Preliminary detailed assessment of the generic site description and the assessment of doses to the public and to wildlife for General Nuclear System Limited's UK HPR1000 design - AR07

Version 1, 11 January 2021

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Executive summary

This report covers our Generic Design Assessment (GDA) of General Nuclear System Limited's (GNSL's) submission on 2 related topics - generic site and radiological assessment. This is for the United Kingdom Hualong Pressurised (Water) Reactor design (UK HPR1000) as required in Table 1 of our Process and Information Document (P&ID) (Environment Agency, 2016a).

Our assessment has considered GNSL's submission in relation to relevant UK policy, legislation and guidance. These include the Environment Agency's Radioactive Substances Regulation (RSR) Environmental Principles (REPs) (Environment Agency, 2010); Nuclear National Policy Statement (UK Parliament, 2011a, 2011b) and the Dose Principles document (Environment Agency et al., 2012). We also considered relevant guidance provided by the National Dose Assessment Working Group (NDAWG) and other technical documents from Public Health England (PHE).

For the generic site characteristics, we found that GNSL's submission had taken into account the sites listed in the Nuclear National Policy Statement (UK Parliament, 2011a, 2011b). The policy statement lists sites potentially suitable for new nuclear power plants; most of which are adjacent to existing nuclear power plants. GNSL's generic site description is influenced by the Bradwell site characteristics.

We consider that the generic site characteristics are justified and reasonable for the GDA stage for new reactors and represent an appropriate UK site. The parameters chosen for the generic site are quite cautious and will tend to form a bounding case for liquid discharges to the marine environment. The parameters and values that define the generic site for the UK HPR1000 are appropriate to use in assessing the radiological impact of the UK HPR1000 at the GDA stage.

GNSL's submission on radiological assessment was of the prospective (future) doses to members of the public arising from the expected disposal of liquids and gaseous radioactive waste to the environment from a single UK HPR1000.

GNSL's submission indicates that, potentially, the highest total dose to members of the public will be between 10 and 23 micro-Sieverts a year (μSv/y) depending on age group. The highest dose would be to an adult member of a 'fishing family' who are most affected by discharges of liquids. That is a family assumed to be living near the site, eating fish and foods farmed around the site. Half of the dose to the adult is predicted to occur from the intake of local foodstuffs affected by liquid discharges. The rest of the dose is from exposure to discharges to the atmosphere and from direct radiation. Carbon-14 contributed 95% to 99% of the dose from discharges. GNSL's submission showed that doses from enhanced short duration releases to atmosphere were between 6 and 10 μSv per release depending on age group.

We appointed a technical support contractor (TSC) to carry out an independent assessment of the radiological impact of the UK HPR1000 at the generic site on our behalf.

Our independent assessment indicates that the highest doses range from 10 to 23 μSv/y. The most exposed group is a local resident farming family. The biggest contribution to doses is from discharges to the atmosphere. The highest dose is to an infant consuming locally produced foods. Carbon-14 contributed 96% to 99% of the dose from discharges. Direct radiation is a less significant component of the dose because the farming family are assumed to be 300m from the site where direct radiation is lower. Doses from enhanced short duration releases to atmosphere were between 6 and 8 μSv per release depending on age group.

The small differences in outcomes are due to the independent assessment assuming occupancy at the location where ground level air concentrations are highest (300m from the release point) and including doses by eating locally produced milk products. In GNSL's submission occupancy is assumed to be at 100m from the release point, which gives slightly lower air concentrations, and doses from milk products are not included. The dose from atmospheric discharges assessed at 300m are higher than those established assuming a 100m distance. The independent assessment uses less cautious dispersion information for the marine environment around the generic site than GNSL does. Therefore doses from liquid discharges are predicted to be lower in the independent assessment than from GNSL's.

Our preliminary conclusions are that the discharges to atmosphere and liquid discharges of radioactive wastes at proposed limits from a single UK HPR1000 at the generic site is likely to result in doses to the public that are well below the dose constraint for members of the public of 300μSv/y. The assessed doses are also well below the public dose limit of 1,000uSv/y specified in EPR16 (UK Parliament, 2016). We consider that the assessment GNSL carried out is cautious, reasonable and has used an appropriate approach. Our independent assessment has a similar outcome.

Discharges of radioactive wastes from a UK HPR1000 at the generic site are unlikely to pose a risk to wildlife. We consider the assessment GNSL carried out to be cautious and reasonable, and we consider that GNSL has used an appropriate approach to assess the radiological impacts of the UK HPR1000 on wildlife. The dose rates range from 0.00043μGy/h to 0.15μGy/h. Our independent assessment outcomes are similar ranging from 0.03μGy/h to 0.13μGy/h. All are well below the dose rate criterion of 10μGy/h.

This assessment is a prediction of the radiological impact for discharges made from a single reactor at a generic site. A detailed radiological assessment will be needed to support any application for an environmental permit in future. The radiological assessment would be based on site-specific environmental characteristics.

We have not identified any potential GDA Issues or Assessment Findings (AFs) related to the radiological assessment. However, the importance of the carbon-14 discharges to the assessed dose indicates that abatement may need to be considered for carbon-14. This is related to option studies and optimisation of the plant operation in future. Therefore, Assessment Findings have been raised in our BAT assessment report (Environment Agency, 2020c) related to carbon-14 abatement; assessment of chemical form of carbon-14 discharged to the environment and the optimisation of the balance between gaseous, liquid and solid phases of carbon-14.

Contents

1. Introduction

This report provides our detailed assessment of GNSL's submission in relation to the 2 linked areas of generic site and radiological impact in the UK HPR1000 design for GDA purposes.

This report is based on information received from GNSL at the time of writing. Any subsequent or updated information will be assessed alongside the responses to our consultation. Our and ONR's detailed assessment process will continue through and beyond the period of Environment Agency public consultation. Therefore our work on this topic is ongoing. Our final assessment results will be published in our Decision Document at the end of GDA. We are targeting completing GDA in early 2022.

We use a 2-stage process to carry out GDA: initial assessment, followed by detailed assessment. The findings from our initial assessment are set out in the Initial assessment: Statement of findings report published in November 2018. Our initial conclusions were that for a coastal site:

- the annual dose constraints and limits are unlikely to be exceeded by this design
- the action level for non-human species are unlikely to be exceeded by this design
- we required further information on:
    - the detail of generic site parameters and their justification for use
    - the justification for the chosen modelling tools
    - improved underpinning of the direct dose assessment
    - a detailed stage 3 dose assessment
    - an assessment of a short duration release

In order to assess the potential impact of a particular reactor design on the environment we need to know the characteristics of the generic site proposed by General Nuclear System Limited (GNSL). We recognise that at the GDA stage the proposed specific location of the nuclear plant may not be known so our assessments for GDA are based on the generic site. However the generic site description presented by GNSL has used some characteristics of the Bradwell site. At the site specific stage, when a proposed location for a plant is confirmed, a site-specific assessment will always be required as part of the application for an environmental permit. At the GDA stage, we need to satisfy ourselves that:

- the reactor design is such that any environmental impacts would be acceptable under relevant UK legislation
- any particular features of the reactor design that could lead to impacts of a type or scale that could constrain the locations at which such a plant could be located are identified
- any radiological impacts of new build reactors in the UK are as low as reasonable achievable (ALARA), as required by the Environmental Permitting Regulations 2016 (Schedule 23) (UK Parliament, 2016)

In GDA, we require a typical (generic) site to be defined in order to assess the environmental impacts of the reactor design. GNSL has made a radiological impact assessment (GNSL, 2020c) using its generic site description (GNSL, 2020a). Our assessment of the generic site is presented in this report.

We require GNSL to demonstrate that the radiological impact of its operations would be consistent with the UK dose constraints and dose limits for the public and meet the dose rate criteria for the radiological impact on wildlife, which are non-human species that require protection (see glossary).

As part of our assessment, we commissioned our own radiological assessment, which is independent of the one GNSL submitted. We have published the full report of this independent assessment separately (Environment Agency, 2020a). We appointed a technical support contractor (TSC), (Cavendish Nuclear Ltd) to make the assessment on our behalf. The generic site used for our independent assessment took into account the relevant characteristics of other UK locations where a new reactor might be constructed in future based on the UK siting report (UK Parliament, 2011a and 2011b). In the assessment, our TSC predicted environmental activity concentrations by modelling and made an assessment of the radiological impact on people and wildlife of the UK HPR1000 discharges (Environment Agency, 2020a).

1.1. Generic site

The parameters that are part of the generic site description include:

- the position of the reactor and the environment around it
- environmental parameters such as meteorological conditions, dispersion of liquids and atmospheric dispersion
- the distance to the nearest occupied buildings, farmland and centres of population
- habits of the local population
- potential designated or protected wildlife sites

GNSL has derived its generic site characteristics for the UK HPR1000 assuming the UK HPR1000 will be located on the coast. The generic site characteristics have been chosen to represent sites where a new UK HPR1000 might be located and adopt some of the environmental characteristics of the current Bradwell site.

The main assumptions declared for the generic site are:

- The site is in a coastal or estuarine location and the topography of the site is flat.
- There is no water extraction from aquifers and no standing water at the site.
- There are no freshwater bodies on or adjacent to the site.
- The nearest human receptors are assumed to be a fisherman family and local resident family.
- Discharge routes are assumed to be discharges of gases (and some particulates) to atmosphere and liquid (aqueous) discharges to the marine/estuarine environment adjacent to the site.
- Human receptors are the local resident family and fisherman family;
- There are no sites adjacent to the generic site;
- There is no incinerator on the site.

The design assumes once-through seawater cooling and has been factored into the generic site.

We note that the generic site has adopted the characteristics of the Bradwell site. At the Bradwell site and at most other UK locations there are other power stations operating or decommissioning on an adjacent site. Therefore a UK HPR1000 is likely to be adjacent to at least one another power station.

1.2. Radiological impact

In England, the Environment Agency regulates the discharges of radioactive waste into the environment during normal operation, making sure that any radiation exposure of the public is below the statutory dose limit and dose constraints. The Office for Nuclear Regulation (ONR) is responsible for regulating nuclear safety, including making sure that doses to the public resulting from direct radiation during normal operation are acceptable and below the statutory dose limits. Direct radiation is radiation from radioactive sources within a nuclear power plant boundary, instead of indirectly as a result of radioactive discharges.

