

**Generic design assessment
AP1000 nuclear power plant design by
Westinghouse Electric Company LLC**

**Assessment report
Radiological impact on
members of the public**



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Generic design assessment

AP1000 nuclear power plant design by Westinghouse Electric Company LLC

Assessment report – Assessment of radiological impact on members of the public

Protective status

This document contains no sensitive nuclear information or commercially confidential information.

Process and Information Document¹

The following sections of Table 1 in our Process and Information document are relevant to this assessment:

Section 2.7 Prospective dose assessment for the generic site at the proposed limits for levels of discharge. This should include:

- annual dose to most exposed members of the public for liquid discharges;
- annual dose to most exposed members of the public for gaseous discharges (identifying separately the dose associated with on site incineration where applicable);
- annual dose to the most exposed members of the public for all discharges from the facility;
- annual dose from direct radiation to the most exposed member of the public;
- annual dose to the critical group for the facility;
- potential short-term doses, including via the food chain, based on the maximum anticipated short-term discharges from the facility in normal operation;
- a comparison of the calculated doses with the relevant dose constraints; and
- an assessment of whether the build-up of radionuclides in the local environment of the facility, based on the anticipated lifetime discharges, might have the potential to prejudice legitimate users or uses of the land or sea.

All assumptions made should be set out and reasons for their validity given.

Section 2.8 Collective dose assessments for discharges from the facility truncated at 500 years to the UK, European and World populations.

Assumptions made in carrying out these assessments should be set out.

Section 2.9 Sufficient assumed data for others to be able to carry out all dose assessments including as relevant :

- radionuclide composition of each release;
- gaseous release points (including heights, effective heights and volumetric flow rates);
- liquid release points;
- fractions of releases made via each release point (including incinerators);
- release rate;
- information used to estimate incinerator releases (i.e. expected quantities of wastes to be incinerated, expected radionuclide composition and concentrations, and retention factors for any abatement provided; and
- hydrographic data (mean volumetric flow for any inland water courses, such as rivers, or volumetric exchange rate for estuaries/coasts that receive discharges).

Additionally, detail of assumptions made concerning the following will be helpful to enable others to refine any assessment made:

- dose receptor points;
- weather data;
- chemical form of the activity discharged;
- deposition velocities, washout coefficients and surface roughness factors;
- dose per unit intake factors;
- food consumption rates;
- critical group habits data;
- nearest food production location; and
- nearest habitation(s).

**Radioactive
Substances
Regulation
Environmental
Principles²**

The following principles are relevant to this assessment:

Fundamental Principle E – Protecting Human Health and the Environment

SEDP1 General RSR Principle for siting new facilities - When evaluating sites for a new facility, account shall be taken of the factors that might affect the protection of people and the environment from radiological hazards and the generation of radioactive waste.

SEDP2 Movement of radioactive material in the environment - Data shall be provided to allow the assessment of rates and patterns of movement of radioactive materials in the air and the aquatic and terrestrial environments around sites.

SEDP3 Ambient radioactivity - Levels of ambient radioactivity around the sites of new facilities shall be assessed.

SEDP4 Multi-facility sites - In the case of nuclear and other sites on which there are already one or more facilities, the radiological impact of the whole site on people and the environment shall be assessed when considering the suitability of the site for any new facility.

RPDP1 Optimisation of protection - All exposures to ionising radiation of any member of the public and of the population as a whole shall be kept as low as reasonably achievable (ALARA), economic and social factors being taken into account.

RPDP2 Dose limits and constraints - Radiation doses to individual people shall be below the relevant dose limits and constraints.

RPDP4 Prospective dose assessments for radioactive discharges to the environment - Assessments of potential doses to people and to non-human species shall be made prior to granting any new or revised authorisation for the discharge of radioactive wastes into the environment.

Report author Julie Tooley

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

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

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

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

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1 Summary

- 1 We have assessed information in the generic design assessment (GDA) submission made by Westinghouse for the AP1000 with respect to prospective doses to members of the public as a result of the disposal of aqueous and gaseous radioactive waste from the AP1000 to the environment.
- 2 We appointed contactors to undertake the verification and validation of assessments made by Westinghouse for the AP1000 at the generic site and to make an independent assessment of doses to members of the public from the AP1000 at the generic site.
- 3 We conclude that all the doses assessed by Westinghouse are below the dose constraint for members of the public of $300 \mu\text{Sv y}^{-1}$ and the dose constraint recommended by the Health Protection Agency (HPA) for new nuclear build of $150 \mu\text{Sv y}^{-1}$.
- 4 We conclude that sum of doses to the representative person at our proposed limits is below the source dose constraint.
- 5 A number of the sites listed in the Nuclear National Policy Statement as potentially suitable for a new nuclear power station are adjacent to existing nuclear power stations. In GDA the specific site at which an AP1000 might be located is not known but we consider, in the light of our assessment that the highest total dose is estimated to be $11 \mu\text{Sv y}^{-1}$, it is very unlikely that doses at the site will exceed the site dose constraint of $500 \mu\text{Sv y}^{-1}$. We consider that site dose should be assessed at the site specific stage.
- 6 Comparison against the dose limit can only be done at site specific permitting when contributions from all sources of radiation can be included.
- 7 In line with usual procedures we will require a detailed site specific impact assessment to be carried out at site specific permitting based on the actual environmental characteristics of the proposed site to demonstrate that doses to members of the public and non-human species from the AP1000 at the proposed site will be ALARP and below relevant dose constraint and dose limits.
- 8 Our findings on the wider environmental impacts and waste management arrangements for the AP1000 reactor may be found in our Consultation Document (Environment Agency, 2010a).

