Nuclear Restoration Services

Site Restoration Programme:

Winfrith End State Project: Accompanying report to the Non-radiological Inventory of SGHWR, Dragon Reactor Complex and Backfill

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Review/Revision Register

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

Date	Author	Amendments / Change
August 2022	D Graham	Formatting and text improvements. Version updated to WP Draft
May 2024	T Sanderson	Updated based on new information.

TABLE OF CONTENTS

1 Introduction and Background

The end states for the SGHWR and Dragon reactor were defined through a detailed optimisation process that is presented in a business case, endorsed by the NDA [1]. This concluded that the reactor below ground structures should be left in-situ and decontaminated to a level required to ensure protection of people and the environment, as set out in a Site Wide Environmental Safety Case, SWESC [2] and consistent with the ’Guidance on Requirements for Release of Nuclear Sites from Radioactive Substances Regulation, GRR’ 2018.

It was acknowledged that the in-situ structures would require backfilling to provide a surface finish suitable to provide and end state of ‘Heathland with Public Access’. The structures will be backfilled with site derived demolition materials as disposal for a purpose of radioactive waste and deposit for recovery of non-radioactive demolition arisings and stockpiled material.

For non-radiological risk assessment and environmental protection purposes a non-radiological inventory (NRI) of the in-situ structures and the proposed backfill material is required.

2 Purpose

The purpose of the SGHWR and Dragon non-radiological inventory is to quantify the mass, volume and concentration of the non-radiological material and contaminants that will remain at the site’s Interim End State (IES). The inventory underpins the source in the conceptual site model “source, pathway, receptor”. The methods used to assemble the inventories are described and uncertainties, assumptions and gaps in the available information and data are identified. No assessment of the environmental impact of the disposed non-radiological inventory is made in this report as that is the subject of the HRA (in preparation).

This report is to be read in conjunction with the spreadsheets ES(21)SS/09 and ES(21)SS/10 which contain the non-radiological inventory for the SGHWR and Dragon end state structures and the material proposed for use as backfill the below ground voids.

Any refinements made to the existing estimations will be integrated into the spreadsheets as additional information and data becomes available. This report will then be up issued to reflect changes.

2.1 Site wide non-radiological inventory

There is a site wide NRI which considers all structures and land within the site boundary [3]. It includes all remaining non-radiological features, such as current buildings, rubble in-fill material, sub-surface structures to be left in-situ, contaminated land, and buried services / structures. It also presents the non-radiological properties of these features. The NRI of the SGHWR and Dragon end states described in this report and in the associated spreadsheets feeds into the site wide NRI.

The GRR regime requires an assessment of the disposal options for radioactive waste, including on-site options and an assessment of the non-radiological properties of the radioactive waste. The impacts of the disposal of the radioactive properties of the waste are assessed under the GRR regime through a Site Wide Environment Safety Case, SWESC [2] and supporting radiological Performance Assessments, PAs.

The recovery, re-use, or disposal of other non-radiological materials (not falling under GRR regime) in backfilling reactor voids will be managed under the Environmental Permitting Regulations 2016 by way of a Deposit for Recovery, DfR permit. The DfR process will be used for backfilling voids at SGHWR and Dragon and requires an assessment of the risks to the environment from use of material / waste.

Therefore, the non-radiological components of both the radioactive and non-radioactive wastes require a parallel assessment to determine their suitability for on-site disposal and recovery.

For completeness, non-radiological in-situ structures associated with SGHWR and Dragon are also included in the NRI, although they are not a waste and therefore do not require permitting.

3 Building data

All voids and volumes that have been derived for SGHWR and Dragon reactors have been established on their respective cut lines. The Dragon cut-line is 1 m below ground level, whilst the Dragon cut-line is ground level. Terms referring to below ground volumes are with respect to their cut lines.

3.1 SGHWR

Building data for SGHWR comes from estimations of the volumes of the above and below ground structures. These are fundamental assumptions as the chemical inventory's masses have been based on the volume and mass of the structure of SGHWR that is to remain in-situ.

The entire below cut line volume, excluding foundations, has been estimated from conceptualisation of the structure [4]. The volume of the below ground voids in the structure has been estimated to be 29,739 m^3 [5]. The volume of the SGHWR structure to remain in situ has been estimated to be 17,322 m^3 [23].

