HORIZON NUCLEAR POWER

WYLFA NEWYDD

ENERGY WORKING FOR BRITAIN

Wylfa Newydd Project

6.2.14 ES Volume B - Introduction to the environmental assessments B14 - Radiological effects

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14 Radiological effects

14.1 Introduction

14.1.1 This chapter provides an introduction to the technical basis for the radiological effects assessment for the Wylfa Newydd Project. It includes a summary of legislation, policy and guidance; key points arising in consultation that have guided the radiological effects assessment; and assessment methodologies and criteria.

14.1.2 Reactor operations and subsequent waste treatment activities result in authorised discharge, storage, transport and disposal of radioactive material. Radioactive discharges from the operation of fossil fuel combustion units are assumed to be negligible.

14.1.3 Radiological effects include potential adverse effects on human and non-human species through interaction between radiation, tissues and cells.

14.1.4 The potential health effects of radiation exposure are expressed in terms of effective and absorbed dose. The unit of effective dose to humans is the sievert (Sv). However, in terms of typical exposures, the sievert is a very large quantity and typical doses from environmental exposures are expressed in millisieverts (mSv) or microsieverts (μSv). For non-human organisms, radiation exposure is expressed in terms of absorbed dose which has the unit of the gray (Gy). Throughout this chapter the generic term “dose” will be used to refer to both effective and absorbed dose.

14.1.5 The distribution of potentially long-lived radioactive material through the global circulation of sea or ocean and air currents may result in smaller effects further from a discharge point, which are assessed as collective dose.

14.1.6 In this chapter, the assessment of doses to humans is undertaken for members of the public. Doses to workers will be tightly regulated as part of site operating procedures as required by the Ionising Radiations Regulations 2017 and the Nuclear Site Licence.

14.1.7 Doses to humans and non-human species can result from exposure to:

- radioactive discharges either directly (e.g. via inhalation or from direct radiation from the plume) or indirectly (e.g. via the food chain or from direct radiation from deposited/adsorbed material incorporated into environmental media);
- discharges of radioactive wastes and operational activities resulting in direct radiation exposure from Power Station buildings; and
- direct radiation due to small exposures to transported radioactive materials during travel, including pauses during the journey through the local road network.

14.1.8 The assessment of radiological effects is included in chapter D14 (radiological effects) (Application Reference Number: 6.4.14) for the WNDA Development.

14.1.9 The management of radioactive wastes at the Power Station during operation and decommissioning is described in appendix D14-1 (radioactive waste, Application Reference Number: 6.4.97).

14.1.10 The assessment of effects from potential accidental release scenarios is described in appendix D14-2 (analysis of accidental releases, Application Reference Number: 6.4.98). This material has been reported as a separate appendix because of the technical nature of the assessment.

14.2 Legislation, policy and guidance

14.2.1 This section outlines the legislation, policy and guidance that has been used to inform the scope and content of the radiological effects assessment; assist in the identification of potential effects and mitigation; and influence the design of the Wylfa Newydd Project to reduce the significance of effects.

14.2.2 The science of how radiation and radioactive materials may affect human health has been studied over a long period and is regularly reviewed by international and national scientific bodies. Recommendations on the approach to be taken to protect people from the effects of radiation exposure are made by the International Commission on Radiological Protection (ICRP) and reviewed periodically. ICRP recommendations form the basis of the worldwide framework for radiation protection standards, provided by the International Atomic Energy Agency (IAEA) Basic Safety Standards. The EU Basic Safety Standards Directive, which is implemented into UK law, is developed alongside and is consistent with the IAEA Basic Safety Standards.

14.2.3 The UK is signatory to international agreements, and compliance with the requirements of these agreements also confers certain implied regulatory requirements. Relevant to this topic of radiological effects are some of the requirements of the Euratom Treaty (such as the Basic Safety Standards Directive and Article 37), the OSPAR (Oslo and Paris Convention for the Protection of the Marine Environment of the North-East Atlantic) and Espoo (The Convention on Environmental Impact Assessment in a Transboundary Context) conventions, which are discussed in the key policy section below.

Key legislation

14.2.4 The relevant legislation and how it relates to the radiological effects assessment are set out in table B14-1.

Table B14-1 Summary of key legislation

Legislation	Description
Environmental Permitting (England and Wales) Regulations 2016	These regulations seek to ensure that authorised activities and their discharges do not endanger the environment or human health; Environmental Permits must be sought from Natural Resources Wales (NRW) (in Wales) and the Environment Agency (in England). The regulations combine the requirements for an integrated waste management approach and for waste management. This

Legislation	Description
	provides a framework for regulation that enables NRW and the Environment Agency to assess permitting and compliance with a common approach. An Environmental Permit establishes limits on the activity of radioactive waste that can be disposed of from a facility and defines the management arrangements the operator is required to have in place. In addition, as part of the application and ongoing regulation of the permit, the operator must satisfactorily demonstrate how Best Available Techniques (BAT) is applied to minimise disposals of radioactive wastes.
The Ionising Radiations Regulations 2017	This legislation defines the control of radiation exposures and the primary dose limits to workers and members of the public in the UK.
Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009	This legislation incorporates the European Agreement concerning the International Carriage of Dangerous Goods by Road and the Regulations concerning the International Carriage of Dangerous Goods by Rail. It defines the requirements for the safe transportation of radioactive waste materials.
Nuclear Installations Act 1965	The legislation establishing the arrangements for the licensing of a nuclear site to operate, including power stations. Horizon Nuclear Power has applied for a nuclear site licence to construct and operate the Wylfa Newydd Project.
Infrastructure Planning (Environmental Impact Assessment) Regulations 2017	This legislation replaces the Infrastructure Planning (Environmental Impact Assessment) Regulations 2009 and transposes the Environmental Impact Assessment Directive (2014/52/EU) into UK Law. This updated directive includes the requirement that for certain projects (because of their vulnerability to major accidents, and/or natural disasters) "*it is important to consider their vulnerability (exposure and resilience) to major accidents and/or disasters, the risk of those accidents and/or disasters occurring and the implications for the likelihood of significant adverse effects on the environment*". While these regulations do not formally apply to the Wylfa Newydd Project, the material on accidental releases included in appendix D14-2 (Application Reference Number: 6.4.98) is

Legislation	Description
	provided in support of these requirements.
The Conservation of Habitats and Species Regulations 2017	These regulations implement the provisions of the Habitats Directive (92/43/EEC) and the Birds Directive (2009/147/EC). They provide for the designation and protection of European Designated Sites and species and the adaptation of planning and other controls for the protection of European Designated Sites. The presence of protected habitats and ecosystems, particularly Natura 2000 sites ('European sites') near to the Wylfa Newydd Development Area, introduces legislative requirements that must be taken into account by Horizon in assessing radiological effects. This is achieved through a Habitats Regulations Assessment which will accompany the application for development consent, and will be informed by the radiological assessments undertaken as part of the permitting process for the Power Station.
Council Directive 2013/59/EURATOM	This is the EU Basic Safety Standards Directive which implements the IAEA Basic Safety Standards into European law and is required to be implemented in national legislation. It is used to define the regulatory dose limits, and implemented in UK law as the Ionising Radiations Regulations 2017.
Commission Recommendation 2010/635/EURATOM	Within the EU, every time a Member State alters the way it plans to dispose of radioactive waste or proposes a new facility that may increase emissions, it must make a submission to the European Commission as part of the Euratom Treaty, known as an Article 37 Submission. This has to include enough data to determine whether such plans are liable to result in the radioactive contamination of the water, soil or airspace of another Member State and so an assessment of the effects of gaseous and aqueous discharges and solid waste disposals at these locations is required. It is noted that an Environmental Permit (see below) cannot be issued without a positive opinion from the European Commission on the Article 37 submission.
The Convention for the Protection of the Marine Environment of the North-East	This convention is key in coordinating Member States to meet their obligations under the EU Marine Strategy Framework Directive (2008/56/EC). Under the radioactive substances

Legislation	Description
Atlantic (the 'OSPAR Convention')	area, the ultimate aim is to reduce concentrations in the environment to near background values for naturally occurring radioactive substances and close to zero for artificial radioactive substances. In achieving this objective, the legitimate uses of the sea, technical feasibility, and radiological impacts on man and non-human species should be taken into account.
The Convention on Environmental Impact Assessment in a Transboundary Context (the 'Espoo Convention').	This convention sets out the obligations of parties to assess the environmental impact of certain activities at an early stage of planning. It also lays down the general obligation of states to notify and consult each other on all major projects under consideration that are likely to have a significant adverse environmental impact across boundaries. The material on accidental releases included in appendix D14-2 (Application Reference Number: 6.4.98) is provided in support of these requirements.

Key policy

14.2.5 The relevant international, national and local plans and policies, and how these relate to the radiological effects assessment, are described in table B14-2.