2 Introduction

- 9 This assessment considers the radiological impact of the AP1000 on members of the public arising from discharges into the environment.
- 10 Regulation of public radiation exposure is shared between the Environment Agency (EA) (in England and Wales) and HSE. The Environment Agency regulates doses to the public resulting from discharges of radioactive waste into the environment during normal operation. HSE regulates doses to the public resulting from direct radiation (i.e. direct radiation originating from within the site boundary) during normal operation. HSE require site operators to measure direct radiation at the site perimeter and estimate exposure to a reference person on an annual basis. Direct radiation is radiation received directly from a source such as a nuclear power station, instead of indirectly as a result of radioactive discharges.
- 11 The assessment considers the information provided by Westinghouse Electric Company (Westinghouse) for its AP1000 design.
- 12 We appointed contractors (Enviros Consulting Ltd) to make an independent assessment of environmental activity concentrations from the AP1000 at the generic site (Environment Agency, 2009g). We have produced a separate assessment report on the generic site proposed by Westinghouse (Environment Agency 2010e).
- 13 This assessment does not cover radioactive discharges arising from decommissioning at the end of the reactor lifecycle.
- 14 The assessment aims to establish whether the design could be operated in the UK in line with UK Statute, policy and guidance on radioactive waste as currently written but it is recognised that the assessment should be kept under review to reflect changes in statute, policy and guidance that may occur between now and plant commissioning.

3 Assessment

- 15 This assessment considers the radiological impact of discharges from an AP1000 on members of the public. We have taken into account Statutory guidance to the Environment Agency concerning the regulation of radioactive discharges into the environment (DECC, 2009) which sets out the principle that:
- a) regulatory justification of practices should be carried out 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;
 - g) the polluter pays principle;
 - h) 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.

3.1 Assessment methodology

- 16 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 radiological impact of discharges from an AP1000 on members of the public to demonstrate that doses to members of the public from the AP1000 at the proposed site will be as low as reasonably practicable (ALARP) and not exceed dose constraints and limits;
 - e) decide on any potential GDA Issues or other issues to carry forward from GDA in our Statement of Design Acceptability, if issued.
- 17 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. Westinghouse completely revised its submission during 2008 and provided an Environment Report with supporting documents.
- 18 We assessed information contained in the Environment Report but found that while much improved from the original submission there were some areas where we required further information.
- 19 We issued a Regulatory Observation (RO-AP1000-32) on 1 June 2009 relating to statements made by Westinghouse in its submission about the dilution of liquid radioactive waste for discharge.
- 20 We raised 42 Technical Queries (TQs) on Westinghouse during our assessment. Six were relevant to this report:
- a) TQ-AP1000-150 – Dose assessment assumptions – effective release height. 1 June 2009.
 - b) TQ-AP1000-151 - Dose assessment assumptions – short term releases. 1 June 2009.
 - c) TQ-AP1000-152 - Generic site – location of nearest properties. 1 June 2009.
 - d) TQ-AP1000-164 - Liquid radioactive waste – grouping of radionuclides in discharge limits. 17 June 2009.
 - e) TQ-AP1000-165 - Gaseous radioactive waste – grouping of radionuclides in discharge limits. 17 June 2009.
 - f) TQ-AP1000-169 – Short term release dose assessment - atmospheric dispersion modelling system (ADMS) input data. 19 June 2009.
- 21 Westinghouse responded to the TQ's. They reviewed and updated the Environment Report in March 2010 to include all the relevant information provided by the TQs. This report only uses and refers to the information contained in the updated Environment Report (UKP-GW-GL-790(Rev3)) and its supporting documents.

3.2 Assessment objectives

- 22 Key areas of the submission made under the GDA arrangements by Westinghouse for the AP1000 design that have been considered are:
- a) Is the radiological impact assessment carried out by Westinghouse reasonable and justified?
 - b) Can the radiological impact assessment carried out by Westinghouse be independently validated?
 - c) Are predicted doses to members of the public below dose constraints and limits?

3.3 Westinghouse documentation

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

Document reference	Title	Version number
UKP-GW-GL-790	UK AP1000 Environment Report	3
UKP-GW-GL-026	AP1000 Nuclear Power Plant BAT Assessment	1
UKP-GW-GL-025	Generic Site Report	1
EPS-GW-GL-700	AP1000 European Design Control Document	0

3.4 Summary of assessment findings

24 This report summarises the outcomes of our assessment of the information provided and the assessment carried out by Westinghouse with respect to prospective doses to members of the public as a result of the disposal of aqueous and gaseous radioactive waste from the AP1000 to the environment.

25 In order to assess potential impacts we required Westinghouse to carry out dose assessments set out in section 2.7 of our Process and Information Document. In order to assess doses we also required Westinghouse to describe a generic site on which the dose assessment was based and which represented likely sites where an AP1000 might be located. A separate assessment report (Environment Agency, 2010e) has been prepared setting out our assessment of the generic site parameters provided by Westinghouse. For consistency the generic site description was also used in the assessment of potential impact on non-human species, see our assessment report (Environment Agency, 2010f).

26 In order to assess doses to members of the public, in addition to the description of the environmental features of the generic site, we required Westinghouse to provide information about discharges of aqueous and gaseous radioactive waste from the AP1000 and these are set out in our respective assessment reports (Environment Agency 2010c,d)

27 In order to verify and validate the dose assessment carried out by Westinghouse we appointed a contractor to comment on the assumptions made by Westinghouse with respect to dose assessment parameters, to repeat Westinghouse's dose assessment and provide a methodology by which we could calculate doses to members of the public at our proposed discharge limits (Environment Agency, 2010g).