The masses of the structures have been derived based on a density of reinforced concrete of 2400 kg/m^3. Steel rebar has been considered, as has structural steel cast in the structure to provide structural integrity.

The foundations for Region 2 are shown on drawings to be of a weak mix concrete however there is currently no estimate of the volume of material associated with the foundations. This is captured as a gap in section 10.

3.2 Dragon

The building dimensional data for the Dragon below ground structure, as with that of SGHWR, has been used to calculate the estimated chemical inventory. The void volume of the structure below ground level is 6,544m^3 from the Dragon project concrete and void volumes estimate [6]. The volume of the in-situ structure volume to remain in-situ has been estimated to be 4,200m^3.

The Dragon mortuary tube below ground dimensions have been taken from drawings used in the Dragon Complex End State Radioactive Inventory [8] and from figures in the non-radiological HRA issue 2 [4]. The total below ground volume of the mortuary tubes has been estimated to be 400 m^3, the void volume inside the tubes being 27m^3 and the volume of concrete in the below ground structure estimated to be 370m^3.

As with SGHWR, the masses of the concrete structures have been based on a reinforced concrete density of 2400kg/m^3. Steel rebar has been considered, as has the structural steel that is cast in the structure.

4 Concrete

4.1 SGHWR

The bulk mass of the SGHWR structure is concrete. For the purposes of inventory, a typical construction concrete of 1-part OPC (Ordinary Portland Cement), 2 parts sand and three parts gravel has been assumed. The concentrations of cement minerals were calculated in the non-radiological HRA issue 2 [4] from a knowledge of a typical OPC composition and its hydration products.

4.2 Dragon

As with SGHWR, the bulk of the Dragon structure (foundations, reactor, mortuary tubes) is concrete and the same concrete composition has been assumed as for SGHWR. There is a quantity of baryte concrete in some regions of Dragon, but the volume is small. The uncertainty surrounding this was screened out during the Tier 3 Detailed Quantitative Risk Assessment undertaken during the Hydrogeological Risk Assessment [26].

5 Chemicals Inventory

5.1 In-situ structures

5.1.1 SGHWR

The chemical inventory has been derived from the analysis of samples and the assumed properties of the structure anticipated to be part of the SGHWR end state. Eleven cores were taken from SGHWR's floor and walls were characterised for a range of elements, including arsenic, barium, beryllium, chromium, and iron. The results were reported in GAU4010 [9] and GAU2388/GAU2955 [10].

There are two chemical inventories, a Total Inventory, and a Readily Available Inventory. This aligns with the analytical results. The Total Inventory is formed from the total contaminant concentrations associated with the solid phase of the samples. The Readily Available Inventory comes from the mass of contaminant in leachate when one-part rubble is mixed with ten-parts water. Not all samples were analysed for both the total concentrations and the leachable concentrations, and therefore the Total Inventory and the Readily Available Inventory have been based on different sample groupings.

The Total Inventory used the means of the results from the SGHWR cores in GAU4010 [9] for the contaminants analysed for. It should be noted that the analytical data [9] indicates significant amounts of iron present in the samples analysed. Elevated levels of chromium were also observed for some concrete samples compared with chromium detected in concrete from the existing rubble piles [11]. It is not clear whether the higher levels of iron and chromium in SGHWR concrete is from iron and chromium atoms bound to the concrete matrix, or from iron present in rebar (or other metallic structures embedded in the concrete) contributing to the inventory [4]. For some samples in GAU4010 [9] it was stated that when rebar was present in the characterised cores it had been removed prior to analysis, but this was not confirmed for all samples. The Readily Available Inventory was estimated from mean SGHWR cores analyses reported in GAU2388/GAU2955 [10].

It should be noted not all samples analysed had detectable contaminants and therefore limit of detection (LOD) results were reported. Where LOD results were recorded, they were included in the computation of the mean values at the LOD value.

When deriving the masses of the chemical inventory, a cautious approach was taken. The density for reinforced concrete (2400 kg/m^3) has been using a lower density of 2300 kg/m^3 for bulk concrete without reinforcement, since the presence of iron in the SGHWR core sample analysis results suggested rebar was present in some of the cores.

5.1.2 Dragon

Concrete from the Dragon below ground structure has not been characterised. It was assumed in the non-radiological HRA Issue 2 that the concrete was similar to the concrete used in SGHWR. This assumption has been used in the spreadsheet ES(21)SS/10 and captured in section 10. The Dragon inventory has been derived in the same way as the SGHWR inventory, based on analytical data and known structure dimensions anticipated to remain in-situ.