This 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. It is recognised however, that the assessment should be kept under review to reflect changes in the statute, policy and guidance that may occur between now and plant commissioning and operation.

The radiological assessment does not cover radioactive discharges arising from decommissioning at the end of the reactor life cycle. These are out of the scope of GDA. Discharges during operation of the reactor will dominate the overall radiological discharges from the UK HPR1000 plant. The decommissioning phase at the end of operation normally leads to a substantial reduction in discharges to the environment.

The radiological assessment outcome is dependent on the generic site definition and description (GNSL, 2020a). Consequently, the radiological assessment for humans and wildlife and the generic site have been assessed together in a single assessment report.

Dose to public

To assess the potential radiological impact of a reactor design, the potential future (prospective) doses of radiation to members of the public need to be determined. These can result from discharges of radionuclides to the environment from a reactor (within a nuclear power plant) and its associated facilities. Doses may also arise from any exposure offsite from direct radiation from radioactive sources within the reactor structures. Prospective dose assessments are required to determine the potential radiological impact of a reactor design and to inform optimisation decisions at the design stage.

The assessment GNSL provided includes the predicted levels of radionuclides from discharges into the environment (at the proposed discharge limits) from the UK HPR1000 and the radiological impact from direct radiation (GNSL, 2020b). We have assessed GNSL's submission to make sure that it is comprehensive, is based on a valid approach and is technically correct. We have compared the prospective doses with the dose constraints and the legal dose limit set by government (UK Parliament, 2016).

Dose to wildlife

To assess the potential radiological impact of a reactor design, the prospective impact of radiological discharges on wildlife also needs to be determined.

Our assessment considers the information GNSL provided for its UK HPR1000 design. GNSL's submission presents an assessment of the impact of radiological discharges, assumed to be discharged at proposed discharge limits, on wildlife from a single UK HPR1000 reactor (GNSL 2020c). Our assessment of GNSL's submission will ensure that it is comprehensive, based on a valid approach and technically correct.

1.3. Additional information

During the assessments we identified that, in some cases, we needed existing information to be clarified or further information provided. We managed this using the system of Regulatory Queries (RQs) and through technical discussion. We did not raise any Regulatory Observations or Regulatory Issues during our assessment of the generic site or radiological impact of the UK HPR1000. Our overall assessment process is set out in our Process and Information Document (P&ID) (Environment Agency, 2016).

2. Assessment

We assessed the generic site and the radiological impact during our initial assessment (Environment Agency, 2018). This assessment is a review and continuation of the earlier work and considers the generic site described by GNSL and the radiological impact on public and wildlife.

2.1. Assessment method

Our assessment method is summarised as follows:

- We considered the Pre-Construction Environmental Report (PCER) and its supporting documents submitted by GNSL (see section 2.3 below).
- We used technical meetings with GNSL to clarify our understanding of the information presented and explain any concerns that we had with that information.
- We raised RQs to clarify information supplied by GNSL.
- We assessed the generic site characteristics that GNSL proposed to decide if they were reasonable and applicable to the UK.
- We assessed the methods used against UK guidance input parameters to ensure they were applicable to the UK, and outcomes of the radiological assessment that GNSL carried out for the public and wildlife.
- We carried out an independent assessment of the radiological impact.

The radiological assessment outcomes are dependent on discharges of radionuclides. Discharges of radionuclides are presented in a separate submission (GNSL, 2020b) and we have assessed these separately (Environment Agency, 2021b). The radiological assessment outcomes are also affected by direct radiation. Information on direct radiation was summarised in the GNSL radiological assessment. The radiation protection submission contains more detailed information on direct radiation from the UK HPR1000 (GNSL 2018; GNSL 2020d).

2.2. Assessment objectives

Objectives were set for our assessment of the generic site, radiological impact on the public and radiological impact on wildlife.

For our assessment of the generic site, our objectives were to confirm the following:

- Are the generic site characteristics reasonable, justified and well described?
- Are the conditions and parameters described appropriate for possible locations in the UK?
- Are there any aspects of the generic site that could rule out any location at site-specific permitting?
- How does GNSL's defined generic site compare with our independent assessment?

For our assessment of radiological impact on the public, our objectives were to confirm the following:

- Is the radiological impact assessment carried out by GNSL reasonable and justified?
- Does the GNSL radiological assessment follow established UK methods and guidance?
- Are the predicted doses to members of the public below the relevant dose constraints?
- Is the radiological impact assessment valid and are the outcomes consistent with our independent assessment?

For our assessment of radiological impact on wildlife, our objectives were to confirm the following:

- Is the radiological impact assessment carried out by GNSL reasonable and justified?
- Does the GNSL radiological assessment follow established UK methods and guidance?
- Can the radiological impact assessment carried out by GNSL be reproduced so that we can understand how GNSL carried out its assessment?
- Are the predicted dose rates to wildlife below the relevant dose rate criteria?

2.3. Submissions assessed

For this assessment, we considered the documents submitted by GNSL shown in Table 1.

Table 1. Documents submitted by GNSL which were considered in this assessment

Document number	Revisions	Title	Reference
HPR/GDA/PSR/0026	001	Preliminary Safety Report Chapter 26 - Environment	GNSL 2017
HPR/GDA/PCER/0002	001-1	Pre-Construction Environmental Report Chapter 2 - Generic Site Description	GNSL 2020a
HPR/GDA/PCER/0006	001-1	Pre-Construction Environmental Report Chapter 6 - Quantification of Discharges and Limits	GNSL 2020b
HPR/GDA/PCER/0007	001 + 001-1	Pre-Construction Environmental Report Chapter 7 - Radiological Assessment	GNSL 2020c
GHX00620022KPGB02GN	Rev E	Pre-Construction Safety Report Chapter 22 - Radiological Protection	GNSL 2020d

2.4. Guidance and standards

There are no specific UK standards for assessing the generic site and radiological impact. However, there are technical reports, good practice guides and principles. We used guidance, principles and published methods in our assessment, including the Radioactive Substances Regulation Environmental Principles (REPs) (Environment Agency 2010), the requirements specified in the P&ID (Environment Agency 2016), the Principles document for Prospective Dose (Environment Agency et al. 2012); good practice guides and technical methods issued by the National Dose Assessment Working Group (NDAWG) and specific technical guidance and methods issued by Public Health England (PHE) (which provides radiation protection advice to the UK). Data and methods have been derived from the International Atomic Energy Agency (IAEA) and the International Commission on Radiological Protection (ICRP).

Radioactive Substances Regulation Environmental Principles (REPs)

Table 2 presents the Radioactive Substances Regulation Environmental Principles (REPs) (Environment Agency, 2010) that are relevant to assessing GNSL's submissions on generic site (GNSL 2020a) and radiological impact (GNSL 2020c).

Table 2 The Regulatory Environmental Principles (REPs) relevant to the definition of a generic site and radiological assessment

REP	Description
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.
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.
RPDP3 **Protection of non-human species**	Non-human species (wildlife) should be adequately protected from exposure to ionising radiation.
RPDP4 **Prospective dose assessments for radioactive discharges to the environment**	Assessments of potential doses to people and to non-human species (wildlife) shall be made before granting any new or revised authorisation for the discharge of radioactive wastes into the environment.

Process and Information Document (P&ID) requirements

Our P&ID (Environment Agency 2016) sets out our requirements to the Requesting Party (RP) at the start of this GDA process. Tables 3a and 3b summarise the information that a Requesting Party is required to provide in its submission to address the generic site and radiological assessment.

Table 3a. Information required in the P&ID for generic site

Generic site information requirements
Identification of discharge points to the environment for discharges to atmosphere and liquid radioactive wastes.
Description and characteristics of the generic site (or sites) that the Requesting Party will use to provide its dose assessment. Any statement of acceptability we issue after our assessment will be on the basis of these characteristics. A range of generic sites might be chosen with coastal, estuarine and inland characteristics.

Table 3b. Information required in the P&ID for prospective radiological impact assessment

Radiological assessment information requirements
Prospective radiological assessment at the proposed limits for discharges and for any onsite incineration.
Annual dose to the most exposed members of the public from liquid (aqueous) discharges.*
Annual dose to the most exposed members of the public for discharges to atmosphere, identifying separately the dose associated with onsite 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 members of the public.
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.
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.
Collective dose up to 500 years to the UK, European and world populations.
Dose-rate to non-human species.
Identify the models used to calculate these doses and why they are appropriate, and set out all the data and assumptions, with reasoning, that was used as input to the models.

For those items above marked with an asterisk (*), we recommended using our initial radiological assessment tool - IRAT (which is available on request), refining the default data to reflect the characteristics of the facility and generic site.

Principles for assessing prospective dose

There are 13 published principles which should be applied when assessing prospective doses (Environment Agency et al. 2012). Their main purpose is for assessing the discharges of radionuclides from nuclear and non-nuclear sites. Some of the principles apply directly in the radiological assessment at GDA and these are identified in Table 4.

The National Dose Assessment Working Group (NDAWG) published discussion papers, methods and guidance notes in the area of dose assessment. Some are relevant to GDA and are as listed in Table 4.

