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Review of LLW Repository Ltd's "Requirement 2" submission

Technical Review of Volume 5: Performance Update for the LLWR

NWAT/LLWR/09/005 [Sector Code]

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Introduction

1.1 Site history

1.1.1 The Low Level Waste Repository near Drigg, Cumbria (LLWR) is located six miles south of the Sellafield site in the northwest of England. Radioactive waste disposal began at the site in 1959 when the LLWR was managed by the United Kingdom Atomic Energy Authority (UKAEA). The LLWR site occupies around 100 hectares; waste disposal operations take place in the northern 40 hectares of the site. During the early period of disposal operations, solid low level radioactive waste (LLW) was tipped and buried in shallow, clay-lined trenches, a practice similar to that used now in the landfill industry. Between 1959 and 1995, approximately 800,000 m^3 of waste was disposed in seven trenches. These trenches are now covered by an interim earth cap, which incorporates a plastic membrane to minimise water ingress.

1.1.2 In 1986 the House of Commons Environment Committee published a report on radioactive waste (House of Commons, 1986). In response to the report's recommendations, the LLWR operator at the time, British Nuclear Fuels plc (BNFL), made major changes to disposal operations. Since 1988, wastes have been disposed of in containers emplaced in an engineered concrete vault (Vault 8). Typically, the waste is put into steel drums which are then compacted into 'pucks'. These pucks are packed into freight containers that conform to published standards of the international standards organisation ISO. The wastes in full containers are encapsulated in cement grout before being placed in the vault. Vault 8 has a total capacity of 200,000 m^3; at the time of writing it is nearly full. The current operator of the LLWR, LLW Repository Ltd, plans to build additional vaults to accept further waste, subject to receiving planning permission from Cumbria County Council.

1.2 Regulatory background

1.2.1 The Environment Agency of England and Wales (the Agency; also referred to as "we" and "us") is responsible for authorising disposal of radioactive waste under the amended Radioactive Substances Act 1993 (RSA 93). In accordance with government policy, we periodically review authorisations for the disposal of radioactive waste. When we review an authorisation, we consider a wide range of information, including our conclusions from reviews of the environmental safety cases (ESCs) produced by the operators of a disposal facility.

1.2.2 The Health and Safety Executive (HSE), through its Nuclear Installations Inspectorate (NII), regulates nuclear safety. It ensures that radioactive waste on nuclear licensed sites is managed, conditioned and stored safely. The NII also has regulatory responsibility for accident risk management.

1.2.3 In 1999, we started a review of the RSA 93 authorisation for the LLWR, which was then held by BNFL. At that time, however, BNFL had not updated the impact assessment carried out in the 1980s by the National Radiological Protection Board (NRPB, now part of the Health Protection Agency, HPA). Our review was therefore unable to assess the potential impact of the site from existing and future (predicted) disposals. Consequently, in January 2000 we changed (varied) the LLWR authorisation and required BNFL to provide information about the environmental safety of the LLWR during its operational lifetime (Operational Environmental Safety Case, OESC) and after its final closure (Post Closure Safety Case, PCSC). BNFL submitted these two ESCs in September 2002 (BNFL, 2002a and 2002b). Between 2002 and 2005 we carried out a detailed assessment of the safety cases (Environment Agency, 2005a) which raised a number of criticisms, many of which were formally recorded in Issue Assessment Forms (IAFs)[1].

1.2.4 Following the review of the 2002 ESCs, we reviewed the RSA 93 authorisation and in May 2006 granted a new one (Environment Agency, 2006a) to the operator, which by that time had become known as British Nuclear Group Sellafield Limited (BNGSL). In addition to the ESCs submitted by BNFL in 2002, this authorisation review also took account of the legislation and guidance in effect at the time (RSA 93, and the UK environment agencies' Guidance on Requirements for Authorisation (the GRA), Environment Agency *et al*., 1997). Our concerns regarding the safety cases presented in 2002 led us to authorise disposals only to Vault 8, and required the operator to deliver an updated ESC by May 2011.

1.2.5 The LLWR site is now owned by the Nuclear Decommissioning Authority (NDA) and is operated on behalf of the NDA by a Site Licence Company (SLC). The SLC was initially BNGSL, but the authorisation was transferred in 2007 to a new SLC, LLW Repository Ltd, with no major changes to the authorisation. This change in SLC paved the way for the NDA to open the operation of the site to competitive tender. In 2008 United Kingdom Nuclear Waste Management Ltd (UKNWM Ltd) was awarded a contract from the NDA to manage and operate the LLWR. Shares in the SLC were transferred to UKNWM Ltd on 1 April 2008 and the SLC continues to be known as LLW Repository Ltd.

1.2.6 LLW Repository Ltd is currently authorised to dispose of solid low-level radioactive waste in Vault 8 of the LLWR, and to discharge from the site gaseous and liquid effluents associated with the LLW disposal operations. LLW Repository Ltd has planning permission to construct Vault 9 at the site to *store* LLW, but does not have planning permission or authorisation to *dispose* of LLW to Vault 9.

1.2.7 In Schedule 9 of the current authorisation we set a number of legal requirements for the operator to carry out improvements or supply us with additional information by defined dates (e.g. reviews of best practice and establishing a research and development programme). This report relates to our review of LLW Repository Ltd's work to fulfil Schedule 9 Requirement 2 and their progress towards fulfilling Schedule 9 Requirement 6.

1.2.8 Requirement 2 states that the operator, by 1 May 2008, must "provide the Agency with a full report of a comprehensive review of national and international developments in best practice for minimising the impacts from all waste disposals on the site. This shall include a comprehensive review of options for reducing the peak risks from deposit of solid waste on the site, where those risks arise from potential site termination events (e.g. coastal erosion and glaciation) and potential future human action."

1.2.9 In discussions with LLW Repository Ltd we agreed that, in addition to the specifics of Requirement 2, their response would also aim, as far as possible, to address the wider expectations expressed in our 2006 Decision Document (Environment Agency, 2006a), to:[2]

(a) demonstrate that best practice is being applied to keep the peak risks from the site as low as reasonably achievable (ALARA);
(b) substantiate a proposal for the radiological capacity of the site (the maximum amount of waste that could be disposed of while still maintaining the site's environmental safety).

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[1] Issue Assessment Forms (IAFs) are detailed records of concerns raised as part of the Environment Agency's review of BNFL's 2002 environmental safety cases. In a systematic manner they record issues that we expect the operator of the LLWR to address prior to submission of the next fully updated ESC in 2011.

[2] In section 4.6 of the Decision Document (Environment Agency, 2006b) we stated that "we will not authorise LLW disposals to the proposed Vault 9, until … BNGSL has provided us with adequate information to allow the radiological capacity of the site to be determined … and we will undertake a full review on the radiological capacity of the site and publish our findings." Later in the same section we stated that "we will not allow BNGSL to construct the final cap over the existing Vault 8 and trench disposals until BNGSL has provided us with the outcome of a wide-ranging risk management study … that demonstrates that future impacts will be As Low As Reasonably Achievable (ALARA)." The latter decision is clearly reflected in Requirement 2. We have interpreted the former decision also to be reflected in Requirement 2 as it comes from the same section of the Decision Document. We have confirmed to LLW Repository Ltd that this is the case and they have agreed to include their proposals on radiological capacity in their Requirement 2 submission.

1.2.10 Requirement 6 states that, by 1 May 2011, the operator must "update the Environmental Safety Case(s) for the site covering the period up to withdrawal of control and thereafter." This update should address our criticisms of the 2002 ESCs and supporting programmes (Environment Agency, 2005a, 2005b, 2006b). It should also take account of developments since the 2002 ESCs were produced, such as evolution of operating practices, additional information about the site, the design of the repository and the waste inventory, changes in ownership, and developments in government policy (Defra, 2007) and regulatory guidance (Environment Agency *et al.*, 2008).

1.2.11 Since 2006, we have had regular dialogue with LLW Repository Ltd about progress towards meeting the Schedule 9 requirements. We expected the information in LLW Repository Ltd's response to Requirement 2 would provide some indications of progress on the updating of the ESC, and so serve as a milestone for assessing progress towards the 2011 deadline for the submission of the ESC.

1.3 Objectives of our review

1.3.1 The main objectives of this review are to:

(a) assess whether the information supplied by LLW Repository Ltd represents a satisfactory response to Requirement 2;
(b) identify from the information supplied any immediate implications for the conditions of LLW Repository Ltd's authorisation;
(c) assess the information supplied against the new regulatory guidance (Environment Agency *et al.,* 2008[3]), and to provide additional guidance to LLW Repository Ltd on its programme to develop an ESC that appropriately addresses the requirements of the GRA;
(d) identify any additional assessment that we might need to carry out, such as independent R&D, model development, conduct of independent calculations, or examination of further documents, so that we can effectively and efficiently assess the ESC when it is provided.

1.4 LLW Repository Ltd's submission

1.4.1 On 1 May 2008, LLWR Repository Ltd delivered to us five volumes setting out its response to Requirement 2:

i. Volume 1 (LLW Repository Ltd, 2008a) summarises the submission and directly addresses the issues raised in Requirement 2;
ii. Volume 2 (LLW Repository Ltd, 2008b) summarises the "comprehensive review of options for reducing the peak risks from deposit of solid waste on the site";
iii. Volume 3 (LLW Repository Ltd, 2008c) summarises developments in characterising the inventory and near field processes;
iv. Volume 4 (LLW Repository Ltd, 2008d) summarises developments in site understanding (including geology, hydrogeology and coastal evolution);
v. Volume 5 (LLW Repository Ltd, 2008e) summarises updates (since the 2002 ESCs) to LLW Repository Ltd's assessment of the future performance of the facility.

1.4.2 These five volumes refer to a large number of supporting documents that provide details of the analyses, assessments and evidence that underpin the arguments presented in the top level volumes. In our assessment of LLWR Repository Ltd's submission we have also

[3] A consultation draft of the GRA for near surface disposal was issued in May 2008 (Environment Agency *et al.,* 2008), and a final version (Environment Agency *et al.,* 2009) in February 2009. In conducting this review we had access to the consultation draft, and initial indications of modifications likely to be made in finalising the GRA for near surface disposal. The final version was published as we were finalising our documentation of this review, and so was not explicitly taken into account. However, we do not believe that any differences between the consultation draft and the final version would significantly alter any of our conclusions or recommendations.

reviewed the supporting documentation to the extent we considered necessary for us to establish the soundness of the submission.

1.5 Our review

1.5.1 Our review considers LLW Repository Ltd's submission primarily in relation to:

(a) Schedule 9 Requirement 2;
(b) the April 2008 consultation draft of the environment agencies' Guidance on Requirements for Authorisation for near surface disposal, as an indication of progress towards meeting Schedule 9 Requirement 6; and
(c) the IAFs from the review groups participating in our review of the 2002 ESCs.

This report and our four other main review reports (Environment Agency, 2009a–d) present our findings in relation to Requirement 2, the GRA/Requirement 6, and any general or significant observations arising from our consideration of the IAFs. Our full review of the submission against the IAFs will be reported separately to LLW Repository Ltd as part of our continuing dialogue leading up to the delivery of the full ESC due in 2011.

1.5.2 We report here on our technical review of LLW Repository Ltd's response to the technical authorisation requirement we set out in the RSA 93 authorisation granted to the LLWR operator in 2006. This does not constitute a review of LLW Repository Ltd's authorisation, although it will be taken into account in the periodic review of the authorisation, which is due to be completed in early 2009. This review may also provide input into future periodic reviews.

1.5.3 We have aimed in our review to identify all significant issues arising from the Requirement 2 submission and supporting documents. Where we do not comment on a particular point in the submission or accompanying documentation, it is unlikely (based upon the information presented to us at this stage) that we would raise that point as an issue in the future (particularly in our review of the full ESC). However, this cannot be taken as an absolute guarantee; we reserve the right to revisit any issues that we think warrant attention at any time in the future.

1.5.4 Where we have made recommendations to LLW Repository Ltd in this and the four other main review reports, we have classified them to assist in the prioritisation of action:

(a) **Category A**
Relatively major issues for which the appropriate course of action is not immediately obvious. For these issues, we expect LLW Repository Ltd to provide substantial additional information, evidence or analysis in the full ESC. We also expect LLW Repository Ltd to report to us on their progress between now and delivery of the ESC. Such reporting might, for example, include detailed plans of action, descriptions of proposed approaches, models or data, or results from interim or provisional analyses.
(b) **Category B**
Relatively major issues for which it is fairly clear what needs to be done. For these issues, we expect LLW Repository Ltd to provide substantial additional information, evidence or analysis in the full ESC. We will keep these issues under a degree of review via the regular dialogue between ourselves and LLW Repository Ltd and we will provide further guidance if requested. However, we will not require LLW Repository Ltd to report formally on progress.
(c) **Category C**
Issues for which LLW Repository Ltd will need to provide some additional information, evidence or analysis in the full ESC, and report some or all of this to us between now and delivery of the ESC. Generally, we estimate the effort needed to address Category C recommendations will be substantially less than for Category A.
(d) **Category D**
Issues for which LLW Repository Ltd will need to provide some additional information, evidence or analysis in the full ESC, without the need for formal reports on progress.

