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BWRX-300 UK Generic Design Assessment (GDA)

Chapter E5 - Radioactive Waste Management Arrangements

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EXECUTIVE SUMMARY

The purpose of this Preliminary Environmental Report (PER) chapter is to present the arrangements for management of the radioactive wastes (including Spent Fuel (SF)) arising from commissioning, operation, and subsequent decommissioning of the BWRX-300 SMR in compliance with United Kingdom (UK) requirements.

The arrangements presented include considerations for the management of SF as radioactive waste, since it is presently assumed, in line with UK government policy, that SF will not be reprocessed and will therefore be redefined as radioactive waste at a point in the future.

The chapter presents a level of detail commensurate with a two-step Generic Design Assessment (GDA).

The scope of this chapter covers the Radioactive Waste Management (RWM) systems integral to the BWRX-300 design as presented for GDA and includes discussions of the upstream systems that generate radioactive wastes. The document provides indicative information on the additional ‘on-site’ RWM capabilities that will be required to provide a holistic set of arrangements that are fully compliant with UK requirements, noting that related strategic decision making, and demonstration of Best Available Technique are beyond the scope of GDA Step 2.

System interfaces/dependencies are identified, and suitable cross references used to direct the reader to the relevant interfacing chapters of the PER.

This chapter supports the overall claim that “the BWRX-300 is capable of being constructed, operated and decommissioned in accordance with the standards of environmental, safety, security and safeguard protection required in the United Kingdom”, and provides information to support the environmental Level 1 claim that “the design of the BWRX-300 SMR has been optimised to reduce environmental impacts to As Low as Reasonably Achievable throughout the whole lifecycle (construction, commissioning, operation and decommissioning)”.

The disposability of Higher Activity Wastes generated through the commissioning, operation and subsequent decommissioning of the BWRX-300 has been assessed by Nuclear Waste Services (NWS) through their ‘Expert View’ process RWPR63-WI11, “Preparation of Expert Views to support Step 2 of the Generic Design Assessment Process,” (Reference 5-1). NWS have confirmed in LTR/WMIDA-582826885-13386, “GDA Step 2 Expert View on the Disposability of Wastes and Spent Fuel arising from the GE-Hitachi Nuclear Energy BWRX-300,” (Reference 5-2) that a disposability case could be made for the wastes and spent fuel from the BWRX-300. Section 5.6.2 provides further information.

Appendix A provides an overview of the Low-Level Waste Repository Ltd waste services contract structure, which provides a range of treatment and disposal services for low level radioactive waste in the UK.

Appendix B provides a Forward Action Plan, which includes future work commitments and recommendations for future work where ‘gaps’ to GDA expectations have been identified.

An overview of the management arrangements for the main waste categories is presented in Appendix C, Appendix D and Appendix E.

A preliminary quantification of the radioactive wastes and SF arising from the commissioning, operation and subsequent decommissioning of a single BWRX-300 unit is presented in Appendix F.

ACRONYMS AND ABBREVIATIONS

Acronym	Explanation
ABWR	Advanced Boiling Water Reactor
AHU	Air Handling Unit
ALARA	As Low As Reasonably Achievable
ALARP	As Low As Reasonably Practicable
BAT	Best Available Technique
BL3	Baseline 3
BWR	Boiling Water Reactor
CFD	Condensate Filters and Demineralizers System
CRB	Control Rod Blade
CST	Condensate Storage Tank
CUW	Reactor Water Cleanup System
DP	Differential Pressure
DSILW	Dry Solid Intermediate Level Waste
EFS	Equipment and Floor Drain System
EPR16	Environmental Permitting (England and Wales) Regulations 2016 (as amended)
ESBWR	Economic Simplified Boiling Water Reactor
EUST	End User Source Term
FAP	Forward Action Plan
FPC	Fuel Pool Cooling and Cleanup System
GAC	Granular Activated Carbon
GDA	Generic Design Assessment
GDF	Geological Disposal Facility
GEH	GE-Hitachi Nuclear Energy Americas, LLC
GT	Gamma Thermometer
HAW	Higher Activity Waste
HHGW	High Heat Generating Waste
HLW	High Level Waste
HVS	Heating, Ventilation and Cooling System
ICC	Isolation Condenser Pools Cooling and Cleanup System
IICC	Irradiated In-Core Components
ILW	Intermediate Level Waste
IWS	Integrated Waste Strategy
LAW	Lower Activity Waste
LHGW	Low Heat Generating Waste
LLW	Low Level Waste
LLWR	Low Level Waste Repository

NEDO-34222 Revision B

Acronym	Explanation
LoC	Letter of Compliance
LPRM	Local Power Range Monitor
LWM	Liquid Waste Management System
NDA	Nuclear Decommissioning Authority
NSD	Near Surface Disposal
NWS	Nuclear Waste Services
ONR	Office for Nuclear Regulation
PCF	Pre/Post Conditioning Filter
PER	Preliminary Environmental Report
POCO	Post Operational Clean Out
PSR	Preliminary Safety Report
RO	Reverse Osmosis
RPV	Reactor Pressure Vessel
RWM	Radioactive Waste Management
RWST	Refueling Water Storage Tank
SDD	System Design Description
SF	Spent Fuel
SMR	Small Modular Reactor
SWM	Solid Waste Management System
UK	United Kingdom of Great Britain and Northern Ireland
U.S.	United States of America
VLLW	Very Low Level Waste
WAC	Waste Acceptance Criteria
WRNM	Wide Range Neutron Monitor
WSILW	Wet Solid Intermediate Level Waste

SYMBOLS AND DEFINITIONS

Term	Definition
Becquerel	The unit of radioactivity used in the International System of Units (SI). A measure of the amount of ionizing radiation released when a radioactive element spontaneously emits energy as a result of the radioactive decay (or disintegration) of an unstable atom. 1 Becquerel (Bq) represents a rate of radioactive decay equal to 1 disintegration per second.

Symbol	Definition
Bq	Becquerel
GBq	Gigabecquerel
GBq/t	Gigabecquerels per Tonne
MBq	Megabecquerel

TABLE OF CONTENTS

EXECUTIVE SUMMARY	iii
ACRONYMS AND ABBREVIATIONS	iv
SYMBOLS AND DEFINITIONS	vi
REVISION SUMMARY	x
5 RADIOACTIVE WASTE MANAGEMENT ARRANGEMENTS	1
5.1 Regulatory Context	6
5.1.1 United Kingdom Radioactive Waste Categories and Disposition Requirements	6
5.2 BWRX-300 Operational Radioactive Wastes.....	11
5.2.1 Higher Activity Wastes	11
5.2.2 Lower Activity Wastes	21
5.3 BWRX-300 Decommissioning Wastes.....	25
5.4 Anticipated Waste Quantities	27
5.5 Assumptions	28
5.6 Conclusion	29
5.6.1 Higher Activity Wastes	29
5.6.2 Higher Activity Waste Disposability	30
5.6.3 Lower Activity Wastes	31
5.6.4 Future Responsibilities.....	31
5.7 References.....	44
Appendix A OVERVIEW OF LOW-LEVEL WASTE REPOSITORY LIMITED WASTE SERVICES CONTRACT	48
Appendix B FORWARD ACTION PLAN	49
Appendix C MANAGEMENT OF SPENT FUEL AND IRRADIATED INCORE COMPONENTS.....	53
Appendix D MANAGEMENT OF WET SOLID INTERMEDIATE LEVEL WASTE....	54
Appendix E MANAGEMENT OF LOWER ACTIVITY RADIOACTIVE WASTES	55
Appendix F QUANTIFICATION OF BWRX-300 SOLID RADIOACTIVE WASTES..	56

LIST OF TABLES

Table 5-1: List of Assumptions	33
Table B-1: Forward Actions – Radioactive Waste Management Arrangements.....	49

LIST OF FIGURES

Figure 5-1: UK Radioactive Waste Categories	39
Figure 5-2: Waste Hierarchy	40
Figure 5-3: BWRX-300 Fuel Pool showing Fuel Cask Position.....	41
Figure 5-4: GE Ultra™ Control Rod.....	42
Figure 5-5: Overview of BWRX-300 Process Water Management.....	43
Figure A-1: Overview of Low Level Waste Repository Limited Waste Services Contract....	48
Figure C-1: Process Flow Diagram for Spent Fuel and Irradiated Incore Components Management	53
Figure D-1: Process Flow Diagram for Wet Solid Intermediate Level Waste Management..	54
Figure E-1: Process Flow Diagram for Lower Activity Waste Management	55

NEDO-34222 Revision B

REVISION SUMMARY

Revision #	Section Modified	Revision Summary
A	All	Initial Issuance
B	All	Update for end of GDA Step 2 consolidation

5 RADIOACTIVE WASTE MANAGEMENT ARRANGEMENTS

Introduction

The purpose of this Preliminary Environment Report (PER) chapter is to set out the arrangements for management of the solid radioactive wastes generated by the commissioning, operation, and subsequent decommissioning of a generic United Kingdom (UK) installation of the GE-Hitachi Nuclear Energy, Americas, LLC (GEH) BWRX-300 Small Modular Reactor (SMR). The BWRX-300 is the tenth evolution of the Boiling Water Reactor (BWR) design and an evolution of both the Economic Simplified Boiling Water Reactor (ESBWR) and the Advanced Boiling Water Reactor (ABWR).

The arrangements presented for the management of radioactive wastes arising from the commissioning, operation and subsequent decommissioning of a BWRX-300 SMR include considerations for the management of Spent Fuel (SF) as radioactive waste, since it is presently assumed, in line with UK government policy CP 1009, "Civil Nuclear: Roadmap to 2050," (Reference 5-3), that SF will not be reprocessed and will therefore be redefined as radioactive waste at a point in the future.

The overall objective of the Generic Design Assessment (GDA) submissions for the BWRX-300 is to demonstrate that the BWRX-300 is capable of being constructed, operated, and decommissioned in accordance with the standards of environmental, safety, security and safeguard protection required in the UK.

With specific regards to the management of radioactive wastes (including SF) arising from the commissioning, operation, and subsequent decommissioning of a BWRX-300 the chapter provides further and more detailed information in support of the claims presented in NEDO-34223, "BWRX-300 UK GDA Chapter E6: Demonstration of Best Available Techniques Approach," (Reference 5-4).

A UK variant of the ABWR (the UK ABWR) was previously submitted for GDA by GEH, supported by its UK subsidiary Horizon Nuclear Power Ltd.

The UK ABWR was granted Design Acceptance Confirmation by the Office for Nuclear Regulation (ONR), and a Statement of Design Acceptability by the Environment Agency, supported by Natural Resources Wales (hereafter referred to as 'the environmental regulators') in December 2017.

Predictably, the radioactive wastes generated through the commissioning, operation, and decommissioning of the BWRX-300 are similar in nature to those generated by predecessor BWR designs.

The BWRX-300 is a GEH design, and as such it is more aligned to the ESBWR design and reflects a significant design effort to simplify the design, reduce the amount of plant and systems and simplify its operation. These simplifications also contribute to a reduction in manufacturing and construction costs, thereby increasing the commercial viability of the BWRX-300 and enabling it to support UK Government aspirations with respect to decarbonising the UK economy to meet the declared Net Zero target by 2050, outlined in "Net Zero Strategy: Build Back Greener," (Reference 5-5).

The generation of radioactive waste is a direct and inevitable consequence of the use of nuclear energy for power generation. The generation of radioactive waste is justified by balancing the benefits of generation of large quantities of low carbon electricity, and wider beneficial societal impacts, with the detriments associated with managing, storing, and ultimately disposing of the radioactive wastes generated.

Section 5 of the document NEDO-34228, "BWRX-300 UK GDA Integrated Waste Strategy," (IWS) (Reference 5-6) for the BWRX-300 provides a broad justification against the principle

NEDO-34222 Revision B

of sustainability, and, specifically, shows how new nuclear build supports achievement of the relevant United Nations Sustainable Development Goals from “The 17 Goals: Sustainable Development,” (Reference 5-7).

NEDO-34221, “BWRX-300 UK GDA Chapter E4: Information about the Design,” (Reference 5-8) provides more detailed information relating to the relevant systems within the BWRX-300 design which have a bearing on the generation and subsequent management of radioactive wastes and SF arising from commissioning and operation of a BWRX-300.

Consideration of the solid radioactive wastes arising from subsequent decommissioning of BWRX-300 are presented in this chapter.

At this early stage of development, the BWRX-300 design does not fully reflect alignment with UK expectations and requirements for the compliant management of radioactive wastes arising from its commissioning and operation. In order to present an indicative alignment of BWRX-300 wastes with ‘typical’ UK practices a large number of assumptions have been defined in this document. A summary of the assumptions is presented in Table 5-1.

Appendix A provides an overview of the Low-Level Waste Repository Ltd waste services contract structure, which provides a range of treatment and disposal services for low level radioactive waste in the UK.

Appendix B provides a Forward Action Plan, which includes future work commitments and recommendations for future work where ‘gaps’ to GDA expectations have been identified.

An overview of the management arrangements for the main waste categories is presented in Appendices C, D and E.

A preliminary quantification of the radioactive wastes and SF arising from the commissioning, operation and subsequent decommissioning of a single BWRX-300 unit is presented in Appendix F.

The following chapters and submissions of the BWRX-300 Preliminary Environmental Report (PER) are key interfaces with this topic:

- NEDO-34221, “BWRX-300 UK GDA Chapter E4: Information about the Design,” (Reference 5-8)
- NEDO-34223, “BWRX-300 UK GDA Chapter E6: Demonstration of Best Available Techniques Approach,” (Reference 5-4)
- NEDO-34224, “BWRX-300 UK GDA Chapter E7: Radioactive Discharges,” (Reference 5-9)
- NEDO-34228, “BWRX-300 UK GDA Integrated Waste Strategy,” (Reference 5-6)
- NEDO-34229, “BWRX-300 UK GDA Demonstration of Disposability for Higher Activity Radioactive Wastes (Including Spent Fuel),” (Reference 5-10)

Whilst these chapters are the key interfaces, there are also relevant interfaces with the Preliminary Safety Report (PSR), particularly the following chapters:

- NEDO-34174, “BWRX-300 UK GDA Chapter 11: Management of Radioactive Waste,” (Reference 5-11)
- NEDO-34193, “BWRX-300 UK GDA Chapter 21: Decommissioning and End of Life Aspects,” (Reference 5-12)
- NEDO-34198, “BWRX-300 UK GDA Chapter 26: Interim Storage of Spent Fuel,” (Reference 5-13)

Scope

The scope of this chapter covers the management of all anticipated solid radioactive wastes arising from the commissioning, operation, and eventual decommissioning of a BWRX-300 reactor, including the arrangements for management of SF, on the assumption from CP 1009 (Reference 5-3) that SF will not be reprocessed and will ultimately be disposed of to a national Geological Disposal Facility (GDF) as High Heat Generating Waste (HHGW) as defined in WPS/240/02, "Waste Package Specification and Guidance Documentation: Specification for High Heat Generating Waste Precursor Product," (Reference 5-14).

This chapter does not present information relating to the management arrangements for liquid and gaseous discharges. This information is presented in PER Chapter E7 "Radioactive Discharges" (Reference 5-9).

The wastes associated with the commissioning, operation, and decommissioning of the BWRX-300 are similar to those produced by the ABWR, but with a few notable differences that are detailed in this report. The wastes will arise through four primary means:

- Treatment and purification of aqueous fluids (reactor coolant, condensate, feedwater, pools, and plant drainage systems) giving rise to secondary (wastes arising as a result of materials coming into contact with radioactive substances) wet solid wastes
- Generation of SF
- Operational, maintenance and repair/refurbishment activities giving rise to several waste types
- Decommissioning, giving rise to a final batch of SF and a range of decommissioning wastes

At this early stage, the BWRX-300 design comprises the power block which houses the reactor, turbine, radwaste, control and service buildings and this is presented as a generic design capable of being deployed anywhere in the world. In order for the design to integrate into a UK context, and to align with UK regulatory expectations, additional capabilities will be required outside of the power block to provide additional support functions, such as radioactive waste processing and storage and SF storage. Since these capabilities are not included within the power block design and require 'tailoring' to fit appropriate UK strategy and context, they are presented as 'indicative scope' which will be subject to more detailed consideration, design development, and associated justification and substantiation at the site-specific development stage. It is recognised that considerations, such as siting multiple units on a site, are likely to significantly impact decision making relating to these aspects and it is therefore appropriate to present them as 'indicative only' at this stage.

