Environment Agency

Generic design assessment

AP1000® nuclear power plant design by Westinghouse Electric Company LLC

Final assessment report

Aqueous radioactive waste disposal and limits

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Final 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	Original – Tooley, E. J. Review and revision to final report – Green, R.

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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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 Our conclusions have changed since our consultation. Many respondents were concerned about compliance with the UK's obligations under OSPAR. We undertook more assessment in regard to this topic, a summary is provided in section 2.9 below. We were unable to complete our OSPAR assessment as the AP1000 design does not include treatment options for certain aqueous wastes that are incompatible with the design standard of filtration and ion exchange. The AP1000 design includes space and facilities for operators to bring in mobile systems to treat small volume and infrequently produced aqueous wastes such as chemical and detergent wastes that are incompatible with the normal treatment options. We had already identified this gap and include an assessment finding (AP1000-AF05) below. It will be for future operators to show on a site-specific basis that their proposals for aqueous radioactive waste management will ensure that their discharges to the sea will comply with the UK obligations under OSPAR. An assessment finding on carbon-14 was identified and is shown below. Our conclusions now reflect that the AP1000 design does not include treatment techniques for aqueous radioactive wastes that are incompatible with filtration and ion exchange.

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

a) during routine operations and maintenance;

b) from anticipated operational events.

4 We conclude that, for aqueous wastes that are incompatible with filtration and ion exchange, the AP1000 has no suitable treatment technique. We have left the treatment of these small volume wastes as a matter for future operators to determine, see our assessment finding below.

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

6 We conclude that any operational, single AP1000 unit should comply with the limits and levels set out below for the disposal of aqueous radioactive waste. The limits and levels will be the starting point for any site specific permit, but will be reviewed as part of the site permitting process based on any additional information provided by a future AP1000 operator. The limits would also be reviewed periodically thereafter, as data becomes available from operational AP1000 reactors.

Radionuclides or group of radionuclides	Proposed Annual limit (GBq)	Proposed 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

7 As part of our assessment we identified the following assessment findings:

a) Information relating to the provision of secondary containment for the Monitor tanks shall be provided at site specific permitting.(AP1000-AF04)

b) Future operators shall, at the detailed design phase, provide an assessment to demonstrate that techniques to minimise the discharge of all aqueous radioactive wastes are BAT for their location. In particular, the omission of an evaporator will need to be justified. (AP1000-AF05)

c) Future operators shall, during the detailed design stage, provide a predicted mass balance showing how their proposed aqueous radioactive waste management regime will affect the disposal of carbon-14 to the gaseous, solid or aqueous routes. For each route the form of carbon-14 expected shall be provided. For solid wastes the quantities of each type of waste shall be provided with expected carbon-14 content. (AP1000-AF06)

8 Our findings on the wider environmental impacts and waste management arrangements for the AP1000 reactor may be found in our Decision Document (Environment Agency, 2011a).

1 Introduction

9 We originally published this report in June 2010 to support our GDA consultation on the AP1000 design. The consultation was on our preliminary conclusions. It began on 28 June 2010 and closed on 18 October 2010.

10 We received additional information from Westinghouse after June 2010 and also undertook additional assessment in response to consultation responses. This report is an update of our original report covering assessment undertaken between June 2010 and the end of March 2011 when Westinghouse published an update of their submission. Where any paragraph has been added or substantially revised it is in a blue font.

11 We do not specifically deal with consultation responses in this report, they are covered in detail in the Decision Document (Environment Agency, 2011a). However, where a response prompted additional assessment by us this is referenced, the key to GDA reference numbers is in Annex 7 of the Decision Document. The conclusions in this report have been made after consideration of all relevant responses to our consultation.

12 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.

13 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).

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

15 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.

1.1 BAT to minimise discharges of aqueous radioactive waste

16 In addition to using BAT to prevent and, where that is not practicable, minimise the creation of radioactive waste (as discussed in our report EAGDAR AP1000-03, see Environment Agency, 2011b), we also expect new nuclear power plant to use BAT to minimise the impact of discharges of radioactive waste to the environment.

17 This report assesses the aqueous radioactive waste created and whether the AP1000 uses BAT to minimise the impact of its discharge. We compare discharges with other comparable stations across the world and propose disposal limits and notification levels for those discharges.

18 We set out in our Process and Information Document (Environment Agency, 2007) (P&ID) the requirements for a Requesting Party to provide information that:

a) shows BAT will be used to minimise the discharge and disposal of aqueous radioactive wastes (reference 1.5);

b) describes sources of radioactivity and matters which affect aqueous wastes arising (reference 2.1);

c) gives design basis estimates for monthly discharges of aqueous radioactive waste (reference 2.2); and

d) gives their proposed annual limits with derivation for aqueous radioactive waste (reference 2.3).

19 Statutory Guidance (DECC, 2009) to us in 2009 reinforced the requirement to use BAT, paragraph 23:

a) "*In relation to any designs for new nuclear power stations, the Environment Agency should ensure that BAT is applied so that the design is capable of meeting high environmental standards. This requirement should be applied at an early stage so that the most modern or best available technology can be incorporated into the design of the stations, where this would ensure improved standards. The application of BAT should ensure that radioactive wastes and discharges from any new nuclear power stations in England and Wales are minimised and do not exceed those of comparable stations across the world*."

20 In our Radioactive Substances Regulation Environmental Principles (REPs, Environment Agency, 2010a), principle RSMDP3 (Use of BAT to minimise waste) states that:

a) "*The best available techniques should be used to ensure that production of radioactive waste is prevented and where that is not practicable minimised with regard to activity and quantity.*"

21 The methodology for identifying BAT is given in principle RSMDP4 and the application of BAT is described in principle RSMDP6. We also published in 2010 our guidance '*RSR: Principles of optimisation in the management and disposal of radioactive waste*' (Environment Agency, 2010b). The guidance initially says:

a) *'BAT are the means an operator uses in the operation of a facility to deliver an optimised outcome, i.e. to reduce exposures to ALARA'* [ALARA: as low as reasonably achievable, economic and social factors being taken into consideration, applied to radiological risks to people].

22 BAT replaces, and is expected to provide the same level of environment protection as, the previously used concepts of best practicable environmental option (BPEO) and best practicable means (BPM). BAT includes an '*economic feasibility*' element. [Clarification prompted by several respondents]

23 We keep BAT under consideration and review permits regularly to see if improvements are needed to reflect developments and improvements, for example in plant, techniques or operator practice. Our permits include conditions requiring

the use of BAT and BAT requires that operators continually assess whether more can be done to reduce discharges. [Clarification prompted by several respondents]

24 In this report we assess the techniques Westinghouse use in the AP1000 to minimise the discharge and impact of aqueous radioactive wastes and present our conclusions on whether BAT is demonstrated.

25 Westinghouse provided its submission to GDA in August 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*".

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

27 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. We raised a Regulatory Observation (RO), RO-AP1000-034 on Westinghouse in June 2009 that had actions to provide:

a) a comprehensive Integrated Waste Strategy;

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

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.

28 We raised 43 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.

29 We also liaised with the Office for Nuclear Regulation[1] (ONR) on matters of joint interest and used their Step 3 and Step 4 reports to inform our assessment.

30 Westinghouse responded to all the ROs and TQs. They reviewed and updated the Environment Report in March-April 2010 to include all the relevant information provided by the ROs and TQs. This version of the ER was referenced by our Consultation Document and publicly available on the AP1000 website.

31 Additional information on some topics was submitted by Westinghouse after March 2010. Westinghouse reviewed and updated the ER to include all submitted information in March 2011. This report only uses and refers to the information contained in the updated Environment Report (UKP-GW-GL-790 (Rev 4))(ER) and its supporting documents in particular the AP1000 BAT Assessment (UKP-GW-GL-

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[1] The Office for Nuclear Regulation (ONR) was created on 1st April 2011 as an Agency of the Health and Safety Executive (HSE). It was formed from HSE's Nuclear Directorate and has the same role. In this report we therefore generally use the term "ONR", except where we refer back to documents or actions that originated when it was still HSE's Nuclear Directorate.

026 (Rev 2))(AP1000 BAT), publicly available on the AP1000 website (www.ukap1000application.com).

1.2 Comparison of discharges with other stations

32 We commissioned a study to help us compare discharges from designs put forward for GDA with currently operating nuclear power plant. Our Science Report SC070015/SR1 "*Study of historic nuclear reactor discharge data*" was published in September 2009. We used data from this report and our own sources to establish annual discharge ranges for significant radionuclides for "*comparable stations across the world*", see Annex 4 of our Decision Document (Environment Agency, 2011a).

33 This report compares the predicted aqueous discharges from the AP1000 with the ranges quoted in Annex 4 of the Decision Document.

Radionuclides or group of radionuclides	AP1000 predicted annual discharge	AP1000 normalised to 1000 MWe	Range for 1000 MWe station
Tritium (TBq)	33.4	29.9	2 - 30
Carbon-14 (GBq)	3.3	3	3 - 45
Iodine radionuclides (MBq)	15	13.4	10 - 30
Other radionuclides not specifically limited (GBq)	2.7	2.4	<1 - 15

34 The Committee on Medical Aspects of Radiation in the Environment (COMARE) (GDA130) suggested that as '*part of a new generation of plants, it might be expected that discharges would be lower than existing facilities, rather than 'within the range of historic discharges' which seems to be the criterion being applied by EA*'. We discuss the data we used to confirm discharges were comparable to current power stations in the Decision Document, Annex 4. We had difficulty that data was very variable and affected by matters such as shutdowns for periods that were not known. Also the data for the AP1000 are based on predictions as no AP1000 is yet running. Therefore attempting comparison to show lower discharges for the AP1000 was not possible. We have indicated throughout this report areas where the AP1000 has been improved and the discharge reductions that are expected.