Table B14-2 Summary of key policy

Policy	Description
National Policy Statement for Nuclear Power Generation (EN-6) (NPS EN-6) [RD1]	This is the principal document that sets the framework for the consideration of applications for development consent for new nuclear power stations. NPS EN-6 recognises that: "The UK has robust legislative and regulatory systems in place for the management (including interim storage, disposal and transport) of all forms of radioactive waste that will be produced by new nuclear power stations." (paragraph 2.11.6) The licensing and permitting of nuclear power stations by the nuclear regulators is a separate regulatory process which nuclear power stations have to undergo. To avoid unnecessary duplication and / or delay and to ensure that planning and regulatory expertise are focussed on the most appropriate areas, when considering a development consent application the IPC should act on the basis that: • "the relevant licensing and permitting regimes

Policy	Description
	will be properly applied and enforced; and • it should not duplicate the consideration of matters that are within the remit of the Nuclear Regulators." (paragraph 2.7.3) For radiological effects and impacts on health, NPS EN-6 summarises that: "Radiation from nuclear power stations requires careful management during and beyond the operational life of the power station. However, safety systems in place in the designs of new nuclear power stations and compliance with the UK's robust legislative and regulatory regime mean that the risk of radiological health detriment posed by nuclear power stations (both during normal operation and as a result of an unplanned release) is very small". (paragraph 3.12.4) In relation to long-term radioactive waste management, "Annex B of NPS EN-6 sets out that other facilities for the interim storage of waste may come forward. However, in the absence of any proposal the [Infrastructure Planning Commission] should expect that waste would be on site until the availability of a GDF [Geological Disposal Facility]". (paragraph 2.11.5)
UK Strategy for Radioactive Discharges [RD2]	This revised the UK Strategy for Radioactive Discharges and updated Government policy and described how the UK will continue to implement the agreements reached at the 1998 OSPAR ministerial meeting, and subsequent OSPAR meetings on radioactive substances, particularly the radioactive substances strategy.

Key guidance

14.2.6 The radiological effects assessment has been undertaken in line with a number of key technical guidance documents. These guidance documents are widely used across the UK and represent standard good practice for the assessment for the various consenting regimes. These are summarised in table B14-3.

Table B14-3 Summary of key guidance

Guidance	Description
New Nuclear Build at Wylfa: Supplementary Planning Guidance [RD3]	The overarching purpose of this Supplementary Planning Guidance is to provide guidance on important local, direct and indirect matters. It sets out the Isle of Anglesey County Council's (IACC's) vision and objectives for the new nuclear

Guidance	Description
	development at Wylfa Head and is the most up-to-date guidance available for the Wylfa Newydd Project. The guidance does not include reference to the assessment of radiological effects, beyond a general requirement that the release of potentially polluting substances to air, land and water should/must be minimised. The guidance also contains provisions relating to interim nuclear waste storage facilities such that the council expects the promoter to demonstrate that proposals for such interim waste storage are fully justified and will have no impact on local communities.
Statutory Guidance to the Environment Agency concerning the regulation of radioactive discharges into the environment [RD4]	This provides guidance to NRW officers on the assessment of public doses for the purposes of determining radioactive waste discharge permits or authorisations, so that the approach to assessments is consistent and transparent. It informs holders of Environmental Permits about NRW's approach to the assessment of public doses and thus provides guidance on the preparation of radiological assessments in support of permit or authorisation applications.
Radioactive Substances Regulation – Environmental Principles [RD5]	This is high level guidance on how NRW regulates radioactive substances activities under the Environmental Permitting (England and Wales) Regulations 2016. It provides a standardised framework for technical assessments and judgements that NRW's radioactive substances regulators have to make. It provides technical guidance that underpins the decisions regarding radioactive substances regulation, including those about permitting and compliance.
The regulation of radioactive substances activities on nuclear licensed sites [RD6]	This guidance describes the application of Environmental Permitting regulation to licensees and tenants on nuclear sites so far as is necessary to present a comprehensive picture of the regulatory requirements for such sites and covers the following topics. • The permitting process for nuclear licensed sites. • The principles of radiological protection. • Statutory requirements and government policy in

Guidance	Description
	relation to radioactive waste management. • Operators' radioactive waste management arrangements.
Principles for the Assessment of Prospective Public Doses arising from Authorised Discharges of Radioactive Waste to the Environment. [RD7]	Adopted by NRW for use in Wales, this sets out principles and guidance for the prior assessment of doses to the public arising from exposure to ionising radiation which may arise from planned discharges to the atmosphere and to the aquatic environment. The results of assessments undertaken in accordance with these principles and guidance are used as an input to the process of determining whether discharges of radioactive waste to the environment should be authorised.
Impact Assessment of Ionising Radiation on Wildlife [RD8]	This describes the approach to assessment of doses to non-human species and provides guidance on dose levels in a regulatory context.

14.3 Consultation

14.3.1 This section provides a topic-specific account of scoping, statutory and non-statutory consultation undertaken to support the assessment. For a full overview of the environmental consultation activities undertaken for the Wylfa Newydd Project, please refer to chapter A6 (EIA scoping report and addendum) (Application Reference Number: 6.1.6) and chapter A7 (consultation with environmental stakeholders) (Application Reference Number: 6.1.7).

Planning Inspectorate Scoping Opinion

14.3.2 In March 2016, Horizon submitted an updated Wylfa Newydd Project EIA Scoping Report to the Planning Inspectorate. In May 2017, Horizon submitted an Addendum to the March 2016 Wylfa Newydd Project EIA Scoping Report to the Planning Inspectorate (and to NRW). Following a period of consultation with stakeholders, a further Scoping Opinion was received from the Secretary of State (SoS) (via the Planning Inspectorate) on 14 June 2017.

14.3.3 The Wylfa Newydd Project EIA Scoping Report, Addendum and the subsequent Scoping Opinions inform the approach to the assessment. Table B14-4 provides an account of how comments raised by stakeholders in the Scoping Opinion have been considered in the radiological effects assessment.

Table B14-4 Key issues raised through Scoping

Key issue raised	Action taken
The Planning Inspectorate: "The Scoping Report notes that radioactive waste would be stored on-site and Section 2.2.4 acknowledges the Applicant's need to demonstrate that such waste storage could be safely and securely achieved until such time that it could be disposed to a geological disposal facility, as required by paragraph 2.11.5 of NPS EN-6. NPS EN-6 states that geological disposal is currently expected to be available from around 2130. The Secretary of State therefore expects the EIA for the proposed development to reflect this in terms of the description of the development and assessment of environmental effects." The IACC: "…the County Council remains concerned to ensure that the longer term potential impacts of radiological storage are effectively captured within the ES [Environmental Statement]. In particular consideration should be given to the possibility of waste remaining on-site following the station's operational phase in the event that a GDF is not available. Radiological storage can also give rise to negative perceptions and the resulting effects upon human health should be	The management of radioactive waste is discussed in the Radioactive waste appendix D14-1 (Application Reference Number: 6.4.97). That appendix includes the assumptions and details of the treatment and storage of radioactive waste and spent fuel aligned to the availability of the GDF. The doses resulting from extended storage will be bounded by those calculated from direct radiation in chapter D14 (Application Reference Number: 6.4.14), since those doses are calculated assuming the waste stores are full, at the end of the Power Station life. The Government plan to provide a GDF by 2130 is a base assumption of the assessment. Section 14.4 of chapter D14 (Application Reference Number: 6.4.14) describes the approach to considering radiological effects during decommissioning. Section 14.6 of chapter D14 (Application Reference Number: 6.4.14) summarises the results of that bounding assessment.

Key issue raised	Action taken
considered within relevant EIA topics rather than solely within the Health Impact Assessment." "In the current absence of a GDF, consideration should also be given to the alternative of retaining such waste on-site once the remainder of the generating station has been decommissioned even if the consideration of any resulting effects is only covered to a certain extent given the current requirement for decommissioning to require EIA in its own right." Public Health England (PHE): "The radiological impact of any solid waste storage and disposal should also be addressed in the assessment to ensure that this complies with UK practice and legislation; information should be provided on the category of waste involved (e.g. very low level waste, VLLW). It is also important that the radiological impact associated with the decommissioning of the site is addressed."	
The Planning Inspectorate: "The Secretary of State draws the Applicant's attention to article 15 of 2014/52/EU which states that for certain projects it is important to consider their vulnerability (exposure and resilience) to major accidents and/or disasters,	An assessment of accidental releases has been included in appendix D14-2 (Application Reference Number: 6.4.98).

Key issue raised	Action taken
the risk of those accidents and/or disasters occurring and the implications for the likelihood of significant adverse effects on the environment". The Secretary of State notes that the Applicant has committed to meet the requirements of the new Directive and therefore advises the Applicant gives consideration to assessing accidental radiological releases within the EIA." PHE: "Any radiological impact assessment should also consider the possibility of short-term planned releases and the potential for accidental releases of radionuclides to the environment. This can be done by referring to compliance with the Ionising Radiations Regulations and other relevant legislation and guidance."	
The Planning Inspectorate: "The ES [Environmental Statement] should define the parameters used for dispersion modelling of combustion emissions. Section 3.2.1.1 of the Scoping Report states that the emissions stack would have an approximate height of between 70m and 80m; therefore the implications of stack height and dispersion should be clearly explained within the ES [Environmental Statement]. The Secretary of State recommends that dispersion	The main reactor stacks will not be used for routing and releasing combustion emissions as discussed in the air quality chapters B5, (Application Reference Number: 6.2.5), and D5, (Application Reference Number: 6.4.5). For permitted radioactive discharges from the reactor stacks, effective stack height selection to ensure that a worst case scenario is assessed is discussed in detail in the Environmental Permit Radiological Substances Regulation (EP-RSR) application [RD9] and is summarised in the design basis and activities section 14.4 of chapter D14 (Application Reference Number: 6.4.14).