Generally, we estimate the effort needed to address these points will be substantially less than for Category B.

Where our recommendations or other observations are not assigned to any of the above categories, we do not expect or require a specific response from LLW Repository Ltd. Nevertheless, LLW Repository Ltd may wish to consider these points as suggestions because they may, individually or collectively, affect our general confidence in the ESC or the ease with which we can review it. For example, individual typographical errors in reports may be considered trivial, but if persistent or present in large numbers, they could affect our confidence in the quality controls applied by LLW Repository Ltd.

1.5.5 We recognise that some of the issues raised in our review may be at least partly addressed in the updated and expanded Safety Case Approach document that LLW Repository Ltd produced at the end of 2008 (Baker *et al.,* 2008), but we have not included consideration of the Approach document in this review.

1.5.6 Our review mirrors the structure of LLW Repository's submission. Four separate technical review documents address Volumes 2–5 of the submission (and the supporting documentation), and an overarching summary review document provides specific comments on any aspects of Volume 1 not covered elsewhere and presents our overall assessment of the submission.

1.5.7 This technical review document addresses Volume 5: Performance Update for the LLWR.

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1 Review of Volume 5 and key supporting documents

2.1 General

2.1.1 Overall, we found that Volume 5 presents a concise but coherent overview of developments in the assessment of the long-term performance of the LLWR. Considering the breadth and complexity of the issues addressed, this is a creditable achievement.

2.1.2 Sometimes, for conciseness or emphasis, Volume 5 provides examples rather than a complete set of descriptions or results (e.g. a graph based on calculations for one scenario rather than a series of graphs covering all scenarios). This is a commendable approach for an overview document, but it is not always clear from the text that the example is used to illustrate or emphasise a point. It is not always clear why a particular example has been selected.

2.1.3 We note the point, emphasised in this volume and elsewhere, that Volume 5 is not intended to present a full environmental safety case (ESC). Nevertheless we do believe that this submission presents a good opportunity for us to review and comment on LLW Repository Ltd's progress towards a full ESC (due by May 2011). We have therefore included comments related to the preparation of the full ESC, but we have aimed to distinguish clearly between any conclusions that relate to the suitability of the submission as a response to Requirement 2 (and any resulting regulatory decisions), and our recommendations on issues which in our view should be considered by LLW Repository Ltd in their work towards an updated ESC.

2.1.4 In this context, we note one particular observation on the submission as a whole. A quantitative assessment of the long-term performance of the LLWR necessarily requires the use of computational models, implementing mathematical models that in turn represent conceptual models. These are inevitable features of an environmental safety case and we fully support the use of models for these purposes. However, an ESC must also provide adequate evidence that any model used in the assessment is fit for the particular purpose to which it is put and that the results from the model can therefore be considered to be meaningful. A recurring theme in our comments on many different aspects of the Requirement 2 submission is the failure of LLW Repository Ltd to provide sufficient evidence to justify its modelling work. This may well be a feature of the interim nature of the performance update; we recognise that several of the models are to some extent work in progress and we take this into account when commenting on these specific models and their output. Nevertheless, we have found a consistent lack of evidence in the submission, so it is appropriate for us to provide clear, advance notice now of our expectations for the full ESC.

2.1.5 We make a general observation that different documents list radionuclides and elements in different orders, some alphabetically, others by atomic number. This is apparently trivial, but in reality is surprisingly irritating for the reader and makes comparisons between tables unnecessarily difficult. The situation is easily remedied and we request that LLW Repository Ltd require all of its contractors to follow one convention or the other.

2.2 Approach and criteria for assessments

Interpretation and application of the GRA

2.2.1 We have based our review on the consultation draft of the GRA for near surface disposal, issued on 15 May 2008 (Environment Agency *et al*., 2008). We have done this because the final version of the near surface GRA is expected to have been issued before any substantive decisions are taken on the basis of the review. The publication of the consultation draft post-dates the deadline for submission of LLW Repository Ltd's response to Requirement 2, and therefore the submission necessarily refers to the extant version of the GRA published in 1997 (Environment Agency *et al.*, 1997) which covers both near-surface and deep geological disposal. We have taken account in our review of differences between the GRA referenced in the submission and the new guidance in the consultation draft. We have made some observations and clarifications concerning the different versions of the GRA, but we conclude that changes in the GRA have not made any substantial difference to this review or its outcome.

2.2.2 The consultation draft contains six principles and 15 requirements (compared to four principles and 11 requirements in the 1997 GRA). It is now made clear (para. 3.5.1 of the Consultation Draft) that all near surface disposal facilities for which an RSA 93 authorisation is in force or being sought are expected to meet the principles, and to meet *"each requirement in a manner proportionate to the level of hazard the waste presents."* The intent of the 1997 GRA was broadly the same, although this may not have been stated explicitly.

2.2.3 In relation to existing facilities for which an RSA 93 authorisation is in force[4], para. 3.5.5 of the consultation draft states:

> *"If an existing facility … is significantly deficient in relation to any of the requirements … we shall expect the holder of the RSA 93 authorisation to propose improvements and may well include these as conditions in the authorisation. … Requirement R9, concerning optimisation, entails judgement to find the best way forward by balancing many different considerations. We envisage that the balance of judgement for an existing facility will be significantly different from the balance of judgement for a new facility. But the holder of the RSA 93 authorisation will still need to show that all the requirements are met."*

2.2.4 This is more explicit than the 1997 GRA and essentially reflects current practice. Based on this guidance, we do not agree, as a matter of principle, with LLW Repository Ltd's position on the most appropriate criteria for judging the assessed long term-performance of the trenches. In its submission LLW Repository Ltd contend that dose criteria for intervention are most appropriate, but our interpretation of the guidance indicates that we should continue to require a risk assessment for the trenches (except for human intrusion). However, we will judge consistency with the guidance levels in light of the fact that the trenches were designed and largely filled under a significantly different regulatory regime. Furthermore, the adequacy of LLW Repository Ltd's case that the risks from the trenches are ALARA will also be an important consideration. This part of LLW Repository Ltd's case is rather more consistent with the qualitative description of their approach (Section 2.4.1 of Volume 5) than with their arguments for applying intervention criteria. In practice, however, it does not appear that this difference in interpretation is likely to substantially affect the arguments put forward by LLW Repository Ltd or our judgement on those arguments.

GRA requirements

2.2.5 The key requirements from the 1997 GRA referred to in the submission all have counterparts in the consultation draft; one new requirement is also relevant.

2.2.6 Requirement R2 from 1997 (risk target) is replaced by Requirement R7 (risk guidance level). There are some changes in terminology, but the essence of the new requirement is unchanged, except that its scope now excludes risks associated with human intrusion, which are addressed through the new Requirement R8 (see below).

[4] Para. 3.5.6 of the Consultation Draft makes clear that the guidance does not apply to closed facilities where no relevant RSA 93 authorisation is still held. Such facilities would rightly be considered in terms of intervention. However, the LLWR trenches do not fit this description – disposal is not considered to be complete, the facility is not closed and an RSA 93 authorisation is still in place.

2.2.7 One minor change has been made to the application of the risk target/guidance level (Requirement R2/R7). In Section 2.4.2 of Volume 5, LLW Repository Ltd quote para. 6.25 of the 1997 GRA, which states that, if the assessed risks are below the risk target and good science and engineering have been applied, *"…then no further reductions in risk need be sought".* This has no counterpart in the consultation draft because the principle of optimisation requires that reasonably achievable reductions in risk should always be sought. However, it is implicit in the principle that major efforts or expenditure to further reduce risks that are already very low are unlikely to be warranted. This difference in interpretation does not appear to materially affect LLW Repository Ltd's arguments or our appraisal of them.

2.2.8 Requirement R3 from 1997 (use of BPM) is replaced by Requirement R9 (optimisation). Again, there are some changes in terminology but the intent of the new requirement is essentially unchanged. It may be noted, however, that Requirement R9 now explicitly requires radiological risks to the environment (as well as those to humans) to be ALARA.

2.2.9 Requirement R4 from 1997 (environmental radioactivity) is replaced by Requirement R10, which clarifies the intent of the requirement. Whereas the old Requirement R4 referred to a need to avoid *"significant increases in the levels of radioactivity in the accessible environment"* without any reference to impacts, the new Requirement R10 explicitly requires that the radiological effects on the accessible environment be demonstrated to be acceptably low. The new requirement makes the requirement for the radiological protection of non-human species more explicit (whilst acknowledging that there are currently no established numerical criteria). In the context of the LLWR, this has to date been addressed separately through Schedule 9 Requirement 11, but the expectation would be that this will be integrated into the updated ESC due to be completed by May 2011.

2.2.10 Requirement R8 from 1997 (waste form and characterisation) is replaced by Requirement R14 (waste acceptance criteria (WAC)). The requirement to establish WAC that are consistent with the ESC and with handling and transport requirements is essentially unchanged, but Requirement R14 adds explicitly a requirement to *"demonstrate that these can be applied during operations".*

2.2.11 Requirement R8 in the consultation draft (human intrusion) has no counterpart in the 1997 GRA. It requires the assessment of potential consequences of human intrusion and indicates guidance levels for judging the acceptability of such consequences (3–30 mSv/year depending on whether the exposures are likely to be chronic or short-lived). Requirement R8 also requires the operator to consider practical measures to reduce the likelihood and potential consequences of human intrusion.

Assessment of human intrusion

2.2.12 LLW Repository Ltd's approach to the assessment of human intrusion appears to be broadly consistent with the new Requirement R8. The information provided in Volume 5 is appropriate for consideration against Requirement R8 and the generic criterion of 10 mSv/year used in the submission is within the range of values for dose guidance level specified in the consultation draft (3–30 mSv/year).

2.2.13 Para. 6.3.33 of the GRA consultation draft indicates that the dose guidance level applies to human intrusion directly into a facility and to *"other human actions that damage barriers or degrade their functions".* This allows some flexibility for an ESC to present arguments that natural features (e.g. a region of host rock) as well as engineered barriers should be treated as "barriers" for the purposes of Requirement R8. Para. 6.3.34 makes clear that this flexibility does not extend to the sinking of a well into an aquifer contaminated by radionuclides from the facility. LLW Repository Ltd may not have been aware of this possibility, however they have not presented arguments for the existence of any "barriers" beyond the engineered ones.

2.2.14 We do not accept LLW Repository Ltd's argument that doses from large scale human intrusion scenarios should not be taken into account during the determination of the radiological capacity of the vaults. The text of the new Requirement R8 makes clear that measures to reduce the chance of such intrusion should be considered and implemented where appropriate, but it also requires a quite separate appraisal of the consequences of human intrusion *"on the basis that it is likely to occur".* Furthermore, para. 6.3.42 indicates that the doses associated with human intrusion scenarios are *"likely to be important in deriving facility-specific authorisation limits and conditions, such as inventory limits and allowable activity concentrations for specified radionuclides."* Of course LLW Repository Ltd could not have been expected to take account of the new guidance as they had not seen it prior to their submission of the Requirement 2 response. Furthermore, LLW Repository Ltd claim that the assessed doses which represent the highest reasonable potential impact of human intrusion for the proposed vault inventory (which is, in effect, the proposed radiological capacity) are in the region of 1 mSv/year; the exclusion of human intrusion may therefore not be essential to their case. Nevertheless, our assessment of an appropriate radiological capacity will have to take some account of the potential consequences of reasonable human intrusion scenarios.

2.3 Cross-pathway issues

2.3.1 Volume 5 is structured according to the four main types of pathway to exposure: via groundwater, gas, coastal erosion and human intrusion. In the following sections we comment on the assessment of these four pathways in turn. In this section, we comment on some issues that cut across the assessment of the different pathways. In particular we address the approach to identify and characterise potentially exposed groups (PEGs). PEGs are the hypothetical groups of people in the future whose habits will lead to them coming into contact with radionuclides from the LLWR via the different pathways. Although they are hypothetical, they need to be chosen so that the calculated doses and risks to PEGs give a reliable indication of the highest impacts that might reasonably be expected by real people in the future.

2.3.2. LLW Repository Ltd's general approach to defining PEGs is summarised in Section 2.2 of Volume 5; the application of this approach to the different pathways is described briefly in the relevant sections of Volume 5. A more detailed discussion regarding how PEGs have been identified and characterised is provided in a supporting document by Thorne (2007). We provide some more detailed comments on this supporting document in Appendix 1 of this review, but in general the approach described seems reasonable. We particularly note that the local resource dominated PEGs considered in the 2002 PCSC (BNFL, 2002a) are no longer included in the analysis: this is consistent with recommendations from our review of the 2002 PCSC (Environment Agency, 2005a).