35 Westinghouse compared the AP1000 total predicted aqueous radioactive waste discharges from the AP1000 with published discharges from other nuclear reactors operating over the period 1995-1998. The reactors chosen by Westinghouse for the comparison are South Texas 1, Braidwood 1, Cook 1, Vogtle 1 and Sizewell B. These reactors were chosen because they are recently built Westinghouse PWRs in the USA and UK. Westinghouse claim that the data indicates that the predicted AP1000 annual discharges normalised to 1000 MWe output are lower than those from all but one of the reactors and are similar to that one. Examination of updated Westinghouse data shows the predicted AP1000 annual discharges normalised to 1000 MWe output are lower than those from Cook 1 and Sizewell B, but higher than those from South Texas 1, Braidwood 1 and Vogtle 1. (AP1000 BAT Table 4-11)

1.3 Discharge limits and levels

1.3.1 Radionuclides on which limits should be set

36 We recommended in the P&ID that RPs should take account of our Science Report SC010034/SR "*Development of Guidance on setting limits on discharges to the Environment from nuclear sites"* (Environment Agency, 2005). The report 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.

This advice from the report was essentially confirmed in the *Considerations* section of RSMDP12 in our REPs.

37 In addition our Considerations document (Environment Agency, 2009) recommends the 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 manSv;

c) The EWCPD exceeds 1 TBq per year;

d) 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.

38 We used the above advice and criteria to determine appropriate radionuclides and groups of radionuclides on which to set limits.

1.3.2 Time basis of limits

39 We decided that the most appropriate limit basis was that of a rolling 12 month period. This provides 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.

40 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 such things as the OSPAR Convention[2] and in UK publications such as the annual publication on Radioactivity in Food and the Environment (e.g. Environment Agency *et al* 2009).

[2] Convention for the Protection of the Marine Environment of the North-East Atlantic, 1992 ("OSPAR Convention")

41 We discarded the concept of discharge limits set in terms of activity discharge per cycle as this adds 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.

42 For simplicity we use the term *Annual Limit* later in this report and in the Decision Document but it should be taken that this would be expressed in a permit as a *12 month rolling limit*.

1.3.3 Limit setting

43 Our limit setting report recommends the use of a formula to determine the headroom which is appropriate to apply to average discharges to give operational flexibility and to take into account other conditions which might change during the period for which the limits would apply. The report recommends the use of a formula to calculate the "*worst case annual plant discharge*" (WCPD):

44 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.

45 The discharge setting report recommends that WCPD for new plant should be a factor of 2 times the best estimate of discharges of radioactive waste.

46 Subsequent to the report Statutory Guidance (DECC, 2009) to us states that we should set limits:

a) *based on the use of BAT; and*

b) *at the minimum levels necessary to permit "normal" operation of a facility.*

47 The Statutory Guidance also states "*Where the prospective dose to the most exposed group of members of the public from discharges from a site at its current discharge limits is below 10 µSv y^{-1} the Environment Agency should not seek to reduce further the discharge limits that are in place, provided that the holder of the authorisation applies and continues to apply BAT".* While this applies to existing sites we consider the 10 µSv y^{-1} is an appropriate guide to consider when deciding if BAT are used to minimise the impact of radioactive discharges for new sites.

48 We assessed that the total impact of radioactive discharges from the AP1000 to the most exposed person to be 8 μSv y^{-1} with the contribution from aqueous discharges being <1 μSv y^{-1} (our report EAGDAR AP1000-11, (Environment Agency, 2011c). We indicate in our assessment below the impact attributable to each considered radionuclide or group of radionuclides and have targeted our assessment time at those with the highest contribution to the total. Where some radionuclides have only minimal contribution to the impact we have reduced our assessment time.

49 Our REPs reiterate the Statutory Guidance in relation to limits in the *Considerations* for principle RSMDP12:

a) *limits should be based on the level of releases achievable by the use of BAT by operators;*

b) *limits should be set such that there is a minimum headroom between actual levels of discharge expected during normal operation and the discharge limit.*

50 Westinghouse provided design basis estimates for discharges of aqueous radioactive waste that should include normal operational events such as start-up, shutdown, refuelling and maintenance (reference 2.2 P&ID). These were the '*representative 12-month plant discharge*' values given in the table below. These were the starting point for determining limits, our methodology allows the addition of contingencies to allow for such matters as uncertainty (an AP1000 has not yet operated so all figures are predictions) or infrequent but foreseeable events. The methodology also allows a factor to be applied to the expected value (up to x2 for a new plant) so that a limit is somewhat above the normally expected value to allow for operational variance and measurement accuracy. Westinghouse applied our methodology (see ERs6.1.2) and provided their '*worst-case plant discharge*' values as proposed limits. We reviewed the basis of both sets of values to decide ourselves the right limit to set.

1.3.4 Notification level setting

51 Our REPs state, in the *Considerations* for principle RSMDP12, that advisory levels should be set that:

a) *prompt review of whether the best available techniques are being used; and*

b) *ensure early assessment of the potential impact of increased discharges*.

52 Advisory levels should also require early reporting of:

a) *operational performance issues leading to increases in discharges; and*

b) *events that have given rise to higher than normal short term discharges*.

53 We have in the past set quarterly, weekly or daily advisory levels. We consider that as the radioactivity discharges from the AP1000 are of a relatively low quantity and reasonably even over time that only quarterly notification levels (QNL) should be set.

54 The QNL is defined precisely by a condition in any permit we issue, a typical condition would be:
If, in any quarter, the activity in waste discharged of any radionuclide or group of radionuclides specified in (the relevant Table) exceeds the relevant Quarterly Notification Level, the operator shall provide the Agency with a written submission which includes:

a) *Details of the occurrence;*

b) *A description of the techniques used to minimise the activity of waste discharged;*

c) *A review of those techniques having regard to the following:*

i) The operator shall use the best available techniques to minimise the activity of radioactive waste produced on the premises that will require disposal to be disposed of on or from the premises;

ii) The operator shall use the best available techniques in respect of the disposal of radioactive waste pursuant to this permit to:

a) minimise the activity of gaseous and aqueous radioactive waste disposed of by discharge to the environment;

b) minimise the volume of radioactive waste disposed of by transfer to other premises;

c) dispose of radioactive waste at times, in a form, and in a manner so as to minimise the radiological effects on the environment and members of the public.

Not later than 14 days from making the record which demonstrates such excess.

55 The exceedence of a QNL set in a permit is not an offence. But it would be an offence for an operator to fail to notify us of the exceedence of a QNL in accordance with the relevant condition of the permit.

56 Normally we would use operational discharge data over at least 5 years to set QNLs. But as the AP1000 has not yet operated anywhere in the world we cannot do this at GDA. The simplest way to set a QNL would be to take a proportion of the annual limit, say 25%. However annual limits have contingency factors built in and we need to get early warning if discharges are above normal (without any contingency) so that we can ensure that BAT are still being used. We have therefore usually taken the "*expected performance*" figures quoted in the ER as our start point to set QNLs. The detail of how we set each QNL is given below.

57 It is possible that with operational discharge data from AP1000s currently under construction will become available during specific site permitting. We will review this and may need to revise the QNLs for any permit we issue.

58 A future operator (GDA128), was concerned that our rationale for setting QNLs as well as not being able to be based on operating data did not take account of operator or site specific factors. We accept that different operators may have different waste management practices and there may be site specific factors. Operators may propose their own basis for QNLs when applying for their permit. We have proposed an initial set of QNLs to show that we intend QNLs to reflect actual predicted discharges and provide notification to us for unusual discharges. The limits have contingencies built in and should not be considered as a starting point for QNLs.

59 An individual respondent (GDA124) considered some QNLs set at too high a level. When we have set a QNL at high level compared to a limit this is because we expect most of an annual discharge to be made in one quarter around a shutdown. We accept this may give us inadequate notification of high discharges in 'normal' operating times, we are considering using two levels of QNL, one for 'normal' operation and one for a shutdown period. This will need to be decided at site-specific permitting when we have the operators' proposed discharge management regime.

60 An individual respondent suggested that QNLs should be based on limits but we use QNLs to help us ensure BAT is being used. QNLs should be based on expected normal discharges without any contingencies, a notification will warn us of unusual discharges and we can question if BAT was used. If BAT is used then limits should be complied with as they are based on BAT.

61 An individual respondent asked that limits and QNLs be kept under review to ensure they are appropriate. We confirm that we review limits and QNLs whenever circumstances warrant this but also on a regular periodic basis.

2 Assessment

2.1 Assessment Methodology

62 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 was 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) liaise with ONR on matters of joint interest;

f) decide on any GDA Issues;

g) identify assessment findings to carry forward from GDA.

h) compare aqueous discharges from the AP1000 to ranges quoted in Annex 4 of the Decision Document (Environment Agency, 2011a);

i) assess the Westinghouse proposals for limits, compare with our own methodology and then propose our own limits and levels.

2.2 Assessment Objectives

63 Key areas of the submission made under the GDA arrangements by Westinghouse for the AP1000 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.

2.3 Westinghouse documentation

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

Document reference	Title	Version number
UKP-GW-GL-790	UK AP1000 Environment Report	4
UKP-GW-GL-026	AP1000 Nuclear Power Plant BAT Assessment	2
UKP-GW-GL-028	Proposed Annual Limits for Radioactive Discharge	2
EPS-GW-GL-700	AP1000 European Design Control Document	1
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

2.4 Origins of aqueous radioactive waste

65 Westinghouse has provided information on the sources of aqueous radioactive waste (ER s3.4.1) and expected effluent arisings. (ER Table 3.4-1)

66 Reactor coolant system (RCS) effluents arise from two sources:

a) leaks and drainage from primary systems collected in the reactor coolant drain tank of 3.4 m^3;

b) letdown from the chemical and volume control system (CVS) usually as a result of coolant system heat up, boron concentration changes or RCS level reduction for refuelling.

