Environment Agency

Generic design assessment

AP1000 nuclear power plant design by Westinghouse Electric Company LLC

Assessment report
Aqueous radioactive waste disposal and limits

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Assessment report – discharges of aqueous radioactive waste

Protective status	This document contains no sensitive nuclear information or commercially confidential information.
Process and Information Document[1]	The following sections of Table 1 in our Process and Information document are relevant to this assessment: 1.2 General information relating to the facility. 1.5 An analysis should be provided that includes an evaluation of options considered and shows that the Best Available Techniques will be used to minimise the production and discharge or disposal of waste. 2.1 A description of how radioactive wastes will arise, be managed and disposed of throughout the facility's lifecycle. 2.2 Design basis estimates for monthly discharges of gaseous and aqueous radioactive waste 2.3 Proposed annual limits with derivation for radioactive gaseous and aqueous discharges
Radioactive Substances Regulation Environmental Principles[2]	The following principles are relevant to this assessment: RSMDP3 – Use of BAT to minimise waste RSMDP4 – Processes for Identifying BAT RSMDP7 – BAT to Minimise Environmental Risk and Impact: RSMDP9 – Characterisation RSMDP12 – Limits and Levels on Discharges
Report author	Julie Tooley

1. Process and Information Document for Generic Assessment of Candidate Nuclear Power Plant Designs, Environment Agency, Jan 2007.

   http://publications.environment-agency.gov.uk/pdf/GEHO0107BLTN-e-e.pdf

2. Regulatory Guidance Series, No RSR 1: Radioactive Substances Regulation - Environmental Principles (REPs), 2010.

   http://publications.environment-agency.gov.uk/pdf/GEHO0709BQSB-e-e.pdf

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1 Summary

1 This report presents the findings of the assessment of information relating to aqueous radioactive wastes from the Westinghouse Electric Company's AP1000 reactor design submitted to the Environment Agency under the UK Generic Design Assessment process.

2 We conclude that overall the AP1000 utilises the best available techniques (BAT) to minimise discharges of aqueous radioactive waste:

a) During routine operations and maintenance.

b) From anticipated operational events.

3 However our conclusion is subject to a number of other issues which will have to be addressed at site-specific permitting:

a) The capability to include boron recycle in the AP1000 design shall be kept under review and a BAT assessment provided at site specific permitting to demonstrate whether boron recycle represents BAT.

b) Detailed arrangements for the hand over between Westinghouse and future operators shall be provided at site specific permitting, in particular with respect to matters that relate to the use of BAT to minimise radioactive discharges.

c) The suitability and availability of appropriate mobile equipment for waste which is not compatible with the aqueous radioactive waste system shall be demonstrated at site specific permitting.

d) Information relating to the provision of secondary containment for the Monitor tanks shall be provided at site specific permitting.

e) A detailed and robust justification of options for carbon-14 abatement in radioactive waste discharges shall be provided at site specific permitting.

4 We conclude that the aqueous radioactive discharges from the AP1000 should not exceed those of comparable power stations across the world.

5 We conclude that any operational AP1000 should comply with the aqueous limits and levels set out below.

Radionuclides or group of radionuclides	Annual limit (GBq)	Quarterly notification level (GBq)
Tritium	60,000	11,000
Carbon-14	7	2.5
Cobalt-60	0.5	0.18
Caesium-137	0.05	0.018
All other radionuclides (excepting tritium, carbon-14, cobalt-60 and caesium137)	5	1.8

6 Our findings on the wider environmental impacts and waste management arrangements for the AP1000 reactor may be found in our Consultation Document (Environment Agency, 2010a).

2 Introduction

7 This assessment considers the design of the plant which gives rise to aqueous radioactive waste, the foreseeable levels of radioactivity in aqueous radioactive waste and techniques that have been included in the design to minimise discharges of aqueous radioactive waste. The assessment considers the information provided by Westinghouse Electric Company (Westinghouse) for their AP1000 design, and the assessment aims to establish whether the design could be operated in the UK in line with UK Statute, policy and guidance on radioactive waste, and if so key issues that should be taken forward into any discharge permit that may be issued in the form of relevant limitations and conditions, along with any areas where insufficient information has been provided in GDA, which results in a GDA Issue being set out at this stage of our considerations.

8 With respect to aqueous radioactive waste, along with detailed information about waste treatment plant and techniques, key data relates to estimated discharges both on a monthly and annual basis. Our consideration as to the acceptability of proposed discharges has been carried forward into our impact assessment both in terms of impact on members of the public and impact on non-human species. As part of this assessment and the impact assessments, we recognise that whilst monthly discharge data is important we need also to consider the profile of emissions over longer periods of time. Annual cycles may vary depending on the operational state of the reactor and the monthly profile of emissions over longer periods, beyond single operating cycles, is important in this assessment as it enables us to assess short-term impacts for any peak emissions. It also enables us to compare the design with current operating power stations across the world. The discharge data should include radioactive waste arisings from all scenarios (e.g. routine operation, start-up and shut-down etc) and all reasonably foreseeable events (e.g. breakdown maintenance).

9 This assessment does not cover aqueous radioactive waste arising from decommissioning at the end of the reactor lifecycle.

10 The assessment aims to establish whether the design could be operated in the UK in line with UK Statute, policy and guidance on radioactive waste as currently written but it is recognised that the assessment should be kept under review to reflect changes in statute, policy and guidance that may occur between now and plant commissioning.

3 Assessment

11 This assessment considers the discharges of aqueous radioactive waste from the AP 1000 and the techniques employed to minimise discharges. We expect new nuclear power plant to be designed to use BAT to minimise discharges of radioactive wastes in accordance with Statutory Guidance to the Environment Agency (DECC, 2009a) and our REPS (see Environment Agency, 2010b, principle RSMDP7).

12 The assessment has also considered the AP1000 design in the light of UK Statute, policy and guidance.

13 The key legislative areas that have been taken into account are:

a) EU Commission Recommendation 2004/2/Euratom which sets out requirements for monitoring and reporting on radioactive discharges (EC, 2004).

b) Environmental Permitting Regulations (EPR 10) (which replaced the Radioactive Substances Act 1993 (RSA93)) which is aimed at the control of radioactive substances (including waste) (see Defra, 2010).

c) Statutory guidance to the Environment Agency concerning the Regulation of Radioactive Discharges into the Environment (DECC, 2009a) which sets out principles for:

   i) regulatory justification of practices by the Government;

   ii) optimisation of protection on the basis that radiological doses and risks to workers and members of the public from a source of exposure should be kept as low as reasonably achievable (the ALARA principle);

   iii) application of limits and conditions to control discharges from justified activities;

   iv) sustainable development;

   v) the use of Best Available Techniques (BAT);

   vi) the precautionary principle;

   vii) the polluter pays principle;

   viii) the preferred use of ‘concentrate and contain’ in the management of radioactive waste over ‘dilute and disperse’ in cases where there would be a definite benefit in reducing environmental pollution, provided that BAT is being applied and worker dose is taken into account.

14 Bearing in mind the legislative framework and our REPs this assessment aims to establish the acceptability of the AP1000 design with respect to aqueous radioactive waste.

3.1 Assessment Methodology

15 The basis of our assessment was to:

a) consider the submission made by Westinghouse in particular the Environment Report and its supporting documents;

b) hold technical meetings with Westinghouse to clarify our understanding of the information presented and explain any concerns we had with that information;

c) raise Regulatory Observations and Technical Queries where we believed information provided by Westinghouse insufficient;

d) assess the techniques proposed by Westinghouse to prevent or minimise discharges of aqueous radioactive waste using our internal guidance and regulatory experience and decide if they represent BAT;

e) decide on any GDA Issues or other issues to carry forward from GDA in our Statement of Design Acceptability.

16 Westinghouse provided their submission to GDA in August 2007, against our guidance (our Process and Information Document (P&ID, Environment Agency, 2007)). We carried out our initial assessment and concluded we needed additional information. We raised a Regulatory Issue on Westinghouse in February 2008 setting out the further information that we needed. In particular we believed P&ID reference 1.5 had not been addressed by the submission and required "a formal BAT assessment for each significant waste stream".

17 Westinghouse completely revised their submission during 2008 and provided an updated Environment Report with supporting documents.

18 We assessed information contained in the Environment Report but found that while much improved from the original submission it still lacked the detail we require to demonstrate BAT is used.

19 We raised a Regulatory Observation RO-AP1000-034 on Westinghouse in June 2009 that had actions requiring Westinghouse to provide:

a) a comprehensive Integrated Waste Strategy;

b) a demonstration that BAT will be used to prevent or minimise the production and disposal of wastes; and

c) a demonstration that a Radioactive Waste Management Case can be developed to show the long term safety and environmental performance of the management of higher activity waste from their generation to their conditioning into the form in which they will be suitable for storage and eventual disposal.

20 During our assessment of the submission we also noted that from time to time the Environment Report (UKP-GW-GL-790 (Rev1)) and the AP1000 European Design Control Document (EPS-GW-GL-700 (Rev 0)) made reference to the dilution of liquid radioactive waste and in particular the AP1000 European Design Control Document referred to meeting activity concentration limits and offsite dose limits specified by the US NRC.

21 At the time of the submission the UK policy relating to liquid radioactive discharges was set out in the UK Strategy for Radioactive Discharges 2001–2020 which was published in 2002. The strategy was under review and was the subject of a public consultation exercise being undertaken by DEFRA. The consultation document stated that activities involving ionising radiation are subject to controls which include:

a) optimisation of protection on the basis that radiological doses and risks to workers and members of the public from a source of exposure should be kept as low as reasonably achievable (the As Low As Reasonably Achievable (ALARA) principle);

b) application of limits and conditions to control discharges from justified activities to ensure that individuals (workers and members of the public) and sensitive environmental receptors are not exposed to unacceptable radiation risks from these practices.

22 This has subsequently been endorsed in the UK Strategy for Radioactive Discharges which was published in 2009 (see DECC, 2009b). The new strategy is based on a number of principles which include the use of Best Available Techniques (BAT) in England and Wales to prevent and, where that is not practicable, minimise waste generation and discharges to the environment. The application of BAT is broadly equivalent to Best Practicable Means (BPM) and Best Practicable Environmental Option (BPEO), as described in the 2001-2020 strategy. It also sets out the preference for the use of 'concentrate and contain' in the management of radioactive waste over 'dilute and disperse' in cases where there would be a definite benefit in reducing environmental pollution, provided that BAT is being applied and worker dose is taken into account.

23 We raised a Regulatory Observation (RO-AP1000-032) on 1 June 2009 because the regulatory approach in England and Wales requires the use of BAT to minimise discharges and deliver environmental impacts which are ALARP. This is in contrast to the US system which is based on demonstrating compliance with standards set out by the US regulators and we considered that this difference in approach should be reflected in the GDA submission.

24 We required Westinghouse to review the submission made under the GDA process for the AP1000 design to take into account UK policy and practices with respect to the discharge of liquid radioactive waste.

25 Westinghouse responded to the Regulatory Observation RO-AP1000-032 on 23 June 2009 stating that they would comply with our requirement to submit a fully compliant document (Environment Report) including supporting references by 31st December 2009.

26 Westinghouse submitted a revised UK AP1000 Environment Report (UKP-GW-GL-790 (Rev 2)) in December 2009.

27 We raised 42 Technical Queries (TQs) on Westinghouse during our assessment. Four were relevant to this report:

a) TQ-AP1000-146 – Liquid radioactive waste – limits and levels of discharges. 1 June 2009.

b) TQ-AP1000-147 - Liquid radioactive waste – tanks and associated systems. 1 June 2009.

c) TQ-AP1000-153 - Liquid radioactive waste – ion exchange systems. 1 June 2009.

d) TQ-AP1000-164 - Liquid radioactive waste – grouping of radionuclides in discharge limits. 17 June 2009.

28 Westinghouse responded to all the ROs and TQs. They reviewed and updated the Environment Report in April 2010 to include all the relevant information provided by the ROs and TQs. This report refers to the information contained in the updated Environment Report (UKP-GW-GL-790 (Revision 3))and its supporting documents.

3.2 Assessment Objectives

29 Key areas of the submission made under the GDA arrangements by Westinghouse for the AP 1000 design that have been considered are:

a) Are all the sources of aqueous radioactive waste identified?

b) Are all the significant radionuclides relating to aqueous radioactive waste identified and quantified, and has the quantity of secondary waste arisings from processing of aqueous radioactive wastes been included in estimates of waste streams?

c) Are all the assumptions in the submission relating to aqueous radioactive waste valid? For example assumptions about the efficacy of abatement, the extent of gaseous/aqueous partitioning which have a bearing on potential discharges need to be justified.

d) Have the proposed treatment techniques been identified and are these similar to those used in comparable reactors? Are there any novel features?

e) Are installed tanks and containment of adequate capacity for foreseeable operations?

f) Are tanks and containment of suitable design and construction?

g) Are measures in place to detect leakage and prevent contamination of the environment?

h) Has variability in the nature of aqueous radioactive waste, ie in form and quantity, been identified and explained?

i) Have all discharge routes for aqueous radioactive wastes been identified? Has BAT been applied to all aqueous radioactive waste streams and where appropriate has BAT been applied to particular radionuclides within a set of waste streams. The requirement to use BAT applies to both the treatment of wastes prior to disposal and the method of operation of the process giving rise to the waste. BAT should take into account both the best technology and techniques available now, and any technology and techniques that they could avail themselves of in the foreseeable future.

j) Specific requirements for aqueous disposals may include:

    i) the use of BAT to minimise the activity of waste discharged for example by filtration, settling, ion exchange treatment, evaporation and condensation;

    ii) the use of BAT to provide good dispersion e.g. location of discharge point, of approved routes, timing of tidal discharges; and

    iii) controls on pH and temperature, and the use of BAT to minimise oils, solvents, miscible solvents, solids and entrained gases.

k) Are discharges segregated as far as reasonably practicable? The details of the methods to be used for the segregation and characterisation of wastes and the practicable steps taken to avoid dilution should be stated. It is noted that our preference on radioactive discharges is to ‘concentrate and contain’ rather than ‘dilute and disperse’.

l) Are the proposed discharges of aqueous radioactive waste justified and reasonable and include a justified and reasonable contingency for variations in discharge levels during operations.

