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Issue 3

Assessment of Hunterston A SILWE Gaseous Radioactive Discharges in relation to the Best Practicable Means requirement

Issue 3

[redacted]

REVISION/REVIEW REGISTER

A REVIEW/CHANGE OF THIS DOCUMENT WAS CARRIED OUT AS FOLLOWS:

DATE/ ISSUE NO.	CARRIED OUT BY	SIGNATURE	AMENDMENT AND BRIEF REASON
Issue No 1, September 2018	[redacted]		1st Issue
Issue No 2, April 2023	[redacted]		Considered a new waste inventory, and operational throughput assumptions. Also incorporated new release fraction data from encapsulation of FED at Trawsfynydd and applied a new methodology for assessing radioactive wastes.
Issue No 3, June 2023	[redacted]		Considers change to the time that the boxes will be held in SILWE after grouting, before moving them to the ILWS. This has increased from 84 to 168 hours. Estimates the proportion of the box processing discharges into SILWE and ILWS. Document reformatting to make the changes clearer.

SUMMARY

The Solid Intermediate Level Waste Encapsulation (SILWE) facility at Hunterston A (HNA) will discharge the gaseous radionuclides tritium (H-3), carbon-14 (C-14) as well as radioactive particulate when operational. Magnox must use the principle of Best Practicable Means (BPM) in the design and operational management of their facilities in order to minimise such discharges. This principle means that Magnox must take all reasonably practicable measures to minimise gaseous discharges from SILWE to achieve a high standard of protection for the public and the environment.

This assessment provides an estimate of the radioactive discharges and associated dose to public from SILWE to inform the demonstration of BPM for processing the waste. This will also inform the appropriate limits that will be required for a variation to the site authorisation.

Since Issue 1 this assessment has been revised to consider new waste inventory information and operational throughput assumptions. The assessment also incorporates recent release fraction data from encapsulation of FED at Trawsfynydd and applies a new methodology for assessing radioactive releases.

This revision also includes some assumptions and estimates of the proportion of gaseous H-3 and C-14 that could be released in the ILWS following the transfer and storage of encapsulated SILWE waste packages to inform the BPM.

GLOSSARY OF ABBREVIATIONS

ALARA	As Low as Reasonably Achievable
BPM	Best Practicable Means
DF	Decontamination Factor
DPUR	Dose Per Unit Release
EASR	Environmental Authorisations (Scotland) Regulations 2018
FED	Fuel Element Debris
GBq	Giga-becquerel
HEPA	High Efficiency Particle Air
HNA	Hunterston 'A'
HVAC	Heating Ventilation and Air Conditioning System
ILW	Intermediate Level Waste
ILWS	Intermediate Level Waste Store
MAC	Miscellaneous Activated Components
MCI	Miscellaneous Contaminated Items
MILWEP	Modular Intermediate Level Waste Encapsulation Plants
NFED	North FED
RF	Release Fractions
SAWB	Solid Active Waste Building
SAWBR	Solid Active Waste Bunker Retrievals
SEPA	Scottish Environment Protection Agency
SFED	South FED
SILW	Solid Intermediate Level Waste
SILWE	Solid Intermediate Level Waste Encapsulation
TRA	Trawsfynydd
XST	Cross Site Transporter

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TABLES

1 INTRODUCTION

The main function of the Solid Intermediate Level Waste Encapsulation (SILWE) facility is to encapsulate the Solid ILW from SAWB Retrievals (SAWBR) and render it passively safe for storage in the Intermediate Level Waste (ILW) Store. Active commissioning is due to begin in October 2025, with full operation starting from June 2026 [1].

The SILWE facility will present a source of radioactive discharges resulting from the waste encapsulation process. In order to ensure compliance with the Environmental Authorisations (Scotland) Regulations 2018 authorisation and demonstrate Best Practicable Means (BPM) [2] the estimated gaseous discharges and dose to public from the SILWE facility have been assessed. This best estimate of discharges provided in this report will help determine BPM[1] and inform the appropriate limits required in a variation to the site authorisation to include SILWE.

This assessment is informed by operational data from another Magnox site, Trawsfynydd (TRA) which is already using a grout encapsulation process of solid ILW similar to SILWE. This assessment follows on from previous work carried out in Issue 1 of this report [3], published in 2018. How this report develops from Issue 1 and 2, and how it takes the learning from Trawsfynydd is discussed in more detail in the sections below.

1.1 Assessment of Hunterston A SILWE Gaseous Radioactive Discharges in relation to the Best Practicable Means Requirement, Issue 1 [3]

The assessment carried out in Issue 1 [3] found that the SILWE would release 6.00E+00 GBq of H-3 and 5.50E-01 GBq of C-14 per year, over a 2-year operational period, assuming all waste from the SAWBR would be encapsulated. These discharge estimates were based on operational data from the encapsulation of solid Fuel Element Debris (FED) ILW at Trawsfynydd. The justification for the use of the Trawsfynydd FED encapsulation data to estimate SILWE discharges was that this was real operational data using a similar waste form and process.

Issue 1 of this report recommended that:

- Any further data that becomes available (e.g., conditioning of graphite wastes), should be used to further underpin the above estimates.

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1 *SEPA's Best Practicable Means (BPM) principles are laid out in "Satisfying the optimisation requirement and the role of Best Practicable Means" [2]. For this report we are demonstrating if the managing of waste in SILWE meets requirement 2, "Use BPM to minimise the total activity of radioactive waste that is discharged to the environment". This report aims to give a "best estimate" of discharges to help determine if this principle is met, or if further optimisation is required.*

The BPM requirement is that Magnox must take all reasonably practicable measures to minimise gaseous discharges from SILWE to achieve a high standard of protection for the public and the environment to ensure doses are As Low as Reasonably Achievable (ALARA).

- Gaseous discharges are closely monitored during active commissioning of SILWE so that these estimates can be revisited.
- Active commissioning should also look at the longer-term evolution of gaseous discharges to look for any anomalous patterns of discharge as was observed in South FED (SFED) as shown in

- Appendix C, Issue 1 (2018) Results. This pattern indicates a few boxes have a larger release than predicted, which may lead to a larger annual release if the pattern is repeated long term.
- As further operational data from TRA becomes available this should be assessed to further refine the discharge estimates, prior to the active commissioning of SILWE.

For the results of Issue 1 of this report, refer to

Appendix C, Issue 1 (2018) Results.

1.2 Trawsfynydd Data

The North FED (NFED) Plant is retrieving and processing waste from the North Vault, Magnox Debris Handling and Sorting Facility (MDHSF) and Ponds North Void (PNV) at Trawsfynydd Site. At a high level, NFED encapsulates bulk solid waste comprising Magnox FED, Miscellaneous Contaminated Items (MCI), Miscellaneous Activated Components (MAC), and solid PNV waste in 3m^3 stainless steel boxes.

The learning from TRA is that:

- The overall average release fraction (RF) including anomalies of H-3 and C-14 from both NFED and SFED plants for encapsulating FED Magnox waste is 0.01% and 0.006% respectively.
- The average RFs were highly skewed by a few outlier boxes, and when these were excluded, a Release Fraction (RF) of H-3 and C-14 is 0.004% and 0.009% respectively; [3]
- The overall learning is that H-3 and C-14 gaseous discharges from SILWE are likely to represent an extremely small part of the waste inventory and the encapsulation process meets the BPM objective of minimising gaseous discharges to the environment.

1.2.1 Trawsfynydd Data Since Issue 1

Since Issue 1 [3] more data from the encapsulation of FED at Trawsfynydd has been made available to help refine the release fractions for H-3 and C-14.

The new data [4] from an additional 16 boxes has been combined with the initial data from the 16 boxes in 2018, to generate more refined release fractions for H-3 and C-14 using the total 32 boxes. To provide a more conservative estimate and allow for any uncertainties, the outlier boxes were included in the calculation of release fractions. The methodology is discussed further in Section 5.3.

2 PURPOSE AND SCOPE

The purpose of this document is to refine the previous SILWE discharge estimates from Issue 1[3] for the encapsulation of SAWB (i) Bunker 1 and (ii) Bunkers 2-5 waste. The discharge assessment takes into consideration revised inventory data new operational throughput assumptions and more recently available data from Trawsfynydd to inform RF's. The discharges from Bunker 1 and Bunkers 2-5 will be reported separately.

This document will also carry out an off-site dose assessment associated with the discharge estimates for SILWE to inform the demonstration of BPM for the waste processing and determination of the appropriate limits that will be required for a variation to the site authorisation.

This report assesses the proportion of the total gaseous H-3 and C-14 SILWE discharges which could be released in the ILWS following the transfer and storage of the encapsulated SILWE waste packages. This provides some discharge and dose estimates for the ILWS which can be used to inform the BPM assessment. The ILWS are a proportion of the total estimated releases generated from the SILWE process and are not additional discharges.

