Sizewell C Project

SIZEWELL C SITE DATA SUMMARY REPORT

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1 INTRODUCTION

NNB GenCo intends to build a twin UK-EPR new nuclear power station, at Sizewell in Suffolk. The plant that will be known as Sizewell C (SZC) is to be located in close proximity to the existing Sizewell nuclear licensed sites. The Sizewell B (SZB) nuclear licensed site has an operational Pressurised Water Reactor (PWR). The Sizewell A (SZA) nuclear licensed site contains twin Magnox reactors and associated plant that are currently being decommissioned. All fuel has been removed from the SZA site.

The SZC project is currently preparing to apply for a Nuclear Site Licence (NSL) for the proposed SZC site. As part of the application, it must be demonstrated that this site represents a suitable location from a nuclear safety point of view for hosting a twin UK-EPR nuclear power station.

The overall justification for the suitability of the site is presented in the “Justification of Site Suitability Report” (JSSR) [Ref. 1].

1.1 Purpose of the Site Data Summary Report

The Site Data Summary Report (SDSR) feeds into the JSSR [Ref. 1] and its overall purpose is to summarise the site-specific external hazards characterisation (in terms of magnitude and associated return periods / frequency of each external hazard), and to identify a suitable Design Basis for each external hazard applicable to the SZC site.

1.2 Structure of the Site Data Summary Report

The SDSR summarises the site data in three main sections:

Section 2 details the General Site Data. This section provides a history of the Site Investigation campaigns and details the general site characteristics.

- Section 3 details the Site Data for External Hazards. This section describes and presents the results of the site-specific external hazard characterisation studies. It characterises the SZC ‘Site Challenge’ (See Section 3.1.4 for definition of ‘Site Challenge’) and justifies the design basis of each External Hazard to be considered in the SZC design and future safety reports.
- Section 4 provides a summary of each section/hazard’s status based on the site challenge data that is available at the time of writing.

1.3 Versions of the Site Data Summary Report

There are three planned versions of the SDSR:

- Version 1 (previous version) – included site challenge data that was available at the time of drafting of Version 1 (Summer 2019). It also provided the ‘vision’ for the completed SDSR enabling early stakeholder engagement and any feedback to be incorporated as a part of Version 2.
- Version 2 – (previous version) includes site challenge data that was available by June 2020 such that design basis values are defined where possible. It is largely complete but does not define a design basis of the seismic hazard and solar activity.
- Version 4[1] – (current version) presents the complete version of the SDSR.

The SDSR will eventually become a key reference to the site-specific Pre-Construction Safety Report (PCSR) for SZC. An outline of how the safety case will be developed post NSL grant is included in the “Lifetime safety case strategy for SZC” [Ref. 2]. To enable the SDSR to become part of the Safety Case, further up-issues

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[1] Version 3 represented an intermediate step in the governance arrangements for the approval of Version 4.

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beyond Version 4 are likely to be necessary (e.g. to remove information pertinent to NSL and include information more relevant to construction milestones).

1.4 HPC Replication at SZC

The intention is to replicate the HPC design as far as possible at SZC. The SZC SDSR aims to justify the use of the HPC design basis values as detailed in HPC SDSR [Ref. 3] where this is appropriate.

The HPC design basis values are typically conservatively derived and there is consequently substantial 'head room' in the HPC design basis compared to the SZC 'site challenge' (See Section 3 for definition of site challenge). This means that in a large number of cases the HPC external hazards design basis values can be adopted for SZC based on the hazard characterisation work that is summarised for each external hazard in Section 3 of this report.

There are instances where the site characterisation work conducted to date indicates that a SZC 'site challenge' external hazard value is not necessarily bounded by the equivalent HPC design basis value or that the margin between the SZC challenge and the HPC design basis is substantially eroded (compared to the margin between HPC site challenge and HPC design basis). In these situations, appropriate justification for the adoption of the HPC design basis values is included in Section 3.

1.5 Identification of External Hazards which are covered by this SDSR

The external hazards included in this SDSR are detailed in Appendix A . The list of external hazards has been derived from a Hazard Listing Report [Ref. 4] that has previously been produced for SZC. Appendix A provides further details on the history of the derivation of on the hazard listing and further justification for the hazard listing where required.

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2 GENERAL SITE DATA

As described in Section 1.2, this Section provides a history of the Site Investigation campaigns and provides details of the general site characteristics.

2.1 Location and Pre-Development Land Use

2.1.1 Location

The proposed SZC site is located on the East Suffolk coast, approximately 35 km to the south of Lowestoft and 35 km to the northeast of Ipswich, in the parish of Aldringham cum Thorpe in the District of Suffolk Coastal.

The proposed site is situated in close proximity to an existing Nuclear Power generating site (SZB, a single PWR station), and a site undergoing decommissioning (SZA, a Magnox twin reactor site). All fuel has been removed from SZA while SZB is currently still operating. The hazards posed by these sites have been considered in the characterisation of industrial hazards (see Section 3.4). The main settlements surrounding the site are:

- the village of Sizewell (about 500m to the south);
- the village of Aldringham (about 1.5km to the southwest);
- the village of Thorpeness (about 2km to the south);
- the village of Theberton (about 1km to the northwest);
- the town of Leiston (about 2km to the west);
- the town of Lowestoft (about 35 km to the north); and
- the town of Ipswich (about 35km to the southwest).

The SZC site has an approximate grid reference of TM473640. Its position is indicated in Figure 1 and Figure 2 below.

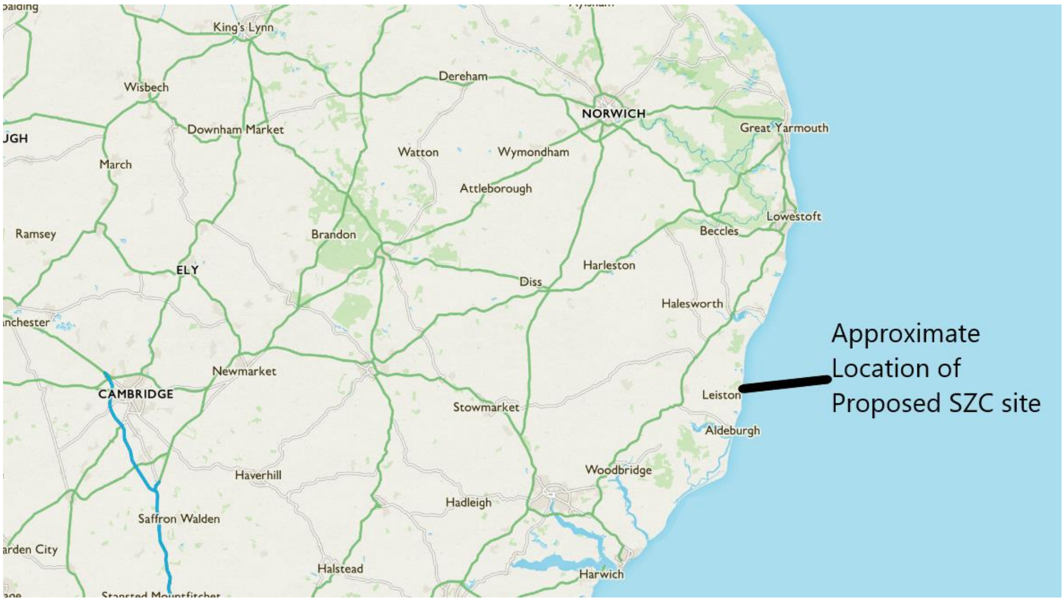

Figure 1: Approximate Location of Proposed SZC in Suffolk

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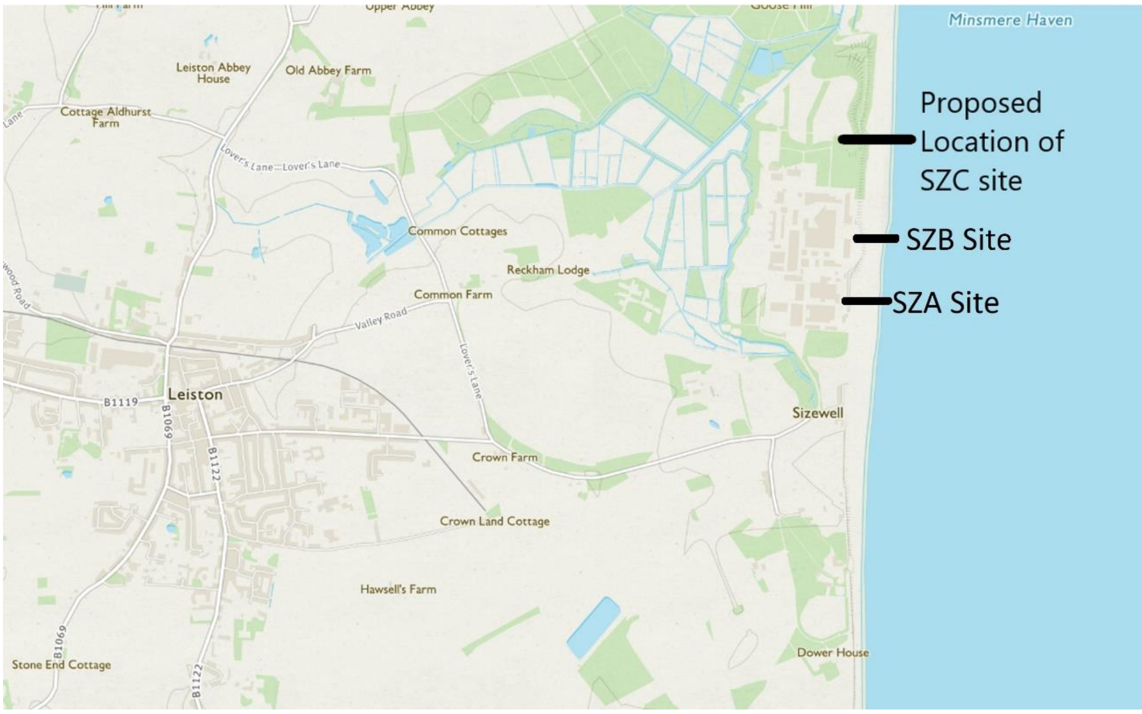

Figure 2: Location of Proposed SZC Site (Zoom In)

2.1.2 Pre-Development Land Use

The majority of the land on which the proposed SZC nuclear licensed site will occupy, is an area of made ground associated with the construction of the SZB power station. This area is now generally characterised by grassland, regenerating scrub and planted tree belts. The North East corner of the proposed SZC licensed site also has marshland and drainage ditches. The areas of the proposed SZC Licence Site immediately adjacent to (North of) the SZB licensed site, are occupied by the visitor centre and some ancillary structures associated with SZB, and parking areas. These will require removal / relocation as a part of the development the SZC licensed site.

The coastal strip adjacent to the proposed licensed site is characterised by a vegetated engineered embankment, known as Bent Hills and a lower vegetated bund that together form the sea defences to the existing Sizewell power stations. East of the lower bund is a shelving shingle beach with two constructed crests that act as sea defences and landscaped features.

Examination of various OS maps of the area of the Sizewell sites (going back to 1882) indicates that prior to SZB construction, the proposed SZC site was rural undeveloped land.

The made ground within the site is present from the ground level (around +1.50 m AOD / + 2 m AOD), down to the elevation varying from -2 m AOD down to -6.65 m AOD. The made grounds essentially consist in reworked Crag sand material removed during the construction of SZA and SZB power plants (excavations for building foundations, as the Crag at SZA and SZB were set at a higher elevation than at SZC). Further information on the site geology is available in Section 2.3.

2.1.3 SZC Development Site

The SZC Development Site encompasses a total area of 729 ha, comprising 362 ha of land onshore and an offshore area of 367 ha [Ref. 7]. For the purpose of describing the properties of the SZC Development Site, it is useful to divide the site into zones (as illustrated in Figure 3).

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- **Main Construction Area (MCA)**: located at the east of the site and comprises the main site platform onto which the two EPR units and associated plant and buildings will be built. The MCA is generally low-lying and flat with elevations ranging from +0.2 to +2.5 m AOD. The Sizewell Marshes Site of Special Scientific Interest (SSSI) and associated drains are located in the north-western section of this zone.
- **Temporary Construction Area (TCA)**: primarily located to the north-west of the MCA and largely comprises of agricultural land and open fields with a few residential properties (farms), lanes and tracks. Several forested areas (including Dunwich Forest, Great Mount Wood, Ash Wood and Greenhouse Plantation) are also present within this zone. The land is required on a temporary basis to facilitate the construction of the power station and will include contractor compound areas, borrow pits, spoil management zones, an accommodation campus and caravan site, extensions to rail infrastructure, a site entrance hub, and areas for material storage.
- **Ancillary Construction Area (ACA)**: a small section of the TCA located to the north east of Leiston ~1.7 km south-west of the MCA. This zone comprises of open fields and is bounded by Valley Road to the west, Lovers Lane to the east and the Eastlands Industrial Estate to the south-west. This zone will be used for temporary storage during the construction works.

The offshore area is located to the east of the MCA and includes the foreshore area and the North Sea.

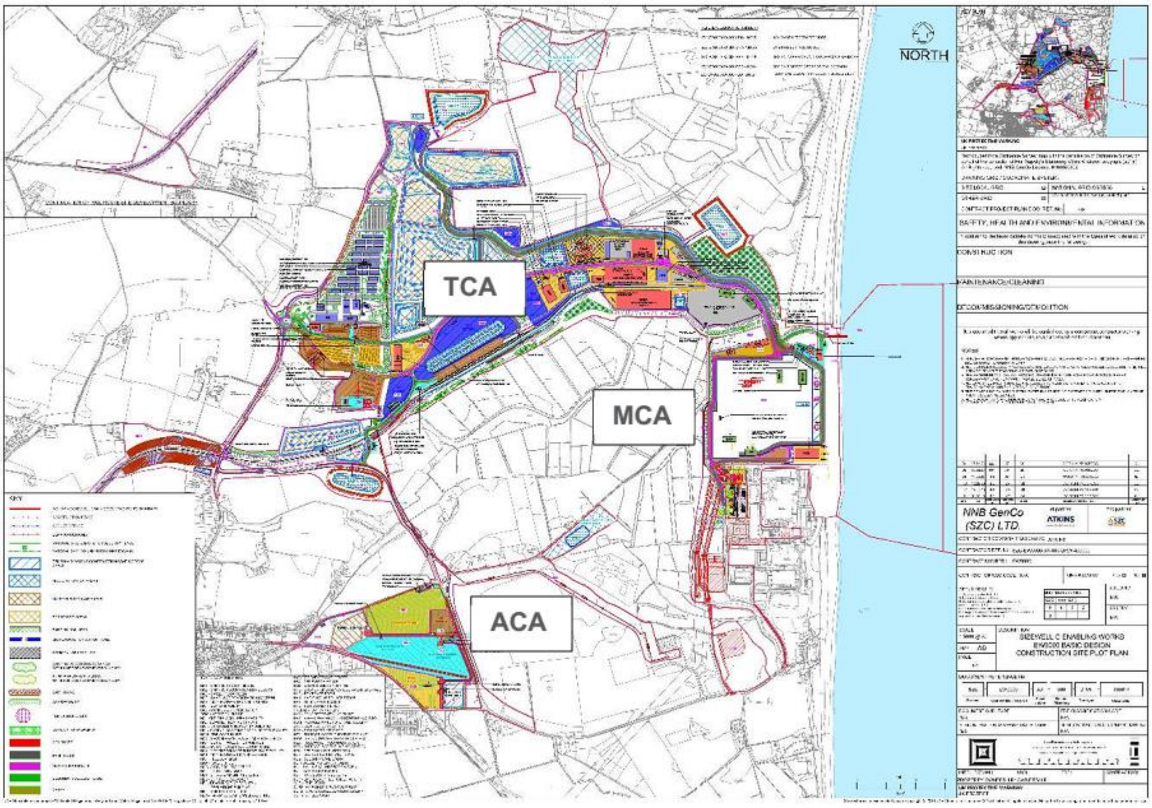

Figure 3: The onshore and offshore area of the SZC development site [Ref. 7]

2.2 Site investigations

A comprehensive programme of preliminary Onshore and Offshore site investigation has been undertaken at SZC. Site Investigation studies have been planned and executed in controlled stages to build up a detailed geological understanding of the site and its environment, to establish the geotechnical properties of the soils

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and rocks, and to gain an understanding of the hydrogeological conditions. Relevant data has been obtained from the following sources:

- Existing geological, hydrogeological, and geotechnical information, including:
    - Geological mapping;
    - Borehole logging surveys;
    - Soil maps;
    - Geological, geotechnical, and geophysical reports;
    - Subsidence records;
    - Existing piezometers at the SZC site;
    - Hydrogeological maps, hydrological and tidal data; and
    - Seismic data and historical earthquake records;
- Experience of ground conditions and performance at the SZA and SZB sites.

The findings of the Phase 1 site investigations are reported in the Preliminary Onshore Investigations - Ground Investigation Report [Ref. 8]. This report formed the basis for the production of the Step 1 Interpretative Report [Ref. 9].

The findings of the Phase 1 investigations informed a second programme of more comprehensive investigations to characterise the SZC site (Phase 2). The results of the Phase 2 investigations are presented in the Phase 2 Ground Investigation Report [Ref. 10], which provides a summary of the ground investigations undertaken between 1957 and 2018 and presents the results from the most recent onshore and offshore ground investigations undertaken in 2019.

2.3 Geological Conditions

Intrusive site investigation work has been completed. The Phase 2 Ground Investigation Report (GIR) [Ref. 10] has been updated since the publication of Revision 2 of this report to include laboratory test results from 2019 investigations, delayed due to the COVID-19 pandemic. This update also included further analysis of soil data for the purposes of the Probabilistic Seismic Hazard Assessment (PSHA).

A final revision to the Phase 2 GIR is planned for issue by the end of September 2021, which will include further analysis of test data and editorial changes to improve readability and the line of the Golden Thread. The main conclusions of the report are not expected to change significantly.

2.3.1 Onshore Geology

The geology of the SZC site and surrounding area has been characterised through the site investigations outlined above. Boreholes, piezometers, in-situ testing, laboratory testing and geophysical surveys have been carried out to characterise the site, and to establish the various ground models presented in the Phase 2 Ground Investigation Report [Ref. 10].

The SZC site has a lower topography than the SZA and SZB sites, since it exists in an old marsh area partially backfilled during the construction stages of the SZA and SZB sites. The different strata at the SZC site are sub-divided into several layers from the surface to the maximum investigated depth (~120m below ground level) as follows [Ref. 10]:

- **Topsoil and Made Ground**: comprising of material excavated during the construction of the SZA and SZB sites. The Made Ground is composed of reworked Crag sand material. The most common facies

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observed from the Made Ground are orange/brown fine sands, but it can also include occasional gravel or cobble beds.

- Recent Deposits:
    - **Alluvial Clay**: a layer observed in the upper part of the Recent Deposits, the thickness and lateral extension of the clay is not constant over the intended main excavation. Furthermore, clay is absent in some parts or is mixed with peat and areas of soft sandy clay have been observed within the peat.
    - **Peat**: usually located underneath the alluvial clay and is frequently mixed with sandy and clayey facies (i.e. clay bands within the peat).
    - **Other deposits**: sand and gravel formations (accumulated as sand waves) are observed in the eastern boundary of the site extending upwards to the ground level. Sandy facies from reworked Crag lie just below the peat or at the same elevation (where peat is absent in the southern boundary) – these are difficult to differentiate from the upper Norwich Crag (C1) fine sands.
- **Crag Group:** these deposits are divided into 3 main groups as follows:
    - **Norwich Crag (C1)**: the upper part of the Norwich Crag consists of a uniform layer of moderately dense to dense fine to very fine sand. The colour varies from dark (grey to blue/grey) to brown or orange. The lower part of the Norwich Crag is made of fine sand (brown to grey), similar to the upper Norwich Crag, but below -11 m AOD, they can include fine lenses of clay giving a layered sand aspect and some shell fragments.
    - Red Crag:
        - **Thorpeness member (C2)**: the upper Thorpeness member contains numerous shell debris made of fine sand but appear as coarse sand due to their size (usually up to 5 mm). They are also characterised by their high density (dense to very dense) which distinguishes them from the overlying facies from the Norwich Crag. An intermediate facies within the Thorpeness Crag is observed in some areas, and corresponds to the presence of clay, appearing as fine clayey beds or clay nodules. The lower Thorpeness member is the same as the upper member, containing numerous shell debris made of dense to very dense fine sand appearing as a coarse sand (with shell fragments of 2 mm).
        - Sizewell member (C3): The base of the Crag is sometimes marked with the presence of clay (hard laminae of clay in 2011_CBH_6U) as a transition with the Thames Group or with flint pebbles.
- Thames Group:
    - **Wrabness member**: present as a continuous thick layer of brown silty clay, occasionally turning into clayey silts. It is characterised by a series of centimetric to decimetric stone bands (either limestone or laminae of dark claystone in the upper part of the layer) and its base is marked by glauconite.
    - **Orwell member**: a layer of plastic silty clay (~5 m in thickness) with pockets of silts and sands.
    - **Ipswich member**: corresponds to the base of the Thames Group and consists of a decimetric band of rounded flint gravel.
- Lambeth Group:
    - **Reading Formation**: the upper part of the Lambeth Group is predominantly sand and bounded by two layers of clay.

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  - **Upnor Formation**: the lower half of the Lambeth Group is predominantly clay. The contact with the underlying Montrose Group is discontinuous (due to erosion).

- **Montrose Group**: this corresponds to the Lista Formation, consisting of the Ormesby Clay Member. The upper unit (OC4) is absent at Sizewell, the OC3 unit is made of silty clay (grey/brown and partly glauconitic in and reddish brown in the lower OC2 unit. The base unit (OC1) is characterised by a bed of flint gravels and cobbles sitting above the chalk group.

- **Chalk Group**: a layer of chalk (estimated thickness of ~300 m) lies underneath the clay sequence and is considered as the deep bedrock. The upper part of the chalk at SZC corresponds to the Portsdown Chalk Formation from the White chalk sub-group.
  - **Beeston Chalk Member**: this upper member is characterised by numerous large flints and reduced marl content. The base level contains numerous belemnites.
  - **Weybourne Chalk Member**: this member is glauconitic and is characterised by increased marl content.
  - **Pre-Weybourne Chalk Member**: this member is characterised by having high marl content, with the marl mainly located in burrows.

A summary of the stratigraphy at the SZC site from previous ground investigations is presented in Table 1.

Group	Sub-group	Formation	Member	Age		Indicative level (m AOD)	Indicative thickness (m)
Made Ground (including topsoil)		-		Recent	-	Ground level (+1.5 to +2.0) down to -2 to -6.65	-
Recent Deposits	-	-		Quaternary	Holocene	-2 to -7	-
Crag Group	-	Norwich Crag Formation	Chillesford sand member		Pliocene – Pleistocene	-7 to -11 (upper) -11 to -17/-19 (lower)	-
		Red Crag Formation	Thorpeness member			-17/-19 to -32	-
			Sizewell member			-32 to -41	
Thames Group		Harwich Formation	Wrabness member	Tertiary (Paleogene)	Eocene	-	7 to 10
			Orwell member			-	
			Ipswich member			-	
Lambeth Group		Reading Formation			Palaeocene	-	~6
		Upnor Formation				-	~2.5
Montrose Group		Lista Formation	Ormesby Clay member			-	~9
Chalk Group	White Chalk	Portsdown Chalk Formation	Pre-Weybourne, Weybourne, Beeston	Cretaceous		-78 to -320	-

Table 1: Summary of the stratigraphy in the Onshore Area of the SZC site (adapted from Reference [10])

Further details are provided in the Phase 2 Ground Investigation Report [Ref. 10].

2.3.2 Structure

There is no evidence of any significant structural anomalies at the site or in the surrounding area [Ref. 11].

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Faulting has been proven not to affect the Crag Group or underlying strata at the site or in the surrounding area. Minor faults would be difficult to recognise in the Crag Group due to the nature of the lithology and it is considered unlikely that such features would affect the groundwater flow regime [Ref. 11].

2.3.3 Offshore Geology

Published geological maps generally indicate that the offshore area is underlain by marine sediments (tidal flat mud deposits, sand bank deposits, sand, and gravel shoreface and beach deposits) overlying bedrock comprising the Red Crag Formation, Norwich Crag Formation, Coralline Crag Formation, London Clay Formation, Lower London Tertiaries (Harwich, Woolwich & Reading, and Thanet Formations) and the Chalk Group [Ref. 12]. A summary of the stratigraphy in the offshore area of the SZC site is presented in Table 2.

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Group	Sub-group	Description
Marine Deposits	Sand and Gravel	Present at seabed level with an average thickness between 2 and 10 m, comprising grey to yellow/brown interlaminated silty, sandy, and gravelly clay; silty, gravelly, and clayey sand; and rare laminations of sandy silt with many shell and shell fragments and layers of peat.
Crag Group	Norwich Crag Formation Red Crag Formation	Present at seabed level and up to -17 m AOD, comprising grey to dark yellow/brown, dense to very dense fine clayey sand, with numerous shells and shell fragments.
	Coralline Crag Formation	This formation is only present in the offshore area near the extremity of the tunnels and consists of a continuous layer of dense to moderately cemented sands. In the lower part of the layer, the clay becomes more widespread at the transition with the underlying layer of clay: clay-layered sands (from -34.9 to -36.6 m AOD) turn to fine green glauconitic sands, including some dark organic levels that are highly clayey and dense. Some cylindric nodules (assumed to be phosphates) are present at the base. The total thickness of this formation ranges from approximately 15 m (between -14 and -29.9 m AOD) and 24 m (from the seabed to -38 m AOD).
Thames Group	London Clay Formation	This formation has only been preserved in the offshore area (below the south-eastern dome of Coralline Crag) and is present at depths of between -36 and -46 m AOD (indicative thickness of ~10 m), comprising of firm to very firm brown/dark brown silty clay.
	Harwich Formation	Present at depths of circa. -45 m AOD, comprising firm to very firm fissured dark blue/grey to brown/grey silty and sandy clay with occasional shell fragments. The full thickness of the Wrabness and Orwell members is ~15 m.
Lambeth Group	Woolwich and Reading Formation	Present at depths of circa. -52 m AOD, comprising very firm dark brown and grey/brown silty clay and firm blue/grey to red, orange, and brown very sandy silt.
Montrose Group	Ormesby Clay Member	Present at depths of circa. -79 m AOD, comprising very weak dark brown/grey and dark green/ grey silty clay and mudstone.
Chalk Group	White Chalk	Present at depths of -83 to -100 m AOD, comprising structureless and very weak to weak, low to medium density white and off-white mottled chalk.

Table 2: Summary of the stratigraphy in the Offshore Area of the SZC site (adapted from Reference [10] and [12])

Further details are provided in the Phase 2 Geo-Environmental Interpretative Report [Ref. 12] and the Phase 2 Ground Investigation Report [Ref. 10].

2.3.4 Site Categorisation

Wave velocity measurements have been made on the SZC site during the ground investigations undertaken at the SZC site during Phase 2 in 2019. Best estimate values for the average shear wave velocity (V_S) at the SZC site are presented in Table 3 (adapted from Section 7.3.1 of Reference 10).

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Layer	Indicative level onshore (m AOD)	Best estimate Vs (m/s)
Made Ground	2.15	150
below water table	0.7	236
Peat & Clay	-4.6	90
Norwich Crag (C1)	-8.9	255
Upper Red Crag (C2)	-19.1	420
Lower Red Crag (C3)	-29.0	515
Coralline Crag	Offshore	555
London Clay		225
Harwich Clay	-42.7	356
Reading Sand	-55.8	309
Lambeth Clay	-63.7	341
Lista Clay	-68.7	397
Upper Chalk	-79.5	1110
Middle Chalk	-165	11125
Lower Chalk	-235	1175
Gault	-280	540
Substratum	-307	1655

Table 3: Best estimate shear wave velocities (V_S) per layer

Shear wave velocity values (V_S) range from 90 to <500 m/s in the Crag and Clay layers (onshore), with values >1100 m/s only measured in the Chalk layers and deeper. These variations arise due to the differences in geological layering and depth profiles.

For comparison, V_S values at HPC were found to range from 504 to 1,178 m/s across the Nuclear Island, resulting in average shear wave velocity values over the upper 30 m of the ground profile (V_{S30}) ranging between 790 and 830 m/s. By reference to the International Atomic Energy Agency (IAEA) Safety Guide NS-G-3.6 [Ref. 13], the site categorisation for HPC was determined as follows: Type 2 Site: 1100 m/s > V_S > 300 m/s. A typical value for the shear modulus (G) for HPC, based on the V_{S30} determinations is ~1,500 MPa.

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The shear wave velocity and shear modulus values calculated for HPC are bounded by the six standard soil types (ranging from 'soft' to 'hard' sites) considered during the Generic Design Assessment (GDA) of the UK EPR. This site categorisation was used to inform the civil design at HPC and the measurements of shear wave velocities on the HPC site were also used to inform the seismic hazard characterisation (refer to Reference [3] for further details).

The IAEA site categorisation is based on the best estimate shear wave velocity (Vs) of the foundation medium just below the foundation level of a structure in the 'natural' condition (i.e. before any site work commences). This is valid on the assumption that the shear wave velocity does not decrease significantly with depth.

Based on the information presented in Table 3 and the discussion above, it is expected that a Type 2 site categorisation is also applicable to SZC, and that the shear wave velocity and shear modulus values calculated for SZC are bounded by the six standard soil types (ranging from 'soft' to 'hard' sites) considered during the Generic Design Assessment (GDA) of the UK EPR. The measurements of shear wave velocities on the SZC site will be used to support the seismic soil structure interaction (SSI) analyses and inform the seismic hazard characterisation described in Section 3.2 of this document.

2.4 Coastal Conditions

2.4.1 Present Geomorphology

A comprehensive description of Coastal Geomorphology adjacent to the proposed SZC nuclear licensed site is provided in Reference [14] and is summarised at a high level below.

The Greater Sizewell Bay (GSB) in which the proposed SZC site will reside extends from Walberswick to Thorpeness. The coastline along the SZC frontage comprises of:

- a shingle beach;
- two sandy, shore-parallel longshore bars;
- the Sizewell–Dunwich Bank; and
- the erosion-resistant Coralline Crag that extends sub-tidally to the northeast from the Thorpeness headland.

The intertidal beach is primarily comprised of shingle (i.e., gravel-sized material) with a smaller sand-fraction that is either mixed with shingle or exists as surface, or sub-surface, veneers [Ref. 15 and 16]. The seaward limit of the shingle beach is an abrupt beach-step that meets a sub-tidal, low sloping, sandy bed. This boundary demarcates the seaward limit of the shingle beach and indicates that cross-shore exchange of shingle occurs almost exclusively landward of the low-tide beach step.