3.3 Westinghouse documentation

30 We referred to the following documents to produce this report:

Document reference	Title	Version number
UKP-GW-GL-790	UK AP1000 Environment Report	3
UKP-GW-GL-026	AP1000 Nuclear Power Plant BAT Assessment	1
UKP-GW-GL-028	Proposed Annual Limits for Radioactive Discharge	1
EPS-GW-GL-700	AP1000 European Design Control Document	0
APP-WLS-M3C-049	Monthly Radiation Emissions from Radioactive Nuclides - AP1000 Calculation Note	2
APP-WLS-M3C-040	Expected Radioactive Effluents Associated with Advanced Plant Design - AP1000 Calculation Note	0

4 Summarised description of the AP1000 Liquid radioactive waste management systems

31 The liquid waste management systems (WLS) described in the submission include the systems that may be used to process and dispose of aqueous waste containing radioactive material. These include the following:

a) Steam generator blowdown processing system.

b) Radioactive waste drain system.

c) Liquid radioactive waste system.

32 Westinghouse claim that the liquid radioactive waste system is designed to control, collect, process, handle, store, and dispose of aqueous radioactive waste generated as the result of normal operation, including anticipated operational occurrences.

33 Westinghouse claim that the liquid radioactive waste system provides the capability to reduce the amounts of radioactive nuclides released in the aqueous wastes through the use of demineralisation and time delay for decay of short-lived nuclides. The management of aqueous radioactive waste is described in detail in the DCD Chapter 11.2.

34 Estimates of the radioactive source terms and annual average flow rate that will be processed in the liquid radioactive waste system or discharged to the environment during normal operation have been provided in Table 11.2-1 of the DCD.

4.1 Sources of aqueous radioactive waste in the AP1000 design

35 The liquid radioactive waste system receives aqueous waste from the following sources:

4.1.1 Reactor Coolant System Effluents

36 The WLS effluent processing subsystem receives borated and hydrogen-bearing aqueous waste from the reactor coolant drain tank and the chemical and volume control system. The reactor coolant drain tank collects leakage and drainage from various primary systems and components inside the containment. Effluent arising as a result of reactor coolant system heat up, boron concentration changes and reactor coolant system, RCS level reduction for refuelling is transferred from the chemical and volume control system to the WLS.

37 The reactor coolant system effluents contain dilute boric acid at concentrations up to 2700ppm. This borated water is the principal input in terms of volume and activity.

38 Westinghouse estimate the normal daily volume of aqueous waste discharges from the chemical and volume control system when required for chemical shim control to be:

Table 1: Estimates of aqueous waste from the chemical and volume control system

Source of waste	Normal daily volume (m^3)	Maximum daily volume (m^3)
CVS shim bleed	1.65	2.94
Boron dilution near EOL	6	26
Reactor coolant system heat up	85	170

4.1.2 Floor Drains and Other Aqueous Wastes with High Suspended Solids

39 Floor drains and other wastes are collected by certain building floor drains and sumps, and are routed to one of two 57 m^3 waste hold-up tanks. These effluents potentially have a high suspended solid content. Westinghouse estimate the normal volumes of this type of waste to be:

Table 2: Estimates of aqueous waste sentenced to the floor drains

Source of waste	Normal daily volume (m^3)	Maximum daily volume (m^3)
Equipment leaks	0.34	54.5
Floor drains	4.54	21.8
Sampling system drains	0.76	3.79

4.2 Detergent Wastes

40 Detergent wastes arise from the plant hot sinks and showers and some cleanup and decontamination processes. They are routed to the single 34 m^3 chemical waste tank.

41 Westinghouse estimate the normal daily volume of detergent waste to be:

Table 3: Estimates of aqueous detergent waste sentenced to the chemical waste tank

Source of waste	Normal daily volume (m^3)	Maximum daily volume (m^3)
Hand wash and showers	0.76	7.57
Equipment and area decontamination	0.15	1.51

42 Detergent wastes are expected to have low concentrations of radioactivity and contain dilute concentrations of soaps and detergents that may not be compatible with the ion exchange resins. If their activity is low enough Westinghouse claim they can be discharged without processing. When detergent waste activity is above acceptable limits it will be transferred to a waste hold-up tank and processed either using on site processing or mobile equipment or removed for off-site processing.

4.2.1 Chemical Wastes

43 Chemical wastes arise from the laboratory and other relatively small volume sources and are transferred to the chemical waste tank. The nature of this waste is variable and it may be a mixture of non-hazardous, hazardous and radioactive wastes or other radioactive wastes with high dissolved-solids content. These wastes are generated at a low rate.

44 Westinghouse estimate the normal daily volume of chemical waste to be:

Table 4: Estimates of aqueous chemical waste sentenced to the chemical waste tank

Source of waste	Normal daily volume (m^3)	Maximum daily volume (m^3)
Chemical waste	0.03	0.05
Decontamination fluid	0	0

45 Chemical wastes are collected in the chemical waste tank. The tank contents are adjusted for pH or other chemical content. The design includes alternatives for processing chemical wastes which may be processed on site using installed or mobile equipment, or removed off site for processing and disposal.

4.2.2 Steam Generator Blowdown Waste

46 Steam generator blowdown is normally non-radioactive and is treated by the steam generator blowdown system. However, if steam generator tube leakage results in significant levels of radioactivity in the steam generator blowdown, the blowdown is redirected to the liquid radioactive waste system for treatment. In this event, one of the waste hold-up tanks is drained to prepare it for blowdown processing. Westinghouse estimate the normal daily volume of blowdown waste to be:

Table 5: Estimates of aqueous steam generator blowdown waste

Source of waste	Normal daily volume (m^3)	Maximum daily volume (m^3)
Steam Generator Blowdown waste	4.22	42.24

47 Our Radioactive Substances Regulation Environmental Principle RSMDP8 deals with the segregation of wastes and requires that best available techniques should be used to prevent the mixing of radioactive substances with other materials, including other radioactive substances, where such mixing might compromise subsequent effective management or increase environmental impacts or risks.

48 We consider that the AP1000 design provides for segregation of waste such that subsequent management is not compromised.

49 We consider that all sources of aqueous radioactive waste have been identified.

50 We note that there is the potential to generate oily liquid radioactive waste which Westinghouse claim will be treated and disposed of along with solid waste. This is dealt with in our assessment report for solid waste (see Environment Agency, 2010c).

51 We consider that the nature, form and quantity of aqueous radioactive waste has been identified in sufficient detail to demonstrate that treatment processes and disposal routes can be envisaged for all aqueous radioactive. We consider that the data provided by Westinghouse relating to the sources of aqueous radioactive waste is comprehensive, justified and reasonable.

5 Storage and Containment of Aqueous Radioactive Waste in the AP1000 design

52 Radioactive liquids will be produced in the AP1000, we expect these liquids to be contained within the facility to prevent contamination of land or groundwater under normal conditions. Under fault conditions we expect BAT to be used to minimise the probability of contamination occurring and the extent of contamination (our REPs RSMDP10 and CLDP1).

53 Under the Environmental Permitting Regulations 2010, a permit is required for the deliberate discharge of certain substances, including radioactive substances, to groundwater, with the aim of avoiding pollution of groundwater.

54 Westinghouse claim that there is no likelihood of direct or indirect discharges of radioactive substances to groundwater. In that case an AP1000 should not need to be permitted by us for a discharge to groundwater under EPR 10.

55 Westinghouse claim that the AP1000 has 'emphasised best practices with respect to prevention of contamination of land and groundwater'. Westinghouse describe techniques that should prevent contamination (ER chapter 2), in particular:

a) simplicity of design reduces lengths of piping and numbers of components reducing potential for leaks;

b) nuclear island is built as a single structure without joints in the concrete and is waterproofed. This prevents leakage from any equipment reaching the environment;

c) use of embedded pipes minimised;

d) use of coolant pumps without mechanical seals;

e) spent fuel pool constructed of ½ inch stainless steel plate joined by full penetration welds. The welds are fitted with leak detection systems. The pool is, as far as possible, located within a building so leaks would be contained within the building;

f) all tanks containing radioactive liquid are within buildings that act as bunds preventing any leaks reaching the environment.

56 In the USA, Regulation 10CFR20.1406 requires applicants for licenses to operate nuclear power plant to show how they minimise contamination of the environment. The US NRC issued Regulatory Guide 4.21 in June 2008 for use in reviewing facilities in regard to minimisation of contamination. Westinghouse claims that AP1000 fully complies with this guidance and we anticipate the US NRC will publish their review findings in 2010 to confirm this. We accept this guide as an example of good practice and we will review the NRC findings and take account of these in our decision document in June 2011.

57 The AP1000 has five types of tanks for collecting aqueous radioactive waste. We raised a Technical Query (TQ-AP1000-147) on 1 June 2009 requesting engineering details for tanks, bunds and other loss prevention systems along with justification for the tank sizes based on expected flow rates. Westinghouse responded on 22 July 2009 and provided additional information on tanks, bunds and other loss prevention systems. The information was included in section 3.4.2 of their Environment Report.

58 Westinghouse state that liquid radioactive waste is collected in 5 tank systems (ER s3.4.2) and provide design, and secondary containment information on these tanks in ER Table 3.4-2 and 3.4-3:

a) Reactor Coolant Drain Tank, 3.4 m^3, within Containment Shell;

b) Effluent Hold-up Tanks, 2 x 106 m^3, secondary containment within Auxiliary Building;

c) Waste Hold-up Tanks, 2 x 57 m^3, secondary containment within Auxiliary Building;

d) Chemical Waste Tank, 34 m^3, secondary containment within Auxiliary Building;

e) Monitor Tanks, 6 x 57 m^3, secondary containment will be provided to UK Regulatory requirements during site specific design.

5.1 Reactor coolant drain tank

59 The design provides one reactor coolant drain tank which has a volume of 3.407 m^3 and is a horizontal tank, 2.184m long and 1.6m high. The reactor coolant drain tank is made of stainless steel to the US ASME III-3 design code. The tank is inerted with nitrogen. The tank has a vent which is hard piped to the gaseous radioactive waste system, and an overflow which operates by a way of a relief valve and is hard piped to the tanks containment sump. The tank is flitted with an ultrasonic level instrument and a high/high level alarm which is displayed in the main control room and on the local liquid and gaseous radioactive waste control panel. On triggering a high level alarm, discharge of the tank contents to the WLS processing subsystems is automatic. Tank contents are recirculated using a sparger fitted in the bottom of the tank if required. Samples of tank contents are taken from the reactor coolant drain tank discharge line.

60 The tank is located in the concrete containment shell which has a floor drain connected to the liquid radioactive waste system (WLS) containment sump. There is a high level alarm fitted to the WLS containment sump and sump contents are pumped to the waste hold up tanks for processing.

5.2 Effluent hold up tanks

61 The design provides two effluent hold-up tanks each with a volume of 106 m^3 and they are horizontal tanks, 11.180 m long and 4.114 m high. The effluent hold up tanks are made of stainless steel to the US ASME III-3 design code. The tank has a vent which contains hydrogen monitoring instrumentation and is hard piped to the radiologically controlled area ventilation system, as is the overflow. The tank is fitted with a differential pressure level transmitter and a high/high, a high and a low level alarm which is displayed in the main control room and on the local aqueous and gaseous radioactive waste control panel. The high/high level alarm indicates that the tank is full, the high level alarm indicates that the tank is close to full and the low level alarm indicates that the pump has been shut off. Tank contents are mixed by recirculation using a pump which takes suction from the bottom of the tank. Samples of tank contents are taken from the recirculation line.

62 The tanks are located in the concrete and steel auxiliary building which has a floor drain connected to the radioactive waste drain system. There is a high level alarm fitted to the sump and sump contents are pumped to the waste hold up tanks for processing.

5.3 Waste hold up tanks

63 The design provides two waste hold-up tanks each with a volume of 56.78 m^3 and they are cylindrical tanks, each 3.657 m in diameter and 6.273 m high. The waste hold up tanks are made of stainless steel to the US ASME III-3 design code. The tank is vented to the room. The tank is fitted with an overflow which is hard piped to the radioactive waste drain system, WRS. The tank is fitted with a top mounted ultrasonic level instrument and a high/high, a high and a low level alarm which is displayed in the main control room and on the local aqueous and gaseous radioactive waste control panel. The high/high level alarm indicates that the tank is

full, the high level alarm indicates that the tank is close to full and the low level alarm indicates that the pump has been shut off. Tank contents are mixed by recirculation using a pump which takes suction from the bottom of the tank. Samples of tank contents are taken from the recirculation line.

64 The tanks are located in the concrete and steel auxiliary building in individual tank rooms, and each tank room is connected by a floor drain to the auxiliary building sump. There is a high level alarm fitted and sump contents are pumped to the waste hold up tanks for processing.

5.4 Chemical waste tank

65 The design provides one chemical waste tank with a volume of 33.69 m^3 and it is a cylindrical tank 3.657 m in diameter and 3.479 m high. The chemical waste tank is made of stainless steel to the US ASME III-3 design code. The tank is vented to the room. The tank is fitted with a relief valve and an overflow which is hard piped to the tanks containment sump. The tank is fitted with a top mounted ultrasonic level instrument and a high/high, a high and a low level alarm which is displayed in the main control room and on the local aqueous and gaseous radioactive waste control panel. The high/high level alarm indicates that the tank is full, the high level alarm indicates that the tank is close to full and the low level alarm indicates that the pump has been shut off. Tank contents are mixed by recirculation using a pump which takes suction from the bottom of the tank. Samples of tank contents are taken from the recirculation line.

66 The tank is located in the concrete and steel auxiliary building in an area where the floor drains are normally plugged to prevent the chemical waste entering systems where treatment equipment is not designed to deal with such waste. These plugs can be removed to allow suitable waste to enter the floor drain which is connected to the auxiliary building sump. There is a high level alarm fitted to the auxiliary building sump and sump contents are pumped to the waste hold up tanks for processing.

5.5 Monitor tanks

67 The design provides six monitor tanks each with a volume of 56.78 m^3 (total storage capacity for treated effluent of 342 m^3). This capacity allows around 42 days storage during normal power operations at normal daily rates of aqueous radioactive waste production. The tanks are cylindrical tanks 3.657 m in diameter and 6.273 m high. The monitor tanks are made of stainless steel to the US ASME III-3 design code. The tank is vented to the room. The tank is fitted with an overflow which is hard piped to a WRS floor drain. The tanks are fitted with a top mounted ultrasonic level instrument and a high/high, a high and a low level alarm which is displayed in the main control room and on the local aqueous and gaseous radioactive waste control panel. The high/high level alarm indicates that the tank is full, the high level alarm indicates that the tank is close to full and the low level alarm indicates that the pump has been shut off. Tank contents are mixed by recirculation using a pump which takes suction from the bottom of the tank. Samples of tank contents are taken from the recirculation line.

