Document Ref No: 2301005

Submarine Dismantling Project

Rosyth Royal Dockyard Limited - Permit Variation Application

Document Ref No: 2301005

ISSUE

Issue	Date	Comment	Author (name in full)	Checked (name in full)	Approver (name in full)
Draft A	19/01/23	First Draft	[redacted]	[redacted]	[redacted]
Issue 01	07/02/23	Internal Review Comments Addressed	[redacted]	[redacted]	[redacted]
Issue 02	13/03/23	Stakeholder Comments Addressed	[redacted]	[redacted]	[redacted]

Document Ref No: 2301005

CONTENTS

1. ABBREVIATIONS / TERMS USED IN THIS DOCUMENT

AHU	Air Handling Unit
ALARP	As Low As Reasonably Practicable
AWAF	Active Waste Accumulation Facility
BPM	Best Practicable Means
DOP	Dispersed Oil Particulate
Dstl	Defence Science and Technology Laboratory
ERC	Emergency Response Centre
ETC	Effluent Transport Container
GDF	Geological Disposal Facility
HEPA	High Efficiency Particulate Air
HHISO	Half Height ISO
HPGe	High Purity Germanium
HVAC	Heating, Ventilation, and Air Conditioning
IDI	In-Dock Installation
IHM	Inventory of Hazardous Materials
ILW	Intermediate Level Waste
ISOCS	In-Situ Object Counting System
ISOLUS	Interim Storage of Laid Up Submarines
LAED	Low Activity Effluent Discharge
LAM	Large Article Monitor
LfE	Learning from Experience
LLC	Local Liaison Committee
LLW	Low Level Waste
LLLW	Large Low Level Waste
LOD	Limit of Detection
LUSM	Laid Up Submarine
MOD	Ministry of Defence
NDA	Nuclear Decommissioning Authority
NORM	Naturally Occurring Radioactive Materials
PETP	Portable Effluent Treatment Plant

PFC	PreFabricated Containment
PST	Primary Shield Tank
RAMS	Radiation Alarm Monitoring System
RC	Reactor Compartment
RCL	Radiochemistry Laboratory
RCT	Resin Catch Tank
RPV	Reactor Pressure Vessel
RPVTC	Reactor Pressure Vessel Transport Container
RRDL	Rosyth Royal Dockyard Limited
SDP	Submarine Dismantling Project
SEPA	Scottish Environment Protection Agency
SME	Subject Matter Expert
SQEP	Suitably Qualified and Experienced Person
TLD	Thermoluminescent Detector
UKAS	United Kingdom Accreditation Service
UKHSA	UK Health Security Agency
VETS	Vessel Equipment Tracking System
WRHC	Waste Resin Holding Container

TERMS USED IN THIS DOCUMENT

µSv	microsievert: small unit of radiation dose which is used to quantify the effect of radiation on people
µGy	microgray: small unit of dose used to quantify the effect of environmental doses on people, plants and animals. For the purposes of this report one microgray is equal to one microsievert.
Out of Scope Waste	waste which has activity concentrations which are below the levels regulated by the Environmental Authorisations Scotland Regulations 2018

2. EXECUTIVE SUMMARY

This document presents the permit variation application that Rosyth Royal Dockyard Limited (RRDL) is making to the Scottish Environment Protection Agency (SEPA).

The Submarine Dismantling Project (SDP) aims to fully dismantle 27 of the UKs nuclear submarine fleet, most of which are now out of service. Of those 27, 7 are stored safely afloat in the non-tidal basin at Rosyth Business Park with their fuel removed before storage.

SDP is a staged project with Stage 1 completed successfully and safely on four of the submarines at Rosyth so far. For Stage 1 (Low Level Waste removal) to commence, RRDL had to apply to SEPA for a new Authorisation. SEPA granted RRDL this Authorisation in 2016 and dismantling activities commenced that year. The Authorisation allowed the removal of Low Level Waste (LLW) and permitted gaseous and liquid discharges to specific limits. Historic data has shown that RRDL has operated below the permitted limits in each Authorisation held. With the introduction of the Environmental Authorisations (Scotland) Regulations 2018 (EASR18), Authorisations became Permits. The RRDL Authorisation was therefore re-issued as a Permit, but no permitted limits were changed.

SDP has now reached the point where Stage 2 (Intermediate Level Waste removal) is being planned. To allow RRDL to receive Intermediate Level Waste (ILW) from the submarines, primarily the Reactor Pressure Vessel (RPV), the RRDL permit requires to be varied. This will allow RRDL to remove all radioactive waste (including ILW) from the submarines in preparation for them to be fully dismantled and structural steel and non-active components either reused or recycled, where practicable.

Stage 2 is new work for the site and to accommodate this, a new facility is being built at 2 Dock on Rosyth Business Park within the nuclear licensed site. This has been specifically designed for the Stage 2 processes. The new building requires the installation of an active ventilation system. A new authorised gaseous discharge point is therefore applied for.

A review was undertaken of the current facilities and their aqueous and gaseous discharges today and projected for the future increase in loading due to Stage 2, as well as incorporating a change in calculation methodology using the limit of detection as the lowest value attributable. With the current work, future work and the new building, an increase to the current aqueous and gaseous discharge limits is also required. The proposed limits are summarised in the table below. These have been calculated using actual data or the best information currently available, underpinned by Best Practicable Means (BPM) assessments. These limits will allow the site to continue flexibly with SDPs proposed activities without further application. This report contains the underpinning for the request.

The proposed limits were modelled and assessed to determine whether there would be any environmental impact. Both PC CREAM and ERICA software were used to assess the representative person dose, collective dose, dose to non-human species and transboundary dose to the nearest country outside the UK. All the results were well below the public dose limit of 1000 µSv/y and the value of 10 µSv/y, which is described by the regulators as the value at which there is potentially no regulatory concern. Where an individual dose is stated, this is compared to the public dose limit by calculating what fraction of the dose limit it represents. For non-human species the dose rate is compared against a screening dose rate of 10 µGy/h. The actual calculated dose values are shown in the tables below:

<u>Proposed Authorisation Limits and Resulting Exposures to the Public</u>

Aqueous				
	Current Limit (MBq)	Proposed Limit (MBq)	Total Dose to Representative Person (µSv/y)	Fraction of 1000 µSv/y Public Dose Limit (%)
Co-60	100	100	0.0294	0.00294
Tritium	300	1600		
Others	100	220		
Gaseous				
	Current Limit (MBq)	Proposed Limit (MBq)	Total Dose to Representative Person (µSv/y)	Fraction of 1000 µSv/y Public Dose Limit (%)
Tritium	10	2800	0.672	0.0672
C-14	50	5700		
Others	0.1	1.5		

Assessment	Dose Group	Result	Fraction of 1000 µSv/y Public Dose Limit (%)
Aqueous	Collective	0.000384 person Sv	N/A
Gaseous	Collective	0.00361 person Sv	N/A
Transboundary	Representative Person (Atmospheric)	0.0000151 µSv	0.00000151
	Representative Person (Marine)	0.0000369 µSv	0.00000369
Assessment	Dose Group	Result	Fraction of 10 µGy/y Screening Dose Rate (%)
Non-Human Aqueous	Marine	0.0000283 µGy/h	0.000283
Non-Human Gaseous	Terrestrial	0.000542 µGy/y	0.00542

3. INTRODUCTION

The Submarine Dismantling Project (SDP) was established by the Ministry of Defence (MOD) and aims to safely dismantle and manage the resulting materials and waste from 27 submarines, the majority of which are now out of service. SDP was originally known as ISOLUS (Interim Storage of Laid Up Submarines) and started in 2000.

Before SDP began physical works the MOD launched two public consultations, one in 2011 [1] and the second in 2014 [2]. These were to help inform the strategy, siting and approach to take for the removal of radioactive substances (first consultation) and to identify the location for the interim storage of waste (second consultation).

The public consultation of 2011 had three main aspects to it. These were:

- How the radioactive waste was to be removed from the submarine.
- The location for the removal of radioactive waste (Rosyth/Devonport or both).
- Which type of site would be used for the interim storage of any Intermediate Level Waste (ILW) removed.

The public consultation noted that there were concerns regarding the removal and storage of the Reactor Compartment (RC) as a whole and the MOD's preferred option was to remove and store the Reactor Pressure Vessel (RPV), the main ILW component. The dual site option to remove radioactive waste at Rosyth and Devonport dockyards was seen to be the more pragmatic option over a single dockyard site approach. There was no definite preference from the consultation over the type of site for the storage of ILW, but MOD preference was for a Nuclear Decommissioning Authority (NDA) site.

The second public consultation in 2014 focussed on which site, from a list of potential sites, should be used for the storage of the Reactor Pressure Vessels inside their bespoke Transport Containers (RPVTCs). A list of five sites was presented to the public with CNS Capenhurst (as it was at the time) identified as the preferred site.

Before the public consultations the original strategy had not considered the removal of LLW and ILW separately. During consultation, however, this changed and a two stage approach was adopted. Stage 1 was to be the removal of all LLW (not the Primary Shield Tank (PST)) and Stage 2 removal of the PST/RPV i.e., ILW.

3.1. SDP at Rosyth

There are seven defueled laid up submarines (LUSMs) stored at Rosyth to be dismantled, and each submarine will have all LLW and ILW removed before being fully dismantled. Some components that are not radioactive waste will either be reused or recycled, where practicable.

SDP started at Rosyth in 2016 with the demonstrator submarine, LUSM Swiftsure. The initial strategy for Stage 1 was to remove all the LLW from the RC however for LUSM Swiftsure, it was decided to not remove Large LLW (LLLW) items and other selected LLW components.

To date, four submarines (Swiftsure, Resolution, Revenge and Repulse) have gone through Stage 1 with the scope of the LLW removal increasing with Resolution to the original Stage 1 scope (removal of Large LLW) carried out on Revenge. For Repulse all LLW except the LLLW items have been removed. The LLLW will be removed later when the submarine is docked for Stage 2. All LLW removal on the submarines has been successfully and safely completed to time and cost. In addition to this, a world first was achieved on Revenge with the successful removal of two main steam generators from a nuclear submarine.

As each submarine has gone through Stage 1, a Learning from Experience (LfE) register has been kept. This has allowed learning from each submarine to be tracked and implemented for future submarines. This learning has included changes to procedures on how systems are removed and keeping note of any hazards found on board.

One of the main hazardous substances that needs to be dealt with is asbestos. Asbestos is a component in lagging that was originally used in the submarine RC. Although the lagging was later changed to a version that did not contain asbestos, on the older submarines it is possible for pockets of the old lagging to remain, especially in hard to access areas. De-lagging of the submarine RCs (the first part of Stage 1) therefore proceeds as an asbestos de-lag. Before the lagging is removed it is characterised to determine if it is in scope of radioactive substances legislation. The lagging can therefore be in scope of radioactive substances regulation and have a hazardous property which restricts its disposal to asbestos licensed facilities.

Each of the submarines has a green passport, now called an Inventory of Hazardous Material (IHM), which identifies hazardous materials that are on board. These can be used as a starting point however, materials have been found in areas not listed. This knowledge can therefore be added and can influence techniques used during future dismantling and training that operators are required to have.

3.2. Stage 2

The primary aim of Stage 2 is the removal of the RPV and PST. In all submarines, the RPV sits inside the PST and, in accordance with the SDP public consultation, the RPV and PST will be removed together as a single assembly through a large hole cut into the side of the submarine. The first submarine which will have these removed will be Swiftsure. Any LLW that was not removed from the submarines that have undergone Stage 1 will be removed before the PST/RPV assembly is removed. The PST/RPV will be removed as one assembly, then separated within a new dockside waste processing facility to allow the RPV to be loaded into its RPV Transport Container (RPVTC).

To do this the PST/RPV assembly will be cut from the submarine and lowered to the dock bottom. From there the assembly will be moved along the dock bottom before being raised to the dock side. It will then be moved into a new dedicated dockside facility (see Section 4.2), which is being designed, for processing.

Inside the new facility on the side of 2 Dock, the RPV will be separated from the PST by cutting any connecting structures and then raising the RPV. This will allow the RPV to be transferred into its

RPVTC. Once in the RPVTC the RPV will then be transported to the Capenhurst nuclear licensed site for storage.

The PST, which is LLW, will be moved to a different facility in the building where it will then be processed for separate disposal using the same methods and procedures demonstrated to be BPM under our current SEPA permit.

The PST is filled with potassium chromate solution with the water acting as a radiation shield and the potassium chromate a corrosion inhibitor. During Stage 2 the potassium chromate solution will need to be removed from the PST, before the PST/RPV is removed from the submarine, and transferred into another container. Potassium chromate is a hazardous substance, and classified as a relevant liquid. It will be transferred to a facility licensed to handle it for disposal. Characterisation of the potassium chromate in each submarine will be conducted in advance to determine whether it is in scope of radioactive substances regulation.

To allow SDP to progress to Stage 2 and remove ILW from the submarines, a variation is required to the Scottish Environment Protection Agency (SEPA) Permit [3] to allow Rosyth Royal Dockyard Limited (RRDL) to accept ILW from MOD and to increase aqueous and gaseous discharge limits to include the new facility. In addition, a review has been conducted of the entire site limits to ensure that these reflect the future requirements of SDP. This includes Stage 3 and 4 (radiological clearance and dismantling of the entire submarine) which will continue using current methods of recycling and clearance, with a large portion of the submarine sentenced as waste which is out of scope of the EASR18 regulations.

3.3. Overview of the Rosyth Business Park Site

Rosyth Business Park is situated in Fife on the bank of the river Forth, approximately 3 km west of the Forth Bridges. Activities through the lifetime of the dockyard have included the refitting and maintenance of warships, auxiliaries and supporting operational units of the naval fleet, activities which continue.

The refitting and maintenance of operational nuclear submarines were the primary nuclear activities carried out at the site until these ceased in 2003.