28 During the dose assessments certain matters were identified and dealt with using the Regulatory Observation and Technical Query system.

29 A Regulatory Observation, RO-AP1000-32, was raised on 1 June 2009 requiring Westinghouse to review the submission made under the GDA process for the AP1000 design to take into account UK policy and practices with respect to the discharge of liquid radioactive waste because we noted that from time to time that both the AP1000 European Design Control Document and the Environment Report made reference to the dilution of liquid radioactive waste. In particular the AP1000 European Design Control Document referred to meeting activity concentration limits and offsite dose limits specified by the US Nuclear Regulatory Commission (NRC). In response Westinghouse has prepared AP1000 Nuclear Power Plant BAT Assessment (UKP-GWGL-026, Revision 1) to demonstrate that Best Available Techniques are included in the design of the AP1000 and which takes into account UK policy and practices.

30 Technical Query TQ-AP1000-150 was raised on 1 June 2009 which required Westinghouse to justify the extent to which building downwash had been considered in

- the calculation of the value for effective release height for the main stack used in its dose assessments. Westinghouse responded on 20 August 2009 and its response included a reassessment of doses using an effective release height of 22.5 m which had been calculated taking into account building downwash. This was also taken into account by the contractor undertaking the validation and verification of Westinghouse's dose assessment. The information was included in Environment Report UKP-GW-GL-790 Rev 2 and 3 (s 5.2.1.2) along with a revised dose assessment (Chapter 5).
- 31 Technical Query TQ-AP1000-151 was raised on 1 June 2009 and required Westinghouse to provide information on certain assumed data they had used in its short-term dose assessment. Westinghouse responded on 22 June 2009 and its response was taken into account by the contractor undertaking the validation and verification of Westinghouse's dose assessment. The information was included in Environment Report UKP-GW-GL-790 Rev 2 and 3 (s 5.2.1.4)
- 32 Technical Query TQ-AP1000-152 was raised on 1 June 2009 and required Westinghouse to provide information on data they had used in its generic site description relating to the location of the nearest properties. Westinghouse responded on 30 June 2009 and its response was taken into account by the contractor undertaking the validation and verification of Westinghouse's dose assessment. The information was included in Environment Report UKP-GW-GL-790 Rev 2 and 3 (s 5.2.1.2)
- 33 Technical Query TQ-AP1000-164 was raised on 17 June 2009 and required Westinghouse to provide information on the approach they had used to identify groups of radionuclides in liquid radioactive waste discharge limits. Westinghouse responded on 20 August 2009 and its response was taken into account by the contractor undertaking the validation and verification of Westinghouse's dose assessment. The information was included in Environment Report UKP-GW-GL-790 Rev 2 and 3 (s 6.1.1 and table 6.1-2)
- 34 Technical Query TQ-AP1000-165 was raised on 17 June 2009 and required Westinghouse to provide information on the approach they had used to identify groups of radionuclides in gaseous radioactive waste discharge limits. Westinghouse responded on 20 August 2009 and its response was taken into account by the contractor undertaking the validation and verification of Westinghouse's dose assessment. The information was included in Environment Report UKP-GW-GL-790 Rev 2 and 3 (s 6.1.1 and table 6.1-1).
- 35 Technical Query TQ-AP1000-169 was raised on 19 June 2009 and required Westinghouse to provide information on ADMS input data they had used in its short-term dose assessment. Westinghouse responded on 13 August 2009 and its response was taken into account by the contractor undertaking the validation and verification of Westinghouse's dose assessment. The data was included in Environment Report UKP-GW-GL-790 Rev 2 and 3 (s5.2.1.4 and table 5.2-3).
- 36 The outcomes of the dose assessment were compared with limits and constraints set out in Council Directive 96/29/Euratom, laying down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionising radiation and enacted in England and Wales by the Radioactive Substances (Basic Safety Standards) (England and Wales) Direction 2000. The limits and constraints are:
- a) UK dose limit for members of the public: 1 mSv (1000 µSv) per annum individual effective dose.
 - b) UK dose constraints:
 - i) 300 µSv per annum individual effective dose from a single new source, (in their 2009 publication Application of the 2007 Recommendations of the ICRP to the UK (RCE-12) the Health Protection Agency has advised the UK Government to

select a constraint value for members of the public for new nuclear power stations that is less than 0.15mSv (150 μ Sv) per year),

- ii) 500 μ Sv per annum individual effective dose from a single site not including exposures arising from direct radiation.

37 There are no regulatory limits and constraints for collective dose. Collective dose information is normally used for comparisons across sites or facilities. The International Atomic Energy Agency (IAEA) suggest that practices which give rise to collective doses less than 1 man Sv per year of operation may be exempted from regulatory control.

38 In its submission Westinghouse described a generic site and discharge data and using these they undertook a dose assessment to meet the requirements of our Process and Information Document. The dose assessment was provided to us in the Environment Report Chapter 5 (UKP-GW-GL-790 Rev 2 and 3).

39 In early 2009 we invited tenders from contractors using our framework contract to carry out a validation and verification exercise on Westinghouse's dose assessment and undertake an independent dose assessment of the AP1000. The contract was let to Enviros Consulting Ltd. We consulted with the Health Protection Agency, the Food Standards Agency and the UK National Dose Assessment Working Group (NDAWG) on the contract specification prior to the tendering exercise and incorporated their comments in the final technical specification for the contract.