This chapter includes a number of waste process diagrams as appendices. The diagrams indicate the full lifecycle 'cradle to grave' strategy for the management of each waste stream from generation to eventual disposal, and clearly state the provision of waste management capabilities within and outside of the power block (defined as definite scope and indicative scope respectively). Detail of certain aspects that cannot be confirmed at this stage (for example repackaging of SF into a final disposable form) are excluded from scope and clearly identified on the waste process diagrams – see Appendices to this document. As outlined above, indicative scope will be subject to future development and decision making, including the establishment of relevant Best Available Technique (BAT) and As Low As Reasonably Practicable (ALARP) justifications.

The environmental regulators have stated an expectation in the "New Nuclear Power Plants: Generic Design Assessment guidance for Requesting Parties," (Reference 5-15) that AOOs (analogous to "frequent design basis faults" as defined by the Office for Nuclear Regulation in their document NS-TAST-GD-006, "Nuclear Safety Technical Assessment Guide – Design

NEDO-34222 Revision B

Basis Analysis," (Reference 5-16)) that result in an environmental radiological impact, should be identified as an inclusive consideration of environmental radiological discharges and radioactive wastes arising from normal operation of the BWRX-300.

A preliminary review of 005N3558, "BWRX-300 Fault Evaluation," (Reference 5-17), has not resulted in the identification of any relevant AOOs. The current safety analysis relates primarily to reactor faults and, as such, faults that could primarily result in fuel damage. All of the faults listed present adequate mitigation through design and therefore do not give rise to environmental impact consequences within AOO frequency.

The environmental regulators have also stated an expectation that the arrangements for management of failed fuel are discussed. Fuel clad failure is not currently defined as an AOO (since it is the consequence of faults and not a fault in itself) but as the predicted frequency for fuel clad defects falls within the AOO frequency range it is discussed further in Section 5.2.1.1.

It is recognised that further work is required to assess the wider BWRX-300 design for faults that could give rise to environmental consequences, resulting in the generation of radioactive wastes, at frequencies that would define them as AOOs. This is identified as a forward action.

FAP.PER5-110 – A future developer/operator shall undertake a systematic review of initiating events across the entirety of the BWRX-300 design to identify a comprehensive list of faults that may result in an environmental radiological impact, through an increase in radioactive discharges, waste volumes or activities, and at frequencies that would define them as AOOs. The findings shall be incorporated into the relevant documentation.

This chapter presents relevant information in the following sections:

- Section 5.1: Overview of the UK regulatory context with respect to radioactive waste and SF management, including explanation of UK Radioactive Waste Management (RWM) classifications and categories
- Section 5.2: Description of the sources and characteristics of solid radioactive wastes arising from BWRX-300 commissioning and operation, and how these wastes are anticipated to be managed to comply with UK regulatory requirements
- Section 5.3: Description of the sources and characteristics of solid radioactive wastes arising from BWRX-300 decommissioning, and how these wastes are anticipated to be managed to comply with UK regulatory requirements
- Section 5.4: A table presenting current estimates of the anticipated quantities of solid radioactive wastes and SF arising from commission, operation and decommissioning of the BWRX-300 is presented at Appendix F.
- Section 5.5: Table of assumptions made within this document
- Section 5.6: Presentation of the conclusions drawn regarding the compatibility of BWRX-300 radioactive waste management arrangements with relevant UK requirements.

Purpose

The overall objective of the PER is to demonstrate that the design of the BWRX-300 SMR has been optimised to reduce environmental impacts to As Low As Reasonably Achievable (ALARA) throughout the whole lifecycle (construction, commissioning, operation, and decommissioning).

The objective of this chapter of the PER is to set out the arrangements for managing the solid radioactive wastes generated through the commissioning, operation, and eventual

NEDO-34222 Revision B

decommissioning of a BWRX-300 reactor, and to demonstrate their compliance with applicable UK regulatory requirements and expectations. There is an emphasis on demonstrating how those arrangements serve to minimise the environmental impact associated with commissioning, operating, and decommissioning the BWRX-300 SMR to levels that are ALARA.

In support of this broad demonstration of ALARA this chapter supports the following environmental Level 2 claims and related arguments presented in PER Chapter E6 (Reference 5-4):

- Prevention or, where this is not practicable, minimisation of the creation of radioactive waste and SF.
- Minimisation of the activity of aqueous radioactive waste disposed of by discharge to the environment
- Minimisation of the volume of solid radioactive waste disposed of by transfer to other premises.
- Selection of the optimal disposal routes for wastes and SF.

5.1 Regulatory Context

This chapter of the PER presents information on how the solid radioactive waste produced by the BWRX-300 are anticipated to be generated, characterised, and managed in compliance with relevant UK regulatory requirements and expectations.

A summary of the applicable UK policies, strategies, legislation, and guidance that apply to the management of solid radioactive wastes in the UK is provided in a first iteration of the IWS (Reference 5-6) for the UK BWRX-300. These policies are set out in the document "UK Policy Framework for Managing Radioactive Substances and Nuclear Decommissioning," (Reference 5-18). This document has been developed by the UK Government and devolved administrations. Its purpose is to provide a coherent UK-wide policy framework for managing radioactive substances and nuclear decommissioning.

This chapter provides an overview of the UK requirements derived from the policy framework that will need to be satisfied under the RWM topic. The IWS goes into greater detail on specific UK requirements arising from national policy, strategy, legislation, regulations, good practice guidance etc. It will be necessary to incorporate these UK specific requirements into the requirements management system for the onward development of a UK BWRX-300.

FAP.PER5-111- A future developer/operator shall identify sources of UK RWM compliance requirements from the comprehensive suite of documentation identified in the IWS, and incorporate the relevant UK RWM compliance requirements into the BWRX-300 requirements management system.

5.1.1 United Kingdom Radioactive Waste Categories and Disposition Requirements

This section outlines the UK arrangements for management of solid radioactive wastes, providing an overview of the classification scheme and the related disposition requirements for each disposal category.

5.1.1.1 United Kingdom Radioactive Waste Categories

The IWS (Reference 5-6) provides clear definition of the meaning of the term 'waste'. With respect to the specific definition of the term 'radioactive waste' the EA Guidance "Check if your material is waste," (Reference 5-19) provides guidance on the practical application of "The Environmental Permitting (England and Wales) Regulations 2016" (as amended), (EPR2016) (Reference 5-20). A summary definition for radioactive wastes can be derived from the EPR2016:

"Any waste material that contains or is contaminated with radioactive substances or radioactive material which is subject to regulation under the radioactive substance activity permitting."

A more overarching definition for both conventional and radioactive wastes, that ties back to the wider definition of waste is provided by the Nuclear Decommissioning Authority (NDA), "What is radioactive waste?" (Reference 5-21):

"Waste is any substance or object that the holder intends to, or is required to discard. Radioactive waste contains radioactivity above certain levels defined in the legislation."

Radioactive waste is then classified according to how much radioactivity it contains and the heat that this radioactivity produces. The broad definitions are provided in the corporate report "UK Radioactive Waste Inventory 2022," (Reference 5-22). These relate to the disposal requirements and designate radioactive wastes as 'Higher Activity Waste' (HAW) or 'Lower Activity Waste' (LAW).

HAW comprises High Level Waste (HLW), Intermediate Level Waste (ILW) and a small fraction of Low Level Waste (LLW).

NEDO-34222 Revision B

LAW comprises both LLW and Very Low Level Waste (VLLW).

The waste categories are then further defined in relation to the specific disposal requirements associated with UK RWM policy. Figure 5-1 provides an overview of the classification structure defined in “NDA Integrated Waste Management Radioactive Waste Strategy,” (Reference 5-23).

The outline specification for each UK radioactive waste category is provided below.

HLW	Wastes in which the temperature may rise significantly as a result of their radioactivity. The heat therefore has to be taken into account in the design of storage or disposal facilities. Typical characteristics of HLW are thermal power above about 2 kW/m ³ , as described in “Basic principles of RWM – An Introduction to the Management of HAW on Nuclear Licensed Sites” (Reference 5-24). This classification would include SF that has been determined to be radioactive waste – see Section 5.2.1.1.
ILW	Wastes exceeding the upper boundaries for LLW, as defined in “What are the Main Waste Categories?,” (Reference 5-25) but do not generate sufficient heat to be considered in the design of storage or disposal facilities. Includes LLW that is not compliant for disposal as LLW.
LLW	Wastes having relatively low levels of radioactive content, not exceeding 4 Giga-becquerels (GBq) per tonne (t) of alpha activity or 12 GBq/t of beta/gamma activity (see Reference 5-25).
VLLW	A sub-category of LLW. It comprises waste that can be safely disposed of with municipal, commercial, or industrial waste, or can be disposed of at specified landfill sites.

In addition to the above categories, where wastes that have the potential to be exposed to radioactive contamination or neutron irradiation can be shown to contain radioactivity at levels below the requirement for them to be managed as radioactive waste, these wastes can be classified as ‘out of scope of regulatory control’ (i.e., the wastes are not considered radioactive for purposes of UK legislation) and are termed ‘Out of Scope’ wastes.

5.1.1.2 United Kingdom Radioactive Waste Disposition Requirements

Provision of services and facilities for the disposition of solid radioactive waste in the UK are primarily provided by the NDA through its subsidiary organisation, Nuclear Waste Services (NWS) Ltd, hereafter referred to as NWS. NWS encompasses and replaces the two former organisations, Low Level Waste Repository (LLWR) Limited and Radioactive Waste Management (RWM) Limited. It should be noted that a number of reference documents still identify these former organisations as the author. It is anticipated this will change to NWS when the documents are updated.

NWS operates the LLWR for disposal of LLW, and also provide a waste services contract which can be used to access additional packaging, characterisation, transport, LLW pretreatment and VLLW disposal services. Some of these services are provided by third party commercial organisations and can also be accessed directly via the respective service provider. NWS provides an overview of these services in their LLWR brochure, “Logistic Services,” (Reference 5-26)¹.

An overview of the LLWR Waste Services Contract is provided in Appendix A.

¹ It is noted that the brochure was withdrawn on 9 August 2022 for updating, however the resource remains indicative of the LLWR Services available via NWS.

NEDO-34222 Revision B

A suite of Waste Acceptance Criteria (WAC) detailing the specific compliance criteria for these services are available from NWS, as described in WSC-WAC-OVR, "Waste Services Contract: Waste Acceptance Criteria – Overview," (Reference 5-27). The suite of WAC documents comprise:

Service	WAC Reference	Issue & Date
WAC Overview	WSC-WAC-OVR	Version 3, April 2012
LLW Disposal	WSC-WAC-LOW	Version 5, Issue 1, July 2016
Supercompaction	WSC-WAC-SUP	Version 3, April 2012
Incineration	WSC-WAC-COM	Version 3, April 2012
VLLW Disposal	WSC-WAC-VER	Version 3, April 2012
Metal Melting	WSC-WAC-MET	Version 3, April 2012

Note: Individual service providers may also provide their own specific WAC requirements if being engaged directly.

NWS are also responsible for the provision and operation of HAW disposal facilities including the GDF and, potentially, alternate Near-Surface Disposal (NSD) facilities (see Section 5.1.1.2.1).

NWS provide published guidance for "Creating Standardised Waste Packages," (Reference 5-28), an extensive suite of waste packaging specification and guidance documents that advise waste producers on the requirements for compliance with anticipated GDF disposal criteria. Older releases of documents in this suite were published under the RWM Ltd name.

5.1.1.2.1 High Activity Waste Disposition

At present, there is no UK capability for the receipt and ultimate disposal of HAW, and nuclear site licensees are required to retain HAW on site pending the provision of such capabilities. As indicated in Section 5.1.1.2 this could include both GDF and NSD facilities. Programmes of work are underway to provide these capabilities, and these are led by NWS on behalf of the NDA.

The latest planning assumption presented in the UK Government website "Geological Disposal – a programme like no other," (Reference 5-29) is that a GDF could be ready to receive ILW between 2050-2060, with HLW and SF from 2075.

It should be noted that this facility will be a single capability, servicing the needs of the whole UK nuclear industry (with the exception of Scotland, which has an alternate policy). There are already several thousand 'final waste packages' in storage across UK nuclear licensed sites (both civil and defence) that are destined for disposal in the GDF, with many more to be produced from ongoing operational and decommissioning activities. These existing packages are assumed to take precedence in terms of the 'queue' for access to the GDF.

It is therefore reasonable to assume that a new nuclear facility will be required to retain HAW on site for at least 100 years. The regulators have stated clear expectations that HAW is required to be processed into a passively safe and disposable form at the earliest practicable opportunity.

Joint Regulatory Guidance, "The Management of Higher Activity Radioactive Waste on Nuclear Licensed Sites," (Reference 5-30).

"Wastes should be conditioned to a safe, passive, transportable and disposable form as soon as is reasonably practicable."

ONR Safety Assessment Principle: RW.5 Storage of Radioactive Waste and Passive Safety from CM9 Ref 2019/367414 “Safety Assessment Principles for Nuclear Facilities,” (Reference 5-31).

“Radioactive waste should be stored in accordance with good engineering practice and in a passively safe condition.”

ONR Safety Assessment Principle: RW.6 Passive Safety Timescales (Reference 5-31).

“Radiological hazards should be reduced systematically and progressively. The waste should be processed into a passive safe state as soon as is reasonably practicable.”

Environment Agency Radioactive Substances Regulation – Developed Principle 11 – Storage in a Passively Safe State, from “Radioactive substances management: generic developed principles,” (Reference 5-32).

“Where radioactive substances are currently not stored in a passively safe state and there are worthwhile environmental or safety benefits in doing so then the substances should be processed into a passively safe state.”

In the absence of a GDF, NWS have put in place arrangements to ensure that HAW packaged now and in the immediate future will be acceptable for disposal to a future GDF. These arrangements include the provision of a suite of ‘Waste Packaging Specifications and Guidance’ material, (see Reference 5-28) that specify how wastes should be packaged to comply with the requirements of a future GDF. A ‘Letter of Compliance’ (LoC) process is presented in “Our work with Radioactive Waste Producers,” (Reference 5-33) and is applied to enable waste producers to submit packaging proposals to NWS for assessment prior to packaging the wastes. The provision of a Final Stage LoC from NWS provides assurance to the waste producer that their waste packaging proposals have undergone a satisfactory disposability assessment, and provided the waste is packaged in line with the detail provided in the packaging proposal, the wastes should be suitable for acceptance into the future GDF.

Waste producers are therefore required to apply the NWS waste packaging specifications in developing their arrangements for processing HAW into a passively safe and disposable form.

For GDA Step 2 GEH have engaged with NWS to obtain their expert view on the disposability of HAW and SF arising from the commissioning, operation and subsequent decommissioning of a UK BWRX-300. A summary of the outcome is presented in Section 5.6.2.

It should also be noted that the UK is currently considering the possibility of an intermediate ‘Near Surface Disposal’ solution that is positioned between a GDF and a LLW surface repository, on the basis of relative radiological hazard. At present this remains an early-stage consideration, and no precise specification is available on the requirements for NSD within the NDA document “Near-Surface Disposal Strategic Position Paper,” (Reference 5-34). Nonetheless, it is appropriate for waste producers, in assessing their disposal options, to consider areas where non-foreclosure of packaging options is justifiable to facilitate optimisation of waste disposal, taking due account of all relevant options and related criteria.

5.1.1.2.2 Lower Activity Waste Disposition

UK radioactive waste capabilities exist for the disposition of LAW. These capabilities include: the LLWR disposal facility in West Cumbria, operated by NWS, for receipt and disposal of LLW; a number of landfill sites that are permitted to receive VLLW for disposal; and options for processing of LAW to minimise disposals in accordance with application of the waste hierarchy. Figure 5-2 provides an illustration of the waste hierarchy as provided by the NDA within “NDA Strategic Position on Radioactive Waste Treatment,” (Reference 5-35).

NEDO-34222 Revision B

Waste producers are required to demonstrate compliance with the LLWR WAC listed in Section 5.1.1.2 when generating, packaging, characterising and consigning their LLW.

The LLWR WAC provide a number of options for waste disposition that align with the requirements of the waste hierarchy and promote practices to minimise the amount of waste consigned for disposal. Arrangements for management of LAW arising from the operation of a UK BWRX-300 will be implemented during the site-specific development phase to conform to UK relevant good practice through compliance with the LLWR WAC documents.

FAP-PER5-396 – A future developer/operator shall develop arrangements for the management of LAW to demonstrate that disposition will comply with UK requirements.

VLLW landfill sites are operated by a number of companies and each provide their own acceptance criteria, based on the specific conditions present in their environmental permits. Waste producers are required to demonstrate compliance with these criteria in generating, packaging, characterising, and consigning their VLLW. Access to VLLW disposal sites can either be procured through the NWS waste services contract or directly with the operators of the sites.