These sources are directed to the degasification subsystem in the liquid radwaste system (WLS).

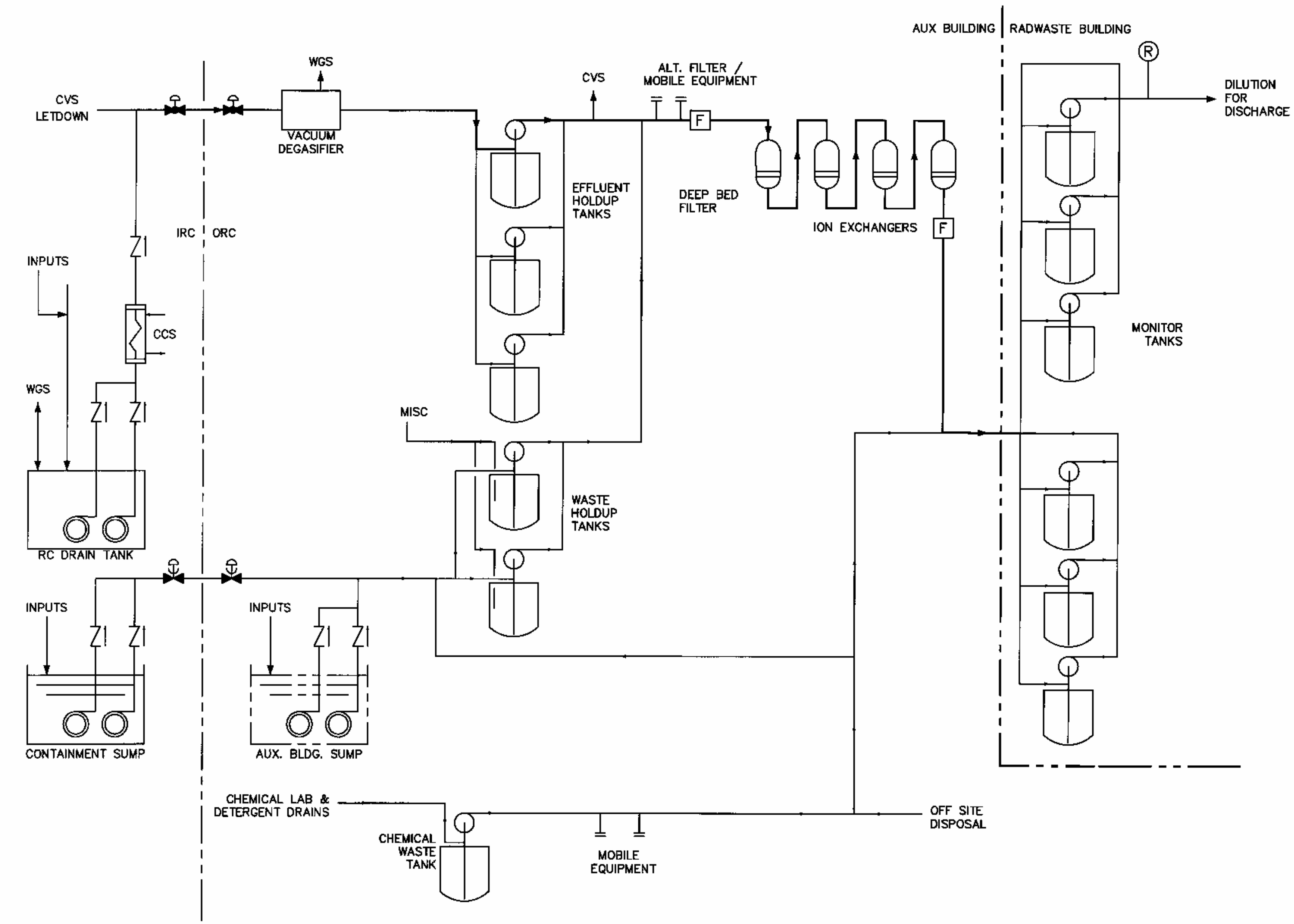
67 **Floor drains** and other waste with potentially high suspended solids contents are routed to one of two waste hold-up tanks. Each of these tanks has a usable volume of 57 m^3 and is normally discharged to the filtration and ion exchange subsystem of the WLS.

68 **Detergent wastes** from the plant hot sinks and showers and some cleanup processes are routed to the chemical waste tank. The chemical waste tank has a volume of 34 m^3. If the radioactivity of this waste is low, the tank contents can be sent to the monitoring tanks for discharge without treatment. If the waste is above an acceptable level for direct discharge, it can be sent to a waste hold-up tank for treatment in the WLS. However, some waste is chemically incompatible with the resins in the WLS and could cause damage. This waste would be treated using mobile treatment plant or by sending the liquids off-site for treatment and disposal. On a normal basis detergent wastes will be non-ionic cleaning agents. (ER3.4.3.9)

69 **Chemical waste** collected from laboratories and other small sources is also routed to the chemical waste tank and treated along with detergent waste. (ER3.4.3.10)

70 **Steam generator blowdown** is normally non-radioactive and discharged through a separate blowdown system. If there are steam generator tube leaks, the blowdown could contain radioactivity and, in this event, it is routed to a waste hold-up tank before treatment in the WLS.

71 The WLS is designed to control, collect, process, handle, store and dispose of aqueous radioactive waste generated as a result of normal operations of the AP1000. (ERs3.4 and 3.4.3, a schematic of the system is at ER Figure 3.4-1, repeated below).



AP1000 liquid radwaste system (ER Fig 3.4-1)

72 Westinghouse provides data on the annual amount of radioactivity in aqueous discharges that it has calculated using the revised GALE Code (NUREG-0017) and modified by proprietary calculations (ER table 3.4-6). Westinghouse also proposes disposal limits (ER s6.1 and Table 6.1-8). We have summarised the information below and included information on our proposed limits and QNLs which are explained further below.

	Representative 12-month plant discharge in months 7 to 18 of the cycle (GBq y^{-1})	**Westinghouse estimate of worst-case plant discharge (WCPD) (GBq y^{-1})**	**Annual limit proposed by Environment Agency (GBq y^{-1})**	**QNL proposed by Environment Agency (GBq in any 3 calendar months)**
Tritium	35,090	57,900	60,000	11,000
Carbon-14	4.42	7.30	7	2.5
Cobalt-60	0.301	0.497	0.5	0.18
Caesium-137	0.03	0.0497	0.05	0.018
Other radionuclides (excepting tritium, carbon-14, cobalt-60 and caesium-137) taken together	2.95	5.35	5	1.8

73 Westinghouse has considered the requirements of the EU Commission Recommendation 2004/2/Euratom to justify the basis for reporting aqueous radioactive waste discharges.

74 We will set limits and levels 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. We have assessed the information within the ER against our criteria described above as follows:

a) critical group dose greater than 1 μSv y^{-1}: carbon-14 at 2.6 μSv y^{-1} and "all other radionuclides" at 1.2 μSv y^{-1} (total including cobalt-60 and caesium-137) (ER Table 5.2-1);

b) discharge exceeds 1 TBq y^{-1}: tritium;

c) indicator of plant performance:

   i) cobalt-60 indicates effectiveness of corrosion controls and the filter and demineralisation system in the WLS;

   ii) caesium-137 is an indicator of fuel cladding failures.

75 We have set out our proposed disposal limits for tritium, carbon-14, cobalt-60, caesium-137 and other radionuclides in the Table above. "All other radionuclides" will be more completely defined in any permit we issue, for example "*All other radionuclides means the sum of all radionuclides as measured by the methods defined in this permit except those specified individually in the Table*". We do not consider it proportionate to set a limit for iodine radionuclides as discharge levels and impact are low and measured levels may well be below detection thresholds of monitoring methods.

76 Our Radioactive Substances Regulation Environmental Principle RSMDP8 deals with the segregation of waste and requires that best available techniques should be used to prevent mixing radioactive substances with other materials, including other radioactive substances, where mixing might compromise subsequent effective management or increase environmental impacts or risks. We conclude that the AP1000 design provides for segregating aqueous wastes so that subsequent management is not compromised.

77 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, 2011d).

78 Our assessment concluded that:

a) all sources of aqueous radioactive waste have been identified;

b) the nature, form and quantity of aqueous radioactive waste has been identified in enough detail to demonstrate that treatment processes and disposal routes can be envisaged for all aqueous radioactive waste;

c) the data Westinghouse has provided relating to the sources of aqueous radioactive waste is comprehensive, justified and reasonable at the GDA stage.

2.5 AP1000 liquid radwaste system (WLS)

79 The WLS is primarily located in the nuclear island auxiliary building and includes a number of waste treatment techniques:

a) **Degasification -** Reactor coolant system 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 a 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. (ERs3.4.3.1) 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. The effluent hold up tanks each have a usable volume of 106 m^3. The contents of the effluent hold-up tanks can be:

   i) returned to the RCS through the CVS;

   ii) passed through the filtration and ion exchange units of the WLS before being sent to the monitor tanks for discharge.

b) **Pre-filtration -** 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. 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 90 per cent for 25 µm particles. (ER3.4.3.2)

c) **Deep bed filtration -** The deep bed filter is a stainless steel vessel containing a layered bed of activated charcoal above a zeolite resin. 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 waste. 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. The zeolite resin is clinoptilolite zeolite that is provided for caesium removal. Westinghouse claims that deep bed filtration has a decontamination factor of 1 for iodines, 100 for caesium /

rubidium (Cs/Rb) and 1 for other radionuclides. (ERs3.4.3.3)

d) **Ion exchange** - 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 claims that this capacity provides an adequate margin for processing a surge in the generation rate of this waste. At the operational stage the ion exchange media will be selected by the plant operator to optimise system performance according to prevailing plant conditions. Typically the resin beds will use the following resins:

   i) the first bed will contain a cation exchange resin and Westinghouse claims that this resin will have a decontamination factor of 1 for iodine, 10 for Cs/Rb and 10 for other radionuclides;

   ii) 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;

   iii) 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.