40 The aim of the independent assessment was to:

- a) Validate and verify the assumptions made by Westinghouse in its dose assessments.
- b) Validate and verify the outcomes of the dose assessments carried out by Westinghouse.
- c) Carry out independent dose assessments to demonstrate that the dose assessments carried out by Westinghouse were realistic.

41 We required the contractor to use PC CREAM to model dispersion and calculate doses to the reference group and collective doses for all exposure pathways including any unusual pathways. PC CREAM is a long recognised system for dose assessment developed for the EC.

42 We considered that:

- a) Site specific habits data should be used where available however we recognised that at the generic stage the dose assessment would be carried out using parameters relating to the generic site provided by the Westinghouse.
- b) In the absence of site specific habits data generalised habits data from NRPB W41 should be used (NRPB, 2003). NRPB W41 gives generalised food intake rates, generalised inhalation and water intake rates, inadvertent ingestion rates, critical group ingestion rates of aquatic food, coastal, lakeside and river bank occupancy factors and indoor occupancy.
- c) For site specific dose assessments at sites where new facilities are close to existing nuclear facilities, consideration needs to be given to doses which may arise as a result of discharges from the existing facilities, bearing in mind the dose constraint of 500 μ Sv per annum individual effective dose from a single site, not including exposures arising from direct radiation.
- d) In order to compare to the dose limit, significant future doses from historic discharges at the site or nearby sites, and future direct radiation from other sites need to be added to future doses due to discharges and direct radiation from the site being assessed.

- e) For assessments of individual dose, it is appropriate to take account of accumulation of radionuclides in the environment, usually by undertaking the assessment for the year in which the highest critical group dose is likely to occur. This ensures that future generations are afforded the same level of protection as the current generation. Assuming no change in discharge limits, the highest critical group dose is generally predicted to occur during the last few years of discharges from a plant / site. Once discharges cease or are reduced significantly, the highest environmental activity concentrations near the discharge point generally start to decline. An accumulation time-scale of 50 years is usually selected for new plants and for plants / sites where it is difficult to specify a closure date. Where radionuclides build-up to an equilibrium level more quickly in the environment, then a shorter time-scale may also be adopted. Generally, the highest radionuclide concentrations in the environment, from a given site, tend to decline following a reduction in discharges. A key exception is where there is in-growth of a daughter radionuclide from its parent (e.g. americium-241).
- f) We noted that in their 2009 publication '*Application of the 2007 Recommendations of the ICRP to the UK*' (RCE-12) the Health Protection Agency (HPA) advised that the term 'representative person' should be gradually adopted to replace the term 'critical group' in order to ensure consistency with ICRP advice and terminology. In line with their advice we consider the terms 'critical group' and 'representative person' to be equivalent and to refer those individuals in the population of interest who receive or are expected to receive the highest dose. The report from Enviros Consulting Ltd (Environment Agency, 2010g) uses the term 'critical group' and this should be taken to mean the same as 'representative person'.

43

We required the contractor to undertake:

- a) Prospective assessment of doses from potential gaseous and aqueous discharges from the AP1000 design for the members of the public, using information on potentially exposed members of the public set out by the Westinghouse for its generic site and taking account of direct radiation for comparison with the source dose constraint. Where applicable assessments should be carried out for 'normal discharges', 'worst case discharges' and at any discharge limits proposed by the requesting party.
- b) Prospective assessments of:
- i) annual dose to most exposed members of the public for aqueous discharges;
 - ii) annual dose to most exposed members of the public for gaseous discharges;
 - iii) annual dose to the most exposed members of the public for all discharges from the facility;
 - iv) annual dose from direct shine radiation to the most exposed member of the public;
 - v) annual dose to the critical group for the facility;
 - vi) potential short-term doses based on the maximum anticipated short-term discharges from the facility in normal operation.

Information generated on peak concentrations of radionuclides in foods as part of the dose assessment should be identified for ready comparison with the Community Food Intervention Levels (EC, 1989).

- c) Assessment of the collective doses from gaseous and aqueous discharges from the AP1000 design for the populations identified by Westinghouse for its generic site. Where applicable assessments should be carried out for 'normal discharges', 'worst case discharges' and at any discharge limits proposed by the Requesting Party (RP).

- 44 In order to carry out the assessments we assessed the submission made by Westinghouse to ensure it provided the following data for its generic site:
- a) For atmospheric dispersion modelling and dose assessment:
 - i) Effective release height
 - ii) Volumetric flow rate
 - iii) Activity of each radionuclide in annual foreseeable discharges
 - iv) Location of receptors such as nearby residents, local food production sites, persons most exposed via inhalation of the plume, any free food sources
 - v) Meteorological data
 - vi) Surface roughness length
 - vii) Stability category
 - viii) Deposition velocity
 - ix) Washout coefficient
 - x) Terrestrial food consumption habits
 - b) For marine dispersion modelling and dose assessment:
 - i) Activity of each radionuclide in annual foreseeable discharges
 - ii) Volumetric exchange rate for receiving water
 - iii) Location of discharge
 - iv) Consumption rates of locally caught seafood
 - v) Inhalation rates
 - vi) Beach occupancy rates
 - vii) Location of any receptors

- 45 The methodology and outcome of the work carried out by the contractor is set out in the report 'Independent Dose assessment' (IMAS/TR/2010/06) (Environment Agency, 2010g) and the outcome is summarised below:

In the Westinghouse submission, it is assumed that the AP1000 would be located on the coast. 'Representative discharges' and discharges at Westinghouse's proposed discharge limits for radioactive liquid and atmospheric discharges were used as the basis for assessing doses to the local population and collective doses.