68 Westinghouse state that details on secondary containment for the Monitor tanks will be provided to UK Regulatory requirements during site specific design.

69 We will require information relating to the provision of secondary containment for the Monitor tanks to be provided at site specific permitting and we raise this as an other issue to our findings at this stage:

a) Information relating to the provision of secondary containment for the Monitor tanks shall be provided at site specific permitting.

5.6 Tank capacity

70 The information provided in the UK AP1000 Environment Report Tables 3.4-1 and 3.4-2 on expected normal and maximum daily flow rates and tank capacities when taken together can be summarised as follows:

Table 6 Normal daily flow rates

Receiving tank	Total receiving tank(s) capacity (m^3)	Waste stream	Normal flow rate (m^3/day)		Time taken to reach capacity normal daily flow rate (days)
Waste hold up tank	113.56	SG Blowdown Floor drains and other wastes	4.22 7.29	Total 11.51	9.87
Effluent hold up tanks	212	Reactor effluent after cooling in RC drain tank	93		2.33
Chemical waste tank	33.69	Detergent waste Chemical waste	0.91 0.03	Total 0.94	35.84
Monitor tanks	342	All treated waste	103.45		3.31

Table 7 Maximum daily flow rates

Receiving tank	Total receiving tank(s) capacity (m^3)	Waste stream	Maximum flow rate (m^3/day)		Average time taken to reach capacity at maximum daily flow rate (days)
Waste hold up tank	113.56	SG Blowdown Floor drains and other wastes	42.24 83	Total 125.24	0.9
Effluent hold up tanks	212	Reactor effluent after cooling in RC drain tank	199		1.08
Chemical waste tank	33.69	Detergent waste Chemical waste	9.08 0.05	Total 9.13	3.66
Monitor tanks	342	All treated waste	330.37		1.03

71 In assessing the adequacy of the provided tank capacity, it is recognised that it is unlikely that certain operations will be undertaken at the same time. For example the predicted volume of aqueous waste includes wastes from steam generator, SG blowdown, wastes from reactor coolant system, RCS heat up, and end of life, EOL boron dilution. It is considered unlikely that such operations will be undertaken at the same time and generate wastes for simultaneous treatment. Taking into account that the reactor coolant will be minimised by the use of mechanical shim control wherever possible, and SG blowdown will occur rarely, the routine underlying flow of effluent to the monitor tanks will comprise floor drain effluent from the waste hold up tank, and chemical and detergent waste from the chemical wastes tank, with a combined normal daily flow rate of 6.55 m^3 providing capacity for 52.21 days operations.

72 Our Radioactive Substances Regulation Environmental Principle ENDP15 relating to containment requires that best available techniques should be used to prevent and/or minimise releases of radioactive substances to the environment, either under routine or accident conditions.

73 Westinghouse state that the site of an AP1000 should have a network of boreholes for sampling groundwater established during construction. A conceptual site model should be developed for each specific site and this will aid location of boreholes. The network will remain in place during operation and be used to monitor groundwater quality and detect any contaminants that inadvertently reach the water table. We expect operators to contact us at the early stages of site specific designs so that we can advise on the appropriate location and construction of boreholes. The requirement for boreholes and a routine groundwater monitoring programme will be within our permit. (ERs6.2.2.1)

74 We conclude at this stage that the AP1000 uses BAT to contain liquids and prevent contamination of groundwater in normal operation. The techniques employed should also minimise contamination under fault conditions. However we will require information relating to the provision of secondary containment for the Monitor tanks to be provided at site specific permitting.

6 Liquid Radioactive Waste Treatment System in the AP1000 design

75 The liquid radioactive waste treatment system (WLS) is located in the nuclear island auxiliary building. The liquid radioactive waste treatment system allows a number of waste treatment practices.

6.1 Degasification

76 Reactor Coolant System (RCS) effluent entering the reactor coolant drain tank is potentially at high temperature. The design provides for recirculation through a heat exchanger for cooling. The cooled reactor coolant system effluents then pass to vacuum degasifier to remove hydrogen and dissolved radioactive gases before storage in the two effluent hold-up tanks. The stripped gases are vented to the gaseous radioactive waste system (WGS). The degasifier column is designed to reduce hydrogen by a factor of 40, assuming inlet flow of 22.7 $m^3 h^{-1}$ at 54°C.

6.2 Pre-Filtration

77 The contents of the effluent hold-up tanks and waste hold-up tanks are normally passed through a treatment system comprising an upstream filter followed by four ion exchange resin vessels in series and a downstream filter.

78 A pre-filter is provided to collect particulate matter in the effluent stream before ion exchange. The unit is constructed of stainless steel and uses disposable filter bags. The pre-filter has a nominal particulate removal efficiency of 98% for 25 µm particles.

6.3 Deep Bed Filtration

79 The deep bed filter is a stainless steel vessel containing a layered bed of activated charcoal above a zeolite resin.

80 The activated charcoal provides an adsorption media for removal of trace organics and provides protection for the ion exchange resins from contamination with oil from floor drain wastes. The activated charcoal collects particulates and, being less dense than the zeolite, can be removed without disturbing the underlying zeolite bed which minimises solid waste production.

81 The zeolite resin is clinoptilolite zeolite which is provided primarily for caesium removal.

82 Westinghouse claim that deep bed filtration has a decontamination factor of 1 for iodines, 100 for Caesium (Cs) / Rubidium (Rb) and 1 for other radionuclides.

6.4 Ion Exchange

83 The design provides three ion exchange beds after the deep bed filter. The ion exchange vessels are vertical, cylindrical pressure vessels made of stainless steel. They have inlet and outlet process nozzles plus connections for resin addition, sluicing, and draining. The process outlet and flush water outlet connections are equipped with resin retention screens designed to minimise pressure drop. The design flow through the vessels is 17 $m^3 h^{-1}$. Westinghouse claim that this capacity provides an adequate margin for processing a surge in the generation rate of this waste.

84 At the operational stage the ion exchange media will be selected by the plant operator to optimise system performance according to prevailing plant conditions.

85 Typically the first bed will contain a cation exchange resin and Westinghouse claim that this resin will have a decontamination factor of 1 for iodine, 10 for Cs/Rb and 10 for other radionuclides.

86 The second bed will contain a mixed bed resin and Westinghouse claim a decontamination factor of 100 for iodine, 2 for Cs/Rb and 100 for other radionuclides.

87 The third bed will contain a mixed bed resin and Westinghouse claim a decontamination factor of 10 for iodine, 10 for Cs/Rb and 10 for other radionuclides.

88 The ion exchange vessels can be manually bypassed and the last two can be interchanged to ensure that the ion exchange resin is used completely.

89 The ion exchange beds operate in the borated saturated mode. This means that the boric acid present in the reactor coolant effluent is not removed by the ion exchange beds.

90 We raised a Technical Query (TQ-AP1000-153) on 1 June 2009 requiring further information about the arrangements for by-passing ion exchange systems. Westinghouse responded on 15 July 2009 stating that 'routine bypass of the liquid radioactive waste system ion exchangers is not anticipated'. However, they did acknowledge that in certain cases such as in the event of the actuation of the fire water system in the radiologically controlled area of the plant, a significant volume of uncontaminated fire water might be collected by the liquid radioactive waste system. In this case, Westinghouse considered it may be acceptable and preferable to bypass one or more of the liquid radioactive waste system ion exchangers, in order to maximise the life of the ion exchange resins, thereby minimising solid radioactive waste arisings and associated occupational radiation exposure.

91 The selection of WLS ion exchange vessels in and out of service is made through alignment of manually operated valves under administrative control to prevent an advertent bypass of demineralisers or sub-optimal treatment of waste. In all cases the processed water is collected in a monitor tank, which is sampled prior to discharge to the environment. Westinghouse included this information in the ERs 3.4.3.7.

6.5 After Filter

92 This filter is provided downstream of the ion exchangers to collect particulate matter, such as resin fines. The unit is constructed of stainless steel and uses disposable filter cartridges. The design filtration efficiency is 98% removal of 0.5 µm particles.

6.6 System flexibility

93 The liquid radioactive waste system is designed to be flexible and capable of handling a relatively wide range of inputs, including both high grade water (from reactor effluents) and low grade water (floor drains). The flexible design is claimed to allow the operator to make an evaluation to determine the optimum processing technique.

94 To aid this evaluation each collection tank (effluent hold-up tank, waste hold-up tank) will typically be mixed and sampled prior to processing. The sample will be analysed to provide information on the chemistry and radiological content of the tank contents.

95 It is anticipated that all ion exchangers and filters will be in service and routine bypass of the ion exchangers is not anticipated, however there may be circumstances where it may be acceptable. The selection of ion exchange vessels

in and out of service is made through alignment of manually operated valves. These valves are opened and closed by an operator and are under administrative control to prevent an advertent bypass of demineralisers or sub-optimal treatment of waste.

96

6.7 Use of Mobile and Temporary Equipment

97 Westinghouse claim that the liquid radioactive waste system is designed to handle most aqueous effluents and liquid wastes from other anticipated events using installed equipment. However, for events occurring at a very low frequency, or producing effluents not compatible with the installed equipment, temporary equipment may be brought into the radioactive waste building mobile treatment facility truck bays. Any treatment of aqueous waste by mobile or temporary equipment will be controlled and confirmed by plant procedures.

98 Mobile equipment connections are provided to and from various locations in the liquid radioactive waste system to allow mobile equipment to be used in series with installed equipment or as an alternative to it. Treated aqueous liquids would be returned to the liquid radioactive waste system or removed from the site for disposal elsewhere.

99 We will require Westinghouse to demonstrate that appropriate mobile equipment is suitable and available for waste which is not compatible with the liquid radioactive waste system at Phase 2. This is raised as an other issue to our assessment findings.

7 Information on the treatment and abatement of radionuclides in aqueous radioactive waste

100 Westinghouse have provided information on the techniques for abatement of certain radionuclides that they would expect to utilise during AP1000 operations. They have provided information for tritium, carbon-14, strontium-90, iodine-131, caesium-137, plutonium-241 and beta emitting particulates (cobalt-58, cobalt-60, iron-55 and nickel-63) in aqueous radioactive waste.

101 For each radionuclide Westinghouse have considered the options for abatement and have scored the options against the following attributes:

a) Proven technology

b) Available technology

c) Effective technology

d) Ease of use

e) Cost

f) Impact in terms of doses to the public

g) Impact in terms of operator dose

h) Environmental impact

i) The ability to generate suitable waste forms

j) Secondary and decommissioning waste

102 The outcomes of the BAT optioneering exercise carried out by Westinghouse are as follows:

7.1 Tritium

103 Westinghouse predict that averaged over the 18 month cycle 33.4 TBq y^{-1} tritium will be discharged in aqueous radioactive waste. The discharges of tritium in the highest 12 months of the 18 month cycle are estimated to be 35.09 TBq. Westinghouse estimate the impact of discharging 35.09 TBq of tritium in 12 months will be 2.4E-02 µSv y^{-1} to the fisherman family (1% of total dose to fisherman family). (ER table 5.2-1) (BAT Assessment form 1)

104 Westinghouse have identified the following options for abatement:

a) Adsorption

b) No abatement– direct discharge of aqueous radioactive waste to the environment

c) Isotopic concentration/separation

d) Use of carbon delay beds

e) Use of a condenser

f) Cryogenics

g) Minimisation of plant shutdowns

105 The highest scoring options were direct discharge, the use of a condenser and the minimisation of plant shutdowns. Westinghouse claim that using a condenser will divert tritium into the aqueous waste stream where the impact on the environment and members of the public are reduced. Westinghouse claim that a condenser is included in the AP1000 design.

106 Westinghouse have provided little detail on the techniques for abatement of tritium. They considered adsorption, but no application of adsorption for H-3 removal has

been found. We consider the optioneering study contains insufficient detail to identify the best option, however, we recognise that the impact of tritium discharges without abatement is likely to be low.

107 We recognise however that minimising plant shutdowns will be an issue for future operators of the AP1000 and we will continue to seek assurances that the hand over between Westinghouse and future operators will address this issue. We conclude that this issue will need to be addressed at site specific permitting, and raise it as an other issue to our assessment findings.

108 Westinghouse predict that the annual average discharge of tritium from the AP1000 to sea will be 33,400 GBq. (ER Table 3.4-6)

109 Westinghouse propose a discharge limit for tritium from the AP1000. They have predicted monthly discharges over an 18 month cycle and used data from the 12 months in which the discharges are highest (months 7 – 18) to calculate the representative 12 month plant discharge to be 35090 GBq. Westinghouse have applied our limit setting methodology (Environment Agency, 2005) to calculate the annual worst case plant discharge (WCPD) which they have rounded to give their proposed limit. (ERs6.1-3)

110 Westinghouse propose an annual limit of 60,000 GBq for tritium in aqueous radioactive waste discharges. (ER Figure 6.1-8 and ER Table 6.1-6).

111 From our examination of historic discharges from European and US PWRs operating over the last 10 to 15 years we conclude that the range for the sector in terms of discharge to water of tritium is 2000 to 30,000 GBq per annum for a 1000 MWe power station. (see Annex 3 of our Consultation Document for AP1000). The predicted annual average aqueous discharge of tritium from the AP1000 normalised for power is slightly above the range, however, the impact is low. We conclude that aqueous discharge of tritium is comparable to other power stations across the world.

112 Westinghouse estimate that the radiological impact from the representative 12 month plant discharge of tritium to sea will result in a dose to the local fisherman family of 0.024 μSv y^{-1}. (ER table 5.2-1)

113 We have independently calculated limits for tritium discharges that we may grant and based on the information provided by Westinghouse for GDA our proposed disposal limit for tritium by discharge to the sea is 60,000 GBq in any 12 rolling calendar months. The current limit for tritium in aqueous radioactive waste from Sizewell B is 80,000 GBq.

114 Based on the information provided by Westinghouse for GDA our proposed quarterly notification level for tritium is 11,000 GBq.

7.2 Carbon-14

115 Westinghouse predict that on average 3.3 GBq y^{-1} carbon-14 will be released in aqueous radioactive waste from the AP1000. The discharges of carbon-14 in the highest 12 months of the 18 month cycle are estimated to be 4.42 GBq. Westinghouse estimate the impact of discharging 4.42 GBq of carbon-14 in 12 months will be 1.6 μSv y^{-1} to the fisherman family (70% of total dose to fisherman family). (ER table 5.2-1).