The subtidal beach is sandy and features an inner longshore bar 50-150 m from shore of -1.0 to -3 m AOD[2] elevation, as well as a larger outer bar 150 – 400 m from shore of -2.5 to -4.5 m AOD elevation. The bars are approximately shore-parallel and play an important role in dissipating wave energy (through wave breaking) and reducing wave angle at the shore/bar line. During larger storms, when both bars are part of the surf zone, high suspended sand concentrations will drive sand transport along the bar crests and troughs, which accounts for most of the low annual (net average) ca. 10,000 m^3 of southerly sediment transport [Ref. 17]. That is, the bars are the primary sand transport corridor during storms.

Seaward of the bars, a 1200-m-wide channel (up to 9 m deep) separates the coast from the Sizewell – Dunwich Bank. Whilst primarily sandy, muds are found in a narrow stretch just landward of the bank. Muddy

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[2] Although not apparent in BEEMS or EA bathymetric surveys, the inner bar was emergent in the summers of 2018 and 2019, suggesting beach building summer conditions and/or an abundance of sand.

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sediments dominate the area to the north of the Dunwich end of the bank, whilst the bank itself is comprised of well-sorted fine sands.

The Sizewell – Dunwich Bank is a single sedimentary feature, 8 km in length and with a landward flank located 1.2 – 1.7 km from shore. Its higher north and south ends, often referred to as Dunwich Bank (-4 to -5 m AOD) and Sizewell Bank (-3 to -5 m AOD) respectively, are joined by a lower elevation saddle (-7 m AOD). Due to its large size (633 ha above the -8 m AOD; [Ref. 18] the bank is not regularly surveyed; however it is apparent in recent soundings and radar data that it can remain stationary for several years or longer. Historical records indicate that the bank tends to migrate landward at an average rate of 6 – 7 m/yr in its central and northern sections [Ref. 19]. Records over the last decade show that Sizewell Bank has remained static in its position. However, the development of a 300 m wide, 600 m long, northward extending spur along its seaward flank increased bank height locally by 0.4 – 1.0 m.

In contrast, Dunwich Bank exhibited greater variability in both its morphology and position with:

- erosion north of 267000N, resulting in bank lowering of 0.5 – 1.5 m;
- a decrease in its northern extent of approximately 250 m;
- landward movement (200 – 475 m) of the northernmost 2.75 km of its seaward flank;
- accretion/migration on its landward flank adjacent to its peak and most landward position (between approximately 267000N – 267600N); and
- ongoing migration of the landward flank for the 6 to 10 m (ODN) contours (approximately 6 m/yr) [Ref. 18].

Growth in Sizewell Bank is considered to be sustained by sand supply from the coast. There are several strands of evidence supporting the coast to bank sand transport pathway:

- trends in sediment size and colour;
- bedform orientation;
- patterns of erosion and accretion observed over successive bathymetric surveys;
- sediment build up (accumulations) and release episodes seen in radar data;
- the size and north-east orientation of Coralline Crag ridges; and
- modelled hydrodynamics and sediment transport.

The erosion resistant Coralline Crag outcrops at Thorpeness form a shallow platform and a series of descending shallow ridges that extend seaward (north-east) to Sizewell Bank. Sediment grabbing is difficult in this area where the ridges are exposed or only thinly covered in sediment. The presence of the crag at Thorpeness fixes the location of the headland, which subsequently controls the local tidal streams (e.g., offshore diversion of the ebb stream) that maintain the bank's stable form[3].

2.4.2 Future Geomorphology

The rationale behind the definition and projection of a likely future shoreline baseline during the operational phase of SZC is set out in Reference [20]. Its objectives were to determine:

- whether the shoreline is likely to erode and expose the hard coastal defence feature (a scenario without Additional Mitigation (also referred to as Secondary Mitigation));
- a plausible future shoreline baseline (without SZC); and

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[3] The historic stability of the Sizewell end of the bank can be linked to the fixed position of the crag ridges; in comparison the northern Dunwich end is more mobile and has no anchoring feature.

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- a plausible future shoreline with SZC, highlighting the likely effects.

Shoreline change is driven by several factors whose importance and interaction cannot be accurately predicted several decades into the future either separately or in combination. Moreover, there is no current computational modelling platform able to accurately integrate the numerous environmental processes that drive shoreline change (especially for mixed gravel/sand beaches), and there is no published evidence that shoreline change models can be reliably applied over the required multi-decadal timescale [Ref. 14]. Nevertheless, identification and assessment of plausible future geomorphological scenarios (and associated Bathymetry) has been carried out in Reference [22] using expert judgement, supported by evidence where possible. The projection of the shoreline during construction was not required because the onsite activities associated with the construction of the site sea defences will alter the local SZC coastline.

Reference [22] indicates that over the next 60–100 years there could be coastal physical hazards to any structures located in the trough between the Dunwich-Sizewell bank and the coast, from, for example, smothering by sediment. Indeed, several scenarios discussed in Reference [22] relate to infilling or similar of the trough between the shoreline and the bank. Reference [22] notes that careful consideration needs to be given to the location and design of any emplaced structures and planned coastal and marine works such that coastal geo-hazards faced by water intake and outfall pipes should be minimized by emplacement of both seawards of the present Sizewell Bank.

The proposed SZC intake and outfall tunnels will extend seaward >3km such that the intake / outfall heads will be situated east of the stationary Sizewell Bank and not in the trough between the bank and the coast. Only plausible scenarios were taken forward for further consideration in Reference [22] and none of these related to the Dunwich-Sizewell bank expanding /moving seawards / eastwards towards the intake heads.

One of the plausible scenarios in Reference [22] relates to depletion of the Dunwich-Sizewell bank, leading to a loss of natural sea defence. However, as coastal erosion is a slow process that will be monitored over the lifetime of the plant, it is not considered as a coastal flooding initiator (see Section 3.5.1.1).

2.4.3 Bathymetry

In July 2016 a Multi-Beam Echo Sounder (MBES) bathymetric survey of four shoaling corridors in the nearshore coast off Sizewell [Ref. 21] was conducted between 24th and 29th July 2016.

The work consisted of the acquisition of MBES bathymetric data running lines at 10m spacing on the W-E lines and by running shore parallel N-S lines operating at a nominal frequency of 250kHz. Full coverage was not achieved due to the presence of the SZB outfall structure and static fishing gear within the survey area, mainly located within the southern survey corridors.

Bathymetry across the survey site ranged from approximately -18 m AOD at its deepest point offshore to its shallowest around -1.3 m AOD around the existing SZB outfall and -2.2 m on the slope towards the coastline.

The four corridors surveyed portrayed similar seabed characteristics across the survey site. There is a consistent slope from the coastline towards offshore from approximately -3 m AOD to -7 to -8 m AOD. The crest of Sizewell Bank shows lies at between -7.5 m AOD and -4 m AOD. The seabed then falls away to -18 m AOD deep (Figure 4). The SZC intake tunnel heads for intake tunnels 1 and 2, and the common discharge are situated several hundred metres east of the Sizewell Bank where the Bathymetric depth is approximately -18m AOD. Further information on bathymetry is also available in Reference [14].

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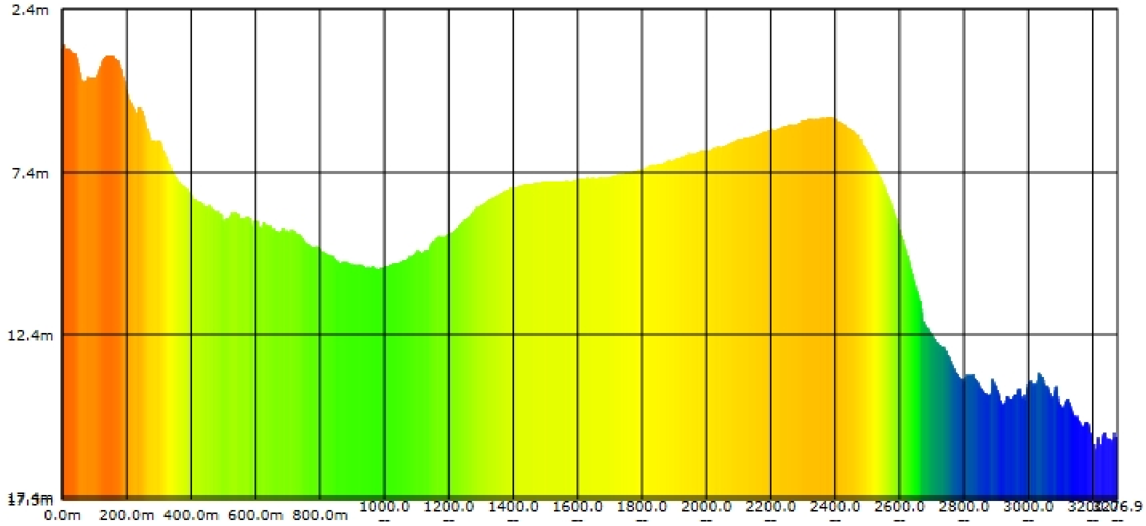

Figure 4: Profile Running from Nearshore to Offshore Across Sizewell Bank

2.4.4 Tidal data

The tidal currents in the GSB are semi-diurnal. The tidal range increases from North to South across the region with spring tides of 1.9 m at Lowestoft, 2.2 m at Sizewell and at 3.5 m at Felixstowe. Water movement is dominated by tidal currents that flow south for most of the rising (flood) tide (1.14 m/s (peak) seaward of Sizewell Bank) and flow north for most of the falling (ebb) tide (1.08 m/s). The water column is thermally well mixed throughout the year due to the strong tides and shallow bathymetry. The only exception to this is in the vicinity of the SZB discharge plume, but this is of insufficient spatial extent to affect the flow regime. As expected, tidal currents reduce close to shore and peak at about 0.2 m/s 50 m from the shoreline [Ref. 23].

The TELEMAC2D tidal flow model was used to simulate the tidal regime of the GSB [Ref. 24]. The model was run for the validation period (7/11/2013 to 6/12/2013) to enable a direct comparison between model and observed data [Ref. 14].

Reference [26] infers present day astronomical tide levels for Sizewell based on data from the Proudman Oceanographic Laboratory which utilises and maintains the Class A tide gauge network and derives astronomical tidal levels for the tide gauge locations. Data for Lowestoft and Felixstowe were used to derive the Values for Sizewell. Present-day astronomical tidal levels inferred for Sizewell are shown in Table 4.

Tide Type	Level
HAT: High Astronomical Tide	1.68m AOD
MHWS: Mean High Water Spring	1.22m AOD
MHWN: Mean High Water Neap	0.83m AOD
MSL: Mean Sea Level	0.16m AOD
MLWN: Mean Low Water Neap	-0.42m AOD
MLWS: Mean Low Water Spring	-1.01m AOD
LAT: Low Astronomical Tide	-1.61m AOD

Table 4: Present-day astronomical tidal levels for SZC

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2.5 Surface watercourses

The proposed SZC site is located in a coastal location in eastern Suffolk and lies within the catchment of a number of controlled waters[4] i.e. the Rivers Minsmere, Leiston Drain and Scotts Hall Drain, with a combined catchment area of approximately 80 km2. The catchment has a variable soil composition, is predominantly rural and receives relatively low annual rainfall of less than 600 mm [Ref. 25]. The catchment is illustrated in Figure 5 and described below:

- The River Minsmere rises south-west of Halesworth before flowing eastwards, bypassing the villages of Yoxford and Middleton. Downstream of Eastbridge, the embanked Minsmere New Cut flows through the Minsmere Levels Site of Special Scientific Interest (SSSI), whilst the Old Minsmere River drains the northern areas of the RSPB Reserve, re-joining the New Cut just upstream of the Minsmere Tidal Sluice structure.
- The Scotts Hall Drain routes water from the northern and eastern areas of the Minsmere Levels towards the Minsmere Tidal Sluice. The Leiston Drain is a small watercourse in the vicinity of the Sizewell Nuclear Power Plants and the town of Leiston and drains the southern area.
- The Minsmere Tidal Sluice drains freshwater by gravity through two outfall pipes discharging into the North Sea. The sluice structure has four flap gates (two for the Minsmere New Cut, one for Scotts Hall Drain and one for Leiston Drain). The main chamber is divided internally into two low level chambers separated by a wall over which water spills if it exceeds the top of the dividing wall at approximately 1.07 m AOD.

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[4] Controlled waters (as defined in Part III, Chapter IV, Section 104 of the Water Resources Act 1991) include virtually all freshwaters, public supply reservoirs, underground waters, tidal waters, and coastal waters up to three nautical miles out to sea. Exceptions include small ponds and reservoirs that do not supply water to other watercourses.

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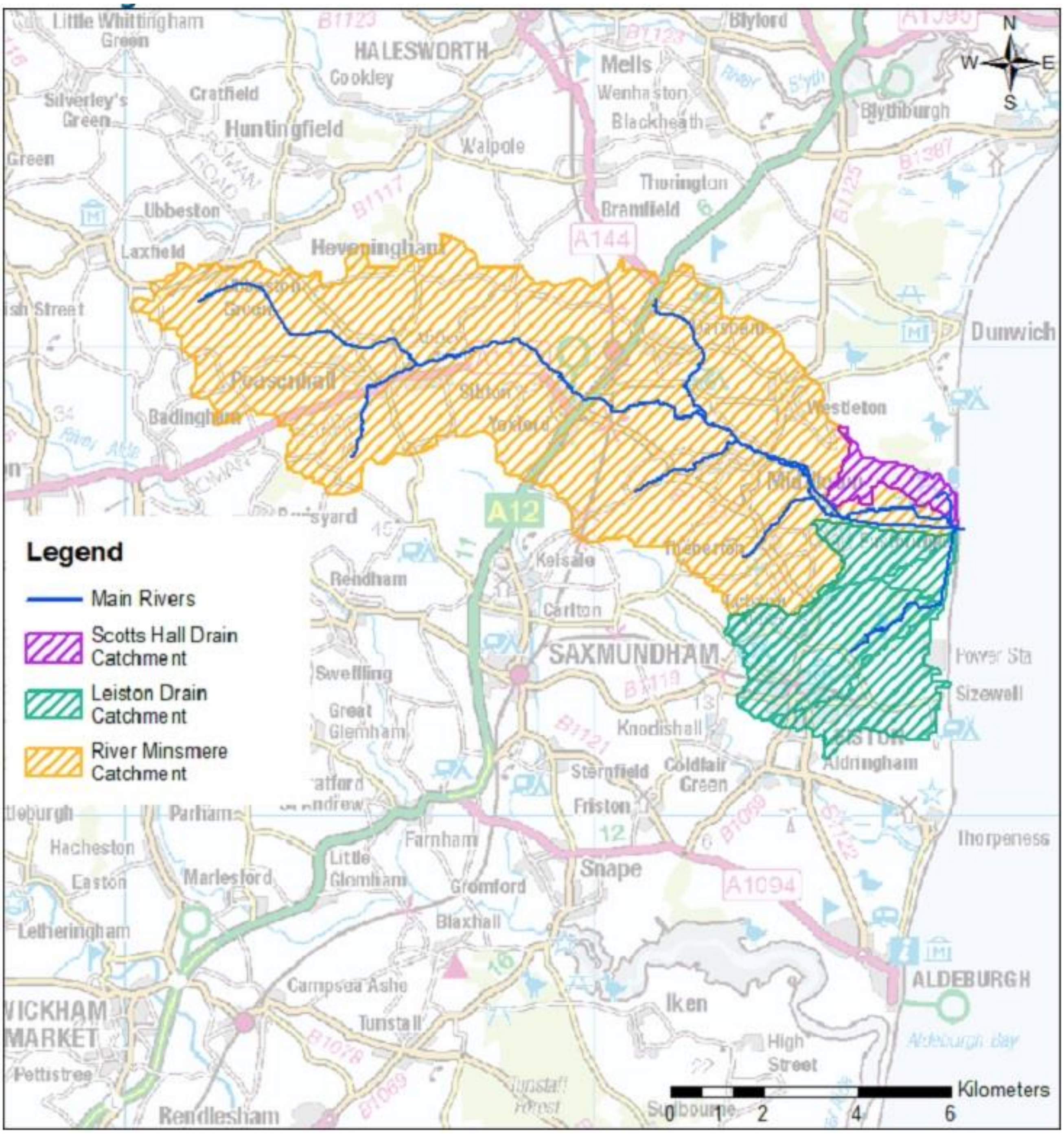

Figure 5: River Minsmere Catchment Area and Drainage Network [Ref. 25]

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2.6 Fauna and flora

Extensive baseline ecological studies of the terrestrial and marine environments have been carried out and are summarised in Chapters 14 and 22 of the Environment Statement [Ref. 28 and 29]. They identified the key sensitive ecological receptors (habitats and species) in the vicinity of the proposed SZC site. They notably include:

- Minsmere-Walberswick Heaths and Marshes is a designated Site of Special Scientific Interest (SSSI), to the north of the proposed SZC site, part of which is also designated as a Special Protection Area (SPA), Special Area of Conservation (SAC) and Ramsar site.
- Sizewell Marshes SSSI lies immediately to the north and to the west of the SZC site and a small part of the proposed site lies within the SSSI.
- Leiston-Aldeburgh SSSI and Sandlings SPA to the south and south west of the Sizewell site.
- Outer Thames Estuary SPA to the east of the Sizewell site is classified for the protection of the largest aggregation of wintering red-throated diver in the UK, and for the protection of little tern and common tern.

2.6.1 Terrestrial Fauna and Flora

A number of different surveys were carried out to identify protected species of wildlife within the SZC site; details of these surveys can be found within Chapter 14 of the Environmental Statement [Ref. 28] of the Development Consent Order (DCO).

2.6.2 Marine

A number of different surveys were carried out to identify protected species of wildlife within the SZC site; details of these surveys can be found within Chapter 22 of the Environmental Statement [Ref. 29] of the Development Consent Order (DCO).

2.7 Grid reliability

The reliability of the SZC grid connection concept design is summarised and assessed within Reference [27]. It presents the SZC Loss of Off-Site Power (LOOP) frequencies and justifies that the design of the SZC grid connections does not contribute significantly to the overall LOOP frequency, of which the dominant contributor is external hazards. The report also justifies that the LOOP frequency for SZC as a result of grid connection design is not expected to be significantly different to HPC because the SZC grid connection design will conform to modern standards and specifications such as the Grid Code [Ref. 30] and Security and Quality of Supply Standard (SQSS) [Ref. 31].

Electricity from the SZC generators will be stepped up to 400kV via the main transformer and transferred via overhead lines to a new National Grid 400kV substation. This new substation will be interconnected to the existing substation enabling the electricity generated by both the existing SZB and new SZC power stations to be exported to the National Electricity Transmission System. The SZC grid connection design will contain in-built redundancy via two double circuit connections (“4-circuit”) and associated off-site overhead line connections along with overhead line and underground cabling connections on site to the UK EPR reactor unit.

The design will use modern components and will conform to modern standards and technical specifications including the Security and Quality of Supply Standard (SQSS) and the UK National Grid Code. Meeting the requirements of the SQSS and the Grid Code ensures that a LOOP is unlikely because the SQSS states that a single failure of an overhead line section or a busbar should not lead to either a loss of supply (greater than

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1500MW) or unacceptable frequency conditions. The requirements of the Grid Code ensure that an electrical system provides secure and efficient functioning.

Reference [27] examines the accepted SZC site specific LOOP frequencies (provided below in Table 5) which have been derived from British Energy and UK nuclear reactor Operating Experience (OPEX) in combination with Generic Design Assessment (GDA) data.

Through analysis of hazards that could induce LOOP Reference [27] provides confidence that the SZC grid connection design itself does not provide a significant contribution to the LOOP frequencies and that the accepted SZC site specific LOOP frequencies (which are dominated by the contribution from external hazards) are appropriate. Further, the accepted SZC LOOP frequencies (as shown below) are not significantly different to those for HPC for any class of LOOP [Ref. 3].

LOOP Event	Frequency Per Reactor-Year (pry) / Per Reactor Trip (prt)	Basis
Short LOOP (Lasting up to 2 hours)	[redacted]	Historical U.K. OPEX from British Energy and Nuclear Reactor operation
Long LOOP (Lasting between 2 and 24 hours)	[redacted]	
Extended LOOP (Lasting between 24 and 192 hours)	[redacted]	Generic Design Assessment (GDA)
Consequential LOOP (Where a reactor trip causes a LOOP)	[redacted]	GDA – Based on Sizewell Data

Table 5: SZC LOOP Frequencies

Reference [27] also considers the impact of climate change on LOOP frequencies. It concludes that due to the redundancy in the SZC Grid Connection design, any increase to LOOP frequency as a result of climate change will be small and, due to the nature of climate change, will occur over relatively large timescales, such that changes to the safety case or design can be implemented if required through periodic safety reviews.

2.8 Local Industrial Environment and Transportation

The industrial environment local to SZC, including fixed installations, road transportation and shipping, has been assessed with respect to the potential impact on nuclear safety [Ref. 32]. A general description of the local industrial environment is discussed hereafter, and site-specific data relevant to hazards resulting from the Local Industrial Environment and Transportation is provided in Section 3.4.

2.8.1 Fixed Industrial Installations

The following local industrial installations were identified in Reference [32]:

- SZB – classified as a lower tier Control of Major Accident Hazards (COMAH) site, with a close boundary to the SZC site. SZB is an operational nuclear power station with a single four loop PWR.
- The next nearest COMAH site is some 29 km away.
- No records of chemical plant or chemical production facilities were identified within a 10 km radius of the SZC site.

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- No explosive handling facilities were identified within a 10 km radius of the SZC site. However, it is noted that there is potential for unexploded World War II (WWII) ordnance to be located off the coast of the SZC site.

2.8.2 Fixed Oil and Gas Networks

The assessment in Reference [32] investigated the local oil and gas networks, the following can be noted:

- No records of refineries were identified within a 10 km radius of the SZC site;
- No records of oil exploration activity in the vicinity of SZC site have been identified;
- No records of existing pipelines were identified within a 5 km radius of the site; the nearest National Grid high pressure gas pipeline runs over 30 km from the SZC site.

2.8.3 Road Transport

The existing main access road serving Sizewell is the minor road “Sizewell Gap”, which runs from Sizewell through the village of Leiston and then joins the B1069. The Sizewell Gap is an unlit, single carriageway rural road. It is subject to the national speed limit for such roads of 60 mph. The nearest motorway is the M11 which is over 90 km to the west of the SZC site. Hazards presented by this motorway are not considered further based on the distance from the site. The A12 road is over 9 km to the west of the SZC site and is a major trunk road.

The construction of SZC requires a dedicated access road during construction and operation. The new access road will link from the north of the main development site platform to the B1121 via a new roundabout junction off the B1122 to the west. The access road route follows the alignment of the construction haul road. During SZC operation it will be an unlit single carriageway with footpath/cycle track on one side.

The SZA site is in the ‘Care & Maintenance Preparations’ phase. During this phase, the site is considered to be in a passive state with some vehicle activity on site as materials are delivered and removed. It is considered that such hazards are bound by those associated with road deliveries to the SZB and SZC sites. Hazards associated with deliveries to the SZB and SZC sites are discussed further in Section 3.4.

2.8.4 Rail Transport

The nearest railway line is located over 1 km from the SZC site. However, this branch line was closed to general passenger and freight trains in the 1960’s. It is currently only used for the transportation of building material and nuclear flasks for the Sizewell power stations. The main line, which may be used to transport hazardous materials not destined for the Sizewell power stations, is over 7 km from the SZC site. However, such hazards are not considered to pose a risk to the SZC site based on the distance from the site.

The construction of the Sizewell C Project will necessitate the delivery of substantial amounts of construction materials including (but not limited to) aggregates, cement, reinforced steel, and containerised goods. SZC Co. has developed proposals for the use of rail in the delivery of freight during the construction phase of the Sizewell C Project, reducing heavy goods vehicle (HGV) movements on local roads. The proposed development would be used by SZC Co. during construction of the Sizewell C Project to transport materials to the Sizewell C main development site. A temporary rail extension (green rail route) of approximately 4.5km is proposed from the existing Saxmundham to Leiston branch line to a terminal within the main development site. Once the green rail route is no longer required for the construction of the Sizewell C Project, it will be removed and the land reinstated.

2.8.5 Shipping

Shipping heading to the Port of Felixstowe, Port of Lowestoft and other commercial ports pass the SZC site. A summary of potential hazardous shipping vessels passing within 10 nautical miles of the SZC site over a 12-

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month period has been provided in Reference [33]. The minimum closest point of approach (CPA) of any hazardous cargo is approximately 3.5 km from the SZC site, although for Liquefied Petroleum Gas (LPG) / Liquefied Natural Gas (LNG) carriers this is much further at around 11.8 km.

Reference [33] shows the vessel types within 10nm of SZC. The vessels have been grouped into; fishing, military, dredger/subsea, High Speed Craft, tug, passenger, cargo, tanker, other, recreation, oil and gas and wind farm. Cargo vessels contributed the largest proportion of vessel types (32%), followed by wind farm related vessels (23%). Cargo vessels and tankers contributed 39% of all vessels passing within 10nm of the location.

Hazards associated with shipping are discussed further in Section 3.9.

2.8.6 Aviation

Five airfields have been identified within a 20km radius of the SZC site [Ref. 6]. Of these, three have been found to be disused. The remaining two are both unlikely to be used for a significant number of regular movements as one is an old Royal Air Force (RAF) airfield closed in 1993, while the army announced that the other airfield is to close by 2027 [Ref. 6].

3 SITE DATA FOR EXTERNAL HAZARDS

3.1 Introduction

3.1.1 Purpose

External hazards are natural or man-made events originating outside of the proposed site boundary, or otherwise outside of the control of the future Licensee, that could pose a threat to nuclear safety. As the range of hazards and their magnitudes is in general site-specific, the purpose of this section is to:

1) Summarise the site investigations which have been carried out in order to characterise the site-specific external hazards;
2) Present and justify the design basis of each external hazards to be considered in the SZC design and future safety reports.

3.1.2 Terminology

In order to ensure a consistent use of terminology throughout this report and the SZC project, the following key statistical terms are defined:

- Percentile or Centile: a value representing a point below which a given percentage of observations in a dataset falls.
- Quantile: a value representing a point below which a given proportion of observations in a dataset falls. It should be noted that the 84th quantile and 84% centile are equivalent definitions for the same point.
- Best estimate: an estimate (e.g. of a parameter or return level) derived from a statistical model which fits the observed data best.
- Median: the value separating the higher half from the lower half of a probability distribution.
- Confidence Interval (CI): A range of values within which the true value is found with a stated level of confidence: a CI can be represented by a range of values above a lower stated quantile and below an upper stated quantile (e.g. for the 70% CI, the true value will be contained between the lower bound and upper bound 7 times out of 10).

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3.1.3 Requirements

The approach for the characterisation of external hazards and selection of design basis events has been set in accordance with the NNB GenCo Nuclear Safety Design Assessment Principles (NSDAPs) [Ref. 34]. Under this approach, the following requirements have been set for the definition of design basis external hazards:

a) All natural hazards with an Initiating Event Frequency (IEF) greater than 1.0E-4 per annum (p.a.), or man-made hazards with a frequency greater than 1.0E-5 p.a., which pose a threat to nuclear safety shall be included within the SZC safety analysis as a design basis external hazard.

b) Where amenable, for each external hazard included within the design basis, a design basis hazard level shall be defined corresponding to the conservatively derived, 84th quantile, site specific hazard with an IEF of 1.0E-4 p.a. for natural hazards or 1.0E-5 p.a. for man-made hazards.

c) For those natural hazards potentially susceptible to climate change, the design basis hazard level shall include an allowance for Reasonably Foreseeable climate change. For HPC this was defined as an allowance in line with the UK Climate Projections Science Report 2009 (UKCP09) Medium Emissions Scenario' (based on the Intergovernmental Panel on Climate Change (IPCC) emission scenario A1B) incorporating at least 84% of the uncertainty in the scenario, and accounting for the full lifetime of the plant. UKCP18 which replaces UKCP09 provides updated climate change projections using the latest climate change science, modelling, and understanding. A specific analysis has been undertaken to determine how reasonably foreseeable climate change should be defined in the context of UKCP18 [Ref. 35]. It concludes that reasonably foreseeable climate change is defined as an allowance in line with the UKCP18 scenario RCP8.5 incorporating at least 50% of the uncertainty (50th centile) in the scenario, and accounting for the full lifetime of the plant.

For external hazards that are not amenable to the derivation of a design basis event based on frequency and magnitude relationships, the appropriate codes and standards are used to define the level of plant protection.

3.1.4 Methodology

In order to meet the requirements defined above, the characterisation of external hazards is conducted in a staged process.

Stage 1 – Identification of External Hazards

A hazard identification, screening, rationalisation and grouping exercise was carried out in 2015 to identify potential external hazards affecting the SZC site [Ref. 4]. This list was based on a thorough review of international practice and recommendations with consideration of the applicability of each hazard to SZC. The list of hazards considered within this sub-chapter is aligned with the outcome of this regrouping exercise – see Appendix A – Justification of SZC SDSR External Hazards List for further details.

Stage 2 – Site-specific Hazard Characterisation and Definition of Site Challenge

For each hazard incorporated within the design basis, site-specific, or if this is not appropriate, best available relevant data is used to determine the relationship between event magnitudes and their frequencies. Using this relationship, the site challenge is defined as the 84th quantile, site-specific hazard level with an IEF of 1.0E-4 p.a. (or 1.0E-5 p.a. for man-made hazards), including an allowance for Reasonably Foreseeable climate change where appropriate.

For the most safety-significant external hazards (i.e. those with potentially widespread or significant consequences, such as seismic and coastal flooding), a more conservative site challenge may be defined by aligning it with a higher CI.

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The equivalent HPC site challenge for each hazard is also identified (where appropriate) in the SDSR for comparison reasons. It should be noted that in general the HPC site challenge is defined as the best estimate, site specific hazard level with an IEF of 1.0E-4 p.a.

Stage 3 – Selection and Justification of Design Basis Hazard Level

As discussed in Section 1.3, the replication strategy for SZC involves the adoption of HPC design basis values where possible. As such, where relevant, a comparison is made between the SZC site challenge and the HPC design basis value. The HPC design basis value is adopted where it bounds the SZC site challenge and where there has been no significant erosion of safety margins between the SZC site challenge and the HPC design basis compared to the HPC site challenge and the HPC design basis. Where this is not the case, appropriate justification for the adoption of the HPC design basis values is included in Section 3.

Stage 4 – Identification of Inherent Margin within the Design Basis

Within the scope of the external hazards safety analysis, it is necessary to consider the impact of beyond design basis events, i.e. external hazards with a larger magnitude (and hence generally lower frequency of occurrence) than those accounted for in the design basis. The purpose of considering these events is to demonstrate that there are no “cliff-edge” effects from external hazards of magnitudes beyond the design basis.

In order to conclusively demonstrate an absence of cliff-edge effects an accurate design of Structures, Systems and Components (SSCs), including knowledge of fragilities, is required. This is outside of the scope of the SDSR; however, it is possible to gain preliminary confidence by quantifying the different components of the margin between the site challenge and the level at which a potential cliff-edge may be reached (i.e. some level beyond the design basis). This margin can be thought of as the combination of three components:

1) Inherent Margin, defined as the margin between the site challenge and the SZC design basis (i.e. this is the difference between the outputs of Stages 2 and 3 above).
2) Margins incorporated through the use of conservative methodologies, for example in the conversion of a meteorological phenomenon to a design parameter (load case).
3) Margin between the SZC design basis and the hazard magnitude at which a cliff-edge may occur.

