Winfrith End State:

Supporting Document to the Winfrith RSR-C5 permit application

Report – ES(24)P408 Issue 2, May 2025

Review/Revision Register

A review/change of this document was carried out as follows:

Version	Date	Author	Amendments / Change
Issue 1	December 2024	J Roberts	First Issue
Issue 2	May 2025	J Roberts	Update to reflect minor changes to human intrusion doses within the Radiological Performance Assessment.

Glossary/Acronyms

ALARA	As Low As Reasonably Achievable
ALES	Active Liquid Effluent System
BAT	Best Available Techniques
bgl	Below ground level
CCE	Central Cautious Estimate
CEFAS	Centre for Environmental, Fisheries and Aquaculture Science
CQAP	Construction Quality Assurance Plan
CSM	Conceptual Site Model
DfR	Deposit for Recovery
DGL	Dose Guidance Level
DQRA	Detailed Quantitative Risk Assessment
DSR	Design Substantiation Report
EA	Environment Agency
ECML	Environmental Media Concentration Limits
EMP	Environmental Monitoring Plan
ERICA	Environmental Risk from Ionising Contaminants: Assessment and Management
ESSD	Environmental Setting and Site Description
GIM	Generic Intrusion Model
GIS	Geographical Information System
GQRA	Generic Quantitative Risk Assessment
GRR	“Guidance on the Requirements for Release” (Environment Agencies, 2018).
HRA	Hydrogeological Risk Assessment
IEP	Interim End Point
ILW	Intermediate Level Waste

LLW	Low Level Waste
NDA	Nuclear Decommissioning Authority
NRI	Non-Radioactive Inventory
NRS	Nuclear Restoration Services
OoS	Out of Scope
PA	Performance Assessment
RGL	Risk Guidance Level
RMP	Restoration Management Plan
RQ	Risk Quotients
SGHWR	Steam Generating Heavy Water Reactor
SIMP	Staged Inventory Management Plan
SQEP	Suitable Qualified and Experienced Person
SRS	Site Reference State
SWMMP	Site Wide Materials Management Plan
VLLW	Very Low Level Waste

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1 INTRODUCTION

This document provides information in support of the RSR-C5 application to vary the Winfrith radioactive substances permit[1]. This permit variation is required to enable the proposed on-site disposals of the Steam Generating Heavy Water Reactor (SGHWR) and the Dragon reactor to take place. These on-site disposals include for both SGHWR and Dragon:

- Disposal in-situ of the below ground structures;
- Disposal of the above ground structures for the purpose of filling the below ground voids.

In addition, non-radioactive demolition arisings from the SGHWR and Dragon structures and waste material currently stockpiled on-site will be recovered for infilling the below ground voids.

The totality of the proposal will be permitted through both an RSR-C5 application (for the radioactive waste structure and radioactive waste used in backfilling) and a separate Deposit for Recovery (DfR) application (for non-radioactive material). The DfR application is being submitted in parallel to this Radioactive Substances Regulations (RSR) permit application.

Non-radioactive parts of the in-situ structures are defined as 'land in-situ' through waste legislation and do not require specific permissioning. Nevertheless, the volumes and materials have been accounted in the inventories and risk assessments to present a holistic case for the environmental safety of proposals.

2 PROJECT VISION

Why our work matters

At Nuclear Restoration Services (NRS), we are dedicated to the safe, secure, and sustainable decommissioning and restoration of nuclear sites. Our mission extends beyond merely dismantling reactors; we aim to create a positive legacy for future generations and bolster resilient local economies.

Transforming Winfrith for the future

The decommissioning and restoration of the Winfrith site is set to be the first of its kind in the UK. Our approach not only considers the technical challenges but also places a strong emphasis on the community and environment. By restoring the site to heathland, we're creating valuable habitats for local wildlife and providing amenity value for the local community. The decommissioning and restoration of the site will be a world leading example in sustainable decommissioning that is built on the views of the local community. Restoration of the site will support development of valuable and rare habitats that are unique to Dorset.

The next planned use for Winfrith is 'heathland with public access'. Delivering this outcome requires the completion of all decommissioning and waste management activities at the site. The overall purpose of this work is to create the right conditions for heathland habitat to establish and allow public access. The Winfrith site contains several designated habitats and is in close proximity to several other nature conservation areas. The next planned land use was defined through consultation with the local community in 2006.

[1] Termed 'the application' within this document.

The End State for the site, that delivers heathland with public access, has been defined to include:

- On-site disposals of radioactive wastes at SGWHR and Dragon, including managing he sub-surface structures in-situ and backfilling with radioactive and non-radioactive wastes to provide a surface finish suitable for the next planned land use;
- Decommissioning and demolition of all other above ground structures on the site, with removal of wastes for off-site management;
- Assessment of land quality on the site and remediation of contamination to meet suitable risk criteria;
- Removal of subsurface structures to 1 meter below ground level, to allow for reestablishment of habitats;
- Decommissioning of the site drainage infrastructure to reinstate a natural hydrograph;
- Creation of a mire habitat to manage the water balance on site after removal of drains;
- Removal of roads;
- Removal of the fence and any other infrastructure.

After completion of decommissioning, implementation of disposals and reinstatement of the site surface finish, public access to the site will be permitted. This is identified as the Interim End Point (IEP).

NRS will continue to manage the site, through a stewardship phase which includes validation monitoring, until such a time as the site achieves the Site Reference State (SRS) and the environmental permits can be surrendered.

A significant body of work has been completed to demonstrate that the proposed disposals are safe, optimised and supported by the local community. This work is summarised within the Winfrith Waste Management Plan (**WMP**) (Ref. 1) and Site-Wide Environmental Safety Case (**SWESC**) (Ref. 2) that accompany the application.

3 PURPOSE

The purpose of this document is to provide further information in support of the RSR-C5 application form to vary the NRS Winfrith site environmental permit (No: EPR/PB3898DC).

The purpose of the application is to seek permission for the proposed on-site disposals of radioactive wastes at SGHWR and Dragon (Ref. 3). This document provides an overview of the case that the on-site disposals meet the requirements of the GRR.

The scope of this document has been informed by the RSR-C5 guidance note (Ref. 4), and provides the underpinning to the application form with details of:

- How NRS, and the proposals presented in the SWESC and WMP, meets the 5 principles and 15 requirements of the GRR:
    - The waste proposed for on-site disposal, including its classification, form, volume and radioactivity content;
    - The in-situ structures to be disposed (structure, dimensions, location);
    - The waste to be used in backfilling, both as radioactive disposal and non-radioactive recovery activities;
    - The radionuclides present in the wastes and the total activity and which radionuclides contribute significantly to the radiological impacts from the disposal;
    - The physical and chemical properties of the waste being disposed, recovered and structures remaining in-situ;
    - The proposed radionuclide limits for the disposal of radioactive waste;

  - A technical description of the waste disposal including the disposal location (geology, hydrogeology etc.), the design of the proposed disposal and the proposed method of disposal;
  - The optimisation completed to date meets the requirements of Principle 2 and Requirements R1 and R13;
  - The proposed disposal, meets the GRR numerical standards (R9 to R12);
  - Provides protection to a) the environment (R14) and b) against non-radiological hazards (R15);
  - Details of how the performance of the disposals will be monitored and the ongoing environmental monitoring programme;
  - The radiological assessment both during and after the period of regulation;
  - The transboundary assessment completed for the disposals;
  - The dose impact on reference organisms at the proposed limits of the disposal.
- How the proposals meet other environmental regulation requirements:
  - Compliance with groundwater regulations;
  - Are sufficiently resilient to reasonably foreseeable climate change scenarios;
  - The non-radiological hazards and corresponding risk assessment.

4 SCOPE

The scope of this application includes:

SGHWR

- Disposal in-situ of below ground structures which are intended to remain in place;
- Disposal for a purpose of radioactive waste created through demolition of the above ground structures or to enable backfilling of the below ground structures.

Dragon

- Disposal in-situ of below ground structures which are intended to remain in place;
- Disposal for a purpose of radioactive waste created through demolition of the above ground structures or to enable backfilling of the below ground structures;
- Disposal in-situ of the Dragon mortuary holes and B78 base slab.

The scope includes radioactivity associated with 'Out of Scope' land remaining on-site.

The radioactive waste included in the proposal includes both activated and contaminated wastes.

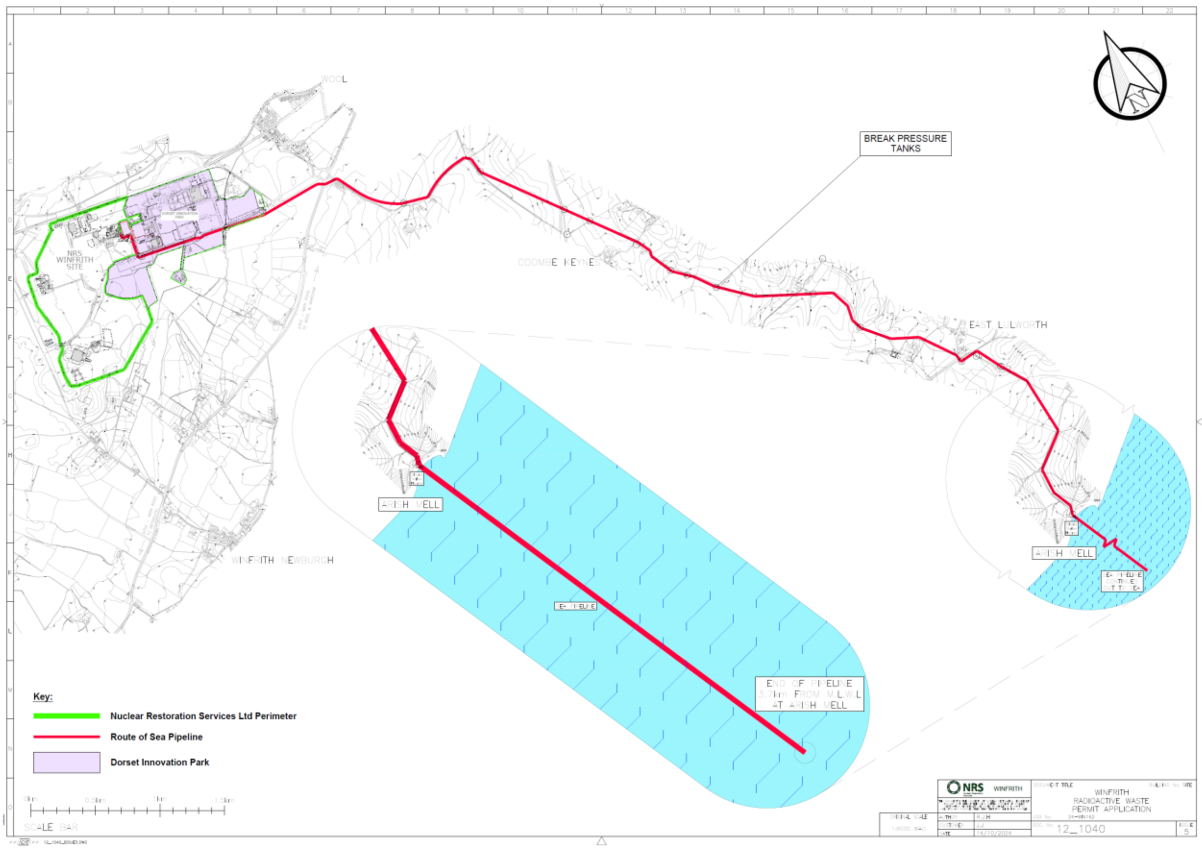
The scope includes radioactive wastes associated with the SGHWR and Dragon building structures.

The non-radiological assessments includes contributions from radioactive wastes, non-radioactive wastes and non-radioactive structures remaining in-situ that form part of the overall proposals.

The scope includes assessment of disposals in current conditions, conditions after the IEP has been achieved and in climate change scenarios relevant to the assessments.

The scope of the SWESC and WMP includes all land and structures in the Permitted boundary as set out in Figure 1.

Figure 1: Map of the Winfrith Permit area



4.1 Exclusions from scope

The scope of the application for on-site disposals excludes:

- On-site disposal of any other buildings or structures. Optimisation conducted to date has demonstrated that there is no case for on-site disposal elsewhere on the Winfrith site;
- Land contaminated with radioactivity to 'in scope' levels. Optimisation assessments have demonstrated that remediation of radiologically contaminated land is the preferred approach;
- The Winfrith Sea Discharge Pipeline, ancillary equipment and any potentially contaminated land. Optimisation assessment has shown that the preferred approach for the Pipeline is to remove all wastes, equipment and potentially contaminated land.

In meeting the GRR, the SWESC, WMP and supporting documents provide details of how these areas will be managed through the remaining lifecycle of the site, however there is no intention for these areas to be managed as on-site disposals.

5 APPLICATION OVERVIEW

To enable the proposed on-site disposals NRS is applying for:

- A variation to the site's RSR permit (EPR/PB3898DC), for the disposal of the low-level radioactive waste on-site, including:
  - Disposal in-situ of below ground structures at the SGHWR and Dragon reactors and associated with the Dragon mortuary holes and B78 base slab;
  - Disposal of radioactive wastes generated in demolition of above ground structures at both SGHWR and Dragon reactors for the purpose of filling the SGHWR and Dragon underground voids.
- A DfR permit, to enable the recovery of non-radioactive wastes generated in demolition of the above ground structures and waste currently stockpiled at D630 for the purpose of filling the underground voids.
- Planning permission to undertake the waste activity, engineering and restoration activities elsewhere on the site as well as the change of land use for the site.

A large volume of technical work has been completed to underpin these applications. The project has been developed by an integrated team that has considered all of the regulatory and engineering requirements together. The applications (GRR, DfR and Planning) therefore share many common documents to ensure they are consistent and coherent. Additionally, the GRR and DfR applications specifically have a common non-radiological inventory and hydrogeological risk assessment to fully represent the risks associated with the activities proposed for SGHWR and Dragon.

5.1 Context of this application

The SWESC and WMP provided with this application are in compliance with the EA's requirements as set out in the GRR, in that they are site wide documents that demonstrate the overall approach to waste and environmental management for the remaining lifecycle of the site operations and activities required to achieve the end state.

NRS is seeking to vary the Winfrith RSR Permit to allow on-site disposal at SGHWR and Dragon facilities only. These facilities, and the proposed disposals to be constructed are addressed in detail through the underpinning to the SWESC and WMP. All other areas of the site will be remediated to levels suitable to be defined as Out of Scope of RSR prior to reaching the end state.

The NRS Winfrith site is progressing towards the IEP, which is currently programmed to be achieved before 2040. The end state includes making on-site disposals at SGHWR and Dragon as a core part of delivering the next planned land use for the site of Heathland with Public Access. To that end, this application includes provision for disposals at both the SGHWR and Dragon reactors, as well as the Dragon mortuary holes and B78 base slab as these operations will commence in relatively close succession.

Following the end state, there will be a period of Stewardship of the site where the disposals (and recovery activity) will continue to be permitted, with on-going monitoring and management of the disposals. Once the Stewardship period has demonstrated that the performance of the disposals is as expected , NRS will request to surrender the Environmental Permit at the SRS.

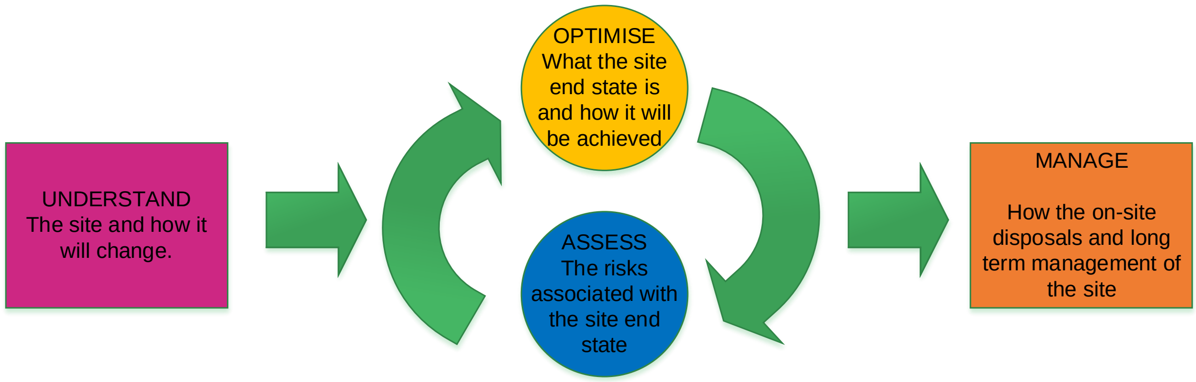
There are no other planned on-site disposals at Winfrith, therefore this is expected to be the only request to vary the site environmental Permit to support on-site disposals. Further submissions of the SWESC and WMP are planned, to reflect completion of the disposals (if approved), the site reaching the end state, routine updates through the Stewardship phase and finally as demonstration that the site has achieved its SRS.

The building blocks of the GRR application can be grouped into four categories:

- Understanding the site now and how it will change through the end state and in climate change conditions;
- Optimising the Winfrith end state and how it will be delivered;
- Assessing the risks of the proposed end state and comparing these against the relevant requirements;
- Manage, how the disposals will be controlled to ensure that they are implemented in accordance with the requirements of the SWESC and WMP.

These component parts have and will continue to be developed in an iterative approach that ensures that the design of the proposed disposals is further optimised. This approach is illustrated in Figure 2.

Figure 2: Process for developing the case that underpins the GRR application



The following sections deal with the main activities shown in Figure 2.

