomed. However we have previously noted [4] that the range of uranium solubility considered in earlier assessments of the LLWR was limited relative to what has been considered for cementitious systems by Nirex (now RWMD), which are somewhat analogous with the LLWR vaults (i.e. both systems are reducing alkaline environments⁷⁹). We note significant differences in the elicited data relative to the RWMD case [5], as illustrated by a comparison of the data ranges (Table 1).

⁷⁸ Mobility enhancing species are those which enhance solubility and/or reduce sorption or act as a transport vector for radionuclides. These might include co-disposed complexants, complexing species that may form in the disposal environment via the degradation of disposed materials and colloids.

⁷⁹ We recognise that the RWMD case is based on a higher maximum pH range and a proposed cementitious backfill which differs both physically and chemically from the LLWR grout.

	LLWR grout reducing conditions [1].	⁸⁰ RWMD gDSSC for a cementitious engineered barrier system [6].
Solubility range (mol litre ⁻¹)	10 ⁻¹⁰ to 10 ⁻⁶	10 ⁻¹² to 10 ⁻³
Sorption (Kd) range (cm ³ g ⁻¹)	3.10 ² to 3.10 ⁵	5.10 ⁻¹ to 10 ⁶

Table 1. Comparison of solubility and sorption ranges for uranium in cement based systems.

We acknowledge that such a direct comparison may not be entirely appropriate⁷⁹ and that the elicited data used by RWMD are somewhat dated. However, the differences are notable and the extremes of the LLWR ranges are less conservative⁸¹ in relation to uranium mobility (i.e. the maxima for solubility is a factor of 1000 higher and the minima for sorption is a factor of nearly 1000 lower in the RWMD case).

In the RWMD approach solubility enhancement and sorption reduction factors have been used to represent the effects of cellulose degradation products on radionuclide mobility. Such effects, and those of other mobility enhancing species as may be present (as above), have not been directly represented in the 2011 ESC presented by LLWR to date. We observe (see (3) below) that the variant assessment cases, which independently assume zero sorption and unlimited solubility, may not appropriately bound the associated uncertainty.

(2) Model output does not encompass site monitoring data

The assessment model predictions of uranium concentrations (at early times prior to assumed site oxidation) do not encompass the range in concentrations which have been observed in the site monitoring programme. In fact they are lower by a factor of 1000 than the highest observed leachate measurements. The site monitoring data, it is argued in [6], reflect a differing chemical environment to that which will develop within the site following closure:

"The discrepancy in the case of uranium arises because, on the basis of the discussion in subsection 3.2.4, uranium solubility limits and sorption coefficients were determined on the basis of reducing conditions in the trenches. The model results for uranium in Table 3.1 therefore represent the estimated uranium concentrations under reducing conditions. The leachate measurements are higher for two reasons. First, the uranium wastes will be disposed in the form of much more soluble U(VI). In addition, it is unlikely that reducing conditions will have been established in the trenches at the times that the leachate measurements were made."

We wish to understand whether it has been established that the higher measured uranium concentrations in the site monitoring programme reflect the "*much more soluble U(VI)*". We note that they do not always correspond with high fluoride concentrations, if disposed U-bearing fluoride phases are the source (see Figure 4 in [7]). It is not entirely apparent why selected trench monitoring data can be interpreted as reflecting oxidising conditions⁸², where U(VI) predominates, whilst others reflect reducing conditions, where U(IV) predominates. Elsewhere it has been argued with supporting data that the trenches are (currently) reducing and this is reflected in site monitoring data. For example, reducing conditions are reflected in significant concentrations of acetate and the presence of reduced Fe(II) colloids.

⁸⁰ In the RWMD case "sorption reduction factors" and "solubility enhancement factors" are included to reflect the effects of cellulose degradation products.

⁸¹ We note, for example, that in the RWMD case [5] there is a (circa.) 90% probability of U sorption less than the best estimate value and a 70% probability of a uranium solubility equal to or higher than the best estimate value used in the LLWR case [1].

⁸² If this argument is based on measured leachate Eh values (or similar) in the high uranium concentration samples then the data should be presented to support the interpretation.

We also note that, following site closure, there may be a period of time for reducing conditions to establish and for reduction of any U(VI) species to occur within the vaults. This is because:

- We understand that the kinetics of U(VI) to U(IV) reduction are slow in alkaline systems given that the reaction involves four hydronium ions which are sparse at high pH.
- Microbial mediation of redox process may be limited at high pH due to low population densities.
- Reduction of uranium by interaction with zero valent metals (e.g. disposed iron) requires direct contact of uranium species with reactive metal surfaces.

Hence we conclude that an early period of enhanced solubility (reflecting the persistence of U(VI) species in the vaults) cannot be fully discounted and the timescales of any such period have not been established.

We would also observe that the timescales of site wide reoxidation depend on many uncertain factors (e.g. rates of groundwater ingress, rates of biologically mediated processes) and are hence significantly uncertain.

(3) The treatment of uncertainty relating to uranium behaviour

The results of the 2011 LLWR assessment models suggest that risks via the groundwater pathway are sensitive to the sorption (especially) and solubility of uranium, as per the results of assessment cases R12 and R14 [8].

Based on the arguments presented above it is therefore unclear whether the reference case groundwater pathway risks as presented to date appropriately reflect the uncertainty in the solubility and sorption of uranium (in both the trench and the vault environments).

It is accepted that assuming zero sorption and unlimited solubility of uranium are physically unrealistic, bounding extremes. However in the R12 and R14 assessment cases uranium solubility and sorption extremes are considered individually and in isolation [8]. We note that, as per the details of the assessment model [8], sorption in the unsaturated zone influences release to the saturated zone where both sorption and solubility control then influence release (of uranium) and the projected risks via the groundwater pathway. Thus, it would appear, sorption and solubility are not totally independent variables in the assessment models for elements that are both sorption and solubility controlled.

Given the possible combined effects of solubility and sorption, and the concerns outlined above, it is unclear whether the associated uncertainty is appropriately bounded by the R12 and R14 cases presented to date. We wish to see the results of a variant case that includes high solubility and reduced sorption of uranium in combination. This case might be based on high end (solubility) and low end (sorption) values for uranium that are taken from appropriate data ranges for these parameters. The analysis should also consider how the presence of mobility enhancing species might affect the assessment outcomes.

References

[1] SERCO/E.003796/010 Issue 2.

[2] 2002 Drigg Post-Closure Safety Case: Near-Field Biogeochemistry.

[3] Wilson, J. and Metcalfe R. pH Buffering and Carbonation in the LLWR Vaults: Insights from Thermodynamic and Reactive-transport Modelling, Quintessa report QRS-1443E-R1 Version 1.1, 2009.

[4] Environment Agency, 2008. Review of LLW Repository Ltd's "Requirement 2" submission. Review of LLW Repository Ltd's "Requirement 2" submission. GEHO0210BRWR-e-e (p. 15, Para. 2.7.5).

[5] RWMD (2010). Geological Disposal Radionuclide behaviour status report, NDA/RWMD/034

[6] Serco/TAS/003796/011 Issue 6, p. 47-48.

[7] Small, J.S., Lennon, C., Kwong, S., Scott, R.J. (2008). Development and validation of a model of uranium release to groundwater from legacy disposals at the UK Low Level Waste Repository. Materials Research Society Symposium Proceedings, 1107, pp. 657-664.

[8] Serco/TAS/003796/011 Issue 6, p. 82-82.

Technical Query Actions

ESC-TQ-INF-026-A1	<p>Consider the elicited values that have been derived for the solubility and sorption of uranium in light of the above observations. As a starting point, and for the reducing vault environment as envisaged, justify the narrow ranges in elicited parameters for uranium sorption and solubility relative to those derived historically by RWMD for a reducing cementitious system. If appropriate, define revised parameter ranges for the sorption and solubility of uranium that encompass current understanding and uncertainties.</p> <p>Develop an approach which enables suitable representation of the potential presence of mobility enhancing species, the full range of plausible environmental conditions within the disposal system (e.g. lower pH values within regions of the vaults) and uncertainty in understanding of site monitoring data. The approach might include, for example, the use of “enhancement factors” to represent the presence of mobility enhancing species and to explore the uncertainty therein.</p> <p>Apply any revised approach and elicited data ranges within the assessment models and present the output in terms of projected risks via the groundwater pathway.</p>
ESC-TQ-INF-026-A2	<p>For completeness, please also present the results of assessments that consider <u>in combination</u> high solubility and reduced sorption of uranium (e.g. the results of a case based on the highest projected solubility and the lowest projected sorption). Extend such an analysis to consider the effects of mobility enhancing species using any revised approach and elicited data ranges arising as output of the above action.</p>

LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	29/06/2012
Comment: Responses to the actions will be provided.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	08/02/2013
A response is provided in LLWR/ESC/Mem(12)188.		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 28/10/2013
Approved by: Environment Agency	Date: 12/11/2013

In Action A1 of this Technical Query (TQ), we asked LLW Repository Ltd to investigate the potential impacts of mobility enhanced species on the elicited values for uranium solubility and sorption that were used within the 2011 ESC. We questioned whether the range chosen was sufficient to cover the impacts of enhanced mobility species such as complexes and colloids on uranium. We also asked why the elicited ranges chosen within the 2011 ESC were significantly narrower than those chosen by RWMD/NIREX for a Geological Disposal Facility (GDF).

We note that the response to this TQ did not specifically address the issue of complexation, however further work undertaken by LLW Repository Ltd has addressed this question (Ref 1). We have asked LLW Repository Ltd to carry out further work to improve the quantity and range of data utilised within this assessment and the impacts of complexants such as EDTA in Forward Issue ESC-FI-009. It should, however, be pointed out that these issues relate primarily to radionuclides other than uranium.

The information provided by Ref (2) has adequately addressed our concerns relating to the range of values that had been chosen for uranium solubility and sorption within the 2011 ESC. The arguments presented appear reasonable as to why LLW Repository Ltd has applied a narrower range of elicited values than those chosen by NIREX/RWMD.

In Action A2 we noted that the variant cases of enhanced solubility and reduced sorption had been addressed separately in the 2011 ESC assessment. We consider that this does not present a realistic scenario as it is likely that enhanced solubility and reduced sorption will occur simultaneously. We asked LLW Repository Ltd to assess a combined case. In response, the company has assessed a number of variant cases for the trenches and vaults and has demonstrated that the risk guidance level is not exceeded for uranium as a result of the combined effects of high solubility and reduced sorption (Refs 2, 3). We consider that the variant cases presented appropriately address Action A2.

We consider that LLW Repository Ltd has appropriately addressed the concerns raised within this TQ and this TQ can be closed.

References

1. Reviews of the Potential Effects of Complexants on Contaminant Transport at the LLWR, Taylor, F., Baker, A.J., LLWR/ESC/R(13)10054, 2013.
2. Response to Issue Resolution From ESC-TQ-INF-026 (Understanding & Modelling of the Behaviour of Disposed Uranium), Baker, A.J., LLWR/ESC/MeM(12)188.
3. Appendix: Table of Results LLWR/ESC/Mem(12)188.

Actions completed, Technical Query resolved and Form closed

Owner: Environment Agency	Date: 12/11/2013
Approved by: Environment Agency	Date: 12/11/2013

ESC-TQ-INF-032: Containers located within Vault 8 and waste tracking

Title	Containers located within Vault 8 and waste tracking
Date raised	19/12/2012
Acknowledgment required by	21/12/2012
Response required by	18/01/2013
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	INF
Approved by	Environment Agency

History

Status	Date	Description
Raised	19/12/2012	
Acknowledged	19/12/2012	
LLWR Response	24/05/2013	
Response Assessed	27/08/2013	
Transferred	27/08/2013	
Closed	07/11/2013	

Statement of Technical Query

The following Technical Query seeks reassurance that containers and packages which could give rise to settlement greater than standard packages have been appropriately managed and taken account of in the 2011 ESC.

Two specific examples are presented in the Level 2 report 2011 Environmental Safety Case, Optimisation and Development Plan LLWR/ESC/R(11)10025.

Location of out of specification re packed full height containers in Vault 8.

LLW Repository Ltd's knowledge about the placement of containers within Vault 8 is important in understanding how the cap will behave, as the numerous types of wastes degrade. It is also playing a critical role in supporting the initial design of the cap and ensuring that the cap design can meet the expected performance criteria.

A critical parameter to understand within the waste packages is the total voidage present, as this will have important implications in both the design of the initial cap and in the overall performance of the cap.

We note that within the Level 2 report 2011 Environmental Safety Case, Optimisation and Development Plan LLWR/ESC/R(11)10025, it states:

"The majority of waste emplacements to Vault 8 prior to 1995 needed to be retrieved for upgrading (at the LLWR Grouting Facility) to meet the new standard. Not all of the re-worked containers completely met requirements for control of void space. In some cases (where full-height ISO containers has been used for non-compacted wastes) the contents were removed and processed (via WAMAC) prior to repackaging. Others were deemed unsuitable for processing of the contents

and such containers were typically repositioned at the top of the container stacks, in order to minimise their load-bearing requirements....”

This statement appears to indicate that even the containers that were repacked did not meet the new standards for controlling the degree of voidage within a container. Thus an emplacement strategy was implemented by LLWR Ltd to ensure that these containers were located at the top of a stack, to ensure that the load bearing through these containers was acceptable.

Assessing the 2011 ESC reports there is no indication as to the number of these containers which the above statement refers to, nor does the ESC give any indication of the location and distribution of such containers within Vault 8.

We seek clarification as to how LLW Repository Ltd subsequently ensured that the containers in question have remained at the top of the stacks and thus the emplacement strategy suggested by LLW Repository Ltd has been appropriately implemented. Without an appropriate understanding of how the out of specification containers were managed and placed we cannot assess the implications of these containers, nor can it be assured that these containers are located at the top of a stack. In addition, we note that these containers were placed at the top of the stack to minimise the load bearing through these containers, thus we question whether an assessment of the load by placement of capping materials has been assessed.

Management of non standard items in Vault 8

Level 2 report 2011 Environmental Safety Case, Optimisation and Development Plan LLWR/ESC/R(11)10025 goes onto say:

“Vault 8 has also received small arisings of large items of waste (such as uranium hexafluoride cylinders and the heat exchangers from the Windscale Advanced Gas-Cooled Reactor) that were judged at the time to be impracticable to size reduce into standard containers. Such items have mostly been grouted in-situ using mobile grouting facilities; however not all large items disposed to Vault 8 in this way were grouted internally.”

The statement above appears to indicate that not all items that were grouted in-situ within Vault 8 have been grouted internally. Thus, those which were not grouted internally may have a significant voidage associated with the waste. We could not locate within the 2011 ESC (or reference too) the number of items that were not grouted internally, what these items were, nor could we locate within the ESC where these items are located within Vault 8 and the potential implications on the cap, Thus LLW Repository Ltd should demonstrate to the Environment Agency that they possess this information and can demonstrate that they are aware of the implications of such disposals, in terms of cap integrity and design.

Technical Query Actions

ESC-TQ-INF-032.A1	Please provide documentary evidence of the extent of knowledge of the current location and stack position of containers which could not be repackaged (re-worked containers referred to above). Please provide evidence that the WTSD is capable of, and has ensured that, these containers have remained at the top of stacks as suggested in the Level 2 report.
ESC-TQ-INF-032.A2	Please provide assurance that the 2011 ESC cap performance assessment has taken into account the voidage associated with non compliant full height containers and non standard items with residual voidage in the presented cap settlements. If the potential settlement associated with non compliant full height containers and non standard items is greater than that predicted in the 2011 ESC, then demonstration of the ability of the cap to accommodate the predicted additional settlement should be provided. (We recognise this response may draw upon recent work on voidage in Vault 8)
ESC-TQ-INF-032.A3	LLWR Ltd should provide evidence that they know what items

	within Vault 8 have not been grouted internally, how many items there are, where these are located and the implications of such disposals on cap integrity and design. (We recognise this response may draw upon recent work on voidage in Vault 8)
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	19/12/2012
Comment: The further information requested will be provided.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	24/05/2013
<p>The Technical Query “seeks reassurance that containers and packages which could give rise to settlement greater than standard packages have been appropriately managed and taken account of in the 2011 ESC”. Two specific examples are referred to, namely re-packed full-height containers and non-standard items. Each of these types of consignments are discussed below.</p> <p>Work has been carried out to assess potential voidage in consignments within Vault 8, see reference (LLWR 2012), in order to underpin cap performance assessment and the future Waste Emplacement Strategy. The study assessed voidage in these consignments, including the full-height containers and non-standard items. The outcome of that study is drawn on in the responses below. Further details (and definitions of voidage terms) are given in the report itself.</p> <p>Re-packed Full-height Containers</p> <p>As the ESC and Technical Query note, some of the full-height backlog consignments held in Vault 8 contain wastes that were not suitable to be processed through WAMAC. In some cases, for example non-compacted wastes in drums, repackaging was carried out. All consignments have been grouted to reduce inaccessible voidage. Some of these containers, known as ‘Backlog Waste’ contained waste in drums that may have had more than 10% voidage and so needed to be prepared in a way that would ensure they would meet the WAC (CfA at the time) after grouting. Trials were carried out to determine the effectiveness of grout penetration into the drums and assess the impacts of different patterns and locations of piercing. This work is reported in a backlog waste project report, see reference (LLWR 2012). The report concluded that the proposed method of preparation of the drums should ensure that grout penetration was sufficient to meet the CfA (discounting internal inaccessible voidage).</p> <p>The Technical Query refers to the ESC Optimisation and Development Plan report LLWR/ESC/R(11)10025, where it states that those consignments deemed unsuitable for processing were ‘typically repositioned at the top of the container stacks, in order to minimise their load-bearing requirements’. This has been considered further and the comment traced to the 2002 ESC Site Development Plan (and supporting reports), where on fuller consideration it can be seen that it relates to half-height containers of the old (Group 1) design, e.g. Type 2032. The positioning at the top of the stacks was to allow infilling by capping materials of the voidage within the old style lid design and to achieve a uniform load</p>		

distribution at the base of the stack. The Waste Tracking System shows that of the about 1250 such containers 95% are in stack positions 4 and 5⁸³ and only a few are at the base position. (The statement did not relate to the full-height containers as, at that time, it was envisaged that the contents of these would all be processed through WAMAC and no grouting within full-height consignments was planned.) This positioning spreads the container voidage across the vault and as a result only one of these containers is located in each stack reducing any associated differential settlement.

Since the 2002 ESC, LLWR has reconsidered the need for load distribution and concluded that spreading of the load exerted by the mass of the waste stack and the overlying capping materials is not of significant concern. Load distribution will therefore be managed as part of the cap construction.

In terms of the full-height containers, the Waste Tracking System shows these are mainly double stacked, except for a few stacked with half-height containers. However, as noted above, the load bearing ability of stacks is not considered to be a significant issue and will be managed as part of the cap construction. In addition, it is noted that the mass density of these consignments is within the range of consignments in general and it is not expected that this group of consignments will give rise to a higher loads compared with other areas of the vault.

The question of additional voidage associated with the older design of containers, both half- and full-height has been considered in the work on voidage within Vault 8 consignments, see Quintessa (2013) and LLWR (2012) and summarised below.

The uncompacted backlog wastes in full-height containers in Vault 8 are of two principal types. Some contain uncompacted drummed type wastes, whilst the remainder principally contain large items. The total number of consignments is 217, only about 2% of the total number of consignments. The consignments with drummed wastes (about half) were those deemed unsuitable for processing through the WAMAC facility for a number of reasons. These drums contain Special Wastes or had already been grouted. As discussed above, the drums were pierced to allow grout penetration and the full-height ISO then grouted internally.

Notwithstanding this the voidage was analysed as part of the assessment reported in Quintessa 2013. From this analysis of grout mass and container volumes in the Consignment Database, grout penetration within the drums was calculated on average to be about 50% effective, but is very variable. The remaining voidage within the drums is defined in Quintessa 2013 to be a combination of Inaccessible and Compression Voidage. In addition, the nature of these wastes is such that they may comprise a significant fraction of organic materials, with the associated potential for Biodegradation Voidage. However, only five consignments have declared material composition that is not reported as 100% 'other' so the cautious assumption of 50% TPV on the waste container is assumed in the assessment.

For the consignments that principally contain the large items within the full-height containers (106 consignments), the quantities of grout added are variable. The nature of the wastes is likely to be broadly similar to the waste in the consignments directly disposed to the repository (i.e. uncompactable wastes) and Inaccessible Voidage is therefore considered potentially important. Biodegradation Voidage is considered to be relatively low and Compression Voidage is expected to be minimal.

Ullage voidage has also been considered for all these full-height consignments but, based on the recent container survey work, is lower than those for directly disposed consignments, with a mean value of only 3% voidage. Also, by their nature (as backlog consignments) all these wastes are in older containers of Group 1 design (full-height). They therefore have additional voidage estimated to be about 9%, associated with voids in the container structure.

The results of the voidage assessment for the backlog full-height consignments, using the

⁸³ Depending on the heights of containers in the stacks (half or third height) the Type 2032s are either in position 4 or 5 but are all at the same level in the vault.

Voidage Fraction approach, shows only 0.5% of consignments exceed the 35% Total Potential Voidage (TPV) criterion for these locations and stack height. This is not dissimilar to the results for direct disposed wastes. There are about 60% (drummed wastes) of consignments with TPV in the range 26 to 35%, with about 40% (large items) of consignments having TPV of less than 10%. Overall, the indicative total settlement maps in the appendix to the report also show that the areas with the backlog full-height consignments are not significantly worse than other vault areas. However, when the Container Voidage is added the group of consignments with voidage exceeding 35% increases significantly to 60%, although none exceed 40% TPV.

The results of the assessment indicate that about 130 consignments exceed the 35% TPV criteria but that none have more than 40% TPV, see Quintessa 2013. The calculated TPV in these consignments of up to 40% would lead to slightly more potential settlement of the cap but any settlement is likely to be small and not challenge any of the performance assessments related to the cap in the ESC.

It is noted that the results for the backlog full-height consignments show a highly bimodal distribution, corresponding to the split between consignments with drums (at higher assessed voidage) and those without. The recorded waste composition for all nearly all of these consignments are given as 100% 'Other Material' and the associated assumptions are therefore especially important to the assessment. Variations in the extent of grout penetration within the drummed wastes are also important in assessing voidage and variability between consignments⁸⁴. With improved assumptions, specific values for the voidage distribution within these stacks would also aid in assessing how individual stacks compare with the voidage criteria.

Importantly, the wastes are located in only three specific areas of Vault 8 (Sections 11, 15 and 64 at or near the north end of the vault). These represent less than 5% of the vault area. As part of the cap resilience work, see LLWR 2013, these areas will be given specific consideration in terms of cap detailing that could be implemented to mitigate the potential future settlement. The Vault 8 closure plan will also consider the extent to which higher stacking in Vault 8 will be implemented. The assessments discussed here will be used to inform and substantiate this decision.

Non-standard Items

The technical Query refers to the ESC Optimisation and Development Plan report LLWR/ESC/R(11)10025 and that not all non-standard items disposed of have been fully grouted internally. The Technical Query notes that those which were not grouted internally may have a significant voidage associated with the waste. The potential voidage associated with these was considered in the LLWR Position Paper (LLWR 2012) and the assessment taken further in the recent Vault 8 voidage study (Quintessa 2013).

Non-standard disposals comprise wastes in non-standard containers such as redundant fuel flasks, resin catch tanks, grouted WAGR boxes and also wastes not disposed of in containers such as metal ingots and concrete blocks. There are approximately 360 consignments, about 4% of the total number of consignments within Vault 8.

The Position Paper and the voidage study show that only the following disposals have voidage potentially in excess of the relevant criterion:

- 148 hex cylinders, in eight consignments, not grouted internally but grouted externally at LLWR after vault emplacement. The TPV has been estimated as 47% over an area of over 150 m² [3]. These are located in Area 58 on the shelf at the north end of Vault 8. For the shallow depth of the shelf, compared with four high stacks, a TPV value greater than 35% can be justified; this will be assessed further as part of cap design and additional measures taken if necessary.

⁸⁴ Whilst it is noted that some of these stacks have two drum type consignments, and hence are both of higher voidage, comparison of specific voidage values for individual stacks with the voidage criteria is not warranted on current data due to the averaging applied within the assessment.

- Three 3972 containers, each of 87 m³ gross volume, containing calcium alumino magnesium silicate slag contained within steel/iron pots, encased in light-weight concrete. The assessed potential maximum voidage reported in Quintessa 2013 is about 60%. These are also located in Area 15 at the north end of the vault. These equate to about three-high stacking of standard containers. No additional consignments are in these stacks at present. When account is taken of the light-weight concrete, the current voidage associated with these consignments is considered to be within the voidage criteria of 35% TPV but further information is required to assess the longer-term potential for Compression Voidage associated with the foamed concrete. This will be carried out as part of detailed cap design in the cap resilience work (LLWR 2013).