Generally, the scope is limited to the identification of Inherent Margins. However, preliminary discussion of beyond design basis external flooding is also included.

3.2 Earthquake

3.2.1 Ground Motion

3.2.1.1 Description of Hazard and Historical Context

‘Ground Motion’ refers to the acceleration at surface level experienced during an earthquake. This ground motion can have a direct impact on NPPs due to the energy imparted onto safety related SSCs and also lead to indirect effects due to the consequential failure of non-safety related SSCs.

The region of Suffolk in which the SZC site is situated is associated with a low level of seismicity. The site overlies the northeast edge of the relatively stable Anglo-Brabant Platform, which is a crustal block that extends from Wales to Belgium and has, as its core, the Midland Massif. This crustal mass is believed to have suffered only limited deformation in at least the past 300 million years. The Anglo-Brabant platform is bounded by zones of more pronounced deformation. Some distance to the northeast of Sizewell the platform is bounded by the edge of the North Sea Basin, to the south, the platform is bounded by the Variscan Front, and to the west of the Sizewell area the platform merges with the Midland Massif. The NW-SE Caledonian structural trend is assumed to have dominated the orientation of faulting that is currently

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seen onshore and in seismic sections offshore within these Mesozoic and later rocks. Within the Sizewell Region there are some NW-SE orientated normal faults identified in the Tertiary sequence which are reported to have considerable lateral persistence but relatively minor vertical offsets. Local perturbations in the strata surfaces were within the expected tolerances and were deemed not to be attributed to, or associated with, faults.

The seismic hazard at SZC was characterised using a Probabilistic Seismic Hazard Assessment (PSHA) study [Ref. 115] and [Ref.120] in line with Relevant Good Practice.

The earthquakes hazard characteristics characterised in this Section are:

- Design Basis Earthquake (DBE). The identified risk arising from a DBE is direct or indirect damage to equipment needed to bring the plant to, and maintain it in, a safe shutdown state. Indirect damage is associated with the failure of adjacent equipment or structures, or consequential internal hazards resulting from the earthquake.
- Minor earthquake (or inspection earthquake or operating basis earthquake), The approach for minor earthquakes is to define an "Inspection Earthquake" level below which there will be no requirement for specific inspection or verification of the safety significant components before continued normal operation or return to service. If the Inspection Earthquake level is exceeded, an inspection procedure is followed to determine if the Plant has to shut down.

3.2.1.2 Site Evaluation Studies

3.2.1.2.1 Present Day

The SZC specific Capable Faulting Studies (CFS) and PSHA study [Ref. 120] represent a detailed understanding of the ground motion seismic hazard Site Challenge. This programme of work was carried out according to modern techniques and standards; key aspects in achieving this were the use of modern data, techniques and seismic hazard calculations, expert elicitation, logical treatment of uncertainties, and peer review and oversight.

The results of this PSHA are presented in the form of a Uniform Hazard Spectrum (UHS) which gives the frequency-dependent response at a given return period and confidence level.

Horizontal UHS were produced for both onshore and offshore regions, with outputs at 12 frequencies ranging from 0.33 Hz to 100 Hz, five confidence levels ranging from the 5th percentile to the 95th percentile and four return periods ranging from 1,000 years to 1,000,000 years [Ref. 115].

The vertical component of the ground motion was derived using vertical-to horizontal spectral acceleration (V/H) ratios calculated using empirical models. These models allow the vertical UHS to be estimated at an equivalent return period and confidence level to the corresponding horizontal UHS.

3.2.1.2.2 Climate Change Allowance

There is no direct effect of climate change on seismic activity, so it is not be considered in the definition of the site challenge.

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3.2.1.3 SZC Site Challenge

The results of the SZC PSHA in the horizontal and vertical directions are shown in Figures 6, 7, 8 and 9, which are taken from [Ref. 115]. The mean UHS for AFoEs of 10^{-4} and 10^{-5} are compared with the site-specific ground-motion response spectrum (GMRS) as defined in RG 1.208 (UNSRC, 2007). The 84th percentile hazard response spectrum for the 10^{-4} Annual Frequency of Exceedance (AFoE) is also plotted for comparison. A good agreement between the latter and the GMRS is observed, confirming that the spread of the hazard percentiles captures the epistemic uncertainty in a manner consistent with the slope of the mean hazard curves considered in the GMRS computation. Figures 6, 7, 8 and 9 show that the SZC onshore and offshore 84th response spectrum at the target level horizon for AFoE of 10^{-4} and the GMRS are bounded by the SZC DBE. The interim SZC DBE has now been confirmed as the SZC DBE [Ref. 38]. Therefore, where Figures 6, 7, 8, and 9 indicate the SZC Interim DBE, this should be taken as the confirmed SZC DBE [Ref. 38].

[redacted]

Figure 6 – [redacted]

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[redacted]

Figure 7 - [redacted]

[redacted]

Figure 8 - [redacted]

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[redacted]

Figure 9 - [redacted]

3.2.1.4 SZC Design Basis

3.2.1.4.1 Design Basis Definition

The final definition of the Site Challenge has permitted the confirmation of the previously termed “interim Design Basis Earthquake (DBE)” as the final SZC DBE hazard spectrum, which will be applied in the seismic analysis and design of SZC SSCs [Ref. 119].

[redacted]

The work done to characterise the ground motion seismic hazard, which has resulted in the production of the PSHA study and the SZC specific DBE, provides a high degree of confidence that this hazard does not preclude the site from providing secure long-term support to the necessary SSCs.

3.2.1.4.2 Inspection Earthquake Definition

The Inspection Earthquake spectrum corresponds to the SZC site-specific spectrum scaled to 0.05g Peak Ground Acceleration (PGA). Assessing the Inspection Earthquake load case as “1/3 of SZC site specific Design Basis Earthquake” load case is an acceptable option and is in line with IAEA guidance.

The Alert Earthquake is defined as a horizontal or vertical acceleration of 0.01 g measured on the structures.

3.2.1.4.3 Justification of Design Basis and Inherent Margins

In terms of safety, there is no requirement to have margins above the UHS spectrum. However, given that the 84th response spectra are close to the SZC DBE (particularly around 1Hz), some additional arguments for the validity of the SZC DBE are presented hereafter:

- There are significant margins across most of the frequency range.

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- For the NI, the SZC free field DBE is considered directly at foundation level without deconvolution, which means any attenuation of the ground motion from the deconvolution process is ignored.
- THs generation with respect to ASN 2.01 guidelines induces an average margin of 4% to 5% on the whole frequency range of the DBE. Any analysis that uses THs as an input will therefore have an approximate 4% margin embedded in.
- Soil structure interaction analyses cover significant uncertainties in the soil column modulus and in structure response, which prevent over dependence on a single frequency range. SSCs do not have mono-modal behaviour, so the frequency range of interest is wide and if one main mode lies at a frequency with very little margin, other modes will likely have significant margins.

3.2.2 Long Period Ground Motion (LPGM)

3.2.2.1 Description of Hazard and Historical Context

LPGM, defined as the ground motion associated with an earthquake at low frequencies (1 Hz and below), may induce a response in SSCs with modes at low frequencies. Due to its unique effects and the difficulty in characterising the hazard using traditional PSHA (which tends to be dominated by near field earthquake sources with high frequency responses), LPGM is generally considered a separate albeit infrequent hazard relative to the ground motion described in section 3.2.1.

3.2.2.2 Site Evaluation Studies

3.2.2.2.1 Present Day

LPGM in the UK was investigated by the Central Electricity Generating Board (CEGB) in 1985. The CEGB found that, at the 1 x 10-4 p.a. level, sources of LPGM affecting the UK would be limited to surface wave magnitudes below 8.6 and distances beyond 15° (~1,600 km). On this basis, the CEGB used semi-empirical techniques to produce response spectra for the UK between 0.01 Hz to 0.5 Hz. A subsequent review of the CEGB spectra has concluded that they are accurate for frequencies below 0.1 Hz [Ref. 118]. Above this frequency, it is recommended to use empirical Ground Motion Prediction Equations (GMPEs) to characterise the LPGM hazard.

The GMPEs proposed for the LPGM site challenge are consistent with those selected during the SZC PSHA (described in section 3.2.1) and in [Ref. 116].

3.2.2.2.2 Climate Change Allowance

There is no direct effect of climate change on seismic activity, so it is not be considered in the definition of the site challenge.

3.2.2.3 SZC Site Challenge

The site challenge is defined by the response spectra produced by the CEGB in [Ref. 118] and the selected GMPEs presented in Section 2.1.4 of [Ref. 116].

3.2.2.4 SZC Design Basis

3.2.2.4.1 Design Basis Definition

Although [Ref. 118] was written for HPC, given the nature of the LPGM hazard, it can be considered as equally applicable to SZC:

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This leads to the following conclusions:

- For SSCs that respond above 0.25 Hz, LPGM is bounded by the generic Ground Motion hazard, and so no LPGM hazard analysis is required.
- For SSCs that respond below 0.25 Hz, an assessment is required against the LPGM site challenge defined in 3.2.2.3 above.

3.2.2.4.2 Justification of Design Basis and Inherent Margins

As events contributing to LPGM occur hundreds of kilometres away from both HPC and SZC, and are driven by path effects, the eventual long period motion can be considered similar for both HPC and SZC sites. Surface waves of such long periods are essentially sensitive to crustal scale structures and are not likely to be affected by the shallow ground below the site. Regarding the presence of sedimentary basins along the path, they would only have a local effect on the amplitude of ground motion due to the wave entrapment within the basin, so it would not affect the SZC site.

3.2.3 Liquefaction

3.2.3.1 Description of Hazard and Historical Context

Liquefaction is the process by which a saturated soil, when put under sudden stress, loses stiffness and begins to behave as a liquid. Were this to happen to the foundation material for civil structures, this could lead to significant structural damage.

3.2.3.2 Site Evaluation Studies

3.2.3.2.1 Present Day

An assessment of the potential for liquefaction at the SZC site has been carried out [Ref. 113], also taking into consideration the work done previously within the scope of the pre-application report [Ref. 114]. The assessment is in two steps: firstly, an assessment of whether the material (foundation or fill) is susceptible to liquefaction, and secondly whether the material will liquefy under the site-specific hazard conditions.

The liquefaction susceptibility of the materials is assessed using the general recommendations of Eurocode 8, part 5. For natural ground, the demonstration is made that the excavation design within the cut-off wall area will address the risk of liquefaction, by removing the unsuitable recent deposits and the top of Norwich Crag formation that does not present a sufficient resistance.

The Theoretical Bottom of Excavation (TBOE) is defined based on two criteria:

- A geological criterion which considers the removal of all the Recent Deposits and non-competent upper Norwich Crag in the CoW area ("Stratigraphy criteria").
- A geotechnical criterion which considers the absence of risk of liquefaction under seismic conditions within the Norwich Crag layer ("Liquefaction criteria").

This highlights that the absence of liquefaction is an input for the definition of the excavation level, and not a consequence from a pre-set excavation level.

Concerning engineered backfills, the various types of fills that are planned to be used for the construction of the site are not subject to the risk of liquefaction: either they are by nature not subject to the phenomenon (for bound fills with high technical requirements), or they are designed to reach a sufficient level of strength (design by performance) to withstand liquefaction and offer acceptable Factor of Safety against Liquefaction. In relation with the absence of liquefaction within the backfill, the earthquake induced settlements within

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these engineered materials are calculated as being negligible or very limited (order of magnitude only of few millimetres).

The risk of liquefaction is absent from the Sizewell C site due to the Design considerations that will be implemented on the project: strategy for the excavation of potentially liquifiable materials, and the design of backfills.

Outside of the cut-off wall the risk of liquefaction is being investigated separately, as there are no plans to remove the recent deposits before founding structures such as the sea defence. Instead, ground strengthening schemes are being proposed, such as rigid inclusions or deep soil mixing to support the sea defence structure. If the ground is found to be liquefiable the ground strengthening solution and associated structural analysis will be adapted accordingly.

3.2.3.2.2 Climate Change Allowance

Climate change does not have an impact on liquefaction, beyond the impacts on groundwater level, which are discussed in section 3.5.3.

3.2.3.3 SZC Site Challenge

There is a risk of liquefaction at the SZC site. Nevertheless, this risk is managed due to the design considerations that have been implemented, i.e., the strategy for TBOE definition and design of the performances of backfills

3.2.3.4 SZC Design Basis

3.2.3.4.1 Design Basis Definition

Liquefaction is treated as a design basis hazard that is managed through design considerations as discussed above.

3.2.3.4.2 Justification of Design Basis and Inherent Margins

Due to the nature of the hazard, a design basis level for liquefaction is not defined. Therefore, no inherent margin is defined.

3.2.4 Capable Faulting

3.2.4.1 Description of Hazard and Historical Context

An assessment of the capability of fault movements in or around the SZC location was carried out in Reference [117], in line with the PSHA.

3.2.4.2 Site Evaluation Studies

3.2.4.2.1 Present Day

The IAEA and ONR define a capable fault as one that has a significant potential for any displacement at, or near, the ground surface. To identify such faults, the following two stage process was followed:

- Stage 1: Regional geological datasets were used to identify Prominent Basement Structures that occur within the Mid Region and might have extended into the Near Region (Sections 2 and 3). Site-specific geophysical surveys were used to screen the Site Vicinity for similarly large structures (Section 4). As a guide, structures that might potentially cause a capable faulting hazard would be expected to be at least 3 km long. This is the minimum expected fault length

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that would be able to host a 5+ Mw earthquake, and 5 Mw is generally considered to be the minimum magnitude that might lead to a surface rupturing event. Typical published scaling relationships indicate that the rupture area for a 5.0 Mw event would be around 10 km^2. Faults or structures (e.g., that may represent blind faults) less than 3 km long would be unlikely to have significant potential for displacement at or near the ground surface, and were screened out

- Stage 2: For any fault that occurs in the Site Vicinity that can't be screened out on length, identify whether there is any evidence for:
    - Vertical displacement of Pliocene or Quaternary strata that overlies the fault
    - The fault being associated with one or more 3+ Mw earthquakes.

No tectonic faults of note that might have potential to generate 5+ Mw earthquakes have been identified within or close to the Site Area. Minor faulting (vertical displacements typically <5 m) has been identified and movement on these faults occurred between ~53 million years ago and 3 million years ago, but has not, and cannot be, constrained further due to the limitations of the available evidence. From a detailed appraisal of all relevant regional geological evidence, the movement would have most likely occurred between ~36 and ~20 million years ago.

The absence of any evidence for capable faults at the SZC site is consistent with the conclusion of the SZC seismic source model.

3.2.4.2.2 Climate Change Allowance

Climate change does not have an impact on capable faulting, beyond the impacts on groundwater level, which are discussed in section 3.5.3.

3.2.4.3 SZC Site Challenge

There are no capable faults in the site area. The capable faulting hazard at the site is considered insignificant.

3.2.4.4 SZC Design Basis

3.2.4.4.1 Design Basis Definition

Based on the absence of a credible site challenge, capable faulting is screened out as a design basis hazard at SZC.

3.2.4.4.2 Justification of Design Basis and Inherent Margins

Various investigation methods, fieldwork, desk-top studies, and laboratory studies were considered throughout the course of the capable faulting study [Ref. 117]. Each one was evaluated to determine its potential to provide further information to help assess the capable faulting hazard and progressed where it was proportionate to do so. Following the detailed study, the capable faulting hazard at the site was deemed to be insignificant.

3.3 Accidental Aircraft Crash

3.3.1 Description of Hazard and Historical Context

Accidental aircraft crash relates to a non-malicious aircraft impact onto the SZC site. Malicious aircraft crash will be covered by the SZC security case.

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There are no major aerodromes, licensed civil airfields, unlicensed airfields nor military airfields within 20 km of the SZC site that will be open beyond 2027. The Department for Transport imposes restrictions on flying in the vicinity of all existing nuclear power stations in the UK. For Sizewell, the restricted area takes the form of a circle of radius 2 nautical miles up to an altitude of 2000 ft above mean sea level, centred on the point 521250N 0013707E, and identified as R217 on aeronautical charts [Ref. 6]. This restricted area does not apply to aircraft using the existing SZB helipad, subject to obtaining permission from the on-site controller.

3.3.2 Site Evaluation Studies

3.3.2.1 Present Day

A 2014 study [Ref. 5] provides background and airfield-related crash rates in mainland UK for the period 2001 to 2012 (with a larger period of 1988 to 2012 used for large transport aircraft in order to capture more events).

For the purposes of crash risk assessments, aircraft are classified into different categories because of the different flying characteristics and reliabilities of different types of aircraft. Also, impact characteristics such as mass and velocity can be very different from one aircraft to another, which affects the consequences of a crash. The five aircraft categories usually considered are as follows:

- Light civil aircraft: fixed wing aircraft generally falling into the Civil Aviation Authority (CAA) classification of less than 2.3 tonnes Maximum Take-off Weight Authorised (MTWA). This category also includes light military aircraft used for training and which are less than 2.3 tonnes MTWA.
- Helicopters: all civil and military helicopters.
- Small transport: fixed wing aircraft covering the mass range 2.3 tonnes to 20.0 tonnes MTWA, including civil and military transport aircraft.
- Large transport aircraft: any other fixed wing aircraft, civil or military, not covered in the light aircraft, small transport or military combat and jet trainer categories.
- Military combat and jet trainers: all military fixed wing aircraft with MTWA up to 40 to 50 tonnes used for, or capable of, aerobatics style flying.

Given that the background aircraft crash rates are based on data from across the UK, it is necessary to review their applicability to SZC. A study [Ref. 6] has been produced to consider the impact on the aircraft crash rate of the aeronautical features local to SZC, including:

- Airfields and Airports;
- Airways (flight-paths);
- Military activity;
- Areas of Intense Aerial activity;
- Airspace restrictions;
- Proposed Helipad at SZC (that is no longer planned).

The conclusion of this study is that the use of background crash rates is conservative, i.e. they bound the expected contribution from the above features. Therefore, the background crash rates are used in the definition of the site challenge for SZC.

Note that currently, there is no helipad planned for SZC. It is anticipated that the helipad currently used for SZB is to be removed. It is possible that a future helipad could be located somewhere off-site and if one were to be constructed it would be for use in emergencies only. However, it would require safety consideration regarding effects on crash rates for SZC.

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3.3.2.2 Climate Change Allowance

Climate change is not believed to have a direct impact on the hazard and, as such, is not considered in the definition of the site challenge. Although climate change is not considered, trends in aviation activity have been reviewed and indicate a decreasing crash rate, supporting the use of current background crash rates [Ref. 6].

3.3.3 SZC Site Challenge

As discussed above, the site challenge is based on background crash rates. The background crash rates for the UK, calculated based on data from the period 2001 to 2012, are shown in Table 6 below [Ref. 6].

Aircraft Category	Crash Rate (km^{-2} y^{-1} x10^{-5})
Light aircraft	1.76
Helicopters	0.97
Small transport aircraft	0.06
Large transport aircraft	0.08
Military combat aircraft	0.28
Total	**3.19**

Table 6: Background crash rates for the period 2001 – 2012.

3.3.4 SZC Design Basis

3.3.4.1 Design Basis Definition

Based on the crash rates presented in Table 6, an accidental aircraft impact of any type on the SZC site has an approximate annual frequency of 1.0E-5 p.a. Therefore, it is chosen to incorporate accidental aircraft crash as a design basis hazard for SZC using the UK background crash rates. Accidental drone crash will also be considered as part of the accidental aircraft crash hazard.

3.3.4.2 Justification of Design Basis and Inherent Margins

Based on the approximate frequency of occurrence, accidental aircraft crash is incorporated as a design basis hazard at SZC in accordance with the requirements set out in Section 3.1. As the Site Challenge is defined probabilistically, it is not possible to quantify any Inherent Margin.

3.4 Hazards Associated with the Industrial Environment

3.4.1 External Explosion

3.4.1.1 Description of Hazard and Historical Context

External explosion refers to an accidental explosion occurring offsite leading to an airborne pressure wave. The hazard posed by underwater explosions is considered separately in Section 3.9.8. Potential sources of external explosions around the SZC site include nearby industrial sites, shipping, and road transportation.

3.4.1.2 Site Evaluation Studies

3.4.1.2.1 Present Day

A review of the industrial and transportation sources local to SZC and an assessment of the consequences, including external explosions, has been carried out [Ref. 32 and 40]. The explosion can result from the

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ignition of flammable gas or the rupture of a vessel containing compressed gas or superheated liquid. The following hazard sources identified were:

Shipping:

- Ammonium nitrate, combustible fertiliser in drifting ship off the coast of the SZC site;
- LPG, liquefied flammable gas in drifting LPG tanker off the coast of the SZC site;
- Oil Tanker off the coast of the SZC site.

Road Transport:

- Carbon dioxide, delivery route on SZB;
- Hydrogen, delivery route on SZB;
- Hydrogen, delivery entrance to SZC;
- Nitrogen, delivery entrance to SZC;
- Nitrogen, delivery route on SZB.

SZB Storage:

- Carbon dioxide, cryogenic storage on SZB;
- Hydrogen, hydrogen trailer storage on SZB;
- Nitrogen, cryogenic nitrogen storage on SZB.

Of the sources identified, References [32] and [40] recognise the following as having the potential to affect nuclear safety on the proposed SZC nuclear licensed site:

- Ammonium nitrate, combustible fertiliser in drifting ship off the coast of the SZC site;
- LPG, liquefied flammable gas in drifting LPG tanker off the coast of the SZC site;
- Oil Tanker off the coast of the SZC site;
- Hydrogen, flammable gas; delivery entrance to SZC (northern or southern site).

Ammonium nitrate and LPG explosions are not taken forward to the site challenge based on their low frequency of occurrence (i.e. below the design basis cut off of 1.0E-5p.a.). As indicated in Section 2.8.5 above, over a 12-month dataset period [Ref. 33], the minimum closest point of approach (CPA) of any hazardous cargo was around 3.5 km from the SZC site. For Liquefied Petroleum Gas (LPG) / Liquefied Natural Gas (LNG) carriers this is much further at around 11.8 km. At these distances, Reference [32] shows that the effects would be bounded by the design basis defined below in Section 3.4.1.4. At closer range, this would not be the case. However, the likelihood of a ship drifting towards SZC and causing an explosion in close enough proximity to affect nuclear safety would be extremely low and is considered to be below the design basis. For this to occur would require:

(1) total loss of power of a ship containing Ammonium nitrate or LPG in the shipping lanes adjacent to SZC [Ref. 32] indicates that the presence of such ships in these shipping lanes is relatively infrequent);
(2) inability of the coast guard to effect a rescue;
(3) the necessary conditions for the ship to drift towards the coast;
(4) the necessary conditions arising to support the formation of a potentially explosive scenario.

Analyses performed in Reference [40] demonstrates that the frequency of a ship explosion in close proximity (<200m) to the seawater intakes sufficient to affect nuclear safety is 1.88E-7p.a. This is below the man-made external hazards design basis cut-off of 1.0E-5p.a. and therefore requires no further assessment.

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3.4.1.2.2 Climate Change Allowance

There is no direct effect of climate change on either the frequency or magnitude of external explosions, so it is not considered in the definition of the site challenge. However, it should be noted that the operational lifetime of SZB will end before that of SZC and therefore some of the identified hazard sources will be removed in the future.

3.4.1.3 SZC Site Challenge

One hazard scenario is retained for the site challenge. That is a hydrogen explosion involving a delivery at the entrances to SZC (northern or southern site entrances) involving a single hydrogen cylinder. Reference [32] shows that the overpressure wave from this scenario will encroach onto the proposed licensed site and that a 100mbar overpressure contour has the potential to reach CI/BOP buildings (HOJ (Fire Fighting Water Distribution Building) at the northern entrance and HHK (spent fuel building at the southern entrance). Reference [32] shows that the impulse (time integrated over pressure acting on a structure) falls off to near negligible levels within a few metres of the source.

3.4.1.4 SZC Design Basis

3.4.1.4.1 SZC Design Basis Definition

The proposed design basis in terms of overpressure and impulse criteria, are the same as HPC.

The design basis is defined as a standard load case characterised by a triangular overpressure wave profile shaped with a vertical edge; maximum overpressure 100 mbar; duration time 300 ms (See Figure 10 below). Impulse associated with this standard load case is 15,000mbar.ms. For further details on how this design basis was applied in practice to the different geometry HPC buildings (and hence how it will apply to the SZC buildings) refer to HPC PCSR3 Sub-chapter 13.1, Section 4.2.1.1 [Ref. 39].

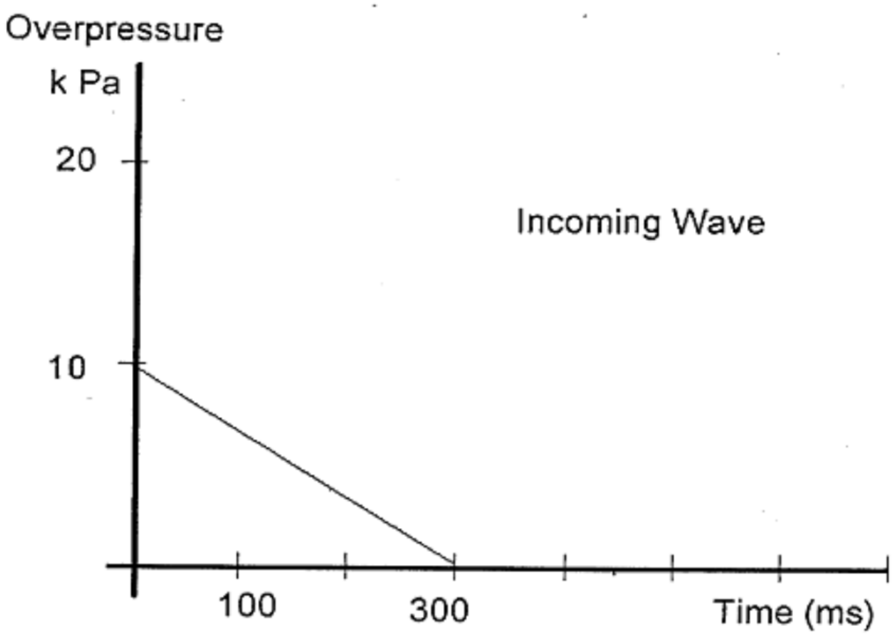

Figure 10: Standard Load Time Function for External Explosion Pressure Wave

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3.4.1.4.2 Justification of Design Basis and Inherent Margins

The design basis external explosion has been adopted from HPC and is equivalent to the site challenge experienced at SZC. It therefore provides a robust assurance that the hazard can be managed at SZC. As the design basis is set at the level of the site challenge, no inherent margin is identified.

3.4.2 External missiles

3.4.2.1 Description of Hazard and Historical Context

An external missile refers to an accidentally generated projectile released from a source outside of the SZC site boundary. Potential sources of external missiles are road transportation and local industrial sites, the latter including turbine missiles generated at SZB.

3.4.2.2 Site Evaluation Studies

3.4.2.2.1 Present Day

An assessment of external missiles from industrial and transportation sources local to SZC resulting from rupture of a storage vessel / an explosion, has been carried out [redacted] The following sources of missiles are assessed in [redacted]

Road Transport:

- Carbon dioxide, delivery route on SZB;
- Hydrogen, delivery route on SZB;
- Hydrogen, delivery entrance to SZC;
- Nitrogen, delivery entrance to SZC;
- Nitrogen, delivery route on SZB.

SZB Storage:

- Carbon dioxide, cryogenic storage on SZB;
- Hydrogen, hydrogen trailer storage on SZB;
- Nitrogen, cryogenic nitrogen storage on SZB.

Note that missile generation resulting from explosion of shipping containing ammonium nitrate or LPG is dismissed in Reference [32] on the basis that the nature / characteristics of these explosions would not generate significant missiles (See section 4.1.1 of Reference [32] for further details).

Reference [32] demonstrates that all potential missiles from Hydrogen, Nitrogen and Carbon dioxide storage would have a frequency of any fragment impacting the SZC site of <<1.0E-5p.a.

An assessment of impact frequencies associated with turbine missiles originating from SZB has been carried out [Ref. 41]. The equations of motion were modelled to calculate the range of initial ejection angles through which a missile must be ejected to hit a target. The strike frequencies were calculated by combining the IEF with missile numbers and the range of ejection angles for which a strike is possible. The assessment includes both normal overspeed failure and runaway overspeed failure modes of the low-pressure turbine rotor.

The strike frequencies of the representative SZC structures screened into the assessment are in the range of 1.0E-7p.a. to 1.0E-8p.a. Due to the orientation of the SZB turbines relative to the SZC site, low trajectory single impact probabilities are at least four orders of magnitude smaller than the high trajectory contribution.

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High trajectory missiles are primarily dependent on the plan area of the targets, where the larger the plan area, the greater the likelihood of a high trajectory turbine missile strike. The dry fuel store (HHK) is the bounding case for SZB missiles on SZC targets due to the structure's large plan area. An impact frequency of 2.49E-07p.a. has been estimated [Ref. 41]. However, the risk of a SZB turbine missile strike on HHK is less than implied by the strike frequency because dry fuel casks will only be stored in HHK after many years of operation. Furthermore, SZB will have ceased operation by the time HHK is fully occupied.

Based on the calculated results for HHK, HPF-U2, HR-U1 and HR-U2, all other safety-important targets on the SZC site are expected to have an impact frequency of the order of 1.0E-8p.a. or lower.

3.4.2.2.2 Climate Change Allowance

There is no direct effect of climate change on either the frequency or magnitude of external missiles, as such it is not considered in the definition of the site challenge. However, it should be noted that the operational lifetime of SZB will end before that of SZC and therefore some of the identified hazard sources will be removed in the future.

3.4.2.3 SZC Site Challenge

Given that sources of missiles from rupture of vessels / explosion are dismissed in [redacted] on low frequency grounds, the site challenge for external missiles is defined in terms of the building specific turbine missile impact frequencies given in Reference [41].

3.4.2.4 SZC Design Basis

3.4.2.4.1 SZC Design Basis Definition

Although the impact frequency of SZB turbine missiles on individual SZC targets is low, due to the significance of the hazard, turbine disintegration as a source of missiles is incorporated within the design basis. The characteristics of missiles generated from SZB turbines are given in Reference [41].

3.4.2.4.2 Justification of Design Basis and Inherent Margins

The SZC external missile design basis conservatively includes turbine missiles from SZB despite the low strike frequency. As the Site Challenge is defined probabilistically, it is not possible to quantify any Inherent Margin.

3.4.3 Off-site Fire

3.4.3.1 Description of Hazard and Historical Context

The most-likely sources of off-site fire able to affect SZC are the neighbouring sites (SZA and SZB) as well as deliveries to these sites and SZC. Non-industrial sources, such as woodland fire, are not considered due to the nature of the surrounding land (i.e. absence of woodlands etc.).

3.4.3.2 Site Evaluation Studies

3.4.3.2.1 Present Day

Reference [32] has identified the following potential off-site sources.