Table 4 - Dose principles and NDAWG guidance relevant to GDA

	Dose principle	NDAWG guidance
1	Prospective dose assessment methods, data and results should be transparent and made publicly available.	NDAWG GN 1: Overview of guidance on the assessment of radiation doses from routine discharges of radionuclides to the environment. (NDAWG 2008a)
2	When determining discharge permits or authorisations, the dose to the representative person should be assessed.	NDAWG GN 7: Use of habits data in prospective dose assessments. (NDAWG 2013) NDAWG GN 3: Guidance on exposure pathways. (NDAWG 2009)
3	Doses to the most affected age group should be assessed to determine discharge permits or authorisations. Assessment of doses to 1 year olds, 10 year olds and adults (and foetus, when appropriate) is adequate age group coverage.	NDAWG GN 7: Use of habits data in prospective dose assessments. (NDAWG 2013)
4	The dose to the representative person which is assessed for comparison with the source constraint and, if appropriate, the site constraint, should include all reasonably foreseeable and relevant future exposure pathways.	NDAWG GN 7 Use of habits data in prospective dose assessments. (NDAWG 2013)
5	Where a cautious estimate of the dose to the representative person exceeds 0.02mSv/y, the assessments should be refined and, where appropriate, more realistic assumptions made. However, sufficient caution should be retained in assessments to provide confidence that actual doses received by the representative person will be below the dose limit.	NDAWG GN 2: Guidance on initial/simple assessment tools. (NDAWG 2008b)

	Dose principle	NDAWG guidance
6	The assessment of dose to the representative person should take account of accumulation of radionuclides in the environment from future discharges.	N/A
7	The dose assessed for operational short-term release at proposed notification levels or limits should be compared with the source constraint (maximum of 0.3mSv/y) and the dose limit (1mSv/y), taking into account remaining continuous discharges during the remainder of the year and contributions from other relevant sources under control.	NDAWGGN 6A: Guidance on short-term release assessments. (NDAWG 2019)
8	For permitting or authorisation purposes, collective doses to the populations of the UK, Europe and the world at 500 years, should be estimated.	N/A
9	Where the assessed mean dose to the representative person exceeds 0.02mSv/y (20μSv/y), the uncertainty and variability in the main assumptions used for the dose assessment should be reviewed.	NDAWG GN 4: Guidance on considering uncertainty and variability in radiological assessments. (NDAWG 2011)

2.5. Independent assessment

An independent assessment was carried out for us by a technical services contractor. The assessment supports our detailed assessment of GNSL's submission and provides a reference point for comparison with the GNSL submission. It allows an indirect validation of the assumptions and methods GNSL used in its generic site definition and in its assessment of the radiological impact. The independent assessment is provided in a separate report (Environment Agency 2020a).

3. Technical assessment

3.1. Generic site

The submissions related to the generic site description assessed during the GDA process are shown in Table 1.

The generic site assumptions provide a simplified representation of a potential UK site. Some of the simplifications in the assumptions lead to no assessment of specific aspects of the environment and exposure pathways - specifically, no groundwater and no freshwater exposure pathways, including impact on freshwater wildlife. However, if an application for an environmental permit is made in future at a particular site, it will be supported by a site-specific assessment, taking into account all the main environmental features around the site.

Our initial assessment

During our initial assessment (Environment Agency 2018), we compared GNSL's submission with the relevant Radioactive Substances Regulation Environmental Principles (REPs) (Table 2) (Environment Agency 2010), the P&ID (Table 3) (Environment Agency 2016) and the dose principles document (Table 4) (Environment Agency et al. 2012). GNSL submitted a 3-tier radiological assessment, with stages 1 and 2 being screening assessments. Each stage of the tiered assessment used information from the generic site description. Stage 1 and stage 2 assessments were completed, however the third assessment stage was described, but only partially completed. The generic site description used general information, which has been augmented by some information from the Bradwell nuclear site. We reviewed and verified the stage 1 and stage 2 outcomes.

Our detailed assessment

During our detailed assessment of the updated submission from GNSL (GNSL 2020a), we reviewed the submission against our REPs, the P&ID, and the dose principles document, as for the initial assessment. In the updated GNSL submission, all 3 stages of the assessments were complete. We reviewed and verified the stage 1 and stage 2 outcomes. We found that the generic site description used some information on environmental dispersion (meteorological data and marine dispersion data) that is consistent with the Bradwell site. Information on habits, land use and exposed groups was taken from UK wide data sources, with additional information from the area around the Bradwell site. These are considered in more detail below.

Meteorological data

For the assessment of continuous releases, GNSL has used meteorological data based on Pasquill stability categories, as used in the R-91 aerial dispersion model (NRPB 1979). For the stage 1 and stage 2 assessments GNSL has used our initial radiological assessment tool (IRAT). The atmospheric conditions assumed in IRAT are 50% category D, which is conservative (Environment Agency 2006a and 2006b).

For the stage 1 assessment using IRAT the outcomes are likely to be cautious, mainly because of the baseline assumption of a ground level release.

For the stage 3 detailed assessment, GNSL selected conditions of 65% category D, which is representative of some coastal conditions around the UK and encompasses conditions around the Bradwell site (NRPB 1979). In our independent assessment, we have established that the range of meteorological data available for the UK (50% to 80% category D) and used in the modelling can influence ground level air concentrations by a factor of about 30%. The 65% category D leads to air concentrations that are in the middle of the range and are appropriate for assessing the generic site for the UK HPR1000.

Meteorological data specific to modelling short-term releases are discussed in the prospective dose modelling submission (GNSL 2020c). Parameters were derived for the ADMS model that were approximately equivalent atmospheric conditions to the Pasquill stability classes used for continuous discharge assessment, which is considered appropriate for GDA.

For any future dose assessment in support of permitting, it is expected that site-specific meteorological data would be used.

Marine environment modelling data

For the stage 1 assessment default marine dispersion data (volumetric exchange) were taken from IRAT (Environment Agency 2006a; 2006b). The volumetric exchange rate is a parameter that defines the mixing rate between local and regional waters. This default is very cautious for most coastal sites and reasonably cautious for most estuarine locations. It is, therefore, an appropriate upper bound assessment for GDA. For the stage 2 assessment using IRAT (Environment Agency 2006a and 2006b), GNSL adopted a volumetric exchange rate based on the Bradwell site. These volumetric data were also used in the stage 3 assessment.

We raised a concern that the stage 2 and 3 dose impact assessments had used data for the Bradwell site without clear justification. GNSL confirmed that it was aware that under GDA a specific site is not being selected. However, a generic site using Bradwell characteristics is likely to be cautious and the radiological assessment will represent an upper estimate.

Our analysis in the independent assessment indicates that the generic site defined by GNSL is conservative.

Exposed groups

Based on the above assumptions for the site, GNSL has determined that the most exposed members of the public for radioactive discharges to air will be a 'local resident family' and for discharges to sea will be a 'fisherman family'. These are consistent with the exposure groups we use in the IRAT (Environment Agency 2006a and 2006b). These assumptions are appropriate for GDA. Site-specific exposure routes will be assessed during any future environmental permitting process.

The exposed group representing the local resident family at the generic site was assumed to be consistent with the underlying assumptions in the IRAT system and the stage 1 and stage 2 assessment. IRAT assumes that the local resident lives 100m from the release point and that a range of food is produced 500m from the release point. These basic assumptions were retained for the stage 3 assessment. We raised an RQ related to the expected size of the reactor and other buildings on the site to support the assumptions around the location of the local residents and to provide a justification for this assumption. We were content with the response.

In our independent assessment, we have explored the effect of increasing the receptor distance from 100m to 1km from the release point on ground level air concentration. For a 20m stack height, ground level air concentrations at 300m can be higher than at 100m. The range in the factors depends on the meteorological conditions assumed and data used. At 65% Pasquill stability category D, the ground level air concentrations 300m from the release for a release height of 20m are up to 3 times higher than at 100m. However, the exposure pathways directly related to the plume at 100m and 300m are of relatively low significance and so the effect on total dose is small. This was considered further in our independent assessment.

Habits data

The IRAT system (Environment Agency 2006a; 2006b) has generic habits data (for example, food intake rates) taken from UK generic habits data published by the National Radiological Protection Board (NRPB) (NRPB, 2003). Therefore, we are confident that parameters appropriate for the generic site have been applied for the stage 1 and stage 2 assessments.

GNSL has also reviewed site-specific habits data local to the Bradwell site and selected additional habits. GNSL identified in the local habits surveys that there are people who live on houseboats for a large part of the year and have high occupancy above intertidal sediments. The local habits surveys also identified higher rate intakes of some foods (fish, seaweed, vegetables and fruit). These were substituted for some of the UK generic habits data in the GNSL assessment. We are content that the method and data are appropriate to use for a generic site. However, substituting Bradwell site habits data where the data is higher than in UK generic habits data may lead to a more conservative estimate of dose to the public.

Wildlife

GNSL's submission concerned with generic site (GNSL 2020a) states that it will use the ERICA tool (Beresford et al. 2007, Brown et al. 2007, Brown et al. 2016) and the Ar-Kr-Xe dose calculator (Vives i Batlle et al. 2015) to assess the radiological impact of discharges from the HPR1000 on wildlife. We are content that these are reasonable methods that can be used in the assessment. The ecological receptors considered for GDA are the reference organisms defined in the ERICA tool. GNSL uses these reference organisms to represent sensitive habitats and protected species which may be located at the generic site. We are content that using the ERICA reference organisms is appropriate for the GDA stage. Specific designated wildlife sites would be defined and assessed at any future site-specific environmental permitting stage.

The GNSL submission (GNSL 2020a) states that radiological discharges from the UK HPR1000 are aerial discharges to the atmosphere and liquid (aqueous) discharges to the estuary. GNSL has, therefore, considered the terrestrial and marine reference organisms in its assessment. As there are no freshwater bodies on or adjacent to the generic site, GNSL has not considered the freshwater ERICA reference organisms. We are content that this approach is appropriate for GDA. If at any future site-specific stage, relevant freshwater bodies are identified, an assessment of freshwater ecological receptors would be required.

Dose rates to wildlife depend on the concentrations of radionuclides in the environment. For this assessment, GNSL calculated the accumulation of radionuclides in air, soil and seabed sediment from the HPR1000 over an assumed 60-year period of operations. These environmental activity concentrations were used as input data into the wildlife dose assessments. The environmental activity concentrations were derived based on a ground level release and Pasquill stability category D for 50% of the time and the wildlife receptors are assumed to be 100m from the release point.

Independent assessment

The independent assessment we commissioned (Environment Agency 2021a) included a review of the generic site. The review considered 8 locations identified for possible new nuclear power plants. In our independent assessment, our contractor considered the effect of varying the main environmental factors that influence dispersion of discharges at the 8 sites. For liquid discharges, the main factor is exchange rates of marine water at the discharge point (volumetric exchange rate). Values for each of the 8 locations identified as possible locations for new nuclear power plants. This showed considerable variation in the predicted local water concentration of a factor of up to 25. The generic site data from the Bradwell site generated the highest predicted water concentrations.