2.3.3 Our only other comment on the approach to PEGs is that the definition of PEGs seems to be started 'from scratch' for each different scenario. As a result, relatively minor differences in habits can occur between PEGs in different scenarios, presumably because they have been derived on different bases or using different references. For example, it is not clear why people assumed to make use of water from the Drigg stream in Case D of the groundwater pathway (release to near surface pathways) would be different from the smallholders using the cap area in human intrusion scenarios. We would have expected these two PEGs to have common habits because there is no particular reason for them to have different habits. We do not see any evidence that these differences create any serious discrepancies, but when they are presented without explanation it appears to be an unnecessary source of possible inconsistencies. We suggest some cross-checking of PEGs across scenarios.

2.3.4 Another general point concerns the interrelationship between assessment reports and supporting documents. Supporting documents (for example, the data reports by Thorne (2007, 2008)) often present more information and discussion than is used in the assessment. In these cases, assessment reports should be absolutely clear about which information they have taken from supporting documents and (if necessary) why it has been used. On a few occasions, the Requirement 2 submission does not do this, as outlined below:

(a) Some of the habit data recommended by Thorne (2007) refer to both “typical” and “high” values, but it is not always explicit in Volume 5 (or the more detailed assessment report by Paksy and Henderson (2008)) which values have been used as the “reference” values in the assessment.

(b) Some of the recommendations for soil K_ds in Thorne (2008) are dependent on the characteristics of the soil, but it is not explicit in the assessment reports which soil type has been assumed.

(c) It is not entirely clear exactly which animal products have been considered for each PEG, nor the basis for their selection. For the groundwater pathway it appears that a range of animal products (excluding goat products) has been considered with data specific to each animal, whereas the assumption is made that the smallholders considered for the scenarios of site occupation following human intrusion keep goats, modelled as generic animals.

2.3.5 Finally on general matters - and perhaps most significantly - we accept that LLW Repository Ltd’s assumption that the facility is likely to be destroyed by coastal erosion within a few thousand years is robust, and that the main focus of the ESC should therefore be on impacts that might reasonably be foreseen within that time frame. We will nevertheless expect a full ESC to include some appraisal of the potential consequences if, for whatever reason, the erosion did not occur as assumed. This consideration falls into two categories, outlined in the following sections.

2.3.6 The first category is the possibility that erosion occurs, but significantly later than assumed. This possibility should be covered within the sensitivity analysis of the assessment of impacts from the various pathways. We stress that this does not only apply to the assessment of the coastal erosion scenario: the possible effect of later erosion on impacts from all scenarios and pathways should be considered.

2.3.7 The second category is the possibility that erosion does not occur. There has been rapid and sometimes dramatic development in understanding of climate change and coastal evolution over recent years; considerable uncertainties remain regarding the course of climate change, particularly when short and medium-term projections are extrapolated to the timescales relevant to the LLWR. We do not think that these uncertainties would significantly alter current understanding to such an extent as to invalidate the assumption that the facility will be eroded, but history suggests that we cannot entirely rule out the possibility that current understanding is wrong. We must also consider the possibility (which was outside the scope of the coastal evolution work) that some currently unforeseen human actions (intentional or not) or natural event could modify or override the processes currently in place and stop or reverse current trends so as to invalidate the projections into the future. Again, we do not consider this to be at all likely, but again we cannot entirely rule it out. We will therefore require LLW Repository Ltd to provide some evidence in the ESC that, if such a situation were to arise, impacts in the very long term would not be unacceptable. We will, however, expect the effort devoted to this question to be proportionate to the low probability of such eventualities. Similarly, we will take account of the low probability when judging whether potential impacts are unacceptable.

2.4 Groundwater pathway and impacts

2.4.1 Volume 5 summarises the assessment of impacts via the groundwater pathway. The assessment is described in more detail in a supporting document by Paksy and Henderson (2008), which in turn draws on supporting documents on the near field and geosphere. The supporting documents that deal with geological and hydrogeological topics are covered primarily in our review of Volume 4 of the submission. The documents that address the inventory and near field are addressed primarily in our review of Volume 3, although some comments are made below, in particular on the model of flows from the near field described in Paksy (2008). More detailed comments on Paksy and Henderson (2008) and on Paksy (2008) are provided in Appendix 1 at the end of this report, but the more important points are incorporated in the discussion below.

2.4.2 The calculation scheme used for the groundwater pathway appears to be as follows:

i. The groundwater flow paths to be modelled were derived from the near field water balance model described in Paksy (2008).

   This model takes account of the planned engineered features of the LLWR, and also draws upon results from site-scale hydrogeological modelling. Four cases were defined:

   - Case A represents the expected performance of the facility but with the current geosphere;
   - Case B represents the expected performance of the facility but with the geosphere modified by coastal erosion;
   - Case C represents failures of the engineered systems leading to increased vertical flows (into the regional groundwater);
   - Case D represents failures of the engineered systems leading to increased horizontal flows (in the upper groundwater).

ii. Results from the DRINK model from the 2002 PCSC, modified to incorporate changes described in Volume 3 (particularly the updated inventory and the new dissolution model for uranium wastes), were used to calculate radionuclide concentrations in the groundwater.

   Combined with the flows from step i, this gave radionuclide fluxes into the geosphere for the different cases.

iii. GoldSim models were developed to represent transport in the geosphere for the different cases.

   These were derived from an assessment of the more complex geological and hydrogeological models described in Volume 4.

iv. Biosphere models were used to assess doses to a number of defined PEGs resulting from the discharges from the geosphere in the different cases.

Near field

2.4.3 In our review of Volume 3 of the Requirement 2 submission we comment on the technical basis for assessment modelling of the near field, including the inventory, the biogeochemical evolution of the near field and the near field engineering performance. The comments in this review of Volume 5 focus on the representation of the near field in the assessment modelling, which is summarised in Section 4.3.1 of Volume 5 and described in more detail in Paksy and Henderson (2008).

2.4.4 We note the assessment's assumption (Section 2.2.3 of Paksy and Henderson (2008)) that both leaching and sorption of radionuclides are characteristic of a homogeneous saturated system. We do not dispute this choice as a reference case for a deterministic assessment. However, we expect a full analysis to consider other possibilities. For example, leaching in an unsaturated heterogeneous system (e.g. flow through cracks in grout) could be locally enhanced compared to the homogeneous saturated case while the potential for sorption could be reduced. It is not obvious how such a case would affect the release to groundwater and how it would compare with the reference case.

2.4.5 From the description of 'Trench region B' in Section 2.2.3 of Paksy and Henderson (2008), it is not clear whether the higher uranium and fluoride concentrations in this region can be fully explained or whether they are an observed phenomenon that is not understood. If the former, then it would be helpful to include in the description a brief explanation. If the latter, then we recommend that the phenomenon is investigated further rather than simply taken at face value.

2.4.6 The near field water balance model of Paksy (2008) plays a central role in the treatment of the groundwater pathway. We consider it is important therefore to note a number of limitations in the basis for this model and its use:

(a) The descriptions in Paksy (2008) about the derivation of the model and its underlying assumptions seem to refer to few 'hard facts'.

They generally sound sensible, but it is far from clear that an equally plausible set of explanations might not have been constructed, leading to quite a different model.

(b) Cases have been run for no rise in sea level and for a 6.5 m rise, but not for the higher sea level rise considered in the coastal evolution work (23.8 m above the current level) (Thorne and Kane, 2007).

(c) The eight calculation cases assessed with the model cover the two sea level scenarios described above, combined with upper and lower bound assumptions for three other sets of parameters, but only in certain defined combinations that do not seem particularly systematic.

The result is that the combinations of parameter values may not be such as to provide the full range of possible outputs from the model.

(d) Paksy (2008) acknowledges that the results are very sensitive to several key parameters, values for which are derived from other models or from elicitation/estimation exercises; there may be complex interactions between the effects of the different parameters.

This being the case (even just based on the limited investigation of sensitivity represented by the eight calculation cases), it is a little surprising that the assessment of the groundwater pathway is based on the results from just one deterministic run of the model.

2.4.7 We recognise that the limited scope of the performance update means that the uncertainties implied by these issues have not yet been fully addressed. However, this makes it very difficult to determine at this stage which 'conclusions' derived from the model are robust and which are not. In some cases these 'conclusions' could have profound implications. For example, the model results are used to support the assumption that no upper groundwater paths from the trenches are thought to be feasible in the future. Given that the groundwater paths actually observed at the site to date are from the trenches to upper groundwater, the assumption that these paths are not plausible in the future would need much more robust justification than has been provided so far.

2.4.8 We note that the entire treatment of the groundwater pathway also assumes that there will be vertical drains between the trenches and the vaults and that all flow that reaches these drains will be directed into the regional groundwater in the sandstone. No indication is given of what would happen if the vertical drains were not present or did not work as intended. Clearly the full ESC will need to confirm the intended design of the drains and demonstrate that the assumptions made are valid, or adequately address the potential consequences of failure of the vertical drains. LLW Repository Ltd acknowledge that they have not attempted to do this in the performance update.

2.4.9 There is considerable discussion in the submission and supporting documents about the assumed performance of the future site cap, but very little about that of the current interim cap. The groundwater pathway modelling starts at 1995, but throughout the modelling the performance of the cap is assumed to be that of the final cap. Since the scope of Requirement 2 focuses on long-term performance, this may not be critical, but the full ESC will need to address the effects of the interim cap.

2.4.10 There is some confusion in the descriptions of the upper groundwater pathway from the future vaults. The error appears to be in Figure 4.3 of Volume 5 (which is identical to Figure 3 of Paksy and Henderson (2008)). This figure shows a flow from the future vaults to the East-West Stream, but the descriptions of the pathway and the modelling used suggest that this flow is to the Drigg Stream. There are also one or two misleading references to the East-West Stream in the text.

Geosphere transport

2.4.11 Our review of Volume 4 of the Requirement 2 submission provides comments on the technical basis for modelling of the geosphere. The comments here focus on the representation of the geosphere in the assessment modelling, which is summarised in Section 4.3.2 of Volume 5 and described in more detail in Paksy and Henderson (2008).

2.4.12 Although it seems unlikely to be a major issue, for completeness we expect some explanation why 1/100 is considered to be a suitable vertical transverse dispersivity (Section 2.3.2 of Paksy and Henderson (2008)).

2.4.13 Section 3.2.3 of Paksy and Henderson (2008) briefly describes the GoldSim implementation of the geosphere model. We have the following two observations on this description:

(a) We note some increases to the flow rates into the geosphere model as described by Arthur *et al.* (2008) to allow for higher flow rates out of the near field calculated using the model of Paksy (2008).
Besides reiterating our observations about the sensitivity of the Paksy model (see para. 2.4.6 above), we expect a full ESC to resolve any inconsistencies between models by iteration rather than by a quick 'fix' at the implementation stage of the assessment model.

(b) For some modelling tools, it could not be assumed that the division of the geosphere path length into three (in order to observe intermediate results) would not affect the behaviour of the model.
This particularly requires explanation in view of the use of 1/10 of the pipe length as a mixing depth to calculate dilution (Appendix 2 of Paksy and Henderson (2008)). We expect to see some confirmation either that GoldSim pipe lengths in general have no effect on model results or that there is no significant effect in this particular case.

Biosphere and PEGs

2.4.14 Paksy and Henderson (2008) describe the basic structure of the biosphere model; the data describing the compartments of the biosphere model and the transfers between them; and the models and data used to calculate doses. The supporting report on the biosphere database (Thorne, 2008) provides a detailed account of recommended values for element-dependent biosphere data, namely K_d values for soils and sediments, concentration factors applied to terrestrial crops from soil and to aquatic foods from water, and transfer coefficients to animal products.

2.4.15 Some detailed comments on the biosphere database report (Thorne, 2008) are provided in Appendix 1 at the end of this report. These are mostly minor points of detail, particularly since:

(a) overall, the biosphere database report appears to be a thorough, coherent and largely well reasoned review of the data;
(b) long-term modelling of the biosphere and PEGs will inevitably be arbitrary to a degree, because the detailed evolution of the biosphere will be essentially unpredictable far into the future, so provided the biosphere modelling is reasonable, we would expect effort on the groundwater pathway to focus on the somewhat more predictable areas of near field and geosphere;
(c) the risks from the groundwater pathway are relatively low;

2.4.16 One comment that does seem worthy of note here, however, is that Thorne (2008) makes little reference to sources of data that reflect local conditions, for example data from Sellafield as well as the LLWR. Even allowing for the fact that local conditions might not persist indefinitely, such data could provide a useful context, particularly in cases where generic ranges of parameter values are very large because of how behaviour varies with different conditions.

2.5 Gas pathway and impacts

2.5.1 Volume 5 summarises the assessment of impacts via the gas pathway. The assessment is described in more detail in a supporting document by Ball *et al.* (2008). Some detailed comments on the supporting document are provided in Appendix 1 at the end of this report.

