CHAPTER 6: EVALUATION OF EXTERNAL EVENTS

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Author declaration: I declare that appropriate diligence and quality assurance was applied in the compilation of this report. As such I am confident in the results here described and the conclusions drawn.

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EXECUTIVE SUMMARY

Chapter 6 of the TSSR provides a summary of external events (EEs) important to the design and safety of the proposed new nuclear installation(s) (NNI) within the Thyspunt site as detailed in ***Chapter 5***.

The main purpose of ***Chapter 6*** is to summarise the information on EEs and to perform a preliminary screening of those events identified in ***Chapter 5***. This is an initial step in determining the degree at which the design of the NNI may be impacted by the identified hazards and to identify potential implications on the standard designs of the potential NNI against the PPE. The complete analysis of how EEs can interact with the SSCs of an NNI will be carried out in the next licensing phase involving the specific NNI design as part of Normal Operations (including Anticipated Operational Occurrences (AOO)), Design Basis Accident Conditions and Design Basis Extension Conditions (DBEC) (National Nuclear Regulator, 2018).

Table 6.14 lists the EEs assessed and screened for the NNI. A qualitative screening status is assigned to each EE as follows:

- screened out unconditionally;
- screened out conditionally (a measure of uncertainty exists, and design confirmation or further studies are required);
- screened in (design mitigation is required or the site is potentially excluded).

The screening criteria are applied with caution since the layout and detailed design of the NNI to be built are not available at this stage. EEs screened out unconditionally should not require additional consideration as a potential design basis external event for an NNI. There are events that are screened out conditional to confirmation when assessing the detailed NNI design.

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Table 6.14: External Events Screening

External Event	Screening Status	Comment
Earthquake induced Ground Shaking	In	Thyspunt PSHA final data to be incorporated in design envelope spectrum
Surface faulting	Out	Subject to confirmation during excavation of the nuclear footprint
Volcanism	Out	Event has a very low probability of occurrence
Groundwater level and quality	Out (conditional)	Further combined site and design specific studies required to confirm screening status
Loss of freshwater supply	Out	-
Collapse, subsurface or uplift of the site surface	Out (conditional)	Further combined site and design specific studies required to confirm screening status
Soil liquefaction	Out (conditional)	Further combined site and design specific studies required to confirm screening status
Slope instability	Out (conditional)	Further combined site and design specific studies required to confirm screening status
Meteorological events (severe and extreme)	Out	Except for those mentioned below
Wind gusts and wind generated missiles	In	To be considered in the design
Tornados	In	Tornado parameters at 1E-07/y and missile spectrum to be aligned
Ambient temperature	In	To be considered in the design
Rainfall	Out	-
Snowfall	Out	-
Lightning	Out	-
Hail	Out	-
Frost	Out	-
Fog	Out	-
Relative humidity	Out	-
Atmospheric pressure	Out	-
Corrosivity	Out	-
Floods - sea	In	To be allowed for in the nuclear installation design

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External Event	Screening Status	Comment
Floods – human-made retaining structures (off-site)	Out	-
Floods - river	Out	-
Flood – on-site hydrology	In	Further combined site and design specific studies required to confirm screening status
Flood - waterspouts	Out	Very low probability of occurrence
Flood – snow melt	Out	Very low probability of occurrence
Flood – landslide into water	In	To be allowed for in the nuclear installation design
Low sea water level	In	To be allowed for in the nuclear installation design
Cooling water temperature (high)	In	To be allowed for in the nuclear installation design
External fires	Out (conditional)	Further combined site and design specific studies required to confirm screening status
Biological phenomena	In	To be allowed for in the nuclear installation design
Erosion from the sea	In	To be allowed for in the nuclear installation design
Accidental aircraft crash	Out	-
Hazardous material – land-based (static and transport)	Out	-
Hazardous materials and oil transported by ship	In	To be allowed for in the nuclear installation design
LOOP	In	To be allowed for in the nuclear installation design
Electromagnetic interference	Out (conditional)	Further combined site and design specific studies required to confirm screening status
Extra-terrestrial events	Out	These events, in accordance with EUR requirements for Light Water Reactor (LWR) Nuclear Power Plants (EUR, 2001), should not be considered in the design.

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6 EVALUATION OF EXTERNAL EVENTS

6.1 Introduction

The Regulations on Licensing of Sites for New Nuclear Installations (Department of Energy, 2011) define external events (EEs) as, *"events not associated with the operation of the nuclear installation(s) that could have an effect on the safety of the installation(s).*" The International Atomic Energy Agency (IAEA) (International Atomic Energy Agency, 2019) similarly defines these events as events that originate either off the site or within the boundaries of the site but from sources that are not directly involved in the operational states of the nuclear installations.

Events external to a nuclear installation which could challenge nuclear safety have to be identified and evaluated for the site. The site characteristics and the design and operation engineered safety features of a nuclear installation must ensure acceptable nuclear safety in respect of EEs through compliance with regulatory safety criteria.

This chapter of the TSSR focuses on EEs (both naturally and man-made) important to the design and safety of the proposed new nuclear installation(s) (NNI).

Although EEs are identified and evaluated in the TSSR, the assessment of the expected impact of each hazard and the potential propagation mechanism and predicted effects on the installation does not form part of the scope of the TSSR. The TSSR does however provide a summary of those hazards that may require further attention in terms of the design consideration for NNI.

6.2 Purpose and Scope

The purpose of this chapter is to provide a summary of EEs from detailed information presented in ***Chapter 5*** (Site Characteristics).

The main purpose is to summarise the information on EEs and to perform a preliminary screening of those events identified in ***Chapter 5*** against the Plant Parameter Envelope (PPE) criteria for NNI (Eskom, 2024). This is the initial step in determining to what degree a NNI may be impacted by the identified hazards and to identify potential implications on the

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standard designs of the potential NNI against the PPE. The complete analysis of how EEs can interact with the systems, structures and components (SSCs) of an NNI will be carried out in the next licensing phase involving the specific NNI design.

It is important to note that the PPE criteria were specifically developed for purposes of a nuclear installation site licence (NISL) for an NNI of GEN III PWR technology.

Considerations relating to the physical protection of the nuclear facilities against wilful actions by third parties are outside the scope of this chapter and are addressed in the relevant security documentation, as such information is classified and cannot be presented in this SSR.

6.3 Regulatory Framework

The regulatory requirements for the evaluation of external events are stipulated below. Other relevant international standards, guides and recommendations are provided in ***Chapter 2*** (Legal and Regulatory Basis) and the relevant Sections in ***Chapter 5*** of the TSSR.

6.3.1 Regulations

The regulatory requirements relevant for the evaluation of external events are stipulated in the following two documents:

- R.388, Safety Standards and Regulatory Practices (Department of Minerals and Energy, 2006);
- R.927, The Regulations on Licensing of Sites for New Nuclear Installations (Department of Energy, 2011).

In terms of Regulations on Safety Standards and Regulatory Practices (SSRP) (Department of Minerals and Energy, 2006), section 3.4 requires that installations having an impact on radiation or nuclear safety must be designed, built and operated in accordance with good engineering practice.

Section 3.8 of the regulations requires that where a prior safety assessment or operation safety assessment has identified reasonable

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possibility of a nuclear accident, accident prevention and mitigation measures based on a principle of defence in depth must be established, implemented, and maintained. Defence in depth is provided by an appropriate combination of specified systems and measures, one of which is “Adequate site selection and the incorporation of good design and engineering features providing safety margins, diversity and redundancy” (IAEA, 2015). The Regulations (Department of Energy, 2011) that are specifically relevant to EEs included in ***Chapter 6*** are:

“4(5) Natural phenomena and potential man-made hazards must be appropriately accounted for in the design of the new nuclear installation(s), and that adequate emergency plans and nuclear security measures can be developed.”

“5(3) The characteristics of the site relevant to the design assessment, risk and dose calculations, including inter alia:

(a) external events;

(b) meteorological data;

(c) land use;

(d) population demographics;

(e) regional development”.

6.3.2 Regulatory Position Papers, Guides and International Practice

The NNR documents relevant to the analysis of site-specific external events are as follows:

- Position Paper PP-0009 - Authorisations for Nuclear Installations, Rev 0 (National Nuclear Regulator, 2012). It defines siting as the process of selecting a suitable site for a nuclear installation(s), including appropriate assessment of site characteristics/hazards and definition of the related site parameter envelope. The external hazards must be appropriately characterised to address all safety issues, and the site parameter envelope has to be adequately

quantified considering the impact and risk to the public from all nuclear installations planned on the site and in the vicinity of the site.

- Position Paper PP-0014 - Considerations of External Events for New Nuclear Installations (National Nuclear Regulator, 2014). The purpose of this document is to outline considerations for conducting site investigations for evaluation of hazards related to external events. It discusses the derivation of target safety goals which are required when establishing the design basis parameters for the design of nuclear installations against external events using the performance-goal based approach. It clarifies the NNR position on the selection of design basis hazard levels applicable to new nuclear installations.
- RG-0011 - Interim Guidance for the Siting of Nuclear Facilities (National Nuclear Regulator, 2016). This document provides guidance on the implementation of the regulatory requirements as contained in the draft General Nuclear Safety Regulations, the draft Specific Nuclear Safety Regulations for Nuclear Facilities and the draft Nuclear Security Regulations as it pertains to the siting of nuclear facilities (these regulations have not been published yet but are available to be referenced in respect of specific regulations in them).
- RG-0019 – Interim Guidance on Safety Assessments of Nuclear Facilities (National Nuclear Regulator, 2018). This document provides guidance on the performance of safety assessments demonstrating safety of the nuclear facility and compliance with applicable regulatory requirements.

Relevant international standards and recommendations for the identification, categorisation and analyses of external events consulted, include but is not limited to the following:

- International Atomic Energy Agency (IAEA) Specific Safety Requirements No. SSR-1, Site Evaluation for Nuclear Installations (International Atomic Energy Agency, 2019):
    - Potential external hazards associated with natural phenomena, human induced events and human activities

that could affect the region shall be identified through a screening process.

The compliance for the various EEs external event technical input and results against guidelines and regulations is provided in the ***Chapter 5*** sections.

6.4 Approach to the Screening of External Events

The two main categories of external events are:

- of natural origin, e.g. geological, meteorological, hydrological events affecting the nuclear installation.
- of human-induced origin, e.g. industrial and transportation accident affecting the nuclear installation.

The hazard parameters characterising the external events are evaluated, e.g. mean wind speeds at different annual probabilities or the peak pressure from a hazardous material explosion. Expected changes in external hazards during the lifetime of the nuclear installation(s) are taken into account (e.g. climate change), based on current knowledge and understanding of the site characteristics and the sources of external events.

The objective of the screening is to identify those EEs that may have an impact on the suitability of the site for the construction, licensing and operation of an NNI. The screening also identifies those EEs for which the design of the NNI will need to be checked or special considerations made in terms of the design and safe operation of the installation. The information can be used to support the safety analysis for the design basis external events and beyond design basis external events.

A graded approach is applied in identifying the hazard. The EEs screened and evaluated are based on the list of EEs included in (Eskom, 2024). These EEs were selected based on consideration of a comprehensive list of EEs included in ***Appendix C***. The site specific information for each

EE is summarised based on the detailed information in the relevant sections of ***Chapter 5***.

The EEs relevant to the site and nuclear safety were identified using the following main steps:

- establish a comprehensive list of EEs that require consideration in the siting and design of the power plant; identify any external hazards unique to the site and add potential events that can arise from these hazards to the list of EEs; assess available data collected on the natural aspects of the site, e.g. geology, meteorology, oceanography and identify natural hazards; collect all relevant data (site specific and generic) in order to identify human induced events, phenomena and mechanisms associated with potential stationary[1] and mobile[2] sources of hazardous materials, industries and other human activities;
- perform an initial screening of the EEs and identify those relevant to the site (e.g. an avalanche is not relevant to the site); EEs not relevant to the site are screened out;
- evaluate EEs not screened out; evaluate means the process of determining hazard parameter values as a function of return periods/annual probability of exceedance for natural events or annual occurrence frequencies for human induced external events/accidents;
- for NNI and existing facilities, compare the EEs to determine:
    - the suitability of the site; EEs may be screened out using the criteria in ***Section 6.6***;
    - identify those EEs for which the nuclear installation design will need to be checked/confirmed;

[1]Sources of external human induced events, for which the location of the initiating mechanism (explosion centre, point of release of explosive or toxic gases) is fixed, such as chemical plants, oil refineries, storage depots and other nuclear facilities at the same site **(IAEA, 2021)**.

[2]Sources of external human induced events, for which the location of the initiating mechanism is not totally constrained, such as any means of transport for hazardous materials or potential projectiles (by road, rail, waterways, air, pipelines). In such cases, an accidental explosion or a release of hazardous material may occur anywhere along a road or other way or pipeline **(IAEA, 2021)**.

- identify those EEs for which special consideration will need to be taken and/or design mitigation implemented on the site; EEs screened in.

For an NNI, the potential impact on the design is assessed against the PPE. Information on EEs screened out is not discarded and will be used when the NNI specific design is assessed against NNR deterministic and risk licensing criteria during the next licensing phase. A major part of the process of licensing of an NNI is the safety analysis of the specific design that has to account for EEs screened in. It involves the application of methods of deterministic and probabilistic analysis. It establishes and confirms the design basis for the items important to safety and demonstrates that the design can meet the prescribed and acceptable limits for radiation doses and releases for each plant condition category (normal operation, anticipated operational occurrences and accidents), and that defence in depth has been achieved. Both the deterministic and probabilistic safety analysis processes will require the definition of a set of Postulated Initiating Events (PIEs) which includes EEs.

Although EEs are identified and evaluated in the TSSR, the TSSR only provide a summary of those hazards that may require further attention in terms of the design consideration for an NNI.

6.5 Approach to the Evaluation of External Events

6.5.1 External Events of Natural Origin

EEs are evaluated by analysis of available data for the site and determining event frequency statistics. These statistics are return periods and annual probabilities of exceedance of hazard parameter values characteristic of the EE severity, e.g. wind speed, or depth of flooding. The statistical data were prepared as part of ***Chapter 5***. Data are provided for very low return periods for some of the natural hazard parameters (return periods of 1E08 years). There is, however, general agreement that the uncertainty in the data for natural hazards may prevent reasonable prediction of events for frequencies lower than one in 1E04 years (International Atomic Energy Agency, 2006).

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The target frequency for the design basis EEs (DBEEs) of the proposed NNI will be decided with due consideration of the NNR position paper on EEs for new nuclear installations (National Nuclear Regulator, 2014). It must be noted that the return period of up to 1E08 years does not necessarily imply that the plant design should be assessed against such a return frequency. The requirements relevant to the design of nuclear power plants are established in SSR-2/1 (International Atomic Energy Agency, 2016).

Where possible, investigation of EEs considered the return periods of hazard parameter values and the duration of exposure of the nuclear installation to the hazard considering the lifetime of the installation.

Return period is defined as the average time between consecutive events of the same or greater severity. A given event of return period, T, is generally assumed equally likely to occur any year, thus the probability of that event being exceeded in any one year is 1/T. The annual probability of exceedance, P, of an event is the reciprocal of the return period of that event (i.e., P ~ 1/T). For an event with return period, T, and annual probability of exceedance, P, the exceedance probability, P_E, over design life, n years, is calculated as follows (U.S. DOE, 2012):

$$P_E = 1- (1-P)^n$$

$$= 1-(1-1/T)^n$$

$$\approx 1-e^{-n/T}$$

P_E and P vary from 0 to 1, and n and T are expressed in years.

As an example, consider a typical design life of 60 years and a 24-hour rain event with a return period of 100 years. In this case, the annual probability of exceeding 192 mm rain in 24 hours, for example, is 45 per cent. This calculation can be repeated for the final NNI design to be selected for the site and its safety assessment, should its design life be different to 60 years, e.g. 80 years.

6.5.2 Human-induced External Events

Human-induced EEs are considered accidental events (e.g. oil spills and hazardous material explosions). Two methods are used to evaluate human induced events:

- The EE can be assessed deterministically by evaluating the consequences should the event take place. An example is an explosion as a result of hazardous materials at industrial facilities at a fixed distance from the nuclear installation and the resulting pressure pulse as a function of distance. A screening distance value (SDV) for such an event can then be calculated beyond which no damage to the nuclear installation will occur. If there is no hazardous installation located inside this distance, the event can be screened out.
- When the concept of SDV cannot be applied, an event can be evaluated probabilistically by determining the annual occurrence frequency, e.g. an accidental aircraft crash or a ship accident (oil spill) that could impact the cooling function of the installation. A screening probability value (SPV) can then be applied.

6.6 Screening Criteria

Screening in respect of EEs was carried out in TSSR Rev 0 (Eskom, 2015) on the basis of (American National Standards, 2007). The criteria are listed together with the corresponding numbered NNR criteria in (National Nuclear Regulator, 2014) written in italics:

- Criterion 1 - the design basis event is of equal or lesser damage potential than the similar hazard for which the plant has been designed for.

  (2) A phenomenon which in itself has no significant impact on the operation of a nuclear power plant and its safety assessment.
- Criterion 2 - the event cannot occur close enough to the installation to affect it.

  (*4) in case of NNI, locate the nuclear power plant sufficiently distant from the postulated phenomenon to mitigate its effects.*
- Criterion 3 - the event is included in the definition of another event.

(5) A phenomenon which is included or enveloped by design for another phenomenon. For example, storm surge and seiche are included in the probable maximum tsunami[3]; toxic gas is included in pipeline accident or industrial or military facility accident.

- Criterion 4 - the event has a significantly low mean frequency of occurrence when considering regulatory target safety goals, taking into account the uncertainties in the estimates, where available data permit.

  (3) A phenomenon which by itself has a probability of occurrence less than the 10^{-8} per year (event sequence frequency).

- Criterion 5 - the event is slowly developing, and it can be demonstrated that there is sufficient time for measures to eliminate it or to provide adequate response. *(1) A phenomenon which occurs slowly or with adequate warning with respect to the time required to take appropriate protective action*.

The potential evolution of a hazard during the lifetime of the installation was also considered in the screening of EEs for the site. Examples are the anticipated evolution of human activity around the site and climate change (e.g. effect on sea level rise).

Hazards shall be considered in designing the layout of the plant and in determining the postulated initiating events and generated loadings for use in the design of relevant items important to safety for the plant. Screening criteria are applied with caution during the assessment of the suitability of the site for a NNI since the layout and detailed design of the installation(s) to be built are not available at this stage. Some events can be screened out *unconditionally* and should not require additional consideration as a potential DBEE. There are events that are screened out conditional to confirmation when assessing the detailed nuclear installation design. A screening status is therefore assigned to each event as follows:

[3] Note that lake flooding is not applicable to NNIs at coastal sites such as Thyspunt.

- screened ***out unconditionally*** (e.g. on the basis of an SDV or low probability of occurrence*);*
- screened ***out conditionally*** (a measure of uncertainty exists, and design confirmation is required);
- ***screened in*** (design mitigation is required or the site is potentially excluded; also refer to ***Section 6.7***).

An event that is screened in does not imply that the site is excluded (refer ***Section 6.8***).

The NNR introduced the concept of Target Safety Goal (TSG) (National Nuclear Regulator, 2014) which can be used to establish design basis parameters for the design of nuclear installation(s) against external events such as non-seismic events (seismic events have a specified PPE aligned with internationally accepted return periods). In order to meet the core damage frequency design basis Safety Goal limit with sufficient margin, the licensee needs to aim for a more conservative Target Safety Goal as follows:

- TSG_{CDF} = 5E-06 per year,

To meet the Large Early Release Frequency (LERF) Safety Goal, the licensee needs to aim for a more conservative Target Safety Goal of:

- TSG_{LERF} <1E-06 per year.

It could also be used to calculate the combination of the design factors and the mean hazard exceedance probability value required to achieve a set safety goal subject to NNR acceptance.

When it is not possible to relate a safety goal to an EE hazard parameter exceedance probability (for example when the risk equation for the event sequence does not exist) then the following applies. The design basis parameter value is obtained from the hazard curve by making a conservative assumption that the exceedance probability is at least equal to the safety goal for design basis events (1E-05/y) plus margin, and therefore 1E-06/y. However, the interim guide on safety assessment of

nuclear facilities (RG-0019) (National Nuclear Regulator, 2018) categorizes events with an occurrence frequency equal to or greater than 1E-05 per year as a Design Base Condition.

An event screened out in terms of design basis considerations for the proposed NNI may still require detailed consideration in the assessment of the NNI in scenarios related to normal operation, anticipated operational occurrences, design basis and beyond design basis events, in particular when combinations of events are assessed, even if the EEs individually meet the PPE limiting values. This information will also be required when performing probabilistic safety analysis (PSA) of the detailed design of the installation. Examples of screening criteria used in PSA analyses of a specific design are listed in ***Table 6.1*** (American National Standards, 2007).

Table 6.1: PSA Screening Criteria

Screening Criterion No.	Description
1	The current DBEE has a mean frequency $<10^{-5}$/y, and the mean value of the conditional core damage probability (CCDP) is assessed to be $<10^{-1}$.
2	The core damage frequency, calculated using a bounding or demonstrably conservative analysis, has a mean frequency $<10^{-6}$/y.
3	Screen out events of which the frequency is so low that elimination of the event will not modify the risk profile.
4	The risk contribution of the event is minor and acceptable.
5	A bounding analysis of the core damage frequency/fuel damage frequency due to the external event yields a result $< 10^{-9}$ per year.

6.7 Site Exclusion Criteria

Exclusion criteria represent requirements that, if not satisfied by site conditions, would preclude a site licence for greenfield sites or the potential termination of an operating licence for a site with an existing NI. They are used to eliminate sites based on consideration of go/no-go situations (EPRI, 2022).

A site is excluded when design solutions cannot be found for EEs screened in, i.e. a nuclear installation design basis will not meet NNR principal safety criteria and Eskom PPE criteria. The exclusion of a site includes results of measurement against evaluation requirements in (International Atomic Energy Agency, 2019) and which are the following:

- Where reliable evidence of capable faults that has the potential to challenge the safety of the nuclear installation in terms of ground motion and/or fault displacement hazards and for which no practicable engineering solution is available.
- The presence of features that can cause permanent ground displacement such as fault displacement and settlement or subsidence, swelling soils and shale, or other hazards including underground cavities, landslides, or periodic flooding that may make engineering design difficult and may require extensive additional investigations.
- The potential for soil liquefaction is found to be unacceptable unless practicable engineering solutions are demonstrated to be available.
- Hazards due to volcanic activity that have the potential to affect the safety of the nuclear installation and for which no practicable engineering solutions are available.
- Extreme and rare meteorological hazards: Extreme meteorological hazards and their possible combinations that have the potential to affect the safety of the nuclear installation and for which no practicable solution is available.
- Hazards due to flooding, considering natural and human induced events including their possible combinations, with the potential to affect the safety of the nuclear installation and for which no practicable solution is available.
- Other natural phenomena that are specific to the region and which have the potential to affect the safety of the nuclear installation unless practicable engineering solutions exist.
- Activities that involve the handling, processing, transport and storage of chemicals having the potential for explosions or for the production of gas clouds capable of deflagration or detonation that

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take place in the site vicinity and for which there are no practicable solutions available.

- If the effects of release of flammable, explosive, asphyxiant, toxic, corrosive or radioactive materials stored, processed, transported and otherwise dealt with in the site region would produce an unacceptable hazard for which no practicable solution is available.
- If there are installations in the site region that may give rise to missiles of any type that could affect the safety of the nuclear installation and the effects of these occurrences would produce an unacceptable hazard and if no practicable solution is available.
- The potential for accidental aircraft crash hazards is unacceptable and if no practicable solutions are available.

6.8 External Events Evaluation and the Eskom PPE

The evaluation of the EEs and their screening status are reported in ***Sections 6.9*** to ***6.11***. The PPE values specified by Eskom (Eskom, 2024) are listed in ***Table 6.2*** and included in ***Appendix 6-C***.

Table 6.2: Plant Parameter Envelope and External Event Limiting Values

External Event	Plant Parameter Envelope Reference Values
Natural Events	
Geological Hazards	
1) Earthquakes	
1.1) Earthquake induced ground shaking	Horizontal PGA: 0.3 g Vertical PGA = Horizontal PGA (The higher PGA value was used instead of the 0.25 g in the European Utility Requirements) .
1.2) Capable Faults	No fault displacement potential within the site area due to earthquakes at the design basis is permitted.