'Representative discharges' are the discharges in the highest 12 months of the 18 month operating cycle (usually month 7 to 18 inclusive as monthly discharges tend to rise throughout the 18 month operating cycle).

3.5 Westinghouse's dose assessment

- 46 Westinghouse used the Environment Agency's initial radiological assessment approach at Stage 2 for its assessment. Westinghouse also provided estimates of the collective doses to the UK, European and World populations (truncated at 500 years), estimated using PC CREAM 98. They also predicted doses from expected short-term releases using the atmospheric dispersion model ADMS 4.1.
- 47 As part of the validation and verification activity the approaches applied by Westinghouse were reviewed and repeated.
- 48 **Doses from gaseous discharges** - Using the Stage 2 approach for gaseous discharges, Westinghouse estimated a dose to local residents of 7.6 $\mu\text{Sv y}^{-1}$ from the annual representative discharges and 12 $\mu\text{Sv y}^{-1}$ from discharges at its proposed

limits. It was possible to repeat these assessments using the Westinghouse assumptions.

49 **Doses from aqueous discharges** - Using the Stage 2 approach for aqueous discharges, Westinghouse estimated a dose to the fisherman family of $2.3 \mu\text{Sv y}^{-1}$ from the annual representative discharges and $3.8 \mu\text{Sv y}^{-1}$ from discharges at its proposed limits. It was possible to repeat these assessments using the Westinghouse assumptions.

50 **Doses from direct radiation** - Exposure of the public from direct radiation from nuclear sites in the UK is the responsibility of the HSE. HSE require site operators to measure direct radiation at the site perimeter and estimate exposure to a reference group on an annual basis. The Westinghouse assessment of direct radiation was based on measured values for Sizewell B which is the only PWR operating in the UK. The direct radiation dose rate measured at the site perimeter fence during 2007 of $4 \mu\text{Sv y}^{-1}$ was used in the Westinghouse assessment.

51 **Doses from short term releases** – Westinghouse also assessed the impact of short duration releases to atmosphere at higher discharge rates. They assumed that the highest planned monthly discharge was released over 30 minutes. They initially assessed doses due to short term releases to be $5.1 \mu\text{Sv}$ to an infant (Environment Report (Rev 2)). It was not possible to reproduce this assessment and as a result Westinghouse reviewed its assessment of doses due to short term releases and made the following changes:

- a) The initial assessment used the dose per unit intake (DPUI) factor for carbon-14 in vapour form. In their reassessment Westinghouse used the DPUI for carbon-14 in particulate form set out in our initial assessment methodology.
- b) In the initial assessment Westinghouse used habit data given in NRPB-W54. In its reassessment Westinghouse used the habit data in NRPB-W41.

As a result of their reassessment Westinghouse calculate the dose due to short term releases to be $12 \mu\text{Sv}$ and this has been reflected in section 5.2.1.4 of the Environment Report (Revision 3).

52 **Doses to the representative person** - The dose to the representative person from the site assessed by Westinghouse was therefore $14 \mu\text{Sv y}^{-1}$ for representative discharges and $20 \mu\text{Sv y}^{-1}$ for limit discharges. This is based on a conservative summation of doses from atmospheric discharges, liquid discharges and direct radiation and excludes doses due to short duration discharges to atmosphere.

53 We conclude that all the doses assessed by Westinghouse are below the dose constraint for members of the public of $300 \mu\text{Sv y}^{-1}$ and the dose constraint recommended by the HPA for new build of $150 \mu\text{Sv y}^{-1}$.

54 **Collective dose** - Westinghouse has estimated the collective doses to the world population (truncated at 500 years) from representative atmospheric discharges to be of the order of 12 to 13 manSv per year of discharge to atmosphere and 0.05 to 0.055 manSv per year from representative aqueous discharges.

55 The results of Westinghouse’s dose assessment are summarised below:

Dose to public from AP1000 Representative Discharges $\mu\text{Sv y}^{-1}$				
Candidate Critical Group	Stack 1	Marine	Direct Radiation	Short term releases
CCG1 - local resident (high rate terrestrial food consumer)		2.3	4.0	12.0
CG2 - local fisherman (high marine exposure)	7.6		4.0	12.0

Total dose for members of the public exposed to both gaseous and aqueous disposal at representative discharge levels is $14 \mu\text{Sv y}^{-1}$ (excluding doses from short term releases). This is the sum of the numbers highlighted in red in the above table.

Dose to public from AP1000 Discharges at Westinghouse’s proposed limits $\mu\text{Sv y}^{-1}$				
Candidate Critical Group	Stack 1	Marine	Direct Radiation	Short term releases
CCG1 - local resident (high rate terrestrial food consumer)		3.8	4.0	12.0
CG2 - local fisherman (high marine exposure)	12		4.0	12.0

Total dose for members of the public exposed to both gaseous and aqueous disposal at Westinghouse’s proposed discharge limits is $20 \mu\text{Sv y}^{-1}$ (excluding doses from short term releases). This is the sum of the numbers highlighted in red in the above table.

3.6 Our independent assessment of doses from maximum expected discharges

56 Westinghouse did not undertake a detailed assessment which is sometimes made following on from the initial radiological assessment. A more detailed independent assessment was undertaken on our behalf by Enviro Consulting Ltd. This assessment took into account good practice and published assessment guidance and used PC CREAM 98, a long recognised system for dose assessment developed for the EC.