5.2 BWRX-300 Operational Radioactive Wastes

The generation of solid radioactive waste is a direct and inevitable consequence of the use of nuclear energy for power generation. The BWRX-300 SMR will generate quantities of solid radioactive waste throughout its operational lifetime. Additional solid radioactive wastes will be generated at the end of its operating life when the plant is decommissioned and dismantled.

It is assumed that no solid radioactive wastes will be generated until the point at which nuclear fuel is first brought onto site at an appropriate stage during the commissioning phase. For the purposes of this document radioactive wastes (including SF) arising during the commissioning phase are considered part of the overall inventory generated during the operational life of the plant.

It is recognised that there is a risk of generating solid radioactive waste from remediation of pre-existing radiologically contaminated land identified during the construction phase, but this is entirely dependent on the site selected for construction and its prior history. No further consideration is given to this risk in this document since it is a site-specific consideration for a future developer/operator to address.

At the point that new nuclear fuel and radioactive sources are brought onto site, numerous operating practices will come into force to provide appropriate radiological protection for operators working in the proximity of these materials, and to protect people and the environment from the risks of incidents involving their receipt, handling, storage, and use. These practices will begin to generate radioactive wastes in the form of protective clothing and 'barrier wastes' (wastes generated due to access/egress activities associated with the radiologically controlled area). Once new fuel is introduced to the fuel pool, and subsequently the reactor, the various cleanup systems will begin to generate secondary radioactive wastes in the form of filter backwash sludges and spent resins. Once the reactor is taken critical for the first time, neutron irradiation of the coolant and plant and components in the vicinity of the core will commence. This is the point at which routine generation of operational solid radioactive wastes will commence.

This section describes the range of solid radioactive wastes that will be generated through operation of the BWRX-300. The wastes will be described in relation to their anticipated category and classification as outlined in Section 5.1.1.

5.2.1 Higher Activity Wastes

HAW comprises HLW, ILW and a small fraction of LLW that is not suitable for disposal to the LLWR. Normal operation of BWRX-300 is anticipated to generate the following HAW streams:

- SF (assumed HLW if designated as radioactive waste)
- Irradiated In-Core Components (IICC) (assumed HLW when generated)
- Wet solid wastes (assumed ILW when generated)

5.2.1.1 Spent Fuel

In the UK, SF is no longer processed and the UK government Department for Energy Security and Net Zero (DESNZ) advised in 2024 that new build vendors (i.e. those organisations considering the construction of new nuclear power plants in the UK) should proceed on the assumption that plans for disposal of SF as a solid radioactive waste should be progressed, in accordance with guidance (Reference 5-14).

Department for Energy Security and Net Zero (DESNZ) - Civil Nuclear: Roadmap To 2050, January 2024 (Reference 5-3).

"Spent fuel can either be managed through interim storage prior to final disposal or through reprocessing. Interim storage involves safely and securely storing the spent fuel, potentially for several decades, until it is conditioned and permanently disposed of as waste in a GDF or reprocessed. Decisions on the management of spent fuel are a matter for the owner of the spent fuel."

The UK reprocessed spent fuel on an industrial scale from the 1950s to 2022. Commercial industrial scale reprocessing came to an end in the UK with the closure of the Thermal Oxide Reprocessing Plant in 2018. There is currently no industrial scale reprocessing in the UK. The government has not received any credible proposals from industry to restart reprocessing and has no plans to pursue, or provide financial support for, industrial scale reprocessing of spent nuclear fuel.

In the absence of reprocessing proposals from industry, owners of spent fuel, including from new or advanced reactors, should proceed on the basis that spent fuel will not be reprocessed and waste management plans, including financing, should reflect this."

SF will emit radiogenic heat at levels that require heat to be taken into account in the design of storage or disposal facilities. SF is therefore considered HLW for the purposes of on-site management as solid radioactive waste and is required to be managed as HHGW for the purpose of disposal to GDF, in accordance with guidance (Reference 5-14).

It is assumed that SF arising from operation of a UK BWRX-300 will be stored on-site pending eventual disposal to a national GDF, as described in "National Policy Statement for Geological Disposal Infrastructure," (Reference 5-36). This is consistent with advice provided by the UK regulators within ONR-GDA-GD-007 "New Nuclear Power Plants (NPPs): Generic Design Assessment Technical Guidance," (Reference 5-37).

ONR-GDA-GD-007 - New Nuclear Power Plants (NPPs): Generic Design Assessment Technical Guidance, May 2019

"The UK government's Base Case strategic assumption is the spent fuel from a new nuclear power station will be kept in interim storage on the site of the power station until the point at which it is disposed of in a GDF, and that the packaging of spent fuel will also be carried out on-site."

"It may not be necessary for Spent Fuel Interim Storage to be available at the start of reactor operations if the RP can demonstrate there is sufficient storage capacity in the spent fuel pool for a number of fuel cycles (and provide adequate storage for removal of all fuel from the reactor core as a result of an emergency)."

Since the specific disposal requirements are not available at this time, the SF is assumed to be stored in an interim state and will therefore require repackaging into a disposable form once a disposal specification has been provided. In so doing, future options for alternate treatment (e.g., reprocessing) will not be foreclosed.

SF is initially stored in the fuel pool to undergo cooling prior to packaging in a SF cask. The fuel pool can be accessed on level 13.0 m of the Reactor Building (RB) from the operating deck. The fuel pool provides storage for new and used fuel, along with equipment used during refueling.

The BWRX-300 core comprises 240 fuel bundles (Reference 5-38). The functional requirements for the BWRX-300 fuel pool are presented in system design description 006N5377, "BWRX-300 Refueling and Servicing Equipment," (Reference 5-39). This states a wet storage capacity of at least 8 years of operation plus one core load of new fuel and one full core offload (removal of all fuel bundles from the core).

NEDO-34222 Revision B

For GDA purposes it is assumed that the BWRX-300 will operate on a 12-month fuel cycle with 32 fuel bundles replaced during each refueling outage. For a 60-year operating life this equates to an initial core load of 240 bundles, plus 59 reloads of 32 bundles, giving rise to 2,128 SF bundles.

For the purpose of conservatism, a similar calculation has been performed for a 24-month operating cycle on the basis that this generates 72 SF bundles every other year within DBR-0057741, "BWRX-300 Plant Performance Envelope," (Reference 5-40). This would give rise to 2,368 SF bundles for a 60-year operating life.

Dry cask storage of SF from light water reactors (described in "Dry Cask Storage," (Reference 5-41) is a well-established storage method with significant worldwide precedent, extensive operational experience, and a range of commercially available solutions. It is assumed that a UK BWRX-300 will employ dry cask storage as the technical basis for SF storage in alignment with 006N5339, "BWRX-300 Irradiated Fuel Management Plan," (Reference 5-42). Dry cask storage involves emplacing SF bundles in a sealed and inerted high integrity canister and placing this canister inside a shielded cask for long term storage. This method of SF storage has UK precedent at Sizewell B power station and is also planned at Hinkley Point C power station, as evidenced by EPR/ZP3690SY/V005, "RSR Permit Variation," (Reference 5-43).

The timing of construction for a SF storage capability is not yet determined, but it is noted that the regulators accept in the GDA technical guidance (Reference 5-37) that storage in the fuel pool is acceptable for an initial period provided there is a demonstration of adequate capacity.

The design of the fuel pool incorporates a position for receipt, handling, loading, and export of SF casks as shown in Figure 5-3 and derived from 005N1730, "General Arrangement Drawing – Reactor Building," (Reference 5-44).

At this early stage no decision has been made on a specific design or vendor for SF casks.

Once packaged, SF casks are assumed to be exported from the RB for on-site storage. Again, at this early stage no decision has been made on a specific design or vendor for SF cask storage. It is assumed that SF cask storage will be required for multiple decades until such time as a GDF is made available and a disposal specification for SF provided. As with HAW storage, it is assumed this could be for at least 100 years.

Fuel failures are not quantified as AOOs as they are the consequence of faults, rather than faults in themselves (for example fuel clad fretting as a result of particle ingress into the fuel bundle). Operating experience derived from NEDC-33415P, "Nordic GNF2 Operational Experience Update," (Reference 5-45) identifies a failure rate of 2.1 failures per 1000 fuel bundles in service. Based on an anticipated 2,128 fuel bundles arising from operation of BWRX-300 over a 60-year operating life this would indicate 5 failed fuel bundles over the life of the plant (or one every 12 cycles). This gives a failure frequency greater than the threshold for AOOs and therefore it is appropriate to discuss the planned approach for management of failed fuel.

Arrangements for the management of failed fuel are assumed to be developed in line with the selection of a cask storage system, as any additional containers used for either whole bundles or single fuel pins will need to be compatible with the chosen cask system. The requirement for use of additional containment is itself dependent on the extent of the failure, and in some instances may not be necessary. The fuel pool provides the capability to either manage a failed bundle as a whole or to extract and manage a single failed pin if this is deemed necessary. Failed fuel is therefore assumed to be stored in a similar manner to the main population of SF (but with potential for additional containment on a case-by-case basis) and would be repackaged to meet GDF disposal requirements once the fuel had cooled sufficiently and a disposal specification is made available.

NEDO-34222 Revision B

GNF2 fuel bundles are loaded into the core inside a fuel channel. The fuel channels contain each fuel bundle within the reactor core to direct the coolant flow and contain the boiling regions. The dimensions of the fuel channels for BWRX-300 are not yet confirmed but are anticipated to be similar to the UK ABWR design submitted as GA91-9901-0022-00001, "UK ABWR Generic Design Assessment: Radioactive Waste Management Arrangements," (Reference 5-46).

Under normal operations the fuel channel is assumed to remain with the SF bundle for placement into a SF cask. At the point of SF repackaging, it is assumed that the fuel channel would be removed, segregated, and sentenced for management as HLW/ILW dependent on prevailing radioactivity level at that point.

Since there is a possibility that a fuel bundle may be disassembled in the fuel pool to recover a failed fuel pin, it is assumed that a fuel channel removed for this purpose would be disposed of as an irradiated item along with other IICC. Operational arisings of fuel channels as solid radioactive waste items are therefore considered as ad hoc arisings only.

5.2.1.2 Irradiated Incore Components

IICC includes spent Control Rod Blades (CRBs) and instrumentation used to measure neutron flux and gamma radiation levels in the reactor core as part of the control system.

5.2.1.2.1 Control Rods

CRBs are neutron absorbing components which provide negative reactivity into the core to allow for the control of reactor power. BWRX-300 uses GE Ultra™ control rods (see Figure 5-4). The control rods are cruciform shaped elements that occupy alternate spaces between fuel assemblies throughout the core. The neutron absorber material is typically boron carbide or hafnium (Reference 5-38).

GE Ultra™ control rods are an evolutionary design based on learning from prior operational experience and feature a simplified design using less stainless steel and reduced cobalt. These enhancements are expected to result in a reduction in irradiation induced radioactivity for spent control rods.

There are 57 control rods in the core(Reference 5-38). During normal operation of the BWRX-300 a 'control group' of four (4) control rods are inserted into the reactor core to control neutron flux when the reactor is critical, the other 53 are fully withdrawn.

The four 'control group' rods are exchanged at each operating cycle to balance control rod depletion over time across all of the control rods.

As part of this overall process for management of the control rods it is conservatively assumed that four control rods will be replaced every 3rd cycle. This would equate to 19 cycles x 4 = 76 rods replaced during the operational life of the plant. At end of life (cycle 60) all rods would be removed from the core once the fuel core had been removed, giving rise to a further 57 rods. The total inventory of spent control rods over a 60-year operating life is therefore calculated to be 133.

5.2.1.2.2 Nuclear Instrumentation

The nuclear (core) instrumentation consists of 13 Local Power Range Monitor (LPRM) instrument tubes, each comprising 4 LPRM detectors and 8 Gamma Thermometers (GTs), and 10 Wide Range Neutron Monitor (WRNM) detectors(Reference 5-38). Each of the WRNMs has a single detector contained in a dry tube.

Each 'string' is a small-diameter vertical instrument tube located at the intersection of four fuel bundles in the reactor core and has an array of detectors spaced vertically along the approximate 3.7 m (12 feet) height of the core. The string extends vertically to the top of the core and below the core to the vessel bottom, where the electrical leads of the monitoring

NEDO-34222 Revision B

instruments are brought through penetrations to the under-vessel connectors. The instrument tubes are therefore in the region of 8.0 m long and may require some form of size reduction to facilitate waste handling and packaging. It is anticipated that, once size-reduced, there will be an opportunity to segregate sections of the instrument tube for sentencing in accordance with the waste hierarchy.

The instrument tubes are not anticipated to be replaced on a fixed periodicity so are assumed to arise on an ad hoc basis. Instrument tubes are removed and replaced during refueling outages as it is necessary to remove the four (4) surrounding fuel assemblies prior to removing the instrument tube. Size reduction of the instrument tubes is assumed to take place in the fuel pool. Specific arrangements for size reduction are not finalised at this point and may involve either cutting or folding to facilitate placement in a storage canister.

5.2.1.2.3 Irradiated Incore Components Management

IICC are anticipated to meet the HLW criteria on production due to elevated levels of radiogenic heat emission ($>2 \text{ kW/m}^3$). These components are managed via the fuel pool where they undergo initial cooling prior to packaging.

IICC will initially be packaged and stored in a very similar manner to SF. IICC are assumed to undergo decay storage and cooling in SF casks in the same storage location as the SF until they decay to the point where radiogenic heat has reduced to satisfy the Intermediate Level Waste criteria ($<2 \text{ kW/m}^3$), according to the basic principles of RWM (Reference 5-24). They will then be recovered, processed, and repackaged in compliance with NWS criteria in "Low Heat Generating Waste (LHWG) Specifications," (Reference 5-47).

Appendix C presents an overview of the anticipated through life management arrangements for SF and IICC arising from operation of a UK BWRX-300.

5.2.1.2.4 Spent Dry Storage Containers

Dry storage canisters are anticipated to arise as a radioactive waste stream when they are emptied and the spent fuel and IICC is repackaged for disposal. Since there is presently no certainty on when a GDF will become available or when specific disposal criteria will be published it is conservatively assumed that repackaging and disposal activities will take place as part of decommissioning scope. This is supported by the assumption that the last arisings of these wastes will only occur at the end of the last operational cycle, so will effectively form part of Post Operational Clean Out (POCO) scope. No decision is yet made on the specific form of dry spent fuel storage and therefore precise detail on the resultant wastes cannot be quantified at this point.

This waste stream is therefore included in the waste quantification table at Appendix F as a decommissioning waste.

5.2.1.3 Wet Solid Radioactive Wastes

5.2.1.3.1 Generation of Wet Solid Radioactive Wastes

BWRs utilise a single reactor coolant, steam, condensate, and feedwater circuit design whereby water is boiled in the Reactor Pressure Vessel (RPV) to generate steam and this steam passes directly to the turbine to generate electrical power. Exhausted steam is drawn into the condenser and cooled to produce condensate. The condensate is returned to the reactor via the feedwater circuit in a continuous process. The single circuit design places a great emphasis on water purity and the BWRX-300, in-keeping with previous BWR designs, incorporates 'on-line' (i.e. integral to the reactor coolant circuits) treatment processes to remove soluble and insoluble impurities from these recirculating process fluids, to maintain water quality to meet the requirements of technical requirements specification 006N6766, "BWRX-300 Water Quality," (Reference 5-48). Operation of these systems results in the

NEDO-34222 Revision B

generation of wet solid radioactive waste in the form of spent ion exchange resins and filter backwash sludges.

1. 006N7941, "BWRX-300 Fuel Pool Cooling and Cleanup System," (Reference 5-49). The Fuel Pool Cooling and Cleanup System (FPC) is based on separate backwashable fine filtration and deep bed demineraliser technologies and generates wet solid wastes in the form of filter backwash sludge and spent bead resin.
2. 006N7741, "BWRX-300 Condensate Filters and Demineralizers (CFD)," (Reference 5-50). The CFD system is based on separate backwashable fine filtration and deep bed demineraliser technologies and generates wet solid wastes in the form of filter backwash sludge and spent bead resin.
3. 006N7609, "BWRX-300 Reactor Water Cleanup System" (Reference 5-51). In the BWRX-300 design the Reactor Water Cleanup System (CUW) effluent is routed upstream of the CFD and utilises the CFD filters and demineralisers for effluent treatment. CUW flow into CFD represents 1% of total feedwater flow.
4. 006N7345, "Isolation Condenser Pools Cooling and Cleanup System" (Reference 5-52). The Isolation Condenser Pools Cooling and Cleanup System (ICC) is based on deep bed demineraliser technology and generates wet solid waste in the form of spent bead resin.