External Event	Plant Parameter Envelope Reference Values
2) Volcanism	History and/or evidence of volcanic activity in recent geologic times (<10 000 years) in the site region (≤50 km).
Geotechnical Hazards and Events	
3) Collapse, subsurface or uplift of the site surface (e.g. quarrying, caverns, mines, water and oil wells, and karst formations)	Site specific issue – not permitted
4) Soil liquefaction	Site specific issue. Not permitted on the NPP terrace To be engineered out or the site moved.
5) Slope instability	Site specific issue. Slope instability which could affect the safe operation of the NNI or which could hinder emergency response is not permitted and must be engineered out where necessary.
6) Behaviour of foundation materials (soil shrink-swell, etc.)	Dependent on compliance with seismic PPE.
Meteorological Hazards and Events	
7) Wind speed	Basic wind speed = 43 m/s Extreme wind speed = 70 m/s The revised SANS 10160 code of practice gives a maximum basic wind speed of 52 m/s for the whole country.
8) Tornadoes	
8.1) Maximum Atmospheric Pressure Drop	40 mbar
8.2) Maximum Rotational Speed	57 m/s
8.3) Maximum Translational Speed	14 m/s

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External Event	Plant Parameter Envelope Reference Values
8.4) Maximum Wind Speed	72 m/s
8.5) Missile Spectra	130 kg steel pipe having a velocity of 24 m/s, 1 178 kg automobile having a velocity of 24 m/s, and 0.0669 kg solid steel sphere having a velocity of 6 m/s
8.6) Radius of Maximum Rotational Speed	45.7 m
8.7) Rate of Pressure Drop	13 mbar/s
9.1) Maximum Ambient Temperature	Long term base (> 7 days) = 42°C Short term daily (6 hours to 7 days) = 46°C Instantaneous (6 hours) = 50°C
9.2 Minimum Ambient Temperature	Long term base (> 7 days) = 2.8°C Short term daily (6 hours to 7 days) = 0°C Instantaneous (6 hours) = -2°C
10) Rainfall	Maximum rainfall rate limiting values: Rainfall depth of 100 mm in one hour and a depth of 400 mm in 24 hours. Once these precipitation loads are determined for design purposes, they are typically multiplied by load factors, which range between 1.5 and 2.0.
11) Snowfall/ice/hail	Covered by the standard vendor design for 1:100 year recurrence interval. Minimum value of 0.4 kPa.
12) Lightning	First stroke: 200 kA, 10/350 µs Second stroke: 50 kA, 0.25/100 µs
13) Humidity conditions	
13.3) Design basis maximum external humidity	Summer: 60% at 37°C (dry bulb), Winter: 100% at -25°C
Hydrological Hazards and Events	

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External Event	Plant Parameter Envelope Reference Values
14) Site flooding	Terrace to be located above the tsunami design basis. Mitigating action to be incorporated into the design for the beyond design basis. All site flooding requirements are addressed; probable maximum storm surge, wind and wave effects and tsunami.
14.1) Floods and related dynamic actions	Terrace to be located above the design basis external event.
14.2) Tsunami (Wave height, impact force and drawdown).	Terrace to be located above the tsunami design basis. Mitigating action to be incorporated into the design for the beyond design basis.
14.3) Probable Maximum Storm Surge	Terrace to be located above the probable maximum storm surge elevation.
14.4 Wind and Wave Effects	Terrace to be located above the probable maximum elevation for this event.
16) External fire	SDV: 1 to 2 km
Human Induced Events	
17) Aircraft crash	Distance from commercial airports and runway orientation not to be controlling factors. Design basis to include aircraft in the general, military and commercial categories. Impact to be calculated separately for the mass of the aircraft engine and/or landing gear as well as the mass of the aircraft. Generally, the engine impact will govern the minimum thickness of the structural element i.e. local effects and the aircraft impact, the global structural damage. Impact to be defined in terms of force time histories. Functional damage to SSC as a result of shock loads / vibratory effects to be checked. Fire damage to be checked in the crash zone. Aircraft crash analyses to be performed for general aircraft such as the Cessna 210 and the Lear Jet 23, military aircraft, and commercial aircraft such as the Boeing 777. The site specific aircraft crash hazard study will dictate whether other aircraft should be included.
18) Hazards from nearby land-based Installations	

External Event	Plant Parameter Envelope Reference Values
18.1) External missiles in general (from tornadoes, high-energy rotating machinery, etc.)	Missile parameters for rotating machinery to be defined for each postulated missile.
18.2) External explosion (*pressure, fire, projectiles, smoke, vibrations, etc*), solid, liquid or gaseous	$P_{wave} = 10^4$ Pa Duration = 300 ms Velocity = 4 500-7 000 m/s
18.3) Industrial facility incident	The effects of a rupture of pressure vessels, fluid pipelines and so forth that serve industrial facilities located near a nuclear power plant. Pressure and heat loads resulting from chemical energy dissipated. Distance to pipelines to be limited such that they do not constitute controlling events for transient pressure waves. Pressure wave to be less than stated in 18.2. Mitigating action to be taken to protect the safe operation of the NNI against the potential discharge of toxic liquids/ gases.
18.4) Military facility incident	Distance to military facilities to be limited such that they do not constitute controlling events. Preventative actions to be taken such that missile and heat loads may not originate from such installations. Pressure wave to be less than stated in 18.2.
18.5) Pipeline Accident 18.6) Transportation accident	Pressure and heat loads, toxic / flammable vapour clouds or liquids – distance to pipelines to be limited such that they do not constitute controlling events for transient pressure waves. Pressure wave to be less than stated in 18.2. Mitigating action to be taken to protect the safe operation of the NPP against the potential discharge of toxic liquids/ gases.
18.7) Release of radioactive material from off-site sources	< NNR limits

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External Event	Plant Parameter Envelope Reference Values
18.8) Electromagnetic interference from off-site and/ or on-site activated sources. The process in which external signals are emitted and super-imposed on fundamental signals controlling critical plant instrumentation resulting in false, erroneous, inaccurate and/ or unwanted operation of equipment.	Hazard to be mitigated. Preventative action to be taken in the design phase to prevent an impact on the safe operation of the NNI.
18.9) Release of asphyxiant and toxic gases	Distance to potential sources to be limited such that they do not constitute controlling events. Preventative action to be taken in the design phase to prevent an impact on the safe operation of the NNI.
18.10) Release of corrosive gases and liquids, including atmospheric attack (salt) and aerosols.	
19) Extra-terrestrials: Meteorites; Satellite re-entry	Generally, not considered in the design. Impact resistance of safety related structures designed for aircraft crash.

6.9 Events of Natural Origin

6.9.1 Geological Events

Geological investigations that contribute to the knowledge base for the site have been conducted over more than 25 years. These studies include geological mapping, onshore and offshore geophysical studies, geochronological analyses, geomorphic studies, palaeoseismic studies and geotechnical investigations.

Consistent with existing NNR guidance and international regulatory guidance and standards, the full range of methods and tools were applied, and the investigations included the recommended increasing levels of specificity ranging from the site region, site vicinity, and site area to site location. The result of the investigations conducted for the site was

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also integrated with studies conducted by a large number of investigators within the geological community and published in the professional literature, resulting in a strong, complete geological knowledge base for the site region, site vicinity, site area and site location.

The geological data and knowledge documented in the TSSR are the primary basis for the seismic source characterisation conducted for the Probabilistic Seismic Hazard Analysis (PSHA). The geological information provides input to the evaluation of the potential for surface faulting and vibratory ground motion.

From that standpoint, the available geologic, seismologic, and geophysical data are sufficient and adequate for purposes of assessing both the seismic hazard at the site and the suitability of the site.

Surface Faulting

The approach to assessing the potential for surface deformation related to surface faulting hazard follows the guidance provided in US NRC Regulatory Guide 1.208 (United States Nuclear Regulatory Commission, 2007) and the IAEA guidance in SSG-9 (International Atomic Energy Agency, 2010).

Bedrock geological mapping in the site vicinity and the evaluation of all available data, identified no evidence for surface faulting or deformation that would suggest capable faults in the Thyspunt site area (see ***Section 5.13***, ***Subsection 5.13.5.2 (b) iii***). The basis for this conclusion is the absence of geomorphic features indicative of Quaternary (past 2.58 million years) deformation, as reported in the previous siting reports and literature, and inferred from the results of marine terrace and field studies conducted as part of the Thyspunt geological investigations programme.

In accordance with the guidance in Regulatory Guide 1.208 (United States Nuclear Regulatory Commission, 2007), the floors and walls of excavations for all safety related structures for the Thyspunt nuclear facilities will be mapped in detail in the next licensing stage, to confirm the results of these studies.

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Screening Status: *Out (Conditionally)*

(Conditional upon confirmation during the nuclear installation foundation excavation).

Volcanism

Volcanic events can present significant hazards to a nuclear installation(s) during its lifetime. Volcanic hazards arise from phenomena that have broad ranges of physical characteristics. These phenomena may occur in isolation or in combination with other phenomena, even during a single volcanic eruption. Some of these phenomena can occur long before or long after an eruption. Therefore, based on the international recommendations (International Atomic Energy Agency, 2019) and (International Atomic Energy Agency, 2012), the term volcanic event is adopted in this SSR to indicate a set of potentially hazardous phenomena that may occur before, during, or after volcanic eruptions.

Volcanic events are infrequent, relative to most other natural events that can affect the safety and performance of a nuclear installation. Some volcanoes have erupted after lying dormant for thousands of years, or even longer. As a general guide, volcanoes that have erupted during the past 10 000 years are usually considered active (International Atomic Energy Agency, 2012).

The preliminary information and the initial assessment of the potential volcanism in the site region (see ***Section 5.13***, Geology) indicate that volcanism occurred in the region more than 10 million years ago.

Screening status: *Out (unconditionally)*
Criterion 4 – the event has a significantly low mean frequency of occurrence when considering regulatory target safety goals, taking into account the uncertainties in the estimates, where available data permit.

6.9.2 Geohydrological Hazards

A thorough understanding of the groundwater at the site and its potential effects on the foundations of the nuclear installation(s) is required. The detailed site groundwater investigations (***Section 5.11***, Geohydrology) presented the following results:

- There are two aquifers present: an upper intergranular Algoa Aquifer and the underlying fractured rock Table Mountain Group (TMG) Aquifer. The former is a major aquifer and has a basal, discontinuous cobble layer up to 6 m that is highly transmissive.
- Groundwater levels are relatively shallow in the illustrative footprint areas, i.e. 4.8 to 10.2 m bgl[4], being deeper in some elevated dune areas further inland, i.e. 21.55 to 22.45 m bgl.
- Groundwater flow is generally in a southerly to southeasterly direction towards the Indian Ocean.
- High rainfall events show insignificant and delayed effects on groundwater levels due to overflow into wetlands, due to the highly absorptive capacity of the Algoa Aquifer sand and efficient drainage properties of the underlying cobble layer.
- Groundwater quality is moderate to good with electric conductivity below 150 mS/m. The groundwater is slightly acidic to alkaline and of a mixed sodium chloride and calcium bicarbonate type. Provision for corrosion resistant materials should be made for all subsurface installations.
- Extensive use is made of groundwater in the region, with the towns of Oyster Bay, Humansdorp and St. Francis Bay all being supplied from this resource.
- Estimates for potential inflows to a nuclear installation excavation of 20 m depth for the illustrative footprint varies from 21 ℓ/s to 25 ℓ/s, the latter taking into account the effects of sea level rise by 2134. However, it is likely that construction will take place closer to 2034 than 2134 and so c.22 ℓ/s is the more likely value. Experience indicates that actual volumes required to be pumped for dewatering could be about 30 per cent higher, but still within an easily manageable range.
- Numerical model simulation of a 1.76 m to 3.28 m (2134) rise in sea level indicates a 0.8 m rise in groundwater level to a maximum

[4] Below ground level

distance of 350 m inland. This rise can be managed using appropriate groundwater control measures and poses no additional significant risk to a nuclear installation(s).

- Contaminant transport modelling indicates that a liquid leak from the nuclear installation would be confined to the Nuclear-1 footprint. Groundwater monitoring would detect such an event and remedial action would be taken to contain contamination.

Although the investigation and monitoring period has been extensively short, the conceptual and numerical models are considered robust and adequate to provide a realistic representation of the geohydrological conditions at the site.

Currently available site data has not shown any concerning or anomalous trend that could affect nuclear safety, apart from the need to allow for corrosive conditions below the water table. Monitoring will continue and the numerical flow model will be updated if new data indicate significant deviations from established trends.

Screening status: *Out (conditionally).*
Criterion 5 – the event is slowly developing, and it can be demonstrated that there is sufficient time for measures to eliminate it or provide adequate response.

6.9.3 Loss of Freshwater Supply

The water supply (non-cooling) characteristics presented in ***Section 5.12*** (Water Supply) shows that the freshwater requirements could vary between 23 ℓ/s during site establishment, 104 ℓ/s for construction and 69.4 ℓ/s during normal operation of the nuclear installation(s). This is for units to supply an initial 4 000 MWe.

The quantities for 10 000 MWe capacities are estimated at about 173 ℓ/s.

The site establishment requirements of 23 ℓ/s can be met from site groundwater sources in the Algoa and Table Mountain Group aquifers under dry climatic conditions.

Apart from establishment requirements, the water requirements cannot be sourced or guaranteed from existing conventional water supply schemes or from groundwater resources at and around the site. However, groundwater sources could be developed on site to supply initial construction supply requirements.

Securing a reliable fresh water supply from other sources such as new schemes, re-use of wastewater, site storm water run-off and/or water trading is not considered to be viable due to existing and future demand and the risk of water deficits due to droughts.

Should conventional supply sources, either existing or new, ever be considered for fresh water supply, then agreement would need to be reached with the local authority, Kouga Municipality, Nelson Mandela Bay Municipality and the Department of Water and Sanitation to secure the required supply.

Desalination of seawater offers the best short and long-term option for fresh water supply to support the safe operation of the nuclear installation with least environmental impact and highest assurance of supply and is the preferred option.

It can therefore be concluded that an adequate water supply can be sourced for short-term construction and long-term operational requirements.

Screening status: *Out (unconditionally).*
Criterion 5 – the event is slowly developing, and it can be demonstrated that there is sufficient time for measures to eliminate it or to provide adequate response.

6.9.4 Seismic Hazard

Seismic hazard characterisation at the site is based on a PSHA conducted as a Senior Seismic Hazard Analysis Committee (SSHAC) Level 3 process. The SSHAC Level 3 process was adopted to conduct the PSHA within a framework specifically designed to capture “the centre, body and the range of technically defensible interpretations”, or the CBR of the TDI, of available data, methods, and models. The Participatory

Peer Review Panel (recognised international experts in the field of seismic hazard analysis), in their closing letter, stated unambiguously that the CBR of the TDI was effectively captured in the Thyspunt PSHA.

Earthquake Induced Ground Shaking

The ground motion response spectrum (GMRS) is defined as the basic site demand in terms of ground shaking and is the basis for seismic design of nuclear installations. The GMRS is defined as the uniform hazard response spectrum (UHRS) with a mean annual frequency of exceedance (AFE) of 1E-04 multiplied by a design factor (DF), calculated at each oscillator period from the ratio of the UHRS ordinates at mean AFEs of 1E-05 and 1E-04 and is presented in ***Figure 6.1***. The final requirement in terms of representation of the ground shaking hazard is the vertical response spectrum. The resulting vertical GMRS, together with the horizontal GMRS is shown in ***Figure 6.2*** below.

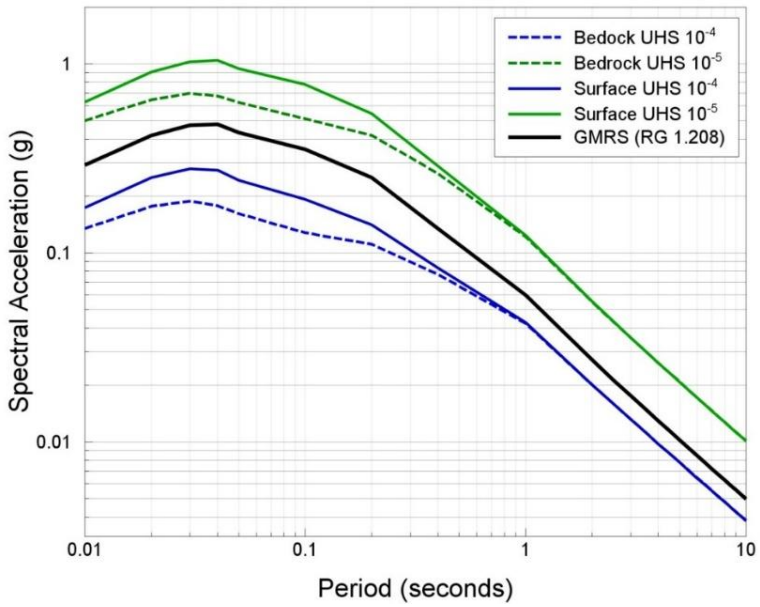


Figure 6.1: Uniform Hazard Spectra at the Bedrock (dashed) and Surface (solid) Elevations for AFEs of 1E-04 and 1E-05 and the Resulting GMRS

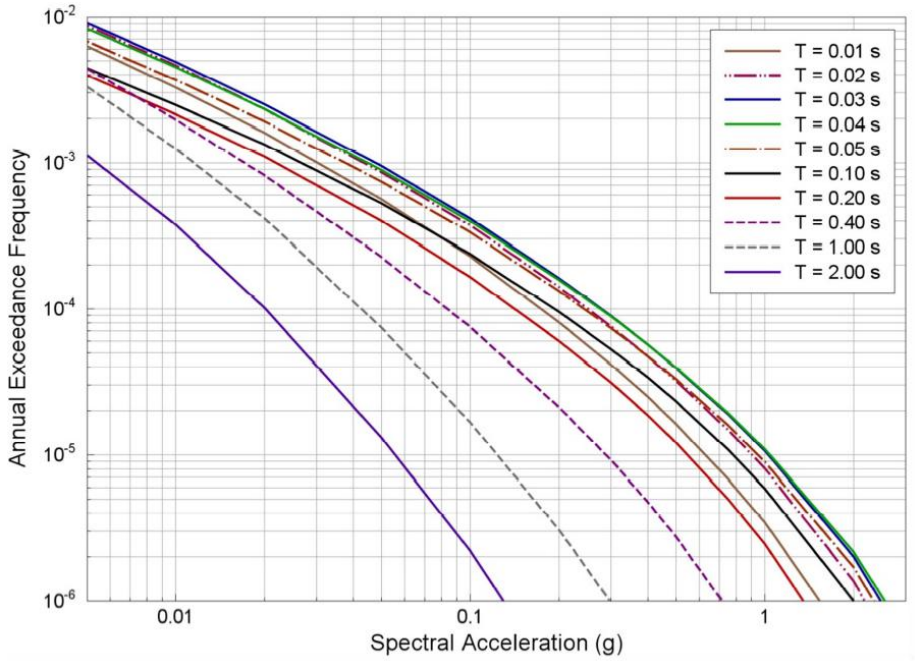


Figure 6.2: Horizontal and Vertical GMRS at the Surface Elevation

Comparison of the resulting horizontal and vertical GMRS with the standard AP1000 design spectra (***Figure 6.3***), shows an appreciable margin between the Thyspunt GMRS and the AP1000 spectrum. The design spectrum is exceeded only at short oscillator periods, reflecting the widely recognised inadequacy of the standard design spectra used for hard rock sites at the time, which should not become constant above frequencies as low as 40 Hz.

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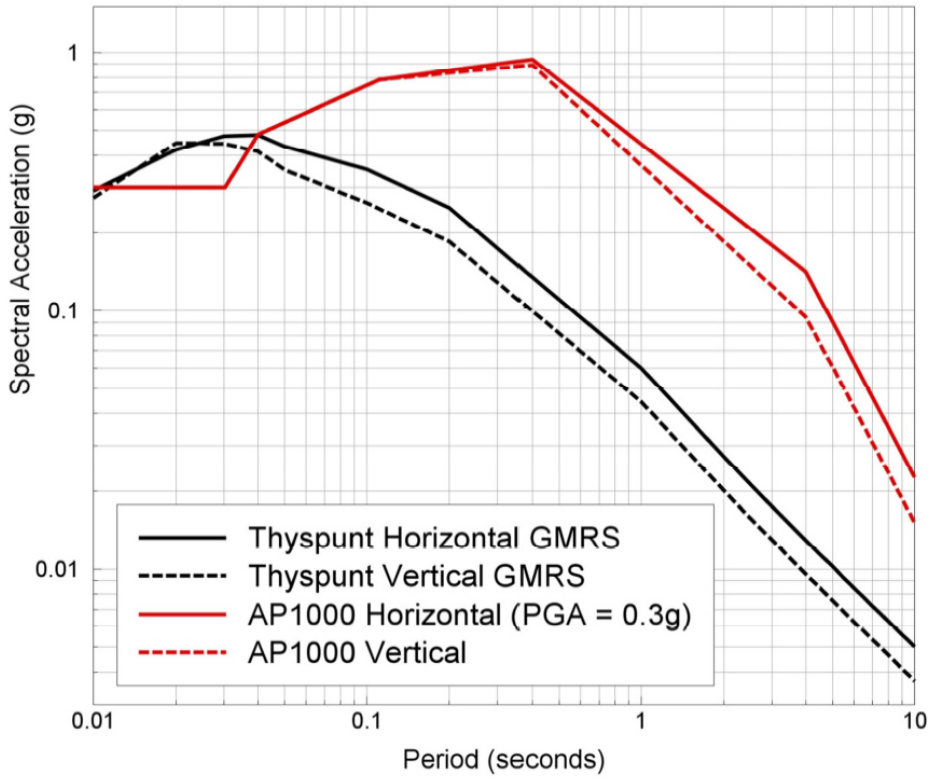


Figure 6.3: Comparison of Thyspunt Horizontal and Vertical GMRS to AP1000 Spectrum

Screening Status: *In*

6.9.5 Geotechnical Events

Screening and Evaluation of Geotechnical Events

The final assessment of geotechnical events is dependent on engineering solutions and the specific nuclear installation design to demonstrate compliance with PPE and an acceptable design basis. The geotechnical events that were investigated and to be considered in a future nuclear installation design are discussed here.

Collapse, Subsurface Movement or Uplift of the Site Surface

The two main sources of collapse, subsurface movement or uplift of the site surface that need to be considered (International Atomic Energy Agency, 2019), are:

- natural induced phenomena (e.g. caverns, quarries and karst formations);
- human induced phenomena (e.g. mines, boreholes/water wells and oil wells).

As presented in detail in ***Figure F 5.13.145*** of ***Section 5.13***, the site is underlain by Table Mountain Group sandstones dominated by the Skurweberg (near the sea) and the Goudini (further inland) formations. These formations do not possess any physical attributes that could result in development of subsurface voids (e.g. caves) and karst features (which develop in limestone/dolomite). Extensive drilling programmes carried out on the site have not encountered any voids or karst features that could pose external hazards to the site.

The geotechnical profile presented in ***Section 5.15*** (Geotechnical Characterisation), ***Subsection 5.15.5*** lists the following features, which could be potentially hazardous to an NNI:

- previous use of the site (e.g. mining activities);
- gas pockets, and swelling rocks[5];
- zones of weakness or discontinuities in crystalline rocks;
- indicators of potential cavities and susceptibility to ground collapse in the context of:
    - sinks, sink ponds, caves and caverns;
    - sinking streams;
    - historical ground subsidence;
    - natural bridges;
    - surface depressions;

[5] However, interbedded shales are commonly encountered in the profile and these rocks are sometimes prone to weathering down to expansive clays

- springs;
- rock types such as limestone, dolomite, gypsum, anhydrite, halite, terra rossa soils, lavas, weakly cemented clastic rocks, coal or ores;
- non-conformities in soluble rocks.

Information gathered to date from historical investigations and through intrusive investigations carried out for this SSR indicate that none of the above features are present on the site, apart from springs at the sea (which are present due to the phreatic surface daylighting in the intergranular aquifer. To confirm this statement in the proposed NNI footprint area, the pre-operational and operational stages of the geotechnical investigation will specifically investigate the occurrence of these features on localised foundation footprints, but as indicated in ***Section 5.15***, there is no evidence to suggest that any unduly onerous challenges may arise due to any of these features (individually or cumulatively considered). There is also certainty that the features mentioned above are not features characteristic of the TMG rocks.

In addition, as the NNI is planned to be founded on (or in) bedrock (see ***Section 5.15***), no subsidence, collapse or uplift is anticipated at the site during the lifetime of the facility as minimum values of unconfined compressive strengths of the rocks measured at the site exceed the minimum required bearing capacity of the PPE (Eskom, 2024).

Once the position of any future nuclear installation is finalised, additional geotechnical investigations will be required through both intrusive (drilling) investigations and through detailed mapping of the exposed bedrock surface as was done for KNPS.

Mining activities within 16 km of the site, i.e. the site vicinity (see ***Section 5.7***, nearby Transportation, Industrial and Military Facilities, ***Subsection 5.7.13.3***) were considered to identify potential sources of human induced events. The site evaluation concluded that there are no mining activities within the 16 km radius of the site that could affect surface stability.

A limited number of quarries, sand mines and brickfields were identified, as illustrated in ***Drawing 5.7.6*** in ***Section 5.7***. These activities are directly

related to the construction industry and occur in areas close to existing towns where most new construction takes place. These operations tend to change location as sand and stone reserves at a particular locality are exhausted and new sources become known.