Understand

This work has identified the site's characteristics both now and in the future, including:

- The **Site Description** (Ref. 5) outlines the principal features of the site e.g., location, geology, habits/land use, effects of climate change and the features of the site that will remain at the IEP;
- The **Hydrogeological Interpretation** (Ref. 6) describes the occurrence, movement and quality of the groundwater on the site both now and in the future;
- The Conceptual Site Model (**CSM**) (Ref. 7) defines the source, pathway and receptor model for the site;
- The Site Wide Materials Management Plan (**SWMMP**) (Ref. 8) defines the volume of voids and waste material generated by the demolition of the remaining concrete structures on-site (including SGHWR and Dragon);
- The climate change assessment (Ref. 9) models how the site's natural processes might be altered as a result of different climate change scenarios;
- The soil and groundwater radiological and chemical backgrounds (Ref. 10) for the site;
- Radioactive (Ref. 11) and Non-Radioactive Inventories (Ref.12) for the proposed disposals.

Optimise

This work includes three main elements a) community and stakeholder engagement, b) assessment of waste management options and c) development of compliant and optimised engineering design for the disposals. This work has determined that disposal of the SGHWR and Dragon reactors on-site has local community support, is optimised and can be implemented successfully;

The WMP provides a detailed summary of the options assessments completed thus far as well as an outline of the planned further work;

Details of how the local community has been engaged in the decision-making is presented within the Statement of Community Involvement (Ref. 13);

The Design Substantiation Report (**DSR**) describes the concept design for the disposals and the engineering assessments that have been completed in developing the design (Ref. 14).

Assess

The risks and potential impacts from the proposed disposal have been assessed:

- Risks from radioactive contaminants are assessed within the Performance Assessment (**PA**) (Ref.15);
- Risks from non-radioactive contaminants are assessed within the Hydrogeological Risk Assessment (**HRA**) (Ref.16);
- Compliance with groundwater regulations (both now and under future climate change conditions) are assessed within the Groundwater compliance report (Ref. 17);
- Hydro-ecological assessment, considers how the disposals and preparations for the next planned land use might alter groundwater pH and the impact this may have on the acidic heathland habitat (Ref. 18).

Manage

NRS has developed a set of management plans that detail how the disposal and recovery activities will be controlled, developed or managed, i.e.:

- How the inventory will be further developed prior to the disposals taking plan is described within the Staged Inventory Management Plan (**SIMP**) (Ref.19);
- The disposals will be controlled in accordance with the Emplacement Acceptance Criteria (**EAC**) (Ref. 20);
- The plans for monitoring the performance of the disposals within the Environmental Monitoring Plan (**EMP**) (Ref. 21) and how the site will be managed through to the SRS in the **Stewardship Plan** (Ref. 22);
- The Construction Quality Assurance Plan (**CQAP**), sets out how the disposal's design will be implemented (Ref.23).

Question 1: About the Permit being varied

This application is with reference to the NRS Winfrith nuclear site, Permit number EPR/PB3898DC.

Question 2: Other Applications

NRS is submitting an application for an Environmental Permit to undertake Deposit for Recovery activities on the Winfrith site, alongside and in parallel with this RSR application. The applications, and their associated activities, relate to the same physical locations (SGHWR and Dragon).

Question 3: About your proposed changes

3a: Type of variation

This application is in support of a request to vary the radioactive substances activity Permit currently held by NRS for the Winfrith site to allow on-site disposal of solid radioactive wastes. The SWESC and WMP provided with the application support this proposal, alongside underpinning technical reports and data.

3b: Changes to disposal of radioactive waste

NRS requests a permit variation for the following activities:

- In-situ disposal of the SGHWR and Dragon reactor basement structures to remain in place;
- In-situ disposal of the Dragon mortuary holes and the B78 base slab;
- Disposal for a purpose of radioactive wastes to be used in backfilling the SGHWR and Dragon reactor basement structures, to a level suitable for capping and reinstatement of habitats in preparation for the sites next land use.

3c: Provide a technical description of your on-site disposal of radioactive waste

The Winfrith nuclear site, located in Dorset, is a former nuclear power research and development site, which housed research and prototype reactors as well as laboratories. The site included nine experimental reactors in total, each with a unique design, with construction commencing in 1957 up the point when the last operational reactor shut down in 1995. The site, owned by the Nuclear Decommissioning Authority (NDA) and operated by NRS, is currently being decommissioned. The SGHWR and Dragon reactor buildings are located towards the western boundary of the Winfrith site as shown in Figure 3. The B78 fuel storage building containing the Dragon reactor mortuary holes and B78 slab lie north-northeast of the Dragon reactor (Figure 4).

Figure 3: Principal features of the Winfrith Site and its surroundings

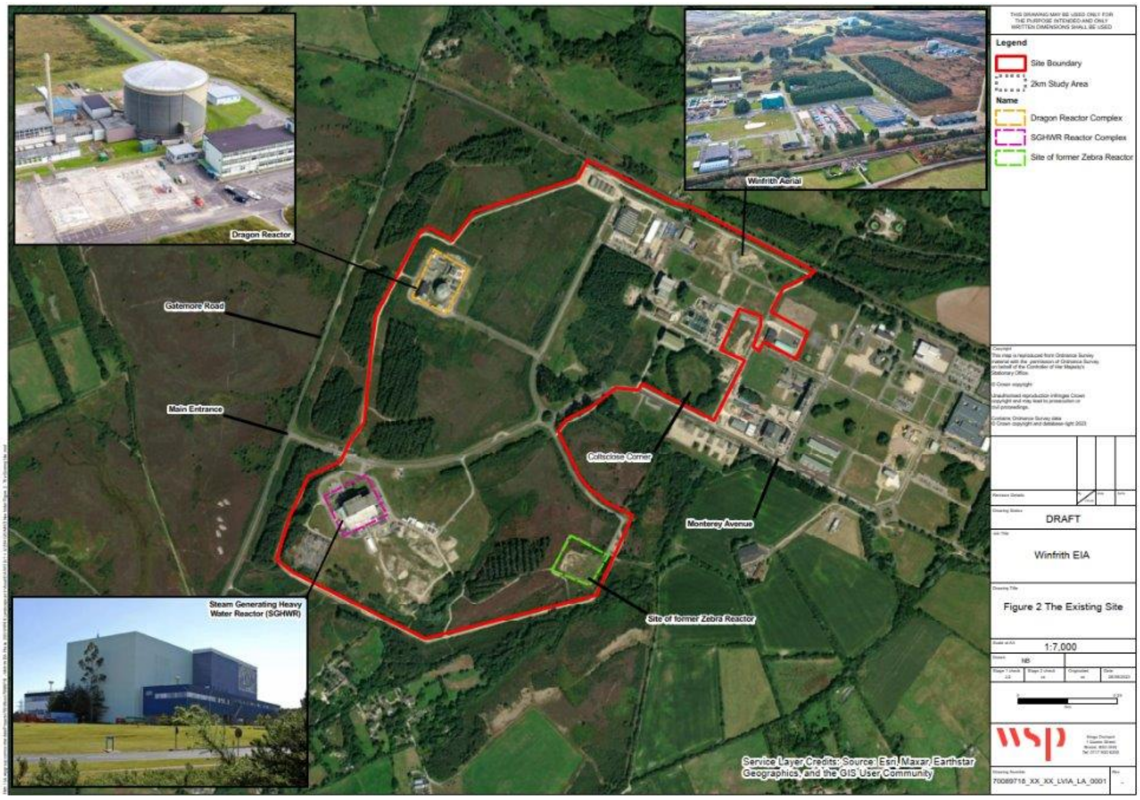


Figure 4: Aerial photograph of the Dragon reactor complex showing location of the mortuary holes

SGHWR

The SGHWR building comprises 10 levels, three of which are below the level of the surrounding ground surface (below ground). Above ground, the structure is a steel-clad metal frame with masonry (brick) and concrete internal structures. Below ground, the structure is mainly formed from reinforced concrete. Although SGHWR comprises many rooms, the below ground level structure can be simplified into four regions:

- Region 1: The reactor bioshield, primary containment and immediate surrounds;
- Region 2: The steam labyrinth to the west of the primary containment, the delay tank room, and turbine hall;
- The South Annexe, including the pump pit to the north of the turbine hall; and
- The North Annexe.

A summary of the floor slab elevation and thickness of the floor in each region of the SGHWR is presented in Table 1.

Table 1: Summary SGHWR below ground structures

Component	Top of Floor Slab Elevation (m AOD)	Floor Slab Thickness/Description
SGHWR Region 1	28.8	2.74 m thick reinforced concrete
SGHWR Region 2	30.6 to 35.4	Turbine hall - 2.74 m reinforced concrete Delay tank room - 0.91 m reinforced concrete Steam labyrinth 0.69 m reinforced concrete
SGHWR North Annexe	37.8	Typically, 0.33 m reinforced concrete
SGHWR South Annexe	35.4 to 36.6	Variable – between 0.23 m and 0.53 m reinforced concrete

In preparation for the End State, the concept design is for SGHWR to be demolished to 1m below ground level (m bgl). Most internal walls in the subsurface structure will remain in-situ unless they need to be removed to allow deposition of the infill material.

A plan and cross section view of SGHWR is presented in Figure 5 and Figure 6.

Figure 5 Plan showing the four regions of the SGHWR building.

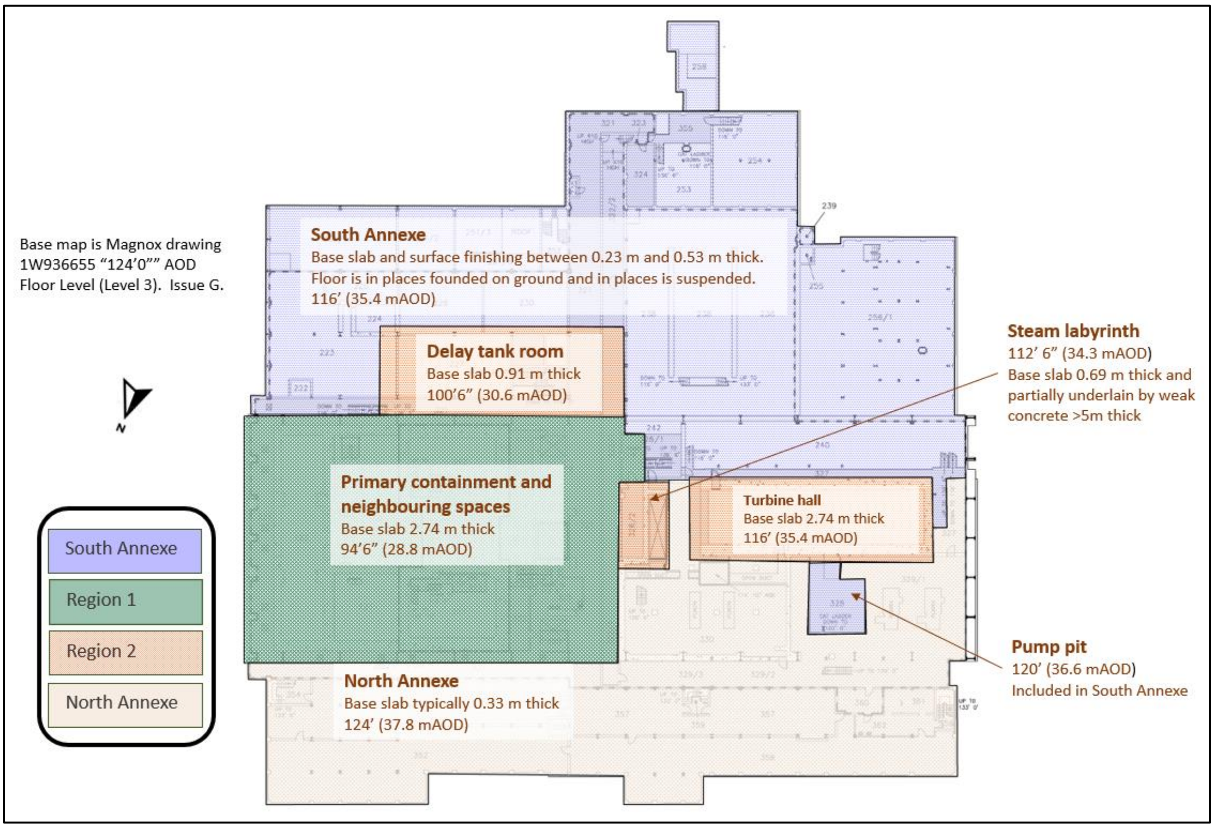
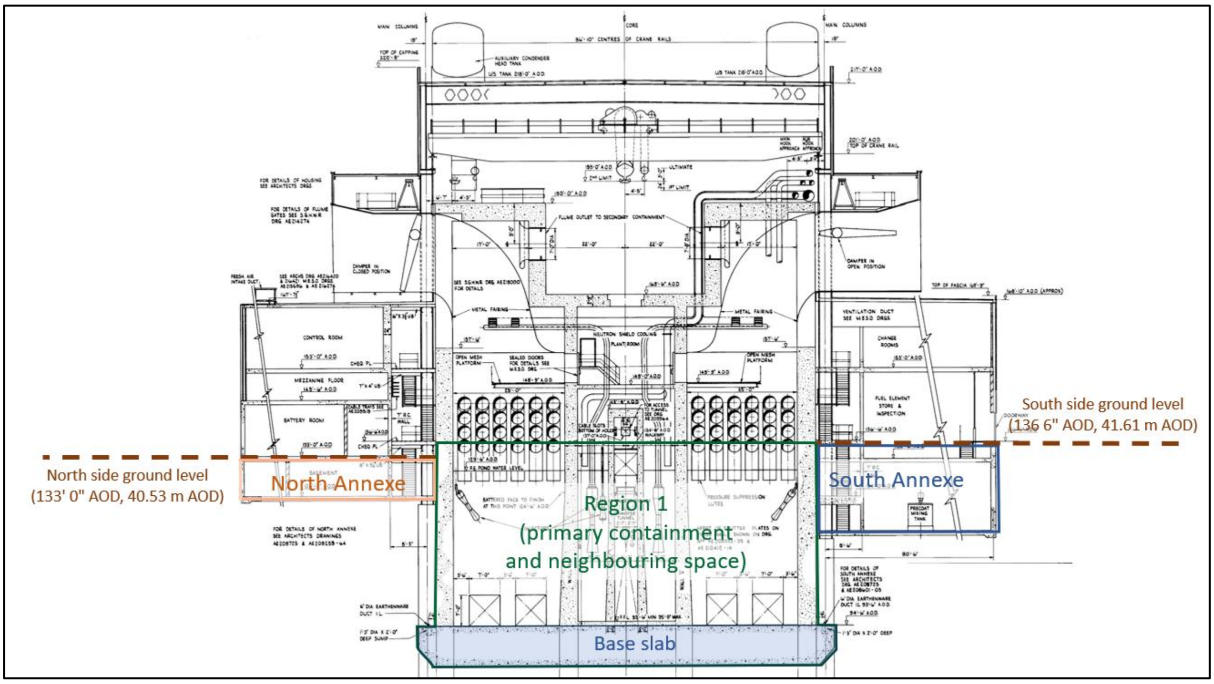


Figure 6: Cross section through the SGHWR building



Dragon

The elevation of the top of the floor slab of the Dragon reactor is 27.34m AOD and its base slab is typically 3.7m thick reinforced concrete.

The Dragon reactor is shown in plan on Figure 7 and in cross section on Figure 8. The Dragon reactor is circular in plan-view and has four concentric concrete walls referred to sequentially from the outside in as Wall A, Wall B, Wall C and Wall D. There are penetrations between Wall A and the services duct. Wall B includes brick-filled apertures. A steel shell is located within a void between Wall B and Wall C. The reactor reinforced concrete bioshield is referred to as Wall D.

Figure 7: Plan showing the four regions of the Dragon building.