The majority of non-standard disposals have therefore been assessed as having acceptable levels of TPV, many with minimal voidage. Only those above have been identified that may have TPV in excess of relevant voidage criteria. These consignments represent a very small area of the total of Vault 8 and their potential for settlement will be considered further, including if necessary detailing as part of the cap design.

Summary

This information on voidage within Vault 8 consignments shows that there are some consignments that may exceed the relevant voidage criteria, but that these are relatively few in number. LLWR is undertaking a programme of work to determine the implications of the increased voidage on cap performance as part of the forward engineering plans (LLWR 2013). If necessary, the voidage assessment will be refined if practicable. We have concluded that the performance of the cap assumed within the ESC is still valid but for some existing stacks in Vault 8 it may be necessary to either place limits on waste consignments that can be placed on top of existing containers, place limits on stacking height or undertake some additional engineering measures to further minimise local settlement. It is noted that all the full-height backlog and non-standard item consignments that may have unresolved questions that need to be addressed further are all located in a very limited number of areas of Vault 8. Furthermore, these are all relatively close to each other at the north end of the vault, simplifying the implementation of any additional measures that may be found to be necessary. Consideration of all these options will be addressed as part of the detailed design of the engineering.

References

Quintessa, *LLWR Waste Emplacement Strategy: Assessment of the Implications of Voidage in Vault 8*, Quintessa Report QRS 1443ZP-1, Version 2.1, May 2013.

Washington, *Drigg Backlog Waste Project: Report of Multi-Drum Grouting Trials*, RP/0103179/PROJ/00087, Rev A, May 2004.

LLWR, *Vault 8 Containers Issues Project: Position Paper*, RP/LLWRGR/PROJ/00139, Issue 1, December 2012.

LLWR, *Engineering Forward Plan to Support the Environmental Safety Case*, RP/LLWRGR/PROJ/00142, Issue A, April 20

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 27/08/2013
Approved by: Environment Agency	Date: 07/11/2013

The response from LLW Repository Ltd with regards to Action A1 provides us with the relevant detail requested. The company has provided a breakdown of its understanding of the current location of re-worked containers using the information derived from the container condition work programme.

The container condition work programme has delivered significant improvements in the company's understanding of the nature and distribution of potential voidage within the containers. However, we note that only 95% of the containers are located at the top of the stacks as required. Thus 5% of the containers are located elsewhere within the stack. LLW Repository Ltd has demonstrated in Ref (1) that this will be of limited significance in terms of voidage and therefore stack and cap settlement and the company will consider it further as part of the forward engineering programme prior to capping Vault 8. We accept this conclusion.

We consider that a robust waste tracking system is important to the safe and effective management of past and future waste disposals at the LLWR and should aid in the implementation of emplacement strategies. Within Forward Issue ESC-FI-020 we ask for LLW Repository Ltd's plans for the development of a new fit-for-purpose and flexible waste tracking system with the aim of ensuring the effective and transparent management of the entire LLWR inventory of radioactive waste. In the meantime, prior to the implementation of any new system, we will seek assurances that waste tracking and emplacement strategies are effectively managed utilising appropriate procedures and tools.

LLW Repository Ltd's report on the assessment of the impacts of voidage (Ref 1) adequately addresses Action A2. However, the report was not designed to provide assurance that the 2011 ESC cap performance assessment took into account the different nature of the non-compliant containers; instead it provided, amongst other things, visualisation of the nature and extent of potential settlement likely to result from the presence of non compliant containers within container stacks. We consider that the information derived from the report should be used taking due account of the uncertainties associated with container voidage.

The work carried out by LLW Repository Ltd and described here will significantly improve the understanding of the nature and extent of settlement potential. It supersedes the information presented within the 2011 ESC, which did not demonstrate that the settlement from non-standard containers could be accommodated by the cap. As part of the ongoing forward engineering programme, LLW Repository Ltd will improve the robustness of the final engineered cap design and its ability to withstand TPV values of up to 40% (Ref 2).

The outcome of the forward engineering programme may result in localised changes to the final cap design. We will assess any such changes when they are made. We ask LLW Repository Ltd to develop and implement an optimised cap design and waste stack heights, which will take these issues into account, in Forward Issue (ESC-FI-01).

LLW Repository Ltd has demonstrated that it has knowledge of all non-standard disposals that have been consigned to Vault 8 (Ref 3). This report presents a significant improvement in the understanding and characterisation of non-standard items. It also provides information on whether the non-standard items are grouted internally or not. Thus we are content with LLW Repository Ltd's response to Action A3.

Overall, we consider that LLW Repository Ltd has provided satisfactory information in response to this TQ, and that it can be closed.

References

1. Quintessa, 2013. LLWR Waste Emplacement Strategy: Assessment of the Implications of Voidage in Vault 8, Quintessa Report QRS 1443ZP-1, Version 2.1.
2. Shaw, N., 2013. Engineering Forward Plan to Support the Environmental Safety Case. LLW Repository Ltd Report RP/LLWRGR/PROJ/00142 Issue A, April 2013.
3. LLW Repository Ltd, 2012. Vault 8 Containers Issues Project: Position Paper, RP/LLWRGR/PROJ/00139, Issue 1.

Actions completed, Technical Query resolved and Form closed

Owner: Environment Agency	Date: 07/11/2013
Approved by: Environment Agency	Date: 07/11/2013

ESC-TQ-INF-035: Impacts on the radon gas pathway

Title	Impacts on the radon gas pathway
Date raised	19/12/2012
Acknowledgment required by	21/12/2012
Response required by	08/02/2013
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	INF
Approved by	Environment Agency

History

Status	Date	Description
Raised	19/12/2012	
Acknowledged	20/12/2012	
LLWR Response	18/03/2013	
Response Assessed	10/09/2013	
Transferred	12/09/2013	
Closed	27/09/2013	

Statement of Technical Query

The 2011 Environmental Safety Case presented by LLW Repository Ltd has assessed the impacts of the gas pathway on the PEGs for both the operational period and the post closure period. The operational period is dominated by ³H whilst the post closure period is dominated by C-14 and Rn-222.

This TQ focuses on the Rn-222 assessment and in particular seeks clarification on a number of points within the assessment.

1) We note that within the ESC Level 2 Assessment of Long Term Radiological Impacts, LLW Repository Ltd states that:

“The results indicate that provided the low permeability clay layer in the cap retains its properties then Rn diffusion through the cap will be negligible...” (Section 6.3.6 (d) p.144 Paragraph 3)

We note that this may indeed be the case, however, there is also the potential for the clay layer to age and degrade which could lead to enhanced fluxes of Rn-222 through the cap. This could subsequently increase the dose to the PEGs upon the cap. LLW Repository Ltd notes this within the ESC and states:

“This demonstrates that substantial cap degradation would have to occur for there to be any appreciable release of Rn-222 at the cap surface. However, in highly degraded local areas, the Rn-222 flux at the upper surface of the cap could be comparable with the rate of evolution from the upper surface of the wastes.” (Level 3 Report Rn222 Gas Pathway Assessment Version 3, Section 3.2.2 Page 49 Last Paragraph)

We acknowledge that LLW Repository Ltd states that localised degradation is possible and would subsequently enhance the flux of Rn-222 through the cap layer. However, we note within the statement that the flux can be similar to that emanating from of the waste, however it is not clear from the ESC submission what impact this will have on doses to PEGs. Within the ESC it does not

appear that LLW Repository Ltd has assessed such a scenario and the subsequent dose to the PEGs. We expect LLW Repository Ltd to assess the potential impact of these localised fluxes though the cap and in particular the potential dose to occupiers of a dwelling located upon the cap.

2) Within the Level 2 Assessment of Long Term Radiological Impacts report LLW Repository Ltd has measured the percentage of Rn-222 retained within the trenches. This varies from 85-93%, which subsequently means that 7-15% escapes from the trenches. At present LLW Repository Ltd has been unable to determine the emanation of Rn-222 from the iso-containers and thus an assumption has been made about the emanation of Rn-222 from these waste packages. LLW Repository Ltd has stated the following:

“For the calculations set out below (Subsection d) we assume a source of Radon in pore space gas could vary between 7 and 15% of the Ra-226 concentration in the waste: we consider that 15% is cautious but representative for the trenches and 7% is representative of the vaults” (Level 2 Assessment of Long Term Radiological Impacts, Section 6.3.6, Section (b), last paragraph p.139)

We note that LLW Repository Ltd appears to have chosen the lower value for the vaults as a result of the integrity of the wasteform, as in the Level 2 Assessment of Long Term Radiological Impacts Section 6.3.6. (b) it states that the lower flux of Rn-222 is as a result of the integrity of the wasteform and thus preventing the ingress of air and subsequent release of Rn-222 from the package. However, from the ESC it is not clear why the value of 7% has been chosen as a cautious approach and why LLW Repository Ltd has assumed that this low value within the trenches corresponds to a cautious value for the vaults. We seek clarification from LLW Repository Ltd as to why this value has been chosen.

In addition we note that when LLW Repository Ltd has assessed the hydraulic conductivity for the wastes present within the trenches and vaults within the Level 3 Elicitation of Uncertainties (see Table 1) report it would appear that the wasteform for the vaults has a higher hydraulic conductivity than for the trenches. This would appear to indicate that the wasteform for the vaults could potentially be more open to transport of water and potentially gas than for the trenches. This leads us to question the low emanation factor for the vaults when compared with the trenches.

Table 1 Hydraulic Conductivities for the Trenches and Vault Long Term

Area of LLWR	Upper Value	Central Value	Lower Value
Very Long Term Hydraulic Conductivity of Waste Contents	10^{-9}	10^{-6}	10^{-4}
Hydraulic Conductivity for the Trenches in Long Term	10^{-9}	10^{-8}	10^{-6}

Thus LLW Repository Ltd should provide greater clarification of the chosen emanation factor for the vaults, and also should assess the impact if this value were to be higher than the Rn-222 gas pathway value already assessed.

3) Within the ESC and as part of the Rn-222 assessment, LLW Repository Ltd has assessed the impact of varying cap thicknesses on the flux of Rn-222 and the subsequent dose to the PEGs. The table below provides an example of the LLW Repository Ltd assessment of this variabl

Source	Assumed Cover Layer	Rn-222 in Soil (Bqm ⁻³)	Rn-222 in Building (Bqm ⁻³)	Hypothetical Annual Dose (mSv)
All Vaults	1m coarse material	2.3E+5	3.5E+2	8.8E0
	1.5m coarse material	9.7E+4	1.5E+2	3.7E0
	2m coarse material	2.9E+4	4.3E+1	1.1E0
	2.1m coarse material, 0.9m fine	N/S	N/S	N/S

It is not clear from LLW Repository Ltd's assessment why the limiting thickness has been chosen as 1 m and not 0 m. LLW Repository Ltd should demonstrate why the 1 m layer for the eroded cap is justified and presents a cautious case. Within the ESC no reference is made to back up the assessment that 1 m is the limiting thickness of the eroded cap, and why 0 m has not been assessed. We note that LLW Repository Ltd has stated that buildings cannot be constructed directly on the waste material and thus we seek a justification for this statement.

Technical Query Actions

ESC-TQ-INF-035.A1	LLWR Ltd to assess the implications of higher Rn-222 localised fluxes to PEGs located on the cap, as a result of localised cap degradation.
ESC-TQ-INF-035.A2	LLWR Ltd to provide clarity as to why the 7% emanation value for the vaults is a cautious approach and to clarify why values closer to 15% or higher are not deemed more appropriate. LLWR Ltd should assess any impacts as a result of any changes to the emanation factors resulting from this re-assessment.
ESC-TQ-INF-035.A3	LLWR Ltd to justify use of a 1 m limiting thickness for the eroding cap as a cautious case, as discussed in this TQ.

LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	20/12/2012
Comment: The requested assessment, clarification and justification will be provided.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	18/03/2013
A response is provided in ESC Project memo LLWR/ESC/Mem(13)205.		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 11/09/2013
Approved by: Environment Agency	Date: 27/09/2013

Action A1 in this Technical Query (TQ) queried the impact of localised degradation of the cap and the subsequent impact that this would have on radon transfer through the cap, and its subsequent impact on the risk associated with the gas pathway. In the 2011 ESC LLW Repository Ltd states the importance of the cap in limiting the release of radon. However, we note the gas barrier layer in the cap is constructed of clay, which can crack if moisture is lost. Localised cracking of the clay layer may therefore lead to higher fluxes of Rn-222 through the cap, which in turn could lead to higher impacts as a result of Rn-222 doses.

In response, LLW Repository Ltd states that cracking is unlikely to occur in the lifetime of the facility, prior to the impact of coastal erosion on the site. LLW Repository Ltd also emphasises that it has separately assessed the impact of Rn-222 on a dwelling on the cap where the foundations directly tap into the gas storage layer. We note that this is a worst case scenario, as it removes any protection provided by the clay layer. It therefore represents a more cautious assessment than cracking of the clay layer leading to enhanced Rn-222 emanation.

However, although we agree that cracking of the clay layer in the cap due to loss of moisture is unlikely within the lifetime of the facility, we are not convinced that cracking has been demonstrated to be unlikely due to potential localised differential settlement in the cap. LLW Repository Ltd has proposed programmes of work to address differential settlement potential further and we would expect this work to also investigate the nature and significance of localised settlement on the integrity of the low permeability element of the engineered capping system (see Forward Issue ESC-FI-001). We ask LLW Repository Ltd to assess the design and performance of the functional layers of the final engineered cap in Forward Issue ESC-FI-027, including the assessment of failure scenarios.

Localised cracking of the cap will result in the release of Rn-222 direct to the atmosphere. However, in this case the risk to Potentially Exposed Groups will not be significant as a result of the gas being able to diffuse and disperse from this location. We are content with this response.

Action A2 queried why an emanation factor of 7% had been chosen for the vault waste, whereas a factor of 15% was used for the trenches, which was determined from direct measurement of Rn-222 release. LLW Repository Ltd responded indicating that the vault waste is encapsulated in grout which will slow the diffusion of Rn-222 through the wasteform, thus resulting in a significantly lower emanation factor than that for the trench waste. LLW Repository Ltd demonstrates the ratio of Rn-222 in air within the vaults to the Ra-226 within the waste is at least a factor of 2 less than for the trenches. This provides evidence that the Rn-222 is diffusing slower from the vault waste compared to the trenches. The emanation factor of 7% used by LLW Repository Ltd for the vaults therefore represents a cautious upper value. A true value may in fact be lower. Based upon this evidence we are content with the response to Action A2.

Action A3 requested clarification of LLW Repository Ltd's assumptions for the assessment of the dose associated with differing thicknesses of profiling material should a dwelling be built on a disrupted cap. The response has clarified the company's assumptions and justified why it considered the limiting case for building a dwelling on the cap as including 1 m of profiling material. In response to the query LLW Repository Ltd also notes that even if the dwelling was built with a 0 m cover layer, then the annual effective dose would only be increased by a factor of 2.

Overall, we are content with the response to this TQ and can close it.

Actions completed, Technical Query resolved and Form closed

Owner: Environment Agency	Date: 24/09/2013
Approved by: Environment Agency	Date: 27/09/2013

ESC-TQ-SUE-010: Isostasy monitoring

Title	Uncertainty associated with isostatic changes at the LLWR
Date raised	19/11/2012
Acknowledgment required by	26/11/2012
Response required by	21/12/2012
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	SUE
Approved by	Environment Agency

History

Status	Date	Description
Raised	19/11/2012	
Acknowledged	21/11/2012	
LLWR Response	05/02/2013	
Response Assessed	22/07/2013	
Transferred	25/07/2013	
Closed	28/01/2014	

Statement of Technical Query

The LLWR site is subject to ongoing isostatic changes which will result in localised changes in relative sea level. Over the whole life of the repository isostatic movement could influence the magnitude of sea level change.

It was noted in the 2011 ESC that the LLWR is located on an axis point between rising isostatic levels to the north and falling isostatic levels to the south of the site. This is probably correct, but because of the distance to the nearest measured datum it is not possible to confirm this assumption. It would be valuable if site or locally derived information could be used to confirm this assumption and to provide site specific data for input into site specific sea level change predictions.

In the first instance we seek an assessment of the viability, usefulness and practicality of taking site derived measurements of relative ground height, at a useful level of accuracy, over an extended timeframe. The assessment should consider the equipment needs, appropriate testing frequencies and the ability to use a site based datum.

An alternative approach would be to identify an existing measurement point located at a closer and more representative location than that presented in the ESC.

Technical Query Actions

ESC-TQ-SUE-010-A1	Please carry out an assessment of the viability, usefulness and practicality of taking site derived isostasy measurements of relative ground height, at a useful accuracy, over an extended timeframe. The assessment should consider the equipment needs, appropriate testing frequencies and the ability to use a
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	site based datum. An alternative response would be to identify an existing measurement point located at a closer and more representative location than that presented in the ESC.
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	21/11/2012
Comment: An assessment will be performed and reported to the Agency.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	05/02/2013
A response is provided in ESC Technical Memo LLWR/ESC/Mem(13)195, 05/02/2013, which references a Halcrow Technical Note, Subject: Feasibility, practicability and cost of installing GPS to monitor land-level change, 17/12/2012.		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 23/07/2013
Approved by: Environment Agency	Date: 28/01/2014

This Technical Query (TQ) sought to clarify the viability and usefulness of ongoing measurement of relative ground height to quantify the impact of isostasy.

LLW Repository Ltd's response is documented in a technical memo (ESC Technical Memo LLWR/ESC/Mem(13)195, 05/02/2013), which in turn references a Halcrow document (Halcrow Technical Note, Subject: Feasibility, practicability and cost of installing GPS to monitor land-level change, 17/12/2012).

We have reviewed the information provided by LLW Repository Ltd and accept that the uncertainty associated with the measurement of local isostasy is minor compared with the predicted range of sea level change. Thus the effect of local isostasy will have a minimal influence on the assessment and the overall ESC. We conclude that no additional benefit would be provided by the onsite measurement of isostatic uplift.

Based on the evidence that measurement of isostatic uplift would have very limited benefit in reducing uncertainty in the assessment, we will not require LLW Repository Ltd to carry out such measurements. However, this situation may change as sea level change predictions and modelling are improved. We therefore recommend that LLW Repository Ltd should revisit this issue at a relevant point in the future (see Recommendation SUE37 of Environment Agency 2015, Review of LLW Repository Ltd's 2011 Environmental Safety Case: Site Understanding).

This TQ can therefore be closed.

Actions completed, Technical Query resolved and Form closed

Owner: Environment Agency	Date: 28/01/2014
Approved by: Environment Agency	Date: 28/01/2014

ESC-TQ-SUE-011: Slope stability

Title	Slope stability assessment of the eroding waste mass
Date raised	30/01/12
Acknowledgment required by	02/02/12
Response required by	29/02/12 (ESC-TQ-SUE-011.A1) 30/03/12 (ESC-TQ-SUE-011.A2)
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	SUE
Approved by	Environment Agency

History

Status	Date	Description
Raised	13/01/2012	
	30/01/2012	Amendments to TQ to take account of discussions with LLWR on 19/1/12
Acknowledged	01/02/2012	
LLWR Response	23/02/2012	To Action A1
LLWR Response	22/05/2012	To Action A2
Response Assessed	14/03/2014	
Transferred	15/08/2014	
Closed	15/08/2014	

Statement of Technical Query

Because of the uncertainty associated with the failure scenario of the repository during coastal erosion and the importance of assessing the dose consequences of human exposure to the eroded waste mass it is considered important that a realistic range of waste failure geometries are used to assess the rate and nature of erosion on the vaults and trenches. In order to achieve this objective we believe an appropriate geotechnical assessment should be carried out of the eroding waste.

The most realistic presented coastal erosion scenarios indicate that the waste mass will be eroded by undercutting. The assessment assumes that this erosion will result in the formation of vertical/near vertical cliffs with slumped materials present at their base. Waste will then slump to form a storm beach in front of the cliffs. The slumped material is predicted to protect the exposed waste face from further erosion.

We seek geotechnical validation of the presented cliff regression model and identification of realistic failure modes using a best practice geotechnical slope assessment. The assessment should where possible use site specific material properties. Ideally the assessment should be carried out at a number of key points in the erosion of the facility or as a continuous erosion sequence corresponding with the erosion of the site.

The assessment might utilise the following constraints and assumptions:

1. Using the reference case scenario erosion which assumes undercutting of the concrete vault (with undercutting at a nominal depth of 5 metres below the base of the slab). The amount of under cutting in any one storm event will be limited by the geometry of the exposed erosion front. Undercutting will either remove the under liner granular drainage material or both the underlying glacial till and the granular materials.
2. The model should assume that during a storm event any storm beach at the toe of the waste is removed to expose the disposal system. Any stability benefits derived from the presence of the storm beach at the base of the slope should not be considered for the assessment. A separate assessment incorporating the benefits derived from the presence of a storm beach at the toe of the slope could be carried out in order to represent a stabilised cliff form.
3. Assuming erosion takes place in a west to east direction, the extent of the waste that is affected by the formation of the exposed 'cliff' thickness will increase towards the centre of the dome landform before reducing again.
4. The geotechnical properties and geometry of the vaults and trenches need to be appropriately assessed.
5. Site specific geotechnical properties of the degraded concrete slab, engineering layers and waste mass should be used where possible. The ESC assumes for the 300 year erosion case the waste mass is less degraded than the waste at the 1000 year reference case and the 3000 year extended erosion case. These changes in waste material properties should be appropriately assessed in different model runs. Because of the uncertainties associated with the condition of the ISO freight containers it is suggested that calculations incorporating block/toppling failure and granular failure modes are carried out. It may also be useful to assess rotational/translational stability and any deformation via finite element modelling.
6. Assume all groundwater and leachate can freely drain.
7. The assessment should take account of changes to the geometry of the capping layer during erosion process.

An expert workshop could be used to scope the assessment and identify realistic failure scenarios and input parameters, the workshop could scope the following aspects:

- The geotechnical appropriateness of the presented ESC repository erosion model
- Identify realistic alternative failure modes and scenarios
- Derive realistic geotechnical parameters for use in the model and the likely consequences of an extended timeframe and waste degradation on waste and engineering materials
- The likely equilibrium state for the waste taking into account the presence of storm beach materials at the base of the cliff slope
- Realistic worst case failure case scenarios for the differing waste degradation states (300 years after present and the reference case of 1000 years)

The outputs from the workshop should be used to inform a fit for purpose interpretive slope stability assessment report identifying realistic failure modes for the eroding waste form. An assessment should also be made of any impact upon dose assessments undertaken, based upon any alternative realistic failure modes.

Technical Query Actions

ESC-TQ-SUE-011.A1	LLWR to outline the timing, scope and attendees at an expert workshop
ESC-TQ-SUE-011.A2	Based upon the outputs of the workshop in Action ESC-TQ-SUE-011.A1, LLWR to produce a fit for purpose interpretive slope stability assessment report identifying a realistic range of failure mode for the eroding waste form, along with an assessment of any impacts upon the dose assessment.

LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	01/02/2012
<p>Comment: Our proposed approach is to organise a workshop involving people with expertise in coastal erosion, slope stability and the approach taken to radiological impact assessment of coastal erosion in the 2011 ESC. We will review our approach to the assessment, our knowledge of the evolving system, and what slope analysis is feasible. Based on this review, we will discuss and draw conclusions on the usefulness of further work on slope stability in improving confidence in our coastal erosion impact assessment. Depending on the outcome of the workshop, we will undertake a slope stability assessment and an assessment of its implications for the radiological impact assessment. We believe it is highly desirable for the Agency to attend the workshop.</p>		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	23/02/2012
<p>Response to action: ESC-TQ-SUE-011.A1</p> <p>The objective of the workshop will be to review our understanding of coastal erosion, the nature of the eroding cliff/slope and the coastal erosion impact assessment, to ascertain what, if any, further work is warranted to build confidence that the assessment provides an adequate treatment of uncertainty. A briefing pack will be provided, based on some initial work undertaken prior to the meeting. The initial work will develop and refine our understanding of the mode of erosion of the wastes, partly based on simple stability assessments and underpinning calculations. Initial consideration will also be given to the implications of the output of this work for the impact assessment. A record of the meeting will be produced.</p> <p>The workshop is planned for March or early April, depending on the availability of the attendees.</p> <p>The attendees, their organisations and their areas of expertise are as follows:</p> <p>Environment Agency – Geotechnical and ESC specialist Halcrow (Engineering Consultants)– coastal erosion Halcrow (Engineering Consultants) – geotechnics Quintessa (Radiological Impact Consultant) – coastal erosion assessment Quintessa (radiological Impact Consultant) – coastal erosion assessment LLW repository Ltd – radiological assessment LLW Repository Ltd – ESC Project Manager LLW Repository Ltd – ESC Technical Specialist LLW Repository Ltd – ESC Technical Specialist (site characterisation)</p> <p><i>Note, attendee names have been removed, they can be found on the original Technical Query form.</i></p> <p>Response to action: ESC-TQ-SUE-011.A2. 22/05/2012</p> <p>The results of the workshop and work undertaken in association with it are reported in Quintessa report QRS-1443ZO-1, Version 1, May 2012. The conclusions we have drawn relating to radiological impacts on humans and non-human biota are set below.</p> <p>Radiological impact on humans</p> <p>Geotechnically informed consideration of the stability of the wastes and cap materials during coastal erosion has provided a more detailed description of the likely form and nature of the open face of the eroding facility. Consideration of the possibilities for a recreational user of</p>		

the beach to access the eroding slope areas leads to the conclusions that:

- the stacked grouted waste containers of the vault are liable to form a generally steep cliff that would not be readily accessible and the assumptions of access incorporated in the calculations in support of the 2011, e.g. occasional clambering on the cliff for 10h/y, remain valid;
- the compacted loose tipped trench wastes will be less stable, and there is likely to be a shallower slope over these wastes, bounded by somewhat steeper slopes above and below, providing possibilities for paths traversing parallel to the coast over these wastes.