The independent assessment considered the atmospheric dispersion conditions and the resulting ground level air concentrations at each of the 8 locations identified as possible locations for new nuclear power plants. This analysis showed that ground level air concentrations varied by only a factor of 1.25 between the various possible locations. The Bradwell site atmospheric conditions resulted in predicted air concentrations that were in the middle of the range.

The independent assessment adopted the staged dose assessment process, with an initial cautious assessment (stage 1) followed by a more refined assessment (stage 2). For these first 2 stages, the assessments also used the IRAT system. For the discharges to atmosphere, the assumption is that the receptor points are a family living 100m from the release point and eating all their food which is produced 500m from the release point. For the releases to the marine environment, the IRAT assumption is that the most exposed group is a fishing family spending time on intertidal areas and consuming high rates of fish and shellfish caught locally.

For the detailed stage of the assessment (stage 3) for releases to atmosphere, the independent assessment positions the resident farming family at 300m from the release point, coinciding with the highest ground level air concentrations. Food production, however, is still assumed to occur at 500m from the atmospheric release point. Therefore, it may be expected that doses associated with non-food pathways such as doses from inhalation and external doses might be higher than those for the GNSL assessment, while dose from direct radiation would be lower. Our independent assessment showed that most of the dose was from carbon-14 in food, which is the same as GNSL's submission.

Our assessment included a review of the available habits data. This concluded that UK generic data are appropriate for most of the assessment.

The independent assessment also used fish consumption data and information on houseboat occupancy from the local habits survey. This is similar to the GNSL approach to use of habits data.

The generic site used in the independent assessment is therefore similar to that defined by GNSL, except for the position of the local resident receptor and assumptions about milk product consumption.

3.2. Radiological impact - public

The submissions related to the radiological impact assessed during the GDA process are shown in Table 1.

Main assumptions

The main assumptions GNSL used in the radiological assessment have been consistent throughout the development of its assessment. The main influencing factors for dose assessment are the generic site and the expected discharges (the radionuclides and the quantities discharged). The generic site assumptions (GNSL 2020a) were assessed as described in section 3.1.

Assumptions about discharges

The assessment was made on the assumption that discharges will be made for 60 years at the proposed limits and will be accumulated in the soil, air and marine sediment.

For the staged assessment process, it was assumed that discharges to atmosphere are released at ground level. This assumption results in the highest activity concentrations in air at ground level. Discharges from the UK HPR1000 would be made from a stack that is well above ground level, leading to greater dispersion and dilution than a release at ground level. The later stages of the assessment take this into account.

We are content that the assumptions concerned with discharges are appropriate and acceptable.

Assumptions about models and methods

The radiological assessment requires models that can calculate the transfer of radionuclides from the point of discharge through the environment. The dispersion of radionuclides in the environment and predictions of radionuclide concentrations in air, soil, food, water and sediment at future times can be made. The predicted radionuclide concentrations are then combined with information on human habits such as occupancy times and food consumption data to provide estimates of dose to the public.

GNSL has used several models for predicting environmental dispersion (GNSL 2020c and 2020d). GNSL used the PC-CREAM 08 software system (Smith et al. 2009) in assessing the dispersion of radionuclides expected to be discharged over the generating lifetime of the reactor (60 years).

The PC-CREAM 08 software system (Smith et al. 2009) contains a series of models specifically designed for assessing environmental concentrations from continuous discharge of radioactive wastes made under normal operation. The models are suitable for assessing the fate of long-term, continuous, radioactive discharges, and calculate average concentrations of radionuclides over a number of years – from discharges to the atmosphere and of liquid waste to the water (aquatic) environment. The software uses the predicted concentrations to calculate the annual radiation doses to members of the public.

The environmental concentrations predicted by PC-CREAM 08 take into account build-up of discharged radionuclides over the period of discharges. Environmental concentrations can be calculated, allowing for build-up in soil, vegetation and farm animals, sea water, suspended sediment, sea bed sediment, fish and shellfish.

In addition to the continuous discharges made at a steady rate, there is a need to consider potential elevated discharges over short periods of time as a result of foreseeable events during operations. Enhanced discharges may occur during shutdown at the end of the fuel cycle or during start-up. Problems with fuel cladding during operation may result in release of fission products into the reactor over a short time frame, some of which may be released to the environment.

The PC-CREAM 08 system is designed for assessing the dispersion and effects of continuous releases, but is not suitable for assessing short duration releases. Environmental models are available to assess the dispersion of short duration releases to the atmosphere. Appropriate short duration release models include ADMS (CERC 2012) and AERMOD (US EPA 2004). GNSL has used ADMS version 5 (CERC 2012). This model can provide estimates of transient concentrations of pollutants in air at ground level from a defined release over short time frames such as 30 minutes. Deposition onto the ground and through the environment, including in soil and plants, is derived from the short duration air concentrations.

Collective doses to the UK, Europe and the world from continuous discharges also need to be assessed. This takes into account the distribution of radioactivity over these population groups. The PC-CREAM 08 system is suitable for calculating collective doses from discharges of gases and particulates to atmosphere and liquid discharges. GNSL has used PC-CREAM 08 (Smith et al. 2009) to estimate collective doses over 500 years to these populations per year of discharge.

Initial assessment

We made an initial assessment of the radiological impact GNSL provided in its submission (GNSL 2017). We reviewed the assumptions and repeated the stage 1 and stage 2 assessment. We reviewed the assumptions for the stage 3 assessment and sought clarification of parts of the technical approach to the assessment via Regulatory Queries (RQs) - see section 3.4.

Detailed assessment

We carried out a detailed assessment of the PCER-002 and PCER-007 (Table 1). The assessment considered the resolution of the RQs raised during the initial assessment (Table 11), a review of the completed method and results for the detailed assessment; the verification of the dose assessment outcomes and our independent dose assessment.

We reviewed the assumptions and repeated the stage 1 and stage 2 assessment. We reviewed the assumptions for the stage 3 assessment and sought more information and clarification of the updated assessment via further RQs. The RQs raised during our detailed assessment are summarised in Table 11.

The direct radiation dose to members of the public was assessed based on modelling and calculations and justified by operational experience. However, there will be additional sources of direct radiation (spent fuel store and radioactive waste store) that will be arise during future operations in the UK. These buildings are currently at concept design stage and, therefore, the doses to the public have been assessed based on the conservative assumption that the stores are full of spent fuel and radioactive waste (GNSL 2019; GNSL 2020d).

Results

The results of the dose assessment were compared with the dose constraints and limits for the public set by the Environmental Permitting Regulations 2016 for Radioactive Substances Activities (Schedule 23) (UK Parliament 2016). The dose impact results may also be included in decisions around BAT and abatement options.

There are no regulatory limits and constraints for collective dose. Collective dose is mainly an input when comparing options. In addition, collective doses can be converted to per capita doses, which give an indication of average annual doses and can be assessed against criteria set by Public Health England (PHE).

Stage 1 and stage 2

The initial assessments provide an early indication of the size of doses and generally follow a very conservative and generic approach. The dose criterion for initial assessment is 20μSv/y. Initial assessment of the impact and decisions can be made using a stage 1 assessment. There is a need for a refined assessment at the second stage if doses are above 20μSv/y. There is limited additional effort to refine the assessment. The second stage, therefore, is to refine the initial assessment using any more specific data related to expected dispersion of the source term. If doses from the second stage remain above 20μSv/y, a third stage using a more detailed assessment is carried out using a more detailed model if appropriate.

GNSL reported the following doses for stage 1 and 2 (Table 5):

Table 5. GNSL stage 1 and stage 2 doses

Route	Stage 1 doses (μSv/y)	Stage 2 doses (μSv/y)
Liquid discharges	27.8	21.4
Discharges to atmosphere	140	22.3
Direct radiation	6.3	6.3
Total	174	50.0

The main change in predicted doses between stage 1 and stage 2 is due to changes in the modelling assumptions for environmental dispersion. For discharges to atmosphere, stage 1 assumes a release at ground level. Stage 2 assumes an effective stack height of 20m (see glossary for definition). Increasing the effective stack height leads to more dilution of the release and lower air concentration at ground level at the distances of interest.

Stage 1 for discharges of liquids assumes a cautious initial volumetric exchange of sea water between the local compartment and the compartment representing the open sea. This is the default cautious value for an initial assessment. Volumetric exchange is crucial to dispersion of sea water and radionuclides at the release point. The stage 2 assessment adopts published values for the Bradwell area for volumetric exchange, which are greater than the default used for initial assessment. The volumetric exchange for the Bradwell area is a greater initial dispersion, leading to lower predicted radionuclide concentrations in the water.

Stage 3 - Individual doses

GNSL carried out a detailed assessment (stage 3). The assessment included doses from discharges to atmosphere, liquid discharges and offsite direct radiation. The results are summarised below.

The radiological assessment results in GNSL's submission version 1.1 (GNSL 2020c) are summarised in the tables below.

Table 6 shows the individual doses to several groups. Adults most exposed to discharges of liquids received the highest doses. The adult was a member of a fishing family living close to the reactor and consuming local food (Table 6a). Their doses were predicted to be 16.5μSv/y from liquid discharges and discharges to atmosphere. In addition, a dose of 6.3μSv/y from direct radiation is expected, giving a total dose of 22.8μSv/y. The largest dose pathway is from eating fish and shellfish (11μSv/y). In the same group, the total doses to other ages are lower (9.6μSv/y to infants and 12.4μSv/y to children).

Carbon-14 is the main radionuclide, accounting for more than 95% of the dose from discharges.

The GNSL submission also presents doses to a local resident farming family most exposed to discharges to atmosphere (Table 6b). Doses to adults in this group are slightly lower than those in the fishing family, but doses to infants and children are higher. Doses from discharges are in the range 12 to 15.7μSv/y, of which discharges of liquids contribute 0.6 to 3.0μSv/y. This group, who also live close to the reactor, are also projected to receive a dose from direct radiation of 2.2 and 6.3μSv/y. Their total doses are 17.9μSv/y to infant, 15.8μSv/y to child and 18.3μSv/y to adult.