Road transport:

- Diesel fuel oil, delivery entrance to SZC;
- Diesel fuel oil, delivery route on SZB;
- Ethanolamine, delivery entrance to SZC;

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- Hydrogen, delivery route on SZB;
- Hydrogen, delivery entrance to SZC.

SZB Storage:

- Diesel fuel oil, Auxiliary Boiler Fuel Oil Tanks on SZB;
- Diesel fuel oil, Diesel Fuel Oil Bulk Tanks on SZB;
- Diesel fuel oil, Battery Charging Diesel Fuel Oil Bulk Tanks on SZB;
- Diesel fuel oil, Diesel Fuel Oil Day Tanks;
- Diesel fuel oil, Battery Charging Diesel Fuel Oil Day Tanks on SZB;
- Hydrogen, hydrogen trailer storage on SZB.

It is considered that the passive state of the SZA site (care and maintenance) during the period of operation of SZC should ensure that no significant off site fire hazard should arise from the SZA site. The off-site fire hazard from SZA to SZC is bounded by off-site fire hazards from SZB and road transport / delivery to SZB/SZC.

3.4.3.2.2 Climate Change Allowance

There is no direct effect of climate change on either the frequency or magnitude of off-site fire around the SZC site, as such it is not considered in the definition of the site challenge. However, it should be noted that the operational lifetime of SZB will end before that of SZC and therefore some of the identified hazard sources will be removed in the future.

3.4.3.3 SZC Site Challenge

Diesel Fires

The analysis presented in Reference [32] shows that it is possible for some buildings on the SZC site to be impaired due to a diesel fuel oil pool fire as a result of the catastrophic rupture of a diesel fuel oil road tanker. However, the frequency of such a scenario is above 1.0E-7p.a. but is below 1.0E-5p.a. For the bunded diesel pool fire on SZB, no buildings on the SZC site are impaired.

Ethanolamine Fires

The analysis presented in Reference [32] indicates that plant safety will not be threatened by an ethanolamine pool fire at the closest point of approach to the SZC site, since HUA and HUB are not safety significant buildings. Hazards associated with the carriage and storage of ethanolamine within the SZC site are covered by the internal hazards assessment.

Hydrogen Fires

The consequence assessment performed in Reference [32] indicates that a thermal radiation of 8 kW/m^2 (a French Regulatory threshold, which is conservatively chosen to be applicable to safety-classified buildings and structures, in order to provide protection to the target SCCs) would be exceeded on the SZC site due to a fireball. However, the fireball only lasts a very short time (<1 s) and therefore the extent of damage would be minimal, if any. The frequency of such a scenario is estimated as 2.29E-6p.a.

3.4.3.4 SZC Design Basis

Given the site challenge frequency is well below 1.0E-5p.a., it is not necessary to retain the above scenarios for inclusion in the design basis.

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3.4.4 Chemical Release (Including Radiological Release)

3.4.4.1 Description of Hazard and Historical Context

Chemical release (including radiological release) refers to the accidental release of harmful substances from man-made sources. The main sources are likely to be the neighbouring sites and road transport deliveries to this site as well as SZC. The impact of this hazard is primarily on the operators at SZC who could potentially be incapacitated.

3.4.4.2 Site Evaluation Studies

3.4.4.2.1 Present Day

Reference [32] has identified the following off-site sources.

Road Transport:

- Ammonium hydroxide, delivery entrance to SZC;
- Ammonium hydroxide, delivery route on SZB;
- Carbon dioxide, delivery route on SZB;
- Hydrazine, delivery route on SZB;
- Hydrazine, delivery entrance to SZC;
- Nitrogen, delivery route on SZB;
- Nitrogen, delivery entrance to SZC.

SZB storage:

- Ammonium hydroxide, storage on SZB;
- Carbon dioxide, storage on SZB ;
- Hydrazine, hydrazine storage on SZB;
- Nitrogen, storage on SZB.

Ammonium hydroxide and Hydrazine are toxic. Nitrogen and Carbon dioxide are not toxic but have the potential to asphyxiate the SZC operators if released in sufficient quantities.

Reference [36] assesses the radiological releases from SZB on SZC to assess the potential doses to operators in the Main Control Room (MCR).

Note that due to SZA being in a defueled state and fuel having been removed from site, SZB (an operational PWR) radiological releases are assumed to be bounding of SZA releases.

3.4.4.2.2 Climate Change Allowance

There is no direct effect of climate change on either the frequency or magnitude of chemical or radiological releases, as such it is not considered in the definition of the site challenge. However, it should be noted that the operational lifetime of SZB will end before that of SZC and therefore some of the identified hazard sources will be removed in the future.

3.4.4.3 SZC Site Challenge

Ammonium hydroxide
SZB deliveries

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The analysis presented in Reference [32] demonstrates that the release of ammonium hydroxide following the catastrophic rupture of the SZB delivery road tanker would result in the IDLH (Immediately Dangerous to Life or Health concentration threshold) for ammonia being exceeded on the SZC site, although only for a short time. However, the frequency of such a scenario is estimated as being below 1.0E-7p.a. Similarly, for a full-bore rupture of a transfer hose during transfer the IDLH concentration for ammonia would be exceeded on the SZC site. In this case the frequency of such a scenario is estimated at 8.0E-6 p.a. In addition, Reference [32] notes that use of the IDLH concentration may be significantly conservative.

SZB Storage

The analysis presented in Reference [32] demonstrates that the release of ammonium hydroxide following the catastrophic rupture of the SZB delivery road tanker would result in the IDLH concentration for ammonia being exceeded on the SZC site, although only for a short time. In addition, Reference [32] notes that use of the IDLH concentration may be significantly conservative. The frequency of such a scenario is assessed 8.0E-6 which is above the 1.0E-7 p.a. criteria for being screened out but is below 1.0E-5 p.a. criteria for inclusion in the design basis.

SZC Deliveries

The analysis presented in Reference [32] demonstrates that the release of ammonium hydroxide following the catastrophic rupture of a SZC delivery drum would result in the IDLH concentration for ammonia being exceeded on the SZC site, for deliveries at either the northern or the southern entrance. However, the frequency of such a scenario is estimated as being below 1.0E-7p.a.

Carbon Dioxide

The concentration of carbon dioxide on the SZC site, because of a catastrophic rupture of the delivery tanker or the storage tank on the SZB site, does not exceed the IDLH concentration for carbon dioxide.

Hydrazine

The analysis presented in Reference [32] indicates that the hydrazine IDLH concentration is exceeded over small areas of the SZC site, in particular reaching parts of the HHK building (Spent Fuel Building). However, it is not considered reasonably foreseeable that plant safety would be threatened by dispersion of hydrazine due to a catastrophic rupture of the delivery drum at the closest point of approach to the SZC site. The frequency of such an event is estimated as being <1.0E-5 p.a. In addition, Reference [32] notes that use of the IDLH concentration may be overly conservative, particularly when the concentration of chemicals is elevated for only a short duration such as in the event of a catastrophic release.

Nitrogen

The analysis presented in Reference [32] indicates that the concentration of nitrogen on the SZC site, as a result of a catastrophic rupture of a SZC delivery trailer pack cylinder, does not exceed 190,500ppm (Reference [32] calculates this value as the threshold for asphyxiation based on oxygen depletion as there is no agreed IDLH concentration for nitrogen). However, for the SZB storage vessel, a concentration of 190,500 ppm is only just exceeded for a few meters within the outer SZC security fence. Therefore, since a concentration of 190,500 ppm does not reach far onto the SZC site and certainly not as far as the Main Control Room or Remote Shutdown Station, this hazard can be screened out.

Radiological Release

Regarding radiological releases, the impact on SZC of an accidental release from SZB has been analysed and assessed [Ref. 36]. The assessment considers two source term (TS1 and TS2) that correspond to a frequency of occurrence of 1E-5p.a. and 1E-6p.a. respectively. The bounding design basis radiological release faults have frequencies and consequences as shown in Table 7 below.

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HVAC Flow Rate	TS1			TS2		
	Dose Rate Maximum (mSv/h)	8 Hour Integrated Dose (mSv)	14 Hour Integrated Dose (mSv)	Dose Rate Maximum ((mSv/h)	8 Hour Integrated Dose (mSv)	14 Hour Integrated Dose (mSv)
5,000 m^3/h	1.05E-2	4.36E-2	4.61E-2	1.58	6.27	6.75
2,500 m^3/h	5.11E-3	3.13E-2	4.09E-2	6.96E-1	4.1	5.17
No ventilation – 112m^3/h air renewal only	5.39E-2	1.47E-1	4.15E-1	7.3	23.1	61.1

Table 7: Dose rates and integrated doses in the SZC MCR for two bounding radiological releases from SZB corresponding to a frequency of 1E-5 p.a. and 1E-6 p.a.

3.4.4.4 SZC Design Basis

3.4.4.4.1 SZC Design Basis Definition

For each of the assessed chemical scenarios except the storage of ammonium hydroxide on SZB, the site challenge frequency is well below 1.0E-5 p.a., or the chemical release cannot threaten nuclear safety on SZC due to low concentration and low reach onto the SZC site (i.e. Main Control Room and Remote Shutdown station will not be reached by dangerous concentrations). It is therefore not necessary to retain the above chemical release scenarios for inclusion in the design basis from an external hazards point of view. For the storage of ammonium hydroxide on SZB, given the frequency of release being below 1.0E-5, the conservatisms in the assessment, and the very short duration the IDLH is exceeded, this chemical release scenario is also not retained as a design basis external hazard.

With regard to radiological release, the HPC design basis values for radiological releases from off-site sources will be adopted at SZC.

3.4.4.4.2 Justification of Design Basis and Inherent Margins

A SZC specific assessment of doses to SZC operators from a radiological release from SZB has been carried out and shows that doses to SZC operators following bounding SZB design basis radiological release faults are significantly lower than the doses received by HPC operators following HPB bounding design basis radiological release faults [Ref. 112]. Therefore, adopting the HPC design basis values at SZC is judged to be adequate.

3.4.5 Animal Infestation

Animal infestation (primarily insects and rodents) is associated with two particular hazards, the blockage of the air intakes or any other systems that require an air supply, and the loss of electrical equipment and insulation material by rodents. Seawater animals are treated in Section 3.9.5.

Due to the nature of the hazard, and no adverse OPEX from SZB, it is neither practical nor proportionate to assess it in a similar manner to other external hazards and, as such, the hazard is not subject to detailed characterisation. Instead, the hazard will be managed primarily by the use of good housekeeping practice that will be outlined in the SZC PCSR.

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3.5 External flooding

3.5.1 Coastal flooding

3.5.1.1 Description of Hazard and Historical Context

Being situated in a maritime environment, SZC is exposed to the risk of coastal flooding. The SZC site is naturally at a low elevation and the following are considered to represent reasonably foreseeable coastal flooding initiating events [Ref. 4]:

- Extreme still sea water level – this is a combination of high tide and events such as storm surge and barometric effects;
- Extreme waves – this includes all the surface waves that could overtop/erode sea defences and flood the SZC site platform and associated safety classified buildings;
- Tsunami – this is a high amplitude, long period wave that is created following a landslide or an undersea earthquake;
- Climate change (reasonably foreseeable).

The following hazards are not considered as coastal flooding hazard initiators:

- Seiche – the North Sea is too large for long period standing waves to occur [Ref. 4];
- Coastal erosion[5] – this phenomenon is a slow process that will be monitored during the lifecycle of the site and will be considered as part of the Coastal Process Monitoring and Mitigation Plan (CPMMP).

Present day tidal levels are almost fully deterministic and are defined in Section 2.4.4. However, coastal flooding can be due to more than tidal action alone. It can be caused by a high tide in combination with a positive storm surge and strong waves. While the sub-hazards are characterised individually, the protection provided against them is designed to be robust to appropriate combinations

Global warming is the ongoing rise of the average temperature of the Earth's climate system and is a major aspect of climate change. Climate change can result in higher wind speeds, higher wave heights and a rise in sea level. It is not considered as an individual hazard but as a contributor to the site challenge of individual hazards when those hazards could be affected by climate change.

3.5.1.2 Extreme Still Seawater Level

3.5.1.2.1 Site Evaluation Studies

Present Day

A number of studies have been carried out to estimate extreme sea water levels at Sizewell. The most recent was performed by EDF Energy R&D UK Centre using the latest available data [Ref. 48]. The assessment provides estimates of extreme still sea water levels at extreme return periods using the Skew Surge Joint Probability Method (SSJPM). SSJPM models the joint probability of skew surge and predicted high tide. Before using SSJPM, the analysis provides a review of the methods that can be used to characterise extreme still seawater level. It concludes that SSJPM (which is considered to be the most representative indicator of the meteorological impact on sea level) should be used because it resolves statistical challenges or over-conservatisms that exist within other approaches such as the Joint Probability Method.

In order to provide a present-day estimation of extreme still seawater level, data from Lowestoft, the closest location to the Sizewell site, was taken from the UK National Tide Gauge Network. Full details of the

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[5] There are two distinct mechanisms for coastal erosion: (i) erosion of the seabed and (ii) platform undercutting.

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statistical approach carried out using this data are available in Reference [48]. In order to account for the distance between Lowestoft and Sizewell a conversion factor based on data from the Environment Agency's (EA) Coastal Flood Boundary Report was applied. The very strong correlation between the results of the analysis and the EA model at Lowestoft reported in Reference [48] provide a very high degree of confidence that the conversion factor is accurate.

The present extreme still sea water levels at Sizewell derived in this study are presented in Table 8 below for return periods of 10 years up to 100,000 years.

Return Period (years)	Extreme Still Sea Water Level – 50th percentile (m AOD)	Extreme Still Sea Water Level – 84th percentile (m AOD)	Extreme Still Sea Water Level – 95th percentile (m AOD)
10	2.51	2.57	2.62
100	2.98	3.12	3.21
200	3.11	3.28	3.39
500	3.30	3.52	3.68
1,000	3.42	3.69	3.88
10,000	3.88	**4.34**	4.65
100,000	4.54	-	-

Table 8: Return levels and associated uncertainty percentiles of sea level at Sizewell based on the present climate (2019). The values are calculated by SSJPM analysis of data from Lowestoft tide gauge and adjusted to the Sizewell site using comparison with data from the EA model

Climate Change Allowance

Climate change allowances have been derived based on UKCP18 data. Further background information on the process followed for constructing the models and data sets used by the UKCP18 project to provide its marine data is available in Reference [48].

Climate change adjustment factors were estimated using the climate change scenario RCP8.5 [Ref. 48]. The results for the 10,000-year return period are presented in Table 9.

Year	Climate Change Adjustment Factor (m AOD)			
	50th Centile	70th Centile	84th Centile	95th Centile
2030	+0.08	-	-	+0.16
2050	+0.22	+0.26	+0.29	+0.34
2080	+0.48	+0.55	+0.63	+0.73
2090	+0.59	-	-	+0.89
2100	+0.69	-	-	+1.05
2110	+0.8	+0.91	+1.05	**+1.23**
2140	+1.13	+1.28	+1.48	**+1.75**
2190	+1.62	-	-	+2.58

Table 9: Climate change adjustment factors to be added to the present-day still water return levels (Table 8) to calculate the return levels based on climate change projections up to selected future years, derived using UKCP18 data. The uncertainty percentiles are based on the variability between model runs in UKCP18.

Reasonably foreseeable climate change is generally defined for the SZC project as RCP8.5 at the 50th percentile but for specific hazards, an alternative approach for adjusting for climate change may be adopted as required on a case-by-case basis [Ref. 35].

For sea level rise, EA guidance recommends using RCP8.5 at the 70th centile as the design allowance, with the 95th centile used to test the sensitivity of the design to more severe climate change [Ref. 95]. Therefore, for

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the extreme still seawater hazard, based on the EA guidance an additionally conservative climate change adjustment of RCP8.5 at the 95th centile is taken into account when characterising the site challenge.

3.5.1.2.2 SZC Site Challenge

In order to define the site challenge for extreme still seawater, it is necessary to describe a suitable combination of the:

- The present day extreme still sea water level at a 10,000 year return period at the 84th centile;
- an allowance for 'reasonably foreseeable' climate change.

3.5.1.3 The appropriate extreme still sea water levels from Table 8 and Table 9Waves

Site are used to define the site challenge as follows:

- 2110: +5.57m AOD;
- 2140: +6.09m AOD.

3.5.1.3.1 SZC Design Basis

Design Basis Definition

The design basis extreme high (still) water level for SZC is taken to be:

- 2110: +5.95m AOD;
- 2140: +6.88m AOD.

The 2110 design basis value of +5.95m AOD was originally adopted for the SZC project from the generic value provided as part of the Generic Design Assessment of the EPR. The sections above demonstrate the adequacy of this value being used in the SZC design because it bounds the site challenge value. The 2140 design basis value aligns with the value used in the DCO application [Ref. 46] and its use increases the margin between the site challenge and the values used as inputs to the design[6].

Justification of Design Basis and Inherent Margin

The design basis extreme still sea water level is estimated at a high Confidence Interval (CI) and includes allowances for reasonably foreseeable climate change. Moreover, the design basis in 2110 and 2140 are higher than the site challenge (by 0.38m and 0.79m respectively).

The design basis extreme still sea water levels can also be compared to relevant aspects of the SZC design in order to judge whether cliff-edge effects are possible. The principal risk posed by extreme sea water levels is flooding of the SZC site platform. The platform height is set at +7.3m AOD, providing a margin of 1.35m above the design basis extreme still sea water level in 2110 and 0.43m in 2140 [Ref. 42].

Furthermore, a Joint Probability Analysis (JPA) of extreme sea water level and significant wave height has been undertaken in order to determine the coastal flooding risk to the SZC site (including allowances for sea level rise and increase in wave height due to climate change) [Ref. 47]. It was concluded that the level of protection provided by the main sea defence with crest levels of 12.6m AOD (for reasonably foreseeable climate change) and 16.4m AOD (for maximum credible climate change) were sufficient to avoid significant overtopping discharge from the sea onto the site platform.

As well as being designed using an adjustment for climate change based on RCP8.5 at the 95th centile, the sea defences are being designed in line with the principle of 'managed adaptability' [Ref. 96]. For this, credible

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[6] The value of +6.88m AOD aligns with a 1 in 10,000 return period present day event of 5.06m AOD [Ref. 97] (that is now considered to be superseded by Reference [48]) plus an adjustment for climate change of +1.82m [Ref. 46]

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maximum climate change is being taken into account as a design case which results in a sea defence with a managed adaptive sea crest of 16.4m AOD. Further information on this aspect of the design is available in the Flooding Summary Report [Ref. 47].

This provides confidence that the SZC site will not be challenged by a beyond design basis event over its lifetime, because the sea defences are designed considering both reasonably foreseeable and credible maximum climate change to 2140.

3.5.1.4 Waves

3.5.1.4.1 Site Evaluation Studies

Present Day

Present day wave conditions were initially derived by HR Wallingford [Ref. 98]. This work was developed by the Centre for Environment, Fisheries, and Aquatic Science (CEFAS) [Ref. 97] which identified that there were two significant wave directions. The work by CEFAS took account of a longer record of data made available by the UK Met Office that better replicated conditions in the relatively shallow water of the southern bight of the North Sea. This work is presented in Table 10 and Table 11. The wave-sea level joint probabilities have been calculated by the Join-Sea method based on estimates of 1E-4p.a. significant wave heights from Sector 1 and 4 at the 95th centile.

Frequency per annum (p.a.)	**Conditions for Sea Levels at 2008 Baseline**				
Sector 1 (from 330 - 40 °N)	**Joint Probability Curve Point Name**	**Significant Wave Height, H_S (m)**	**Water Level (m ODN)**	**Mean Period (s)**	**Wind (m/s)**
1E-4	A1	8.14	2.06	12.1	30
1E-4	E1	7.46	3.35	11.6	26
1E-4	B1	5.68	4.54	10.2	21
1E-4	F1	4.94	4.93	9.5	19
1E-4	C1	3.46	5.2	8.1	15
1E-3	A2	7.1	1.89	11.3	25
1E-3	E2	6.28	3.03	10.7	22
1E-3	B2	5.21	3.62	9.8	20
1E-3	F2	4.47	4.02	9.1	18
1E-3	C2	3.23	4.22	7.8	14
5E-3	A3	6.38	1.76	10.8	23
5E-3	B3	4.83	3.18	9.4	19
5E-3	C3	3.05	3.66	7.6	13

Table 10: Offshore baseline (2008) wave conditions for Sector 1 waves and various return periods [Ref. 97] using the 1E-4 p.a. significant wave height at the 95th centile.

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Frequency per annum (p.a.)	Conditions for Sea Levels at 2008 Baseline				
Sector 4 (from 135 - 210 °N)	Joint Probability Curve Point Name	Significant Wave Height, H_S (m)	Water Level (m ODN)	Mean Period (s)	Wind (m/s)
1E-4	A1	6.09	0.85	6.9	22
1E-4	B1	4.94	2.04	6.6	19
1E-4	E1	3.88	3	6.2	16
1E-4	C1	2.81	3.87	5.6	12
1E-4	D1	0.35	5.2	2.5	0.5
1E-3	A2	5.4	0.8	6.7	21
1E-3	B2	4.3	2.04	6.5	17.5
1E-3	C2	3.0	3.04	5.7	13
1E-3	D2	0.35	4.27	2.5	0.5
1E-3	A3	5.02	0.75	6.6	20
5E-3	B3	3.95	2	6.2	16.5
5E-3	C3	3.07	2.53	5.7	13
5E-3	D3	0.35	3.65	2.5	0.5

Table 11: Offshore baseline (2008) wave conditions for Sector 4 waves and various return periods [Ref. 97] using the 1E-4 p.a. significant wave height at the 95th centile

Climate change allowances

UKCP18 used an ensemble of seven global wave models to explore potential changes in mean and mean annual maximum significant wave height (SWH) under RCP8.5 scenario. Results from these simulations suggest an overall decrease in mean SWH around most of the UK coastline of 10-20% over the 21st century, but the sign of change differs among models and coastal location [Ref. 100].

Despite this indication of an overall decrease in SWH under RCP8.5, climate change allowances based on guidance published in 2020 by the EA [Ref. 95] have been considered. In order to account for the uncertainties associated with both the future position of the storm track over the UK and the projections of wind and wave climate, a conservative increase in wave height of 10% is adopted for the reasonably foreseeable scenario with no change in the predominant wave direction, see Table 12 [Ref. 100].

3.5.1.4.2 SZC Site Challenge

The SZC Site Challenge for waves is defined for offshore conditions. This is to allow nearshore wave conditions to be modelled using appropriate software (e.g. TOMOWAC) accounting for all relevant parameters and the location of interest. In line with this approach, the baseline wave heights from Section 3.5.1.4.1 are increased by 10% to account for potential changes to wave conditions as a result of climate change. These values are presented in Table 12.

Scenario	Hs (baseline) (m)	Hs (m) (10% climate change allowance
A1	8.14	8.95
E1	7.46	8.21
B1	5.68	6.25
F1	4.94	5.43
C1	3.46	3.81

Table 12: SZC site challenge wave heights [Ref. 99]

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Only Sector 1 waves are considered when defining the SZC site challenge because waves from Sector 4 have a low correlation between wave heights and tidal surge. Furthermore, the presence of the outer Sizewell-Dunwich bank means that most of the waves coming from Sector 4 (wave approach angle is between 136°N – 210 °N) will be depth limited and, hence, they break on the offshore bar and are reduced in height compared with storm waves from the north east that are associated with higher total water levels due to storm surge effects [Ref. 99].

3.5.1.4.3 SZC Design Basis

Design Basis Definition

The SZC site challenge given in Table 12 is used to define the SZC design basis for this hazard.
It should be noted that input values for a given structure require the Design Basis offshore conditions to be transposed to the relevant location, taking account of the required relevant information (e.g. bathymetry)[7].

Justification of Design Basis and Inherent Margins

The design basis wave values have been set considering the latest available studies. Most importantly, they include a 10% increase in wave height to account for uncertainty associated with climate change. This is despite evidence suggesting an overall decrease in in mean SWH around the UK under the RCP8.5 scenario [Ref. 100].

As the design process is iterative, work is ongoing to ensure that the site challenge and design basis wave heights are adequate and in line with latest Relevant Good Practice (RGP) [Ref. 47]. However, given the conservatism already included within the characterisation of this hazard, and the verification work already completed as part of the basic design of the sea defences [Ref. 47], the definition of the SZC design basis for this hazard is judged to be adequate at this phase of the project.

3.5.1.5 Tsunami

3.5.1.6 Site Evaluation Studies

Present Day

Tsunamis are large scale waves generally caused by either seismic events or massive movements of land. Tsunami sources which could affect the UK were reviewed in a study commissioned in 2005 by the Department for Environment, Food and Rural Affairs (DEFRA) [Ref. 43]. The study investigated the threat posed by seismically generated and landslide tsunamis. A follow up study in 2006 [Ref. 44] commissioned by DEFRA, the Health and Safety Executive (HSE) and the Geological Survey for Ireland presented more detailed modelling of certain seismically generated tsunami sources. These studies have been supplemented by a site-specific analysis [Ref. 49] which conducted a thorough review of potential tsunami sources for SZC site, the results of which are presented in Table 13.

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[7] For certain specific structures (the intake heads and outfall structures) a bespoke analysis has been used to characterise offshore extreme seawater level-wave conditions using a multivariate method that is then transposed to the specific locations of the structures [Ref. 103].

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Tsunami source location	Tsunami type	Frequency of waves reaching SZC site (offshore)	Amplitude of waves reaching SZC Site (offshore)
UK coastal waters including North Sea	Seismic	< 1E-4 p.a.	< 0.3m
	Landslide	Not estimated	Negligible (< 0.1m)
North-west Europe continental slope	Seismic	< 1E-4 p.a.	< 0.25m
	Landslide	< 1E-4 p.a.	< 1.5m
		The bounding source is a "Storegga-type" tsunami originating in the North Sea Fan area. The landslide tsunami potential in the Storegga area is significantly lower (< 10-7 p.a.) due to erosion of extensive deposits in the slide which occurred 8200 years ago.	
Plate Boundary area West of Gibraltar	Lisbon-type seismic	< 1E-3 p.a.	Negligible (< 0.1m)
Canary Islands	Volcanic island flank collapse landslide – multi-stage, best estimate volume	< 1E-3 p.a.	Negligible (< 0.1m)
	Volcanic island flank collapse landslide – single event upper end volume	< 1E-5 p.a. (possibly > 1E-7 p.a.)	< 0.5m
Mid-Atlantic Ridge	Seismic	< 1E-4 p.a.	Negligible (< 0.1m)
	Landslide	< 1E-4 p.a.	Negligible (< 0.1m)
Eastern North America continental slope	Seismic	< 1E-4 p.a.	Negligible (< 0.1m)
	Landslide	< 1E-4 p.a.	Negligible (< 0.1m)
Caribbean	Seismic	< 1E-4 p.a.	Negligible (< 0.1m)
	Landslide	< 1E-4 p.a.	Negligible (< 0.1m)
Meteorite impact		~1E-8 p.a.	Could be several metres high
Meteo-tsunami		< 1E-3 p.a.	< 0.5m

Table 13: Potential sources of tsunami for SZC and their associated frequency and severity [Ref. 49].

Table 13 shows the potential tsunami sources that could affect the SZC site. The most significant wave height is generated from a meteorite impact, but this event has a frequency of ~1E-8p.a. and therefore requires no further consideration. The bounding tsunami event with a frequency of 1E-4p.a. is a landslide event in north-west Europe similar to the Storegga event. In simple terms a "Storegga-type" event occurs as a result of a large-scale movement of undersea deposits causing a Tsunami wave.

Climate Change Allowance

In terms of the sources of tsunami, climate change has been identified as potentially affecting submarine landslides. As these sources of tsunami can be initiated by disturbances or by a reduction in internal friction

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due to temperature/pressure changes or gas hydrate dissociation[8], their stability may be affected by climate change [Ref. 49]. As climate change develops, this will continue to be monitored.

The tsunami risk at SZC is linked to seawater level, which is expected to increase as a result of climate change. Therefore, over the life of the station, the risk change to SZC from tsunami as a result of increased sea levels must be considered.

3.5.1.6.1 SZC Site Challenge

Reference [49] states that “Storegga type” events are judged to have frequencies of less than 1E-4 p.a. but higher than 1E-5 p.a. and would generate a wave amplitude of less than 1.5m. All other tsunami sources would generate lower wave amplitudes at Sizewell or have an event frequency below the level which should be considered when defining the site challenge. Therefore, it is judged appropriately conservative to consider a tsunami wave with an amplitude of 1.5m as the SZC site challenge for tsunami.

Given the independence between the triggering of a tsunami event and meteorological conditions over the SZC site, it is not judged to be appropriate to consider a tsunami in conjunction with a storm (and the associated storm surge). Therefore, the sea level to be considered is not the extreme still seawater as defined in Section 3.5.1.2 because this includes a contribution from storm surge.

Monthly tides are defined as ‘Springs’ or ‘Spring tides’ when the tidal range is at its highest. The height of Mean High-Water Spring (MHWS) is the average throughout the year, of two successive high waters, during a 24-hour period in each month when the range of the tide is at its greatest (Spring tides). As MHWS is representative of the average high tide level, its use in defining the SZC site challenge for tsunami is adequately conservative because it is bounding of >90% of tidal levels. When combining this with the tsunami event frequency of >1E-4 p.a. it results in a combined event frequency of >1E-5 p.a. The MHWS level to be considered is 1.22m AOD [Ref. 101].The sea level to be considered also must take into account an adjustment for climate change in line with EA guidance [Ref. 95] (RCP8.5 at 70th centile[9]) for the relevant future epoch being considered (see Table 9). The resulting sea levels to be considered are:

- 2110: +2.13m AOD;
- 2140: +2.50m AOD.

3.5.1.6.2 SZC Design Basis

Design Basis Definition

The SZC design basis for tsunami is aligned with the site challenge given in Section 3.5.1.6.1. This is a tsunami with a wave amplitude of 1.5m considering the MHWS tides adjusted for climate change.

Justification of Design Basis and Inherent Margins

A detailed tsunami study has been undertaken to help inform the design of the SZC sea defences [Ref. 49]. This study demonstrates that the threat from high amplitude meteorite impact tsunamis at the SZC site can be discounted on low frequency grounds (frequency of impact is $<10^{-8}$ per annum). Of the other potential sources of tsunami, the largest wave amplitude that could be generated with a frequency to be considered in line with

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[8] As gas hydrates are only stable at high pressures and low temperatures, warming of bottom water on high latitude continental slopes after periods of glaciation or due to climate change may cause dissociation and expansion of the evolved methane leading to rapid increases in pore pressure [Ref. 43].

[9] For extreme high still seawater level, RCP8.5 at the 95th centile was conservatively used to define the climate change adjustment. When considering the climate change adjustment to consider to sea level rise in conjunction with a tsunami, RCP8.5 at the 70th centile is judged to be adequate. This is because extreme high still seawater level includes a contribution from storm surge, so the higher centile accounts for uncertainty in changes to future storminess. Whereas for the tsunami hazard the contribution to seawater level from storm surge does not need to be considered.