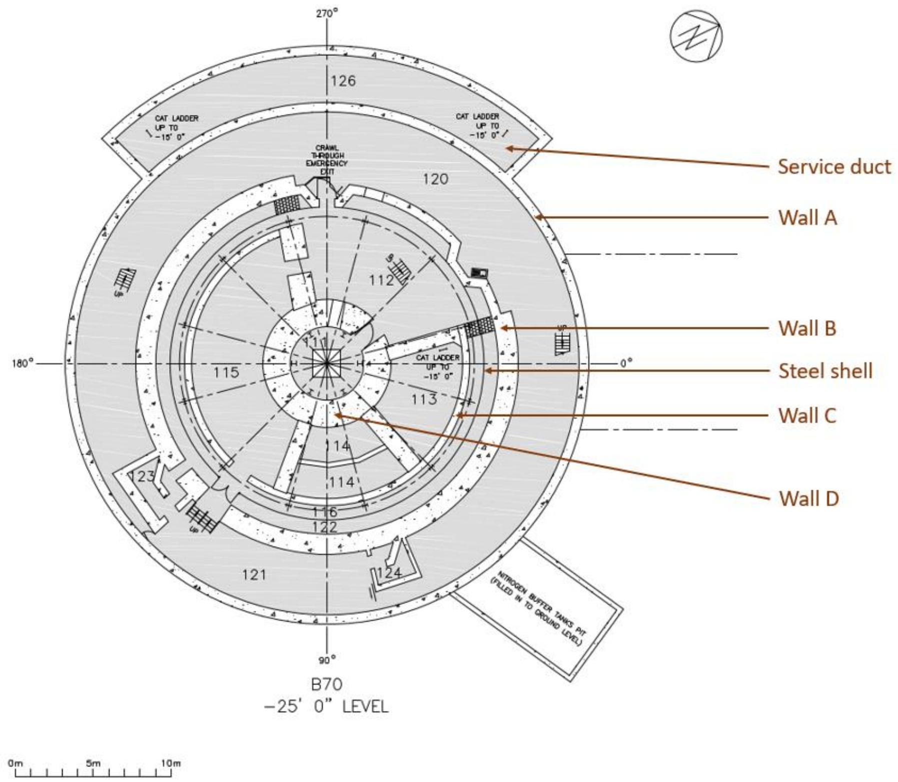
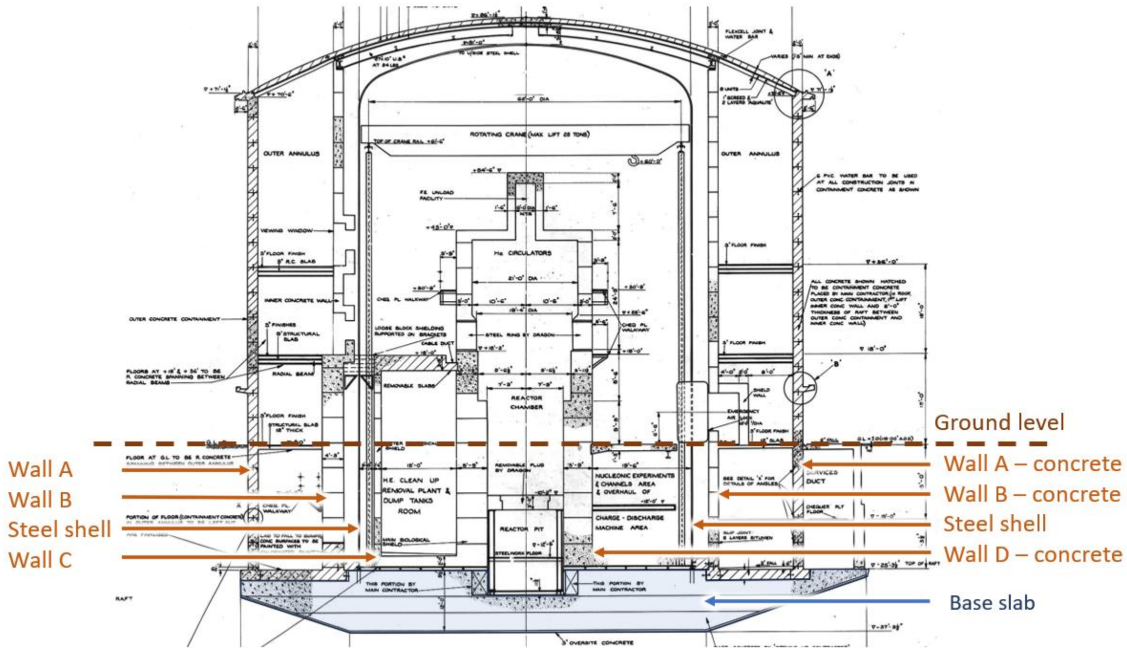


Figure 8: Cross section through the Dragon building



Dragon mortuary holes and B78 base slab

The Dragon mortuary holes are located to the north of Dragon. The mortuary holes comprise a pit excavated below ground level and infilled with concrete, within which were housed galvanised mild steel holes for storing spent fuel. The basal elevation is approximately 30.3m Above Ordnance Datum (AOD). The primary mortuary holes system comprises 50 vertical mild steel storage holes, with external diameter 0.27 m, wall thickness 13 mm and depth 4.2 m.

The top of the mortuary holes sit flush with the B78 base slab (which covers the footprint of the building at ground level).

Disposal end state concept designs

End state concept designs have been developed for the SGHWR, Dragon and mortuary hole disposals.

In broad terms, the SGHWR and Dragon below ground concrete structures will remain in place. The in-situ structures include both radioactively contaminated wastes and out of scope wastes. Internal walls in the below ground structure will remain in-situ unless they need to be removed to gain access for deposition of the infill material.

The below ground voids will be backfilled with a combination of large concrete blocks and demolition rubble. Blocks will be generated from cutting of above ground structures and will be preferentially placed in the deeper parts of the reactor basements. The blocks and rubble will also include both radioactively contaminated and out of scope demolition arisings.

The SGHWR structure will be filled to approximately 1m below ground level. The Dragon structure will be backfilled to the current ground level, which is lower than the current local topography.

The Dragon mortuary holes sit at ground level. There is no intent to modify or alter the existing configuration as part of the end state. The mortuary holes will be filled with cementitious materials to stabilise remaining contamination.

The SGHWR and Dragon (including mortuary hole and B78 base slab) disposals will be covered with an engineered cap to prevent human or animal intrusion and to inhibit surface water ingress. The engineered caps will in turn be covered with locally derived soil to enable reestablishment of habitats.

Concept designs have been developed for both SGHWR and Dragon disposals in accordance with the Harwell-Winfrith Design Management manual (Ref. 24) and these are detailed within the DSR (Ref. 14). The **DSR** is underpinned by substantial technical assessments and studies.

The concept design will be developed to a detailed design suitable for implementation. This will include input from specialist contractors and incorporating any requirements from the environmental permits and planning permission. The requirements for environmental performance in the detailed design are specified through a set of functional requirements (FR's) (Ref. 25). The functional requirements must be met through the detailed design and implementation works.

Once complete, the disposals be subject to a period of on-going monitoring and assessment.

Disposal context

The site is located within the low-lying valley of the River Frome. The site is bordered by two rivers. To the north, the River Frome and, skirting the south-east of the site, the smaller River Win (a tributary to the Frome). The site itself is relatively low-lying, with ground elevations ranging from 20 m AOD to 50 m AOD, and with the ground sloping downwards towards the Rivers Win and Frome from the summit of Blacknoll Hill at 62 m AOD just south of the south-west corner of the site.

The bedrock geology of Dorset is dominated by Cenozoic and Mesozoic formations that are folded in a broad synclinal basin, termed the Wareham Basin. The main Cenozoic Groups underlying the Winfrith site are the Bracklesham and Thames Groups, of which the Poole and London Clay Formations are the main units, and these are underlain by the Mesozoic age White Chalk, of which the local formation is termed the Portsdown Chalk Formation.

During preparations for the end state, NRS will return the site to a more naturalised hydrological function. This will be achieved by removing or blocking the site drainage system and introducing a passive water management system that will both encourage a wet-heathland habitat and protect neighbouring areas from flooding.

The **Hydrogeological Interpretation** report presents an assessment of the occurrence and movement of groundwater at the Winfrith Site under current and predicted future conditions (Ref. 6). It includes details of the present-day topography, meteorology, geology, hydrology, hydrogeology, below ground structures (including drainage) and groundwater quality.

Of importance to the near surface hydrogeology of the site are the Poole Formation and London Clay Formation geological strata which directly underlie the Site. In addition, developed parts of the feature areas of made ground and head/river terrace deposits are present across much of the site (up to 4m thick).

A description of the local environment, and the source, pathway, receptor model is provided within the site's **CSM** (Ref. 7), this outlines:

- How contaminants will migrate through the SGHWR and Dragon end state structures;
- The saturated and unsaturated pathway through the geosphere;
- How dissolved contaminants will attenuate through the geosphere pathway (e.g., via dilution, dispersion, biodegradation sorption/desorption and radioactive decay);
- How alkalinity will attenuate in the disposal and in the environment.

The CSM also describes the different receptors relevant to the proposed disposals, i.e.:

- Groundwater (as a receptor);
- Water dependant terrestrial ecosystems (wet heath, acid mire);
- Surface waters (rivers Win and Frome).

Question 4: Operating techniques

<u>4a - Describe how you manage the on-site disposal of solid radioactive waste to protect the environment and to optimise the protection of members of the public.</u>

The optimised approach to management of radioactive wastes has been assessed in accordance with industry best practice and as set out in company standard S-391 (and preceding procedures). A structured approach to defining and assessing the relative performance of options has been followed throughout the development of the proposed end state.

Options assessments completed to define the end state for structures have included attributes to specifically address the potential risks and impacts that would be associated with on-site disposals have been included where required, notably:

- Public dose – site land condition;
- Time to significant hazard reduction;
- Conventional risk to the public;
- Radiological impacts on the Environment: Site Land Condition;
- Non-radiological impacts on the Environment: Site Land Condition;
- Loss of amenity value;

- Development risk;
- Future burden.

In some options assessments, additional attributes have been defined to address potential challenges from on-site disposals that are not addressed in the above attributes. These include blight and landowner views in relation to the Sea Discharge Pipeline options assessment and impact on national disposal capacity in relation to the SGHWR structure optimisation.

The performance of options has been assessed for the remaining site lifecycle, up to the SRS. For example, estimates for on-site disposal options included costs for stewardship and liability management, as well as the on-going risk to people and the environment.

In accordance with the requirements of the GRR (Requirements 3 and 4) community and stakeholder engagement has been sought throughout the options assessment process and development of the end state and proposals for on-site disposal. At a strategic level (GRR Requirement 1), the options assessment panel for managing the structures at SGHWR and Dragon included representatives of the community and local stakeholders (Natural England, Dorset Council, Dorset Wildlife Trust). At a detailed level (GRR Requirement 13), when defining the preferred approach to implementing the disposals, the weighting of attributes reflects the priorities identified by stakeholders and through local community engagement.

The **WMP** demonstrates that the End State for the site, and the individual radioactive components, is optimised as set out in Table 2.

Table 2: Summary of optimisation assessments in accordance with Requirement 1 of the GRR

Feature/Assessment reference	Preferred option	Key benefits of preferred approach
Active Liquid Effluent System (ALES) facility	Disposal off-site	Insufficient underground voids available to support on-site disposal.
Sea Discharge Pipeline – shallow sections	Disposal off-site	Removes the hazard and long-term liability from third party land and allows near term re-development.
Sea Discharge Pipeline – marine sections	Disposal off-site	Consistent with Policy and Guidance on off-shore Pipelines. Removes liability and maintenance requirements.
Sea Discharge Pipeline – deep sections	Disposal off-site	Compliance with groundwater regulations and protection of groundwater resources.
A59 land area	Remediate ground to out of scope levels	Removes the hazard and long-term liability from third party land.
D69 land area	Remediate ground to out of scope levels	Removes hazard and is lowest cost.
SGHWR	***Disposal on-site***	Reduced worker risk, environmental impact and cost.
Dragon reactor, B78 base slab and Mortuary Holes	***Disposal on-site***	Reduced worker risk, environmental impact and cost.

On-site disposals (disposal in-situ and for a purpose) are the optimised End State for SGHWR and Dragon structures as this approach:

- Reduces worker risk, through minimising high risk operations such as excavating foundations, and minimising overall worker hours;
- Minimises impact on local communities and habitats through minimising road transport and minimising excavation requirements on-site, therefore minimising nuisance;
- Minimises road transport miles and carbon footprint as it minimises the amount of waste being managed off-site;
- Can deliver the next planned land use of Heathland with Public Access in shorter timescales;
- Reduces cost and site decommissioning programme.

Options assessments have also been used to define the Best Available Technique (BAT) for implementation of the disposals:

- The preferred method and configuration for backfilling voids is to place large concrete blocks in the deepest parts of structures. This supports the structural integrity during implementation, minimises dust generation and operative risk during implementation, minimises the potential for leachate generation by controlling the surface area and reduces the risk of differential settlement across the disposal (Ref. 26);
- The levels of decontamination required in specific areas of Dragon has been defined, balancing short term doses to operatives and long term risks to the environment;
- The BAT for managing non-radiological contaminants present in structures, such as steel, bound/encapsulated asbestos, fibre glass and oil staining on structural concrete.

It is anticipated that further detailed options assessments will be required as the concept designs evolve into detailed designs and the demolition plans are finalised.

The SWESC demonstrates that the proposals for the site end state, including on-site disposals, ensure risks to individuals and the population are As Low As Reasonably Achievable (ALARA). The SWESC is supported by detailed radiological risks assessments, set out in the radiological Performance Assessment (**PA**), that assesses risks from natural evolution of the site, site occupancy and inadvertent human intrusion into the proposed disposals. The scenarios addressed include expected evolution, a range of climate change scenarios and bounding ‘what-if’ worst case events. The risk assessments are based on the **Radiological Inventory** prepared as cautious estimate of the contaminants remaining in the end state.

As of the date of submission of this application, the outcome of this process is an optimised “Concept Design”, as set out in the DSR. The configuration of the proposed disposals has been assessed as set out in the SWESC and meets all dose and risk guidance levels set out in the GRR (Requirements 9, 10, 11 and 12). The DSR also demonstrates how the proposed disposals will meet the groundwater requirements, notably ‘prohibition’ of direct discharges to groundwater and ‘prevent and limit’ of indirect discharges.

Implementation of the End State for the reactor disposals will need to be in accordance with the SWESC, DSR and supporting risk assessments to ensure compliance with GRR and groundwater regulations.

Management arrangements for implementation of disposals

NRS has a strong environmental safety culture that is underpinned by mature management arrangements. These aspects are described in detail within the SWESC and are summarised below.

Environmental safety culture

All staff and on-site contractors (as appropriate) are required to undertake mandatory training both upon starting within the company and on an annual 'refresher' basis. This includes training on specific safety issues (e.g. environment, radiation and fire safety) as well as training on expected behaviours for fostering a respectful work environment (e.g. diversity, equality and discrimination).

Specific roles in NRS that relate to safety, security and environmental compliance are managed through Authorisation Instructions. This process requires those seeking an Authorisation have to demonstrate suitable training, qualifications, experience and on the job training to be appointed into a position. Individuals cannot undertake roles until they have received appropriate Authorisations.

NRS and Winfrith management arrangements

NRS controls its activities through a written management system that defines and implements its mission to safely and securely deliver its 12 sites to closure. This includes policy statements, process documents and topic specific standards that together ensure that work is identified and executed to the correct standards in an integrated manner. The Winfrith management manual (Ref. 27) implements the company management arrangements on the site.

The site manual specifies the organisational structure at the site and this is kept under review to ensure that it meets the changing needs and priorities of the business. This structure includes specific roles and responsibilities for ensuring compliance with radioactive substances regulations.

Arrangements for complying with the limits and conditions of the site's legal commitments (including those that relate to compliance with RSR) are specified and persons responsible for compliance are suitable trained and qualified for these roles.

Environmentally significant plant and operations are identified, maintained and subject to review or maintenance as appropriate. Records are made and appropriately stored of all aspects of RSR compliance including decision making, monitoring, measurements and training.

Finally NRS employs several measures to ensure that it identifies and learns from operational experience i.e. improvement programme; assurance programme; corrective and preventative actions; and management review.

End state management controls

A number of management arrangements have been developed that detail how the disposals (and deposits) will be implemented and managed to meet the requirements of the SWESC and underpinning risk assessments, thereby protecting the people and the environment. So far as possible, common approaches have been developed to manage the radioactive disposals (in-situ and for a purpose) and the deposit of non-radioactive waste to ensure consistency and aid implementation.

The Construction Quality Assurance Plan (**CQAP**) (Ref. 23) has been produced to assure construction of the end states of the SGHWR and Dragon are carried out in a manner that is consistent with the claims presented in the SWESC and underpinning assessments. An Application version of the CQAP has been produced which describes:

- Appropriate actions and controls before structures are demolished and demolition arisings are placed in the reactor basements. This includes CQA controls on enhancing the environmental protection function of the below cutline structures, pre-demolition radiological and non-radiological characterisation and verification, and controls on pre-demolition planning;

- CQA of in-process demolition characterisation and backfilling, and in process engineering verification;
- CQA of the engineered cap, drainage and cover soils;
- Post-construction quality assurance.

The CQAP draws from underpinning assessments to define the quality controls on implementing the disposals and constructing the caps to ensure compliance and performance requirements will be met and that doses are ALARA. The CQAP also provides details on the records to be generated and retained on implementation of the disposals.

The CQAP sets out the characterisation required prior to and during implementation to ensure the wastes disposed/deposited are within the criteria stipulated in the SWESC and supporting risk assessments.

The **EAC** (Ref. 20) sets the radiological, chemical, physical and biological acceptance criteria for material remaining in-situ, new material emplaced in voids for engineering purposes and waste disposed/deposited in the voids. Complying with the EAC will ensure that the disposals are compliant with the Claims and Arguments set out within the SWESC.

The EAC are based on the risk assessments and underpinning inventories. The EAC specifies:

- The physical form of wastes that can be used including material types and particle sizes, based on the requirements in the SWESC and underpinning assessments;
- The levels of radioactivity that can be retained or emplaced in the disposals/deposits, based on the current radiological inventories and risk assessments. The maximum activity of individual radionuclides to be disposed of within the proposed disposals and the total limits proposed are presented within the responses for Question 5b;
- The chemical components and contamination levels that can be retained or emplaced in disposals/deposits.

The proposed limits are based upon an estimate of the expected inventory with specific limits set for radionuclides that either make up a large part of the overall inventory or present the most significant dose hazard. A limit is also placed on the total activity of the radionuclides not subject to a specific limit. This approach is outlined within Question 5b.

The Stewardship Plan provides details of how the disposals will be managed and monitored once implemented to ensure the on-going performance requirements are met and to validate the performance of disposals (including aftercare of the deposited wastes). The Stewardship Plan sets out:

- The management control arrangements for the End State following the construction of the proposed disposals and deposits at the SGHWR and the Dragon reactor;
- The environmental monitoring programme that will be carried out to validate the performance of the disposals and the site end state including ensuring protection of people and the environment;
- Confirm the requirements for managing the site into the next planned land use, as described in the Restoration Management Plan (**RMP**) (Ref. 28) through to the SRS.