3 SILWE PROCESS DESCRIPTION

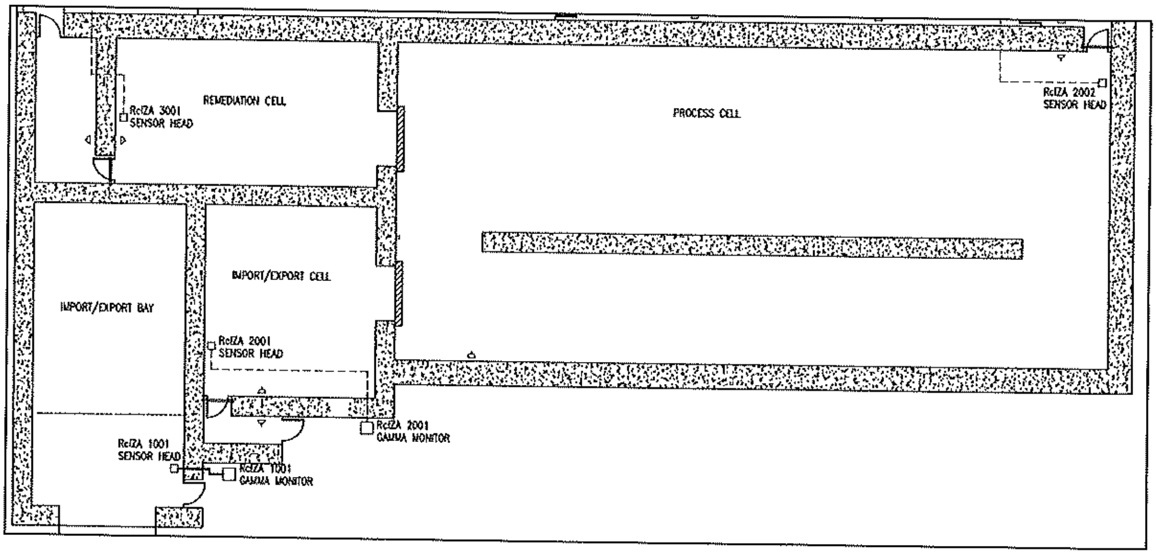
The main function of the SILWE facility is to encapsulate the Solid ILW from SAWB Retrievals (SAWBR) and render it passively safe for storage in the Intermediate Level Waste (ILW) Store.

There will be two encapsulation processes within the SILWE facility which are explained in more detail in the sections below. More detail on SILWE can be found in [6]. At a high level, SILWE will encapsulate:

- Bulk solid ILW waste comprising Magnox FED, FED graphite, Miscellaneous Contaminated Items (MCI), Miscellaneous Activated Components (MAC), and FED Fuel Channel Components (FCC) in 3m^3 stainless steel boxes; and
- Fines, particles <5mm in diameter, comprising mostly graphite (but could be any combination of that which makes up the solid waste) in drums [7].

The SILWE facility will be running for 6 years from Summer 2026, with around 200 boxes encapsulated annually [1]. A more detailed process description is provided in [7]. The facility will encapsulate approximately 4 boxes per week [8]. The general layout of the SILWE facility is presented in Figure 1.

Figure 1: ***Layout of the SILWE process areas***



3.1 Solid ILW Waste

The Solid ILW is made up of Magnox and graphite Fuel Element Debris (FED). At the time of writing, Bunkers 2-5 have been emptied, and >95% of Bunker 1 has been recovered. The unencapsulated waste from these bunkers is currently stored in the ILWS. It is retrieved and packaged into 3m^3 boxes by the SAWBR plant.

The boxes will first be transported from the ILWS to the SILWE facility using the Cross Site Transporter (XST). Once received into the Import/Export cell of the SILWE facility the vent and grout plugs on the boxes will be removed, following which the boxes are transferred to the process cell. The process cell contains the grouting stations and the quarantine line.

When a box is transferred to the process cell it is positioned at the Grouting Station to start encapsulation. During encapsulation grout is pumped via a feed hose into box via the grout port at a rate of 30 L/min. Grout within the box after filling is allowed to settle. If the level drops below the high-level fill point more grout is added to bring it back up to that point. At the same time the grout is added, air is extracted directly from the box via the vent port. The ventilation extract is equipped with flow instrumentation and a sample point for hydrogen gas, which can be released when certain wastes are encapsulated.

The encapsulated waste is then allowed time to cure in the boxes. After this further grout is added to provide the capping within the box. This is carried out using the same process as before, but at a delivery rate of 20 L/min. The box is then transferred to the quarantine line where it is left to cure. During curing in the process cell, the main process cell is monitored for hydrogen. After a minimum of 168 hours and once hydrogen generation rates drop to the acceptable level[2] of 5 lh^{-1}, the boxes will be transferred out of the process cell back into the import / export area where the vent and grout port plugs are replaced. The boxes are then transferred to the ILWS for storage using the Cross Site Transporter (XST).

3.2 Fines

The fines are particles <5mm in diameter and will mainly be dried pond sludge from Bunker 1 and graphite dust from Bunkers 2-5. The dry fines wastes are retrieved into boxes from SAWBR and are to be encapsulated in drums in SILWE. Two boxes of fines, retrieved from Bunkers 2-5 are currently un-encapsulated in ILWS. The remaining fines have not yet been retrieved but it is expected that a further 6 boxes will be retrieved from Bunker 1 in SAWBR. An estimated 8 boxes of Fines will be encapsulated in SILWE.

The fines boxes will be transferred to the SILWE facility on the XST where they will be received into the Import/Export cell and transferred to the remediation cell via the process cell.

In the remediation cell the vent and grout plugs on the box are removed and stored. The fines are then transferred from the box to an empty drum containing a sacrificial paddle which is positioned next to it. Once the empty drum and box are in position the fines transfer can commence. Circa 678 litres of water are metered to the drum and the paddle rotation is started. The fines are then transferred via a vacuum transfer system at a rate of 20 kg/min to

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2 Hydrogen rates will need to be below the acceptance level for storage in the ILWS. This is to mitigate the risk of flammable gas hazards.

minimise airborne dust generation. Once complete, the paddle rotates at a higher speed and approximately 1.06m3 of grout is transferred to the drum. Mixing continues after fill height is reached for either a fixed period or until a set torque level is reached. The mixture is then left to set for approximately 24 hours, following which the drum is transferred to the quarantine area for curing.

If present, bleed water is not removed, instead it is allowed to be reabsorbed and any residual to evaporate. The drum is capped after any bleed water has dissipated and then allowed to cure. After curing, the lid is replaced, and the drum is exported via conveyor system to the import/export bay as per normal box export (waiting 168 hours before going to ILWS).

3.3 SILWE Ventilation and discharge arrangement

The areas of the SILWE facility where radioactive discharge releases will be generated (described in more detail in section 5.3) is the process cell and the remediation cell.

The process cell (C2) and the remediation cell (C3) are separate areas but air extracted from these will be directed to the Cell Area extract system which is fed through a primary and secondary HEPA filter bank and an iso kinetic stack sampling system prior to discharge [9] via a stack located on the outside of SILWE facility. The Cell extract system is monitored for H-3, C-14 and hydrogen.

Within the process cell are the grouting stations and the quarantine line. In addition to the main process cell extract system there are also box extract systems located on the grouting stations. The box extract systems extract air from the boxes during addition of the grout at the grouting stations.

The box extract system (separate to the main cell extract) is fed through a primary and secondary HEPA filter bank and an iso kinetic stack sampling system prior to discharge [9] via a stack located on the outside of SILWE facility. The box extract air is sampled for H-3, C-14 and hydrogen.

The external stack has two outlet pipes, one for the cell area extract and one for the box extract system. The external stack height is 21m above ground [9].

3.4 ILWS Vent Arrangements

The ILWS has an installed ventilation system designed to maintain environmental conditions (Temperature and humidity) to reduce the risk of corrosion of waste packages. The ventilation consists of a supply and extract system (resulting in the ILWS being maintained at a slight negative depression) [10].

The discharge point is located at the west of the building, at a height of 5.3m [11].

The Hunterston ILWS does not have an authorised discharge outlet. EA(S)R standard condition (H.2.1) allows sites to discharge from outlets which are not authorised if it can be demonstrated that directing the gaseous waste does not represent BPM for management of that type of gaseous waste.

4 WASTE INFORMATION

Due to the nature of how the waste was separated during the SAWB process, Bunker 1 has a very different waste fingerprint to bunkers 2-5.

For this reason, the discharge estimates have been calculated and presented separately for Bunker 1 and then Bunkers 2-5. This will be discussed further in Section 5.

As seen in Bunker 1 has a much larger amount of Magnox and much less Graphite than Bunkers 2-5.

This waste information has been updated since Issue 1 of this report, based on the data from [12].

Table 1: Waste Streams and Mass per bunker (in tonnes) [9]

		Bunker Waste amount (In Tonnes)								
	Number of Boxes	FED	Graphite	FSMs	Zr- D bars	Small MAC	Thermocouples	Fuel Fragments	Sludge	Filter Dust Bags
Bunker 1	305[3]	140.022	4.82	0.238	0.035	0.035	0.084	0.05	0.427	3.72
Bunker 2	277	0.27	609	74.7	4.176	4.176	0.033	0	0.066	13.56
Bunker 3	278	0.088	559	69.9	3.831	3.831	0.242	0	0	12.36
Bunker 4	275	0	544	67.7	3.729	3.729	0	0	0	15.72
Bunker 5	62	0	105	12.6	0.718	0.718	0.051	0	0	2.08

There will be 1200 boxes of waste total, including an estimated 8 boxes of Fines. Two boxes of fines will be from Bunkers 2-5 and an estimated 6 boxes from Bunker 1.