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

   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. (ERs3.4.3.4).

e) **After filter** - 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 per cent removal of 0.5 μm particles. (ERs3.4.3.5)

80 The WLS 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.

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

82 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.

83 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.

84 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 inadvertent bypass of demineralisers or sub-optimal treatment of waste.

85 Westinghouse claims that the liquid radioactive waste system is designed to handle most liquid effluents and other anticipated events using installed equipment. However, for infrequent events or for effluent that is not compatible with the installed equipment, temporary equipment may be brought into the radioactive waste building mobile treatment facility truck bays. Any treatment of liquid waste by mobile or temporary equipment will be controlled and confirmed by plant procedures.

86 Mobile equipment connections are provided to and from various locations in the liquid radioactive waste system to allow mobile equipment to be used alongside or instead of installed equipment. Treated liquids would be returned to the liquid radioactive waste system or removed from the site for disposal elsewhere. (ERs3.4.3.8)

87 We are not satisfied that BAT has been demonstrated for minimising discharges of all aqueous radioactive wastes. We accept that the AP1000 design allows for additional techniques to be installed and do not consider this a fundamental GDA Issue. However, future operators will need to demonstrate to us that BAT for their location is used to minimise discharges of aqueous radioactive wastes. In particular the provision of evaporation may be a BAT requirement (see section 2.9 on OSPAR).

88 Our assessment concluded that BAT has not been demonstrated for minimising discharges of all aqueous radioactive wastes. However, for those aqueous wastes compatible with treatment by filtration and ion exchange we accept that the AP1000 utilises BAT.

89 Assessment finding: Future operators shall, at the detailed design phase, provide an assessment to demonstrate that techniques to minimise the discharge of all aqueous radioactive wastes are BAT for their location. In particular, the omission of an evaporator will need to be justified. (AP1000-AF05)

90 Westinghouse has provided a BAT case for the WLS that supports using ion exchange and a cartridge filter. Two alternatives are discussed below. (ERs3.4.4)

91 An individual respondent (GDA39) asked if '*conventional effluent treatment plant were used to control pH, dissolved solids etc*'. The AP1000 uses conventional techniques to control pH (the addition of acid or caustic as required to neutralise waste). The ion exchange resins mentioned above remove radioactive materials (such as cobalt-60) dissolved in the waste and we consider represent BAT for nuclear plant rather than conventional effluent treatment using precipitation.

2.5.1 Evaporation in place of ion exchange

92 Westinghouse recognises that effluents could be treated by evaporation. (ER Figure 3.4-2). The evaporator bottoms would need to be treated to create a solid waste for disposal. The distillate could be discharged to water after treatment and polishing with demineralisers and filters but would still contain radioactivity. Westinghouse has compared using evaporators against ion exchange in ER Table 3.4-5.

93 Westinghouse claims that it is common for reactors located in Europe on rivers to use evaporators to minimise radioactive liquid discharges as rivers have less capacity for dilution and dispersal of effluents. The AP1000 GDA case is for

discharge of aqueous radioactive waste to sea where dispersal is less of an issue.

94 Westinghouse claims that evaporators tend to be complex and need significant maintenance, with associated occupational radiation exposure of workers. There is also the cost of steam supply to run the evaporators, which diverts steam away from generating electricity.

95 Westinghouse estimates that 102 m^3 of evaporator bottoms would need to be disposed of each year. (ER Table 3.4-5) The treatment and disposal of the evaporator bottoms concentrate would have an impact in terms of radiation exposure to workers and costs.

96 Westinghouse claims that using ion exchange and filters offers a simpler and safer option that will still effectively control discharges of radioactivity. Westinghouse believes its impact assessment for the GDA generic site demonstrates that discharges are not excessive. It concludes that the proposed WLS is BAT. (ERs3.4.4.1)

97 We accept that the evaporation of all aqueous waste may not be BAT when the treatment and disposal of the evaporator bottoms is considered within an assessment. However, Westinghouse state that some aqueous wastes will not be compatible with ion exchange treatment. They allow for mobile equipment to be brought into the AP1000 to treat this. We said above that this does not demonstrate BAT for minimising the discharge of all aqueous wastes. We have left the treatment of these wastes outside GDA and put an assessment finding on future operators to demonstrate BAT for the treatment options they intend to install at their sites. We consider the use of an evaporator must be considered as an option for aqueous wastes to minimise the discharge of radioactivity from the site so that exposures of any member of the public and the population as a whole are kept as low as reasonably achievable (ALARA) and to protect the environment.

2.5.2 Filtration options

98 The WLS includes a final 0.5 µm disposable cartridge filter to remove particulate material greater than 0.5 µm in size. Westinghouse has considered other filter technologies that potentially could remove smaller particulate material at sizes from 0.1 to 0.001 µm. These include:

a) microfiltration;

b) ultrafiltration.

99 Westinghouse claims that these techniques have disadvantages that outweigh the benefit of reduced particulates because:

a) high pressure systems are needed which may increase the risk of leaks;

b) system designs are more complicated;

c) membranes used in the system may be subject to degradation by radioactivity;

d) higher maintenance requirements may lead to potential for higher occupational radiation exposure;

e) more equipment may be produced which needs to be disposed of as radioactive waste at decommissioning;

f) higher capital and operating costs.

100 Westinghouse concludes that using cartridge filters is BAT for final liquid filtration in the AP1000. (ERs3.4.4.4)

101 Our assessment concluded that the use of 0.5 µm disposable cartridge filters is BAT for the AP1000 at this time. Future operators will need to keep other filter technologies under review when they update their BAT assessments.

2.6 Specific radionuclides, BAT, disposals and limits

102 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.

103 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

104 The outcomes of the Westinghouse BAT options assessment are below, with our conclusions on BAT followed by impact information and then our proposals for limits and QNLs:

2.6.1 Tritium

105 Tritium is present as tritiated water in the reactor coolant. Coolant is processed in the CVS and Westinghouse states that approximately 800 m^3 each year will be sent to the WLS for discharge to sea after processing.

106 The filtration and ion exchange systems in the WLS do not effectively remove tritium. Westinghouse reviewed abatement techniques to determine techniques that represent BAT for tritium in aqueous radioactive waste from the AP1000 (AP1000 BAT Form 1):

a) adsorption - Westinghouse claims this has no known application for tritium;

b) wet scrubbing – Westinghouse claims this is only applicable to particulate in air and not tritiated water;

c) evaporation – Westinghouse claims there is no benefit in evaporation as tritiated water behaves as water and no separation is achieved;

d) precipitation / filtration – Westinghouse claims this is not applicable for tritiated water;

e) ion exchange – Westinghouse claims this is not applicable for tritiated water;

f) isotopic concentration / separation – Westinghouse recognises this is a possible technique for abating tritium but the technology is as yet undeveloped and the costs to develop the technology and apply it to the AP1000 would be significant and difficult to justify against the impact of unabated discharges;

g) decay by delay – Westinghouse claims this is impractical as the half-life of tritium is 12.3 years.

107 Westinghouse claims that, in relation to tritium discharges to sea, direct discharge is BAT. Westinghouse also claims that plant operation can significantly affect the

amount of tritium produced and that the AP1000 design that optimises plant availability contributes to minimising tritium production. Management techniques such as operator training which optimise operations are relevant to reducing the production of tritium.

108 Westinghouse provides only basic details on the techniques for abatement of tritium in aqueous radioactive waste discharges. However we recognise that the impact of tritium in liquid discharges without abatement is low, therefore we accept that, at this time, direct discharge to the sea is BAT for the AP1000.

109 Optimising plant availability to minimise plant shutdowns and tritium production will be a matter for future operators of the AP1000. We will continue to seek assurances that the hand over between Westinghouse and future operators will address this matter. This is covered in more detail in our Decision Document, section 6.3.

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

111 Westinghouse proposes a discharge limit for tritium from the AP1000. It has predicted monthly discharges over an 18-month cycle and used data from the 12 months in which the discharges are highest (month 7 – 18) to calculate the representative 12-month plant discharge to be 35,090 GBq. Westinghouse has applied our limit setting methodology (Environment Agency, 2005) to calculate the annual worst-case plant discharge (WCPD), which it has rounded to give its proposed limit. (ERs6.1.3)

112 Westinghouse proposes 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).

113 We examined historic discharges (where available) from European and US PWRs operating over the last 10 to 15 years and we consider that the range of discharges to water of tritium is 2000 to 30,000 GBq per year for a 1000 MWe power station. The predicted annual average aqueous discharge of tritium from AP1000 normalised for power is 29,908 GBq. We conclude that aqueous discharge of tritium is comparable to other power stations across the world.

114 Westinghouse estimates 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, selected to represent the exposure pathways associated with discharges from the AP1000 to the coastal environment, of 0.024 μSv y^{-1}. (ER table 5.2-12). The fisherman and his family are assumed to spend time on intertidal sediments in the area and consume high levels of locally caught fish and shellfish as well as smaller amounts of locally produced fruit and vegetables from local sources up to 500 m from the aerial discharge point. This group live far enough from the site not to be exposed to direct radiation from atmospheric releases.