This Stewardship Plan includes requirements on management of surface features, management of the landscape and habitat and the environmental monitoring required to validate the on-going performance of disposals. The Stewardship Plan is based on underpinning management plans:

- The EMP sets out the environmental monitoring programme required to assess performance of the disposals within the boundaries of the SWESC and the underlying risk assessments;

- The RMP sets out the requirements and approach to managing surface landscape and habitats to ensure disposals are not compromised and legal requirements are met;
- Details of records management required for the proposed disposals (and deposits).

<u>4b Describe how you manage the on-site disposal of solid radioactive waste to protect members of the public and the environment from any non-radiological hazards of the radioactive waste</u>

In parallel to requesting a variation to the Winfrith site RSR Permit, an application for a Environmental Permit for a DfR activity is being submitted. The DfR application is for the use of non-radioactive demolition arisings in backfilling voids, alongside radioactive arisings. The DfR application is supported by an Environmental Setting and Site Description (ESSD) report. There is significant commonality between the SWESC and ESSD.

The GRR and DfR case are supported by a single Non-Radiological Inventory (NRI) that includes all potential non-radiological contaminants present in the end state proposals:

- The non-radioactive constituents of the radioactive waste being disposed in-situ and disposed for a purpose through backfilling (GRR Requirement 15);
- The constituents of recovered non-radioactive waste used in backfilling the voids;
- The constituents of the non-radioactive structures that are to remain in place and are identified as land in-situ and not subject to permitting.

This ensures that the **HRA** (Ref. 16) fully assesses the risks from the proposals, irrespective of the applicable regulatory framework.

A common approach has also been used for assessing risks from non-radiological and radiological contaminants wherever possible:

- A **NRI** has been produced as a cautious estimate of the chemical properties of the completed disposals/deposits;
- The non-radiological and radiological assessments share common approaches for assessment, including a common Hydrogeological Interpretation and CSM;
- A **HRA** has been prepared based on the total inventory and using a tiered approach to the risk assessment in line with EA guidance. The SWESC and HRA also provide details of potential impacts from conventional contaminants of concern, but also assess potential impacts from alkalinity (pH) on sensitive habitats. Risks and impacts have been assessed against national standards or site specific values where appropriate. Notably, habitat specific values for pH sensitivity have been derived based on site data;
- As set out in the **WMP**, options assessments have included the risks and impacts arising from non-radiological properties of the proposed disposals/deposits in determining the BAT approach, for example:
    - The BAT approach to managing oil stained concrete, fibreglass and encapsulated asbestos bound into the concrete has been assessed as part of the overall end state;
    - The BAT assessment for backfilling identified the use of large concrete blocks in the basement structures as the preferred approach as it minimises the potential for leachate generation and supports the long term integrity of the disposals. This option also has the best short term performance in minimising risk to operatives and dust generation from operations.

The EAC sets out the non-radiological properties of wastes (radioactive and non-radioactive) that can be disposed of or recovered as part of the proposals for SGHWR and Dragon. The EAC also applies to any materials (non-waste) in the completed disposals.

The SWESC and underpinning assessments set out how the disposals, including the non-radioactive components, meet the requirements for protection of groundwater (the prohibition of direct discharges to groundwater and requirement to prevent and limit indirect discharges).

This work has concluded that the concentrations of non-radiological contaminants in the pore water, near-field and groundwater are lower than those set out in the relevant national standards and demonstrates an equivalent level of protection to the standards set for directive waste.

Question 5: Disposal of radioactive waste

5a: Provide a description and quantitative estimates of the radioactive waste to be disposed of on site

Location of wastes

As outlined previously, the proposed radioactive disposals consist of:

- Disposal in-situ, of the underground structures of both Dragon and SGHWR;
- Disposal for the purpose of filling the underground voids of Dragon and SGHWR, this will consist of radioactive wastes arising from the demolition of the Dragon and SGHWR above ground structures;
- Disposal in-situ of the Dragon mortuary holes and the B78 base slab.

The radioactive demolition arisings will be supplemented with non-radioactive wastes (recovered under a DfR activity) to complete filling of voids at SGHWR and Dragon. The non-radioactive wastes originate from demolition of the above ground SGHWR and Dragon structures (where non-radioactive) and the D630 rubble stockpiles which were generated from demolition elsewhere on the site.

Categorisation of wastes

The majority of the waste will be Very Low Level Waste (**VLLW**) with a smaller proportion of Low Level Waste. Waste that is above the threshold for Low Level Waste (**LLW**) will not be disposed of as part of these proposals.

The majority of the wastes managed on-site are expected to have specific activity levels less than 200Bq/g. Some activity levels above this are anticipated and will be assessed and optimised on a location specific basis.

Volumes and quantities (in-situ and for a purpose)

The volume of the voids that require filling and the material available for filling the voids is described within the CSM (Ref. 7) and represented within Table 3.

Table 3: Voids and material volumes for SGHWR and Dragon

Component	Void Volume (m^3)[a]	Volume Occupied by Blocks (m^3)	Volume Available for Demolition Arisings (m^3)[b]	Volume Available for Demolition Arisings (Total for the SGHWR/ Dragon reactor)	Volume of Demolition Arisings Generated In Situ (m^3)	Void Volume to be Filled using Material from the D630 Stockpiles (m^3)
SGHWR Region 1	11,649	6,300	5,349	23,439	5,840	17,599
SGHWR Region 2	3,425	None	3,425			
SGHWR North Annexe	4,164		4,164			

Component	Void Volume (m^3)[a]	Volume Occupied by Blocks (m^3)	Volume Available for Demolition Arisings (m^3)[b]	Volume Available for Demolition Arisings (Total for the SGHWR/ Dragon reactor)	Volume of Demolition Arisings Generated In Situ (m^3)	Void Volume to be Filled using Material from the D630 Stockpiles (m^3)
SGHWR South Annexe	10,501		10,501			
Dragon reactor – within Wall C	1,891	400	1,491	6,144	4,891	1,253[f]
Dragon reactor – outside of Wall C	4,653	None	4,653			

The disposals will be completed in two phases. Disposals will be undertaken at Dragon first, with detailed design commencing in 2026/27.

Nature and form

The radioactive wastes disposed on-site will predominantly consist of:

- Bulk reinforced concrete associated with the underground structures being disposed in-situ;
- Concrete blocks and broken concrete and brick from the demolition of above ground structure, being disposed for a purpose.

The Dragon mortuary holes are a solid concrete structure encasing steel lined channels. The mortuary holes, together with the connecting B78 base slab (reinforced concrete), will be disposed of in-situ.

Both the radioactive and non-radioactive wastes will be assessed against the EAC to define what materials can remain in-situ and can be used in backfilling.

Physical and chemical properties

The majority of the radioactive waste to be disposed would, in directive waste classification, be identified as inert and conforming to EWC codes 17-01-01, 17-01-02, 17-01-03 and 17-01-07 (concrete, brick/masonry and tiles/ceramics arising from construction and demolition activities).

In addition to these wastes, BAT assessments have been completed to assess the preferred management approach for non-hazardous and hazardous materials that will be difficult to remove from the in-situ structures, including:

- Structural steel and rebar present in the structures that form the in-situ disposals and large concrete blocks used in disposals for a purpose;
- Asbestos where it has been encast into concrete structures;
- Fibreglass pond liner present on the pond walls;
- Oil stains on structural concrete in the SGHWR below ground structures.

NRS will endeavour to remove all non-hazardous and hazardous wastes, excluding concrete and brick, prior to commencing demolition activities. The EAC sets out what can remain as part of the disposals and the CQAP will be used to ensure contaminants are removed where feasible.

Treatment and storage

The decommissioning, demolition and backfilling process for radioactive wastes will be continuous, with no intention for storage of wastes for any significant periods (>12 months).

There is no intention to treat the wastes. Notably, crushing of wastes has been excluded in the backfill options assessments, as crushing:

- Increases the surface area of the waste, which in turn can lead to generation of higher contaminant concentrations in leachate;
- Can lead to uneven loading and differential subsidence (compared to using large blocks or demolition rubble);
- Can lead to generation of secondary waste through contamination of equipment.

Activity levels and radionuclide breakdown

Assessed levels of radioactivity for the disposals at SGHWR, Dragon and the Dragon mortuary holes (including the B78 floor slab) are set out in the question 5b.

All other radioactively contaminated structures and future waste arisings from the Winfrith site will be managed via off-site routes. The SWMMP sets out the proposed management routes for remaining demolition wastes on-site. The Sea Discharge Pipeline will be removed and managed through an appropriate off-site route.

There is no intention to retain any radioactively contaminated soil as part of the End State. All contaminated soil will be remediated to levels below Out of Scope thresholds.

5b: Provide your proposed limits for the disposal of radioactive waste

The radioactive inventory (Ref. 11) presents a cautious but credible inventory of the planned disposals at SGHWR and Dragon.

This inventory is based upon characterisation and other survey data taken from across both facilities through the decommissioning and waste management process. Certain areas of the facilities are inaccessible, and decommissioning and Intermediate Level Waste (ILW) processing is on-going. Therefore, the inventory provided with the application will develop through to the final decommissioning and demolition of facilities. Care has therefore been taken to ensure the inventory presented is cautious. Where assumptions have been made to provide an estimate an uncertainty has been identified and recorded within the **Uncertainties Management Database** (Ref. 29).

The **SIMP** (Ref. 19), identifies how the inventory will be developed which includes the following 3 milestones:

- Stage 1 – The application inventory (Ref. 11), this inventory is considered to be sufficiently developed to underpin the PA and the SWESC;
- Stage 2 – The pre-disposal inventory. an inventory defined through further characterisation in the remaining decommissioning lifecycle. This inventory will be compared with the application inventory to determine if the associated risk assessments remain valid;
- Stage 3 – The post disposal inventory - a final inventory defined using the records collected through the implementation of the SGHWR and Dragon disposals. Again, this inventory will be checked against previous inventories to ensure the risk assessments are valid and will for the final record of the disposals.

The radioactive inventory (Ref. 11) includes a reference case (which is a cautious estimate) and an alternative case (which is an estimate of the upper bound of the inventory). The potential impacts of both the reference and alternative inventories on people and the environment are assessed within the PA (Ref. 15). The impacts from the reference case have been used to determine the proposed limits for the disposal (Ref. 30).

SGHWR radioactive inventory

The radioactive inventory for the proposed SGHWR disposal is presented within Table 4.

Table 4: SGHWR disposal inventory - reference date 01/01/2027

Radionuclide	Total estimate (MBq)	Percentage of total activity %
^{3}H	4.69E+05	76.63
^{14}C	5.59E+03	0.91
^{134}Cs	2.26E-01	0.00
^{137}Cs	4.13E+04	6.75
^{57}Co	9.33E-03	0.00
^{60}Co	2.29E+03	0.37
^{241}Am	9.49E+02	0.16
^{94}Nb	3.36E+01	0.01
^{125}Sb	2.74E+00	0.00
^{152}Eu	1.89E+04	3.09
^{154}Eu	8.91E+02	0.15
^{155}Eu	3.94E+01	0.01
^{55}Fe	2.20E+03	0.36
^{63}Ni	1.62E+04	2.65
^{90}Sr	1.33E+04	2.17
^{241}Pu	2.65E+03	0.43
^{133}Ba	3.92E+03	0.64
^{99}Tc	4.49E+01	0.01
^{129}I	1.27E+02	0.02
^{36}Cl	1.08E+02	0.02
^{233}U	5.46E+02	0.09
^{234}U	1.07E+03	0.17
$^{235}U^{\#}$	4.00E+02	0.07
$^{236}U^{\#}$	1.84E+01	0.00
^{238}U	1.38E+03	0.23

Radionuclide	Total estimate (MBq)	Percentage of total activity %
^{238}Pu	1.38E+02	0.02
^{239}Pu	6.36E+02	0.10
^{240}Pu	6.27E+02	0.10
^{242}Pu	4.68E+00	0.00
^{242}Cm	4.140E-06	0.00
^{243}Cm	2.20E-01	0.00
^{244}Cm*	1.41E+02	0.02
^{252}Cf*	1.63E-01	0.00
^{226}Ra	4.71E+02	0.08
^{40}K	1.57E+03	0.26
^{39}Ar	1.66E+03	0.27
^{41}Ca	4.11E+03	0.67
^{113m}Cd	1.51E+01	0.00
^{151}Sm	3.07E+03	0.50
^{204}Tl	1.50E+01	0.00
Sub-total	**5.93E+05**	96.90
^{3}H (bulk)	1.86E+04	3.04
Total	**6.12E+05**	100.00

The inventory has a reference date of 01/01/2027 as this would be the earliest disposal date for the Dragon reactor structure. For simplicity the same decay date has been used for SGHWR, although disposal is planned to start a number of years later.

The proposed SGHWR disposal inventory is dominated by tritium (H-3), where the combination of the in-situ and backfill components tritium accounts for nearly 80% of the total inventory. The only other component that constitutes more than 5% of the inventory is Caesium-137 (Cs-137) (6.75%).

Dragon reactor building, mortuary holes and B78 floor slab radioactive inventory

The radioactive inventory for the proposed Dragon disposal is represented within Table 5.

Table 5: Radionuclide breakdown of the estimated inventory for the proposed disposals at Dragon - reference date 01/01/2027

Radionuclide	Total Activity (MBq)			Percentage of total dragon complex activity
	B70 Building Sub-total	B78 Building Sub-total	Dragon Complex Total	
^{3}H	4.23E+03	3.84E+01	4.26E+03	59.75
^{14}C	3.42E+01	5.09E-01	3.47E+01	0.49
^{36}Cl	1.27E+00	0.00E+00	1.27E+00	0.02
^{41}Ca	3.34E+01	0.00E+00	3.34E+01	0.47
^{55}Fe	1.81E+00	4.63E-03	1.81E+00	0.03
^{60}Co	7.70E+00	3.54E-02	7.73E+00	0.11
^{63}Ni	1.38E+02	4.39E-02	1.38E+02	1.94
^{90}Sr	3.33E+02	9.06E+00	3.42E+02	4.80
^{137}Cs	1.81E+03	1.92E+01	1.83E+03	25.67
^{133}Ba	9.76E+01	0.00E+00	9.76E+01	1.37
^{148}Sm	1.87E-27	0.00E+00	1.87E-27	0.00
^{151}Sm	9.50E+00	0.00E+00	9.50E+00	0.13
^{152}Gd	4.02E-12	0.00E+00	4.02E-12	0.00
^{152}Eu	2.04E+02	0.00E+00	2.04E+02	2.86
^{154}Eu	5.59E+00	0.00E+00	5.59E+00	0.08
^{210}Pb	3.47E-01	1.16E-02	3.58E-01	0.01
^{226}Ra	6.63E-01	2.21E-02	6.85E-01	0.01
^{228}Ra	8.80E-03	2.94E-04	9.10E-03	0.00
^{227}Ac	1.51E-05	5.14E-07	1.56E-05	0.00
^{228}Th	6.76E-03	2.25E-04	6.98E-03	0.00
^{229}Th	1.69E-13	1.59E-04	1.59E-04	0.00
^{230}Th	1.69E-02	5.78E-04	1.75E-02	0.00
^{232}Th	1.35E-02	4.49E-04	1.39E-02	0.00
^{231}Pa	1.18E-04	4.15E-06	1.22E-04	0.00

Radionuclide	Total Activity (MBq)			Percentage of total dragon complex activity
	B70 Building Sub-total	B78 Building Sub-total	Dragon Complex Total	
^{233}U	6.17E-10	4.88E-01	4.88E-01	0.01
^{234}U	7.38E+00	5.55E-01	7.93E+00	0.11
^{235}U	3.32E+00	2.41E-02	3.35E+00	0.05
^{236}U	0.00E+00	2.67E-04	2.67E-04	0.00
^{238}U	3.48E+01	8.52E-02	3.49E+01	0.49
^{237}Np	3.29E-05	2.19E-06	3.51E-05	0.00
^{238}Pu	2.18E+00	8.35E-01	3.02E+00	0.04
^{239}Pu	1.09E+01	1.13E-01	1.10E+01	0.15
^{240}Pu	1.52E+01	1.13E-01	1.53E+01	0.21
^{241}Pu	4.31E+01	2.79E+00	4.59E+01	0.64
^{241}Am	3.51E+01	1.37E+00	3.65E+01	0.51
^{243}Am	0.00E+00	2.66E-08	2.66E-08	0.00
^{243}Cm	0.00E+00	3.27E-02	3.27E-02	0.00
^{244}Cm	7.56E+00	2.84E-02	7.59E+00	0.11
Total	**7.06E+03**	**7.37E+01**	**7.13E+03**	100.00

The Dragon radioactive inventory is also dominated by H-3 (59.8%) with Cs-137 (25.7%) and Sr-90 (4.8%) being also of note.

<u>Defining the disposal limits for SGHWR and Dragon</u>

The PA (Ref. 15) has estimated the possible doses to the public and to non-human biota for a number of reference and variant scenarios, the reference scenario represents a cautious model of how the disposals are expected to evolve.

A review of the peak dose rates through the assessed pathways has been completed to determine appropriate limits for the proposed disposals (Ref. 30). This has included both exposures to people and other non-human biota through the natural evolution and site occupancy pathways.

In defining the proposed limits for the disposals NRS has identified which radionuclides dominate the peak dose rates over the full period of the assessment. Figure 9 shows how the dose rates change with time for the different Representative Persons (RP) modelled.