5 METHODOLOGY

5.1 Assumptions

1. The releases mechanisms will be similar to the encapsulation of FED at Trawsfynydd.
2. There will be a total of 1200 boxes encapsulated, across 6 years. Bunker 1 will be encapsulated in the first 1.5 year, and Bunkers 2-5 the following 4.5 years [1]. This equates to about 200 boxes encapsulated annually.
3. There will be 8 boxes made up of fines, that will be encapsulated differently to the rest of the boxes. Two from Bunkers 2-5 and a maximum of 6 from Bunkers 1. The annual releases for the fines are calculated to be released over 6 years, in line with the timescales for Bunker 1 and Bunkers 2-5.
4. A conservative approach is assumed for the gaseous release fractions which includes outliers in the Trawsfynydd data. This approach, described in Section 5.3 assumes that:
   - for H-3, 87.5% of the 1200 boxes, will release a lower RF of 0.0082%, and 12.5% of the boxes will release a higher RF of 0.0732%.
   - and for C-14 94% of the 1200 boxes, including Fines will release a lower RF of 0.0089, and 6% of the boxes will release a higher RF of 0.3512%.
5. A RF of 1E-5 is assumed for particulate (alpha and beta) for the physical disturbance and agitation during grout pouring and transfer of fines. This RF is only assumed to apply to waste streams that contain loose fine particles that could become airborne. From Bunker 1, this is assumed to be waste streams; Magnox, Sludge and Filter bags, and for Bunkers 2-5 Graphite and Filter Dust Bags. There are some small MCI

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3 305 boxes are a forecast, but there is reasonable confidence in what has been recovered (>95%) and what is left to still be recovered.

amounts (>1% per package), because this is a small percentage this has not been included.

6. The aerial discharges from the SILWE facility will be extracted by a ventilation system using HEPA filters. These filters prevent release of particulate contamination with an efficiency of ~99.97%. To allow for this a decontamination factor of 10,000 has been applied to particulate releases which is in line with S-731 [13].
7. The encapsulated boxes will remain in SILWE for a minimum of 168 hours (7 days) after grouting, before they are then transferred to the ILWS. It is assumed that after this there would be a significant decline in H-3 and C-14 releases.
8. It is assumed that a proportion of the total gaseous discharges of H-3 and C-14 resulting from box processing could be released in the ILWS. The estimated particulate discharges will only be released within the SILWE facility. This is discussed further in 5.5.
9. It is assumed there will be no particulate release from packages within the ILWS.
10. Bunker 1 will be processed first. Following this there will be a mixture of boxes from the Bunkers 2-5 encapsulated.

5.2 Limitations

The limitations around this assessment are mainly linked the assumptions, as listed in Section 5.1. However, there are additional limitations including:

- An average box weight per bunker means that some boxes will weigh more, and therefore may give off bigger releases. If numerous heavier boxes are encapsulating successively, the releases may increase over that time.
- There are inherent levels of uncertainty with the waste inventory, as laid out in [5]. These include uncertainty in trace element concentrations, neutron fluxes and Bunker 5 package inventories.
- The level of corrosion of FED and radioactive releases in Hunterston wastes may be different to other sites, such as Trawsfynydd.
- There may be more than 8 boxes of Fines, or more particulate in the solid waste boxes.
- 200 boxes may not be encapsulated annually, there may be less.

To allow for the limitations and uncertainties identified, a conservative approach to the discharge estimates has been taken and a sensitivity analysis is also provided in Appendix B. These should be taken into consideration when determining appropriate authorisation limits for the site.

5.3 Mechanisms for aerial release and selected Release Fractions

5.3.1 Gaseous Releases

Since Issue 1 [3] more data from the encapsulation of FED at Trawsfynydd has been made available to help refine the release fractions for H-3 and C-14.

The new data from an additional 16 boxes from Trawsfynydd has been combined with the initial data from the 16 boxes in 2018, to generate more refined release fractions for H-3 and C-14 using the total 32 boxes. The calculated release fractions from the 32 Trawsfynydd boxes is presented in

Table 2. Some of the calculated RF data presented in

Table 2 are considered to be outliers where they deviate from the mean by more than 1 standard deviation. Boxes 3 and 4 were considered to be extreme outliers as they apply to both the C-14 and the H-3 result and for C-14 deviates from the mean by >3 standard deviations. For this reason, an option could be to remove these from the dataset. However, given the relatively limited data set and to address uncertainties, a conservative approach to include all of the outliers is proposed.

Release fraction data will be refined once monitoring data is obtained in active commissioning of the SILWE facility. See forward actions.

To allow for the outliers in proportion of how many occurred in each dataset (for C-14 and H-3), the following method was applied to.

The average RF for 'non outlier' boxes and the percentage of non-outliers which occurred in each dataset was calculated to generate a RF which would be applied to the majority of the Hunterston waste.

The average RF for 'outlier' boxes and the percentage of outliers which occurred in each dataset was calculated to generate a RF which would be applied to the minority of the Hunterston waste.

Table 2: Calculated RFs from 32 Trawsfynydd NFED and SFED boxes encapsulated in 2023 and 2018, with outlier boxes highlighted [3,4]

Box Data			RF	
			C-14	H-3
2023 Box data	NFED	Box 25	0.0096%	0.0052%
		Box 26	0.0095%	0.0054%
		Box 27	0.0044%	0.0018%
		Box 30	0.0143%	0.0051%
		Box 36	0.0047%	0.0067%
		Box 46	0.0107%	0.0474%
		Box 51	0.0046%	0.0105%
		Box 89	0.0196%	0.0061%
	SFED	Box 01	0.0110%	0.0050%
		Box 03	0.0110%	0.0060%
		Box 12	0.0040%	0.0070%
		Box 19	0.0060%	0.0140%
		Box 20	0.0110%	0.0100%
		Box 29	0.0060%	0.0180%
		Box 34	0.0060%	0.0440%
		Box 37	0.0070%	0.1620%
2018 Box data	NFED	Box 3	0.0029%	0.0057%
		Box 4	0.0026%	0.0054%
		Box 5		0.0004%
		Box 10	0.0014%	0.0109%
		Box 11	0.0003%	0.0051%
	SFED	Box 1	0.0171%	0.0056%
		Box 2	0.0120%	0.0047%
		Box 3	0.1329%	0.0354%
		Box 4	0.5694%	0.0481%
		Box 5	0.0087%	0.0021%
		Box 6	0.0078%	0.0027%
		Box 7	0.0114%	0.0029%
		Box 8	0.0309%	0.0043%
		Box 9	0.0162%	0.0308%
		Box 10	0.0053%	0.0025%
		Box 11	0.0035%	0.0028%

The non-outlier and outlier RFs calculated and the percentages to which each will be applied to the Hunterston waste are presented below in

Table 3.

Table 3: Calculated RFs for C-14 and H-3

	C-14	H-3
Mean (non-outliers)	0.0089%	0.0082%
% Boxes non-outliers	94%	87.5%
Mean of the outliers	0.3512%	0.0732%
% Boxes as outliers	6%	12.5%

For both H-3 and C-14 the mean excluding the outliers has been calculated, giving 0.0082% and 0.0089% respectively. Additionally, the mean of the outliers has also been calculated giving 0.0732% for H-3 and 0.3512% for C-14. These larger percentages (representing the outliers) will be applied to the given percentage of boxes and will be outlined in the methodology in Section 5.3.

5.3.2 Particulate release

Particulate release or re-suspension can arise from physical agitation or disturbance of the waste during the addition of grout, transfer of fines or in drum mixing. Two different release fractions have been used for the particulate generated during addition of grout and transfer of fines, and another for the in-drum mixing of fines. These are only applied to the waste streams that contain loose fine particles that could become airborne. From Bunker 1, this is assumed to be waste streams; Magnox, Sludge and Filter bags, and for Bunkers 2-5 Graphite and Filter Dust Bags.

5.3.3 Summary of release fractions

The potential mechanisms and aerial release points which are assumed for the SILWE process are presented in Table 4. These include the calculated release fractions for gaseous and the RFs for particulate which have been selected from previous literature. A justification is provided on why each RF has been selected.

Table 4: Release Fractions for the Different Mechanisms

Mechanism	Release fraction description	Waste Type	Release Location	Release Type	RF	Justification	Ref
1	Resuspension of loose contamination as particulate matter (alpha and beta) resulting from physical disturbance and agitation of the waste. This applies to the pouring of grout encapsulant onto the waste and the transfer of fines from the box to the drum. This release mechanism is only assumed to apply to waste streams that contain loose fine particles that could become airborne e.g., dried sludge and the fines.	Solid/Fines	Process cell via the box extract system	Particulate (Alpha and Beta)	1E-5	The RF of 1E-5 was selected for resuspension of loose contamination was selected based on the mishandling or dropping of encrusted powders from between 1- 3 m [1314]. This was considered a conservative RF, as it is unlikely that there would be more resuspension from grout pouring and transfer through a vacuum line compared to dropping encrusted powders 1-3m.	[13]
2a	Release of gaseous H-3 from the exothermic reaction during encapsulation and curing of solid wastes. This is based on the mean of the non-outliers from the Traws data.	Solid	Process cell via the box extract system	Gaseous	0.0082%	The RF of 0.0082% was chosen for H-3 release from based on the TRA data, as outlined in 5.3, calculated from the mean of the non-outliers. To be applied to 87.5% of the waste inventory	N/A
2b	Release of gaseous H-3 from the exothermic reaction during encapsulation and curing of solid wastes. More conservative, this is the mean of the outliers from Traws data.				0.0732%	The RF of 0.0732% was chosen for H-3 release from based on the TRA data, as outlined in 5.3, calculated from the mean of the outliers. To be applied to 12.5% of the waste inventory.	N/A
3a	Release of gaseous C-14 from the exothermic reaction during encapsulation and curing of solid wastes. This is based on the mean of the non-outliers from the Traws data.	Solid/ Fines	Process cell via the box extract system	Gaseous	0.0089%	The RF of 0.0089% was chosen for C-14 release from based on the TRA data, as outlined in 5.3, calculated from the mean of the non-outliers. To be applied to 94% of the waste inventory.	N/A