2.5.2 The calculation scheme used for the gas pathway appears to be as follows:

i. The DRINK model of near field processes produces estimates of gas releases from the wastes, based on modelling of the processes generating gas and those that prevent some of it being released in gaseous form (namely dissolution of gases in near field groundwater and reaction of CO_2 with cement).
   These estimates are not fed directly into the main assessment model for the gas pathway, but are used manually to set up that model. Although there is some discussion of factors that would affect the results from DRINK – notably current knowledge of the nature of the wastes making up the C-14 inventory – results from the 2002 PCSC model have continued to be used for assessment purposes.

ii. The main assessment model, DEGAS, represents the generation and transport of gas and calculates the rate at which gas is released to the accessible environment.
   The sub-model representing gas generation is set up to give releases of gas similar to those predicted using the DRINK model. The DEGAS model used for this submission is essentially unchanged from that used for the 2002 PCSC, but the assumed rates of gas generation have been changed, based on a reinterpretation of results from the DRINK model.

iii. The RIMERS model calculates the concentration of C-14 in crops resulting from C-14-labelled gases being released into the soil.
   The model represents the behaviour of C-14 in the biosphere, i.e. the various processes by which it transfers between soil, plants and air. The RIMERS model has been significantly modified since the 2002 PCSC after it was compared with a new model developed for the Food Standards Agency (FSA) (Thorne, 2005).

iv. No exposure model is used to represent inhalation of gases released to the atmosphere.
   For gases containing C-14, based on results from the 2002 PCSC, the doses via inhalation are assumed to be much lower than those calculated with the RIMERS model. Exposure via inhalation is not modelled for radon[5] because the amounts of gas expected to penetrate the cap (at any time prior to the assumed destruction of the facility by coastal erosion) are too small to give significant doses to anybody on the surface.

2.5.3 Compared to the 2002 PCSC, the estimated inventory of C-14 is now lower by a factor of 2 to 3 and the peak rates of gas generation (fed into DEGAS from examination of DRINK results) are now lower by a factor of 15 to 100. However, the updated RIMERS model (Thorne, 2006) predicts substantially higher concentrations of C-14 in crops for a given release of gas to the soil, so the overall effect is that estimated doses are lower than in the 2002 PCSC, but by a factor of no more than about 2.

2.5.4 We note that Ball *et al.* (2008) conclude that entrainment of radon by landfill gas appears to be occurring now and could occur in future, however the Requirement 2 submission assumes that any effects of entrainment are not significant. This does not seem unreasonable as an interim position, but we expect to see the issue addressed more completely in the full ESC, either by substantiating the assumption made for Requirement 2 or by assessing the potential effects of entrainment. In particular, it seems to be argued that generation rates for landfill gas are highest in the near future so any effects of entrainment will be cancelled out by controls over the site. However, it is clear that landfill gases will continue to be generated – albeit at lower rates – in the more distant future, when the effects of any entrained radon might not be mitigated.

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[5] Note that potential doses from indoor radon inside buildings constructed on the site in the future are addressed under the human intrusion pathway, not in this section.

2.5.5 From the limited tiers of documentation considered in this review, it is not clear why there are such large differences between the initial rates for gas evolution used in the 2002 PCSC and those used in the Requirement 2 submission. The more recent calculation is set out in Equation 4 in Ball *et al.*, but no similarly concise description appears to be available of the corresponding calculation from the 2002 PCSC. One alteration that is mentioned has been the use of a gas production profile with a half-life of 250 years instead of the 50 years used in the 2002 PCSC. This change seems sensible in the context of the time dependence of the DRINK results shown in Figure 18 of Ball *et al.*, but the figure is rather misleading in other ways. If both assessments had used Equation 4, the initial (peak) gas generation rate for the 50-year half-life would be five times higher than that for the 250-year half-life, not approximately the same as shown in Figure 18. However, a factor of five is not sufficient to explain the difference in generation rates.

2.5.6 The other parameter from Equation 4 that is discussed explicitly in Section 4.4.2 ("Updated scoping calculations") of Ball et al. is the cellulosic volume fractions of the wastes. The adopted values are claimed to be conservative, but it is not clear whether the discussion in this section is meant to imply that the 2002 PCSC calculations assumed cellulosic volume fractions of 1. If they did, the 2002 calculations would be conservative beyond any doubt (and probably excessively so), and this conservatism could explain to a much larger extent the difference between the calculated generation rates.

2.5.7 Some care is needed to support claims that radon is not a significant concern while the proposed engineered barriers – notably the cap – are in place and there is no possibility of buildings on the site. It is evident that radon is currently passing through (or otherwise bypassing) the interim cap in non-trivial amounts (via venting or cracks, by diffusion or entrainment). The 20 Bq/m^3 that is quoted as the "background level" for the site is not only several times higher than UK average outdoor radon levels – indicating that there is a significant local source – but is comparable to average indoor radon levels in the UK. With a very high occupancy, this radon level could give annual doses up to 1 mSv/year. Even allowing for a lower occupancy and a contribution from naturally occurring radon, there is scope for the facility to cause doses that challenge the GRA risk guidance level. A full ESC will need to demonstrate (rather than assert) that the final cap will perform significantly better than the interim cap in this regard, and that the future 'unmanaged' situation with regard to radon will be better than the current 'managed' one.

2.5.8 The various stages of modelling exposures from C-14-bearing gases seem to rest on layers of models and assumptions; it is not obvious to what extent this approach is supported by any comparisons with real data (see, for example, para. 2.5.5 of this report, above). Indeed, at times the text slips into describing modelling results as though they were reality. While some of the claims that elements of the modelling are conservative are clearly true, it is less clear whether the overall assessment is reliably conservative because some elements do not seem to be conservative. For example, it is stated that the factor for uptake by plants could be a factor of 10 higher. Perhaps more significantly, the origin of the assumptions ("corrections") that 20 per cent and 10 per cent of the C-14 inventory in the trenches and vaults, respectively, may be released in gaseous form is cited as McGarry (2003a), but this document actually refers to a 2002 PCSC parameter input form (Lee, 2003). This parameter input form derives the values from a graph of DRINK output, but does not explain why the 20 per cent value after 100 years is chosen rather than the 70 per cent or so indicated by the graph for times closer to the 50 years assumed as the half-life for cellulosic degradation. Furthermore, it is not entirely clear that these "corrections" do not already cover some of the conservatism subsequently claimed on the basis of the forms of waste making up the C-14 inventory.

2.5.9 Given that the GE Healthcare waste stream 1A09 ("incinerated waste") is estimated to represent more than 40 per cent of the C-14 inventory for future vaults, we would expect LLW Repository Ltd to have a better understanding of the nature of the waste stream than is apparent in the submission. We therefore recommend dialogue with GE Healthcare to clarify the status and nature of this waste and whether it is likely to be suitable for disposal at the LLWR.

2.6 Coastal erosion and impacts

2.6.1 Volume 5 summarises the assessment of impacts during, and immediately following, the assumed coastal erosion of the facility. The assessment is described in more detail in a supporting document by Galais and Fowler (2008). Some detailed comments on the supporting document are provided in Appendix 1 at the end of this report.

2.6.2 The current view is that the LLWR is likely to be destroyed by coastal erosion within a few thousand years, so we attach particular importance to the assessment of risks during the erosion of the facility. The exposure scenarios and models used in the 2002 PCSC were framed more like 'what-if' scenarios and addressed what was at the time an emerging issue. Understanding has now shifted considerably; we now expect the assessment of coastal erosion to be based on a level of analysis and underpinning more like that applied, for example, to the groundwater pathway. We recognise that there are substantial inherent uncertainties in the exact nature, sequence and timing of events in the erosion of the facility; simple robust modelling – supported by a robust analysis of sensitivities – might still be the most defensible approach. However, we expect to see evidence that the potential impacts, and the uncertainties surrounding those impacts, have been explored with a thoroughness appropriate to the 'normal' or expected evolution of the site.

2.6.3 As well as this general concern, we have some more specific points, as follows. Firstly, we are keen to understand fully why the conditional risks quoted in the performance update are so much lower than those quoted in the 2002 PCSC (1,000 times lower in the case of large sources on the beach), particularly if the models are broadly the same as before. Some changes are apparent – indeed some were introduced during the review of the 2002 PCSC (Penfold, 2004) – but these do not account for all of the difference in the calculated values. Unfortunately the documentation from the various stages of the work does not make it easy to trace all of the assumptions and identify all of the sources of difference. We expect LLW Repository Ltd to provide us with a breakdown of the changes they have made to the modelling of the coastal erosion scenarios since the 2002 PCSC and how their contributions have altered the results.

2.6.4 The absence of exposure scenarios to accompany the 'increasing sediment' scenarios (reflecting a barrier-lagoon and/or expanded Ravenglass Bay) is a significant omission, which we expect to be rectified in the Requirement 6 submission. This scenario could be significantly different in terms of both the types of PEG and the distribution of radionuclides from the facility. We expect to see at appropriate times LLW Repository Ltd's proposed approach to the modelling of these cases and preliminary results indicating the likely magnitude of risks.

2.6.5 We recognise that it is probably true that impacts via marine pathways following the dispersion of eroded material into the sea will be substantially lower than those from other pathways during coastal erosion (as stated, for example, in Section 2.2 of Galais and Fowler (2008)). Nevertheless, since erosion of the facility into the sea is now considered to be the most likely course of events (rather than, as in 2002, a possibility), we consider that a complete ESC should include an explicit assessment of the impacts arising from that course of events. It may be possible to base this assessment on the marine model used for the groundwater pathway, but we would expect some appraisal of any effects arising from the different form in which radionuclides would enter the sea.

2.6.6 The assumption that exposure comes from a facility-wide average concentration of radionuclides is probably reasonable for the majority of the time while erosion is taking place. However, we do not accept that this will always be an adequate representation of the *"average over all the wastes exposed at any one time"* (Volume 5, p. 82). The gradual progression of erosion will be slow compared with the timescales for dispersal and mixing of waste materials once they are in the accessible environment (Galais and Fowler (2008) quote an average residence time for eroded material on the beach of about a month) and compared with the lifetimes of individuals. Given the highly heterogeneous distribution of some radionuclides that contribute significantly to the risk (e.g. radium-226), there would seem to be a real possibility that doses could be significantly higher than the average values assessed here over a period of some years when erosion is affecting an area of high radionuclide concentrations. This is a stage that is likely to occur in the expected evolution of the site (only the exact timing is undefined); it is not a random event that might or might not occur. Since this situation is expected to occur at some point in time, and since the impact is likely to be relatively insensitive to timing, it would not be appropriate to dismiss such a variation in exposure by probability arguments. It would not be sensible to speculate on the exact composition of the waste eroded in each specific year, but we expect some assessment of exposure to waste at average concentrations that are more representative of the cross-section of waste likely to be exposed during periods when known areas of high concentrations of key radionuclides are being eroded.

2.6.7 Section 3.4 of Volume 5 indicates that the models and data used for assessing these scenarios are largely the same as for the 2002 PCSC (Penfold, 2003 and 2004). It should also acknowledge that we raised a number of questions in our review of the 2002 PCSC about the suitability and justification of those models and data. Some aspects were not sufficiently substantiated in the 2002 PCSC and our concerns remain unresolved: we expect these to be substantiated in the full ESC.

2.6.8 Some form of figure would help those who are not particularly familiar with the geography of the site to visualise the different areas used by the PEGs and their relative orientation. For example, it is not clear why the (soundly based) occupancy for leisure use of a coastal area (300 h/year) should be divided into 100 h/year near an eroding cliff face, 100 h/year on a beach and 100 h/year on a contaminated foreshore. In particular, it would seem logical to imagine that the waste on the beach would be near the foot of the eroding cliff, and that somebody on the beach would be exposed to both sources simultaneously (i.e. occupancy should be 200 h/year for each ‘pathway’).

2.6.9 The exclusion from the analysis of a beach hut, in which radon might accumulate, is not unreasonable. However, the raised sea level scenarios generally imply higher temperatures and therefore it is not too difficult to envisage the possibility of increased leisure use of the Cumbrian coastline. It might therefore be easier to justify the inclusion of a beach hut in a full safety case, but with realistic characteristics of such a hut, namely shielding and ventilation parameters closer to those relevant outdoors than to the inside of a substantial, permanent structure.

2.7 Human intrusion and impacts

2.7.1 Volume 5 summarises the assessment of impacts resulting from possible future human intrusion affecting the facility. The assessment is described in more detail in a supporting document by Galais and Fowler (2008).

2.7.2 Section 3.4 of Volume 5 indicates that the models and data used for assessing these scenarios are largely the same as for the 2002 PCSC (Penfold, 2003 and 2004). It should also acknowledge that we raised a number of questions in our review of the 2002 PCSC about the suitability and justification of those models and data. Some aspects were not sufficiently substantiated in the 2002 PCSC and our concerns remain unresolved: we expect these to be substantiated in the full ESC.

2.7.3 It is notable (though not surprising) that the peak doses from the trenches are in most cases obtained at the latest date considered in the analysis. In other words, the potential doses are still rising when the assessment is cut off at 5,000 years from now. It is not clear whether a peak dose arising after more than 5,000 years in any of the cases for the vaults would exceed that within the assessed period. In a complete appraisal of human intrusion, we would expect to see an estimate of the actual peak in the potential dose curve (which could of course, if appropriate, be accompanied by arguments as to the relevance of that peak value in the light of other factors such as the expected erosion of the facility).