Production boreholes/wells would have to be sited close to the NNI to have any possible effects due to drawdown of groundwater levels based on yield testing carried out on the site (***Section 5.11***, ***Subsection 5.11.7.1***). Such boreholes would, of necessity, be owned and controlled by Eskom as they would fall within the site boundaries. A water level monitoring programme will be instigated (***Subsection 5.11.9***).

There are currently two offshore exploration rights under application in the site region, namely Sungu Sungu (322ER) where *PetroSA* is conducting an appraisal of Cretaceous shallow marine gas fields, and New Age Algoa/Rift Petroleum (201ER) where the prospectivity evaluation of the synrift and post rift sequences is ongoing (***Figure 6.4***).

In addition, *TotalEnergies*, *Main Street*, *Qatar Petroleum* and *CNR* had a production right under application immediately to the south of the site region (013PR). Gas discoveries were made in Block 11B/12B in 2019 and 2020 (***Figure 6.5***) through the drilling of the Brulpadda and Luiperd wells, [redacted] (***Section 5.6***, ***Subsection 5.6.6.8***).

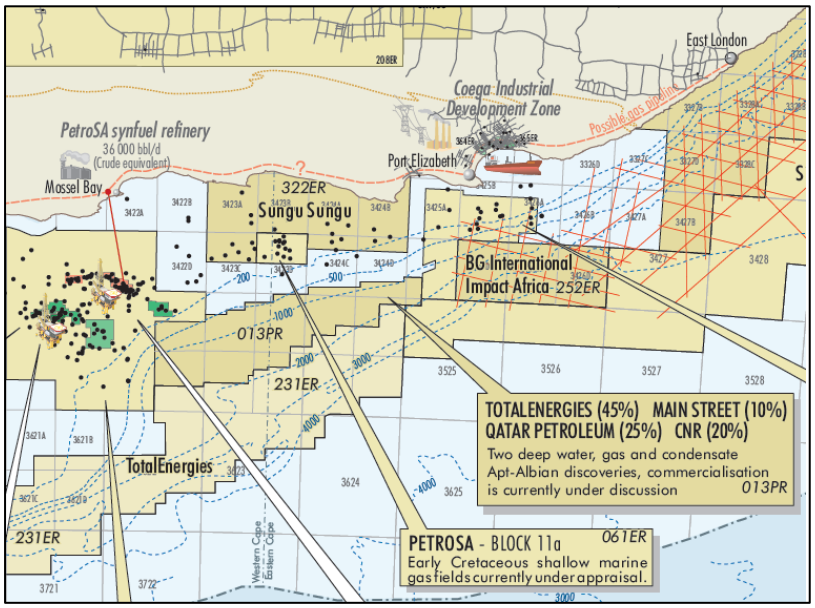


Figure 6.4: Petroleum Exploration and Production Activities relative to the Site Region

The project was in its approval stage and was expected to start commercial operation by 2026, however, in July 2024, *Total Energies*, *QatarEnergy* and *CNR* gave notice to the joint venture partners that they were withdrawing from their interest in Block 11B/12B. Mainstreet retained their interest in Block 11B/12B. The future extraction of this resource is therefore currently uncertain and will need to be monitored.

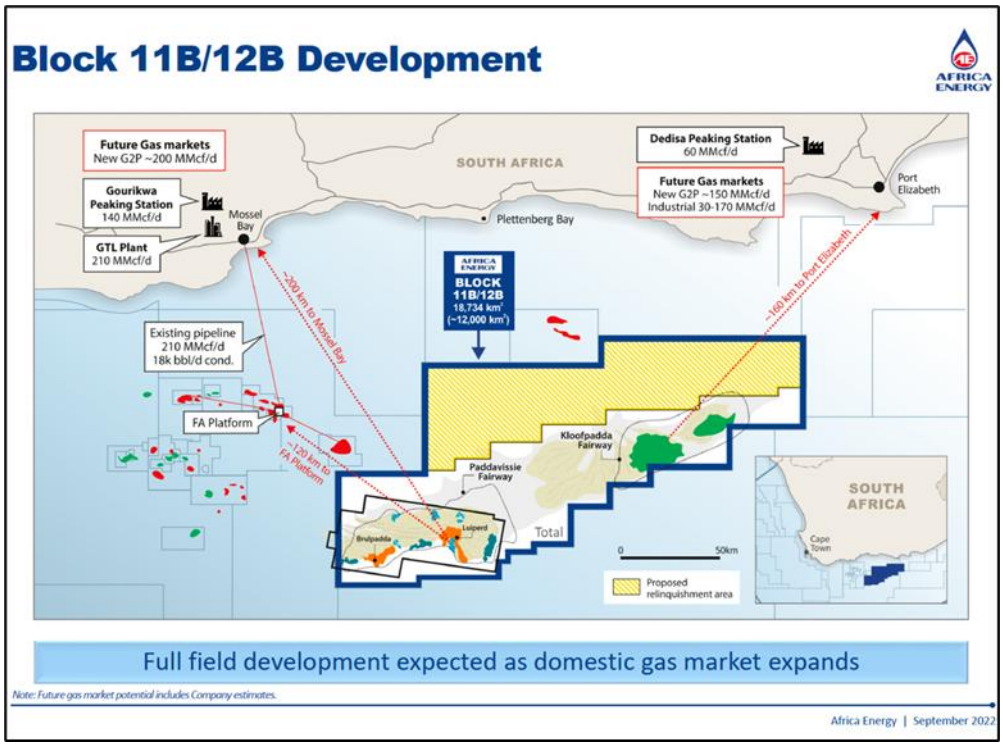


Figure 6.5: Block 11B / 12B Development indicated by the Red dashed Circle

Based on the current information about the site and the region, no collapse, subsurface movement, or uplift of the site surface, due to caverns and karst formations is expected to occur during the lifetime of the NNI. The future extraction of gas resources needs to be monitored and assessed for its impact on the site when more information becomes available.

Screening status: *Out (conditionally)*

Criterion 1 - the event is of equal or lesser damage potential than the events for which the NNI is planned to be designed.

Liquefaction Potential

Liquefaction is a phenomenon in which the strength and stiffness of a soil is reduced by earthquake shaking or other rapid (dynamic) loading. Liquefaction can occur most commonly in saturated sandy and silty soils. It is a consequence of a significant decrease in effective overburden pressure, i.e., the force between the soil particles decreases significantly because of an increase in pore pressure caused by e.g., an earthquake. A more technical definition is the sudden loss of shear strength in saturated, cohesionless soils induced by groundwater elevations and earthquake induced vibratory ground motion. Significant damage can occur to civil structures supported on soils that liquefy and liquefaction presents significant risks to slope stability. Based on the PPE (Eskom, 2024) liquefaction is not permitted on the nuclear installation terrace. The site is disqualified if liquefaction cannot be dealt with by engineering design.

At earthquake magnitudes and peak ground acceleration levels derived from the PSHA study, minor portions of the site are susceptible to liquefaction with the following conclusions relating to it:

- Current analysis indicates that liquefaction potential exists in isolated areas, but in general the site does not exhibit a high liquefaction risk.

- Poorly consolidated soils in the upper horizons will, however, exhibit liquefaction potential should these horizons become saturated in future.

Liquefaction risks at the site can be dealt with in the final power station design, e.g. through founding the plant basemat on bedrock and/or through robust dewatering systems and carefully designed soil improvement measures that have proved successful with the development of Koeberg Nuclear Power Station.

***Screening status**: In*

Criterion 3 - the event is included in the definition of another event.

Slope Instability

Slope instability is a phenomenon resulting from steep slopes, high groundwater, and/or vibratory ground motion but not related to surface faulting. Slope instability can result in landslides and general earth movements that could affect the safe operation of the NNI. It could also hinder emergency response. Slope instability is not permitted at the site and must be dealt with by engineering design (Eskom, 2024).

As presented in ***Subsection 5.15.5***, perhaps the single most significant geotechnical characteristic of the site is the extensive, cohesionless overburden overlying the bedrock and the fact that an intergranular aquifer underlies the entire site. The illustrative Nuclear-1 footprint is positioned with overburden deposit on the northwest corner suggesting that excavation to bedrock in this area will be ~40 m deep.

The finished levels of the nuclear installation(s) are expected to be above 10 m msl[6]. Areas therefore exist on the site where remnant slopes[7] will feature after construction of the nuclear installation(s) (i.e. should the footprint be located inland where topography and the groundwater levels are elevated).

The following observations are made about the coastal zone and inland surroundings:

- In the eastern part of the site, slope heights from proposed nuclear installation level to natural ground level are limited to approximately 10 m (vertical height) for 600 m inland. The groundwater table in this 600 m zone is between 10 and 15 m msl (i.e. 0 to 5 m above nuclear installation level) and minor saturation of remnant slopes is expected.

- In the central and western parts of the site, remnant slope heights of 10 m or less will only be possible within 100 to 200 m from the sea. The groundwater table in this zone is between 10 and 15 m msl (i.e. 0 to 5 m above NI level) and minor saturation of remnant slopes is expected.

[6] metres relative to mean sea level

[7] slopes remaining after construction of the nuclear installation(s)

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- Moving inland from the coastal zone, remnant slope heights rapidly increase within the dunes to about 80 to 90 m between 1.2 km and 1.5 km distance from the sea (throughout the site).

- The position of the groundwater table above nuclear installation level, however, varies and remnant slopes in the south-eastern and central zones are less susceptible to saturation than in the northern, western and eastern areas.

In summary, a narrow coastal strip (600 m in the east and between 100 and 200 m in the central and western region) will present a geotechnical profile in which the design of stable slopes will be considerably less onerous. Positioning of the nuclear installation(s) in the far west, central, northern or north-eastern parts of the site will introduce more challenging designs as slope heights and the presence of elevated groundwater come into play.

On the basis of the current site data, the site can be considered suitable as civil engineering design requirements will exclude slope instability as a design basis event.

***Screening status**: Out (conditionally).*

Criterion 1 - the event is of equal or lesser damage potential than the events for which the nuclear installation(s) is planned to be designed.

Behaviour of Foundation Materials

A minimum bearing capacity is required of the load bearing foundation materials to support the load exerted by nuclear installation plant structures. These loads will be determined during the detailed design of the NNI.

Extensive investigation of the site bedrock through field and laboratory investigations revealed that the site is underlain by hard quartzitic (sandstone dominated) Skurweberg Formation rocks in the south and less hard (quartzitic sandstone dominated) Goudini Formation rocks in the central and northern parts of the site (see ***Sections 5.13*** and ***5.15***).

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The Skurweberg and Goudini formation rocks appear to have varying characteristics related to uniaxial compressive strength (UCS). In essence, the Skurweberg Formation rocks tend to have a higher average UCS than the Goudini Formation rocks. Average UCS in the Skurweberg is 120 MPa and in the Goudini is 35 MPa. The distribution of UCS in these rocks is, however, rectangular and high ranges in values are evident, with Skurweberg UCS ranging from 3.8 MPa to 254 MPa and the Goudini from 1.7 MPa to 196 MPa (see ***Table T-5.15.18*** in ***Section 5.15***). The distribution of UCS in the Skurweberg rocks envelopes the distribution of UCS in the Goudini rocks.

At present, the primary consideration for the nuclear installation(s) foundation safety remains the variability in the geotechnical profile. This variability creates a challenge for the nuclear installation(s) design. Therefore, differential rock bearing capacity[8] and potential for differential dynamic loading conditions should be noted.

The site rock properties vary throughout and across lithological boundaries and soil consistency varies vertically and laterally. The Illustrative Nuclear 1 footprint is located on the Goudini sequence and does not straddle lithological boundaries.

The site rock variability, however, does not present unduly onerous challenges to the design of the nuclear installation(s) foundations considering that future geotechnical investigations will be carried out to close out uncertainties under localised safety sensitive structures. Once footprints within the Illustrative Nuclear 1 footprint area for safety related structures are selected, this variability can be investigated in detail on a localised scale to assess variability that will immediately affect founding.

Comparison of the general foundation soil characteristics requirements for a nuclear installation(s) and the currently available data for the site (see ***Table 6.3***) dictate building the nuclear installation foundations on (or in) the site bedrock.

[8] Bearing Capacity: The carrying capacity of soil/rock materials as an indicator of what loads can safely be placed on such materials.

Table 6.3: Soil Parameter Values

Soil	Parameter Values[9]	Site Values (see ***Section 5.15***)
Average Allowable Static Soil Bearing Capacity	Greater than or equal to 8 600 lb/ft^2 (412 kPa) over the footprint of the nuclear island at its excavation depth	Soils will not have bearing capacity >200 kPa even with mechanical ground improvements – desired bearing capacity in excess of this will require cement stabilisation.
Maximum Allowable Dynamic Bearing Capacity for Normal Plus Safe Shutdown Earthquake (SSE)	Greater than or equal to 35 000 lb/ft^2 (1.7 MPa) at the edge of the nuclear island at its excavation depth	To be defined after excavation to bedrock.
Lateral Variability	Soils supporting the nuclear island should not have extreme variations in subgrade stiffness. Case 1: For a layer with a low strain shear wave velocity greater than or equal to 2 500 ft (762 m/s), the layer should have approximately uniform thickness, should have a dip not greater than 20°, and should have less than 20 per cent variation in the shear wave velocity from the average velocity in any layer. Case 2: For a layer with a low strain shear wave velocity less than 2 500 ft/s (762 m/s), the layer should have approximately uniform thickness, should have a dip not greater than 20°, and should have less than 10 per cent variation in the shear wave velocity from the average velocity in any layer.	Localised and lateral variability not likely to be an issue in soils but may be an issue if the nuclear installation(s) is founded on rock.
Shear Wave Velocity Liquefaction Potential	Greater than or equal to 1 000 ft/sec (304.8 m/s) based on low-strain, best-estimate soil properties over the footprint of the nuclear island at its excavation depth	225 to 610 m/s (averaging 350 m/s)

[9]AP1000

The bearing capacity of the founding rocks at the site does not present as much of a design challenge as the variability of these materials. In the pre-construction stage, this variability will be explored in greater detail, i.e. upon exposure and mapping of the founding materials once overburden sands are removed – as was done for the Koeberg Nuclear Power Station.

Design of the foundations to accommodate variability exposed at this stage will not be unduly onerous based on the information gathered to date. It is likely that there is a greater differential in dynamic rock characteristics, with preliminary shear wave velocity values ranging considerably between the Skurweberg and Goudini rocks. The implications of varying site response to dynamic loading (see ***Subsection 5.15.7***) cannot be ignored and it is critical to the nuclear installation safety that the footprint does not straddle these formations. It is unlikely to expect any safety related design challenges should the nuclear installation(s) be founded in either the Skurweberg or Goudini formation rocks, but complications will arise should the contact between these two formations be straddled.

With respect to damped foundations, the site could be defined as suitable on the condition that the confirmed seismic response spectra are considered in the final nuclear installation design to ensure site safety and that the foundations are positioned such that lithological boundaries and/or shear/fault zones are not spanned.

Screening status*: Out (conditionally)*.

Criterion 1 - the event is of equal or lesser damage potential than the events for which the nuclear installation(s) is planned to be designed

6.9.6 Meteorological Hazard Parameters

In accordance with international recommendations (International Atomic Energy Agency, 2019) two main types of meteorological phenomena and events need to be evaluated in the site evaluation stage, i.e., extreme values of meteorological hazard parameters and rare meteorological phenomena, as follows (see ***Section 5.8***, Meteorology):

- extreme values of meteorological parameters (measurable) such as air temperature and wind speed that characterise the meteorological or climatological environment - These parameters are measured routinely over a network of fixed stations by international, national, local, or private meteorological services.
- rare meteorological phenomena that occur infrequently (immeasurable) - At any particular station, the instruments used for routine measurements would rarely register characteristics of these phenomena.

All measurements and studies of meteorological conditions that have been performed for this SSR are presented and discussed in detail in ***Section 5.8*** of this SSR.

Results of meteorological investigations and measurements indicate that the site can potentially experience severe weather in the form of thunderstorms, hail, hurricane force winds and possibly tornadoes. Many of the severe storms occurring in the Eastern Cape are compound, producing various potential combinations of hail, wind, tornado, lightning and flash flooding. Damaging winds associated with severe thunderstorms include tornadoes, downbursts (macrobursts or microbursts), straight-line winds, gust fronts and derechoes[10].

Historical records, covering a period of about 160 years of severe weather events in the region (radius of 100 km), lists 20 gale force or severe wind events and 3 tornadoes up to 2023. The same record also lists 6 severe rain and 32 flood events (***Section 5.8***).

6.9.6.1 Tropical Cyclones

The site region is not on a hurricane (tropical cyclone) track or adjacent to a warm ocean. Therefore, it is not expected that the site will experience a hurricane, or at least there is a very low probability. Tropical cyclones are generated in areas, where the ocean surface temperature is greater than 27°S and between latitudes 5°S to 30°S. The site is located at approximately 33°S and is therefore not subject to tropical cyclones. It is

[10] The term 'derecho' is used to describe larger scale straight-line winds advancing very quickly ahead of a well organised, long-lasting squall line or a large-scale multiple cell storm (refer to ***Section 5.8***)

not clear how climate change will affect the occurrence of cyclones and it has not been presented in the 5th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) (Intergovernmental Panel on Climate Change, 2013).

6.9.6.2 Extreme Wind

The site is said to experience hurricane force winds. Hurricane force winds refer to a wind speed scale described by the Beaufort Scale as winds with speeds above 118 km/h (32.8 m/s). This wind speed (as a gust) has been exceeded on 16 days (2008 and 2007)) over the 20-year monitoring period at the Cape St. Francis WS. The highest gust of 45.8 m/s occurred on 18 August 2020. The Thyspunt WS, albeit less than 9 years of data, recorded one hurricane force wind (37.9 m/s) on 2 September 2013.

The PPE values for extreme wind speed (gust) is given as 70 m/s and the maximum basic wind speed as 43 m/s in ***Table 6.2***. The revised SANS 10160 code of practice gives a maximum basic wind speed of 52 m/s for the whole country.

From the results in ***Table 6.4*** the site is expected to experience this wind speed between return periods of 1E05 and 1E06.

6.9.6.3 Tornadoes

Results of the meteorological evaluation investigations also indicate an increase in tornado activity within an 80 km radius from the site. Whilst climate change may have contributed to increases in tornado frequencies, it may also simply be that the reporting of tornadoes has increased due to population spread as well as the associated damage to property. Tornadoes are amongst the most violent and destructive of all extreme weather phenomena. Tornadoes in South Africa are typically associated with very hot air masses and severe thunderstorms.

The tornado frequencies per severity is given in ***Table 6.5***. The results indicate that EF0 tornadoes have an expected probability of 1.3E-06 per year per km², EF1 tornadoes an expected probability of 2.1E-06, EF2 tornadoes an expected probability less than 1E-07 per year and EF3

tornadoes well below 1E-07 per year. Using the EF scale, the estimated maximum tornado wind speeds (3 s gust estimates) are between 60 m/s and 75 m/s.

Extreme winds should be considered in the design of the nuclear installation, under design basis extension conditions (DBEC) and does not preclude the site from locating the proposed new nuclear facility.

6.9.6.4 Extreme Rainfall

Rainfall measurements at the site over the 40-year monitoring period indicates that the highest hourly, 24-hourly, monthly, and annual precipitation was 37.4 mm, 157.8 mm, 366.0 mm and 972.2 mm, respectively. The probable maximum precipitation (PMP) value that can be accommodated by the proposed plant designs according to the PPE is 100 mm/hr and 400 mm in 24 hours. The expected probability for reaching a PMP value of 400 mm in 24 hours is below 1E-06 per year.

6.9.6.5 Ambient Temperatures

The lowest and highest extreme hourly temperatures recorded at the Thyspunt WS were 6.7°C and 38.2°C. The extreme hourly temperatures recorded at Cape St. Francis WS were 4.9°C and 38.5°C. The projected lowest and highest temperatures including climate change for the site is 7.4 °C and 41.7°C in 2100. The maximum air design temperature in the PPE document is given as follows: long term base (> 7 days) is 42°C; short term daily (6 hours to 7 days) is 46°C and instantaneous (6 hours) is 50°C. According to the results, a short term daily temperature of 46°C has a return frequency of 100 years considering the near-horizon climate change projections (see ***Table 6.4***).

6.9.6.6 Other Meteorological Hazards

Freeze-thaw

The freeze-thaw phenomenon is not considered an issue at the site. Freeze-thaw occurs when concrete (or rocks) is saturated with water and the temperature drops, freezing the water molecules. However, besides the frequency of freeze–thaw cycles, the frost intensity should also play

an important role. The frost intensity describes how long and to what extent the temperature falls below the 0°C transition. According to (Walder & Hallet , 1985), most of the damage potential can be assumed for a temperature of -10°C.

However, this temperature range has not been observed at the Thyspunt site, with the recorded lowest hourly average of 4.9°C (Cape St. Francis WS) and 6.7°C (Thyspunt WS). The 1E04-year return period projects a temperature below 0°C, i.e. -0.5°C. The projected 1E08-year return period estimate of -7.7°C does not reach -10°C. The possibility of freeze-thaw from frozen water in the pores is therefore not likely at the site and hence freezing thaw phenomenon is not considered an issue for the site.

Additionally, regarding the possibility of ice occurring in the sea surrounding the site, the lowest seawater temperature measured in all the data sets described in ***Section 5.9*** is 7.9°C, and an extreme value analysis of the minimum measured temperatures at Site C (-3 m msl) was above 0°C at an exceedance of 1E0-8 per year. On this basis ice is not anticipated to form in the sea at the site.

Table 6.4 and ***Table 6.5*** list the main results from ***Section 5.8*** of this SSR**.** Design basis and extreme values are based on the maximum values measured at the site.