Mechanism	Release fraction description	Waste Type	Release Location	Release Type	RF	Justification	Ref
3b	Release of gaseous C-14 from the exothermic reaction during encapsulation of fines waste. More conservative, this is the mean of the outliers from Traws data.				0.3512%	The RF of 0.3512% was chosen for C-14 release from based on the TRA data, as outlined in 5.3, calculated from the mean excluding the outliers. To be applied to 6% of the waste inventory.	N/A
4	Re-suspension of particulate matter from the in-drum mixing of fines (particulate releases)	Fines	Remediation cell	Particulate	2.22E-04	A RF of 2.22E-04 was selected for in-drum mixing during fines encapsulation for particulate release based on previous RF used for MILWEP at Berkley, Hinkley Point A and Chapelcross [14]. This was selected as the mixing process is similar, and there are no specific RF values for in drum mixing. Similar to the above RF, is a conservative estimate as due to the process used to mix the grout, it is unlikely that there would be much suspension.	[14]
5a	Release of gaseous H-3 from the exothermic reaction during in-drum encapsulation of fines waste. This excludes the outliers from the Traws data.	Fines	Main remediation cell and process area (quarantine line)	Gaseous	0.0008%	The RF of 0.0008% for grouting and curing of drum waste was chosen based on RF 2a, reduced by a factor of 10 as laid out in Ref 11. This makes the assumption that less H-3 will be released as the waste is in a drum and is not loose. Applied to 87.5% of the fines waste.	[11]
5b	Release of gaseous H-3 from the exothermic reaction during in-drum encapsulation of fines waste. More conservative, this is the mean of the outliers from Traws data.				0.0073%	The RF of 0.0073% for grouting and curing of drum waste was chosen based on RF 2b, reduced by a factor of 10 as laid out in Ref 11. This makes the assumption that less H-3 will be released as the waste is in a drum and is not loose. Applied to 12.5% of the fines waste.	

5.4 Box Processing Discharge Assessment

5.4.1 Solid Waste

Although Bunker 1 was calculated separately to Bunkers 2-5, the same method was used for all Bunkers:

1. The waste inventory information provided weights for all of the boxes in each bunker. Using this the average box weight for each bunker was calculated, using excel.
2. To calculate the inventory per box, the following approach was used:
   a. For H-3 and C-14, total activity (GBq) in each bunker was for the respective nuclide were selected and the average box inventory was calculated by multiplying the GBq/t values by the average box mass for that bunker [12].
   b. For Alpha and Beta particulates, the waste inventory was first separated into Alpha and Beta emitting nuclides, excluding H-3 and C-14 for each of the total waste stream inventories that are assumed to result in particulate release from resuspension.
   - For Bunker 1, these waste streams were Magnox, Sludge and Filter bags, and for Bunkers 2-5 the waste streams were Graphite and Filter Dust Bags were selected. These were identified as likely particulate in the Sites Radioactive Management Case definition of Particulates (9J62) [6].
   - To calculate the weight of the waste stream type per box, the percentage contribution of each waste type was used to generate an estimated weight per average box.
   - Then the activity (GBq) for each waste stream was calculated by multiplying the GBq/t for that waste stream by the weight of waste in an average box.
   - The results for each waste stream were then added to give the overall Alpha and Beta Particulate GBq for each average box in a bunker.
3. The inventories estimated from the above were then multiplied by the relevant release fraction, as laid out in 4.
   - For Solid Waste RF's, mechanism 1 (Table 4) was selected for particulate and 2a, 2b, 3a and 3b were selected for H-3 and C-14.
   - For H3 releases, to allow for the anomalies in the Trawsfynydd monitoring data, the lower RF 2a was applied to 87.5% of the 1200 boxes and a higher RF 2b was applied to12.5% of the boxes. of 0.0732%.
   - Similarly, for C14 releases, to allow for the anomalies in the Trawsfynydd monitoring data, the lower RF 3a was applied to 94% of the 1200 boxes, including Fines. A higher RF 3b was applied to6% of the boxes.
   - This gave the gaseous discharge data per average box from that Bunker.
4. For Alpha and Beta Particulates, RF mechanism 1 was used to account for the disturbance and agitation to the waste when the grout is added. A Decontamination Factor (DF) of 10,000 was applied to represent the aforementioned primary and secondary stage HEPA filtration. This is in line with S-731 [13].
5. The per box release was then multiplied by the number of boxes in each Bunker. This generated a total release per Bunker.
6. To calculate the average annual release each Bunker was divided by the number of years it would take to encapsulate equally. For Bunker 1, this was divided by 1.5 as it is being encapsulated first. For Bunkers 2-5 the total releases per bunker were

added and then divided by 4.5 (to equate to four and a half years) as they will be encapsulated after Bunker 1. This was based on the commissioning plan [1]

7. The most conservative annual discharge was also calculated by taking the most conservative nuclide/ particulate per bunker. This can be found in Appendix A Further Results.

5.4.2 Fines

It is estimated there will be 8 boxes of fines processed in SILWE. Currently two of the boxes from Bunkers 2-5 have been encapsulated as fines and the remaining six boxes will be made up from Bunker 1 fines.

The method for calculating the Fines discharges was similar to the method used for solid waste discharges:

1. As the fines will be mostly made up of particulate, it was assumed that only those waste streams listed in Section 5.4.1b would make up the Fines boxes.
2. To calculate the Fine's inventories the per Bunker particulate data calculated in Section 5.4.1b was used as a basis in combination with the H-3 and C-14 inventory information for each identified waste stream listed previously.
3. For Bunkers 2-5 the average for each nuclide/ group was taken to determine the discharges of the 2 boxes, whereas the actual output was taken for Bunker 1.
4. For the Fines RF's, mechanisms 1,3a, 3b, 4, and 5a and 5b were applied (Table 4). For H-3 RF 5a and b were used to account for the fact that less H-3 would be released from a drum compared to the loose waste RF.
5. For C14 releases, to allow for the anomalies in the Trawsfynydd monitoring, it was assumed that 94% of the releases, will be a lower RF (3a), and 6% will release a higher RF (3b).
6. For Alpha and Beta Particulates, RF mechanism 1 was applied to account for the disturbance during transfer of the fines to the empty drum. RF 4 was applied to account for the agitation of the waste during the in-drum mixing. A Decontamination Factor (DF) of 10,000 was applied to represent the primary and secondary stage HEPA filtration. This is in line with S-731 [10].
7. For Bunkers 2-5, the per box discharge was multiplied by two, and for Bunker 1 the per box was multiplied by six. These results were then added together to generate the releases for 8 boxes of fines.
8. To calculate the annual releases for the fines, to total discharges for all 8 boxes were divided by 6 (years) which is the total assumed processing for bunkers 1 (1.5 years) and bunkers 2-5 (4.5 years).

5.5 SILWE/ ILWS DISCHARGES SPLIT

It is assumed that a proportion of the total gaseous discharges of H-3 and C-14 resulting from box processing could be released in the ILWS. The following section describes the method of how the ILWS proportion was estimated.

5.5.1 ILWS Discharges

Gaseous H-3 and C-14 releases are expected as a result of the exothermic reaction during the encapsulation and curing of the waste packages. Data from Trawsfynydd provides some evidence of the pattern of hydrogen, H-3 and C-14 releases following the first grout pour during the encapsulation of FED wastes. The reports [19,20] containing this data were produced at the early phases of the SFED encapsulations to evaluate the encapsulation process performance. No recent similar reports are available, so it is recognised that the data on the trends of hydrogen and radioactive releases after grouting is limited.

However, this information can be used to make some assumptions on the possible gaseous releases of H-3 and C-14 in the ILWS from the SILWE encapsulated waste packages following transfer.

The risk posed by hydrogen means that waste packages will not be transferred from the SILWE plant to the ILWS until hydrogen generation has dropped to an acceptable level, which is currently proposed to be 5 litres per hour [7]. The SILWE process times between the first grout pour in a box and the cap grouting is 22 hours in total. The SILWE waste packages will not be transferred to the ILWS for a minimum of 168 hours after grouting, but this could be longer if the hydrogen generation rate has not reduced to an acceptable level.

Figures 2 and Figure 3 show the trends of hydrogen, H-3 and C14 from two boxes encapsulated in the Trawsfynydd SFED plant between 2005 and 2006 [19,20].

It can be seen that hydrogen, H-3 and C-14 rates peak within the first 72 hours following the first grout pour following which there is generally[4] a rapid decline in all releases, which fall to negligible levels after 16 days.

Based on the SILWE process times and the evidence from Trawsfynydd it cannot be ruled out that there may be some residual release from the waste packages once they are transferred to the ILWS.