Reactor water quality and related circuit cleanliness is further enhanced by an integrated water chemistry regime comprising Hydrogen Water Chemistry, On-Line NobleChem™ and GE Zinc Injection Passivation. The water chemistry regime is anticipated to result in further reduction of corrosion and erosion particulate, leading to reduced volumes of filter backwash sludge, and minimisation of cobalt deposition on coolant facing surfaces which are expected to have a beneficial impact on decommissioning waste volumes.

Further information on the water treatment systems described above is presented in PER Chapter E4 (Reference 5-8).

In addition to these four 'on-line' systems the Liquid Waste Management System (LWM) provides further filtration and demineralisation in the form of a skid mounted abatement system. This system replaces the separate high and low conductivity wastes systems found in earlier BWR designs and provides a common set of treatment functions for plant water collected by the Equipment and Floor Drain System (EFS (Reference 5-53). The function of the LWM is to clean this water to meet the reactor water quality specification (Reference 5-48), such that plant water can be reused, to achieve maximum recirculation, thereby retaining as much of the process fluids in the plant as possible and minimising disposal of aqueous liquid wastes to the aquatic environment. Whilst termed a 'waste management system', LWM actually performs the function of process water treatment to facilitate recirculation of plant water, and thereby avoids the generation of aqueous waste in line with the principle of waste hierarchy application.

Figure 5-5 provides an overview of the arrangements for process water management for the BWRX-300 and is a composite image derived from:

- 006N7941, "BWRX-300 Fuel Pool Cooling and Cleanup System", (Reference 5-49)
- 006N7741, "BWRX-300 Condensate Filters and Demineralizers" (Reference 5-50)
- 006N7345, "Isolation Condenser Pools Cooling and Cleanup System" (Reference 5-52)
- 006N7729, "BWRX-300 Liquid Waste Management System (LWM)," (Reference 5-54)
- 006N7733, "BWRX-300 Solid Waste Management System (SWM)," (Reference 5-55)

NEDO-34222 Revision B

- 008N0988, "BWRX-300 Power Block General Arrangement" (Reference 5-56)
- 006N7828, "BWRX-300 Nuclear Boiler System" (Reference 5-57)
- 006N7757, "BWRX-300 Main Condenser and Auxiliaries System" (Reference 5-58)

The diagram presents a simplified line diagram of the reactor and turbine fluid circuit and shows where all of the cleanup systems interact with the circuit, as well as plant water drainage routes from the plant leading to the LWM. The wet solid waste routes from the various abatement systems are shown linking to the SWM storage tanks. The connection to the aqueous liquid waste discharge route is also shown. The discharge route is provided to facilitate the disposal of aqueous liquid waste when plant conditions require it, but as described above the application of the maximum recirculation philosophy is intended to minimise discharges so far as is reasonably practicable. It should be noted that this is the intent of the design and provides a future developer/operator with the requisite flexibility to operate the plant in an optimal manner whilst complying with UK regulatory expectations.

Sources of plant water directed to the LWM collection tanks include:

- Drained plant water collected by the EFS.
- Excess water from CUW.
- Excess water from the Shutdown Cooling System, described in 006N7708, "BWRX-300 Shutdown Cooling System" (Reference 5-59).
- Excess water from the Refueling Water Storage Tank (RWST), as described in the LWM System Design Description (SDD) (Reference 5-54).
- Return line water from the LWM sample tanks.
- Decant water from the SWM, as described in the SWM SDD (Reference 5-55) storage tanks.

Application of appropriate abatement technologies in LWM enables all drained plant water generated during normal operation to be cleaned and purified to achieve water quality that meets the requirements of the reactor water quality specification (Reference 5-48). It is therefore feasible to integrate both drainage streams into a single combined treatment system.

LWM, as defined in the LWM SDD (Reference 5-54), utilises the latest water purification technologies to provide a comprehensive capability that can treat all drained plant water to meet the reactor water quality specification (Reference 5-48). This enables the BWRX-300 to recycle up to 100% of drained plant water, enabling application of the maximum recirculation philosophy during normal operations (including routine refueling outages). Evidence that a BWR can be operated on this basis is presented in NEDC-34279P, "Analysis of Environmental Discharge Data for US Nuclear Power Plants," (Reference 5-60), demonstrating effective application of the waste hierarchy (water re-use), minimisation of waste, and providing the capability to eliminate aqueous liquid waste discharges from the plant under normal operating conditions.

BWRX-300 utilises a 'skid mounted' approach to provide a series of water treatment sub-systems that can be configured to cope with an array of scenarios arising from upstream plant events. This provides significant mitigation against upstream faults and errors that could result in the generation of batches of process water that are beyond the normal plant parameters (e.g., increased fission products due to a fuel clad failure, ingress of foreign materials such as organics, oils, greases from a foreign materials intrusion, or chloride ingress from a main condenser tube leak).

This approach is consistent with that applied at the Tokyo Electric Power Company Fukushima-Daiichi site as part of the Advanced Liquid Processing System, as presented in

NEDO-34222 Revision B

“Overview of the Multi-nuclide Removal Equipment (ALPS) at Fukushima Daiichi Nuclear Power Station,” (Reference 5-61) and this provides a substantial amount of operating experience to support further design development of the LWM.

Sampling of process fluids in the collection tank, aided by upstream sampling of individual feeds, would inform the series of treatments required for each individual tankful of water. Further information on sampling arrangements is presented in PER Chapter E7 (Reference 5-9).

It should be noted that LWM design is presently at a conceptual stage and may be subject to future revisions. Additional information regarding LWM is presented in PER Chapter E4 (Reference 5-8).

LWM is anticipated to comprise the following abatement stages:

- Sludge Consolidation Filter
- Pre-Conditioning Filter (PCF)
- Ozone System
- Ion Exchanger
- Reverse Osmosis (RO) System
- Polishing Ion Exchanger

A provisional explanation of the secondary wastes anticipated to arise from operation of LWM is provided in Section 5.2.2.2.

Collected process water is treated by LWM to achieve the water quality parameters as specified in the reactor water quality specification (Reference 5-48) and returned to the Condensate Storage Tank (CST) for reuse. In the event of a requirement to discharge surplus water from the plant, a discharge route to the outfall side of the Circulating Water System is provided.

LWM also incorporates a separate backwashable fine filtration system for cleanup of water drained from the reactor cavity at the start and end of refueling outages. The filtered water is routed to the RWST, a component of LWM, and reused for refilling the reactor cavity.

5.2.1.3.2 Management of Wet Solid Radioactive Wastes

Operation of the process fluid cleanup systems described in Section 5.2.1.3 is anticipated to result in the generation of wet solid wastes in the form of filter backwash sludges, spent bead resins, and Granular Activated Carbon (GAC). The wet solid wastes arising from these abatement systems are routed to SWM for onward management.

It is assumed that spent GAC, sludge consolidation filters and RO modules will arise as LAW. Further consideration of these streams is presented in Section 5.2.2.

It should be noted that filter backwash sludges and spent bead resins have been classified as ILW based on source term data within 008N0133, “BWRX-300 Solid Waste Management System – Contained Source Activity,” (Reference 5-62). This source term has been derived to provide bounding and conservative values for the purposes of dose and shielding calculations. A related conservative assumption on classification of the wastes provides a bounding consideration for their management. Should subsequent refinement of the source term result in the wastes being classified as LLW this would simplify the requirements for their management.

A realistic model (best estimate) radioactive waste End User Source Term (EUST) is therefore required in order to determine a more realistic classification for these wastes. This should be provided before any further consideration is made of the discrete processing and storage

NEDO-34222 Revision B

requirements for these wastes. The FAP should therefore include activity to develop a Realistic Model radwaste EUST for wet solid wastes.

FAP.PER5-113 – A future developer/operator shall derive Realistic Model EUST Values for BWRX-300 wet solid waste streams to provide an estimated inventory of these wastes under normal operating conditions, to allow strategic decision-making for provision of appropriate processing and storage arrangements aligned with UK relevant good practice and related regulatory requirements.

Mixed anion and cation bead resins are used in the demineralisers in CFD, FPC, LWM, and ICC. The resin beds are non-regenerative and will therefore be depleted over time. The spent bead resins from all systems are discharged by backwashing the demineralisers and transferred to the spent resin storage tank in the Radwaste Building (RWB) for storage prior to processing.

BWRX-300 bead resins are assumed to be either a styrene divinylbenzene copolymer or cross-linked polystyrene matrix in a fine bead form, similar to those used in the ABWR and described in WN0908-HZCON-PAC-REP-00003, "Radioactive Substances Regulation – Environmental Permit Application," (Reference 5-63). Wet bead resin is assumed to arise as an aqueous slurry with a wet density of 1.165 t/m³ (Reference 5-63). The resin is used in reactor coolant cleanup systems and LWM to remove dissolved impurities (both radioactive and non-radioactive). The density value stated is derived from ABWR information and will require confirmation as the design progresses. A forward action has been raised for this and documented in the Demonstration of Disposability document (Reference 5-10).

Filter backwash sludges will arise from backwashing of high flow fine filters in CFD, FPC and LWM. The sludge is made up of predominantly ferrous Corrosion Products (CPs) that will arise during reactor operations. The CPs will accumulate as particulate sludges entrained in the coolant circuit filtrations systems. The sludge is assumed to arise as an aqueous slurry with a wet density of 1.1 t/m³, as in the ABWR environmental permit application (Reference 5-63). This density value stated is derived from ABWR information and will require confirmation as the design progresses. A forward action has been raised for this and is documented in the Demonstration of Disposability document (Reference 5-10).

The filter backwash sludges from all systems are discharged by backwashing the filters and transferring the sludges to one of two sludge storage tanks in the Radwaste Building (RWB) for storage prior to processing.

The Wet Solid Intermediate Level Waste (WSILW) streams are assumed to be transferred to an on-site WSILW processing capability, where they will be packaged and conditioned to form passively safe, disposable Final Waste Packages (FWPs).

The current power block arrangement includes the use of High Integrity Containers (HIC) for the receipt, dewatering and off-site transfer of wet solid wastes for disposal. This reflects US regulatory requirements under 10 CFR Part 61.56, "Waste characteristics," (Reference 5-64). This arrangement does not align with UK requirements for on-site processing of wet solid wastes to achieve a passively safe and disposable final waste package. Therefore, in a UK context the HIC may be considered as a means of on-site transfer to downstream processing capabilities only, but may not represent the BAT or ALARP option for this function.

A forward action has been placed for this aspect to be considered by the future developer/operator in arriving at an appropriate overall technical solution for wet solid wastes management.

FAP.PER5-336 – A future developer/operator shall undertake formal decision making to determine a means of transferring wet solid wastes from the power block to downstream on-site processing capabilities that demonstrably employs BAT and reduces risks to ALARP.

NEDO-34222 Revision B

The wastes are assumed to be packaged and conditioned in an appropriate design of NWS approved ILW container (if classified as ILW). Note that the final choice of waste container and related immobilisation method will be subject to appropriate consideration of actual waste characteristics and demonstration of BAT during site-specific design development, as detailed in PER Chapter E6 (Reference 5-4). Packaging will comply with the relevant NWS waste packaging specifications/WAC. Proposals for packaging and conditioning of HAW will be substantiated through the NWS disposability assessment and LoC process. In order to provide appropriate segregation of spent bead resins on the basis of radioactivity content (to align with UK waste classifications) the SWM design incorporates sufficient flexibility to allow the spent resins to be managed on a 'batch' basis, with individual batches being received into the spent resin tank and forwarded to downstream on-site processing capabilities as required. This arrangement provides the future operator with sufficient flexibility to manage the resins appropriately once a radioactive waste EUST has been developed and waste classifications are better defined.

Dependent on the specific technical option adopted for a site-specific design there may be requirements for management of water associated with wet solid wastes transfer and processing. The SWM design incorporates arrangements for removing decant water from the resin and sludge storage tanks. In determining the preferred options for on-site transfer and subsequent processing of the wet solid wastes for a UK BWRX-300 installation the future developer/operator will need to consider requirements for water removal/addition and the management of any 'excess' water as part of the overall water balance model for the plant.

A forward action has been placed for this aspect to be considered by the future developer/operator in arriving at an appropriate overall technical solution for wet solid wastes management.

FAP.PER5-376 – A future developer/operator shall consider the requirements for management of process water associated with on-site transfer and processing of wet solid wastes and shall incorporate this within the overall water balance model for the plant.

For GDA Step 2, the Demonstration of Disposability document (Reference 5-10) has been produced in accordance with published guidance from NWS (Reference 5-1). NWS has reviewed the demonstration of disposability document and provided their expert view, in the form of a formal letter (Reference 5-2), on the suitability of the BWRX-300 HAW (including SF) streams for disposal in the GDF. This confirms that a disposability case could be made for the wastes and spent fuel from the BWRX-300 (Reference 5-2).

The resultant FWPs are anticipated to be transferred to an appropriately designed on-site storage facility for storage pending eventual disposal to a national GDF. A final decision on WSILW management strategy will be made at a future site-specific stage and will need to take account of a wider range of factors reflecting the site-specific design, to include consideration of a solution for a multiple unit site, and related considerations of shared facilities etc.

An overview of the anticipated WSILW management process is presented in Appendix D.

In 006N7938, "BWRX-300 Process and Radiation Monitoring," (Reference 5-65) capabilities for both automated online sampling and grab sampling of the various systems related to the production of radioactive effluents and wet solid wastes are described. An onsite laboratory is located on the first floor of the RWB, as presented in the BWRX-300 Power Block PSAR General Arrangement (Reference 5-56) for analysis of samples recovered from the Process Radiation and Environmental Monitoring System. The laboratory will provide radioactive waste characterisation data in support of waste assessment, waste inventory derivation and sentencing activities. NEDO-34225, "BWRX-300 UK GDA Ch 8: Approach to Sampling and

NEDO-34222 Revision B

Monitoring," (Reference 5-66) provides additional information on the sampling and monitoring arrangements for the BWRX-300.

LWM incorporates a discharge route to provide a means of disposing of aqueous liquid waste. In general, it is considered that it will be possible to maintain plant water balance using designed storage capacity in the numerous water storage tanks (LWM collection and sample tanks, CST, and RWST) without recourse to use of the discharge route.

In 006N7673, "BWRX-300 Water Balance," (Reference 5-67) it is demonstrated that the system water storage capacities are designed to cope with the maximum water transfer volumes that occur during refueling outages and include adequate capacity to support the maximum recirculation philosophy for the plant.

As with the on-line abatement processes, operation of LWM will result in the generation of wet solid wastes in the form of filter backwash sludges and spent bead resins. These are also routed to SWM for onward management.

It is recognised that a small amount of radiologically contaminated water will be lost from the plant through evaporation from the RB pools. This evaporate is swept from the pool surface by the RB pool ventilation system and discharged via the plant Heating, Ventilation, and Cooling System (HVS), as per 006N7781, "BWRX-300 Heating Ventilation and Cooling System," (Reference 5-68). A small amount of high purity water make-up is therefore required to compensate for evaporative losses, and this is provided by the Water, Gas, and Chemical Pads System, 006N7797, "BWRX-300 Water, Gas, and Chemical Pads (WGC)," (Reference 5-69).

In the event of off-specification water due to an abnormal event or, in exceptional circumstances, when water balance requires water to be discharged from the plant, an aqueous liquid discharge line is provided downstream of the LWM abatement, sampling and monitoring sub-systems to demonstrate that radioactivity content in discharges is within permitted limits prior to discharge. The aqueous liquid discharge is routed into the circulating water system at the outgoing side of the main condenser, captured in 006N7761, "BWRX-300 Circulating Water System," (Reference 5-70).

5.2.2 Lower Activity Wastes

LAW comprises both LLW and VLLW. Normal operation of BWRX-300 is anticipated to generate the following LAW streams:

- Ventilation filters.
- Aqueous effluent filter cartridges and Reverse Osmosis (RO) modules.
- Fine filter modules.
- Non-aqueous wet solid and liquid wastes.
- Heterogeneous dry solid wastes.

Additional information on these waste streams is presented below and in Appendix F.

5.2.2.1 Ventilation Filters

The BWRX-300 design incorporates a number of Air Handling Units (AHUs) serving various parts of the plant, as per the HVS SDD (Reference 5-68). Those extracting air from active (and therefore potentially contaminated areas) of the plant will give rise to used ventilation filters that have the potential to be contaminated and will therefore be managed as dry solid radioactive waste. Since it will initially be difficult to quantify levels of radioactivity on spent ventilation filters, it will be important that arrangements are in place to segregate and characterise filters to apply the correct disposition route in line with application of the waste hierarchy. It is anticipated that ventilation filters will be a LLW stream, but where

characterisation indicates spent filters meet VLLW or out of scope criteria they would be managed accordingly in line with the waste hierarchy.