Table 6.4: Site Specific Meteorological Parameters Part 1[11]

Meteorological Parameter		Baseline	Climate Change Projections	
			Near-Horizon (2050)	Far Horizon (2100)
Annual Average Wind Speed (m/s) at Thyspunt WS		5.4 ± 0.01	4.9 -0.5+1.5	5.4 -1.0+1.0
Annual Average Wind Speed (m/s) at Cape St Francis WS		6.0± 0.01	5.5 -0.5+1.5	6.0 -1.0+1.0
Hourly Maximum Wind Speed (1) [m/s] (Thyspunt WS 8 m above site ground level) **Return Periods Wind Speed** [m/s] (2) (Cape St Francis WS 10 m above site ground level)	Extreme Observed & Projected Thyspunt WS	19.6 ± 0.0	19.1 -0.5+1.5	19.6 -1.0+1.0
	Extreme Observed & Projected Cape St Francis	23.2 ± 0.0	22.7 -0.5+1.5	23.2 -1.0+1.0
	10 Year Return	22.0 ± 1.2	21.4 ± 1.2	22.0 ± 1.2
	100 Year Return	24.7 ± 2.1	24.0 ± 2.1	24.7 ± 2.1
	1 000 Year Return	27.3 ± 3.1	26.6 ± 3.1	27.3 ± 3.1
	10 000 Year Return	29.9 ± 4.1	29.2 ± 4.1	29.9 ± 4.1
	100 000 Year Return	32.6 ± 5.1	31.7 ± 5.1	32.6 ± 5.1
	1 000 000 Year Return	35.2 ± 6.1	34.3 ± 6.1	35.2 ± 6.1
	10 000 000 Year Return	37.9 ± 7.0	36.9 ± 7.0	37.9 ± 7.0
	100 000 000 Year Return	40.5 ± 8.0	39.5 ± 8.0	40.5 ± 8.0

[11] TSSR Section 5.8

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Meteorological Parameter		Baseline	Climate Change Projections	
			Near-Horizon (2050)	Far Horizon (2100)
Wind peaks (gusts) (3) [m/s] (Thyspunt WS 8 m above site ground level) **Return Period Gusts** [m/s] (2) (Cape St Francis WS 10 m above site ground level)	Extreme Observed & Projected Thyspunt WS	32.2 ± 0.0	31.7 -0.5+1.5	32.2 -1.0+1.0
	Extreme Observed & Projected Cape St Francis	45.8± 0.0	45.3 -0.5+1.5	45.8 -1.0+1.0
	10 Year Return	38.1 ± 3.5	37.6 ± 3.5	38.1 ± 3.5
	100 Year Return	44.3 ± 6.2	43.7 ± 6.2	44.3 ± 6.2
	1 000 Year Return	50.2 ± 8.8	49.6 ± 8.8	50.2 ± 8.8
	10 000 Year Return	56.2 ± 11.4	55.5 ± 11.4	56.2 ± 11.4
	100 000 Year Return	62.2 ± 14.1	61.4 ± 14.1	62.2 ± 14.1
	1 000 000 Year Return	68.2 ± 16.7	67.3 ± 16.7	68.2 ± 16.7
	10 000 000 Year Return	74.2 ± 19.3	73.2 ± 19.3	74.2 ± 19.3
	100 000 000 Year Return	80.2 ± 22.0	79.1 ± 22.0	80.2 ± 22.0
Ambient temperature [°C] (Thyspunt WS 2 m above site ground level) **Return Periods Dry Bulb Temperature** [m/s] (4) (Cape St Francis WS 10 m above site ground level)	Average daily maximum dry bulb temperature	20.8 ± 0.1	22.5 0.0+0.0	24.1 -0.04+0.2
	- coincident wet bulb temperature (5)	18.2 ± 0.2	19.4 1.0+1.8	20.1 1.0+2.3
	Average daily maximum wet bulb temperature (5)	16.7 ± 0.1	17.3 0.0+0.5	17.9 0.0+0.9
	Extreme Observed Thyspunt WS & Projected dry-bulb maximum	38.2 ± 0.0	39.7 -0.5+0.5	41.7 -1.5+0.5
	Extreme Observed Cape St Francis WS & Projected dry-bulb maximum	38.5 ± 0.0	40.0 -0.5+0.5	42.0 -1.5+0.5

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Meteorological Parameter		Baseline	Climate Change Projections	
			Near-Horizon (2050)	Far Horizon (2100)
	10 Year Return	37.0 ± 1.8	42.8 ± 2.9	45.6 ± 3.1
	100 Year Return	42.4 ± 3.1	48.1 ± 4.3	50.9 ± 4.5
	1 000 Year Return	47.7 ± 4.5	53.4 ± 5.7	56.2 ± 5.9
	10 000 Year Return	53.0 ± 5.9	58.7 ± 7.2	61.5 ± 7.4
	100 000 Year Return	58.3 ± 7.4	64.0 ± 8.7	66.9 ± 8.9
	1 000 000 Year Return	63.7 ± 8.9	69.3 ± 10.2	72.2 ± 10.4
	10 000 000 Year Return	69.0 ± 10.4	74.6 ± 11.6	77.5 ± 11.9
	100 000 000 Year Return	74.3 ± 11.9	80.0 ± 13.1	82.8 ± 13.4
	Maximum temperature of 3-hour duration [6]	37.0 Corresponding Wet Bulb Temperature 19.7 ± 1.8	38.7 0.0+0.0	40.3 -0.04+0.2
	Maximum temperature of 6-hour duration [6]	33.1 Corresponding Wet Bulb Temperature 18.8 ± 0.9	34.8 0.0+0.0	36.4 -0.04+0.2
	Maximum temperature of 7-day duration [6]	19.3	21.0 0.0+0.0	22.6 -0.04+0.2

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Meteorological Parameter		Baseline	Climate Change Projections	
			Near-Horizon (2050)	Far Horizon (2100)
		Corresponding Wet Bulb Temperature 16.8 ± 0.1		
	Average daily minimum dry bulb temperature	14.4 ± 0.1	16.1 0.0+0.0	17.7 -0.04+0.2
	- coincident wet bulb temperature (5)	11.8 ± 0.1	12.2 -0.1+0.2	12.6 -0.3+0.4
	Average daily minimum wet bulb temperature (5)	12.6 ± 0.1	13.0 0.0+0.3	13.5 0.0+0.6
	Extreme Observed Thyspunt WS & Projected dry-bulb minimum	6.7	9.2 -1.5+0.5	9.2 -0.5+1.5
	Extreme Observed Cape St Francis & Projected dry-bulb minimum	4.9	7.4 -1.5+0.5	7.4 -0.5+1.5
	10 Year Return	5.0 ± 0.7	6.0 ± 1.1	5.7 ± 1.2
	100 Year Return	3.2 ± 1.2	1.6 ± 1.6	3.8 ± 1.7
	1 000 Year Return	1.3 ± 1.7	-0.2 ± 2.1	2.0 ± 2.2
	10 000 Year Return	-0.5 ± 2.2	-2.0 ± 2.6	0.2 ± 2.7
	100 000 Year Return	-2.3 ± 2.7	-3.8 ± 3.1	-1.6 ± 3.2
	1 000 000 Year Return	-4.1 ± 3.2	-5.6 ± 3.6	-3.4 ± 3.7
	10 000 000 Year Return	-5.9 ± 3.7	-7.5 ± 4.1	-5.2 ± 4.2
	100 000 000 Year Return	-7.7 ± 4.2	-9.3 ± 4.7	-7.0 ± 4.7

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Meteorological Parameter		Baseline	Climate Change Projections	
			Near-Horizon (2050)	Far Horizon (2100)
	Minimum temperature of 3-hour duration (6)	7.2 Corresponding Wet Bulb Temperature 5.4 ± 0.3	8.9 0.0+0.0	10.5 -0.04+0.2
	Minimum temperature of 6-hour duration (6)	7.7 Corresponding Wet Bulb Temperature 6.0 ± 0.2	9.4 0.0+0.0	11.0 -0.04+0.2
	Minimum temperature of 7-day duration (6)	15.5 Corresponding Wet Bulb Temperature 13.3 ± 0.1	17.2 0.0+0.0	18.8 -0.04+0.2
Rainfall [mm] (0.7 m above site ground level)	Average Annual Total Thyspunt WS	774.4	777.5 -22.73+18.76	762.5 -32.33+6.4
	Average Annual Total Cape St Francis WS	619.5	622.6 -22.73+18.76	607.6 -32.33+6.4
	Extreme Annual Total	972.0	975.1 +18.76 -22.73	960.1 -32.33 +6.4
	Annual Re-occurrences			
	10 Year Return	858.7 ± 84.8	861.8 ± 84.8	846.8 ± 84.8
	100 Year Return	1187.9 ± 147.1	1191.0 ± 147.1	1176.0 ± 147.1
	1 000 Year Return	1511.2 ± 212.2	1514.2 ± 212.2	1499.2 ± 212.2
	10 000 Year Return	1833.8 ± 278.4	1836.9 ± 278.4	1821.9 ± 278.4
	100 000 Year Return	2156.4 ± 345.0	2159.5 ± 345.0	2144.5 ± 345.0
	1 000 000 Year Return	2479.0 ± 412.0	2482.1 ± 412.0	2467.0 ± 412.0

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Meteorological Parameter		Baseline	Climate Change Projections	
			Near-Horizon (2050)	Far Horizon (2100)
	10 000 000 Year Return	2801.6 ± 479.0	2804.7 ± 479.0	2789.6 ± 479.0
	100 000 000 Year Return	3124.2 ± 546.2	3127.2 ± 546.2	3112.2 ± 546.2
	Extreme 24-hour Storm Thyspunt WS	113.5	124.9 -0.0+11.4	Assume same as Near-Horizon
	Extreme 24-hour Storm Cape St Francis WS	157.8	173.8 -0.0+15.8	Assume same as Near-Horizon
	24-Hour Re-occurrences:			
	10 Year Return	99.0 ± 20.8	108.9 ± 20.8	99.0 ± 20.8
	100 Year Return	151.4 ± 38.8	166.6 ± 38.8	151.4 ± 38.8
	1 000 Year Return	202.9 ± 56.8	223.2 ± 56.8	202.9 ± 56.8
	10 000 Year Return	254.3 ± 74.9	279.7 ± 74.9	254.3 ± 74.9
	100 000 Year Return	305.6 ± 93.0	336.2 ± 93.0	305.6 ± 93.0
	1 000 000 Year Return	357.0 ± 111.1	392.7 ± 111.1	357.0 ± 111.1
	10 000 000 Year Return	408.4 ± 129.2	449.2 ± 129.2	408.4 ± 129.2
	100 000 000 Year Return	459.7 ± 147.3	505.7 ± 147.3	459.7 ± 147.3
	Extreme 1-hour Storm	51.9	57.1 0.0+5.2	Assume same as Near-Horizon
Mean Sea Level Atmospheric pressure [hPa]	Daily Minimum	999.1 ± 0.2	Not available (7)	Not available (7)
	Daily Maximum	1037.4 ± 0.2	Not available (7)	Not available (7)
	Extreme Lower (Hourly))	994.1 ± 0.2	Not available (7)	Not available (7)
	Average Annual	1016.3 ± 0.2	Not available (7)	Not available (7)

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Meteorological Parameter		Baseline	Climate Change Projections	
			Near-Horizon (2050)	Far Horizon (2100)
	Extreme Upper (Hourly))	1040.6 ± 0.2	Not available (7)	Not available (7)

Notes:

(1) Thyspunt WS included 7 years of measurements. The maximum wind speeds were on average 20% lower at the Thyspunt WS than the observations at the Cape St Francis WS (highest wind speed 23.2 m/s)

(2) Extreme analyses were completed using the measurements from the Cape St Francis WS since the database included 19 years of data compared to the 7 years of measurements at the Thyspunt WS. These extremes are biased by the 20% on average higher wind speed observations than at the Thyspunt WS and are likely conservative projections.

(3) Thyspunt WS included 7 years of measurements. The maximum wind speeds were on average 20% lower at the Thyspunt WS than the observations at the Cape St Francis WS (highest gust of 45.8 m/s)

(4) Extreme analyses were completed using the measurements from the Cape St Francis WS since the database included 19 years of data compared to the 7 years of measurements at the Thyspunt WS. The maximum dry bulb temperature extremes are slightly different, i.e. 38.2 °C at Thyspunt WS compared to 38.5°C at the Cape St Francis WS. The minimum dry bulb temperature extremes are more significantly different, i.e. 6.7 °C at Thyspunt WS compared to 4.9 °C at the Cape St Francis WS. The lower temperatures at the Cape St Francis WS therefore provides a more conservative estimate of the minimum temperature return periods.

(5) Wet-bulb temperature projections are not part of the primary meteorological variables provided by the climate change model used in the analyses. The projections provided in the table are based on using the daily minimum, average and maximum temperature projected increases and assuming ±25% variation in the corresponding moisture content.

(6) Temperatures of 3-hour, 6- hour and 7-day durations assumed projected temperature increases as per the climate change model.

(7) Global climate projections from the ARP5 indicate relatively small changes in the projected mean sea-level atmospheric pressure over South Africa (max seasonal increase of 0.5 hPa in summer and reduction of 0.5 hPa in winter for the far horizon).

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Table 6.5: Site Specific Meteorological Parameters Part 2

Meteorological Parameter			Value			
Tornadoes	Tornado Probability (EF - Enhanced Fujita Scale)	Based on 116-year database 1905 - 2020	All(2)	6.8 x 10^{-6} per year per km²		
			EF0	1.3 x 10^{-6} per year per km²		
			EF1	2.1 x 10^{-6} per year per km²		
			EF2	6.6 x 10^{-7} per year per km²		
			EF3	<1.0 x 10^{-8} per year per km²		
			EF4	<1.0 x 10^{-8} per year per km²		
			EF5	<1.0 x 10^{-9} per year per km²		
		Based on 25-year database 1996 - 2020 (1)	All(2)	3.2 x 10^{-6} per year per km²		
			EF0	4.0 x 10^{-5} per year per km²		
			EF1	2.3 x 10^{-6} per year per km²		
			EF2 (3)	6.6 x 10^{-7} per year per km²		
			EF3(3)	<1.0 x 10^{-8} per year per km²		
			EF4(3)	<1.0 x 10^{-8} per year per km²		
			EF5(3)	<1.0 x 10^{-9} per year per km²		
	10^{-7} per year wind speed: - maximum wind speed - maximum translational - maximum rotational		75.0 m/s 15.0 m/s 60.0 m/s			
			Lower Quartile	Upper Quartile	Median	Average
	Path Width [m]:					
	EF0 tornado (40% to 64% probability)		22.9	68.6	45.7	54.9
	EF1 tornado (36% to 48% probability)		68.6	182.9	91.4	163.8
	EF2 tornado (0% to 4% probability)		137.2	402.3	228.6	344.1
	EF3 tornado (0% to 4% probability)		339.5	1005.8	548.6	736.3
	Path Length [km]:					
	EF0 tornado (40% to 64% probability)		0.29	2.7	0.8	2.27
	EF1 tornado (36% to 48% probability)		1.77	9.33	4.4	7.1
	EF2 tornado (0% to 4% probability)		4.53	19.25	10	14.3

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Meteorological Parameter		Value			
	EF3 tornado (0% to 4% probability)	12.38	36.34	23	29.1
	Pressure drop for 10^{-7} per year wind speed	40 hPa			
	Maximum rate of pressure drop for 10^{-7} per year wind speed	13 hPa/s			
Atmospheric Turbulence (Sigma-Theta Method)	Convective (A)	3.33%			
	Unstable (B)	1.84%			
	Moderately Unstable (C)	4.88%			
	Neutral (D)	40.89%			
	Moderately Stable (E)	46.14%			
	Stable (F)	2.92%			
	Very Stable (G)	0.01%			
Prolonged Inversions	Likelihood	Annual	30%		
		Summer	19%		
		Winter	44%		
Snowfall (3)	Average	0.0 mm/h			
	Maximum load	0.0 N/m³			
Lightning	Flashes/year/km²	1.0 flash/year/km² (range 0.02 to 1.0)			
	Average strokes per flash	5			
	Maximum strokes per flash	16			
	Average peak current	25 kA			
	Highest peak current	166 kA			
Thunder	Average number of days with thunder	7.2 days/year			
Hail	Average number of days with hail	0.8 days/year			
Frost	Average number of days with frost	0 days/year			
Fog	Average number of days with fog	25.4 days/year (Thyspunt WS) 24.3 days/year (Cape St Francis WS)			
Relative humidity	Summer (relative humidity at 37 ºC, dry bulb)	17.6% (Thyspunt WS) 14.7% (Cape St. Francis WS)			

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Meteorological Parameter		Value	
	Winter (relative humidity at -25 ºC, dry bulb)	78.8% at 6.6 °C (Thyspunt WS) 81.0% at 4.9 °C (Cape St. Francis WS) Assume 100% at -25ºC	
Solar Radiation	Lowest daily total	8.4 MJ/m^2.day (June)	
	Highest daily total	26.3 MJ/m^2.day (January)	
Penman-Monteith Evapotranspiration	Monthly Total Minimum	84.8 mm (June)	
	Monthly Total Minimum	146.1 mm (January)	
Corrosivity	Rate in 1st year	Carbon steel	68.0 (50.6-81.6) µm/year
		Zinc	2.8 (2.2-3.4) µm/year
		Copper	1.8 (1.5;1.9) µm/year
		Aluminium	1.0 (0.7;1.2) µm/year
	Average rate over 20 years	Carbon steel	8.8 to 11.1 µm/year
		Zinc	1.3 to 1.6 µm/year
		Copper	0.4 to 0.5 µm/year
		Aluminium	0.3 to 0.4 µm/year

Notes:

(1) Tornado activity has increased since 1987 within an 80 km radius from the site. Whilst climate change may have contributed to increases in tornado frequencies, it may also simply be that the reporting of tornadoes has increased due to population spread as well as the associated damage to property.

(2) The “All” tornado entry combines all frequencies from EF0 to EF4 in the table.

(3) No tornadoes of strength higher than EF2 were observed during the last 34 years of reporting and therefore assumed the same values as for the long-term analysis.

(4) This reflects current observation; however extreme minimum temperatures (excluding climate change projections) indicate temperatures well below freeze point for water and may result in the occurrence of snow at the site.

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Screening status: *Out (Conditionally)*

All meteorological parameters with the exception of ambient temperatures, extreme winds and tornadoes have been screened out.

Criterion 1 - the event is of equal or lesser damage potential than the events for which the NNI is planned to be designed.
Criterion 4 - the event has a significantly low mean frequency of occurrence when considering regulatory target safety goals, taking into account the uncertainties in the estimates, where available data permit.

Wind-Borne Missiles

A meteorological event that is of particular importance is the potential impact of wind-borne missiles on SSCs. ***Section 5.8*** reports the following results.

To ensure the safety of nuclear power plants in the event of a tornado or hurricane strike in the Unites States the NRC regulations require that nuclear power plant designs consider the impact of tornado or hurricane-generated missiles in addition to the direct action of the wind (United States Nuclear Regulatory Commission, 2007b; United States Nuclear Regulatory Commission, 2011). As per these NRC regulations, the wind speeds used to determine the wind gust are nominal 3-second peak-gust values corresponding to an exceedance frequency of 10^{-7} per year measured at an approximate height of 10 m above ground level in flat open terrain. From an analysis of wind gusts observed at the 10 m level of the Cape St. Francis WS for the period 2004 to 2023, the wind gust corresponding to an exceedance frequency of 10^{-7} per year is estimated to be between 74.2 m/s and 92.3 m/s (see ***Subsection 5.8.6.2.2***).

Wind velocities in excess of 34 m/s are capable of generating missiles from objects lying within the path of tornadoes and from debris of nearby damaged structures. The estimated 10^{-7}/y tornado rotational wind speed is 60 m/s.

Screening status: *In (Conditionally)*

Criterion 1 - the event is of equal or lesser damage potential than the events for which the NNI is planned to be designed.

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Electromagnetic Interference from Lightning Strikes

The main source of potential electromagnetic interference at the nuclear installation(s) is lightning. The severity of lightning strikes at the site is listed in ***Table 6.5*** in ***Subsection 6.9.3***.

Design of nuclear installations includes standard protection requirements for lightning hazards and PPE parameters are provided (Eskom, 2024). Lightning can typically cause partial or complete loss of offsite power, which is the main impact of lightning.

Screening status: *Out (unconditionally)*
Criterion 1 - the event is of equal or lesser damage potential than the events for which the NNI is planned to be designed.

Other Extreme Meteorological Events

Extreme events such as ice and ice cover, blizzards and drought are discussed in ***Section 5.8*****.** These events are screened out because of the meteorological data presented in ***Table 6.4*** and ***Table 6.5*** and the fact that the sea serves as a heat sink. In ***Subsection 6.9.7.3*** it is stated that ice is not anticipated to form in the sea at the site and the minimum cooling water intake temperature of -0.5°C will be met.

As presented in ***Table 6.4***, strong winds can occur at the site, and hence large exposed sandy areas could cause windblown dust. The vegetation found on the site and off-site in the dominant wind direction (southeast), acts as a natural mitigation measure.

According to the IAEA (IAEA, 2011), the frequency of dust storms and sandstorms can be identified through hourly weather observations when visibility is 10 kilometres or less, the wind speed exceeds a threshold value (i.e. 7.5 m/s), and relative humidity is below a threshold value (i.e. less than 70 per cent).

The highest dust loading during the monitoring period occurred from 01h00 to 21h00 on 27 August 2018. The time integrated dust loading for this period was calculated to be 22.3 mg-h/m³ and the duration, 21 hours. The average dust concentration during this period was 0.964 mg/m³. The average wind speed for the 21-hour period was 9.6 m/s (hourly average minimum of 7.5 m/s and

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maximum of 12.7 m/s) which occurred from the southwest (202.4°), with maximum gusts up to 22.8 m/s.

Based on the observed frequency of dust events, June, October and November are the months most likely to experience dust storms, whereas March, April and May are the months least likely to experience dust storms. The summer season is likely to have between 7 and 10 days of dust events in total. The NNI design will have to consider this effect, but it is expected that mitigation against abrasive dust should be simple to accommodate in the design, as is done at many other coastal sites, including KNPS.

Screening status: *Out* (unconditionally).

6.9.7 Hydrological Events involving the Sea

6.9.7.1 Flooding from the Sea

Flooding from the sea is identified as a significant hazard that will need to be taken into account in the design of the nuclear installation(s) (refer to ***Section 5.9***).

Flooding from the sea can occur due to:

- Storm wave run-up with sea level rise, high tides, positive storm surge and wave set-up; and
- Tsunami run-up combined with sea level rise, high tides and positive storm surge.

The flooding hazard increases over time due to climate change which causes sea level rise and associated coastline recession, a rotated wave climate, and increases in storm wave height and storm surge.

An initial THA was undertaken for Section 5.9 of the previous Thyspunt SSR in 2012 (Eskom, 2015b). That study assessed distant earthquake tsunamigenic sources at Sumatra (Indonesia), Karachi (Pakistan) and the South Sandwich Islands (South Atlantic Ocean). For each source region the probable maximum earthquake magnitude and the corresponding fault parameters were defined, and a numerical model was then used to propagate the tsunami waves to the

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Thyspunt site. Based on these results the following tsunami run-up levels were recommended at the Thyspunt site:

Tsunami run-up height of 2.5 m;

Tsunami drawdown of -2.0 m.

These are the maximum tsunami-induced run-up height and drawdown relative to the antecedent water level, which must be added to these values to obtain the total tsunami run-up and drawdown levels.

The initial THA also assessed local tsunamigenic sources in the form of submarine slumps on the South African shelf margin in the Agulhas and Cape Town slump regions. However, since a quantitative assessment of the risk of occurrence and geometry of future slump events along the South African shelf margin was not available at that time, this assessment was qualitative only. Even though the analysis were qualitative, it does provide an indication of the size of slump that would be required to have a significant impact at the site. In this way the results provide insides of the maximum run up important to the design of the proposed nuclear installation whilst future geological research can be focused on characterising other slumps which will form input into future updates of the TSSR.

To address the limitations of the 2012 tsunami study at the Duynefontyn site (which were the same as described for the TSSR above), a deterministic Tsunami Hazard Analysis was undertaken in 2022 as part of the update of the SSR for the Duynefontyn site, comprising both the existing Koeberg Nuclear Power Station (KNPS) and the planned development of new nuclear installation(s) (NIs). Although this analysis was for Duynefontyn rather than Thyspunt.

These results showed that the PMT for the new NIs at the Duynefontyn Site was due to volcanic flank collapse at Tristan da Cunha, with a tsunami run-up height in 2130 of 12.27 m reaching a level of 15.82 m msl at a frequency of 1E-06.

The deterministic and probabilistic THAs undertaken for Duynefontyn showed that volcanic flank collapse caused significantly larger tsunamis at the Duynefontyn site compared to other potential tsunamigenic sources. Based on these results, it is anticipated that volcanic flank collapse will also cause the largest tsunamis at the Thyspunt site.

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Considering the distance between the volcanic island sources and the site, as well as the slide frequencies and volumes it is anticipated that Marion Island will likely pose the largest tsunami hazard to the Thyspunt site (among the sources assessed for Duynefontyn), and that this hazard will be comparable to the hazard posed to the Duynefontyn site by Tristan da Cunha, i.e., a tsunami run-up height of approximately 13 m above antecedent water level at a frequency of 1E-07 which is below the screening frequency for the design basis of the NI in terms of RG-019 (National Nuclear Regulator, 2018).

Although it is not possible to estimate the tsunami run-up levels at Thyspunt without a site specific Probabilistic Tsunami Hazard Analysis, considering the distance between the volcanic island sources and the site, as well as the slide frequencies and volumes, it is anticipated that Marion Island (with an estimated frequency of 8E-06) will likely pose the largest tsunami hazard to the Thyspunt site (from among the sources assessed for Duynefontyn). The frequency probability of the Marion Island suggest that this hazard should be considered in the Design Basis Extension Conditions (DBEC) of the proposed NNI, this, in line with the required specific design of the plant, will be done in the preceding licensing stages.

Screening status: *In*

6.9.7.2 Extreme Low Sea Water Levels

Extreme low water levels at the cooling water intakes can occur due to:

- Storm wave drawdown combined with low tides and negative storm surge; and
- Tsunami drawdown combined with low tides and negative storm surge.

The extreme low water levels are based on the storm wave drawdown only.

Extreme low water levels at the three proposed cooling water intakes in depths of -28 to -30.0 m msl for all exceedance frequencies are provided in ***Table 6.6***. If a tunnel intake in a depth of -30 m msl is selected for the NNIs, the results show that the intake should be designed to accommodate a best estimate minimum water level of -7.6 m msl, which is driven by the 1E-08 y^{-1}

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storm event in 2134. Such events will be considered in the design basis extension conditions for the proposed new nuclear installation.

Table 6.6: Extreme Low Water levels due to Storm Waves

Exceedance Frequency	Uncertainty	Minimum Vertical Drawdown Level at Intakes	
(y^{-1})		(m msl)	
		2034	2134
1E-02	5th Percentile	-6.09	-6.49
	Mean	-6.01	-6.43
	Best Estimate	-6.01	-6.43
	95th Percentile	-5.94	-6.37
1E-04	5th Percentile	-6.85	-7.16
	Mean	-6.70	-7.05
	Best Estimate	-6.71	-7.05
	95th Percentile	-6.56	-6.95
1E-05	5th Percentile	-7.00	-7.38
	Mean	-6.84	-7.25
	Best Estimate	-6.84	-7.25
	95th Percentile	-6.67	-712
1E-06	5th Percentile	-7.17	-7.59
	Mean	-6.96	-7.43
	Best Estimate	-6.97	-7.44
	95th Percentile	-6.77	-7.28
1E-07	5th Percentile	-7.41	-7.69
	Mean	-7.18	-7.50
	Best Estimate	-7.18	-7.51
	95th Percentile	-6.95	-7.33
1E-08	5th Percentile	-7.65	-7.78
	Mean	-7.39	-7.57
	Best Estimate	-7.39	-7.58
	95th Percentile	-7.13	-7.38

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6.9.7.3 Cooling Water (Sea) Temperatures

The maximum seawater temperature at the cooling water intakes will depend on:

- The intake and outfall layout, the power output and the resultant ΔT due to recirculation from the outfall to the intake; and
- The extreme maximum background seawater temperature at the intake location and climate change.