Figure 9: Dose rates for RPs modelled within the Reference Case

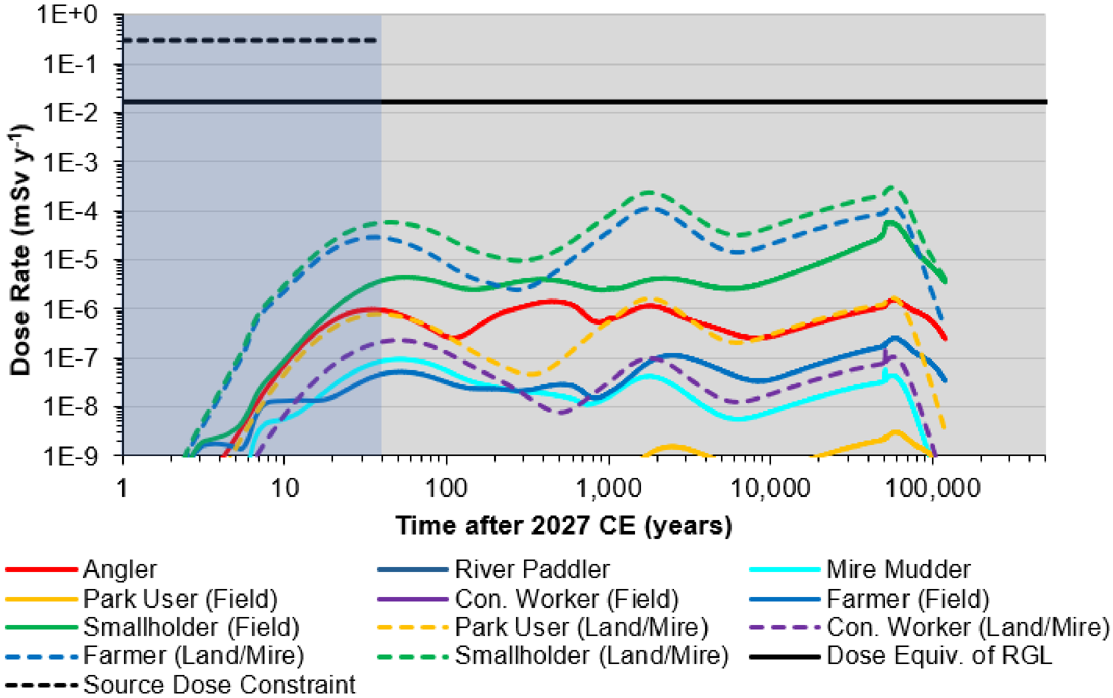


Figure 9 shows that the peak doses rates are associated with the Smallholder (Land/Mire and Field) RPs and the Farmer (Land/Mire) RP. Also, three peaks can be identified which occur ~40 years, ~2,000 years and 50-60,000 years after 2027.

The dominant nuclides associated with these three peaks are constrained by the proposed limits.

The proposed limits for the SGHWR and Dragon disposals are provided within Table 6.

Table 6: Proposed radionuclides for limits within the Dragon and SGHWR disposals (2027 values)

	Total activity limit (MBq)	
Radionuclide	**SGHWR limit[2]**	**Dragon limit[3]**
Sr-90	1.33E+04	3.42E+02
I-129	1.27E+02	-
Ra-226	4.71E+02	6.85E-01
U-233	5.46E+02	4.88E-01
U-234	1.07E+03	7.93E+00
U-235	4.00E+02	3.35E+00
U-238	1.38E+03	3.49E+01
Pu-238	1.38E+02	3.02E+00
Pu-239	6.36E+02	1.10E+01

[2] Values taken from Table 2.47 within Ref. 1.
[3] Values taken from Table 3.46 within Ref. 1.

	Total activity limit (MBq)	
Radionuclide	**SGHWR limit[2]**	**Dragon limit[3]**
Pu-241	2.65E+03	4.59E+01
Pu-242	4.68E+00	-
Am-241	9.49E+02	3.65E+01
Total activity	**6.12E+05**	**7.13E+03**

Question 6: Monitoring

6a - Provide a description of the sampling arrangements, techniques and systems for measurement and assessment of discharges of radioactive and other substances from the disposal

The **EMP** forms a core part of the long term stewardship of the Winfrith site, from the time of the first disposal, until the SRS. The EMP is designed to meet the requirements of validation monitoring in the GRR and the 'aftercare' requirements for the DfR Permit.

The EMP has been prepared in accordance with Company standard for preparing an environmental monitoring plan S-045 (Ref. 31), the Environment Agencies guidance on radiological monitoring (Ref. 32) and the EA's guidance on DfR aftercare and monitoring leachate (Ref. 33 and 34).

The EMP sets out the scope of environmental monitoring required to validate the performance of the SGHWR and Dragon (including mortuary holes/B78 base slab) disposals (Ref. 21). Assessing the performance of the disposals will be limited to:

- Assessing performance of the disposals by measuring migration of contaminants in groundwater;
- Assessing the performance of disposal caps, and their on-going functionality in preventing water ingress into the disposals.

Gas monitoring (in-disposal and ground gas) is not included within the monitoring plan as there is negligible potential for generation of gas, given the restriction on radiological and chemical/biological properties set out in the EAC. In-disposal gas monitoring creates additional risk of surface water ingress into the disposals which is a priority for the disposals.

The risk of non-radiological gas generation is addressed in the ESSD and the potential for radiological gas generation is assessed in radiological PA.

Similarly, in-disposal leachate monitoring has been excluded. The radiological and non-radiological risk from the radioactive disposals and non-radioactive deposits are well below relevant regulatory guidance levels. Therefore in-disposal leachate monitoring would introduce risk of water ingress, without offering substantial benefits in assessing performance.

Groundwater monitoring

Groundwater monitoring will be conducted both up and down-gradient of the proposed disposals to assess and validate whether the disposals/deposits are performing as anticipated in the supporting SWESC and risk assessments.

The EMP has incorporated requirements from the current groundwater monitoring programme at Winfrith:

- Using a quality assurance framework that is compliant with BS ISO 5667-14-2006 (Ref. 35);
- The 'Nuclear Industry Code of Practice for Routine Water Quality Monitoring' (Ref. 36);

- The field procedures, sample collection, storage and despatch are managed by a set of Data Quality Objectives, indicators and assessment criteria;
- Laboratory data quality is assured through using BS EN ISO/IEC 17025:2017 (UKAS) accredited laboratories for all analysis of the groundwater samples.

Groundwater monitoring will occur in boreholes located in positions where contaminants emanating from the two disposals would be detected. Groundwater monitoring is performed by specialists in accordance with a contract specification. This specification details how:

- The depth to groundwater, free product and to the base of each monitoring well is measured;
- Groundwater is purged from the monitoring well prior to monitoring being completed;
- Well head parameters are measured;
- Groundwater is sampled.

Cap and ground settlement

The aim of cap monitoring is to ensure:

- Cap integrity is maintained by assessing whether there has been human or animal intrusion;
- Assess settlement and the risk of differential settlement across the caps;
- Allow early intervention should the cap deteriorate more quickly than expected from the design.

Cap settlement will be assessed in-line with ‘aftercare’ requirements set out in the DfR guidance. In particular, routine visual assessments will be used to assess whether any intrusion or erosion has occurred. Topographic measurements will be taken annually to confirm whether undue settlement has occurred between inspections.

Additional monitoring

In line with the DfR aftercare requirements, meteorological information will continue to be collected.

Habitat monitoring will be carried out periodically to assess whether the restoration objectives are being met. Habitat monitoring requirements are set out in the RMP and reflected in the Stewardship Plan.

Data assessment and management

Field and laboratory data is assessed by suitably qualified and experienced personnel (SQEP) for appropriate quality checks (‘data validation’) prior to being used. The aim of this approach is to identify errors and inconsistencies and the checking will, where possible, be undertaken with sufficient time for laboratory analysis to be repeated within sample holding times. Once validated results will be reviewed by SQEP personnel to trending purposes.

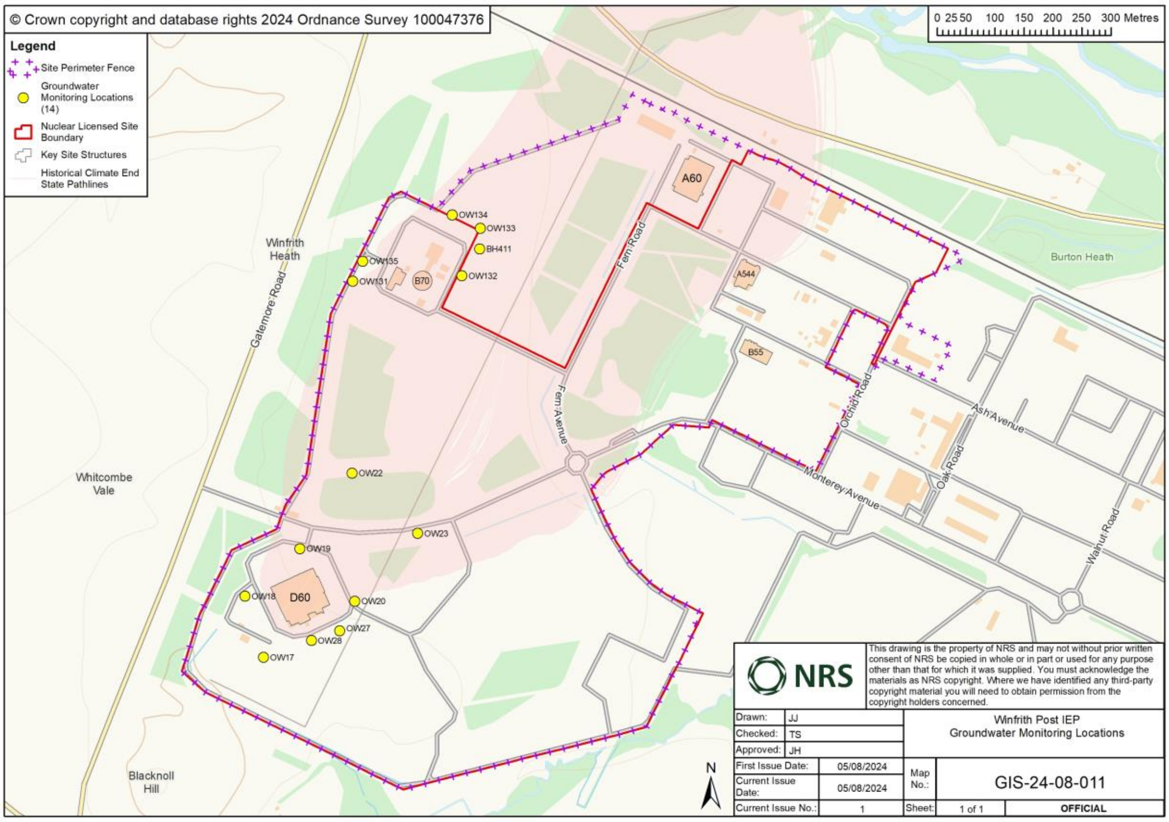
Field and laboratory results are recorded within IMAGES data capture templates and uploaded to the IMAGES database as is currently undertaken as part of the routine monitoring of groundwater and surface water at the site.

The EMP sets out how the current monitoring arrangements will develop when the first disposals are made (Dragon and Dragon mortuary holes), through to the IEP (after SGHWR disposal) and up to the SRS.

6b Provide a description of your environmental monitoring programme.

In summary, this includes groundwater monitoring in the locations identified in Figure 10.

Figure 10: Locations of validation monitoring for the proposed SGHWR and Dragon disposals



The groundwater monitoring will be:

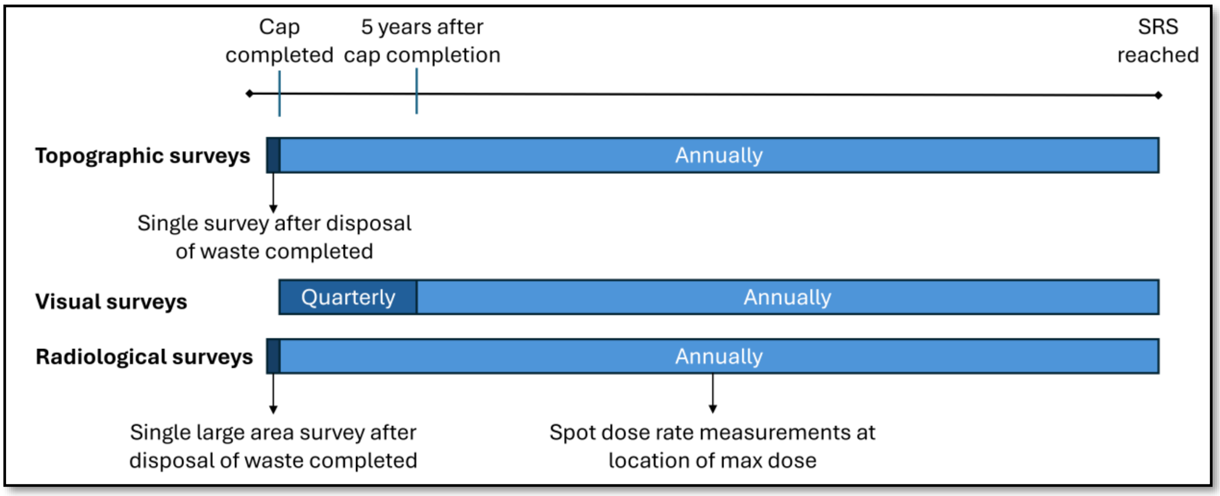
- Continuous measurements of groundwater flow will be taken at OW133 (down gradient of Dragon) and at OW19 (downgradient of SGHWR) from one year before and one year after the disposals. This is to identify if the disposals have an impact on groundwater flow;
- Groundwater will be measured quarterly to ensure that any impact on groundwater quality through seasonal changes in rainfall can be determined.

The selected determinands for analysis of groundwater samples are:

- Gross alpha;
- Gross beta;
- Tritium;
- Gamma spectrometry;
- Metals (dissolved): As, Ba, Cd, Cr (total and Cr(VI), Cu, Hg, Mo, Ni, Pb, Sb, Se and Zn;
- Major ions: Ca, Na, K, Mg, Cl, F, SO4, nitrate, total alkalinity (pH).

The type and frequency of cap monitoring is set out in Figure 11.

Figure 11: Type and frequency of cap monitoring



The EMP will be routinely reviewed throughout the Stewardship period. Where monitoring data indicates performance of any aspect of the disposals is deviating from the expected or modelled standard, the plan will be reviewed and remedial actions taken as necessary. The review requirements and remedial measures are set out in the EMP and the Stewardship Plan.

Question 7: Radiological assessment

Question 7a: Provide a prospective dose assessment at the proposed limits of the disposal

The radiological PA (Ref.15) considers the radiological risk to the public and the environment though three pathways:

- Natural evolution – radioactivity is released from the disposals using a source-pathway-receptor-model. This includes the near field (source), the geosphere (pathway) and the biosphere (receptor). The model includes three biosphere receptors where humans may be exposed to contamination: an on-site Mire, the River Frome and an off-site field adjacent to the River Frome. For most of the assessment cases, the doses have been assessed for a set of seven RPs that are based upon surveys of local habits, these are:
  - Angler;
  - River paddler;
  - Mire mudder (a person participating in a 'tough mudder' obstacle course event);
  - Park user,
  - Construction worker;
  - Farmer;
  - Smallholder.

  A variant case of a well abstractor is also modelled. Doses through the natural evolution pathway have been assessed using the GoldSim modelling software;
- Site occupancy – potential doses resulting from direct shine from the disposals to people using the site have been determined assuming the subsurface contamination is undisturbed. As the site will remain under regulatory control up to the SRS some scenarios are assumed not to occur until after the SRS date (assumed to be 2066). Modelling has been completed using the MicroShield modelling software;
- Inadvertent human intrusion – the doses as a result of intrusions into the disposal is modelled for both the person(s) intruding and to members of the public exposed through reuse of any excavated contaminated material. Doses from this pathway have been assessed using the NRS Generic Intrusion Methodology (GIM) tool.

The radiological PA calculates the doses for:

- A reference case that represents a cautious but realistic assessment of the most likely evolution scenario. This case assumes the reference inventory as detailed within the responses to Question 5;
- A range of variant, alternative and 'what if' cases. These cases test the assumptions made within the model by modifying the parameters to reflect uncertainties, assess the sensitivity of the case to individual parameters and provide a pessimistic assessment of the risks, for example:
    - The natural evolution alternative cases include changes to modelling parameters, conservative interpretations of the inventory, different groundwater release scenarios, reasonable worst case and extreme climate change conditions, different configurations of backfill (blocks, rubble etc.) and instantaneous hydraulic degradation of the underground structures and cap.
    - The human intrusion and site occupancy alternative cases include changes to cap cover thickness, RPs, human intrusion dates and use of the alternative inventories.

Modelled outputs are compared to the:

- Site dose constraint (applicable to the period before the SRS) i.e. 0.3mSv/yr;
- Risk Guidance Level (RGL) (applicable to the period after the SRS) i.e. a risk of death or heritable defect of 10^{-6}/yr. For the RGL, a dose equivalent has been used (1.7E-02mSv/yr) to aid comparison with assessed doses. This approach conservatively assumes that risks do occur (i.e. events have a likelihood of 1);
- Dose Guidance Level (DGL) for inadvertent human intrusions occurring after the SRS. The DGL is 3.0mSv/yr for prolonged exposures and 20mSv/yr for transitory exposures.