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4 *A smaller peak is observed in Box 2 (Figure 2) when the cap grout is poured however in this case the cap grout is delayed until 480 hours after the initial grout pour.*

Figure 2: Hydrogen, H-3 and C-14 trends following the first grout pour of a Trawsfynydd SFED Box 1 encapsulation [19]

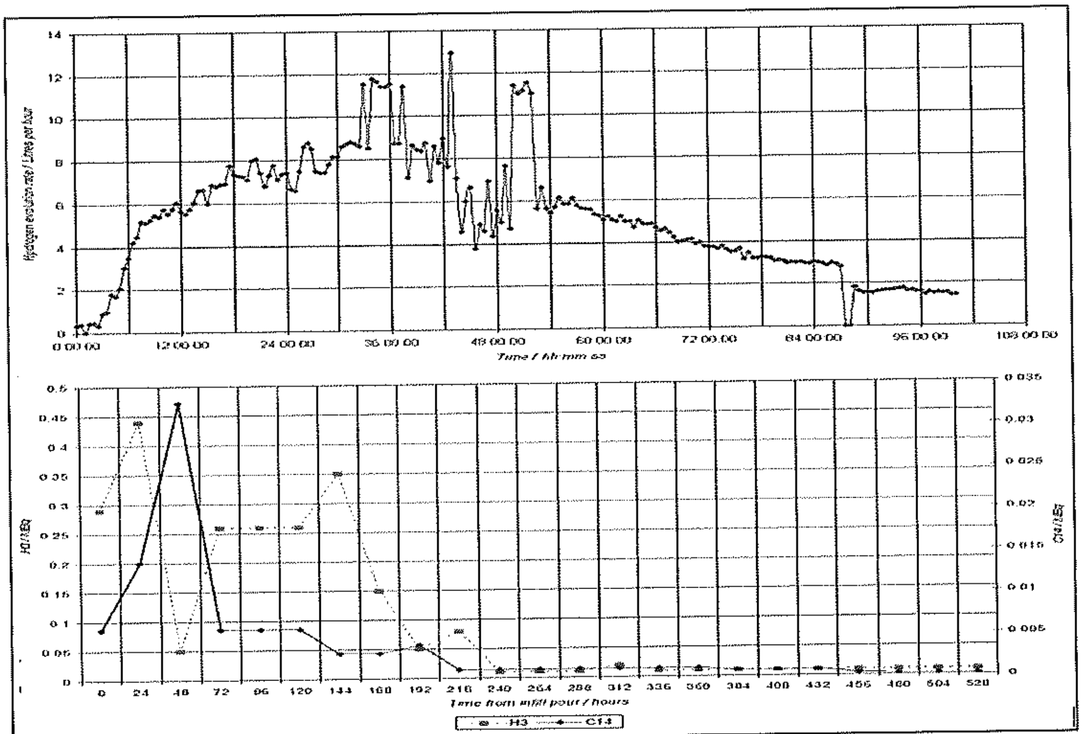
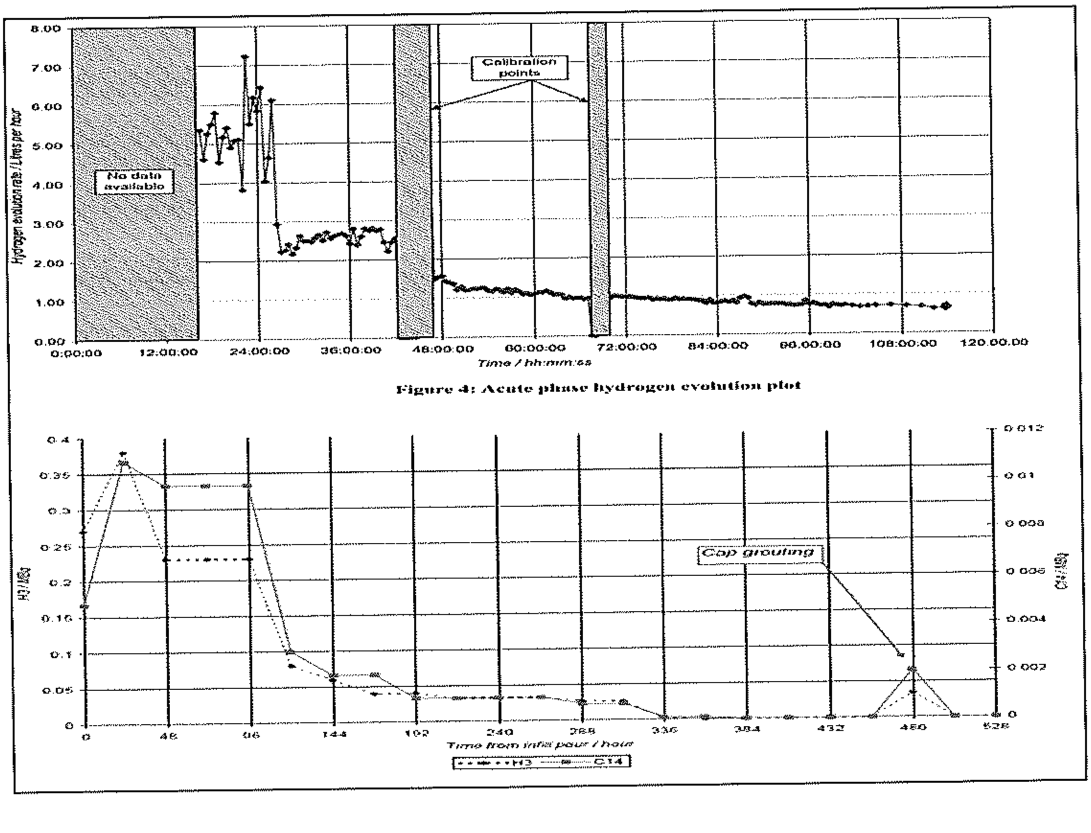


Figure 3: Hydrogen, H-3 and C-14 trends following the first grout pour of a Trawsfynydd SFED Box 2 encapsulation [20]



The understanding of the mechanisms for gaseous releases and the trends shown from the Trawsfynydd data provide confidence that releases in the HNA ILWS will be minimal especially as the boxes will not be transferred to the ILWS until a minimum period of 168 hours has passed after grouting when discharges should have already peaked. The transfer of the boxes will also not occur until hydrogen levels have fallen to 5l/h. Once a decline in hydrogen has been observed, it is assumed that the discharge rate of H-3 and C-14 also decline at the same time or soon after. This assumption is supported by the evidence from Trawsfynydd presented in Figures 1 and 2.

Further support to the assumption that gaseous H-3 and C-14 releases in the ILWS will be minimal, is the monitoring data available from the Trawsfynydd ILWS. Trawsfynydd monitored for H-3 and C-14 between August 2017 and December 2018 [21] when encapsulated FED wastes and encapsulated sludge packages had started to be transferred and stored. Data from seven sampling points during this time was presented, providing a representative sample from across the period.

The sample results indicated that H-3 and C-14 were not detectable at levels above background for the period, which provided justification that routine monitoring for H-3 and C-14 was no longer required [22]. It was recognised that the store was not yet full, and the site recognised the potential for tritium releases as more packages were added. However, these were anticipated to remain trivial (with the source limited to FED packages). A Best Available Techniques (BAT) [21] study for the store concluded that: "*tritium is released during grout encapsulation and subsequent curing. The rate of hydrogen released decrease exponentially with time during curing and therefore tritium releases are essentially limited to times if or when freshly cured packages are loaded into the ILW Store. An upper bound estimate of the tritium discharges in the month when freshly cured packages are loaded into the ILW Store is 0.38 MBq.*" Based on the anticipated releases, Trawsfynydd site has made the justification not to monitor the ILWS for radioactive gaseous release. It was also noted in [22] that encapsulated packages would be checked for any surface contamination prior to entry into the ILWS (as will be the case at HNA SILWE), which would mitigate any potential for particulate discharges in the ILWS.

To support the justification at Trawsfynydd that H-3 in the ILWS would remain trivial once there had been a substantial increase in the number of packages, a more recent assessment has been conducted. The assessment reviewed H-3 measurements taken between April 2022 and August 2022 [23] within the Shielded Inner Building of the ILWS were monitored. The H-3 measurement on average over this time period was found to be 3.9Bq/m^3 which was far below the 1,000Bq/m^3 minimum detection limit performance specified in 2004/2/Euratom recommendation therefore justifying that the levels are negligible and that no routine monitoring would be required in the ILWS. The assessment also concluded that the level of beta particulate had remained unmeasurable within the store.

In order to inform BPM and an approach for defining Standard reporting values (SRV's) for the ILWS at Hunterston, some assumed estimates of the possible proportion of SILWE H-3 and C-14 discharges which could be released in the ILWS have been developed. The uses some conservative assumptions informed by the trends in gaseous releases of the Trawsfynydd boxes observed in Figures 1 and 2.

As a minimum the waste packages will not be transferred from SILWE for 168 hours. Using the Trawsfynydd box data presented in Figures 1 and 2 the percentage decrease in H-3 and C-14 releases from the peak to 168 hours (after the first infill pour) was calculated. These are presented in Table 5 below.

Table 5: Difference between the peak H-3 and C-14 releases and 168 hours after the first grout pour for two Trawsfynydd boxes.

	Nuclide	Peak (MBq)	168 hours after pour	Decrease between peak release and 168 hours (MBq)	Decrease between peak release and 168 hours (%)
Box 1	H-3	0.44	0.15	0.29	65.91%
	C-14	0.46	0.04	0.42	91.30%
Box 2	H-3	0.38	0.04	0.34	89.47%
	C-14	0.37	0.07	0.3	81.08%

The mean % decrease across boxes 1 and 2 was calculated for both H-3 and C-14.

For H-3, the mean % decrease in releases from peak to 168 hours is 77.7%. For C-14 the mean % decrease from peak to 168 hours is 86.2%. It is therefore assumed that the amount of H-3 and C-14 released in the ILWS is 22.3% and 13.8% respectively, of the total SILWE estimated gaseous releases.

Additionally, it is assumed that particulate is only released in SILWE, as the waste packages in the ILWS will be grouted and so there is no mechanism for release. Packages will also be monitored prior to export from SILWE to ensure there is no surface contamination.