115 We have independently calculated limits for tritium discharges that we may grant and based on the information Westinghouse provided for GDA, our proposed disposal limit for tritium by discharge to the sea is 60,000 GBq in any 12 rolling calendar months.

116 Some attendees to our stakeholder seminar and '*Stop Hinkley*' (GDA159) expressed concern with the tritium discharge limits and that we give tritium discharge insufficient importance. We said in chapter 8 of our Decision Document that we consider that BAT is used in the AP1000 to minimise the production for tritium at source. The AP1000 will discharge considerably less tritium than the current AGR stations where the limits are 650,000 GBq y^{-1} while generating similar electricity (1117 MWE for the AP1000 against up to 1261 MWe for an AGR). The calculated impact at 0.024 μSv y^{-1} is low and should not be significant.

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

2.6.2 Carbon-14

118 Carbon-14 is present in the coolant mainly as dissolved hydrocarbon gases. These gases are mostly removed in the CVS and WLS degasifier and are discharged through the WGS to the air. Westinghouse claims only a small portion of carbon-14 remains in the liquid effluent, although we note ONR have queried how using zinc acetate may increase the amount of carbon-14 remaining as graphite particles in the liquid. Of the total predicted production of 662 GBq y^{-1}, Westinghouse predicts 53 GBq will be in solid waste, 606 GBq will be discharged to air and 3.3 GBq discharged to the sea. (AP1000 BAT Form 2)

119 Westinghouse claims that the nuclear industry does not currently use any specific techniques to minimise the carbon-14 content of aqueous radioactive waste.

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

a) ion exchange - The AP1000 design provides ion exchange beds as the primary abatement technique for removing trace dissolved metal radionuclides. These beds will also be effective at removing any carbon-14 in the form of carbonates or bicarbonates, which will result in carbon-14 in certain solid waste, mainly in spent resins.

b) evaporation – Westinghouse has considered using evaporation but claim this would have little effect as many forms of carbon-14 would remain with the distillate for disposal to the sea.

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

121 Westinghouse claims, considering the low proportion of carbon-14 remaining in aqueous radioactive waste after the ion exchange beds, that direct discharge is BAT for the AP1000.

122 Our assessment concluded that, at this time, direct discharge to the sea is BAT for the AP1000.

123 We included the need for a '*detailed and robust justification of options for carbon-14 abatement*' as an other issue in our Consultation Document. We now consider that other options for carbon-14 abatement are unlikely to be available in the short term and have not carried forward as an assessment finding for GDA. We will look for future operators to consider in their periodic BAT reviews.

124 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)

125 Westinghouse proposes a discharge limit for carbon-14 from the AP1000. It has predicted monthly discharges over an 18-month cycle and used data from the 12 months in which the discharges are highest (month 7 – 18) to calculate the representative 12-month plant discharge to be 4.42 GBq. Westinghouse has 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)

126 Westinghouse proposes an annual limit of 7 GBq for carbon-14 in aqueous radioactive waste discharges. (ER Figure 6.1-9 and ER Table 6.1-6)

127 We have limited information about carbon-14 discharges from PWRs operating over the last 10 to 15 years but we consider that the range of discharges to water of carbon-14 is 3 to 45 GBq y^{-1} for a 1000 MWe power station. The predicted annual average aqueous discharge of carbon-14 from 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.

128 Westinghouse estimates 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 5.2-12)

129 We have independently calculated limits for carbon-14 discharges that we may grant and, based on the information Westinghouse has provided for GDA, our proposed disposal limit for carbon-14 by discharge to the sea is 7 GBq in any 12 rolling calendar months.

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

2.6.3 Iodine radionuclides

131 Iodine radionuclides are formed in the fuel and are only present in the coolant in the event of fuel cladding defects. While it is not their primary function, the mixed bed demineralisers in the CVS purification loop will remove significant amounts of iodine radionuclides (AP1000 BAT Form 5).

132 Westinghouse claims that the only technique that might be used to further reduce iodine radionuclides in aqueous radioactive waste is chemical trapping. This would add appropriate chemicals that trap iodine (for example, hydrazine hydrate) to the spray system or to the reactor sump. Westinghouse claims that chemical trapping is not a developed technique, and costs to develop the technology and apply it to the AP1000 would be significant and difficult to justify against the impact of unabated discharges.

133 Westinghouse has provided little detail on the techniques for abatement of iodine radionuclides in aqueous radioactive waste discharges from the AP1000. However, we recognise that using demineralisers may contribute to reducing the amount of iodine radionuclides in aqueous radioactive waste.

134 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.

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

136 We have limited information about iodine discharges from PWRs operating over the last 10 to 15 years, but we consider that the range of discharges to water of iodine radionuclides is 0.01 to 0.03 GBq per annum for a 1000 MWe power station. The predicted aqueous discharge for iodine 131 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.

137 Westinghouse does not propose an annual disposal limit to sea for iodine radionuclides.

138 Westinghouse has not assessed the impact in terms of dose resulting from the disposal of iodine radionuclides by discharge to the sea.(ER table 5.2-12)

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

2.6.4 Other radionuclides

140 Aqueous radioactive waste can contain other radionuclides as well as those specifically considered above. These include activation products and fission products. Activation products, for example cobalt-58 and cobalt-60, may be formed by neutron activation of materials within the reactor which may be released into the coolant by corrosion processes and may be present dissolved in the coolant or as particulate material. The reactor materials and coolant chemistry are chosen to minimise both the potential for activation and corrosion. Fission products, for example, caesium-137 may enter the coolant in the event of a fuel pin failure. The coolant is recycled through filters and demineralisers in the purification loop of the CVS to remove suspended and dissolved radioactive materials. However, low concentrations are still found in managed discharges and minor leaks of coolant reaching the WLS.

141 **Strontium-90** is released into the coolant in the event of fuel pin failure. The mixed bed demineraliser and filters in the WLS will remove strontium from aqueous radioactive waste. (AP1000 BAT Form 4)

142 Westinghouse identifies the following abatement techniques for strontium-90 in aqueous radioactive waste:

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.

143 Westinghouse claims that the most effective techniques for abating strontium-90 is ion exchange. The AP1000 design includes ion exchange, although it is recognised that the choice of ion exchange resin in the AP1000 is not specifically aimed at strontium-90 removal but is optimised over a range of radionuclides.

144 Westinghouse provides little detail on the techniques for abatement of strontium-90 in aqueous radioactive waste discharges from the AP1000. We consider the optioneering study does not contain enough detail to identify the best option, however we recognise that ion exchange is likely to be the best option.

145 Westinghouse predicts that the annual average discharge of strontium-90 from the AP1000 to sea will be 0.00025 GBq. (ER Table 3.4-6)

146 Westinghouse calculates a discharge limit for strontium-90 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 (month 7 – 18) to calculate representative 12-month plant discharge to be 0.000324 GBq. Westinghouse has applied our limit setting methodology (Environment Agency 2005) to calculate the annual worst-case plant discharge (WCPD), which they have rounded to give its calculated limit. (ERs6.1.3)

147 Westinghouse calculates an annual limit of 0.0005 GBq for strontium-90 in liquid discharges. (ER Table 6.1-6)

148 Westinghouse estimates that the radiological impact from representative 12-month plant discharge of strontium-90 to sea will result in a dose to the local fisherman

family of 0.0000015 μSv y^{-1}. (ER table 5.2-12)

149 We do not consider that a specific limit should be set for strontium-90 in aqueous radioactive waste discharges, but in any permit we may issue we will require that operators demonstrate that BAT is used to minimise the amount of all radionuclides, including striontium-90 discharged in liquid waste. Strontium-90 is included in the limit we set for 'all other radionuclides (excepting tritium, carbon-14, cobalt-60 and caesium-137)'.

150 **Caesium-137** is a fission product which may be present in aqueous radioactive waste as a result of fuel failure or from tramp uranium.

151 Westinghouse considers the following abatement techniques for caesium-137 aqueous radioactive waste (AP1000 BAT Form 6):

a) Demineralisation - zeolite beds and cation resins 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 removing insoluble species, but most caesium radionuclides are soluble in water, therefore filtration has limited application for removing caesium.

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

152 Westinghouse claims that demineralisation is BAT for caesium-137. It recognises that demineralisation costs more than direct discharge and will produce secondary waste. But, 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 suitable for disposal as solid waste.

153 Our assessment concluded that Westinghouse has demonstrated that BAT is used to minimise discharges of caesium-137 in aqueous radioactive waste from the AP1000.

154 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)

155 Westinghouse calculated a discharge limit for caesium-137 from the AP1000. It has predicted monthly discharges over an 18-month cycle and used data from the 12 months in which the discharges are highest (month 7 – 18) to calculate the representative 12-month plant discharge to be 0.0301 GBq. Westinghouse has applied our limit setting methodology (Environment Agency 2005) to calculate the annual worst-case plant discharge (WCPD), which they have rounded to give its calculated limit. (ERs6.1.3)

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

157 Westinghouse estimates 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 0.0034 μSv y^{-1}. (ER table 5.2-12)

158 We have independently calculated limits for caesium-137 discharges that we may grant and, based on the information Westinghouse has provided for GDA, our proposed disposal limit for caesium-137 by discharge to the sea is 0.05 GBq in any 12 rolling calendar months.

159 Based on the information Westinghouse has provided for GDA, our proposed

quarterly notification level for caesium-137 is 0.018 GBq.

160 **Plutonium-241** can be produced by successive neutron capture of uranium in the AP1000. (AP1000 BAT Form 7)

161 Westinghouse identifies the following abatement options for plutonium-241:

a) Filtration / ion exchange;

b) evaporation;

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

d) monitoring of discharges delay tank – delay tanks can be used to delay discharges to take advantage of radioactive decay;

e) adsorption;

f) wet scrubbing;

g) no abatement – direct discharge of aqueous radioactive waste to the environment;

h) precipitation.