The Dragon in-situ chemical inventory has also been separated into a “Total Inventory” and a “Readily Available Inventory”.

A non-radiological inventory for the Dragon mortuary tubes exists, however, due to the relative impact of this being small compared to Dragon as a whole, its exclusion in the Hydrogeological Risk Assessment was justified [4]. [4]Sensitivity calculations have been covering any potential risk for the mortuary tubes.

The Total Inventory for Dragon was estimated using the mean analysis results from the SGHWR cores in GAU4010 [9] for the contaminants analysed. The Readily Available Inventory used the mean results for the contaminants in SGHWR cores in GAU2388/GAU2955 report [10].

5.2 Backfill

The SGHWR and Dragon backfill will consist of reactor demolition arisings with rubble from the existing stockpiled rubble piles also used for the volume deficit [12].

5.2.1 SGHWR

The Design Substantiation Report [13] states that the SGHWR below ground structure will be backfilled with large concrete blocks created during deconstruction and rubble from the demolition of SGHWR and from the existing rubble stockpiles. The volume of the blocks available for backfilling SGHWR has been estimated to be 6,300 m^3 [12]; the remaining void volume of 21,900 m^3 would be backfilled with rubble from the demolition of SGHWR and the existing rubble stockpiles.

5.2.1.1 Blocks

The blocks will have the same inventory as the in-situ below ground structure from which they are cut [4] and the same methodology as used in section 5.1.1 has been used to generate the concrete block inventory.

Blocks will be emplaced where it is practicable to do so.

5.2.1.2 Existing Stockpile Rubble

The analysis results from the D630 rubble stockpile [11] have been used to estimate the backfill inventory.

5.2.1.3 Anticipated origins of backfill arisings

Table 1 - Anticipated origins of SGHWR backfill arisings

Total SGHWR Void Volume (m^3)	SGHWR Demolition Arisings (m^3)	SGHWR Blocks (m^3)	D630 stockpile (m^3)
29, 739 [23]	5,840 [23]	6,300 [12]	17,599 [23]

5.2.2 Dragon

The backfill of the Dragon below ground structure will consist of large concrete blocks created during deconstruction and rubble from the demolition of Dragon. The concrete block volume estimated to be generated from Dragon reactor demolition was 400m^3 [12]. The remaining 6,100 m^3 void (i.e., excluding the volume of internal walls and structures to remain in situ) is to be backfilled with rubble from the demolition of the Dragon reactor building and, if needed, from the existing rubble stockpiles.

5.2.2.1 Blocks

The blocks will have the same inventory as the in-situ below ground structure from which they are cut [4] and the same methodology as used in section 5.1.1 has been used to generate the concrete block inventory.
Blocks will be emplaced where it is practicable to do so.

5.2.2.2 Existing Stockpile Rubble

The D630 rubble stockpile analyses [9] was used for the inventory of the backfill rubble.

5.2.2.3 Anticipated origins of backfill arisings

Table 2 - Anticipated origins of Dragon backfill arisings

Total Dragon Void Volume (m^3)	Dragon Demolition Arisings (m^3)	Dragon Blocks (m^3)	D630 stockpile (m^3)
6,544 [23]	4,891 [23]	400 [23]	1,253* [23]

*Note: * demolition arisings from D630 may be reduced by 154 m^3 if arisings from the above ground B78 demolition are utilised.*

5.2.2.4 Mortuary Tubes

The mortuary tubes (numbers 41-90) backfill inventory was based on a typical pozzolanic cement as the mortuary tubes end state is anticipated to be grouted and capped [4]. The specific weight of the trace elements in the cement was estimated using a grout density of 1700kg/m^3 multiplied by the mortuary tubes volume.

The ‘new’ fuel holes (numbers 1-40) are to be removed during the Dragon demolition. The location of the ‘new’ fuel holes will be outside of the proposed capped area of Dragon reactor and mortuary holes. The void remaining from removal of the new fuel holes will be backfilled, with a suitable permissioning path to be defined.

6 Steel

The reactor end states allows for structural steel to remain in place. This is mainly associated with steel rebar in concrete and structural steel in the form of I-beams. There is no intention to remove metalwork that provides structural integrity or is embedded in concrete. Therefore, the inventory of iron and other mild steel constituents will need to be considered in non-radiological assessments.