116 Westinghouse have considered the following options for abatement of carbon-14 in aqueous radioactive waste:

a) Ion Exchange - carbon-14 in the form of carbonate or bicarbonate can be removed by mixed resin beds.

b) Evaporation – evaporation of aqueous radioactive waste containing carbon-14 can result in the carbon-14 becoming partitioned in evaporator residues for disposal as solid waste and being released into the atmosphere.

c) No abatement – direct discharge of aqueous radioactive waste to the environment

117 Westinghouse have scored the options against the attributes described in their BAT Assessment and the highest scoring option is direct discharge without abatement. The use of ion exchange has a mid range score. The use of an evaporator scores the lowest as Westinghouse claim that this technology is the least effective, the most difficult to use, the highest cost and has greatest impact on operator dose. Westinghouse recognise in the scoring however that evaporation has less of an impact on the environment and on doses to members of the public than direct discharge.

118 In terms of the environmental impact of the direct discharge option Westinghouse predict that dose to the marine critical group (fisherman family) will be 1.6 μSv y^{-1} and carbon-14 in aqueous discharges will account for around 70% of the marine critical group dose.

119 Our conclusion is subject to the following other issue:

a) A detailed and robust justification of options for carbon-14 abatement in radioactive waste discharges shall be provided at site specific permitting.

120 Westinghouse claim that ion exchange and direct discharge without abatement are included in the AP1000 design.

121 We provisionally conclude that the AP1000 design is BAT for minimising the aqueous discharge of carbon-14.

122 Westinghouse predicts that the annual average discharge of carbon-14 from the AP1000 to sea will be 3.3 GBq. ER Table 3.4-6.

123 Westinghouse propose a discharge limit for carbon-14 from the AP1000. They have predicted monthly discharges over an 18 month cycle and used data from the 12 months in which the discharges are highest (months 7 – 18) to calculate the representative 12 month plant discharge to be 4.42 GBq. Westinghouse have applied our limit setting methodology to calculate the annual worst case plant discharge (WCPD) which they have rounded to give their proposed limit. (ERs6.1-3)

124 Westinghouse propose an annual limit of 7 GBq for carbon-14 in aqueous radioactive waste discharges. (ER Figure 6.1-4 and ER Table 6.1-6)

125 From our limited information about PWRs operating over the last 10 to 15 years we conclude that the range for the sector in terms of discharge to water of carbon-14 is 3 to 45 GBq per annum for a 1000 MWe power station (see Annex 3 of our Consultation Document for AP1000). The predicted annual average aqueous discharge of carbon-14 from the AP1000 is 3.3 GBq, well within this range. We conclude that aqueous discharge of carbon-14 from the AP1000 is comparable to other power stations across the world.

126 Westinghouse estimate that the radiological impact from the representative 12 month plant discharge of carbon-14 to sea will result in a dose to the local fisherman family of 1.6 μSv y^{-1}. (ER table 5.2-1)

127 We have independently calculated limits for carbon-14 discharges that we may grant and based on the information provided by Westinghouse for GDA our proposed disposal limit for carbon-14 by discharge to the sea is 7 GBq in any 12 rolling calendar months. There is no limit for carbon-14 in aqueous radioactive waste from Sizewell B, however, there is a requirement to use BAT to minimise discharges.

128 Based on the information provided by Westinghouse for GDA our proposed quarterly notification level for carbon-14 is 2.5 GBq.

7.3 Strontium-90

129 Westinghouse predict that on average 0.25 MBq y^{-1} of strontium-90 will be discharged in aqueous radioactive waste. The discharges of strontium-90 in the highest 12 months of the 18 month cycle are estimated to be 0.324 MBq. Westinghouse estimate the impact of discharging 0.342 MBq of strontium-90 in 12 months will be 1.5E-06 μSv y^{-1} to the fisherman family (0.00007% of total dose to fisherman family). (ER Table 5.2-1)

130 Westinghouse has identified the following abatement techniques:

a) Ion exchange

b) Wet scrubbing

c) No abatement– direct discharge of aqueous radioactive waste to the environment

d) Evaporation

e) Precipitation/filtration

f) Adsorption

g) Isotopic concentration/separation

h) Delay tank– delay tanks could be used to delay discharges to take advantage of radioactive decay

131 Westinghouse have scored and ranked the options for abating strontium-90 and ion exchange scores the highest followed by precipitation/filtration, however Westinghouse recognise that this is not particularly effective for strontium. The AP1000 design includes ion exchange.

132 Westinghouse have provided little detail on the techniques for abatement of strontium-90. Westinghouse considered adsorption and wet scrubbing but no application of adsorption or wet scrubbing of SR-90 removal has been found. We consider the optioneering study contains insufficient detail to identify the best option however we recognise that ion exchange is likely to be the best option.

7.4 Iodine-131

133 Westinghouse predict that on average 0.015 GBq y^{-1} of iodine-131 will be discharged in aqueous radioactive waste.

134 Westinghouse have not provided information for iodine-131 discharges in aqueous radioactive waste but we understand that it has been included in aggregated data for discharges of 'other isotopes' and similarly in their assessment of the impact of 'other isotopes' in aqueous radioactive waste. Westinghouse estimate the impact of 'other isotopes' in aqueous radioactive waste to be 9.8E-03 μSv y^{-1} to the fisherman family. (ER Table5.2-1)

135 Westinghouse have considered the following abatement techniques for iodine-131 in aqueous radioactive waste:

a) Demineralisation – Westinghouse has not provided information about the removal efficiency of the demineraliser beds with respect to iodine-131 in aqueous radioactive waste.

b) Chemical trapping – Westinghouse claim that iodone-131 can be trapped by adding chemicals such as hydrazine hydrate in the spray system or reactor sump but no further information has been provided.

136 Westinghouse have scored the options against the attributes in their BAT assessment and the highest scoring option is demineralisation.

137 Westinghouse have provided little detail on the techniques for abatement of iodine-131 in aqueous radioactive waste. We consider the optioneering study contains insufficient detail to identify the best option, however we recognise that the use of demineralisers may contribute to a reduction of the amount of iodine-131 in aqueous radioactive waste.

138 ER Table 3.4-6 gives the expected annual release of iodine radionuclides in liquid effluent discharged to the sea as:

a) iodine-131 – 0.015 GBq, half-life 8 days;

b) iodine-132 – 0.020 GBq, half-life 2.3 hours;

c) iodine-133 – 0.029 GBq, half-life 20.8 hours;

d) iodine-134 – 0.006 GBq, half-life 52.6 minutes;

e) iodine-135 – 0.024 GBq, half-life 6.61 hours.

139 The short half-lives of the iodine radionuclides other than iodine-131 mean they rapidly become insignificant and only iodine-131 is usually considered.

140 From our limited information about PWRs operating over the last 10 to 15 years we conclude that the range for the sector in terms of discharge to water of iodine radionuclides is 0.01 to 0.03 GBq per annum for a 1000 MWe power station (see Annex 3). The predicted aqueous discharge of iodine 131 for the AP1000 is 0.015 GBq which is within this range. We conclude that aqueous discharge of iodine radionuclides from the AP1000 is comparable to other power stations across the world.

141 Westinghouse do not propose an annual disposal limit to sea for iodine radionuclides.

142 Westinghouse have not assessed the impact in terms of dose resulting from the disposal of iodine radionuclides by discharge to the sea. (ER table 5.2-1)

143 We do not consider that a specific limit should be set for iodine radionuclides in aqueous radioactive waste discharges but in the permit we grant we will require that operators demonstrate that BAT is used to minimise the amount of all radionuclides including iodine radionuclides discharged in liquid waste.

7.5 Caesium-137

144 Westinghouse predict that on average 0.023 GBq y^{-1} of caesium-137 will be discharged in aqueous radioactive waste. The discharges of caesium-137 in the highest 12 months of the 18 month cycle are estimated to be 0.031 GBq. Westinghouse estimate the impact of discharging 0.031 GBq of caesium-137 in 12 months will be 3.4E-03 μSv y^{-1} to the fisherman family (~0.1% of total dose to fisherman family). (ER Table 5.2-1)

145 Westinghouse have considered the following abatement techniques for caesium-137 in aqueous radioactive waste:

a) Demineralisation - mixed beds and cation beds can remove caesium isotopes. During normal operation the reactor coolant contains lithium hydroxide and the demineraliser in the CVCS used to routinely clean-up reactor coolant on-load can be saturated with lithium ions, making it less effective at removing some radionuclides including caesium-137. A cation resin bed demineraliser located downstream of the mixed bed demineralisers can be used intermittently to control the concentration of lithium-7 (pH control) and caesium concentration in the reactor coolant system.

b) Filtration – filtration can be used for the removal of insoluble species however most caesium radionuclides are water soluble therefore filtration has limited application for caesium removal.

c) No abatement – direct discharge of aqueous radioactive waste to the environment.

146 Westinghouse have scored the options against the attributes in their BAT assessment and the highest scoring option is demineralisation in terms of the proven effectiveness of the technology. Westinghouse claim that demineralisation is BAT for caesium-137. They recognise that demineralisation costs more than direct discharge and will produce secondary waste but that this is outweighed by reduction in doses to members of the public and environmental impact, bearing in mind that the secondary waste is highly likely to be in a waste form suitable for disposal as solid waste.

147 We consider that the techniques considered by Westinghouse for the abatement of caesium-137 in the AP1000 are sufficiently comprehensive and represent feasible proven techniques.

148 We consider that Westinghouse have demonstrated that BAT is used to minimise discharges of caesium-137 in aqueous radioactive waste from the AP1000.

149 Westinghouse predicts that the annual average discharge of caesium-137 from the AP1000 to sea will be 0.023 GBq. (ER Table 3.4-6)

150 Westinghouse propose a discharge limit for caesium-137 from the AP1000. They have predicted monthly discharges over an 18 month cycle and used data from the 12 months in which the discharges are highest (months 7 – 18) to calculate the representative 12 month plant discharge to be 0.0301 GBq. Westinghouse have applied our limit setting methodology to calculate the annual worst case plant discharge (WCPD) which they have rounded to give their proposed limit. (ERs6.1-3)

151 Westinghouse propose an annual limit of 0.05 GBq for caesium-137 in liquid discharges. (ER Table 6.1-6)

152 Westinghouse estimate that the radiological impact from the representative 12 month plant discharge of caesium-137 to sea will result in a dose to the local fisherman family of 3.4 E-03 μSv y^{-1}. (ER table 5.2-1)

153 We have independently calculated limits for caesium-137 discharges that we may grant and based on the information provided by Westinghouse for GDA our proposed disposal limit for caesium-137 by discharge to the sea is 0.05 GBq in any 12 rolling calendar months. The current limit for caesium-137 in aqueous radioactive waste from Sizewell B is 20 GBq.

154 Based on the information provided by Westinghouse for GDA our proposed quarterly notification level for caesium-137 is 0.018 GBq.

7.6 Plutonium-241

155 Westinghouse predict that on average 0.0814 MBq y^{-1} of plutonium-241 will be discharged in aqueous radioactive waste. The discharges of plutonium-241 in the highest 12 months of the 18 month cycle are estimated to be 0.108 MBq. Westinghouse estimate the impact of discharging 0.108 MBq of plutonium-241 in 12 months will be 2.76E-06 μSv y^{-1} to the fisherman family (~0.0001% of total dose to fisherman family). (ER Table 5.2-1)

156 Westinghouse have identified the following abatement options for plutonium-241:

a) Filtration/ion exchange

b) Evaporation

c) Fuel storage pond cooling and clean up system - The fuel storage pond water chemistry can be controlled to minimise fuel-clad corrosion and minimise the release of radioactivity into the pond water

d) Monitoring of discharges

e) Delay tank – delay tanks can be used to delay discharges to take advantage of radioactive decay

f) Adsorption

g) Wet scrubbing

h) No abatement – direct discharge of aqueous radioactive waste to the environment

i) Precipitation

157 Westinghouse have scored and ranked the options for abating plutonium-241 and monitoring of discharges scores the highest. Westinghouse claim that in the event of a higher than normal level of plutonium-241 in the aqueous radioactive waste the discharge would be terminated.

158 Westinghouse claim that the next highest scoring options which are filtration/ion exchange and the use of the fuel storage pond cooling and clean up system are included in the AP1000 design.

159 Westinghouse claim that the use of filtration and ion exchange and the use of the fuel storage pond cooling and clean up system along with monitoring of discharges is BAT for plutonium-241. Westinghouse claim that in the event of a higher than normal level of plutonium-241 in the aqueous radioactive waste, the discharge would be terminated.

160 We do not consider that monitoring of discharges is an abatement technique, however, we recognise that filtration/ion exchange and use of the fuel storage pond cooling and clean up system will provide abatement for plutonium-241.

161 Westinghouse predicts that the annual average discharge of plutonium-241 from the AP1000 to sea will be 0.00008 GBq. (ER Table 3.4-6)

162 Westinghouse propose a discharge limit for plutonium-241 from the AP1000. They have predicted monthly discharges over an 18 month cycle and used data from the 12 months in which the discharges are highest (months 7 – 18) to calculate representative 12 month plant discharge to be 0.000108 GBq. Westinghouse have applied our limit setting methodology to calculate the annual worst case plant discharge (WCPD) which they have rounded to give their proposed limit. (ERs6.1.3)

163 Westinghouse propose an annual limit of 0.0002 GBq for plutonium-241 in aqueous radioactive waste discharges ER Table 6.1-6

164 Westinghouse estimate that the radiological impact from representative 12 month plant discharge of plutonium-241 to sea will result in a dose to the local fisherman family of 2.7E-06 μSv y^{-1}. (ER table 5.2-1)

165 We do not consider that a specific limit should be set for plutonium-241 in aqueous radioactive waste discharges but in any permit we may grant we will require that operators demonstrate that BAT is used to minimise the amount of all radionuclides including plutonium-241 discharged in aqueous radioactive waste. Plutonium-241 is included in the limit we set for 'all other radionuclides (excepting tritium, carbon - 14, cobalt-60 and caesium-137)'.

166 There is no limit for plutonium-241 in aqueous radioactive waste from Sizewell B however there is a requirement to use BAT to minimise discharges.