Key issue raised	Action taken
modelling considers a range of possibilities and seeks to ensure that the 'worst case' scenario is assessed, for example the 'worst case' may occur as a short term impact."	
The Planning Inspectorate: "It is unclear how the radiological assessment will be presented as the Scoping Report mainly refers to the production of an EP-RSR application and the Article 37 Submission. The Secretary of State would expect there to be an assessment within the ES [Environmental Statement] itself and the ES [Environmental Statement] should provide details of the assessment methodology and refer to any guidance used." NRW: "NRW advise that the EIA should include a chapter on radiological issues, setting out potential effects and proposed mitigation measures." PHE: "PHE expects promoters to carry out the necessary radiological impact assessments to demonstrate compliance with UK legislation and the principles of radiation protection. This should be set out clearly in a separate section or report and should not require any further analysis by PHE. In particular, the important principles of justification,	Guidance and methodology are discussed in this chapter, and the dose assessment is presented in chapter D14 (Application Reference Number: 6.4.14). All these points have been covered.

Key issue raised	Action taken
optimisation and radiation dose limitation should be addressed. In addition, compliance with the Euratom BSS and UK legislation should be clear." "When considering the radiological impact of routine discharges of radionuclides to the environment PHE would expect to see a full radiation dose assessment considering both individual and collective (population) doses for the public and, where necessary, workers. For individual doses, consideration should be given to those members of the public who are likely to receive the highest exposures (referred to as the representative person, which is equivalent to the previous term, critical group). Different age groups should be considered as appropriate and should normally include adults, one-year old and ten-year old children. In particular situations doses to the foetus should also be calculated. The estimated doses to the representative person should be compared to the appropriate radiation dose criteria (dose constraints and dose limits), taking account of other releases of radionuclides from nearby locations as appropriate."	
The Planning Inspectorate: "The Secretary of State advises that the ES	During construction and operation, radioanalysis, geophysics, radiography and security will use radioactive sources in a

Key issue raised	Action taken
[Environmental Statement] considers the potential for mobilisation of radionuclides during construction works, both terrestrial and within the marine environment." IACC: "The council notes that it is not the intention of the applicant to consider radiological issues for Off-Site Power Station Facilities. Whilst this approach is possibly correct, the council would wish to see the statement linked to evidence, for example from environmental monitoring data published in the context of the existing station and baseline data derived from the EIA monitoring campaigns." "The introduction section also states that construction activities will not generate radiological issues. The council appreciates that a certain amount of ground working will take place under the site preparation and clearance contract but would still expect substantiation of the claim that there will be no radiological impact from construction activities. In particular, consideration should be given to existing contamination in soil that could be re-suspended as dust, groundwater through dewatering or marine sediments being disturbed by the construction of the water discharge and intake systems and the Marine Off-	controlled manner. No contamination will be introduced at the Off-Site Power Station Facilities by Horizon's activities. For potential existing contamination, the baseline section 14.3 of chapter D14 (Application Reference Number: 6.4.14) includes information from on-site measurements and also of sediment sampling measurements and campaign monitoring results with respect to baseline concentrations of radioactivity in the environment. These form the basis of the construction assessment in section 14.4 of chapter D14 (Application Reference Number: 6.4.14).

Key issue raised	Action taken
Loading Facility (MOLF)." NRW advise that there should be consideration of the potential for mobilisation of radionuclides during construction works on-site and within the marine environment.	
The Planning Inspectorate: "Limited information is provided within the Scoping Report regarding transportation of fresh fuel and radioactive waste during the operation of the development and how this will be assessed. The ES [Environmental Statement] will need to include available information regarding proposed transport methods, including frequency, likely modes and routes, and an assessment of potential impacts."	Assessment of radiological effects from transportation of nuclear material is described in section 14.4 of this chapter, and the input data related to transport methods, frequency and routes, and the results of the assessment are reported in chapter D14 (Application Reference Number: 6.4.14).
IACC: "When considering the appropriateness of either location for the radioactive waste storage building, and when assessing the environmental effects arising from the preferred location, the applicant should ensure that consideration is given to the criteria set out within the Wylfa Newydd Supplementary Planning Guidance GP17. Consideration of decommissioning as referenced within GP17 will also be important as will the possible effects of the alternative scenario which is	Supplementary Planning Guidance is listed in the key guidance in table B14-3 and was used to define the scope of the assessment on radiological effects. Section 14.4 of chapter D14 (Application Reference Number: 6.4.14) shows that results of external exposures from the selected location for the radioactive waste storage buildings are very low (<10µSv/yr). Section 14.4 of chapter D14 (Application Reference Number: 6.4.14) describes the approach to considering radiological effects during decommissioning. Section 14.6 of chapter D14 (Application Reference Number: 6.4.14) summarises the results of that assessment. The doses resulting from extended storage will be bounded by those calculated from direct radiation in chapter D14 (Application Reference Number: 6.4.14), since those doses are calculated assuming the waste

Key issue raised	Action taken
the retention of the storage building, post-generating plant decommissioning, should a national GDF facility not be available."	stores are full, at the end of the Power Station life.
IACC: "The scoping chapter does not mention decommissioning; and the applicant's approach to the consideration of radiological issues associated with decommissioning should also be set out within the ES [Environmental Statement]."	Section 14.4 of chapter D14 (Application Reference Number: 6.4.14) describes the approach to considering radiological effects during decommissioning. Section 14.6 of chapter D14 (Application Reference Number: 6.4.14) summarises the results of that assessment.
NRW: "The ES [Environmental Statement] should assess, through appropriate modelling, the transfer of radionuclides present in the gaseous and aqueous radioactive wastes through the environment. The assessments should predict the dispersion of the radionuclides in the air or the sea, their transfer to, and accumulation in, other environmental media."	The radiological effects chapters (section 14.4 of this chapter and section 14.4 of chapter D14, Application Reference Number: 6.4.14), now present the methodologies and results for dose calculations and assessments based on the EP-RSR submission.
NRW: "The scoping report considers impacts as a result of discharges (asserted to be below 20µSv) but makes no further reference to shine impacts. Shine should be explicitly considered."	External irradiation doses ("shine") are included as a specific pathway within the dose calculation methods (see section 14.4 of this chapter) and results (section 14.5 of chapter D14, Application Reference Number: 6.4.14).
NRW: "The radiological impacts on non-human species as a result of liquid and atmospheric discharges from the Power Station	Doses to non-human species from environmental discharges of radioactivity are included within the dose calculation methods (see section 14.4 of this chapter) and results (section 14.5 of chapter D14, Application Reference Number: 6.4.14).

Key issue raised	Action taken
should be assessed with respect to the four broad habitat groups that are representative of the range of habitats in the locality of the Power Station (i.e. marine, freshwater, terrestrial and coastal). This assessment should use appropriate modelling to support the [Environmental Statement] and HRA."	
PHE: "Collective doses should also be considered for the UK, European and world populations where appropriate. The methods for assessing individual and collective radiation doses should follow the guidance given in '*Authorisation of Discharges of Radioactive Waste to the Environment Principles for the Assessment of Prospective Public Doses Interim Guidance*', August 2012. In addition, the promoter might find it helpful to consider guidance published by the National Dose Assessment Working Group on its website (www.ndawg.org). It is important that the methods used in any radiological dose assessment are clear and that key parameter values and assumptions are given (for example, the location of the representative persons, habit data and models used in the assessment)."	Collective and individual doses are calculated and summarised in section 14.5 of chapter D14 (Application Reference Number: 6.4.14).
PHE: "The radiological assessment should consider	The consideration of intrusion scenarios and doses some thousands of years into the future are more relevant to a radioactive

Key issue raised	Action taken
exposure of members of hypothetical representative groups for a number of scenarios including the expected migration of radionuclides from the facility, and inadvertent intrusion into the facility once institutional control has ceased. For scenarios where the probability of occurrence can be estimated, both doses and health risks should be presented, where the health risk is the product of the probability that the scenario occurs, the dose if the scenario occurs and the health risk corresponding to unit dose. For inadvertent intrusion, the dose if the intrusion occurs should be presented." "PHE advises that assessments of radiological impact during the operational phase should be performed in the same way as for any site authorised to discharge radioactive waste. PHE also advises that assessments of radiological impact during the post-operational phase of the facility should consider long timescales (possibly in excess of 10,000 years) that are appropriate to the long-lived nature of the radionuclides in the waste, some of which may have half-lives of millions of years."	waste disposal site. No radioactive wastes will be disposed of on the Power Station Site, and so once the site has been de-licensed there will be no residual contamination at the Power Station Site (as may be required by the guidance on requirements for the release of sites from radioactive substances regulation). An EIA will be undertaken before decommissioning commences, as currently required by the Nuclear Reactors (Environmental Impact Assessment for Decommissioning) Regulations 1999 (amended), which will assess impacts to relevant receptors during the decommissioning phase.
PHE: "Amongst other permits and consents, the development	The application of BAT is summarised within the mitigation section (sections 14.5 and 14.6 of chapter D14, Application Reference