2.7.4 It is assumed that waste disturbed by human intrusion will only be suitable for growing crops if it is diluted with soil, and a dilution factor of 10 is used in the assessments (Volume 5, Section 7.4.3). A chain of references for the value of 10 (Galais and Fowler, 2008; Penfold, 2003; Thorne and Kane, 2003) does not reveal an explanation for this choice, except that it is considered by the authors to be reasonable. The value seems at least plausible in the context of the materials making up the waste in the trenches and Vault 8, but future vaults are projected to contain waste that is 48 per cent soil (Volume 3 Figure 4.3). Volume 3 also indicates that most of the Ra-226 (one of the key radionuclides) in the future inventory of the vaults is from contaminated land remediation at Aldermaston, and so is likely to be more than 48 per cent soil. Furthermore, it appears from the descriptions in Galais and Fowler (2008) that this factor of 10 is independent of any dilution of waste for other reasons (e.g. where the volume disturbed by the intrusion is insufficient for the exposure scenario). If the rationale is to make the soil just suitable for cultivation, then it seems illogical that it should be the same in all cases. How is the factor of 10 justified in general, and in particular how is it justified for future vaults?

2.7.5 The sensitivity of the calculated doses from human intrusion to heterogeneity in radionuclide concentrations is discussed quantitatively, but the discussion is confined to Volume 1 of the submission; there is only a qualitative mention in Volume 5. Nevertheless, the notional doses for intrusion in areas of higher-than-average concentration are interesting as indicators of the robustness of the case:

(a) We agree with the implied argument that the 38 mSv value, based on intrusion into only the 20 worst contiguous bays of Trench 3, is sufficiently implausible to be inappropriate for comparison with the primary dose criteria (although the fact that the notional dose is well below 100 mSv provides some additional reassurance).
(b) We attach somewhat more weight to the 3 mSv figure, calculated using the average Ra-226 concentration in Trench 3 and a 'realistic' exposure model.

An excavation would be highly unlikely to follow the shape of Trench 3's footprint, but the assumption generally reflects excavation over an area that represents a reasonable basis for averaging concentrations. Since the 40:60 dilution of waste assumed in these calculations is already on the cautious side, it seems reasonable to be cautious also in assumptions for the exposure modelling or for waste heterogeneity, but perhaps not both. The combination of a cautious exposure model and an overall average waste concentration produces a lower dose (1.3 mSv according to Volume 5 Table 7.7) than the realistic exposure model and higher waste concentration. We therefore believe that the 3 mSv might be an appropriate 'high' figure for comparison with the primary dose criteria.

Exposures from radon and thoron

2.7.6 The largest assessed doses from human intrusion scenarios arise from the inhalation of radon isotopes in a building constructed on the site following large scale disruption of the facility at some time in the future. The models used to assess these doses are therefore of particular importance. The model used for the 2002 PCSC aimed to simulate the processes involved in:

(a) the generation of radon gas (Rn-222 and Rn-220, the latter known commonly as thoron) from its solid parent radionuclides in the waste (radium isotopes Ra-226 and Ra-224 respectively);
(b) the migration of this gas through the mixture of waste and soil;
(c) its release into the air above the ground;
(d) its distribution in indoor and outdoor air.

This model used several parameters whose values were highly uncertain, and therefore the results from the model were either extremely cautious or difficult to justify as robust. A quite different approach has been used for the Requirement 2 submission, based on a much simpler empirically based model.

2.7.7 The new model is based on an assumption that radon and thoron levels in buildings are broadly correlated with the concentrations of radium isotopes in the material underneath the building. There is extensive information on measured radon and thoron levels in buildings and on radium concentrations in soils in the UK and worldwide. This work can be used to derive a typical ratio of Bq/m^3 radon/thoron in buildings to Bq/kg radium in soil. This ratio is applied to concentrations of Ra-226 and Ra-224 in the waste-soil mixtures estimated to arise in human intrusion scenarios at the LLWR.

2.7.8 It is acknowledged by LLW Repository Ltd that this is a considerable simplification of reality, and that radium concentration in soil near the surface is actually only one of a number of factors that determine radon and thoron levels in buildings. However, we consider that this is a reasonable and robust means of estimating radon concentrations that might typically be expected in a hypothetical building of unknown design under unknown conditions.

2.7.9 We agree that the new approach provides a sensible, robust way to scope the likely impacts of human intrusion; it also avoids many of the drawbacks of the previous process-based modelling. Although considerable uncertainties remain and are acknowledged, this approach makes the uncertainties more visible and more understandable.

2.7.10 It must be recognised, however, that it is much less clear that the empirical model is pessimistic overall. Particular care is needed in making any claim that assessments based on averages are pessimistic. Future work should focus on providing a firmer understanding of the variability of doses and the key factors that cause this variability, in order to provide robust underpinning evidence for the definition of ‘reasonably cautious’ cases.

2.7.11 It seems slightly inconsistent with other arguments presented in this submission that the “extreme case” for radon and thoron exposure following human intrusion is included. This scenario could only occur if the cap had first been largely eroded (or otherwise removed), which is elsewhere considered implausible within the timescales prior to the expected destruction of the facility. So long as the cap remains largely intact, it is difficult to imagine anything approaching the “extreme case”. However, this case may be worthwhile as an illustrative ‘what-if’case.

2.7.12 On the other hand, while it is clear that the “cautious case” is notably pessimistic for thoron, it is less clear that it is so for radon. The average (background) radon concentration measured outdoors on the surface of the trenches is quoted as 20 Bq/m^3, i.e. between five and 10 times average outdoor radon levels in the UK. The average Ra-226 concentration in the trenches is quoted as 110 Bq/kg, i.e. less than five times the national average concentration in soil. The average Ra-226 concentration in Trench 3 (according to Volume 3) is approximately five times the average for the trenches as a whole; measured concentrations on the trenches vary by a factor of 4 (10–40 Bq/m^3). These figures tend to suggest that Ra-226 concentrations in soil may be quite a good indicator of the airborne radon level – and more pertinently these measured values do not suggest that assuming such a correlation is necessarily pessimistic to a significant degree.

2.7.13 The one parameter value in the new model that is not derived directly from an authoritative reference is that 6 per cent of the thoron in the building is assumed to derive from the soil. The only basis for this figure appears to be that it is one-tenth of the value quoted by UNSCEAR (2000) for radon, but the choice of one-tenth has no particular basis. The actual processes represented by this fraction are rather different from those that apply for radon, so there is no obvious reason for any connection between the two. The UNSCEAR value for radon simply allows for radon from sources other than the soil, notably underlying rocks and building materials, which typically contributes to the concentration in a building. The lower fraction for thoron reflects the fact that much of the thoron in a building comes from building materials rather than the soil; this is because of the short half-life of thoron and the disequilibrium that results from its decay to longer lived daughters, neither of which play such a role in the case of radon. However, since the model with this parameter value predicts a ratio of radon to thoron concentrations in buildings that is consistent with the observed ratio, we must conclude that 6 per cent is a reasonable value.

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2 Conclusions in relation to Schedule 9 Requirement 2

3.0.1 In relation to Requirement 2, the function of the performance update is to support LLW Repository's position on the two main elements of the requirement:

(a) A demonstration that best practice is being applied to keep the peak risks from the site ALARA.
(b) A substantiated proposal concerning the radiological capacity of the site (the amount of waste that could be disposed of while still allowing a satisfactory environmental safety case to be made).

3.0.2 In their arguments on the question of whether risks are being kept ALARA, LLW Repository Ltd make little explicit reference to the assessment of post-closure impacts; their conclusions (tentative as they are) do not rely in detail on the results of the performance update. However, the broad indications of impacts outlined in the performance update do appear to have had some implicit influence on the reasoning behind these conclusions.

3.0.3 The need for Requirement 2 was mainly due to the high assessed risks from the trenches in the 2002 PCSC. It seems to have been implicit in the recent ALARA work (and stakeholders involved in the associated workshops were given the impression) that the performance update would show that assessed risks from the trenches were much lower, much more similar to those from the vaults, and not too far from regulatory criteria. We cannot pinpoint specific judgements that have been fundamentally affected, but there is a general sense that consideration of measures to reduce actual risks from the trenches may be regarded as less urgent, based on the assumption that the assessed risks have become less of a concern. We therefore think it appropriate to comment on the extent to which the performance update supports this assumption.

3.0.4 In our view, and for reasons given elsewhere in this report of our review, there seems to be clear evidence that some of the highest assessed risks from the 2002 PCSC will be reduced significantly by the updated understanding of coastal evolution (which shortens the timescales for the main assessment) and by more realistic modelling of exposure due to indoor radon and thoron following large scale human intrusion. At this stage, we also regard the claimed reductions in assessed risks due to updated understanding of the inventory and the dissolution behaviour of uranium as credible, but unproven. We believe it is likely that, coupled with the reduced timescales for the main assessment, assessed risks could also be reduced significantly with a more detailed appraisal of the effects of the engineered barriers, although the latter analysis is not yet sufficiently complete to provide any reliable quantification of any effect.

3.0.5 In our view the performance update does not yet provide a fully substantiated case that assessed risks from C-14-bearing gases will not be higher than indicated by the 2002 PCSC. Overall, when we take account of the likely relative sizes of effects on the assessed risks from the trenches and the vaults, we conclude that the performance update provides evidence that the maximum assessed risks from the trenches (absolute risks and relative risks to those from the vaults) are likely to be reduced significantly, but that the extent of the reduction remains to be substantiated.

3.0.6 In light of the considerations above, we consider that the conclusions of LLW Repository Ltd's ALARA work are sufficiently tentative and not distorted by an unwarranted confidence in the results of the performance update. In this sense, we conclude that the performance update adequately supports LLW Repository Ltd's position on this element of Requirement 2.

3.0.7 We stress that this conclusion rests in part on the fact that LLW Repository Ltd's conclusions are tentative; we will require further refinement and application of the methodology before the final configuration of the trenches is decided. Such future work to refine the ALARA analysis, whether generally or in the context of specific potential actions, may need to be supported by assessments of the risks that are underpinned more robustly.

3.0.8 The connection between the performance update and proposals for the radiological capacity is in principle much more direct. Ideally, firm proposals for the radiological capacity would be supported by robust assessments of the risks. At this stage, however, we do not think that the assessments of the risk in the performance update are sufficiently robust and we would not accept the current performance update as a basis for firm decisions on radiological capacity. Apart from the various specific weaknesses identified elsewhere in this review, while the performance update lacks a systematic treatment of uncertainty, we cannot reach firm conclusions about the overall acceptability of the risks. However, LLW Repository Ltd's proposals on radiological capacity in this submission are tentative, and therefore the standard of support needed is lower. The question of whether such tentative proposals are sufficient to meet Requirement 2 is discussed in our Overview report (Environment Agency, 2009a). Here we consider whether the performance update is adequate to support the tentative conclusions presented by LLW Repository Ltd.

3.0.9 LLW Repository Ltd's basic proposal is that, for the time being, the radiological capacity should be the current reference inventory, and that this should be reviewed in the light of the results of the full ESC due by 1 May 2011. In the mean time, the current CFA (LLW Repository Ltd, 2008) should be retained. This decision appears to rest on two conditions, namely that:

(a) it is credible that a full ESC could demonstrate that disposal of the reference inventory is acceptable (if its disposal was clearly found to be unacceptable, then continuing any further on the basis of that inventory could not be justified);
(b) application of the CFA between now and a decision on radiological capacity (post-2011) will not lead to waste being prepared for or accepted by LLW Repository Ltd that cannot be disposed of in the LLWR while maintaining an acceptable ESC.

3.0.10 Bearing in mind the weaknesses identified in the performance update, and without pre-judging any future decisions, we consider that LLW Repository Ltd have provided evidence that an acceptable ESC could be made. Clearly our position is subject to the issues identified in this review being adequately addressed, but we believe that their resolution is plausible.

3.0.11 We consider that the condition set out in para. 3.0.9(a) is already met; we believe that condition in para. 3.0.9(b) is likely to be met with respect to waste streams that do not depart too far from the 'typical'. The second condition might not be met if specific waste streams, identified as presenting particular challenges to the ESC (see below), were due to arrive at the LLWR within the next five years or so. We understand that this is not the expected case, but we would expect LLW Repository Ltd to ensure that this does not happen. Pending full resolution of the radiological capacity, LLW Repository Ltd should err on the side of caution when considering whether to accept waste streams that potentially pose particular challenges to the ESC.

3.0.12 LLW Repository Ltd suggest that the radiological capacity may be defined by the physical capacity of the planned facilities coupled with limits on the average activity concentration of radionuclides in wastes. This definition is based on an expectation that the highest risks assessed by the full ESC will result from scenarios in which the risk (or dose, in the case of human intrusion) depends on the activity concentration rather than the total activity. Such scenarios would include those used in the performance update for assessing risks from human intrusion and coastal erosion. The performance update provides some support for the view that this is likely to be the case, but the full ESC would have to provide a robust and substantiated demonstration. However, LLW Repository Ltd's proposals at this stage do not rest on this expectation.

3.0.13 Overall, we conclude that the performance update does adequately support LLW Repository Ltd’s tentative conclusions on radiological capacity.