Based on this method the assumed proportions of the total SILWE discharges released in each facility are presented in Table 6.

Table 6 Proportion of the total SILWE estimated discharges released in each facility

Nuclide	SILWE	ILWS
H-3 (Gaseous)	77.7%	22.3%
C-14 (Gaseous)	86.2%	13.8
Particulate	100%	0%

This is based on limited data and so once monitoring data can be obtained the proportion of discharges and subsequent estimates will be reviewed, please see forward actions.

6 DOSE ASSESSMENT

For the Dose Assessment, DPUR values were selected from the EA's guidance [15]. Default DPUR values for Beta and Alpha were selected which would result in the highest dose for each category and discharge scenario, therefore providing a conservative assessment, The dose assessment is carried out for the total estimated discharges (across both SILWE and ILWS), the proportion of dose for both SILWE and ILWS are presented in 8.3.

Table 7: DPUR Values used in the assessment [13]

Total DPURs	µSv/Bq
DPUR (H-3) (µSv/Bq)	9.80E-13
DPUR (C-14) (µSv/Bq)	7.00E-11
DPUR (alpha particulate proxy, Pu-239) (µSv/Bq)	1.10E-06
DPUR (beta particulate proxy, Pb-210) (µSv/Bq)	2.80E-08

These values were then multiplied by the box processing annual discharges from Bunker 1, and the conservative annual figure from Bunkers 2-5 to generate the Predicted Public Dose (uSv/y).

6.1 SILWE Stack Height Assessment

A stack height assessment has been carried out to determine whether increasing the stack height would have any significant dose benefit. This will inform the BPM assessment.

For the SILWE stack height assessment, the EA's initial radiological assessment tool [16] was used to calculate the local resident dose at both 20 m and 25 m.

For H-3 and C-14 these were calculated for the SILWE only (i.e., that 77.7% and 86.2% of the total box processing for H-3 and C-14), whereas it was applied to the full discharge for particulate.

6.2 ILWS Stack Height Assessment

A stack height assessment has been carried out to determine whether installation of a stack at ILWS would have any significant dose benefit. This can be used to inform the BPM assessment.

For the ILWS stack height assessment, the EA's initial radiological assessment tool [16] was used to calculate the local resident dose resulting from releases at both 5 m (existing outlet height) and 10 m. These release heights can be compared to the default doses calculated in 8.3 which assume ground height release. Doses for the different release heights were calculated for the proportion of H-3 and C-14 estimated to be released form the ILWS (22.3% and 13.8%), %). This does not assess particulate as it is assumed that particulates there would be no particulate release from the ILWS.

7 HUNTERSTON A AUTHORISED LIMIT

Table 8: Current Site Authorisation Limits [15]

Radionuclide or Group of Radionuclides	Annual Limit (GBq)
Tritium	2.00E+01
Carbon-14	2.00E+00
All other radionuclides (excluding tritium and carbon-14)	3.00E-03

Hunterston A site authorisation limits are presented in Table 8, in accordance with the authorised disposal limits granted to the site by SEPA in [15].

8 RESULTS FROM SILWE BOX PROCESSING

8.1.1 Solid Waste

To ensure the even spread of discharges from Bunkers 2-5, the total GB/q per bunker was decided by the number of years (4.5 years) that the encapsulation would take place. This equates to roughly 200 boxes encapsulated per year.

For each Bunker discharge the pre-abatement release for particulates is shown to highlight the efficiency of the HEPA filtration, when the DF is applied. Abatement is not being carried out for H-3 and C-14, as it is cost disproportionate and therefore not BPM [18].

Table 9: Bunker 1 Annual Discharges (GBq)

Bunker 1	Annual discharge (GBq)	Pre- abatement annual discharge (GBq)	As a % of annual site limit (With abatement)
H-3	3.29E-01		1.64%
C-14	6.22E-02		3.11%
Alpha total	2.84E-08	2.84E-04	0.02%
Beta total (excluding H-3 and C-14)	6.05E-07	6.05E-03	

For Bunker 1 the annual releases are estimated to be 3.29E-01 GBq for H-3, and 6.22E-02 GBq for C-14, both of which are far below the site limits shown in 7. The annual discharges are based on a processing timescale of 1.5 years.

Table 10: Bunkers 2-5 Average annual discharges (GBq) over 4.5 years

Average Bunker 2-5	Annual discharge (GBq)	Pre- abatement annual discharge (GBq)	As a % of annual site limit (With abatement
H-3	9.80E+00		49.00%
C-14	2.32E+00		116.18%
Alpha total	1.52E-08	1.69E-04	0.07%
Beta total (excluding H-3 and C-14)	2.16E-06	2.16E-02	

For Bunkers 2-5 the annual release for H-3 and C-14 is 9.80E+00 GBq and 2.32E+00 GBq respectively. As can be seen in 8, this exceeds the site permit for C-14 and is just under half the permit limit (49%) for H-3. This indicates, that with the proposed throughput HNA site permit limits will need to be increased.

For comparison to show the contribution of discharges across all bunkers, Table 11 summarises the annual discharges of each bunker. This has been calculated using the total release per bunker divided by the number of years that bunker will be encapsulated (1.5 for Bunker 1 and 4.5 for Bunkers 2-5 combined). Further results can be found in Appendix A Further Results.

Table 11: Discharge Summary for Annual Release from each Bunker

	Bunker 1 Annual Discharg e (GBq)	Bunker 2 Annual Discharge (GBq)	Bunker 3 Annual Discharge (GBq)	Bunker 4 Annual Discharge (GBq)	Bunker 5 Annual Discharge (GBq)	Conservative Bunkers 2-5 Annual Discharge (GBq)
H-3	3.29E-01	1.51E+00	2.64E+00	4.57E+00	1.08E+00	1.50E+01
C-14	6.22E-02	7.28E-01	7.37E-01	7.07E-01	1.52E-01	2.38E+00
Alpha total	2.84E-08	1.19E-10	7.00E-09	8.07E-09	1.73E-09	2.64E-08
Beta total (excluding H-3 and C-14)	6.05E-07	1.25E-08	8.15E-07	1.08E-06	2.50E-07	3.54E-06

8.1.2 Fines

The release for 8 boxes of fines can be seen in Table 12 . As these are so small, they should not make a difference to the average annual output when encapsulated. The annual discharges for the fines are divided by 6 (years) to allow for processing over the 1.5 and 4.5 year for bunker 1 and bunkers 2-5.

Table 12: 8 Boxes of Fines Annual discharge over 6 years.

8 Boxes of Fines	Pre-abatement total discharge (GBq)	Annual discharge (With abatement) (GBq)
H-3		1.04E-03
C-14		2.48E-03
Alpha total	5.54E-04	9.24E-09
Beta total (excluding H-3 and C-14)	9.90E-03	1.65E-07

8.2 Discharge Summary

In summary, Table 9 and Table 10 show the SILWE discharges for Bunker 1 and then Bunkers 2-5. Table 12 presents the discharges for the fines which are assumed to be discharged over the 6 years and so the totals for the fines should be added to both Bunker 1 and Bunkers 2-5. For the purposes of informing appropriate authorisation limits these totals are presented in Table 13 below.

Table 13: Aerial release totals for Bunker 1 and Bunkers 2-5 both including fines

Nuclide	Bunker 1 and Fines Annual discharge (GBq)	% Current Authorisation	Bunkers 2-5 and Fines Annual discharges (GBq)	% Current Authorisation
H-3	3.30E-01	1.65%	9.80E+00	49.01%
C-14	6.47E-02	3.23%	2.33E+00	116.31%
Alpha	3.76E-08	0.03%	2.62E-08	0.08%
Beta	7.70E-07		2.33E-06	

Table 14 presents the total annual discharges from box processing and the proportion of the total discharges within SILWE and ILWS in line with Table 6.

Table 14 Discharges from box processing

	Nuclide	Total Annual discharges from box processing (GBq)	SILWE Annual release (as a proportion of the total annual discharges from box processing) (GBq)	ILWS Annual release (as a proportion of the total annual discharges from box processing) (GBq)
Bunker 1 and Fines	**H-3**	3.30E-01	2.56E-01	7.36E-02
	C-14	6.47E-02	5.44E-02	8.93E-03
	Alpha	3.76E-08	3.76E-08	**0**
	Beta	7.70E-07	7.70E-07	**0**
Bunkers 2-5 and Fines	**H-3**	9.80E+00	7.62E+00	2.19E+00
	C-14	2.33E+00	2.00E+00	3.21E-01
	Alpha	2.62E-08	2.62E-08	**0**
	Beta	2.33E-06	2.33E-06	**0**

Based on the approach in 5.5.1, it is assumed that the annual H-3 and C-14 releases in the Hunterston ILWS will be 77.7% and 86.2% less respectively, than the total estimated annual releases presented in Table 9 and Table 10.

As it is not known when the Fines will be processed these have been combined with both Bunker 1 and Bunkers 2-5 estimates. The ILWS and SILWE discharges are presented in Table 14. It should be noted that the ILWS discharge estimates are not in addition to the total SILWE H-3 and C-14 releases but represent a proportion of the SILWE estimates that could be released in the ILWS.

This is a very conservative estimate which at present addresses the uncertainties and limitations in the available data. In reality it is expected that the majority of H-3 and C-14 will be released within the SILWE facility. In light of the uncertainty, a forward action is to review the ILWS release estimate assumption, BPM and SRV's once monitoring data is gathered during the active commissioning of SILWE and any subsequent SRV's will be reviewed.