6.1 SGHWR

The steel inventory has used data based on the properties and quantity of reinforced concrete in use at the time of construction recorded in construction drawings, along with an estimate of the volume of structural concrete anticipated to remain in situ in the end state [14]. As noted in section 5.1, there was iron present in SGHWR core samples that has been included in the chemicals inventory. This may represent double counting as the iron inventory estimated from the core samples was 550t, whilst the metal estimate from the anticipated volume was 3,200t. A cautious assumption has been made to consider both values.

6.2 Dragon

The estimate of the Dragon reactor metal to remain in-situ was made from drawings and from the radiological inventory spreadsheet for Dragon [15]. The metals to remain include steel rebar in concrete walls, rebar in the bioshield, the steel shell, rebar in the base slab, the steel base plate, and in the mortuary tubes. As for SGHWR, there is again a possibility of double counting that also applies to Dragon.

7 Other contaminants: Asbestos, Oil, Fibreglass

7.1 SGHWR

7.1.1 Asbestos

. Asbestos has been removed, where practicable, in SGHWR. The only remaining asbestos within the Secondary Containment of SGHWR is residual insulating asbestos, ‘snots’, on walls and penetrations [19]. If ‘snots’ are forming part of the structure, these will remain in-situ, if not they will be removed where practicable. Asbestos has already been removed from the Primary Containment of SGHWR. It did not contain asbestos snots like those observed in the Secondary Containment [19]. A BAT assessment [19] was undertaken on residual asbestos within SGHWR, where the optimised assessment was to paint walls and cracks with a sealant to fix any residual asbestos in place to minimise the risk posed.

Whilst not negating the presence of residual asbestos within the SGHWR structure, laboratory analysis of asbestos containing materials from SGHWR indicates that it is primarily composed of amosite and chrysotile, with no crocidolite fibres detected. The presence of amosite and chrysotile poses lower human health toxicity risk than that of crocidolite.

The classification of hazardous waste for asbestos is >0.1% asbestos. A conservative assessment of 4 m^3 of brick/concrete which may be contaminated with asbestos residues has been calculated [19]. Assuming 4 m^3 of asbestos contaminated material, and a void space of 29,739 m^3 for SGHWR, the asbestos residue contaminated bricks contribute 0.013% of the void space, thereby significantly below the hazardous waste threshold (>0.1%).

7.1.2 Oil

Operations in SGHWR led to oil spills. Free oil has been removed however oil stains remain close to areas where machinery was used. The extent of oil contamination is low and to support a BAT assessment to determine the optimal management route for the oil stains, an estimate of the oil quantity was based on literature values for similar scenarios to those seen in SGHWR [17]. An initial conservative estimate of 10% of the secondary containment, and 25% of the primary containment being contaminated with oil was made based on site knowledge [17].

A visual survey of oil contamination was conducted on 26th July 2023 [22] to corroborate and visually analyse the samples obtained in 2022. The visual inspection estimated that 2% [22] of the secondary containment was contaminated with oil, however, the estimate of 25% coverage of the primary containment remained unchanged as widescale decontamination (shot blasting and scabbling) and painting of surfaces means there is none ability to inspect. Following the visual survey physical sampling was undertake with a range of cores and chips being collected and analysed at an accredited lab [22]..

Visual inspection of core locations and concrete chips revised the estimations of penetration depth from 10 mm to 3 mm for the oil, thereby reducing the volume of oil contaminated concrete to 0.47 m^3 [22]..

Concrete samples, alongside a neat sample of Castrol Hyspin oil were analysed for Total Petroleum Hydrocarbons (TPH-CWG) and Polycyclic Aromatic Hydrocarbons (PAH). Most samples showed oil contamination with a chemical makeup comparable to the Hyspin oil sampled, indicating oil contamination is from lubricating oil. The likeness of oils to Hyspin is furthered by the aromatic-aliphatic C21-C35 fraction is characteristic of mineral oils [22].

Table 3 - Calculation of oil mass in SGHWR

	Total TPH aliphatic Concentration C8-mg/kg	Total TPH aromatic concentration mg/kg	Total PAH concentration mg/kg	Total mass of aliphatic and aromatic oil kg
Average of all samples	2,300	6,677	1.47	10
Sample with maximum TPH aromatic oil concentration^	1,510	86,500	1.33	98
Sample with maximum TPH Aliphatic oil concentration*	6,880	1,760	1.5	10
Sample with maximum PAH concentration †	627	550	1.92	8

Samples were identified as meeting criteria for non-hazardous under the WM3 classification [22].