Such paths are likely to be intermittent both spatially (i.e. unlikely to be continuous over long distances) and temporally (i.e. liable to destruction by minor slope failures or erosion) and not provide a viable course along the whole face of the eroding trenches.

Calculations have been made of the effective dose to the recreational user of the beach on the assumption that this individual might spend 20% of the 300 hours/year allotted in the 2011 ESC calculations on such paths. This is considered to be cautious. Modifying the assumed habits of the recreational user of the beach in this way leads to a calculated peak annual dose of 100 μSv , related to external exposure from progeny of Th-232 present in the trenches. This compares with about 20 μSv determined in the 'reference case', and about 60 μSv for the 'direct erosion' case to this exposed individual in the 2011 ESC. This peak annual dose occurs for a period of about 200 years during the time in which the wastes of Trenches 4 and 5 are eroding.

Given the relatively low likelihood that such paths persist for any prolonged period of time, and cautious allocation of time to their use assumed in the calculating an annual dose of 100 μSv , we consider that assessed risks to future beach users can be considered to be consistent with the risk guidance level set in the GRA. We also note that the dose is calculated to arise from historical disposals in the trenches.

Radiological impact on non-human biota

As noted above, the stacked grouted waste containers of the vault are liable to form a generally steep cliff and the assumptions for occupancy and exposure for non-human biota in the 2011 ESC assessment remain valid.

The compacted loose tipped trench wastes will be less stable, and there is likely to be a shallower slope over these wastes, bounded by somewhat steeper slopes above and below, providing possibilities for an environment that may be suitable for burrowing animals such as rabbits and bank or ground-nesting birds. The slopes will be exposed and well drained with poor vegetation and unlikely to encourage reptiles.

As described in reference [1], dose rates to organisms making use of the eroding cliff area, storm beach and foreshore have already been assessed. Peak concentrations in environmental media and estimated absorbed dose rates are reported in Appendix F of reference [2].

Table F.3 of reference [2] shows dose rates ($\mu\text{Gy h}^{-1}$) for the terrestrial assessments calculated by summing doses related to peak concentrations of each radionuclide (see Tables F.1 and F.2) irrespective of time of occurrence. Selecting results from that table, the following dose rates are estimated for organisms of greatest interest on the cliff slopes:

	Dose Rates ($\mu\text{Gy h}^{-1}$) for the organisms on the cliff and cliff slopes			
	Bird	Egg	Mammal	Grasses & herbs
External	0.7	0.7	2	0.7
Internal	5	9	4	23
Total	5	10	6	24

A first comparison is to 10 $\mu\text{Gy h}^{-1}$ generic screening level advised by the Agency.

The highest total dose rate is for grasses and herbs, but these are not especially radiologically sensitive. In addition, examination of Table F.6 shows that the key radionuclides contributing to this dose rates are Tc-99 28%, Th-228 25%, Ra-226 13%, i.e. contributed to by radionuclides from both the vaults and the trenches.

In the case of bird and bird egg it should be borne in mind that species nesting on the cliff slopes are liable to be coastal birds, gaining at least some sustenance from the beach and foreshore areas. This would raise the internal dose somewhat (maximum of 50%) if a large part of their sustenance came from the beach area or reduce it substantially (order of magnitude) if a large part of their sustenance came from the foreshore area.

In the case of mammals, the possible sources of sustenance for a rat could be bird eggs or scavenging on the beach, which could marginally increase or reduce the dose estimate. For a rabbit, one might envisage burrowing in the cliff slopes but grazing over a wider area including inland from the cliff, thus reducing the total dose rate.

Overall, we conclude that the shallower angle of the cliff slope while the trenches are eroding could provide a more varied habitat for non-human biota, but dose rates will not be much different to those calculated in the case of the steeper cliffs assumed in existing assessments in support of the 2011 ESC. The ameliorating factors for the cliff and beach areas noted in reference [1] still apply, notably that the cliff and beach are transient environments with continual turnover, migration and movement of organisms between the potentially contaminated area adjacent to the LLWR, other areas of beach and further afield. Thus, even if there is potential for radiological detriment to individual organisms, there is no potential for significant harm to local populations, or at local colony levels.

References

1. LLWR, *The 2011 ESC: Assessment of Impacts on Non-human Biota*, LLWR/ESC/R(11)10030, May 2011.
2. Thorne MC and Schneider S, *Assessment of the Impacts on Non-human Biota for the LLWR 2011 ESC*, Serco Report SERCO/TCS/00435/01 Issue 2, April 2011.

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 15/08/2014
Approved by: Environment Agency	Date: 15/08/2014

This Technical Query (TQ) documented our concerns that the conceptualisation of the eroding waste mass presented in the 2011 ESC did not take sufficient account of the geotechnical properties of the waste and associated geological materials. We consider that the nature, shape and rate of the eroding waste mass is important in developing the scope and approach of assessment of the eroding waste mass. We assess the company's response to each of the TQ actions below:

Action A1

Because of the need to take account of both geotechnical and radiological assessment factors, we considered that the best means of addressing the TQ was for LLW Repository Ltd to hold a workshop with attendance from relevant ESC team and external experts. Discussions at the workshop were informed by 2 documents (LLW Repository Ltd 2012a, b).

The workshop was effective in bringing together geotechnical, geomorphological and radiological assessment experts in order to better understand the nature of the problem. Outcomes from the workshop were incorporated into a further report (LLW Repository Ltd 2012c). We believe that the workshop facilitated the conceptualisation of more realistic waste erosion scenario than used in the 2011 ESC assessment. We consider that this action can be closed.

Action A2

LLW Repository Ltd's updated slope stability assessment is documented in LLW Repository Ltd (2012c) and is summarised in the company's response to this TQ above. This work has improved the understanding and description of the eroding waste mass, and has changed some of the assumptions made within the 2011 ESC with regards to beach users. We consider that the resulting description of the eroding wastes is more realistic than that presented in the 2011 ESC.

An important benefit of the geotechnical assessment of slope failure has been the presentation of more realistic coastal profiles; these will assist in LLW Repository Ltd's communication of site evolution. Figure 18 within LLW Repository Ltd (2012c) is particularly effective in showing the different failure forms which may occur during repository erosion. In addition, the erosion sequencing shown in Figures 31 and 32 in Section 5 will assist in communication of the site erosion sequence.

LLW Repository Ltd considers that the grout and waste present in the ISO containers will behave similarly to a gravel. The container form will dominate the main failure mechanism by providing obvious failure planes. Taking account of the learning from the container condition investigations, it is considered likely that once the structural integrity of the container is lost, the grout will exhibit limited cohesion or resistance to erosion. This will result in rapid degradation. We agree with these findings.

We consider that the use of local cliffs as analogues to visualise erosion form is useful. However, where waste represents a significant proportion of the cliff, the profile is likely to diverge from the local cliff shape and composition and therefore be easily identified by the local beach users.

We consider that this action can be closed.

Conclusions

The interaction between beach users and the eroding waste is an important element of the assessment model used within the ESC. The eroding waste front presents a direct exposure pathway that may be present over hundreds of years whilst erosion progresses. The site evolution assessment identified the most likely direction and form of repository erosion. It is therefore possible to consider how the waste will erode and the nature of the beach and cliff that the eroding repository may produce. The work carried out by LLW Repository Ltd to address this TQ has improved the understanding of the likely form and behaviour of this aspect of the assessment. This in turn has improved understanding of the potential interactions between beach users and the eroding waste.

We consider the LLW Repository Ltd has appropriately responded to this TQ and that it can be closed. However, due to the significance of this issue to the ESC, we believe it is important that LLW Repository Ltd continues to develop its understanding of both the eroding waste mass and the behaviour of the repository during the erosion process. As documented in Forward Issue ESC-FI-028, we require LLW Repository Ltd to investigate further nature of waste erosion into its forward work programme. The output from this work should be used to inform updates to the ESC. The objective of this work is to reduce the known uncertainties and improve the conceptualisation of the repository erosion.

Examples of areas of potential investigation include:

- the impact of changes to the waste from anaerobic to aerobic conditions during the erosion process
- the introduction of large volumes of infiltration into the remaining waste mass as a result of the complete removal of the engineering barriers
- further investigations into the nature, rate and extent of waste degradation and its impact on the rate and form of repository erosion
- consideration of the heterogeneity of wastes and its impact on the erosion and beach users
- improved understanding of beach user patterns during the erosion process

References

LLW Repository Ltd, 2012a. Briefing Notes for a Workshop in Response to ESC-TQ-SUE-011: "Slope Stability Assessment of the Eroding Waste Mass", QRS-1443-ZO, 23 March 2012.

LLW Repository Ltd, 2012b. LLWR Slope Stability Workshop, Wednesday 28th March 2012 10:00-16:00 at, Washington House, URS, Risley.

LLW Repository Ltd, 2012c. Slope Stability of the eroding waste mass, QRS-1443Z)-1 May 2012.

Actions completed, Technical Query resolved and Form closed

Owner: Environment Agency	Date: 15/08/2014
Approved by: Environment Agency	Date: 15/08/2014

ESC-TQ-SUE-019: Extreme events

Title	The role of extreme storm surge events and their impact on the rate and extent of coastal evolution
Date raised	15/01/2013
Acknowledgment required by	21/01/2013
Response required by	15/03/2013
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	SUE
Approved by	Environment Agency

History

Status	Date	Description
Raised	15/01/2013	
Acknowledged	15/01/2013	
LLWR Response	18/03/2013	
Response Assessed	25/07/2013	
Transferred	25/07/2013	
Closed	24/01/2014	

Statement of Technical Query

Low frequency storm surge events will occur throughout the lifetime of the Low Level Waste Repository (LLWR) and will affect the morphology of the Drigg coast. The frequency and severity of these events is predicted to increase as a result of climate change.

Storm surge events will result in greater water depths, which can bring about rapid and potentially significant changes in the shoreline environment on the coastal frontage adjacent to the site.

Because of the high level of uncertainty, complexity and extended time of consideration over which the 2011 Environmental Safety Case (ESC) assessment models operate, the effects of discrete extreme events have not been superimposed onto the projections of future coastal change in the ESC due to of the projected greater importance of sea-level rise. Instead, the presented models generate a linear regression of the coast which removes single events by averaging.

The impact of low frequency extreme storm surge events could result in any of the following impacts:

- Erosion of the coastline with the removal of storm beaches and redistribution of sediments within the coastal cell. For clay lithologies horizontal and vertical erosion could occur. Sand lithologies may be rapidly eroded with local redistribution of sand and removal of features.
- Coastal surface water and fluvial flooding beyond normal high water levels.
- Changes in the coastal and off-shore morphology, mostly associated with mobile sand features. On a larger scale, changes in geomorphology such as changes to the rivers route and breaching of the dune system could occur.

A number of raised features have been identified along the Drigg coast that are attributed to the effects of contemporary storm surges⁸⁵. These include 'raised' features along the coast including gravel ridges at 5 to 6 m AOD at the south of the Drigg promontory, and high elevation beaches with crests at 7 to 8 m AOD such as those with beach front properties at Nethertown and Coulderton. We seek clarity on how future events, similar to those that may have created such features, could affect the morphology of the Drigg coast and the timing and mode of erosion of the LLWR.

The following processes which may be caused or magnified by the effects of extreme weather conditions and storm surges are of relevance to the ESC:

Coastal Erosion

Erosion during extreme events is likely to affect both granular and till features. Under such conditions the zone of sediment movement becomes more extensive and coarser material, including boulders will be mobilised.

For granular features, erosion is likely to occur on a larger scale, but could also exploit discrete morphological features such as gullies and till low points (paleo features such as buried valleys). During normal conditions, the presence of coarse, granular material will have a limiting effect on the erosion of finer lithologies. However, this may not be the case during extreme storm events as it can be assumed that cobbles and bolder sized clasts can be entrained. The extent of the erosion will therefore be controlled by the height of the surge and the wave energy impacting on the shoreline during the storm event.

For more resistant clay features, it is reasonable to assume that storm beaches will be removed allowing greater wave energy to impact the cliffs. This could result in greater cliff retreat rates than envisaged solely resulting from regular winter storms.

Coastal, surface water and fluvial flooding

The surge component of a storm is likely to increase the height of wave action and generate increased water levels in the Irt Estuary. Extreme flooding events may be more significant as the coast line approaches the repository and sea levels rise, with potential flooding from the west and the south.

Changes in off-shore morphologies

Extreme events have the potential to significantly change the shape and form of off-shore sea bed morphology. This could result in short and long term changes in the wave patterns and direction.

On a larger scale potential changes could include the breaching of the gravel spit to the south of the site, the removal of the dunes or the re-alignment of the River Irt.

For the majority of the assessment period storm surges can be accommodated within an average model. However, as the coastline recession approaches the repository, the magnitude of extreme events may become more important. We are therefore interested in potential events which could inundate or erode the repository prior to the main erosion front encountering the repository boundary. We would be interested to understand if this could lead to more rapid erosion of the LLWR than currently assumed and alternative modes of erosion. We also wish to understand the effects of inundation of the LLWR by storm surges and the implications on cap erosion and contaminant migration pathways.

Climate Forcing Factors

The only climate forcing function used in the conceptual coastal change model is relative sea-level. For a complex system such as the Drigg coast, morphological changes can occur in response to variations in the forcing (e.g. wave, wind or tidal energy flows) or the materials (e.g. the geology exposed at the shoreline at a particular point in time). We wish to understand the significance of other identified climate forcing factors on coastal erosion.

⁸⁵ Fish et al., 2010. Forecasting the Development of the Cumbrian Coastline in the Vicinity of the LLWR Site. Quintessa and Halcrow report QRS-1443X-1.

For all of the actions set out below, our expectation is the provision of expert opinion and commentary backed up with appropriate references. All responses can be descriptive in nature. The current magnitude and frequency of storm surges should be used in this response.

Technical Query Actions

ESC-TQ-SUE-019.A1	Please provide a description of the modelling approach used to assess the evolving coastline in the vicinity of the LLWR. Reference should be made to how the model takes account of extreme events over the entire erosion sequence.
ESC-TQ-SUE-019.A2	Could an extreme event result in alternative modes of erosion causing localised disruption of the site, for example, caused by erosion of the cap during inundation by storm surges? Does the presented modelled erosion timeframe take account of the potential for earlier disruption of discrete areas prior to the arrival of the main erosion front?
ESC-TQ-SUE-019.A3	Please provide expert opinion of the likelihood of a different coastal alignment, other than the assumed north south linear shoreline. This should be on a smaller scale (finer scale features) than used in the assessment and take account of the presence of erodible geologies adjacent to the repository.
ESC-TQ-SUE-019.A4	Please confirm that climate forcing factors other than sea level will not play a significant role in the predicted coastal erosion.

LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	15/01/2013
<p>Comment: A response will be provided explaining:</p> <ul style="list-style-type: none"> - the potential for extreme storm events under future climate conditions; - their impact on coastal morphology / erosion and how they are accounted for in ESC quantitative models and assessment assumptions; - the potential for impact on the repository itself and impact on the radiological assessment. 		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	18/03/2013
A response is provided in Halcrow Technical Note: TQ Response – Extreme Events.		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 25/07/2013
Approved by: Environment Agency	Date: 24/01/2014

We asked LLW Repository Ltd to clarify how the coastal evolution sequence presented in the 2011 ESC took account of extreme and rare weather events in this Technical Query (TQ). We assess the company's response as documented in the Halcrow technical note (TQ response: Extreme Events, ESC-TQ-SUE-019, February 2013) against each of the TQ actions below:

Action A1

The technical note appropriately describes how extreme events were taken into account in the derivation of the 2011 ESC coastal evolution sequence. We note that changes due to storminess were not taken into account in the long-term projection of climate change impacts. However, storminess is considered in the 2011 ESC assessment; the frequency and magnitude of the storms used in the models were based on the historic events impacting the west coast of Cumbria.

If the nature and magnitude of storms is predicted to change as a result of climate change, then we would expect future versions of the ESC site evolution assessment to take this into account. We accept that this omission does not have any significant impact on the model at the moment. However, LLW Repository Ltd should maintain a watching brief on the development of understanding of long-term changes in storminess associated with climate change (see Recommendation SUE38 of Environment Agency 2015, Review of LLW Repository Ltd's 2011 Environmental Safety Case: Site Understanding). We consider that this action can be closed.

Action A2

The technical note answers the first part of our query with regards to whether an extreme event could result in alternative modes of erosion causing localised disruption of the site, but not the second with regards to whether the presented modelled erosion timeframe takes account of the potential for earlier disruption of discrete areas prior to the arrival of the main erosion front. We therefore requested a further response from LLW Repository Ltd⁸⁶, which we take into account in our assessment.

LLW Repository Ltd acknowledges the impact of the known heterogeneity in the glacial geology on the form of the erosion front. These differences in the geology may result in the formation of localised headlands and bays. LLW Repository Ltd states that 'Some limited part of the repository might be eroded (most likely by undercutting) sometime in advance of the erosion along the full frontage of the repository. In the case of rapid sea level rise and erosion, this can only be a few decades in advance, since the whole repository is eroded out in a matter of centuries. In the case of slow sea level rise and erosion, this might be about a century in advance, given the whole repository is eroded over millennia.' We consider this statement appropriately describes the likely nature of the disruption of the repository. LLW Repository Ltd is confident that the large range of times for the commencement of site disruption that is considered in the 2011 ESC accommodates this uncertainty. We agree with this statement.

We conclude LLW Repository Ltd has appropriately taken into account the impact of extreme events on the form and commencement of repository disruption in the 2011 ESC and that localised repository erosion is unlikely to occur outside of the presented timescales. We consider that this action can be closed.

Action A3

The technical note provides the requested information. We consider that this action can be closed.

Action A4

The technical note provides the requested information. We consider that this action can be closed

Conclusions

We consider that LLW Repository Ltd has provided a comprehensive response to this TQ. The company has provided additional information on the behaviour of the coastal system, which improves the description of the nature of the commencement of repository disruption presented in the 2011 ESC.

We are satisfied with the evidence that backs up these conclusions and consider that this TQ can be closed. To better understand the nature and timing of the beginning of repository disruption, we recommend that future updates of the ESC should investigate the viability of providing improved understanding of the effects of extreme events as the coast approaches and encounters the

⁸⁶ Email from Amy Huntington Dated 31st July 2013 entitled RE; Response to IRF ESC-TQ –SUE-019.

repository. These investigations could, for example, seek to quantify the nature and extent of coastal recession resulting from single storm events or seasons (see Recommendation SUE38 of Environment Agency 2015, Review of LLW Repository Ltd's 2011 Environmental Safety Case: Site Understanding).

Actions completed, Technical Query resolved and Form closed

Owner: Environment Agency	Date: 15/08/2014
Approved by: Environment Agency	Date: 24/01/2014

ESC-TQ-SUE-022: Understanding the role of the dune system in the ESC

Title	Understanding of the role of the dune system in the ESC
Date raised	20/11/2012
Acknowledgment required by	29/11/2012
Response required by	05/01/2013
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	SUE
Approved by	Environment Agency

History

Status	Date	Description
Raised	20/11/2012	
Acknowledged	29/11/2012	
LLWR Response	20/12/2012	
Response Assessed	20/07/2013	
Transferred	20/07/2013	
Closed	20/08/2014	

Statement of Technical Query

We do not consider that the role and significance of the dune system in the evolution of the coast line has been clearly described in the 2011 ESC. We would like to see the Environmental Safety Case address and communicate in more detail the role (or lack of role) and significance of the dunes in the erosion of the repository.

This Technical Query specifically seeks to address the following questions:

1. Confirmation that the erosional and depositional behaviour of the sand based lithologies has been clearly defined and assessed.
2. Clarification of the role and significance of the dune system in the coastal recession assessment.
3. Description of the role and behaviour of the Drigg dune systems in response to the changing coastal conditions occurring during the erosion sequence.
4. Confirmation of the current sand budget status of the Drigg dune system, are the dunes eroding or accreting?

In the first instance we are seeking responses to the above questions, with appropriate reference to the ESC. Where appropriate responses may be in a simple narrative form and at this stage we do not envisage the need for any further details assessment work.

Confirmation that the behaviour of the sand based lithologies has been appropriately assessed.

The presence of the dune system and associated post glacial sand rich surface deposits is recognised and investigated in the ESC using site investigation and geophysical information.

What is not clear is how the various coastal regression models take account of the distinct erosion characteristics of non-cohesive sands and the different proportion of sands in the retreating shore front. This is particularly relevant to areas of the shoreline where dune sands are present across a significant proportion of the distance between the shoreline and the sites western and southern perimeter. (Geophysical Report, January 2010 (for example geophysics profile E and F)).

Where recent sand lithologies are located within the predicted range of sea level rise and will be subject to wave action we would like clarification of the response of the model to the complete removal of the more robust clay and gravel based lithologies from the erosion front.

The removal of the recent sands from the Drigg spit could, for example, result in the avulsion of the course of the Irt to its former east to west route through the current position of the Drigg spit. The Halcrow report (Ref. 1) states that *“the pathway taken by the Irt to the sea is predicted to remain approximately as it is today. This is due to the projected increase in gravel supply to the Drigg barrier beach to the north which will prevent any major avulsion of the Irt to a more westerly outlet to the sea”*. This statement was made prior to the geophysical survey information being available. The geophysical survey shows that parts of the spit are entirely covered with recent sand and that the former Irt channel flows through the spit (east to west). Please assess the possibility for avulsion and its impact on the development of the local coast and impact on the LLWR site and disposal area

Clarification of the role and significance of the dune system in the coastal recession assessment.

Please confirm that the larger scale behaviour of sand rich lithologies has been incorporated into the coastal recession model. Does the model assume that the presence of sand does not play any role in the rate of coastal recession once it has been eroded?

Identification of the role and behaviour of the Drigg dune systems in response to the changing coastal conditions occurring during the erosion sequence

We consider that the Drigg dune system is considered to be an important part of the coastal system. Dune systems can respond to a number of environmental changes in ways which could influence the rate and form of coastal erosion. These changes could have a negative or positive impact on the rate and form of erosion predicted in the ESC. We seek a quantification of the potential significance of the impacts on the rate and form of erosion from that presented in the ESC. The quantification need be in a narrative form only.

Some examples of environmental changes which may influence the behaviour of the dune system and the response of the coastline might include:

- Rising (or falling) sea levels, including the potential impact on dune system stability associated with changes in groundwater levels below the dune system
- Increased wave energy and storm magnitude and energy
- Changes in sediment supply to the dune system (both positive and negative inputs) from outside of the dune system, for example as a result of the construction of flood defences to the south of the site
- Changes in the depth of the dune hinterland and effect of domed cap landform as the distance between the coast and the LLWR repository reduces
- Changes in the total footprint and lateral extent of the dune system
- Land use changes such as grazing and leisure usage
- Synergistic combinations of the above changes

Outlined below are some examples of potential outcomes which could occur as a result of changes to the dunes:

- Rapid erosion either over a large area or small discrete erosion feature resulting in earlier disruption of the site

- Provision of additional protection to the shore line and slowing of the rate of coastal erosion as a result of sand accretion and new dune formation.
- Interactions (including feedback) associated with the interaction between the shoreline and the dune system with the hard structures of the site
- Changes to the height and recharge of groundwater within facies A

Current Status of the Dune system

The ESC assumes that the generation of the dunes was the result of historic sea level fall, most probably associated with the mid-Holocene period and that they are essentially a historic feature with no active generation/feeding mechanisms. We seek clarification on whether the dunes are a current active element of the coastal system with both accretion and erosion of sand into the dune system from the marine environment. This should take account of the status of the whole dune system and not just the exposed shore front.