Therefore, the GNSL assessment shows that the representative person (see glossary for definition) is an adult member of a possible fishing family who live close to the reactor and are most exposed to discharges of liquids, with some exposure to discharges to atmosphere and direct radiation. The total dose to the adult is expected to be 22.8μSv/y (rounded up to 23μSv/y) from one reactor.

The highest dose to infants and children are as members of a different group - resident farming family who live close to the site and are most exposed to discharges to atmosphere. Their doses are 15.8 to 18.3μSv/y.

Doses from short duration releases to the atmosphere are shown in Table 6c and range from 5.8μSv/y for adults and children to 9.7μSv/y for infants. GNSL has assumed that radionuclides may be discharged as part of the short duration release under normal operation. The assessment assumed a release of radionuclides equivalent to a month's worth over 24 hours, in summer, later in the growing season and before harvesting. The majority of the dose (87-89%) is from carbon-14. The consumption of foods and the time of year assumed for the release (summer and before harvest) tends to maximise the doses from food. These doses can be included with the dose to the representative person dose. Adults most exposed to liquid discharges plus the dose from short duration releases - gives a dose of 28.6μSv/y to adult.

In its submission, GNSL has included doses from short duration releases to the assessed doses from ongoing discharges. GNSL presents a cautious bounding outcome of dose of 33.1μSv/y to adult; 22.9μSv/y to child and 27.9μSv/y to infant.

Doses estimated during GDA can be compared with several dose criteria. The main criterion is the source dose constraint of 300μSv/y, (UK Parliament 2016). Doses for comparison are total doses to the public offsite from a single source - comprising doses from future discharges and doses from future direct radiation. Another criterion is the site dose constraint of 500μSv/y. Doses for comparison with the site constraint are doses to the public from future discharges. The doses from discharges should include doses from any other source-making discharges - where the source is on an adjacent site.

The potential doses from the UK HPR1000 are well below the source dose constraint for the public of 300μSv/y, (UK Parliament 2016).

All of the sites listed in the Nuclear National Policy Statement (UK Parliament 2011a, 2011b) as potentially suitable for a new nuclear power plant are adjacent to existing nuclear power plants. During GDA, the specific site at which a UK HPR1000 will be located is not yet confirmed. However, it is very unlikely that doses from future discharges at any of the potential sites will exceed the site dose constraint of 500μSv/y or the overall dose limit for members of the public of 1,000μSv/y (1mSv/y). However, if we receive an application for a permit for a site where UK HPR1000s will operate, another dose assessment will be required using site-specific factors and the outcomes compared with the site dose constraint and dose limit for the public.

Table 6. Summary of individual doses from a UK HPR1000 in the GNSL submission (Stage 3 assessment) (GNSL 2020c)

Table 6a Overall prospective dose μSv/y to the local fishing family (most exposed to liquid discharges)

Age group	Liquid discharges	Discharges to atmosphere	Direct exposure	Total
Adult	11.2	5.3	6.3	22.8
Child	4.3	4.9	3.2	12.4
Infant	0.9	6.5	2.2	9.6

Table 6b Overall prospective dose μSv/y to the local resident family (most exposed to discharges to atmosphere)

Age group	Liquid discharges	Discharge to atmosphere	Direct exposure	Total
Adult	2.2	9.8	6.3	18.3
Child	3.0	9.6	3.2	15.8
Infant	0.6	15.1	2.2	17.9

Table 6c Dose μSv to the local resident family most exposed to a short term discharge to atmosphere.

Age group	Total
Adult	5.8
Child	5.8
Infant	9.7

Stage 3 - Build-up of radionuclides in the environment

In its submission, GNSL has included modelling of the build-up of radionuclides in the environment (sea bed sediment, sea water and soil) from 60 years of discharges to the marine environment and to the air. Modelling build-up is to estimate the maximum predicted concentrations in the environment from ongoing discharges and to take them into account appropriately in the assessment. The modelling shows radionuclides increase in concentration in the environment with time. The modelling presented by GNSL shows that radionuclides reach equilibrium in 20 years or less in the marine environment. For soil, concentrations of some radionuclides increased for a longer time, taking up to 60 years to approach equilibrium. The GNSL assessment is made for a 60-year operation and release period and uses concentrations predicted for the 60th year. Therefore, GNSL's radiological impact assessment takes into account build-up in the environment.

Stage 3 - Collective dose

Collective dose is the sum of all individual effective doses over a defined period of space and time. Collective doses can be used when making optimisation decisions, including decisions on abatement options.

GNSL has estimated collective doses per year of discharge for the UK, Europe and the world. The calculations are made, using appropriate models, taking into account the levels of radioactivity in the environment, including food and global circulation. Results have been calculated for the UK, Europe and the world from one year of discharge. The collective doses are calculated over a period of (or truncated at) 500 years (Table 7). Collective doses range from 0.7 man-Sievert (man-Sv) per year of discharge for discharges to atmosphere for the UK population to 29.7mSv per year of discharge for the world population. Carbon-14 in discharges to atmosphere is the main contributor to the collective doses due to its long half-life and its mobility which allows global circulation. Collective doses from liquid discharges were lower, less than 1 man-Sv per year of discharge for all populations.

Table 7. Summary of collective doses (up to 500 years) man-Sv per year of discharge from a UK HPR1000 in the GNSL submission

Population	Dose from liquid discharges (manSv/y)	Dose from discharges to atmosphere (manSv/y)	Total
UK	0.013	0.68	0.69
EU-12	0.078	3.59	3.67
EU-25	--	3.88	3.88
World	0.743	29.7	30.4

Collective doses can be used to estimate average annual individual doses in a population by calculating per caput doses (Health Protection Agency, 2009). Average annual individual doses for a population group in the nano-Sievert per year (nSv/y) range or below can be ignored in the decision-making process as the contribution to total doses to individuals is very small. Higher annual average doses, up to a few micro-Sievert per year (µSv/y), are still low but may require some consideration, particularly if they are approaching a few micro-Sieverts. Calculated annual average individual doses in excess of a few micro-Sievert should prompt careful consideration of the potential discharge options (Environment Agency et al. 2012).

In the GNSL assessment, the collective doses were used to derive average individual doses. The average doses from a single UK HPR1000 unit from liquid discharges are 0.22nSv/y, 0.22nSv/y and 0.007nSv/y for the populations of the UK, Europe and the world, respectively. The average individual doses from discharges to atmosphere are 11.4nSv/y; 10.0nSv/y; and 2.97nSv/y for populations of the UK, Europe and the world, respectively.

Independent assessment

Our independent assessment included an initial assessment at stage 1, stage 2 and, in detail, at stage 3. For the initial assessment, the stage 1 outcome from discharges was 148µSv/y and the doses were mostly from releases to atmosphere. For the initial assessment at stage 2, our assessment outcome from discharges was 44µSv/y. In the stage 2 initial assessment, the outcome was balanced between doses from discharges to atmosphere and discharges to the marine environment.

For the detailed assessment at stage 3, our independent assessment results are summarised in Table 8 (individual doses). More details of the independent dose assessment will be published separately (Environment Agency 2021a).

Table 8. Summary of individual doses from a UK HPR1000 from our independent dose assessment

Table 8a Overall prospective dose µSv/y to the local fishing family (most exposed to liquid discharges)

Age group	Liquid discharges	Discharges to atmosphere	Direct exposure	Total
Adult	8.0	7.0	0.44	15.4
Child	2.4	7.7	0.22	10.3
Infant	0.61	9.8	0.15	10.6

Table 8b Overall prospective dose µSv/y to the local resident family (most exposed to discharges to atmosphere)

Age group	Liquid discharges	Discharges to atmosphere	Direct exposure	Total
Adult	0.98	11	0.44	12.4
Child	0.68	12	0.22	12.9
Infant	0.43	21	0.15	21.6

Table 8c Dose µSv to the local resident family (most exposed to discharges to atmosphere) for a short-term discharge

Age group	Total
Adult	6.9

Age group	Total
Child	6.0
Infant	7.8

Doses to the group most exposed to discharges of liquids (fisherman family) ranged from 0.6μSv/y (infant) to 8.0μSv/y (adult). The majority of the dose is from carbon-14 (up to 99%). The doses are lower than those GNSL assessed from liquid discharges, which ranged from 0.8μSv/y (infant) to 11.0μSv/y (adult). The main reason is due to differences in the definition of the marine environment at the release point. GNSL used a lower volumetric exchange rate and larger volume of marine water at the release point than the independent assessment - this leads to higher water concentrations and higher doses.

Total doses to the fisherman family - that include all sources of discharge (liquids and gases and some particulates to atmosphere) and direct radiation range between 10.3μSv/y (infant) and 15.4μSv/y (adult). These doses are lower than those GNSL assessed, which ranged from 9.6μSv/y (infant) to 22.8μSv/y (adult). The doses GNSL predicted are higher due to several factors. Firstly, the contribution from liquid discharges is higher for the reasons described above. Secondly, the contribution from direct radiation is higher due to GNSL assuming exposure at 100m from the source. The independent assessment assesses doses at 300m where the direct radiation dose rate is lower.

The dose from direct radiation in the independent assessment is low (<1μSv/y). GNSL predicted doses of between 2.2 and 6.3μSv/y. This is because in the independent assessment the exposed group is assessed further from the site (300m from the release point). In the GNSL assessment, the receptor is at 100m. A distance of 300m is used in the independent dose assessment because the ground level air concentrations are higher at 300m compared with 100m, but direct radiation dose rates are lower.

For the group most exposed to discharges to atmosphere, the independent assessment shows doses ranging from 11 to 21μSv/y across the age groups. The majority of the dose is from carbon-14 (up to 96%). The doses are similar to, but higher than, the GNSL assessment in which the estimated doses from discharges are between 12.0 and 15.7μSv/y. The main reasons are that in the independent assessment the radiological impact assumes the group is at 300m from the release point. The air concentrations are higher at 300m than at 100m, which is used in the GNSL assessment. In addition, the independent assessment uses generic habits data which include consuming (drinking and eating) milk products. Consuming milk products is not included in GNSL's assessment.

Doses from short duration releases to atmosphere are between 6.0 and 7.8μSv for each event. Doses from short duration releases in our independent assessment are close to those in GNSL's submission. Both assessment outcomes are dominated by ingestion of carbon-14 in food.