This document reports the doses associated with the reference case as well as highlighting any of the alternative cases that are above the dose constraint, RGL or DGL as applicable.

<u>Doses from the A59 land area</u>

As well as doses from the proposed Dragon and SGHWR disposals the PA also assesses doses associated with the A59 land area, which will be remediated to OoS levels before the end state.

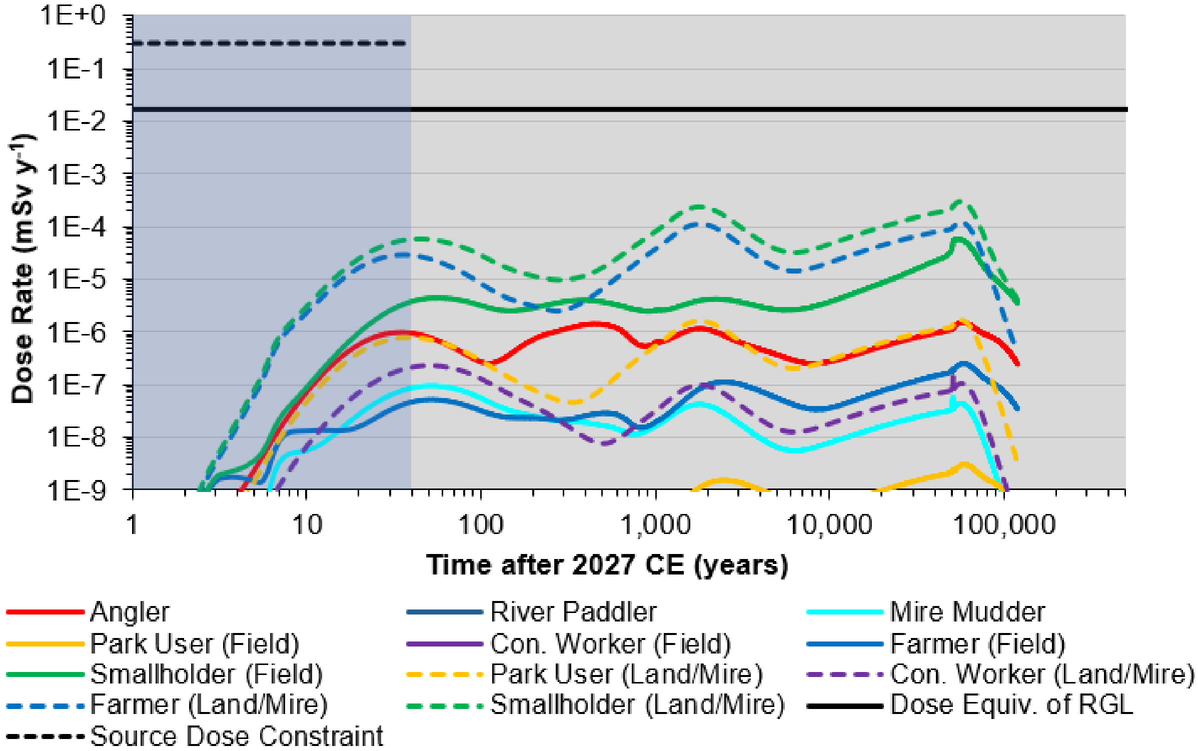
Currently, the A59 land area consists of two areas which are potentially in-scope of RSR and the 'rest of the A59' area which has been demonstrated to be OoS of RSR. The optimised approach for the part of A59 that is potentially in-scope of RSR is to remediate the land to OoS levels (Ref. 37). Following this only OoS soil will remain in place. The potential doses from the OoS soil remaining (i.e. soil that is below regulatory thresholds, but contains some radioactivity) has been modelled and included in the radiological performance assessment and is reported here, in the SWESC and in supporting assessments for completeness and transparency.

As the strategy for A59 is to remediate to OoS, therefore it does not form part of this application to vary the Winfrith RSR permit.

<u>Doses to people through natural evolution of the proposed disposals - Reference case</u>

The dose rates against time for each of the RPs applicable to the natural evolution pathway are presented in Figure 12. The solid black line shows the dose rate equivalent of the RGL and the dashed black line shows the dose constraint to the SRS. Note that this figure only shows calculated dose rates down to 1E-09 mSv y^{-1}, the River Paddler and Construction Worker (Field) RP dose rates are not shown as the associated dose rates are below this level.

Figure 12: Dose rates for Representative Persons modelled within the Reference Case



The PA (Ref. 15) identifies the key dose contributors as Sr-90 (all RPs except the Smallholder (Field)), I-129 (Angler, Mire Mudder and Farmer (Field) RPs), Pb-210 (all RPs), Ra-226 (all RPs except Angler, Mire Mudder and Smallholder (Field) RPs), and certain actinides – Ac-227, Th-229, Th-230, Pa-231, U-234, U-235, U-238, Pu-240 and/or Am-241 (all RPs).

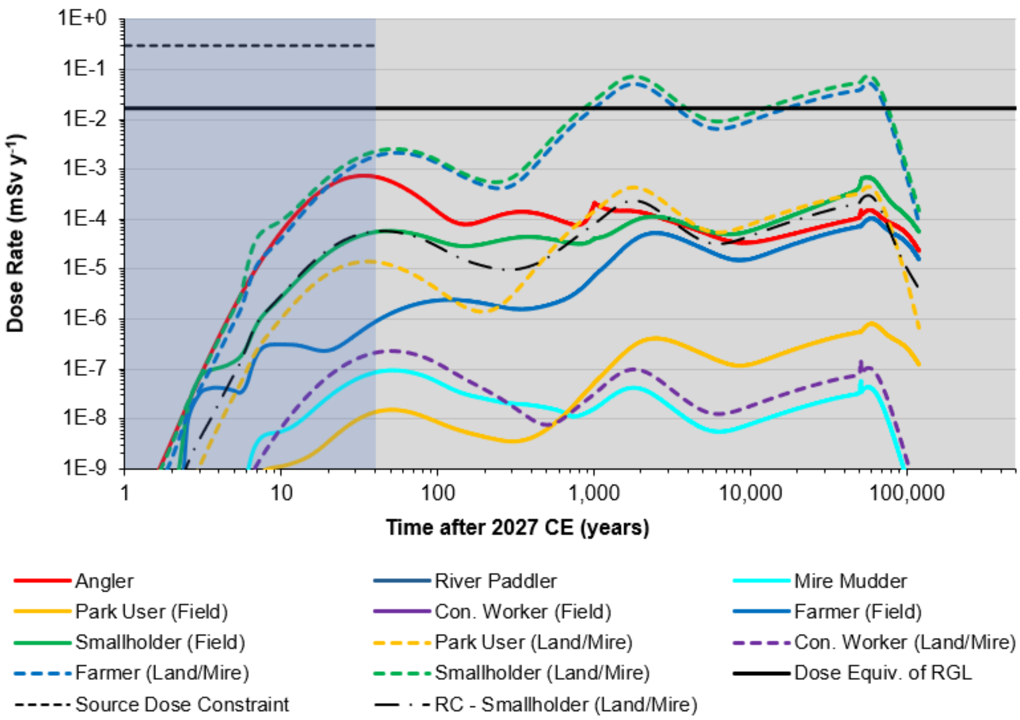
A peak dose of 3.0E-04mSv/yr occurs to a smallholder 56,800 years after the IEP, with the dose dominated by Pb-210. This is 50 times lower than the dose equivalent of the RGL, 1.7E-02mSv/yr.

Alternative/Variant and 'What if' scenarios

The peak doses for all of the alternative, variant and 'what if' scenarios are also below the DGL or the dose equivalent to the RGL, with the following exceptions.

Dose rates are highest for the case considering maximum foodstuff biosphere uptake factors. The peak dose rate for the Farmer and Smallholder RPs in the Land/Mire compartment exceeds the dose rate equivalent of the RGL by about a factor of approximately ten after 1,000 years (Figure 13), however this represents a very conservative assessment. The calculation considers the extreme of the parameter value range for every radionuclide for foodstuff uptake. This model also assumes a probability of one for a smallholder living directly on the contaminated area. In reality the probability would be expected to be much less than one as it would not be reasonable for that the Farmer RP consumes their entire meat and vegetable intake from their own produce produced on a small parcel of land. Moreover, whilst farming in the area is a probable activity, doing so on the contaminated area is less likely.

Figure 13: Dose rates over time to each RP arising from natural evolution of the proposed on-site disposals in Alternative Assessment Case EE.1.16 (maximum biosphere uptake factors). The reference case Smallholder (Land/Mire) RP dose rate is shown for comparison (Ref. 15).



Dose rates to a person consuming all of their drinking water from a well sunk 1m downstream of the A59 land area has a peak dose rate of 1.6E-1 mSv y-1 within 2 years of 2027. The dominant radionuclide is Sr-90. At this time the dose constraint of 3.0E-01mSv/yr applies. Figure 14 presents a time plot for changes in dose rate to a well abstractor from the SGHWR and Dragon disposals and the A59 OoS land area.

Figure 14: Dose rates for the Well Abstractor RP in the variant concept scenarios, with a well located 1 m down-gradient of each feature group

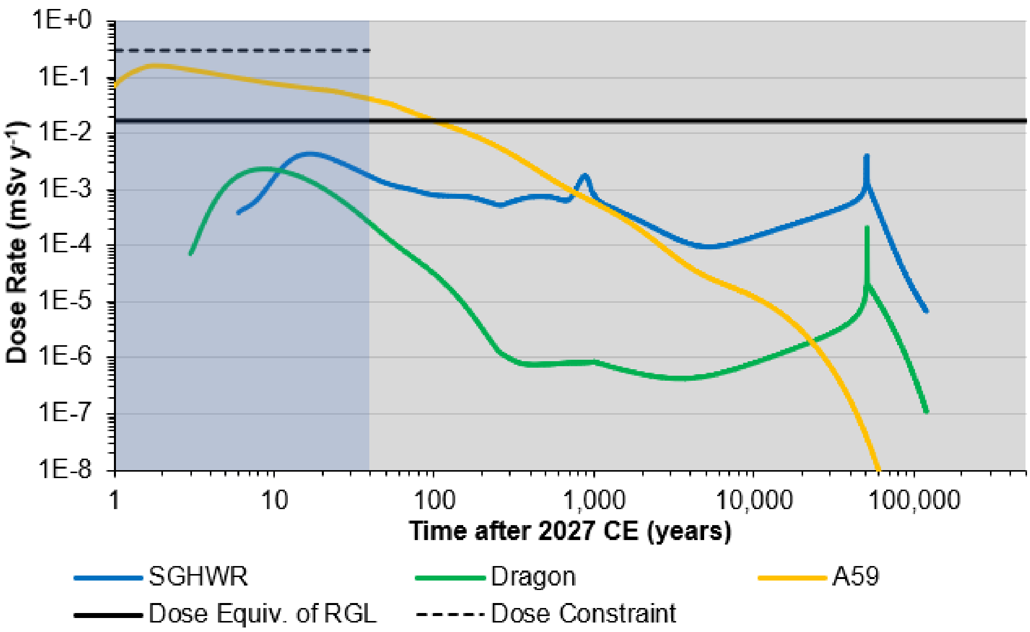


Figure 14 shows that during the period of regulatory control (i.e. before the SRS), the dose to the well abstractor is (for all cases) less than the site dose constraint (0.3mSv/yr). That said, such an activity cannot occur during the period as NRS will retain control of the site and sinking of a drinking water well would not be permitted.

Figure 14 also shows that dose rates to a well abstractor (drinking water from a well 1m downstream of A59) are above the dose equivalent to the RGL between approximately 40 years and 100 years after 2027. The A59 feature will be remediated to satisfy the RSR OoS criteria and so does not form part of the proposed on-site disposals.

It is important to note that the probability of a dose being received through this pathway has been cautiously assumed to be unity (i.e. it is a conditional dose). However, it is considered very unlikely that an RP would receive a radiological impact in excess of the RGL as:

- CEFAS regional habits surveys, as summarised in the Site Description Report, suggest construction of a residential well is relatively uncommon. Commercial groundwater abstraction in the area around Winfrith does occur but it also relatively rare. The PA estimates the probability that a well is sunk in this location to be 1E-03. Applying such a factor to the dose rates identified in Figure 14 would reduce the risk to substantially below the RGL;
- Given the large land area over which a well could be sunk, it is even less probable that a well would be sunk such that it intercepts exactly the migrating contamination. The calculations presented above are bounding, assuming that the well is drilled immediately adjacent to (1 m downstream) each modelled feature and do not account for transverse dispersion in the groundwater. The intercepted concentration will reduce with distance from the feature;
- The PA also assumes that the receptor meets their entire annual drinking water needs from the well, which, again, is unlikely.

<u>Site Occupancy Pathway</u>

The PA has assessed the doses incurred by people via direct radiation from the disposals or from the activity remaining within the A59 land area.

<u>Reference case</u>

Doses to RP's are considered separately for the scenarios that can occur during and following the period of regulatory control. The peak dose rates at the IEP and the SRS for the reference (that is most realistic) case are outlined in Table 7.

Table 7: Peak site occupancy dose rates to Representative Persons at the IEP (2036) and the SRS (2066)

Site Feature	Peak dose rate at IEP (mSv/yr)	Representative Person	Peak dose rate at SRS (mSv/yr)	Representative Person	Dominant radionuclides
SGHWR	6.05E-14	Dog Walker	2.39E-13	Caravan Dweller	Eu-152
Dragon	5.49E-14	Dog Walker	1.14E-12	Caravan Dweller	Th-232, Ra-226, Ra-228 (2036) Th-232 (2066)
A59	9.49E-06	Dog walker	1.03E-04	Caravan dweller	Cs-137

Table 7 shows that the doses to the RPs are within the dose constraint (at the IEP) and the dose equivalent of the RGL (at the SRS).

Alternative/Variant Scenarios

The reference model for the site occupancy pathway has been tested through a number of alternative and variant scenarios in order to inform optimisation assessments and the developing design of the disposals. These alternative and variant scenarios assessed the doses incurred if:

- The alternative inventory is assumed. All site occupancy doses in this alternative scenario are more than an order of magnitude below the dose equivalent of the RGL;
- The thickness of the engineered cap (for SGHWR and Dragon) or the thickness of clean cover material (over A59) is reduced. In the case of reducing cap thickness for the SGHWR and Dragon disposals the site occupancy doses remain significantly below the dose equivalent of the RGL;
- Only when considering the unrealistic scenario of a caravan dweller lying horizontally for an entire year with no cover material directly above the A59 OoS area in 2066 is a dose comparable to that of the RGL calculated (2.4E-2 mSv y-1 compared to 1.7E-2 mSv y-1). Even discounting how unrealistic this scenario is, the ground survey that will be completed as part of remediation of the A59 area and the site closure process will ensure that there is appropriate clean cover material in place.

Human intrusion pathway

The PA has estimated the doses incurred as a result of inadvertent human intrusion into the SGHWR and Dragon disposals as well as the A59 OoS land area.

Doses are estimated for RPs who are either directly involved in the intrusion e.g. a construction worker, as well as for RPs who are exposed through the re-use of the excavation materials e.g., a child in a play area.

As for the other assessed pathways the doses associated with inadvertent human intrusions are estimated for a reference case (using the most realistic assumptions) and for a range of alternative and variant scenarios that are designed to enable the importance of the different underlying assumptions to be understood.

In accordance with GRR, inadvertent human intrusions are modelled to occur after the SRS as it is assumed that such activities cannot occur during the period of regulatory control.

Doses for human intrusion are compared to GRR lower DGL (3.0 mSv y^{-1}) for prolonged exposures (for example, the child in a play area) and to the GRR upper DGL (20.0 mSv y^{-1}) for transitory exposures (such as to a construction worker).

SGHWR Reference case

The model estimates the doses for a variety of intrusion scenarios into different parts of the disposal. The doses to people either directly involved in the intrusion or through reuse of the excavated material are below the dose guidance levels specified within the GRR in all cases except for intrusions into the SGHWR Mortuary Tubes.

The SGHWR Mortuary Tubes are currently storing radioactive material and cannot therefore be characterised until this material is removed in the ILW processing campaign. The inventory has been estimated based upon a number of conservative assumptions and the resulting reference case dose estimate exceeds the GRR DGL in the following intrusion scenarios:

- A large deep intrusion – gives a peak dose of 23.8mSv/yr to an infant exposed by living on contaminated material. This compares to the GRR DGL of 3.0mSv/yr (for a prolonged exposure);
- Drilling of 5 boreholes – gives a peak dose of 3.58mSv/yr again this is incurred by an infant exposed by living on contaminated material. This compares to the GRR DGL of 3.0mSv/yr (for a prolonged exposure).

The reference case also estimates the doses from an intrusion into the SGHWR Mortuary Tubes once the tubes have been cleaned and the inventory has been removed. Under this scenario all of the doses incurred are below both the transitory (20.0mSv/yr) and prolonged (3.0mSv/yr) DGLs specified within GRR.

These results emphasise the importance of characterising the SGHWR Mortuary Tubes and revising the human intrusion risk assessment once the inventory is better understood. Once completed this will allow the optimised approach for decontamination of the SGHWR Mortuary Tubes to be determined.

SGHWR Alternative and Variant Scenarios

As was completed for the other pathways the assessment of the doses through inadvertent human intrusion have been tested by changing the underpinning assumptions through a series of alterative and variant scenarios. These include a) earlier intrusions (occurring in 2056), b) use of the alternative inventory, and c) reduced cap thicknesses (for SGHWR and Dragon) and reduced thicknesses of clean cover material (for A59).