The best estimate frequency to exceed 30ºC at the intakes is presented in ***Table 6.7***.

Table 6.7: Extreme Maximum Seawater Temperatures at the Intakes (Including Recirculation)

Location	Best Estimate Frequency to Exceed 30ºC at Intakes (y^{-1})		
	2034	2114	2134
Intake 1	7.8E-51	6.5E-18	7.9E-11
Intake 2	5.1E-52	1.5E-18	2.7E-11
Intake 3	2.3E-52	1.0E-18	2.0E-11

These results show that the exceedance frequency of the maximum specified PPE intake temperature of 30ºC is 7.8E-51 y^{-1} (in 2034) and 7.9E-11 y^{-1} (in 2134), thus the intake temperature at the site will be less than the maximum specified in the PPE.

Regarding the possibility of ice occurring in the sea surrounding the site, the lowest seawater temperature measured in all the data sets described in ***Section 5.9***, is 7.93ºC, and an extreme value analysis of the combined minimum measured temperatures was above 0ºC at an exceedance of 1E-08 y^{-1}. On this basis ice is not anticipated to form in the sea at the site and the minimum cooling water temperature of -0.5 ºC will be met.

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Screening status: *Out*

6.9.7.4 Erosion from the Sea

In order to assess the potential instability of the coastline near the site, the following physical processes and timescales have been considered:

- long-term coastline trends;
- seasonal variation in coastline;
- erosion due to a 10^{-6} y^{-1} storm event;
- horizontal coastline recession due to a vertical sea level rise of 1.2 m to the year 2100.

The results of the coastline stability assessment at the site are as follows.

- The coastline erosion increases over time due to climate change which causes sea level rise and associated coastline recession, a rotated wave climate and increase in storm wave height and storm surge.
- The erosion is more severe in Thysbaai than on the rocky coastline in the west, driven by recession due to sea level and coastline changes due to wave climate change which affect sandy coastlines.
- By 2134 the Nuclear Installation Corridor is exceeded by the erosion lines for all storms with exceedance frequencies of 1E-02 y^{-1} and lower, at a limited number of locations along the rocky coastline west of Thyspunt and Thysbaai. The maximum horizontal erosion lines in front of the NNIs for 2034, 2134 and 2134 with high sea level rise are provided in ***Figure 5.9-91***, ***Figure 5.9-92*** and ***Figure 5.9-93*** in ***Section 5.9*** of the TSSR.

Coastline erosion is identified as a significant hazard that will need to be taken into account in the design of the nuclear installation(s), either by positioning the infrastructure an additional 130 m inland relative to the present-day topography or by the construction of revetment structures to prevent shoreline erosion.

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6.9.7.5 Thermal Plume Dispersion and Recirculation

It is proposed that the NNI will be cooled using a once-through seawater cooling system. A conceptual layout for the seawater cooling intake and outfall system has been developed and thermal plume dispersion modelling has been performed to demonstrate the technical feasibility of the site in Section 5.9.

The PPE specifies a maximum ΔT of the re-circulated cooling water between the discharge and the intake of less than 1.5ºC.

The modelled recirculation ΔTs at the intakes are presented in ***Table 6.8***.

Table 6.8: Recirculation at the Intakes

Annual Probability of Exceedance (y^{-1})	ΔT at Intakes (ºC)		
	50th Percentile	95th Percentile	99th Percentile
Intake 1	0.06	0.38	0.51
Intake 2	0.02	0.29	0.44
Intake 3	0.01	0.25	0.41

The results above show, the worst case 99th percentile ΔT at the intakes is 0.51ºC, which is below the specified 1.5ºC maximum allowable ΔT at the intakes (Eskom, 2024).

Screening status: *Out*

6.9.7.6 Sedimentation at Intakes

The proposed seawater intake is a tunnel extending to approximately –30 m msl water depth, with the intake opening positioned 3 to 5 m above the seabed. Sediment transport modelling was carried out to assess the volume of sand drawn into the intakes which will have to be removed from the proposed landslide intake basin. The results presented in ***Table 6.9*** are conservatively based on the suspended sediment concentrations 1 m above seabed.

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Table 6.9: Sand Volume Drawn into Cooling Water Intake Tunnels

Exceedance Frequency (y^{-1})	Case	Units	Intake at -30 m msl		
			1 m above bed	3 m above bed	5 m above bed
-	Operational Conditions	m^3/y	2 900	650	390
10^{-2}	Storm event	m^3/event	2 500	460	290
10^{-4}	Storm event	m^3/event	10 000	2 200	1 400
10^{-5}	Storm event	m^3/event	18 000	4 100	2 700
10^{-6}	Storm event	m^3/event	30 000	7 600	5 500
10^{-7}	Storm event	m^3/event	54 000	15 000	10 000
10^{-8}	Storm event	m^3/event	96 000	28 000	21 000

Notes:

(a) These sand volumes apply for a 10 000 MWe power station and an associated intake flow of 445 m^3/s. They can be reduced proportionally for a lower power and flow rate.

For operational conditions the volume of sand drawn into the tunnel intakes which will have to be removed from the proposed landslide intake basins is less than 2 900 m^3/y. This is significantly less than the average maintenance dredging volume of the existing KNPS intake basin of approximately 132 000 m^3/y.

For extreme storm events the sand volume increases significantly and the 1E-02 y-1 storm event results in similar sand volumes over the 5.4-day event as the annual maintenance dredging requirements. The intake basin will need to be designed to accommodate these sediment volumes without blocking the pumps.

A maintenance dredging programme will be required to prevent excessive sedimentation in the basin and to keep a sufficient buffer for storm events.

Screening Status: *Out*

Criterion 5 - the event is slowly developing and it can be demonstrated that there is sufficient time for measures to eliminate it or to provide adequate response.

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6.9.7.7 Waterspouts

One occurrence of a waterspout was witnessed, albeit along the coast at Herold's Bay, which is approximately 215 km west of the site. Similar to a tornado on land, a waterspout is a rotating column of air that occurs over a body of water, usually appearing as a funnel-shaped cloud in contact with the water and a cumuliform cloud. The rarity of waterspouts off the coast near the site, is likely because these occur mostly in tropical and subtropical areas.

This phenomenon is enveloped by the information provided in ***Subsection 6.9.3***.

Screening status*: Out (unconditionally).*
Criterion 3 - the event is included in the definition of another event.

6.9.7.8 Snow Melt

As reported in ***Section 5.8*** and ***Section 6.9.4.4*** above, snow is unlikely to occur in the site region and hence will be unlikely to lead to flooding, e.g. rising of upstream water level due to stream obstructions.

Screening status*: Out (unconditionally).*
Criterion 3 - the event is included in the definition of another event.

Criterion 4 - the event has a significantly low mean frequency of occurrence when considering regulatory target safety goals, taking into account the uncertainties in the estimates, where available data permit.

6.9.8 External Flooding from Other Sources

International experience shows (IAEA, 2021) that apart from flooding from the sea, there are other flooding scenarios that have to be considered for the nuclear installation(s) on the site. These scenarios could induce a transient in water level at the site resulting in static effects (water weight) and dynamic loads on the nuclear installation(s). Operational experience from existing nuclear installations provides evidence for external flood induced events in which the functionality of safety related equipment has been impaired. Most of these are related to insufficient measures for site protection, to poor maintenance of the drainage systems and to effects of ice on river sites. Much evidence has also been recorded recently on leakage in nuclear installations, essentially through poor sealing in structural joints or cable conduits and inspection openings. The

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provisions for such events are mainly design related, but attention should be paid to the possibility of the groundwater table rising as a consequence of a flood, as its maximum level is a design basis for the nuclear installation(s) (IAEA, 2021).

Failure of Human-made Water Retaining Structures

Hydrological and seismic events, as well as faulty operation can result in the failure of water retaining structures.

There are no significant dams or defined watercourses situated within the quaternary catchment K80F which drain towards the Thyspunt site. There is a catchment divide (Northern and Southern zone) and the Northern zone drains into the dunes and does not reach the enveloping footprint. The existing water bodies create natural storage areas which would not result in significant backup of headwater. There are no man-made embankments crossing the watercourse which could significantly increase the head of water and potentially breach during a storm event causing surges and damage to downstream infrastructure. According to the National Water Act No. 36 of 26 August 1998, (Republic of South Africa, 1998) a dam is classified as a safety risk when the dam has a storage capacity > 50 000 m^3 and with a maximum wall height > 5 m. In view of the above, there are no significant dams upstream of the site (nor associated watercourses traversing through or near the site) which may impact on the safety of the nuclear installation(s) and no further investigation on possible dam failure is required (see ***Section 5.10***, Hydrology and Hydraulics).

Screening status: *Out (unconditionally).*
Criterion 2 - the event cannot occur close enough to the nuclear installation(s) to affect it.

Changes in the Natural Channel for a River (Including River Diversions)

International experience has shown that an analysis of the integrity of all dams along the path to the site should be performed and, unless non-failure can be established, failure should be postulated and the floods resulting from all assumed dam failures should be routed to the site (IAEA, 2021).

The Krom River lies to the north of the site and falls into a different catchment area which drains into Krom Bay approximately 12 km from the site. On this basis no flooding hazard from this river is expected at the nuclear installation(s). The

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Slang River lies to the west of the site and falls into a different catchment and drains into Slang Bay approximately 5 km from the site and therefore is not a flooding hazard. There are two minor tributaries traversing the site, the catchments of which are very small, giving small run-off peaks and hence low flood levels. These levels are not expected to pose a hazard but this will have to be confirmed when the nuclear installation site elevation is defined.

Infrastructure flooding risk as a result of ice slides does not exist since temperatures in the area are well above freezing point, which has been established from meteorological data in the nuclear installation area (see ***Section 5.8*** and ***Section 5.9***).

Screening status: Out *(conditionally).*
Criterion 1 - the event is of equal or lesser damage potential than the events for which the nuclear installation(s) is planned to be designed.

On-site Hydrology Aspects

The on-site hydrology aspects are discussed in ***Section 5.10***. There are watercourses and ponding areas on the site (and thus potentially within the nuclear installation footprint), and a flood hazard assessment has been performed. The following preliminary conclusions for the regional safety consequence assessment were made:

- There are two non-perennial watercourses close to the site. One is situated along the western boundary (TP2-Riv1) of the site and the other (TP4-Riv2) along the eastern boundary of the site. TP2-Riv1 is expected to have no safety consequences (Refer to ***Drawing D-5.10.2*** in ***Section 5.10***). TP4-Riv2 is expected to have a medium to high safety consequence if the final site is situated below the 1:10 000 year flood level. One of the watercourses on the site (referred to as TP4-Riv2) may have a medium impact on the nuclear installation safety, based on the current site location as the high water level will fall within the footprint of the proposed nuclear installation facility if the floor elevation is not above the high water level.

- Surrounding ponding areas are expected to have a medium to high impact on the nuclear installation safety based on the current site location as the temporary ponding could cause low lying infrastructure associated with the nuclear installation(s) to be flooded. Wetland depressions within the mobile

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dunefields can contain significant volumes of water, depending on the seasonal rains (also referred to as duneslack wetlands): These are depressions that occur in an otherwise sloped terrain. The wetlands form against the leeward toe of the two largely unvegetated mobile dune systems and collectively comprise an extensive band of seasonally (or at least non-permanently) inundated pools, ranging from less than 30 cm in depth to over 2 m. The wetlands and other water retaining structures located on the site in future, will be assessed against the specific nuclear installation design when it becomes available.

- The site is considered suitable for the development of a nuclear installation(s) from a hydrology and hydraulics perspective. Refined calculations will be performed once the detailed design is available regarding final location of the footprint as well as grading of the site. The specific flooding design solutions can only be determined more accurately once the final footprint is specified.

***Screening status**: In.*

Landslide into Water

Landslides have not been specifically assessed. This phenomenon will need to be evaluated further in order to decide whether it can pose a hazard to the nuclear installation(s). This will also depend on the location of the footprint and on the selected reactor design.

However, the site is on flat terrain therefore there is no hazard posed by landslides.

***Screening Status:** Out (conditionally)*

External Flooding from Terrestrial Sources

International experience shows (IAEA, 2002) that apart from flooding from the sea, there are other flooding scenarios that have to be considered. These scenarios could induce a transient in water level at the site resulting in static effects (water weight) and dynamic loads on the NNI. Operational experience from existing nuclear installations provides evidence for external flood induced events in which the functionality of safety related equipment has been impaired.

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Most of these are related to insufficient measures for site protection, to poor maintenance of the drainage systems and to effects of ice on river sites. Much evidence has also been recorded recently on leakage from nuclear installations, essentially through poor sealing in structural joints or cable conduits and inspection openings. The provisions for such events are mainly design related, but attention should be paid to the possibility of the groundwater table rising as a consequence of a flood, as its maximum level is a design basis for the NNI (IAEA, 2021).

Screening Status: *Out (conditionally)*

6.9.9 Biological Phenomena and Related Events

Marine organic material has the potential to cause a loss of the sea as heat sink. A change in environmental conditions such as rapid and uniform water temperature increases, long sunny weather periods and changes of sea level, for example, can result in the growth and drifting of algae and clogging of the sea water intake structures. The arrival of massive numbers of marine organisms in cooling water intake basins is an external event that has been recorded at some coastal nuclear installation(s). ***Section 5.3*** indicates that the probability for this event is low at the site due to the following:

- Jellyfish are not considered to pose any threat to the nuclear installation(s) at the site, as these organisms do not reach high enough densities along this section of coastline. Similarly, kelp is absent from this region.

- The colonisation by sessile organisms, such as mussels and barnacles, may result in the blockage of cooling pipes but this can be controlled through ongoing management.

The site should be no different to other sites when considering the hazards from terrestrial fauna and flora. Protection against rodents, for example, will require the same protection measures as being applied at other hazardous facilities. Ventilation systems, for example, need to be designed to prevent invasion by insects, etc.

Based on the KNPS and worldwide experience, it can be concluded that the NNIs intakes could be designed to cope with the marine species found at the site and to minimise the risk of complete blockage of the intake.

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For the NNI, the safety function of an ultimate heat sink may be provided by auxiliary cooling towers. This design feature must be taken into consideration when assessing the risk of a loss of ultimate heat sink in the next licensing stage.

Screening Status: *Out (conditionally)*

6.9.10 External Fires

External fires are fires occurring outside the nuclear installation site boundary, e.g. forest/veld fires and oil spills at sea. Potential hazards posed by external fires are a loss of offsite power (LOOP), forced isolation of the installation's ventilation and a potential impact on control room habitability. Protection against fires is achieved by minimising the probability of a fire and providing barriers against external fires. A fire of external origin must not prevent the performance of safety functions.

Site clearing that already starts at construction stage, usually prevents fires from spreading onsite. Management of the site vegetation will have to take cognisance of the information presented in ***Section 5.3*** (Ecology). Fynbos vegetation, which is highly fire-prone, covers a significant part of the site and could lead to naturally occurring fires at and around the site. There is also highly combustible invasive alien vegetation present at the site and its surrounds, although an eradication programme is being implemented at the site. Land use around the nuclear installation(s) will have to be managed so that an external fire cannot propagate towards the plant.

Examples of mitigation against the effects of a fire included in nuclear installation design are:

- ventilation system can be protected by isolation of the systems from outside air by means of dampers with reliance on alternative systems to accomplish the functions of the ventilation system;
- adequate supply of air to all diesel generators required to perform necessary safety functions - Segregation in respect of air intakes and distance between intakes are some preventative measures.
- safety related instrumentation and control systems vulnerable to smoke and dust have to be environmentally qualified.

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- placement of equipment that depends on air to be away from site boundaries

Screening status: *Out (conditionally)*
Mitigation against the occurrence of veld fires resulting in air pollution is included in nuclear installation design of ventilation systems. The event is therefore considered to be of equal or lesser damage potential than the events for which the NNI is planned to be designed.

6.10 Human-induced External Events

6.10.1 Accidental Aircraft Crash

International Practice and Regulatory Requirements

The NNR requires a design-specific assessment of the effects on an NNI of the impact of a large, commercial or military aircraft (National Nuclear Regulator, 2014). The nuclear installation(s) must be designed to withstand the impact of a design basis aircraft crash without loss of any safety function.

An Aircraft Crash

The current expected annual aircraft crash rate per km^2 for the site for aviation categories is provided in ***Table 6.10***.

Table 6.10: Total Crash Rate for the Different Aircraft Categories for the Thyspunt Site

Aviation Category			Annual Crash Rate (/y/km^2)			
			Mean	5%tile	50%tile	95%tile
Civil Aviation	Commercial Aviation		2.08E-07	4.91E-08	1.90E-07	4.07E-07
	General Aviation	Fixed-Wing	5.42E-06	3.66E-06	5.40E-06	7.25E-06
		Helicopters	1.75E-06	1.27E-06	1.73E-06	2.29E-06
Military Aviation		Large	1.09E-07	1.94E-08	9.18E-08	2.59E-07
		Small	1.64E-07	4.47E-08	1.46E-07	3.44E-07
		Helicopters	1.67E-04	1.74E-05	1.68E-04	3.18E-04

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The current expected annual aircraft crash rate study shows that fixed wing civil aviation and military helicopters have occurrence frequencies greater than 1E-06 per year per km^2. It should be noted that the in-flight crash rate for military helicopters was mainly based on a previous assessment since recent data are not complete and inconsistent. Also, there are much less air operations taking place due to the unserviceability of about 85 per cent of the South African Air Force aircraft fleet as per formal response to a Parliamentary enquiry in 2023. Therefore, the assessment performed for military aviation should be considered very conservative. The predicted future growth in aircraft movements is also considered to not have a significant impact on the projected overall aircraft crash rate for the site.

NNI aircraft crash is included as a standard event with specific load functions in the design basis of the reference nuclear installations, irrespective of aircraft crash frequency considerations. Both the Westinghouse AP1000 and the Areva EPR reactors, for example, which are included as reference nuclear installations for the site, have designs that have been approved by the US NRC. Their designs are certified as being able to withstand the impact of a large commercial aircraft and include the following safety features (US NRC, 2011):

- performing the cooling function with reduced use of operator action.
- intact containment: “(1) will not be perforated by the impact of a large, commercial aircraft; and (2) will maintain ultimate pressure capability, given a core damage event until effective mitigation strategies can be implemented. Effective mitigation strategies are those that provide, for an indefinite period of time, sufficient cooling to the damaged core or containment to limit temperature and pressure challenges below the ultimate pressure capability of the containment”.
- spent fuel pool (SFP) integrity: “The ‘SFP integrity’ criterion in 10 CFR 50.150(a)(1) is satisfied if the impact of a large commercial aircraft on the SFP wall or support structures would not result in leakage through the SFP liner below the required minimum water level of the pool”.

Screening status: *Out (conditionally)*

Confirm deterministic approach followed for GEN III NNI for beyond design basis aircraft.

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6.10.2 Hazardous Materials – Land-Based Stationary and Transport Sources, Harbours and Shipping Lanes

Hazardous Material Inventories and Screening Distance Values

A hazard assessment study was performed and is reported in (Riscom, 2012) and is based on information in ***Section 5.7***.

A summary of the main findings of the study is presented here. Only hazardous materials not associated with the nuclear installation(s) are discussed. Hazardous materials required for the nuclear installation(s) will be included in the design specific safety assessment.

The consequences from external events involving hazardous substances would either damage nuclear installation SSCs or incapacitate operating personnel as a result of toxic gases, thermal radiation and/or explosion overpressures.

The limiting hazard parameter values where the consequences would be considered 'safe' and would not pose a threat to life because of events, e.g. failure of structures, are given in ***Table 6.11***[12].

Table 6.11: Limiting Values for External Events Associated with Hazardous Material

Hazard	Hazard Parameter	Screening Value
Pool Fire	Thermal radiation (1)	2.9 kW/m^2
Jet fire	Thermal radiation	2.9 kW/m^2
Flash Fire	Flammable limits	½ LFL(3)
BLEVE (2)	Thermal radiation	2.9 kW/m^2
Explosion	Overpressure	2 kPa

[12] (1) The screening value of 2.9 kW/m2 has been adjusted for the maximum daily solar radiation value of 1.1 kW/m2

(2) BLEVE: Boiling Liquid Expanding Vapour Explosion

(3) LFL: Lower Flammable Limit

(4) IDLH: Immediately Dangerous to Life or Health (IDLH) and refers to the maximum concentration to which a healthy person may be exposed for 30 minutes and escape without suffering irreversible health effects or symptoms that impair escape (ranging from runny eyes that temporarily impair eyesight to a coma).

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Hazard	Hazard Parameter	Screening Value
Toxic Cloud	Concentration	IDLH (4)

The distance from the release to the limiting values gives the SDV. These values are based on the worst-case meteorological conditions. The release of some hazardous materials can involve more than one hazard parameter, e.g. flammability, explosivity and toxicity. In these cases, each hazardous material needs to be evaluated separately and the hazard parameter with the largest value is retained for the SDV.

The SDV for generic installations of varying inventories was derived in (Riscom, 2012) and are listed in ***Table 6.12***. The values indicated in the table are the largest hazard parameter values for fires, explosions and toxic releases.

Table 6.12: Screening Distance Values for Hazardous Materials

No.	Hazard Material and Storage/Transport Status when Release Event Occurs	Screening Distance (m)
1	*Petroleum tank farm up to 10 000 m^3 tank storage*	423
2	*Petrol/gasoline transportation*	
	50 m^3 Road tanker	200
	70 m^3 Rail tanker	505
3	*Liquefied Petroleum Gas (LPG) transportation and storage*	
	9 kg Cylinder	37
	48 kg Cylinder	91
	9 m^3 Vessel	523
	45 m^3 Road tanker	912
	70 m^3 Rail tanker	1 060
	1 000 m^3 Vessel	2 600
4	*Hydrogen transportation and storage*	

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No.	Hazard Material and Storage/Transport Status when Release Event Occurs	Screening Distance (m)
	1 kg Cylinder	47
	5 m^3 Vessel	64
	100 m^3 Vessel	205
	200 kg Trailer	53
5	*Chlorine*	
	70 kg Cylinder	1 960
	70 kg Cylinder	1 300
	1 000 kg Drum	6 000
	1 000 kg Drum	6 000
	10 m^3 Tanker	10 000
	10 m^3 Tanker	10 000
6	*Ammonia*	
	68 kg Cylinder	240
	2 000 kg Bullet	370
	10 m^3Road tanker	2200
	55 m^3 Rail tanker	4 700
7	Nitrogen	
	18 t Vessel	51
	100 t Vessel	161
8	*Pipelines*	
	Petroleum products (liquid at atmospheric conditions) (1)	423
	LPG	3 700
9	*Condensed Phase Explosion TNT equivalence*	
	1 kg TNT	46

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No.	Hazard Material and Storage/Transport Status when Release Event Occurs	Screening Distance (m)
	100 kg TNT	214
	1 000 kg TNT	460
	10 000 kg TNT	991
	100 000 kg TNT	2 135.
	1 000 000 kg TNT	4 600

Notes:

(1) Loss of containment pool limited to 3 000 m^2 SDV used for this hazard is set to the Petroleum Tank Farm scenario which was developed on a larger flammable pool.

(2) A condensed phase explosive contains its own oxygen so that it can explode even in the absence of air and include explosions of munitions, commercial explosives and ammonium nitrate. The explosive which serves as the reference standard is TNT.

Transportation of Hazardous Materials not Related to the Nuclear Installation(s)

Fuels

The only petroleum and diesel transported within the vicinity of the site is along the R330 towards the St. Francis Bay service station. During the year, an average of one tanker travels along the R330 road per week. During peak season (mid-December to mid-January) the volume increases to 3 times per week. The tanker trucks carry on average a mix of 40 000 ℓ of petrol and diesel, and originate from Port Elizabeth. On average, one truck carrying LPG tanks travels on the R330 twice per month, and carries on average 18 tanks (9-48 kg) (***Section 5.7***).

The R330 and St. Francis Bay is beyond the SDV for petrol a small volume LPG cylinders and can thus be excluded from the study.

Transportation of Other Chemicals

The major chemical suppliers and transport contractors in the region have no records of chemical transportation within the 16 km radius of the site. There are also no activities in Oyster Bay or St. Francis Bay requiring large quantities of chemicals to be delivered.

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The area around the site contains mainly dairy farms where chemicals and fertilisers are used in unknown quantities. The distance to Oyster Bay is approximately 5 km and beyond the SDV for small quantities of fuel and chemicals.

Screening status: *Out (unconditionally).*
Criterion 2 - the event cannot occur close enough to the nuclear installation(s) to affect it.

Explosives and Ammunition

The South African National Defence Force confirmed that there are no military facilities within the 16 km radius of the site and that no explosives are transported within this area.

The transportation of all explosives, other than military, requires a license from the Chief Inspector of Explosives (Eastern Cape). The SAPS Commander: Explosives Control has confirmed that no explosives are known to be transported within the vicinity of the site.

The Commander has assured that any permitted transportation of explosives will not create any danger to a National Key Point, such as Thyspunt.