7.7 Beta emitting particulates

167 Westinghouse predict that beta emitting particulates, also referred to as fission and activation products, will be present in aqueous radioactive waste in the following amounts (BAT Assessment form 9):

Radionuclide	Average annual activity GBq	Activity on highest 12 months of 18 month cycle (GBq)	Dose to fisherman family (μSv y^{-1})	% of total dose to fisherman family
Cobalt-58	4.1E-01	5.44E-01	2.9E-02	
Cobalt-60	2.3E-01	3.01E-01	6.4E-01	
Iron-55	4.9E-01	6.42E-01	1.5E-04	
Nickel-63	5.4E-01	6.91E-01	1.9E-03	
Total			6.8E-01	~30

168 Westinghouse have provided information on the abatement options for beta particulate activity (cobalt-58, cobalt-60, iron-55 and nickel-63) in the AP1000:

a) Flocculation

b) Particulate separation

c) Effluent monitoring - to ensure effective use of filters

d) No abatement - direct discharge of aqueous radioactive waste to the environment

e) Evaporation

f) Precipitation/filtration

g) Hydrocyclone

h) Mixed bed demineralisers

i) Ultrasonic fuel cleaning

j) Minimising plant shutdown

169 Westinghouse have not supplied detailed information on the options but have scored and ranked them against their chosen attributes.

170 Westinghouse claim the most effective option for abating beta emitting particulates in aqueous radioactive waste is to minimise plant shutdowns because plant shutdowns perturb the corrosion characteristics of the primary circuit and may cause more corrosion products to enter the coolant. This, taken with an increase in the amount of effluent for processing as a result of additional letdown, increases the amount of beta emitting particulates in the aqueous radioactive waste. In addition the AP1000 design includes mixed bed demineralisers.

171 Westinghouse claim that the other techniques they have considered are not particularly effective and would be costly to implement and are not included in the AP1000 design.

172 We consider that the techniques considered by Westinghouse for the abatement of fission and activation products in the AP1000 are sufficiently comprehensive and represent feasible techniques at this stage however we recognise that techniques may be developed in the future which may be worthy of consideration.

173 Westinghouse predicts that the annual average discharge of the following activation and fission products from the AP1000 to sea will be: (ER Table 3.4-6 and ER Table 6.1.6)

a) iron-55 – 0.49 GBq

b) cobalt-58 – 0.41 GBq

c) cobalt-60 – 0.23 GBq

d) nickel-63 – 0.54 GBq

e) other activation and fission products - 1 GBq

174 Westinghouse has proposed a discharge limits for activation and fission products from the AP1000. They have predicted monthly discharges over an 18 month cycle and used data from the 12 months in which the discharges are highest (months 7 – 18) to calculate representative 12 month plant discharge (Table 6.1-6). Westinghouse have applied our limit setting methodology to calculate the annual worst case plant discharge (WCPD) which they have rounded to give their proposed limit. (ERs6.1-3)

175 Westinghouse have proposed annual limits for the following radionuclides in liquid discharges: (ER Figure 6.1-3 and ER Table 6.1-7)

a) iron-55 – 1.0 GBq

b) cobalt-58 – 0.9 GBq

c) cobalt-60 – 0.5 GBq

d) nickel-63 – 1.0 GBq

e) other activation and fission products - 2 GBq

176 From our examination of historic discharges from European and US PWRs operating over the last 10 to 15 years we conclude that the range for the sector in terms of discharge to water of fission and activation products is of 0.5 to 5 GBq per annum for a 1000 MWe power station (see Annex 3 of our Consultation Document for AP1000). The predicted annual average aqueous discharge of other radionuclides from the AP1000 is within this range. We conclude that the aqueous discharge of other radionuclides from the UK AP1000 is comparable to other power stations across the world.

177 Westinghouse estimate that the radiological impact from the representative 12 month plant discharge of iron-55, cobalt-58, cobalt-60 and nickel-63 to sea will result in a dose to the local fisherman family of 0.67 μSv y^{-1}. (ER table 5.2-1)

178 We have independently calculated limits for discharges of cobalt-60, and 'all other radionuclides (excepting tritium, carbon -14, cobalt-60 and caesium-137)' that we may grant and based on the information provided by Westinghouse for GDA our proposed disposal limits for activation and fission products discharged to the sea in any 12 rolling calendar months are:

a) Cobalt-60 – 0.5 GBq

b) All other radionuclides (excepting tritium, carbon-14, cobalt-60 and caesium137) taken together – 5 GBq

179 There is no individual limit for cobalt-60 in aqueous radioactive waste from Sizewell B however there is a requirement to use BAT to minimise discharges.

180 The current limit for all other isotopes without limits in aqueous radioactive waste from Sizewell B is 130 GBq.

181 Based on the information provided by Westinghouse for GDA our proposed quarterly notification level for cobalt-60 is 0.18 GBq and for ‘all other radionuclides (excepting tritium, carbon-14, cobalt-60 and caesium137) taken together’ is 1.8 GBq.

8 BAT Assessments for Aqueous Radioactive Waste Treatment and Abatement

182 Informed by their BAT optioneering assessment, Westinghouse claim there are a number of measures in the design of the AP1000 which will represent the best available techniques to prevent or minimise the discharges of aqueous radioactive waste including:

a) Ion exchange to minimise the discharges of carbon-14 and strontium-90

b) Demineralisation to minimise the discharges of caesium-137

c) Ultrasonic fuel cleaning to minimise the discharges of beta emitting particulates

d) Minimising plant shutdown to minimise the discharges of beta emitting particulates and tritium

e) Filtration/ion exchange to minimise the discharges of plutonium-241

f) Use of the fuel storage pond cooling and clean up system to minimise the discharges of plutonium-241

g) Monitoring of discharges to minimise the discharges of plutonium-241

h) Use of a condenser to minimise the discharges of gaseous tritium and divert tritium to the aqueous waste stream where its impact is estimated to be lower

183 Westinghouse state that the AP1000 design does not include any abatement to minimise the discharges of carbon-14 and tritium which will be discharged directly into the environment.

184 Our Radioactive Substances Regulation Environmental Principle RSMDP4 on processes for identifying BAT requires that best available techniques should be identified by a process that is timely, transparent, inclusive, based on good quality data, and properly documented.

185 We consider that the BAT assessment carried out by Westinghouse is qualitative in nature and there is a lack of data provided to back up scoring and ranking. Additionally Westinghouse have considered the use of techniques in isolation and have not considered the use of combinations of techniques. Westinghouse have not included a consideration of the effect of each technique on other waste streams in detail. For example, diversion of carbon-14 from the aqueous waste stream to the atmospheric waste stream may reduce doses to members of the public but this may be offset by other factors such as cost.

186 The BAT assessment does not include a demonstration of the optimisation of such issues as filter pore size and ion exchange column capacity which may affect the efficiency of the removal of certain radionuclides. We recognise however that where filtration and ion exchange are provided for in the design, there may be scope to select filter and ion exchange medium to optimise radionuclide removal efficiency at the operational stage.

187 We consider that Westinghouse have identified a range of accepted techniques for the treatment of aqueous radioactive waste which are similar to those used in comparable reactors. Westinghouse have not proposed any novel techniques for the treatment of aqueous radioactive waste.

188 Whilst we recognise the overall outcome of the BAT assessment may be valid based on the information provided, the outcomes have not been demonstrated conclusively. However, taking into account the low magnitude of the impact of aqueous radioactive waste we believe the BAT assessment is suitable for purpose at this stage. We believe the BAT assessment should be kept under review to reflect developments in techniques to prevent and minimise the production of aqueous radioactive waste.

9 Further consideration of techniques for discharge abatement

189 Westinghouse have considered certain techniques for discharge abatement in more detail and have reached the following conclusions:

9.1 Ion Exchange vs. Evaporation

190 The relative merits of ion exchange and evaporation have been evaluated by Westinghouse. Westinghouse have identified that in Europe many nuclear reactors are located on major rivers and not on coastal sites. Such river locations may restrict the volume and levels of radioactivity in discharges of aqueous radioactive waste and it is common for these reactors to be equipped with evaporators to minimise the radioactive aqueous discharges. The standard AP1000 design does not have evaporators.

191 Westinghouse have carried out an assessment of natural circulation evaporators, forced circulation evaporators and ion exchange techniques to identify which technique represents BAT for the AP1000. The assessment they have carried out considers the maturity of the technology, its effectiveness, flexibility, costs, safety, reliability, operability and maintainability, occupational radiation exposure, secondary solid waste production and ease of decommissioning.

192 The outcome of the Westinghouse assessment is as follows:

'Compared to traditional evaporator-based liquid radioactive waste system, the ion-exchange based AP1000 system provides effectiveness and simplicity, and will tend to minimise operator doses and solid radioactive waste arisings. The complexity of the traditional evaporator design leads to significant maintenance with associated occupational radiation exposure, and also gives more opportunity for operator errors. The relatively passive nature of the ion-exchange based AP1000 system provides effective operation without the issues of the evaporator-based system and at lower capital and operating cost.

At Sizewell B two evaporators were constructed; one for recycling boric acid from the reactor coolant system, and one for abatement of aqueous radioactive waste. Evaporation of aqueous for either purpose is not currently considered BPM or ALARP and the evaporators are not in use. This is because the benefit of reducing aqueous discharges, in terms of the consequent small reduction of public dose, is much less than the potential harm of increased operator doses. In addition, the small reduction in public dose would not justify the cost of processing (evaporator and encapsulation) and the cost of providing sufficient high quality steam to run the evaporators. The ion exchange treatment process has been shown to effectively control off-site discharges.

For the generic site it has been demonstrated that the AP1000 effluent discharges can be released to the coastal environment without contributing excessively to marine ecosystem dose rates.

193 *It is concluded that the proposed WLS treatment system using ion exchange beds and filtration rather than evaporation is BAT.'*

9.2 Boron Discharge vs Boron Recycle

194 Westinghouse report that US reactor designers and operators have observed a capital and operating cost benefit in the reduced use of boron, as well as a major reduction in the complexity of the plant.

195 The AP1000 adopts several approaches which minimise the production of aqueous radioactive waste. Westinghouse claim that the use of mechanical shim control

rather than chemical shim control during normal load follow operations substantially reduces the quantities of boron used as a moderator. They claim this in turn reduces the amount of boron that needs to be removed from the reactor coolant water and therefore reduces the amount of aqueous radioactive waste produced.

196 Westinghouse claim that the AP1000 is designed such that it does not require a high quality boron source. Natural boron is used rather than enriched boron which contains enhanced levels of boron-10 and this reduces the economic incentive for recycling boron.

197 The outcome of the Westinghouse assessment is as follows:

'Boron recycling requires a significant amount of additional equipment. The borated water cannot be reused until the start of the next fuel cycle and must be stored for long periods. This storage presents an additional safety issue and an additional source of operator dose which is not considered ALARP. The additional equipment also presents increased operator dose during maintenance and decommissioning. Assuming the monitor tanks contain water with the upper limit of 2700mg/l of boron and that the effluent is discharged at 22.7m3/h into the seawater cooling return flow of 36275m3/h, the boron concentration in the cooling return would be increased by 450 µg/l. At an average aqueous radioactive waste effluent flow rate of 8m^3/d, such a discharge would only occur for 128 hours per year.

It is concluded that the boron discharge is negligible in relation to the annual average Environmental Quality Standard of 7000µg/l for the protection of saltwater life and that discharge of boron to seawater meets BAT and ALARP criteria.'

198 We expect that the capability to include boron recycle in the AP1000 design should be kept under review. We have, therefore, made an other issue that a BAT assessment should be provided at site-specific permitting to demonstrate whether boron recycling represents BAT.

199 HSE would be involved in review of any proposal from Westinghouse to adopt Boron recycling since this could impact on their assessments of reactor chemistry and operator dose.

9.3 Cartridge Filtration vs Cross Flow Filtration

200 The AP1000 liquid radioactive waste system incorporates an after filter downstream of the ion exchangers to collect particulate matter, such as resin fines. The disposable filter cartridges have a design filtration efficiency of 98% removal of 0.5 µm particles. Westinghouse claim that the radioactive particulate load in the liquid radioactive waste system influent is already reduced by passage through the pre-filter, deep bed filter and three ion exchange beds before the after filter. The use of cartridge filters offers a low pressure system that is suitable for the low flow rates (~8m^3/day) associated with the liquid radioactive waste system. The filters are readily replaceable and treated as LLW.

201 Westinghouse state that cross-flow filtration techniques of microfiltration, ultrafiltration, nanofiltration and reverse osmosis potentially offer increasingly effective particulate removal efficiency (ranging from 0.1 µm to <0.001 µm) compared to cartridge filtration. All these techniques use membrane processes which use the pressure difference across the membrane to segregate an aqueous fraction that permeates through a membrane from a concentrate which is retained.

202 The outcome of the Westinghouse assessment is as follows:

'*The disadvantages of these processes are as follows:*

a) *High pressure systems to drive the filtration process which carries with it increased potential for leaks. The pressure requirements increase as follows: microfiltration < ultrafiltration < nanofiltration < reverse osmosis.*

b) *Complicated return, recycling and bleed system designs to deal with the concentrate stream.*

c) *Polymeric membranes used, particularly in ultrafiltration, nanofiltration and reverse osmosis, are subject to degradation by decay of captured radioactive particulates.*

d) *The complexity of these systems relative to the proposed cartridge filtration system has the potential for greater levels of maintenance and higher associated operator dose.*

e) *More equipment that will become radioactive waste during decommissioning.*

f) *Higher capital and operating costs than cartridge filtration.*

It is concluded that the proposed use of cartridge filters is BAT for filtration after the ion exchange beds.'

10 Aqueous waste discharge systems in the AP1000 design

203 We have identified four effluent release points for the AP1000 and allocated references as below (see ER Figure 6.2-2):

a) W1 – discharge for liquid radwaste monitor tanks serving the liquid radioactive waste system (WLS);

b) W2 – discharge line of the wastewater system (WWS) from the wastewater retention basin;

c) W3 – discharge line of the circulating water system (CWS);

d) W4 – discharge line of the service water system (SWS).

204 Treated radioactive effluent from the liquid radioactive waste system is collected in 6 monitor tanks, each of 57 m^3, located in the radwaste building. Westinghouse claim that the average daily radioactive liquid waste arisings are approximately 8 m^3, the monitor tanks will thus provide up to 42 days potential storage capacity in normal operation. This storage period will be reduced for short periods during higher discharges associated with boron dilution near the end of core life and during RCS heat up following refuelling. (ERs3.4.3.6)

205 There are no direct continuous discharges to the sea. Westinghouse claim that the release of treated aqueous waste from any monitor tank to the environment will be undertaken only if sampling of the tank contents indicates that such a release would comply with any permit in force at the time. A sample of the proposed discharge will be taken from the monitor tank and analysed prior to discharge. A record will be kept of planned discharges of aqueous radioactive waste. If the effluent does not meet the limitations and conditions of the relevant permit it will be returned to a waste hold-up tank or subject to further treatment by recirculation through the filters and ion exchangers.