Spent filters will arise in the form of pre-filters and high efficiency particulate air filters from extract AHUs serving radioactive areas of the plant, and from a number of localised filters where air is extracted from potentially contaminated areas such as tank rooms. Precise details on the type, size and number of filters is not yet available but it is assumed that spent filters will undergo safe change (i.e. radiological containment of the spent filter will be maintained throughout the filter change process) and will be presented as waste already contained in protective packaging (in the form of bagged filters). It is further assumed that, as with other dry solid wastes, the bagged filters will be placed into appropriate waste containers to afford appropriate mechanical protection of the filters as close as practicable to the point of arising, and prior to on-site movement. Since the wastes are assumed to be LLW, it is considered good practice to ensure that the containers conform to NWS packaging specifications, found in the brochure (Reference 5-28). This will enable efficient and compliant disposition via the relevant waste route.

Ventilation filters are assumed to have an operational life of up to 10 years. Those that operate in areas that have the potential to be exposed to moisture (steam or pool evaporate) are assumed to require replacement more frequently.

5.2.2.2 Aqueous Effluent Filter Cartridges and Reverse Osmosis (RO) Modules

As indicated in Section 5.2.1.3.1, the design of LWM is still at a conceptual stage and may be subject to future revisions. The information presented below should therefore be considered preliminary at this stage.

The PCF, sludge consolidation and RO sections of LWM are also anticipated to generate spent activated carbon, filter cartridges and RO membrane modules that will require periodic replacement.

Spent PCF media is anticipated to arise in the form of GAC and is anticipated to be classified as a LAW stream that would be managed via SWM. At present no inventory data is available for this stream. It is currently assumed that GAC may be generated as waste either in the form of modules or as loose material (wet solid waste).

The sludge consolidation filter is anticipated to generate spent filtration cartridges. These are anticipated to be classified as a LAW stream that would be managed via SWM. At present no inventory data is available for this stream.

The RO system is anticipated to generate spent RO modules. These are anticipated to be classified as a LAW stream that would be managed via SWM. At present no inventory data is available for this stream.

FAP.PER5-112 – A future developer/operator shall provide further design detail and Realistic Model EUST Values for wastes arising from BWRX-300 Liquid Waste Management system operation including Granular Activated Carbon, sludge consolidation filters and RO modules, in order to quantify secondary waste generation from this system.

On removal, the filters, cartridges, and RO modules may require size reduction in order to be packaged to an appropriate waste container. Once packaged, the filter modules are anticipated to be consigned for off-site disposition and may undergo further volume reduction (incineration or super-compaction) prior to disposal, in line with application of the waste hierarchy.

5.2.2.3 Fine Filter Modules

Spent fine filter modules will arise from periodic maintenance of the fine filters in CFD, FPC and RWST.

The fine filters undergo regular backwashing when differential pressure (DP) across the filter reaches a predetermined level. Backwashing removes accumulated particulate in the form of an aqueous sludge (see Section 5.2.1.3.1) and restores pressure drop across the filter to normal operational values.

Over time the underlying DP across the filter will rise, largely as the result of clogging of the very fine pores in the filter media itself. At a predetermined level this will indicate that the filter media requires replacement. Fine filter modules in previous BWR designs have been in operation for in excess of 10 years. Filter design details are preliminary at this stage and an estimate of change frequency cannot be quantified at this point.

Based on previous assessment undertaken for UK ABWR the filter modules are anticipated to arise as Lower Activity Waste (LAW).

5.2.2.4 Non-Aqueous Wet Solid and Liquid Wastes

Non-aqueous wastes in the form of laboratory samples, chemical wastes, and oily waste will be collected in segregated EFS non-aqueous sumps, as discussed in the EFS SDD (Reference 5-53). The wastes would be accumulated in nominal 205 l drums conforming to UK LLW WAC. Where appropriate, the evaporator which forms part of SWM, in accordance with the civil nuclear roadmap (Reference 5-3), may be utilised as a form of pre-treatment to ensure wastes conform to the specific requirements of LLWR WSC-WAC-OVR (Reference 5-27). The drum evaporator removes excess moisture, through evaporation, which is routed to the RWB ventilation system for elimination. The remaining waste in the drum would be sent offsite via the appropriate waste route in accordance with the waste hierarchy and relevant LLWR WAC. This could include use of the incineration route for oils, oily wastes and conforming chemical/laboratory wastes.

The function of the drum evaporator, within a UK radioactive waste management context, is not fully quantifiable at this stage, although its inclusion is seen as potentially useful as a pretreatment step in the management of a number of lower activity waste streams. A forward action has therefore been placed for the function of the drum evaporator to be considered and justified in a UK context.

FAP-PER5-351 – A future developer/operator shall consider the function of the SWM drum evaporator within the context of UK radioactive waste management requirements and provide appropriate justification for its inclusion in a UK specific design.

5.2.2.5 Heterogeneous Dry Solid Wastes

A range of dry solid wastes will be generated through operational, maintenance and repair/refurbishment on an ad hoc basis associated with activities undertaken in the radioactive areas of the plant throughout the operating life of the BWRX-300, as discussed in the SWM SDD (Reference 5-55). A range of similar wastes are anticipated to be generated during the decommissioning phase, and these are considered separately in Section 5.3.

Dry solid radioactive wastes will arise as a wide variety of contaminated articles and substances.

Articles may include air filters, rags, plastic bags and packaging, paper, disposable clothing, personal protective equipment, tools, laboratory wastes, plant items including motors, cables and pipes, valves, actuators, instruments, miscellaneous filters, strainers etc. and other miscellaneous equipment utilised in radioactive areas of the plant.

NEDO-34222 Revision B

The substances are anticipated to include metals, hard wastes, soft wastes, inert wastes, and organic wastes, plastics, rubber, paper, card, wood, glass, building materials, insulation etc.

Heterogeneous LLW may be generated anywhere within the active facilities throughout the power block. Dry solid wastes are expected to be collected, segregated, collated, and initially characterised in nominal 205 l drums. These drums would be located in appropriate areas throughout the plant, as dictated by volume of wastes generated during operation and maintenance, and the segregation criteria defined by downstream disposition routes, as specified in the LLWR services brochure (Reference 5-26). Filled waste containers would be sealed and moved to controlled access enclosed areas for temporary storage and final characterisation, pending disposition.

The waste characteristics will be diverse and will include a range of materials, sizes, shapes, masses, and densities. It is assumed that, wherever practicable, wastes will be generated in quantities/sizes that are manageable using the 'standard' range of LLW containers used in the UK, as per the brochure (Reference 5-28). Where any requirement for size reduction of wastes to facilitate packaging is identified, it will be necessary to demonstrate that this can be done in a safe and contained manner that minimises operator risks to ALARP.

It is assumed that increased volumes of waste are generated during outages due to an increase in intrusive work on the plant and the greatly increased footfall of personnel necessary during an outage.

5.2.2.6 Management of Lower Activity Wastes

An overview of the anticipated arrangements for management of LAW is presented in Appendix E.

It will be necessary for a future developer/operator of a UK BWRX-300 to engage with NWS to establish off-site waste disposition routes for LAW via the NWS waste services contract, noting that the developer/operator also has recourse to engage directly with LAW pretreatment service providers and VLLW disposal sites.

FAP.PER5-115 – A future developer/operator shall engage with Nuclear Waste Services and/or other LAW service providers to establish off-site routes for LAW disposition.

Routine operation of BWRX-300 may entail periodic requirements for decontamination activities to be undertaken, either in-situ or within dedicated maintenance areas located within controlled contamination areas of the plant. Precise details on the decontamination techniques to be utilised are not established at this stage but it is anticipated there is potential for the generation of both aqueous and non-aqueous wet solid wastes in the form of decontamination sludges. Further consideration with respect to management of the resultant wastes is provided in Appendix F.

5.3 BWRX-300 Decommissioning Wastes

Decommissioning of the BWRX-300 SMR is addressed in 006N8745, “BWRX-300 Incorporation of Decommissioning in Design Considerations,” (Reference 5-71). Decommissioning is assumed to be conducted in a similar manner to that applied to existing LWRs:

- POCO
- Reactor coolant circuit decontamination
- RPV dismantling
- POCO of fuel pool, equipment pool and reactor cavity
- Balance of plant dismantling and demolition

POCO wastes are anticipated to comprise further wastes analogous to those produced during operation:

- Final core offload of SF
- All control rods
- All reactor instrumentation assemblies
- Final batches of filter backwash sludges and spent resins, HVS filters
- Offload of spent charcoal from offgas system delay beds
- Contaminated and irradiated plant and equipment from pools, including fuel storage racks

Actual sequence of waste arisings will be dependent on the decommissioning strategy and sequence applied.

It is assumed that repackaging of stored SF and IICC will be undertaken during the decommissioning phase, as the last batches of these wastes will not be generated until the end of the last operating cycle, and these wastes will then need to undergo requisite cooling in the fuel pool prior to packaging. Following repackaging the spent dry storage containers are likely to be considered a radioactive waste stream. Further characterisation will be necessary to determine waste classification and development of an appropriate management strategy.

Following POCO, it is assumed that the coolant circuit will undergo appropriate in-situ decontamination using an intrusive chemical/mechanical process that generates a concentrated sludge/particulate waste stream. If a liquid transport medium is used as a component of the applied in-situ decontamination technique this will also need to undergo appropriate abatement, resulting in further sludges and potentially further spent resins/filtrates/filters etc.

It is anticipated that RPV dismantling will focus on the establishment of a cutting plan that enables resultant metal sections to be segregated according to waste category. This may also entail decay storage strategies dependent on levels of activation of the cut sections. Since the BWRX-300 utilizes a taller ‘chimney’ design, it is assumed that some RPV components (moisture separator, steam dryer etc.), located a greater distance from the neutron flux, would be less irradiated than similar components in previous designs, such as ABWR. This may reduce the volume of decommissioning HAW.

Fuel storage racks in the fuel pool are anticipated to undergo a degree of neutron irradiation from storage of irradiated SF. It is anticipated that these may be irradiated to ILW levels and would be managed as a decommissioning ILW stream.

US Protective Marking: Non-Proprietary Information
UK Protective Marking: Not Protectively Marked

NEDO-34222 Revision B

All other wastes arising from decommissioning are assumed to meet UK LAW disposal criteria and will be managed in line with prevailing disposal requirements at the time.

5.4 Anticipated Waste Quantities

Appendix F presents descriptive narrative and a summary of current estimated SF and radioactive waste quantities for the anticipated 60-year operating life of a BWRX-300 SMR, including commissioning and decommissioning. At this relatively early stage of development of the UK BWRX-300 it is not possible to provide quantification for all waste streams. This is clearly stated where applicable and largely relates to LAW streams. A forward action has been placed for these wastes streams to be better quantified once better information is available.

FAP PER5-397 A future developer/operator shall provide quantification for LAW streams that are not currently quantified in PER Chapter E5.

5.5 Assumptions

At this early stage of development for a UK installation of BWRX-300 a large number of assumptions have been made within this chapter. These assumptions are summarised in Table 5-1. The table entries for each assumption state the source, either an external reference or a section within this chapter, together with the stated basis for defining and including the assumption.

5.6 Conclusion

The RWM arrangements for the BWRX-300 presented in this chapter provide a demonstration of how the BWRX-300 can be developed to integrate with UK RWM and wider environmental protection requirements. Since GDA step 2 represents a single unit design in a non-specified location it does not demonstrate that the design has been fully optimised for UK deployment.

The BWRX-300 SMR design has evolved from the previous ESBWR and ABWR designs but is primarily influenced by the design simplifications introduced for the ESBWR. This has resulted in corresponding simplifications in systems that produce radioactive wastes and on the resultant radioactive wastes themselves.

5.6.1 Higher Activity Wastes

The use of high efficiency backwashable filters and deep bed demineralisers throughout the design has reduced the number of wet solid radioactive waste streams to two, namely:

- Filter backwash sludges
- Spent bead resins

At present, based on the SWM source term (Reference 5-62), these wet solid wastes align to the UK radioactive waste classification of ILW, which necessitates on site management and eventual disposal to GDF, inferring a requirement for on-site processing and storage capabilities. It should be noted that the current source term is highly conservative and has been derived to present a bounding case for the purposes of radiation protection and shielding design. A FAP action has been defined to provide a realistic model (best estimate) radwaste EUST – see Section 5.2.1.3.

It should also be noted that the BWRX-300 design incorporates enhanced design aspects that have the potential to further reduce radioactivity in these waste streams. These include:

- Use of improved GNF2 fuel described in NEDC-34159P, “BWRX-300 UK GDA Fuel Summary Report,” (Reference 5-72) – this is anticipated to result in a lower incidence of fuel cladding failures that will positively impact on all downstream source term values.
- Increased use of stainless steel throughout the design – this is anticipated to result in reduced corrosion and erosion particulate generation throughout the plant. This will both reduce wet solid waste volumes and result in fewer particles undergoing irradiation in the core, reducing the overall radioactivity of the filter backwash sludges produced. Reduced presence of particles in the RPV is also complementary to reduced fuel clad failures.
- Reduced cobalt inventory – the BWRX-300 material selection strategy presented in 006N5956, “BWRX-300 Materials and Process Controls,” (Reference 5-73) focusses on reducing cobalt inventory wherever practicable throughout the plant design.
- Enhanced water chemistry regime – this is anticipated to result in further reduction of corrosion and erosion particulate as above, and minimisation of cobalt deposition on coolant facing surfaces.

These design enhancements are presently difficult to quantify in terms of their contribution to an improved radwaste EUST. As with considerations for the UK ABWR, it is therefore prudent to consider that the designs for on-site wet solid wastes processing and storage would be improved by using waste data from the First of A Kind (FOAK) unit wherever practicable. Due to the potential construction of BWRX-300 SMRs in a number of countries, it is considered that the FAP should include an activity to utilise wet solid waste characterisation data from the first operating BWRX-300 SMR(s). Dependent on the timing of availability of FOAK data, and a UK construction schedule, this has potential to improve decision making on the design of

on-site wet solid waste processing and storage capabilities for a UK version of the BWRX-300 SMR.

FAP.PER5-114 – A future developer/operator should utilise available wet solid waste stream characterisation data from the first operating BWRX-300 SMR(s) to inform decision-making relating to waste processing and storage capabilities for a UK version of the BWRX-300 SMR, wherever practicable.

BWRX-300 design is predicated on United States (U.S.) requirements, and the RWM arrangements provide the interface to the U.S. radioactive waste classification scheme and related disposition criteria. It is recognised that there are differences between U.S. and UK RWM policy and the design of a UK BWRX-300 SMR will require alignment with UK requirements. Assessment of the source term for wet solid radioactive wastes (Reference 5-62) indicates that they would meet the UK criteria of ILW, resulting in a requirement for on-site processing and storage pending availability of a national GDF (and noting that the present source term is design basis and considered conservative and bounding – see FAP.PER5-110).

Other HAW streams arising from operation of the BWRX-300 SMR are very similar to those previously considered for the UK ABWR:

- SF bundles
- Irradiated control rod
- Irradiated instrumentation assemblies

These are considered to present no significant issues for management and disposal to GDF. SF disposal requirements are awaited from NWS before firm decisions can be reached on the precise arrangements for packaging for disposal. Irradiated wastes will initially be managed as HLW in a similar manner to SF and will subsequently be recovered and repackaged as Dry Solid Intermediate level Waste (DSILW) after an appropriate decay storage period.

5.6.2 Higher Activity Waste Disposability

Regulatory guidance on the GDA process (Reference 5-15) requires the RP to include a plan for engaging with NWS, to obtain an expert view on the disposability of radioactive wastes, including any more challenging wastes (such as problematic or novel waste streams) arising across the reactor lifecycle.

GEH has prepared and submitted a Demonstration of Disposability document (Reference 5-10) to NWS, in accordance with the requirements of the NWS Expert View process (Reference 5-2).

Based on the information from the Demonstration of Disposability document, NWS have provided their expert view (Reference 5-2), confirming that HAW and SF arising from the commissioning, operation and subsequent decommissioning of a BWRX-300 SMR are not significantly different to those which would arise from GW-scale boiling water reactors, such as the ABWR. NWS advised that it has previously completed a full GDA disposability assessment of the UK ABWR design, and whilst the ABWR is not directly comparable to the BWRX-300, there is enough analogy to give confidence that a disposability case could be made for the wastes and spent fuel from a UK BWRX-300.

In undertaking their review NWS has noted that there are some areas where more information is required to fully establish this position and have provided advice relating to 4 areas of risk and 7 areas of uncertainty. Three of the risks are classified as being of low severity and all uncertainties are considered capable of being addressed through provision of more detailed information in a future phase. It is therefore considered that the identified risks and uncertainties can largely be addressed through the development of HAW and SF

packaging proposals to enable NWS to undertake formal disposability assessments as part of the site-specific development phase. The following forward action has been placed.