3 Recommendations in relation to the environmental safety case

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4.0.1 In a number of areas, the performance update represents significant progress compared to the 2002 PCSC. It goes some way towards addressing some of the issues we identified in our review of the 2002 PCSC (Environment Agency, 2005a). It also touches on some significant advances in understanding of the site and its impacts. However, as is acknowledged in the submission, there are issues that have not yet been addressed and others for which the advances claimed in the performance update need to be further underpinned.

4.0.2 The structure and presentation of the update itself and of the documentation describing it are substantially improved compared to the 2002 PCSC. We take some comfort that LLW Repository Ltd understand our expectations for the full ESC due in 2011. The key arguments are generally presented clearly and concisely, and in most cases the evidence to support arguments within the main volume and supporting documents is well signposted. There are some areas where we would expect improvement for the full ESC, as documented in this report, but these are of a number and nature that might reasonably be expected in an interim update.

4.0.3 LLW Repository Ltd does not claim that the performance update is a full ESC. We have identified in this review – and in detailed feedback prepared for LLW Repository Ltd on various issues still outstanding from our review of the 2002 PCSC – many specific areas in which we expect to see additional work reflected in the full ESC due by 1 May 2011. We expect LLW Repository Ltd to address all the issues that we have identified (and any further issues identified by the Environment Agency in the course of our dialogue in the coming years). However, we also expect LLW Repository Ltd to remain alert to and address any further issues arising out of their work, which they may identify themselves or have drawn to their attention, for example by their Independent Peer Review Group.

4.0.4 For the majority of the issues identified, we are essentially content for LLW Repository Ltd to proceed with whatever work they consider necessary; we expect to see the issues addressed in the full ESC. Nevertheless, these issues will be kept under a certain level of review via our regular dialogue with LLW Repository Ltd; we will engage in more detailed dialogue or provide further guidance on these issues if requested, but we do not intend to seek or require any further specific reporting. For the few issues that we believe are of particular importance, or where the extent and nature of the work required is currently unclear, we expect LLW Repository Ltd to provide us with more detailed and explicit information at defined times, for example detailed plans of action, descriptions of proposed approaches, models or data or results from interim or provisional analyses. These issues are discussed below. We recognise that some of these important issues may be addressed, at least in part, by the updated and expanded safety case approach document that LLW Repository Ltd produced in late 2008 (Baker et al., 2008), but we include all the issues here for completeness.

4.0.5 A fundamental requirement of the full ESC is to identify and address systematically the uncertainties associated with the performance of the disposal system. Our review of the 2002 PCSC identified a large number of issues relating to the treatment of uncertainty in many different areas of the case. LLW Repository Ltd acknowledge that the performance update for the Requirement 2 submission does not include a systematic treatment of uncertainty, and therefore the issues raised in relation to the PCSC have not been resolved. This was not explicitly required by Requirement 2, but we consider it to be a priority for the development of the ESC. We expect LLW Repository Ltd (**Category A recommendation**) to provide us at an early date with details of their proposed strategy and approach for addressing uncertainty in the ESC. In the absence of such information in the

Requirement 2 submission, we cannot with confidence agree or disagree with LLW Repository Ltd's claim that the performance update results are generally cautious.

4.0.6 LLW Repository Ltd also need to address more systematically the sensitivity of assessment results to waste heterogeneity and to changes in operation of the LLWR. Waste heterogeneity is discussed in various parts of the submission, but is not addressed systematically or coherently. We expect to see a more comprehensive analysis of heterogeneity and its effects in the full ESC. We recognise that this analysis will often rely on judgements, so dialogue with us during development of the approach may be helpful. The effects of changes in operation of the LLWR are barely addressed in the submission, despite clear statements of intent from LLW Repository Ltd[6]. The future inventory, and its behaviour, will be affected by proposed improvements to the segregation of VLLW from LLW, reductions in voidage (and hence grout content), increased flexibility in packaging, etc. We recognise that this is just one of a number of areas of uncertainty about the future inventory. However, they are matters over which LLW Repository Ltd have considerable control, and therefore we expect the ESC to consider the potential effects of these proposals. We suggest (**Category C recommendation**) early dialogue with us to discuss LLW Repository Ltd's intentions and their anticipated effects on the ESC.

4.0.7 Given the fundamental shift to an assumption that the facility will be eroded within a few thousand years, we expect LLW Repository Ltd (**Category B recommendation**) to provide a more carefully justified and robust assessment of the exposures that could arise when that erosion takes place. The exposure scenarios and models used in the performance update are essentially the same as those used in the 2002 PCSC, when they were designed to explore an emerging issue. Overall, we expect the assessment of coastal erosion in the ESC to be consistent with its status as the 'normal' or expected evolution of the site. We also expect LLW Repository Ltd to give specific attention to the following points identified from our review:

(a) No exposure scenarios have yet been defined for the 'increasing sediment' scenarios, reflecting a barrier-lagoon and/or expanded Ravenglass Bay. This is a significant omission from the Requirement 2 submission, which we will expect LLW Repository Ltd to rectify in the full ESC. This scenario could be significantly different from those already considered, for example in terms of both the types of individuals exposed and the distribution of radionuclides from the facility. We expect LLW Repository Ltd (**Category A recommendation**) to provide us with updates to describe the proposed modelling approach and early indications of likely results (e.g. from preliminary calculations) for this scenario.

(b) LLW Repository Ltd should clarify and justify the details of the assessment calculations used to estimate impacts during erosion of the facility. As a first step, we expect LLW Repository Ltd (**Category C recommendation**) to explain the large differences between the results from coastal erosion scenarios in the 2002 PCSC and in the performance update, by itemising and justifying the differences between the calculations.

(c) The activity concentrations assumed in calculations need to be more carefully considered. We accept that, for most exposed individuals, annual doses in a given year are likely to be determined by the average activity concentrations in waste exposed during that year. However, this average will change from year to year due to heterogeneity in the wastes being eroded. By analogy with other pathways, we expect the peak risk to be calculated for the year in which the average concentration exposed is highest. We recognise that the timing and size of that peak in the average concentration will be uncertain, but we expect LLW Repository Ltd (**Category D recommendation**) to consider explicitly the time variation in risks during erosion.

(d) In addition, we expect LLW Repository Ltd (**Category D recommendation**) to consider the possibility that individual discrete items from the LLWR might be found on the beach following erosion, e.g. by considering potential doses to a 'beachcomber'. This possibility may be adequately covered elsewhere in the assessment (e.g. by a human

[6] We note that the Requirement 2 submission was in the final stages of preparation at the time these proposed changes were being formalised in site Lifetime Plans.

intrusion scenario), but we wish to be reassured that all possibilities that are reasonable in the context of the wider assessment have been covered. For example, LLW Repository Ltd might consider whether pieces of insoluble calcium fluoride matrix containing uranium from the trenches might appear on the beach.

(e) We recognise that risks resulting from waste after it has been dispersed into the sea are likely to be lower than those from other pathways. However, for completeness, we expect LLW Repository Ltd (**Category D recommendation**) to assess these risks as part of the 'normal evolution' scenario.

4.0.8 At the same time, we do not regard erosion of the facility on the timescales described by LLW Repository Ltd as an absolute certainty. For the Requirement 2 submission, we accept that it was reasonable to focus on risks and doses up to the expected time of erosion. However, in the full ESC we will expect LLW Repository Ltd (**Category B recommendation**) to assess the potential effects that a delay in erosion – either for a relatively modest time, a very long time or indefinitely – may have on impacts via the various pathways. This consideration should be proportionate, given that such a course of events is of low likelihood. We will take account of the low likelihood of delayed erosion when we decide on whether the indicated level of impacts is acceptable.

4.0.9 We agree with LLW Repository Ltd (**Category B recommendation**) that further attention should be given to the well pathway in the groundwater scenario. The assessment of this pathway must provide a reasonable and robust indication of the risk associated with this possibility. In the light of the simplistic nature of the assessment, we do not consider the conditional risks from the well pathway calculated for the Requirement 2 submission to be a major concern in relation to the risk guidance level – the calculations are generally pessimistic and they are conditional risks. However, these calculations highlight two broader concerns:

(a) LLW Repository Ltd need to obtain a more reliable understanding of future waste streams. In particular, it is important to have reliable estimates for wastes with significant levels of long-lived mobile radionuclides such as C-14, Cl-36 and Np-237. LLW Repository Ltd ultimately will need to ensure that the suitability of such waste streams for disposal in the LLWR are carefully assessed.

(b) In view of legislative trends, notably the Groundwater Daughter Directive, we may have to consider not only what the updated calculations for the well pathway indicate about risks to humans, but also whether they indicate adequate protection of groundwater as a resource.

4.0.10 Further to para. 4.0.9(a) above, we expect the ESC to demonstrate that, in general, disposal of the proposed future inventory in the LLWR is the optimum solution for those wastes. This analysis would be one element of the demonstration that best practice will be applied to keep the risks from disposals in the vaults ALARA (see the Overview document of our review (Environment Agency, 2009a)). We may ultimately also expect to see an additional, more specific demonstration that disposal in the LLWR is the optimum solution for particular waste streams that are major contributors to the risk (i.e. on current evidence, those containing the bulk of the future inventory of C-14, Cl-36, Ra-226 and Np-237), but this may be beyond the scope of what can reasonably be expected of LLW Repository Ltd for the full ESC due 1 May 2011. As a step towards this, however, for the full ESC we expect LLW Repository Ltd (**Category B recommendation**) to have at least reviewed the accuracy of the current characterisation of future waste streams to obtain as reliable a picture as possible of which waste streams are likely to present challenges to the ESC by virtue of their long-lived radionuclide content.

4.0.11 We do not accept LLW Repository Ltd's arguments that the assessed conditional doses for human intrusion scenarios can be excluded from the assessment of radiological capacity. We would not expect radiological capacity to be constrained by the inclusion of a highly improbable extreme worst case, but we consider that reasonably cautious human intrusion scenarios should be taken into account. There are a range of possible scenarios and (in the consultation draft of the GRA (Environment Agency *et al.*, 2008)) a range of dose criteria that could be applied to human intrusion scenarios. We expect LLW Repository Ltd

(**Category A recommendation**) to propose, in broad terms, appropriate scenarios for us to approve. Once appropriate scenarios have been agreed, we intend to determine which criterion (from the range of dose guidance levels specified in the GRA) we consider appropriate to apply to each scenario, taking account of the plausibility of the scenarios. We expect this process to be completed before the full ESC is submitted, and we will therefore require proposals from LLW Repository Ltd in good time to allow that process to occur.

4.0.12 It has been assumed throughout the Requirement 2 submission that vertical drains – or some other engineered feature having a similar effect on near field flows – will be included in the design of future vaults and that these will be completely effective at whatever time in the future they are called upon to operate. If LLW Repository Ltd decide that the optimised design includes such features, we will expect (**Category C recommendation**) to see, as soon as possible, evidence for the assumptions to be made about their performance.

4.0.13 For clarity, we repeat briefly in the following table the recommendations from the main text of this report that we expect to see addressed in the full ESC. These recommendations may be considered **Category D recommendations** unless otherwise stated – they are listed in order of occurrence in the text, not of priority.

Recommendation	Para(s) in text
Development of assessment	
Consider using identical habits in different PEGs if they are intended to represent broadly the same behaviour.	2.3.3
Improve the near field water balance model and/or its underpinning, particularly to include a consideration of uncertainty (**Category B recommendation**).	2.4.6–2.4.7
Include in assessments realistic assumptions about the nature and performance of the cap in place at any given time.	2.4.9
Consider including an assessment for a beach hut, but taking account of its high ventilation rate.	2.6.9
Ensure the empirical model for indoor radon exposure is cautious by considering variability in ratios of radon level to soil concentration.	2.7.10
Justification of assumptions	
Show that models are appropriate for the range of conditions and timescales being represented (**Category B recommendation**, but effectively a compilation of comments on specific models).	2.1.4
Confirm that assumption of a homogeneous saturated medium is conservative compared to a heterogeneous unsaturated one.	2.4.4
Clarify reasons for high uranium and fluoride levels observed in Trench Region B.	2.4.5
Clarify and justify discretisation assumptions used in implementing the geosphere model in GoldSim.	2.4.13
Improve the justification for not considering explicitly entrainment of radon with landfill gas.	2.5.4
Explain more clearly the change in C-14-bearing gas generation rates from the 2002 assessment.	2.5.5
Clarify current ambient radon levels above the interim cap.	2.5.7
Demonstrate that the final cap will contain radon sufficiently that ambient levels above the cap do not differ significantly from background.	2.5.7

Recommendation	Para(s) in text
Address recommendations from IAFs on impact assessment models for coastal erosion from 2002 (to the extent that the models are used in the ESC).	2.6.7
Address recommendations from IAFs on human intrusion models from 2002 (to the extent that the models are used in the ESC).	2.7.2
Justify the factor of 10 dilution in human intrusion calculations for 'soil quality' and use of the same factor for all trenches and vaults.	2.7.4
Documentation	
Clarify when data, figures, graphs, etc, in the main volumes are intended as examples or illustrations and when they are meant to give a complete picture.	2.1.2
List radionuclides consistently, either alphabetically or by atomic number.	2.1.5
Clarify exactly which data from supporting documents (e.g. data reviews) have been used in assessments.	2.3.4
Provide an annotated map of the area around the site to aid understanding of descriptions of PEG locations and behaviour.	2.6.8

4.0.14 Appendix 1 at the end of this report lists a substantial number of relatively minor observations from our review of several key documents supporting the presentations in Volume 5. Any substantial issues from these documents have been covered in the main text of this report. We recommend (**Category D recommendation**) that LLW Repository Ltd take note of these comments, and act upon them as appropriate, in preparing the full ESC.