206 In order to provide real time information, the design includes a radiation monitor located on the common discharge line downstream of the monitor tanks. The radiation monitor will provide a signal to terminate aqueous radioactive waste releases if the radioactivity of the discharge in the line exceeds a predetermined set point. If an unexpected high level is detected, the isolation valve in the discharge line will automatically close to prevent any further discharge from the liquid radioactive waste system and an alarm will sound. Additionally the monitor tank pumps will be stopped automatically.

207 The monitor tank discharge pumps have a design flow rate of 22.7 $m^3\ h^{-1}$. The final common discharge line is fitted with a flowmeter and sampler to provide permit compliance data, our release point W1.

208 The disposal route is initially to join the high volume direct sea water cooling flow (136,275 $m^3\ h^{-1}$), the combined flow is then sent to an outfall discharging some distance out from the shore. While we do not accept dilution as a reduction technique, once discharges have been minimised by other techniques, pre-dilution in a large flow before discharge to the environment is acceptable to reduce initial concentrations before dispersion in the receiving waters.

209 Westinghouse claim that the AP1000 design will be able to accommodate various systems with administrative procedures and interlocks to avoid inadvertent discharge from monitor tanks before sampling and analysis has confirmed the suitability of the aqueous radioactive waste for discharge, and discharge of a monitor tank whilst filling or further processing is being undertaken. Westinghouse claim that such systems and administrative measures are site specific and will be defined by the operator. We will consider proposals for such systems and administrative procedures during the site specific permitting phase.

210 The design and location of outfalls will be a highly site specific issue. The Operator for each specific site will need to demonstrate by modelling that the outfall proposed will be BAT for adequate dispersion in local waters.

211 The wastewater system, the circulating water system and the service water system should contain only non-radioactive wastewaters in normal operation. Only in the event of steam generator tube leaks is there any possibility of these waters being contaminated with radioactivity.

212 The wastewater system collects normally non-radioactive waste water into the turbine building sumps. There is a radiation monitor on the common discharge line from the sumps to the wastewater retention basin (WWRB). If activity is detected the wastewater is diverted to the liquid radioactive waste system (WLS).

213 The contents of the wastewater retention basin are only discharged intermittently after sampling and analysis to confirm discharge can be permitted. The discharge line is fitted with a flowmeter and sampler to provide permit compliance data, our release point W2.

214 The circulating water system is a high volume once through seawater cooling system for the main condensers. There will be a sampling point on the discharge of this system, our release point W3. We believe the risk of radioactivity at this point will be minimal and do not intend to impose any disposal limits. Periodic spot sampling will be required at W3 to confirm no contamination has taken place.

215 The service water system is a much lower volume once through seawater cooling system for cooling water used for cooling components in the turbine building. There will be a sampling point on the discharge of this system, our release point W4. There will also be a continuous radiation monitor installed at W4. If radiation levels detected are above acceptable levels the operator will need to take action. We believe the risk of radioactivity at this point will be minimal and do not intend to impose any disposal limits. Periodic spot sampling will be required at W4 to confirm no contamination has taken place.

11 Estimates of annual aqueous radioactive waste discharges from the AP1000 design

216 Estimates of annual aqueous radioactive waste discharges have been provided based on proprietary calculations determined from the revised GALE Code (NUREG-0017)). We raised a Technical Query (TQ-AP1000-146) on 1 June 2009 requesting Westinghouse to:

a) provide further information on the derivation of values for annual discharges of aqueous radioactive waste;

b) to clarify and reconcile the date in the DCD and in various submission documents;

c) to explain the adjustment applied to aqueous radioactive waste discharge values in the DCD to take into account contingencies; and

d) to reconsider their approach to deriving 12 month rolling discharge values.

217 Westinghouse responded on 14 July 2009 and set out their approach to estimating aqueous radioactive waste discharges in which they benchmarked values derived using the current GALE methodology against operating plant data. The approach included a review of aqueous radioactive waste discharge data from operational plants, and a comparison of that data with values derived using the GALE code, and then the modification of either input parameters or the computer code to give results that reflect the actual plant data. Operating data from US plants relating to discharges made between 2001 and 2004 were used. Westinghouse claim that the comparison is appropriate as the data is fairly recent and reflects the waste management techniques and approaches that have been incorporated into the AP1000 design. They do not, however, take into account certain design improvements that have been made in the AP1000 design and on this basis Westinghouse claim that the estimates are likely to be conservative. Westinghouse claim the following design improvements are expected to result in lower discharges of aqueous radioactive waste:

a) fewer valves and components which reduces the number of potential leakage paths;

b) the use of zinc acetate in reactor water chemistry control;

c) the use of low or no cobalt materials;

d) state of the art primary coolant chemistry controls applied from beginning of plant life.

218 We noted in our assessment that the aqueous radioactive waste discharges data set out in the European DCD differed from that in the Environment Report and Westinghouse claim this is as a result of the changes made to the GALE code during the benchmarking exercise, and that the data in the Environment Report is more realistic than that in the DCD. Westinghouse intend to amend the data relating to estimates of aqueous radioactive waste discharges in the European DCD at the next revision. With this in mind we have considered the data provided in the Environment Report in our assessment.

219 As a result of Technical Query TQ-AP1000-146 Westinghouse amended their estimates of 12 month rolling values for aqueous radioactive waste discharges to represent the values for the 12 months at the end of each 18 month cycle when discharges are highest. The revised estimates were included in the Environment Report at Table 6.1-6.

220 Westinghouse have provided data for annual average water discharges which take no account of short term variability of releases. Summarised data is given in Table 8 and further detailed data is given in Annex 1.

Table 8: Estimate of annual activity of aqueous radioactive waste discharges

Radionuclide	Estimate of annual activity to be discharged (GBq) averaged over an 18 month cycle
Tritium	3.34E+04
Carbon 14	3.30E+00
Cobalt 60	2.27E-04
Caesium 137	2.28E-05
Other radionuclides taken together (excepting tritium, carbon 14, cobalt 60 and caesium 137)	2.21E+00

221 The data includes a contingency for radioactivity that may be discharged following operational fluctuations by virtue of the benchmarking carried out by Westinghouse which used operational data which should reflect operational fluctuations.

222 As fuel burnup increases over the fuel cycle, less boron is needed in the reactor cooling water. This adjustment in boron concentration is achieved by bleeding borated water from the reactor coolant system and replacing it with unborated water. A larger volume of water needs to be removed each month, and therefore, the radioactive discharges increase each month of the cycle. This results in the variability in activity in aqueous discharges from the reactor coolant by month over each cycle. In general total aqueous discharge activity rises on a month by month basis throughout the cycle as shown in Table 9.

Table 9: Predicted activity in aqueous discharges (GBq) by month of cycle

Month	Total predicted activity in aqueous discharges (GBq)
1	2473
2	2481
3	2489
4	2499
5	2510
6	2522
7	2537
8	2554
9	2574
10	2600
11	2631
12	2671
13	2724
14	2799
15	2909
16	3092
17	3455
18	4550
Total	**50070**

223 Profiles of aqueous discharges on a month by month basis are given in the Environment Report for tritium, carbon-14, iron-55, cobalt-58, cobalt-60, nickel-63, strontium-90, caesium-137, plutonium-241 and other particulates. The activity of each of these radionuclides in aqueous radioactive waste discharges all follow a similar trend and rise towards the end of the 18 month cycle, with the largest monthly increases in month 17 and 18. Westinghouse claim this is because the adjustment in boron concentration is achieved by bleeding borated water from the reactor coolant system and replacing it with unborated water. A larger volume of water needs to be removed each month, and therefore, the radioactive discharges increase each month of the cycle.

224 The volume of liquid from non-reactor coolant system sources is expected to be almost constant during each month of the cycle, and therefore, the radioactive non-reactor coolant system discharges are expected to be constant.

11.1 Comparison of radionuclides in AP1000 data with the requirements of EU Commission Recommendation 2004/2/Euratom

225 Recommendations for the radionuclides to be determined in aqueous discharges and the relevant limits of detection are specified in EU Commission Recommendation 2004/2/Euratom of 18 December 2003 on standardised information on radioactive airborne and aqueous discharges into the environment from nuclear power reactors and reprocessing plants in normal operation (EC, 2004).

Table 10: Radionuclides to be determined in aqueous discharges as specified in Commission Recommendation 2004/2/Euratom

Key Nuclides	Requirement for the detection limit (in Bq m^{-3})
H-3	1E+05
S-35	3E+04
Co-60	1E+04
Sr-90	1E+03
Cs-137	1E+04
Pu-239 + Pu-240	6E+03
Am-241	5E+01
Total alpha	1E+03

226 Westinghouse have provided predicted annual discharges for a range of radionuclides including tritium, cobalt-60, strontium-90, caesium-137, plutonium-239, plutonium-240, americium-241 and other nuclide-specific alpha emitters. Data for sulphur-35 has not been provided as this is relevant only to gas cooled reactors. Total alpha data has not been provided, however this is required only if nuclide-specific information on alpha-emitters is not available.

227 We consider that the range of radionuclides for which Westinghouse have provided data on predicted activity levels in aqueous discharges is adequate for assessment under the generic phase of the GDA process.

11.2 Comparison of AP1000 Aqueous Radioactive Waste Discharges with Other European Pressurised Water Reactors

228 Westinghouse have compared the AP1000 predicted aqueous radioactive waste discharges from the AP1000 with published discharges from European nuclear reactors operating over the period 1995-1998. They claim that the data indicates that the predicted AP1000 discharges of tritium are similar to Sizewell B discharges, but above the European average for all European PWRs. Westinghouse claim that the predicted AP1000 tritium discharges are less than those from Magnox and AGRs, but higher than discharges from BWRs. They also claim that it is practically very difficult to reduce discharges of tritium and that the radiological impact of tritium is relatively small and radiological impact of discharges is usually very low.

229 Westinghouse have compared the predicted non-tritium radioactive aqueous discharges from the AP1000 against published data for European nuclear power stations between 1995 and 1998 and claim that the AP1000 emissions are predicted to be approximately 50% of the average PWR discharges. The predicted discharges are also considerably lower than the average Magnox, AGR, BWR and Sizewell B discharges.

230 We have compared aqueous discharges from the AP1000 with historic discharges from European and US PWRs operating over the last 10 to 15 years and the results are shown in Table 11.

Table 11: Comparison of aqueous discharges from the AP1000 with historic discharges from European and US PWRs operating over the last ten to 15 years

Radionuclides or group of radionuclides	Average annual discharges (GBq) 12/18 of discharges over 18 month cycle	Average annual discharges normalised to power (GBq/1000MWe) Based on 1117MWe	Representative annual discharges (GBq) Discharges in highest 12 months of 18 month cycle	Representative annual discharges normalised to power (GBq/1000MWe) Based on 1117MWe	Normal operating range (GBq/1000MWe)	Comments
Tritium	33400	29901	35090	31414	2000 - 30000	Just above top of range but impact low
Carbon-14	3.3	2.95	4.42	3.95	3 - 45	Within range
Cobalt-60	0.23	0.206	0.301	0.269	<1 to 15 for all fission and activation products	Adding Co-60, Cs-137 and others give 2.94GBq which is within the benchmark range
Caesium-137	0.023	0.0206	0.0301	0.0269		
All other radionuclides (excepting tritium, carbon-14, cobalt-60 and caesium137)	2.28	2.04	2.95	2.64		
Iodine-131	0.015	0.0134	Not given	-	0.01 – 0.03	Within range (assuming benchmark data refers to I-131)

11.3 Orphan aqueous waste

231 Westinghouse claim that the liquid radioactive waste system is designed to handle most aqueous effluents and other anticipated events using installed equipment. However, for events occurring at a very low frequency or producing effluents not compatible with the installed equipment, temporary equipment may be brought into the radioactive waste building mobile treatment facility truck bays. Any treatment of aqueous waste by mobile or temporary equipment will be controlled and confirmed by plant procedures.

232 Mobile equipment connections are provided to and from various locations in the liquid radioactive waste system to allow mobile equipment to be used in series with installed equipment or as an alternative to it. Treated aqueous liquids would be returned to the liquid radioactive waste system or removed from the site for disposal elsewhere.

233 We recognise that some waste will not be compatible with the aqueous radioactive waste treatment system and that it is important that such waste is segregated until it is either treated in such a way as to make it compatible with the aqueous radioactive waste treatment system or disposed by of by some other route. Currently there are limited opportunities in the UK for the disposal of non-aqueous liquid radioactive waste to a third party. Such waste might be amenable to solidification and disposal with solid radioactive waste subject to the waste form being acceptable or be disposed by alternative techniques such as incineration. Incineration facilities do exist which might be suitable for the disposal of certain types of non-aqueous liquid radioactive waste. As part of the site specific permitting phase we will require the site operator to provide information to demonstrate that disposal routes exist for such waste and evidence that the site operator has gained agreement in principle for disposal of the waste by third parties.

234 **We conclude that the availability of appropriate mobile equipment for waste, which is not compatible with the liquid radioactive waste system has not been demonstrated. We have made this an other issue that will need to be demonstrated at site-specific permitting.**

12 Measures for the prevention of contamination in the AP1000 design

235 Westinghouse claim that the welded construction of the liquid radioactive waste system will minimise leakage, and that air-operated diaphragm pumps, or pumps with mechanical seals which are used will minimise system leakage, in the form of releases of radioactive gas that might be entrained in the leaking fluid, to the building atmosphere.

236 Westinghouse claim that provisions are made to control spills of radioactive aqueous liquids due to tank overflows. The design includes provisions for tank level indication, alarms, and overflow disposition for liquid radioactive waste system tanks outside containment. In addition, the radioactive waste collection tanks (i.e., the effluent hold-up tanks, waste hold-up tanks, and chemical tank) are located within the auxiliary building, which is well sealed and equipped with an extensive floor drain system. The radioactive waste monitor tanks are located in the auxiliary building and in the radioactive waste building, which has a well sealed, contiguous basemat with integral curbing and a floor drain system. Routing of both of the auxiliary building and radioactive waste building floor drain systems are to the liquid radioactive waste system to eliminate the potential for undetected tank leakage to the environment.