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

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

164 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)

165 Westinghouse calculates a discharge limit for plutonium-241 from the AP1000. It has predicted monthly discharges over an 18-month cycle and used data from the 12 months in which the discharges are highest (month 7 – 18) to calculate representative 12-month plant discharge to be 0.000108 GBq. Westinghouse has applied our limit setting methodology (Environment Agency, 2005) to calculate the annual worst-case plant discharge (WCPD), which they have rounded to give its calculated limit. (ERs6.1.3)

166 Westinghouse calculates an annual limit of 0.0002 GBq for plutonium-241 in aqueous radioactive waste discharges (ER Table 6.1-6)

167 Westinghouse estimates 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 0.0000027 μSv y^{-1}. (ER table 5.2-12)

168 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 issue 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)’.

169 **Beta emitting particulates -** 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 (AP1000 BAT Form 9):

Radionuclide	Average annual activity GBq	Activity on highest 12 months of 18 month cycle (GBq)	Dose to fisherman family ($\mu Sv\ y^{-1}$)	% 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

170 Westinghouse provides a review of other techniques that are available for removing particulates in liquid such as (AP1000 BAT Form 9):

a) flocculation;

b) particulate separation;

c) evaporation – Westinghouse claims operational experience has shown problems, and that drawbacks outweigh the benefits;

d) precipitation / filtration;

e) using a hydrocyclone;

f) mixed bed demineralisers;

g) ultrasonic fuel cleaning;

h) minimising plant shutdown.

171 Westinghouse claims 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.

172 Westinghouse claims 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.

173 We conclude that the techniques Westinghouse has considered for the abatement of fission and activation products in the AP1000 are comprehensive enough and represent feasible techniques at this stage. However, we recognise that techniques may be developed in the future which may be worth considering.

174 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)

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.

175 Westinghouse calculates discharge limits for activation and fission products from the AP1000. It has predicted monthly discharges over an 18-month cycle and used data from the 12 months in which the discharges are highest (month 7 – 18) to calculate representative 12-month plant discharge (Table 6.1-6). Westinghouse has applied our limit setting methodology (Environment Agency 2005) to calculate the annual worst-case plant discharge (WCPD), which they have rounded to give its calculated limit. (ERs6.1.3)

176 Westinghouse has calculated annual limits for the following radionuclides in liquid discharges: (ER Table 6.1-6)

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.

177 We examined historic discharges (where available) from European and US PWRs operating over the last 10 to 15 years and we consider that the range of discharges to water of fission and activation products is of 0.5 to 5 GBq per year for a 1000 MWe power station. The predicted annual average aqueous discharge of fission and activation products from the AP1000 is 2.67 GBq and within this range. We conclude that the aqueous discharge of fission and activation products from the UK AP1000 is comparable to other power stations across the world.

178 Westinghouse estimates that the radiological impact from 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 $\mu Sv\ y^{-1}$. (ER table 5.2-12)

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

a) cobalt-60 – 0.5 GBq;

b) caesium-137 – 0.05 GBq

c) all other radionuclides (excepting tritium, carbon-14, cobalt-60 and caesium137) taken together – 5 GBq.

180 Based on the information Westinghouse has provided for GDA, our proposed quarterly notification level for cobalt-60 is 0.18 GBq, for caesium-137 is 0.018 GBq and for 'all other radionuclides (excepting tritium, carbon-14, cobalt-60 and caesium-137) taken together' is 1.8 GBq.

2.7 AP1000 aqueous waste storage

181 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.

182 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.

Reactor coolant drain tank

183 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.

184 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.

Effluent hold up tanks

185 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.

186 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.

Waste hold up tanks

187 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.

188 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.

Chemical waste tank

189 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.

190 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.

Monitor tanks

191 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.

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

193 We will require information relating to the provision of secondary containment for the Monitor tanks to be provided at site specific permitting and we identify this as an assessment finding:

a) Information relating to the provision of secondary containment for the Monitor tanks shall be provided at site specific permitting.(AP1000-AF04)

Tank capacity

194 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:

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

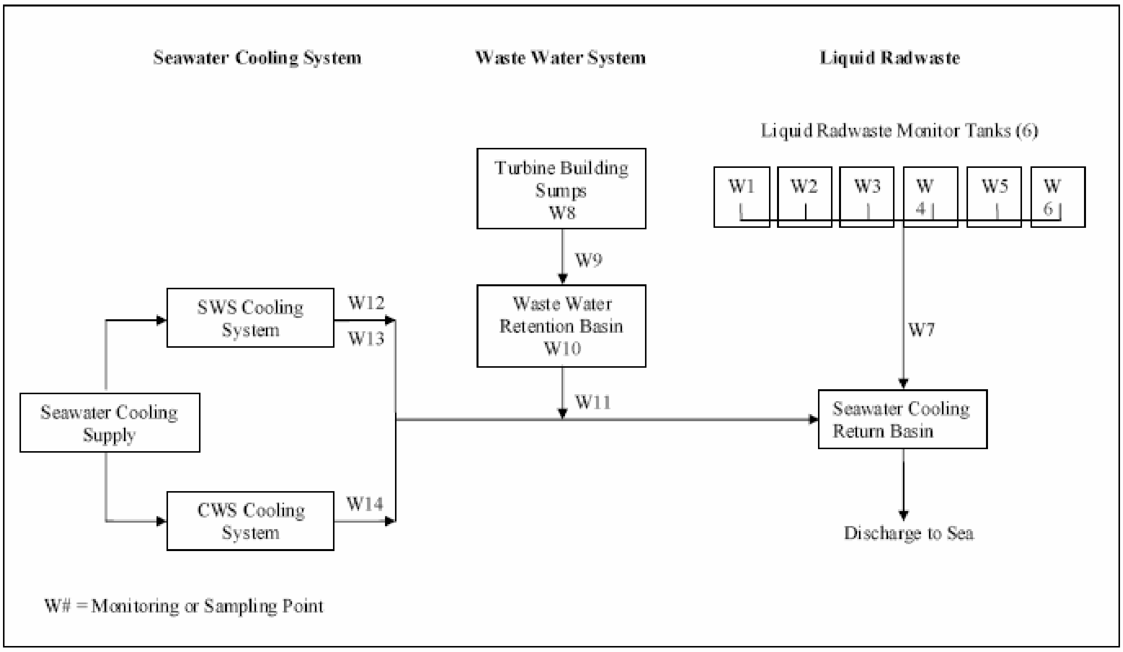
Maximum daily flow rates

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

195 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.

2.8 Disposal to the environment

196 The effluent system of the AP1000 is shown in ER Figure 6.2-2:



197 If we permit aqueous radioactive waste discharges from an AP1000 reactor at the site-specific stage, we would place controls on four effluent release points in a permit:

a) W7 – discharge for liquid radwaste monitor tanks serving the WLS;

b) W11 – discharge line of the wastewater system (WWS) from the wastewater retention basin;

c) W14 – discharge line of the circulating water system (CWS);

d) W12 – discharge line of the service water system (SWS).

198 Treated radioactive effluent from the WLS is collected in six monitor tanks, each with a usable capacity of 57 m^3, located in the radwaste building. Westinghouse claims that the average daily radioactive liquid waste arisings are approximately 8 m^3. The monitor tanks will, therefore, provide up to 42 days typical storage capacity in normal operation. This storage period will be longer for most operations but reduced for short periods during higher discharges associated with refuelling. (ERs3.4.3.6)

199 There are no direct continuous discharges from the WLS to the sea. When a tank needs to be discharged, its contents are sampled and analysed. Data on the volume and activity of contained radionuclides are used to decide if discharge can be permitted. All data will need to be recorded as operational records – a permit condition. The monitor tank discharge pumps have a design flow rate of 22.7 $m^3\ h^{-1}$. We will require the final common discharge line to be fitted with an MCERTS (our certification system for measuring equipment) flowmeter and flow proportional sampler to provide permit compliance data, our release point W7. A radiation monitor will also be installed on the discharge line.

200 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.

201 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.

202 The WWS, the CWS and the SWS should contain only non-radioactive wastewater in normal operation. Only in the event of steam generator tube leaks is there any possibility of these waters being contaminated with radioactivity.

203 The WWS collects normally non-radioactive waste water into the turbine building sumps. There is a radiation monitor (W9) on the common discharge line from the sumps to the wastewater retention basin (WWRB). If activity is detected the wastewater is diverted to the WLS.

204 The contents of the WWRB are only discharged intermittently after sampling and analysis to confirm discharge can be permitted. The discharge line will need to be fitted with an MCERTS[3] flowmeter and flow proportional sampler to provide permit compliance data, release point W11.

205 The CWS 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, release point W14. 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 W14 to confirm no significant contamination has taken place.

206 The SWS 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, release point W12. There will also be a continuous radiation monitor installed at W13. 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 W12 to confirm no significant contamination has taken place.

[3] The Environment Agency's Monitoring Certification Scheme, see www.mcerts.net

2.9 The Convention for the Protection of the Marine Environment of the North East Atlantic (OSPAR)

207 Several respondents (GDA83, 99, 134, 150 and 156) as well as attendees at our stakeholder seminar raised the topic of compliance with the UK's obligations under OSPAR. In particular the use of evaporation to treat aqueous radioactive waste was suggested. We have included in this section a summary of OSPAR, relevant information, and our conclusions on this matter.