Key issue raised	Action taken
will require an Environmental Permit from Natural Resources Wales to operate (under the Environmental Permitting (England and Wales) Regulations 2010). Therefore, the installation will need to comply with the requirements of best available techniques (BAT). PHE is a consultee for bespoke environmental permit applications and will respond separately to any such consultation."	Number: 6.4.14).
June 2017 Scoping Opinion, the Planning Inspectorate: "Radiological effects for all associated development – on the basis that the activities at the associated development sites would not have any bearing on radiological issues. Effects associated with these environmental topics will be addressed in the EIA for the Power Station Site only (i.e. Volume D of the [Environmental Statement]). The SoS agrees to this approach."	None needed other than to note the scoping out of the consideration of radiological effects for sites other than the Power Station.
June 2017 Scoping Opinion, the Planning Inspectorate: "The SoS welcomes that the potential for accidental radiological release will be included within the [Environmental Statement]. The Scoping Report addendum states that the assessment will draw on previously prepared information, including that required for the Article 37 assessment of the Euratom	'Accidental releases' is a new EIA topic and so has not previously been discussed with NRW. Discussions will be undertaken with NRW on the Accidental releases EIA methodology as discussed in appendix D14-2 (Application Reference Number: 6.4.98) as part of the 'statement of common ground' meetings.

Key issue raised	Action taken
Treaty (2010). The SoS is not entirely clear how this will be translated to an assessment in EIA terms; the Applicant is advised to discuss and agree its approach with NRW and clearly describe their methodology within the [Environmental Statement].”	
June 2017 Scoping Opinion, IACC: “At paragraph 6, bullet 3 reference is made to the fact that there will be no radioactive material added during construction of Wylfa Newydd. Any decision not to address the potential effects of accelerated migration should be justified.”	The assessment of potential effects of accelerated migration is now assessed as part of the construction effects assessment in section 14.4 of chapter D14 (Application Reference Number: 6.4.14).
June 2017 Scoping Opinion, IACC: “At paragraph 11, the Council would query whether there will be any consideration of doses associated with the future transportation of intermediate level waste (ILW) wastes and in connection with paragraph 18, questions the source of the 0.5mSv/y dose constraint for site.”	Doses associated with the future transportation of ILW are discussed within the assessment in section 14.4 of chapter D14 (Application Reference Number: 6.4.14). The 0.5mSv/y dose constraint for site is taken from [RD6], but is not used within the assessment criteria described in table B14-10, because the source constraint of 0.3mSv/y gives a more even spread of impact magnitudes.
June 2017 Scoping Opinion, IACC: “In connection with comments made in relation to the 2016 Scoping Report the Council notes that its request for a sensitivity analysis of potential doses does not appear to have been addressed. Furthermore, HNP does not	The radiological effects chapters (section 14.4 of this chapter and section 14.4 of chapter D14, Application Reference Number: 6.4.14) now present the methodologies and results for dose calculations and assessments based on the EP-RSR submission. A sensitivity study of doses is undertaken as part of the EP-RSR submission but upon inspection of the resulting range of doses, the conclusion was that this would not alter

Key issue raised	Action taken
appear to have considered impacts on the local representative person."	the impact and significance of effects calculated as part of the assessment in chapter D14 (Application Reference Number: 6.4.14).

Statutory consultation

Pre-Application Consultation Stage One

14.3.4 The aim of Pre-Application Consultation Stage One, undertaken in late 2014, was to share information available at the time with Horizon's key consultees and stakeholders, in order to consider feedback in ongoing design development. Table B14-5 outlines how key issues raised during Pre-Application Consultation Stage One have been considered in the assessment.

Table B14-5 Key issues raised during Pre-Application Consultation Stage One

Key issue raised	Action taken
IACC: "The [Environmental Statement] should assess the doses to Representative Persons and non-human species via the transfer of radionuclides present in the gaseous and aqueous radioactive wastes through the environment."	Guidance and methodology are discussed in this chapter and the dose assessment is presented in chapter D14 (Application Reference Number: 6.4.14). All these points have been covered.
IACC: "The likely location and duration of storage of ILW after the site is decommissioned."	The management of radioactive waste is discussed in the radioactive waste appendix (D14-1, Application Reference Number: 6.4.97). That appendix includes the assumptions and details of the treatment and storage of radioactive waste and spent fuel aligned to the availability of the GDF. The Government plan to provide a GDF by 2130 is a base assumption of the assessment.
IACC: "Information on volumes of very low level and low level waste for off-site transport and disposal requested."	Further information on management of radioactive wastes including volumes is provided in appendix D14-1 (Application Reference Number: 6.4.97).
IACC:	Assessment of radiological effects

Key issue raised	Action taken
"Include consideration of transport effects."	from transportation of nuclear material is described in section 14.4 of this chapter, and the results of the assessment are reported in chapter D14 (Application Reference Number: 6.4.14).

Pre-Application Consultation Stage Two

14.3.5 In September 2016, Horizon shared a Preliminary Environmental Information report as part of Pre-Application Consultation Stage Two. This presented preliminary details of the predicted environmental effects and mitigation measures for any adverse effects identified. Table B14-6 outlines how key issues raised during Pre-Application Consultation Stage Two have been considered in the assessment.

Table B14-6 Key issues raised during Pre-Application Consultation Stage Two

Key issue raised	Action taken
Food Standards Agency: "This section makes no reference to the monitoring and surveillance provisions which the operator will have in place to support the technical assessment in the event of an unplanned off-site release of radioactive material. We would be interested to know what resources the operator plans to have for monitoring and sample analysis."	Monitoring arrangements during an emergency are part of site and district emergency plans which will be prepared as a requirement of the Radiation (Emergency Preparedness and Public Information) Regulations 2001.
Food Standards Agency: "While initial surveys show radiological contamination on the site is at background levels, during the construction phase we would expect the operator to monitor extracted soils and sediments to verify this initial assessment. Monitoring should also be carried out to provide reassurance relating to the disturbance of soils which may be contaminated by previous nuclear activities adjacent to this site. Where extracted soils and sediments are reused for landscaping, consideration should be given to the levels of contamination in relation to the potential for future use of this	A focused soil and sediment sampling programme of the proposed construction area and the offshore environment has been undertaken with samples analysed for radioactivity content. Results are summarised in chapter D14 (Application Reference Number: 6.4.14). Further opportunistic sampling and analyses of soils is planned during upcoming exploratory/ preliminary site works.

Key issue raised	Action taken
land for food production."	
National Farmers Union Cymru: "Therefore regular and open monitoring of radioactivity levels and how this is done is an absolute must before the Project starts. There will be a clear overlap between the new and existing Wylfa."	The routine monitoring programme for radioactivity in local environmental materials will be a requirement of the Environmental Permit, regulated by NRW. Monitoring of the current environment is reported in annual Radioactivity in Food and the Environment (RIFE) reports from the regulators, and by the Existing Power Station which are made available to Horizon.
NRW: "Dose estimation, waste quantification and BAT underpinning of the decommissioning case are absent."	Chapter D14 (Application Reference Number: 6.4.14) contains estimates of decommissioning doses. Preliminary waste quantification information is also presented in Chapters 4 and 5 of EP-RSR permit application [RD9].
NRW: "Paragraph B13.107 discusses cumulative effects from other sources and states 'there are no other Wylfa Newydd Project sources of radioactivity and radiation other than the Power Station'. However, the [Environmental Statement]/shadow Habitats Regulations Assessment should consider the inter-development effects of the adjacent Magnox station and other nuclear new build sites cumulatively with Wylfa Newydd."	Quantitative assessments of combined effects with the decommissioning of the Existing Power Station are now included in chapter D14 (Application Reference Number: 6.4.14).
IACC: "Doses due to radioactive materials transport require consideration. The potential impact of cumulative doses from the transport of radioactive materials to and from site along with the movement of decommissioning wastes from the 'A' station."	Chapter D14 (Application Reference Number: 6.4.14) includes a quantitative assessment of doses during transport. Cumulative effects with the Existing Power Station are also considered accounting for available data.
IACC:	Quantitative assessments of

Key issue raised	Action taken
Consideration of the cumulative radiological impact of station operation and decommissioning of the Magnox plant.	combined effects with the decommissioning of the Existing Power Station are now included in chapter D14 (Application Reference Number: 6.4.14).
IACC: Radiological impacts of long-term waste storage.	The dose assessment discussed in chapter D14 (Application Reference Number: 6.4.14) takes account of the waste storage facilities.