7.1.3 Fibreglass

The SGHWR ponds are coated in fibreglass and a BAT assessment [19] concluded that the optimal management approach was to leave the fibreglass in situ as part of the SGHWR end state. It was calculated that the amount of fibreglass was 9700 kg, based on surface area and lining thickness, with an assumed density of 1950kg/m^3.

7.1.4 Polychlorinated Biphenols (PCBs)

Concrete core samples obtained from D60 as part of the oil stain analysis reported in Section 7.1.2 were sampled for PCBs. Concentrations of PCBs extracted from the concrete cores are presented in Table 4.

Despite elevated PCB concentrations in core samples D60/242/Oil/Floor Core/01, D60/321/Oil/Floor Core/01 and D60/329/Floor Core/01, all PCB concentrations from this have fallen below the WM3 non-hazardous classification. To ensure conservatism, the WM3 classification has used the highest concentrations of all PCB cogeners analysed. Using a compound sample of highest PCB cogeners (highlighted in Table 4), the WM3 waste classification remains non-hazardous.

Table 4 - D60 Concrete Core Sample Polychlorinated Biphenol concentrations

	PCB28 (µg/kg)	**PCB52 (µg/kg)**	**PCB101 (µg/kg)**	**PCB118 (µg/kg)**	**PCB138 (µg/kg)**	**PCB153 (µg/kg)**	**PCB180 (µg/kg)**	**Total PCB (µg/kg)**
D60/124/Oil/Floor Core/01	<1	<1	<1	<1	<1	<1	<1	<7
D60/124/Oil/Floor Core/02	1.8	3.4	8.1	2.6	9.0	11	9.9	<47
D60/240/Oil/Floor Core/01	6.2	6.5	13	<1	27	32	29	113
D60/240/Oil/Floor Core/02	12	15	31	12	80	89	81	320
D60/240/No Oil/Floor Core/03	4.4	5.2	15	<1	38	44	49	157
D60/242/Oil/Floor Core/01	37	**57**	215	**160**	320	280	100	1169
D60/242/Oil/Floor Core/02	24	34	122	32	240	270	190	912
D60/243/Oil/Floor Core/01	<1	<1	<1	<1	29	27	53	112
D60/243/Oil/Floor Core/02	<1	1.8	<1	<1	5.7	7.5	6.1	24
D60/321/Oil/Floor Core/01	**24**	39	**670**	**160**	**4400**	**4900**	**6700**	16893
D60/321/Oil/Floor Core/02	19	19	32	16	130	140	160	526
D60/326/Oil/Floor Core/01	<100	<100	<100	<100	<100	<100	<100	<700
D60/326/Oil/Floor Core/02	<100	<100	<100	<100	<100	<100	<100	<700
D60/329/Oil/Floor Core/01	9.4	24	480	146	3000	3200	4700	11559

	PCB28 (µg/kg)	PCB52 (µg/kg)	PCB101 (µg/kg)	PCB118 (µg/kg)	PCB138 (µg/kg)	PCB153 (µg/kg)	PCB180 (µg/kg)	Total PCB (µg/kg)
D60/329/Oil/Floor Core/02	<1	4.9	69	21	330	260	580	1366

*Note: Where concentrations are in **bold**, these have been used for the WM3 waste classification compound sample.*

7.2 Dragon

7.2.1 Asbestos

Residual asbestos left within the facilities during decommissioning is of minimal risk to intrusion scenarios. The only identified asbestos present in the Dragon facility is located in between the bio-shield and the metal thermal shield [19, 25]. The asbestos found within Dragon is in the form of blocks, rather than sprayed asbestos as found in SGHWR [25]. The current plan is to remove 7 of the 8 layers of thermal shields during remote decommissioning, with the final asbestos layer trapped behind the final layer of steel. Once the reactor and final steel layer removed, the asbestos will be manually removed [25]. Once all asbestos blocks are removed, a 4-stage clearance process will be undertaken to remove all traces of asbestos from the Dragon facility prior to demolition [19, 25]. Asbestos removed from Dragon is to be disposed of as a hazardous waste consignment, under European Waste Catalogue (EWC) 17 06 01* if no radiological contamination is present.