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the design basis is a “Storegga-type” tsunami. Reference [49] estimated the frequency of this type of event as lower than 1E-4p.a., but nevertheless, this event was conservatively defined as within the SZC design basis for this hazard. All other tsunami sources are found not to be capable of generating waves at the SZC site of amplitude that could exceed the coastal flooding run-up protection.

3.5.2 Rainfall and Surface Run-Off (Including Hail)

3.5.2.1 Description of Hazard and Historical Context

Rainfall represents a direct hazard to the proposed SZC nuclear licensed site as a result of the possibility of overwhelming the site drainage systems and causing flooding at platform level. In addition to the direct hazard of rainfall on-site, there is a potential risk posed by surface run-off from offsite sources. Fluvial flooding is flooding that occurs when a river or water course bursts its banks as a result of excess rainwater. Pluvial flooding occurs when heavy rainfall saturates the ground causing surface water to accumulate in any natural catchments.

If either the direct or the indirect effects of rainfall are extreme enough then they could lead to flooding of the site, and potentially impair the safety systems that will be in place at SZC.

A related, although rarer, form of precipitation is hail, which can occur during convective storms. Updrafts within the storm can cause water vapour to rise and cool, eventually freezing and acting a nucleation point for further freezing; this process will continue until the ice particle becomes too heavy to be held by the updraft, at which point it will fall as hail. The hazards associated with hail may include static loading on civil structures, dynamic impact energy or blockage of openings, depending on the quantity and size of hail produced.

3.5.2.2 Rainfall

3.5.2.2.1 Site Evaluation Studies

Present Day

The UK Meteorological Office operates several rainfall gauges in the vicinity of Sizewell with different time resolutions and different data series lengths.

A study has been undertaken to assess extreme rainfall at SZC [Ref. 50]. This has been achieved using extreme value analysis (EVA), which is a statistical approach that can be used to explicitly model the extremes that may be possible in the future but may not necessarily have been previously observed. The 10,000 year return period events have been estimated for extreme rainfall at different timescales using observational data from rainfall gauges at several sites in the vicinity of SZC (i.e. Westleton (31 years of data), Wattisham (59 years of data) and Hemsby (12.5 years of data)). The 10,000-year return period present day estimates at 70% CI are presented in Table 14.

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Return Period (years)	Storm Duration	Present day Best Estimate (mm)	Present day (2018 baseline) 70% CI	
			Lower bound (15th quantile) (mm)	Upper bound (85th quantile) (mm)
10,000	5 minutes	17.2	6.9	27.4
	10 minutes	30.5	12.6	48.5
	12 minutes	30.7	10.9	52.6
	15 minutes	30.7	10.9	52.6
	1 hour	84	53	126
	1 day	265	148	433

Table 14: Results of the extreme rainfall assessment at SZC

Climate Change Allowance

The analysis of observational data provides an estimate of extreme rainfall values in the present day; however, climate change can result in an increase in rainfall intensity. It is therefore necessary to understand the impact that climate change may have on extreme rainfall during the lifetime of SZC.

Future climate change adjusted extreme rainfall values have been estimated as follows [Ref. 50]:

- Taking the upper bound of the 70% CI of the 10,000-year return level for the present day based on observations (as these include conservatism in the statistical modelling);
- Determine a climate change adjustment factor for estimating the change over a 100 year period (noting that UKCP18 data is available from 1980 to 2080), based on UKCP18 projections at the 84th quantile of the RCP8.5 scenario;
- Adding the values from the two previous steps to produce a future estimate for the climate change adjusted value.

Return Period (years)	Storm Duration	Climate change adjustment 84th Quantile (mm)
10,000	5 minutes	6.2
	10 minutes	11.1
	12 minutes	11.1
	15 minutes	11.1
	1 hour	21.8
	1 day	77.3

Table 15: Results of the extreme rainfall assessment at SZC adjusted for climate change [Ref. 50]

3.5.2.2.2 SZC Site Challenge

The SZC site challenge is based on return level estimates from the observations and climate change factors. In this instance, the upper bound of the 70% CI (i.e. 85th quantile) for the present day 10,000-year return level and climate change adjustment factors are used as presented in Table 16.

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Storm Duration	Upper bound (85th quantile) (mm)	Climate change adjustment (mm)	Future estimates (mm)
5 minutes	27.4	6.2	33.6
10 minutes	48.5	11.1	59.6
12 minutes	52.6	11.1	63.7
15 minutes	52.6	11.1	63.7
1 hour	126	21.8	147.8
1 day	433	77.3	510.3

Table 16: SZC Site Challenge Extreme Rainfall Values

3.5.2.2.3 SZC Design Basis

Design Basis Definition

The design basis is defined as a 10 minute rainfall of 59.6mm and an hourly rainfall of 147.8mm; these being consistent with the 10,000 year return period extreme rainfall values adjusted for climate change.

Justification of Design Basis and Inherent Margins

The resultant design basis rainfall profile provides a representation of the extreme brief, intense rainfall hazard at SZC. The derivation of the site challenge for SZC is conservative since it incorporates climate change factors that are based on UKCP18 projections at the 84th quantile of the RCP8.5 scenario. This is considered to be more conservative than the ‘reasonably foreseeable’ assertion for climate change (in Section 3.1.3).

3.5.2.3 Hail

3.5.2.3.1 Site Evaluation Studies

Present Day

No records are available that can directly define a 1 in 10,000 year extreme hail event; however, as a hypothetical worst case, it can be proposed that the maximum hail possible at a given return period is equivalent to the total rainfall at the same return period (i.e. assuming a 100% conversion of rain in a storm into hail). On this basis, the hail hazard was originally evaluated in a 2015 paper [Ref. 52] utilising extreme rainfall analysis for SZC performed in a Met office report [Ref. 53].

The Met office report, however, is based on older data than the 2019 EdF R&D report on extreme rainfall [Ref. 50] discussed in Section 3.5.2.2 above. Notwithstanding this, the approach of assuming 100% conversion to hail in Reference [52] is considered otherwise appropriate. The data from Reference [51] together with the approach in Reference [52] is therefore used to define the Site Challenge below.

Climate Change Allowance

As part of the assessment of extreme hail, the impact of climate change was considered in Reference [52]. It is considered that in the worst cases the prevalence of hail will remain constant. Should the climate change in line with the predictions then hail-generating weather in the south of England is more likely to decrease.

3.5.2.3.2 SZC Site Challenge

The site challenge is defined as the 10,000 year return period extreme rainfall utilising the 1-day resolution: 265mm (rainwater equivalent depth). As was done in Reference [52], this can be converted to a hail

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equivalent depth by multiplying by 1.6 (424mm). This pessimistically assumes that hail density is equal to that of ice (i.e. high bulk density).

When considering the dynamic impact energies associated with hail, it is necessary to characterise an extreme hailstone size. For this purpose, a maximum hailstone diameter of 100 mm is considered this being consistent with the maximum intensity category defined by the TORnado and storm Research Organisation (TORRO).

3.5.2.3.3 SZC Design Basis

Design Basis Definition

To achieve the HPC replication intent and because of the inherent pessimisms in deriving the SZC site challenge, the HPC design basis is used as the SZC design basis.

The HPC (and hence SZC) design basis is defined as a depth of 366.1 mm of hail (228mm rain equivalent depth) falling over a period of 24 hours, with a maximum hailstone size of 100 mm.

Justification of Design Basis and Inherent Margins

The SZC site challenge is 37 mm (in rain equivalent depth) greater than the design basis defined above. Reference [39] indicates that the UK-EPR building can withstand 250mm of standing water. This means that if 424mm of Hail (265mm of water) were to accumulate on the roofs, the roofs could become overloaded by the additional 15mm (rain equivalent depth).

However, this assumes conservatively that all rain converts to hail and hence cannot drain way. As indicated above, in terms of mass, hail production rarely exceeds 10% of the rainfall and is typically just a few percent. As such, either the water equivalent of hail precipitation would not exceed 10% of 265mm rail equivalent depth, in which case the hail loading would be less than the design loading, or it would require >90% of the rain to convert to hail in order to overload the roofs. It would be overly conservative to assume this, and hence the use of the HPC design basis for use at SZC is considered to be justified.

3.5.3 High Groundwater Level

3.5.3.1 Description of Hazard and Historical Context

Groundwater refers to the presence of water beneath the ground surface, within the soil, for example that is absorbed following rainfall events. The high groundwater level hazard refers to the maximum height reached by the groundwater table at a given return period. The mechanisms through which groundwater poses a hazard at SZC are penetration into basement areas, uplift of civil structures and, in the most extreme cases where the water table reaches the platform height, site flooding.

The SZC main site consists of a permeable aquifer (Crag) overlain by impervious upper layers (peat and clay deposits). Construction work will therefore require the casting of a cut-off wall (geotechnical enclosure), prior to earthworks, for the purposes of dewatering and to allow unsuitable soil layers to be removed and substituted by backfilling with permeable materials of a suitable quality. The hydrogeological conditions on the SZC main site will therefore be modified and this necessitates a thorough understanding of the expected groundwater conditions.

3.5.3.2 Site Evaluation Studies

Rainfall recharge provides the driving mechanism for groundwater flow. Groundwater can seep or spring out if the water table intercepts the surface against outcrops of lower permeability strata and provides base flow to surface watercourses.

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The assessment of Groundwater Levels (GWL) is based on knowledge of the hydrogeological site investigations that were carried out alongside the geological investigations during Phase 1 between August 2010 and April 2011, and between October 2013 and July 2014 and during Phase 2 in 2019 [Ref. 10]. These investigations included installing a network of 21 piezometers to study the hydrogeological characteristics across the entire proposed SZC site.

Rainfall intensity and sea levels are anticipated to increase in the future as a result of climate change. The GWL has been found to be influence by local tide levels as sea level rise will result in a steady increase in GWL in the platform area and increases in rainfall intensity will lead to more pronounced short-term GWL increases following extreme events. The combination of these factors means that flood events of a given return period will result in higher GWLs in the future.

Long-term increases in rainfall intensity are based on UKCP18 projections and have been estimated using intermediate climate change scenario recharge inputs (i.e. UKCP18 RCP6.0 simulation giving the 50th percentile of both temperature and rainfall). Long-term increases in sea level have been estimated from the UKCP18 95th percentile of sea level rise (utilising the UKCP18 dataset for the period 2007-2300) [Ref. 102].

GWLs are estimated in operational phase conditions i.e. after construction, accounting for earthworks, building foundations, changes in recharge condition and site drainage, for the remaining lifetime of the plant (including decommissioning). The 2110 GWL values (applicable to all structures except HHI and HHK) proposed for the SZC main site inside the cut-off wall and the 2140 GWL values (applicable to HHI and HHK) are presented in Table 17. These GWLs are design values based on numerical modelling and without any mitigation [Ref. 102].

Groundwater designation	**Definition**	**Proposed GWLs (m AOD)**	
		2110	**2140**
$G_{k,wl}$ Permanent level	Permanent actions due to the permanent level of groundwater table. This is the GWL that will not be exceeded for 50% of plant design working life.	+1.05	+1.21
$Q_{k, wl, EF}$ Frequent (high) level	Frequent value of effects due to the variations of level of the groundwater table from its mean value. This value is associated with the groundwater table level which may be exceeded for only 1% of plant design working life.	+1.48	+1.78
$Q_{k, wl, EH}$ Characteristic (high) level	Characteristic value of effects due to the variations of level of the groundwater table from its mean value. This value is associated with a return period of 100 years.	+2.11	+2.61
$A_{d, wl}$ Accidental level	Design value of action due to flooding. This value is associated with a return period of 10,000 years.	+2.21	+2.72

Table 17: Detailed groundwater level assessment for the SZC main site inside the cut-off wall

A comparison between the GWLs for various structures at HPC and SZC is presented in Table 18 [Ref. 51]. A positive number indicates that the GWL is higher at SZC than at HPC.

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Groundwater designation	Difference between HPC and SZC GWLs with respect to platform level				
	Nuclear Island (NI)	**East of NI 1**	**Turbine Hall (HM) / Non-Classified Electrical Building (HF) CI-BOP**	**Operational Service Centre (HBX) CI-BOP**	**Pumping Station (HP)/ Forebay (HPF) CI-BOP**
$G_{k,wl}$ Permanent level	-0.3	**+0.4**	**+0.6**	**+0.5**	**+0.7**
$Q_{k,\,wl,\,EF}$ Frequent (high) level	-1.3	0.0	**+0.5**	**+0.2**	**+0.5**
$Q_{k,\,wl,\,EH}$ Characteristic (high) level	-1.2	**+0.5**	**+1.0**	**+0.7**	**+1.0**
$A_{d,\,wl}$ Accidental level	-2.8	-0.1	**+0.7**	**+0.2**	**+0.7**

Table 18: Comparison of design GWL levels between HPC and SZC (in 2110)

The design values are only favourable for the Nuclear Island since the GWL is lower relative to the platform at SZC than at HPC, whereas the design values are not favourable for the CI-BOP since the GWL is higher relative to the platform at SZC than at HPC.

3.5.3.3 SZC Site Challenge

The SZC site challenge is defined as the GWLs in Table 17. It is noted that the HPC site challenge and the HPC design basis are assessed based on the presence of the HGS drainage gallery. A groundwater control system at SZC would not include a drainage gallery (as is the case for HPC) due to differences in geology, hydrogeology, and rainfall recharge. Therefore, the site challenge is set without considering a groundwater control system.

3.5.3.4 SZC Design Basis

The SZC design basis is defined as the GWLs in Table 17. Depending on the structure in question, it is possible that the local groundwater levels will drive the requirement for groundwater mitigation measures to control the GWL to within civil design parameters.

3.6 Extreme Climatic Conditions

3.6.1 Snow

3.6.1.1 Description of Hazard and Historical Context

Snowfall in the UK is generally intermittent and of relatively short duration compared to that of continental Europe, where snow may accumulate throughout the winter. When snowfall does occur in the UK, it tends to fall mostly in the east/north-east of the country where weather patterns producing snow prevail from the east, and in highland areas since temperatures are colder and orographic rainfall is more likely. As such, altitude is one of the main influencing factors of snowfall amounts. In general, less snowfall is observed around the coast due to warming from coastal waters and lower altitudes. Despite this pattern, the spatial distribution of snowfall is highly variable and can vary significantly over short distances. There are on average between 5 to 10 days with snow annually near SZC (recorded between 1981 – 2010). SZC is located on the coast at low altitude, 7.3 m above sea level (ASL) and on average, it still sees relatively few days with snow lying compared to other parts of the UK. It is also important to highlight that the snowfall amounts differ from the amount of snow lying, specifically in the coastal areas where the snow can quickly melt between snowfalls from different weather systems.

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Snow can pose two main hazards to a power station, the loading imposed by snow onto the rooftops, and the blockage of air vents and entrances caused by drifting snow. Drifting snow is a condition that occurs when particularly fine powdery snow occurs during a period of high wind. It can lead to the snow being banked into drifts in sheltered areas.

3.6.1.2 Site Evaluation Studies

3.6.1.2.1 Present Day

A summary of the studies on extreme snow at Sizewell has been carried out [Ref. 54] and is reproduced below.

The Met Office EVA report [Ref. 55] estimates the 10,000-year return levels of extreme snow depth and snow load for the design of the EPR Nuclear power station planned for construction at SZC. The methodology applied for estimating the extreme snow load in HPC in Reference [56] is repeated in the study of SZC. EVA is applied to the pooled observed snow depth near Sizewell and the results are transformed into snow loading using suitable choices of the Snow Water Equivalent Function (SWEF) that have been previously adopted by the Met Office and within the Eurocode standard.

Reference [55] applied two different Generalised Pareto Distribution (GPD) fits in order to provide a comparison analysis of the extreme snow depth estimation in Sizewell and to be consistent with the HPC snow depth analysis. The use of GPD statistical approach is considered Relevant Good Practice (RGP).

These are:

- Stationary GPD;
- Non-stationary GPD with altitude above sea level as a covariate in the shape parameter.

The stationary GPD has been chosen as the preferred approach [Ref. 55], due to the flat orography of East Anglia, the observations data available and the results of the statistical tests.

Table 19 below presents the 10,000 year best estimate and 70% CI conservative snow depth and snow loads from the stationary model in Reference [55].

Return Period (yrs.)	Stationary Model Extreme Snow Depth (cm)		Snow Load (kN/m^2) (SWEF 1.46 Met Office for SZC)	
	Best Estimate Snow Depth	Snow Depth 70% CI [15th quantile, 85th quantile]	Best Estimate	Snow Load 70% CI [15th quantile, 85th quantile]
10,000	53	[39; 66]	0.75	[0.56; 0.94]

Table 19: SZC stationary EVA Estimates for Extreme Snow Depth and Snow Loading

Reference [54] summarises the extreme snow depth and loading for the SZC evaluated using the methods in the Eurocode BS EN 1991-1-3 [Ref. 57] and the UK National Annex [Ref. 58], with parameters appropriate to the Sizewell site. The snow load results are presented in below in Table 20.

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Parameter	Characteristic Ground Snow Load at Sea Level (50 year return period) (kN/m^2)	Characteristic Ground Snow Load[10] at SZC (50 year return period) (Sk) (kN/m^2)	Exceptional Ground Snow Load Event[11] (10,000 year return period) (SAd = Cesl . Sk) (kN/m^2)
Ground Snow Load	0.3	0.5	1.0

Table 20: Summary of the results from the SZC Site Challenge Eurocode 1991-1-3 Snow Load assessment

3.6.1.2.2 Climate Change

The impact of climate change on snow remains unclear. The competing effects of increasing temperatures and shifting precipitation patterns remain complex and challenging. Reference [55] identifies that there is currently a lack of a clear consensus on the effect of climate change on snowfall. It is conservatively assumed that the extreme snow load estimated from observations over the 20th century will remain valid under future climate change (since winter temperatures are likely to increase and thus the number of snow days is likely to decrease under climate change) [Ref. 55]. Therefore, it is considered a reasonable assumption that snowfall amounts remain constant over time. As a result, no adjustments for climate change have been made to extreme snow load estimations.

3.6.1.3 SZC Site Challenge

The SZC site challenge shall be a conservatively derived 10,000 year return period event taken at the best-estimate level. In this case, it is chosen to use the more onerous Eurocode, rather than Met Office EVA prediction, in order to capture additional conservatism.

The SZC site challenge is therefore a snow load of 1 kN/m^2.

3.6.1.4 SZC Design Basis

3.6.1.4.1 Design Basis Definition

The snow design basis at SZC is 1.3 kN/m^2, representing an extreme undrifted snow load. In line with the SZC replication strategy, the snow design basis value is the same as the value adopted at HPC. Protection against the extreme snow hazard is primarily provided by designing the civil structures against this load case. However, a lower design value may be adopted for individual buildings where appropriate, for example those for which the consequences of failure during an extreme snow event are low.

3.6.1.4.2 Justification of Design Basis and Inherent Margins

Reference [55] has utilised the most up to date statistical methodology and data to estimate extreme return levels for snow depths and snow loads at SZC and replicates the methodology used to derive the HPC EVA. Table 21 presents the comparison of Site Challenge snow loading and the SZC Design Basis.

SZC Site Snow Load (kN/m^2)				
EVA Best Estimate	EVA 84th quantile	Eurocode	SZC Site Challenge	SZC Design Basis
0.75	0.94	1.0	1.0	1.3

Table 21: Comparison of Snow Loading Site Challenges and the SZC Design Basis

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[10] This is the ground snow load at 100m of altitude defined by Eurocode 1, the maximum for Sizewell from zone 3 of ground snow load map in the UK National Annex

[11] Based on Eurocode 1-1-3 Annex D 'Adjustment of the ground snow load according to return period', where V=0.95 taken from [Ref. 54]

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Table 21 shows that the design basis value of snow loading for the SZC of 1.3kN/m^2 bounds the site challenge snow load for SZC. The "Inherent Margin" in the design is considered sufficient to demonstrate an absence of cliff-edge effects corresponding to structural failure due to beyond design basis snow loads.

3.6.2 Wind

3.6.2.1 Description of Hazard and Historical Context

Extreme wind can result in a direct threat to the plant buildings due to the associated dynamic pressure or can indirectly affect the facility by imparting energy onto missiles.

Following the strong winds which occurred in 1987, the Meteorological Office issued a report entitled `The Storm of 15/16 October 1987'. In this report gusts of up to 106 knots (54.6 m/s) were quoted for the weather station at Gorleston; these were the strongest gusts reported for the storm over Britain. Subsequently the Meteorological Office has confirmed that the wind speeds quoted for Gorleston were incorrect due to damaged anemometer cups, which became bent. The correct gust speed for that event is now quoted as 85 knots (43.8 m/s).

3.6.2.2 Site Evaluation Studies

3.6.2.2.1 Present Day

A summary of the studies on extreme wind at Sizewell has been carried out [Ref. 54] and is reproduced below.

Two Met Office studies on extreme winds at Sizewell were carried out in 2013 [Ref. 59 and 60] on behalf of Exelon and NNB respectively. The Extreme Value Analysis (EVA) was extended to include gust wind speeds [Ref. 61].

A later Met Office study for Sizewell [Ref. 62] compares the results from the previous EVA, with new results that attempt to account for some of the uncertainties in modelling strategy from the previous SZC studies. Reference [62] then produced revised estimates of the 10,000-year wind speeds near Sizewell. Reference [62] noted that the earlier analyses recommended that the meteorological data recorded at Gorleston was the most representative of the Sizewell site, and found that new estimates for Gorleston are also in good agreement with those found previously. Reference [62] also concluded that the non-stationary EVA models with return levels varying with the North Atlantic Oscillation (NAO) and wind direction do not adequately describe the wind direction dependence.

The assessment in Reference [63] considered the HPC design basis for extreme wind and compared the extreme wind challenge derived from EVA and the Eurocode. It concludes the use of non-stationary EVA on meteorological phenomena and the use of covariate-based approaches for design substantiation as a novel approach, which may require more R&D work and further peer review. Therefore, NNB GenCo currently do not endorse the use of the non-stationary predictions of the extreme wind speeds. Given the similarities between the HPC and SZC designs, Reference [63] also includes an assessment on whether the use of Eurocode for the SZC extreme wind design basis is appropriate.

Table 22 below presents the summary of the results from the stationary EVA studies for the 10,000-year gust and mean hourly wind speeds respectively. The 84th quantile is estimated from the 10,000 year return period EVA results.

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Parameter	Location	Best Estimate 10,000 Year Return Period Wind Speed (m/s) [Ref. 61 & 62] (2.5th quantile,97.5th quantile)	Conservative 10,000 Year Return Period Wind Speeds (m/s) [Ref. 54] (84th quantile)
Gust (3 Second)	Gorleston	52.7 (44.1, 64.4)	57.1
Hourly Average	Gorleston	32.9 (30.5, 35.7)	34.2

Table 22: Stationary EVA results for SZC Extreme Wind Gust and Hourly Average Wind Speeds

The SZC extreme wind has also been estimated from a 50-year return period fundamental basic wind velocity based on Eurocode 1 BS EN 1991-1-4 [Ref. 64] and the corresponding UK National Annex [Ref. 65].

Reference [54] estimates a fundamental basic wind velocity (Vbmap) at Sizewell of 22.8 m/s. This is the 10 minute average wind speed that would be observed once every 50 years at a postulated site 10 m above ground in open country. The subsequent conversion of the fundamental basic wind velocity into the corresponding 10,000-year return period extreme hourly average and maximum gust wind speeds is presented in Annex A of Reference [54].

The derivations of the extreme wind speeds predicted by the Eurocode method are presented in Reference [54] and a summary of the results is shown in Table 23 below.

Parameter	Symbol	Wind Speed (m/s) 10,000 Year Return Period
Basic Wind Velocity	$V_{b,0}$	29.0
Gust (3-Second)	$V_{p(z)}$	48.6
10-Minute Average	$V_{m(z)}$	34.0
Hourly Average	$V_{m(z)}/1.06$	32.0

Table 23: The SZC Site Extreme Wind Speeds derived from Eurocode 1991-1-4.

3.6.2.2.2 Climate Change

The SZC extreme wind hazard studies recognise the requirement to consider the effects of “reasonably foreseeable” climate change on any naturally occurring hazards such as wind.

Reference [61] considered wind speed extremes with regard to climate change, as relevant to the proposed new installation. The NNB study concluded that there was no evidence of a climate change component with respect to extreme wind speeds.

Furthermore, the general consensus from Met Office UKCP18 [Ref. 66] and the ONR assessors’ guide [Ref. 67], is that:

"An increase in near surface wind speeds over the UK for the 2nd half of the 21st century for the winter season is indicated. However, the increase in wind speeds is modest compared to natural variability from month to month and season to season.

The naturally occurring North Atlantic Oscillation (NAO) is an important influence on winter climate in northern Europe, and it is considered that the NAO is likely to become slightly more positive on average which would favour milder, wetter, and windier winters in the UK. However, the influence of climate change on the NAO is expected to be much smaller than the natural variability it exhibits from month to month and season to season."

Therefore, the estimates for extreme wind speeds presented in this Section do not include a climate change allowance on the basis that:

- There is currently no evidence of a climate change component with respect to extreme wind speeds;

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- It is considered that the wind loads are unlikely to be the dominant loads on the structures. This will be confirmed during the detailed structural design;
- Regular monitoring of climatic data trends along with periodic reviews of RGP will be undertaken through the life of the station.

3.6.2.3 SZC Site Challenge

A number of studies have estimated the extreme wind speed site challenge at Sizewell using EVA. Reference [54] concludes that the hourly average predictions from EVA demonstrate very good agreement with the Eurocode calculated value and this is considered to provide a strong justification for the use of the Eurocode for the SZC Site Challenge.

Although EVA for wind gusts does not seem to support the use of the Eurocode calculation of wind gusts for the SZC Site Challenge, Reference [63] considers that EVA does not accurately estimate extreme short duration winds. It was observed that the hourly EVA predictions are very close to the Eurocode values whereas there is a large difference between the results for gusts, despite the fact that in both cases the analyses are based on the same weather station. It is concluded that Eurocode 1 is appropriate for defining the SZC Site Challenge extreme wind speed at SZC [Ref. 54].

The SZC site challenge is chosen to be the Eurocode derived 10,000 year return period event taken at the best-estimate level. The SZC extreme wind site challenge is defined in Table 24 below.

Parameter	SZC Site Challenge Extreme Wind Speed (m/s)
Gust (3-Second)	48.6
10-Minute Average	34.0
Hourly Average	32.0

Table 24: SZC Extreme Hazard Wind Site Challenge

3.6.2.4 SZC Design Basis

3.6.2.4.1 Design Basis Definition

The SZC design basis values for wind are given in Table 25.

Parameter	SZC Design Basis Eurocode 10,000 Year Return Period Wind Speed (m/s)
Gust (3-Second)	49.3
10-Minute Average	34.5
Hourly Average	32.5

Table 25: SZC Extreme Hazard Wind Design Basis

In line with the SZC replication strategy, the SZC design basis values for wind are the same as the equivalent HPC design basis values.

In addition, a design basis maximum wind generated missile speed of 55.5 m/s is defined. This corresponds to the maximum missile speed that light missiles with a large surface area could potentially reach during an extreme gust.

3.6.2.4.2 Justification of Design Basis and Inherent Margins

Comparing the SZC Site Challenge gust, 10-minute and hourly average wind speeds in Table 24 derived from Eurocode 1991-1-4 with the equivalent design basis values in Table 25 shows that the SZC site challenge values for wind are bound by the SZC design basis values for wind.

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3.6.3 Tornado

3.6.3.1 Description of Hazard and Historical Context

A tornado is a rotating column of air that extends to the ground from a cloud in the shape of a funnel; the spinning column of air can attain extremely high speeds and very low pressures which are of great risk to property and life. Compared to strong winds from other meteorological conditions, the rotational forces of tornadoes may have a significantly different impact on buildings and objects. Tornadoes also generate airborne missiles of varying size, which can cause impact damage.

Tornadoes are considered in terms of tornadic wind speed, in m/s, and of tornado strength, or tornadic intensity, using the UK the international T-scale from T0 to (highest) to T10.

Data in Tornadoes in the UK is gathered principally by the Tornado and Storm Research Organisation, TORRO, and held in the TORRO database.

3.6.3.2 Site Evaluation Studies

There have been a number of technical assessment studies of tornado occurrence in the UK that have been reviewed and summarised in Reference [68]. The two main reference documents considered for the purposes of assessing the SZC 10,000 year site challenge tornado are: the TORRO/Meaden 2011 study [Ref. 69], which has relevance as a reference point for considering the tornado hazard at other locations such as Sizewell; and the Met Office 2015 study [Ref. 70], which assessed tornado strength and frequency (or return period) at EDF's UK nuclear power station sites. The results from these two studies are summarised in Table 26 below:

Probability / Return Period	**Met Office SZC Finite Damage Area method**	**Met Office SZC Finite Site Area method**	**TORRO 2011 Southern Britain avge**	**TORRO 2011 Southern Britain avge x 2.5 (Bristol/Bath)**	**TORRO 2011 Southern Britain avge x 0.7 (Hinkley)**
1.0E-4 p.a. / 1 in 10,000 yrs	40.7 m/s	43.4 m/s	31.8 m/s [extrapolation]	45.2 m/s	26.0 m/s [extrapolation]
1.0E-5 p.a. / 1 in 100,000 yrs	61.3 m/s	57.3 m/s	61.1 m/s	(70.5 m/s) (high uncertainty)	57.3 m/s

Table 26: Summary of 10,000 year and 100,000 year Return Period Tornadic Wind Speeds

3.6.3.2.1 Climate Change

The effect of climate change on the frequency and strength of tornadoes is uncertain and as such, no allowance has been specifically quantified. UKCP18 [Ref. 71] includes no information specifically relating to tornadoes. Further information is provided in Section 3.6.3.4.1.

3.6.3.3 SZC Site Challenge

Based on the information available from the site evaluations, Reference [68] concludes that the estimated velocity of a tornado with an IEF greater than 1.0E-4 at SZC is 45m/s. This is consistent with a T3 tornado which is adopted as the SZC site challenge for tornado.

3.6.3.4 SZC Design Basis

The design basis tornado is aligned with a T5 event. The specific T5 tornado parameters incorporated into the SZC design are summarised in Table 27 below. These parameters are generally characteristic of a T5 tornado in the UK [Ref. 72].

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Parameter	T5 Tornado
Maximum Wind Speed	65 m/s
Tornado Translational Velocity	13 m/s
Maximum Pressure Drop	26 mbar
Maximum Pressure Drop Rate	7.5 mbar/s
Radius of Maximum Velocity	45m

Table 27: T5 tornado parameters incorporated into the SZC design basis [Ref. 72]

3.6.3.4.1 Justification of Design Basis and Inherent Margins

The SZC Design Basis T5 tornado with a wind speed of 65 m/s is significantly bounding of the SZC site challenge T3 tornado with a wind speed of 45 m/s by a large (20 m/s) margin. This margin is likely to provide adequate margin in the absence of an easily quantifiable climate change allowance.