Total doses that include all sources of discharge (gases and particulates to atmosphere and liquids); direct radiation and doses from short duration releases to atmosphere range between 16 and 29μSv/y.

- This broad agreement strongly indicates that the potential dose from discharges from the reactor will be well below the source dose constraint for the public of 300μSv/y.
- Discharges to atmosphere and liquid discharges both contribute to the doses in the independent dose assessment. Doses from discharges to atmosphere are higher than doses from liquid discharges. Milk production consumption and higher ground level air concentrations at the receptor contribute to higher doses from discharges to

atmosphere and higher marine dispersion parameters result in lower doses from discharges of liquids.

- Carbon-14 is the dominant nuclide in terms of the doses from discharges (up to 99% of the dose).

Collective doses from our independent assessment are summarised in Table 9.

Table 9. Summary of collective doses (up to 500 years) man-Sv per year of discharge from a UK HPR1000 from our independent dose assessment (Environment Agency 2021a)

Population	Dose from liquid discharges	Dose from discharges to atmosphere	Total
UK	0.013	0.71	0.72
EU	0.078	4.1	4.18
World	0.74	30	30.7

Consultation with other bodies

For GDA, there are no statutory consultees for dose assessment. However, we will notify interested bodies (including SEPA, NRW, the Food Standards Agency (FSA), the Health and Safety Executive (HSE), Public Health England (PHE), Natural England and the Nuclear Decommissioning Authority (NDA)) of this consultation and invite them to respond.

Interfaces with ONR assessment

The main interface with the Office for Nuclear Regulation (ONR) is in the area of radiological protection from direct radiation offsite (to the public). Direct radiation of the public offsite is regulated by ONR. We have consulted with ONR to confirm the offsite dose rates to the public. There are several potential sources of direct radiation from a site, including the reactor, radioactive waste stores and spent fuel stores. Dose rate data from the sources on site waste stores and spent fuel store are at concept design only and are based on calculations rather than measurements. A regulatory observation (RO-UKHPR1000-0028) on Adequate Justification of the Estimated Public Doses for UK HPR1000 was raised by ONR. This sought to ensure that GNSL provided a demonstration that public doses close to a power plant similar to and representative of the UK HPR1000 are in the measurable range of background and to provide information to allow ONR to judge whether the direct radiation doses from the UK HPR1000 will be reduced So Far As Reasonably Achievable. Environment Agency questions were included in a number of regulatory queries to resolve RO-0028, which has now been closed. The conclusions and findings of RO-0028 are consistent with those report by GNSL in their submission (GNSL 2020c). GNSL have provided additional information about the measurements of doses rates in the environment near power stations in China and information on the assessment of doses by modelling and calculation. This information has been used to refine the direct radiation doses to the public presented in GNSL submission (GNSL 2020c).

3.3. Radiological impact - wildlife

Main assumptions

GNSL based its wildlife radiological assessment on the following main assumptions:

- Radioactive waste from a UK HPR1000 was discharged at proposed permitted limits.
- Radiological discharges accumulated in the environment for 60 years of operation.
- Discharges to atmosphere were assumed to occur at ground level.
- PC-CREAM 08 was the tool used for environmental dispersion or radionuclides in terrestrial and marine environments.
- ERICA was the tool used for wildlife dose assessment (plus the Ar-Kr-Xe dose calculator for assessing noble gases).
- Wildlife was located 100m from the release point for assessing dose rate from discharges to atmosphere.
- Wildlife was located in the local marine environment for assessing dose rates from liquid discharges.
- The dose rate criterion for wildlife dose assessments, used to compare outcomes with, was 10µGy/h.

Assumptions on discharges

It is suitably conservative to base this radiological assessment on the assumption that discharges were made for 60 years at proposed limits and that they accumulated in the soil, air and seabed sediment. It is also conservative to assume that discharges to atmosphere are made at ground level. This assumption results in the highest activity concentrations in air. In reality, discharges to atmosphere will be from a stack, enabling more dispersion and dilution than a release at ground level. We are content that these assumptions concerned with discharges are appropriate and acceptable.

Assumptions on tools

Radiological assessment to wildlife involves dispersion modelling to predict the radionuclide activity concentrations in the environment resulting from gaseous and liquid discharges, followed by an assessment of the impact of these radionuclides in the environment on wildlife.

PC-CREAM 08 is a widely accepted tool used for dispersion modelling to derive radionuclide activity concentrations in the environment from routine discharges (Smith and Simmonds 2009). PC-CREAM 08 can be used to predict radionuclides concentrations in soil, sediment, air and water from the expected atmospheric and liquid discharges made over a set time period. The concentrations can be used to assess dose rates and risks to wildlife.

A number of systems have been developed to assess the dose rate and risk to wildlife from ionising radiation in the environment. The accepted system for use in European ecosystems is the ‘Environmental Risk from Ionising Contaminants: Assessment and Management’ (ERICA) integrated approach (Beresford et al. 2007; Brown et al., 2007; Brown et al. 2016).

The ERICA tool calculates the radiation dose rate that wildlife is likely to receive from a defined environmental activity concentration of a radionuclide. Due to the lack of species-specific transfer data available, a reference organism approach is used to represent species of interest. The reference organisms included in the ERICA tool have been selected to be typical or representative of European ecosystems and include terrestrial, freshwater and marine environments.

The ERICA integrated approach is organised into 3 separate tiers:

- Tier 1 is simple and conservative – it requires a minimal amount of input data, the user can select radionuclides from a default list and the results are for the combination of reference organisms that are exposed to the highest dose rates.
- Tier 2 is more specific and less conservative – the user can enter input data such as radionuclides that are not on the default list and edit transfer parameters. The results are calculated for each reference organism individually.
- Tier 3 is a probabilistic risk assessment in which uncertainties within the results may be determined using sensitivity analysis, and biological effects data needs to be considered - the situations requiring a tier 3 assessment are likely to be complex and unique.

The results produced from the ERICA tool includes a risk quotient, which provides a probability that the selected dose rate criteria may be exceeded.

The ERICA tool does not allow the assessor to consider the impact of radioactive noble gases. One tool that does allow this is the Argon-Krypton-Xenon (Ar-Kr-Xe) dose calculator (Vives i Batlle, J et al., 2015). This tool is based on the R&D 128 methodology (Copplestone et al. 2001) and consists of a basic tool with limited radionuclides which carries out a conservative assessment for reference organisms. This is the appropriate tool to use for assessing dose rates to wildlife from noble gases. The ERICA tool and the Ar-Kr-Xe dose calculator contain the same terrestrial reference organisms so dose rates can be summed to give a total dose rates to terrestrial wildlife.

We are content that GNSL has used the appropriate tools for environmental dispersion modelling and dose assessment for wildlife.

Assumptions on the location of wildlife receptors

We issued RQ-828 in May 2020, requesting clarification of receptor locations used for the wildlife radiological assessment. GNSL responded in June 2020 providing these details. GNSL assumed that terrestrial wildlife was located 100m from the point of atmospheric discharge for the terrestrial assessment. This is consistent with the location of human receptors for the public radiological assessment. GNSL assumed that marine wildlife was located in the local environment for the marine assessment. We are content that the assumptions GNSL made regarding wildlife receptor locations are appropriate for GDA.

Assumptions on dose rate criteria

The doses to wildlife are absorbed dose rate in units of µGy/h. The default dose rate screening value in the ERICA tool is a dose rate of 10µGy/h to be used for all ecosystems and all organisms. The criterion of 10µGy/h is a screening value that is appropriate to use for a generic site when we cannot determine what impacts there may be from other sources of radioactive waste. For site-specific assessment, the Environment Agency, Natural England and Natural Resources Wales have agreed a dose rate criterion of 40µGy/h, below which it is concluded that there are no adverse effects on the integrity of Natura 2000 sites. GNSL used a dose rate criterion of 10µGy/h. As GDA is based on a generic site, we agree that the appropriate dose rate criterion for wildlife is 10µGy/h.

Assessment

In its submission, GNSL detailed the wildlife radiological assessment (GNSL, 2020c).

GNSL used PC-CREAM 08 to derive radionuclide activity concentrations in soil and seabed sediment. GNSL then used the ERICA tool (version 1.3) and the Ar-Kr-Xe dose calculator to calculate dose rates to wildlife. Assessments of the impact of discharges to atmosphere were made to the default terrestrial reference organisms in the ERICA tool. Assessments of the impact of liquid discharges were made to the default marine reference organisms in the ERICA tool. GNSL states that the UK HPR1000 will not make any discharges to the freshwater environment and, therefore, it did not consider impact on reference organisms inhabiting the freshwater environment. ERICA assessments were carried out at tier 2 as tier 1 did not include all of the radionuclides that GNSL predicts will be discharged from the UK HPR1000.

GNSL has used the following parameters in its ERICA tier 2 assessment:

- default ERICA reference organisms were used for the terrestrial and marine environments
- default ERICA values for transfer parameters were used where available
- where default values for transfer parameters were not available in the ERICA tool, values were manually assigned, including those for iron (Fe), bromine (Br), sodium (Na), molybdenum (Mo) rubidium (Rb) and yttrium (Y)

We issued RQ-UKHPR1000-0518 in October 2019 to clarify the reference organisms GNSL used and the justification for using them. GNSL responded in December 2019 confirming details of the ERICA default reference organisms used in its assessment and also justifying their use as being suitable to represent UK wildlife. We accepted this response. The ERICA tool and its reference organisms are designed to represent species in European ecosystems. Therefore, we are content that it is appropriate to use these reference organisms to represent UK wildlife. In addition, it is appropriate to use the default transfer parameters in the ERICA tool for this assessment. We agree that the approach GNSL used to fill data gaps is appropriate and conservative.

GNSL has not considered the impact that discharges of radionuclides might have on freshwater organisms as the UK HPR1000 design assumes no discharges are made to freshwater bodies. As part of any site-specific assessment, any future operator will need to consider if an assessment to freshwater organisms is needed.