Appendix 1: Review of supporting references

This appendix provides detailed comments on a number of the documents cited in support of the Requirement 2 submission (Volume 5). The main points arising from our review of these documents are, however, addressed in the main text.

Thorne, M. C., 2007. Data for Exposure Groups and for Future Human Actions and Disruptive Events, Mike Thorne and Associates Ltd MTA/P0022/2007-4: Issue 2, Nexia Solutions Report 8856, Issue 2.

The first section of the report refers to the 2002 OESC (BNFL, 2002b). Since no parts of the OESC have been updated for the Requirement 2 submission, we have not reviewed this section in detail. We note in passing, however, that Table 1 gives no information for Trenches 5, 6 and 7.

Descriptions of the different parts of the Drigg area, such as those in Section 2.3 of the report, are considerably easier to follow with the benefit of a simple annotated map showing the different parts referred to in the text. We have indicated this to LLW Repository Ltd, and they have provided such a map to us for this review. In future, we suggest that such a map be included in relevant documents.

Section 2.3.2 of the report (the cliff) does not seem to take account of all of the coastal evolution scenarios whereas Section 2.3.8, for example, refers to the lagoon-type scenarios as well as the linear cliff erosion ones. We recognise that the lagoon-type scenarios have not been included in the assessments for the Requirement 2 submission, but the documentation should take a consistent approach.

We understand from discussions with LLW Repository Ltd and their contractors that they consider the range of PEGs and habits to be sufficiently broad to provide reasonable coverage of the types of behaviour that might occur if, in a future warmer climate, West Cumbria were to become a popular location for beach holidays and the Ravenglass estuary became a substantial bay (potentially with a harbour). If this is the case, a brief explanation to that effect should be given.

We are content to accept the approach (Section 2.5.2) that only generic animal products needed to be modelled for the Requirement 2 submission. For a full ESC we would expect either a more robust justification of this approach to be included in the documentation or the separate modelling of different animal products.

The descriptions of PEGs and their habits are generally clear. However, some further brief comments would be helpful to clarify:

(a) whether bait digging is included in the assumed habits of the occupational beach users;
(b) why no freshwater fish catches are considered for the surface waters affected by near surface groundwater pathways;
(c) why 95th percentile food intake rates are used to represent “high” consumers, rather than the 97.5th percentile commonly used in defining critical groups (see, for example, Smith and Jones (2003)).

We note that the uncertainty-related issues discussed in Section 3.1.4 do not appear to have been picked up in the assessment work. We assume that this aspect will be followed up as the treatment of the uncertainty in the assessment is developed, but we note in passing that the discussion here does not mention uncertainty in the inhalation pathways.

The discussion of smallholders' habits (Section 3.2.2) mentions that goat's milk is enriched in some trace elements compared to cow's milk. This appears to contradict the earlier discussion indicating that generic animal products may be used as representative of all animals.

A general feature of supporting documents of this type is that they present more information and discussion than is necessarily used in the assessment that the document supports. It is primarily the responsibility of the authors of the assessment reports to be absolutely clear about what information from the supporting documents they have used and how.

Paksy, A. and Henderson, E., 2008. Assessment of Radiological Impacts for the Groundwater Pathway, Nexia Solutions Report 9449, Issue 2.

Near field

The ease of reading the report is not helped by the references to Calculation Cases A–D, Trench Regions A–D and Smallholders A–C. Some variation in designations might help clarity (e.g. Trench Regions i–iv, Smallholders a–c).

The assumed characteristics of the Trench Regions A–D are not well explained in Appendix 1 of the report. It is not clear why a different concentration of dissolved uranium is considered appropriate for Region B (perhaps this is explained in Volume 3 or its supporting documents, but a brief summary of the reason in Volume 5 would be useful), and it is not clear what is different in Regions C and D compared to Region A: all three regions appear to have a concentration of 1E-07 mol L^{-1}.

It is also unclear why the solubility limit for the vaults should be set at 1E-09 mol L^{-1} ("*under the alkaline conditions of the vaults"*) when that is the lower bound of the range of *"uranium concentrations under vault pH conditions"*.

The discussion of "lower bound performance" is perhaps literally correct, but rather confusing in the context of the performance of the vault walls. The term "lower bound performance" apparently refers to the numerical lower bound of the range of permeabilities *("very low or negligible flow into the near field from the Upper groundwater"*), but in common parlance this would surely be considered the best performance.

The presentation of decay chains in Table 19 of the report may be closely linked to the way data are represented in the GoldSim model, but is rather peculiar to the general reader.

The presentation of estimated vault flows (Tables 26 and 27) to four, five and even six significant figures surely gives a false impression of precision.

Geosphere

Some explanation should be given for the use of 1/10 of the pipe length as a mixing depth to calculate dilution, especially since the pipe length has been arbitrarily divided into three to provide intermediate outputs. The calculated doses from Case B, where the path length is shortened but represented by only one pipe, are lower than those for Case A, but it is unclear whether this is simply an artifice caused by the assumption of a mixing depth of 64 m in Case B (10 per cent of 640 m) rather than 22.5 m in Case A (10 per cent of the length of Drift 1).

Again, quoting values to up to six significant figures (Tables 32, 33, 35 and 36) seems unduly precise given the context.

Biosphere and PEGs

For the well water pathway (Section 2.4.5), there is a reference to “contaminated pasture and soil”, but it is not clear how pasture comes to be contaminated. It is unusual in the UK for pasture to be irrigated; in our discussions with LLW Repository Ltd and their contractors we had understood that animals took in radionuclides only with drinking water from the well.

In relation to the land that is irrigated by the smallholders, it is not clear why the 0.2 m/year irrigation rate quoted from the BIOMASS Reference Biospheres work is regarded as an upper bound. The summer moisture deficit in Cs* conditions[7] is 0.432 m, and this might perhaps have been considered a more definitive upper bound.

The dose coefficients for inhalation and ingestion listed in Table 43 represent the effective dose committed by an intake of 1 Bq of the named radionuclide (including in-growth of daughters after intake). However, the dose coefficients do not appear to take account of the fact that the short-lived daughters of some radionuclides are likely to be present in secular equilibrium with the parent before intake. The environmental transport of these daughters has evidently not been modelled explicitly – reasonably, as they would not have time to demonstrate any environmental behaviour independent of the parent.

In this circumstance the normal procedure would be to assume that any intake of 1 Bq of the parent is accompanied by an intake of 1 Bq each of the short lived daughters, and increase the effective dose coefficients for the parent accordingly. With the exception of Pb-210, for which a contribution for Po-210 has been added, this has not been done. Fortunately, this makes little difference in most cases. The largest differences in the ingestion dose coefficients used would be for Th-228 (1.4E-7 Sv/Bq instead of 7.2E-8, mostly due to Ra-224), Np-237 (1.6E-7 Sv/Bq rather than 1.1E-7 when Pa-233 is added in), and Th-229 (6.1E-7 Sv/Bq rather than 4.9E-7 due to Ra-225 and Ac-225). We have not checked the inhalation values, but we would expect similar discrepancies (the modelling of the inhalation of radon and thoron – for which the treatment of short-lived daughters would be critical – does not use these coefficients). These discrepancies do not invalidate any conclusions in the Requirement 2 submission, but we would expect them to be corrected for the full ESC.

The dose coefficients for external exposure come from a different source and are less readily checked against authoritative references. In this case, the discrepancies could be substantially greater, but should also be easier to spot. There are no obvious signs of a similar omission, but we recommend that all of the data in Table 43 be checked to ensure that short-lived daughters have been handled correctly.

Tables 47–49 give data for compartments representing the Drigg Stream but not the East–West stream. If the latter is not modelled, then the text and table headings should be amended to refer only to the Drigg Stream.

It is not clear why the near surface pathways require a separate set of assumptions. In particular, it is not clear why characteristics of one or more of the smallholder PEGs could not have been used, rather than creating a new set of habits.

Paksy, A ., 2008. Near-field engineering performance: methods and data, Nexia Solutions Report 9275, Issue 3.

Key assumptions for the groundwater pathway calculations reported in Volume 5 (state of saturation, how much leachate goes where and when, etc.) come from the water balance model described in this supporting report. As the report stands, we have some doubts that the basis of this model is sound; our comments below focus on this aspect.

The descriptions of what was done in the expert elicitation process, how the model works and what is assumed seem to refer to little in the way of hard facts. The steps taken and assumptions made

[7] Cs* designates a climate state similar to those currently observed in Mediterranean countries.

generally appear sensible, but we are not convinced that an equally plausible set of explanations might have been constructed, leading to quite a different model.

Cases have been modelled for no rise in sea level and for a rise of 6.5 m, but not for the higher sea level rise considered in the coastal evolution work (23.8 m above the current level). If the intention is to scope the range of near field flows that might be experienced, then this seems to be a significant omission.

The eight calculation cases considered cover the two sea level scenarios described above combined with upper and lower bound assumptions for three other sets of parameters – the *elicited* near field component data, the *estimated* near field component data and the heads. However, these parameters are used only in certain defined combinations that do not seem particularly logical and do not seem to explore the full range of possibilities. For example, the estimated and elicited parameters are never varied together, even though it might be reasonable to suppose that the experts could systematically over- or underestimate the elicited parameters, so there is a good chance the project team might do the same with the estimated values. The higher regional groundwater head associated with a 6.5 m sea level rise (which is supposedly considered more likely than no sea level rise) is also not considered in combination with the other parameter variations.

The report acknowledges that the model results are very sensitive to several key parameters that derive their values from other models or from elicitation/estimation exercises. The report also notes that there may be complex interactions between the effects of the different parameters. This being the case (even just based on the limited investigation of sensitivity presented here), it is surprising that the assessment is then based on the results from one deterministic run. We recognise that in general the performance update is not intended to include a full treatment of uncertainty, but in this particular case there seems to be the potential for the results from the chosen deterministic case to be misleading rather than simply incomplete.

Thorne, M. C., 2008. The Biosphere Database for use from the Present Day through to Scenario Termination, Mike Thorne and Associates Ltd MTA/P0022/2007-3: Issue 2, Nexia Solutions Report 8854, Issue 2

Introductory text

The text refers to a requirement to evaluate uncertainties in the assessed radiological impact, presumably referring to the Environment Agency's IAF BIO_006. We interpret this IAF to imply a quantitative evaluation of uncertainty in the transport of radionuclides through the biosphere but not in the characteristics of PEGs. The discussion of uncertainty in this document seems to be consistent with our interpretation.

As stated previously, the assessments in the Requirement 2 submission do not include systematic treatments of uncertainty – much of the information in this document on ranges of parameter values has not been used in the Requirement 2 submission. This review therefore pays less attention to the discussion of ranges than to the reference values used in the assessment.

We note that the biosphere database does not include data for goats. Our understanding of the documentation is that the smallholder PEGs used for some human intrusion scenarios are assumed to keep goats, but that the modelling of radionuclide transfer to goat products is based on data for generic animals. However, it is not entirely clear whether our understanding is correct, nor (if it is) why existing data specific to goat products have not been used. We do not necessarily think that more detailed analyses would be justified, but we expect to see a more explicit statement of what has been done and why it is considered appropriate.

The balance of this document seems slightly inconsistent with the assessment presented in the Requirement 2 submission. This document relates primarily to the groundwater pathway, for which the overall assessment in the submission indicates that the impacts arise largely from releases to the marine environment. Yet the larger part of the discussion of biosphere parameters in this supporting document concerns terrestrial parameters. There is no clear indication that this focus is to the detriment of the appraisal of marine parameters – we recognise that this is a reflection of the greater number of parameters needed for the terrestrial parts of biosphere models – but it does give a slightly strange impression.

We recognise that there may be a particular issue regarding proportionate assessments in the context of the Requirement 2 submission.. The Requirement 2 assessment overall suggests that the groundwater pathway does not dominate the risks from the LLWR, and the biosphere is probably not the most critical component of the modelling of the groundwater pathway. Therefore, while we offer comments on this document taken at face value, we recognise that the effort expended to address them should not be grossly disproportionate to the importance of these data to the overall ESC.

We would welcome some clarification of the author's comments on the sorption data in IAEA Technical Report 422 (IAEA, 2004). It is not clear whether these are recognised limitations in the IAEA data that are acknowledged in the IAEA report itself or discussed elsewhere, or are criticisms by Thorne of the approach followed by the authors of the IAEA report.