After 2003 the main nuclear activities were the safe management of legacy radioactive wastes, the maintenance and hull preservation of the seven submarines berthed in the non-tidal basin and the initial phase of decommissioning buildings that had been used to support the previous refitting operations. This was a step down in operations from the refitting. At this time the authorised discharge limits were also reduced to reflect this change. Stage 2 now requires an increase in discharge limits with the change in work.

The commencement of SDP work required new buildings on 2 Dock, including an In-Dock Installation (IDI) for access to the submarine. Modifications were also needed to existing infrastructure for the new programme of work. These changes only allowed Stage 1 to begin; further changes and new infrastructure is now needed to allow Stage 2 to start. This is discussed further in Section 4.2.

Within Rosyth Business Park there is a nuclear licensed site which is split into two distinct areas. These are 2 Dock and the Active Waste Accumulation Facility (AWAF), and most SDP activities occur on these areas. There are supporting facilities within Rosyth Business Park, but off the licensed site, which are also relevant and support submarine dismantling. These are the Radiochemistry Laboratory (RCL), Health Physics Laundry, and the Discharge Facility.

Further details related to these areas are found in Section 4.

3.4. Current Status and Variation

The SEPA permit limits for site were reduced as the site moved from refitting submarines into site decommissioning and storage of defueled submarines. The current permit held by RRDL, allows gaseous and aqueous discharges (to within defined limits) and for RRDL to receive LLW removed from the laid-up submarines at Rosyth Business Park. Although the permit has been sufficient for Stage 1 activities, it is recognised that Stage 2 cannot commence without changes being made to the permit.

These changes are:

- to be able to remove ILW, and continue LLW removal, and
- increase the limits for aqueous and gaseous discharges.

The current permit only allows the removal of LLW. To remove the RPV from the submarines the permit requires to be varied to allow ILW removal. ILW removal is discussed in Section 4.2 and Section 5.

The current limits for aqueous and gaseous discharges in the permit are detailed in Table 1 and Table 2 respectively.

Aqueous Limits	
Radionuclide	Limit
Tritium	300 MBq
Co-60	100 MBq
All other radionuclides not individually specified	100 MBq

Table 1: Current Aqueous Discharge Limits

Gaseous Limits	
Radionuclide	Limit
Tritium	10 MBq
Carbon-14	50 MBq
All other radionuclides not individually specified	0.1 MBq

Table 2: Current Gaseous Discharge Limits

These limits are site limits and apply on a 12-month rolling basis. RRDL currently operate below these limits and historic data has shown that the site has operated below the limits in each permit it has held.

With the work to be carried out as part of Stage 2, and other projects, it has been established that the current limits will not be sufficient going forward. Stage 2 will also have a new building requiring an additional authorised gaseous outlet.

A variation to the discharge limits is therefore required to facilitate Stage 2, current improvements to facilities and other projects that are ongoing. The proposed new limits being applied for are summarised in Table 3. The justification for each of the limits, and the application to accept ILW are detailed in Section 4 which detail the various facilities on site, the work carried out in each, the discharges, and quantities likely to result.

Aqueous Limits	
Radionuclide	Limit
Co-60	100 (unchanged) MBq
Tritium	1600 MBq
All other radionuclides not individually specified	220 MBq
Gaseous Limits	
Radionuclide	Limit
Tritium	2800 MBq
C-14	5700 MBq
All other radionuclides not individually specified	1.5 MBq

Table 3: Proposed New Discharge Limits

4. Facilities on Site Impacting Discharges

The sub-sections that follow give an overview of each facility currently on site and future buildings. The overview includes the type of work carried out in each, the radioactive wastes generated and the systems to deal with the radioactive wastes. The contribution that each facility makes to the proposed site discharge limits is calculated.

A site review has been recently conducted by a Heating Ventilation and Air Conditioning (HVAC) Subject Matter Expert (SME) and recommendations to optimise the current systems on site have been provided. These may impact the gaseous discharge calculations, and this has been considered in the application request.

All calculations are fully detailed in reference [4].

Any discharges of radioactivity from these facilities will demonstrate Best Practicable Means (BPM).

There are three main principles to BPM [5];

1. Use BPM to minimise the activity and volume of radioactive waste generated
2. Use BPM to minimise the total activity of radioactive waste that is discharged to the environment
3. Use BPM to minimise the radiological effects of radioactive discharges on the environment and to members of the public.

These principles are included as part of the standard conditions of the current RRDL permit and therefore are applied to the Stage 1 work currently carried out at RRDL. Across all the facilities, similar systems are in place to minimise the activity and volume of radioactive waste generated, and to minimise the total activity of gaseous and aqueous discharges into the environment. A site wide evidence-based assessment demonstrates these systems implement BPM [6] as described in general below. These same systems will be used in the new Stage 2 dockside waste processing facility.

For any facilities that have specific BPM information not included in the site wide BPM, this will be described under that facility.

BPM relating to solid wastes are also addressed where appropriate under each facility, however solid waste is discussed in general in Section 5.

4.0.1 Gaseous Discharges

Active ventilation is installed at all the facilities on site that may generate gaseous radioactive waste. These ventilation systems have been designed to prevent the release of any radioactive substances and ensure that extracts from these systems are discharged only through authorised points. The authorised stacks have been built to the relevant standard to ensure effective air flow dispersion.

All ventilation systems use High Efficiency Particulate Air (HEPA) filters. All the ventilation systems are on a maintenance schedule which includes carrying out regular Dispersed Oil Particulate (DOP) testing on the HEPA filters. Within the maintenance schedules it is recognised that the HEPA filters have a 10-year lifetime and will be replaced within this timeframe if they haven't already been replaced in accordance with manufacturer's guidelines. Along with the HEPA filters any pre-filters will also be checked to ensure they are not blocked. For systems that have warning alarms these are also checked as part of the maintenance to ensure they are operating correctly.

Pre-filters are used on air intakes. These prevent the intake of particulate which could cause damage to the HEPA filters and allow particulate to enter active areas.

At all facilities where cutting, or intrusive work may take place, containment and local extracts are utilised. By making use of these, should there be any airborne release, the majority of the activity is prevented from going through the ventilation system. Personnel involved in cutting activities have been trained and are a Suitably Qualified and Experienced Person (SQEP). This includes an understanding of the types of cutting used to ensure the correct method is selected and to minimise the generation of secondary radioactive wastes.

All facilities also have a monitoring schedule for both radiation and contamination. These surveys are used to inform tasks to reduce the likelihood of particulate being released, or where it is appropriate for a containment to be used.

4.0.2 Aqueous Discharges

Recognising that there are no out of scope values for aqueous liquids, where possible the generation of aqueous wastes is prevented. Segregation of aqueous liquids where possible is used to ensure the aqueous liquid could not have come into contact with radioactivity. Empty containers that are used for the storage of radioactive waste are closed properly to prevent any water ingress, and therefore generation of aqueous waste. This is especially important for empty containers that are stored outside.

Any aqueous wastes that are generated are collected in carboys. An operating instruction for the carboys is that they should only ever be 2/3 full. This is for ergonomic reasons but also reduces the potential of a spill when the carboy is being filled. Carboys are then stored in a bund. This can vary from a tray (which will limit the number of carboys that can be accommodated) to a self-bunded store. All carboys are sampled to determine if they are suitable for treatment or not through the on-site Portable Effluent Treatment Plant (PETP). This is mainly determined by the radionuclide content of the liquid with 0.1 Bq/ml being the decision point. The carboy results are reviewed by SQEP personnel who determine whether the liquid is suitable for treatment or not.

All facilities/plant which process aqueous liquid have filtration. The filtration is designed for the contents of the aqueous liquid that will be put through it. An example is the filtration required at the laundry will be different from that of the PETP. The sources of aqueous liquid are different and therefore the particulate size likely to be found will vary. The filtration is therefore selected to be optimised for the facility.

On pieces of equipment used for the treatment and storage of aqueous liquids e.g., tanks, leak detection equipment is installed. This is typically linked to a central alarm system which is monitored and gives an early indication that there is a problem.

These systems are maintained, including bunds, to ensure that they remain watertight.

4.1. LUSM

To date, Stage 1 has been undertaken on four submarines, Swiftsure, Resolution, Revenge and Repulse (see Section 3.1). The remaining three submarines will go through Stage 1 after Stage 2 has commenced.

To remove waste from the submarine reactor compartment (RC), various steps are required.

Before any waste pipework can be cut, the RC requires to be de-lagged if not already carried out. The lagging will have been sampled to determine whether it is radioactive or not and as described in Section 3.1. Due to the potential for asbestos in unsampled locations it is removed in compliance with asbestos removal regulations. Once the de-lag is complete the bags may be stored securely on the submarine until they can be safely removed at some point while the submarine is in dock. On removal the bags are transferred to the AWAF for further monitoring before being transferred to the appropriate waste permitted person for disposal.

On bringing the submarine into 2 Dock, and docking down, it is initially fully sealed up. To install the IDI, preparatory works need to be carried out in the RC before the side insert in the submarine hull can be cut. This is where the IDI connects to allow access to the RC.

The IDI is a modular structure which allows it to be lifted out of the dock when the dock is flooded to move a submarine in or out. Each of the modules in the IDI has its own purpose and when installed the IDI provides an easier access route into the RC, a health physics barrier for personnel entering the RC, monitoring on exiting the RC and a route for waste removal and ventilation. When connected to the submarine the modules provide an airtight structure.

The Air Handling Unit (AHU) for the submarine is contained within the Heating, Ventilation and Air Conditioning Plant Room which is in one of the modules. The air from here cascades through the modules and across the access bridge into the submarine RC. The air intake is filtered with a pre-filter and main filter unit on the supply AHU to prevent any debris from entering active areas. The air supply always flows from the area with least risk of contamination (IDI modules) to the highest risk of contamination (submarine RC). Air is only extracted from the submarine RC which assists with providing containment. The air is filtered through HEPA filters before being discharged through the IDI stack. The stack is attached to the dock wall and extends to 3m above the dockside. The stack remains in place and is disconnected from the IDI modules when they need to be lifted out of the dock. The contribution from the gaseous discharges from the submarine is calculated in Section 4.1.1. The IDI is on a maintenance schedule to ensure it is regularly maintained. The filters are also protected against freezing in adverse conditions by the installed electric frost coil. The IDI also has systems that monitor the performance of the HEPA filters. Should it be found that the HEPA filters are not within parameters an alarm will sound alerting operators that there may be an issue.

Before connection of the IDI, ventilation is provided by mobile ventilation plant which sit on the submarine casing. The mobile ventilation has been designed to provide calculated air changes through an alarmed HEPA filtration system. The work carried out with the mobile vents in place is limited to secondary systems and work in way of the side insert being cut.

All items of waste are given a Vessel Equipment Tracking System (VETS) number, when generated, which allows the waste to be tracked as it is generated, processed, assayed, and prepared for disposal. The VETS number will also indicate which waste stream the item should be placed into based on the provenance of the system, with further monitoring to confirm. Before the IDI is in place the removal of waste from the RC is complicated due to not having an easy exit route. The waste is therefore segregated and stored temporarily in the RC until the IDI is fitted. The waste is clearly separated into potentially out of scope and LLW through the use of signage, physical demarcations, and the use of waste identification markers [6].

Lead shielding may also need to be removed from the hull to allow the side insert to be cut. Any lead removal is carried out by SQEP operators who also undergo worker health checks to comply with lead handling legislation. Any lead removed is bagged which reduces the risk of touching the lead when it is being handled during removal from the RC. The lead is monitored to confirm it is out of scope before being passed to special waste services for onwards management. The mobile vents are also utilised when the IDI is installed for certain operations. The IDI ventilation is not intended to be used as a local exhaust ventilation to cater for grinding, burning or similar activities. While these activities are carried out, the mobile ventilation is utilised as a local extract to prevent most fumes entering the IDI ventilation system.

Once all work in way is removed, the side insert can be cut, and the IDI attached. With the IDI attached, it provides an easier removal route for the potentially out of scope waste that will have been cut as part of the work in way or removal of secondary systems. A metallic box is lifted to a platform which is attached to the IDI and then moved into the IDI where it can be filled. An overview of the out of scope process is given in Section 5.2.

After the IDI has been attached removal of primary systems, and therefore LLW, can commence. Before any cuts are made a radiation and contamination survey is carried out of the work areas to identify potential sources of airborne particulate. For cutting operations air samplers are run within the RC and, where required, containments are put in place for cuts to reduce the potential for the spread of airborne contamination. For primary circuit cuts local extract ventilation is also in place. The waste items are placed into a metallic box which, in the case of LLW, is moved to the AWAF for further processing.

When the submarine was initially laid up, a drain down of its systems will have taken place. However, it has been found that in both the secondary and primary systems effluent can still be present. Before any cuts are made each system is checked, especially in dead legs, and where required drained into carboys. This reduces the risk of spills or spread of contaminated effluent during cutting. The carboys are removed from the submarine and stored in a bunded store at 2 Dock. The carboys are then sampled to determine whether they are suitable for treatment through the PETP. As well as the radioactivity content, the conductivity of the effluent and pH is also analysed. The PETP and effluent from carboys is discussed further in Section 4.3 and will therefore not be considered further here.

The IDI and mobile vents are both currently authorised discharge outlets in the SEPA Permit held by RRDL. As such the ventilation systems are designed so the air from the systems only discharges through these points.

As part of a review undertaken on all the current facility ventilation systems for moving forward with Stage 2, and the continuation of Stage 1, potential changes to optimise the system performance were identified. These include joining the mobile vent extracts to the IDI stack (so they also discharge through the stack), increasing running time of the ventilation and making changes to the sampling arrangement. A schedule will be established to deliver the required work to optimise ventilation performance after the appropriate reviews of the recommendations have been conducted.

The IDI will mainly be used for the same work as has been carried out during Stage 1, however the preparations of Stage 2 work will be carried out on the submarine. To account for the preparatory work for Stage 2 an increase has been applied to the submarine particulate value contribution.

When calculating the contribution from the submarine to the site gaseous discharges, these future improvements and future work have been accounted for and are described in the calculation in Section 4.1.1.