FAP-PER5-349 A future developer/operator shall prepare and submit HAW and SF packaging proposals to enable NWS to undertake formal disposability assessments as part of the design development process for the waste processing and storage facilities. Waste packaging proposals shall be prepared in line with NWS guidance WPS/908/05: Generic Guidance on the Preparation of Submissions for the Disposability Assessments of Waste Packaging Proposals, July 2016.

NWS have however identified one risk which is categorised as 'Medium' and requires more significant attention since it has a potentially larger impact on GDF development. This relates to the criticality safety aspects of the GDF post-closure safety case and the fact that, at present, the case does not take adequate account of the inclusion of SF from BWRX-300. GEH have acknowledged that this gap will require addressing as part of the development of a disposability case for BWRX-300 SF and have identified the following forward action.

FAP-PER5-374 A future developer/operator shall arrange for stakeholder interaction with NWS on scope of BWR spent fuel criticality assessment for GDF post-closure safety case, to support nuclear site license and environmental permit applications.

5.6.3 Lower Activity Wastes

LAW streams arising from operation of the BWRX-300 SMR are very similar to those previously considered for the UK ABWR:

- Ventilation filters.
- Aqueous effluent filter cartridges and Reverse Osmosis (RO) modules.
- Fine filter modules.
- Non-aqueous wet solid and liquid wastes.
- Heterogeneous dry solid wastes.

These are considered to present no significant issues for management and disposition as LAW. Waste management arrangements will be implemented to ensure compliance with the relevant NWS WSC-WAC-OVR (Reference 5-27), and to ensure appropriate application of the waste hierarchy to optimise disposal. Wastes will be appropriately segregated, packaged, characterised, sentenced, and consigned in accordance with the requirements of the relevant NWS WAC document.

5.6.4 Future Responsibilities

During a future site-specific development phase decisions will be required on some of the areas that are highlighted as incomplete in this document, and this is likely to include exploration of the economic viability of a plant and considerations of important aspects such as multiplication of units to form a nuclear licensed site. Specifically in relation to SF and RWM arrangements, this may include determination of appropriate strategies for the on-site management of waste from multiple units, taking into account economies of scale, demonstration of an optimised approach, construction timings, and required design integration activities.

The following key aspects are therefore considered the future responsibilities of an organisation undertaking a UK site-specific development of the BWRX-300 SMR:

- Considerations of the implications of a multiple unit site with respect to BAT, optimisation, facility integration and sizing, construction timings etc.

NEDO-34222 Revision B

- Technical decision making and related demonstration of BAT and optimisation relating to:
 - SF management, including siting, sizing, and form of dry cask storage.
 - HLW management, including integrated storage with SF casks, decay storage period, and provision of future DSILW processing capability.
 - WSILW Management, including decision making on choice of final waste container, immobilisation method and form of ILW storage facility (i.e. shielded or unshielded), and store sizing taking account of potential additional requirement for storage of packages arising from processing of decay stored DSILW.
 - Arrangements to align DSILW management with the UK LLW waste services framework, including on-site segregation, packaging, and characterisation requirements to enable application of the waste hierarchy and compliance with relevant LLW WSC-WAC-OVR (Reference 5-27).

Table 5-1: List of Assumptions

No	Assumption	Source	Basis
1	It is assumed that a UK BWRX-300 will have an operating life of 60 years.		Planning assumption applied to establish waste estimates. Based on design life for Primary Containment System.
2	It is assumed that SF will not be reprocessed and will ultimately be disposed of to a national GDF as HHGW.	CP 1009 (Reference 5-3)	Alignment with UK national policy.
3	It is assumed that a GDF could be ready to receive intermediate level waste between 2050-2060, with high level waste and SF from 2075.	“Geological Disposal – a programme like no other” (Reference 5-29)	Assumption derived from published NWS information relating to GDF provision.
4	It is assumed that currently existing final waste packages on UK nuclear sites will take priority over new wastes in timing of disposal to the GDF.	Section 5.2.1.1	Planning assumption applied to establish site timeline assumptions.
5	It is assumed that a new nuclear facility will be required to retain HAW (including SF) on site for at least 100 years.		Site timeline assumption based on GDF assumptions.
6	It is assumed that no radioactive wastes will be generated until the point at which nuclear fuel is first brought onto site at an appropriate stage during the commissioning phase.	Section 5.2	First point at which radioactive material is present on site.
7	It is assumed that SF arising from operation of a UK BWRX-300 will be stored and repackaged on-site pending eventual disposal to a national GDF.	CM9 Ref 2019/367414 (Reference 5-31)	Planning assumption based on previous GDAs and alignment with UK national policy.

NEDO-34222 Revision B

No	Assumption	Source	Basis
8	It is assumed that BWRX-300 will operate on a 12-month fuel cycle with 32 fuel channels replaced during each refueling outage.	Section 5.2.1.1	Planning assumption applied to establish waste estimates.
9	It is assumed that UK BWRX-300 will employ dry cask storage as the technical basis for SF storage.		Based on extant BWR operational experience and current UK precedents.
10	It is assumed that failed fuel will be packaged for on-site dry cask storage in a similar manner to SF.		Based on extant BWR operational experience.
11	It is assumed that specific arrangements for the management of failed fuel will be developed in line with the selection of a cask storage system.		Containers used for the management of failed fuel will need to be compatible with the chosen storage cask system.
12	It is assumed that fuel channels will not be segregated from fuel bundles at the point spent fuel is loaded to storage containers and will be co-stored during the storage period.		Based on extant BWR operational experience.
13	It is assumed that when SF is repackaged for disposal, the fuel channels will be segregated and managed separately as IICC.		Based on identified opportunity to optimise disposition.

NEDO-34222 Revision B

No	Assumption	Source	Basis
14	It is assumed that IICC will be classified as HLW on generation and will decay to meet ILW classification criteria during the storage period.	Section 5.2.1.2	Planning assumption based on UK ABWR precedent.
15	It is assumed that IICC will be stored in the fuel pool until a sufficient quantity has been accumulated to load a cask.		Planning assumption to minimise number of casks produced.
16	It is assumed that dry storage casks containing IICC will not be recovered for repackaging until the last stored waste has decayed to ILW levels.		Planning assumption to minimise the duration of the repackaging schedule.
17	It is assumed that four (4) control rods will be replaced every 3rd fuel cycle.		GEH planning assumption.
18	It is assumed that size reduction of the instrument tubes by folding or cutting takes place in the fuel pool.		Location assumption as part of overall management process.
19	It is assumed that IICC will undergo decay storage and cooling in SF casks in the same storage location as SF.		Planning assumption based on UK ABWR precedent.
20	It is assumed that once IICC has decayed to meet the ILW classification it will be recovered from cask storage and repackaged to produce FWPs that conform to GDF disposal criteria for LHGW.		Planning assumption based on UK ABWR precedent.
21	It is assumed that wet solid wastes (filter backwash sludges and spent resins) will be classified as ILW on generation.	Section 5.2.1.3	Based on current conservative design basis source term data.

NEDO-34222 Revision B

No	Assumption	Source	Basis
22	It is assumed that BWRX-300 resins will be either a styrene divinylbenzene copolymer or cross-linked polystyrene matrix in a fine bead form, similar to those used in the ABWR.	WN0908-HZCON- PAC-REP-00003 (Reference 5-63)	Planning assumption based on UK ABWR precedent.
23	It is assumed that wet bead resin will arise as an aqueous slurry with a wet density of 1.165 t/m ³ .		Planning assumption based on UK ABWR precedent and used to establish waste estimates.
24	It is assumed that filter backwash sludges will arise as an aqueous slurry with a wet density of 1.1 t/m ³ .		Planning assumption based on UK ABWR precedent and used to establish waste estimates.
25	It is assumed that spent GAC, sludge consolidation filters and RO modules arising from LWM operation will be classified as LAW.		Planning assumption based on extant BWR operational experience.
26	It is assumed that GAC may be generated as waste from LWM either in the form of modules or as loose material (wet solid waste).	Section 5.2.2.2	Planning assumption to cover both options, since design is not yet finalised.
27	It is assumed that carbon media used in the OGS system will only arise as a decommissioning waste.		Carbon beds in OGS designed to last the lifetime of the plant.

NEDO-34222 Revision B

No	Assumption	Source	Basis
28	It is assumed that spent ventilation filters will undergo safe change (i.e. no breach of radiological containment during filter changing) and will be presented as waste already contained in protective packaging (in the form of bagged filters).	Section 5.2.2	Based on relevant good practice for management of radiologically contaminated ventilation filters.
29	It is assumed that bagged ventilation filters will be placed into appropriate waste containers to afford appropriate mechanical protection of the filters as close as practicable to the point of arising.		Based on relevant good practice for management of radiologically contaminated ventilation filters.
30	It is assumed that spent ventilation filters will be classified as LLW.		Planning assumption based on extant BWR operational experience.
31	It is assumed that ventilation filters will have an operational life of up to 10 years.		Planning assumption based on nuclear industry operational experience.
32	It is assumed that ventilation filters serving areas that have the potential to be exposed to moisture (steam or pool evaporate) will require replacement more frequently.		Planning assumption based on extant BWR operational experience.
33	It is assumed that, wherever practicable, wastes will be generated in quantities/sizes that are manageable using the 'standard' range of LLW containers used in the UK.		Based on relevant good practice for lower activity radioactive wastes.
34	It is assumed that increased volumes of waste will be generated during outages due to an increase in intrusive work on the plant and the greatly increased footfall of personnel necessary during an outage.		Planning assumption based on extant BWR operational experience.

NEDO-34222 Revision B

No	Assumption	Source	Basis
35	It is assumed that decommissioning of the BWRX-300 SMR will be conducted in a similar manner to that applied to existing LWRs.	Section 5.3	Planning assumption based on extant LWR decommissioning experience.
36	It is assumed that the BWRX-300 fluid circuit will undergo in-situ chemical descaling as part of decommissioning POCO activities.		Planning assumption based on extant LWR decommissioning experience.
37	It is assumed that some RPV components (moisture separator, steam dryer etc.), situated at a greater distance from the neutron flux will be less irradiated than similar components in previous designs, such as ABWR.		Planning assumption based on BWRX-300 design information



Figure 5-1: UK Radioactive Waste Categories



Figure 5-2: Waste Hierarchy

NEDO-34222 Revision B

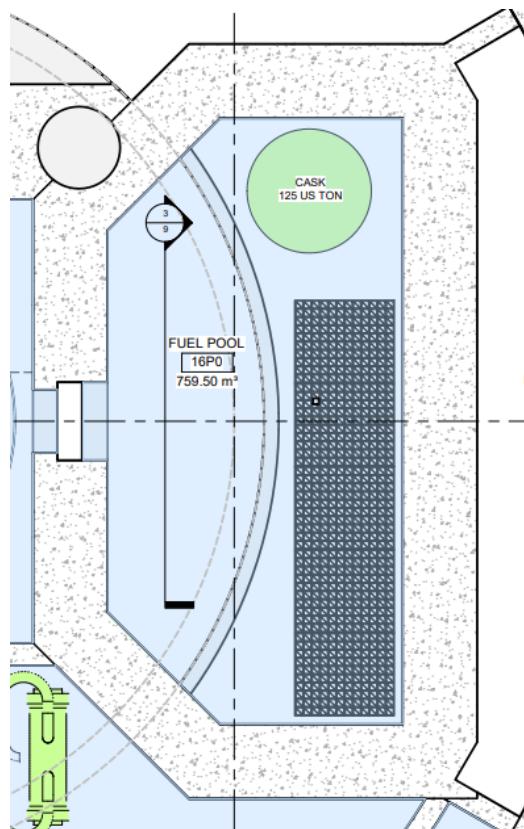


Figure 5-3: BWRX-300 Fuel Pool showing Fuel Cask Position

US Protective Marking: Non-Proprietary Information
UK Protective Marking: Not Protectively Marked

NEDO-34222 Revision B

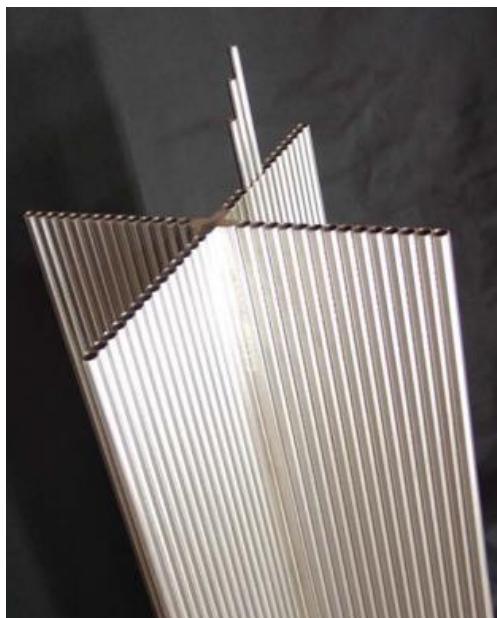


Figure 5-4: GE Ultra™ Control Rod

NEDO-34222 Revision B

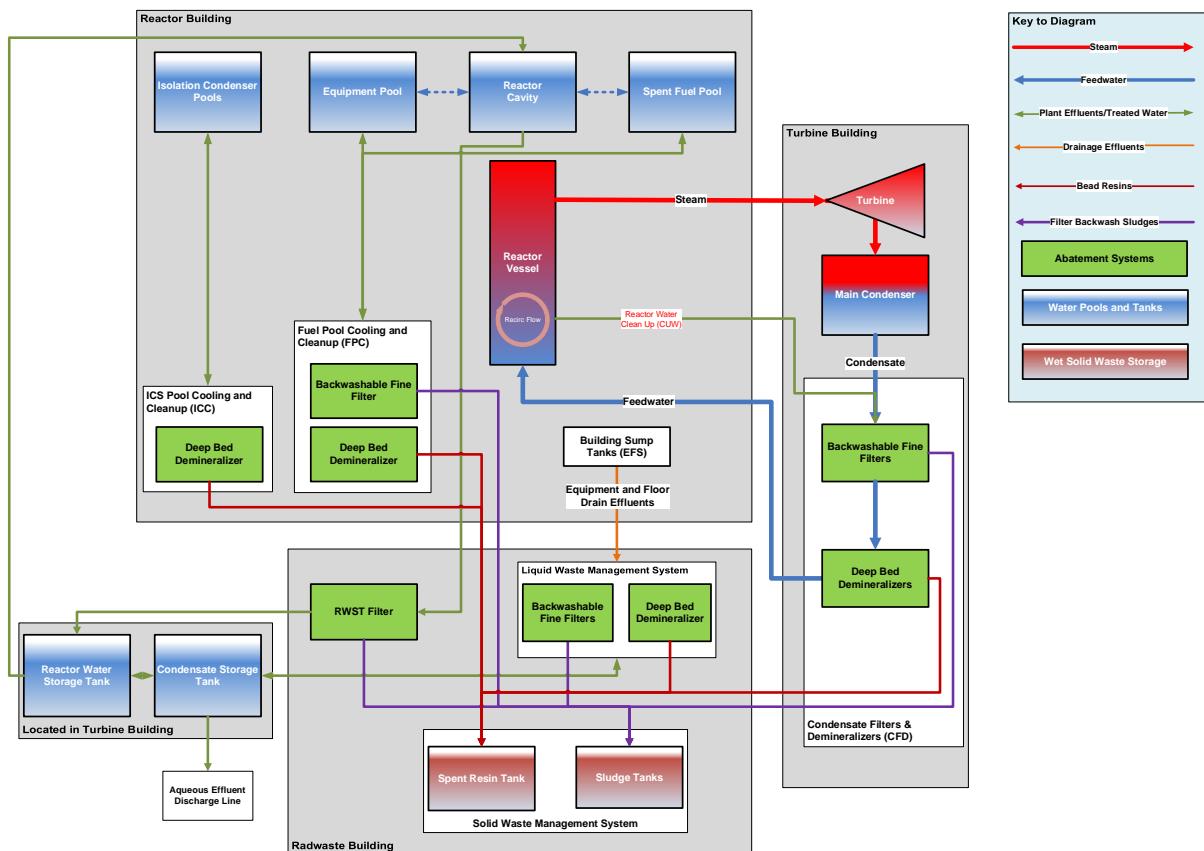


Figure 5-5: Overview of BWRX-300 Process Water Management.