Pre-Application Consultation Stage Three

14.3.6 Horizon shared updated design information for the Wylfa Newydd Project as part of Pre-Application Consultation Stage Three. No further comments were received from statutory consultees in relation to radiological effects in response to that exercise.

Consultation on Additional Land

14.3.7 In February 2018, Horizon undertook consultation on additional land that had not been consulted on previously. The additional land was required to:

- accommodate proposals to create or enhance wetland sites across Anglesey as Ecological Compensation Sites;
- create two new ecological mitigation areas, and minor changes to the connection to the national grid at the Wylfa Newydd Development Area; and
- update the order limits for the A5025 Off-Line Highway Improvements, and minor refinements to the boundaries of the Off-Site Power Station Facilities and Logistics Centre.

14.3.8 The feedback from the consultation has been reviewed and there were no radiological effects issues raised.

Non-statutory consultation

Environmental Impact Assessment Progress Report

14.3.9 An EIA progress report was provided to the IACC and NRW in 2016 with updated information on the design development and associated environmental assessment. Table B14-7 outlines how key issues raised in feedback from these stakeholders have been considered in the assessment.

Table B14-7 Key issues raised in response to the EIA Progress Report

Key issue raised	Action taken
NRW: “The radiological assessment does not include an assessment of the	Guidance and methodology are discussed in this chapter, and the dose assessment is presented in

Key issue raised	Action taken
radiological impacts of the operation of the station. An assertion is made that impacts from discharges and shine will be below 'regulatory concern' but this is not underpinned. An estimate is expected." "Site-specific assessments would be expected to be carried out with respect to the human population in order to determine the following radiological impacts: 1. Doses to the selected critical groups from routine, continuous releases of liquid and atmospheric discharges. The critical groups represent those individual members of the public in the surrounding area who, because of their location and day-to-day activities are expected to receive the highest doses. Within each critical group, doses to adults, children and infants should be calculated. 2. Annual doses to the most exposed members of the public from direct radiation exposure. 3. Collective doses to the UK, European and World populations from routine releases of liquid and atmospheric discharges and representative 'per caput' doses (the latter refers essentially to the average dose to individuals within each of these large populations). 4. Potential doses to hypothetical members of representative persons as a result of short-term operational atmospheric discharges. 5. Doses due to potential build-up of radionuclides in the environment as a result of discharges during the whole of the proposed 60 year operational phase of the Power Station. 6. The radiological impact of the transport of radioactive materials to and from the Power Station and	chapter D14 (Application Reference Number: 6.4.14). All these points have been covered.

Key issue raised	Action taken
required in support of its normal operational activities and also of the radiological impacts on non-human species as a result of liquid and atmospheric discharges from the Power Station should be assessed with respect to the four habitats that are representative of the range of habitats in the locality of the Power Station (i.e. marine, freshwater, terrestrial and coastal). The locations of the habitats should be selected to include ecologically-designated sites or those where radionuclide concentrations would be highest." "We advise that Radiological Effects be included as an EIA chapter. The chapter should be updated in light of recently received information produced to support the GDA Generic Environmental Permit submission and allowing prospective assessments of discharge impacts for the Wylfa Newydd site."	

Draft Environmental Statement

14.3.10 During September 2017, draft Environmental Statement chapters were provided to statutory and key non-statutory stakeholders. Table B14-8 outlines key issues raised and how these have been addressed within the Environmental Statement.

Table B14-8 Key issues raised in response to the Draft Environmental Statement

Key issue raised	Action taken
Table B14-6. NRW previously raised the issues that dose estimation, waste quantification and Best Available Technique underpinning of the decommissioning case were absent. HNP action is incomplete either because the action taken list is not representative of work that has now been completed or because not all the points have been addressed - please clarify.	The response to this point in table B14-6 now refers to the relevant sections of the EP-RSR application.
Para B14.4.26 et seq. Should clarify the	Text clarifying the points raised

Key issue raised	Action taken
methodology, is the collective dose in the first year of discharges or estimated over the lifetime of the station and the worst/conservative dose used in the 'first pass collective dose'. Clarify that estimates are made at the limits applied for (though actual discharges will be expected to be considerably lower). Clarify that doses presented are annual doses.	has been added to paragraph 14.4.30 of this chapter where the integration period is described. Discharges are described in chapter D14 (Application Reference Number: 6.4.14).
In relation to paragraph D14.3.7, IAEA value is relevant with respect to the overarching legal framework but the legal values in the UK are those in statute. Quote accordingly compliance with UK requirements. If IAEA values are more conservative, then please state.	The relevant UK statute value is used in place of the IAEA value. This has been done at all other points where these comparisons are made.
In relation to paragraph D14.4.21, clarify that this paragraph applies to expected discharges. These have been estimated during plant design not developed.	This point has been clarified in chapter D14 (Application Reference Number: 6.4.14).
In relation to paragraph D14.4.52 and table D14-17, this information would be better presented if the lifecycle phase was included. An understanding of the relatively low number of transports during operation compared with the number during the period of shipment to the Geological Disposal Facility would be beneficial. This comment applies to D14-19 too.	A paragraph summarising the periods during which different transport doses will occur has been added to chapter D14 (Application Reference Number: 6.4.14).
Various technical comments on the radioactive waste appendix D14-1.	These technical comments were addressed in the final version of appendix D14-1 (Application Reference Number: 6.4.97).

Topic-specific stakeholder engagement

14.3.11 In addition to the three formal stages of consultation outlined above, topic-specific consultation has been undertaken with relevant stakeholders. Table B14-9 summarises the details of the consultation that has taken place with respect to the radiological effects assessment.

Table B14-9 Summary of topic-specific consultation

Date	Stakeholder	Title and format	Issues arising	Action taken
25 November 2014	NRW, Office for Nuclear Regulation, Environment Agency	Meeting to discuss the methodology to be used for radiological modelling.	The meeting was held to discuss and collect regulators' initial comments on Horizon's proposed approach to radiological effects modelling and assessment to support the EIAs, Environmental Permits, Article 37 and Habitats Regulations Assessment required for the Wylfa Newydd Project.	The approach was agreed following close-out of actions.
September 2015 onwards	NRW, Office for Nuclear Regulation, Environment Agency	Monthly progress meetings.	Monthly meetings to discuss progress on radiological assessments required for the Environmental Permit submission.	As required

14.4 Topic-specific methodologies and assessment criteria

Introduction

14.4.1 The overarching approach to the EIA, including the approach to the assessment of cumulative effects, is provided in chapter B1 (introduction to the assessment process) (Application Reference Number: 6.2.1). This section outlines the specific methodology used to assess the radiological effects of the Wylfa Newydd Project. It outlines the methods and criteria used to:

- define the study area and identify topic receptors;
- establish the environmental baseline for topic receptors; and
- determine the value/sensitivity of receptors, the magnitude of change and significance of effect.

14.4.2 The methodologies summarised in this chapter are used to estimate doses from radioactive discharges from the Power Station and from direct radiation from the relevant Power Station buildings and transport sources.

14.4.3 The approach to detailed assessment of radiological effects makes use of the information presented in the permit submission made as part of the application under Schedule 23 of the Environmental Permitting (England and Wales) Regulations 2016. The approach to the calculation of doses for that submission was agreed with the relevant regulators (Office for Nuclear Regulation and NRW, see table B14-9).

Assessment of parameters

14.4.4 As outlined in chapter B1 (Application Reference Number: 6.2.1), the approach adopted for the design of the WNDA Development, Off-Site Power Station Facilities and Associated Development is to set parameters, where necessary, for the extent of the development and key aspects of that development. The final design and construction methodology would be limited to these parameters and limits of deviation. The approach to assessment of radiological effects within the context of the parameters and limits of deviation for the WNDA Development is outlined in chapter 14 within volume D (Application Reference Number: 6.4.14).

Identification of study areas

14.4.5 The geographical area for the assessment of radiological effects on members of the public and on non-human species extends from the Power Station Site for as far as is necessary to take account of those members of the public in the UK and in other countries who comprise candidates for the Representative Person [RD7]. It also extends as far as necessary to identify the highest doses to non-human species in coastal, marine, freshwater and terrestrial environments. In addition, average doses to populations in the UK, Europe and the World are calculated as collective doses.

14.4.6 The study area is described by the habit data and modelling assumptions used to define exposure via these pathways:

- radiation exposures to individuals and populations arising from authorised gaseous and aqueous discharges of radioactivity;
- radiation exposures arising from direct irradiation from buildings on the Power Station Site;
- radiation exposures arising from transport of radioactive materials to and from the Power Station Site; and
- radiation exposures to non-human species arising from the authorised discharge of radioactivity to air and the marine environment.

Identification of receptors

14.4.7 The basis of assessing the potential effects arising from exposure to radiological discharges is the identification of groups of individuals (who comprise candidates for the Representative Person) and non-human species whose behaviour and habits are likely to mean they would receive the highest individual radiological doses. Implementation of measures to control these highest exposures such that dose criteria are met ensures protection of humans and the environment.