4.1.1. Gaseous Discharges

The IDI and mobile vents have been in use since the beginning of SDP, therefore historic data can be used as the basis for the calculations e.g., Limit of Detection (LOD) and volumetric flow rates. Due to the work carried out in the submarine RC there are only particulate samplers installed. A review was undertaken of gaseous discharges to determine the processes that could generate gaseous discharges.

It was recognised that there is the potential for tritium and C-14 to be generated during any drain down of the systems in the RC however, a technical basis document [7] explains why negligible amounts are expected and demonstrates it is BPM to report by calculation instead of installing monitoring equipment.

It is assumed that the material will always be at standard temperature and pressure which gives a release fraction of 1E-04. This is deemed a suitable estimate for the release of radioactivity from the water phase and aligns with industry practice for releases from aqueous liquid spills [8]. For the calculation, the tritium and C-14 aqueous effluent values used for carboys under Section 4.3 are used.

Using historic data and accounting for future work, the calculation assumptions are:

- Ventilation will be on 24/7
- LOD is 0.1 Bq/filter paper for Co-60
- Filter papers are changed monthly
- Volumetric flow rates are
    - IDI: 4320 m^3/h
    - Mobile Vents (per vent): 1659 m^3/h, total volume 3318 m^3/h

- Sampler flow rate: 60 l/min (3.6 m^3/h)
- Assume LOD on filter paper but don't apply TGN1 [9]
- Average hours in a month = 744 h
- C-14 and tritium are calculated by applying a release fraction of 1E-04
- Increase of 10 to the particulate LOD to account for future work and optimisation recommendations

To calculate the particulate from the IDI the following equation can be used:

$$Discharge = \left(\frac{LOD}{Sampler\ flow\ rate\frac{m3}{h} x\ month\ length\ h}\right) x \left(Volumetric\ Flow\ Rate\frac{m3}{h} x\ month\ length\ h\right)$$

Using the above assumptions for the particulate discharge this gives:

$$Discharge\ = \left(\frac{0.1}{3.6\ x\ 744}\right) x\ (4320\ x\ 744)$$

$$= 120 Bq\ per\ month$$

Equation 1: Calculation of particulate gaseous discharge from the submarine

Over a 12-month period, this gives the Co-60 discharge as 1440 Bq. Applying the relevant fingerprint based on data from the characterisation of primary circuit metallic waste, [10] this gives a total discharge (inc. Co-60) of 3099 Bq.

For the tritium and C-14, the activity from the drain down of the primary and secondary system as described in Section 4.3 is used. Applying the release fraction of 1E-04 to these activities gives values of 0.0440 MBq and 0.0102 MBq respectively.

For the mobile vents, tritium and C-14 are not included as draining activities are not conducted using these vents. The figures can be summarised as follows:

IDI	
Others (inc Co-60)	0.031 MBq
Tritium	0.044 MBq
C-14	0.0102 MBq
Mobile Filtration	
Others (inc Co-60)	0.024 MBq

Table 4: Contribution to proposed gaseous limits from the IDI

4.2. Proposed New Stage 2 Facility

To facilitate Stage 2 dismantling works a new waste processing building will need to be constructed on 2 Dock. Stage 2 is primarily the removal of the RPV, PST and associated components from the RC, the subsequent handling and separation of these items and the management of any secondary wastes generated.

On bringing the submarine into 2 Dock, the IDI will be attached to the side of the submarine hull in the same way it has already been attached for Stage 1. This will allow the removal of any remaining LLW not removed during Stage 1 and preparatory works for RPV/PST removal. These works include the removal of the bulk inventory of potassium chromate from the PST. The PST is filled with water which was used as shielding and the potassium chromate was added as a corrosion inhibitor. The potassium chromate will be stored in buffer storage, and sampled if required, before being transferred off site for disposal. Due to the properties of the potassium chromate, it meets the definition of a relevant liquid [11]. This allows it to be treated as a solid since it cannot be discharged directly to the environment. Characterisation has shown that the potassium chromate in two submarines is out of scope of radioactive substance legislation, with an ongoing programme to sample the remaining five. Previous optioneering from other projects have shown that disposal of potassium chromate by incineration is BPM. To account for any potential technology changes or new disposal routes, a new BPM study will support potassium chromate disposal.

A temporary RPV/PST cradle is installed on the dock bottom before cutting operations to separate the RPV/PST assembly from the submarine. The RPV/PST assembly is then removed from the submarine and transferred along the bottom of 2 Dock, lifted to dockside and transferred into the new purpose-built facility.

Once in the facility, the RPV/PST assembly is transferred to the Preparation & Separation Area. At this stage additional water will be added into the RPV for shielding purposes. A full optimisation process will be undertaken to assess the water arisings from refilling and will be used to underpin a detailed BPM study [12]. The BPM will follow the format to that prepared for the site-wide BPM [6].

In summary, from the information obtained so far from RPV water characterisation, it is expected that the majority of the activity in the water will be from the existing activity in the water. Whether the RPV is refilled or not, this activity will still require treatment before discharge but will not have a significant impact on discharges to the environment. A water filled RPV is the current basis for the dismantling approach since it provides shielding, reducing dose to operators by up to a factor of 140 [13]. By not using the water as shielding, the facility would require extensive additional shielding and would not guarantee the same dose reduction seen by filling the RPV. Refilling of the RPV is a practical shield for reducing worker dose to As Low As Reasonably Practicable (ALARP) and it mitigates against hazards from airborne contamination which could lead to increased gaseous discharges. Since it does not significantly impact the activity in discharges, the information at this stage indicates that it is BPM to refill the RPV. This decision will be further demonstrated to be BPM prior to filling any RPV with water.

Refilling of the RPV will enable the RPV closure head to be removed, the interior surveyed, and a blanking head fitted. A blanking head is required to be fitted as a replacement to the closure head to help lift the RPV out of the PST. The new blanking head is required as it is a key component of the transport safety case protecting the RPV from any impacts. It also enables the RPV to fit into the RPVTC which would not be the case with the existing closure head. A key interface with the RPVTC, the blanking head is still required to provide shielding from the internals of the RPV during the transport of the RPVs from site. The use of the blanking head will be underpinned by a detailed BPM.

The bulk of the effluent in the RPV will be removed by mechanical means with the remainder being removed by warm air drying. This does not contribute to any increase in discharges. Once the RPV and PST are separated a dimensional scan of the RPV is conducted.

An empty RPVTC will be imported into the building and prepared for loading. The separated RPV is then transferred to the RPVTC. Once the lid is fitted the RPVTC is fully prepared for transport and tested to ensure it meets transport regulations and package requirements before it is loaded onto a transport vehicle for transporting to the interim storage site.

The separated PST is transferred to the PST/Waste Management Area of the facility. There further components are removed, and size reduced along with the PST. LLW that is generated from these operations and from elsewhere in the facility will be contained before being assayed. The assay system will be In-Situ Object Counting System (ISOCS) or similar. The assay area has been designed based on operating the system currently used at the AWAF described in Section 4.3. Using the assay data, the LLW can be transferred to the waste loading area for loading into an appropriate ISOFreight container e.g., Half Height ISO container or, storage in a suitable container before transport and disposal.

Any potential out of scope solid wastes generated during Stage 2 activities will be segregated and stored in a specific area. The waste will then go through the same, or very similar, monitoring process to that carried out for Stage 1 for potentially out of scope items (see Section 5.2).

The activities from Stage 2 will generate active effluents. These will be from the RPV internal water and drying, cutting activities and other activities e.g., potential decontamination of equipment. The effluents will be treated through the PETP (see Section 4.3), to reduce the radioactivity present, before discharge. As well as the radioactivity the effluent will be characterised to ensure there are no other properties that could prevent discharge e.g., pH, and if required treated.

Given the activities being carried out, an active ventilation system will be required. The HVAC for the facility has been designed to cascade from low potential contamination areas to high potential contamination areas. The air is then filtered through a bank of HEPA filters before being discharged through the building stack.

Since this is a new building, a new authorised gaseous outlet is being applied for. The stack will be at the top of the new building and extend above the roof height. The top of the stack will therefore be at a height of 24 m above the ground, which is 3 m above the height of the new building.

Both the HVAC system and the stack are being designed in accordance with the relevant standards and implementing BPM practices that are currently used on site.

On the duct leading from the HEPA filters to the stack a particulate sampler and bubblers for tritium and C-14 will be installed. The particulate sampler is being designed such that the sampling will be isokinetic and therefore provide representative sampling of the discharges.

A full BPM assessment will be carried out on the building as it progresses through the design and build stages. The work will be carried out and evidenced in a similar manner to the site-wide BPM [6].

4.2.1. Gaseous Discharges

To calculate the discharges from the stack, assumptions from current systems are applied where possible or estimated based on current designs. It is assumed that the particulate LOD currently used for filter papers and the LOD used for bubblers will remain the same along with the monitoring period. With installed monitoring systems and the use of LOD to calculate the discharge over the time these systems run, the number will be higher than for facilities where the discharge is exclusively from calculation. It is assumed that the ventilation system will be running 24/7. The volumetric flow rate used is from design flow rates and takes account the tasks being carried out and industry standard values [14].

The following assumptions are therefore made:

- LOD of 0.1 Bq per filter paper for Co-60
- Bubbler LODs of:
    - 0.1 Bq/ml for tritium
    - 0.21 Bq/ml for C-14
- LOD used but TGN1 not applied
- Bubbler volume total 400ml for each
- Ventilation is running 24/7
- Particulate sampler rate is 37 l/min (2.22 m^3/h)
- Volumetric flow rate through system is 9.5 m^3/s (34200 m^3/h)
- Bubbler flow rate is 40 l/h (0.04 m^3/h)
- Particulate filter paper changed monthly
- Bubbler changed weekly
- Particulate figure multiplied by 12 months
- Bubbler figure multiplied by 52 weeks
- Relevant fingerprint applied to Co-60 value to include ‘all others’ [10]

Using the same equation as in Section 4.1.1 the particulate contribution is calculated. Eqn 2 below calculates the contribution from tritium and C-14. The tritium has been calculated as an example. All results are in Table 5.

$$Activity\ Discharged = \left(\left(\frac{LOD\ x\ bottle\ volume}{sampler\ volume\ in\ week}\right) x\ volumetric\ flow\ rate\ in\ week\right) x\ 52$$

$$Tritium = \left(\left(\frac{0.1\ x\ 400}{6.72}\right) x\ 5745600\right) x\ 52 = 1778.4\ MBq$$

Equation 2: Calculation of the gaseous discharge from tritium and C-14

Radionuclide	Activity (MBq)
‘All Others’ (Inc Co-60)	0.040
Tritium	1778.4
C-14	3734.6

Table 5: Contribution to proposed gaseous limits from the new Stage 2 facility

4.2.2. Aqueous Discharges

As described in Section 4.2, active effluents will be produced. The main operation that will produce effluent is the removal of bulk water from the RPV, with smaller amounts from decontaminating wastes and cutting operations. Although the effluent will be treated through the PETP which is in the AWAF, with this being a new process the calculation is being attributed to the Stage 2 facility.

Recent RPV inspections of some of the submarines and subsequent analysis of the water samples have given an indication of the likely activity levels present in the RPV water. Using these results and information from the models of the RPV, a bounding estimate of the activity concentration in the RPV liquor was made [13].

The RPV inspections showed that the water level varies in each RPV. However, the RPVs will need to be filled completely with water to provide shielding to workers while tasks are carried out due to the dose rates present. The water from this refill will also need to be considered as part of the discharges. It is likely that the water levels will be topped up but for the purposes of the calculation, it is assumed that the volume already present in the RPV is removed before the RPV is then refilled to provide shielding. To account for any waste effluent generated by cutting up the PST, a LOD is assumed for Co-60 and a fingerprint which has been derived by activation modelling has been applied for the other radionuclides [10]. Based on the fingerprint it is assumed no tritium will be generated during the cutting operations.

The PETP is discussed further is Section 4.3 but decontamination factors of 1 for tritium and 1000 for all other radionuclides can be applied to effluent treated through the PETP based on a single pass.

The assumptions used for the contribution from operations the new Stage 2 waste processing facility are:

- Average volume of water in RPV = 3m^3
- Fill volume of RPV = 10m^3
- Bounding activity for the water contents is from [13]
- Decontamination factors from [15]
- Decontamination waste volume = 1.5 m^3
- Cutting operations contribute a standard activity
- Relevant fingerprint applied to Co-60 for other radionuclides [13]
- Water LOD values based on post treatment results for RPV refill

Based on the above assumptions the new facility contributions are calculated using Eqn 3.

$$Discharge\ (MBq) = \frac{Volume\ (m3) x\ analysis\ value\ (\frac{Bq}{cm3} or \frac{Bg}{g})}{Decontamination\ factor}$$

Equation 3: Calculation of the activity discharged after treatment through the PETP

The results are given in Table 6.

Radionuclide	Approx. Volume (m^3)	Bounding Activity (MBq)	Decontamination Factor	Total Activity (MBq)
		RPV Drain		
Co-60	3	9000	1000	9
Tritium	3	127.5	1	127.5
‘All Others’	3	9000 * 2.01	1000	18.09
		RPV Refill		
Co-60	10	0.1	1000	1
Tritium	10	1	1	1
‘All Others’	10	0.1 * 2.01	1000	2.01
		Decontamination Wastes		
Co-60	1.5	4500	1000	4.5
Tritium	1.5	63.75	1	63.75
‘All Others’	1.5	4500 * 2.01	1000	9.05
		Cutting Operations		
Co-60	-	-	-	1
Tritium	NA	NA	NA	NA
‘All Others’	-	-	-	2.01
Co-60				15.5
Tritium				192.25
‘All Others’				31.16

Table 6: Contribution to proposed aqueous limits from the new Stage 2 facility

4.3. Active Waste Accumulation Facility

The Active Waste Accumulation Facility (AWAF) is used for the storage and processing of LLW predominantly from the submarine, and for the storage of legacy radioactive resin waste used previously as part of the decontamination of the submarine primary circuits.