Results

Initially, GNSL did not provide details of dose rates for each reference organism/radionuclide combination, instead only providing total dose rates for each reference organism from all radionuclides. We issued RQ-UKHPR1000-0205 (Table 11) in February 2019 requesting more details on the wildlife radiological assessment, including a breakdown of dose rates for each reference organism/radionuclide combination, details of any non-default ERICA parameters used and details of the carbon-14 and tritium air concentrations used in the assessment. GNSL responded in March 2019 providing these details to us and including them in a later revision of the submission (GNSL 2020c).

The GNSL terrestrial wildlife dose assessment identified that the reference organism exposed to the highest dose rates was reptile, which received a dose rate of 0.15µGy/h.

The GNSL marine wildlife dose assessment identified that the reference organism exposed to the highest dose rate was the polychaete worm, which received a dose rate of 0.0063µGy/h.

As the ERICA tier 2 assessment criteria were met, GNSL did not carry out an ERICA tier 3 assessment.

GNSL has shown that the dose rates to reference organisms in the terrestrial and marine environments are well below the dose rate criterion of 10µGy/h.

During our assessment, we reviewed GNSL's submission and repeated its wildlife dose assessments, using its input parameters to check its assessment. We initially assessed version 001, dated January 2020 (GNSL 2020c). When we repeated the GNSL assessment using its input parameters, we obtained results that were consistent with GNSL's for the marine assessment. However, for the terrestrial assessment, there were apparent discrepancies in some of the data. The concentration ratio data presented in revision 001 of the submission reported to be ERICA default data, but did not match the default data in the ERICA tool. Also, there appeared to be some errors in the reporting of dose rates from the noble gas assessment.

A full response to RQ-UKHPR10000-0830 (Table 11) was received in June 2020, which gave clarification and corrections, which were included in the submission PCER 007 revision 001-1 (GNSL 2020d). We repeated the terrestrial and marine wildlife dose assessments using the ERICA tool, and obtained results that were consistent with GNSL's. When we repeated the noble gas assessment, most of the results we obtained were consistent with GNSL's results except for dose rates from argon-41 and also the dose rates to the reference organism shrub. It appeared that GNSL had inaccurately transcribed some results from the Ar-Kr-Xe dose calculator tool, reporting results from incorrect reference organisms for argon-41, and also reporting dose rates of zero for shrub resulting from exposure to radionuclides of krypton and xenon. However, the Ar-Kr-Xe dose calculator tool actually reports very low dose rates to the shrub reference organism from krypton and xenon. We are content that these inaccuracies are limited to reporting errors and are not as a result of incorrectly using the tool or inappropriately inputting the data. The dose rates to wildlife from discharges of noble gases are very low and the reporting errors make no difference to the overall conclusions of the assessment. However, it does change the worst affected terrestrial reference organism to bird, receiving a dose rate of 0.14µGy/h.

In summary, we are content that the wildlife radiological assessment GNSL carried out is suitably conservative and repeatable, noting the minor reporting errors for the noble gas assessment. We will highlight these to GNSL so it can correct them.

Independent assessment

We employed a technical support contractor (TSC) (see section 2.5) to carry out an independent wildlife dose assessment, using our independently derived environmental activity concentrations of radionuclides (Environment Agency 2020a).

The results of GNSL's assessment and our independent assessment differed slightly, due to differences in the input parameters used. However, our independent assessment shows that dose rates to wildlife are well below the dose rate criterion of 10µGy/h, see Table 10.

Table 10: Results of the GNSL assessment and our assessment of dose rates to wildlife

Table 10a: Terrestrial assessment from discharges to atmosphere (Highest dose rate to worst affected reference organism (µGy/h))

Data source	GNSL results	Our results
GNSL	0.15 (reptile)	0.14 (bird)
Independent assessment	Not applicable*	0.13 (mammal - large and small burrowing)

Table 10b: Marine assessment from liquid discharges (Highest dose rate to worst affected reference organism (µGy/h))

Data source	GNSL results	Our results
GNSL	0.0063 (polychaete worm)	Same as GNSL
Independent assessment	Not applicable*	0.023 (mammal)

*our independent assessment did not repeat these parts of the GNSL assessment

The dose rates GNSL derived are slightly lower than those from our independent assessment. These differences are due to variations in the assumptions and parameters used including:

- location of wildlife receptors: GNSL assumed that terrestrial wildlife was located 100m from the release point, while our independent assessment assumed a location of 300m from the release point, where modelled activity in air concentrations were higher
- concentration ratios (CR): GNSL and our independent assessment used ERICA default data where available. Where concentrations ratios were not available in the ERICA tool, GNSL assigned the highest CR for any radionuclides for reference organisms. Our TSC assigned CR data published by IAEA where available (IAEA 2004)

Consultation with other bodies

No other bodies were consulted during this assessment.

Interfaces with ONR assessment

This assessment did not interface with ONR.

3.4. Regulatory Queries raised

A series of Regulatory Queries were raised during the initial assessment and the detailed assessment. These are shown in Table 11.

Table 11. Regulatory Queries raised on the generic site submission PCER-002 and radiological assessment submission PCER-007

RQ number	Content
RQ-UKHPR1000-0061	Clarification if a stage 3 public dose assessment of the effect of discharges on the environment will be made and provided.
RQ-UKHPR1000-0062	Further information request - the method used to make the assessment of a short duration releases.
RQ-UKHPR1000-0063	Further information request – model selection for assessing impact of discharges on the environment.
RQ-UKHPR1000-0201	Comparison of doses with criteria.
RQ-UKHPR1000-0202	RQ-UKHPR1000-0063. Further information request - model selection and use for the effect of discharges on the environment.
RQ-UKHPR1000-0203	Legitimate uses of the environment.
RQ-UKHPR1000-0204	Summary of doses.
RQ-UKHPR1000-0205	Non-human biota (Wildlife) radiological assessment: ERICA inputs and outputs.
RQ-UKHPR1000-0249	Incomplete response to RQ-UKHPR1000-0205.
RQ-UKHPR1000-0517	Assessment of foetal exposure.
RQ-UKHPR1000-0518	Justification of data PCER-02 generic site.
RQ-UKHPR1000-0519	Habits data used – clarity of information.
RQ-UKHPR1000-0520	Presentation of doses in the submission – clarity of information.
RQ-UKHPR1000-0521	Short-term release assessment.
RQ-UKHPR1000-0523	Build-up of radionuclides in the environment over time.
RQ-UKHPR1000-0522	Stage 2 assessment of discharges – possible error.
RQ-UKHPR1000-0828	Receptor positions not presented in PCER-002.
RQ-UKHPR1000-0829	RQ - several queries on PCER-007.
RQ-UKHPR1000-0830	Non-human biota (wildlife) assessment - several queries on PCER-007.

For each of these queries we received a satisfactory response.

3.5. Assessment Findings

We are content that the generic site defined is appropriate to use in this GDA and there are no Assessment Findings.

The radiological assessment shows that the radiological impact will be low, and that the dose to the public meets the dose constraint. Similarly, dose rates for wildlife meet the dose rate criteria. Our independent assessment and our verification confirm the low impact.

Discharges of carbon-14 to the atmosphere and as liquid to the marine environment will give more than 90% of the total dose from discharges.

Assessment Findings are given in the BAT assessment report requiring a future operator to review the practicability of techniques for abating carbon-14; for a future operator to assess the chemical form of carbon-14 discharged to the environment and use this to inform future dose assessments and optimise the balance between gaseous, liquid and solid phase of carbon-14 (Environment Agency 2020c).

3.6. Compliance with Environment Agency requirements for GDA

Compliance with Environment Agency requirements are summarised in Tables 12a, 12b and 12c.

Table 12a Compliance with Environment Agency requirements for generic site for GDA

Requirement from P&ID or REPS	Comments
P&ID Table 1 (generic site)	Appropriate data provided, for coastal site.
REP SEDP1 - General principle for siting of new facilities.	Appropriate government policy documents relating to siting of new reactors are identified and referenced and relevant factors are taken into account in generic site description.
REP SEDP2 - Migration of radioactive material in the environment.	The generic site description allows for an assessment of migration of radioactivity in the environment by providing information that can be used for modelling the process.

Table 12b Compliance with Environment Agency requirements for radiological assessment - Public for GDA

Requirement from P&ID or REPs	Comments
REP Fundamental principle E	
REP Protecting human health and the environment	The radiological assessment in GNSL's submission is part of this.
REP RPDP1 Optimisation of protection	The radiological assessment outcomes are an input to optimisation of protection.
REP RPDP2 Dose limits and constraints	The radiological assessment outcomes have been compared with the dose constraint.
REP RPDP4 Prospective dose assessments for radioactive discharges to the environment	Prospective dose assessment is part of the GNSL submission PCER 007.

Table 12c Compliance with Environment Agency requirements for radiological assessment - Wildlife for GDA

Requirement from P&ID or REPs	Comments
REP RPDP3 Protection of non-human species	An assessment of dose rates to wildlife is part of the GNSL submission PCER 007.

4. Public comments

There have been no comments from the public to GNSL's GDA comments process up to 30 June 2020 relating to selecting the generic site for GDA.

There have also been no comments from the public to GNSL's GDA comments process up to 30 June 2020 directly relating to the radiological assessment from the UK HPR1000 reactor for GDA.

There have been comments about health effects and radiation which are not directly related to the UK HPR1000. The comments include inferred high levels of mortality around the Bradwell site, the overall risk from radiation and suggested increases in discharges from another nuclear power plant at another location. However, the radiological assessments made for the UK HPR1000 show that the UK HPR1000 can meet the current UK radiation protection arrangements, the requirements for optimisation and the dose constraints for the public.

Comments received during our consultation and those submitted to GNSL's GDA comments process after 30 June 2020 will be considered in the final revision of this document.