7.2.2 Oil

An oil spill survey was carried out in buildings B78 and B70 [18]. All accessible areas were inspected. Three areas of oil contamination were identified in the operational areas of the reactor. Oil contamination will be removed during decommissioning therefore no hydrocarbon contamination is defined in the NRI for Dragon.

7.2.3 Fibreglass

There is no fibreglass in the Dragon facility or mortuary holes.

7.3 D630 Stockpiles

7.3.1 Asbestos

Trial pitting of the D630 stockpiles (D6N, D6S, D64 and A51/A52) has occurred over 2 phases [24]. No asbestos fibres were detected during the two phases (38 samples) with a laboratory detection limit of <0.001 % asbestos content. The results from the sampling illustrate that following the removal of foreign materials to meet the Emplacement Acceptance Criteria (EAC) then the contents of the D630 stockpiles would meet EWC's 17 01 01, 17 01 02 and 17 01 07.

8 Inventory Robustness

The current inventory is based on the data available as well as cautious assessments and interpretations of data.

The current inventory will be supplemented by additional data that may arise between now and the GRR / DfR permit application submission. The input of new data and recharacterisation of existing data is illustrated by the SGHWR oil contamination estimates. The additional data to be incorporated includes an improved understanding of the Dragon mortuary tube inventory. andinformation generated on implementing the EAC. Additional facilities, or areas of reactors, may become available for characterisation as their accessibility changes through decommissioning.

The EAC will be applied to the backfill, as well as structures, to ensure that only acceptable material will form part of the end state. It should be noted that accessibility in some areas will become more restricted as decommissioning progresses, prior to being released for characterisation pending demolition.

Section 10 captures the areas of inventory uncertainty. Uncertainties can exist where data that is generic or associated with an area has been used to interpret the contamination of an area that has not been sampled and analysed. This occurred when data from an SGHWR concrete sample was used to estimate the inventory of Dragon concrete. Additionally, D630 rubble inventory data has occasionally been used to support an estimate of SGHWR concrete. It is recognised that the D630 rubble originated from a range of different facilities of different ages, with other potential contaminants of concern and greater quantities of brick than is found in the reactor structures. Caution should be implored when interpolating with alternative data due to the uncertainties derived from using alternate data sources.

Whilst there are uncertainties, proportionality needs to be applied to the magnitude of risk associated with the masses and distributions of materials within the facilities and how accurate the knowledge on them needs to be in order to support the case. All rubble from the D630 stockpile will be assessed against EAC before it can be accepted for backfilling the reactor below ground voids. Material that does not meet the criteria will be managed off-site.

Several conservative assumptions have been made in the inventory and these will continue to be explored where appropriate through the uncertainties assessments:

- Iron in the structures may have been over-estimated with data arising from analytical samples and from volume estimates;
- The steel rebar estimate for Dragon has been based on a pessimistic assumption in the radioactive inventory [21] that there is 150 kg/m^3 rebar in bioshield concrete, where the minimum rebar amount specified for construction was 36kg/m^3;
- Conservative estimates of the hydrocarbon content in SGHWR oil stains have been made as oil contamination has been assumed to be present through all inaccessible areas;
- It has been assumed that non-radiological concentrations reported as LoD values are present at the LOD level, which clearly is an over-estimate;
- The density of reinforced concrete of 2400kg/m^3 has been used for all concrete rather than using the concrete only density of 2300kg/m^3.
- A sensitivity analysis could be introduced if a “Total” chemical inventory was used, rather than what was “Readily Available” through leaching. “Total” concentrations are often many orders of magnitude higher than “Readily Available” concentrations for relatively insoluble species;
- Gaps in the data need to be dealt with or the lack of data justified:
  - The SGHWR raft foundations below the voids have not been included the current inventory and a reasonable estimate of the inventory should be made, recognising there may be uncertainties associated with any assumption;
  - An estimate of the barium inventory in the baryte concrete is not available. The Detailed Qualitative Risk Assessment (DQRA) screening [26] demonstrate barium / barytes concrete is not a contaminant of concern for the HRA, therefore has not been considered further. However, should regulatory review identify this as significant interest, a reasonable assumption for the content should be made to support sensitivity calculations in the HRA.

9 Conclusions

The inventory spreadsheets are a flexible method of capturing the data based on current estimates and assumptions.

The inventory will be kept up to date as new information becomes available.