14.4.8 As candidates for the Representative Person are defined by their habits, it may not be possible to identify specific receptor locations for these individuals. For example, for candidates for the Representative Person identified as being high fish consumers, it is assumed that those fish are caught in local waters where radioactivity concentrations will be highest. However, it may not be possible to identify residential locations of these Representative Persons, who may live some distance away.

14.4.9 For non-human species, the process involves the identification of the locations of habitats with the highest predicted environmental radioactivity concentrations, as these lead to the highest predicted doses to species identified within these habitats, which can again be compared to regulatory criteria.

Identification of baseline conditions

14.4.10 Unlike other technical areas, the baseline is not included as part of the assessment calculation. This is because the doses resulting from discharges and direct radiation are compared directly to regulatory criteria.

14.4.11 The baseline described in chapter D14 (Application Reference Number: 6.4.14) provides contextual information on current levels of radioactivity in the local environment and doses arising from operations at the Existing Power Station. Doses resulting from typical exposures of the local population to natural radioactivity and radiation are also described.

14.4.12 Monitoring of local radioactivity concentrations and external gamma dose rates around the Existing Power Station is undertaken by both the operator and by the regulators and are summarised in chapter D14 (Application Reference Number: 6.4.14).

14.4.13 Horizon has undertaken an extensive sampling programme around the Power Station Site. Concentrations of radioactivity in soils and sediments at the Power Station Site and the Marine Off-Loading Facility area are summarised in chapter D14 (Application Reference Number: 6.4.14).

Modelling methodologies

14.4.14 The methodologies used for the assessment of radiological doses resulting from the Power Station are largely based on those reported in the EP-RSR submission [RD9].

14.4.15 This section summarises the methods used to calculate:

- radiation exposures to candidates for the Representative Person arising from the authorised discharge of radioactivity to air and the marine environment;
- radiation exposures to UK, European and World populations (via collective doses);
- radiation exposures arising from direct irradiation from the turbine hall and from the storage of radioactive wastes and spent fuel in engineered facilities on the Power Station Site;
- radiation exposures arising from transport of radioactive materials to and from the Power Station Site; and
- radiation exposures to non-human species arising from the authorised discharge of radioactivity to air and the marine environment.

Assessment of doses to the Representative Person from discharges

14.4.16 Radiation effects due to radioactive discharges into the environment may result in the exposure of members of the public from a number of pathways. Doses are calculated to candidates for the Representative Person in three age groups, infant (one year old), child (10 years old) and adult (18 years old or greater).

14.4.17 Assessments are required for the impacts of aerial and aqueous radioactive discharges.

14.4.18 For aerial radioactive discharges due to routine operations, the principal exposure pathways are:

- inhalation of radioactive substances in the plume;
- immersion dose due to gamma and beta emitters in the plume (cloud shine);
- external exposure due to the deposition of gamma and beta emitters on the ground (ground shine);
- ingestion of foodstuffs containing radioactive substances due to deposition or root uptake; and
- inhalation of radioactivity attached to soil/dust that has been re-suspended into air.

14.4.19 For aqueous radioactive discharges from the Power Station outfall, the principal exposure pathways are:

- ingestion of contaminated foodstuffs (fish, crustaceans, molluscs and seaweed);
- exposure to beta and gamma radiation from contaminated sediments;
- exposure to beta and gamma radiation from contaminated fishing equipment; and
- inhalation of sea spray.

14.4.20 Computer modelling is used to assess the potential effects of radioactive emissions to the environment, via the pathways listed above. The computer code PC-CREAM 08® [RD10] comprises a number of modules that predict the dispersion of radionuclides in the environment. PC-CREAM 08® is a well-documented and tested software package developed for the assessment of continuous radioactive discharges from nuclear facilities in the EU and is the assessment tool used by the environmental regulators in their independent review of EP-RSR Permit applications.

14.4.21 PC-CREAM 08® and its underlying dispersion models are seen to be robust, fit for purpose [RD7] and have been verified against environmental data [RD10]. PC-CREAM 08® has been used for many other dose assessments in the UK. Its strengths are that it includes a number of modules that assess the impact from continuous gaseous and aqueous discharges of a large number of radionuclides.

14.4.22 PC-CREAM 08® enables the assessment of individual and collective doses due to gaseous and aqueous discharges via the following generic pathways that encompass all the specific pathways listed in paragraphs 14.4.17 and 14.4.18:

- internal and external exposure;
- deposition and accumulation in the environment;
- inhalation of re-suspended material including sea spray; and
- ingestion of contaminated foodstuffs.

14.4.23 The models embedded within PC-CREAM 08® have been developed over many years. The current version is maintained by PHE who provide support for and updates to the software.

14.4.24 The modules within PC-CREAM 08® used for this assessment are as follows.

- PLUME: The atmospheric dispersion model which predicts the air activity concentrations, deposition rates and external gamma dose rates from radionuclides in the plume per unit discharge rate.
- RESUS: Estimates activity concentrations in air arising from the resuspension of previously deposited radionuclides per unit deposition rate.
- GRANIS: Models the external gamma dose from radionuclides deposited on the soil per unit deposition rate.
- FARMLAND: Predicts the transfer of radionuclides into terrestrial foods following deposition on the ground. Activity concentrations are calculated for a unit deposition rate.
- DORIS: The marine dispersion model.

14.4.25 Once activity concentrations and gamma dose rates in environmental media have been calculated using the individual models, they are used in ASSESSOR; the dose assessment part of PC-CREAM 08®. ASSESSOR scales the derived activity concentrations and dose rate per unit activity by

the calculated marine concentrations, or air concentrations and deposition rates. These are then combined with activity discharge rates, site-specific data, habit data and dose coefficients to calculate annual doses for the relevant exposure pathways.

14.4.26 In order to perform a dose assessment, it is necessary to acquire information and make assumptions regarding the habits of people living near to the Power Station Site. The Centre for Environment, Fisheries and Aquaculture Science undertakes periodic (normally five yearly) surveys of the diet and behaviours of members of the public residing close to major nuclear licensed sites in the UK. These surveys collate information on the food consumption rates and occupancy habits of adult, child and infant age groups, as well as other relevant occupational and recreational activities that take place close to nuclear licensed sites that could result in the exposure of members of the public to radioactivity in the environment. The output from these surveys provides information on the habits of members of the public which may influence their radiation exposure, and can be used to develop definitions of the Representative Person.

Assessment of collective dose to populations

Modelling of collective dose

14.4.27 Collective doses are also estimated using PC-CREAM 08®. Population and agricultural production distribution are provided by the in-built database for each site on the PC-CREAM 08® database. The Existing Power Station is in the database and is a suitable model representation for the Power Station.

14.4.28 PC-CREAM 08® divides the area around each discharge point into a number of annular segments, and assumes that the population and agricultural production distributions are uniform within each segment. The distributions of individual dose and radionuclide concentrations in the environment are also assumed to be uniform. Individual external and inhalation doses in each annular segment are scaled by the population in that segment to calculate the collective dose.

14.4.29 For aqueous discharges, collective doses are calculated using the radionuclide concentrations in each marine model compartment, summed to obtain the total collective dose. Aqueous discharge doses to individuals will usually be highest close to the discharge point.

14.4.30 The collective dose methodology [RD10] makes the assumption that the magnitude of the population of the EU remains constant over all time, that habits remain the same and that the whole population are adults. The models, food production and habitation data [RD10] have been integrated into PC-CREAM 08®.

14.4.31 Collective doses are determined for the UK, European and World populations for discharges in a single year and present integrated results for both first pass and global circulation scenarios, truncated at 500 years in accordance with statutory guidance [RD7]. The integrated dose is assigned to the year of discharge but the doses are incurred at varying rates over the integration period.

14.4.32 The first pass collective dose is the collective dose due to the dispersion of the initial discharge whereas the global circulation collective dose is that due to circulation of mobile, longer-lived radionuclides in the oceans and in the atmosphere, i.e. carbon-14, tritium and krypton-85.

Assessment of doses from direct radiation exposure

14.4.33 Doses from direct radiation exposure are calculated on the basis of computer modelling of the external doses resulting from sources at the Power Station. There are two potential radiation sources likely to result in off-site doses; the turbine hall and the spent fuel storage facility. Off-site external doses from the ILW storage facility have been assessed as negligible.

14.4.34 When at power, the turbines in the turbine building contain nuclear activation products in the generated steam (resulting from the interaction of neutrons with the molecules in cooling water).

14.4.35 There are three radiation sources associated with the spent fuel storage facility. These are:

- cobalt-60 in activated steel associated with the structures around the fuel;
- gamma rays associated with radioactive decay in the fuel; and
- neutrons associated with radioactive decay in the fuel – these neutrons may then produce secondary gamma rays as they pass through materials.

14.4.36 There are two types of High Level Waste considered. These are:

- hafnium and boron carbide control rods; and
- reactor components, i.e. local power range monitors, start-up range monitors, traversing in-core probes and neutron sources will also be generated as High Level Waste during operations.

14.4.37 These wastes are irradiated by neutrons in the reactor core producing activation daughter species. The waste streams are removed from the spent fuel pond and placed in the spent fuel storage facility 10 years after their removal from the reactor core. Beyond this time, the activation products important for direct radiation dose rates are dominated by cobalt-60.