We would also recommend that the following documents are consulted when making your response as they provide insight into the role and significance of dunes in eroding coastlines.

- Sand dune processes and management for flood and coastal defence: Part 1: Project overview and recommendations
- Sand dune processes and management for flood and coastal defence: Part 2: Sand dune processes and morphology
- Sand dune processes and management for flood and coastal defence: Part 3: The geomorphological and management status of coastal dunes in England and Wales
- Sand dune processes and management for flood and coastal defence: Part 4: Techniques for sand dune management

Reference

1. Coastal Studies forward programme data compilation and position statement, August 2009.

Technical Query Actions

ESC-TQ-SUE-022-A1	Please provide confirmation that the behaviour of the sand based lithologies has been appropriately assessed in the assessment.
ESC-TQ-SUE-022-A2	Please provide clarification of the role and significance of the dune system in the coastal recession assessment.
ESC-TQ-SUE-022-A3	Please provide information on the role and behaviour of the Drigg dune systems in response to the changing coastal conditions occurring during the erosion sequence, addressing the queries raised within this TQ.
ESC-TQ-SUE-022-A4	Please assess the possibility for avulsion and its impact on the development of the local coast and impact on the LLWR site and disposal area
ESC-TQ-SUE-022-A5	Please confirm the current status of the dunes. (eroding or accreting)

LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	29/11/2012
Comment: Responses to the actions will be provided.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	29/11/2012
A response to the three actions is provided in a Halcrow Technical Note, <i>Significance of the dune system at Drigg</i> , 11 December 2012.		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 20/07/2013
Approved by: Environment Agency	Date: 20/07/2013

We have reviewed the Halcrow technical note on 'Significance of the dune system at Drigg' and consider that it provides the necessary clarity on the significance of the dune system during coastal erosion, in particular with respect to potential impacts on the lifespan of the LLWR.

We have made the following conclusions, which correspond to the five actions in this Technical Query (TQ):

- A1. The dunes that front the LLWR and which form the northern part of the Drigg promontory rest on top of till deposits that constrain the rate of coastal recession. The dunes of the southern part of the Drigg promontory rest on gravels that may erode, but this would have little impact on future recession. The contribution of sand-sized material to the beach sediment budget is accounted for in the coastal erosion modelling. We consider this action to be closed.
- A2. The dunes have a limited significance in the evolution of the coastline over the timescale of a few hundred to a few thousand years covered by the 2011 ESC. Under future conditions of rising sea level and limited supply of sand-sized sediment, there is little opportunity for expansion of the existing dune system or formation of new dune systems. Scope remains for the incorporation of dune and dune precursor habitats into the final restoration design, if required at a later time. The incorporation of these features is unlikely to significantly change the timing of the commencement of repository erosion. We consider this action to be closed.
- A3. The entire frontage of the LLWR and the northern part of the Drigg promontory are underlain by a till ridge. Therefore, the erosion assessments are based on cliff recession modelling and do not consider the response of dunes to direct wave attack. Under future conditions of potentially rapid rising sea level and limited supply of sand-sized sediment, existing sand dunes will be eroded. We consider this action to be closed.
- A4. The evidence for past avulsion of the River Irt course is equivocal, but even if avulsion were to occur in the future, it would not affect the timing of erosion of the disposal area, which is determined by erosion of the coastal frontage. We consider this action to be closed.
- A5. The dunes are stable under current climate and land management conditions. Geological evidence suggests dune accretion has occurred over the past c. 6,000 years, but had ceased by c. 200 years ago. We consider this action to be closed.

We are satisfied with the evidence that backs up these conclusions and consider that this TQ can be closed.

We note that additional commentary on the site evolution sequence is provided in the Appropriate Assessment prepared under the requirements of the Habitats Regulations (Environment Agency, 2014. Form HR02: Proforma For Stage 3 Appropriate Assessment, Drigg Low Level Waste Repository, Environmental Permit Variation EPR/YP3293SA/V002, July Updated October 2014). This document contains a description of the expected evolution of designated habitats located within the dune system.

Actions completed, Technical Query resolved and Form closed

Owner: Environment Agency	Date: 15/08/2014
Approved by: Environment Agency	Date: 20/08/2014

ESC-TQ-SUE-023: Cap slope stability assessment request

Title	Cap Slope Stability Assessment Request
Date raised	19/11/2012
Acknowledgment required by	26/11/2012
Response required by	17/12/2012
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	SUE
Approved by	Environment Agency

History

Status	Date	Description
Raised	19/11/2012	
Acknowledged	21/11/2012	
LLWR Response	13/02/2013	
Response Assessed	25/07/2013	
Transferred	25/07/2013	
Closed	24/01/2014	

Statement of Technical Query

As part of LLW Repository Limited's response to ESC-TQ-SUE-011, a stability assessment was carried out on the stability of the cap when subject to undercutting by costal erosion. The stability assessment demonstrated that the 1:25 slope angle seen across the majority of the site was stable with a factor of safety greater than 1. This assessment was useful and provided us with re assurance of the long term stability of the majority of the capping design.

As part of our wider assessment of the LLWR ESC we are seeking demonstration that all elements of the proposed restoration design will remain stable throughout the life of the site. We therefore request the following assessment of the undisturbed capping and restoration design.

Using a similar appropriate slope stability approach to that used to address ESC-TQ-SUE-011, we would like the following two slope configurations assessed:

- a) typical 1:10 side slope element
- b) worst case side slope element (assumed to be 1:5)

Scenarios for the two configurations should include:

- Prior to cap degradation incorporating all engineering elements (including the provision of geo synthetic slope stabilisation measures such as roughened flexible membrane);
- After cap geo synthetic material degradation; and
- With removal of the toe of the slope as a result of an unforeseen erosion event.

The following realistic assumptions can be used:

- All assessments should incorporate the presence of vegetation in the restoration layers; and
- No groundwater will be present in the capping layers.

Technical Query Actions

ESC-TQ-SUE-26-A1	Using an appropriate slope stability approach, we would like the following two slope configurations assessed: a) typical 1:10 side slope element b) worst case side slope element (assumed to be 1:5)
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	21/11/2012
Comment: Requested assessments will be provided.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	Chief Engineer	13/02/2013
<p>The stability of the final cap slope of 1v:25h was considered in the Engineering Design report (LLWR/ESC/R(11)10020) and the risk of instability considered to be minimal.</p> <p>The stability of the final cap at the edges, therefore outside the footprint of underlying waste, of 1v:10h (worst case of 1:5) was also considered and calculated as > 1.3. Further consideration was given (LLWR :Site Optimisation and Closure Works, Regulation 22 Response - Engineering Design, March 2012, URS) to cap stability (Subsection 3.3.2), including the factors contained in the report, of slope instability failure being 'forced' at the surface of the geomembrane/geotextile boundary. The report concluded that the factor of safety, against slope instability, was >1.3, therefore the slope design is considered adequate in the long term.</p> <p>The slope stability analysis undertaken was at the edges of the final cap, outside the footprint of the waste, being the worst case of slope angle. The final cap design is such that the primary geomembrane is curtailed within the proposed cut-off wall and therefore a substantial distance from the toe of the final cap slope. (Minimum height of 3m capping layers = 15m from toe of slope. This is conservative as the likely minimum is in the range 4 to 5m, leading to a 20 – 25m long slope edge.) The calculated minimum circular slip and block failures are located such that the failure plane does not lie on (or near) the plane of the primary geomembrane. The condition of the primary geomembrane (as installed or degraded), in this situation, is therefore not considered to be a design concern. (Other, secondary, geotextiles are included in the final cap edge design and the impact included in the stability calculations.)</p> <p>The above calculations were considered to be worst case scenario - no vegetative cover – representing the short term, as establishment of vegetative cover will enhance the slope stability through mechanical effects and reduce the potential for erosion.</p> <p>Toe erosion, to the extent that will affect the performance of stability of the cap is unlikely primarily due to the rock and drainage material present at this location. This will be further examined and substantiated through the development of the detail design and specification for the cap installation.</p>		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 25/07/2013
Approved by: Environment Agency	Date: 25/09/2013

The information presented by LLW Repository Ltd above provides reassurance that the company has given appropriate consideration to the long-term stability of the final restoration system. The

presented information provides a conceptual indication of maximum and typical slope designs across the whole of the restored single dome final cap.

We consider that LLW Repository Ltd's slope stability assessments are realistic and appropriate. However, LLW Repository Ltd's drive to maximise physical disposal capacity has resulted in a restoration cap design that has several slopes steeper than most repository or conventional landfill designs. We expect these slopes to be reduced during the design development and justification process (see Recommendation O&E15 of Environment Agency 2015, Review of LLW Repository Ltd's 2011 Environmental Safety Case: Optimisation and Engineering). Where steep slopes remain, we would recommend that long-term stability investigations are carried out to support the design proposals (see Recommendation O&E15 of Environment Agency 2015, Review of LLW Repository Ltd's 2011 Environmental Safety Case: Optimisation and Engineering).

Overall, we believe that LLW Repository Ltd has provided sufficient information outlining the assumptions used to support the 2011 ESC single dome restoration cap design. We therefore consider this Technical Query can be closed.

Actions completed, Technical Query resolved and Form closed

Owner: Environment Agency	Date: 27/09/2013
Approved by: Environment Agency	Date: 24/01/2014

ESC-TQ-SUE-024: Concrete slab performance

Title	Assumed Concrete Slab Performance
Date raised	30/05/2012
Acknowledgment required by	07/06/2012
Response required by	29/06/2012
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	SUE
Approved by	Environment Agency

History

Status	Date	Description
Raised	30/05/2012	
Acknowledged	01/06/2012	
LLWR Response	29/06/2012	
Response Assessed	25/07/2013	
Transferred	25/07/2013	
Closed	25/09/2013	

Statement of Technical Query

The LLWR Vault design incorporates a cast reinforced concrete slab on which waste is placed. The functionality of the concrete slab relates mostly to the need to provide an appropriate structural surface on which to place the stacked containers. Throughout the ESC credit is given to the containment capability of the slab as part of the engineered containment system.

The base and side walls of the all of the vaults incorporate joints. The inclusion of these joints is good engineering practice and allows the thermal expansion and contraction of the concrete slab. These joints are sealed with a 'Mastick' type polymer which has a limited lifespan as an effective water proofing seal. The 'Mastick' is applied after the pouring of the slabs from above.

The Level 3 document on 'Elicitation of Uncertainties for LLWR' attributes hydraulic conductivity performance to the as built concrete slab and wall. A log normal probability distribution is attributed with 5% value of $10^{-13} \text{ m.s}^{-1}$, 50% value $10^{-12} \text{ m.s}^{-1}$ and 95% value of $10^{-11} \text{ m.s}^{-1}$.

These values are then subject to elicitation to represent the aging of the concrete at 2180, 3180 and 7000. By 2180, the joints will have been assumed to have failed and in filled with silt resulting in a higher hydraulic conductivity through the joints. A statement is made that the hydraulic conductivity of the base (and side lips) would be dominated by the contribution from the joints.

This TQ is divided into two discrete parts, the first relates to the assumed performance of the vertical joints and the second on how the joints are treated in the ESC hydrogeological and near field modelling.

Performance of the joints

The ESC takes account of the degradation of the joints over an extended period, however we question a number of the assumptions used in the ESC.

1. **Life span of the joints:** The ESC assumes that the joints will have failed by 2180. We seek confirmation that failure of the joints will not occur over a much shorter time period. Please provide evidence the expected lifespan of the installed vertical joint seals, especially when they are open to the atmosphere and taking account of the difficulties encountered in placing the mastic. It cannot be assumed that the joints can be serviced or repaired because of access restrictions. In some circumstances it is reasonable to assume that limited repairs can be made to exposed joints. If possible evidence from Vault 8 and Vault 9 should be used. This shorter term degradation should, if appropriate, be incorporated into the Period of Authorisation Performance Assessment.
2. **Degradation of the concrete slab:** The ESC assumes that only the mastic element of the joints fail and there is no degradation and widening of the joints. A joint width of 2 mm is assumed. Observation of the exposed joints in Vault 9 shows variability in the as built thickness of the joints and degradation of the slab joints. Please provide evidence to support the assumption that the joints are only 2mm wide and will not widen as a result of degradation from weathering and tracking.
3. **Siltation of the joints.** The ESC assumes that the failed joints will infill with silt grade material, from this a permeability is derived. While it is accepted that the joints are liable to infill with silt, it cannot be guaranteed that this will occur over the entire joint area and that high flow pathways will not remain. Please justify why 10^{-8} m/sec represents a realistic maximum hydraulic conductivity for all joints in the base of the vaults.

Modelling of the joints

The ESC states that the hydraulic conductivities of the bases and walls would be dominated by the contribution from the joints. Despite being a small area of the total base area, the joints are laterally extensive and will occur at or around the lowest point of the vaults meaning that even with leachate management the slab will leak.

Please clarify and present in a single location the modelled parameters and assumptions used throughout the ESC. Where applicable any potential performance changes identified should be compared against the modelled assumptions.

Technical Query Actions

ESC-TQ-SUE-024	LLWR should address the performance and modelling queries raised above.
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	01/06/2012
Comment: A response will be provided.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	29/06/2012
A response is provided in ESC Technical Memo LLWR/ESC/Mem(12)154.		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 25/07/2013
Approved by: Environment Agency	Date: 25/09/2013

We have reviewed LLW Repository Ltd's response to this Technical Query (TQ) provided in Response to IRF ESC-TQ-SUE-024 Concrete Slab Performance ESC Technical Memo LLWR/ESC/Mem(12)154. This memo effectively clarified a number of performance assumptions used in the hydrogeological modelling of the vault engineering systems.

We accept that it was appropriate to use elicited values to assess the long-term performances of engineering systems in the 2011 ESC. However, we expect LLW Repository Ltd to ensure that opportunities to better understand the long-term performance of engineering systems are pursued, as discussed in Forward Issue ESC-FI-026.

We consider that this TQ can be closed.

Actions completed, Technical Query resolved and Form closed

Owner: Environment Agency	Date: 25/09/2013
Approved by: Environment Agency	Date: 25/09/2013

ESC-TQ-SUE-025: Coastal erosion

Title	Timing of disruption of the LLWR by coastal erosion
Date raised	04/05/2012
Acknowledgment required by	15/05/2012
Response required by	15/06/2012
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	SUE
Approved by	Environment Agency

History

Status	Date	Description
Raised	04/05/2012	
Acknowledged	04/05/2012	
LLWR Response	20/07/2012	
Response Assessed	23/08/2012	
Transferred	23/08/2012	
Closed	10/10/2013	

Statement of Technical Query

The LLWR Environmental Safety Case seeks to identify the rate and consequences of site erosion as a result of coastal regression. A suite of information is presented as part of the ESC.

The analysis of potential future sea level rise in the long-term undertaken in the Site Evolution L2 volume of the ESC estimated that a sea level rise of between 1.1 m and 21.1 m would have occurred by 1,000 years after present (AP) and that a rise of between 7.3 m and 24.6 m would have occurred by 3,000 years AP, taking into account the effects of isostatic uplift⁸⁷. These bounding high and low sea level rise scenarios were input into projections of coastal recession in the vicinity of the LLWR. Two separate modelling approaches were used in forecasting the development of the coastline in the vicinity of the LLWR site: empirical cliff recession modelling; and process-based modelling using the Soft Cliff and Platform Erosion (SCAPE) model⁸⁸. The outputs of these models were reasonably consistent. The empirical model projected that the eroding coastline will reach the site boundary within 500-800 years AP (low sea level rise scenario) or within 400-600 years AP (high sea level rise scenario). This model predicted loss of the entire disposal facility by 1500–1900 years AP. The SCAPE model provided a lower estimate of the eroding coastline reaching the site boundary between 300-400 years AP and an upper estimate of 800-900 years AP. The high sea level scenario would be considered a worst case scenario for sea level change.

⁸⁷ LLW Repository Ltd, 2011. The 2011 Environmental Safety Case. Site Evolution. LLWR/ESC/R(11)10023.

⁸⁸ Fish, P., Thorne, M., Moore, R., Penfold, J., Richards, L., Lee, M. and Pethick, J., 2010. Forecasting the Development of the Cumbrian Coastline in the Vicinity of the LLWR site, Quintessa Report Ref: QRS-1443X-1 Version 1.

On the basis of the available evidence, we believe that the projections of future sea level and coastal change provide a reasonable estimate of the timescales for erosion of the LLWR. However, from the results summarised above, we query the selection of 1,000 years AP as “appropriate as a reference time for coastal recession to reach the disposal area site boundary (i.e. for the onset of erosion of the disposal facility)”. The basis of the selection of 1,000 years AP, and whether it was considered representative or realistic, is unclear. We therefore seek justification of the selection of 1,000 years for commencement of vault erosion, including clarification of the term “appropriate,” given LLW Repository Limited’s model outputs suggest earlier commencement.

Technical Query Actions

ESC-TQ-SUE-025.A1	Please provide a clear justification for why 1,000 years was selected as an “appropriate” reference time for coastal recession to reach the disposal area site boundary.
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	04/05/2012
Comment:		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Technical Specialist	20/07/2012
A response is provided in ESC Project Memo LLWR/ESC/Mem(12)158, 20/07/2012.		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 23/08/2012
Approved by: Environment Agency	Date: 10/10/2013

ESC Project Memo LLWR/ESC/Mem(12)158 provides a useful summary of the uncertainties in making projections of coastal recession and the use of expert judgement.

We consider that the role of expert judgement in the 2011 ESC documentation could have been better described, for example the statement in the memo that ‘we consider it likely that there is a significant bias towards overestimate of the rate of erosion in the longer term’ is not captured in Level 1, Level 2 or key Level 3 or other Level 3 documentation. However, with the aid of this memo, we consider that this Technical Query has been addressed to our satisfaction and may be closed.

Actions completed, Technical Query resolved and Form closed

Owner: Environment Agency	Date: 23/08/2012
Approved by: Environment Agency	Date: 10/10/2013

ESC-TQ-SUE-026: Seismic assessment of cap stability

Title	Seismic assessment of cap stability
Date raised	03/08/2012
Acknowledgment required by	10/08/2012
Response required by	28/09/2012
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	SUE
Approved by	Environment Agency

History

Status	Date	Description
Raised	03/08/2012	
Acknowledged	03/08/2012	
LLWR Response	13/02/2013	
Response Assessed	25/07/2013	
Transferred	24/01/2014	
Closed	24/01/2014	

Statement of Technical Query

The weight of evidence suggests that the LLWR site is currently, and will continue to be, exposed to a limited risk of seismic hazard from nearby, shallow earthquakes of moderate magnitude, short duration and modest peak intensity⁸⁹. In the vicinity of the LLWR, the highest peak ground acceleration (PGA) for a 1 in 10,000 year return period earthquake is predicted to be 0.25g.

Within the 2011 ESC Level 2 Engineering Design report⁹⁰, the final capping design is assessed against extreme or disruptive events, including seismic events. The 2002 Post-Closure Safety Case (PCSC) carried out a seismic assessment, focussing on the 1:4 slopes around the shoulder of the cap⁹¹. The 2011 ESC directly references this assessment in order to justify cap stability in the event of an earthquake⁹², stating that "*This was shown to be satisfactory for slopes of up to 1 in 4 for the 2002 PCSC [42] and not of concern for the considerably flatter slopes of the Reference Design*". However, the 2002 PCSC did note the potential for both shallow and deep slips to occur around the shoulder of the cap in the event of an earthquake following a period of intense rainfall when the surface capping layers were saturated, with displacements of up to 0.5 m depending on earthquake magnitude.

While it is accepted that the 2002 seismic assessment was appropriate to support the 2002 PCSC, we seek confirmation that the demonstration of safety is still applicable to the 2011 reference

⁸⁹ Hunter, J., 2003. An overview of seismic hazard at Drigg. DTP/148.

⁹⁰ LLWR, 2011. Engineering Design. LLWR/ESC/R(11)10020.

⁹¹ BNFL, 2002. 2002 Drigg Post-Closure Safety Case: Engineering design report.

⁹² LLWR, 2011. Engineering Design. LLWR/ESC/R(11)10020.

design for the final cap and that the assessment method still achieves the current Office for Nuclear Regulation (ONR) design expectations. The seismic assessment should be carried out on the steepest proposed cap slope elements and should address both saturated and unsaturated conditions in the upper layers. We would also expect the relevant elements of the 2002 assessment to form part of the presented 2011 ESC suite of documents.

The 2002 PCSC seismic assessment notes that most of the concern in relation to seismic events relates to the operational phase. However, the 2002 assessment does not cover the operational phase of the site prior to the completion of the capping and restoration. This is assumed to be as a result of the waste and capping system being non-confined with a number of operational slopes. We require confirmation that this statement remains applicable to the different operational and restoration design and approach seen in the 2011 reference design.

For the whole cover and restoration system we require demonstration that the waste and engineering covers will remain seismically stable over the potentially long periods that the cover systems provide a containment function.

In the light of the Fukushima accident, the ONR has updated its engineering Technical Assessment guidance⁹³. This document *“recommends that for civil engineering structures which are required to resist seismic loading that the soil and rock properties for use in dynamic analysis should be determined. Consideration should also be given to the possibility of liquefaction of the foundation material under seismic loading.”*

We therefore would expect the ESC to demonstrate that the seismic assessment meets the objectives set out in the most recent applicable ONR guidance.

Technical Query Actions

ESC-TQ-SUE-026.A1	<p>Please present evidence that the 2002 PCSC seismic assessment remains relevant to the 2011 ESC reference design and continues to represent best practice. In the response address comments raised within this TQ.</p> <p>We also seek confirmation that the 1:4 slopes assessed in the 2002 PCSC remain a valid worst case.</p>
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	03/08/2012
Comment: The evidence and confirmation requested will be provided.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	Chief Engineer	13/02/2013
<p>In addition to the statement (Para (c), Subsection 2.4.4 : LLWR/ESC/(R11)10020) regarding the seismic hazard relating to the 2011 ESC reference design it is confirmed that the 1:4 slopes, as considered in the 2002 PCSC ‘worst case’ scenario, are worse than those within the 2011 ESC reference design. The 2011 ESC reference design has the majority of the final cap with 1:25 slopes, with some nominal 1:10 slopes at the centre of the final cap dome, to facilitate inclusion of the ‘mushroom cap’ design for gaseous venting around the final membrane, and margins. At the margins, due to physical restraints of the site boundary/cap extent, slopes of 1:5 (Subsection 8.2.3) may be installed. These are ‘shallower’ than the 1:4 slopes considered in the 2002 PCSC and therefore the evaluation remains valid.</p>		

⁹³ HSE, 2006. Technical Assessment Guide. Structural Integrity: Civil Engineering.

The 2002 PCSC states that though stable *'under both the PGA and MDBE earthquake loads, 'minor instability' (Subsection 9.4.5) as a consequence of 'ineffective drainage in the upper layers' could develop as potential shallow slips. 'Under these conditions the expected slips were confined to the growing medium (ie the top 0.7m) and did not penetrate the underlying bentonite layer.'* Table 16 indicates that displacement of up to 0.54m (MDBE) could occur, though this is for slips within the *'growing medium'*. The analysis did not take account of additional resilience afforded by a vegetative cover (4.3.2, RP_103169_PROJ_00022 (DTP/22)). In addition, the 2011 reference design of the final cap incorporates additional layers of granular material that will enhance the potential drainage of the upper layers, thus reducing the potential for ineffective drainage and therefore shallow slips. No penetration of the underlying bentonite layer is therefore anticipated.

ONR guidance now states "Facilities which could give rise to doses between 1 mSv and 10 mSv (evaluated on a conservative basis) to any person off-site or 20 mSv to 200 mSv to a worker may be designed against a design basis event, defined on a sliding scale, that conservatively has a predicted frequency of being exceeded no more than once in 100 to no more than once in 1000 years. For some facilities the external hazard loads arising from application of normal industrial standards may provide an appropriate design basis and compliance with Building Regulations may be sufficient."

No scenario on LLWR exceeds these values and therefore seismic resistance is not a requirement on any LLW facilities.

Notwithstanding this, the concrete structures existing and proposed, are not part of the containment system (the basal concrete and underlying Bentonite liner are considered in both 2002 PCSC and 2011 ESC to ultimately fail in the 'long term'). The lateral containment system is a vertical Bentonite cut-off wall that is to be installed with a 'self-healing' Bentonite material.