Furthermore, the 20m/s margin between the SZC site challenge and design basis demonstrates a large degree of Inherent Margin and subsequently provides confidence for an absence of cliff-edge effects.

3.6.4 Volcanic Ash

3.6.4.1 Description of Hazard and Historical Context

Volcanic Ash and Airborne Particulate (VAAP) released from a volcanic eruption in relatively close proximity to the U.K. (Iceland, the Atlantic, or the European mainland) has the potential to challenge nuclear safety. The potential challenges could include damage or failure of high voltage transmission systems and civil structures, as well as clogging of Heating Ventilation and Air Conditioning (HVAC) filters and Emergency Diesel Generator intake filters.

However, it has been demonstrated that for volcanic eruptions with an IEF greater than 1.0E-4 p.a, there is no credible risk to nuclear safety [Ref. 73]. This is primarily because of the large distance of the SZC site from Icelandic Volcanoes (1,100 miles), which provide the dominant eruption risk. As a result of this large distance, the U.K. will have a number of days to prepare before any ashfall arises, which is expected to be extremely minor (<0.1mm) even in extreme eruption events with frequency as low as 1.0E-5 p.a. Furthermore, even in extreme eruption events, the duration of any extremely light ashfall that does arise is of low duration (maximum of ~30 hours) [Ref. 73].

3.6.4.2 SZC Site Challenge

It has been demonstrated that the maximum levels of volcanic ash and airborne particulate predicted from volcanic eruptions with an IEF greater than 1.0E-4 p.a. do not challenge nuclear safety and hence no site challenge is defined.

3.6.4.3 SZC Design Basis

As per the requirements set out in Section 3.1.3, no specific design basis is defined for VAAP because nuclear safety is not challenged when considering a volcanic eruption with an IEF greater than 1.0E-4 p.a.

3.6.5 Extreme Heat (Air)

3.6.5.1 Description of Hazard and Historical Context

Extreme heat (air) temperature, if not properly considered in the design has the potential to undermine systems designed to cool and maintain equipment with nuclear safety functions, at an appropriate temperature.

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3.6.5.2 Site Evaluation Studies

3.6.5.2.1 Present Day

Extreme high air temperatures have been characterised by EDF R&D in References [74] and [75]

In Reference [74] observations of hourly dry-bulb, wet-bulb, and atmospheric pressure (atmospheric pressure is used to calculate enthalpy) during the summer months (June, July, August) between 1980-2019 from the Wattisham meteorological station have been used to estimate extreme conditions under the present climate. For reasons provided within Reference [74], Wattisham is judged to be the appropriate data source for characterising temperature conditions at Sizewell, including it being inland (and therefore generally warmer) than the coastal Sizewell site. In this study, univariate Extreme Value Analysis (EVA) was applied to observed dry-bulb temperatures, wet-bulb temperatures, and derived enthalpy for various temporal averaging periods: daily maximum; 12-hour average; 24-hour average; 2-, 3-, 4- and 5-day averages.

In Reference [75], heatwave profiles for SZC are generated using observed daily maximum and minimum dry-bulb air temperature data taken from the Wattisham gauge over the period 1980-2017. The heatwave profiles are constructed using multivariate EVA. The main results are a ‘best estimate’ heatwave profile (median value of simulated heatwave events) and an 84th quantile heatwave profile (which permits additional conservatism).

3.6.5.2.2 Climate Change

In Reference [74], a set of 12km regional climate model data from the UKCP18 using RCP8.5 ensemble have been analysed to calculate climate change adjustment factors for extreme air (dry bulb) temperatures in the vicinity of SZC. This data is also taken into consideration in the generation of the heat wave profiles in Reference [75]. As detailed in Section 3.1, the climate change adjustment factor is derived from the 50th quantile (i.e. best estimate) of the UCKP18 RCP8.5 data ensemble.

Due to the difficulty in accurately predicting the effects of climate change on enthalpy, no allowance has been quantified. However, this omission is offset by the conservative decision to consider independently derived air temperatures and humidity values concurrently in the design basis (see Section 3.6.5.4 below).

3.6.5.3 SZC Site Challenge

The SZC extreme heat (air) hazard site challenge is defined using the results of the analyses discussed in Section 3.6.5.2 by combining the present day and future estimates of extreme temperatures [Ref. 76]. Table 28 show the 1.0E-4 p.a. values for extreme heat (air) at SZC using the 85th centile present day values and an adjustment for climate change out to 2110. The extreme high air temperature site challenge values have been defined in order to cover the period up to the end of power generation operations on site plus a 20-year allowance to transfer fuel to the Interim Spent Fuel Store (ISFS) (i.e. present to 2110). For SSCs operating beyond 2110 and up to 2140 (such as the ISFS) the SZC Design Basis values for enthalpy and temperature are to be defined in line with the design and safety case schedule of the SZC project. This is raised as an Open Point in Reference [76].

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[redacted]

Table 28: [redacted]

3.6.5.4 SZC Design Basis

3.6.5.4.1 [redacted]

[redacted]

- [redacted]
- [redacted]

3.6.5.4.2 Justification of Design Basis and Inherent Margins

The justification of the design basis for extreme heat (air) is detailed in Reference [76]. The analysis presents an overview of the studies carried out to characterise the extreme heat (air) hazard at SZC and uses this information to define the SZC Site Challenge for extreme heat (air) up to 2110. The analysis compares the values at SZC with the HPC RC2 design basis for extreme heat (air) to find that the SZC Site Challenge dry bulb temperature is slightly elevated rather than being clearly bounded, while the SZC Site Challenge enthalpy value is clearly bounded. In order to define the SZC design basis for extreme heat (air) the analysis presents the arguments and key points below to support the claim that ‘the adoption of the HPC design basis air temperatures at SZC up to 2110 will result in a design for which an adequate safety demonstration will be made in the SZC PCSR’.

- The use of data from Wattisham in the characterisation of the present day 1E-4 p.a. extreme high air temperature is conservative when compared to the SZC site.
    - Wattisham is an inland site, and therefore generally experiences higher temperatures than a coastal site (Section 5.1 of Ref. [76]).
- The climate change adjustment factor has been defined conservatively.

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  - The climate change adjustment factor has been defined using RCP8.5 which is a scenario characterised by a level of greenhouse gas emissions that can only be reached through an increase above the present-day emission rates (Section 5.2 of Ref. [76]).
  - The model that has been used to estimate the climate change adjustment factor runs hotter than other equally valid and robust global climate models from CMIP5 (Section 5.2 of Ref. [76]).
- When taking into account the diurnal cycle of extreme temperature events as characterised by longer averaging periods and the heatwave profile, the resulting temperatures are significantly below the temperatures used in the HVAC system margin assessments (Section 5.3 of Ref. [76]).
- Margin assessments carried out on the HPC design demonstrate that when considering very conservative scenarios, the assessed HVAC systems provide sufficient cooling with margin to ensure their safety functions (Section 5.4 of Ref. [76]).
- The SZC project lifecycle will provide multiple systematic opportunities, ensured through Licence Condition arrangements, to reassess and reconfirm the adequacy of the SZC safety demonstration in regard to the extreme heat hazard (Section 5.5 of Ref. [76]).

As a result of the arguments and evidence summarised above, the analysis concludes that the adoption of the HPC design basis air temperatures at SZC will result in a design for which an adequate safety demonstration will be made in the SZC PCSR. Therefore, the SZC design basis extreme heat air temperatures given in Section 3.6.5.4.1 are justified.

3.6.6 Extreme Cold (Air)

3.6.6.1 Description of Hazard and Historical Context

For Sizewell, the nearest and most relevant data was from a weather station at Gorleston. Observations of daily minimal temperatures are available over a 28 year period. The lowest instantaneous minimum temperature recorded in that time period was approximately -6°C and the lowest 7-day average was approximately -3°C [Ref. 77].

3.6.6.2 Site Evaluation Studies

3.6.6.2.1 Present Day

Reference [77] provides an analysis of cold extremes for Sizewell by re-using Extreme Value Analysis (EVA) that was done for HPC. For HPC EVA was done using various datasets, including that from local weather stations (Rhoose and Nettlecombe) and also the Met-offices Central England Temperature dataset (CET). The EVA outputs used to define the site challenge for HPC are justified in HPC PCSR3 Sub-chapter 2.1 [Ref. 3].

With respect to SZC, Reference [77] provides a comparison of the 28 years of data from the Gorleston weather station to the equivalent 28-year period within the CET dataset. The CET dataset is demonstrated in Reference [77] to be bounding of SZC for that 28-year period. This is expected as Sizewell is a coastal site and hence generally less susceptible to extreme low temperature. The EVA that was generated using the CET dataset is then chosen in Reference [77] because the wider period over which the data was collected gives more credence to the EVA performed (132 years of data in the CET dataset was utilised in the EVA). It is this EVA that underpins the definition of the SZC site challenge below.

3.6.6.2.2 Climate Change

No allowance for climate change is made as climate change is likely to raise the values rather than reduce them.

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3.6.6.3 SZC Site Challenge

In this instance, the site challenge is defined as the best estimate 10,000 year temperature for each averaging period. Use of the best estimate is considered appropriate in this situation given that the CET dataset used in the EVA is clearly a pessimistic representation of a coastal site. Reference [77] provides the following data:

- Long duration (7 days) = -8.8°C;
- Short duration (24 hours) = -12.2°C;
- Instantaneous temperature = -20.3°C.

3.6.6.4 SZC Design Basis

3.6.6.4.1 Design Basis Definition

Given the intent to replicate HPC design at SZC as far as possible, the HPC design basis values for extreme cold air temperature are adopted as the design basis values for SZC.

- Long duration (7 days) temperature: -10 °C (assumed to exist permanently for design purposes, characterised by a seven day average value);
- Short duration (24 hours) temperature: -15 °C (assumed to exist for seven days for design purposes, characterised by a 24 hour average temperature);
- Instantaneous temperature: -25 °C (assumed to exist for six hours for design purposes, characterised by the instantaneous or daily minimum temperature).

3.6.6.4.2 Justification of Design Basis and Inherent Margins

Each of the design basis low air temperatures is bounding of the corresponding site challenge. As well as the large margin in the values themselves, there is also conservatism in the way they have been derived. In particular, the use of the CET dataset in the EVA used to define the site challenge (which is relevant to more inland and a potentially colder site in winter than a coastal site such as Sizewell). There is also a degree of conservatism in the application of the design basis. This is due to the fact that the design values are applied in the design for periods of time longer than their comparable site challenge value (e.g. the extreme 24-hour average low air temperature is applied for seven days).

3.7 Lightning and Electro-Magnetic Interference

3.7.1 Lightning

3.7.1.1 Description of Hazard and Historical Context

Lightning strikes can have a variety of different effects depending on where on the plant the strike hits as well as the strike’s intensity. Possible effects include damage to electrical equipment, damage to mechanical equipment through heating, or direct harm to human life.

There are two main types of cloud-to-ground lightning strikes, positive and negative. Generally, the polarity ratio of 10% positive and 90% negative is assumed [Ref. 80]. Furthermore, the characteristics of the two types of strikes are different resulting in separate lightning parameters published in standards [Ref. 80].

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3.7.1.2 Site Evaluation Studies

3.7.1.2.1 Present Day

A joint study for SZC and HPC was performed by EA technologies [Ref. 78] that provided an analysis of lightning activity data for the period 1999 to 2010. It provides data for lightning intensity within both a 20 km and a 10 km radius of the SZC site. The data has been collected by aerials placed at six locations throughout the UK. The aerials are able to detect electromagnetic waves created by the electrical discharge when lightning strikes occur. The geographical location of the strikes is calculated by triangulation, and the peak current estimated based on the strength of the electromagnetic waves received.

The study analysed parameters such as:

- Strike Location;
- Strike Date and Time;
- Strike Strength – the intensity of the strike in terms of peak current (kA);
- Multiplicity (Re-strokes) – after a strike occurs, it is possible that further currents follow down the same path as the initial strike; these post strikes are called re-strokes.

The largest strike intensity observed during the 11 year survey was a peak current of 300 kA recorded on the 10th September 2005, at a distance of 27.87 km from the site. This observation is broadly in line with the upper bound of lightning strike intensity, which is estimated to be 300 kA for a temperate climate, when considering the inherent uncertainty in the indirect best practice method applied to estimate the lightning strength.

3.7.1.2.2 Climate Change Allowance

There is an uncertainty in the impact that climate change will have on lightning strikes on a local scale, although it could lead to an increase in overall activity. The UKCP18 Convection Permitting Models (CPM) projections science report concludes that further work is needed to evaluate the lightning output from the CPM and understand the causes of any deficiencies, before a recommended use of this output can be given to stakeholders [Ref. 79]. Therefore, in the absence of a standard method for quantifying the impact of climate change, no allowance is incorporated within the site challenge.

3.7.1.3 SZC Site Challenge

The lightning hazard is characterised by considering three factors, the strike or flash density of the location being considered, the size of the area being struck and the lightning peak current exceedance probability. These in turn provide the characteristic of the lightning strike to be considered in the design of the protection. The greater the flash density, area or peak current, the higher severity characteristics of the strike to be considered in the design. Therefore, to define an appropriate site challenge for SZC, it is necessary to scale the observed strike rates within the 20 km radius centred on SZC with an appropriately defined ‘collection area’.

From a simplified perspective, all of the SZC site could be struck, so the whole site area could be used to characterise the severity of the hazard. However, this approach is overly conservative because of several reasons. Firstly, defining the whole site area as the collection area does not reflect the protection provided by the segregation of redundant plant within the design. Secondly, it results in the hazard at every unique point on site being characterised as if its size is equivalent to the area of the SZC site. Unlike other hazards (e.g. earthquake or flooding), the effects of lightning originate from the location which is struck. So, while anywhere on the site could be struck, the effects differ depending on the location struck. A strike on a SSC in the north east corner of the site will affect that differently compared to the effect of that same strike on a SSC in the south west corner of the site (approximately 1km away). In other words, lightning strikes a specific

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location from which the effects propagate. From this perspective, it is logical to consider the size of the SSCs being struck (e.g. building/structure size). However, using individual buildings/structure to characterise this hazard has been judged not to provide a sufficiently conservative characterisation of the hazard.

Another option is (the approach that was adopted at HPC) where the hazard is characterised in terms of an EPR 'power plant block' which is defined in terms of the typical collection area of a single EPR unit. The equivalent area is significantly larger than an individual structure but less than the whole Permanent Development Site. This ensures that the hazard is characterised considering an adequately conservative area, accounting for connections between structures but not assessing the hazard for an individual location based on the total size of the Permanent Development Site which will include many areas not relevant to nuclear safety. This is the approach that has been used on HPC and which is being replicated on SZC. The collection area defined in line with an EPR 'Power Plant Block' is given by length 145 m, width 80 m, and height 47 m. This gives a collection area of 0.1375 km^2 (based on Equation A.2 in Reference [80]).

The objective for hazards protection is to define a site challenge with an annual event frequency of 1.0E-4. Considering the EPR Power Plant Block target area (A), the number of lightning strikes (B) in the lightning survey area (circle of radius 20 km) (C) over the course of the survey (11 years) (D) and the distribution of strike currents (to give the lightning peak current exceedance probability) (E), it can be deduced that an appropriate lightning site challenge is 200 kA.

This is based on estimating the strikes per EPR power block per year ((A x B) / (C x D)) and multiplying the resulting frequency by the proportion of strikes above a given amplitude (using E). This gives a frequency of a strike above a given amplitude for an EPR power block located within the survey area. Within the 20km radius of the area centred on SZC considered in the assessment, there were 8 lightning strikes (out of 12406) of 170kA or above and only 4 strikes of 200kA or above. Accounting for the uncertainty in measurement and conservatively including the larger number of strikes, the frequency of an EPR power block area being struck by lightning of greater than 170kA is less than 1E-04 p.a.. Therefore, 200kA is judged to be an adequately conservative definition of the SZC Site Challenge.

3.7.1.4 SZC Design Basis

3.7.1.4.1 Design Basis Definition

The design basis lightning characteristics adopted for design purposes are related to Level 1 protection as defined by the standard BS EN 62305, section 1 [Ref. 80]. The positive and negative strike characteristics are provided in Table 29 below. The use of these characteristics, in line with Level 1 protection, is commensurate with the risk from this hazard and the definition of the Site Challenge at 200kA.

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Parameter	Characteristic	Value
First Positive Impulse	Value of Peak Current	200kA
	Front Time	10µs
	Time to Half Value	350 µs
	Impulse Charge	100C
	Specific Energy W/R	100MJ/ Ω
First Negative	First Return Arc Peak	100 kA
	Front Time T1	1 µs
	Time to Half Value T2	200 µs
	Average dI/dt with I_{max}	100 kA/µs
Subsequent Impulse	First Return Arc Peak	50 kA
	Front Time T1	0.25 µs
	Time to Half Value T2	100 µs
	Average dI/dt with I_{max}	200 kA/µs
Long Duration Stroke	Maximum Charge	200 C
	Duration	500 ms

Table 29: Level 1 Protection from BS EN 62305

3.7.1.4.2 Justification of Design Basis and Inherent Margins

The design basis has been set in line with a site challenge for lightning which has been characterised by considering two factors, the strike or flash density of the location being considered, and the size of the area being struck. In regard to flash density, a bespoke analysis has been undertaken which considers a circle of radius 20km, providing higher resolution and improved data compared to the flash density map provided in BS EN 62305. In regard to the size of the area being struck, a number of different options have been considered with the EPR power block being judged to be the appropriate collection area. A smaller, individual building size is not sufficiently conservative while considering the whole site area would effectively treat each individual potential strike point on the site as if it had an area of approximately 1km^2 and would not reflect the protection provided by the segregation of redundant plant within the design. The site specific conditions have been used to define a conservative Site Challenge. The lightning characteristics associated with Level 1 protection is used to define the lightning Design Basis as they align with the Site challenge which has been conservatively derived.

Furthermore, as part of the development of the SZC hazards safety case, including consideration of beyond design basis hazard levels, the absence of cliff edges associated with larger intensity strikes will be confirmed. Given the high level of replication between the HPC and SZC designs, the development of the HPC safety case will be used to inform the SZC safety case. HPC studies to assess the margin in the design up to 300kA considering direct strike effects on surge protection on overhead lines provide confidence in the adequacy of design [Ref. 81]. This work demonstrates that there is significant margin in the protection even with strikes of 300kA.

3.7.2 External Electro-Magnetic Interference

3.7.2.1 Description of Hazard and Historical Context

External Electro-Magnetic Interference (EMI) refers to the impact that off-site anthropogenic sources, such as radio broadcasts, as well as natural sources, such as lightning and solar activity, can have on electronic equipment.

3.7.2.2 Site Evaluation Studies

An Electro-Magnetic Field (EMF) site survey was carried out at the SZC site to verify the absence of significant local sources of EMI [Ref. 82]. The study essentially consists of two parts:

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- A desk-top review of transmitters within a 10 km distance of the site;
- A radio frequency emission survey at the site.

The findings from the desk-based study indicated potential for electromagnetic fields with a magnitude below normal industrial environment immunity levels, and typically much less. The emission survey found actual electro-magnetic field levels were lower than the values calculated from the desktop review.

From the desktop review the largest amplitude calculated was associated S Band Radar with a frequency of 2.9 to 3.1 GHz and amplitude of 5.7 V/m. From the survey undertaken the largest amplitude measurement was the Low Frequency Band (LF) Timing Signal at frequency 60 kHz with amplitude of 1.45 mV/m.

The conclusions of Reference [82] are that the application of appropriate codes and standards (e.g. EMC standards IEC EN 61000-6-7 and IEC EN 61326-3-1) in the design, manufacture and testing of equipment will ensure it is immune to the worst case calculated electromagnetic fields identified by the site survey.

3.7.2.3 SZC Site Challenge

The maximum levels of observed EMI are judged to not to pose a risk to nuclear safety and so no site challenge is defined.

3.7.2.4 SZC Design Basis

Protection against EMI is provided by designing, manufacturing, and testing the electrical and Instrumentation and Control (I&C) equipment at SZC in accordance with the relevant standards.

3.8 Solar Activity

In 2011 the UK recognised extreme space weather (ESW) events as an example of a high impact natural hazard with a low probability of occurrence in any given year. It was included for the first time as part of the National Risk Assessment, and subsequently added to the National Risk Register. UK space weather preparedness strategy has been formulated [Ref. 104] setting out the UK approach to space weather preparedness.

The Royal Academy of Engineering produced a report in 2013 on the impacts of ESW on engineered systems and infrastructure [Ref. 105]. The scope of this report is broad as it considered all aspects of space weather, including disturbances to the geomagnetic field and ionosphere. However, the report also identified a key risk to infrastructure from another aspect of space weather –relativistic (highly energetic) particles from the Sun.

3.8.1 Geomagneticallly Induced Current

3.8.1.1 Description of Hazard and Historical Context

A super storm which occurred in 1859, now referred to as the 'Carrington event' is the largest geomagnetic storm to be recorded. Various studies suggest that a reasonable range for the average return period for a similar event is 100-250 years. However, this is based on a data set that extends back only around 170 years. The Royal Academy of Engineering [Ref. 104] states that in the UK, for planning purposes, a reasonable worst case super storm with the strength of the Carrington event is currently considered to be a 1 in 100-year event. It is thought this type of event would have a significant impact on the national electricity grid. The RAE estimates some local electricity interruptions lasting a few hours. In addition, around six Super Grid Transformers in England and Wales and a further seven grid transformers in Scotland could be damaged and taken out of service.

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According to the RAE, the time for an emergency transformer replacement, when a spare is available, is normally 8 to 16 weeks, with a record of four weeks delay in reinstating the electrical grid.

3.8.1.2 Site Evaluation Studies

3.8.1.2.1 Present Day

It is suggested that GIC generated by geomagnetic storms should be expected to cause serious grid voltage irregularities or LOOP. However it is acknowledged that current understanding of the vulnerabilities of modern infrastructure to severe space weather and the measures developed to mitigate them are based largely on experience gained during the past 20 to 30 years.

For SZC GIC has been characterised using models of ground conductivity, earth electric fields and the electric power grid [Ref. 110].

3.8.1.2.2 Climate Change Allowance

Climate change is not considered to have a significant influence on the definition of the site challenge.

3.8.1.1 SZC Site Challenge

The site challenge for GIC has been defined by considering an event with a return period of 1E-4p.a. and by conservatively including the maximum level of uncertainty from both the electric grid and electric field models to give a value of 564A [Ref. 110].

3.8.1.2 SZC Design Basis

3.8.1.2.1 Design Basis Definition

The site challenge value of 564A[12] is adopted as the design basis.

3.8.1.2.2 Justification of Design Basis and Inherent Margins

The design basis has been set at the same level as the site challenge so there is no inherent margin between them. However, the site challenge has itself been defined conservatively by including the uncertainty in the electric grid and electric field models.

3.8.2 Ground Level Enhancement

3.8.2.1 Description of Hazard and Historical Context

During ESW events, highly energetic particles from the Sun arrive at Earth, with the potential to result in an increase in ground level atmospheric neutron flux. Such events could pose a risk to ground level infrastructure, through Single Event Effects (SEE) in microelectronic components that can lead to the malfunction and even failure of electronic control systems.

Ground Level Enhancement (GLE) concerns the interaction of energetic particles, generated during solar storms, with the terrestrial atmosphere that leads to the creation of atmospheric cascades, most commonly neutrons. These events can be indirectly detected by neutron monitors at ground level, so long as the position of monitors is suitable in relation to the configuration of the Earth's magnetic field at the time of an event. Increases in neutron fluxes at ground level could pose a risk for infrastructure. For instance, microelectronic equipment could malfunction due to a SEE.

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[12] It should be noted that the current value defined by the Site Challenge would be distributed over the affected transformers such that each individual transformer would experience a lower value [Ref. 110].

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It is acknowledged that the characterisation of GLEs is difficult as they have only been detectable since the mid-20th century; frequency and severity are therefore difficult to determine.

3.8.2.2 Site Evaluation Studies

3.8.2.2.1 Present Day

[Ref. 106] identifies that a number of different attempts have been made to evaluate the GLE worst-case scenario. They are summarised in [Ref. 107], i.e. the estimation of the total fluence and peak flux of neutrons at latitudes of interest and a range of annual exceedance probabilities (AEPs). NNB, NG, EDF DIPNN-DT asked the EDF Energy R&D UK centre to re-evaluate the worst-case scenario. [Ref. 106] estimates the return level of the total fluence and peak flux of neutrons for UK latitudes based on a new analysis delivered by the consortium Single Event Effects in Ground Level Infrastructure (SEEGI), alongside an EVA applied to Dourbes (Belgium) neutron fluence and peak flux data, and on comparisons with the previous studies. The different analyses have used different data and methodology:

- In the SEEGI project, the worst-case scenario is based on the February 1956 event for which the neutron spectrum has been carefully reconstructed at ground level. The extrapolation to higher frequencies is based on a simplistic extrapolation of intense GLE historical records that permits the evaluation of a factor to apply to the February 1956 neutron estimate at ground level.
- For the Dourbes neutron monitor data analysis, the neutron peak flux and total fluences have been reconstructed at ground level using data from the Dourbes neutron monitor for 54 GLEs; EVA has been applied to this data. The 10,000-year return level of the neutron peak flux can be considered as 75 neutron.s^{-1}.cm^{-2}. This value is 3 times lower than the previous estimates given by [Ref. 108].

Although the return level estimates are based on a comparison with historical records, they have been shown to be in agreement with the results obtained from EVA (based on the same rigidity magnetic of 3 Giga Electron Volts (GeV)). A conservative approach is taken in [Ref. 106] by assuming that the magnetic rigidity of the terrestrial magnetic field line at UK latitudes will be close to 0 GeV in case of an extreme event. The 10,000-year return level of the neutron fluences can then be evaluated as 1,000,000 neutron.cm^{-2}.

Table 30 presents the return level estimates recommended for the neutron fluences and peak flux.

Return Period (years)	Total fluence (neutrons.cm^{-2})	Flux peak (neutron.s^{-1}.cm^{-2})
10	-	0.15
100	9,300	-
1000	130,000	45
10000	1,000,000	75

Table 30: Recommended return period estimates of the neutron total fluence and flux peak for a GLE worst-case scenario

3.8.2.2.2 Climate Change Allowance

Climate change is not considered to have a significant influence on the definition of the site challenge.

3.8.2.3 SZC Site Challenge

On the basis of the analysis results summarised in Table 30 above, the GLE site challenge is defined at the 10,000 year return period row in Table 30.

[Ref. 109] provides estimates of the duration of geomagnetic storms, based on two space weather parameters: the geomagnetic index aa_h and the magnitude of the solar wind magnetic field *B*. This has been done using multivariate EVA. The analysis concludes that the duration of geomagnetic storms for a

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Carrington-type event (based on aa_H and with a peak at 1000nT) has been estimated as 42 hours, with an upper quantile 95% of 75 hours.

3.8.2.4 SZC Design Basis

It is acknowledged by the ONR that the subject of space weather as an External Hazard is an immature field in terms of the characterising the event and the engineering the protection [Ref. 67]. NNB are addressing the issue by constructing a safety case for space weather.

3.9 Heat sink specific hazards

3.9.1 Extreme Heat (Sea)

3.9.1.1 Description of Hazard and Historical Context

Water intake temperature is an important factor in the design and operation of a nuclear power station. A high seawater temperature could impact the cooling efficiency of the power plant during operation, shutdown, or accident conditions. The design of the cooling systems must be such that they can cater for the range of temperatures that could be encountered within the design basis.

Seawater temperature can undergo significant seasonal variation, while also being impacted by long periods of warm weather and high solar irradiance. In summer, when sea temperatures are at their highest, seawater tends to heat up in the day and cool at night, heating the air above it and losing long wave radiation to space. A scenario where there are continually cloud free days that maximises solar irradiance and cloudy nights which inhibit heat loss, such that heat is built up and maintained, is unlikely but not impossible. An alternative heating scenario resulting from the settling of central European air masses over the eastern UK, bringing warm night time temperatures, as well as high daytime temperatures, is also meteorologically feasible.

3.9.1.2 Site Evaluation Studies

Site evaluation studies were initially carried out by CEFAS [Ref. 83] and EDF R&D [Ref. 84], resulting in an updated analysis using the latest data from a wider variety of sources [Ref. 85]. The present day and future values in the sections below are taken from the latest analysis of the hazard [Ref. 85].

3.9.1.2.1 Present Day

The present-day extreme was estimated using data from 6 different sensors, 5 located at different positions in the SZB forebay, and 1 sea surface temperature sensor located <1km from Sizewell. The data was analysed to identify the appropriate data series based on the completeness, quality and length of the data series, the locations and calibration of the sensors as well as conservatism considering the proposed location of the SZC intakes. As part of the analysis the diurnal cycle of sea temperatures and the standard error of the temperature sensors were used in a statistical analysis to demonstrate the adequacy of using daily mean data when estimating extreme high sea temperatures. Furthermore, an assessment was conducted to determine the adjustment factor that should be incorporated into the results to account for the difference in location and depth between the SZC intakes and the SZB intakes. Despite evidence that the location and depth of the SZC intakes results in a lower temperatures than SZB, a conservative approach of including no adjustment factor has been adopted [Ref. 85].

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Return Period (Years)	Return Level (°C)		
	50th Centile	84th Centile	95th Centile
10	21.8	22.0	22.2
100	22.6	23.1	23.4
1,000	23.0	23.8	24.3
10,000	23.2	24.2	24.9

Table 31: Sea temperature return levels with corresponding uncertainty percentiles expected at the proposed SZC cooling water intakes. These values are derived using the block maxima approach to observational data from the SZB sea water intakes. The uncertainty percentiles are calculated using the delta method [Ref. 85].

3.9.1.2.2 Climate Change Allowance

Future climate projections suggest there is likely to be a warming trend in sea water temperatures over the next century [Ref. 85]. Proudman Oceanographic Laboratory Coastal Ocean Modelling System (POLCOMS) climate projection data were used to calculate the temperature difference expected at 2100 due to climate change under the emissions scenario RCP8.5.

POLCOMS is a well-established physical model with the ability to simulate regions that include both the deep ocean and the continental shelf. The model tracks the movement of water and the transfer of energy and momentum in three dimensions, enabling the water temperature, salinity, and currents to be modelled. The POLCOMS model has been validated by its creators through comparison to satellite data, using monthly values for years 1998-2015. To project future seawater temperature, the POLCOMS model is driven by data included within the Coupled Model Intercomparison Project Phase 5 (CMIP5). Other recommended climate projection projects such as the UKCP18 projections do not have seawater temperature as an output from the open access datasets so has not been used in the analysis.

Three different statistical approaches have been applied to the POLCOMS data to estimate the climate change adjustment factor in extreme high seawater temperature: linear regression (applied to several subsets of the data); block maxima approach, and through identification of the greatest temperature differences between current and future temperatures.