Before permits are issued, the blasting company must provide a blast plan and when any blasting is intended within 500 m of any other institution's property, such as overhead power lines, Telkom line etc., consent letters from such an institution must be provided and also written consent must be obtained from the local authority's Chief Inspector of Occupational Health and Safety (Republic of South Africa, 2003) (***Section 5.7***).

The transportation and the use of commercial explosives are closely monitored and an inspector of the explosives office is usually present. Since it is a developing area, the Chief Inspector of Explosives expects that there will be an increase in the issuance of permits for blasting within the 16 km radius in and around St. Francis Bay, Oyster Bay and the Impofu Dam area (***Section 5.7***)

The SDV for explosives is 4.6 km. No explosives are handled, stored or transported within the SDV.

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***Screening status**: Out (unconditionally).*
Criterion 2 - the event cannot occur close enough to the nuclear installation(s) to affect it.

Hazardous Waste

There was a solid waste tipping site located within the vicinity of the site, at St. Francis Bay (13.27 km to the east northeast). However, this facility is no longer operational. The Kouga Local Municipality Integrated Waste Management Plan states that a closure permit has been secured, but the site has not been rehabilitated (***Section 5.7***).

The nearest operational waste disposal site to the Thyspunt site is the Humansdorp Landfill (18.71 km north-northeast), which falls outside of the site vicinity. Neither landfill stores hazardous waste. The permits issued for both landfills were for general waste only (***Section 5.7***).

***Screening status**: Out (unconditionally).*

Criterion 2 - the event cannot occur close enough to the nuclear installation(s) to affect it.

Pipelines

No hazardous chemical pipelines are within the SDV value of 3.7 km from the site. There are also no pipelines planned within the site vicinity (***Section 5.7***).

***Screening status**: Out (unconditionally).*
Criterion 2 - the event cannot occur close enough to the nuclear installation(s) to affect it.

Railway Lines

No railway lines are present or planed within the SDV value of 4.7 km (for hazardous chemicals) from the site (**Section 5.7**).

***Screening status**: Out (unconditionally).*
Criterion 2 - the event cannot occur close enough to the nuclear installation(s) to affect it.

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Hazardous Chemical Inventories and Storage (Industrial Activities)

The St. Francis Bay industrial area contains the only industrial activities within the 16 km radius of the site. These are light industries, and no explosive chemicals are stored on any premises within this area. There are also no quarries, brickfields or coal-burning facilities that store explosive chemicals on-site.

The St. Francis Bay service station, located 12.66 km east-northeast, is the only service station in the vicinity of the site. REDACTED

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Petrol, diesel and LPG stored at St. Francis Bay are beyond the SDV of the respective substances.

Nuclear installation structures are typically designed to accommodate extreme loadings such as those resulting from aircraft impacts, tornado generated pressure and missile loads or earthquakes. Such structures, with reinforced concrete walls with a minimum thickness of about 0.5 m and with consistent attention paid to structural connections, should be capable of withstanding

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substantial overpressures without compromising the essential functions of the systems important to safety that they house. It should be unnecessary, therefore, to apply additional design measures to mitigate the effects of design basis external explosions.

***Screening status**: Out (unconditionally).*
Criterion 2 - the event cannot occur close enough to the nuclear installation(s) to affect it.

Hazardous Materials and Oil Transported by Ship

A ship accident occurrence frequency was estimated to determine whether it has to be considered as a DBEE. A ship accident could for example result in an oil spill, release of hazardous gases and damage to cooling water intake structures.

Oil entrained in the cooling water intake system would be taken up into the condenser, foul the inside of the tubes resulting in the deterioration of heat transfer. The consequences of an oil spill and release of hazardous materials resulting from a ship accident are reported in (Moldan, 2008) and (Thevik, 2010).

Ships can stray from mandatory shipping lanes and approach the area where the cooling water intake structure is located and potentially damage this structure. Oil tankers, for example, categorised as Ultra Large Crude Carriers can have a draft that exceeds 30 m and could damage submerged cooling water intakes.

Ship accident risk analysis typically involves assessment of the following accident types (***Reference 6.36***):

- collision - The frequency of inter-ship powered collisions at a given geographical location is estimated by considering close quarters encounters. A probability of a collision for each encounter provides the collision frequency. This probability is related to a number of factors including the visibility conditions and the extent of internal and external vigilance.

- powered grounding - The frequency of powered groundings that result from marine traffic lanes located in close proximity to the shoreline or shallow water is calculated. It is mainly based on a failure to make a critical course change.

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- drift grounding - It is assumed that drift grounding occurs when a ship loses the ability to navigate, due to steering or engine failure, and is subsequently forced onto the shoreline through the action of wind or current. Fault tree analysis can be used to determine the frequency of propulsion and steering system breakdown. Probabilities for self-repair and rescue by anchoring or tug assistance within given time limits are included in the calculational model.

- structural failure - The frequency of such accidents is calculated by applying an accident frequency factor per vessel hour at sea while underway. The frequency factor applied takes account of the severity of the sea conditions.

- fire and explosion - The frequency of such an accident is controlled by the number of vessel miles travelled. A frequency factor is derived from the historical data.

A detailed oil spill risk assessment for the Duynefontyn site, for example, (ALCADIA, 2006) concluded that a definite risk does exist from oil spillages in the area of the Duynefontyn nuclear power plant. The probability of an oil spill originating from either an accident occurring during the transit of a vessel in a sea lane or an accident occurring within the Port of Cape Town and entering the cooling water intake basin within 10 hours would be 1.05E-04/y. It is expected that a similar detailed study for the Thyspunt site will yield a much lower frequency than for Duynefontyn but not lower than the screening frequency. The event and its potential consequences have to be considered in the design basis.

Screening Status: *In*

6.10.3 Consideration of Hazardous Material Aspects in NNPS designs

On-site Hazardous Materials

An overview is provided in the following two sub-sections of the design safety features claimed by the EPR and AP1000 NNIs in respect of hazardous materials.

6.10.3.1.1 AP1000

The AP1000 NNI design provides for protection from explosions outside of the nuclear island (Westinghouse, 2018). Any smoke or toxic gases that penetrate the AP1000 site boundary are considered in the context of internal or external

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hazards. The AP1000 plant main control room is designed to provide isolation from toxic smoke and gases generated on-site. The main control room is pressurised to a positive pressure using compressed air for a period of 72 hours which prevent toxic gases from entering.

The AP1000 design has been developed in accordance with US NRC Regulatory Guide 1.91 (U.S. NRC, 2013) which defines the safe distance from an explosion as the point at which the blast wave overpressure is limited to approximately 7 kPa (70 mbar); below this value no significant damage would be expected. (This is a higher value, for example, than 5 kPa specified for KNPS).

For those sources of flammable material, present outside the nuclear island which can form an explosive atmosphere, analysis has been performed to determine the distance from the centre of the vapour cloud explosion (VCE) by which point the blast overpressure would have dropped to 7 kPa.

The civil/structural design criteria define the overpressure resistance requirement for the external walls of the nuclear island as 34 kPa. The external walls of the nuclear auxiliary building are composed of nominally 0.6 m thick reinforced concrete walls. Similarly, the containment shield building (which envelops the reactor containment building) is constructed from two external 19 mm thick steel plates infilled with concrete, giving an overall thickness of 0.91 m.

Based on the standard plant layout, the assessments of explosions originating from the bulk hydrogen storage and other chemicals conclude that the blast overpressure would not exceed the 7 kPa threshold at the nuclear island exterior walls. The safety Class 1 SSCs within the nuclear island would therefore be unaffected by the postulated explosions and would continue to deliver their safety functions.

The examples of assessments of AP1000 hazardous materials are representative of the hazard assessments that have to be presented as part of safety case for an NNI to be constructed on the site. Specific design measures are described to reduce hazardous materials risks and include maximising the distances between the plant gas system, standby diesel fuel oil system, and the nuclear island, for example. These design lay-out features minimise the effects from a catastrophic loss of a bulk container of liquefied gas. Pipework is routed away from areas where safety important SSCs are present or where personnel are involved in safety-related operations. Hazardous materials involved in the

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operation of the AP1000 include the following and it is expected that these materials are common to PWR type NNIs:

- hydrogen;
- carbon dioxide;
- nitrogen;
- boric acid;
- lithium hydroxide;
- hydrazine;
- sodium hydroxide;
- diesel oil;
- trisodium phosphate (TSP);
- hydrogen peroxide;
- bottled gases;
- chemical inhibitors;
- refrigerant gases.

An overview is provided in (Eskom, 2024) of the hazardous and storage safety aspects associated with on-site bulk storage of toxic, corrosive, asphyxiating and flammable materials used in the operation of the AP1000.

6.10.3.1.2 The EPR reactor

The safety design of the EPR includes similar consideration as described for the AP1000. The EPR development took external hazards into consideration at the NNI design stage consistent with internal events or internal hazards, i.e. to determine if EEs can act as interacting events that can contribute to the core damage frequency (CDF). The objective of the design provisions against external hazards is to ensure that the safety functions performed by the safety classified SSCs which are required to bring the plant in the safe shutdown state, are not affected by these hazards. Design provisions were made as necessary to limit the consequential failures of SSCs which could be sources of internal events or internal hazards (EDF, 2011).

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The design includes extensive detail on the safety of the main control room against radiological and toxic gases. Design considerations include protection that may be achieved by geographical separation of the required systems or components against hazards which have localised effects such as chemical spills and explosions. Protection is justified by analysis of the consequences of a failure of unprotected equipment on a probabilistic basis.

EPR design verification for a construction licence has to be carried out in respect of explosions which require site specific information. The objective of the design verification is to evaluate, for each accident scenario, the safe distance similar to an SDV, beyond which a potential explosion/spill will not threaten any basic safety function, because the consequential pressure wave/impact on safety related SSCs has to be lower than the design load case. This evaluation assumes worst case meteorological conditions for the explosive gas cloud drift before the explosion or migration of the chemical/s involved. Where this deterministic approach does not allow the risk from external explosion to be excluded, a probabilistic assessment is carried out.

6.10.3.1.3 Conclusions

The design safety features of a selected NNI in respect of on-site hazardous material will have to be confirmed during the next licensing stage, taking into consideration the specific NNI layout and the site specific EEs. It must be verified that the selected design provide assurance that the functions which are needed to achieve the primary safety objectives are not compromised by events resulting from EEs, including human induced on-site EEs.

Screening Status: *In*

6.10.4 Loss of Off-Site Power

A loss of off-site power (LOOP) event is considered to be a total loss of external power supplies to the site. International experience and especially the recent events at Fukushima show that the LOOP together with the failure of on-site backup systems can have severe consequences. The site specific mean frequency and length of interruption to the main grid transmission lines have to be provided for the site when more detail on the grid, its interaction with the site and NNPS design become available. The European Utility Requirements (EUR) describes LOOP events applicable to the French grid and data is presented in

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Table 6.13. Examples of load follow and grid requirements are those for the standard design of the EPR (EUR, 2001):

- minimum short-circuit power of the main grid: 5 000 MWA;
- minimum short-circuit power of the stand by offsite grid:
  - 110 kV: 2 000 MWA;
  - 225kV: 3 000 MWA.

A LOOP should be assumed coincident with any extreme external event (e.g. extreme flood) if a direct or indirect causal relationship cannot be excluded (International Atomic Energy Agency, 2021). For EEs that could result in an unplanned turbine trip or reactor trip that would increase the potential for grid instability, a coincident LOOP is normally postulated for purposes of design basis analysis.

Table 6.13: Examples of Loss of Off Site Power Parameters for a PWR

Event	Mean Time for Grid to Recover	Estimated Annual Frequency	Comment
Short time LOOP	0.5 h	5×10^{-2}	Short time LOOP corresponds to most frequent grid failures, with a short recovery time.
Medium time LOOP	24.0 h	2×10^{-4}	Medium time LOOP corresponds to switchgear accidents, being a common cause for both normal and auxiliary line power supply failure.
Long time LOOP	192.0 h	1×10^{-3}	Long time LOOP is composed of less frequent grid faults between the plant and the transformer and off-line accidents due to climatic causes in the vicinity of the plant, both associated with a long recovery time.

Screening status: *In*

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6.10.5 Electromagnetic Interference (other than solar storms)

Potential sources of electromagnetic interference that could cause malfunction in or damage to safety related equipment or instrumentation have to be identified. ***Section 5.7*** (***Subsection 5.7.15.1***) describes the electromagnetic infrastructure in the site vicinity. If such interference is possible, protective measures should be allowed for in the design of the plant.

Operational experience from the nuclear industry indicates that the interference can be initiated by both on-site (high voltage switch gears, portable telephones, portable electronic devices and computers) and off-site (radio interference and telephone network) sources (International Atomic Energy Agency, 2021). Design of safety systems normally includes qualification in terms of potential electromagnetic environments and the Eskom set of reference for new nuclear installation(s) represents the latest nuclear technology.

Screened status: *Out (conditionally)*

Screening Criteria: Criterion 1 - the event is of equal or lesser damage potential than the events for which the nuclear installation(s) is planned to be designed.

6.11 Extra-Terrestrial Events

It is assumed that the event and frequency at the site of events of this nature, e.g. asteroids, and meteors, is beyond the design basis. These events, in accordance with EUR requirements for Light Water Reactor (LWR) Nuclear Power Plants (EUR, 2001), should not be considered in the design. However, an exception is the occurrence of extreme space weather events such as a solar storm.

Screening status: *Out*

6.12 Combination of External Events

6.12.1 Introduction to identifying combinations of external events

The IAEA Expert Mission to Fukushima in June 2011 states in their report that severe long-term combinations of EEs should be adequately covered in design and operations of a nuclear installation (IAEA, 2011). The Fukushima Dai-ichi NNI survived the earthquake of a magnitude that caused ground motion beyond

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the design basis of some NNI structures. It was the subsequent tsunami that resulted in a severe accident progressing into a BDBA.

Lessons learnt from the Fukushima Dai-ichi accident have been taken into account in the design of GEN III NNIs. External event reviews and so-called stress tests have also been carried out to identify potential weaknesses in currently operating NNIs should extreme EEs be experienced, also for KNPS (Eskom, 2015). The insights obtained from the stress tests are used to strengthen the design and improve response to design basis extension conditions beyond the design basis. The following example is provided of an NNI that had to demonstrate inclusion of lessons learned and resulting design consideration following the Fukushima Dai-ichi accident. It is accepted that the NNR will request similar evidence from a future vendor during a licensing stage subsequent to a NISL.

The UK Office for Nuclear Regulation (UK ONR) raised an issue with EDF and AREVA during the generic design assessment (GDA) of the EPR NPS (also referred to as UK EPR™) (UK HSE, 2013). This GDA issue requested evidence how lessons learnt from the events at Fukushima were accounted for. The approach taken by EDF and AREVA was to review the robustness of the UK EPR™ design against severe external events and, where appropriate, to identify and develop potential design enhancements recognising developments in other EPR™ projects and wider international initiatives. EDF and AREVA provided reports covering:

- review of UK EPR™ robustness against seismic and external flooding events;
- review of UK EPR™ ability to withstand loss of power and cooling;
- review of UK EPR™ severe accident management arrangements to mitigate the consequences of such events;
- summary of how the recommendations from the Chief Inspector's report have been addressed for the UK EPR™;
- a description of the enhancements identified from EDF and AREVA's post Fukushima reviews;

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- work undertaken to address other GDA issues that identified design changes which improve the robustness of EPR™ against extreme events;
- a new Pre-Construction Environment Report sub-chapter dealing with post Fukushima reviews.

From their reviews EDF and AREVA identified design change proposals for GDA that the regulator accepted provide the following:

- improved flood protection for emergency electrical supplies (both AC and DC);
- extension of the capability and autonomy of emergency electrical supplies (both AC and DC);
- identification of connection points for proposed mobile diesel generators;
- addition of Spent Fuel Pool (SFP) instrumentation into the severe accident management Control and Instrumentation (C&I) systems;
- provision of connections to enable delivery of water via mobile pumps for SFP make-up and containment pressure control.

6.12.2 An approach to assess combinations of EEs

Appendix 6-C includes a comprehensive list of EEs posing potential hazards to an NPS, some of which have been identified for the site and described in earlier sections. The list which was produced by the University of Vienna and co-funded by European Commission (Decker, 2017) resulted in the identification of 577 possible correlations between individual EEs and 82 combinations of mutually exclusive EEs (hazards from EEs which cannot apply to an NPS at the same time). Correlations discriminate between:

1) Causally connected EEs (cause-effect relation) where one EE (e.g., liquefaction) may be caused by another EE hazard (e.g., earthquake); or where one EE (e.g., high wind) is a prerequisite for a correlated EE (e.g., storm surge). The identified causal links are not commutative.

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2) Associated EEs ("contemporary" EEs) which are probable to occur at the same time due to a common root cause (e.g., drought and high temperature).

3) EEs that occur contemporaneously by random coincidence. Such combinations cannot include EEs which are mutually exclusive (e.g., high temperature and surface ice).

An example of a combination of mutually exclusive EEs, i.e. an implausible combination, is to experience a veld fire challenging the off-site power lines while a tropical cyclone accompanied by severe rain is in progress. Combinations should also be credible. The term credible implies that the likelihood of the combination is not insignificantly small. The likelihood a combination of the simultaneous occurrence of a tsunami and aircraft crash is deemed not credible.

The identification of plausible and credible combinations of events is carried out by using an EE combination matrix as is illustrated in ***Appendix 6-D***.

The main purpose of such a matrix is to facilitate a systematic and iterative process to either screen out combinations or to identify combinations of events for further assessment. It requires that each combination has to be interrogated in a systematic manner, using expert opinion, published literature and studies on EEs and prior assessments of single EE (e.g., aircraft crash study for KNPS), if available. Events initially screened out based on an assessment of single event considerations may have to be included in the matrix. The matrix provides an auditable trail of the combination selection process, e.g. the combination of {Organic Material in Intake Basin Sea Water} and {High Sea Water Temperature} and {LUHS (loss of ultimate heat sink)}. It has the purpose of answering the question whether there is a correlation between jellyfish and sea water temperature and whether it can increase the likelihood of a deteriorating heat sink function provided by the sea.

6.12.3 Combined events probabilistically assessed for the Thyspunt site

Combined event assessment was performed for flooding events and takes account of extreme meteorological events. From all of the potential flooding hazards the most severe and relevant hazards for the nuclear installation(s) at the site were combined to obtain the maximum and minimum water levels at the site. The maximum water levels are required for the flooding risk assessment,

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while the minimum water levels are related to the exposure of the cooling water intake (see ***Section 5.9*** and ***Section 5.10***).

Relevant experience from the nuclear industry with specific emphasis on lessons from the Fukushima accident still need to be assessed for the specific design that will be chosen for the site. One of the findings of the IAEA Expert Mission to Fukushima in June 2011, states that severe long-term combinations of external events should be adequately covered in design and operations of a nuclear installation (IAEA, 2011).

A further investigation of event combinations will follow in the next licensing stage.

6.13 Monitoring

The process of site evaluation continues throughout the lifetime of the nuclear installation(s), from siting through nuclear installation design, construction, operation to decommissioning. Therefore, characteristics of the natural and human induced hazards, as well as demographic, meteorological and hydrological conditions of relevance to the nuclear installation(s) at the site will be monitored over the lifetime of the facility (see ***Section 5.2***). Key parameters related to external hazards are identified in ***Sections 5.7*** to ***5.15*** and are being monitored as part of this SSR.

The preliminary external hazard identification and event evaluation for the site presented in this chapter have identified a relevant selection of hazards and events. Periodic review of this selection of events, in terms of completeness and detail on the hazard parameters, is required.

6.14 Management of Uncertainties

The management system to update information and manage uncertainties in data collected for ***Chapter 5*** also applies to the information in ***Chapter 6***. The main approaches adopted for management of uncertainties associated with EEs identified are:

- use of best and most reliable sources of data for the site;
- use of relevant data for the site region;
- continuation with the monitoring activities and where necessary expanding the scope of the programme;

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- update of this SSR at regular intervals in line with the requirements as contained in the siting regulations;
- application of a conservative approach;
- use of experience from other similar facilities and best international standards and recommendations.

Specific consideration has to be given to the evolving nature of human activities and which could develop into significant external hazards. It is difficult to predict the future developments around the proposed nuclear installation(s) at the site, especially the establishment of specialised industries supporting the nuclear installation.

It is reported in ***Section 5.1*** (Geography and Site Location) that from a regional perspective, land use change in the site region is expected to be concentrated in and around existing settlements. Any significant growth that would occur will be concentrated in the Nelson Mandela Bay Municipality and more specifically towards the Coega Industrial Development Zone. The agricultural use of the land in the vicinity of the site is expected to remain a feature of the area. Although some growth is expected to occur within the smaller settlements in the region, the focus is envisaged to be in coastal resort areas, where no significant industrial development, other than the nuclear installation(s) at the site and the Wind Farm development.

6.15 Regulatory Compliance and Management System

Specialist studies followed the interim guidance provided by the NNR (National Nuclear Regulator, 2016) and the NNR position paper on external events (National Nuclear Regulator, 2014). Compliance to NNR requirements and guidance are included in ***Chapter 2*** *and* ***Chapter 5 Sections***. The specialists who carried out studies followed a quality assurance programme that was established to control the effectiveness of the execution of these investigations, the data analysis and the formulation of conclusions on the site acceptability. This conforms to the overall management system for this SSR (***Chapter 10***, Management System).

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Full compliance with the regulations on licensing of sites requires a design specific PSA for NNI, which will only be possible when the final nuclear installation design information is available.

6.16 Conclusions

EEs addressed in this chapter are either:

- screened out unconditionally as the demand from the event on the nuclear installation(s) at the site is less than that specified in the PPE;
- screened out on condition that the screening status be confirmed when the specific design is selected or ongoing studies such as bedrock mapping at the NNI footprint is performed;
- screened in as specific checks will be required in the design qualification of the NNI on the site.

The final design should also be evaluated for potential cliff edge effects for design basis extension flooding, extended loss of offsite power and extended loss of ultimate heat sink.

An External Hazards Bounding Analysis considering the overall risk from the site-specific hazards (i.e. seismic, tornadoes, strong winds), concluded that the annual expected station risks and peak public risks due to these hazards was deemed to be within the NNR risk limits, considering that these hazards induced reactor accidents are based on conservative assumptions.

A summary of the screening status of EEs is provided in ***Table 6.14***.

Table 6.14: External Events Screening

External Event	Screening Status	Comment
Earthquake induced Ground Shaking	In	Thyspunt PSHA final data to be incorporated in the design envelope spectrum
Surface faulting	Out	Subject to confirmation during excavation of the nuclear footprint
Volcanism	Out	Event has a very low probability of occurrence
Groundwater level and quality	Out (conditional)	Further combined site and design specific studies required to confirm screening status

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External Event	Screening Status	Comment
Loss of freshwater supply	Out	-
Collapse, subsurface or uplift of the site surface	Out (conditional)	Further combined site and design specific studies required to confirm screening status
Soil liquefaction	Out (conditional)	Further combined site and design specific studies required to confirm screening status
Slope instability	Out (conditional)	Further combined site and design specific studies required to confirm screening status
Meteorological events (severe and extreme)	Out	Except for those mentioned below
Wind gusts and wind generated missiles	In	To be considered in the design
Tornados	In	Tornado parameters at 1E-07/y and missile spectrum to be aligned
Ambient temperature	In	To be considered in the design
Rainfall	Out	-
Snowfall	Out	-
Lightning	Out	-
Hail	Out	-
Frost	Out	-
Fog	Out	-
Relative humidity	Out	-
Atmospheric pressure	Out	-
Corrosivity	Out	-
Floods - sea	In	To be allowed for in the nuclear installation design
Floods – human-made retaining structures (off-site)	Out	-
Floods - river	Out	-
Flood – on-site hydrology	In	Further combined site and design specific studies required to confirm screening status
Flood - waterspouts	Out	Very low probability of occurrence
Flood – snow melt	Out	Very low probability of occurrence
Flood – landslide into water	In	To be allowed for in the nuclear installation design
Low sea water level	In	To be allowed for in the nuclear installation design

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External Event	Screening Status	Comment
Cooling water temperature (high)	In	To be allowed for in the nuclear installation design
External fires	Out (conditional)	Further combined site and design specific studies required to confirm screening status
Biological phenomena	In	To be allowed for in the nuclear installation design
Erosion from the sea	In	To be allowed for in the nuclear installation design
Accidental aircraft crash	Out	-
Hazardous material – land-based (static and transport)	Out	-
Hazardous materials and oil transported by ship	In	To be allowed for in the nuclear installation design
LOOP	In	To be allowed for in the nuclear installation design
Electromagnetic interference	Out (conditional)	Further combined site and design specific studies required to confirm screening status
Extra-terrestrial events	Out	These events, in accordance with EUR requirements for Light Water Reactor (LWR) Nuclear Power Plants (EUR, 2001), should not be considered in the design.

Based on the information presented in ***Chapters 5*** and ***6*** no fatal flaws were identified that would preclude the siting of an NNI.