208 The UK is a Contracting Party to the OSPAR Convention and the Government has published its 'UK Strategy for Radioactive Discharges' (DECC, 2009d) which sets out a framework for implementing the UK's obligations in respect of the OSPAR Radioactive Substances Strategy[4]. The outcomes expected of the UK Strategy will be:

a) progressive and substantial reductions in radioactive discharges;

b) progressive reductions in concentrations of radionuclides in the marine environment resulting from radioactive discharges, such that by 2020 they add close to zero to historic levels;

c) progressive reductions in human exposures to ionising radiation resulting from radioactive discharges, as a result of planned reductions in discharges.

209 The OSPAR Convention also includes the requirement for Contracting Parties to use Best Available Techniques (BAT) to minimise discharges of radioactivity to the marine environment. The Government gave us guidance in 2009 to base our regulation of radioactive discharges on the use of BAT and highlighted the importance of BAT in the optimisation of doses and the setting of discharge limits (DECC, 2009a). We anticipated the requirement to use BAT and throughout GDA required Westinghouse to demonstrate that the AP1000 uses BAT from the initial generation of radioactivity to final discharge. We consider our approach to GDA contributes significantly to the outcomes of the UK Strategy noted above.

210 This document has set out our conclusions that the AP1000 design uses BAT to minimise most discharges of radioactivity to the sea. The AP1000 GDA design does not have the capability to treat aqueous wastes that are incompatible with ion exchange and relies on mobile plant being brought in when needed. Evaporation is a technique that may be applied to most aqueous wastes. We need to ensure that any power plant built uses BAT to treat all discharges of aqueous waste to show compliance with UK obligations under OSPAR to use BAT. Future operators will be responsible for aqueous waste management and disposal and will need to make decisions on techniques to be used at their sites. We have already raised this matter above and the assessment finding AP1000-AF04 will also cover our concerns under OSPAR:

a) Future operators shall, at the detailed design phase, provide an assessment to demonstrate that techniques to minimise the discharge of all aqueous radioactive wastes are BAT for their location. In particular, the omission of an evaporator will need to be justified. (AP1000-AF05)

211 The impact of radioactive discharges to the marine environment from the AP1000 design will be less than the currently operating nuclear power plants in the UK, and as these are replaced we anticipate a reduction in the total UK discharges.

212 We do not have information on the effect of abatement on carbon-14 contained within the aqueous wastes treated. We will need the future operators to tell us how their proposed management of aqueous wastes will affect the distribution of carbon-14 over all discharge routes. We have therefore included an assessment finding:

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[4] Ministerial Meeting of the OSPAR Commission, Summary Record OSPAR 98/14/1-E, Annex 35.

a) Future operators shall, during the detail design stage provide a predicted mass balance showing how their proposed aqueous radioactive waste management regime will affect the disposal of carbon-14 to the gaseous, solid or aqueous routes. For each route the form of carbon-14 expected shall be provided. For solid wastes the quantities of each type of waste shall be provided with expected carbon-14 content. (AP1000-AF06)

213 We have set out our assessment of the impact of radioactive discharges to the sea from the AP1000 in our report AP1000-11 (Environment Agency, 2011c). We conclude that doses to the public (less than 1 $\mu Sv\ y^{-1}$) from the AP1000 will be as low as reasonable achievable for the generic site. Future operators will need to confirm that assessment for each specific site proposed for a new nuclear power plant.

3 Public Comments

214 The public involvement process remained open during our assessment see http://www.hse.gov.uk/newreactors/publicinvolvement.htm

215 We did not receive any public comments by this route during this assessment relating to the discharge of aqueous radioactive waste.

216 The conclusions in this report have been made after consideration of all relevant responses to our consultation, in particular those relating to OSPAR.

4 Conclusion

217 Our conclusions have changed since our consultation. Many respondents were concerned about compliance with the UK's obligations under OSPAR. We undertook more assessment in regard to this topic, a summary is provided in section 2.9 above. We were unable to complete our OSPAR assessment as the AP1000 design does not include treatment options for certain aqueous wastes that are incompatible with the design standard of filtration and ion exchange. The AP1000 design includes space and facilities for operators to bring in mobile systems to treat small volume and infrequently produced aqueous wastes such as chemical and detergent wastes that are incompatible with the normal treatment options. We had already identified this gap and include an assessment finding (AP1000-AF05) below. It will be for future operators to show on a site-specific basis that their proposals for aqueous radioactive waste management will ensure that their discharges to the sea will comply with the UK obligations under OSPAR. An assessment finding on carbon-14 was identified and is shown below. Our conclusions now reflect that the AP1000 design does not include treatment techniques for aqueous radioactive wastes that are incompatible with filtration and ion exchange.

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

a) during routine operations and maintenance;

b) from anticipated operational events.

219 We conclude that, for aqueous wastes that are incompatible with filtration and ion exchange, the AP1000 has no suitable treatment technique. We have left the treatment of these small volume wastes as a matter for future operators to determine, see our assessment finding below.

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

221 We conclude that any operational, single AP1000 unit should comply with the limits and levels set out below for the disposal of aqueous radioactive waste. The limits and levels will be the starting point for any site specific permit, but will be reviewed as part of the site permitting process based on any additional information provided by a future AP1000 operator. The limits would also be reviewed periodically thereafter, as data becomes available from operational AP1000 reactors.

Radionuclides or group of radionuclides	**Proposed Annual limit (GBq)**	**Proposed 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

222 As part of our assessment we identified the following assessment findings:

a) Information relating to the provision of secondary containment for the Monitor tanks shall be provided at site specific permitting.(AP1000-AF04)

b) Future operators shall, at the detailed design phase, provide an assessment to demonstrate that techniques to minimise the discharge of all aqueous radioactive wastes are BAT for their location. In particular, the omission of an evaporator will need to be justified. (AP1000-AF05)

c) Future operators shall, during the detail design stage, provide a predicted mass balance showing how their proposed aqueous radioactive waste management regime will affect the disposal of carbon-14 to the gaseous, solid or aqueous routes. For each route the form of carbon-14 expected shall be provided. For solid wastes the quantities of each type of waste shall be provided with expected carbon-14 content. (AP1000-AF06)

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(DECC, 2009b)	UK Strategy for Radioactive Substances, DECC, July 2009 http://www.decc.gov.uk/Media/viewfile.ashx?FilePath=What%20we%20do%5CUK%20energy%20supply%5CEnergy%20mix%5CNuclear%5Cradioactivity%5C1_20090722135916_e_@@_dischargesstrategy.pdf&filetype=4
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(Environment Agency, 2005)	Development of Guidance on Setting Limits on Radioactive Discharges to the Environment from Nuclear Sites, (Science Report: SC010034/SR, Environment Agency, December 05) http://publications.environment-agency.gov.uk/pdf/SCHO1205BIVK-e-e.pdf
(Environment Agency, 2007)	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
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(Environment Agency, et al 2009)	*Radioactivity in Food and the Environment, 2008* (RIFE – 14), Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2009.
(Environment Agency, 2010a)	RGS, No RGN RSR 1: Regulatory Environmental Principles (REPs), 2010 http://publications.environment-agency.gov.uk/pdf/GEHO0709BQSB-e-e.pdf
(Environment Agency, 2010b)	RSR: Principles of optimisation in the management and disposal of radioactive waste http://www.environment-agency.gov.uk/static/documents/Business/GEHO0709BQSA-E-E.pdf
(Environment Agency, 2010c)	EAGDAR AP1000-14: Generic design assessment. AP1000 nuclear power plant design by Westinghouse Electric Company LLC. Assessment report – Independent dose assessment http://publications.environment-agency.gov.uk/pdf/GEHO0510BSKO-e-e.pdf

(Environment Agency, 2011a)	Generic design assessment. AP1000 nuclear power plant design by Westinghouse Electric Company LLC. Decision Document. http://publications.environment-agency.gov.uk/pdf/GEHO1211BTOI-e-e.pdf
(Environment Agency, 2011b)	EAGDAR AP1000-03: Generic design assessment. AP1000 nuclear power plant design by Westinghouse Electric Company LLC. Final assessment report – BAT to prevent or minimise the creation of radioactive waste. http://publications.environment-agency.gov.uk/pdf/GEHO1211BTNV-e-e.pdf
(Environment Agency, 2011c)	EAGDAR AP1000-11: Generic design assessment. AP1000 nuclear power plant design by Westinghouse Electric Company LLC. Final assessment report – Radiological impact on members of the public. http://publications.environment-agency.gov.uk/pdf/GEHO1211BTOD-e-e.pdf
(Environment Agency, 2011d)	EAGDAR AP1000-06: Generic design assessment. AP1000 nuclear power plant design by Westinghouse Electric Company LLC. Final assessment report – Solid radioactive waste. http://publications.environment-agency.gov.uk/pdf/GEHO1211BTNY-e-e.pdf
US NRC	NUREG-0017, "Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Pressurized Water Reactors (PWRs)," current revision.

While every effort has been made to ensure the accuracy of the references listed in this report, their future availability cannot be guaranteed.

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
ONR	Office for Nuclear Regulation, an Agency of the HSE (formerly HSE's Nuclear Directorate)
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: AP1000 reactor expected aqueous discharges

223 Westinghouse provided estimates of annual aqueous radioactive waste discharges 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.

224 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.

225 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.

226 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.

227 Westinghouse have provided data for annual average water discharges which take no account of short term variability of releases. Summarised data is given below and further detailed data at the end of this Annex.

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

228 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.

229 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 below:

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**

230 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.

231 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.

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

Nuclide	**Activity Release (1) GBq y⁻¹**			
	Shim Bleed +Equip Drains	**Miscellaneous Wastes**	**Turbine Building**	**Total Release**
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
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

Annex 2: AP1000 effluent volumes

Reactor Coolant System Effluents

232 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.

233 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.

234 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:

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

Floor Drains and Other Aqueous Wastes with High Suspended Solids

235 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:

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

Detergent Wastes

236 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.