We note that little reference is made to experimental data obtained locally, although significant amounts of data exist (e.g. from studies at Sellafield). While such data could not automatically be regarded as preferable to generic values for long-term assessments, there would seem to be merit in giving some consideration to evidence from studies conducted under local conditions (as has been done in the case of technetium in lobsters).

Main analysis and discussion

Overall, we find the text describes a thorough, coherent and largely well reasoned review of the data. Our comments below question what appear to be exceptions to this overall impression, but these are small in number (and mostly relatively minor in nature) in the context of the scope of the review.

The report appears to rest in many cases on a series of individual expert judgements rather than an application of any overriding 'rules'. This is an appropriate approach, but it does provide a greater challenge in terms of documentation. We would expect to see every judgement explicitly explained, briefly but clearly. This has largely been done already, but we note a small number of possible exceptions.

We also suggest that the introduction to the analysis should include a brief statement of the main considerations used in the expert judgements. As this document stands, we can infer what appear to have been some of those considerations, but we cannot be sure without explicit information. An important principle, not surprisingly, seems to have been to avoid seriously underestimating risks, but a brief discussion would be helpful to indicate the parameters for which this approach meant erring on the side of higher or lower values, and for which the effect on doses is less predictable (e.g. soil K_ds) and therefore where caution calls for a more central value. Some consideration also seems to have been given to the continuity of data from previous assessments versus the most recent evaluations, of direct experimental data versus data derived via models, and perhaps others. It would be helpful if these considerations were at least listed in general, and then referred to as needed in individual expert judgements.

It is clear that tritium is always assumed to occur in the form of tritiated water (HTO) and not as organically bound tritium (OBT), but it is not clear why. Given the range of potential environmental conditions, some explanation should be given as to why the occurrence of OBT is not considered possible.

The treatment of strontium as an analogue for calcium (Section 2.4) is a little confusing. For transfers to animal products (Section 2.4.3), EMRAS data for calcium are used as evidence to increase (by an order of magnitude) the values derived from biokinetic modelling for strontium, rather than using the calcium data themselves. Despite indications that strontium may not be an ideal analogue, values for strontium are used for freshwater, estuarine and marine parameters

(Sections 2.4.4 and 2.4.5). There may well be good reasons for these decisions, but some explanation does appear to be needed.

For a number of elements (the first being calcium, Section 2.4) the EMRAS data for transfer to animal products differ somewhat from those derived from biokinetic modelling for the 2002 PCSC. Where the EMRAS values are lower, it is reasonable to retain the biokinetic modelling values, but it seems odd that the ranges are not extended downwards to include the lower values from EMRAS.

For a number of elements (the first being nickel, Section 2.5), soil K_ds are considered to be dependent on characteristics of the soil. There is, however, a gap in the documentation because this document does not make a recommendation for which characteristics are considered similar to soils in the Drigg area. The assessment reports do not make clear which values have been used. We would accept that the primary responsibility for clarifying such matters would lie with the authors of the assessment reports, but it nevertheless seems slightly odd that no mention is made in this document of the nature of soils near the LLWR site.

The text on uptake by marine organisms of nickel (Section 2.5.5) does not appear to fit the choice of 100 L/kg as the reference value for marine fish (c.f. 1,000 for other organisms).

The discussion of parameters for strontium (Section 2.6) gives a slight impression (possibly unintentionally) that the wide ranges of values are to some extent a result of the extensive study of strontium. This could be taken to suggest that the ranges assumed for elements for which data are sparse may be unrealistically narrow, whereas some cases (e.g. soil K_ds for zirconium) actually display large ranges even from few data. It may be inherently impossible to address this suspicion in great detail without the ‘missing’ data, but it might be helpful to include some discussion of the question and explanations (where they are known) of why the ranges for certain elements will genuinely be larger than those for others.

There appears to be a typographical error in the range quoted for strontium’s marine sediment K_d. If the proposed distribution is lognormal, then the first number in the brackets should be the geometric mean (0.05) rather than the lower bound (0.002). Similarly, in Table 2.6 (Section 2.10), if the two observations for root crops are 14 and 79 the average cannot be 4.6.

The discussion of freshwater data for iodine (Section 2.11.4) justifies changing the range of K_d values (which has been done) but might also be taken to justify a change in the reference value (which has not been done).

The discussion of freshwater K_d values for caesium (Section 2.12.4) might be considered to provide enough evidence of a preference for mid-range values to justify a lognormal rather than loguniform distribution.

In the discussion of freshwater K_d values for lead (Section 2.13.4), it is not clear why the perceived limitations in the IAEA (2004) data are assumed to be more important than the obvious limitations of applying data from soils directly to sediments. Given that this assumption results in a reference value that is lower than the lower bound of the IAEA range, some further explanation would appear to be necessary. The same result occurs for sorption of uranium to marine sediments (Section 2.18.5): again the reference value is below the lower end of the IAEA range. Similarly, for thorium and freshwater sediment (Section 2.17.4) the proposed reference value is the minimum of the (large) range cited in IAEA (2004).

In the discussion of protactinium (Section 2.16), it would be helpful to explain why thorium is considered an appropriate analogue for soil-to-plant transfer, but plutonium is used as an analogue for concentration factors in freshwater fish. This may be because higher values are clearly cautious for the latter, whereas it is not clear what is cautious for the former. The reason should be stated briefly.

Ball, M., Willans, M., Cooper, S. and Lennon, C., 2008. Review of the Gas Pathway. Nexia Solutions Report 9277, Issue 2. (Restricted)

We note a conclusion of our Gas Review Group in its report on the 2002 PCSC (Galson Sciences Ltd, 2004d) that: *"The fitness-for-purpose of the DEGAS model and code has been demonstrated adequately through the Program User's Guide for DEGAS version 3.4 … and the Program Verification Report for DEGAS".* Our comments on the Requirement 2 submission therefore address the provenance of DEGAS only where its use may have changed since the 2002 PCSC.

Results are presented from the monitoring of landfill gases above the trenches (Section 2.1) followed by results from modelling the generation of landfill gases using DRINK (Section 2.4). However, no attempt is made to check whether the DRINK predictions bear any resemblance to the observations. We recognise that such a comparison might not have provided very strong evidence for or against the validity of the modelling because the resolution of the DRINK model is low and it represents only the generation of gases, not their transport to probe locations. However, the absence of even a 'broad brush' comparison seems an odd omission.

We note that the contributions to Rn-222 generation from the nuclides above Ra-226 in the decay chain are taken into account in calculations. Nevertheless, the text in Section 2.5 is slightly misleading because it suggests that these contributions will necessarily be negligible on timescales of 2,500 years or so. Ra-226 will approach secular equilibrium with its much longer-lived parent Th-230 with a half-life similar to that of Ra-226 (i.e. 1,600 years), so the in-grown activity of Ra-226 will reach something like two-thirds of the activity of Th-230 in 2,500 years. The fact that the in-grown component will indeed be negligible is therefore more a result of the relatively small inventory of Th-230 than of the timescales.

The discussion in Section 3.3 suggests some similar confusion (although the effects on the assessment may be similarly unimportant). The chemical processing of the Springfields uranic waste would not have separated U-234 from U-238, and so the two isotopes will be in equilibrium with each other. The time at which the uranic wastes could contribute significantly to radon generation therefore depends on the half-life of the longest-lived member of the chain below U-234, i.e. Th-230. In-growth from the uranic wastes could contribute significantly to radon generation on timescales comparable to the half-life of Th-230 (75,000 years). In most trenches the inventory of U-234 is much greater than the initial inventories of Th-230 and Ra-226, and so in-growth would dominate within one half-life. In Trench 3, the starting inventories of Ra-226 and U-234 are similar, so radon generation would fall off over thousands of years as the initial Ra-226 decayed, then increase gradually over tens of thousands of years to eventually approach the initial level. Times of "several millions of years" would be needed for the effects of in-growth to become important only if U-238 and U-234 were substantially out of equilibrium, which would require physical (e.g. gas centrifuge) rather than chemical separation.

The terminology referring to DF as the "degradable fraction" is a little misleading. DF is a rate (units y^{-1}) and therefore "degradation rate" or "fractional degradation rate" would seem to be more appropriate terms.

Since the changes to the RIMERS model substantially increase the calculated doses via the food pathway for a given amount of gas, the assumption that doses from inhalation of C-14-bearing gas are likely to be much lower than those from food seems to be justified. However, we expect the full ESC to confirm this assumption.

The discussion on intakes by PEGs in Section 4.4.3 appears to repeat the explanation given at the end of Section 4.3.1, but does so in different words and without reference to the earlier section. Assuming it is the same argument, then this is simply confusing: if there are in fact two different arguments then it may be misleading.

Galais, N. and Fowler, L., 2008. Assessment of Potential Impacts from Human Intrusion and Coastal Erosion at the LLWR. Nexia Solutions Report 9278, Issue 3

No mention is made in the discussion about the exposure of intruders of the possibility that people handling items contaminated with beta-emitting radionuclides (Section 3.2.1) could receive significant skin doses. Given the levels of effective dose from most pathways, it seems unlikely that any organ equivalent doses could approach levels of concern, but this is one case where it might be conceivable. The full ESC should include either an assessment of skin doses for these scenarios or a demonstration by some other means that they will not be significant.

It is acknowledged in Section 3.3.2 that the assessment of impacts during coastal erosion does not include the possibility of an individual ('beachcomber') recovering a discrete item or piece of material of particular interest from the eroded material on the beach. It is indicated that the human intrusion scenario with small quantities is considered sufficiently similar in terms of potential impact to make an additional scenario unnecessary. If this approach is to be retained in the full ESC, the assumptions and parameter values for that scenario should be reviewed, and adjusted if necessary, to cover the 'beachcomber' case.

An explanation should be given for the statement in relation to Equation 6 (Section 3.4.2) that the dose rate at 10 m from a six-metre band source is one-fifth of the dose rate at 1 m from a semi-infinite slab source.

We note that the calculation of doses from inhalation of dust assumes that the activity per unit mass of resuspended particles is the same as the average in the bulk material. There is evidence that some smaller particles are both more likely to be resuspended and contain more activity per unit mass than average. We expect this possibility to be considered in the full ESC, either by incorporating an enhancement factor into the calculation or through sensitivity studies, as appropriate.

Some explanation should be given for the assumption that PEGs involved in human intrusion activities experience high dust levels for 5 per cent of the time when they are exposed to the wastes and ambient levels for 95 per cent of the time (Section 3.4.3). These values appear to be applied to all scenarios, which seems odd given that the work involved ranges from laboratory analysis to the digging of trial pits or major excavation work.

Given that they are arbitrary assumptions, the duration of exposure values in Table 5 seem oddly precise (two or three significant figures). They are also expressed in odd units, jumping between hours per year, days per year and fractions of a year for no apparent reason. This makes it difficult to compare values across pathways and to consider whether the values used are reasonable. We suggest that all values should be expressed in the same units.

It would be helpful to add a note to Table 6 reminding the reader that this excludes modelling of exposures due to radon and thoron.

Table 10 lists parameter values for transfer to crops and goat's milk. We have not checked all of the values but the transfers to crops appear to be the values recommended by Thorne (2008), whereas the transfers to goat's milk appear to be 10 times the values recommended by Thorne (2008) for cow's milk. However, this latter assumption does not appear anywhere in the documentation we have seen, so should be fully justified or re-assessed.

The dose coefficients for ingestion and inhalation in Table 11 do not include contributions from short-lived daughters taken into the body in equilibrium with the parent radionuclide (see the comments on Paksy and Henderson (2008) above). We have not checked the dose coefficients for external exposure in detail but they appear plausible (although the fact that C-14, Ca-41 and Tc-99 each have one zero and one non-zero value seems slightly odd).

List of abbreviations

ALARA	As low as reasonably achievable
BIOMASS	IAEA Biosphere Modelling and Assessment Programme
BNFL	British Nuclear Fuels plc
BNGSL	British Nuclear Group Sellafield Limited
BPM	Best practicable means
CFA	Conditions for Acceptance by LLW Repository Ltd of radioactive waste for disposal at the LLWR
Defra	Department for Environment, Food and Rural Affairs
ESC	Environmental safety case
GRA	Guidance on Requirements for Authorisation
HSE	Health and Safety Executive
HTO	Tritiated water
IAEA	International Atomic Energy Agency
IAF	Issue assessment form
IRF	Issue resolution form
ISO	International Organization for Standardization
LLW	Low level waste
LLWR	Low Level Waste Repository near Drigg, Cumbria
NDA	Nuclear Decommissioning Authority
NII	Nuclear Installations Inspectorate
NRPB	National Radiological Protection Board
OBT	Organically bound tritium
OESC	Operational environmental safety case
PCRSA	Post-closure radiological safety assessment
PCSC	Post-closure safety case
PEG	Potentially exposed group
R&D	Research and development
RSA 93	Radioactive Substances Act 1993 (as amended)
SLC	Site licence company
UKAEA	United Kingdom Atomic Energy Authority
UKNWM	United Kingdom Nuclear Waste Management Ltd
WAC	Waste acceptance criteria

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