10 Uncertainties (Various Sources) - See Uncertainties Management Plan for how NRS manages the uncertainties.

Reference No.	Feature, Event or Process subject to Uncertainty	Description of Uncertainty (from source document where available)	Treatment of Uncertainty / Statement of Assumption (from source document where available)	Originator's Rating of Potential Significance (High / Medium / Low)	Originator's Recommended Action
AECOM 3	Asbestos Containing Materials	There are uncertainties relating to the quantities and types of asbestos contaminated materials (ACMs) which may be present and potentially left in the infilled basement structures of SGHWR and Dragon.	Further information on the proposed ACM removal strategy and guidance on the classification of waste containing asbestos has been included in the SWMMP.	L	Quantification required. See SWMMP for further information on how asbestos will be managed.
AECOM 7	Information sources	Non-radiological data arises from a variety of sources and is in many cases reported second-hand, not directly from the source. Therefore, the accuracy of the data cannot be determined at this stage	All data has been referenced throughout the report for transparency.	L	Information sources utilised should be verified by Magnox where appropriate. Information sources related to proposed on-site disposals (ISD, DfaP, DfR) will need to be underpinned through the application process, using the Staged Inventory Management Plan (SIMP) and EAC. Information relating to waste being disposed off-site will need to be validated through the standard waste management procedures.
NRI-S-1	SGHWR Building volumes	The volumes and masses of the different regions of SGHWR need be confirmed.	Assumption that voids volume and below ground volumes are reasonable estimates, conceptualisation upon which below ground volume is based is sound.	Medium	Likely to change, volumes in the same region are being used across the project and need alignment.
NRI-S-2	SGHWR Building volumes	Total below ground volume data is available for the North and South Annexe and the “deep” & “shallow” primary containment regions, but the verified void volume is for the entire below-ground structure.	Assumption used that the void volume for each section is proportional to the total volume of that section, so ratios are used.	Medium	Review, it is possible some areas have greater proportion of interior walls remaining and therefore proportionally less void volume available for filling.

Reference No.	Feature, Event or Process subject to Uncertainty	Description of Uncertainty (from source document where available)	Treatment of Uncertainty / Statement of Assumption (from source document where available)	Originator's Rating of Potential Significance (High / Medium / Low)	Originator's Recommended Action
					Likely to change when aligning with other parts of the project.
NRI-S-3	SGHWR raft foundations	The raft foundations are not currently included in the inventory.	Not included.	Medium	Could increase the inventory of trace chemicals significantly therefore should be captured in future issues.
NRI-S-4	SGHWR Concrete	Actual composition data for the concrete used in the structure of SGHWR is not available	Assumed a typical construction concrete composition from the period of construction. Trace elements come from core samples.	Low	No action recommended
NRI-S-5	SGHWR Oil contamination	The volume and composition of oil in stains across SGHWR is unknown.	10% of the secondary containment floor area has been contaminated by oil and 25% of the primary containment area. (draft BAT Analysis for SGHWR Residual Oil Contamination, Galson Sciences, November 2018)	None	Additional characterisation of SGHWR oil characterisation undertaken between 2022 and 2023. It concluded a mass of oil contamination concrete across SGHWR to be approximately 10 kg, a value lower than the 69 kg estimated in the BAT analysis. Furthermore, the composition of leach tests from contaminated concrete cores show a high correlation to Castrol 'Hyspin' AWS ™ hydraulic oil which is non-hazardous.
NRI-S-6	SGHWR Fibreglass	Estimated density has large impact on mass.	Used density in fibreglass BAT, though no source is cited for it.	Low	Impact likely low. No action recommended