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

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

238 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.

Chemical Wastes

239 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.

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

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

241 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.

Steam Generator Blowdown Waste

242 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:

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

Annex 3: Comparison with EU Commission Recommendation 2004/2/Euratom

243 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).

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

244 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.

245 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.

Annex 4: Limit and QNL setting detail

Significant radionuclides

246 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).

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

248 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.

249 Westinghouse state 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.

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

251 In addition Westinghouse say 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.

252 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.

253 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.

254 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.

255 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.

Estimated discharges and proposed discharge limits

256 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.

257 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.

258 Using these factors Westinghouse have estimated values for the WCPD for a range of radionuclides which are given below and have calculated limits based on these values.

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

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.

259 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, 2010c) taking into account our Considerations document (Environment Agency, 2009) and limit setting guidance (Environment Agency, 2005).

260 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 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, 2011c and 2011d).

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[5].

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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5 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.

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

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 – 0.05 GBq 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:

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.

Annex 5: BAT and OSPAR

277 The UK Discharge Strategy (DECC, 2009b), which is Government policy, has objectives:

a) to implement the UK's obligations, rigorously and transparently, in respect of the OSPAR Radioactive Substances Strategy (RSS) intermediate objective for 2020;

b) to provide a clear statement of Government policy and a strategic framework for discharge reductions, sector by sector, to inform decision making by industry and regulators.

278 The expected outcomes of the Strategy are, by 2020, of:

a) progressive and substantial reductions in radioactive discharges [to the extent described in the strategy];

b) progressive reductions in concentrations of radionuclides in the marine environment resulting from radioactive discharges, such that by 2020 they add close to zero to historic levels;

c) progressive reductions in human exposures to ionising radiation resulting from radioactive discharges, as a result of planned reductions in discharges.

279 The Statutory Guidance (DECC, 2009a) provides guidance to the Environment Agency with regard to the Discharge Strategy. In brief this states that "*in relation to its radioactive discharge functions, the Environment Agency should base its regulatory decisions on applying the environmental principles set out in the 2009 UK Strategy*." These principles are:

a) regulatory justification of practices by the Government;

b) 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)**;**

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

d) sustainable development;

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

f) the precautionary principle; the polluter pays principle;

g) 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.

280 The Government has stated in the Statutory Guidance [paragraph 4] that it considers it appropriate that the Environment Agency pursue the objectives set out in the *UK Strategy for Radioactive Discharges*. But this does not mean that there is a policy or legal requirement that we regulate discharges and set limits to ensure that the Discharge Objectives are met at a site, sectoral or national level. Instead the Discharge Strategy states at paragraph 1.6.3 that:

a) *"The Government believes that the application of these principles through the regulatory framework will continue to drive the delivery of progressive reductions in discharges, where practicable, in order to meet the OSPAR intermediate objective for 2020*".

281 In GDA we concentrated on assessing BAT and expected that Requesting Parties would use the latest technology or techniques in their designs to ensure reduced discharges of radioactivity. Any new nuclear power plant we permit to operate in the UK will use BAT to conform to principle e) of the 2009 UK Strategy as noted

above and will, overall, have lower discharges (against electrical output) than current nuclear power plant.

Best available techniques

282 GDA has been done on the basis that new designs need to demonstrate Best Available Techniques are used. This report gives a full evaluation of BAT for aqueous discharges and we concluded that while the AP1000 used BAT to minimise most discharges of aqueous radioactive waste, the AP1000 has no suitable treatment techniques for some aqueous wastes produced.

283 Improvements have been made to the AP1000 design to reduce initial generation of radionuclides – for example reduction in use of cobalt containing materials such as Stellites and better corrosion control by reactor chemistry and the use of zinc injection. Use of abatement techniques such as filters and ion exchange are as existing plant with Westinghouse claiming that advanced techniques such as ultra-filtration have disadvantages that outweigh potential benefits in reduced discharges when compared to impact – 2 µSv/y for the AP1000.

284 Westinghouse assessed the use of evaporation in place of ion exchange but concluded that for its GDA generic site it was not BAT (see section 2.5.1 of this report).

285 The AP1000 does not include boron recycle system in the design for GDA but we identified an assessment finding for Westinghouse to keep the capability to include boron recycle in the AP1000 design under review (AP1000-AF02 – see Environment Agency, 2011b).

286 We have concluded in this report that future operators will need to provide proposals for techniques to treat all aqueous radioactive wastes produced by the AP1000 and demonstrate that these are BAT to minimise discharges at their location. We identified assessment finding AP1000-AF05 on this topic in section 2.5 of this report. The use of evaporators is common in Europe to treat all aqueous wastes, therefore we believe that this technique must be considered in the BAT options assessment provided by future operators.

Discharges

287 We provide below some data that illustrates how the predicted discharges from an AP1000 to the sea will compare with current discharges from the existing plants Hinkley Point B (output 870 MWe) and Sizewell B (output 1191 MWe). Note that this comparison is intended to show that BAT for new plants will generally lead to lower discharges, it is not intended to reflect on the UK Discharge Strategy that applies at a national level. Further, current discharges may reflect reduced operation time due to maintenance or refuelling. Figures are shown as actual and as normalised to 1000 MWe.

Tritium

288 The AP1000 reduces use of boron by using grey rods and burnable poisons and uses lithium hydroxide with <0.1% Li-6 to reduce tritium production compared to predecessor PWRs.

289 Current discharges (reported in 'My Backyard' on our website) TBq:

	Hinkley Point B	Sizewell B
2008	78	52
2009	110	53
2010	150	25
Mean	113	43
Normalised	130	36

290 Representative 12-month/worst case 12-month discharges for new plant:

a) AP1000 = 35 TBq / 58 TBq

b) AP1000 normalised = 31 TBq / 52 TBq

291 New plant will discharge substantially less tritium than existing older plant, Hinkley Point B, the AP1000 is similar to the Sizewell B which is a more recent plant but should produce less tritium on the representative or predicted average basis.

Carbon-14

292 C-14 is unavoidably produced in PWRs by activation of oxygen within the water molecules of the reactor coolant. Most C-14 is discharged to air but some 5-20% can be present in water discharges in various forms.

293 Current discharges (My Backyard) GBq:

	Hinkley Point B	Sizewell B
2008	1	3.3
2009	1	3
2010	1	1.5
Mean	1	2.6
Normalised	1.1	2.2

294 Representative 12-month/worst case 12-month discharges for new plant:

a) AP1000 = 4.42 GBq / 7.3 GBq

b) AP1000 normalised = 4 GBq / 6.5 GBq

295 We have not been able to identify techniques to abate C-14 in aqueous discharges. Evaporation may just cause most C-14 (depending on form) to go with the evaporate and be discharged to sea.

296 We noted in our Decision Document that the range of discharge for existing European and USA plants was 3-45 GBq y^{-1} C-14 for a 1000 MWe plant. The range covers the discharges predicted for the AP1000 so the design is comparable to world wide power stations.

297 C-14 is a naturally occurring radionuclide, global annual production of natural C-14 is around 1000 TBq, so power stations make a small contribution to global levels. The Atlantic has around 5 Bq m^{-3} C-14. An AP1000 reactor with the maximum discharge of C-14 will add approximately 6 Bq m^{-3} to C-14 in the cooling water outflow. A dispersion factor of 10 should be readily achieved within a few 100 metres of discharge point. Therefore we do not believe that the discharge of C-14 from an AP1000 will alter the background level in the wider oceans.

Activated corrosion products – Co-60

298 The production of activated corrosion products, in particular Co-60, has been significantly reduced by use of BAT in the AP1000.

299 Current discharges (My Backyard) MBq:

	Hinkley Point B	Sizewell B
2008	230	990
2009	380	790
2010	230	740
Mean	280	840
Normalised	322	705

300 Representative 12-month/worst case 12-month Co-60 discharges for new plant:

a) AP1000 = 301 MBq / 497 MBq

b) AP1000 normalised = 269 MBq / 445 MBq

301 Note that Co-60 is an issue more with PWRs – it is not such a concern in gas cooled reactors such as Hinkley Point B. The AP1000 will discharge significantly less activated corrosion products than older PWRs.

Fission products

302 FPs should only be present in aqueous discharges from fuel pin failures. Pin manufacture has considerably improved and for Westinghouse 17RFA fuel assemblies pin failures should be less than 10 in a million in a year. So BAT starts with an assurance that quality fuel is used. For abatement we already say that the liquid waste systems using filters and ion exchange is BAT for most aqueous wastes and these will minimise discharge of FPs.

303 Current discharges (My Backyard):
Caesium-137 GBq

	Hinkley Point B	Sizewell B
2008	4.2	4.5
2009	4.5	4.8
2010	3	5.7
Mean	3.9	5
Normalised	4.5	4.2

304 Representative 12-month/worst case 12-month discharges for new plant:

a) AP1000 = 0.03 GBq / 0.05 GBq Cs-137

b) AP1000 normalised = 0.027 GBq / 0.045 GBq Cs-137

305 The discharges of Cs-137 from the AP1000 will be substantially less than from the existing plants.

306 Current discharges (My Backyard):
Iodine-129 MBq

	Hinkley Point B	Sizewell B
2008	<100	<100
2009	<100	<100
2010	<100	<100
Mean	<100	<100
Normalised	-	<100

Representative 12-month discharge for new plant:

a) AP1000 = 15 MBq Iodine-131

b) AP1000 normalised = 13.4 MBq Iodine-131

307 We concluded that iodine radionuclides discharged from the new plants are at such a low level that monitoring would be at or below levels of detection and therefore limit setting is unreasonable. Considered with the short half lives of the iodine radionuclides we consider their discharges ‘close to zero’.

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