57 **Doses from gaseous discharges** - At the discharges to atmosphere assumed by Westinghouse, a dose of around $4 \mu\text{Sv y}^{-1}$ to the most exposed local residents (an infant) consuming locally produced terrestrial foods has been estimated. This assumes an effective stack height of 22.5 m that takes account of the effects of

adjacent buildings. The ingestion of carbon-14 in milk accounts for the majority of the dose predicted from aerial discharges.

58 **Doses from aqueous discharges** - On the basis of the representative liquid discharges estimated by Westinghouse, effective doses of around 1 $\mu\text{Sv y}^{-1}$ to an adult fisherman have been assessed. The dose arises primarily from carbon-14 in fish and shellfish.

59 **Doses from direct radiation** - The assessment of direct radiation was based on measured values for Sizewell B for 2007, for which a value of 4 $\mu\text{Sv y}^{-1}$ has been published.

60 **Doses from short term releases** - A dose of around 13 μSv has been predicted to an adult in the local resident family from a single short-term release, compared to 12 μSv predicted by Westinghouse in its revised assessment. The dose is dominated by the inhalation and ingestion pathways.

61 **Doses to the representative person** - The dose to the representative person from the site assessed in the more detailed independent assessment has been predicted to be around 8.4 $\mu\text{Sv y}^{-1}$, including a contribution from direct radiation but without the inclusion of a contribution from short-term releases.

62 Westinghouse's assessment outcomes were higher than the independent assessment because they are based on conservative assumptions in the initial radiological assessment system and more conservative assumptions about combinations of exposures than those applied in the independent assessment.

63 **Collective doses** -The independent assessment of collective doses calculated collective doses to be 12.2 to 12.6 manSv per year for atmospheric discharges and 0.052 to 0.054 manSv per year for liquid discharges which are essentially equivalent to those calculated by Westinghouse.

64 The results of our independent assessment at representative discharges are summarised below:

Dose to public from AP1000 representative discharges $\mu\text{Sv y}^{-1}$					
Candidate Critical Group	Age Group	AP1000 Discharges			
		Stack 1	Marine	Direct Radiation	Total
CCG1 - local resident (high rate terrestrial food consumer)	Adult	2.64	0.07	4	6.71
	Child	2.87	0.04	4	6.91
	Infant	4.39	0.04	4	8.43
CCG2 - local fisherman (high marine exposure)	Adult	1.61	0.98	0	2.59
	Child	1.87	0.29	0	2.17
	Infant	2.13	0.10	0	2.23

3.7 Our independent assessment of doses from discharges at our proposed limits

65 We used the spreadsheet prepared by Enviro Consulting Ltd to estimate doses at our proposed discharge limits. The discharges at the proposed limits are set out below:

Atmospheric discharges at Environment Agency proposed limits		
Radionuclide	Atmospheric Discharges per Stack (TBq y ⁻¹)	
	Stack 1	Stack 2
Ar-41	2.00E+00	
Ba-140	0.00E+00	
C-14	1.00E+00	
Co-58	0.00E+00	
Co-60	3.00E-05	
Cr-51	0.00E+00	
Cs-134	0.00E+00	
Cs-137	0.00E+00	
H-3	3.00E+00	
I-131	3.00E-04	0.00E+00
I-133	0.00E+00	0.00E+00
Kr-85	1.30E+01	0.00E+00
Kr-85m	0.00E+00	0.00E+00
Kr-87	0.00E+00	0.00E+00
Kr-88	0.00E+00	0.00E+00
Mn-54	0.00E+00	
Nb-95	0.00E+00	
Sr-89	0.00E+00	
Sr-90	0.00E+00	
Xe-131m	0.00E+00	0.00E+00
Xe-133	0.00E+00	0.00E+00
Xe-133m	0.00E+00	0.00E+00
Xe-135	0.00E+00	0.00E+00
Xe-135m	0.00E+00	0.00E+00
Xe-137	0.00E+00	0.00E+00
Xe-138	0.00E+00	0.00E+00
Zr-95	0.00E+00	

Noble gases taken together were treated as krypton-85

Other radionuclides were treated as cobalt-60

Marine Discharges at Environment Agency proposed limits	
Radionuclide	Marine Discharges (TBq y⁻¹)
	Discharge point 1
Ag-110m	0.00E+00
Ba-140	0.00E+00
C-14	7.00E-03
Ce-144	0.00E+00
Co-58	0.00E+00
Co-60	5.50E-03
Cr-51	0.00E+00
Cs-134	0.00E+00
Cs-136	0.00E+00
Cs-137	5.00E-05
Fe-55	0.00E+00
Fe-59	0.00E+00
H-3	6.00E+01
I-131	0.00E+00
I-133	0.00E+00
La-140	0.00E+00
Mn-54	0.00E+00
Na-24	0.00E+00
Nb-95	0.00E+00
Ni-63	0.00E+00
Pr-144	0.00E+00
Pu-241	0.00E+00
Ru-103	0.00E+00
Sr-89	0.00E+00
Sr-90	0.00E+00
Tc-99	0.00E+00
Tc-99m	0.00E+00
Y-91	0.00E+00
Zn-65	0.00E+00
Zr-95	0.00E+00