Whilst liquefaction of the underlying soils is a possibility (as recorded in the 2002 PCSC) it is unlikely and its effect on LLWR would be minimal – an earthquake, magnitude 0.35g, was assessed and the temporary loss of bearing strength resulting in *'extra settlement in the trenches and some damage to the walls of Vault 8'*. Due to confinement within Vault 8, *'containers were not expected to topple, nor any significant off-site radiological hazards anticipated'*. The earlier report RP_103169_PROJ_00022 (DTP/22) also concluded that *'The results of the liquefaction analysis indicated that there is no significant risk of liquefaction in the soils underlying the site.'*

The 2002 PCSC assessed both saturated and unsaturated conditions in its conclusions and therefore is considered to remain relevant to the 2011 ESC reference drawing design evaluation, particularly as evaluated with a 1:4 slope (2011 ESC design is for worst case 1:5 slope). LLWR considers the 2002 PCSC evaluation still valid in that instability could occur during *'extreme'* conditions affecting the margins of the cap if ground water rises to a level over-topping the cut-off wall and resulting in displacement of 0.085 (PGA) and 0.23m (MDPE) which could damage the resistive layer (4.3.3, RP_103169_PROJ_00022 (DTP/22)). The margins of the cap would be accessible after closure and therefore remedial works could be undertaken. It is unlikely that ground water would rise to a level sufficient to over-top the cut-off wall based on topography and underlying hydrogeological conditions.

Currently, it is understood that some trench leachate flows vertically/sub-horizontally to the underlying ground waters. The 2011 ESC reference design does not intercept with this pathway, other than to reduce surface infiltration as a consequence of capping, in the short term. Similar reduction of surface infiltration to the vaults will occur as a result of capping. The reference design collects and discharges vault leachate during operation and immediate post closure phases. Thereafter vertical/sub-horizontal pathways (through the base and/or over the 1m high side walls) to the underlying ground waters, as with the trenches, will transfer leachate. This will promote unsaturated conditions within the waste for a significant period of time.

During operational phases, prior to capping, access to vault operational areas continues to be feasible and therefore restoration can be undertaken. Similarly, access to the trenches disposal area will be accessible and restorative works, although not planned can be undertaken if required. The margins of the phased final capping, during operational phasing,

have slopes shallower than 1:4 and are therefore considered stable, however, these areas remain accessible to remediation.

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 25/07/2013
Approved by: Environment Agency	Date: 24/01/2014

LLW Repository Ltd has provided the information requested by this Technical Query (TQ). The company has clarified the design assumptions used for the 2011 ESC and the relationship with the 2002 PCSC. The presented information demonstrates that the single dome restoration design and associated capping slopes meet relevant seismic performance requirements.

This TQ can therefore be closed.

Actions completed, Technical Query resolved and Form closed

Owner: Environment Agency	Date: 15/08/2014
Approved by: Environment Agency	Date: 24/01/2014

ESC-TQ-SUE-030: Development and assessment of waste fire scenarios during the post operational period

Title	Development and assessment of waste fire scenarios during the post operational period
Date raised	03/01/2013
Acknowledgment required by	10/01/2013
Response required by	03/02/2013
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	SUE
Approved by	Environment Agency

History

Status	Date	Description
Raised	03/01/2013	
Acknowledged	03/01/2013	
LLWR Response	11/02/2013	
Response Assessed	25/07/2013	
Transferred	24/01/2014	
Closed	14/11/2014	

Statement of Technical Query

The Guidance on Requirements for Authorisation of Near Surface Disposal Facilities (GRA) asks for all reasonable scenarios which could result in discharges of radioactivity to the environment to be considered as part of the Environmental Safety Case (ESC). We have identified that the presented ESC does not carry out an assessment of the radiological consequences of a fire occurring in disposed combustible wastes after the period of authorisation.

We believe any fire scenario would most likely be restricted to the trench wastes. A waste fire occurring in the grouted and containerised vault wastes is considered unlikely and does not require an assessment. However, a fire in the trench waste after the period of authorisation is considered a credible, if a low probability event, and could result in a discharge of radioactivity to the environment.

During the post authorisation period we consider that a realistic cause of fire in the trench wastes could include the introduction of oxygen into the waste mass. A possible cause of this would be the exposure of the waste during coastal erosion. The introduction of oxygen into the waste mass could result in exothermic or pyrophoric reactions in individual waste components such as thorium or reactive metals. Such a fire is likely to be shallow seated, with the possibility of direct release of radioactivity to the environment.

Technical Query Actions

ESC-TQ-SUE-030.A1	Please identify the potential presence of waste streams or items within the trenches which could exhibit pyrophoric or exothermic properties when exposed to air or water. Consideration should be given to the presence of sealed vessels containing volatile materials.
ESC-TQ-SUE-030.A2	For the post authorisation period please identify and present reasonable fire scenarios taking account of the disruption and exposure of the waste during coastal erosion, or any other credible mechanism which could cause the introduction of oxygen into the waste mass or initiate waste fires. Please provide a short qualitative assessment of any reasonable fire scenarios which could occur in the trench wastes during the post authorisation period.

LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	03/01/2013
Comment: The assessment requested will be provided.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	11/02/2013
Please see the attached memo: LLWR/ESC/Mem(13)194		
Please see the attached spreadsheet: LLWR_ESC_Mem(13)194_App1.xls		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 25/07/2013
Approved by: Environment Agency	Date: 14/11/2014

ESC-TQ-SUE-030.A1

In response to this action, LLW Repository Ltd has presented a comprehensive review of available trench waste records. The flammability of each waste type is assessed. The company concluded that the materials and conditions in the trenches at any time after the period of authorisation are very unlikely to support combustion, and that any fire events that might occur would be confined to very small volumes of waste with little or no potential for release of radionuclides.

We note that contemporary disposal practices during trench disposals did not seek to fully characterise the chemical composition of wastes and as such the records of past disposals are not as comprehensive as they are today. We are therefore not convinced with LLW Repository Ltd's assumption that the waste acceptance criteria used in the past would have always prevented the disposal of pyrophoric or flammable material, as there is evidence of a number of waste fires during operations of the trenches.

While we accept the findings of the presented trench inventory information, it is subject to a significant level of uncertainty with regards to the non-radiological composition of the waste. Due to the nature of a number of processes that may have resulted in waste being consigned to the LLWR in the past, we consider it likely that other wastes susceptible to pyrophoric or exothermic reactions have been consigned. However, due to the age of the disposals, it is also likely that

much of this material may now have been rendered inert, although there remains a low risk of reactive material remaining contained within larger (still intact) containers.

ESC-TQ-SUE-030.A2

In response to this action, LLW Repository Ltd identified two scenarios which we consider credible for potential fires in trench wastes; the first associated with the exposure of waste during coastal erosion and the second associated with the introduction of oxygen into the anaerobic trench waste during construction of geotechnical boreholes into the waste after the period of authorisation.

With respect to the first scenario, LLW Repository Ltd concluded that the materials and conditions in the trenches at any time after the period of authorisation are very unlikely to support combustion, and that any fire events that might occur would be confined to very small volumes of waste with little or no potential for release of radionuclides. As a result LLW Repository Ltd did not undertake a radiological assessment of the consequences of ignition and subsequent fire during the erosion of the trench wastes. We accept that the likelihood of a fire event at any scale would be low, but because of the long period of waste exposure during the erosion sequence (potentially 100s years), the uncertainty over deliberate human interventions and the uncertainties associated with the exposed waste during the erosion period we consider that such a scenario should be considered as a 'what if' scenario.

We have raised a Forward Issue (ESC-FI-028) which identifies the need for a more comprehensive understanding and conceptualisation of the behaviour of the repository wastes during the predicted repository erosion sequence. Within the resulting forward programme we recommend the potential nature, extent and consequence of waste fires resulting from human actions are further investigated, considering appropriate 'what if' scenarios for waste fires (Recommendation ASS25 of Environment Agency 2015, Review of LLW Repository Ltd's 2011 Environmental Safety Case: Assessments).

LLW Repository also identified a human intrusion scenario associated with the construction of a geotechnical borehole into the waste mass which could give rise to a deep seated waste fire. The company assumed that any fire in a borehole would be short lived and not requiring the involvement of the fire service, with dose only being received by the drillers. The dose to a drilling engineer was calculated at about five times that received by the driller in the absence of the fire event and two orders of magnitude below the dose guidance value that applies to exposures of short duration from human intrusion events.

We disagree with the assumption that a borehole fire will always be short lived and extinguished in 1-2 days with dose only being received by the drillers. Experience from the contemporary landfill sector indicates that deep seated waste fires can be difficult to extinguish and can burn for extended periods (Environment Agency 2007). Assuming the fire is significant then there would be a need for fire service involvement in order to extinguish the fire. Extinguishing of deep seated fires may involve the disturbance of wastes.

Although we continue to consider the likelihood of such fires to be very low, we believe that for completeness LLW Repository Ltd should either provide further justification for the limited duration of such a fire, or undertake further work to extend the scenario in time and those who may be affected (for example, fire service personnel). We have therefore requested that LLW Repository Ltd undertakes a further assessment to take account of an extended duration fire and the involvement of fire personnel as a 'what if' scenario (via Forward Issue ESC-FI-003).

Conclusion

We consider that the further information on the nature of the trench wastes which could give rise to spontaneous combustion provided by LLW Repository Ltd meets our requirements. We accept that the likelihood of a waste fire in the trench disposal remains very low. We consider that LLW Repository Ltd has presented sufficient information to allow this Technical Query to be closed. However, we consider that there is scope for further investigation and conceptualisation of the borehole fire scenario and the potential for fires during the repository erosion sequence in order to better inform future updates of the ESC, as detailed in ESC-FI-003 and ESC-FI-028.

Reference

Environment Agency, 2007. Science Report - Review and Investigation of Deep-Seated Landfill Fires. Environment Agency, March 2007.

Actions completed, Technical Query resolved and Form closed

Owner: Environment Agency	Date: 21/01/2014
Approved by: Environment Agency	Date: 14/11/2014

ESC-TQ-ASO-001: Implementation of emplacement strategies within Vault 8

Title	Implementation of emplacement strategies within Vault 8
Date raised	30/09/2011
Acknowledgment required by	14/10/2011
Response required by	18/11/2011
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	ASO
Approved by	Environment Agency

History

Status	Date	Description
Raised	30/09/2011	
Acknowledged	14/10/2011	
LLWR Response	16/11/2011	
Response Assessed	18/10/2013	
Transferred	18/10/2013	
Closed	28/02/2014	

Statement of Technical Query

The Environmental Safety Case (ESC) proposes certain emplacement strategies within future vaults, such as lower placement of high radium-226 bearing wastes. It is not clear whether there are plans to implement such strategies within Vault 8, either related to existing wastes, or further wastes to be disposed of within the Vault, subject to permitting. In particular would emplacement strategies be applied to any higher stacked wastes? Also, would any of the existing waste within the vaults be moved within (or outside) the vault to aid implementation of such strategies?

Technical Query Actions

ESC-TQ-ASO-001.A1	LLW Repository Limited shall provide a clear statement of their plans in relation to implementation of emplacement strategies within Vault 8 and of waste already within Vault 8.
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	14/10/2011
Comment: A statement will be provided.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	16/11/2011
<p>There are three categories of wastes either currently disposed or stored in Vault 8 or that might be disposed there in the future:</p> <ol style="list-style-type: none">1. Waste currently stored or disposed (waste currently disposed stacked up to a height equivalent to that of four half-height ISO containers or stored in positions above this height up to a height equivalent to that of six half-height ISO containers);2. Waste that will be disposed in the remaining space authorised for disposal (stacked up to a height equivalent to that of four half-height ISO containers);3. Waste that might be higher stacked above the wastes in the first two categories (subject to the necessary permissions being obtained from the Environment Agency and local planning authority). <p>The plans for implementation of emplacement strategies will be described in terms of these three categories of wastes.</p> <p>Category 1</p> <p>It is our intention to undertake an assessment of the extent to which the wastes in containers in Category 1 above already meet the emplacement strategies described in the 2011 ESC, developing a preliminary assessment undertaken during the preparation of the 2011 ESC. If containers in their current positions are found not to meet the strategies, then a BAT assessment will be undertaken to decide on the appropriate approach to managing the wastes. We do not plan to automatically apply the strategies, which might involve, for example, moving many waste containers to access a particular container or moving 'overweight' containers. When considering the appropriateness of this approach, the nature of the four planned emplacement strategies should be borne in mind. One strategy is designed to limit the concentrations of activity near the tops of the stacks. Most of the waste packages currently at the tops of the stacks will not be at the tops of stacks if further higher stacking is adopted in Vault 8. The strategy designed to limit local concentrations of activity throughout the stacks is only expected to apply at most to a very small number of relatively highly active packages. The requirements of the strategy designed to limit loadings on waste containing absorbed liquids will be automatically met for standard weight containers. It should be possible to meet, at least in most cases, the requirements of the last emplacement strategy, designed to limit the voidage in individual stacks of packages, by limiting the voidage in packages placed above the currently disposed wastes. We plan to undertake the initial review this financial year (2011/12).</p> <p>Category 2</p> <p>The remaining space in Vault 8 authorised for disposal is only being slowly filled. Our intention is to apply the emplacement strategies to the waste packages to be disposed in this area once the necessary processes have been developed, procedures and instructions written and formally adopted, and staff training undertaken. Plans for the implementation of the ESC are being developed and have yet to be approved by the LLWR, but it is expected that this aspect of the implementation will be a priority. Any waste disposed before the emplacement strategies can be implemented will be treated in the same way as Category 1 waste.</p> <p>Category 3</p> <p>Wastes in the third category can only be disposed once the necessary permissions have been obtained and this is not expected to happen until some time in 2013. If and when wastes in this category are disposed, we intend to apply the waste emplacement strategies, taking due account of any adjustments necessary resulting from the BAT assessment carried out for any wastes in Category 1 that do not meet the requirements of the emplacement strategies.</p>		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 18/10/2013
Approved by: Environment Agency	Date: 18/10/2013

LLW Repository Ltd has presented a clear statement outlining its approach to the application of emplacement strategies to existing stored and disposed wastes in Vault 8 as well as additional containers brought into Vault 8 from elsewhere. We consider the approach is appropriate for the delivery of the emplacement strategy objectives presented in the ESC. We are satisfied that adequate further information has been provided to close this Technical Query (TQ).

However, since the submission of this TQ in November 2011 there have been a number of developments relating to the management of stored and disposed containers within Vault 8. The majority of these issues were not addressed in the 2011 ESC and as a consequence may change or influence the emplacement strategy with regards to limitation of total voidage within individual stacks. The following text therefore relates specifically to measures which occurred after the submission of the 2011 ESC.

The container inspection and condition work programme^{94, 95, 96} identified that both containers stored in Vault 8 and those intended to be added to the Vault 8 stacks had been subject to a number of degradation processes and the settling of grout and/or waste contents, and that this may impact on container integrity and settlement potential post-capping⁹⁷. As a result of these issues LLW Repository Ltd has proposed further work to understand how settlement can best be controlled by a combination of reduced stack heights and/or enhanced cap engineering to take account of potential settlement⁹⁸. This further work will need to take account of other factors such as loading impact of the construction of granular running layers to achieve higher stacking of containers and the condition of the currently exposed containers.

We note that the information on container voidage derived from the above programmes has a high level of uncertainty associated with it, which must be taken into account when reaching decisions on higher stacking and/or cap enhancements. The use of Best Available Techniques (BAT) should be demonstrated when reaching these decisions, taking into account factors such as the voidage uncertainty, the ability to address voidage through cap improvements and the practicality and safety of accessing and moving relatively inaccessible containers. Where existing stack heights in Vault 8 exceed the maximum settlement potential (Total Potential Voidage, TPV) then the BAT case should support any decision not to move containers so as to reduce this below the maximum level.

We have raised a Forward Issue (ESC-FI-001) to require LLW Repository Ltd to develop, and subsequently implement, a programme of work to deliver an optimised cap design and waste stack heights, which takes full account of all available information on potential for cap settlement.

⁹⁴ LLW Repository Ltd, December 2012, Vault 8 Container Issues Project: Position Paper, RP/LLWRGR/PROJ/00434.

⁹⁵ LLW Repository Ltd, March 2013, Vault 8 Container Issues Project: Action Plan, RP/LLWRGR/PROJ/000141.

⁹⁶ LLW Repository Ltd, March 2013, Vault 8 Containers Issues Project, Container Surveys, RP/LLWRGR/PROJ/00143 ISSUE P1.

⁹⁷ LLW Repository Ltd, May 2013, LLWR Emplacement Strategy: Assessment of the implications of voidage in Vault 8, QRS-1443ZP-1 Version 2.1.

⁹⁸ LLW Repository Ltd, April 2014, Engineering Forward Plan to Support the Environmental Safety Case, RP/LLWRGR/PROJ/00142/Issue A.

Actions completed, Technical Query resolved and Form closed

Owner: Environment Agency	Date: 28/02/2014
Approved by: Environment Agency	Date: 28/02/2014

ESC-TQ-ASO-003: Coastal and marine biosphere and PEG definitions

Title	Coastal and marine biosphere and PEG definitions
Date raised	04/05/2012
Acknowledgment required by	20/05/2012
Response required by	20/06/2012
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	ASO
Approved by	Environment Agency

History

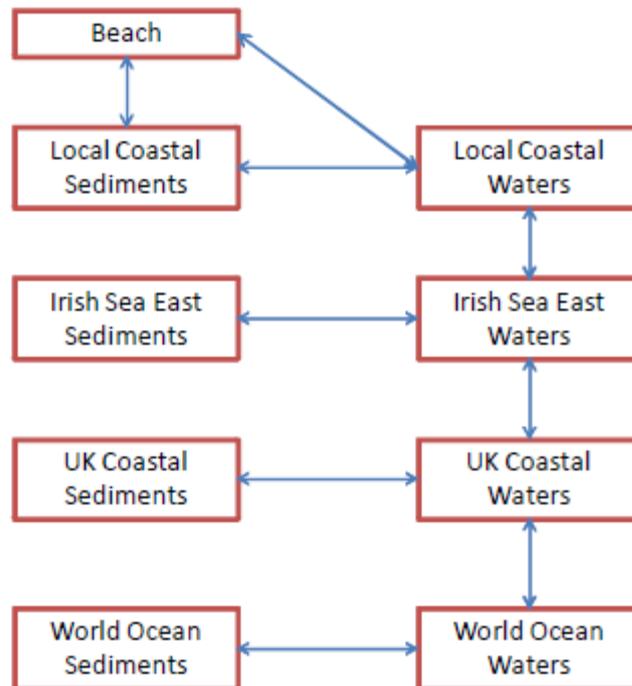
Status	Date	Description
Raised	04/05/2012	
Acknowledged	04/05/2012	
LLWR Response	20/07/2012	
Response Assessed	23/08/2012	
Transferred	10/10/2013	
Closed	10/10/2013	

Statement of Technical Query

The 2011 ESC presents an expected evolution scenario that comprises leaching of radionuclides from the facility followed by transport via the groundwater pathway to the accessible environment (via releases to wells, surface water and the coastal environment) up until the point at which destruction of the facility by coastal erosion commences. There then follows a range of exposure situations associated with exposure to the eroded waste as well as dispersion in the marine environment. Impacts are also assessed via the gas and human intrusion pathways.

The compartmental structure and compartment sizes of the groundwater model biosphere model for the coastal domain release route is shown below (from Thorne *et al.*, 2010⁹⁹) and is very similar to models used in previous assessments of the LLWR. Groundwater discharge to the biosphere is assumed to take place in the intertidal zone (Drigg beach). Transfer rates are specified for the flow of both solids (to which radionuclides could be sorbed) and water (in which radionuclides may be dissolved) between compartments. The model is used to calculate transient concentrations in the biosphere compartments, and hence doses/risks to potentially exposed groups (PEGs) that make use of the environment.

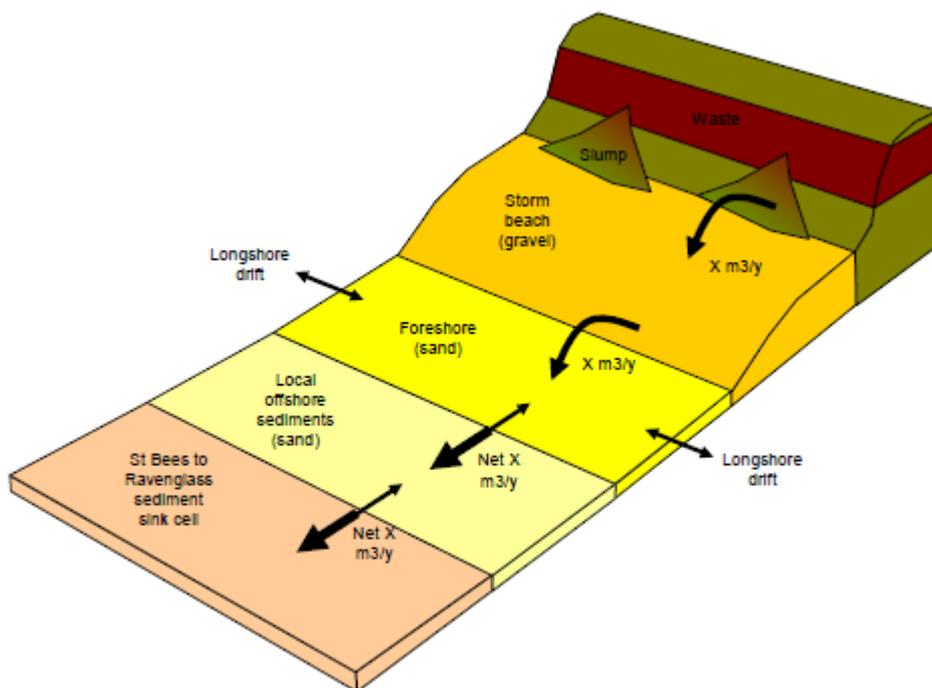
⁹⁹ Thorne, M.C. Kelly, M. and Lambers, B. 2010. Consolidation and Documentation of Biosphere Models. Serco report SERCO/TAS/003796/005 Issue 1.



Compartment	Name	Volume of water (m ³)	Mass of solids (kg)	Basis
1	Beach	6.3E4	3.34E8	Area 8.4E5 m ² , depth 0.3 m, water-filled porosity 0.25, total porosity 0.5, grain density 2650 kg m ⁻³ .
2	Local Coastal Sediments	1.8E7	4.77E10	Area 1.2E8 m ² , depth 0.3 m, water-filled porosity 0.5, grain density 2650 kg m ⁻³ .
3	Local Coastal Waters	2.4E9	1.2E7	Area 1.2E8 m ² , depth 20 m, sediment load 0.005 kg m ⁻³ .
4	Irish Sea East Sediments	1.68E9	4.45E12	Area 1.12E10 m ² , depth 0.3 m, water-filled porosity 0.5, grain density 2650 kg m ⁻³ .
5	Irish Sea East Waters	4.82E11	1.44E9	Area 1.12E10 m ² , depth 43 m, sediment load 0.003 kg m ⁻³ .
6	UK Coastal Sediments	1.5E11	3.975E14	Taken from previous studies.
7	UK Coastal Waters	1E14	3.0E11	
8	World Ocean Sediments	2.25E13	1.9875E16	
9	World Ocean Waters	1.2E18	1.2E14	

The groundwater pathway model may be considered valid up until the point at which it is assumed that destruction of the facility by coastal erosion commences at some time after 300 years after present. An extremely different biosphere model of the coastal and marine environment is presented at this stage. The stylised conceptual model of the coastal erosion coastal/marine biosphere and dispersion of the eroded waste and compartmental data are summarised below

from Towler *et al.*, 2011¹⁰⁰). Radionuclide transfer between compartments may occur via leaching (liquid phase) or erosion (solid phase).



¹⁰⁰ Towler, G.H., Penfold, J.S.S., Limer, L.M.C. and Paulley, A., *Assessment Calculations for Coastal Erosion for the LLWR 2011 ESC*, Quintessa Report QRS-1443ZCR1 Version 3, April 2011.