Reference No.	Feature, Event or Process subject to Uncertainty	Description of Uncertainty (from source document where available)	Treatment of Uncertainty / Statement of Assumption (from source document where available)	Originator's Rating of Potential Significance (High / Medium / Low)	Originator's Recommended Action
NRI-D-1	Dragon building volumes	A “rule of thumb” has been used to estimate the structure and void volume. The 'rule of thumb' value is 30% of the total volume of a structure is the structure itself. 15% has been used in the non-radiological inventory as there are significantly fewer in-situ structures than SGHWR. There is an uncertainty when applying the rule to a specific facility.	Assumption that voids volume and below ground volumes are reasonable estimates	Medium	Use volumes that have greater underpinning
NRI-D-2	Dragon Concrete	Actual composition data for the concrete used in the structure of Dragon is not available	Assumed a typical construction concrete composition.	Low	No action recommended
NRI-D-3	Dragon Concrete	There is no available data on the chemical composition of the foundations below SGHWR and Dragon.	The foundations are assumed to be the same concrete as the structure.	Low	No action recommended
NRI-D-4	Dragon Concrete	It is known there is a quantity of baryte concrete in some regions of Dragon which has not specifically been accounted for.	Not accounted for currently.	Low	Sensitivity calculation on the barium in the inventory.
NRI-D-5	Dragon Chemical inventory	The chemical inventory for Dragon is based on samples from SGHWR. There is no specific analytical data from Dragon.	Assumption that the inventory will be analogous to SGHWR. Therefore, the uncertainties associated with the SGHWR inventory have a direct effect on the Dragon inventory.	Medium/Low	Ensure there are no specific contamination events or other factors for Dragon which would lead to an inventory dissimilar to SGHWRs.
NRI-D-6	Dragon Backfill Chemical inventory	The mortuary tubes inventory uses typical pozzolanic grout trace elements	It will be assumed in the HRA that the Dragon Mortuary Tubes were constructed from pozzolanic concrete containing typical pozzolanic cement trace elements	Low	May need revision if different grout selected
NRI-D-7	Dragon Asbestos	There is a lack of information on asbestos to be left in-situ at Dragon currently	Assumption is that only residual asbestos will remain on the concrete structure	Medium	A BAT for analysis for residual asbestos in Dragon/ up-issue the SGHWR BAT analysis to also cover Dragon.

Reference No.	Feature, Event or Process subject to Uncertainty	Description of Uncertainty (from source document where available)	Treatment of Uncertainty / Statement of Assumption (from source document where available)	Originator's Rating of Potential Significance (High / Medium / Low)	Originator's Recommended Action
NRI-D-8	Dragon Oil contamination	Assumption made that there is no significant oil contamination at Dragon.	Assumption based on statements within the SGHWR Residual Oil Contamination BAT analysis.	None	No known significant oil contamination in the Dragon building. It is not foreseen that any oil contamination will develop during decommissioning. Uncertainty closed.
NRI-D-9	Dragon Fibreglass	Assumption made there is no fibreglass that will remain at the End State.	Assumption there is no significant fibreglass to remain.	None	No known fibreglass in the Dragon building. If any fibreglass is identified during decommissioning, then assessment and BAT will be undertaken. Uncertainty closed.
NRI-SD-1	Sample results	Results are LOD for many of the samples.	Where LOD is recorded as a result, it has been included in the computation of the mean values as the LOD	Low	No action recommended
NRI-SD-2	Iron estimates	There may be double counting in the estimates of iron content as e.g., for SGHWR the iron inventory based on the samples is 550t, the iron inventory in the metals estimate is 3200t. The iron in the chemical inventory cannot be representative of the entire inventory as the laboratory reports indicate rebar was removed from some samples.	The cautious assumption has been made to include both.	Low	No action recommended
NRI-SD-3	Sample results	There are sample results based on different analysis 1) the total contaminant concentrations associated with the solid phase of the sample and 2) the readily available contaminants concentrations from the mass (for each kilogramme of rubble) that was released (leached) to the water phase when one-part rubble was mixed with ten-parts	Inventories are presented with both 1 & 2. Assessment will occur elsewhere.	Medium	Use of the total concentrations for sensitivity analysis considering a low probability worse case. Readily available used in other cases.

Reference No.	Feature, Event or Process subject to Uncertainty	Description of Uncertainty (from source document where available)	Treatment of Uncertainty / Statement of Assumption (from source document where available)	Originator's Rating of Potential Significance (High / Medium / Low)	Originator's Recommended Action
		water. The selection of which samples to use for assessment is an uncertainty.			

Glossary of Abbreviations

BAT	Best available technique
HRA	Hydrogeological Risk Assessment
IES	Interim End State
LOD	Limit of detection
NRI	Non-Radiological Inventory
OPC	Ordinary Portland Cement
SGHWR	Steam Generating Heavy Water Reactor
SWESC	Sit Wide Environmental Safety Case

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Appendix 1

Microsoft Excel file: ES(21)SS09 - Non-Radiological Inventory: SGHWR structure to remain in-situ and Backfill

Appendix 2

Microsoft Excel file: ES(21)SS10 - Non-Radiological Inventory: Dragon structure to remain in-situ and Backfill