Other radionuclides were treated as cobalt-60

- 66 **Doses from gaseous discharges** – The highest doses from gaseous discharges at our proposed limits was 7.1 μSv to an infant and the highest contribution was from carbon-14 in milk.
- 67 **Doses from aqueous discharges** – The highest doses from aqueous discharges at our proposed limits was 2.1 μSv to an adult. The dose arises primarily from carbon-14 in fish and shellfish.
- 68 **Doses from direct radiation** – The assessment of direct radiation was based on measured values for Sizewell B for 2007, for which a value of 4 $\mu\text{Sv y}^{-1}$ has been published in Radioactivity in Food and the Environment, 2007 (Environment Agency, 2008).
- 69 **Doses to the representative person** – Our Stage 3 assessment resulted in the highest estimated doses from an AP1000 is to an infant representative person of 11 $\mu\text{Sv y}^{-1}$, who is most exposed to gaseous discharges. This assessment outcome is for our proposed annual limits on discharges for the AP1000.
- 70 The results of the dose assessment at our proposed limits are summarised below:

Dose to public from AP1000 discharges at Environment Agency limits $\mu\text{Sv y}^{-1}$					
Candidate Critical Group	Age Group	AP1000 Discharges			
		Stack 1	Marine	Direct Radiation	Total
CCG1 - local resident (high rate terrestrial food consumer)	Adult	4.21	0.15	4	8.37
	Child	4.64	0.09	4	8.73
	Infant	7.10	0.08	4	11.19
CCG2 - local fisherman (high marine exposure)	Adult	2.54	2.11	0	4.64
	Child	3.00	0.64	0	3.65
	Infant	3.41	0.21	0	3.62

3.8 Comparison to dose constraints and dose limits

- 71 Source dose constraint (Defra, 2000) - The dose constraint for the maximum dose to people that may result from discharges from a new single source (for example, a new nuclear power station) is 300 $\mu\text{Sv y}^{-1}$ which applies to the dose from proposed discharges and direct radiation.
- 72 We conclude that sum of doses to the representative person at our proposed limits is below the source dose constraint, and below the dose constraint recommended by the HPA for new build of 150 $\mu\text{Sv y}^{-1}$.
- 73 Site dose constraint - The dose constraint for the maximum dose to people that may result from discharges from a site as a whole is 500 $\mu\text{Sv y}^{-1}$ and it applies to the total dose from the discharges (direct radiation is not included) from all sources at a single location, including discharges from immediately adjacent sites.
- 74 A number of the sites listed in the draft Nuclear National Policy Statement as potentially suitable for a new nuclear power station are adjacent to existing nuclear power stations. In GDA the specific site at which an AP1000 might be located is not known but we consider, in the light of our assessment that the highest total dose is estimated to be 11 $\mu\text{Sv y}^{-1}$, it is very unlikely that doses at the site will exceed the site dose constraint of 500 $\mu\text{Sv y}^{-1}$. We consider that site dose should be assessed at the site specific stage.

- 75 We conclude that site dose should be assessed at site specific permitting.
- 76 Dose limit - There is also a dose limit (Defra, 2000) for the maximum dose to any member of the public from ionising radiation. The dose limit is 1 mSv y^{-1} ($1000 \text{ } \mu\text{Sv y}^{-1}$) and it applies to the total dose from all artificial sources including past discharges but excluding medical and accidental exposure.
- 77 Comparison against the dose limit can only be done at site specific permitting when contributions from all sources of radiation can be included.

4 Detailed findings

- 78 The assessment findings are set out in more detail in the independent dose assessment report prepared on our behalf by Enviro Consulting Ltd (Environment Agency, 2010g).
- 79 We consulted the Health Protection Agency and the Food Standards Agency on the draft and their comments, which were minor in nature, were incorporated into the final report.

5 Public comments

- 80 We did not receive any public comments during this assessment relating to the assessment of the radiological impact of discharges from the AP1000 on members of the public.

6 Conclusion

- 81 We conclude that all the doses assessed by Westinghouse are below the dose constraint for members of the public of $300 \text{ } \mu\text{Sv y}^{-1}$ and the dose constraint recommended by the HPA for new nuclear build of $150 \text{ } \mu\text{Sv y}^{-1}$.
- 82 We conclude that sum of doses to the representative person at our proposed limits is below the source dose constraint.
- 83 A number of the sites listed in the Nuclear National Policy Statement as potentially suitable for a new nuclear power station are adjacent to existing nuclear power stations. In GDA the specific site at which a AP1000 might be located is not known but we consider, in the light of our assessment that the highest total dose is estimated to be $11 \text{ } \mu\text{Sv y}^{-1}$, it is very unlikely that doses at the site will exceed the site dose constraint of $500 \text{ } \mu\text{Sv y}^{-1}$. We consider that site dose should be assessed at the site specific stage.
- 84 Comparison against the dose limit can only be done at site specific permitting when contributions from all sources of radiation can be included.
- 85 In line with our usual procedures we will require a detailed site specific impact assessment to be carried out at site specific permitting based on the actual environmental characteristics of the proposed site to demonstrate that doses to members of the public and non-human species from the AP1000 at the proposed site will be ALARP and below relevant dose constraint and dose limits.