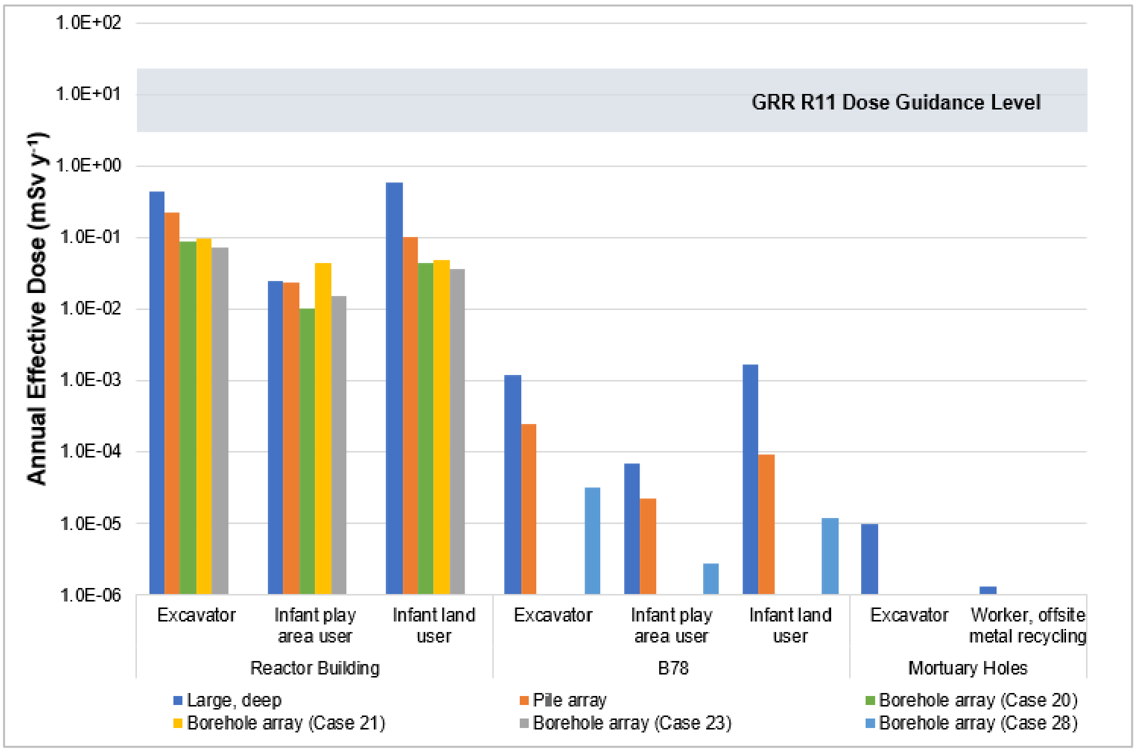
The results of these alterative/variant scenarios demonstrate that the doses from inadvertent human intrusion are not greatly altered when compared to the reference case. Large deep and borehole drilling intrusions into the SGHWR Mortuary Tubes remain as the only scenarios that exceed the GRR DGL (for an infant exposed through reuse of the excavated material).

The alternative/variant scenarios therefore support the conclusions of the reference case in that all expected cases for the site are compliant with respective limits. The exception being the current assessment for the SGHWR Mortuary Tubes demonstrates the need to characterise and decontaminate before the end state. Once the inventory of the SGHWR Mortuary Tubes is better understood the human intrusion calculations will be repeated and the management approach optimised.

Dragon reference case

All of the human intrusion dose rates estimated for Dragon are below the DGLs specified within GRR. These dose rates are presented within Figure 15.

Figure 15: Dose rates to receptors from intrusions into the Dragon reactor building in 2066 for the Reference Case



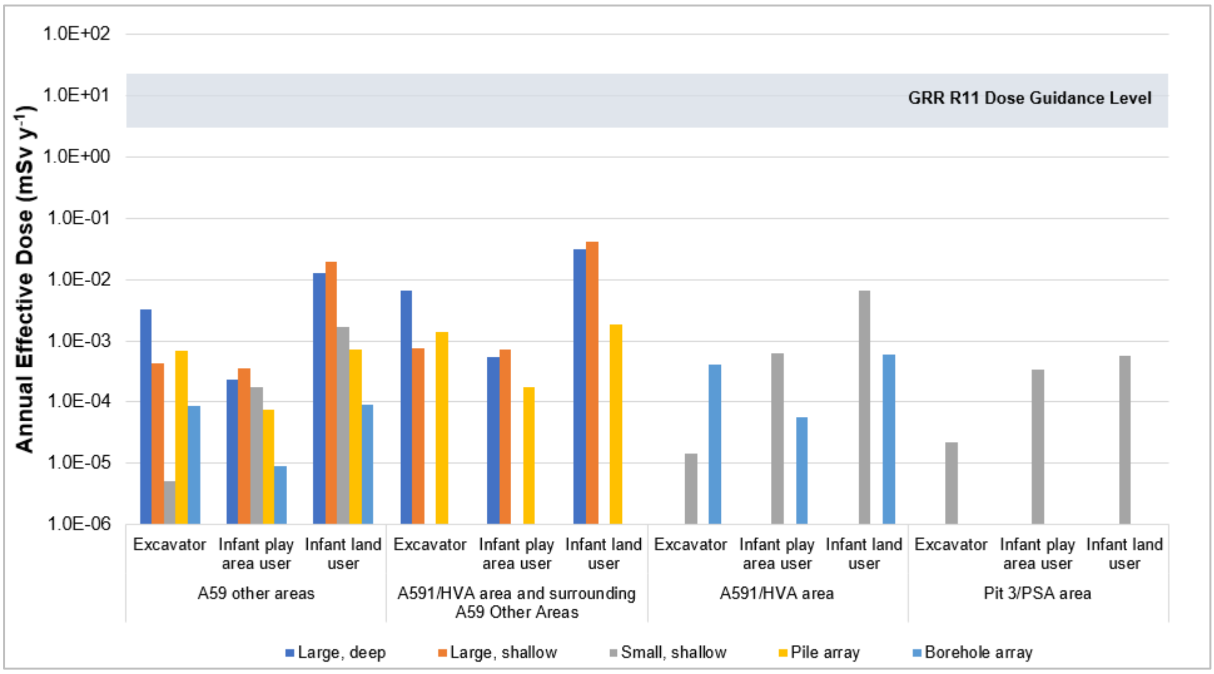
<u>Dragon Alternative and variant cases</u>

The estimated doses through the Dragon alternative and variant cases are all below the transitory and prolonged GRR DGLs.

<u>A59 Reference and Alternative/Variant cases</u>

The dose rates estimated for the reference (Figure 16) and the alternative/variant cases are below the GRR DGLs.

Figure 16: Doses to receptors from intrusions into the A59 in 2066 for the Reference Case



<u>Summary of the results of the prospective dose assessment</u>

The risk to the people and the environment has been assessed within the PA, and shows that the:

- Natural evolution pathway:
  - Reference case: a peak dose rate of 3.0E-04mSv/yr is estimated to be incurred by a smallholder who is assumed to reside, grow, and consume vegetables, fruit and raise and consume livestock, on land contaminated by groundwater releases from SGHWR and A59. This dose is below the dose equivalent of the GRR RGL (1.7E-02mSv/yr) and occurs 56,800 years in the future;
  - Alternative cases: In all but one of the alternative assessment cases considered peak dose rates to all RPs remain below the dose rate equivalent of the RGL. Dose rates are highest for the case considering maximum foodstuff biosphere uptake factors with the peak dose rate for the Farmer and Smallholder RPs in the Land/Mire compartment exceeding the dose rate equivalent of the RGL by about a factor of ten after 1,000 years (peaking at 7.5E-02 mSv y-1 for the Smallholder RP). It is important to recognise that this calculation considers the extreme of the value range for every food product uptake factor for every radionuclide. In addition, these calculations assume that the RP scenarios occur; the probability of a smallholder living directly on the contaminated area in the future would be expected to be much less than one;
  - Variant and 'what if' cases: In all but one of the variant/'what if' scenarios, peak dose rates to all RPs remain below the dose rate equivalent of the RGL. Dose rates are highest for the Well Abstractor RP in the groundwater abstraction variant scenario, where an RP is assumed to abstract and consume groundwater released from a well 1 m down-gradient of the A59 feature group. The peak dose rate exceeds the dose rate equivalent of the RGL by almost an order of magnitude between 2066 (the assumed SRS date) and ~2120. This calculated conditional dose does not account for likelihood – the probability of sinking a well in this location is estimated to be 1E-03 which would reduce the peak risk to significantly below the GRR RGL It is important to also note that

the A59 land area will be remediated to OoS levels and does not therefore form part of the GRR application.

- Site occupancy pathway:
  - Reference case: direct radiation doses to people above the SGHWR or Dragon disposals are significantly lower than the dose equivalent to the GRR RGL. The equivalent doses associated with activities above the A59 OoS land area are also significantly below the dose equivalent of the RGL;
  - Alternative and variant cases: in all but one of the alternative/variant cases the dose to the RPs is less than the dose equivalent of the GRR RGL. In the variant case of a caravan dweller living above the A59 OoS land area with the depth of clean soil cover reduced to 0.0m the dose is marginally above but is consistent with the dose equivalent of the RGL. This scenario is not considered realistic.
- Inadvertent Human intrusion pathway:
  - Reference case: the doses to people either exposed directly or indirectly as a result of an intrusion into the disposals is compliant with the DGL defined within GRR except in the case of an intrusion into the SGHWR Mortuary Tubes. In this case a large/deep or borehole drilling human intrusion exceeds the DGL for an infant that is exposed through the reuse of excavated material. The SGHWR Mortuary Tubes are currently storing radioactive material and cannot be characterised until later in the decommissioning programme. Once this material is removed the SGHWR Mortuary Tubes will be characterised, the risks from human intrusion reassessed and the optimal management of the tubes' inventory determined.
  - Alternative and variant cases: The results of the alterative/variant scenarios show that doses from inadvertent human intrusion are not greatly altered when compared to the reference case. Large deep and borehole drilling Intrusions into the SGHWR Mortuary Tubes remain as the only scenarios that exceeds the GRR DGL (again for an infant exposed through reuse of the excavated material).

7b Provide a prospective dose assessment for the most exposed members of the public in member states of the European Union and/or Norway

EA guidance (Ref. 4) specifies the that a transboundary dose assessment is required if the dose to local RPs exceeds certain radiological criteria.

As the site occupancy and human intrusion pathways both require the RP to be local to the proposed disposals, natural evolution is the only dose pathway that is relevant to transboundary assessments.

Period of regulatory control

The guidance states that a transboundary assessment is required if the dose to a local RP (until circa 2066) is greater than or equal to 10 µSv y^{-1}, or 0.01 mSv y^{-1}.

The SWESC identifies that the highest dose rate in the Reference Case assessment for natural evolution during the period of RSR, considering the credible RPs[4], is to the Smallholder RP in the off-site Field compartment, peaking at around 3.6E-06 mSv y^{-1} (0.004 µSv y^{-1}) at the assumed SRS date. This peak dose rate is three orders of magnitude below the dose rate criterion at which a transboundary assessment is required (10 µSv y^{-1}).

[4] 'Credible RPs' in this case are those that can occur during the period of regulatory control this includes the off-site (field) smallholder but excludes the on-site (Land/Mire) Construction Worker, Farmer and Smallholder RPs.

No alternative assessment cases or variant (including "what-if") scenarios via the natural evolution pathway result in dose rates that exceed 10 µSv y^{-1} during the period of RSR.

After SRS

For the period after regulatory control has ceased (after the SRS) a transboundary assessment is required if the assessed radiological risk to a local RP is greater than or equal to 6.0E-05/yr. This is equivalent to a dose rate of 1mSv y^{-1} (Ref. 2).

The highest dose rate in the reference case assessment for natural evolution (after the period of RSR control) is to the Smallholder RP in the Land/Mire compartment, peaking at 7.0E-04 mSv y^{-1} in 57,000 years. This peak dose rate is several orders of magnitude below the dose rate equivalent (1 mSv y^{-1}) of the radiological risk criterion (6E-05 per year) at which a transboundary assessment is required.

No alternative assessment cases or variant (including "what-if") scenarios result in dose rates that exceed 1 mSv y^{-1} after the period of RSR.

In summary, the assessed dose via the natural evolution pathway falls below the radiological criteria for completing a transboundary dose assessment both before and after the period of regulatory control. Therefore, a prospective dose assessment to the most exposed members of the public in member states of the European Union and/or Norway is not required.

7c Provide an assessment of the impact on the environment at the proposed limits for the disposal

The **PA** identifies the radiological risk to non-human biota using the ERICA assessment tool. A detailed description of the approach to modelling is provided within the PA (Ref. 15).

In short, the ERICA assessment was completed for three biosphere compartments, field, land/mire and the River Frome, with the land/mire compartment being modelled as both a terrestrial and an aquatic ecosystem. .

The potential impact on the full-suite of reference organisms was calculated as Risk Quotients (RQ) which are determined by comparing the modelled environmental concentrations for each radionuclide with those at which each species would be expected to receive a dose equal to the screening level (Environmental Media Concentration Limits or ECMLs).

The results from the Winfrith non-human biota assessment show that, for all organisms in all three compartments (Field, River Frome and Land/Mire, whether modelled as a freshwater or terrestrial ecosystem) and for both the reference and alternative inventories, estimated dose rates are below the 10 µGy h^{-1} screening criterion and the corresponding RQ values are at least an order of magnitude below one.

This demonstrates that the disposals are safe for non-human species within the environment.

Question 8: Non-radiological assessment

The **HRA** (Ref. 16) presents a tiered hydrogeological risk assessment of the proposed SGHWR and Dragon end states. Justifications for screening decisions at each level are set out in the HRA.

The HRA addresses the risks from the non-radiological components of the proposed radioactive waste disposals (in-situ and for a purpose), the non-radioactive waste proposed to be deposited under the DfR Permit and the non-radioactive structures remaining in-situ.

Non-radiological contaminants were modelled using GoldSIM as the industry leading software for assessment of waste disposals. Alkalinity was modelled using PHAST and as the most appropriate approach for assessing the behaviour of hydroxide ions in the environment. Modelling assessments were conducted in line with appropriate EA guidance.

Tier 1 assessment

Tier 1 qualitative risk screening was carried out on all components of the end states of the SGHWR and Dragon reactor structures, the Dragon mortuary holes and the backfill required to deliver the end state. Potential releases of the following contaminants from components of the end state were identified as acceptable and these need no further tiers of risk assessment:

- Contaminants bound within concrete in reinforced reactor concrete structures, concrete blocks and the Dragon mortuary hole/B78 floor slab structure, with the exception of the hydroxide ion (that can generate high pH in water) leached from concrete blocks;
- Contaminants bound within structural steel and rebar in concrete structures and blocks;
- Contaminants bound within paint;
- Contaminants bound within fibreglass;
- The following hydrocarbon fractions in oil staining of structures: <C10 aromatic compounds (including benzene, toluene, ethylbenzene and xylene), >C16 aliphatic compounds and all 16 analysed polycyclic aromatic hydrocarbon species;
- Arsenic and mercury in demolition arisings;
- Constituents of emplaced non-waste materials that will be used to implement the end state of the Dragon mortuary holes as well as to prepare the structures for the disposal/deposits.

Tier 2 assessment

Tier 2 is a Generic Quantitative Risk Assessment (GQRA). The GQRA was assessed by calculating the porewater concentrations of contaminants in the demolition arisings and comparing these with compliance criteria selected from water quality standards that are protective of groundwater and surface water.

The calculated porewater concentration of the following contaminants was lower than the selected compliance criteria:

- Antimony;
- Barium;
- Cadmium;
- Chloride;
- Fluoride;
- Molybdenum;
- Nickel;
- Selenium;
- Sulphate.

The GQRA demonstrated that there are no unacceptable inputs to groundwater from these contaminants and these contaminants therefore need no further risk assessment. The Tier 2 GQRA was insufficient to demonstrate an acceptable risk from alkalinity and several inorganic and organic contaminants (Table 8).

Table 8: Summary of contaminants requiring assessment by Detailed Quantitative Risk Assessment (DQRA)

Component in the SGHWR and Dragon reactor complexes	Contaminants
Concrete blocks	Alkalinity (pH)
Demolition arisings	Alkalinity (pH)
	Chromium (as Cr(III) and Cr(IV)), copper, lead and zinc

Component in the SGHWR and Dragon reactor complexes	Contaminants
	PCB-28, PCB-52, PCB-101, PCB-118, PCB-138, PCB-153 and PCB-180
Oil-stained concrete (SGHWR Regions 1 and 2 only)	TPH-CWG[5] >C10-C12, >C12-C16 and >C16-C21 aromatic fractions

Tier 3 assessment

The HRA (Ref. 16) presents the results of the DQRA for all of the contaminants listed within Table 8.

Concentrations in groundwater for all of the modelled contaminants emanating from both the SGHWR and Dragon proposed disposals are well below the applicable compliance criteria.

Table 9 identifies the contaminants with peak concentrations that were closest to the respective compliance limits. The source of the contaminant i.e. SGHWR or Dragon and the timing of the peak concentration are also identified.