LLW removed from the submarine is moved to the AWAF where it will be assayed and processed prior to storage to await disposal.

Each box/container of waste, or sometimes an individual item, is assayed using the ISOCS. This is an electrically cooled High Purity Germanium (HPGe) detector mounted on a frame with an associated laptop to run the detector and analysis software. The ISOCS is a gamma spectroscopy system which allows an activity to be calculated for all detectable gammas, primarily Co-60. To determine the total activity of the item or box the relevant fingerprint is applied to the Co-60 activity.

To process any metallic waste, there is another facility within the AWAF known as the PreFabricated Containment (PFC). This is a purpose-built unit that has a single room for working in and personnel access through an airlock vestibule. This provides a health physics barrier for monitoring personnel out of the PFC. To provide containment the PFC is normally operated at a negative pressure compared to the AWAF room it is sited in. No other operations are carried out in the AWAF room so the air intake will be from the air the AWAF ventilation is putting into the room. The main processing tasks carried out in the PFC are the security declassification and size reduction of items. The PFC has its own HEPA filtered ventilation. The system has visual and audible alarms to indicate if the filter pressure differential goes outside of tolerance. The discharge from the PFC is into the AWAF room in which it is located and is then taken through the ventilation system of the AWAF.

The AWAF active ventilation is split into four separate systems covering different areas of the AWAF. Each has its own ducted HVAC system and bank of HEPA filters that the air passes through. These systems combine to discharge from two louvred openings on the AWAF roof which is the authorised discharge point. The AWAF has an industrial grade bag filter installed at the inlet [6]. This reduces the number of particles that are drawn into the facility helping to increase the life of the pre-filters and HEPA filters. The pre-filters and HEPA filters are monitored for blockages by pressure cells which are connected to the site wide monitoring. Should any issue be detected by the pressure cells an alarm will be activated which will be responded to. The HEPA filters are DOP tested on a regular basis to ensure they are still performing correctly.

On each of the ducts a particulate air sampler is installed. It was recognised with the upcoming work with resins and the potential for the AWAF to be utilised for Stage 2, tritium and C-14 bubblers may need to be installed. Calculations of the possible discharge from the resin tanks indicated that it would be BPM to install bubblers to monitor the discharges. Bubblers will therefore be installed in the duct system (A) that serves the Resin Catch Tank (RCT) area. The installation of the bubblers was considered as part of the review of the site ventilation systems.

The AWAF is fitted with a Radiation Alarm Monitoring System (RAMS) which consists of perimeter and inside gamma detectors, and beta in air monitors. These are all alarmed and upon activation would alarm locally, in the AWAF foyer and at the Emergency Response Centre (ERC).

There is a second facility operated from within the AWAF, the PETP. The PETP is a replacement for the effluent treatment plant which was decommissioned after submarine refitting finished at Rosyth. The PETP was primarily designed for the treatment of the water inside the resin tanks, but it can treat the effluents generated during SDP.

The PETP has a capacity of 500l but is self-bunded with a bund capacity of 600l. It is fitted with various leak detection features between the skins of tanks, within the secondary containment of the ion exchange column and the bund floor of the trailer. These are all easily accessible and are unlikely to give false alarms.

Effluent is treated using filtration followed by ion exchange. The PETP has the capability to recirculate the effluent for multiple passes if required. The PETP has a coarse filter followed by three fine filters of varying sizes. The coarse filter is made of mesh and is removeable allowing it to be cleaned and replaced. To prevent the generation of ILW, dose rates are measured from the filters (with handheld instruments) to determine when the filter should be changed. The filter may also be changed if the flow rate indicators show that there is reduced flow.

Treated effluent goes into the treated effluent tank where it can then be transferred into an effluent transport container (ETC) for discharge at the site authorised discharge point (as described for the laundry in Section 4.5).

Along with metallic waste from the submarine, bags of soft wastes e.g., gloves, that are generated from the various facilities discussed are taken to the AWAF for monitoring and segregation. The bags are monitored through the Large Article Monitor (LAM) to determine if the bags are out of scope or not. If the bag is out of scope it is transferred into regular waste streams for off-site disposal. For bags that are in scope they are stored in designated metallic storage containers. Once these are full the bags are transferred to a waste permitted person for this waste type for disposal.

The AWAF is used for the storage of legacy resin which is held in a combination of Resin Catch Tanks (RCTs) and Waste Resin Holding Containers (WRHCs). The RCTs are an older version of the WRHCs and a programme is underway to transfer the resin from the remaining RCTs into WRHCs to improve the conditions of storage.

Due to complexing agents contained in the resin it has not been possible to dispose of the resins directly. An assessment has therefore been made by MOD which concluded that the resins should be sent for thermal treatment to achieve removal of the complexants before being disposed of as LLW. The resins will be transported from Rosyth in transport approved containers to another site where they will be treated to remove the complexing agents. Final disposal of the treated resins will be to the UK Low Level Waste Repository site in Cumbria.

To transport the resins, the WRHCs require to be de-watered. A BPM underpinning this requirement is being prepared and, where it is shown to be BPM, the water will be transported with the resin to use for re-fluidisation. However, for the calculations in Section 4.3.2 and for the purposes of this application it is assumed that the water remains at Rosyth and will therefore require treatment through the PETP.

The legacy resins were generated from a variety of different processes, but all utilised ion exchange, to decontaminate the primary circuit of the submarine. By removing activity from the primary circuit, it reduced the dose rates to operators who were carrying out refit tasks on the submarine. Radionuclides within the primary circuit would have included tritium and C-14 which over time and during processing will be changed into a gaseous form. It is this tritium and C-14 that will be released from the tanks upon opening and therefore monitored for.

4.3.1. Gaseous Discharges

To calculate the contribution from the AWAF, assumptions are based on current work being carried out and future projected use of the building.

The AWAF ventilation system runs 24/7 with the particulate sampler filter papers changed monthly. The LOD for the filter papers in 0.1 Bq. Since each active system has a duct sampler, to determine the total particulate discharge from the AWAF the sum of all four systems is required. The volumetric flow rates of each system and the particulate samplers are assumed to be the current values. Analysis of the filter paper by gamma spectroscopy takes place at the RCL with Co-60 being the only radionuclide detected. The fingerprint for the primary circuit metallic waste is applied to the Co-60 value to determine the total activity.

For calculating the particulate discharge from the AWAF the assumptions are:

- All active ventilation systems are operating
- LOD value is 0.1 Bq/filter paper
- Ventilation is running 24/7
- Stack sampler rate is 38 l/min (2.28 m^3/h)
- Volumetric Flow Rates of each system are:
  - AWAF A = 17312 m^3/h
  - AWAF B = 11246 m^3/h
  - AWAF C = 26449 m^3/h
  - AWAF D = 3279.6 m^3/h
- Fingerprint applied to account for other radionuclides [10]
- Filter paper changed monthly
- Hours in a month = 744 h
- Assume LOD on filter paper but don't apply TGN1

Using Eqn 1 (Section 4.1.1) the total activity from each system, and then discharged through the authorised discharge point is given in Table 7.

System	1 Month (Bq)	12 Months (Bq)
A	759.3	9111.6
B	493.2	5918.9
C	1160	13920
D	143.8	1726.1
Total (Co-60)		30676.6
Total all radionuclides		0.066 MBq

Table 7: Calculated activity from particulate discharges from the AWAF

To calculate the tritium and C-14 limits, information based on the RCL capabilities to analyse the bubbler bottles and assumptions on the operation of the bubblers have been made.

The assumptions are summarised below:

- Two 200 ml sample bottles will be used for each radionuclide
- The LODs are:
    - tritium = 0.1 Bq/ml
    - C-14 = 0.21 Bq/ml
- LOD values seen in the bottles, no application of TGN1
- Bubblers will run 24/7
- Bubbler bottles will be changed weekly
- Sampler flow rate of 40 l/h (0.04 m^3/h)
- Will only be installed on AWAF system A
- Volume through sampler in a week = 6.72 m^3
- Volumetric flow rate through system A in a week = 2908416 m^3
- A year is 52 weeks

Equation 2 (Section 4.2.1) is used to calculate the activity discharged in one week and over 52 weeks this gives the values in Table 8.

Radionuclide	Activity (MBq)
Tritium	900
C-14	1890

Table 8: AWAF contribution to the gaseous limits from tritium and C-14

4.3.2. Aqueous Discharges

Aqueous discharges from the AWAF will primarily be from the PETP. Although the effluent in some cases will have come from elsewhere e.g., carboys from primary drain down on the submarine, since the PETP is operated in the AWAF the contribution is considered here, except for Stage 2 effluents which have been accounted for in the new Stage 2 building, Section 4.2.

The calculation uses knowledge of current PETP use, RCL results for analysis of effluents and estimation of future generation of effluents from projects.

For submarine generated effluents attributed to Stage 1, a volume can be estimated from the experience of submarines that have gone through Stage 1 to date and a factor included for future submarines. This has been estimated as 2 m^3 per submarine. Each carboy is analysed at the RCL by gamma spectroscopy (which typically detects Co-60), and tritium/C-14 depending on which system it originated from. The highest value for each identified radionuclide seen across the four submarines is used and is assumed to be the value across the total volume. The 'all others' calculated value is a combination of the C-14 value which is part of the analysis, and Ni-63 added by applying the relevant fingerprint to Co-60.

It is possible to make multiple passes of the effluent through the PETP, if it is BPM to do so, but it is assumed for the purposes of this application that the effluent only makes one pass. The PETP has been determined to have a decontamination factor of 1000 for all radionuclides except tritium where it is 1. Where application of the decontamination factor would give a value less than LOD, the LOD is applied instead [15].

The assumptions for the activity from carboys from drain down is summarised as:

- Volume is 2 m^3
- Highest analysis values are:
    - Co-60 = 19 Bq/cm^3
    - Tritium = 220 Bq/g
- Application of relevant fingerprint
- Decontamination factor of 1000 for Co-60 and all other radionuclides
- Decontamination factor of 1 for tritium
- The 'all others' value is calculated by application of relevant fingerprint to Co-60 [10]
- LOD used if after applying the decontamination factor the value would be < LOD

Using these assumptions and Eqn 3 (Section 4.2.2) gives the values in Table 9 for the contribution from the carboys.

Radionuclide	Volume (m^3)	Highest Result Seen (Bq/cm^3 or Bq/ml)	Decontamination Factor	Total (MBq)
Carboys Drain Down				
Co-60	2	19	1000	0.2
Tritium	2	220	1	440
'All Others'	2	From fingerprint	1000	0.23

Table 9: Calculated activities from treated drain down carboys

For the resins, it is assumed that all the water will require treatment, giving a total volume of ~ $12m^3$. This is based on an estimated water quantity across the 32 tanks that will need to be de-watered. As mentioned previously, optioneering will be completed to identify if this approach is BPM. The activity of the water is based on current knowledge and results of the contents of the resin holding tanks from both Rosyth and Devonport. A resin fingerprint is therefore applied to the Co-60 activity value to give an approximation of the other radionuclides present.

The assumptions are summarised as:

- Total volume of water = 12 m^3
- Activity the same across all tanks
- Use of the highest value seen in the resin water analyses for Co-60 and tritium
- Decontamination factor of 1 for tritium and 1000 for any other radionuclide
- Other radionuclides contribution calculated by applying relevant fingerprint to Co-60

Using these assumptions, the resin water contribution is in Table 10.

Radionuclide	Volume (m^3)	Highest Result Seen (Bq/cm^3 or Bq/ml)	Decontamination Factor	Total (MBq)
Resin Water				
Co-60	12	420	1000	5.04
Tritium	12	6.95	1	83.4
'All Others'	12	Apply fingerprint	1000	17.06

Table 10: Calculated activities in the treated resin water

4.4. Radiochemistry Laboratory

RRDL has its own on-site Radiochemistry Laboratory (RCL). After submarine refitting and the first stages of site decommissioning ended, the RCL has mainly analysed environmental related samples. These samples are from on-site monitoring, both aqueous and gaseous, with off-site monitoring samples sent to the Defence Science and Technology Laboratory (Dstl) for analysis (see Section 6.2). Since the beginning of SDP, the RCL has also started analysing samples relating to the dismantling work being carried out for characterisation purposes.

The RCL holds calibration sources for the calibration of its various instruments. The source holding limits are in the existing SEPA Permit [3] and are listed in Table 11. No change is being applied for to these holdings. The Permit also allows the RCL to accept samples of radioactive waste from external customers.

Radionuclides contained in the Authorised Holdings	Maximum quantity of radioactivity of each radionuclide in all of the Authorised Holdings
Tritium	1 MBq
Carbon-14	2 MBq
Cobalt-60	6 MBq
Nickel-63	4.5 MBq
Lead-210	20 kBq
Americium-241	55 kBq
Any non-alpha emitting radionuclides taken together excluding those listed individually in this table	2 MBq

Table 11: RCL Holdings Limits from SEPA Permit [3]

The scope of analyses the RCL can carry out has increased since the beginning of SDP and is expected to continue increasing as Stage 1 continues and Stage 2 starts. This will mainly be from the types of samples and the radionuclides to be analysed for. During Stage 1 it was recognised that it would be beneficial for the RCL to increase radionuclide capability to allow more in house analysis. All analysis techniques are documented with some being approved by UK Accreditation Service (UKAS). The methods are all carried out by SQEP personnel. Equipment is calibrated before use and is on maintenance schedules. Maintenance contracts are also in place for emergent issues.

To support this application, an exercise was undertaken to determine what would be the likely maximum activity of calibration sources and samples that could be held at the one time in a 12-month period [15]. The majority of the samples in the RCL will be from SDP and RRDL activities. The result of this exercise is presented in Table 12. The radionuclides are based on the holdings list.