7 Compliance with Environment Agency requirements

P&I table 1 section or REP	Compliance comments
<p>Section 2.7 Prospective dose assessment for the generic site at the proposed limits for levels of discharge.</p>	<p>An assessment was carried out by Westinghouse which included an assessment of</p> <ul style="list-style-type: none"> • annual dose to most exposed members of the public for liquid discharges; • annual dose to most exposed members of the public for gaseous discharges (identifying separately the dose associated with on site incineration where applicable); • annual dose to the most exposed members of the public for all discharges from the facility; • annual dose from direct radiation to the most exposed member of the public; • annual dose to the critical group for the facility; • potential short-term doses, including via the food chain, based on the maximum anticipated short-term discharges from the facility in normal operation; • a comparison of the calculated doses with the relevant dose constraints; and • an assessment of whether the build-up of radionuclides in the local environment of the facility, based on the anticipated lifetime discharges, might have the potential to prejudice legitimate users or uses of the land or sea.
<p>Section 2.8 Collective dose assessments for discharges from the facility truncated at 500 years to the UK, European and World populations.</p>	<p>An assessment of collective dose was made by Westinghouse.</p>
<p>Section 2.9 Sufficient assumed data for others to be able to carry out all dose assessments</p>	<p>Sufficient data was provided by Westinghouse and this allowed the independent validation and verification of its dose assessments.</p>
<p>SEDP1 General RSR Principle for siting new facilities - When evaluating sites for a new facility, account shall be taken of the factors that might affect the protection of people and the environment from radiological hazards and the generation of radioactive waste</p>	<p>The generic site proposed by Westinghouse considered factors that might affect the protection of people and the environment. The information about the generic site used in the dose assessments seemed reasonable.</p>

P&I table 1 section or REP	Compliance comments
<p>SEDP2 Movement of radioactive material in the environment - Data shall be provided to allow the assessment of rates and patterns of movement of radioactive materials in the air and the aquatic and terrestrial environments around sites.</p>	<p>Information on the potential movement of radioactive material in the environment was provided by Westinghouse</p>
<p>SEDP3 Ambient radioactivity - Levels of ambient radioactivity around the sites of new facilities shall be assessed.</p>	<p>An assessment of potential doses from direct radiation from the AP1000 was made.</p>
<p>SEDP4 Multi-facility sites - In the case of nuclear and other sites on which there are already one or more facilities, the radiological impact of the whole site on people and the environment shall be assessed when considering the suitability of the site for any new facility.</p>	<p>This will be dealt with at the site specific stage if the AP1000 is located on a multi-facility site.</p>
<p>RPDP1 Optimisation of protection - All exposures to ionising radiation of any member of the public and of the population as a whole shall be kept as low as reasonably achievable (ALARA), economic and social factors being taken into account</p>	<p>ALARP has been demonstrated at this stage however we require Westinghouse to keep ALARP matters under review.</p>
<p>RPDP2 Dose limits and constraints - Radiation doses to individual people shall be below the relevant dose limits and constraints.</p>	<p>Predicted doses to members of the public from the AP1000 at the generic site are less than the relevant dose limits and constraints.</p>
<p>RPDP4 Prospective dose assessments for radioactive discharges to the environment - Assessments of potential doses to people and to non-human species shall be made prior to granting any new or revised authorisation for the discharge of radioactive wastes into the environment.</p>	<p>A prior assessment has been made based on the generic site. We will require that prospective dose assessments are carried out at the site specific stage as part of the permitting process and using information specific to the site in question.</p>

P&I table 1 section or REP	Compliance comments
UK dose limit for members of the public - 1 mSv per annum individual effective dose	Individual doses predicted from the Westinghouse assessment and from the independent assessment were below the UK dose limit for members of the public. We will require that prospective dose assessments are carried out at the site specific stage as part of the permitting process and using information specific to the site in question.
UK dose constraints -300 μ Sv per annum individual effective dose from a single new source, (in their 2009 publication Application of the 2007 Recommendations of the ICRP to the UK (HPA, 2009) the Health Protection Agency has advised the UK Government to select a constraint value for members of the public for new nuclear power station that is less than 0.15 mSv per year (150 μ Sv y^{-1})).	Individual doses predicted from the Westinghouse assessment and from the independent assessment were below the dose constraint of 300 μ Sv y^{-1} and the proposed constraint for new nuclear power stations of 150 μ Sv y^{-1} . We will require that prospective dose assessments are carried out at the site specific stage as part of the permitting process and using information specific to the site in question.
UK dose constraints - 500 μ Sv per annum individual effective dose from a single site not including exposures arising from direct radiation.	Individual doses predicted from the Westinghouse assessment and from the independent assessment were below the dose constraint of 500 μ Sv y^{-1} from a single site assuming the AP1000 is not on a multi-facility site. We will require that prospective dose assessments are carried out at the site specific stage as part of the permitting process and using information specific to the site in question.
IAEA suggest that practices which give rise to collective doses less than 1 man Sv per year of operation may be exempted from regulatory control.	Collective doses predicted from the independent assessment are greater than 1 man Sv per year of operation. The practice will not be exempted from regulatory control.

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Abbreviations

ADMS	Atmospheric Dispersion Modelling System
ALARA	As low as reasonably achievable
ALARP	As Low As Reasonably Practicable
BAT	Best available techniques
DCD	Design Control Document
DPUI	Dose Per Unit Intake
ER	Environment Report
FSA	Food Standards Agency
GDA	Generic design assessment
HPA-RPD	Health Protection Agency – Radiation Protection Division
HSE	Health and Safety Executive
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
JPO	Joint Programme Office
NDAWG	UK National Dose Assessment Working Group
NRPB	National Radiological Protection Board (now part of Health Protection Agency)
P&ID	Process and information document
PCSR	Pre-Construction Safety Report
PWR	Pressurised water reactor
QA	Quality Assurance
REPs	Radioactive substances environmental principles
RGN	Regulatory Guidance Note
RGS	Regulatory Guidance Series
RO	Regulatory Observation
RP	Requesting Party
SODA	Statement of Design Acceptability
TQ	Technical Query
US NRC	United States Nuclear Regulatory Commission
WEC	Westinghouse Electric Company LLC
WGS	Gaseous radioactive waste system
WLS	Liquid radioactive waste system

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