Compartment	Value
Storm Beach	<p>Length of LLWR disposal area, parallel to coast (810 m). Note that in the model the storm beach is sub-divided into North (335 m), mid (325 m) and South (150 m).</p> <p>Present day width. North storm beach 50 m, mid and South storm beach 40 m (based on the range given in Table 7 of Fish et al. [2010]).</p> <p>Depth derived from volume per unit length, which is assumed to be as the present day (Table 3 of Fish et al. [2010]). This gives depths consistent with trial pits recently dug on the storm beach and foreshore (Section 2.3 of Fish et al. [2010]). North storm beach 2.0 m, mid and South storm beach 2.1 m.</p>
Foreshore	<p>Length of LLWR disposal area (810 m).</p> <p>Present day width, 400 m (from Table 7 of Fish et al. [2010]).</p> <p>0.5 m depth based on trial pits described in Section 2.3 of Fish et al. [2010]. Note that Fish et al. describe the thickness as being generally <0.5 m, increasing up to 2m where there are sandbars. 0.5 m taken to be a cautious mean.</p>
Local offshore sediments	<p>Length of LLWR disposal area (810 m).</p> <p>Width 1500 m. Particle mobility assessments indicate that sand can be mobilised by at distances up to 1500 m from mean water.</p> <p>Assume depth as foreshore, i.e. 0.5 m. Consistent with observed foreshore sediment mixing depths, e.g. level changes and movement of sandbars.</p>
St Bees to Ravenglass coastal cell	<p>Length, 25 km (approx. distance from St Bees to Ravenglass).</p> <p>Width 1500 m. Particle mobility assessments indicate that sand can be mobilised by at distances up to 1500 m from mean water.</p> <p>Assume depth as foreshore initially, i.e. 0.5 m. Increases with time to represent amount of uncontaminated material eroded from the entire coastline, i.e. 25 km × average erosion rate × assumed average cliff height of 5 m. A sensitivity calculation is used to examine the effects of assuming an average cliff height of 10 m along the whole coast.</p>
Marine Water	<p>Length, 25 km - correlates with St Bees to Ravenglass sub-cell.</p> <p>Width, 1500 m - correlates with St Bees to Ravenglass sub-cell.</p> <p>Average depth of 5 m (0 m at mean water, 10 m at 1.5 km offshore).</p> <p>Note that the compartment volume is smaller than assumed in the groundwater transport biosphere model [Thorne et al., 2010], but reflects the assumed behaviour of eroded materials, and hence distribution of contaminated sediment.</p>

Although it is understood why there is a need for some differences between the two coastal/marine biosphere models due to the nature of inputs (dissolved contaminants via the groundwater pathway, eroded waste via coastal erosion pathway), the reasons for having such different biosphere models are not justified. In particular, there are a number of inconsistencies between the two biosphere models:

- It is difficult to visualise the differences between the physical domains of the two marine biosphere models. We understand the reasons for the coastal erosion model to cover a smaller geographical area than the groundwater pathway model due to the assumed behaviour of eroded materials, however, it would be useful to see, for example, a map showing the domains covered by each model and justification for the differences.
- It is unclear why the groundwater pathway model (which includes the world's oceans/waters/sediments) covers a much larger model domain than the coastal erosion model (which only includes the St Bees to Ravenglass coastal region), given that it is acknowledged that activity within the eroded waste will leach into the water.

- There are other discrepancies between the two marine biosphere models, for example, why do the foreshore and local offshore sediments compartments in the coastal erosion model have assumed depths of 0.5 m whilst the equivalent beach and local coastal sediments compartments in the groundwater pathway model have assumed depths of 0.3 m?
- Although leaching of contaminants from the waste and the effects of sorption/desorption are discussed in the coastal erosion model, the coastal erosion model does not appear to treat interactions between sediment compartments and overlying water compartments in the same manner as the groundwater pathway model.
- Although it is acknowledged in the coastal erosion model that dissolved radionuclides will be transported out of the local offshore area into the deeper Irish Sea and ultimately the world's oceans, loss of suspended sediment out of the St Bees to Ravenglass sub-cell is not considered. In contrast, transfer of activity in both sediments and waters in the groundwater pathway model occurs from the local coastal waters/sediments into the Irish Sea East and from there into the UK and eventually the worlds ocean waters/sediments.

TQ1: LLW Repository Ltd to justify the discrepancies observed between the groundwater pathway and the coastal erosion pathway biosphere models for the coastal/marine environment.

For the groundwater pathway calculations, two PEGs are considered that receive exposures in the coastal/marine regions:

- adults (fishermen) spending occupational time on the beach and ingesting seafoods; and
- adults spending recreational time on the beach and intertidal zone.

These PEGs are defined in Thorne *et al.* (2010), with key data such as ingestion rates and occupancy factors being sourced from Thorne (2009)¹⁰¹.

For the coastal erosion pathway calculations, the following PEGs are considered:

- recreational user of the beach spending time on the beach;
- occupational user of the foreshore (e.g. fisherman) spending time at sea and on the beach;
- consumer of marine foodstuffs (fish, molluscs and crustaceans); and
- high occupancy occupational user variant case.

Again habit data for these PEGs is defined in Thorne (2009).

Although both sets of PEGs are derived from the same source data it is evident that the groundwater pathway and coastal erosion pathway modes assess impacts to PEGs in different ways (e.g. the groundwater pathway considers a composite set of behaviours including exposures resulting from both time spent on the beach/foreshore environment and consumption of marine foodstuffs). In contrast, the coastal erosion pathway PEGs assess occupancy exposures separately from ingestion of marine foodstuffs.

In order to compare exposures resulting from the groundwater pathway against those from the coastal erosion pathway, we would have expected to see some consistency between the PEGs defined for these pathways.

TQ2: LLW Repository Ltd to justify the differences in PEG definition between the groundwater pathway (coastal environment) and coastal erosion pathway assessment calculations.

Technical Query Actions

ESC-TQ-ASO-003.A1	Please justify the discrepancies observed between the groundwater pathway and the coastal erosion pathway biosphere models for the coastal/marine environment.
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¹⁰¹ Thorne, M C, 2009, LLWR Lifetime Project: Data for Exposure Groups and for Future Human Actions and Disruptive Events, NNL Report NNL 8856: Issue 3, July 2009.

ESC-TQ-ASO-003.A2	Please justify the differences in PEG definition between the groundwater pathway (coastal environment) and coastal erosion pathway assessment calculations.
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LLW Repository Ltd Acknowledgement

<name>	<position>	<date>
Comment:		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Technical Specialist	20/07/2012
A response is provided in ESC Project Memo LLWR/ESC/Mem(12)159, 20/07/2012.		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 23/08/2012
Approved by: Environment Agency	Date: 10/10/2013

We consider that ESC Project Memo LLWR/ESC/Mem(12)159 adequately justifies the reasons for the most significant discrepancies between the groundwater pathway models and the coastal erosion models.

We consider that the Technical Query has been addressed to our satisfaction and can be closed. However, a recommendation for future ESCs is that there should be a greater consistency between the models for different pathways, including both physical representations of the biosphere and PEG habits. Significant differences should be justified and implications on impacts identified (see Recommendation ASS21 of Environment Agency 2015, Review of LLW Repository Ltd's 2011 Environmental Safety Case: Assessments).

Actions completed, Technical Query resolved and Form closed

Owner: Environment Agency	Date: 10/10/2013
Approved by: Environment Agency	Date: 10/10/2013

ESC-TQ-ASO-004: Incorporation of sea level change in the CONNECTFLOW model

Title	Incorporation of sea level change in the CONNECTFLOW model
Date raised	04/05/2012
Acknowledgment required by	20/05/2012
Response required by	20/062012
Related issue numbers	ESC-TQ-SUE-025
Originated by	Environment Agency
Current owner	Environment Agency
Review group	SUE
Approved by	Environment Agency

History

Status	Date	Description
Raised	04/05/2012	
Acknowledged	04/05/2012	
LLWR Response	31/07/2012	
Response Assessed	23/08/2012	
Transferred	08/04/2013	
Closed	10/10/2013	

Statement of Technical Query

The LLWR is located close to the west Cumbrian coastline and available evidence on future climate change and sea level rise leads to the conclusion that the site is very likely to be destroyed by coastal erosion at some point in the future.

The analysis of potential future sea level rise in the long-term undertaken in the ESC estimated that a sea level rise of between 1.1 m and 21.1 m would have occurred by 1,000 years after present (AP) and that a rise of between 7.3 m and 24.6 m would have occurred by 3,000 years AP, taking into account the effects of isostatic uplift¹⁰².

These bounding high and low sea level rise scenarios were input into projections of coastal recession in the vicinity of the LLWR. Two separate modelling approaches were used: empirical cliff recession modelling; and process-based modelling using the Soft Cliff and Platform Erosion (SCAPE) model¹⁰³. The outputs of these models were reasonably consistent. The empirical model projected that the eroding coastline will reach the site boundary within 500-800 years AP (low sea level rise scenario) or within 400-600 years AP (high sea level rise scenario). This model predicted loss of the entire disposal facility by 1,500–1,900 years AP. The SCAPE model provided a lower

¹⁰² LLW Repository Ltd, 2011. The 2011 Environmental Safety Case. Site Evolution. LLWR/ESC/R(11)10023.

¹⁰³ Fish, P., Thorne, M., Moore, R., Penfold, J., Richards, L., Lee, M. and Pethick, J., 2010. Forecasting the Development of the Cumbrian Coastline in the Vicinity of the LLWR site, Quintessa Report Ref: QRS-1443X-1 Version 1.

estimate of the eroding coastline reaching the site boundary between 300-400 years AP and an upper estimate of 800-900 years AP.

The main ESC deliberately does not provide a specific date for the commencement of the erosion because of large amount of uncertainty associated with prediction of coastal erosion processes. Nevertheless, as discussed under ESC-TQ-SUE-025, LLWR have utilised a 1,000 year reference case for the assessment of the radiological impact of coastal erosion in the 2011 ESC. However, it is noted that the CONNECTFLOW model reference case varies from this in that it is based on sea level rise of 10 m occurring by 3180 AD (i.e. about 1,200 years AP)¹⁰⁴. The value of 10 m sea level rise was chosen as a mid point between the elicited range in sea level rise of 1.1-21.1 m at 1,000 years AP. At this stage, it is assumed that the coastline has retreated just short of the repository with about 10 m of ground remaining between the cliff and the vaults. Thus the CONNECTFLOW model incorporates coastal erosion at a slightly later time than projected.

Can LLW Repository Limited confirm that this discrepancy does not have any implications on estimates of environmental risk?

Technical Query Actions

ESC-TQ-SUE-025.A1	Please provide evidence that the selection of the reference case and delayed coastal erosion scenarios for the groundwater pathway assessment and underpinning models has encompassed estimation of a reasonable range of future environmental risks.
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	04/05/2012
Comment:		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	31/07/2012
A response is provide in ESC Project Memo LLWR/ESC/Mem(12)160.		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 23/08/2012
Approved by: Environment Agency	Date: 10/10/2013

We still consider that it is unclear why the timings of elicited properties for the degradation of engineered barriers are slightly inconsistent with the reference time for onset of coastal erosion in the expected natural evolution scenario which has led to the observed discrepancy. However, we accept the position set out in ESC Project Memo LLWR/ESC/Mem(12)160 that this discrepancy does not have a significant effect on calculation of impacts. We consider that the Technical Query has been addressed to our satisfaction and can be closed.

¹⁰⁴ L. Hartley, D. Applegate, M. Couch, J. Hoek, P. Jackson and M. James, 2011. Hydrogeological Modelling for LLWR 2011 ESC, Serco Report SERCO/TCS/E003632/007 Issue 3.

Actions completed, Technical Query resolved and Form closed

Owner: Environment Agency	Date: 10/10/2013
Approved by: Environment Agency	Date: 10/10/2013

ESC-TQ-ASO-005: Human intrusion - aircraft impact

Title	Human Intrusion - Aircraft Impact
Date raised	10/05/2012
Acknowledgment required by	17/05/2012
Response required by	14/06/2012
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	ASO
Approved by	Environment Agency

History

Status	Date	Description
Raised	10/05/2012	
Acknowledged	10/05/2012	
LLWR Response	28/09/2012	
Response Assessed	03/09/2013	
Transferred	06/09/2013	
Closed	26/09/2013	

Statement of Technical Query

Aircraft impact is screened out from the LLWR 'human intrusion' assessment¹⁰⁵. Table 2.1 states:

"A light aircraft crash would impart insufficient energy to penetrate the 3 m engineered cap. A large aircraft crash could be of sufficient energy to penetrate to waste depth, resulting in dispersion of some waste. However, such crashes are rare, and thus highly unlikely to occur within the relatively small area of the site. Therefore, aircraft crash is excluded from the assessment."

The energy imparted to the cap is proportional to the mass of the aircraft, its velocity, the angle of incidence and its payload (fuel). There are low flying military jets in the area and unlike Sellafield, there is no, 'no fly zone' over the LLWR. We are also aware that BNFL commissioned studies for the 2002 PCSC on the likelihood of waste becoming exposed following aircraft impact.

Technical Query Actions

ESC-TQ-ASO-005.A1	LLW Repository Ltd shall provide evidence to back up the claim that light aircraft could not penetrate the 3 m engineered cap.
ESC-TQ-ASO-005.A2	LLW Repository Ltd shall summarise the findings of earlier work commissioned in relation to aircraft impact.

¹⁰⁵ Hicks TW and Baldwin TD, Assessment Calculations for Human Intrusion for the LLWR 2011 ESC, Galson Sciences Report 0977-3 Version 2, March 2011.

LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	10/05/2012
Comment:		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	28/09/2012
A response is provided in LLWR ESC Project memo LLWR/ESC/Mem(12)175 28/09/2012		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 03/09/2013
Approved by: Environment Agency	Date: 26/09/2013

LLW Repository Ltd memo LLWR/ESC/Mem(12)175 28/09/2012 provides calculations on the consequences of aircraft impact, which were absent from the 2011 ESC. Based on some very cautious assumptions, the radiological dose following the impact of a military combat aircraft is likely to be similar to the previously assessed site occupier / smallholder over Vault 8 (a human intrusion event). This may be as high as 60 to 65 mSv yr⁻¹. Owing to the lower dilution factor of wastes to other material in the less likely case of the impact of a large transport plane, radiation doses may be around 50% higher. This is dominated by the dose from radon due to radium from contaminated soils from clean-up of Defence Estates land. LLWR/ESC/Mem(12)175 28/09/2012 goes on to state that if Ra-226 bearing wastes from Defence Estate wastes are not placed in the upper stack position of a stack in the vaults (that is, below the likely depth of any excavation) the dose to site occupants and smallholders would be reduced to less than approximately 6 mSv yr⁻¹. We agree that 6 mSv yr⁻¹ is a more realistic upper estimate of dose, taking account of the application of the emplacement strategies outlined in the 2011 ESC and the development document (LLW Repository Ltd 2013).

Exposure to radium-bearing wastes from other human intrusion events has already been considered in the 2011 ESC (LLW Repository Ltd 2011).

Independently of this TQ, the Office for Nuclear Regulation (ONR) raised a number of questions over errors in aircraft crash frequency data employed in the 2011 ESC and nuclear safety case. LLW Repository Ltd assessed the consequences of the questions raised by ONR and has clarified the position in a letter from LLW Repository Ltd to the ONR dated 24 May that the error has no significance for the ESC calculations.

The scoping calculations demonstrate that the magnitude of doses associated with the aircraft impact scenarios are consistent with those from scenarios already investigated as part of the human intrusion assessment. Both of the questions raised in our TQ have been assessed and found to adequately address our questions. This issue can now be closed.

References

LLW Repository Ltd, 2011. The 2011 Environmental Safety Case. Assessment of Long-term Radiological Impacts. LLW Repository Ltd Report LLWR/ESC/R(11)10028

LLW Repository Ltd, 2013. Developments Since the 2011 ESC. LLW Repository Ltd Report LLWR/ESC/R(13)10058, Issue 1.

Actions completed, Technical Query resolved and Form closed

Owner: Environment Agency	Date: 03/07/2013
Approved by: Environment Agency	Date: 26/09/2013

ESC-TQ-ASO-006: Radiological impacts - close contact to exposed undiluted wastes

Title	Radiological impacts to humans from direct shine and foodstuff pathways in a coastal erosion scenario that involves close contact with exposed, undiluted wastes.
Date raised	29/06/2012
Acknowledgment required by	06/06/2012
Response required by	03/08/2012
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	ASO
Approved by	Environment Agency

History

Status	Date	Description
Raised	29/06/2012	
Acknowledged	29/06/2012	
LLWR Response	22/10/2012	
Response Assessed	15/04/2013	
Transferred	15/04/2013	
Closed	10/10/2013	

Statement of Technical Query

Erosion of the coastline adjacent to the Low Level Waste Repository (LLWR) could allow direct exposure of waste in the eroding cliff line. In addition, there could be direct exposure to blocks of eroded waste that have fallen into the intertidal zone. Depending on the exact nature of the coastal change and any associated site erosion there would appear the possibility that:

- a platform comprising of exposed undiluted waste could develop; and/or
- eroded waste could constitute a significant component of the substrate in a future intertidal zone and/or form the substrate beneath a future tide-washed pasture.

Radionuclide concentrations in foodstuffs grown in direct contact with exposed and undiluted waste may be elevated relative to those grown at a distance from the source term. Likewise dose uptake arising from direct shine will be in part dependent on the exposed inventory at that time, occupancy and proximity (time, distance, shielding etc).

Foodstuffs derived from such environments might include, for example, shellfish that have grown attached to waste in a future intertidal zone, sheep that have grazed tide-washed pasture or wild foods that have grown on, grazed or inhabited the waste materials exposed in the eroding cliff line (e.g. wild fruit and game). We note (from LLWR/ESC/R (11)10030) that doses of up to 80 $\mu\text{Gy h}^{-1}$ (predominantly internal dose) to molluscs and crustaceans are postulated. Given these possible scenarios we wish to better understand how risks arising from ingestion pathways that are based on foodstuffs contaminated via intimate contact with undiluted waste (or via related ingestion routes) have been assessed.

We therefore wish to further understand the perceived radiological hazards¹⁰⁶ and habit related assumptions¹⁰⁷ that underpin radiological safety arguments in the coastal erosion scenario. Specifically we wish to further understand the following:

- LLWR/ESC/R (11)10028 states (p. 183) that “The marine equilibrium sorption model and calculation of marine foodstuffs for Pb-210 with Po-210 in equilibrium is a simplified model, omitting a number of processes that could be important but are difficult to characterise”, and goes on to outline how the approach may not be cautious with respect to risks arising from Po-210. We wish to understand why a “marine equilibrium sorption model” is considered appropriate relative to other possibilities.
- The likely concentration of radionuclides in foodstuffs that might be contaminated by direct exposure to waste and doses arising specifically from ingestion by humans of such foodstuffs, including:
 - shellfish from the intertidal zone;
 - sheep grazing tide-washed pasture;
 - wild fruit (e.g. blackberries and cranberries) growing on the cliff area during the period of erosion;
 - game such as rabbits inhabiting the cliff area during the period of erosion; and,
 - wild fowl inhabiting the cliff area during the period of erosion.
- The coastal erosion assessment includes a consideration of dose to an, “*occupational user of the beach directly below the repository*”. This is described as a “*what-if behaviour assumption*” and we wish to understand the basis of any judgement that this “*has an annual probability substantially less than one*”. In addition, we note that there would appear to be other possible scenarios that might include time spent in closer proximity to undiluted waste than is assumed in this particular “what if” case. The latter might include, for example, time spent fishing from an exposed waste platform (i.e. a fisherman standing or seated directly on exposed waste).
- Any reasonable enhanced radionuclide uptake mechanisms that might arise in such scenarios and related radiological risk and dose implications (e.g. due to activity levels in shellfish as a result of uptake of sediment comprising undiluted LLW in passage through gastrointestinal tracts, including possible higher activity particles that may be associated with specific wastes).

Technical Query Actions

ESC-TQ-ASO-006.A1	Please provide clarification against the specific issues raised in the bullet points above.
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	29/06/2012
Comment: Clarification will be provided.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	22/10/2012
A response is provided in ESC Project Memo LLWR/ESC/Mem (12)167, 19/10/2012.		

¹⁰⁶ Including hazards associated with radionuclide concentrations in foodstuffs arising in such a scenario and dose rates in close proximity to exposed waste.

¹⁰⁷ Including consumption rates for such foodstuffs, assumptions as to how long a person might spend in close proximity to waste and the basis on which these are derived.

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 15/04/2013
Approved by: Environment Agency	Date: 10/10/2013

During and after the destruction of the LLWR by coastal erosion, waste materials will be exposed in the accessible environment, including the cliff and beach. This Technical Query (TQ) queries the assumptions made in the coastal erosion assessment calculations, in that certain scenarios do not appear conservative with respect to potential exposure to undiluted waste.

The assessment calculations provided in the 2011 ESC, along with the arguments presented in memo LLWR/ESC/Mem (12)167, indicate that future doses arising from these scenarios are likely to be low. We agree with this, although we still have some limited reservations around the assumptions used, but are in general content that the assessment presented is reasonable.

The response to the TQ is split into five areas, which are discussed separately below.

1. Whether scenarios encompassing exposure to undiluted waste are non-conservative? The LLW Repository Ltd response centres around the fact that 2011 ESC calculations indicate a factor of 2 dilution of radionuclides between the cliff and the storm beach (based on peak concentrations of Th-232) and the fact that the calculations assume volume as opposed to mass conservation such that, since no credit is taken for the higher density vault materials, the assessment model is cautious by a factor of 2. The claim is that, since these factors effectively cancel each other out, the lack of a formal assessment of exposure to undiluted waste is not of concern. However, it is not mentioned that there is a factor of 45 dilution between the cliff and foreshore (where some exposures for both humans and biota may occur) and that the assumption of volume conservation is unlikely to be significantly conservative for the lower density trench disposals. Peak annual risks associated with the coastal erosion scenario are of the order of 10^{-7} to 10^{-6} (around the risk guidance level of 10^{-6} y^{-1}). We would expect LLW Repository Ltd to consider whether the exposure model is conservative with regard to exposure to undiluted waste in the next ESC.
2. Whether exposure times for the 'what if' occupational PEGs are not conservative? LLW Repository Ltd acknowledges that the PEG definition work was based on 2003 habit data, and that data from the 2007 and 2009 CEFAS radiological habits surveys had not been considered. Although not likely to significantly affect calculated impacts, future calculations should draw upon (along with other relevant information) the latest habitat survey data.
3. We asked for clarification on doses associated with ingestion of foodstuffs that might be contaminated by direct exposure to foodstuffs. We accept that concentrations of radionuclides in such foodstuffs, and likely uptakes, are sufficiently low as to not result in significant doses.
4. LLW Repository Ltd presents new scoping calculations for uptake of radionuclides in seaweed and direct consumption. It states that a more likely exposure scenario is through use of contaminated seaweed as soil conditioner but that in the absence of data to support such calculations, it is assumed that intakes associated with consumption of crops grown on such soil are unlikely to be higher than those due to direct consumption of seaweed. This assumption was based on an HPA study (Brown et al 2009) investigating the concentrations of radionuclides in seaweed, conditioned soil plots and produce (including products from animals that grazed on the seaweed). The calculated annual effective doses associated with consumption of seaweed are relatively low and approximately a factor of 2 below those associated with consumption of shellfish. We accept that impacts associated with this pathway are not significant.
5. Justification of the marine equilibrium sorption model for Pb-210 and Po-210 seems reasonable.

We consider that the majority of issues raised in this TQ have been addressed in memo LLWR/ESC/Mem (12)167. Our outstanding concerns relate to potential non-conservatism in assumptions for the dilution of waste material in the cliff and beach environment. Given the nature of the exposure scenarios, potential non-conservatism are not expected to result in dose

increases by more than a factor of two. We therefore consider this TQ to be closed, but recommend that the next assessment includes a thorough review of the implications of dilution of waste material in the cliff, beach and foreshore, covering both loose trench wastes and vault wastes with higher integrity (see Recommendation ASS22 of Environment Agency 2015, Review of LLW Repository Ltd's 2011 Environmental Safety Case: Assessments).

References

Brown, J. et al, *Transfer of Radioactivity from Seaweed to Terrestrial Foods and Potential Radiation Exposures to Members of the Public*, HPA-RPD-059, FSA report R04003, 2009.

Actions completed, Technical Query resolved and Form closed

Owner: Environment Agency	Date: 10/10/2013
Approved by: Environment Agency	Date: 10/10/2013

ESC-TQ-ASO-007: Selective retrievals study: GDF disposal costs

Title	Selective retrievals study: GDF disposal costs
Date raised	14/01/2013
Acknowledgment required by	21/01/2013
Response required by	01/03/2013
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	ASO
Approved by	Environment Agency

History

Status	Date	Description
Raised	14/01/2013	
Acknowledged	14/01/ 2013	
LLWR Response	16/04/ 2013	
Response Assessed	03/09/2013	
Transferred	06/09/2013	
Closed	15/11/2013	

Statement of Technical Query

Section 12.5 of the Amec (Level 3) report on Selective Retrievals¹⁰⁸ (Disposal costs for target wastes to a future UK Deep Repository) quotes unit cost for disposal and transport to a GDF as, "£15,990 m³ for deep disposal based on conditioned waste volume for the target waste in each option was used, plus a transport cost of £1,960 m³."