14.4.38 The computer code MCNP5 [RD11] has been used to calculate the dose rates due to direct line of sight and sky shine (downward radiation from scattering by particulates and molecules in air). The external dose rates due to radioactive sources at the Power Station are calculated for the identified local receptors. The range of receptor distances from the Power Station Site extends to approximately 1,500m, to allow the modelling to cover all receptor positions. The MCNP models do not consider local mounding or terrain, except for explicitly modelling the different levels of the buildings within the Power Station Site.

14.4.39 MCNP5 is recognised by the UK's nuclear regulators as a standard shielding code. It has been used in this analysis to calculate the dose rates from both

photons and neutrons at the receptor locations. MCNP5 has extensive verification and validation documentation.

14.4.40 The user specifies source definitions as specific volumes or cover surfaces, with defined radioactive inventories. The code calculates the radiation flux around the sources and by the use of dose conversion factors [RD12] allows the external dose rates to be calculated.

14.4.41 Calculations are undertaken to represent both Units operating at full power and with all buildings filled to their design capacity (i.e. after 60 years of operation).

14.4.42 The dose rates from each building of interest for direct dose rates were calculated taking account of the shielding effects of other buildings and taking into account the heights, and different ground levels of all relevant buildings within the Power Station Site.

Assessment of doses from the transport of radioactive materials

14.4.43 Doses from direct radiation exposures due to the transport of radioactive materials to and from the Power Station Site during operations and decommissioning can be estimated from the estimated external dose rates of the approved transport packages for the relevant material [RD13].

14.4.44 The calculation requires data on:

- the radioactive materials to be transported and vehicle numbers;
- the likely routes of travel; and
- the exposure assumptions (durations, locations, etc.).

14.4.45 The radioactive material consignments considered in the assessment are:

- delivery of new fuel;
- delivery of neutron sources;
- removal of low-level waste;
- consignment of ILW to a GDF; and
- consignment of spent fuel.

14.4.46 For each consignment type, the external dose from radioactive material shipments, at distances close to the conveyance, can be approximated by:

$$\mathrm{Dose} = \frac{\mathrm{DR}(1)}{\mathrm{d}} \times \mathrm{T} \times \mathrm{S}$$

and at distances greater than approximately twice the package size, the external dose can be approximated by:

$$\mathrm{Dose} = \frac{\mathrm{DR}(1)}{\mathrm{d}^2} \times \mathrm{T} \times \mathrm{S}$$

where:

DR(1) = dose rate at 1m from the package/overpack, (µSv/hr)

d = the package/overpack to receptor distance, (metres) (although this should be applied as a dimensionless scaling factor)

T = exposure time per shipment, (hours)

S = number of shipments per year.

14.4.47 To give a conservative estimate, no account will be made for shielding provided by buildings.

Assessment of doses to non-human species

14.4.48 The assessment of radiological impacts on non-human species was based on the Environmental Risk from Ionising Contaminants: Assessment and management (ERICA) Integrated Approach [RD14]. The ERICA approach does not include the assessment of radiological impacts arising from releases of noble gases; so it was supplemented with the Environment Agency's R&D128 methodology [RD8] which facilitates such assessment.

14.4.49 The ERICA software tool [RD14] is based upon a joint collaboration between 15 institutions in seven European countries and is compatible with ICRP recommendations.

14.4.50 ERICA has a proven history of use in previous permit applications for nuclear facilities in the UK.

14.4.51 The reference organisms used within ERICA complement the Reference Animals and Plants proposed by the ICRP [RD15]. It uses some of the plant and animal geometries currently outlined within the Reference Animals and Plants, but is also broader in range.

14.4.52 The ERICA tool calculates dose rates to organisms by applying dose conversion coefficients to the concentrations of radionuclides in environmental media or in non-human species. Dose conversion coefficients are defined as the absorbed dose rate (μGy/hr) per unit activity concentration in organisms (Bq/kg fresh weight) or environmental media (Bq/kg or Bq/l media fresh weight).

14.4.53 A range of dose conversion coefficients for internal and external exposures have been calculated for a series of reference organisms and are stored in databases embedded within the ERICA tool. Details of the derivation of the dose conversion coefficients and the calculation of internal and external dose rates can be found in [RD14]; [RD16] and [RD17].

14.4.54 The radiological impact due to the discharge of noble gases has been calculated using the methodology described in the revised 'R&D Publication 128: Impact assessment of Ionising Radiation on Wildlife' [RD18].

14.4.55 R&D128 is widely used by UK regulators and its methodology is recognised within the Environment Agency's guidance [RD19] on applying the Conservation of Habitats and Species Regulations 2017 to radioactive substances activities regulated under EP-RSR. It describes the behaviour and transport of radionuclides in terrestrial, freshwater and coastal habitats, much like ERICA, and the associated spreadsheets calculate dose per unit concentration for a range of radionuclides and species.

14.4.56 ERICA and R&D128 deal with a range of generic habitats and organisms. The range of plant and animal organisms inhabiting the environments around the Power Station Site have been identified following a series of ecological surveys undertaken in support of the various permit and planning applications required [RD20]. These organisms have been compared to the ERICA default reference organisms, which were found to be broadly representative of the local species.

14.4.57 The ecological surveys also confirmed the presence of bat species at several locations around the Power Station Site. Bats are of conservation significance and the potential impact of discharges from the Power Station on these organisms must be considered.

14.4.58 Bats are not currently included specifically in the list of default organisms within the ERICA tool; however, ERICA facilitates the incorporation of new organisms into its database and bat species have been added and assessed along with the default organisms. Bats were modelled using the default radioecology parameters for a small burrowing animal, and are assumed to reside 'on soil' all the time (which represents a conservative assumption for organisms that spend most of their time flying or roosting at height above ground).

14.4.59 Marine organisms (sponges, hydroids, bryozoans, sea squirts, etc.) have been identified by marine ecologists as being integral to the rocky reef habitats surrounding the Cooling Water outfall. These organisms are not present on the ERICA reference organisms list. It was however considered that the identified organisms are closely related to some of the default ERICA organisms (such as the sea anemones and corals, and polychaete worms) and that given the limitations of the ERICA tool, the use of the default organisms would be appropriate.

14.4.60 In order to carry out an assessment of impacts on non-human species, it is necessary to determine the activity concentration of discharged radionuclides in water and soil. The concentrations are used as an input to ERICA.

14.4.61 The dispersion and resulting concentrations in environmental media of radionuclides originating from effluents discharged from the Power Station were modelled using the dispersion modules of PC-CREAM 08®. The methods for determination of concentrations of radionuclides in the terrestrial and marine environment due to gaseous and aqueous discharges are the same as those described earlier in this section.

14.4.62 The accumulation of radionuclides in freshwater habitats from deposition of gaseous releases was calculated using the IAEA generic model for a small lake [RD21]. The deposition rates derived for the terrestrial habitat were conservatively adopted for assessing the radiological impacts to the freshwater habitat.

Assessment of effects

14.4.63 For radiological effects, regulatory guidance [RD7] provides the tiered dose assessment criteria listed in table B14-10. The public dose limit is the legal

limit for anthropogenic exposures (except medically-related ones), set under the Ionising Radiations Regulations 2017. The site and source dose constraints are used by the regulators when assessing Environmental Permit applications, as upper limits such that cumulative effects from adjacent separate facilities will still ensure compliance with the dose limit. The lower dose levels are used by the regulators as optimisation targets (although the application of BAT has still to be demonstrated).

Table B14-10 Dose levels in UK legislation/guidance

Human radiological impacts (dose bands)	Requirement
1.0mSv/y	UK public dose limit.
0.5mSv/y	Dose constraint for exposures from a site.
0.3mSv/y	Dose constraint for exposures from a single source.
0.15mSv/y	PHE recommendations on constraints for new nuclear build.
0.02mSv/y	Basic Safety Objective to be applied for any person off-site. Screening level dose above which more detailed assessments are required but below which a demonstration of ALARP is still required.
0.01mSv/y.	Guidance to the nuclear regulators as doses below which regulators should not seek further reductions in public dose, provided the operator is using BAT to limit discharges.

14.4.64 NRW requires an assessment of the likely combined impact of radioactive discharges from all relevant existing and prospective sites on non-human species as part of the permit application for radioactive substance activities [RD5]. The results of such assessments may be compared to a guideline value of 40µGy/hr, the threshold below which the UK regulators consider there will be no adverse effect on non-human species or the integrity of protected sites [RD8, RD19]. In addition, the ERICA methodology [RD14] has a screening level of 10µGy/hr. As a result, for non-human species, the two lower assessment levels are set as 10µGy/hr and 40µGy/hr. UK guidance also includes higher assessment criteria at 0.4mGy/hr and 1mGy/hr [RD8].

Value of receptors

14.4.65 Two types of receptors have been identified for this chapter, namely:

- members of the public exposed to radiation; and
- non-human species within sites of declared significance or sensitivity.