The climate change adjustment factors range from +2.6°C to +3.7°C. The report authors recommended the value of +3.0°C for the climate change adjustment factor to 2100 to be added to the present climate return levels [Ref. 85]. This is motivated by several reasons:

- This value is the most conservative value derived using linear regression, a method that models the change in sea water temperature well;
- This value is the mean of the calculated adjustment factors;
- The methods that give rise to higher adjustment factors have additional uncertainties to this method:
    - The GEV fits are unrealistically bounded for both the present and future epochs in the POLCOMS climate projections;
    - The month-specific change has one month that has a much higher adjustment factor compared to the other months.

3.9.1.3 [redacted]

[redacted]

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3.9.1.4 SZC Design Basis

3.9.1.4.1 [redacted]

[redacted]

[redacted]

3.9.1.4.2 Justification of Design Basis and Inherent Margins

The design basis high seawater temperature of [redacted] is fully bounding of the site challenge and therefore meets the intent of a design basis event. Inherent Margin is defined as the difference between the design basis and the site challenge. In this case, an Inherent Margin of [redacted] in the design basis can be claimed. Further confidence in the adequacy of the design basis in comparison to the site challenge can be taken from the conservatisms that were used to define the site challenge. Notably, not including an adjustment factor for depth or location despite the SZC intakes being at a colder location and depth in comparison to the input data used in the analysis.

Appendix 2 of Reference 85 provides a detailed comparison of the work that was conducted in that assessment compared to previous assessments and demonstrating the robustness of the approach that has been used to define the design basis. The key points are summarised below.

- Reference 85 analysed data from five temperature sensors in the SZB CWS with a longer time period of between 1994 and 2020. These datasets were corroborated against an additional independent dataset from a buoy positioned offshore of the Sizewell-Dunwich sand bank, closer to the proposed locations of the SZC cooling water intakes. The previous analyses [Ref. 83 and 84] only analysed one dataset of hourly in-situ temperature measurements from one monitor between 1994 and 2018.
- The previous analyses [Ref. 83 and 84] reduced the data values by accounting for the SZC intake heads being several kilometres further from the shore than the SZB intake heads. In Reference 85 there was not sufficient confidence in the methodology for the site adjustment factor in a region with such complex coastal processes and geomorphological features. Therefore, no site adjustment was made, adding an additional later of conservatism to the results.
- In the Reference [85] assessment a thorough data pre-processing procedure was carried out to remove erroneous values from the datasets by using diurnal and annual comparisons. No pre-processing steps were recorded in the previous analyses.
- Regarding the data analysis, different EVA approaches were used between the latest and previous assessments. Reference [83] used the peaks-over-threshold approach, whereas, in Reference [85] the annual maxima approach was used. While these two approaches are both commonly used, for seawater temperature the annual maxima approach is more suitable due to the high thermal inertia of water. This means that extreme temperatures that are clustered in the same week, month, or year are likely to be caused by the same oceanographic processes, making them dependant. This difference in methodology explains the hotter values for return level estimates in Reference [83]. Since their approach selected more extremes from the dataset (i.e. more than one extreme value per year), and their EVA analysis assumes that each of those extremes are independent. Therefore, their EVA model is fit to a higher number of extremes in the same time period compared to the model in Reference [85]. This leads to the model in Reference [83] predicting more frequent and hotter extremes into the future. This difference is made larger by the fact that the selected extremes in Reference [83] do not appear to have been declustered, leading to highly dependent extremes being assumed by the model to be independent.

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- There are differences in the data and methodology used for the future climate change analysis between the latest and previous assessments. In the absence of seawater temperature output from UKCP18, Reference [83] analysed data from UKCP09 under the medium emissions scenario (Special Report on Emissions Scenarios, SRES A1B) while Reference [85] analysed data from the POLCOMS climate projection under the high emissions scenario, RCP8.5. POLCOMS is a more recent projection, however it is driven by one model rather than an ensemble of models like UKCP09. Analysing the higher emissions scenario in the present report gives a layer of conservatism to the results.
- Regarding the methodology for the future climate assessment at SZC, Reference [83 calculated the climate change adjustment between 2006 and 2110 (i.e. independently for January, February, etc.) and added these adjustments to the in-situ data. After selecting extremes using the peaks-over-threshold approach, a Weibull distribution was fit to this augmented dataset and return levels calculated for the future climate. In Reference [85] three independent methods were used:
    - linear regression applied to four different subsets of the data;
    - EVA (using the annual maxima approach) applied to two epochs of the climate projections and the difference between return levels calculated; and
    - calculating the month-specific difference between the mean temperatures in the two epochs.

The peaks-over-threshold approach utilised in Reference [83] for their climate change adjustment has the same pitfalls as their analysis of the present climate, namely that extremes that are likely to be dependant in reality are assumed by their model to be independent, leading to higher values than should be expected.

3.9.2 Extreme Cold (Sea)

3.9.2.1 Description of Hazard and Historical Context

Low seawater temperature could potentially affect the operation of the heat sink at SZC in the form of overcooling and ice formation.

It is generally physically inconsistent to describe a seawater temperature below its freezing point. As such, the site challenge for SZC is conservatively defined as the freezing point (except in the very exceptional case of frazil formation). This is because in reality the colder surface water will tend to sink as it cools and form convection currents with a cycle of heating and cooling.

3.9.2.2 Site Evaluation Studies

3.9.2.2.1 Present Day

The freezing point of seawater depends on salinity and pressure where high levels of salinity reduce the freezing temperature of seawater. A Sizewell specific Extreme Value analysis of salinity has been undertaken by CEFAS [Ref. 83] which indicates a high-level salinity for 10,000-year return period of 35.58ppt.

3.9.2.2.2 Climate Change Allowance

Sea temperatures are expected to rise so coincident low temperature and high salinity events are expected to become less frequent over the lifetime of the station. Therefore, as a conservatism, no climate change allowance is considered for extreme cold seawater temperatures.

3.9.2.3 SZC Site Challenge

Characteristic values of freezing temperature given a salinity level and at atmospheric pressure are given in Table 32 [Ref. 92] below:

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Salinity (ppt)	5	10	15	20	25	30	35
Tf (°C)	-0.28	-0.51	-0.81	-1.08	-1.36	-1.64	-1.92

Table 32: Freezing temperature (Tf) for seawater as a function of salinity at atmospheric pressure

The site challenge salinity level therefore translates into a site challenge freezing temperature of approximately -2°C.

3.9.2.4 SZC Design Basis

3.9.2.4.1 Design Basis Definition

The design basis extreme low seawater temperature is taken as <-1.8°C as per HPC (based on 33ppt salinity).

3.9.2.4.2 Justification of Design Basis and Inherent Margins

The SZC site challenge of approximately -2°C was derived at the 10,000 year return period salinity level using extreme value analysis. On the other hand, the maximum recorded salinity at Hinkley Point over the period 1981 to 2007 (33 parts per thousand) was used to define the HPC site challenge and design basis without extrapolation to the 10,000 year return level for salinity. As such, the SZC site challenge is very conservatively derived compared to the HPC design basis.

In addition, to reach the SZC freezing seawater temperature would also require a coincident cold spell. The combined frequency of this has not been assessed but would undoubtedly have an associated return period of greater than 10,000 years. It is recognised that a concurrent extreme sea salinity and extreme cold spell could lead to the formation of Frazil ice. This is specifically discussed in Section 3.9.3 below.

3.9.3 Clogging – Frazil Ice

3.9.3.1 Description of Hazard and Historical Context

Frazil ice is the formation of small ice crystals. It occurs in turbulent water, which allows the ice to sink rather than float as normal. As the ice begins to nucleate it adheres to any objects in the water, especially if the objects are at a temperature below the freezing point of water. The formation of frazil ice could potentially lead to a blockage of the cooling water intakes at SZC.

Two conditions are simultaneously necessary for frazil ice to form, water at its freezing point, and water being cooled by the environment. The combination of these effects can cause water to be supercooled below its usual freezing point. The greater the supercooling the more unstable the water phase becomes such that there is a greater likelihood of forming frazil ice.

3.9.3.2 Site Evaluation Studies

The appearance of frazil is a complex phenomenon and depends on multiple energy balance components including solar radiation, water temperature, air temperature, evaporation, precipitation, and any other sources / sinks of heat such as river flows. Due to the complexity of all these components, the risk analysis is based on only the water temperature parameter. It is assumed that the probability to reach the freezing temperature is equivalent to the probability for frazil to occur. This leads to a conservative analysis as reaching the freezing temperature is a necessary but insufficient condition on its own.

Seawater temperature is related to its salinity, where lower salinity increases the temperature at which seawater can freeze. Lower salinity (and higher sea temperature) is therefore associated with an increased risk of frazil ice. Site evaluation studies of salinity were carried out that showed that the minimum salinity

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level, associated with an IEF of 1.0E-4 p.a. at the SZC intakes, is 32ppt [Ref. 83]. This equates to a maximum seawater freezing temperature of approximately -1.6°C at a frequency of 1.0E-4 p.a.

An independent review by a Frazil Ice specialist [Ref. 86] concluded that the annual frequency of frazil ice forming at the SZC intakes is less than 3.0E-6 p.a. which is less than the IEF for which a natural external hazard must be included within the design basis

3.9.3.3 Climate change Allowance

As explained in Section 3.9.2.2.2, seawater temperatures are predicted to generally increase due to climate change, which would indicate that frazil ice is less likely to form. Therefore, as a conservatism, no allowance is included for climate change.

3.9.3.4 SZC Site Challenge

The site challenge is defined as the frequency of occurrence of frazil ice at SZC. This has been conservatively assumed to occur at the temperature at which seawater freezes. At an IEF of 1.0E-4 p.a, using the minimum level of salinity at that frequency, the maximum temperature at which seawater could experience freezing is -1.6°C.

3.9.3.5 SZC Design Basis

3.9.3.5.1 Design Basis definition

In line with the conservative characterisation of the SZC frazil ice hazard site challenge as having an IEF of 1.0E-4, frazil ice is incorporated into the SZC design as a design basis hazard.

3.9.3.5.2 Justification of Design Basis and Inherent Margins

The frequency of frazil ice is conservatively estimated as estimated at 1.0E-4 p.a. and is therefore incorporated as a design basis hazard. As a site challenge is not defined in terms of a hazard level for frazil ice, it is not possible to identify any inherent margin. However, the analysis carried out in Reference [86], that considers all aspects required for the formation of frazil ice indicates an IEF of 3.0E-6 p.a. which is approximately two orders of magnitude less than the analysis only conserving seawater freezing temperature through seawater salinity. Therefore, including frazil ice formation in the SZC design basis is conservative.

3.9.4 Clogging – Silting

3.9.4.1 Description of Hazard and Historical Context

Strong tidal currents or high waves can result in highly turbulent environments. Sediment and particulates can become suspended throughout the seawater column such that they can be drawn and block the water intakes.

3.9.4.2 Site Evaluation Studies

3.9.4.2.1 Present Day

A vessel-based survey was carried out in 2019 [Ref. 87] using two seabed landers deployed at the proposed northern and southern cooling water intake head locations at SZC. Subsequently, this study has been developed upon by additional studies that used complementary results and conducted further analysis based on detailed modelling of suspension mechanisms and ingress rates [Ref. 89]. The analysis provided estimates of the total annual ingress at the SZC intake locations for different particle sizes to give average suspended sand and mud concentrations [Ref. 89]:

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- Sand: Between 10 mg/l and 20 mg/l (0.01 kg/m^3 to 0.02 kg/m^3).
- Mud: Between 160 mg/l and 200 mg/l (0.16 kg/m^3 to 0.2 kg/m^3).

3.9.4.2.2 Climate change allowance

Climate change is not expected to have a direct effect on sediment. However, the level of suspended sediment could be influenced by waves and sea levels. Therefore, factors related to these inputs have been included in the assessment.

3.9.4.3 SZC Site challenge

The results of the analysis in Reference [89] are summarised in Table 33. It should be noted that while the results in Table 33 refer to average suspended sediment concentration, the average in this case refers to the average value over the 96-hour duration of the extreme event. The conservatism in these results is derived from the inputs to the assessment which included the use of the wave heights associated with the 95% confidence interval that were also increased by 15% to account for climate change [Ref. 89]. Furthermore, it was established that the year used for the baseline in the assessments was more disturbed (had higher wave activity) than the average for the preceding decade, which indicates an additional level of built-in conservatism.

Site	Type	1.0E-4 p.a. Average Suspended Sediment Concentration (mg/l)
SZC1	Sand	229-323 (38%-45%)
	Silt/Clay	376-389
SZC2	Sand	329-458 (42%-49%)
	Silt/Clay	463-479
Overall	Sand	229-458 (38%-49%)
	Silt/Clay	376-479
	Total	605-937

Table 33: Particle composition of suspended samples at SZC1 and SZC2 (where SZC1 and SZC2 are the expected locations of the SZC intake heads).

3.9.4.4 SZC Design Basis

3.9.4.4.1 Design Basis Definition

The design basis definition for this hazard is set as the site challenge as shown in Table 33.

3.9.4.4.2 Justification of design Basis and Inherent Margins

The analysis used to define the site challenge and design basis includes a number of factors that provide confidence in the adequacy of the results. The analysis of the 1E-4p.a. event considered wave heights that were in the 95% confidence interval of wave heights for SZC and also took into account an increase in wave height of 15% for climate change. Furthermore, to account for the potential of very large tides, the analysis increased the data for the current by 25%.

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3.9.5 Clogging – Fauna and Flora or Anthropic

3.9.5.1 Description of Hazard and Historical Context

Clogging of the cooling water intakes at power plants can occur because of natural (e.g. marine biology) or anthropic (e.g. flotsam) causes.

Many nuclear sites are confronted with clogging of the water intake and filtration equipment. A congress organised by the World Association of Nuclear Operators (WANO) in March 2009 reviewed the severity of such problems, 56 events were reported for the period 2004 to 2008 alone. The main cause of these events was fauna and flora, accounting for 84% of the events [Ref. 90]. The main hazard presented is seaweeds clogging either filter screens, rotary filters, headers, or heat exchangers. As well as a similar risk posed by fish and other marine organisms.

3.9.5.2 Site evaluation studies

3.9.5.2.1 Present day

A combination of historical operational experience and knowledge of the potentially fouling species found allows a general understanding of the fouling risk [Ref. 91].

- Fishes - SZB operating experience shows several occurrences of fish ingress events, especially by sprat, that lead to a reduction of power generation. Massive sprat influxes have also led to shutdowns or required load reductions at SZA.
- Jellyfishes - International operating experience shows that jellyfish and ctenophores massive ingress can occur at a water intake with instantaneous concentration high above the maximum measured during a through year sampling program. Massive ingress of jellyfish can occur at Sizewell water intakes. SZB operating experience shows influxes in the past but the filtration system was able to cope with these events. No shutdowns due to jellyfish or ctenophores ingress have been reported at the SZB site.
- Algae/Seaweed - Algae and seaweed are transported in the environment as a result of environmental conditions only. Adverse weather conditions can dislodge this material from the seabed and potentially push it towards cooling water intakes. The seasonal die back of seaweed species could also lead to material becoming entrained within cooling water systems, especially during periods of increased storms. SZB operating experience shows occurrences of clogging by seaweed, like hydroids (white weed) and red weed.

Reference [91] also includes a conservative assessment of the observed clogging frequency at SZB. Considering all significant clogging events, not only reactor trips, a clogging frequency of 0.13 events p.a. have occurred at SZB.

3.9.5.2.2 Climate change analysis

Climate change could have a potential effect on the clogging of the intakes by fauna and flora. However, given the complex nature of the eco-system and the uncertainty associated with climate change, it is too difficult to robustly predict the effect of climate change on this hazard. The following remarks have been noted from expert analysis [Ref. 91].

- Fish – Depending on the species, total stock biomass around Sizewell seems to be stable or declining in the long term. However, climate change and future rise of North Sea temperature could be a factor to an increase of population for several species. On the other hand, potential population growth is subject to future fishery policies, which cannot be predicted. Therefore, assuming anything other than a stable population at this time is not supported.

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- Jellyfish - Current global increases in jellyfish populations are debatable. However, there is evidence of an increase within the North Sea that because it has been partly linked to climate factors, may continue in areas where sea surface temperature increases. This would be of particular relevance to Sizewell in the next decades given the site location.
- Algae/Seaweed – The Nature of change in algal population is difficult to predict. However, climate change is likely to increase frequency and/or severity of storms, and thus may increase clogging event frequency by algae and/or seaweed at Sizewell.

3.9.5.3 SZC Site Challenge

The observed clogging frequency from marine ingress at SZB is approximately 0.13 event a year. The SZC site challenge for clogging from fauna and flora or anthropic sources is therefore conservatively set at 0.2 events p.a.

3.9.5.4 SZC Design Basis

3.9.5.4.1 Design Basis Definition

Based on the estimated clogging frequency fauna and flora or anthropic clogging, which is greater than the IEF of 1.0E-4 p.a., this hazard is considered within the design basis.

3.9.5.4.2 Justification of Design Basis and Inherent Margins

As a site challenge is not defined in terms of a hazard level for fauna and flora or anthropic clogging, it is not possible to identify any Inherent Margin. Given that the fauna and flora or anthropic clogging hazard is limited in consequences by a Loss of Ultimate Heat Sink (LUHS) fault, it is not believed to be particularly amenable to the definition of a beyond design basis event.

3.9.6 Ship Collision

3.9.6.1 Description of Hazard and Historical Context

A ship collision with the sea water intake heads as a result of a keel strike or foundering has the potential to damage the intakes by direct impact and / or by the ingestion of debris, potentially affecting the ability to supply cooling water to the plant.

3.9.6.2 Site Evaluation Studies

3.9.6.2.1 Present Day

A conservative assessment of Ship Collision of over 100 Gross Tonnage (GT) with the SZC seawater intakes as a result of keel strike or foundering is presented in Reference [93]. The assessment demonstrates that the frequency of ship collision with the SZC seawater intakes is 1.88E-6p.a. and is therefore below the site challenge frequency cut-off for man-made external hazards of 1.0E-5p.a.

3.9.6.2.2 Climate Change Allowance

Climate change will not directly affect shipping in the area, although it is possible that rising sea levels will reduce the likelihood for any collision between a ship and one of the intake heads. This has not been quantified and has not been considered in the definition of the site challenge.

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3.9.6.3 SZC Site Challenge

Reference [93] defines the frequency at which ship collision (for ships > 100GT) with the SZC sea water intakes can be expected to occur (1.88E-6p.a.). It is also conservatively assumed that for any collision with the intakes by a ship of over 100GT, sufficient damage will occur to the intakes to affect nuclear safety.

3.9.6.4 SZC Design Basis

3.9.6.4.1 Design Basis Definition

Although the frequency of a collision involving any number of intake heads (1.88E-6p.a.) is lower than the 1.0E-5p.a. requirement for man-made external hazards, as per HPC, ship collision is considered a design basis hazard.

3.9.6.4.2 Justification of Design Basis and Inherent Margins

Ship collision is incorporated as a design basis hazard, which is conservative with regards to the objectives set out in Section 3.1.3.

As the hazard has been defined in terms of its frequency rather than it its severity, it is not possible to define any inherent margin. However, the geographical separation of the two intake heads and the Forebay Liaison Gallery (HPL) are effective means of managing the risks from this hazard.

3.9.7 Hydrocarbon Pollution

3.9.7.1 Description of Hazard and Historical Context

Hydrocarbon (defined as oil fractions and associated oil products) pollution such as that released in an Oil Tanker spillage event has the potential to cause clogging of the seawater intake heads and / or tunnels, as well of blockage of filtration equipment, affecting the seawater cooling chain. The risk of hydrocarbon spillages is deemed to be reducing due to the declining trend in major worldwide spillage events since the 1970s [Ref. 93].

3.9.7.2 Site Evaluation Studies

3.9.7.2.1 Present Day

Reference [93] conservatively assesses the frequency of pollution at the sea water intakes as a result of a hydrocarbon spillage event of greater than 7 tonnes of hydrocarbons (spillages less than this are deemed to pose no credible hazard) from oil tankers within 10nm of the sea water intakes as 1.53E-4p.a.

3.9.7.2.2 Climate Change Allowance

There is no direct impact of climate change on shipping or hydrocarbon production, as such it is not considered in the definition of the site challenge.

3.9.7.3 SZC Site Challenge

Reference [93] defines the frequency of 1.53E-4p.a. for a hydrocarbon spillage event resulting in >7 tonnes of hydrocarbons being released into the sea within 10nm of the SZC seawater intakes such that nuclear safety is affected.

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3.9.7.4 SZC Design Basis

3.9.7.4.1 Design Basis Definition

Although the risk is deemed to be small, hydrocarbons are incorporated as a design basis hazard at SZC with a frequency of occurrence of 1.53E-4p.a.

3.9.7.4.2 Justification of Design Basis and Inherent Margins

As the hazard has been defined in terms of its frequency rather than it its severity, it is not possible to define any inherent margin. However, the geographical separation of the two intake heads and the Forebay Liaison Gallery (HPL) are effective means of managing the risks from this hazard. Furthermore, given that the hazard is limited in consequences by a LUHS fault, it is not believed to be particularly amenable to the definition of a beyond design basis event.

3.9.8 Underwater Explosion

3.9.8.1 Description of Hazard and Historical Context

An underwater explosion could result from either unexploded ordnance or from the underwater propagation of an explosion on board a ship. Both scenarios could potentially cause damage to the intake heads which in turn could affect the ability to supply cooling water to the plant.

3.9.8.2 Site Evaluation Studies

3.9.8.2.1 Present Day

An assessment of the hazard posed by unexploded ordnance was carried out in Reference [32]. The bounding scenario was judged to be 750 kg of TNT, which is an example of the munitions that could possibly be found in the proximity of the intake heads (This is considered to be a large example of a potential WWII device). Prior to construction, an area of 100 m around each head will be dredged to ensure there are no devices within close proximity of the intake heads. The cases identified for assessment are:

- Unexploded bomb / ordnance explosion in the vicinity of the seawater intakes;
- Unexploded bomb / ordnance explosion on a dredger in the vicinity of the seawater intakes;
- Explosion of unexploded bomb / ordnance which has drifted through tidal action to the area in front of the sea wall.

3.9.8.2.2 Climate Change Allowance

There is unlikely to be a direct effect on the magnitude and frequency of any underwater explosion as a result of climate change as such it is not considered in the definition of the site challenge.

3.9.8.3 SZC Site Challenge

Prior to construction of the seawater intake heads, an area of approximately 100 m around each head will be dredged. This should ensure that any unexploded devices located in these areas are identified and removed. Therefore, for unexploded devices to be within 100 m of the seawater intake heads, such a device would need to be moved into the area by tidal action and then detonate. The following factors are therefore considered:

- Dredging should identify any unexploded bombs / ordnance in the vicinity of the intake heads prior to construction;

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- Movement of unexploded devices into the vicinity of the heads is considered to be unlikely, noting that larger devices with greater explosive potential would have a greater mass and hence less likely than smaller devices to be moved by tidal action;
- Unexploded devices, although potentially viable, are unlikely to detonate unless disturbed or impacted. There are no records of unexploded bombs / ordnance spontaneously detonating in peacetime in the UK.

It is therefore considered in Reference [32] that the frequency of damage to a seawater intake through explosion of an unexploded bomb / ordnance located within 100 m of the intake head off the coast of the Sizewell site is <1.0E-5 p.a.

A frequency assessment is performed in Reference [93] for underwater propagation of an explosion on board a ship damaging the seawater intakes. The frequency of this event is conservatively calculated as 1.88E-7p.a. and is therefore significantly below the frequency cut-off of 1.0E-5p.a. for the man-made external hazards design basis. Notwithstanding this, as per HPC, the hazards of underwater explosion is incorporated in the design basis – See Section 3.9.8.4 below.

3.9.8.4 SZC Design Basis

3.9.8.4.1 Design Basis Definition

Despite the absence of a credible site challenge, underwater explosion is incorporated as a design basis hazard.

3.9.8.4.2 Justification of Design Basis and Inherent Margins

As a site challenge is not defined in terms of a hazard level for underwater explosion, it is not possible to identify any Inherent Margin.

The provision of two water intake tunnels (one per unit) provides redundancy and geographical separation against the effects of explosion. Furthermore, the availability of the forebay liaison galleries (HPL) would allow the long-term supply of water to the affected unit. Furthermore, given that the hazard is limited in consequences by a LUHS fault, it is not believed to be particularly amenable to the definition of a beyond design basis event.

3.9.9 Extreme Low Seawater Level

3.9.9.1 Description of Hazard and Historical Context

During a low water level there is potential for the intake heads to become exposed which, in the most extreme cases, may restrict water flow to the plant.

3.9.9.2 Site Evaluation Studies

3.9.9.2.1 Present Day

Characterisation work on Extreme Low Seawater Level has been carried out in Reference [83]. Best estimate results in Table 34 were obtained using tidal data from SZB and Lowestoft, corrections for differing tidal levels between the two locations, and relevant information regarding negative storm surges. Discussion on the statistical methods and tools is in Reference [94].

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Parameter	Generalised extreme variable GEV	Gumbel	Frechet 3-parameter	Weibull 3-parameter
1.0E-4 p.a.	-3.4mOD	-3.67mOD	-3.78mOD	-3.1mOD
P-Value (1 is a perfect fit)	0.973	0.923	0.918	0.887

Table 34: EVA values for 10,000 year return period extreme low seawater levels

3.9.9.2.2 Climate Change Allowance

The global climate change trend tends to give rise to a relative mean sea level rise. Therefore, no allowance for climate change has been incorporated into the extreme low water level values derived in the above studies.

3.9.9.3 SZC Site Challenge

The SZC site challenge for extreme low seawater level is provisionally taken as -3.40 mOD as the statistical method used to derive this value results in the best fit of the data. Given that no adjustment has been made for sea level rise as a result of climate change, use of the best-estimate is judged to be adequate.

3.9.9.4 SZC Design Basis

3.9.9.4.1 Design Basis Definition

The SZC design basis value for extreme low seawater is defined as -3.7mOD which aligns to the derisking value of extreme low seawater level taken from GDA.

3.9.9.4.2 Justification of Design Basis and Inherent Margins

Given that the Design Basis value for extreme low seawater level is 0.30m lower than the current site challenge and that seawater level is expected to rise in all climate change scenarios within UKCP18, the design basis value is judged to be suitably bounding of the site challenge.

3.9.10 Extreme Low Seawater Level (Tsunami)

3.9.10.1 Description of Hazard and Historical Context

Tsunamis are large scale waves generally caused by either seismic events or massive movements of land. As well as the potential to cause flooding (see Section 3.5), tsunamis cause seawater levels to lower as water is drawn back into the wave prior to its arrival or between wave peaks.

3.9.10.2 Site Evaluation Studies

3.9.10.2.1 Present Day

A detailed tsunami study has been undertaken to help inform the design of SZC [Ref. 49]. This study demonstrates that the threat from high amplitude meteorite impact tsunamis at the SZC site can be discounted on low frequency grounds (frequency of impact is <1E-8 p.a.). All other tsunami sources are found not to be capable of generating waves at the SZC site of an amplitude that could expose the intake heads through drawdown. The intake heads are predicted to remain submerged by at least 4m or 5m of water with no risk of exposure, loss of cooling water or significant air entrainment.

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3.9.10.2.2 Climate Change Allowance

Given that sea level is expected to rise with climate change, in order to be conservative and consider the lowest feasible sea level, the analysis undertaken in Reference [49] does not include an adjustment for climate change.

3.9.10.3 SZC Site Challenge

The maximum level of down draw during a tsunami with an IEF greater than 1.0E-4 p.a. does not challenge nuclear safety and hence no site challenge is defined.

3.9.10.4 SZC Design Basis

As per the requirements set out in Section 3.1.3, no specific design basis is defined for extreme low water (tsunami) because nuclear safety is not challenged when considering a tsunami with an IEF greater than 1.0E-4 p.a.

4 SUMMARY

This version of the SDSR (Version 4) includes a summary of the site hazard characterisation activities such that the site challenge and design basis can be defined and justified. Appendix A – Justification of SZC SDSR External Hazards List provides information on the hazard identification activities that were undertaken. Section 3 of this report then provides the site challenge and design basis for all applicable hazards. A site challenge and design basis has been defined and justified for all applicable hazards except for GLE (Section 3.8). For this hazard, activities are ongoing in collaboration with HPC and will be included in an update of this report when available. Appendix B – Summary of SZC and HPC Hazard Design Basis Alignment provides a summary of the alignment between the design basis values for hazards at HPC and SZC.