The NDA have more recently developed a cost model for disposal of wastes in a Geological Disposal Facility. Recent calculations for disposal of core graphite¹⁰⁹ have concluded that the unit variable costs for disposal of graphite in a shielded 2m or 4m box are £3840/m³ with unit transport costs an additional 1250/m³.

Wastes retrieved from the trenches would not require shielding and we cannot see how LLWR has arrived at these higher unit disposal costs, unless NDA cost data has changed significantly over recent years.

The Amec study states (page 12-4), "New inert material (possibly VLLW) would need to be imported to backfill and make-good the voids remaining in the trenches. Importing a new waste stream is likely to generate only a small income." For the thousands of cubic meters of target wastes retrieved, the income generated by subsequent disposal of VLLW in the freed up trench

¹⁰⁸ The Low Level Waste Repository, Selective Retrievals, LLWRP 675, AMEC Report 15360, August 2009.

¹⁰⁹ Review of baseline assumptions regarding disposal of core graphite in a geological disposal facility, NDA Technical Note 16495644, May 2012. Available at: <http://www.nda.gov.uk/documents/biblio/upload/Review-of-baseline-assumptions-regarding-disposal-of-core-graphite-in-a-GDF.pdf>

space is not insubstantial (~£500/m³) and this income could have been included to offset the quoted costs.

The AMEC report assumes that all retrieved waste items would require storage prior to disposal to a Geological Disposal Facility. We would question the assumption that the GDF is the only potential disposal option for the recovered wastes. For example during the period of storage alternative near surface facilities could be constructed. The cost of near surface disposal to an alternative near surface facility may significantly reduce disposal costs.

The disposal of retrieved wastes from the trenches after storage to an alternative shallow disposal system (LLWR 2) is assessed in the presented ESC. We consider that when constructing a dedicated new disposal facility in a better location it may be possible to dispose of all of the retrieved wastes from the trenches¹¹⁰ to that site. We seek indicative costs related to such a facility, the costing should assume that the new facility would be a direct replacement to the existing LLWR facility with no significant additional costs associated with the disposal of individual trench waste items.

Technical Query Actions

ESC-TQ-ASO-007.A1	LLW Repository Ltd to justify the discrepancies observed between the unit disposal and transport costs to a GDF. If appropriate the more recent NDA cost data should be used.
ESC-TQ-ASO-007.A2	LLW Repository Ltd to review its costings to allow for income generated by the extra available capacity for disposal of VLLW at LLWR trenches.
ESC-TQ-ASO-007.A3	LLWR Repository Ltd should consider indicative alternative costs for storage of the retrieved wastes followed by disposal to an alternative shallow disposal facility.
ESC-TQ-ASO-007.A4	Based upon the actions above, LLW Repository Ltd should consider the significance of any changes to cost data and whether these changes would substantially change the outcome of selective trench retrieval optioneering work as reported within the ESC. Any position should be justified.

LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	14/01/2013
Comment: Responses to the actions will be provided.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	14/01/2013
A response is provided in LLWR ESC Project memo LLWR/ESC/Mem (13) 212.		

¹¹⁰ For the purpose of this TQ a shallow disposal facility could be up to around 80 m below ground level. The disposal facility may operate as a direct replacement to the existing LLWR with a wider WAC due to its more favorable context (e.g. location). It is assumed all retrieved Trench wastes would be acceptable at this facility. Costs may be similar to those associated with the Dounreay LLW facility.

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 03/09/2013
Approved by: Environment Agency	Date: 15/11/2013

In response to this Technical Query (TQ), LLW Repository Ltd provided a memorandum entitled 'Response to IRF ESC-TQ-ASO-007 Costs of disposal associated with retrievals of waste from the trenches'.

We have assessed the memo against the questions raised in this TQ and consider that the responses are reasonable:

- For Action A1, the differences are accounted for by different assumptions on confidence intervals.
- For Action A2, an opportunity cost of up to £63M could be argued if excavated waste was removed and non-target ('background') waste disposed in the vaults, that is, about 10% of the total estimated project cost (£667M).
- For Action A3, storage costs depend mainly on construction cost of stores, which would be designed for a specified store life. There are no plans for a near-surface disposal facility that could accept wastes from the LLWR. Therefore stores would have to be constructed for a life at least sufficient to bring the GDF into operation.
- For Action A4, the assessment indicates a cost reduction of at most 25%, which does not change the judgement that cost of retrieval would be disproportionate given that assessed radiological risks from the trenches, including the Th-232 and Ra-226 target wastes, are already consistent with the GRA risk guidance level, and consistent with the GRA dose guidance range in the case of assessed human intrusion events.

LLW Repository Ltd also updated its GDF disposal cost estimates in line with current NDA figures. The update does not affect LLW Repository Ltd's view that costs of trench waste retrieval and subsequent waste disposition are grossly disproportionate to the benefit gained.

We accept the arguments made by LLW Repository Ltd and we therefore consider that this TQ can be closed.

Actions completed, Technical Query resolved and Form closed

Owner: Environment Agency	Date: 03/07/2013
Approved by: Environment Agency	Date: 15/11/2013

ESC-TQ-ASO-008: Integration between the PoA and Reference Case Assessment

Title	Integration between the Period of Authorisation and Reference Case Assessments
Date raised	03/01/2013
Acknowledgment required by	10/01/2013
Response required by	08/02/2013
Related issue numbers	-
Originated by	Environment Agency
Current owner	Environment Agency
Review group	ASO
Approved by	Environment Agency

History

Status	Date	Description
Raised	03/01/2013	
Acknowledged	14/01/2013	
LLWR Response	18/03/2013	
Response Assessed	15/04/2013	
Transferred	27/01/2014	
Closed	27/01/2014	

Statement of Technical Query

The following Technical Query (TQ) relates to how the presented ESC integrates groundwater impact models for the Period of Authorisation (PoA) and the period after removal of institutional control. We seek confirmation that the two aspects of the ESC, namely the models assessing the PoA and models representing the period after institutional control, achieve the following objectives:

1. are consistent in their input parameters where applicable;
2. their approaches take account of the differing regulatory objectives; and
3. that the post-closure models take account of historic discharges to groundwater so as to present a realistic cumulative groundwater impact.

In our review of the 2002 LLWR ESCs, we suggested that it would be suitable to integrate the analyses for the operational and post-closure periods to “*help eliminate inconsistencies..., ensure that a consistent set of assumptions is used for both sets of analyses, and ease confusion currently created because the periods covered by the 2002 PCSC¹¹¹ and 2002 OESC¹¹² analyses*”

¹¹¹ Post-Closure Safety Case.

¹¹² Operational Environmental Safety Case.

overlap"¹¹³. However, we consider that this issue has not been fully addressed in the 2011 ESC, given that, as described in this Technical Query, separate models, with differing assumptions and a 100 year overlap, are presented for both the radiological and non-radiological assessments.

As a result of the non-integration of the PoA and post-closure models, the cumulative impact of radioactive and non-radioactive groundwater discharges during the operational period are not taken account of. For the vaults this would be less important¹¹⁴, however, for the Trench disposals, radioactive and non-radioactive discharges to groundwater will have occurred from the commencement of operations. This can be seen in the tritium plume present below the Trenches.

By not incorporating discharges occurring during the PoA, it is assumed that the groundwater below the site will be 'clean' at the commencement of leakage. In order to deliver a realistic assessment we consider it essential that the cumulative impact of the authorised activities over the whole life of the site is assessed.

Modelling approach

The Reference Cases for the radiological and non-radiological assessments were run for 1,100 years from emplacement of the final cap in 2080 to 3180, when the coastline reaches the site boundary. No results were given for the first 100 years of either model due to on-going leachate management in that period. Separate models were used for the PoA radiological and non-radiological assessments (1959-2180) to take into account different near field water flows in the pre- and post-final cap periods.

For both the radiological and non-radiological assessments, the main differences between the PoA and the Reference Case models appear to be^{115,116}:

- a separate flow model is used in the PoA assessment to represent flow through the trenches, taking into account the timing of emplacement of the interim cap;
- it is assumed in the PoA model that the trenches remain fully saturated at all times;
- the effects of emplacement of the post-closure engineering, including the final cap (assumed to occur by 2080 in the Reference Case), are not considered;
- the progressive nature of disposals to each trench is considered in the PoA model; and
- water flows through the vaults are not considered as it is assumed that active leachate management is in place throughout the PoA and 100% effective.

Radiological assessment

Guidance on Requirements for Authorisation (GRA) Requirement 5 requires the operator to ensure that the effective dose from the disposal facility to a representative member of the critical group should not exceed a source-related dose constraint and a site-related dose constraint. GRA Requirement 6 states that the assessed radiological risk from the facility to a person representative of those at greatest risk should be consistent with a risk guidance level of 10^{-6} per year. It is therefore appropriate that the results are presented separately for the PoA and post-closure periods. However, we require justification for the differences between the two models such as the omission of the effects of the final cap in the PoA assessment and 100% effectiveness of the vault leachate management system in the period up to 2180.

¹¹³ The Environment Agency's Assessment of BNFL's 2002 Environmental Safety Cases for the Low-Level Radioactive Waste Repository at Drigg NWAT/Drigg/05/001 (Version: 1.0) June 2005.

¹¹⁴ Detailed issues relating to the management of leachate during the PoA will be discussed in the forthcoming engineering workshop.

¹¹⁵ Kelly M, Applegate D, Berry JA and Thorne MC (2011). Radiological Assessment Calculations for the Groundwater Pathway for the LLWR 2011 ESC, Serco/TAS/003796/11, Issue 6, April 2011.

¹¹⁶ Kelly M and Berry JA, Non-Radiological Assessment Calculations for the LLWR 2011 ESC, Serco Report Serco/TAS/003796/012 Issue 5, April 2011.

Non-radiological assessment

GRA Requirement 10 requires the operator to demonstrate that the disposal system provides adequate protection against non-radiological hazards. There is no regulatory requirement for the differentiation between requirements for the PoA and post-closure periods¹¹⁷. Nevertheless, separate models, with differing assumptions and a 100 year overlap, are presented for the non-radiological assessment. We require justification for the approach to non-radiological contaminant assessment taken in the 2011 ESC and justification of significant assumptions such as the omission of the effects of the final cap in the PoA assessment and 100% effectiveness of the vault leachate management system in the period up to 2180.

The results for the PoA are presented in the Level 3 non-radiological assessment calculations for the LLWR in tables of peak and average concentrations in B3 (p102-103); no graphs are provided plotting modelled concentrations against time. We consider that such plots would be useful to determine how closely the PoA model output reflects measured environmental concentrations, where data are available.

A comparison of predicted non-radiological contaminant concentrations in trench leachate from the PoA model against measured data is provided in the Level 3 Non-radiological assessment calculations for the LLWR (p50-51). We would also like to see a comparison of predicted non-radiological contaminant concentrations in the groundwater and groundwater monitoring data. This would be useful to verify the cautious nature of many of the assumptions made in the non-radiological assessment, especially with regard to the inventory for which there is a high degree of uncertainty in both concentration and availability of hazardous substances and non-hazardous materials.

Graphs presented in the Level 3 non-radiological assessment calculations for the LLWR (Appendix 3) show the variation in concentration of key non-radiological contaminants in the B3 groundwater with time. These graphs only contain data post-2180 and thus give the impression that contaminant concentrations in B3 were zero before then. We wish to understand why no attempt was made to integrate the output from the PoA model with that from the Reference Case model. We would like to see single graphs of environmental concentrations of key non-radiological contaminants covering the entire assessment period (i.e. 1959 to 3180), which would also serve as a useful comparison of the outputs from the PoA and Reference Case models.

Technical Query Actions

ESC-TQ-ASO-008.A1	Please justify the approach taken to interfacing between the PoA and reference case assessments (radiological and non-radiological) as discussed in this TQ. Include justification of significant assumptions such as the omission of the effects of the final cap in the PoA assessment and 100% effectiveness of the leachate management system in the period up to 2180.
ESC-TQ-ASO-008.A2	Please update the presentation of key output from the PoA and Reference Case non-radiological assessment models so as to allow better visualisation of whole life and cumulative groundwater impacts and to demonstrate the conservative nature of the model assumptions. This should include: <ul style="list-style-type: none">• comparison of modelled non-radiological contaminant concentrations from the PoA model against measured environmental data (e.g. trench leachate and groundwater contaminant data); and• graphs of environmental concentrations of key non-radiological contaminants covering the entire

¹¹⁷ Best practice for non-radiological hydrogeological risk assessment for landfill disposals would be a single groundwater model covering the entire life of the site.

	assessment period (i.e. 1959 to 3180).
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	14/01/2013
Comment: The requested justification and representation of results will be provided.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	18/03/2013
A response is provided in ESC Project memo LLWR/ESC/Mem(13)198.		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 15/04/2013
Approved by: Environment Agency	Date: 27/01/2014

The reasons for undertaking separate calculations for the Period of Authorisation (PoA) and post-closure assessment period are described in LLW Repository Ltd memo LLWR/ESC/Mem(13)198. These are understood, however, we would expect better integration between these assessment periods in a future ESC.

Justification for the assumption of 100% effectiveness of the leachate management system during the entire PoA was discussed at an engineering workshop on 31 January 2013. LLW Repository Ltd made a commitment to produce a leachate management strategy which should provide reassurance of the performance assumptions and support the evaluation of detail design and specification. Quantification of redundancy and how it varies through the evolution of the facility is to be documented. This scope of the strategy and programme will include:

- review of drainage pathways
- capacity assessments at various times in the evolution
- quantification and assessment of the impacts of any clogging
- quantification and assessment of the development of perched water within the waste mass

LLW Repository Ltd had not provided the leachate strategy at the completion of our review of the 2011 ESC. We have asked the company to validate the performance of the leachate management system in ESC-FI-023. For the purpose of this TQ, we are sufficiently confident that LLW Repository Ltd can demonstrate the claimed 100% leachate collection efficiency as part of the design justification process. Therefore, we consider that Action ESC-TQ-ASO-008.A1 can be closed.

Memo LLWR/ESC/Mem(13)198 presents combined graphs for the PoA and post-closure periods for risk associated with significant radiological contaminants and groundwater concentrations of significant non-radioactive contaminants. Two sets of graphs are presented for each case: one assuming 50 mm/year infiltration through the interim trench cap during the PoA (as presented in the 2011 ESC) and one assuming 300 mm/year infiltration (a later variant calculation based on the results of recent water balance calculations¹¹⁸).

¹¹⁸ Baker, A., 2012. Response to Issue Resolution Form ESC-RO-SUE-001.A1 (Final Capping of the Trenches). LLWR Technical Memo LLWR/ESC/Mem(12)147.

The PoA assessment covers the period up to 2180. The post-closure assessment starts at 2080, although impacts appear negligible pre-2180. Discrepancies between impacts calculated for the two time periods will be dominated by releases from the trenches given the assumption that leachate will be pumped from the vaults during the PoA.

For both PoA infiltration rate variants, total radiological risk is similar at the end of the PoA assessment and at the start of the post-closure assessment. However, there are a number of trends that correlate less well. For example, taking the 300 mm/year infiltration rate case, earlier breakthrough of radionuclides such as Np-237 and Pb-210 is seen during the PoA. Although risks associated with these contaminants are significantly below the risk guidance level, calculated risks during the PoA are greater than peak risks post-closure. Given that predicted future risks are below the risk guidance level for both scenarios (by over an order of magnitude by the end of the PoA), we consider that Action ESC-TQ-ASO-008.A2 can be closed with regards to radiological impacts. However, we would expect a better integration of the PoA and post-closure assessments in a future ESC (see Recommendation ASS2 of Environment Agency 2015, Review of LLW Repository Ltd's 2011 Environmental Safety Case: Assessments).

Discrepancies between non-radioactive contaminant concentrations in the groundwater calculated at the end of the PoA (both variants) assessment and at the start of the post-closure assessment are much greater than in the radiological assessment. Rising trends in contaminant concentrations in groundwater are seen throughout the PoA. However, concentrations at the start of the post-closure assessment are zero and are again seen to increase throughout the assessment period. Taking the 300 mm/year infiltration rate case as an example, calculated concentrations of a number of non-hazardous pollutants (including molybdenum, chromium and uranium) in groundwater at the end of the PoA assessment are greater than concentrations calculated at the end of the post-closure assessment. There is thus concern that the assessment has not properly taken into account the cumulative impact of releases of non-radioactive contaminants to groundwater. Despite this, we consider that the assessment presented is adequately conservative given that impacts to groundwater from non-radioactive contamination in the LLWR disposals are currently monitored and observed concentrations are relatively low. We therefore can close this TQ.

We have asked LLW Repository Ltd to provide an updated non-radiological groundwater risk assessment to demonstrate continued conformity with the GRA and associated supplementary guidance, together with better alignment with landfill practices by 2017, in ESC-FI-006. As part of this update, we will expect LLW Repository Ltd to present a better integration of the period of authorisation and post-closure assessments (see Recommendation ASS2 of Environment Agency 2015, Review of LLW Repository Ltd's 2011 Environmental Safety Case: Assessments).

Actions completed, Technical Query resolved and Form closed

Owner: Environment Agency	Date: 15/04/2013
Approved by: Environment Agency	Date: 27/01/2014

ESC-TQ-ASO-009: Well calculations

Title	Well calculations
Date raised	26/11/2012
Acknowledgment required by	03/12/2012
Response required by	31/12/2012
Related issue numbers	ESC-TQ-ASO-009A
Originated by	Environment Agency
Current owner	Environment Agency
Review group	ASO
Approved by	Environment Agency

History

Status	Date	Description
Raised	26/11/2012	
Acknowledged	29/11/2012	
LLWR Response	22/04/2013	
Response Assessed	30/01/2014	
Transferred	12/02/2014	
Closed	13/02/2014	

Statement of Technical Query

The following TQ relates to the calculation of impacts via the well pathway in the 2011 Environmental Safety Case (ESC). We seek clarification of a number of key assumptions used in these calculations in order to provide reassurance that the calculations are not overly optimistic.

The well pathway is of significance because previous assessments have estimated relatively high risks associated with the ingestion of well water and its use for watering crops and livestock. Peak risks of 2 E-5 y^{-1} were calculated for this pathway in the 2008 interim assessment¹¹⁹. However, LLWR Ltd considered these calculations to be cautious as a result of (i) the well being located on the site boundary where concentrations are highest; (ii) near field releases being represented by a simplified, conservative release model; and (iii) the probability of existence of a well being assumed to be 1. We broadly agree with this interpretation.

Well pathway calculations for the 2011 ESC have sought to address the conservatism in the 2008 assessment. However, without further clarification, we are inclined to consider that the treatment of the well pathway in the ESC may now be optimistic.

Calculations for the well pathway are presented in the Level 3 document on radiological assessment calculations for the groundwater pathway¹²⁰. Three different calculations are undertaken for the well pathway:

¹¹⁹ Paksy, A. and Henderson, E. (2008). Assessment of Radiological Impacts for the Groundwater Pathway. Nexia Solutions (08) 9449: Issue 2, August 2008.

¹²⁰ Kelly M, Applegate D, Berry JA and Thorne MC (2011). Radiological Assessment Calculations for the Groundwater Pathway for the LLWR 2011 ESC. Serco/TAS/003796/11, Issue 6, April 2011.

- Reference Case deterministic calculation which includes the assumption of a well density of 0.1 km⁻² in the vicinity of the Low Level Waste Facility (LLWR).
- Increased well probability deterministic variant calculation in which the well density is increased to 0.3 km⁻².
- A probabilistic calculation case in which probability distribution functions (PDF's) are assigned to nine key parameters including well density.

We seek a number of clarifications relating to these calculations as outlined in the following sections.

Location and likelihood of existence of a well

An experienced hydrogeologist was contracted by LLWR Ltd to review the potential location and types of groundwater abstraction that could occur in the future around the LLWR¹²¹. In the review an area east of the railway line (probably up to the Drigg-Whitriggs Road) was included in the areas identified as having the potential for wells, noting that a cone of depression could develop under the site (previous hydrogeological studies reporting the methodology for the assessment of wells have also noted this as a preferential area to site one or more groundwater supply boreholes). It is noted that there are already buildings in existence here. However, no discussion on the potential impacts of up gradient wells can be found in the ESC documentation. Therefore it is unclear why LLWR Ltd chose not to use this hydrogeological information and have instead constrained the possible location for wells solely to the area between the site and the coast.

We find the methodology LLWR Ltd has used to derive best estimate and upper bound annualised probabilities for the existence of wells to be difficult to follow and not clearly reported. There is little referencing to either these values or their derivation in either the Level 2 long-term radiological assessment report or the Level 3 radiological assessment calculations for the groundwater pathway. Conflicting information is given in the Level 3 reports on the methodology for the assessment of wells¹²² and the elicitation of uncertainties¹²³. We understand that the analysis in the elicitation of uncertainties post-dates the derivation of the methodology for the assessment of wells, however, this is not made clear in the documentation.

In particular, we have concerns that the well densities used in the assessment calculations are at the lower range of local and regional well densities considered in the elicitation process and thus may not be conservative. Specific points to note are:

- Although site-specific reasons are presented for increasing the values of well density (which were derived using the wider west Cumbrian coastal strip dataset), these arguments do not seem to have been given a high weighting whereas more weight seems to have been placed on evidence which could decrease likelihoods. For example, in the case of the caravan/chalet park this approach results in the lower bound being an order of magnitude less than the central value but the upper bound only being around a factor of three higher. Similarly, for the isolated dwelling it is not clear why the central value for the LLWR (0.1 km⁻², as carried through to the reference case calculations) is an order of magnitude lower than that derived by Nirex for the Cumbrian plain (1 km⁻²).
- The elicitation report notes that a study of known abstractions in the coastal strip between Ravenglass and St Bees Head gave a frequency of domestic boreholes of about 0.2 km⁻² within 1 km of the coast. Given that abstractions of less than 20 m³/day do not need to be licensed by the Environment Agency, this may be an underestimate of the true number of abstractions. It is further noted that the current frequency of isolated farms/dwellings is 28 within 500 m of the coast in 68 km of usable/open coast, corresponding to a frequency of slightly less than 1 km⁻²

¹²¹ Brassington, R. (2010). *Review of Potential Groundwater Abstraction at the LLWR Facility, Drigg, West Cumbria*. Rick Brassington Report 1548, May 2010.

¹²² Jackson, C.P., Lever, D.A. and Thorne, M.C. (2009). *Methodology for the Assessment of Wells*. Serco Report SERCO/TAS/002888/001, Issue 01.

¹²³ Jackson, C.P., Couch, M., Yates, H., Smith, V., Kelly, M. and James, M. (2011). *Elicitation of Uncertainties for LLWR*. Serco Report Serco/TAS/E003796/010, April 2011.

(although not all of these dwellings will have boreholes). These data provide further evidence that a central value for well density of 0.1 km^{-2} may not be conservative.

- It is stated in several places in the ESC that the possibility of ephemeral site uses such as caravan parks cannot be ruled out and that, even for a caravan park used for holiday homes, there would be one or more caravans or nearby dwellings occupied by permanent residents, such as site managers, who would use water throughout the year from a borehole associated with the caravan park. It is therefore not clear why the well likelihoods used in the assessment calculations are the lower values elicited for an isolated dwelling rather than the higher values elicited for a caravan/chalet park.

Implementation of the well calculations

Generally LLWR Ltd's presentation of its development and implementation of an approach to calculating potential exposures from a well is complicated by its heavy reliance initially on techniques and approaches developed for geological disposal and then subsequently by the modifications and simplifications made in order to attempt to adapt it to the LLWR.

In order to develop a workable approach to estimating radionuclide concentrations in abstracted groundwater LLWR Ltd has adopted an approach in which the concentrations are averaged over the whole area between the coast and the site. At face value this seems to offer considerable potential for introducing excessive risk dilution into the assessment calculation. We would expect LLWR Ltd to identify the potential for this to occur and undertake checks to assess to what degree, if any, it has occurred. However, we cannot find any such analysis reported and therefore we are unable to judge the acceptability to us of the results of the assessment until we have further information. For example, plots of radionuclide concentrations in the various GoldSim pipes that comprise the modelled plume may be informative.

The justification of the parameters used in the GoldSim model to derive biosphere factors for the abstraction of contaminated groundwater is limited. The parameters (e.g. hydrological, soil properties, agricultural) are described as default values and the model adopted by LLWR Ltd is a generic model developed by their contractor for use by NDA RWMD in its prior generic assessments for deep geological disposal. Limited consideration appears to have been given to the different assessment context of the LLWR compared to that for a generic geological disposal assessment, other than a brief statement on the data for a well drained loam being considered suitable to the LLWR. Contrary to this, however, generic data for human and animal drinking water intakes are discussed in some detail. Therefore, it is not clear that LLWR Ltd has fully considered whether or not any aspects of its selected model should be adapted to the specifics of the LLWR and the 2011 ESC.