Radionuclide	Total Activity (Holding + Samples)
Tritium	111 MBq
Carbon-14	3.24 MBq
Cobalt-60	16.2 MBq
Nickel-63	19.6 MBq
Lead-210	20 kBq
Americium-241	55 kBq
Any non-alpha emitting radionuclides taken together excluding those listed individually in this table	2 MBq

Table 12: Total radioactivity that the RCL could over a 12-month period

All RCL holdings and samples are held securely, and accounting requirements are met as per the Ionising Radiations Regulations 2017 [17] and the current SEPA permit [3]. Any liquid calibration sources or samples are stored in drip trays to prevent the spread of contamination in case of any spills or leaks.

Within the RCL, any sinks that are associated with the laboratory area drain to a tank. This allows the collection of effluent generated in the laboratory from analyses to be sampled ensuring it is suitable for discharge. Due to the small amounts of effluent that are generated with each analysis, it is not practical to accumulate the waste for treatment through the PETP. To treat effluent through the PETP ideally there should be a volume available that will fill the tank. This would require having to keep RCL samples for a long period of time. The samples are therefore disposed of directly to the RCL tank. The tank is sampled before discharge so should any indication be given that radioactivity values are much higher than normal the effluent can be treated by the PETP subject to its other factors. The effluent would need to be checked that it is suitable for PETP treatment as well due to other factors e.g., conductivity. However, for analyses of samples from external customers, any remaining sample is returned and is not disposed of by RRDL. The effluent in the tank is sampled before discharge to check the radioactivity present and the pH of the effluent. Should it not be within the acceptable range, the RCL will dose the tank to bring it within range. To discharge from the tank, an ETC is connected to the tank and filled. This is then taken to the discharge point (see Section 4.5) where it is discharged within the permitted time window.

Until recently the RCL had two tanks that it could use for effluents, however these tanks required upgrading to meet current standards. Given the location of tanks it was easier to upgrade the tank rather than the space they are installed in. Instead of two tanks the RCL will now have one tank which will be double skinned. This means it will be self-bunded as the space in which it sits does not allow for bunding to be installed. The new tank also has inbuilt filtration specific to the particle sizes generated at the RCL. Previously there was only filtration installed at the discharge point (see Section 4.5) which had to cater for both the RCL and laundry discharges to prevent it blocking too quickly.

The extracts from three fume cupboards connect to an active ventilation system installed in the RCL. The extracts join to form one single, currently authorised, discharge point. HEPA filtration is installed, and DOP tested, and a particulate sampler is installed on the extract duct.

The RCL was also part of the recent review of ventilation in facilities. It was noted that there were no bubblers installed to monitor for tritium and C-14. A review of the sampling work that would generate these radionuclides was undertaken. It concluded that the amounts generated are negligible and therefore, it is not deemed appropriate to install sampling bubblers in the RCL [7]. Any discharges are reported by calculation as described in an RRDL procedure [18]. The calculation uses activity information from the analyses carried out in that month, and release fractions associated with that technique. Any release is then discharged through the authorised RCL stack.

4.4.1. Aqueous Discharges

To calculate the activity discharged from the RCL, the historic data from SDP and estimates of future work were considered. To estimate the volume that could be discharged, the highest volume in a rolling 12-month period was used. This gave a volume of 12 m^3. The highest result for Co-60, tritium, gross beta and gross alpha were used from previous results of monthly bulk samples. The latter two are combined to give the 'all others' value.

To account for future analyses, the information from the review of samples was used [15]. This gave estimated activities for the different types of samples, and therefore the type of analysis that would be used for each. Where the total activity of the sample will be in liquid form, the total activity is used as it is assumed this will be disposed of to the RCL tank. For samples where only a part of the sample would be taken e.g., a section from metal, an activity value of 50 % was chosen. The calibrations sources will also provide a contribution with them being disposed of once used. It is assumed that 10 % of each calibration source is used within a 12-month period. With the extra analyses from a larger number of samples, it is assumed that the volume increases double to 24 m^3 which excludes the contribution from the holdings and samples calculated. The contribution from future analyses is assessed from the estimate of maximum sample holdings the RCL could hold [15]. Where a sample is a liquid volume the total activity of the sample is used, for metallic samples it is assumed that 50 % of the sample activity will be taken for the analyses. The assumptions are summarised as:

- Volume is 24 m^3
- Highest value seen in monthly bulk for each radionuclide used
- Future analyses contribution accounted for in two ways
  - Whole activity taken of effluent samples
  - 50 % activity taken from other samples
- 10 % of each calibration source disposed of
- The holdings contribution and future samples contribute directly to discharge values seen
- Relevant fingerprint applied to sample contribution for 'all others'

Using these assumptions, Table 13 shows the RCL contribution to aqueous limits.

Radionuclide	Volume (m^3)	Highest Monthly Bulk Value (Bq/cm^3)	Monthly Bulk Contribution (MBq)	Sample Contribution (MBq)	Holding Disposal (MBq)	Total (MBq)
Co-60	24	0.28	6.72	18.9	0.0529	25.67
Tritium	24	18.66	447.84	3.83	0.02	451.69
'All others'	24	0.14	3.36	21.82	0.0468	25.23

Table 13: Contribution to aqueous limits from the RCL

4.4.2. Gaseous Discharges

To calculate the RCL contribution to the gaseous limits, current knowledge of the RCL discharges and estimates based on future work are used.

The filter paper from the sampler is changed monthly and analysed by the RCL. The LOD for the filter paper is 0.1 Bq/paper for Co-60. The volumetric flow rates for the ventilation and the sampler are assumed to be the same as current values. To account for an increase in the number of samples processed in the RCL, particularly SDP samples, the particulate value will be doubled. As mentioned, the tritium and C-14 values from the RCL are by calculation. To provide an estimate, the highest values since the new process was introduced are used and assumed to be representative for the year based on current work levels. To account for future work, these numbers are also doubled. The primary circuit metallic fingerprint is applied as any activity in the samples analysed will have originated from the submarines.

The assumptions are summarised as:

- Ventilation is running 24/7
- LOD value for particulate is 0.1 Bq/paper
- Use LOD but don't apply TGN1
- Apply relevant fingerprint for 'all others'
- Sampler flow rate is 60 l/min (3.6 m^3/h)
- Volumetric flow rate is 5273 m^3/h
- Number of hours in a month is 744 and is applied to all months
- Tritium and C-14 values from highest month seen to present.
- Double the values to account for future work

Using the above assumptions and Eqn 1 (Section 4.1.1) for the particulate and applying the release fractions the limit contributions are in Table 14.

Radionuclide	12 Months Activity (MBq)	Increased Activity Total (MBq)
Tritium	0.252	0.504
C-14	0.00024	0.00048
'All others' (inc Co-60)	0.0038	0.0076

Table 14: Contribution to the gaseous limits from the RCL

4.5. Laundry

The aqueous effluent from the laundry is currently discharged through the site authorised discharge point located at the middle jetty on Rosyth Business Park. Historically there was a Low Activity Effluent Discharge (LAED) line which carried effluent from the various facilities to the discharge point. As part of the site decommissioning that took place previously, most of the line was decommissioned. Only a small section of the line remains which is from where it joins the middle jetty, then runs to the grid reference where discharges are permitted. There is a second system installed that can be used which also discharges at the site authorised point should the current facility not be available. To access the LAED line so it can continue to discharge effluent a small facility was built which provides connections to connect the ETCs to the LAED line and the ability to flush the line after emptying the ETC. As well as having the grid location within the permit, RRDL also have a condition whereby the discharges can only occur between 1 hours and 4 hours after high tide.

However, it was recognised that the laundry discharges could be discharged to a relevant sewer using standard condition G.4.1 [3].

Reviewing the discharges from the laundry it is possible that all discharges will meet the standard condition, but the ability to use the site authorised discharge point for laundry effluent is being kept.

A new laundry tank has been installed which is double skinned to be self-bunded. The previous tank was installed underground which not only caused issues with bunding, but anyone who needed to access it was working in a confined space. The tank has been moved to above ground providing easier access to the tank. Like the RCL, the new tank has filtration suitable for the expected particle size from the laundry effluent. There is an initial coarse filter between the washing machines and the tank, then a three stage filter at the output of the tank. To ensure discharges are within the Standard Condition limits a sampling point has been installed. This allows discharges to be analysed to ensure adherence to Standard Condition G.4.1. Should the limit associated with this condition be reached, or approached, within a rolling 12-month period the site authorised discharge point will be used.-The capability to transfer effluent to an ETC is being kept so the option of using the site authorised discharge point is always available if required.

The laundry is used for washing coveralls and lab coats that are used on site. At the exits to areas where a clothing change is required, bins are provided to hold used coveralls and lab coats. The bins have bags within them which are used to remove the coveralls/lab coats. Before washing, the coveralls and lab coats are monitored to ensure there is no gross contamination present. Should any contamination be found, the coveralls/lab coat will not be washed and be disposed of as soft LLW. This reduces the amount of activity added to the aqueous liquid discharges.

For the purposes of the calculation of new site limits, it is assumed that the laundry effluent will be discharged through the site authorised point ensuring it can be used for laundry effluent should it be required to divert effluent there. The contribution from the laundry can be calculated by using the current discharge information and making assumptions on the amount that Stage 2 will generate.

4.5.1. Aqueous Discharge

Using historic data from operations since SDP Stage 1 started, the maximum volume generated over a rolling 12-month rolling period is 81m^3. Analysis by the RCL has shown that the laundry discharges are less than the LOD in each of the analyses. To account for the scenario in which results could be above the LOD, the reporting methodology in TGN1 will not be applied and the LOD is used. With the continuation of Stage 1 and the beginning of Stage 2 there will be an increase in operatives. It is estimated that the operational workforce due to Stage 2 work will increase by approximately 25 % which will increase the volume of effluent from the laundry.

The assumptions are:

- Volume = 101.25 m^3 (25 % increase of baseline volume)
- LODs are from the RCL
  - Co-60 = 0.005 Bq/cm^3
  - Tritium = 0.1 Bq/cm^3
  - Gross beta (excl tritium and Co-60) = 0.01 Bq/cm^3
- Use of LOD, don't apply TGN1

The laundry contribution is shown in Table 15.

Radionuclide	Activity (MBq)
Co-60	0.506
Tritium	10.13
'All others'	1.02

Table 15: Contribution to the aqueous limits from the laundry

4.6. Summary of Aqueous and Gaseous Discharges

Rosyth Business Park currently has limits that apply to the whole site. As explained in sections 4.1 – 4.5, each of the facilities contributes towards the site's overall limits for aqueous and gaseous discharges, however the limits being applied for are presented as site limits. In line with the current limits, this will be over a 12-month rolling period.

To be cognisant of future work patterns, there is the potential that in a 12-month rolling period work could take place on two RPV/PST assemblies with elements of Stage 1 also being carried out. Where applicable, values that could be impacted by this work have been doubled or increased to account for the work taking place in the time period e.g., effluent from the RPV. Table 16 shows the values as calculated in the previous sections and the values adjusted for the work pattern.

		Aqueous Limits (MBq)		
Location	Uplift Factor	Co-60	Tritium	All Others
Stage 2 New Facility	2	31	384.5	62.32
AWAF	1.5 (carboys only)	5.34	743.4	17.41
RCL	1	25.70	451.69	25.23
Laundry	1	0.506	10.13	1.02
TOTAL		62.55	1589.72	105.98
		Gaseous Limits (MBq)		
Location	Uplift	Tritium	C-14	Others
LUSM	2 (tritium & C-14)	0.088	0.0204	0.055
Stage 2 New Facility	1	1778.4	3734.6	0.040
AWAF	1	900	1890	0.066
RCL	1	0.504	0.00048	0.0076
TOTAL		2679	5624.6	0.17

Table 16: Total contribution from all the facilities

Using these totals, the proposed new limits being applied for are summarised in Table 17 in comparison with the currently authorised limits. The totals have been rounded up. It is recognised the 'all other' radionuclides category has the potential for the greatest variation predominantly being based on fingerprints or gross alpha/beta analysis. These values are most likely to change or be affected by the new waste processing buildings, characterisation work and changes to current systems. Therefore, these limits have the greatest increase from the totals. These limits will allow the site to continue flexibly with SDPs proposed activities without further application. For the Co-60 aqueous limit, the total calculated is less than the current limit. No change is therefore proposed for this limit. The individually stated radionuclides/grouping are based on currently authorised radionuclides.

Aqueous Limits (MBq)		
	Current Limit	Proposed Limit
Co-60	100	100
Tritium	300	1600
Others	100	220
Gaseous Limits (MBq)		
	Current Limit	Proposed Limit
Tritium	10	2800
C-14	50	5700
Others	0.1	1.5

Table 17: Current and Proposed new limits

5. Solid Wastes

When systems are removed from the submarine, the solid waste generated is initially classified by provenance as to whether it is radioactive or could be potentially out of scope of the regulations. The following sections discuss how these wastes are processed. Only the radioactive waste is subject to authorisation by EASR18. A description of the out of scope waste process is included for completeness.

The only change in the permit required for solid waste disposal is the acceptance of ILW from MOD i.e. the RPV.

5.1. Radioactive Wastes

RRDL is currently only permitted to receive LLW from the seven submarines that are stored safely in the non-tidal basin at Rosyth, when they are moved into the 2 Dock nuclear licensed site. To enable RRDL to complete Stage 2 of SDP, RRDL will need to be able to remove ILW from the submarines, and continue to remove LLW as in Stage 1.

The majority of radioactive waste removed from the submarine falls into the LLW category with the RPV the main component that is classed as ILW but there are smaller components which also fall into the ILW category.

Modelling was used to characterise the activity in the RPV and the resulting data has been supported by physical characterisation. This has supported the design of the new facility where the RPV will be processed before loading into the RPVTC (see Section 4.2).

The LLW and ILW will be managed in accordance with the Standard Conditions that are included in all SEPA EASR18 permits. The amount of LLW and ILW is reduced, where possible, using provenance to identify which systems are LLW and which are out of scope. This allows the waste items to be segregated at the point of generation and avoid cross contamination. As described in

Section 5.2, any metallic potentially out of scope waste goes through a clearance process to confirm that it is out of scope.