5. Conclusion

5.1. Generic site

Based on the latest generic site description in the GNSL submission (GNSL 2020a), our preliminary conclusions are:

- GNSL has selected a coastal site to represent the generic site. As government's National Policy Statement for Nuclear Generation (UK Parliament, 2011a and 2011b) notes that all potential sites for new nuclear power plants are either located on the coast or on large estuaries, we are content that selecting a coastal site is appropriate for GDA
- the generic site is influenced by the characteristics of the Bradwell site. Many of the assumptions are those defined by the current Bradwell site. This means that the generic site is an estuarine location with relatively limited water exchange compared with other more open coastal locations. Therefore, the radiological assessment outcomes from liquid discharges are likely to be cautious and bounding
- for discharges to atmosphere, the atmospheric dispersion around the site is representative of other coastal locations and the radiological assessment outcomes are cautious overall.
- GNSL has assumed that there is no standing water on the site. We consider this to be reasonable and that surface water management will be a site-specific matter
- GNSL has assumed that there are no discharges to freshwater. We consider this a reasonable assumption for a coastal nuclear site based on discharges from existing sites. Therefore, the radiological impact on protected freshwater species has not been assessed. This should be considered at site-specific environmental permitting, if appropriate

- we consider that GNSL included appropriate factors in its generic site considerations as required by the Radioactive Substances Regulation Environmental Principles (REPs) SEDP1 – General principle for siting of new facilities and SEDP2 - Migration of radioactive material in the environment, and is broadly compliant
- we have no Assessment Findings related to the generic site
- we have no GDA Issues related to the generic site

5.2. Radiological assessment – the public

From the radiological assessment GNSL submitted in PCER-007 (GNSL 2020c, 2020d), our preliminary conclusions are:

- all the doses GNSL assessed at the proposed limits are below the source dose constraint for members of the public of 300µSv/y. Doses would also be below the site dose constraint (500µSv/y) and the public dose limit (1,000 µSv/y)
- our independent assessment at the proposed limits showed doses to the public are below the site dose constraint
- GNSL's assessment is based on a generic site that is strongly influenced by Bradwell. There is limited aquatic dispersion at the site and, therefore, doses are likely to be cautious and are expected to be bounding for the sites currently identified as possible locations for new nuclear power plants listed in the Nuclear National Policy Statement (UK Parliament, 2011a, 2011b)
- it is very unlikely that doses at any site where the UK HPR1000 could be operated even where there are several units operated together, would exceed the site dose constraint of 500µSv/y and, therefore, it is very unlikely that the public dose limit of 1,000 µSv/y will be exceeded
- GNSL's assessment shows that the highest total dose from discharges and direct radiation is expected to be between 9.6 and 22.8µSv/y from one reactor.
- GNSL's assessment included doses from short duration releases which ranges from 5.8 to 9.7µSv/y.
- most of the dose to the public is from discharges of carbon-14 to the atmosphere and carbon-14 in liquid discharges. Carbon-14 contributes more than 90% of the doses from discharges.
- our independent assessment provides similar outcomes to GNSL's assessment. The independent assessment confirms low doses to the public (similar to GNSL) and that the majority of the dose from discharges is from carbon-14
- we consider that GNSL included an appropriate range of regulatory factors in its radiological assessment consideration as required by the Radioactive Substances Regulation Environmental Principles (REPs) - see section 3.6 - and is broadly compliant. GNSL has also taken into account good practice offered in the dose assessment principles (Environment Agency, 2012) and the relevant guidance from the National Dose Assessment Working Group.
- we have no Assessment Findings related to the radiological assessment. However, the carbon-14 discharges contribute most to the dose. The outcomes inform assessment findings given in the BAT assessment report - requiring a future operator to review the practicability of techniques for abating carbon-14; for a future operator to assess the chemical form of carbon-14 discharged to the environment and use this to inform future dose assessments and to optimise the balance between gaseous, liquid and solid phase of carbon-14 (Environment Agency 2020c)

- we have no potential GDA Issues related to the radiological assessment
- a detailed site-specific radiological assessment will be carried out if an environmental permit is applied for in future. The site-specific assessment should consider the actual environmental characteristics of the site and the number of reactors that will be present. This assessment will have to demonstrate that doses to members of the public from the UK HPR1000 will be as low as reasonably achievable (ALARA) and below relevant dose constraint and dose limits. Comparison against the dose limit should be carried out at site-specific permitting when contributions from all sources of radiation are known and can be included

5.3. Radiological assessment - wildlife

From the radiological assessment GNSL submitted in PCER-007 (GNSL 2020c, 2020d), our preliminary conclusions are:

- that the atmospheric and liquid discharges from a UK HPR1000 at the generic site are unlikely to pose a risk to wildlife
- the assessment GNSL carried out is cautious and reasonable, and we consider that it has used an appropriate approach to assess the radiological impacts of the UK HPR1000 on wildlife
- for each reference organism, the probability of the dose rates exceeding the dose rate criterion of 10µGy/h is less than 1%
- the highest dose rate to any reference organism from discharges to atmosphere is 0.15µGy/h. The highest dose rate to any reference organism from liquid discharges is 0.0063µGy/h. These dose rates are well below the dose rate criterion of 10µGy/h
- that our independent radiological assessment for wildlife has broadly the same outcomes as GNSL's. The highest dose rate to any reference organism from discharges to atmosphere is 0.13µGy/h. The highest dose rate to any reference organism from liquid discharges is 0.023µGy/h. These dose rates are well below the dose rate criterion of 10µGy/h
- this assessment relates to predictions of impact based on a generic site. A detailed impact assessment will be required at any future site-specific permitting, based on the actual environmental characteristics of the proposed site, to confirm that doses to wildlife will be below relevant dose rate criteria
- we have not identified any Assessment Findings or potential GDA Issues

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Abbreviations

Acronym	*Meaning*
ADMS	Atmospheric dispersion modelling system
AF	Assessment Finding
ALARA	As low as reasonably achievable
ALARP	As low as reasonably practicable
BAT	Best available techniques
BERR	Business Enterprise and Regulatory Reform
CR	Concentration Ratio
ERICA	Environmental Risk from Ionising Contaminants: Assessment and management
GDA	Generic design assessment
GNSL	General Nuclear System Ltd
HPA	Health Protection Agency
HVAC	Heating ventilation and air conditioning system
IAEA	International Atomic Energy Authority
ICRP	International Commission for Radiological Protection
IRAT	Initial Radiological Protection Tool
NDAWG	National Dose Assessment Working Group
NRPB	National Radiological Protection Board
ONR	Office for Nuclear Regulation
P&ID	Process and Information Document
PCER	Pre-Construction Environmental Report

Acronym	*Meaning*
PCSR	Pre-Construction Safety Report
PHE	Public Health England
REPs	Radioactive Substances Regulation Environmental Principles
RI	Regulatory Issue
RO	Regulatory Observation
RP	Requesting Party
RQ	Regulatory Query
Sv	Sievert
TSC	Technical support contractor – employed by the regulator to provide specialist assessment support
UK HPR1000	United Kingdom version of the Hua-long 1 reactor

Glossary

Word/phrase	*Meaning*
Collective dose	The sum of the individual doses received by a specified population from exposure to a specified source of radiation in a given time period. Typically, man-Sievert (man-Sv) usually over (truncated at) 500 years. The discharge is assumed to last for one year and the unit is man-Sv per year of discharge.
Direct radiation	Radiation emitted from fixed structures containing radioactivity and/or radioactive sources on a site, including the reactor circuit, source stores, spent fuel stores, radioactive waste stores.
Discharges to atmosphere	The discharges to atmosphere from the UK HPR1000 are mostly of gases. Discharges to atmosphere are filtered to remove particulates. A small amount of particulates carrying non gas radionuclides may remain and may be discharged. Both are gases and particulates are included as appropriate in the assessment in this report.
Effective stack height (frequently used in modelling gaseous releases)	A representation of the release height of gases to atmosphere, which, where relevant, may be affected by (or may take into account): the physical height of the release point the wake effects or downdraught effects of nearby buildings of a similar height to or higher than the stack the exit velocity of the discharged gases the temperature of the discharged gases geography/terrain (hills or valleys nearby)
Gaussian (plume) model	One of the oldest (circa 1936) and commonly used model types for atmospheric dispersion of pollutants. The model is a mathematical simulation of the dispersion and transport of pollutants in the atmosphere. The model provides a way of estimating the downwind air concentrations following a release, using information about the pollution emission and the nature of the atmosphere. Gaussian (plume) models can be used for predicting the dispersion of continuous, buoyant air pollution plumes originating from ground-level or elevated sources. An adaptation of the Gaussian model may be used for predicting the dispersion of non-continuous releases. The primary algorithm used in Gaussian modelling is the 'Generalised dispersion equation for a continuous point-source plume.
Pasquill stability category (related to	The most widely known scheme for categorising the meteorological conditions into a grouping structure. The values can be used with

Word/phrase	Meaning
modelling dispersion of discharges to atmosphere)	at gaussian plume model. There are six categories (6 stability classes); A, B, C, D, E and F), with class A being the most unstable or most turbulent, and class F the most stable or least turbulent.
Physical stack height (sometimes used in modelling releases to atmosphere)	The height of the top of the stack from which releases to atmosphere may occur relative to the ground.
Per caput doses	Collective doses to the public can be used to calculate per caput doses, the collective dose for a population can be divided by the population to derive 'per caput' doses. Per caput doses provide an approximation to the average individual dose in the population.
Representative person	Characterised individual, either hypothetical or specific, whose dose can be used for determining compliance with the relevant dose constraint. The representative person is 'an individual receiving a dose that is representative of the more highly exposed individuals in the population'. This term is the equivalent of and replaces the average member of the critical group. In selecting the characteristics including habits of the representative person, 3 important concepts should be borne in mind: reasonableness, sustainability, and homogeneity.
Rounded (number)	In this report estimated doses may be calculated to several decimal places. This suggests the result is known to a high level of precision, which is not correct given the uncertainties in the calculation. Therefore, the results may be rounded to one or 2 significant figures. The standard rounding rules for decimals have been followed.
Sievert	The Sievert (Sv) is the SI unit for ionising radiation dose, measuring the amount of energy absorbed in a human's body per unit mass (J/kg). It is the unit of equivalent dose (dose to individual organs and tissues in the body) and the effective dose (representing radiation dose to the whole body). Radiation dose is usually expressed as a fraction of a Sv - milli-Sievert (mSv) or micro-Sievert (µSv). The quantity used in this report for human exposure is effective dose and the unit is µSv/y. The Sv also forms part of the unit for collective dose - man-Sv.
Wildlife	Non-human species (non-human biota) that require protecting. They may reside in protected habitats such as SPAs and SACs. This does not include domestic and/or farmed animals and plants.

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