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APPENDICES

Appendix 6-A: An Estimate of a Ship Accident Frequency in the Vicinity of the Duynefontyn site

A ship accident occurrence frequency can be estimated using ship traffic data in the vicinity of the site to determine whether it has to be considered as a DBEE for an NNPS. The result of the frequency calculation that follows indicates that a ship accident has to be included as a DBEE in the safety analysis for an NNPS on the site. A PSA will require the most recent shipping information when a NNP safety analysis is done for a NIL to site/construct.

Ship accident risk analysis typically involves assessment of the following accident types (Thevik, 2010):

- collision - The frequency of inter-ship powered collisions at a given geographical location is estimated by considering close quarters encounters. A probability of a collision for each encounter provides the collision frequency. This probability is related to a number of factors including the visibility conditions and the extent of internal and external vigilance.
- powered grounding - The frequency of powered groundings that result from marine traffic lanes located in close proximity to the shoreline or shallow water is calculated. It is mainly based on a failure to make a critical course change.
- drift grounding - It is assumed that drift grounding occurs when a ship loses the ability to navigate, due to steering or engine failure, and is subsequently forced onto the shoreline through the action of wind or current. Fault tree analysis can be used to determine the frequency of propulsion and steering system breakdown. Probabilities for self-repair and rescue by anchoring or tug assistance within given time limits are taken into account.
- structural failure - The frequency of such accidents is calculated by applying an accident frequency factor per vessel hour at sea while underway. The frequency factor applied takes account of the severity of the sea conditions.

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- fire and explosion - The frequency of such an accident is controlled by the number of vessel miles travelled. A frequency factor is derived from the historical data.

These methods calculate accident frequencies as the product of two terms and expressed by the following equation:

Accidents per Area and per Year
=
Number of Accident Type per Area and per Year
×
Probability of Accident per Critical Situation ……Equation 6.1

A ship accident probability was estimated for an impact area near the site. Information on global shipping accidents was gathered and combined with South African ship traffic statistics. The site is situated adjacent to the main traffic routes for vessels moving from both south-to-north and north-to-south rounding the tip of Africa. *Equation 6.1* is adapted in order to make use of global ship accident data listed in ***Table 6A.1***, ***Table 6A-2*** and ***Table 6A-3*** (Suyi Li, 2012) and South African ship traffic data in ***Section 5.7***

Table 6A-1: Lloyd's maritime information services ship casualty database

Ship type	Fire and Explosion Frequencies (Number of Accidents per Ship-Hour)
Tankers	4.08×10^{-7}
Bulk ships	3.43×10^{-7}
General cargo ships	2.65×10^{-7}
Ferries	3.51×10^{-7}

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Table 6A-2: Estimated annual frequency per ship of initiating events for container ships worldwide (International Maritime Organisation data 1990 to 2007)

Initial Event	Frequency of Accident (per ship-year)
Collision	1.61×10^{-2}
Contact	3.72×10^{-3}
Grounding	7.49×10^{-3}
Fire	3.65×10^{-3}
Explosion	1.90×10^{-3}
Heavy weather	2.64×10^{-3}
Non-accidental structural failure:	
Double Hull (DH) ships	1.93×10^{-3}
All ships	5.74×10^{-3}

Table 6A-3: Estimated annual frequency per ship of initiating events for container ships

Estimated Annual Frequency per Ship of Initiating Events for Various Ship Types							
	Single Hull Oil Tanker	Double Hull Oil Tanker	Oil / Chemical Tanker	Chemical Tanker	LPG Tanker	Bulk Carrier	LNG Carrier
Collision	9.90×10^{-3}	8.60×10^{-3}	4.30×10^{-2}	9.40×10^{-3}	2.20×10^{-2}	1.90×10^{-2}	6.70×10^{-3}
Contact	4.90×10^{-3}	3.10×10^{-3}	1.20×10^{-2}	4.60×10^{-3}	3.00×10^{-3}	1.10×10^{-2}	2.80×10^{-3}
Fire/Explosion	3.70×10^{-3}	1.10×10^{-3}	1.10×10^{-2}	4.50×10^{-3}	4.30×10^{-3}	2.90×10^{-3}	3.50×10^{-3}

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The frequency of ship accidents in the impact area is estimated using the following conservative assumptions:

- The area at sea where ship accidents could result in accidents and potentially impact on the nuclear site is assumed to be a semi-circle of 50 km radius and includes the transverse ship traffic paths at the site. Section 5.7 reports that the minimum distance that traversing tankers, which do not call at the Port of Cape Town, can pass to the site is some 96 km summer (16 October to 15 March) and 87 km in winter (16 March to 15 October). Dry Cargo vessels need to keep a minimum distance of 65 km off the site. However, when tankers or dry cargo vessels are calling for replenishment off the Port of Cape Town, they may come within 46 km of the site.
- L, the maximum ship travel length in this area is <100 km.
- T, the journey time per ship through this area is assumed to be at most 5 h (100 km at 20 km/h). Typical speeds are nearer to 15 knots (roughly 28 km/h)
- N, the number of ships transiting this area is equal to the number of ships rounding the Cape in east and west directions. This number is 127 747, the maximum reported during 2015 to 2020 in *Section 5.7*. The maximum number of oil tankers in 2019 was 31 857.
- F, the max accident frequency is 4.9×10^{-6} per ship hour (***Table 6A-3***).

The annual oil tanker accident frequency (P) is:

P (oil tankers) $\leq T\times N\times F$

$\leq 5\times 31\,857\times 4.9\times10^{-6}$

$= 0.78/y$

The result appears to be overly conservative and it can be ascribed to the fact that the frequency value F also reflects ship traffic lanes that are much busier per sea surface area, such as near Singapore, than around the Cape. Section 5.7 reports that three ships have sunk/grounded in the site vicinity and an additional eight accidents were recorded in the site region for the period 1994 to 2018. Five significant oil spills have occurred in the site region for the same period.

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The probability value, P, only estimate ship accidents in the impact area. An accident will not necessarily challenge nuclear safety of NPS. Wind direction and emergency response actions, for example, will lower the annual occurrence frequency of an actual impact on the cooling water intake structures and the heat sink safety function. However, the conservative estimates for ship accident frequencies indicate that the event should be considered as a DBEE. An earlier and detailed oil spill risk assessment for the site concluded that a definite risk does exist from oil spillages in the area of the site (ALCADIA, 2006). The study concluded that the probability of an oil spill originating from either an accident occurring during the transit of a vessel in a sea lane or an accident occurring within the Port of Cape Town and entering the cooling water intake basin within 10 hours would be 1.05×10^{-4}/y.

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Appendix 6-B: Additional Information on External Events and Screening

Table 6B 1 provides an extensive list of EEs to be considered for NPSs. It is based on a research project initiated by EURATOM (Decker, 2017).

Table 6B 1: External Events

Code	External Hazard	Hazard definition and impact	Comment
N1	Vibratory ground motion	The hazard is defined by the contemporaneous impact of vibratory ground motion on all civil structures and SSCs of the plant and its surrounding.	Effects of long period ground motion and aftershocks need to be considered.
N2	Vibratory ground motion induced or triggered by human activity (oil, gas or groundwater extraction, quarrying, mine collapse)	The hazard is defined by the contemporaneous impact of vibratory ground motion on all civil structures and SSCs of the plant and its surrounding.	See note: N2
N3	Surface faulting (fault capability)	The hazard is defined in terms of impact on the plant of co-seismic fault rupture and surface displacement. It includes surface rupture at secondary faults.	See note: N3
N4	Liquefaction, lateral spreading	The hazard is defined by the loss of shear strength of foundation soil and its effects on civil structures and underground installations such as pipes or cable trays.	See note: N4.
N5	Dynamic compaction (seismically induced soil settlement)	The hazard is defined by the effects of soil settlement on civil structures and underground installations such as pipes or cable trays. It includes effects of seismically induced surface cracks.	

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Code	External Hazard	Hazard definition and impact	Comment
N6	Permanent ground displacement subsequent to earthquake	The hazard is defined in terms of impact on the plant of permanent ground subsidence or ground heave due to strain release after an earthquake.	See note: N6. Ground settlement (N63) and ground heave (N64) due to other geological processes is treated separately.
N7	Tsunami (seismic, volcanic, submarine land-sliding, meteorite impact)	The hazard is defined by flooding by a series of water waves and the drawdown during the wave troughs.	See note: N7. Earthquake (N1), landslide (N60, N61), and volcanic hazards (N68, N69) are treated separately.
N8	Flash flood: flooding due to local extreme rainfall	The hazard is defined in terms of damage to the plant due to flooding by extreme rain.	See note: N8. Damage due to rain load on structures is treated separately (N25). Note links to other meteorological phenomena.
N9	Floods resulting from snow melt	The hazard is defined by flooding caused by seasonal or rapid snow melt.	Rapid snow melt due to volcanic phenomena is treated separately (N68).
N10	Flooding due to off-site precipitation with waters routed to the site (including river floods)	The hazard is defined in terms of damage to the plant due to flooding by waters routed to the site.	
N11	High groundwater	The hazard is defined in terms of damage to the plant due to flooding by high ground water.	
N12	Flooding or low water level due to obstruction of a river channel (downstream or upstream) by landslide, ice, jams caused by logs	The hazard is defined by flooding due to downstream river impoundment or by the breach of upstream river damming, and low water level due to upstream damming.	

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Code	External Hazard	Hazard definition and impact	Comment
	or debris, or volcanic activity		
N13	Floods or low water level resulting from changes in a river channel due to erosion or sedimentation, river diversion	The hazard is defined by flooding due to changes of a river channel or low water level caused by such phenomena.	Instability of the coastal area due to erosion is treated separately (N23).
N14	Flood resulting from large waves in inland waters induced by volcanoes, landslides, avalanches or aircraft crash in water basins	The hazard is defined by flooding due to large waves in inland waters.	Flooding by wind induced waves is treated separately (N19).
N15	Flood and waves caused by failure of water control structures and watercourse containment failure (dam, dike, or levee failure)	The hazard is defined by flooding due to the failure of dams, dikes, or other water containments, e.g., due to hydrological or seismic effects.	
N16	Seiche	The hazard is defined by flooding due to fluctuations of water level due to standing waves in enclosed or partly enclosed bodies of water.	See note: N16. The effect of seiches may aggravate other hazard phenomena such as tsunami or tides.
N17	Bore	The hazard is defined by flooding due to high tide or spring tide.	
N18	Seawater level: high tide, spring tide	The hazard is defined by flooding due to high tide or spring tide.	
N19	Seawater level, lake level or river: wind generated waves	The hazard is defined by flooding due to wind generated waves including	See note: N19 for rogue waves. Such waves are not

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Code	External Hazard	Hazard definition and impact	Comment
		long-period, short-period, and rogue waves (freak waves).	predictable and progress rapidly.
N20	Seawater level: storm surge	The hazard is defined by flooding due to storm surge.	See note; N20
N21	Seawater level, lake level or river: impact of man-made structures such as wave/tide breaks and jetties	The hazard is defined by flooding caused or amplified by the hydrological effects of manmade structures.	
N22	Corrosion from salt water	The hazard is defined in terms of impact on the plant of corrosion by salt water.	
N23	Instability of the coastal area due to erosion by strong water currents or sedimentation (sea and river)	The hazard is defined in terms of damage to plant structures due to erosion or sedimentation by strong water currents.	
N24	Underwater debris	The hazard is defined in terms of the damage or clogging of cooling water intake or outlet affecting the availability of the Ultimate Heat Sink (UHS). It may result from sediment load swept in by water.	The effects of ice on water intake structures is treated separately (N48).
N25	Precipitation (rain or snow), snow pack	The hazard is defined in terms of damage to the plant due to extreme rain or snow. It includes damage due to rain or snow load on structures.	Flooding by extreme rain (N8) or snow melt (N9) is treated separately.
N26	Extremes of air temperature (high and low)	The hazard is defined in terms of impact on the plant of extremely high temperatures (e.g., the stop of	Impact of high or low water temperature (N28) or ice is treated separately.

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Code	External Hazard	Hazard definition and impact	Comment
		ventilation function) and low temperatures (e.g., freezing of pipes).	
N27	Extremes of ground temperature (high and low)	The hazard is defined in terms of impact on the plant of high or low ground temperature, e.g., leading to freezing of pipes.	The impact of extreme soil frost is treated separately (N38).
N28	Extremes of cooling water (sea, lake or river) temperature (high and low)	The hazard is defined in terms of impact on the plant of high or low cooling water temperature.	Freezing (surface ice; N48) and frazil ice (N49) are treated separately.
N29	Humidity (high and low), extreme atmospheric moisture	The hazard is defined by the impact of moisture on the functionality of safety related equipment and electronic devices (I&C equipment), e.g., by condensation of droplets in electrical and electronic devices.	See note: N29
N30	Extremes of air pressure	The hazard is defined by the impact of moisture on the functionality of safety related equipment and electronic devices (I&C equipment), e.g., by condensation of droplets in electrical and electronic devices.	See note: N29
N31	Extreme drought: low river or lake water level	The hazard is defined as an extended drought period that lowers the water level of lakes, rivers and open water basins challenging the availability of cooling or service water.	High air temperature (N26) and high water temperature (N28) are treated separately. Extremes of ground water level are treated separately (N32)
N32	Low ground water	The hazard is defined by low ground water levels challenging the availability of cooling or service water.	

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Code	External Hazard	Hazard definition and impact	Comment
N33	Low seawater level	The hazard is defined in terms of impact of white frost including switchyards and power lines, and blocking of air intakes by rime.	See note: N35
N34	Icing, freezing fog	The hazard is defined in terms of the impact of ice cover caused by freezing rain or fog. It includes the loading of structures (electric power lines and switchyard) and blocking of air intakes by ice.	See note: N34
N35	White frost, hard rime, soft rime	The hazard is defined in terms of impact of white frost including switchyards and power lines, and blocking of air intakes by rime.	See note: N35
N36	Hail	The hazard is defined in terms of damage to the plant due to extreme hail. It includes damage by the impact of hailstones and hail load.	Flooding due to melting of hail are bounded by flooding due to rain and snow melt (N8, N9). Possible effects on the UHS are judged to be bounded by surface ice hazards (N48).
N37	Permafrost	The hazard is defined in terms of impact of thawing and refreezing of permafrost.	
N38	Recurring soil frost	The hazard is defined in terms of impact of soil frost, e.g., on shallow underground installations such as water pipes.	
N39	Lightning (including electromagnetic	The hazard is defined in terms of damage to the plant due to lightning. The impact may be direct, causing	Fire started by lightning is bounded by external fires

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Code	External Hazard	Hazard definition and impact	Comment
	interference)	structural damage or loss of off-site power, or indirect through an electromagnetic feeder fire started by lightning.	(N73, M 24) and internal fire analysis.
N40	High wind, storm (including hurricane, tropical cyclone, typhoon)	The hazard is defined in terms of damage to the plant by the direct impact of strong winds and wind pressure.	The hazard does not include tornado (N41) due to the unique characteristics of such storms. The hazard does not include the differentiating effects of blizzard, salt spray or sandstorm. However, the wind effects of these hazards are included. Flooding by storm surge is treated separately (N20). Hazards by wind-blown missiles are treated separately (N46).
N41	Tornado	The hazard is defined in terms of damage to the plant due to tornado. It includes the effects of pressure differences and rotating wind.	The hazard is separated from other strong winds (N40) due to the special characteristics of tornados with respect to duration, wind speed, and occurrence frequency. Damage due to windblown missiles is treated separately (N46).
N42	Waterspout (tornadic waterspout)	The hazard is defined in terms of the rotational energy. Waterspouts contain water vapour, not solid water.	See note: N42
N43	Blizzard, snowstorm	The hazard is defined by the impact on the plant by wind-blown snow. It includes contamination of external high-voltage insulation in switch gear	The effects of wind pressure from snowstorms are covered by the hazard high wind (N40). Snow load is treated separately (N25).

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Code	External Hazard	Hazard definition and impact	Comment
		and power lines, and blocking of air intakes.	
N44	Sandstorm, dust storm	The hazard is defined in terms of impact on the plant of storm-borne sand or dust and its abrasive effects. It includes contamination of external high-voltage insulation in switch gear and power lines and blocking of air intake.	The effects of wind pressure from sandstorms are covered by the hazard high wind (N40).
N45	Salt spray, salt storm	The hazard is defined as a storm involving salt covering of plant structures and the corrosive attack by a salty atmosphere. It includes contamination of external high-voltage insulation in switch gear and power lines, and dielectric breakdown caused by salt particles.	The effects of wind pressure from salt storms are covered by the hazard high wind (N40).
N46	Wind-blown debris (external missiles)	The hazard is defined by the damage of the impacts of wind-blown debris resulting from high winds and tornado.	Typical missiles to include are cladding panels, both insulated and uninsulated aluminium, scaffolding planks, scaffolding poles, trees, and cars.
N47	Snow avalanche	The hazard is defined in terms of impact on the plant of avalanches.	Avalanches may be triggered by heavy snow fall or snowmelt.
N48	Surface ice on river, lake or sea	The hazard is defined in terms of the damage or clogging of cooling water intake or outlet by drift ice or thick surface ice affecting the availability of the UHS.	Frazil ice (N49) and ice barriers (N50) are treated separately.

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Code	External Hazard	Hazard definition and impact	Comment
N49	Frazil ice	The hazard is defined in terms of the impact of frazil ice on the cooling water intake or river damming.	See note: N49
N50	Ice barriers	The hazard is defined in terms of impact on the plant of ice barriers, e.g., by clogging the water intake.	Flooding due to down-stream ice barriers is treated separately (N12).
N51	Mist, fog	The hazard is defined in terms of impact on the plant, electric power lines, and switchyard of mist. It includes reduced visibility on site.	
N52	Solar flares, solar storms (space weather); geomagnetic storms	The hazard is defined in terms of malfunction and damage to electrical and electronic equipment by electromagnetic interference and the breakdown of the terrestrial power grid.	See note: N52
N53	Marine/river/lake growth (seaweed, algae), biological fouling	The hazard is defined by excessive growth of algae, seaweed, bacteria or else affecting the availability of cooling water from the UHS.	
N54	Crustacean or mollusk growth (shrimps, clams, mussels, shells)	The hazard is defined in terms of clogging of water intake or outlet by encrusting organisms effecting on the availability of cooling water from the UHS.	
N55	Fish, jellyfish	The hazard is defined by the unavailability of the UHS due to clogging of water intake by exceptional quantities of fish/jellyfish or abnormal fish population in the cooling pond.	Clogging by seaweed (N53) and biological flotsam (N58) is treated separately.

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Code	External Hazard	Hazard definition and impact	Comment
N56	Airborne swarms (insects, birds) or leaves	The hazard is defined in terms of damage to the plant due to blockage of air intake by birds or blockage of ventilation systems by leaves or insects in the filters. It includes blocking of the air intake of emergency diesels.	
N57	Infestation by rodents and other animals	The hazard is defined by damage of cables or wires attacked by rodents (rats, mice), and by undermining of structures by burrowing mammals.	
N58	Biological flotsam (wood, foliage, grass etc.)	The hazard is defined in terms of the damage or clogging of cooling water intake or outlet affecting the availability of the UHS by the accumulation of large quantities of flotsam.	
N59	Microbiological corrosion	The hazard is defined in terms of damage to the plant by microbiological corrosion.	
N60	Subaerial slope instability (landslide, rock fall; including meteorologically and seismically triggered events)	The hazard is defined in terms of impact on the plant of landslide or rock fall including possible clogging of cooling water intake or outlet affecting the availability of the UHS.	The effects of mass movements causing flooding due to the blockage of streams (N12) or by inducing tsunamis in the sea or lakes (N7) are treated separately.
N61	Underwater landslide, gravity flow (including seismically triggered events)	The hazard is defined in terms of impact on the plant of underwater landslide.	Underwater landslides may be due to above water causes, such as prolonged and intense precipitation.

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Code	External Hazard	Hazard definition and impact	Comment
			Underwater erosion (N23) and tsunami triggered by landslide (N7) is treated separately.
N62	Debris flow, mud flow (including seismically triggered events)	The hazard is defined in terms of impact on the plant of debris flows or mud flows. Effects may include clogging of cooling water intake or outlet structures.	Lahar hazard is treated in volcanic hazards (N68).
N63	Ground settlement (natural or man-made by mining, ground water extraction, oil/gas production)	The hazard is defined in terms of impact on the plant of ground settlement.	
N64	Ground heave	The hazard is defined in terms of impact on the plant of ground heave.	
N65	Karst, leeching of soluble rocks (limestone, gypsum, anhydrite, halite)	The hazard is defined in terms of impact to the plant of fissures, sinkholes, underground streams, and caverns caused by chemical erosion.	
N66	Sinkholes (collapse of natural caverns and manmade cavities)	The hazard is defined in terms of impact on the plant of sinkholes resulting from underground collapse.	
N67	Unstable soils (quick clays etc.)	The hazard is defined in terms of impact on the plant of unstable soils.	
N68	Volcanic hazards: phenomena occurring near the volcanic centre	The hazard is defined in terms of impact on the plant of: volcanic vent opening; launching of ballistic projectiles; fallout of pyroclastic material such as ash, tephra, lapilli or pumice; pyroclastic flows; lava flows; debris avalanches, landslides and	The large variety of volcanic phenomena necessitates separate treatment of these phenomena. Earthquakes (N1) and tsunamis triggered

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Code	External Hazard	Hazard definition and impact	Comment
		slope failures; lahars, maars and floods induced by snow melt; air shocks and lightning; release of gases (including 'glowing avalanches'); ground deformation; geothermal and groundwater anomalies; forest fire ignited by volcanic activity.	by volcanic activity (N7) are treated separately.
N69	Volcanic hazards: effects extending to areas remote from the volcanic centre	The hazard is defined in terms of impact on the plant of volcanic phenomena such as fallout of ash.	Earthquakes (N1) and tsunamis (N7) triggered by volcanic activity are treated separately.
N70	Methane seep	The hazard is defined in terms of impact on the plant of methane seeping from soils or rocks.	
N71	Natural radiation	The hazard is defined in terms of impact on the plant of natural radiation.	
N72	Meteorite fall	The hazard is defined in terms of damage to the plant due to meteorite impact (direct impact, shock waves, impact-induced vibration, and fire).	See note: N72. Flooding by tsunami triggered by meteorite fall is treated separately (N7).
N73	Forest/veld fires	The hazard is defined in terms of damage to plant or the loss of off-site power due to fire or threatened operator action owing to the release of smoke and toxic gases. It includes hazard due to sparks igniting other fires and combustion gas of fire.	The hazard is a possible effect of extreme meteorological conditions (high temperatures, drought or storms). Fire caused by human activity is treated separately (M24).

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Code	External Hazard	Hazard definition and impact	Comment
M1	Industry accident: explosion	The hazard is defined in terms of damage to the plant resulting from explosions (deflagration or detonation) of solid substances, liquids or gases that leads to damage to the plant, loss of off-site power or threatened operator action. The damage may be due to pressure impact or impact of missiles.	This hazard is most relevant for chemical or fuel storage facilities (oil refinery, chemical plant, storage depot, other nuclear facilities). Explosions in connection with transportation (M11) and pipeline accidents (M13) are treated separately. Fire due to industrial accident is treated separately (M24).
M2	Industry accident: chemical release (explosive, flammable, asphyxiating, toxic, corrosive or radioactive substances)	The hazard is defined by the impact of releases from industrial plants that lead to damage to the plant or threatened operator action owing to the release of explosive, flammable, asphyxiating, toxic, corrosive or radioactive substances.	This hazard is most relevant for chemical or fuel storage facilities (oil refinery, chemical plant, storage depot, other nuclear facilities). Hazards resulting from transportation accidents (/M12) or pipeline accidents (M14) are treated separately.
M3	Missiles from high energy rotating equipment	The hazard is defined in terms of the impact of missiles from high energy rotating equipment.	
M4	Military facilities (permanent and temporary): explosion, projectiles, missiles and fire	The hazard is defined by the impact accidents in military facilities such as explosion, projectile generation (shrapnel), or missiles.	Chemical releases from military facilities are treated separately (M5). Fire from military facilities is treated with the fire hazard due to human/technological activity (M24).
M5	Military facilities (permanent and temporary): chemical release (explosive,	The hazard is defined by the impact of releases from military facilities that lead to damage to the plant or threatened operator action owing to	

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Code	External Hazard	Hazard definition and impact	Comment
	flammable, asphyxiating, toxic, corrosive or radioactive substances)	the release of explosive, flammable, asphyxiating, toxic, corrosive or radioactive substances.	
M6	Military activities	The hazard is defined in terms of damage to plant resulting from military activity.	Explosion and fire induced by military action should be considered as a minimum.
M7	Ship accident: direct impact	The hazard is defined in terms of the direct impact of a ship.	Collisions with water intake structures and components of the UHS are treated separately (M8). The hazard does not cover consequences of releases in connection with a ship accident (explosion, pollution, intake clogging or release of toxic gases). These hazards are treated separately (M9, M11).
M8	Collisions with water intake and ultimate heat sink components (ship, pontoon, fishing net)	The hazard is defined in terms of damage or clogging of water intakes and UHS structures by collision with ships, pontoons, fishing nets, etc.	The hazard does not cover consequences of releases in connection with a ship accident (explosion, pollution, intake clogging or release of toxic gases). These hazards are treated separately (M9, M11).
M9	Ship accident: solid or fluid (non-gaseous) releases	The hazard is defined in terms of damage or clogging of water intakes and UHS structures by impurities released into the water from a ship, such as oil spills or corrosive fluids, which could affect the availability or quality of cooling water, and its heat exchange capacity.	