Processing of items in the LLW waste stream can also generate potentially out of scope waste. To remove items from the submarine RC it can be necessary to cut items with brackets, backing plates etc still attached. As these items only ever provided a support function, they can be separated from the LLW and transferred to the potentially out of scope waste stream. However, this is dependent on initial monitoring showing that there is no contamination. Diverting waste from the LLW stream reduces the radioactive waste that needs to be sent for disposal and therefore reduces the amount of activity and volume generated.

Metallic solid waste is characterised to determine a fingerprint which can then be used to determine the nuclide content and the options for treatment and disposal. Each submarine is currently sampled to determine a fingerprint for its waste. When taking samples for characterisation, the minimum quantity for the analyses is taken where practicable. In cases where the samples are required to be sent off site, RRDL requests that any remaining sample is returned for disposal with the rest of the metallic LLW. All metallic waste disposal selections are supported by a detailed BPM assessment e.g., Resolution M1 Waste disposal [18].

Soft wastes are also monitored to determine whether they are out of scope or not. If required, the capability exists to be able to sort soft waste bags and remove any radioactive waste. Soft LLW is currently transferred to a waste permitted person where it is then incinerated. This was initially optioneered as BPM and this will continue to be kept under review.

The design of processes and equipment considers the generation of solid waste, with it reduced in accordance with the waste hierarchy where possible. An example is the new WRHCs for the resin. The RCTs are a solid unit and have previously been disposed whole as LLW. In the new WRHCs the metallic liner where the resin sits can be separated from the concrete shielding. This now gives the option of separating the waste with the shielding potentially being out of scope.

The new building is also being designed with consideration given to the equipment required at each stage of the process. Specific lay down areas are being identified to store equipment. This will ensure segregation of equipment that may become contaminated and for equipment that should always stay clean.

The processing of the PST/RPV assembly will also be designed with the separation of potentially out of scope, LLW and ILW considered. Characterisation by modelling has informed which parts of the assembly are expected to be in each waste category and where BPM the generated waste will be separated into out of scope, LLW or ILW. The cut up and disposal of the PST will be supported by a detailed BPM assessment.

Under the 2011 Scottish Government Higher Activity Waste Policy, SDP wastes are from Defence assets and are exempt from the policy. This means that ILW from SDP can be sent anywhere in the UK for treatment, as per the policy, and can be transferred to a waste permitted person for disposal.

In the case of the RPV, it will be stored safely at a facility at Capenhurst in its RPVTC until it can be disposed to the Geological Disposal Facility (GDF).

5.2. Out of Scope Wastes

For systems that have been identified as out of scope they are separated within the RC and put through a separate waste process to the LLW. The potentially out of scope waste is initially monitored in the IDI. Depending on when it is generated, it is either stored in a demarcated area in the RC until the IDI is in place or placed directly into a box once the IDI is attached. To ensure that there is no surface contamination present, it is monitored as it is placed into the box and a survey record generated. The survey results are reviewed by SQEP personnel to ensure the waste can be removed from the submarine. These boxes follow a different waste route to those containing LLW.

The box is then moved from the submarine to dock side storage awaiting transfer to the monitoring facility. The monitoring facility is in the Beatty Building which although within Rosyth Business Park is off the licensed site. This has required an extra monitoring step in the process since the waste is being removed from the nuclear licensed site before confirmation that it is out of scope.

A new facility has been designed specifically for the out of scope waste and this is being constructed within the AWAF licensed site. Once operational, the potentially out of scope waste will then be transferred to this new facility so waste will go from one area of the nuclear licensed site to the other.

The monitoring process in these buildings will however be the same. The process is detailed in [19] but an overview is given here. Each item of waste (or grouping as the weight needs to be > 2kg) is measured through a LAM which determines whether the item is in or out of scope. Items that do not fit in the LAM are size reduced where possible. If the item cannot be size reduced a different but parallel monitoring process is used. The results from the items are exported in batches e.g., after a box has been emptied. The results are reviewed by SQEP personnel who will sign to confirm the items are out of scope. If required, the out of scope waste can then be security declassified before being put in skips for recycling.

Should any items be in scope or identified by the SQEP personnel these are moved to a demarcated quarantine area. The items are then further investigated to try and determine where the contamination is or the cause. From previous experience of items that have been in scope through the LAM, analyses have shown that Naturally Occurring Radioactive Materials (NORM) are present in some materials e.g., insulation. Depending on the outcome of the investigation it can either be sentenced as out of scope or as LLW.

These processes will continue to be used and expanded upon for recycling of the entire submarine in Stages 3 and 4 of the project.

6. Environmental Assessment and Monitoring

In deciding how to assess the proposed limits for environmental impact, an understanding of the most relevant radionuclides is required. In some cases, this will be simple as the limit refers to a single radionuclide, but for both the aqueous and gaseous limits there is an 'all others' category. In these cases, the radionuclides present are assessed as to which are most likely to have the highest impact. The main three nuclides considered for assessment in SDP are Co-60, tritium, and C-14.

Co-60 was originally produced during the operation of the submarines reactor and is the only major gamma emitting radionuclide present throughout the reactor systems [10]. This makes it the most likely radionuclide to be present in both aqueous and gaseous discharges. In terms of radionuclides, it is considered since:

- It has a half life of ~ 5.3 years. This gives it the potential to accumulate in food chains;
- It decays by emitting high energy gamma radiation;
- It is readily adsorbed onto marine sediment.

Tritium is most likely to be discharged in the form of tritiated water, and in greater quantities than the other radionuclides. As described in Section 4, when treating effluents, tritium is not able to be removed which isn't the case for the other radionuclides. Any tritium present in the effluent will therefore be discharged. Tritium can also be released as a gaseous discharge when working with tritium containing effluents. Similar to the aqueous phase, tritium will not be mitigated by HEPA filtration.

C-14 is used as the 'all others' representative radionuclide for aqueous discharges as it has a very long half-life of 5730 years.

To assess the potential impact of the new limits, the proprietary PC CREAM and ERICA models were used to assess how the main radionuclides would disperse in the environment, and the associated dose. The results of these models are discussed in section 6.1. Further information on the inputs to the models are found in appendices 1 - 4.

6.1. Environmental Impact Assessment

The impact of the proposed limits that were calculated in Section 4 and summarised in Table 17 was assessed using the PC CREAM for human exposures and ERICA programmes for non-human species.

Two assessments were run through PC CREAM, one for the assessment of the aqueous discharges and one for the gaseous discharges. Further information on the inputs is in Appendices 1 and 2 respectively. All dose calculations were carried out by SQEP personnel.

The annual dose limit to a member of the public is 1000µSv/y however in SEPA document [19] dose constraints are applied to future discharges. This sets an effective dose constraint of 500 µSv/y with an effective dose of <10 µSv/y being of potentially no regulatory concern.

6.1.1. Assessment of Aqueous Discharges

The radionuclides selected for assessment were Co-60, tritium and C-14 representing the ‘all others’ category. A regional and Rosyth local compartment were used for the assessment. The parameters were kept as the PC CREAM default values unless specific data was available. An example of this is the upper bound of tidal level which was determined using admiralty charts local to Rosyth Business Park instead of the default value. The lower bound was kept as the default.

To calculate the dose to a representative person the parameters within the PC CREAM model were used, but the data was taken from the latest published Rosyth Habits study [20]. For some parameters there was no relevant data in the Habits study, therefore the default value of the model was used.

The most significant radionuclides contributing to the calculated exposure are ‘all other’ radionuclides and Co-60. The significant pathways for these radionuclides are ingestion from fish, and external gamma radiation in sediment sands respectively. The full results are in Table A1.3 of Appendix 1.

The total effective radiation dose assessed for a representative person, based on the new discharge limits, was 2.94×10^{-2} μSv/y. This individual representative dose is 0.00294% of the effective public dose limit of 1000 μSv/y. It is also 0.294% of the 10 μSv/y which is the value of potentially no regulatory concern. As such no further assessment is required.

Result 1: The individual effective dose from our proposed discharge limits is 0.00294% of the public dose.

The collective dose to the European population, truncated at 500 years, was also calculated. The habits study beach occupancy value for Rosyth is not valid for this calculation and therefore the PC CREAM default value is used. The highest contribution is from all other radionuclides in molluscs.

The collective effective dose is 3.84×10^{-4} person Sv which is negligible. For the purposes of a comparison to the public dose limit, the collective effective dose divided over the European population used in the model gives an individual effective dose of 1.07×10^{-6} μSv. The resulting dose is 0.00000011% of the annual public dose limit.

Result 2: The collective effective dose of the European population represented as an individual effective dose from our proposed discharge limits is 0.00000011% of the annual public dose limit.

6.1.2. Assessment of Gaseous Discharges

The radionuclides selected as the inventory were tritium, C-14 and Co-60 to represent the 'all other' category. To represent the weather stability category, the Pasquill MET scheme was used in conjunction with the PC CREAM defaults. A conservative stack height of 0m for the assessment was selected which represents worst case, since the stack is much higher.

Where it was suitable, the Habits Study information was used to provide values for parameters for the calculation of the effective dose to the representative person. If data was not available, then default data from PC CREAM was used. The most significant radionuclide was C-14, and the significant pathways were inhalation dose, and the terrestrial grain dose. The total effective dose to a representative person was assessed to be 0.672 µSv/y.

The individual representative dose from the proposed discharges is 0.0672% of the effective public dose of 1000 µSv/y. It is also 6.72% of 10 µSv/y which is the value of potentially no regulatory concern. As such no further assessment is required.

Result 3: The individual representative dose from our proposed discharge limits is 0.0672% of the annual public dose.

The collective effective dose to the European population was calculated. This assumed a maximum distance of 3000 km and truncated the time at 500 years. The PC CREAM default data was used for the parameters. The C-14 was the highest contributor to the dose calculation. This is to be expected due to the long half-life of C-14. This gave a value of 3.61 x 10^{-3} person Sv which is negligible. To provide a comparison to the annual public dose limit, the collective effective dose is divided by the European population used in the model. This gives an individual dose of 1 x 10^{-5} µSv, which is 0.000001% of the annual public dose limit.

Result 4: The collective dose to the European population represented as an individual dose from our proposed discharge limits is 0.000001% of the annual public dose limit.

The tables of input parameters and full results are shown in Appendix 2.

6.1.3. Assessment to non-human species from aqueous and gaseous discharges

Using the ERICA software, the impact of the proposed discharge limits on non-human species was calculated. Both tier 1 and tier 2 calculations were run although the resulting risk quotients from tier 1 calculations were all much less than 1. By running tier 2 a dose rate could be calculated for the year. The default species for both the marine and terrestrial environments were used as these cover most of the types of species local to Rosyth Business Park. A screening value dose rate of 10 µGy/h was used, which is the default value in ERICA.

From the aqueous discharges Co-60 had the greatest impact with the most affected marine species the polychaete worm with an exposure dose rate of 2.83 x 10^{-5} µGy/h. This is 0.000283% of the screening value.

Result 5: The exposure dose rate from the proposed aqueous discharges is 0.000283% of the screening value.

From the gaseous discharges C-14 had the greatest impact with the most affected terrestrial biota/species being the animal species of amphibian, bird, and mammal (large and small) with an exposure dose rate of 5.42 x 10^{-4} µGy/h, which 0.00542% of the screening value.

Result 6: The exposure dose rate from the proposed gaseous discharges is 0.00542% of the screening value.

The results of the ERICA assessment can be found in Appendix 3.

6.2. Environmental Monitoring

The environmental assessment made in Section 6.1 showed that the impact from the proposed limits will be negligible. However, environmental monitoring will still take place to assess if there is any impact. In accordance with Standard condition J.1.1 RRDL has an environmental monitoring programme that covers both the site and surrounding area. It, along with other monitoring programmes are discussed below.

The off-site environmental monitoring programme carried out by RRDL consists of eight monitoring points that cover the north and south shores of the Firth of Forth [23]. Five of these points are located on the north shore and three on the south shore.

For each monitoring point a frequency has been decided along with the monitoring and sampling that will be carried out at that point. The frequency of monitoring being carried out at the points varies between monthly and quarterly, with sample taking at each point varying between quarterly, bi-annually and annually depending on sample type.

At each of the monitoring locations, environmental and strandline dose rates are taken. The strandline dose rate measurements are at contact to the ground, normally along the line of visible debris that is left at the high water mark. Three measurements are made and then averaged to give a reading for that point. The environmental dose rates are taken at a height of 1 m from the ground, with three taken at the low water mark, and one at the high water mark.

Samples are also taken at the points in accordance with the programme which determines which samples are taken where and at what frequency. The types of samples are sediment, seaweed, and molluscs. In recent years mollusc samples have been difficult to find as the population has disappeared and not yet recovered.

The samples taken are not analysed by the onsite RCL but are sent to Dstl who arrange for the samples to be analysed at UK Health Security Agency (UKHSA) The results of the samples are then sent to RRDL which are then reported in the quarterly reports which are prepared for SEPA and presented at the Local Liaison Committee (LLC).

As well as the monitoring of the aquatic environment outside of Rosyth Business Park, environmental monitoring is also carried out within the Rosyth Business Park and on the two areas of the nuclear licensed site, the AWAF and 2 Dock.

Environmental airborne monitoring around Rosyth Business Park is conducted using Tacky Shades. These are frames that sit in a 'V' shape and are covered in a light sticky material which is designed to trap airborne particulate. The Tacky Shades are located at various locations around Rosyth Business Park and the material is changed on a quarterly basis with analysis being done by the RCL. To ensure there is no damage to the Tacky Shades they are checked on a weekly basis.

Monthly dose rate surveys are carried out by Health Physics Monitors around the perimeter of the licensed site areas. Along with the handheld instrument monitoring, environmental Thermoluminescent Dosimeters (TLDs) are placed on the boundary fence of the AWAF and changed monthly. The use of environmental TLDs was extended recently with TLDs now placed on the Rosyth Business Park boundary to measure the dose rates. By reviewing the results from the off-site and on site monitoring it will give an indication if there is a change in the environment from site discharges.