Additionally, in recognition of the uncertainties and limitations in the assumptions for gaseous releases fractions of H-3 and C-14 in the Hunterston wastes a sensitivity analysis has been undertaken in Appendix B, Sensitivity Analysis.

8.3 Box Processing Dose Assessment

Table 15: Annual Predicted Dose from Bunker 1 and fines

Nuclide	Predicted Public Dose (uSv/y)
H-3	3.23E-04
C-14	4.53E-03
Alpha	4.14E-05
Beta	2.16E-05
Total Dose	4.91E-03

Table 16: Annual Predicted Dose from Bunkers 2-5 and fines

Nuclide	Predicted Public Dose (uSv/y)
H-3	9.60E-03
C-14	1.63E-01
Alpha	1.86E-05
Beta	6.51E-05
Total Dose	1.72E-01

The predicted annual dose for Bunker 1, and annual dose from Bunkers 2-5 are shown in 12 and 13. Once again, the dose for Bunkers 2-5 is shown to be larger, and therefore should be chosen as a conservative figure. However, all the predicted doses are very low, and therefore show that releases should not have an impact on the public, therefore meeting BPM guidance to minimise public dose.

Table 17 Dose associated with the SILWE discharges and also shows the dose split across SILWE and ILWS.

Table 17 Dose from box processing

	Nuclide	Total Public Dose (uSv/y)	Public Dose from SILWE releases (uSv/y)	Public Dose from ILWS releases (uSv/y)
Bunker 1 and Fines	H-3	3.23E-04	2.51E-04	7.2E-05
	C-14	4.53E-03	3.90E-03	6.2E-04
	Alpha	4.14E-05	4.14E-05	NA
	Beta	2.16E-05	2.16E-05	NA
Bunkers 2-5 and Fines	H-3	9.60E-03	7.46E-03	2.1E-03
	C-14	1.63E-01	1.40E-01	2.2E-02
	Alpha	1.86E-05	1.86E-05	NA
	Beta	6.51E-05	6.51E-05	NA

8.4 SILWE Stack Height Assessment

A stack height assessment for SILWE was carried out to determine whether increasing the stack height would have any significant dose benefit.

Table 18: SILWE Annual Dose from Bunker 1 At varying stack heights

	Local Dose at Height (uSv/y)		
Nuclide	**0 m**	**20 m**	**25 m**
H-3	2.51E-04	2.80E-05	2.02E-05
C-14	3.90E-03	6.86E-04	5.03E-04
Alpha	4.14E-05	9.00E-07	5.38E-07
Beta	2.16E-05	1.67E-06	1.18E-06
Total Dose	4.22E-03	7.17E-04	5.25E-04

Table 19: SILWE Annual Dose from Bunkers 2-5 (and fines) at varying stack heights

	Local Dose at Height (uSv/y)		
Nuclide	**0m**	**20 m**	**25 m**
H-3	7.46E-03	8.31E-04	6.00E-04
C-14	1.40E-01	2.47E-02	1.81E-02
Alpha	2.88E-05	6.26E-07	3.7E-07
Beta	6.51E-05	5.04E-06	3.57E-06
Total Dose	1.48E-01	2.55E-02	1.87E-02

As both Table 18 and Table 19 show, the 21 m stack reduces the dose significantly when compared to the dose at ground level (0 m). However, increasing the stack height by 4 m to 25 would not generate a significant reduction in dose and so this should not be a differentiating factor in the BPM.

8.5 ILWS Stack Height Assessment

A stack height assessment was carried out to determine whether installation of a stack at the ILWS would have any significant dose benefit.

Table 20 and Table 21 present the differences in dose; comparing the default (ground) estimates, the existing release height (5m) and if releases were made at 10m.

As can be seen, the differences are negligible and therefore it is suggested that public dose is not a discriminatory factor in determining BPM for the ILWS discharges.

Table 20 ILWS Annual Dose from Bunker 1 At varying stack heights

	Local Dose at Height (uSv/y)		
Nuclide	**0m**	**5 m**	**10 m**
H-3	7.21E-05	3.72E-05	2.01E-05
C-14	6.25E-04	3.94E-04	2.53E-04
Total Dose	**6.97E-04**	**4.31E-04**	**2.74E-04**

Table 21 ILWS Annual Dose from Bunkers 2-5 (and fines) at varying stack heights

	Local Dose at Height (uSv/y)		
Nuclide	**0m**	**5 m**	**10 m**
H-3	2.14E-03	1.10E-03	5.97E-04
C-14	2.25E-02	1.42E-02	9.12E-03
Total Dose	**2.46E-02**	**1.53E-02**	**9.72E-03**

9 CONCLUSIONS AND RECOMMENDATIONS

The SILWE facility will present a source of radioactive discharges resulting from the waste encapsulation process. In order to ensure compliance with the Environmental Authorisations (Scotland) Regulations 2018 authorisation and demonstrate Best Practicable Means (BPM) [2] the estimated gaseous discharges and dose to public from the SILWE facility have been assessed. This best estimate of discharges provided in this report will help determine BPM and inform the appropriate limits required in a variation to the site authorisation to include SILWE.

This assessment has estimated the SILWE releases for processing Bunker 1 and Bunker 2-5 wastes, which are summarised in Table 22. These account for discharges from the fine's wastes.

Table 22 Aerial release totals for Bunker 1 and Bunkers 2-5 both including fines

Nuclide	Bunker 1 and Fines Annual discharge (GBq)	% Current Authorisation	Bunkers 2-5 and Fines Annual discharges (GBq)	% Current Authorisation
H-3	3.30E-01	1.65%	9.80E+00	49.01%
C-14	6.47E-02	3.23%	2.33E+00	116.31%
Alpha	3.76E-08	0.03%	2.62E-08	0.08%
Beta	7.70E-07		2.33E-06	

The annual discharges from the bunkers 2-5 retrievals could vary depending on the sequence of retrievals because of the different inventories of the waste. For example, if 200 boxes were encapsulated from Bunker 4 then the H-3 discharges would be expected to increase. Similarly, if 200 boxes from Bunker 3 were encapsulated then C-14 discharges would be expected to increase. To allow for uncertainties in the processing sequence a forward action has been raised to develop a processing approach. See Forward Actions.

The 8 boxes of fines have extremely low discharges which make negligible difference to the overall annual discharges. However, these have been included in the estimates by assuming that the fines encapsulations are spread out over the total 6 years of processing.

The predicted dose to the public is very low from the total SILWE estimated discharges. As presented in Table 23, these are <20uSv/y and so no further assessment is required as per the SEPA and EA guidance [15,24].

To inform the BPM assessment, a stack height assessment was carried out to determine whether increasing the SILWE facility stack height would have any significant public dose benefit. The differences in dose at varying stack heights was found to negligible. indicating that there would not be a significant benefit in increasing the stack height from 21 m to 25 m.

It is recommended that three protocols for SILWE discharge monitoring are developed for each phase of processing to ensure that the actual releases do not exceed what has been predicted. See Forward actions. The phases are set out below:

Phase 1: During Active Commissioning (October 2025 - June 2026)
Phase 2: The early stages of Bunker 1 encapsulation (From September 2026)
Phase 3: Bunkers 2-5 early stages of encapsulation (After Bunker 1 encapsulation is complete)

It cannot be ruled out that a proportion of the estimated SILWE gaseous H-3 and C-14 discharges could be released in the ILWS following transfer of the encapsulated packages. The proportion of the releases in the ILWS has been estimated based on limited data from Trawsfynydd. Some conservative assumptions have been made to provide interim discharge and dose values for the ILWS to inform BPM and SRV's.

It should be noted that the ILWS discharge estimates are not in addition to the total SILWE H-3 and C-14 releases but represent a proportion of total annual estimates from box processing.

The total discharges and resultant public doses across SILWE and the ILWS based on the calculated proportion estimates are presented in Table 23.

These are very conservative estimates for the ILWS as it is expected that the majority of the estimated SILWE H-3 and C-14 releases will be discharged from the SILWE facility and so the release estimates in the ILWS are expected to be lower.

In light of the uncertainty and limitations on underpinning data, a forward action is proposed to review the ILWS release estimates, BPM and any SRV's once monitoring data is gathered during the active commissioning of SILWE.

In conclusion, as the C-14 estimated releases are above the current site authorisation limits, and the H-3 estimated releases are a large proportion of the current site authorisation limits it is recommended that HNA apply for a variation to increase to the overall site authorisation limits informed by the total discharges presented in Table 22. This is assuming that a mix of boxes from each bunker will be encapsulated for Bunkers 2-5.

However, to allow for limitations and uncertainties in the assumptions for gaseous H-3 and C-14 releases, a sensitivity analysis (Appendix B) has been undertaken. This should also be taken into consideration when determining appropriate authorisation limits for the site.

Table 23 Discharge and dose Summary for SILWE and ILWS

	Nuclide	Total Annual discharges from box processing (GBq)	Percent of total Discharges from box processing released at SILWE	Percent of total Discharges from box processing released at ILWS	SILWE Annual release (as a proportion of the total annual discharges from box processing) (GBq)	ILWS Annual release (as a proportion of the total annual discharges from box processing) (GBq)	Public Dose from SILWE releases (uSv/y)	Public Dose from ILWS releases (uSv/y)
Bunker 1 and Fines	H-3	3.30E-01	77.69%	22.31%	2.56E-01	7.36E-02	2.51E-04	7.2E-05
	C-14	6.47E-02	86.19%	13.81%	5.44E-02	8.93E-03	3.90E-03	6.2E-04
	Total	3.95E-01			3.12E-01	**8.25E-02**	4.15E-03	**7.0E-04**
Bunkers 2-5 and Fines	H-3	9.80E+00	77.69%	22.31%	7.62E+00	2.19E+00	7.46E-03	2.1E-03
	C-14	2.33E+00	86.19%	13.81%	2.00E+00	3.21E-01	1.40E-01	2.2E-02
	Total	1.21E+01			9.62E+00	**2.51E+00**	1.48E-01	**2.5E-02**

10 FORWARD ACTIONS

Following this assessment there is a list of actions that will need to be taken forward to ensure that the recommendations are implemented.