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APPENDIX A OVERVIEW OF LOW-LEVEL WASTE REPOSITORY LIMITED WASTE SERVICES CONTRACT

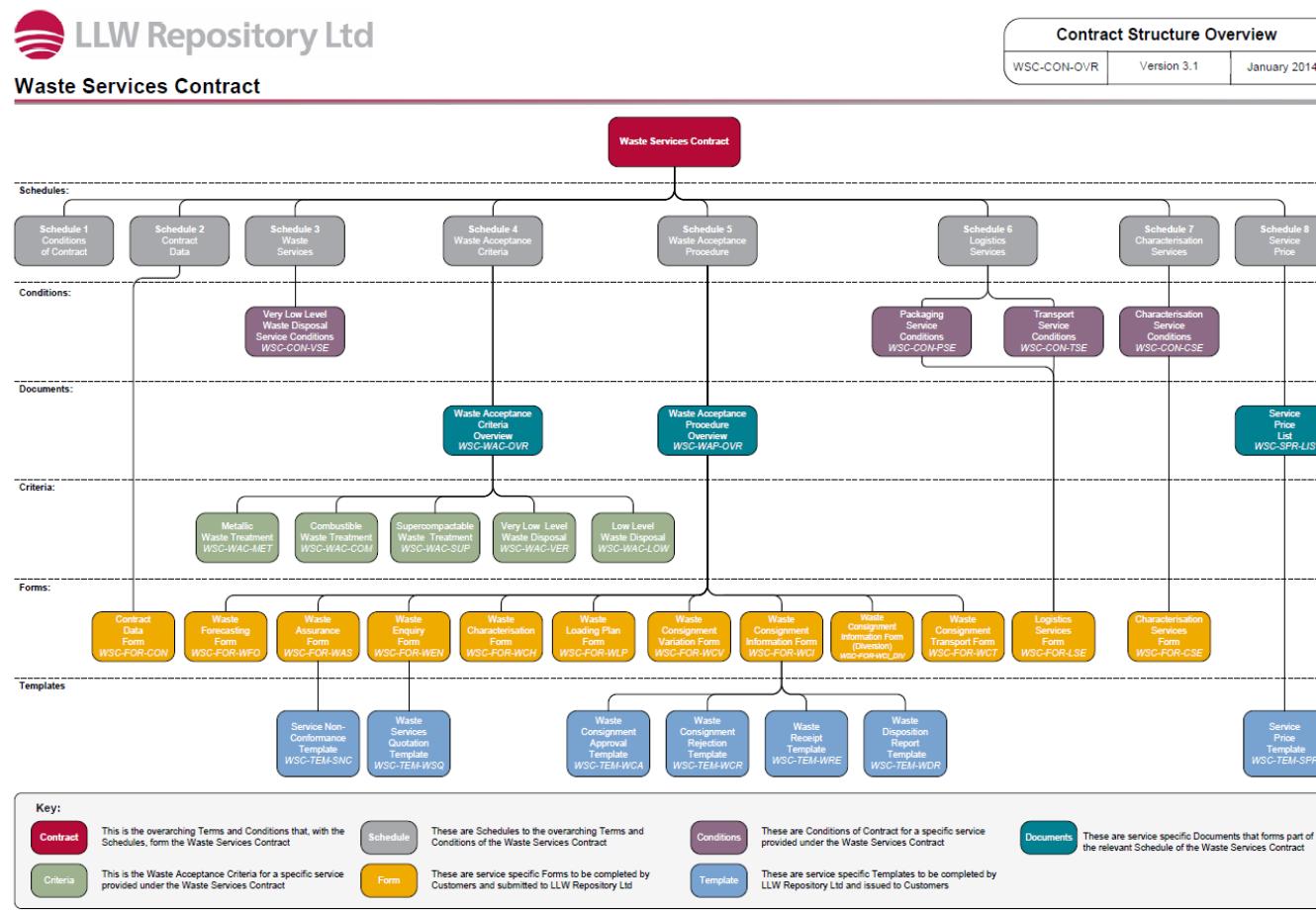


Figure A-1: Overview of Low Level Waste Repository Limited Waste Services Contract

APPENDIX B FORWARD ACTION PLAN

The following actions have been identified for incorporation into the Forward Action Plan for development of a UK version of the BWRX-300 SMR.

Table B-1: Forward Actions – Radioactive Waste Management Arrangements

Action ID	Finding	Forward Action	Delivery Phase
PER5-110	<p>The current BWRX-300 fault list does not identify any AOOs that appear to have consequences in relation to the generation of additional radioactive wastes.</p> <p>Further work is required to assess the wider BWRX-300 design for faults that could give rise to environmental consequences at frequencies that would define them as AOOs.</p>	<p>A future developer/operator shall undertake a systematic review of initiating events across the entirety of the BWRX-300 design to identify a comprehensive list of faults that may result in an environmental radiological impact, through an increase in radioactive discharges, waste volumes or activities, and at frequencies that would define them as AOOs. The findings shall be incorporated into the relevant documentation.</p>	For PCSR/PCER
PER5-111	Current System Design Descriptions (SDD) do not incorporate relevant UK radioactive waste management (RWM) compliance requirements.	A future developer/operator shall identify sources of UK RWM compliance requirements from the comprehensive suite of documentation identified in the IWS, and incorporate the relevant UK RWM compliance requirements into the BWRX-300 requirements management system.	Before Site License Application, Environmental Permit Applications and/or Baseline 3 (BL3) Design Phase
PER5-112	Design documentation does not currently detail or quantify the production of GAC, spent aqueous filters and Reverse Osmosis (RO) modules from the LWM.	A future developer/operator shall provide further design detail and Realistic Model EUST Values for wastes arising from BWRX-300 Liquid Waste Management system operation including Granular Activated Carbon, sludge consolidation filters and RO modules, in order to quantify secondary waste generation from this system.	Before Site License Application, Environmental Permit Applications and/or BL3 Design Phase

NEDO-34222 Revision B

Action ID	Finding	Forward Action	Delivery Phase
PER5-113	Current SWM inventory estimate is based on conservative Design Basis Source Term (DBST) and indicates that wet solid wastes from CFD, FPC and LWM conform to UK Intermediate Level Waste (ILW) definition. This infers requirements for on-site ILW processing and storage capabilities that may not be necessary if the generated wastes are classified as UK LLW.	A future developer/operator shall derive Realistic Model EUST values for BWRX-300 wet solid waste streams to provide an estimated inventory of these wastes under normal operating conditions, to allow strategic decision-making for provision of appropriate processing and storage arrangements aligned with UK relevant good practice and related regulatory requirements.	Before Site License Application, Environmental Permit Applications and/or BL3 Design Phase
PER5-114	A best estimate EUST will be derived from operational experience relating to older BWR designs and may not fully reflect numerous design enhancements on BWRX-300 that further reduce source term (GNF2 fuel, enhanced water chemistry, reduced cobalt inventory, greater use of stainless steel pipework). 'Actual' BWRX-300 data should be used to provide the most accurate quantification of wet solid wastes before committing to final design of UK waste processing and storage solutions	A future developer/operator should utilise available wet solid waste stream characterisation data from the first operating BWRX-300 SMR(s) to inform decision-making relating to waste processing and storage capabilities for a UK version of the BWRX-300 SMR, wherever practicable.	Before Site License Application, Environmental Permit Applications and/or BL3 Design Phase
PER5-115	It will be necessary for a future developer/operator of a UK BWRX-300 to engage with NWS to establish off-site waste disposition routes for LAW via the NWS waste services contract, noting that the developer/operator also has recourse to engage directly with LAW pretreatment service providers and VLLW disposal sites.	A future developer/operator shall engage with Nuclear Waste Services and/or other LAW service providers to establish off-site routes for LAW disposition.	Before Site License Application, Environmental Permit Applications and/or BL3 Design Phase

NEDO-34222 Revision B

Action ID	Finding	Forward Action	Delivery Phase
PER5-336	Use of HICs to perform on-site transfer of wet solid wastes may not be the BAT or ALARP solution and requires review.	A future developer/operator shall undertake formal decision-making to determine a means of transferring wet solid wastes from the power block to downstream on-site processing capabilities that demonstrably employs BAT and reduces risks to ALARP.	Before Site License Application, Environmental Permit Applications and/or BL3 Design Phase
PER5-349	Formal NWS disposability assessment of HAW and SF packaging proposals will be required as part of preparations for nuclear site licence and environmental permit application.	A future developer/operator shall prepare and submit HAW and SF packaging proposals to enable NWS to undertake formal disposability assessments as part of the design development process for the waste processing and storage facilities. Waste packaging proposals shall be prepared in line with NWS guidance WPS/908/05: Generic Guidance on the Preparation of Submissions for the Disposability Assessments of Waste Packaging Proposals, July 2016.	Before Site License Application, Environmental Permit Applications and/or BL3 Design Phase
PER5-351	The role and function of the SWM drum evaporator in a UK radwaste management context is unclear, but it is recognised that it may provide a valuable pretreatment function.	A future developer/operator shall consider the function of the SWM drum evaporator within the context of UK radioactive waste management requirements and provide appropriate justification for its inclusion in a UK specific design.	Before Site License Application, Environmental Permit Applications and/or BL3 Design Phase
PER5-374	The current GDF post-closure case criticality assessment does not include consideration of BWR spent fuels. These have higher maximum enrichment levels than the current bounding case.	A future developer/operator shall arrange for stakeholder interaction with NWS on scope of BWR spent fuel criticality assessment for GDF post-closure safety case, to support nuclear site license and environmental permit applications.	Before Site License Application, Environmental Permit Applications and/or BL3 Design Phase

NEDO-34222 Revision B

Action ID	Finding	Forward Action	Delivery Phase
PER5-376	In determining technical solutions for wet solid waste transfer and processing it will be necessary to consider the management of process water and incorporate this in the overall design.	A future developer/operator shall consider the requirements for management of process water associated with on-site transfer and processing of wet solid wastes and shall incorporate this within the overall water balance model for the plant.	Before Site License Application, Environmental Permit Applications and/or BL3 Design Phase
PER5-396	It will be necessary for a future developer/operator of a UK BWRX-300 to develop arrangements for the management of LAW to demonstrate compliance with LLWR WACs when utilising the NWS waste services contract.	A future developer/operator shall develop arrangements for the management of LAW to demonstrate that disposition will comply with UK requirements.	Before Site License Application, Environmental Permit Applications and/or BL3 Design Phase
PER5-397	Numerous LAW streams are not quantified at GDA Step 2 due to insufficient design information at this early stage.	A future developer/operator shall provide quantification for LAW streams that are not currently quantified in PER Chapter E5.	Before Site License Application, Environmental Permit Applications and/or BL3 Design Phase

APPENDIX C

MANAGEMENT OF SPENT FUEL AND IRRADIATED INCORE COMPONENTS

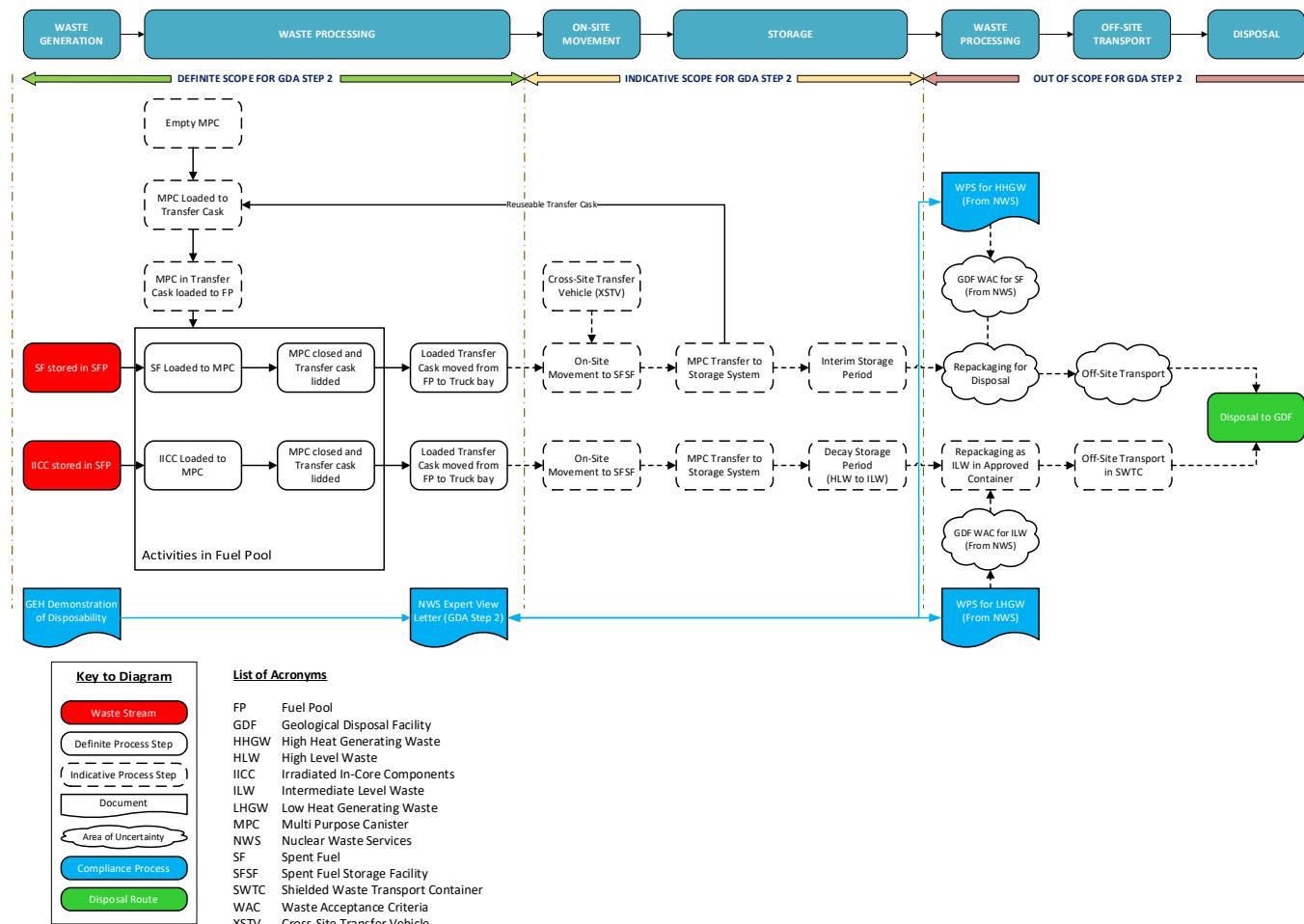


Figure C-1: Process Flow Diagram for Spent Fuel and Irradiated Incore Components Management

APPENDIX D MANAGEMENT OF WET SOLID INTERMEDIATE LEVEL WASTE

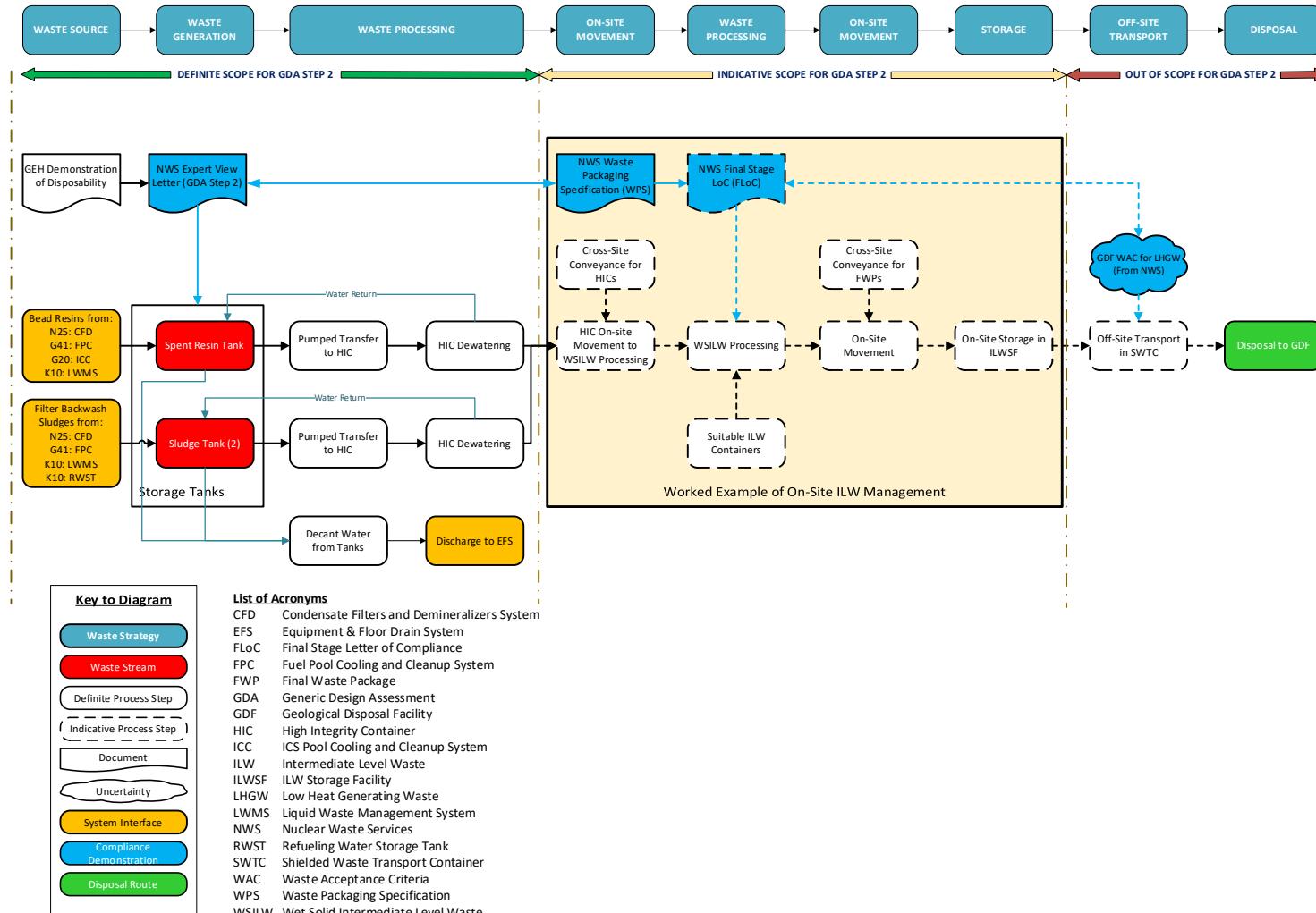


Figure D-1: Process Flow Diagram for Wet Solid Intermediate Level Waste Management