Deterministic variant calculation R18 considered the impact of a shortened (10m) pathlength into the marine environment. It was intended to provide a bounding case for uncertainties about the evolution of the underlying geology during coastal erosion. However, this calculation did not include the well pathway, making it difficult to assess the effect of this uncertainty on the geosphere pathway giving rise to the highest impacts. In contrast, we note that the probabilistic calculations were focussed on the effect of uncertainty in key parameters on risk associated solely with the well pathway. We would expect LLWR Ltd to consider how the potential impacts associated with groundwater abstraction (and their quantification) could vary as a result of the future evolution of the site.

Furthermore, in order to support our decision-making we also require a range of potential exposures to be presented to us with the likelihood that they will be received (c.f. GRA para 6.3.22). Given the inherent uncertainties in characterising future human behaviour we do not consider it inappropriate to include a range of potential exposures associated with abstracted groundwater, given the importance of this exposure pathway. We would therefore expect that LLWR Ltd provide us with results of calculations for a variety of potential exposures associated with abstracted groundwater.

The probabilistic well calculation

The configuration of the probabilistic well calculation case to use 500 realisations was constrained by consideration of an acceptable run time and the output file size (also related to number of output times), rather than whether this number of samples would cover an appropriate amount of

parameter space. We also note that some of the realisations were unsuccessful, further reducing the number of results obtained.

We wish LLWR Ltd to provide evidence that the results they have reported for the probabilistic calculation are stable and not overly sensitive to changes in the number of samples used. LLWR Ltd should also explain why no attempts were made to increase the efficiency of the sampling approach given that they were constrained to so few samples – this could have been done, for example, by using Latin Hypercube Sampling instead of a Monte Carlo approach.

The probabilistic calculation uses PDFs to describe distributions for 9 classes of parameters which LLWR Ltd state were considered in several of the deterministic variant calculations. However, it is not clear whether a number of the parameter ranges used in the deterministic variant calculations are included in the PDFs used in the probabilistic calculation. For example:

- Deterministic calculation R12 considered the impacts of zero sorption onto soil and grout, however, a near zero number does not appear to be part of the sorption PDFs. (see also the comments made in TQ-INF-026).
- Deterministic calculation R14 examined the impacts of increased uranium solubility, however, it is not clear how this was considered to be represented within the PDFs. (see also the comments made in TQ-INF-026).

In addition, the elicitation report¹²³ recommends usage of a log triangular distribution for the probability of a well serving an isolated dwelling with values of 0.03, 0.1, 0.3 km⁻². However, the distribution quoted in the radiological calculations for the groundwater pathway report¹²⁰ is 0.03, 0.1, 3 km⁻². We would like LLWR Ltd to clarify which upper limit was used in the assessment calculations.

In presenting the results of the probabilistic calculation case, LLWR Ltd has taken the mean value as the most appropriate measure to compare with the risk guidance level. This decision should be explained. Instead they describe *“the difference between the risks for the greatest and least results is only around two orders of magnitudes”*. We note that the actual spread of results from minimum to maximum appears to be around four orders of magnitude, and conclude that the quote relates to the spread in relation to the mean result, rather than the overall spread of results. We also note that in the graphical distribution of doses for C-14 (Figure F54 of L3 report on radiological assessment calculations for the groundwater pathway) the mean value seems to cross the 75th percentile which is not statistically correct. We would like LLWR Ltd to clarify these aspects of the results reporting to provide some assurance that the results presented have been transposed correctly.

Once LLWR Ltd has addressed our other comments on the specification of the probabilistic calculation it would be helpful if LLWR Ltd would tabulate fully the results of the probabilistic calculation, as it has done for the deterministic calculations.

Technical Query Actions

ESC-TQ-ASO-009.A1	<p>Provide clarification on the points raised in this TQ relating to:</p> <ul style="list-style-type: none"> • the reasons for solely considering wells located down gradient of the LLWR; • justification of the assumed well densities; • demonstration that the approach to deriving radionuclide concentrations in abstracted groundwater does not result in an unacceptable amount of risk dilution; • clarification of the approach to the GoldSim calculations used to calculate risks via the well pathway; • how the potential impacts associated with groundwater abstraction could vary as a result of the future evolution of the site; • provision of results of calculations for a variety of potential exposures associated with abstracted groundwater;
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	<ul style="list-style-type: none"> • the stability of the probabilistic assessment for the number of successful realisations undertaken; • the relationship between the parameter variations considered in the deterministic calculations and the PDFs derived for the probabilistic assessment; and • presentation of the output of the probabilistic assessment.
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	29/11/2012
Comment: Clarification on the points raised will be provided.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	22/04/2013
A response is given in LLWR ESC Project memo LLWR/ESC/Mem(13)211, which references an associated more detailed technical response by Amec, D.000215/001 Issue 2, 2013.		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 18/06/2013
Approved by: Environment Agency	Date: 13/02/2014

We accept the reasons provided for screening out assessment of a well located up gradient of the LLWR for the abstraction rates considered (Amec report D.000215/001).

We welcome the additional calculations for a well associated with a caravan/chalet site (site manager and permanent resident) (Amec report D.000215/001). The assumptions based on these exposure groups are reasonable, including the assumed probability for existence of such a well. The best estimate value of the probability of such a well per kilometre is based on the observed frequency of caravan sites along the open Cumbrian coast, which is reasonable. Peak risks, associated with the site manager, are $2 \times 10^{-7} \text{ y}^{-1}$, which is a factor of five greater than the peak well risks documented in the 2011 ESC for the similar deterministic calculation but a factor of five below the risk guidance level. We note that the caravan site manager is assumed to maintain a garden and keep hens. Such activities will not be undertaken by all caravan site managers and so risks may well be lower.

We note that LLW Repository Ltd did not present a corresponding probabilistic calculation for the caravan site manager PEG.

The assumed probability of the existence of a well associated with an isolated dwelling appears low, given that the best estimate probability of 0.1 km^{-2} is half an order of magnitude less than the estimated average for the open coast. Although the presence of the Drigg Dunes Special Area of Conservation makes such a development less likely at the present day, this may not be the case in the future. Should the Special Area of Conservation designation be removed, the land is currently of low agricultural value and is likely to remain so prior to its erosion. Such low quality land is less likely to result in the developments than elsewhere. The upper probability limit of 0.3 seems particularly low, given that the observed frequency of isolated farms/dwellings along the coast is slightly below 1 km^{-2} . However, we note that based on the assessment calculations presented, the use of slightly less conservative assumptions (say a best estimate probability of 0.2 km^{-2} , equivalent to the number of known boreholes within 1 km of the coast), peak impacts would still be below the risk guidance level.

LLW Repository Ltd's choice of hydrological parameters for a generic well-drained loam is reasonable; however, we would expect future iterations of the model to make greater use of site-specific data. On a wider scale we would expect LLW Repository Ltd to seek to further utilise site specific properties to inform future assessments.

LLW Repository Ltd elicited values for the likelihood of wells using information consistent with present day conditions at the site and its surroundings and configured a calculation based on consideration of a well being located in the area between the disposal facility and the discharge point assumed to be 500 m away at the location of the present coastline. The probability of a well supplying a dwelling will decrease as land is lost between the LLWR and the coast due to coastal erosion. The company undertook an alternate calculation in the 2011 ESC in which a 10 m groundwater pathway was assessed but did not include the well pathway in the calculation as it considered that this is insufficient land within which a borehole could be credibly located. The probability of a well supplying a caravan park will remain unchanged as land is lost between the LLWR and the coast as it is based on length of coastline as opposed to area. For wells supplying both caravan parks and dwellings there will be a critical distance between the site and coast below which the probability of a well being drilled is negligible due to lack of space or saline intrusion. It is assumed that the likelihood of a well existing will decrease as land is lost, whilst groundwater concentrations will increase slightly due to the reduced distance to the well, noting that the majority of dilution will occur when contamination enters the B3 lithologies.

LLW Repository Ltd has not undertaken an assessment of how sensitive estimated impacts arising from a well to either a dwelling or a caravan park are to the location of the coastline. The impact of saline intrusion is also not considered. These issues are not anticipated to have a significant impact on well pathway risks but should be considered in the refinement of any future assessment (see Recommendation ASS14 of Environment Agency 2015, Review of LLW Repository Ltd's 2011 Environmental Safety Case: Assessments).

The additional probabilistic calculations provide us with confidence that the 500 realisations carried out in the 2011 ESC probabilistic well calculation were sufficient. We welcome the additional tabulation of the results from this assessment in Amec report D.000215/001 and accept the comments provided on the presentation of the results.

We were uncertain about the approach adopted by LLW Repository Ltd for projecting radionuclide concentrations in abstracted groundwater for use in the assessment calculations. The approach involved integrating all the contributions to risk from across the appropriate part of the plume, which, mathematically, can be calculated on the basis of an average concentration. However, the presentation of the methodology was not clear and did not fully resolve our uncertainty. Furthermore, in order to show that this approach is appropriate (that is, not over optimistic), we would have expected to see a discussion on the variation of activity within various parts of the plume. This information was not included in LLW Repository Ltd's response either. Therefore we raised a further Technical Query (ESC-TQ-ASO-009A) with LLW Repository Ltd in which we sought information on the range of radionuclide concentrations both as a result of the estimation technique used in the assessment calculations and due to heterogeneity in hydrogeological properties. We also asked that the impacts of these variations on potential exposures be presented and a breakdown of potential exposures which includes both dose and risk be provided. LLW Repository Ltd response to this additional Technical Query (TQ) is addressed separately.

With the exception of our request for information on the range of radionuclide concentrations within the groundwater plume described above, we consider that LLW Repository Ltd has adequately addressed the questions raised in this TQ. Our conclusion takes account of a number of key assumptions which have significant uncertainties associated with them. These uncertainties are common to any attempt to predict speculative future human activities and are common to any ESC assessment.

In order to provide key PEG behaviour and distribution values for the groundwater well pathway assessment LLW Repository Ltd has utilised analogues based on current coastal land use. We consider that the information used to inform assessments is appropriate. Because of the significance of the groundwater well pathway in the ESC assessment and subsequent radiological capacity calculations we would expect coastal land use information to be further refined and updated on an ongoing basis, both to improve understanding and to take account of any changes which might occur.

After consideration of LLW Repository Ltd's response to both TQs (ESC-TQ-ASO-009 and ESC-TQ-ASO-009A) we recognise that the assessment includes significant uncertainties. However, we consider that these uncertainties have been adequately addressed in the TQ responses and assessment calculations. In developing this conclusion, we believe that there is value in recommending that LLW Repository Ltd develops and undertakes further investigations into the nature and significance of these uncertainties. We therefore expect LLW Repository to set out proposals within a forward plan for the development of the approach and model for projection of risks associated with the well pathway prior to the next major revision of the ESC. We expect this plan to seek to incorporate our recommendations made above and in TQ ESC-TQ-ASO-009a (see Recommendations ASS14 to ASS17 of Environment Agency 2015, Review of LLW Repository Ltd's 2011 Environmental Safety Case: Assessments). This TQ can be closed.

Actions completed, Technical Query resolved and Form closed

Owner: Environment Agency	Date: 12/02/2014
Approved by: Environment Agency	Date: 13/02/2014

ESC-TQ-ASO-009a: Well calculations further information

Title	Reply to LLWR's response to ESC-TQ-ASO-009 Well calculations
Date raised	12/07/2013
Acknowledgment required by	17/07/2013
Response required by	30/08/2013
Related issue numbers	ESC-TQ-ASO-009
Originated by	Environment Agency
Current owner	Environment Agency
Review group	ASO
Approved by	Environment Agency

History

Status	Date	Description
Raised	19/07/2013	
Acknowledged	19/07/2013	
LLWR Response	13/09/2013	
Response Assessed	30/01/2014	
Transferred	12/02/2014	
Closed	13/02/2014	

Statement of Technical Query

This Technical Query (TQ) specifically relates to our response to information submitted by LLWR to ESC-TQ-ASO-009 concerning the estimation of radionuclide concentrations for well pathway calculations and their impact on potential exposures calculated. This TQ should be read in conjunction with ESC-TQ-ASO-009. It is presented as a discrete TQ for clarity. For quality assurance purposes, this should be considered as one TQ.

Environment Agency assessment of LLWR Ltd response

The following TQ relates to the calculation of impacts via the well pathway in the 2011 Low Level Waste Repository (LLWR) Environmental Safety Case (ESC). We seek further clarification of a number of key assumptions used in these calculations in order to provide reassurance that the calculations are not overly optimistic.

Potential exposures estimated via the well pathway are significant in the context of the 2011 LLWR ESC. We note that the revised calculations presented by LLWR Ltd in the response to this TQ now estimate peak risks associated with the well pathway as $1.9\text{E-}07 \text{ yr}^{-1}$.

Estimation of radionuclide concentrations for use in well pathway calculations

LLWR Ltd's approach to estimating radionuclide concentrations in abstracted groundwater averaged the groundwater concentrations over the area of the assumed plume (i.e. the area between the coast and the site). The assessment calculations carried out in GoldSim, as part of the 2011 ESC, used these averaged concentrations in estimating radiological impact. We are uncertain as to the magnitude of variation of radionuclide concentrations that may exist between the calculated average and the range of values present in the plume (as represented by the

various GoldSim pipes¹²⁴). We are therefore also uncertain whether any differences could be significant in understanding the pattern of potential exposures.

We also note that in its response to this TQ LLW Repository Ltd provided an analysis which states that, assuming homogeneous properties, the maximum width of a well's capture zone is around 74 m. This suggests that mixing across the entirety of modelled plume width is unlikely to happen, as is implied by LLW Repository Ltd's approach of considering average plume concentrations.

Furthermore, the calculations undertaken within the GoldSim assessment model assume that the geological strata are homogenous and so the hydrogeological behaviour is also assumed to be homogeneous. However, the geoscientific understanding presented by LLW Repository Ltd elsewhere in the 2011 ESC recognises the substantial heterogeneity exhibited by the geological strata around the site. We are aware that ConnectFlow simulations have been undertaken which explore the impacts of this spatial variability and heterogeneity. In these simulations the particle tracking revealed areas of both preferential and reduced groundwater flow in response to variations in the hydraulic conductivity realisations generated.

We cannot find any information reported on the implications of the variation of modelled groundwater concentrations on the approach used in the well pathway calculations or a commentary on their comparison to conditions expected at the site. Therefore, we are unable to judge the acceptability of LLW Repository Ltd's approach to only use the calculated average radionuclide concentration in its assessment until we have further information.

Range of potential exposures associated with use of a well

In order to support our assessment we also require a range of potential exposures to be presented to us with the likelihood that they will be received (c.f. GRA para 6.3.22). Given the inherent uncertainties in characterising future human behaviour we do not consider it inappropriate to include a range of potential exposures associated with abstracted groundwater in our assessment, given the importance of this exposure pathway.

We would therefore expect that LLW Repository Ltd provide us with information on the potential exposures associated with abstracted groundwater arising from various scenarios. We note that in its response to the initial TQ, LLW Repository Ltd has provided information on the implications of considering Potential Exposure Groups with additional exposure pathways (for example, water consumption by livestock). However we suggest that further scenarios be considered which should include, but not be limited to, consideration of the impacts of the variations of groundwater concentrations (as discussed above) as well as assuming a specific location for an abstraction well (for example, close to the site boundary). Such scenarios could be presented as supplementary calculations, accompanied by any appropriate discussion of potential likelihoods and any implications for the ESC. We consider that the presentation of such information could help the EA in its assessment decision-making and in any engagement with local communities.

In presenting these results it would be informative if LLWR Ltd were able to provide a breakdown of potential exposures which reports both dose and risk.

Technical Query Actions

ESC-TQ-ASO-009A.A1	Provide a comparison of the range of radionuclide concentrations estimated in the GoldSim pipes against the average values used in the ESC assessment calculations.
ESC-TQ-ASO-009A.A2	Provide an analysis of the impacts on radionuclide concentrations in the plume arising from considering site specific heterogeneity in hydrogeological properties.
ESC-TQ-ASO-009A.A3	Provide supplementary information on the potential exposures from use of a well by considering impacts of variations in groundwater concentrations as well as assuming specific

¹²⁴ The GoldSim model represents groundwater flow processes using as series of 'pipes'.

	locations for an abstraction well.
ESC-TQ-ASO-009A.A4	Provide a breakdown of potential exposures which reports both dose and risk.

LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	19/07/2013
The information requested will be provided.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	13/09/2013
A response is provided in report: AMEC/200719/001 Issue 1.1 30 August 2013.		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 12/02/2014
Approved by: Environment Agency	Date: 13/02/2014

The following assessment relates specifically to the outstanding information provided in response to ESC-TQ-ASO-009A only.

LLW Repository Ltd did not include in its response a comparison of the range of radionuclide concentrations estimated in GoldSim pipes against the values used in the assessment. However, LLW Repository Ltd did present a further explanation of the approach used to derive radionuclide concentrations in groundwater, including the mathematical equation used in the estimations. This adequately addressed our query. Therefore we now consider that the approach LLW Repository Ltd used to estimate radionuclide concentrations is unlikely to have resulted in an unacceptable amount of risk dilution¹²⁵.

LLW Repository Ltd provided further information on the impacts on potential exposures of considering locating an abstraction well at particular nodes in the GoldSim pipes and also by using the particle tracking simulations undertaken using ConnectFlow and assuming either homogeneous or heterogeneous hydrogeological properties in the geological media. This provided clarity to the presented model outputs.

LLW Repository Ltd has provided a useful analysis of the potential impacts of spatial variability on the distribution of doses within the plume area assuming either homogeneous or heterogeneous hydrogeological properties. We consider that these are valuable in presenting supplementary information on the potential variation in doses. We recommend that LLW Repository Ltd investigates the potential to develop this work further such that these estimates are more readily able to be compared directly with the assessment calculations. This might for example be achieved by better restricting the ConnectFlow calculations to the plume area between the site and the coastline (see Recommendation ASS16 of Environment Agency 2015, Review of LLW Repository Ltd's 2011 Environmental Safety Case: Assessments).

¹²⁵ Risk dilution, as used in the original Technical Query is probably not the correct terminology. What we are referring to is the potential for the calculation to introduce factors which may have the effect of underestimating radionuclide concentrations and potential exposures.

Within this TQ we noted that only a few spatial heterogeneity simulations were carried out within ConnectFlow and therefore we were uncertain as to whether they represented the full range of variability likely to exist in the potential exposures from the well pathway. In response LLW Repository Ltd stated that it was of the opinion that the greater amount of variability would be within a realisation rather than between realisations. This was based on its experience and no evidence was provided to support this assertion. We have suggested in our review of the 2011 ESC ¹²⁶ that the number of spatial heterogeneity calculations was limited and would benefit from further assessment work (see Recommendation ASS15 of Environment Agency 2015, Review of LLW Repository Ltd's 2011 Environmental Safety Case: Assessments).

LLW Repository Ltd has included in its response a breakdown of potential exposures which reports both dose and risk. We would expect that for future versions of the ESC, the presentation of doses should be accompanied by a clearer indication of the likelihood associated with the potential exposure to enable its context to be more readily understood (see Recommendation ASS10 of Environment Agency 2015, Review of LLW Repository Ltd's 2011 Environmental Safety Case: Assessments).

We recognise that the development and configuration of the well pathway assessment are one of the most significant exposure pathway calculations being within a factor of 5 of the risk guidance level for the Reference Disposal Area. The information presented in response to both well pathway TQs (ESC-TQ-ASO-009 and ESC-TQ-ASO-009A) are subject to a number of key assumptions which have significant uncertainties associated with them. These uncertainties are common to any attempt to predict speculative future human activities and are common to any ESC assessment.

After consideration of LLW Repository Ltd's response to both TQs (ESC-TQ-ASO-009 and ESC-TQ-ASO-009A) we recognise that the assessment includes significant uncertainties.

However, we consider that these uncertainties have been adequately addressed in the TQ responses and assessment calculations. We recommend that LLW Repository Ltd carries out further investigations into the nature and significance of uncertainties associated with the potential for future groundwater usage in future assessments (see Recommendation ASS17 of Environment Agency 2015, Review of LLW Repository Ltd's 2011 Environmental Safety Case: Assessments). We also recommend that LLW Repository Ltd improves the clarity of its presentation of complex assessment areas such as future groundwater usage in future assessments (see Recommendation ASS18 of Environment Agency 2015, Review of LLW Repository Ltd's 2011 Environmental Safety Case: Assessments). This TQ can be closed.

Actions completed, Technical Query resolved and Form closed

Owner: Environment Agency	Date: 12/02/2014
Approved by: Environment Agency	Date: 13/02/2014

¹²⁶ Environment Agency, 2015. Review of LLW Repository Ltd's 2011 Environmental Safety Case: Assessments.

ESC-TQ-ASO-010: Human intrusion into sources

Title	Human intrusion into sources
Date raised	06/02/2013
Acknowledgment required by	08/02/2013
Response required by	28/02/2013
Related issue numbers	ESC-RI-ASO-013
Originated by	Environment Agency
Current owner	Environment Agency
Review group	ASO
Approved by	Environment Agency

History

Status	Date	Description
Raised	06/02/2013	
Acknowledged	07/02/2013	
LLWR Response	15/04/2013	
Response Assessed	03/07/2013	
Transferred	03/07/2013	
Closed	16/12/2013	

Statement of Technical Query

The following Technical Query is a request for further information on the potential consequences of intruding (by drilling) into one of the five previously disposed Sellafield source pots held in Vault 8. The Sellafield source pots collectively contain some 10 GBq of activity.

LLWR Memo 165 (Dose calculations for human intrusion into radioactive sources) states on page 30 (in relation to drilling into Sellafield source pots disposed before the 2005 agreement):

“Lead distorts but is not easily drilled into. Even a ‘hit’ by a geotechnical investigation drill is more likely push the container aside or cause the drill to fail rather than breach the container, although it might damage/distort the container. There are only 5 such containers in Vault 8 (area 27,000 m³), each presenting a projected area of 0.07 m³, so that the chance per borehole of hitting a pot is only 1 in 80,000, or 1 in 8000 for a site investigation in which 10 boreholes are drilled into Vault 8. It seems reasonable, therefore, to neglect this possibility and focus on the radiological impacts if a source pot is recovered.”

We accept the ‘low probability’ argument based on the small size of the items and low occurrence, we do not concur that the source pots could not be penetrated by a geotechnical investigation drill. As a result, we request that ‘what-if’ calculations are carried out on the consequences of a ‘direct hit’ into the worst-case source pot. It was these source pots in particular that we had in mind when raising the original RI (ESC-RI-ASO-013).

Technical Query Actions

ESC-TQ-ASO-010.A1	Calculate the consequences of drilling into the ‘worst case’ source pot (of the five known source pots) containing sources from Sellafield.
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LLW Repository Ltd Acknowledgement

LLW Repository Ltd	ESC Project Manager	07/02/2103
Comment: The calculations requested will be undertaken and the results provided.		

LLW Repository Ltd Response

Provided by:

LLW Repository Ltd	ESC Project Manager	14/04/2103
A response is provided in LLWR ESC Project memo LLWR/ESC/Mem (13) 210.		

Assessment of LLW Repository Ltd Response

By: Environment Agency

Owner: Environment Agency	Date: 03/09/2013
Approved by: Environment Agency	Date: 16/12/2013

LLW Repository Ltd memo LLWR/ESC/Mem (13) 210 addresses the radiological dose consequences of drilling into sources, considering a composite pot that contains the maximum activity recorded in any single pot.

The most likely outcome of human intrusion drilling into a worst case pot is a dose for a few microsieverts from external exposure due to sources or source fragments in the drill cuttings or excavated material.

LLW Repository Ltd calculates a maximum dose of 90 mSv for ingestion of a 1 mm fragment bearing 10% of the highest activity Pu-239 source present. The probability of this event, even assuming the source is intercepted and fragmented into ten 1 mm particles, is estimated at about one chance in 2 million, that is, very unlikely.

A maximum dose of 19 μ Sv is calculated for inhalation of a 10 μ m fragment bearing one millionth of 10% of the highest activity Pu-239 source present. The probability of this event, even assuming the source is intercepted and fragmented into ten million 10 μ m particles, is estimated at about one chance in ten, that is, not the expected outcome but possible.

If the probability of intercepting the single pot that actually contains the Pu-239 source is also taken into account, the probability of the above ingestion and inhalation events fall to one in 80 billion and one in 400,000 respectively. Such probabilities are so low so as to be negligible. We consider that this issue has been adequately responded to and can be closed.

Actions completed, Technical Query resolved and Form closed

Owner: Environment Agency	Date: 03/07/2013
Approved by: Environment Agency	Date: 16/12/2013

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