1. Develop a processing philosophy for the sequence of boxes to be processed from Bunkers 2-5 across the 4.5 years. This needs to address the potential variations in discharges between the bunker wastes.
2. Based on the conclusions of this report develop Environmental Performance Criteria for particulate releases from and SILWE in the BPM.
3. Review the release estimates and proportion in the ILWS once monitoring data is obtained during active commissioning of SILWE. Review also the BPM and any SRV's.
4. Develop discharge monitoring protocols for the three phases set of SILWE processing. This will inform a review of the estimated release fractions and discharges presented in this report.
5. Ensure that S-70 forms for Gaseous Discharges and standard reporting values are aligned for the ILWS and the other outlets on site.

Review the site authorisation limits considering discharges presented in Table 22. These actions should be recorded and tracked on Q-Pulse to ensure they are effectively implemented.

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24. SEPA, Principles For The Assessment Of Prospective Public Doses Arising From Authorised Discharges Of Radioactive Waste To The Environment, RS-JG-016, October 2019

25. SILWE Discharges Calculations Issue 3, Verified but Unissued, 2023

Appendix A Further Results [25]

Overall estimated discharges by Bunker

Table 24: Bunker 1 Discharges

Bunker 1	200 boxes (GBq)	Annual Output (GBq)	Full Bunker (GBq)
H-3	3.24E-01	3.29E-01	4.93E-01
C-14	6.12E-02	6.22E-02	9.33E-02
Alpha total	2.79E-08	2.84E-08	4.26E-08
Beta total (excluding H-3 and C-14)	5.95E-07	6.05E-07	9.07E-07

Table 25: Bunker 2 Discharges

Bunker 2	200 boxes (GBq)	Annual Output (GBq)	Full Bunker (GBq)
H-3	4.89E+00	1.51E+00	6.78E+00
C-14	2.37E+00	7.28E-01	3.28E+00
Alpha total	3.85E-10	1.19E-10	5.34E-10
Beta total (excluding H-3 and C-14)	4.05E-08	1.25E-08	5.61E-08

Table 26 Bunker 3 Discharges

Bunker 3	200 boxes (GBq)	Annual Output (GBq)	Full Bunker (GBq)
H-3	8.56E+00	2.64E+00	1.19E+01
C-14	2.38E+00	7.37E-01	3.31E+00
Alpha total	2.27E-08	7.00E-09	3.15E-08
Beta total (excluding H-3 and C-14)	2.64E-06	8.15E-07	3.67E-06

Table 27 Bunker 4 Discharges

Bunker 4	200 boxes (GBq)	Annual Output (GBq)	Full Bunker (GBq)
H-3	1.50E+01	4.57E+00	2.06E+01
C-14	2.31E+00	7.07E-01	3.18E+00
Alpha total	2.64E-08	8.07E-09	3.63E-08
Beta total (excluding H-3 and C-14)	3.54E-06	1.08E-06	4.87E-06

Table 28 Bunker 5 Discharges

Bunker 5	Annual Output (GBq)	62 boxes (GBq)
H-3	1.08E+00	4.86E+00
C-14	1.52E-01	6.84E-01
Alpha total	1.73E-09	7.81E-09
Beta total (excluding H-3 and C-14)	2.50E-07	1.13E-06

Table 29: Bunkers 2-5 Conservative Annual Discharges (200 boxes) (GBq)

Average Bunker 2-5	Annual discharge (GBq)	Pre-abatement annual discharge (GBq)	As a % of permit (With abatement)
H-3	1.50E+01		74.79%
C-14	2.38E+00		119.22%
Alpha total	2.64E-08	2.64E-04	0.12%
Beta total (excluding H-3 and C-14)	3.54E-06	3.54E-02	

Appendix B, Sensitivity Analysis

The main SILWE assessment has been carried out using the average of the outliers, as presented in 5.3. To allow for the uncertainty in gaseous release fractions, a more conservative annual estimate for H-3 and C-14 releases from SILWE was made by using the 95^{th} percentile of the release fractions shown in

Table 2 , including the outliers. Using the 95th percentile as a basis for RFs for SILWE assumes that SILWE boxes are in the upper extreme of the RF range. Table 30 shows the elevated RFs based on the 95th percentile approach which gives a conservative upper uncertainty for the releases in Table 13.

Table 30: 95 percentile RF

Nuclide	RF
H-3	0.05%
C-14	0.09%

These RF were taken and applied to the SAWBR wastes. The annual discharges were calculated in a similar way to those in Section 5.3.1. The RF was applied to the waste in each bunker, to generate the total amount for that bunker. This was then summed and divided by the years that bunkers 2-5 will be emptied (i.e., 4.5 years).

These results are presented in Table 31. It is important to note that this does not include the fines[5] and does not take account of particulate releases.

Table 31: 95 percentile RF Annual GBq

Nuclide	GBq
H-3	28.6
C-14	6.5

As expected, and as shown in Table 31, the 95th% estimates are greater than those shown in Table 13. Whilst these discharges estimates are deemed unlikely compared to the discharges shown in Table 13, this sensitivity analysis provides some values which should be considered in the determination of new authorisation limits.

5. Fines not included because they provide a negligible contribution of gaseous release

Appendix C, Issue 1 (2018) Results

TRA NFED – FED Magnox.

Table 1: H-3 and C-14 Release Fractions from TRA NFED encapsulation

	Discharges (MBq)		Inventory (MBq)		Release Fractions	
Box #	**H-3**	**C-14**	**H-3**	**C-14**	**H-3**	**C-14**
3	0.974	0.012	17140	412.9	0.0057%	0.0029%
4	0.89	0.011	16470	417	0.0054%	0.0026%
5	0.08	-	22810	555.2	0.0004%	-
10	2.619	0.008	24110	580.8	0.0109%	0.0014%
11	1.55	0.002	30360	731.4	0.0051%	0.0003%
				Average	0.0055%	0.0018%

Note there were no recorded C-14 discharges for Box 5. The average value has therefore excluded this box.

TRA SFED – FED Magnox

Tritium discharges

The H-3 release fractions are shown below for FED encapsulated at SFED from 2005 to 2010.

Table 2: Tritium Release Fractions from TRA SFED encapsulation

Box #	H-3 Inventory (MBq)	H-3 Release (MBq)	H-3 RF
1	4.77E+04	2.66	0.0056%
2	4.06E+04	1.92	0.0047%
3	3.05E+04	10.79	0.0354%
4	3.31E+04	15.92	0.0481%
5	4.24E+04	0.87	0.0021%
6	3.88E+04	1.05	0.0027%
7	3.31E+04	0.96	0.0029%
8	3.36E+04	1.45	0.0043%
9	3.02E+04	9.32	0.0308%
10	2.91E+04	0.73	0.0025%
11	3.25E+04	0.90	0.0028%
Ave. (all)			0.013%
Ave. (excluding high 3, 4 & 9)			0.0034%

Table 3: C-14 Release Fractions from TRA SFED encapsulation

Box #	C-14 Inventory (MBq)	C-14 Release (MBq)	C-14 RF
1	5.60E+02	0.10	0.0171%
2	5.10E+02	0.06	0.0120%
3	4.00E+02	0.53	0.1329%
4	4.20E+02	2.39	0.5694%
5	5.40E+02	0.05	0.0087%
6	4.90E+02	0.04	0.0078%
7	4.40E+02	0.05	0.0114%
8	5.10E+02	0.16	0.0309%
9	4.60E+02	0.07	0.0162%
10	4.30E+02	0.02	0.0053%
11	4.90E+02	0.02	0.0035%
Ave. (all)			0.074%
Ave. (excluding high) 3, 4 & 9			0.012%

Table 4: H-3 and C-14 RF for FED Magnox from NFED and SFED encapsulation6

Overall average from all boxes				
Scenario	RF		No. boxes counted	
	H-3	C-14	H-3	C-14
Average all boxes	0.01%	0.06%	16 (5 NFED, 11 SFED)	157 (4 NFED, 11 SFED)
Average - excluding outliers	0.004%	0.009%	13 (5 NFED, 8 SFED	12 (4 NFED, 8 SFED)

6 All figures quoted to one significant figure.
7 Zero discharge readings were not included in the calculation of average RF to maintain conservatism.

Table 5: Summary of RFs used to estimate SILWE discharges

SILWE Waste Type	Release Fraction used to estimate SILWE discharges	
	H-3	C-14
All Waste	0.004%	0.009%

Overall estimated discharges from SILWE (2018)

Predicted discharges from all waste to be encapsulated through SILWE are shown below in Table 6 and Table , assuming a 2- or 3-year operating period.

Table 6: Estimated H-3 discharges from SILWE

Discharge Per Year (GBq) with 2- & 3-year processing scenarios

	2 years operations	3 years operations
All Wastes combined	6.0	4.0

Table 7: Estimated C-14 discharges from SILWE:

Discharge Per Year (GBq) with 2- & 3-year processing scenarios

	2 years operations	3 years operations
All Wastes combined	5.50E-01	0.37

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