APPENDIX E MANAGEMENT OF LOWER ACTIVITY RADIOACTIVE WASTES

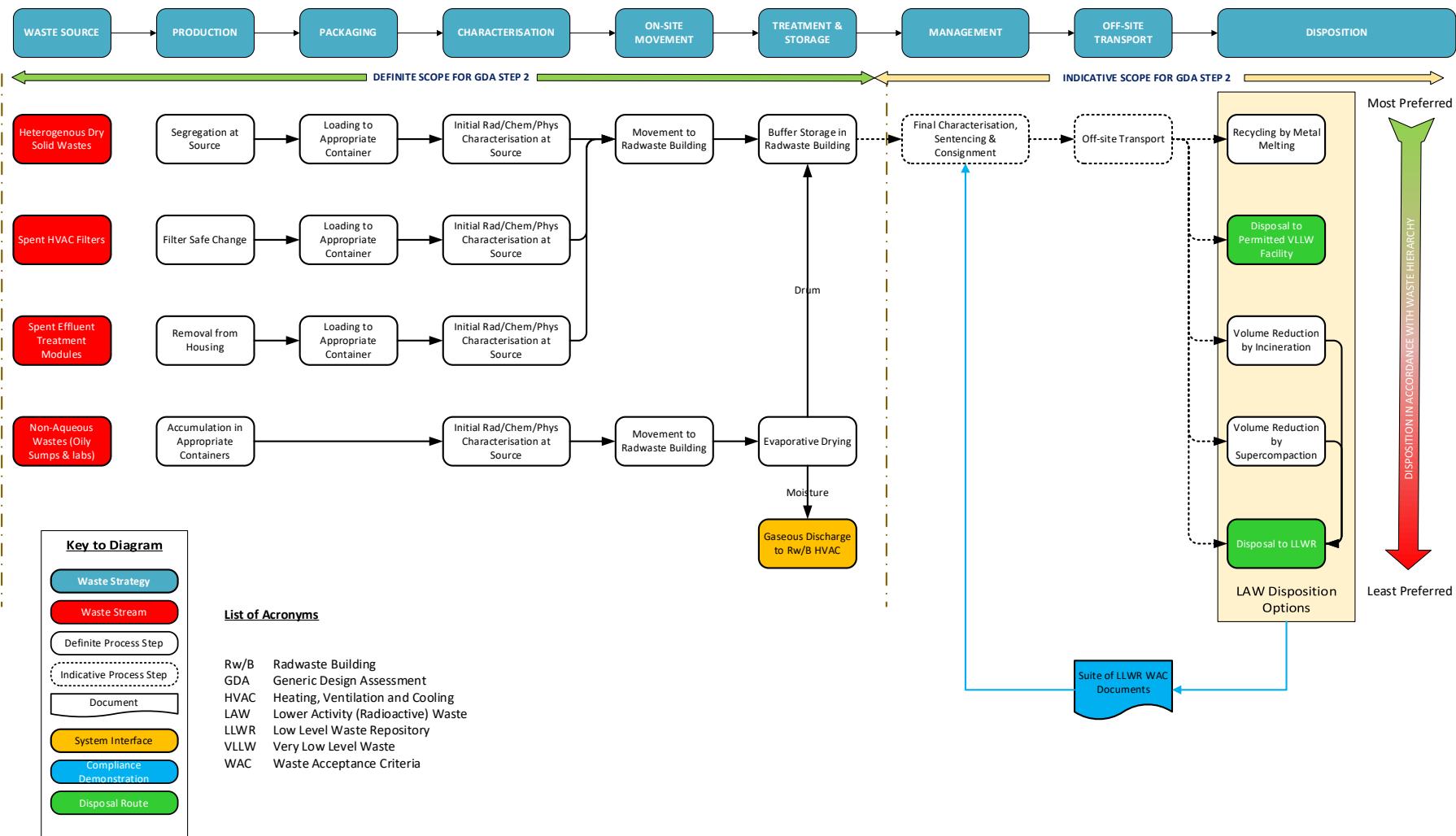


Figure E-1: Process Flow Diagram for Lower Activity Waste Management

APPENDIX F QUANTIFICATION OF BWRX-300 SOLID RADIOACTIVE WASTES

Note: Overall totals are based on an assumed 60 year operating life (See Assumption 1 of Table 5-1).

Waste Descriptor	Quantity	Frequency	Basis	Totals
Spent Fuel				
GNF2 Fuel Bundles – assumed loaded to dry storage canisters complete with fuel channels. No decision is yet made on dry cask vendor and therefore cask numbers cannot be quantified at this point.	240	Initial Core Load	005N9751 (Reference 5-38)	240
	32	59 × 12-month Cycles	PER Chapter E5 Section 5.2.1.1	1888
Overall Total – Spent Fuel Bundles				2128
Irradiated In-Core Components				
Control Rods GE Ultra Control Rods – loaded to dry storage canisters (separate to spent fuel) with no size reduction. Rate of arising assumed as 4 rods every 3rd cycle. No decision is yet made on dry cask vendor and therefore cask numbers cannot be quantified at this point	57	Initial Load	005N9751 (Reference 5-38)	57
	4	19 × 36-month cycles	PER Chapter E5 Section 5.2.1.2.1	76
Overall Total – Control Rods				133
Nuclear Instrumentation 13 LPRM instrument tubes, each comprising 4 LPRM detectors and 8 GTs. 10 WRNM detectors. Nuclear instruments are not anticipated to be replaced on a periodic basis so will arise as waste on an ad hoc basis during the operational life of the reactor. Nuclear instrumentation is assumed to be co-stored in dry casks with other IICC.	13 LPRM 10 WRNM	Initial Load	005N9751 (Reference 5-38)	13 LPRM 10 WRNM
	Ad hoc arisings		PER Chapter E5 Section 5.2.1.2.2	Not quantified
	Overall Total – Nuclear Instrumentation			
Not Quantified				

NEDO-34222 Revision B

Waste Descriptor	Quantity	Frequency	Basis	Totals	
Fuel Channels Each fuel bundle is housed in a fuel channel. Under normal operations the fuel channel remains with the fuel bundle when it is packaged for decay storage. In the event of a fuel failure the fuel channel may be removed and handled as IICC. Arisings are therefore on an infrequent ad hoc basis and cannot be quantified. Separated fuel channels are assumed to be co-stored in dry casks with other IICC.	Ad hoc arisings		NEDO-34198 (Reference 5-13)	Not quantified	
Overall Total – Fuel Channels				Not Quantified	
Wet Solid Wastes					
Filter Backwash Sludges Filter backwash sludges will arise from periodic backwashing of fine filters in CFD, FPC and RWST. The sludges will be transferred to one of two sludge storage tanks in SWM.	CF 0.3 m ³	Annually	008N0133 (Reference 5-62)	18.0 m ³	
	FPC 0.03 m ³	Annually		1.8 m ³	
	RWST 0.37 m ³	Annually		22.2 m ³	
	Annual Total – Filter Backwash Sludges			0.7 m³	
	Overall Total – Filter Backwash Sludges			42.0 m³	

NEDO-34222 Revision B

Waste Descriptor	Quantity	Frequency	Basis	Totals	
Spent Bead Resins Spent bead resins will arise from periodic replacement of demineraliser beds in CFD, FPC, ICC and LWM. Spent resins will be transferred to a spent resin tank in SWM.	CD 18.18 m ³	Annually	008N0133 (Reference 5-62)	1090.8 m ³	
	FPC 3.35 m ³	Annually		201.0 m ³	
	ICC 0.7 m ³	Annually		42.0 m ³	
	LWM 5.4 m ³	Annually		324.0 m ³	
	Annual Total – Spent Bead Resins			27.63 m³	
	Overall Total – Spent Bead Resins			1657.8 m³	
Lower Activity Wastes					
Ventilation Filters Spent ventilation filters will arise as radioactive wastes from periodic replacement of pre-filters and HEPA filters in the exhaust AHU extracting air from contamination controlled areas, and in localized areas of the plant that require HEPA filtration (chemistry lab, Radwaste Building tank rooms etc.). There are two exhaust AHUs for Reactor Building, Radwaste Building and Turbine Building. The design of HVS is preliminary at this stage and therefore no quantification of specific filter numbers is available at this point.	To be determined		006N7781 (Reference 5-68)	Not Quantified	
Aqueous Effluent Filter Cartridges and RO Modules Spent cartridges and modules will arise as radioactive wastes from periodic maintenance of the LWM. These may include prefilters, GAC modules and RO modules. The design of LWM is preliminary at this stage and therefore no quantification of cartridge and module numbers is available for this system at this point.	To be determined		PER Chapter E5 Section 5.2.2.2	Not Quantified	

NEDO-34222 Revision B

Waste Descriptor	Quantity	Frequency	Basis	Totals
<p>Fine Filter Modules</p> <p>Spent fine filter modules will arise from periodic maintenance of the fine filters in CFD, FPC and RWST.</p> <p>Fine filter modules in previous BWR designs have been in operation for in excess of 10 years and the modules are only replaced when underlying differential pressure across the filter reaches a predetermined level. Filter details are preliminary at this stage and arisings are assumed to be on an ad hoc basis and therefore cannot be quantified at this point.</p> <p>Based on previous assessment undertaken for UK ABWR the filter modules are anticipated to arise as Lower Activity Waste (LAW).</p>	To be determined		PER Chapter E5 Section 5.2.2.3 Horizon Nuclear Power Wylfa Newydd Project Radioactive Substances Regulation – Environmental Permit Application Table 5.31 Wylfa Newydd Permit Application (Reference 5-63)	Not Quantified

NEDO-34222 Revision B

Waste Descriptor	Quantity	Frequency	Basis	Totals
<p>Non-Aqueous Wet Solid and Liquid Wastes</p> <p>Non-aqueous wastes in the form of lab samples, chemical wastes, and oily waste from the EFS non aqueous sumps will be collected in nominal 205 litre drums.</p> <p>No production of radioactively contaminated oils or oily wastes is anticipated from the normal operation of a BWRX-300 unit. However, it is possible that during the operational life of the plant accidental spillages or leakages of oil could become radioactively contaminated. It is assumed that any radioactive oil would be contaminated (not activated) and of low volume. Sources of oils are predominantly lubricating oils associated with the main turbine and generating sets, and fuel and lubricating oils associated with diesel generators. This category could also include operational decontamination wastes, but this is dependent on the choice of decontamination method adopted, and this in turn would be informed by specific operational requirements. If an aqueous media were to be selected (e.g. demineralised water) the waste output from decontamination could be an aqueous stream suitable for treatment in LWM. If more aggressive decontamination methods such as bead blasting or use of strippable coatings were utilised this could result in the production of wet solid wastes. Arisings of non-aqueous wet solid and liquid wastes will be on an ad hoc basis, and based on operational requirements, so cannot be quantified at this point.</p>	To be determined	PER Chapter E5 Section 5.2.2.4	Not Quantified	

NEDO-34222 Revision B

Waste Descriptor	Quantity	Frequency	Basis	Totals
Heterogeneous Dry Solid Wastes (Dry Active Wastes) A range of dry solid wastes will be generated through operational, maintenance and repair/refurbishment on an ad hoc basis associated with activities undertaken in the radioactive areas of the plant. Dry solid radioactive wastes will arise in the form of contaminated articles and substances, such as air filters, and miscellaneous wastes including rags, plastic bags and packaging, paper, disposable clothing, personal protective equipment, tools, laboratory wastes, and equipment utilised in radioactive areas of the plant. Since the majority of these wastes typically arise at the point of personnel exiting the radioactive area they are frequently referred to as 'barrier wastes'. The substances are expected to include metals, hard wastes, soft wastes, inert wastes, and organic wastes, plastics, paper, card, wood, glass, building materials, insulation etc. Waste items are expected to include motors, cables and pipes, valves, actuators, instruments, miscellaneous filters, strainers etc. In the absence of a specific dataset for BWRX-300 summary data on annual volumes is taken from the UK ABWR Environmental Permit Application. This data is considered conservatively bounding as maximum volumes that could be generated through operation of a single BWRX-300 unit. Data is presented for a single ABWR unit.	Combustible 91.0 m ³	Annually	006N8745 (Reference 5-71)	5,460.0 m ³
	Compactable 16.0 m ³	Annually	006N8745 (Reference 5-71)	960.0 m ³
	Other 41.0 m ³	Annually	006N8745 (Reference 5-71)	2,460.0 m ³
Annual Total – Dry Active Wastes				148.0 m³
Overall Total – Dry Active Wastes				8,880.0 m³

NEDO-34222 Revision B

Waste Descriptor	Quantity	Frequency	Basis	Totals
Decommissioning Wastes				
Proposed approaches for decommissioning of a BWRX 300 SMR are preliminary at this point but based on prior worldwide experience of Light Water Reactor (LWR) decommissioning. Preliminary waste masses by waste category have been provided. These have been calculated as waste volumes using the following density assumptions: HLW: 7.8 t/m ³ (value for steel) ILW: 1.165 t/m ³ (value for spent resin as bounding for wet solid waste) LLW: 1.0 t/m ³ (generic value for heterogeneous wastes) Decommissioning solid wastes (with the exception of final batch of spent fuel) are anticipated to include: Irradiated Metals from RPV dismantling Final batch of IICC (control rods and instruments) Final batches of filter backwash sludges and spent resins, HVS filters Offload of spent charcoal (carbon media) from Off Gas System (OGS) delay beds Contaminated metals including pipework, pumps, valves and other plant items from RPV and coolant circuit dismantling Irradiated fuel storage racks from fuel pool Contaminated metals from fuel pool, equipment pool and reactor cavity Contaminated wastes from balance of plant dismantling and demolition 'Operational' arisings of heterogeneous dry solid wastes associated with decommissioning tasks Decontamination sludges	HLW 900t 115.4 m ³	Decommissioning Phase		115.4 m ³
	ILW 650t 557.9 m ³	Decommissioning Phase		557.9 m ³
	LLW 8,200 t 8,200 m ³	Decommissioning Phase	006N8745 (Reference 5-71)	8,200 m ³

NEDO-34222 Revision B

Waste Descriptor	Quantity	Frequency	Basis	Totals
Spent Fuel and IICC Dry Storage Canisters Dry storage canisters are anticipated to arise as a radioactive waste stream when they are emptied and the spent fuel and IICC is repackaged for disposal. Since there is presently no certainty on when a GDF will become available or when specific disposal criteria will be published it is conservatively assumed that repackaging and disposal activities will take place as part of decommissioning scope. No decision is yet made on the specific form of dry spent fuel storage and therefore precise detail on the resultant wastes cannot be quantified at this point. Waste volumes for this stream are considered to be included in the overall conservative decommissioning waste volumes presented above.	To be determined	Single arising at point of spent fuel and IICC repackaging for disposal	PER Chapter E5 Section 5.3	Not Quantified
Other 'End of Life' Waste Dependent on the specific form of dry storage adopted there may be additional waste associated with irradiation of the steel components of shielded storage casks or from dismantling of the storage facility itself. It is also assumed that a steel cross-site transfer cask could be utilised and this may also need to be managed as radioactive waste once redundant. Waste volumes for this stream are considered to be included in the overall conservative decommissioning waste volumes presented above.		To be determined.	PER Chapter E5 Section 5.3	Not Quantified.