The conclusions drawn from the results of the environment monitoring programme since its inception have always been that there is no radiological hazard to any member of the public from permitted discharges at Rosyth Business Park.

The environmental monitoring programme is kept under review to ensure it remains fit for purpose. The current programme focusses more on monitoring aqueous discharges. However, with Stage 2 and the increase in limits, particularly gaseous limits, the programme will be reviewed and augmented as appropriate in preparation for Stage 2. This will include sampling of local vegetation and analysis for relevant radionuclides.

As well as the RRDL environmental monitoring programme, other organisations also carry out environmental monitoring which is then reported in published reports e.g., the environmental agencies annual RIFE report. These can provide additional and comparative information to the RRDL programme.

7. Transboundary Assessment

The environmental assessments detailed in section 6.1 show that the environmental impact from the proposed new limits is negligible and therefore will not require a full transboundary assessment. To confirm this, an initial transboundary assessment was carried out.

The nearest neighbour country to Rosyth by distance is Ireland but it is not in the direction of the prevailing wind. Based on the prevailing wind direction (south west), the nearest neighbour would be Norway. However, since activity in air concentrations decline rapidly with increasing distance it was considered more appropriate to select a reference group in Ireland [22]. Habits data was taken from a report published by the Irish Environmental Protection Agency that considered the impact of routine operations from power plants in the UK.

The data for the representative person was taken from a Cefas report following a habit survey that covers the north east coast of Ireland.

The radiation dose to the representative person from gaseous discharges is assessed to be 1.51×10^{-5} µSv/y compared to the dose limit of 1000 µSv/y. The most significant radionuclide contributing to this dose is C-14. The pathway of greatest significance is cow milk products followed by root vegetables.

The radiation dose to the representative person from aqueous liquid discharges is assessed to be 3.69×10^{-5} µSv/y compared to the dose limit of 1000 µSv/y. The most significant radionuclide contributing to this dose is all other radionuclides. The pathways of greatest significance are the ingestion of fish followed by molluscs.

The representative person doses are 0.0000015% and 0.0000037% of the dose limit for members of the public of 1000 µSv/y for gaseous and aqueous respectively. Table 18 lists the results and the fraction of the dose limit.

The representative person doses are also 0.000151% and 0.000369% of the 10 µSv/y which is the recognised dose to be of potentially no regulatory concern.

	Result (µSv/y)	Dose Limit (µSv/y)	Fraction of Dose Limit (%)
Gaseous	1.51×10^{-5}	1000	0.0000015
Aqueous	3.69×10^{-5}	1000	0.0000037

Table 18: Summary of environmental impact to nearest neighbour for transboundary assessment

8. Conclusions

RRDL has safely and successfully undertaken Stage 1 LLW removal on four submarines at Rosyth. To continue to Stage 2 which will remove the RPV, and allow complete dismantling and recycling of the submarine, the SEPA Permit held by RRDL requires variation.

The variation is to allow RRDL to remove ILW from the submarines and continue to remove LLW. LLW and ILW will be disposed to a waste permitted person.

The aqueous limits for tritium and ‘all other’ radionuclides also require to be increased. This is mainly due to additional work associated with Stage 2 and the filling of the RPV with water to mitigate airborne and radiation hazards to workers. Characterisation work is currently being carried out on each submarine. Based on the results of this characterisation, proportions of each of the radionuclides varies dependent on the specific submarine therefore the applicable fingerprints could change, or various fingerprints could be applicable over time. With these changes the ‘all others’ value has the potential to increase from the current limit.

All gaseous limits are being proposed to be increased. The tritium and C-14 limits are driven by processes that can generate tritium and C-14 which will discharge to the air. To monitor the discharges bubblers are being installed at the facilities where there is a higher likelihood of generation. The ‘all others’ category which is predominantly for airborne particulate has been increased to account for the operation of a new dockside waste processing facility and future work.

RRDL will continue to apply BPM practices to all work conducted at site. Work at current facilities has been underpinned by BPM assessments and new assessments are being made for the new waste processing facilities. If a detailed BPM is not yet available, optioneering has been conducted with a full BPM to follow once further information is known.

Environmental monitoring at Rosyth has shown that there has been no radiological hazard to members of the public as a result of the currently permitted discharges. The current environmental monitoring programme mainly covers the aquatic environment but monitoring for any potential airborne particulate is also carried out on site. Environmental monitoring will continue and will be reviewed to ensure it is appropriate to detect and measure the impact of proposed discharges.

Using the proposed limits in this application, environmental assessments were carried out for both aqueous and gaseous discharges to the public and non-human species. The highest dose was 0.672 µSv which is 0.0672% of the public dose limit. For non-human species the highest value was 0.000542 µGy/h which is 0.00542% of the screening value. These all show that the dose or dose rate is much less than the dose limit or dose rate screening value.

Finally, a transboundary screening assessment was carried out. This showed that the doses to our nearest EU neighbour (Ireland) from gaseous and aqueous discharges were 0.0000015% and 0.0000037% of the public dose limit. Due to these very low doses, it was concluded that no further assessment was necessary.

A summary of the current and proposed aqueous and gaseous limits are summarised below in Table 19.

Aqueous				
	Current Limit (MBq)	Proposed Limit (MBq)	Total Dose to Representative Person (µSv/y)	Fraction of 1000 µSv/y Public Dose Limit (%)
Co-60	100	100	2.94×10^{-2}	0.00294
Tritium	300	1600		
Others	100	220		
Gaseous				
	Current Limit (MBq)	Proposed Limit (MBq)	Total Dose to Representative Person (µSv/y)	Fraction of 1000 µSv/y Public Dose Limit (%)
Tritium	10	2800	6.72×10^{-1}	0.0672
C-14	50	5700		
Others	0.1	1.5		

Table 19: Summary of the current and proposed limits

These limits should futureproof the site to continue with SDP to fully dismantle the submarines stored at Rosyth.

Table 20 summarises the results from the environmental assessments for collective dose, non-human species and the transboundary assessment.

Assessment	Dose Group	Result	Fraction of 1000 µSv/y Public Dose Limit (%)
Aqueous	Collective	3.84×10^{-4} person Sv	N/A
Gaseous	Collective	3.61×10^{-3} person Sv	N/A
Transboundary	Representative Person (Atmospheric)	1.51×10^{-5} µSv	0.00000151
	Representative Person (Marine)	3.69×10^{-5} µSv	0.00000369
Assessment	Dose Group	Result	Fraction of 10 µGy/y Screening Dose Rate (%)
Non-Human Aqueous	Marine	2.83×10^{-5} µGy/h	0.000283
Non-Human Gaseous	Terrestrial	5.42×10^{-4} µGy/y	0.00542

Table 20: Summary of environmental assessment results

References

[1] Ministry of Defence, "Submarine Dismantling Project (SDP) - Post Consultation Report," 2012.

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[20] [redacted] "Best Practicable Means - Treatment/Disposal of Mettalic M1 Waste from Resolution," 2203001 Issue 01, 2022.

[21] SEPA, "Environmental Radiological Monioring In Scotland - Radiological Monitoring Technical Guidance Note 2," 2019.

[22] [redacted] "Radiological Habits Survey: Rosyth 2015," 2016.

[23] [redacted] " Review of the Environmental Monitoring Programme," HPH 04-20, 2020.

[24] [redacted] "APPENDIX 4 - TRANSBOUNDARY RADIOLOGICAL ASSESSMENT FOR DISCHARGES OF DISCHARGES OF GASEOUS RADIOACTIVE WASTE AND DISCHARGES OF AQUEOUS LIQUID RADIOACTIVE WASTE TO THE FIRTH OF FORTH FROM SUBMARINE DISMANTLING AT ROSYTH BUSINESS PARK," 2022.

[25] [redacted] "Disaggregation and valuation of collective dose and global circulation dose," *Journal of Radiological Protection,* vol. 25, no. 3, p. 277, 2005.

Appendix 1 – Radiological Assessment for Discharges of Aqueous Radioactive Waste to the Firth of Forth from SDP

This appendix presents the input parameters and results of the radiological assessment for discharges to the Firth of Forth. The assessment was carried out using PC CREAM.

The pathways considered in the assessment were:

- Ingestion of fish
- Ingestion of molluscs
- Ingestion of crustaceans (crabs);
- Inhalation of sea-spray;
- External gamma irradiation from activity in beach sediments;
- External beta irradiation from activity in beach sediments;
- External exposure to gamma radiation in fishing gear;
- External exposure to beta radiation in fishing gear.

The following tables list the parameters and results that were used in assessment for aqueous liquid discharges.

Table A1.1 – Parameter values for Rosyth Local Compartment

Parameter	Value
Regional Compartment	North Sea Central
Volume (m^3)	3.35×10^9
Depth (m)	20
Coastline Length (m)	7.5×10^4
Volumetric Exchange Rate ($m^3\ y^{-1}$)	2.04×10^{10}
Suspended sediment load	5.0×10^{-5}
Sedimentation Rate ($t\ m^{-2}\ y^{-1}$)	2.0×10^{-4}
Sediment Density ($t\ m^{-3}$)	2.6
Diffusion Rate ($m^2\ y^{-1}$)	3.15×10^{-2}

Table A1.2 – Habit Data Assumed for Representative Person

Parameter	Value
Fish Consumption Rate (kg y^{-1})	109
Fraction of Fish Caught in the Local Compartment	1
Fraction of Fish Caught in the Regional Compartment	0
Mollusc Consumption Rate (kg y^{-1})	16
Fraction of Molluscs caught in the Local Compartment	1
Fraction of Molluscs caught in the Regional Compartment	0
Crustacean Consumption Rate (kg y^{-1})	31
Fraction of Crustacean caught in the Local Compartment	1
Fraction of Crustaceans caught in the Regional Compartment	0
Exposure to Exposed Mud in Local Compartment (h y^{-1})	2664
Exposure to Exposed Mud in Regional Compartment (h y^{-1})	0
Exposure to Fishing Gear in Local Compartment (h y^{-1})	1460
Exposure to Fishing Gear in Regional Compartment (h y^{-1})	0
Exposure to Sea-spray (h y^{-1})	2664
Distance for Sea Spray (m)	0
Inhalation Rate (m3 y-1)	8100

Table A1.3 – Representative Person Effective Doses

Nuclide	Doses (μSv)								
	Fish	Crustacean	Mollusc	Sediment Gamma	Sediment Beta	Fishing Gear Gamma	Fishing Gear Beta	Sea-spray	Total
Co-60	5.63E-05	1.60E-04	2.370E-04	1.12E-02	8.70E-06	6.15E-05	2.29E-06	2.95E-10	1.17E-02
H-3	1.53E-07	4.34E-08	2.24E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.78E-11	2.18E-07
Other n.o.s[1]	1.23E-02	3.50E-03	1.81E-03	0.00E+00	3.21E-07	0.00E+00	1.11E-06	1.81E-10	1.76E-02
Total	1.24E-02	3.67E-03	2.05E-03	1.12E-02	9.02E-06	6.15E-05	3.40E-06	4.94E-10	2.94E-02

1 – assumed to be represented by C-14

Table A1.4 – Collective Effective Doses to Europe Truncated at 500 Years

Radionuclide	Collective Dose (person-Sv)					
	Fish	Crustacean	Mollusc	Sediment Gamma	Global Circulation	Total
Co-60	1.13E-07	3.15E-06	1.93E-05	1.61E-07	0.00E+00	2.27E-05
H-3	4.84E-10	8.61E-10	1.85E-09	0.00E+00	1.94E-09	5.14E-09
All other radionuclides (not individually specified)[1]	5.25E-05	7.01E-05	1.51E-04	0.00E+00	8.82E-05	3.61E-04
Total	5.26E-05	7.33E-05	1.70E-04	1.61E-07	8.82E-05	3.84E-04

Appendix 2 – Radiological Assessment for Discharges of Gaseous Radioactive Waste from SDP

This appendix presents the input parameters and results of the radiological assessment for gaseous discharges from SDP at Rosyth. The assessment was carried out using PC CREAM.

Collective dose is a common measure of detriment caused by the operation of a nuclear site. It is the sum of all individual doses resulting from a practice to a defined population and/or over a defined time. As mentioned, the collective dose from authorised radioactive discharges can be very large especially if it is integrated over large populations and periods of time following the discharge. However, large numerical values of collective dose can mask the fact that individuals may only receive tiny doses. The application of collective dose in the context of worker protection is relatively straightforward whereas application to discharges to the environment can give different interpretations depending on the population and the time period considered [23].

In ICRP 77 it was recommended that caution should be taken when interpreting the outcome of a collective dose assessment. It was advised that the collective dose should be disaggregated because of individual dose across the population/time. When considering certain radionuclides e.g., C-14 it is likely that most of the collective dose could come from the globally circulating model. Doses to individuals from the globally circulating model are generally very small. It can therefore be usual to only consider globally circulating doses in relation to collective dose.

The following pathways were included in the assessment:

- Inhalation of radionuclides in the plume;
- External gamma from airborne radionuclides;
- External beta from airborne radionuclides;
- External gamma from deposited radionuclides;
- External beta from deposited radionuclides;
- Inhalation of re-suspended radionuclides;
- Consumption of cow's meat;
- Consumption of cow's milk;
- Consumption of cow's milk products;
- Consumption of cow liver;
- Consumption of sheep meat;
- Consumption of sheep liver;
- Consumption of green vegetables;
- Consumption of root vegetables;
- Consumption of grain.

Document Ref No: 2301005

The following Tables list the parameters and results from the gaseous discharge modelling.