14.4.66 Both types of receptor are judged to be of high value/sensitivity.

Magnitude of change

14.4.67 The magnitude of change is a measure of the scale or extent of the change, irrespective of the value of the receptor(s) affected. The criteria used to determine the magnitude of change are set out in table B14-11 and for humans are derived from the dose bands from the regulatory dose criteria detailed in table B14-10 and are aligned to the generic criteria outlined in

table B1-2 in chapter B1 (Application Reference Number: 6.2.1) of this Environmental Statement. It is judged that exceeding the legal dose limit would result in a large impact, that incurring doses close to the source constraint would be a medium impact and that having assessed doses close to the optimisation levels would be a small impact. For non-human species, the magnitudes of change are derived from the discussion in paragraph 14.4.63.

Table B14-11 Criteria for impact and significance of effect assessment

Magnitude of impact and significance effect	Human radiological impacts (dose bands)	Non-human species radiological impacts
Large magnitude Major significance	0.3mSv/y to 1.0mSv/y 1.0mSv/y is the UK public dose limit 0.3mSv/y is the source dose constraint.	0.4mGy/hr to 1mGy/hr Higher dose guidance in R&D128
Medium magnitude Minor/moderate significance (based on judgement)	0.15mSv/y to 0.3mSv/y 0.3mSv/y is the source dose constraint 0.15mSv/y follows PHE recommendations on constraints for new nuclear build.	0.04mGy/hr to 0.4mGy/hr Higher dose guidance in R&D128 0.04mGy/hr dose limit in R&D128
Small magnitude Negligible significance (for human impacts) Minor significance (for non-human species impacts)	0.01mSv/y to 0.15mSv/y 0.15mSv/y follows PHE recommendations on constraints for new nuclear build 0.01mSv/y follows guidance to the nuclear regulators as doses below which regulators should not seek further reductions in public dose, provided the operator is using BAT to limit discharges.	0.01mGy/hr to 0.04mGy/hr 0.04mGy/hr dose limit in R&D128 0.01mGy/hr ERICA screening dose rate
Negligible magnitude Negligible significance	Less than 0.01mSv/y (follows guidance to the nuclear regulators as doses below which regulators should not seek further reductions in public dose,	Less than 0.01mGy/hr (ERICA screening dose rate)

Magnitude of impact and significance effect	Human radiological impacts (dose bands)	Non-human species radiological impacts
	provided the operator is using BAT to limit discharges).	

Assessment of significance

14.4.68 The degree of significance is influenced by the value of a receptor and the magnitude of the predicted impact. As all receptors for which impacts are assessed are judged to be of high sensitivity, then the significance can also be mapped directly from the calculated dose using the ranges shown in table B14-11 with reference to figure B1-2 and the methodology discussed in chapter B1 (Application Reference Number: 6.2.1) of this Environmental Statement.

14.4.69 From section 1.4 in chapter B1 (Application Reference Number: 6.2.1), an environmental effect may be significant if, in the professional judgement of the expert undertaking the assessment, it would meet at least one of the following criteria:

- it leads to an exceedance of defined guidelines or widely recognised levels of acceptable change;
- it is likely that the consenting authority will reasonably consider applying a planning condition, requirement or legal agreement to the consent to require specific mitigation to reduce or overcome the effect;
- it threatens or enhances the viability or integrity of a receptor or receptor group of concern; or
- it is likely to be material to the ultimate decision about whether or not the consent application should be approved.

14.4.70 The small magnitude impact dose range for humans is from 0.01mSv/y to 0.15mSv/y. Even at the level of 0.15mSv/y, none of the four significance criteria listed above would be triggered, since as long as BAT has been applied, an Environmental Permit can be granted, assuming regulatory principles are applied.

14.4.71 Because of this, for radiological effects in humans, a small magnitude impact is judged as having negligible significance.

14.4.72 Impact significance levels correlate with the magnitude of impact and are described in column 1 of table B14-11.

Limitations

14.4.73 Although the methodologies described in this chapter are considered to provide a robust approach to the assessment of radiological effects, there remain inherent uncertainties in certain aspects of the assessment.

14.4.74 Undertaking any assessment of prospective doses necessarily involves the application of models and the making of assumptions regarding future

transfers, activities and human behaviour. This results in varying degrees of uncertainty. The key uncertainties associated with the dose assessments presented in chapter D14 (Application Reference Number: 6.4.14) are:

- the estimate of the radioactive discharge to the environment;
- the dispersion of radioactivity following aqueous and gaseous discharges to the environment;
- the transfer of radioactivity in the environment;
- assumed habits; and
- dose coefficients for the inhalation or ingestion of radionuclides.

14.4.75 Where considered necessary, a conservative approach is adopted to take into account these uncertainties.

14.5 References

Table B14-12 Schedule of references

ID	Reference
RD1	Department of Energy and Climate Change. 2011. *National Policy Statement for Nuclear Power Generation (EN-6)*. London: The Stationery Office.
RD2	Department of Energy and Climate Change. 2009. *UK Strategy for Radioactive Discharges*. London: The Stationery Office.
RD3	Isle of Anglesey County Council. 2014. *New Nuclear Build at Wylfa Supplementary Planning Guidance*. [Online]. [Accessed: 03 01 2018]. Available from: http://www.anglesey.gov.uk/business/energy-island/energy-island-news/new-nuclear-build-at-wylfa-supplementary-planning-guidance/123426.article .
RD4	Department of Energy and Climate Change and Welsh Assembly Government 2009. *Statutory Guidance to the Environment Agency concerning the regulation of radioactive discharges into the environment*. Department of Energy and Climate Change. London: The Stationery Office.
RD5	Natural Resources Wales (NRW). 2014. *Radioactive Substances Regulation – Environmental Principles*. Regulatory Guidance Series, No RSR 1 v3.
RD6	Natural Resources Wales (NRW). 2014. *Radioactive Substances Regulation – The regulation of radioactive substances activities on nuclear licensed sites*. Regulatory Guidance Series, No RSR 2 v3.
RD7	Environment Agency. 2012. *Principles for the Assessment of Prospective Public Doses arising from Authorised Discharges of Radioactive Waste*.
RD8	Copplestone, D, *et al*. 2001. *Impact Assessment of ionising radiation on Wildlife*. Environment Agency R&D publication 128. Bristol: Environment Agency.
RD9	Horizon. 2017. Wylfa Newydd Project Radioactive Substances Regulation – Environmental Permit Application. WN0908-HZCON-PAC-REP-00003.
RD10	Smith, J.G., and Simmonds, J.R. 2009. The Methodology for Assessing the Radiological Consequences of Routine Releases of Radionuclides to the Environment Used in PC-CREAM 08®. HPA-RPD-058. Chilton: Public Health England.
RD11	Los Alamos National Laboratory. 2003. *X-5 Monte Carlo Team MCNP - Version 5, Vol. I: Overview and Theory*, LA-UR-03-1987. Los Alamos.
RD12	International Commission on Radiological Protection. 2010. *Conversion Coefficients for Radiological Protection Quantities for External Radiation Exposures*. ICRP Publication 116

ID	Reference
RD13	Watson, S.J., Oatway, W.B., Jones, A.l. and Hughes, J.S. 2005. *Survey into the Radiological Impact of the Normal transport of Radioactive Material in the UK by Road and Rail*. NRPB-W66. Chilton: National Radiological Protection Board.
RD14	Beresford, N, Brown, J., Copplestone, D., Garnier-Laplace, J., Howard, B., Larsson, C., Oughton, D., Pröhl G. and Zinger, I. 2007. *D-ERICA - An Integrated Approach to the Assessment and Management of Environmental Risks from Ionising Radiation*. Luxembourg: Commission of the European Communities.
RD15	International Commission on Radiological Protection. 2008. *Environmental Protection – the Concept and Use of Reference Animals and Plants*. ICRP Publication 108 Ann. ICRP 38 (4-6).
RD16	Ulanovsky, A., Prohl, G. and Gomez-Ros, J.M. 2008. Methods for calculating dose conversion coefficients for terrestrial and aquatic biota. *Journal of Environmental Radioactivity*, 99, 1440-1448.
RD17	Brown, J.E., Alfonso, B., Avila, R., Beresford, N.A., Copplestone, D., Pröhl, G. and Ulanovsky A. 2008. The ERICA Tool. *Journal of Environmental Radioactivity*, 99(9): 1371-1383.
RD18	SKN. 2015. *Impact Assessment of ionising radiation on Wildlife. R&D publication 128.* Environment Agency Version 2 as revised by SKN_CEN Belgian Nuclear Research Centre, Version 2.0
RD19	Allott, R., Copplestone, D., Merrill, P. and Oliver, S. 2009. *Habitats assessment for radioactive substances*. Environment Agency Science Report: SC060083/SR1.
RD20	Horizon. 2014. *Wylfa Newydd Project Pre-Application Consultation - Stage One. Preliminary Environmental Information Report - Volume 1*.
RD21	International Atomic Energy Agency. 2001. *Safety Reports Series No.19 Generic Models for Use in Assessing the Impact of Discharges of Radioactive Substances to the Environment*. Vienna: IAEA.