5 ACCRONYMS AND ABBREVIATIONS

Acronym	Meaning
AEP	Annual Exceedance Probability
AFoE	Annual Frequency of Exceedance
AOD	Above Ordnance Datum
BEEMS	British EdF Estuarine and Marine Studies
CAA	Civil Aviation Authority
CEFAS	Centre for Environment, Fisheries, Aquaculture Science
CET	Central England Temperature dataset
CFS	Capable Faulting Studies
CI	Confidence Interval
CI/BOP	Conventional Island / Balance of Plant
CMIP5	Coupled Model Intercomparison Project Phase 5
COMAH	Control of Major Accident Hazards
CPA	Closest Point of Approach
CPM	Convection Permitting Models
CPMMP	Coastal Process Monitoring and Mitigation Plan
DEFRA	Department for Environment, Food and Rural Affairs
DEL	Chilled Water System

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Acronym	Meaning
DVD	Diesel Building Ventilation system
DVF	Ventilation for the Conventional Island Electrical Buildings
DVL	Safeguard Buildings Electrical division, ventilation system
DVP	Circulating Water Pumping Station Ventilation System
EA	Environment Agency
EDRMS	Electronic Document and Records Management System
EMF	Electromagnetic Field
EMI	Electromagnetic Interference
EPR	The trade name for the pressurised water reactor design proposed at Sizewell C
ESW	Extreme Space Weather
EVA	Extreme Value Analysis
GDA	Generic Design Assessment
GeV	Giga Electron Volt
GEV	Generalised Extreme Variable
GIR	Ground Investigation Report
GLE	Ground Level Enhancement
GSB	Greater Sizewell Bay
GT	Gross Tonnage
HBX	Operational Service Centre
HF	Non-Classified Electrical Building
HGV	Heavy Goods Vehicle
HI-STORM	Holtec International Storage Module
HHK	Spent Fuel Building
HL	Safeguard Building Electrical division
HM	Turbine Hall
HOJ	Fire Fighting Water Distribution Building
HP	Pumping Station
HPC	Hinkley Point C
HPF	Forebay
HPL	Fore-bay Liaison Gallery
HSE	Health and Safety Executive
HVAC	Heating Ventilation Air Conditioning
IDLH	Immediately Dangerous to Life or Health
IEF	Initiating Event Frequency
IPCC	Intergovernmental Panel on Climate Change
ISFS	Interim Spent Fuel Store
JPA	Joint Probability Analysis
LF	Low Frequency
LNG	Liquefied Natural Gas
LOOP	Loss of Offsite Power

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Acronym	Meaning
LPG	Liquefied Petroleum Gas
LUHS	Loss of Ultimate Heat Sink
MBES	Multi Beam Echo Sounder
MCR	Main Control Room
MHWS	Mean High Water Spring
MPC	Multi-Purpose Canisters
MTWA	Maximum Take-off Weight Authorised
MWD	Maximum Water Depth
NCC	No Change Committee
NI	Nuclear Island
NRC	Nuclear Regulatory Commission
NSDAPs	Nuclear Safety Design and Assessment Principles
NSL	Nuclear Site Licence
p.a.	per annum
PCSR	Pre-Construction Safety Report
POLCOMS	Proudman Oceanographic Laboratory Coastal Ocean Modelling System
ppm	parts per million
ppt	parts per thousand
PSHA	Probabilistic Seismic Hazard Assessment
PWR	Pressurised Water Reactor
RCP	Representative Concentration Pathway
RGP	Relevant Good Practice
RH	Relative Humidity
SDSR	Site Data Summary Report
SEE	Single Event Effects
SEEGI	Single Event Effects in Ground Level Infrastructure
SQSS	Security and Quality of Supply Standard
SSCs	Structures, Systems, Components
SSI	Site of Special Scientific Interest
SSJPM	Skew Surge Joint Probability Method
SWH	Significant Wave Height
SZA	Sizewell A
SZB	Sizewell B
SZC	Sizewell C
UAV	Unmanned Aerial Vehicle
UKCP09	United Kingdom Climate Predictions 2009
UCKP18	United Kingdom Climate Predictions 2018
UK-EPR	United Kingdom European Pressurised (Water)Reactor
WWII	World War 2

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6 REFERENCES

Ref	Title	Location	Document No.
1	Justification of Site Suitability Report Rev. 3	EDRMS	SZC-SZC-NNBOSL-XX-000-REP-100006 (Teamcenter ID 100813434)
2	Lifetime safety case strategy for SZC	EDRMS	SZC-NNBOSL-XX-000-STR-100000
3	HPC Site Data Summary Report	EDRMS	HPC-NNBGEN-XX-000-REP-100120
4	Sizewell C Hazard Listing Report, Hyder Consulting (UK) Ltd	EDRMS	SZC-NNBGEN-XX-000-REP-100003 (Teamcenter ID 100810769)
5	Review of Aircraft Crash Rates for the UK 2001 to 2012 (P1031/R1)	EDRMS	UKX-3RDREG-XX-000-STU- 100001
6	Sizewell C Project - The Accidental Aircraft Crash Rate at SZC	EDRMS	SZC-SZ0100-XX-000-REP-100029
7	Sizewell C Power Station Construction Site Plot Plan, Rev. 5	EDRMS	SZC-SZ0100-XX-000-DRW-100000
8	UK EPR Sizewell – Preliminary Onshore Investigations (phase 1) – Ground Investigation Report. CEIDRE-TEGG, 2011. Rev. A	EDRMS	SZC-EDTEGG-AU-000-RET-000106
9	EPR UK – Sizewell C – Pre-existing geotechnical data synthesis and Interpretative Report (Step 1). Revision A, May 2014	EDRMS	CBL100100746
10	EPR UK – Sizewell C – Phase 2 Ground Investigation Report. Rev. B. EDF DI-TEGG.	EDRMS	SZC-DIXXXX-XX-000-RET-200010 (Teamcenter ID 100638318)
11	Sizewell Site C: Conceptual Site Model of the Hydrogeological Regime. Atkins, Revision 5, June 2015	EDRMS	SZC-SZ0500-XX-000-REP-100004
12	Sizewell C: Phase 2 Geo-Environmental Interpretative Report. Atkins. Revision 4.0, April 2020	EDRMS	SZC-SZ0200-XX-000-REP-100134
13	Geotechnical Aspects of Site Evaluation and Foundations for Nuclear Power Plants. IAEA Safety Guide No. NS-G-3.6, 2004	NA	NS-G-3.6, 2004
14	TR311 Sizewell Coastal Geomorphology and Hydrodynamics: Synthesis for Environmental Impact Assessment (MSR1 – Edition 4	EDRMS	SZC-SZ0200-XX-000-REP-100041
15	TR420; Sizewell- Directions and magnitudes of shingle transport along Sizewell Beach	EDRMS	SZC-SZ0200-XX-000-REP-100000
16	TR480; Sizewell- Modelling of Sediment Dispersion of Dredge Material from SZC Construction and Operation, Version 3	EDRMS	SZC-SZ0200-XX-000-REP100035

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Ref	Title	Location	Document No.
17	TR329 Sizewell C Shoreline Modelling - future wave and shoreline scenarios	EDRMS	SZC-SZ0200-XX-000-REP-100066
18	TR500; Sizewell C - Sizewell Dunwich Bank	ERDMS	SZC-SZ0200-XX-000-REP-100073
19	TR058; Sizewell- Morphology of coastal sandbanks and impact to adjacent shorelines	ERDMS	SZC-SZ0200-XX-000-REP-100090
20	TR403; Sizewell- Expert Geomorphological Assessment of Sizewell's Future Shoreline Position	ERDMS	SZC-SZ0200-XX-000-REP-100065
21	BEEMS Technical Report TR399, Multibeam Bathymetry Survey at Sizewell, July 2016, Titan Environmental Surveys	EDRMS	SZC-SZ0200-XX-000-REP-100151
22	TR108: Future Geomorphological Scenarios for Sizewell Area	EDRMS	SZC-SZ0200-XX-000-REP-100097
23	TR481; Sizewell- Modelling of the Hydrodynamics and Bed Shear stress around the beach landing facility at Sizewell C	EDRMS	SZC-SZ0200-XX-000-REP-100036
24	TR233 Ed 2; Sizewell- Tidal Modelling with Telemac2D- Validation (word Doc)	EDRMS	SZC-SZ0200-XX-000-REP-100101
25	SZC FRA - Hydrology Review and Design Event Methodology. RHDHV, December 2019	EDRMS	SZC-SZ0200-XX-000-REP-100136
26	Joint probability of waves and sea levels and structure response, Revision 2, May 2010	EDRMS	SZC-EDFENE-XX-000-RET-000002
27	SZC Grid Connection Design and Contribution to Loss of Off-Site Power (LOOP) Frequency. Revision 5	EDRMS	SZC-SZ0100-XX-000-REP-100043
28	Environmental Statement Volume 2: Chapter 14: Terrestrial Ecology And Ornithology	DCO Online SharePoint system	Chapter 14 Terrestrial Ecology and Ornithology
29	Environmental Statement Volume 2: Chapter 22: Marine Ecology and Fisheries	EDRMS	SZC-SZ0200-XX-000-REP-100153
30	The Grid Code, Issue 6, Revision 1, 18/03/2021	Website	https://www.nationalgrideso.com
31	National Electricity Transmission System Security and Quality of Supply Standard, Version 2.5, 01/04/2021	Website	https://www.nationalgrideso.com
32	[redacted]	[redacted]	[redacted]
33	Anatec Ltd, "Hazardous Cargo Assessment Sizewell C Nuclear Power Station", A2979-EDFE-TB-00 Rev 00, 7 November 2016	EDRMS	SZC-SZ0500-XX-000-REP-100003

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Ref	Title	Location	Document No.
34	Nuclear Safety Design Assessment Principles, Revision 2.0, August 2015, NNB GenCo	EDRMS	NNB-202-STA-000002
35	Use of UKCP18 to Define Reasonably Foreseeable Climate Change Rev. 1	EDRMS	100839077
36	Effects of radiological release from SZB/SZC on the SZC Main Control Rooms Rev. 1	EDRMS	100859795
37	Interim PSHA, Rev. 2	EDRMS	100639699
38	SZC Interim DBE Spectra	EDRMS	SZC-NNBOSL-XX-000-PAP-100002
39	PRE-CONSTRUCTION SAFETY REPORT HPC PCSR3 - Sub-Chapter 13.1 – External Hazards Protection	EDRMS	HPC-NNBOSL-U0-000-RES-000205
40	Man-Made Marine External Hazards Assessment for SZC, Revision 01, March 2020.	EDRMS	SZC-SZ0100-XX-000-REP-100042
41	Assessment of Sizewell B and C Turbine Missile Impact Frequencies on Sizewell C	EDRMS	SZC-PD0202-XX-000-REP-100005
42	SZC Platform Height: ALARP Analysis Decision Paper, Version 3	EDRMS	SZC-NNBOSL-U9-ALL-RES-100000
43	DEFRA – The threat posed by tsunami to the UK. June 2005	EDRMS	HPC-NNBOSL-XX-000-REP-000009
44	DEFRA, HSE, Geological Survey of Ireland: Tsunamis – Assessing the Hazard for the UK and Irish Coasts, June 2006	EDRMS	HPC-NNBOSL-XX-000-REP-001828
45	EDF Energy. UK Climate Change Projections 2018 - Review and Proposed Response. Royal HaskoningDHV. Revision 2, October 2019	EDRMS	SZC-SZ0200-XX-000-REP-100137
46	Sizewell C Safety Case – Coastal Flood Risk Modelling. Royal HaskoningDHV, Version 2, June 2020	EDRMS	SZC-SZ0200-XX-000-REP-100138
47	SZC Flooding Summary Report. Revision 4	EDRMS	SZC-SZC-NNBOSL-XXX-000-REP-100005 (Teamcenter ID 100813392)
48	Update to Estimation of extreme high-water levels at SZC, Revision 3	EDRMS	100859811
49	Sizewell C – Tsunami Hazard Assessment Report, Rev B	EDRMS	SZC-NNBGEN-XX-000-REP-100008
50	Extreme Rainfall at SZC, Revision 2, October 2019	EDRMS	SZC-PD0202-XX-000-REP-100001
51	UK EPR Sizewell – Detailed groundwater level assessment for the design. Revision B	EDRMS	SZC-DIXXXX-XX-000-RET-200014 (Teamcenter ID 100638393)

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Ref	Title	Location	Document No.
52	Safety Justification: Threat of Extreme Hail and Fog at SZC.	EDRMS	SZC-NNBOSL-U0-000-REP-100000
53	Extreme Precipitation Analysis at Sizewell: Final Report – Met Office February 2011, Version 2	EDRMS	SZC-SZ0500-XX-000-REP-100006
54	Sizewell C Project Snow and Wind Hazards at SZC	EDRMS	SZC-SZ0100-XX-000-REP-100035
55	Characterising the Risks Posed by Extreme Snow Loads at SZC	EDRMS	SZC-PD0202-XX-000-REP-100002 Revision 01 2019-NNB-D28
56	Study of snow loading for UK nuclear power stations: final report, October 2010, Met Office	EDRMS	HPC-3RDREG-XX-000-STU-100000
57	Eurocode BS EN 1991-1-3 - Actions on structures - Part 1-3: General actions - Snow Load, July 2003	NA	BS EN 1991
58	NA to BS EN 1991-1-3: UK National Annex (Snow Loads)	NA	National Annex to BS EN 1991-1-3
59	Met. Office Technical Report, 2013, Extreme Value Analysis for Sizewell	EDRMS	SZC-SZ0500-XX-000-REP-100007
60	Met Office, Hadley Centre March 21st 2013 Issue 1, Analysis of Extreme Wind Speeds at Sizewell	EDRMS	SZC-NNBOSL-XX-000-RET-000001
61	Extreme Value Analysis for Sizewell: Extended Report to Include Gust Wind Speeds	EDRMS	SZC-3RDREG-XX-000-ANA-100000
62	Sizewell Extreme Wind Speeds	EDRMS	EDFE/JER/DA/MO/0002/16 22 February 2016
63	HPC Design Basis Wind Substantiation – (including Appendix B SZC Design Basis Wind Substantiation)	EDRMS	HPC-NNBOSL-U0-ALL-RET-100001
64	Eurocode 1 BS EN 1991-1-4: Actions on structures - Part 1-4: General actions -Wind actions	NA	BS EN 1991-1-4
65	NA to BS EN 1991-1-4:2005+Al:2010 UK National Annex (Wind Actions)	NA	National Annex to BS EN 1991-1-4:
66	UKCP18 Headline Findings - Accessed 28/09/19	Internet	https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp18-headline-findings-2.pdf
67	ONR Technical Assessment Guide - External Hazards	NA	NS-TAST-GD-013 Rev 7 October 2018
68	SZC – Tornado Site Challenge	EDRMS	SZC-SZO100-XX-000-REP-100036
69	Assessing the Tornado Risk Potential for Coastal Somerset at Hinkley Point In Southern Britain	EDRMS	HPC-NNBOSL-U0-000-RET-000009

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Ref	Title	Location	Document No.
70	Met Office (2015) Investigation into the probability of EDF Energy nuclear power stations in the UK being affected by a tornado (for EDF Nuclear Generation);	EDRMS	EDFE/JER/DA/MO/0005/15.
71	UKCP18 Derived Projections of Future Climate over the UK; MetOffice, 2018.	Internet	https://www.metoffice.gov.uk/pub/data/weather/uk/ukcp18/science-reports/UKCP18-Derived-Projections-of-Future-Climate-over-the-UK.pdf
72	UK EPR tornado safety reference principles. Revision A	EDRMS	UKX-SEPTEN-AU-ALL-STU-000011
73	SZC – Volcanic Ash and Airborne Particulate Assessment	EDRMS	SZC-SZO100-XX-000-REP-100037
74	EdF R&D, Extreme air temperatures at Sizewell C	EDRMS	SZC-SZ0500-XX-000-REP-100000 (Teamcenter ID 100638207)
75	Advanced heatwave profile for SZC	EDRMS	SZC-PD0202-XX-000-REP-100003
76	Justification of Extreme High (Air) Temperature Design Basis Value at Sizewell C Rev 4	EDRMS	SZC-SZO100-XX-000-REP-100031 (Teamcenter ID 100905189)
77	Cold extremes for the Sizewell EPR: daily and 7-day air temperature means	EDRMS	SZC-SZ0500-XX-000-REP-100005
78	EA technologies, Lightning Data Analysis for Hinkley Point and Sizewell Power Station Sites, Issue 3, March 2011	EDRMS	HPC-NNBOSL-U0-000-RET-000005 (Teamcenter ID 100752181)
79	UKCP Convection-permitting model projections: Science report	Website	https://www.metoffice.gov.uk/pub/data/weather/uk/ukcp18/science-reports/UKCP-Convection-permitting-model-projections-report.pdf
80	BS EN 62305, Lightning Protection Standard. Section 1	N/A	BS EN 62305, section 1
81	Analysis Of Impacts In The Case Of Strikes On The OHL With Or Without A Failure From The Surge Protection	EDRMS	HPC-DTXXXX-XX-ALL-STU-200239 (Teamcenter ID 100894163)
82	Sizewell C Electromagnetic Interference (EMI) Study	EDRMS	SZC-NNBGEN-XX-000-REP -100004
83	TR489 Sizewell extremes for maximum sea temperature and combined sea levels and waves at the Sizewell C intakes	EDRMS	SZC-PD0202-XX-000-REP-100000
84	Reproducing CEFAS analysis on extreme sea temperature and salinity for SZC	EDRMS	SZC-PD0202-XX-000-REP-100004
85	Sizewell C Extreme High Sea Water Temperatures Rev. 3	EDRMS	100897283

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Ref	Title	Location	Document No.
86	SZC REPORT - FRAZIL ICE STUDY	EDRMS	SZC-DTXXXX-XX-ALL-NOT-200003
87	Cefas Report TR498 Sizewell C suspended sediment concentration at the proposed cooling water intake locations	EDRMS	SZC-SZ0200-XX-000-REP-100064
88	SZC Silting Analysis HP Report	EDRMS	SZC-CNEPEX-AU-HGZ-REP-200283
89	Sizewell C Power Station – Sediment Ingress at the seawater intake – Ingress rates and amounts	EDRMS	100897319
90	Clogging and in situ growth by marine organisms – Evaluation of risk at Hinkley Point C Power Station – Technical Report, Rev B	EDRMS	HPC-NNBOSL-U0-000-RET-000039
91	SZC Marine animal clogging frequency	EDRMS	SZC-DTXXXX-AU-ALL-REP-200007
92	Hinkley Point C: Evaluation of the risk of heat sink clogging by frazil ice. (ENITSF100024) Revision C, October 2011, EDF	EDRMS	HPC-NNBOSLU0- 000-REP-000013
93	Man-Made Marine External Hazards Assessment for SZC, Revision 01, March 2020.	EDRMS	SZC-SZ0100-XX-000-REP-100042
94	TR139 Sizewell Extremes Report	EDRMS	SZC-SZ0200-XX-000-REP-100152
95	Flood and coastal risk projects, schemes, and strategies: climate change allowances	Website	https://www.gov.uk/guidance/flood-and-coastal-risk-projects-schemes-and-strategies-climate-change-allowances#what-climate-change-allowances-are
96	Principles for Flood and Coastal Erosion Risk Management: Office for Nuclear Regulation and Environment Agency Joint Advice Note	Website	http://www.onr.org.uk/documents/2017/principles-for-flood-and-coastal-erosion-risk-management.pdf
97	BEEMS Technical Report TR319: Derivation of extreme wave and surge events at Sizewell with results of the coastal wave modelling, climate change and geomorphic scenario runs.	EDRMS	SZC-SZC020-XX-000-REP-100001 / 100703696
98	HR Wallingford (2010) Sizewell Power Station Extreme Sea Level Studies. Joint Probability of Waves and Sea Levels and Structure Response	EDRMS	SZC-EDFENE-XX-000-RET-000002 / 100638226
99	EW0601 Sea Defences Calculation Report	EDRMS	SZC-EW0601-XX-000-REP-100007 / 100637906
100	Main Development Site Flood Risk Assessment Appendices 1-7	EDRMS	100888431
101	TR233 Ed 2; Sizewell- Tidal Modelling with Telemac2D- Validation (word Doc)	EDRMS	SZC-SZ0200-XX-000-REP-100101

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Ref	Title	Location	Document No.
102	Sizewell C – Safety Case Study (groundwater level modelling). Atkins Report 5185703, Version 4.0, June 2020	EDRMS	SZC-SZ0200-XX-000-REP-100142
103	Sizewell C Physical model, wave loads on intake and outfall - Physical model method statement	EDRMS	100897264
104	UK Cabinet Office Space Weather Preparedness Strategy Version 2.1 July 2015.	Website	https://www.gov.uk/government/publications/space-weather-preparedness-strategy
105	'Extreme space weather: impacts on engineered systems and infrastructure', P. Cannon, Royal Academy of Engineering, February 2013.	Book	ISBN 1-903496-96-9
106	A. Ruffenach, "Estimation of neutron irradiation from extreme solar storms: comparison of studies," 2017.	EDRMS	UKC-2017-NNB-D13 (/HPC-GEN551-XX-000-REP-100000
107	EDF Energy, A. Ruffenach V01 12th November 2018 Estimating the intensity of neutron irradiation at ground level from extreme solar storms.	EDRMS	HPC-GEN551-XX-000-REP-100001
108	K. A. Ryden and C. S. Dyer, "The Effect of Neutron Irradiation from Solar Storms on Control and Instrumentation (C&I) Equipment," 2014.	EDRMS	100898231
109	EDF Energy, A. Ruffenach, Duration of Geomagnetic Storm - Phase 2	EDRMS	UKC-R-2019-G-D2 V02 21 January 2020
110	EPR SZC Project – Sizewell Station GIC Level Assessment	EDRMS	SZC-DTXXXX-AU-ALL-REP-200014
111	Proposal for a mitigation plan linked to the increase of Geomagnetically Induced Current (GIC) level on SZC	EDRMS	100857416
112	MCR Habitability Initial Assumptions for Radiological Release Assessment Scenarios	EDRMS	100767641
113	UK EPR – SZC – Liquefaction and earthquake induced settlements	EDRMS	SZC-DIXXXX-XX-000-RET-200017 (Teamcenter ID 100902827)
114	EPR UK – SZC – Onshore geotechnical pre-application report (basic stage). Revision B	EDRMS	SZC-DIXXXX-XX-000-RET-200004 (Teamcenter ID 100638312)
115	Sizewell C CFS & PSHA, Site Response Analysis (Volume 2 – Results)	EDRMS	100909351
116	Sizewell C CFS & PSHA, Ground Motion Model	EDRMS	100638742
117	Sizewell C CFS & PSHA, Capable Faulting Study	EDRMS	100638766
118	Relevance of the Long Period Ground Motion spectrum from the 1985 CEGB study, March 2012, EDF.	EDRMS	EDTGG120276 (Teamcenter ID 100825440)

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Ref	Title	Location	Document No.
119	Site Specific DBE Spectra for Sizewell C Project, Rev. 1	EDRMS	100912552
120	Sizewell C CFS & PSHA, PSHA for Sizewell report	EDRMS	100638736

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7 Appendix A – Justification of SZC SDSR External Hazards List

A hazard identification and screening exercise was carried out in 2015 to identify potential external hazards affecting the SZC site [Ref. 4]. The exercise was completed by generating comprehensive list of external hazards by reviewing a variety of relevant information sources and screening out those which do not have the potential to affect the SZC site.

The full list of information sources reviewed and recorded in Reference [4] is provided below:

- NNB GenCo Nuclear Safety Design Assessment Principles (NSDAP);
- SZB Periodic Safety Review 2 (PSR2) – Main Review: Hazards;
- SZB Dry Store - Key Supporting Reference for Hazards;
- ONR Technical Assessment Guides on internal and external Hazards;
- ONR GDA Guidance to Requesting Parties;
- Health and Safety Executive (HSE) Control of Major Accident Hazards Regulations;
- (COMAH) Safety Report Assessment Manual (SRAM);
- International Atomic Energy Agency (IAEA) Safety Standards:
    - External Events Excluding Earthquakes (NS-G-1.5);
    - Protection against Internal Fires and Explosions (NS-G-1.7);
    - Protection against Internal Hazards other than Fires and Explosions (NS-G-1.11);
    - External Human Induced Events (NS-G-3.1);
    - Site Evaluation for Nuclear Installations (NS-R-3);
    - Seismic Hazards (SSG-9);
- Meteorological and Hydrological Hazards (SSG-18);
- Western European Nuclear Regulators’ Association (WENRA) Reactor Safety Reference Levels;
- European Utility Requirements (EUR) for Light Water Reactor (LWR) Nuclear Power Plants (NPP);
- Electric Power Research Institute (EPRI) Advanced Light Water Reactor (ALWR) Utility Requirements Document (URD);
- Organisation for Economic Co-Operation and Development (OECD);
- Nuclear Energy Agency (NEA) Probabilistic Safety Assessment (PSA) of Other External Events than Earthquake;
- US Nuclear Regulatory Commission (NRC) Regulatory Guide on site suitability criteria.

An element of the screening in Reference [4] led to the identification of hazards specifically requiring deterministic consideration for SZC. These are included in the table below. However, it is not appropriate for all of these to be characterised in the Site Data Summary Report. Where this is the case, the reason is recorded in Table 35 below:

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External Hazard	Characterised in Site Data Summary Report (Y/N)	Reason for Not Characterising in Site Data Summary Report
Earthquake, including:		
• Ground motion	Y	
• Long-period ground motion	Y	
• Liquefaction (as a result of earthquake)	Y	
• Capable faulting	Y	
Aircraft Crash – background crash rates	Y	
Hazards associated with the industrial environment and transport routes:		
• Explosion in air	Y	
• Missiles	Y	
• Vibration / ground shock	N	Bounded by Aircraft Crash ground shock. Characterisation of vibrations / ground shocks from construction of Unit 2/ decommissioning at SZA/B, is not necessary and nor can it be done in a meaningful way. In practice the hazard will be controlled by local arrangements when the work takes place.
• Off-site fire (man-made)	Y	
• Chemical release (including radiological release)	Y	
• Animal infestation: ○ Rodents and birds ○ Clogging (leaves, insects) ○ Damage to instrumentation and control lines ○ Microbiological corrosion	Y	
External flooding:		
• Coastal flooding: ○ Tidal effects ○ Wind generated waves ○ Storm surges ○ Tsunami (seismic induced) ○ Tsunami (non-seismic induced)	Y	
• Rainfall and surface run-off: ○ Direct rainfall ○ Run-off ○ Snow melt	Y	
• Channel obstruction	Y	

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External Hazard	Characterised in Site Data Summary Report (Y/N)	Reason for Not Characterising in Site Data Summary Report
• Sudden release of water: natural or man-made	Y	
• High groundwater level	Y	
• Cooling water system trip (e.g. surge event in the forebay)	N	This is an internal hazard.
Extreme climatic conditions:		
• Snow	Y	
• Frost	N	Hazard bound by snow
• Wind	Y	
• Wind generated missiles	Y	
• Tornado	Y	
• Waterspout	N	Hazard bound by tornado
• Extreme cold (air)	Y	
• Extreme heat (air)	Y	
• Humidity	N	Bounded by / included in extreme heat (air)
• Hail	N	Included in Rainfall and surface run-off, Bounded snow, and frost (snow loading), and wind generated missiles (impact damage).
• Fog	N	The hazard of fog has received preliminary consideration in Reference [52]. The impacts of the hazard of Fog on nuclear safety is considered minimal. In general, the safety justification is based on adherence to appropriate transportation rules, standards, and instructions, together with increased care, ensuring that no increase to the background risk occurs during extreme fog events. As such, the hazard of Fog has not been characterised in a way that lends itself to identification of a site challenge or design basis.
• White frost / icing	N	Bounded by snow and frost
• Sea spray	N	Acute effects bounded by Extreme Rainfall. Chronic effects not significant and managed by corrosion resistant design.
Lightning and EMI:		
• Lightning	Y	
• EMI (anthropogenic/man-made and natural sources):		
○ EMI / eddy currents in ground	Y	
○ Grid perturbations	N	Grid perturbations are not covered in the SDSR. Turbine/generator design is robust to grid perturbations, and the hazard is otherwise covered by LOOP.

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External Hazard	Characterised in Site Data Summary Report (Y/N)	Reason for Not Characterising in Site Data Summary Report
○ Solar activity	Y	
Heat-sink specific hazards:		
• Clogging: ○ Fauna and flora clogging or anthropic clogging ○ Silting ○ Frazil ice	Y	
• Ship collision	Y	
• Hydrocarbon pollution	Y	
• Underwater explosion	Y	
• Extreme cold (sea)	Y	
• Extreme heat (sea)	Y	
• Low heat sink water level: ○ Low tides ○ Wave effects ○ Tsunamis	Y	
Ground engineering hazards: • Slope instability • Subsidence/uplift • Soil liquefaction (e.g. as a result of additional loading on embankment) • Behaviour of foundation materials (including soil shrink/swell and drought) • Site erosion	N	These are taken into consideration in the geotechnical design and are covered by the civil design codes. As such, they do not require characterisation from a Safety Case Point of view and do not require specific assessment in relation to nuclear safety.
Volcanic ash	Y	
• LOOP	Y	
• Loss of services or access to site	N	Loss of services or access to site cannot be characterised in a meaningful way, and in practice the effects will be controlled by administrative / procedural measures if they occur. Elevated frequency of occurrence compared to other nuclear sites (e.g. HPC) is not anticipated.

Table 35: External hazard approach for the hazards identified in Reference [4]

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8 Appendix B – Summary of SZC and HPC Hazard Design Basis Alignment

External Hazard		SDSR Section	SZC Design Basis and HPC Design Basis Aligned? (Yes / No-Differing Local Conditions/ NA-below design basis)	Comment
Earthquake		3.2	NA – Differing Local Conditions	The earthquake hazard at SZC is different to HPC and it has therefore been characterised specifically considering local conditions.
Accidental Aircraft Crash		3.3	Y	None.
Hazards Associated with the Industrial Environment	External Explosion	3.4.1	Y	None.
	External Missile	3.4.2	Y	None.
	Offsite Fire	3.4.3	NA- Below Design Basis	The SDSR shows that the magnitude of external chemical releases associated with events with a 1.0E-5p.a. or less frequency, could not challenge nuclear safety. Hence, this fault need not be included in the design basis.
	Chemical Release	3.4.4	NA- Below Design Basis	The SDSR shows that the magnitude of external chemical releases associated with events with a 1.0E-5p.a. or less frequency, could not challenge nuclear safety. Hence, this fault need not be included in the design basis.
	Radiological Release	3.4.4	Y	None.
	Animal Infestation	3.4.5	Y	None.
External Flooding	Coastal Flooding	3.5.1	No- differing local conditions	Local conditions are substantially different, and this necessitates a potentially modified means of managing these hazards (and hence a different design and design basis)
	Rainfall and Surface Runoff	3.5.2	No- differing local conditions	
	High Groundwater Level	3.5.3	No- differing local conditions	
Extreme Climatic Conditions	Snow	3.6.1	Y	None.
	Wind[13]	3.6.2	Y	None.
	Tornado	3.6.3	Y	None.
	Volcanic Ash	3.6.4	NA - Below Design Basis	Hazard not included for HPC. Hazard dismissed on low frequency

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[13] Section 3.6.2 also includes the required information for the definition of the wind generated missile hazard.

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External Hazard		SDSR Section	SZC Design Basis and HPC Design Basis Aligned? (Yes / No-Differing Local Conditions/ NA-below design basis)	Comment
				grounds as being below the design basis for SZC
	Extreme Heat Air	3.6.5	Y	SDSR shows site challenge to be slightly elevated above HPC design basis. However, the identification of conservatisms in its derivation and in the design means that the HPC design can be retained. See Section 3.6.5 above for further details.
	Extreme Cold Air	3.6.6	Y	None.
Lightning and EMI	Lightning	3.7.1	Y	None.
	External Electro-Magnetic Interference	3.7.2	Y	None.
Solar Activity	Geomagnetically Induced Current	3.8.1	No- differing local conditions	The site challenge value for SZC is higher than for HPC. However, as a result of the time period of the event being equivalent for the two sites, and the conservative sizing of the potentially affected components, the increase in the site challenge at SZC does not have an effect on the design [Ref. 111].
	Ground Level Enhancement	3.8.2	Y	Work to define the design basis of this hazard is ongoing for both HPC and SZC. Due to the nature of the hazard no site-specific differences are expected.
Heat Sink Specific Hazards	Extreme Heat Sea	3.9.1	Y	None.
	Extreme Cold Sea	3.9.2	Y	None.
	Frazil Ice	3.9.3	Y	None.
	Silting	3.9.4	Y	None.
	Fauna and Fauna or Anthropic	3.9.5	Y	None.
	Ship Collision	3.9.6	Y	Although the frequency of a collision involving any number of intake heads (1.88E-6p.a.) is significantly lower than the 1.0E-5p.a. requirement for man-made

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External Hazard		SDSR Section	SZC Design Basis and HPC Design Basis Aligned? (Yes / No-Differing Local Conditions/ NA-below design basis)	Comment
				external hazards, ship collision is considered a design basis hazard.
	Hydrocarbon Pollution	3.9.7	Y	None.
	Underwater Explosion	3.9.8	Y	None.
	Extreme Low Sea Level	3.9.9	No-differing local conditions	Local conditions are substantially different, and this necessitates a different design and design basis.
	Extreme Low Sea Level (Tsunami)	3.9.10	NA – below design basis.	Hazard dismissed on low frequency grounds as being below the design basis for SZC

Table 36: Summary of SZC and HPC hazard design basis alignment

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