237 Westinghouse claim that the monitored radioactive waste discharge pipeline is engineered to preclude leakage to the environment. This pipe is routed from the auxiliary building to the radioactive waste building (the short section of pipe between the two buildings is fully available for visual inspection as noted above) and then out of the radioactive waste building to the discharge point. The exterior piping is designed to preclude inadvertent or unidentified releases to the environment; it is either enclosed within a guard pipe and monitored for leakage, or accessible for visual inspection. No valves, vacuum breakers, or other fittings are incorporated outside of buildings. This greatly reduces the potential for undetected leakage or unauthorised discharge to the environment.

13 Proposed discharge limits

238 Our limit setting guidance sets out a number of criteria which we will use to identify radionuclides and/or groups of radionuclides which will be subject to numerical limits on activity in discharges of aqueous radioactive waste. The guidance sets outs that limits should be set on radionuclides and/or groups of radionuclides which:

a) are significant in terms of radiological impact for humans and non human species, including radionuclides that may be taken up in food;

b) are significant in terms of the quantity of radioactivity discharges, whether or not they are significant for radiological impact;

c) have long radioactive half-lives, that may persist and /or accumulate in the environment and that may contribute significantly to collective dose;

d) are good indicators of plant performance and process control; or

e) provide for effective regulatory control and enforcement.

239 In addition the guidance states that discharge limits should be set so as to minimise the 'headroom' between the actual levels of discharges expected during normal operation and the limits themselves.

240 The guidance also states that discharges from new plant should be capped at the levels for which approval is first given for full operation however caps may be reconsidered in the light of operating experience.

241 Notification levels may be set to contribute to the information required to demonstrate BAT.

242 The discharge limit setting guidance sets out our methodology for assessing proposed discharges in order to set annual discharge limits in terms of a rolling 12 month period. We have considered whether limits could be set on the basis of different timescales, for example, activity limits set per cycle or per calendar year.

243 Discharge limits set for a rolling 12 month period provide an element of flexibility for the site operator with respect to normal fluctuation in discharges on a month by month basis whilst exerting a smoothing effect. This encourages operators to ensure that discharges are made, wherever possible, at relatively consistent levels and to avoid short term elevations in the amount of radioactivity discharged which may increase the impact on humans or non human species. However, as part of our assessment of the impact of discharges we have assessed the impact of short term releases above the normal routine levels in order to determine the impact of any foreseeable elevated short term releases on humans. The outcome of this assessment is presented on our Dose Assessment Report (see Environment Agency, 2010d).

244 Discharge limits set on a rolling 12 month basis also allow derivation of information about discharges in any calendar year and such information is used to assess impact in terms of dose which is generally expressed in terms of dose in a calendar year. Additionally discharge limits set on a 12 month rolling basis allow reporting on annual discharges required under the OSPAR Convention and in UK publications such as the annual publication on Radioactivity in Food and the Environment (see Environment Agency et al, 2009).

245 Discharge limits set in terms of activity discharge per cycle add complexity to the regulatory process as in practice cycle lengths may vary from the operational aims of an 18 month cycle and it is difficult to set limits to take into account any unexpected changes in cycle length.

246 After consideration we are minded to set discharge limits on the basis of a 12 month rolling limit on the amount of activity that can be discharged to the environment. In our Process and Information document we required Westinghouse to provide information on discharges of aqueous radioactive waste on a month by

month basis to allow us to come to a view on appropriate 12 month rolling discharge limits on the activity in aqueous radioactive waste discharges.

13.1 Significant radionuclides

247 We raised a Technical Query (TQ-AP1000-164) on 17 June 2009 requiring Westinghouse to provide information on the radionuclides in aqueous radioactive waste which they considered to be significant bearing in mind the criteria set out in our Considerations Document (Environment Agency, 2009).

248 Westinghouse responded on 20 August 2009 and included the information in the Environment Report see section 6.1.1.

249 Westinghouse have provided information on expected discharges of radioactive waste on a month by month basis and proposed limits for discharges of aqueous radioactive waste for a range of radionuclides they consider to be significant.

250 Westinghouse claim that the radionuclides significant in terms of radiological impact are carbon-14, cobalt-60, tritium, and cobalt-58 because in the dose assessment carried out by Westinghouse these radionuclides individually contribute greater than 1% to annual doses to members of the public.

251 Westinghouse claim that tritium is also significant because it contributes greater than 10% of the total activity (in Bq) discharged in a year.

252 In addition Westinghouse claim that carbon-14, nickel-63, caesium-137 and plutonium-241 are significant because they either have long half lives and may persist or accumulate in the environment.

253 In terms of radionuclides which indicate plant performance, Westinghouse claim that iron-55 and nickel-63 are indicators of corrosion levels, caesium-137 is an indicator of fuel leaks and cobalt-60 is an indicator of particulate levels in the reactor coolant.

254 In terms of radionuclides which provide for effective regulatory control, Westinghouse claim that caesium-137 should be monitored continuously and tritium, cobalt-60, strontium-90 and caesium-137 should be monitored in grab samples.

255 We believe that the following radionuclides should be subject to individual limits:

a) Tritium – significant in terms of contribution to the amount of activity released. Tritium accounts for 35.09 GBq out of a total discharge of 35.1 GBq.

b) Carbon-14 – significant in terms of contribution to dose accounting for over 60% of dose to the critical group.

c) Cobalt-60 – significant in terms of contribution to dose accounting for around 30% of dose to the critical group and as an indicator of plant performance.

d) Caesium-137 - significant as an indicator of plant performance.

256 We believe that all other activity discharged should be limited in a grouped limit on all other radionuclides (excepting tritium, carbon-14, cobalt-60 and caesium-137) taken together.

13.2 Estimated discharges and proposed discharge limits

257 Westinghouse have used the methodology set out in our guidance (Environment Agency, 2005) which aims to consider expected discharges and apply a reasonable headroom to the discharge activities in order to provide some flexibility for reactor operations. Our guidance suggest applying factors to the expected discharges to take into account such things as operational fluctuations, increases in throughput or power output, plant ageing, legacy waste, decommissioning and plant improvements in order to derive the 'Worst Case Plant Discharges' (WCPD). Westinghouse claim that at this stage no account need be taken of increases in throughput or power output, decommissioning, legacy waste or plant improvements for their design.

258 Westinghouse have calculated the expected average discharges which would be made in month 7 to 18 of each 18 month cycle when discharges are expected to be highest and applied the following factors:

a) a factor of 1.5 to take into account operational fluctuations; and

b) a factor of 1.1 to take into account increases in discharges that may result from plant ageing.

259 Using these factors Westinghouse have estimated values for the WCPD for a range of radionuclides which are given in Table 12 and Table 13 and have calculated limits based on these values.

Table 12: Discharge limits for aqueous radioactive waste calculated by Westinghouse

	Average monthly discharge in months 7 to 18 of the cycle (TBq y^{-1})	Westinghouse estimate of Worst Case Plant Discharge (WCPD) (TBq y^{-1})	Annual Limit proposed by Westinghouse (TBq y^{-1})
Tritium	35.09	57.90	60
Other radionuclides (excepting tritium)	7.70E-03	1.27E-02	1E-02

Table 13: Breakdown of 'other radionuclides (excepting tritium) in discharge limits calculated by Westinghouse

	Average monthly discharge in months 7 to 18 of the cycle (TBq y^{-1})	Westinghouse estimate of Worst Case Plant Discharge (WCPD) (TBq y^{-1})	Annual Limit proposed by Westinghouse (TBq y^{-1})
Carbon-14	4.42E-03	7.30E-03	7E-03
Iron-55	6.42E-04	1.06E-03	1E-03
Cobalt-58	5.44E-04	8.97E-04	9E-04
Cobalt-60	3.01E-04	4.97E-04	5E-04
Nickel-63	6.91E-04	1.14E-03	1E-03
Strontium-90	3.24E-07	5.35E-07	5E-07
Caesium-137	3.01E-05	4.97E-05	5E-05
Plutonium-241	1.08E-07	1.78E-07	2E-07
Minor radionuclides (1)	1.07E-03	1.76E-03	2E-03
Total of other radionuclides (excepting tritium)	**7.70 E0-3**	**1.27E-02**	**1E-02**

(Note 1) Minor radionuclides are radionuclides not individually listed in Table 13 which are present at very low individual activity levels. The activity given in Table 13 for minor radionuclides is the activity of all such radionuclides taken together.

260 We have considered the information provided by Westinghouse and the independent dose assessment carried out on our behalf by Enviros Consulting Ltd (see Environment Agency, 2010e) taking into account our Considerations document (Environment Agency, 2009[1]) and limit setting guidance (Environment Agency, 2005). The Considerations document recommends that following criteria for identifying radionuclides or groups of radionuclides for which to set plant limits:

a) Critical group dose from the established worst case plant discharges (EWCPD) is greater than 1 μSv per year.

b) Collective dose from the EWCPD is greater than 0.1 man Sv.

c) The EWCPD exceeds 1 TBq per year.

d) The EWCPD exceeds 50% of the current limit (not applicable to a new plant on a new site).

e) Discharges of the radionuclide are a good indicator of plant performance or process control, or limits are otherwise felt to be necessary for effective regulatory control and enforcement.

261 We note from our independent dose assessment that there are no radionuclides in liquid discharges which contribute 1 μSv y^{-1} or more to the critical group dose at representative discharge levels. The highest contribution to the marine critical

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1 Our considerations document was superseded with the introduction of the Environmental Permitting Regulations (EPR 10) in April 2010 and the issue of related guidance documents. We will review our assessment against the EPR 10 guidance before we publish our final decision in June 2011

group dose is from carbon-14 which may contribute 0.96 μSv y^{-1} of which 0.685 μSv y^{-1} is from the ingestion of fish. The total marine critical group dose is calculated to be 0.977 μSv y^{-1}. Our assessment reports provide more detail (see Environment Agency, 2010d and 2010e).

262 Tritium is the only radionuclide with an EWCPD that exceeds 1 TBq y^{-1}. For this reason we consider that tritium should be subject to an individual discharge limit.

263 We consider that cobalt-60 and caesium-137 are good indicators of plant performance and process control. Cobalt-60 levels are a useful indicator of levels of corrosion in the primary circuit which in turn reflects the effectiveness of primary cooling water chemistry control. Caesium-137 is a useful indicator of fuel failures as it would be released in the event of a fuel pin failure in which the fuel cladding were breached. Both of these radionuclides are easy to detect and straightforward to measure and would provide a prompt indication of plant performance and process control. For these reasons we consider that cobalt-60 and caesium-137 should be subject to individual an individual discharge limit.

264 In order to ensure that the discharge of aqueous radioactive waste is controlled we consider a limit should be placed on all other beta or gamma emitting radionuclides (excepting tritium, carbon-14, cobalt-60 and caesium-137) taken together.

265 In summary we consider that aqueous radioactive waste discharge limits should be placed on:

a) Tritium – annual discharge exceeds 1 TBq.

b) Carbon-14 – whilst not exceeding 1 μSv y^{-1} carbon-14 accounts for 98% of the contribution to the critical group dose by all exposure routes.

c) Cobalt-60 – indicator of plant performance.

d) Caesium-137 - indicator of plant performance.

e) All other beta or gamma emitting radionuclides (excepting tritium, carbon-14, cobalt-60 and caesium-137) taken together.

266 Our limit setting guidance recommends the use of other factors to determine the headroom which is appropriate to allow operational flexibility and to take into account other conditions which might change during the period for which the limits would apply. The guidance recommends the use of the formula:

WCPD = (1.5 x D x T x A x B) + C + L + N - I

where

a) 1.5 is an Environment Agency-established factor which relates ‘worst case’ to average discharges and takes account of the requirement to minimise headroom.

b) D is the representative average 12-month plant discharge. The average excludes discharges due to faulty operation of plant but includes discharges arising from minor unplanned events.

c) T is a factor, which allows for any future increases in throughput, power output etc relative to the review period.

d) A is a factor, which allows for plant ageing – that is, for increases in discharges which result from changes within the plant as it ages that cannot be remedied or controlled by the operator.

e) B is a factor, which allows for other future changes that are beyond the control of the operator.

f) C is an allowance for decommissioning work beyond that carried out in the review period (and included in D).

g) L is an allowance for dealing with legacy wastes, beyond those dealt with in the review period (and included in D).

h) N is an allowance for new plant.

i) I is the reduction in discharges expected as a result of introducing improvement schemes before the new authorisation comes into force.

267 The discharge setting guidance recommends that WCPD for new plant should be a factor of 2 times the best estimate of discharges of radioactive waste, however in the light of the amount of detailed information available we have considered each factor in turn.

268 In terms of determining the headroom to be applied to expected discharges of aqueous radioactive waste we consider that the Environment Agency-established factor of 1.5 which relates 'worst case' to average discharges whilst taking into account the requirement to minimise headroom between the actual levels of discharges expected during normal operation and the limits themselves should be applied.

269 We consider that:

a) the representative average discharge levels (D) over 12 months used in limit setting should be the discharges averaged over the highest 12 months in the 18 month cycle which for the AP1000 are those predicted to be made in months 7 to 18 inclusive for all radionuclides.

b) T should be taken to be 1 as we do not foresee any changes in throughput or power output in the early stages of plant operation. Westinghouse have confirmed this to be the case.

c) A should be taken to be 1.1. We recognise that plant ageing is unlikely to result in increased discharges before the first review of any authorisation which we grant but we are mindful of the requirement in the Statutory Guidance that discharges from new plant should be capped at levels for which approval is first given for operation.

d) B should be taken to be 1 as we do not foresee any future changes in operation that are beyond the control of the operator.

e) C should be taken to be 0 as we do not foresee any decommissioning work will take place in the next decade or two.

f) L should be taken to be 0 as there is no legacy waste associated with new build of an AP1000.

g) N should be taken to be 10% because whilst the estimated discharges of aqueous waste from the AP1000 have been calculated using a USNRC recommended computer code (GALE code), and the estimated discharge levels have been compared to discharge levels from other PWRs throughout the world, there is no actual operational data for AP1000 discharges which could be used to verify the estimates. We consider an allowance of 10% should be made for the fact that the AP1000 is a new plant[2].

h) I should be taken to be 0 as at this stage there are no improvement schemes in place which might reduce discharges.