Table A2.1 – PC CREAM 08 Settings

Parameter	Value
Output Time (years)	50
MET file	65% Cat D & 10% rain in C and D
Stack Height (m)	0
Receptor 1 Distance – Inhalation/Direct (m)	100
Receptor 2 Distance – Food Production (m)	300

Table A2.2 – Habit Data Assumed for Representative Person

Parameter	Value
Time at Location 1 (h/y)	5.11E+03
Fraction of Time Spent Indoors	7.1E-01
Cloud Gamma Location Factor	2.00E-01
Deposited Gamma Location Factor	1.00E-01
Cloud Beta Location Factor	1.00E+00
Deposited Beta Location Factor	1.00e+00
Inhalation Location Factor	1.00E+00
Inhalation Rate (m3/y)	8.10E+03
Time at Location 2 (h/y)	0.00E+00
Food Production Location 2	300m from discharge
Cow Meat Consumption Rate (kg y^{-1})	20.8
Cow's Milk Consumption Rate (kg y^{-1})	240.0
Cow's Milk Products Consumption Rate (kg y^{-1})	60.0
Cows Liver Consumption Rate (kg y^{-1})	10.0G
Sheep Meat Consumption Rate (kg y^{-1})	25.0
Sheep Liver Consumption Rate (kg y^{-1})	10.0
Green Vegetables Consumption Rate (kg y^{-1})	68.3
Root Vegetables Consumption Rate (kg y^{-1})	84.7
Grain Consumption Rate (kg y^{-1})	100.0.
Fruit Consumption Rate (kg y^{-1})	38.7

Table A2.3 – Representative Person Effective Doses

Pathway	Doses (µSv)			
	Tritium	Carbon-14	Others n.o.s.	Total
Inhalation	8.70E-04	1.31E-01	1.71E-04	1.32E-01
Cloud Gamma	0.00E+00	0.00E+00	2.25E-07	2.25E-07
Dep Gamma	0.00E+00	0.00E+00	5.71E-03	5.71E-03
Resus	0.00E+00	0.00E+00	1.95E-07	1.95E-07
Cloud Beta	0.00E+00	6.37E-07	1.67E-09	6.38E-07
Dep Beta	0.00E+00	0.00E+00	7.70E-06	7.70E-06
Green Veg	1.00E-04	3.50E-02	1.25E-05	3.51E-02
Grain	1.82E-05	2.31E-01	1.08E-05	2.31E-01
Root Veg	1.24E-04	4.33E-02	6.86E-07	4.35E-02
Cow Meat	2.66E-05	1.60E-02	9.63E-08	1.60E-02
Cow Liver	1.28E-05	7.68E-03	4.64E-06	7.70E-03
Sheep Meat	3.02E-05	1.92E-02	1.72E-07	1.92E-02
Sheep Liver	1.28E-05	7.68E-03	6.90E-06	7.70E-03
Milk	3.95E-04	6.15E-02	1.35E-06	6.19E-02
Milk Produce	4.35E-05	9.23E-02	3.72E-06	9.24E-02
Fruit	5.67E-05	1.98E-02	1.51E-06	1.99E-02
Total	1.69E-03	6.64E-01	5.93E-03	6.72E-01

Table A2.4 – Collective Effective Doses to Population of European Union Truncated at 500 Years

Radionuclide	Collective Dose (person-Sv)
C-14	3.61E-03
Tritium	3.29E-08
All other radionuclides (not individually specified)[1]	0.00E+00
Total	3.61E-03

1 – Assumed to be represented by Co-60

Appendix 3 – Radiological Assessment to Non-Human Species for Discharges of Gaseous and Aqueous Radioactive Waste from SDP

This appendix presents the input parameters and results from the ERICA modelling that was carried out. The assessed exposure is to non-human species that are living in close proximity to Rosyth Business Park.

Non-human species are exposed to radionuclides discharged to the environment and need to be assessed. The assessment uses the activity concentrations that have been calculated in PC CREAM in appendices 1 & 2.

The results are compared against a screening value of 10 µGy/h for all ecosystems and organisms which is a default screening level in ERICA.

The Tables that follow provide the inputs and results of the assessment.

A3.1 – Non-Human Species from the Terrestrial Environment Considered

Organism (animal)	**Organism (plant)**
Amphibian	Grasses & Herbs
Bird	Lichen & Bryophytes
Mollusc – gastropod	Shrub
Reptile	Tree
Annelid	
Arthropod – detritivores	
Flying insects	
Mammal – large	
Mammal - small-burrowing	
Mollusc – gastropod	
Reptile	

Document Ref No: 2301005

Table A3.2 – Non-Human Species from the Marine Environment Considered

Organism (animal)	Organism (plant)
Benthic fish	Macroalgae
Bird	Phytoplankton
Crustacean	Vascular plant
Sea anemones & True coral	Zooplankton
Mammal	
Mollusc – bivalve	
Pelagic fish	
Reptile	
Polychaete worm	

A3.3 – Calculated Dose Rates (in µGy/h) to Terrestrial Biota Resulting from Atmospheric Discharges

Nuclide	Amphibian	Annelid	Arthropod - detritivores	Bird	Flying insects	Grasses & Herbs	Lichen & Bryophytes	Mammal - large	Mammal - small-	Mollusc - gastropod	Reptile	Shrub	Tree
C-14	5.42E -04	1.73E -04	1.72E -04	5.42E -04	1.72E -04	3.59E -04	3.56E -04	5.43E -04	5.42E -04	1.73E -04	5.42E -04	3.59E -04	5.26E -04
Co-60	2.57E -06	2.64E -06	2.64E -06	1.02E -06	9.02E -07	9.61E -07	8.10E -07	8.10E -07	2.48E -06	9.77E -07	2.38E -06	9.08E -07	8.28E -07
H-3	5.60E -06	5.60E -06	5.60E -06	5.60E -06	5.60E -06	5.62E -06	5.60E -06	5.60E -06	5.60E -06	5.60E -06	5.60E -06	5.62E -06	5.62E -06

A3.4 – Calculated Dose Rates (in µGy/h) to Terrestrial Biota and Corresponding Risk Quotients from Atmospheric Discharges

Terrestrial Biota	Total dose rate (µGy/h)	Risk Coefficient (expected)	Risk Coefficient (conservative)
Amphibian	5.50E-04	5.50E-05	1.65E-04
Annelid	1.81E-04	1.81E-05	5.44E-05

Arthropod - detritivores	1.80E-04	1.80E-05	5.40E-05
Bird	5.49E-04	5.49E-05	1.65E-04
Flying insects	1.79E-04	1.79E-05	5.37E-05
Grasses & Herbs	3.65E-04	9.14E-07	2.74E-06
Lichen & Bryophytes	3.62E-04	9.05E-07	2.72E-06
Mammal - large	5.49E-04	5.49E-05	1.65E-04
Mammal - small-burrowing	5.50E-04	5.50E-05	1.65E-04
Mollusc - gastropod	1.79E-04	1.79E-05	5.38E-05
Reptile	5.50E-04	5.50E-05	1.65E-04
Shrub	3.65E-04	9.13E-07	2.74E-06
Tree	5.33E-04	1.33E-06	4.00E-06

Table A3.5 – Calculated Dose Rates (in µGy/h) to Marine Biota Resulting from the Liquid Discharges

Nuclide	**Benthic fish**	**Bird**	**Crustacean**	**Macroalgae**	**Mammal**	**Mollusc - bivalve**	**Pelagic fish**	**Phytoplankton**	**Polychaete worm**	**Reptile**	**Sea anemones**	**Vascular plant**	**Zooplankton**
C-14	3.74E-06	3.74E-06	3.12E-06	2.50E-06	3.74E-06	3.73E-06	3.74E-06	1.65E-06	3.11E-06	3.74E-06	3.72E-06	2.51E-06	3.07E-06
Co-60	1.53E-05	4.10E-07	1.40E-05	1.38E-05	1.33E-06	1.43E-05	3.12E-06	4.79E-07	2.83E-05	1.32E-06	1.35E-05	1.32E-05	8.91E-07
H-3	5.95E-10	5.95E-10	5.95E-10	5.97E-10	5.95E-10	5.95E-10	5.95E-10	5.97E-10	5.95E-10	5.95E-10	5.95E-10	5.97E-10	5.95E-10

Table A3.6 – Calculated Dose Rates (in µGy/h) to Marine Biota and Corresponding Risk Quotients from Liquid Discharges

Marine Biota	**Total dose rate**	**Risk Coefficient (expected)**	**Risk Coefficient (conservative)**
Benthic fish	1.90E-05	1.90E-06	5.71E-06
Bird	4.15E-06	4.15E-07	1.24E-06
Crustacean	1.71E-05	1.71E-06	5.12E-06
Macroalgae	1.63E-05	1.63E-06	4.89E-06

Mammal	5.07E-06	5.07E-07	1.52E-06
Mollusc - bivalve	1.81E-05	1.81E-06	5.42E-06
Pelagic fish	6.86E-06	6.86E-07	2.06E-06
Phytoplankton	2.12E-06	2.12E-07	6.37E-07
Polychaete worm	3.14E-05	3.14E-06	9.41E-06
Reptile	5.06E-06	5.06E-07	1.52E-06
Sea anemones & True coral	1.72E-05	1.72E-06	5.17E-06
Vascular plant	1.57E-05	1.57E-06	4.70E-06
Zooplankton	3.96E-06	3.96E-07	1.19E-06

Appendix 4 – Transboundary Radiological Assessment for Discharges of Gaseous and Aqueous Radioactive Waste from SDP

This appendix presents the input parameters and results from a modelling assessment on the maximum radiological impact to a reference group in a selected notifiable country. In this case Ireland was chosen which presents a bounding case.

The calculations were carried out assuming that radioactivity is discharged continuously at the annual release rates. The activity concentrations as predicted by the model in the 50th year are used. The following pathways were included in the assessment of gaseous discharges:

- Inhalation of radionuclides in the plume;
- External gamma from airborne radionuclides;
- External beta from airborne radionuclides;
- External gamma from deposited radionuclides;
- External beta from deposited radionuclides;
- Inhalation of re-suspended radionuclides;
- Consumption of cow's meat;
- Consumption of cow's milk;
- Consumption of cow's milk products;
- Consumption of sheep meat;
- Consumption of green vegetables;
- Consumption of root vegetables;
- Consumption of fruit.

For the aqueous discharges the following pathways were included in the assessment:

- Ingestion of fish;
- Ingestion of molluscs;
- Ingestion of crustaceans;
- Inhalation of sea-spray;
- External gamma irradiation from activity in beach sediments;
- External beta irradiation from activity in beach sediments;
- External exposure to gamma radiation in fishing gear;
- External exposure to beta radiation in fishing gear.

The Tables that following provide the input parameters and results of the assessments.

Table A4.1 – PC CREAM 08 Settings

Output Time (Years)	50
MET File	65% Category D and 10% Rain in C and D)
Stack Height	0
Receptor Distance (m)	290000

Table A4.2 – Habit Data Assumed for Representative Person for Gaseous Radioactive Waste Discharges

Parameter	**Value**
Time at Location (h/y)	8760
Fraction of time spent indoors	0.9
Cloud gamma location factor	0.2
Deposited Gamma Location factor	0.1
Cloud Beta location factor	1
Deposited beta location factor	1
Inhalation location factor	1
Inhalation rate (m3/y)	8100
Cow Meat Consumption Rate (kg y^{-1})	25.4
Cow's Milk Consumption Rate (kg y^{-1})	77.4
Cow's Milk Products Consumption Rate (kg y^{-1})	113.2
Sheep Meat Consumption Rate (kg y^{-1})	4.9
Green Vegetables Consumption Rate (kg y^{-1})	26.3
Fruit Consumption Rate (kg y^{-1})	17.9
Root Vegetables Consumption Rate (kg y^{-1})	196.0

Table A4.3 – Habit Data Assumed for Representative Person for Aqueous Liquid Radioactive Waste Discharges

Parameter	**Value**
Fish Consumption Rate (kg y^{-1})	42
Mollusc Consumption Rate (kg y^{-1})	35
Crustacean Consumption Rate (kg y^{-1})	18
Inter-tidal activities (h y^{-1})	2520
Handling fishing gear, catch and sediment (h y^{-1})	4100

Table A4.4 – Representative Person Effective Doses Gaseous Discharges

Pathway	Doses (μSv)			
	Tritium	Carbon-14	Others n.o.s.[1]	Total
Inhalation of Plume	7.30E-09	1.10E-06	6.54E-10	1.11E-06
Gamma from Plume	0.00E+00	0.00E+00	7.37E-12	7.37E-12
Beta from Plume	0.00E+00	5.34E-12	6.40E-15	5.35E-12
Gamma from Ground	0.00E+00	0.00E+00	1.13E-08	1.13E-08
Beta from Ground	0.00E+00	0.00E+00	2.89E-11	2.89E-11
Resuspension	0.00E+00	0.00E+00	7.33E-13	7.33E-13
Cow meat	1.33E-09	8.00E-07	2.06E-12	8.02E-07
Cow milk	5.23E-09	8.14E-07	7.63E-12	8.19E-07
Cow milk products	3.36E-09	7.14E-06	1.23E-10	7.15E-06
Fruit	1.07E-09	3.76E-07	1.22E-11	3.77E-07
Green vegetables	1.58E-09	5.52E-07	8.41E-11	5.54E-07
Root vegetables	1.18E-08	4.12E-06	2.78E-11	4.13E-06
Sheep meat	2.57E-10	1.54E-07	5.90E-13	1.55E-07
Total	3.19E-08	1.51E-05	1.22E-08	1.51E-05

1. – Assumed to be Co-60

Table A4.5 – Representative person Effective Doses (Marine Discharges)

Nuclide	Doses (μSv)								
	Fish	Crustacean	Mollusc	Sediment Gamma	Sediment Beta	Fishing Gear Gamma	Fishing Gear Beta	Sea-spray	Total
Co-60	3.14E-08	1.35E-07	7.47E-07	1.49E-05	1.16E-08	2.43E-07	9.06E-09	7.04E-14	1.61E-05
H-3	9.97E-11	4.27E-11	8.31E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.85E-14	2.25E-10
Other n.o.s[1]	9.16E-06	3.93E-06	7.64E-06	0.00E+00	5.65E-10	0.00E+00	5.79E-09	3.04E-13	2.07E-05
Total	9.20E-06	4.06E-06	8.38E-06	1.49E-05	1.22E-08	2.43E-07	1.48E-08	4.03E-13	3.69E-05

1. Assumed to be C-14