Table 9:Contaminants for which the peak concentrations in the Tier 3 DQRA were closest to their compliance limits

Type	Contaminant	Feature	Compliance limit/Peak concentration	Time of peak (year after disposal)
Metals	Chromium (VI)	SGHWR	2.0	996
TPH	C10-C12 Aromatics	SGHWR	163	761
PCB	PCB-101	Dragon	11.3	1251

Table 9 shows the ratio of the compliance limit to its modelled concentration and so is a measure of safety – a value less than one would be non-compliant.

The PHAST modelling results demonstrate that the maximum pH in groundwater is significantly lower than the compliance criterion, despite the use of conservative assumptions.

An assessment of cumulative effects was also undertaken because groundwater flow modelling has shown that, under some circumstances, groundwater flows from the SGHWR end state to beneath the Dragon Reactor and the mortuary holes. The Tier 3 assessment concluded that cumulative impacts will not cause an unacceptable risk to groundwater.

Parameter uncertainties were addressed through a number of variant and alternative scenarios. These demonstrated an acceptable risk to groundwater for all modelled contaminants, thereby providing confidence that the outcomes of the reference scenario are robust.

Based on the three tiers of risk assessment it is concluded that the non-radiological hydrogeological risk from the proposed SGHWR and Dragon reactor disposals to controlled waters is acceptable.

5 Total Petroleum Hydrocarbon Criteria Working Group.

<u>Compliance with groundwater regulations</u>

Groundwater regulations stipulate that:

- Direct discharges of potentially polluting substances into groundwater are prohibited;
- Indirect discharges of hazardous substances must be prevented and indirect discharges of non-hazardous substances must be limited so as not to cause pollution; these are known as the prevent and limit requirements.

The meaning of direct discharge is set out in EA guidance (Ref. 38) and the compliance of the proposed disposals is discussed within the SWESC (Ref. 2).

The **DSR** (Ref. 14) demonstrates compliance with the prohibition on direct discharges through:

- Assessing the current groundwater levels in relation to the SGHWR, Dragon and Dragon mortuary holes structures through on-going groundwater monitoring. Additionally, any groundwater changes from implementing the end state have been modelled;
- The expected peak groundwater levels through a range of future climate conditions have been modelled (Ref. 9);
- Identifying which parts of the proposed disposals will interact directly with the projected groundwater levels (Ref. 39);
- Substantiating the design of the sub-surface structures that interface directly with groundwater (defined as boundary structures) to demonstrate that these are sufficiently robust to ensure that a direct discharge does not occur (Ref. 14);
- Including requirements for sealing penetrations in boundary structures as part of the concept design and in the Functional Requirements (Ref. 40).

The Dragon mortuary holes are not included as EA guidance (Ref. 38) indicates a disposal in-situ cannot constitute a direct discharge.

Table 10 compares the relative depths of the different parts of the proposed disposals with the modelled Central Cautious Estimate (CCE) of changes to groundwater levels as a result of climate change (Ref. 39).

Table 10: Projected groundwater levels and the levels of underground structures of the proposed disposals

Region	Lowest level (AOD, m)	Average CCE groundwater level (AOD, m)	Summary of compliance arguments
SGHWR Region 1	28.8	33.6	Region 1 and Region 2 feature thick reinforced concrete walls and base slabs that will separate the contamination from groundwater. Penetrations within the structure will be sealed prior to demolition taking place.
SGHWR Region 2	30.6 to 35.4		
SGHWR North Annex	37.8		CCE groundwater levels are higher than the base slab of the North Annex for 0% of the time. Any releases from the North Annex would therefore be indirect.
SGHWR South Annex	35.4 to 36.6		CCE groundwater levels are higher than the base slab of the North Annex for 4% of the time. As the groundwater level will only rise above the south annex base slab for short periods of time under extreme

Region	Lowest level (AOD, m)	Average CCE groundwater level (AOD, m)	Summary of compliance arguments
			climate change conditions discharges are judged to remain indirect.[6]
Dragon	27.34	24.9	The predictions are that groundwater levels will remain below the Dragon base slab for all but the most extreme climate change conditions. Under such conditions groundwater levels are modelled to rise above the Dragon base slab for 2% of the time. As groundwater levels are below the bottom of the Dragon's base slab in all but the most extreme climate change conditions it is judged that direct discharges will not occur[6].

[6] This is consistent with the requirement to assess against the 'typical winter water table'.

Question 9: Radioactive waste pre-disposal arrangements

9a Provide details of your arrangements for pre-disposal verification of the waste to ensure control of the disposal of radioactive waste.

The ongoing nature of the decommissioning activities in both SGHWR and Dragon means that the final disposal inventories and detailed designs cannot be produced ahead of the application.

The environmental performance of the disposals/deposits will be dependent on both the materials/wastes disposed or deposited and ensuring the engineering functional requirements are met through to the implementation phase.

The proposed disposals/deposits will be controlled by:

- Removing prohibited materials from the structures prior to demolition or backfilling, so far as reasonably practicable and subject to the optimised approach;
- Assessing/characterising the materials/wastes remaining in-situ against the EAC and engineering requirements;
- Completing remedial measures on the structures remaining in-situ as required by the detailed design and functional requirements;
- Appropriately characterising the wastes to be used in backfilling for disposal/deposit against the EAC;
- Emplacing/depositing waste in the physical form and location specified in the EAC and detailed design.

No treatment of waste is planned.

Requirements and standards for acceptability

The requirements and standards for both the structures remaining in-situ and the waste used in backfilling (by disposal or deposit) are set in two key documents:

- The EAC sets out the radiological, chemical, physical and biological standards for radioactive wastes being disposed (for a purpose and in-situ) and the deposit for recovery of non-radioactive wastes. The EAC also applies to the non-radioactive structure and any new materials being used in the structures, i.e. engineering materials used in remedial works. Compliance with the EAC ensures that risks are within boundaries of both the radiological PA and the HRA. Further optimisation is accommodated within the EAC;
- The DSR sets out the functional requirements that the detailed design and completed disposals must meet to ensure compliance with all regulatory requirements and optimised performance of disposals. This includes requirements such as sealing penetrations, where large concrete blocks are to be placed and how the caps will be constructed.

Characterisation requirements

Characterisation activities to meet the requirements of the EAC began several years ago, with many parts of SGHWR being characterised in accordance with S-324 sufficient to demonstrate compliance with the EAC.

NRS have produced a SIMP that describes how the radiological and non-radiological characterisation of the SGHWR and Dragon structures and backfill will be carried out up to and during the demolition and implementation phases. Further characterisation will be used to supplement the existing radiological and non-radiological inventories.

Characterisation will be conducted in accordance with the company standard (Ref. 41) and industry good practice. Characterisation programmes will be developed and planned to address the uncertainties, assumptions and gaps (Ref. 29) identified for the radiological and non-radiological inventories. Additionally, modelling of alternative scenarios and 'what-if' cases in the radiological PA and HRA will be used to define the key areas to be assessed and parameters to be evaluated.

Engineering requirements

The detailed design for the disposals will be produced in accordance with MAN-004. The detailed design will incorporate any planning and permit requirements, the concept design functional requirements and input from the demolition contractor to ensure that the output can be safely implemented.

Procedures for assessing compliance

The CQAP will be the primary management procedure for assessing compliance with both the EAC and the detailed design. The CQAP will address requirements associated with the disposals of radioactive waste, deposit of non-radioactive waste and compliance with regulatory requirements.

At the application stage, there is a single CQAP setting out the generic approach to:

- Appropriate controls to implement before structures are demolished and demolition arisings are placed in the reactor basements. This includes CQA controls on:
    - Enhancing the environmental protection function of the below cutline structures;
    - Pre-demolition radiological and non-radiological characterisation and verification;
    - Controls on pre-demolition planning.
- CQA of in-process demolition characterisation and backfilling, and in process engineering verification;
- CQA of the engineered cap, drainage and cover soils;
- Post-construction quality assurance.

Once detailed designs, characterisation plans and Permit/Planning conditions are available, an “implementation CQAP” will be produced for each disposal. The individual plans will detail the controls specific to the structure and associated characterisation and engineering requirements. The implementation CQAP’s will also specify what records need to be generated and retained through the implementation phase.

The CQAP will complement existing management system arrangements, specifically in relation to environmental management, waste management, characterisation, design management and works control.

Excluding non-compliant wastes

The in-situ concrete structures that form part of the proposed GRR disposal may be difficult to remove without compromising the structural integrity of the buildings. Therefore, should structural concrete fail to meet the EAC, further optimisation will be completed to determine the preferred management approach.

Wastes being disposed/deposited as backfill (including the above ground structures and rubble), will be assessed, sorted and segregated. Wastes that do not meet the EAC will be excluded and managed via the appropriate off-site disposal route in accordance with the waste category and waste hierarchy.

Records management

Records will be generated through the remainder of the decommissioning phase, prior to demolition and through the implementation phase, as set out in the **CQAP**. Records to be generated and retained include:

- Pre-demolition condition survey;
- Demolition plans/methodologies and justifications (BAT/safety assessments), including details of construction access, sequencing, controls (i.e. hold points), monitoring and emergency arrangements;

- Enhancement measures (materials and techniques), photographic evidence, testing/validation and monitoring of repairs to defects in boundary structures;
- Radiological and non-radiological characterisation of in-situ structures, including characterisation plans, monitoring, sampling and analysis data where appropriate;
- Optimisation/BAT assessments completed to determine the preferred approach to contamination in exceedance of the EAC that cannot be easily removed;
- Details of decontamination of radiological or non-radiological contamination, including the post-decontamination levels;
- Details of radiological and non-radiological characterisation of large concrete blocks placed in voids. Characteristics of large concrete blocks, including size, weight and disposition location;
- Details of the radiological and non-radiological characterisation of above ground structures collected prior to demolition, including any decontamination completed in advance of demolition;
- Details of the demolition process for above ground structures;
- Details of the radiological and non-radiological characterisation of the material currently stored in the rubble stockpiles;
- Details of the backfilling process for stored rubble;
- Records of construction of the engineered caps, including engineering drawings, specification for materials used, accreditation for suppliers of materials, records of sampling/testing of materials, post-construction testing, performance against pass/fail; criteria etc;
- Groundwater monitoring results for the demolition/implementation phase;
- Details of wastes removed from the structures or backfill and disposed off-site;
- The CQAP validation report.

Details recorded will include written records, QA sheets and verification plans as appropriate, alongside ‘as built’ drawings of the disposals/deposits and photographic records.

Records will be held in the IMAGES Geographical Information System (GIS) as the permanent record. Hard copy records of disposals will be held as part of the site permanent records and transferred to the national nuclear archive.

The Stewardship Plans sets out the record management requirements following implementation of the proposed end state.

Question 10: Waste Management Plan and Site wide Environmental Safety Case

<u>Question 10a: Provide relevant extracts from your WMP and SWESC to support your application</u>

Application versions of the Winfrith WMP (Ref. 1) and SWESC (Ref. 2) are provided to support the application for the proposed disposals.

The WMP presents an overview of how the site intends to manage the radioactive wastes and radioactively contaminated land remaining on the site. The WMP sets out how the on-site and off-site management of solid radioactive wastes is optimised and in accordance with BAT. In addition to demonstrating that the generation and management of solid radioactive wastes for off-site management is in accordance with BAT.

A suite of options assessments have been completed to define the optimised management approach for the remaining wastes and radioactively contaminated land on the site. The WMP provides a detailed summary of these options assessments in support of GRR requirements R1 and R13.

The SWESC presents a series of claims, arguments and evidence that together demonstrate that the proposed disposals are safe (to the public and the environment), optimised (taking due consideration of all relevant factors), supported by the local community and other stakeholders and compliant with all other environmental legislation.

Both documents have been supplied and are the main supporting documents for this application.

6 REFERENCES

1 Waste Management Plan, ES(23)P378, Issue 3, December 2024

2 Winfrith End State Site Wide Environmental Safety Case. ES(24)P390, Issue 2, May 2025.

3 RSR C5 application form for the proposed on-site disposals of SGHWR and Dragon, December 2024

4 Environment Agency, How to Apply for an Environmental Permit Form RSR-C5 – Variation to a bespoke radioactive substances activity permit (nuclear site, adding on-site disposal of solid radioactive waste): Guidance Notes, Environment Agency, December 2021.

5 Winfrith End State Site Description Report. ES(18)P196. Issue 1. December 2024.

6 Winfrith Site. Interpretation of Present and Future Hydrogeological Conditions (HI). WSP Ltd. ES(21)P331. Issue 1. December 2024.

7 Winfrith Site. Conceptual Site Model to Underpin a Hydrogeological Risk Assessment and Radiological Performance Assessment of the Steam Generating Heavy Water Reactor and Dragon Reactor Complex End States (CSM). WSP Ltd. 20146580.606/A.2. ES(21)P332. Issue 1. December 2024.

8 Winfrith Site Wide Materials Management Plan (SWMMP). ES(19)324, Issue 4. August 2024.

9 Winfrith End State: Assessment of the Effect of Climate Change on Groundwater Levels. WSP Ltd. 20146580.606/A.2. ES(21)P333. Issue 1. February 2021.

10 Soil and Groundwater Radiological and Chemical Background and Threshold Values for the Winfrith Site. ES(24)P392. Issue 1. October 2024.

11 Winfrith Site: End State Radiological Inventory. GSL Report 1624-10. ES(19)P281. Issue 2. December 2024.

12 Winfrith End State. Non-Radiological Inventory of the SGHWR, Dragon reactor complex and backfill accompanying report. ES(21)P335. Issue 4. May 2024.

13 Winfrith Site End State Engagement. Statement of Community Involvement (SOCI). WSP Report. ES(24)P419. Issue 1. July 2023.

14 Design Substantiation Report (Concept Stage) – SGHWR and the Dragon Reactor. ES(23)P387, Issue 1. October 2024.

15 Winfrith Site: End State Radiological Performance Assessment (PA). GSL Report 2242-01. ES(23)P388. Issue 2. April 2025.

16 Hydrogeological Risk Assessment of the SGHWR and Dragon Reactor (and Mortuary Holes) End States (HRA). 20146580.611/A.0. ES(22)P361, Issue 1. December 2024.

17 Strategy for achieving compliance with the water environment regulations “prohibition” for the SGHWR and Dragon reactor provisional end states, ES20/P329, February 2021.

18 Winfrith Site: Wetland investigation and assessment. Atkins Ltd. ES(24)P400. Issue 1. June 2024.

19 Winfrith End State Staged Inventory Management Plan (SIMP). ES(22)P365 Issue 1. September 2024.

20 Emplacement acceptance criteria to support the Winfrith end state, ES(18)P191, Issue 2, April 2025

21 Winfrith End State Environmental Monitoring Plan (EMP). ES(24)P389. Issue 1. December 2024.

22 Winfrith End State Stewardship Plan. ES(24)P386, Issue 1, December 2024.

23 Application Construction Quality Assurance Plan for the SGHWR and Dragon Reactor End States. WSP report 70109556.603. ES(24)P409, Issue 1. December 2024.

24 Design Management Manual. MAN 0004. Issue 12. March 2024.

25 Functional requirements, constraints and assumptions for the engineering concepts for the SGHWR and Dragon End States. Ref No. ES(18)P224. Issue 1. October 2024.

26 Optimising backfilling SGHWR and Dragon below ground voids to freeze the concept designs. ES(22)P384. Draft in progress

27 Magnox Ltd, *Site Manual for Harwell/Winfrith Sites,* MAN 001 Issue 16, March 2023.

28 WSP, *Winfrith Restoration Management Plan (RMP)*, Project 70089718, ES(24)P399 Issue 1 December 2024

29 Winfrith Site End State. Uncertainties Management Plan (UMP). ES(24)SS/21. Live document.

30 Underpinning of the proposed disposal limits for the proposed on site disposals of SGHWR and Dragon, ES/24/NFR/060, December 2024, Issue1

31 NRS Company Standard S-045. Environmental Monitoring Programme. Issue 5. April 2022.

32 Radiological Monitoring Technical Guidance Note 2 Environmental Radiological Monitoring. Environmental radiological monitoring - GOV.UK (www.gov.uk). Version 1. December 2010. Environment Agency, Food Standards Agency, Scottish Environmental Protection Agency.

33 Environment Agency, “Landfill and deposit for recovery: aftercare and permit surrender,” 30 March 2022. [Online]. Available: https://www.gov.uk/government/publications/landfill-epr-502-and-other-permanent-deposits-of-waste-how-to-surrender-your-environmental-permit/landfill-and-deposit-for-recovery-aftercare-and-permit-surrender. [Accessed 30 April 2024].

34 Environment Agency Guidance. LFTGN02- Guidance on Monitoring of Landfill Leachate Groundwater and Surface Water.

35 BS ISO 5667-14-2006, Water quality. Sampling. Guidance on quality assurance and quality control of environmental water sampling and handling, https://doi.org/10.3403/30260858 (published 31/12/2014)

36 Nuclear Industry Code of Practice for Routine Water Quality Monitoring, (Nuclear Industry Group for Land Quality, 2015)

37 A59 land area: options assessment. ES(23)P381. Issue 2. June 2024.

38 Guidance on protecting groundwater when permitting disposals of radioactive waste. LIT 56124. Published 12/03/2021. Version 1.

39 Winfrith Site: Strategy for Achieving Compliance with the Water Environment Regulations “Prohibition” for the SGHWR and Dragon Reactor Provisional End States. WSP Report 19123012.614/A.3. ES(20)P329. Issue 1. March 2021.

40 Functional Requirements, Constraints and Assumptions for the engineering concepts for The SGHWR and Dragon end states, ES(18)P224, October 2024, Issue 1

41 NRS Characterisation Management standard procedure. S-324. Issue 10. January 2024.

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