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[2] In ERs6.1.2 Westinghouse assume N=0. This is the only difference between the EA and WEC approach

270 We consider therefore that:

WCPD (TBq) = (1.5 x D x 1 x 1.1 x 1) + 0 + 0 + 10% – 0

Which simplifies to: WCPD = 1.815D

271 In cases where our calculations result in higher proposed limits than those proposed by Westinghouse we have reduced our proposed limits to the levels proposed by Westinghouse.

Table 14: Discharge limits for aqueous radioactive waste proposed by the Environment Agency

	Average monthly discharge in months 7 to 18 of the cycle (D) (TBq y^{-1})	Environment Agency Worst Case Plant Discharge (WCPD) (TBq y^{-1})	Annual Limit proposed by Environment Agency (TBq y^{-1})
Tritium	35.09	6.37E+01	60
Carbon-14	4.42E-03	8.02E-03	7.0E-03
Cobalt-60	3.01E-04	5.46E-04	5.0E-04
Caesium-137	3.01E-05	5..46E-05	5.0E-05
Other radionuclides (excepting tritium, carbon-14, cobalt-60 and caesium137) taken together	2.95E-03	5.35E-03	5.0E-03

Table 15: Breakdown of other radionuclides (excepting tritium, carbon-14, cobalt-60 and caesium137) in discharge limits proposed by the Environment Agency

	Average 12 month discharge (TBq y^{-1})	Environment Agency Worst Case Plant Discharge (WCPD) (TBq y^{-1})	Annual Limit proposed by Environment Agency (TBq y^{-1})
Iron-55	6.42E-04	1.17E-03	
Cobalt-58	5.44E-04	9.87E-04	
Nickel-63	6.91E-04	1.25E-03	
Strontium-90	3.24E-07	5.88E-07	
Plutonium-241	1.08E-07	1.96E-07	
Minor radionuclides (1)	1.07E-03	1.94E-03	
Total of other radionuclides (excepting tritium, carbon-14, cobalt-60 and caesium137) taken together	**2.95E-03**	5.35E-03	**5.0E-03**

272 In summary the discharge limits proposed by the Environment Agency are:

a) Tritium – 60 TBq in any 12 calendar months
b) Carbon-14 - 7 GBq in any 12 calendar months
c) Cobalt -60 – 0.5 GBq in any 12 calendar months
d) Caesium-137 – 5 MBq in any 12 calendar months
e) Other radionuclides (excepting tritium, carbon-14, cobalt-60 and caesium137) taken together – 5 GBq in any 12 calendar months

273 To ensure ongoing control of aqueous radioactive waste the Environment Agency considers it appropriate to include the requirement for notification of discharges at certain levels for specific radionuclides. This ensures that operator and regulator attention is drawn to those discharges where, over the specified time period, the discharges reach the notification level. We consider that it is appropriate to set quarterly notification levels for tritium, carbon-14, cobalt-60, caesium-137 and other radionuclides (excepting tritium, carbon-14, cobalt-60 and caesium137) taken together. We consider it appropriate to set the quarterly notification levels to be the sum of the estimated discharges in months 16 to 18 inclusive of the operating cycle as they are expected to be the highest. This means that should discharges exceed the quarterly notification level in any three calendar months the operator should notify the Environment Agency forthwith and take steps to investigate the cause of the exceedence and report the outcome of the investigation to the Environment Agency.

274 We consider the following quarterly notification levels to be appropriate:

Table 16: Proposed quarterly notification levels proposed by Environment Agency

	Annual Limit proposed by Environment Agency (TBq y^{-1})	Quarterly notification level proposed by Environment Agency (TBq in any calendar 3 months)	Decision basis
Tritium	60	11	Highest 3 months
Carbon-14	7.0E-03	2.5E-03	Highest 3 months
Cobalt-60	5.0E-04	1.8E-04	Highest 3 months
Caesium-137	5.0E-05	1.8E-05	Highest 3 months
Other radionuclides (excepting tritium, carbon-14, cobalt-60 and caesium137) taken together	5.0E-03	1.8E-03	Highest 3 months

275 Our Radioactive Substances Regulation Environmental Principle RSMDP12 states that limits and levels should be established on the quantities of radioactivity that can be discharged into the environment where these are necessary to secure proper protection of human health and the environment.

276 We consider that the limits we propose for quantities of radionuclides that can be discharged into the atmosphere are necessary to secure proper protection of human health and the environment.

14 Compliance with Environment Agency requirements

P&I Table 1 section or REP	Compliance comments
1.2 General information relating to the facility	Westinghouse provided general information relating to the facility.
1.5 An analysis should be provided that includes an evaluation of options considered and shows that the Best Available Techniques will be used to minimise the production and discharge or disposal of waste.	Westinghouse provided a BAT Assessment Report which considered BAT in relation to minimising the discharge of radioactive material and waste.
2.1 A description of how radioactive wastes will arise, be managed and disposed of throughout the facility's lifecycle.	Westinghouse provided a description of how radioactive wastes will be managed and disposed of.
2.2 Design basis estimates for monthly discharges of gaseous and aqueous radioactive waste	Westinghouse provided design basis estimates for monthly discharges of aqueous radioactive waste.
2.3 Proposed annual limits with derivation for radioactive gaseous and aqueous discharges	Westinghouse derived and proposed annual limits for discharges of aqueous radioactive waste.
Principle RSMDP3 – Use of BAT to minimise waste: The best available techniques should be used to ensure that production of radioactive waste is prevented and minimised where that is not practicable with regard to activity and quantity.	See below
Principle RSMDP4 – Processes for Identifying BAT: The best available techniques should be identified by a process that is timely, transparent, inclusive, based on good quality data, and properly documented.	Westinghouse provided a BAT Assessment Report which considered BAT in relation to minimising the discharge of radioactive material and waste using a systematic process which identified, scored and ranked options.
Principle RSMDP7 – BAT to Minimise Environmental Risk and Impact: When making decisions about the management of radioactive substances, the best available techniques should be used to ensure that the resulting environmental risk and impact are minimised.	Westinghouse provided a BAT Assessment Report which considered BAT in relation to minimising the discharge of radioactive material and waste which included information on the impact.
RSMDP9 – Characterisation: Radioactive substances should be characterised using the best available techniques so as to facilitate their subsequent management, including waste disposal.	Westinghouse provided design basis estimates for monthly discharges of aqueous radioactive waste by radionuclide for each plant system which will generate aqueous radioactive waste

P&I Table 1 section or REP	Compliance comments
RSMDP12 – Limits and Levels on Discharges: Limits and levels should be established on the quantities of radioactivity that can be discharged into the environment where these are necessary to secure proper protection of human health and the environment	Westinghouse provided design basis estimates for monthly discharges of aqueous radioactive waste and proposed discharge limits.

15 Public Comments

277 No public comments were received during the assessment which related to discharges of aqueous radioactive waste.

16 Conclusion

278 We conclude that overall the AP1000 utilises the best available techniques (BAT) to minimise discharges of aqueous radioactive waste:

a) During routine operations and maintenance;

b) From anticipated operational events.

279 However our conclusion is subject to the following other issues:

a) The capability to include boron recycle in the AP1000 design shall be kept under review and a BAT assessment provided at site specific permitting to demonstrate whether boron recycle represents BAT.

b) Detailed arrangements for the hand over between Westinghouse and future operators shall be provided at site specific permitting, in particular with respect to matters that relate to the use of BAT to minimise radioactive discharges.

c) The suitability and availability of appropriate mobile equipment for waste which is not compatible with the aqueous radioactive waste system shall be demonstrated at site specific permitting.

d) Information relating to the provision of secondary containment for the Monitor tanks shall be provided at site specific permitting.

e) A detailed and robust justification of options for carbon-14 abatement in radioactive waste discharges shall be provided at site specific permitting.

280 We conclude that the aqueous radioactive discharges from the AP1000 should not exceed those of comparable power stations across the world

281 We conclude that any operational AP1000 should comply with the aqueous limits and levels set out below:

Radionuclides or group of radionuclides	Annual limit (GBq)	Quarterly notification level (GBq)
Tritium	60,000	11,000
Carbon-14	7	2.5
Cobalt-60	0.5	0.18
Caesium-137	0.05	0.018
All other radionuclides (excepting tritium, carbon-14, cobalt-60 and caesium137)	5	1.8

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US NRC	NUREG-0017, "Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Pressurized Water Reactors (PWRs)," current revision.

Abbreviations

ALARP	As Low As Reasonably Practicable
BAT	Best available techniques
CFR	Code of federal regulations (US regulatory system)
CVS	Chemical and Volume control system
CWS	Circulating water system
DCD	Design Control Document
EOL	End of life
EPRI	Electrical Power Research Institute – an independent USA organisation
ER	Environment Report
GDA	Generic design assessment
HEPA	high efficiency particulate air filter
HSE	Health and Safety Executive
IAEA	International Atomic Energy Agency
JPO	Joint Programme Office
P&ID	Process and information document
PCSR	Pre-Construction Safety Report
PWR	Pressurised water reactor
QA	Quality Assurance
RCS	Reactor coolant system
REPs	Radioactive substances environmental principles
RGN	Regulatory Guidance Note
RGS	Regulatory Guidance Series
RO	Regulatory Observation
SODA	Statement of Design Acceptability
TQ	Technical Query
US NRC	United States Nuclear Regulatory Commission
VAS	The radiologically controlled area ventilation system
VBS	The non-radioactive auxiliary building ventilation system
VFS	containment air filtration system
VTS	turbine building ventilation system
WCPD	Worst case plant discharge
WEC	Westinghouse Electric Company LLC
WGS	Gaseous radioactive waste system
WLS	Liquid radioactive waste system
WRS	radioactive waste drain system
Zeolite	Adsorbent mineral

Annex 1 - Expected Annual Release of Radioactive Effluent Discharges

(taken from AP1000 European Design Control Document and the Environment Report Table 3.4-6)

Nuclide	Activity Release (1) GBq y^{-1}			
	Shim Bleed +Equip Drains	Miscellaneous Wastes	Turbine Building	Total Release
Tritium				3.34E+4(3)
C-14	3.3E+00(2)	negl.	negl.	3.3E+00(2)
Na-24	3.5E-02	2.3E-04	2.8E-03	3.8E-02
Cl-36	negl.	negl.	negl.	negl.
Cr-51	4.5E-02	1.3E-04	2.8E-04	4.6E-02
Mn-54	3.2E-02	7.2E-05	1.4E-04	3.2E-02
Fe-55	4.8E-01	1.1E-03	2.1E-03	4.9E-01
Fe-59	4.9E-03	negl.	negl.	5.0E-03
Co-58	4.1E-01	1.0E-03	2.0E-03	4.1E-01
Co-60	2.2E-01	5.0E-04	9.4E-04	2.3E-01
Ni-63	5.3E-01	1.2E-03	2.1E-03	5.4E-01
Zn-65	1.0E-02	negl.	4.5E-05	1.0E-02
Nb-94	negl.	negl.	negl.	negl.
W-187	2.8E-03	negl.	1.7E-04	3.0E-03
U-234	negl.	negl.	negl.	negl.
U-235	negl.	negl.	negl.	negl.
U-238	negl.	negl.	negl.	negl.
Np-237	negl.	negl.	negl.	negl.
Pu-238	negl.	negl.	negl.	negl.
Pu-239	negl.	negl.	negl.	negl.
Pu-240	negl.	negl.	negl.	negl.
Pu-241	8.0E-05	negl.	negl.	8.0E-05
Pu-242	negl.	negl.	negl.	negl.
Am-241	negl.	negl.	negl.	negl.
Am-243	negl.	negl.	negl.	negl.
Cm-242	negl.	negl.	negl.	negl.
Cm-244	negl.	negl.	negl.	negl.
As-76	negl.	negl.	negl.	negl.
Br-82	negl.	negl.	negl.	negl.
Rb-86	negl.	negl.	negl.	negl.
Rb-88	3.9E-04	negl.	negl.	3.9E-04
Sr-89	2.4E-03	negl.	negl.	2.4E-03
Sr-90	2.5E-04	negl.	negl.	2.5E-04
Y-91	9.0E-05	negl.	negl.	9.1E-05
Zr-95	6.8E-03	negl.	negl.	6.9E-03

Nuclide	**Activity Release (1) GBq y^{-1}**			
	Shim Bleed +Equip Drains	**Miscellaneous Wastes**	**Turbine Building**	**Total Release**
Nb-95	6.1E-03	negl.	negl.	6.1E-03
Mo-99	1.9E-02	1.1E-04	5.3E-04	1.9E-02
Tc-99m	1.8E-02	1.1E-04	3.8E-04	1.8E-02
Tc-99	negl.	negl.	negl.	negl.
Ru-103	1.2E-01	3.1E-04	6.6E-04	1.2E-01
Ru-106	negl.	negl.	negl.	negl.
Ag-110m	2.6E-02	5.8E-05	1.1E-04	2.6E-02
Sn-117m	negl.	negl.	negl.	negl.
Sb-122	negl.	negl.	negl.	negl.
Sb-124	negl.	negl.	negl.	negl.
Sb-125	negl.	negl.	negl.	negl.
I-129	negl.	negl.	negl.	negl.
I-131	1.5E-02	6.3E-05	2.5E-04	1.5E-02
I-132	1.9E-02	9.1E-05	8.5E-04	2.0E-02
I-133	2.6E-02	1.7E-04	2.7E-03	2.9E-02
I-134	5.8E-03	3.9E-05	negl.	5.9E-03
Cs-134	7.5E-03	negl.	negl.	7.6E-03
I-135	2.0E-02	1.3E-04	3.2E-03	2.4E-02
Cs-136	9.2E-03	negl.	8.5E-05	9.3E-03
Cs-137	2.3E-02	5.0E-05	1.1E-04	2.3E-02
Ba-140	1.3E-02	4.6E-05	1.1E-04	1.4E-02
La-140	1.8E-02	6.6E-05	2.0E-04	1.8E-02
Ce-144	7.9E-02	1.8E-04	3.4E-04	8.0E-02
Pr-144	7.9E-02	1.8E-04	3.4E-04	8.0E-02
All Others	negl.	negl.	negl.	negl.
Total (4)	**5.7E+00**	**6.3E-03**	**2.1E-02**	**5.8E+00(4)**

(1) Values less than 3.7E+4Bq are considered to be negligible, but their values are included in the totals

(2) C-14 from Westinghouse calculation APP-WLS-M3C-056 Rev 0, 2009

(3) Tritium Release based on Westinghouse TRICAL computer code

(4) Excluding tritium

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