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Code	External Hazard	Hazard definition and impact	Comment
M10	Ground transportation accident: direct impact	The hazard is defined in terms of the direct impact of railway trains and wagons, road vehicles outside the site.	The hazard does not cover consequences of releases in connection with transport accidents (explosion, pollution, intake clogging or release of toxic gases). These hazards are treated separately (M11, M12).
M11	Transportation accident: explosion, fire	The hazard is defined in terms of damage to the plant resulting from explosion after ground transportation accidents or due to sea, lake or river transportation accidents. Damage may be due to pressure impact or impact from missiles.	Consequence of other hazards (different prime cause). Hazards due to aircraft crash (M15, M16) or pipeline accident (M13) are treated separately. Toxic effects from a chemical release are treated separately (M12).
M12	Transportation accident: chemical release (explosive, flammable, asphyxiating, toxic, corrosive or radioactive substances)	The hazard is defined by the effects of chemical releases after ground transportation accidents or due to sea, lake or river transportation accidents that affect the plant both externally and internally, damaging or impairing safety related systems and operator action. Releases may originate from transportation accidents, spills or leakages of transported substances.	
M13	Off-site pipeline accident: explosion, fire	The hazard is defined in terms of damage to the plant resulting from explosions (deflagration or detonation) after a pipeline accident (including pumping stations) outside the site. The damage may be due to pressure impact or impact of missiles.	Effects from chemical release are treated separately (M14).

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Code	External Hazard	Hazard definition and impact	Comment
M14	Off-site pipeline accident: chemical release	The hazard is defined by the effects of chemical releases after pipeline accidents (including pumping stations) that affect the plant both externally and internally, damaging or impairing safety related systems and operator action.	Explosion effects from pipeline accidents are treated separately (M13).
M15	Aircraft crash: airport zone	The hazard is defined in terms of damage to the plant by abnormal flights leading to crashes. Damage can by caused by direct impact, explosion, missiles, fire (kerosene), smoke (toxic), and inducted vibration.	The hazard depends on flight frequencies, runway characteristics, and types and characteristics of aircrafts. The aircraft may be commercial, private or military.
M16	Aircraft crash: air traffic corridors and flight zones (military/civil/agricultural)	The hazard is defined in terms of damage to the plant by abnormal flights leading to crashes. Damage can by caused by direct impact, explosion, missiles, fire (kerosene), smoke (toxic), and inducted vibration.	The hazard depends on flight frequencies, characteristics of air traffic corridors, and types and characteristics of aircrafts. The aircraft may be commercial, private or military.
M17	Satellite crash	The hazard is defined in terms of damage to the plant resulting from satellite impact. Damage can be caused by direct impact, induced vibration, or shock wave.	
M18	Excavation and construction work	The hazard is defined in terms of impact on the plant of excavation construction work outside the site area including destructive work on cabling and piping buried underground which may lead to the breach of underground supplies or the release of	

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Code	External Hazard	Hazard definition and impact	Comment
		explosive, flammable, asphyxiating, toxic or corrosive substances.	
M19	Instability of the off-site power grid	The hazard is defined by the impact of disturbances coming from manipulation on the grid and switchyards from outside the site. It includes external grid disturbance leading to voltage surges.	
M20	Industrial contamination of insulation of high voltage in outdoor switchgear and power lines	The hazard is defined by the impact on the insulation of high voltage in outdoor switchgear by industrial contaminants such as dust or chemical releases.	
M21	Electromagnetic interference, radiofrequency interference or disturbance from off-site sources	The hazard is defined in terms of impact of human-induced magnetic or electrical fields, and radio magnetic disturbance that could cause malfunction in or damage to safety related equipment or instrumentation.	The main examples of such fields are those attributable to radar, radio, and mobile telephone systems, or to the activation of high voltage electric switchgears.
M22	High-voltage eddy current into ground (off-site sources)	The hazard is defined by corrosion of underground metal ground components and grounding problems.	
M23	Flooding: malfunction or miss-management of water-gate or dam	The hazard is defined in terms of damage to the plant by high level water and water waves caused by human-induced damage, malfunction or miss-management of water control structures.	The hazard may be enveloped by flood hazard caused by failure of water control structures (dam failure) caused by natural events (N15).
M24	Fire as result to human/technological activity	The hazard is defined in terms of damage to the plant or loss of off-site power resulting from human-induced forest, wildland or grassland fire, or	Fire may result from industrial accident or free time activities.

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Code	External Hazard	Hazard definition and impact	Comment
		fire in urban area. It includes hazard due to sparks igniting other fires, smoke, combustion gas of fire, and heat (thermal flux).	

Additional notes on Natural Occurring External Events:

- N2: Vibratory ground motion induced or triggered by human activity

Seismic ground motion caused by human activity is treated together with natural seismicity due to the identical effects of both phenomena and the difficulties which may arise to discriminate between man-made and natural events. The hazard type includes induced seismicity, which is entirely controlled by human intervention, and triggered seismicity. In the latter case human intervention causes the initiation of the seismic rupture process of a fault while the subsequent rupture propagation is controlled by natural stress. A triggered earthquake is advanced by human intervention and natural stress aggravates the ground shaking. Seismic ground motion may be triggered or induced by oil, gas or deep groundwater extraction (including both producing and empty reservoirs), geothermal heat production, liquid waste dumping in deep boreholes, quarrying and mining.

- N3: Fault capability

The displacement of the Earth’s surface at a fault during an earthquake is referred to as fault capability. Co-seismic displacement may occur at the master fault or splay faults which fractured during the earthquake, or by induced slip at secondary faults which are not directly related to the earthquake fault.

- N4: Liquefaction, lateral spreading

Liquefaction of soil and unconsolidated fine-grained sediment is caused by ground shaking during an earthquake. The process results from the expulsion of pore water and leads to an extreme reduction of shear strength of the soil. In such cases, soil behaves more like a liquid than a solid and is unable to carry loads. Lateral spreading refers to the down-slope flow of liquefied soil. Both phenomena

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may lead to base failure at the foundation of buildings and the destruction of underground infrastructure (e.g., cables, pipes and pillars).

- N6: Permanent ground displacement subsequent to earthquake

Strain release after strong earthquakes may lead to permanent ground displacement of a large area that is caused by the release of elastic deformation (strain) during the earthquake. Elastic strain accumulates in the inter-seismic time period between earthquakes. Well-known examples of permanent ground displacement include cases of regional costal uplift above subduction zones and thrust faults. The type of ground displacement is distinct from the displacement caused by fault capability which is restricted to the earthquake fault or secondary faults.

- N7: Tsunami

A tsunami is a series of waves (wave train) in an ocean or lake that is caused by the displacement of a large volume of a body of water by earthquake, underwater landsliding, landsliding into water, volcanic eruption, or meteorite impact. Tsunamis travel very large distances. The phenomenon that triggered the wave train may therefore have occurred far from the site where the waves arrive.

- N8: Flash flood

Extreme flood events induced by severe stationary storms have been considered as flash floods. Most generally, the storms inducing flash floods lead to local rainfall accumulations exceeding 100 mm over a few hours and affect limited areas: some tens to some hundreds of square kilometres. Larger scale and longer lasting stationary storm events may, however, occur in some meteorological contexts.

- N16: Seiche

Seiches are standing waves that form in enclosed or semi-enclosed water basins due to the reflection of waves at the basin edges. Repeated wave reflections and interference of waves lead to the formation of standing waves. The superposition of waves with frequencies equal to the eigen-frequency of the basin (or multiples of this frequency) lead to resonances in the body of water and amplitude

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amplification. Wave initiation may be due to meteorological effects (wind, atmospheric pressure variations), seismic activity, or tsunamis.

- N17: Bore

A tidal bore is a series of waves propagating upstream as the tidal flow turns to rising. It forms during spring tide conditions when the tidal range exceeds 4 to 6 m and the flood tide is confined to a narrow funneled estuary. Its existence is based upon a fragile hydrodynamic balance between the tidal amplitude, the freshwater river flow conditions and the river channel bathymetry. Tidal bores are characterized by strong turbulence that may lead to sediment erosion beneath the bore wave and on banks. Turbulence may further lead to scouring and sediment entrainment, and impact on obstacles.

- N19: Rogue waves (freak wave)

Freak waves are extraordinarily large water waves whose heights exceed by a factor of 2.2 the significant wave height of a measured wave train. The significant wave height is defined as the mean of the largest third of waves in a wave record. Rough waves often occur as single and steep wave crests that may cause severe damage to offshore/onshore structures and ships. The formation of such waves results, among other factors, from the presence of strong currents or from a simple chance superposition of different waves with coherent phases.

- N20: Storm surge

Storm surge is a coastal flood phenomenon that can result from several different types of storms such as tropical cyclones, extra-tropical cyclones, squall lines (a line of thunderstorms ahead of a cold front), and hybrid storms in low-pressure weather systems. Flood levels are a function of the depth of the water body, the orientation of the shoreline, the wind direction, the storm path, and tides. Two main meteorological factors contribute to storm surge: the long fetch (i.e., the length of water over which wind has blown) of winds spiraling towards the centre of the storm, and the elevated water dome drawn up by low the air pressure in the storm's centre. The second effect is responsible for destructive meteo-tsunamis (a tsunami-like wave of meteorological origin.

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- N29a/b: Humidity (high and low)

Extremes of humidity have an impact on the cooling capacity of nuclear power plants that utilize evaporation based designs for the ultimate heat sink (e.g. mechanical draught cooling towers). Together with other parameters such as wind, precipitation, temperature, and air pressure extremes of humidity may combine to meteorological conditions representing (a) maximum evaporation potential (leading to maximum cooling water consumption) and (b) minimum water cooling (e.g. cooling capacity of the cooling tower).

- N34: Icing

The term refers to clear ice that precipitates from rain or fog and covers cold objects in a sheet-like mass of layered ice. Such ice covers have a higher density than ice crystals formed by frost or rime (refer to N35) and therefore a higher potential to damage objects by loading. Examples of vulnerable structures include power lines and (high voltage) outdoor switchgears of NPSs.

- N35: White frost, hoar frost, hard rime, soft rime

The hazard type summarizes the effects of several types of ice coatings that form in humid and cold air and produce ice crystals in a greater variety of forms. Crystals freeze to the upwind side of solid objects. Rime refers to ice deposits forming from water droplets in freezing fog or mist at calm or light wind. Super-cooled water drops are involved in the formation of rime. Meteorological literature distinguishes hard rime, which has a comb-like appearance and firmly adheres to objects, from soft rime, which consists of fragile and delicate ice needles. In contrast to rime, where vapor first condensates to droplets before freezing, white frost and hoar frost forms by desublimation of ice directly from water vapor. Both types of frost do not form from fog but from air of different degrees of relative humidity at low temperatures. Frost and rime is less dense than solid ice and adheres to objects less tenaciously. Their damage potential is therefore less than that of clear ice covering objects (refer to N34, Icing).

- N42: Waterspout

A waterspout (tornado occurring over water) is a small and weak rotating column of air over water. It consists of a columnar vortex which is upwards connected to a funnel-shaped cloud. The phenomenon is mostly weaker than tornadoes on

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land. Most of the water contained in the funnel of a waterspout is formed by the condensation of droplets, not by sucking up water from the underlying water body. Stronger waterspouts may originate in meso-cyclone thunderstorms.

- N49: Frazil ice

Frazil ice is generally defined as the mass of ice crystals formed in a turbulent flow which is in a super-cooled condition. Super-cooling results in a suspension of loose, randomly oriented needle-shaped ice crystals in water resembling slush. Frazil ice forms in turbulent, supercooled water (rivers, lakes and oceans) when air temperature reaches –6°C or lower. At high speeds of water currents the small ice crystals are not buoyant and may be carried into deeper water instead of floating at the surface. Continuing crystal growth may result in underwater ice adhering to objects in the water such as trash racks protecting water intake structures. This process may proceed very fast and lead to total blockage of trash bars.

- N52: Solar flares, solar storms (space weather); electromagnetic interference

A solar flare is a sudden release of extremely large energy of the Sun caused by electromagnetic phenomena within the Sun. Flares may lead to the ejection of plasma (coronal mass ejection) and particle storms (solar storms) with clouds of electrons, ions, and atoms moving through the corona of the sun into space. Such clouds may reach the Earth within hours or few days after the solar event. Massive solar flares with coronal mass ejections have a strong impact on the space weather near the Earth. They cause temporary disturbances of the Earth's magnetosphere and magnetic field causing geomagnetic storms. The latter may lead to severe disturbances of electrical systems including the disruption of communication by absorption or reflection of radio signals, and the damage of terrestrial electric power grids by moving magnetic fields that induce currents in conductors of the power grid. These currents may particularly damage transformers. Geomagnetic storms may therefore cause long-lasting breakdowns of the electrical power grid. Other effects include the heating of long conductors such as pipelines. Since solar flares affect the whole Earth the assessment of the likeliness of hazardous events is fully not site specific. Occurrence probabilities and hazard severities depend on the geographical latitude. Direct and indirect observations of solar flares show downward-cumulative frequency distributions of fluences of solar energetic particle events.

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- N72: Meteorite fall

Observations and modelling of asteroid impacts support the assumption of uniform impact distribution for all parts of the Earth independent from geographical latitude and longitude. Hazard assessments for meteorite fall therefore are not site specific. Hazard estimates may be derived from globally established correlations between the size of the impacting object (or its impact energy) and the yearly probability to hit the Earth, and the correlation between the size of the area affected by destructive phenomena and the impact energy.

IAEA Site Exclusion Criteria (IAEA, 2003)

- The following exclusion criteria have been used to eliminate postulated hazards from being included as a design basis:
  - A phenomenon which occurs slowly or with adequate warning with respect to the time required to take appropriate protective action.
  - A phenomenon which in itself has no significant impact on the operation of a nuclear power plant and its design basis.
  - A phenomenon which by itself has a probability of occurrence less than the 10^{-7} per year upper limit of acceptable undefined failure probability and consequences.
  - Locate the nuclear power plant sufficiently distant from the postulated phenomenon to mitigate its effects.
  - A phenomenon which is included or enveloped by design for another phenomenon. For example, storm surge and seiche are included in lake flooding; toxic gas is included in pipeline accident or industrial or military facility accident.

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Table 6B 2: External Events

Hazards Natural	Elimination Criteria no.	Remarks
High summer temperature	A phenomenon which occurs slowly or with adequate warning with respect to the time required to take appropriate protective action.	Ultimate heat sink conservatively designed for 30 days evaporation
Waterspout	Locate the nuclear power plant sufficiently distant from the postulated phenomenon to mitigate its effects	Considered in conjunction with tornado. Tornado governs. Loading due to water in spout not governing
Sandstorm	Locate the nuclear power plant sufficiently distant from the postulated phenomenon to mitigate its effects	Extreme wind should include this phenomenon. Blockage of air intakes with particulate matter should be considered separately
Volcanic activity	A phenomenon which by itself has a probability of occurrence less than the 10^{-7} per year upper limit of acceptable undefined failure probability and consequences. Locate the nuclear power plant sufficiently distant from the postulated phenomenon to mitigate its effects	Currently there is no criteria for anti-volcanic design
Fog	A phenomenon which in itself has no significant impact on the operation of a nuclear power plant and its design basis.	Could however increase probability of human made hazard involving surface vehicles or aircraft
Forest fire	A phenomenon which in itself has no significant impact on the operation of a nuclear power plant and its design basis.	Site cleared for such fire. Control room habitability required for smoke.
Drought	A phenomenon which occurs slowly or with adequate warning with respect to the time required to take appropriate protective action.	Assumes multiple sources of ultimate heat sink or ultimate heat sink not affected by drought: e.g. cooling tower with adequately sized basin
Lightning	A phenomenon which in itself has no significant impact on the operation of a nuclear power plant and its design basis.	Plant lightning protected by use of a grounding network
Frost	A phenomenon which in itself has no significant impact on the operation of a nuclear power plant and its design basis.	Snow and ice govern

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Hazards Natural	Elimination Criteria no.	Remarks
	A phenomenon which is included or enveloped by design for another phenomenon. For example, storm surge and seiche are included in lake flooding; toxic gas is included in pipeline accident or industrial or military facility accident.	
Meteorite	A phenomenon which by itself has a probability of occurrence less than the 10^{-7} per year upper limit of acceptable undefined failure probability and consequences.	Less than 10^{-7} per year depending on latitude
Hail	A phenomenon which in itself has no significant impact on the operation of a nuclear power plant and its design basis. A phenomenon which is included or enveloped by design for another phenomenon. For example, storm surge and seiche are included in lake flooding; toxic gas is included in pipeline accident or industrial or military facility accident.	Other missiles govern
Coastal erosion	A phenomenon which occurs slowly or with adequate warning with respect to the time required to take appropriate protective action.	See note 1
Flood	Locate the nuclear power plant sufficiently distant from the postulated phenomenon to mitigate its effects	
Tsunami	Locate the nuclear power plant sufficiently distant from the postulated phenomenon to mitigate its effects	
Retaining structure failure	Locate the nuclear power plant sufficiently distant from the postulated phenomenon to mitigate its effects	
Soil shrink-swell consolidation	A phenomenon which occurs slowly or with adequate warning with respect to the time required to take appropriate protective action.	See note 1

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Hazards Natural	Elimination Criteria no.	Remarks
Low lade or river water level	A phenomenon which occurs slowly or with adequate warning with respect to the time required to take appropriate protective action.	Ultimate heat sink should be conservatively designed for 30 days of evaporation
Avalanche	Locate the nuclear power plant sufficiently distant from the postulated phenomenon to mitigate its effects	
Landslide	Locate the nuclear power plant sufficiently distant from the postulated phenomenon to mitigate its effects	
Wave Action	Locate the nuclear power plant sufficiently distant from the postulated phenomenon to mitigate its effects A phenomenon which is included or enveloped by design for another phenomenon. For example, storm surge and seiche are included in lake flooding; toxic gas is included in pipeline accident or industrial or military facility accident.	Included under flood
Seiche	Locate the nuclear power plant sufficiently distant from the postulated phenomenon to mitigate its effects A phenomenon which is included or enveloped by design for another phenomenon. For example, storm surge and seiche are included in lake flooding; toxic gas is included in pipeline accident or industrial or military facility accident.	Included under flood
Precipitation	Locate the nuclear power plant sufficiently distant from the postulated phenomenon to mitigate its effects A phenomenon which is included or enveloped by design for another phenomenon. For example, storm surge and seiche are included in lake flooding; toxic gas is included in pipeline accident or industrial or military facility accident.	Included under flood
Storm Surge	Locate the nuclear power plant sufficiently distant from the postulated	Included under flood

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Hazards Natural	Elimination Criteria no.	Remarks
	phenomenon to mitigate its effects A phenomenon which is included or enveloped by design for another phenomenon. For example, storm surge and seiche are included in lake flooding; toxic gas is included in pipeline accident or industrial or military facility accident.	
Ice cover	A phenomenon which in itself has no significant impact on the operation of a nuclear power plant and its design basis. A phenomenon which is included or enveloped by design for another phenomenon. For example, storm surge and seiche are included in lake flooding; toxic gas is included in pipeline accident or industrial or military facility accident.	See remark under snow for roof loading. Ice effects on intake structures may require design consideration. Ice blockage of rivers causing flooding is included under river flooding
Snow	A phenomenon which in itself has no significant impact on the operation of a nuclear power plant and its design basis.	When snow (or ice) load in excess of design live loads is considered in the design of power plant structures, the resulting load combination should be treated as an extreme environmental condition with unit load factors
Aircraft crash. Large Aircraft crash. Small	A phenomenon which by itself has a probability of occurrence less than the 10^{-7} per year upper limit of acceptable undefined failure probability and consequences. A phenomenon which is included or enveloped by design for another phenomenon. For example, storm surge and seiche are included in lake flooding; toxic gas is included in pipeline accident or industrial or military facility accident.	If more than 10km from commercial airport flyway Included in tornado design 100 m sec
Surface Vehicle, Pipeline and Military or Industrial facility accident	Locate the nuclear power plant sufficiently distant from the postulated phenomenon to mitigate its effects	

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Hazards Natural	Elimination Criteria no.	Remarks
(Explosion)		
Toxic and Flammable Gas	A phenomenon which is included or enveloped by design for another phenomenon. For example, storm surge and seiche are included in lake flooding; toxic gas is included in pipeline accident or industrial or military facility accident.	Control room habitability required for toxic gas accident. This assumes no operator action outside the control room is required to render the consequences of the event acceptable

Note 1: Site related characteristics, such as subsidence due to subsurface pumping mining sink holes or alteration of groundwater regions active surface faulting liquefaction potential chemically active soils and rocks or volcanic activity which have expansive heave shrinkage characteristics flood plane level are natural phenomena which should be considered and evaluated during the site suitability evaluation process. Such characteristics either result in (1) the site being considered unsuitable or (2) necessary design consideration and construction techniques are employed to mitigate or present the hazard.

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Appendix 6-C: Eskom Plant Parameter Envelope Values and Criteria

PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
0.Plant thermal/ electrical characteristic					
0.1 Electric Output per unit	The electrical output of the plant per unit	1 708 MW (gross) 1 580 MW (net)	maximum	yes	EPR SAR [24] EUR Vol. 2 [11]
0.2 Megawatts Thermal per unit	The thermal output of the plant per unit, including electrical output and rejected heat load	4 616 MW	maximum	yes	EUR Vol. 2 [11] EPR SAR [24]
0.3 Station Capacity Factor	The percentage of time the plant is expected to deliver its stated electrical output over the lifetime of the plant, considering all expected outages	94%	maximum	no	EUR Vol.2 [11] EPR SAR [24] N-REP-1200-10000 [21]
0.4 Plant Design Life	The designed lifetime of the plant, including planned midlife refurbishments	60 yrs + 20 years life extension	maximum	no	EUR Vol. 2 [11] EPR SAR [24] UKP-GW-GL-793NP [34]
0.5 Plant Operating Life Cycle (Time of operation between refuelling)	The normal plant operating cycle length	18 - 24 months	maximum	no	EUR Vol. 2 [11]
0.6 Plant efficiency	The ratio of useful electricity energy output from the plant, over a time period T, to the energy source supplied to the unit	37%	maximum	no	EPR SAR [24]
1.Structure					
1.1 Building Characteristics					

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PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
1.1.1 Height (without stack and cooling towers)	The height from finished grade to the top of the tallest block structure, excluding cooling towers (excludes stairway towers, elevator, etc.)	76.4 m Dependent on the chosen reactor technology	maximum	no	APR 1400 DCD [16]
1.1.2 Foundation Embedment	The depth from finished grade to the bottom of the base-mat or the most deeply embedded power block structure	Approx. 16.4 m from finished grade (11.9 – 25.7 m) Dependent on site specific information	maximum	no	EUR Vol. 2 [11]
1.2 Precipitation (for roof design)					
1.2.1 Maximum rainfall rate	The probable maximum precipitation (PMP) value that can be accommodated by a plant design. Expressed as maximum precipitation for 1 hour in 1 square km and as maximum precipitation for 5 minutes in 1 square km.	100 mm/hr 400 mm in 24 hours 157 mm/5 mins	maximum	no	EUR Vol. 2 [11]
1.2.2 Normal and Extreme Winter Precipitation Events (Snow and ice load) Depth of 48-hour probable maximum winter precipitation (PMWP)	The loads on structure roofs due to the accumulation of snow and ice that can be accommodated by a plant design (i.e. the weight of the 100 year period ground level snowpack and the weight of the 48 hour probable maximum winter precipitation (PMWP)	Design-basis level snow Loading: 0.4 kPa. Upper design limit: 1.5 kPa Addition for man access: 0.75 kPa	minimum	no	EUR Vol. 2 [11]
1.2.3 Hail	The maximum 100-year return interval snow load on structure roofs that can be accommodated by a plant design.	Covered by the standard vendor design for 1:100 year recurrence interval. Minimum value of 0.4 kPa (quantities of derived liquid subject to ice density).		no	EUR Vol. 2 [11]

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PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
1.3 Geology and Seismology (Safe Shutdown Earthquake (SSE)					
1.3.1 Design Response Spectra (n/a)	The assumed design response spectra used to establish a plant's seismic design	To be determined based on site specific information	n/a	no	Reg Guide 1.60 [25]
1.3.2 Peak Ground Acceleration	The maximum earthquake ground acceleration for which a plant is designed; this is defined as the acceleration, which corresponds to the zero period in the response spectra taken in the free field at base mat elevation. The PGA is associated with the response spectrum shape as defined in the relevant standard and should not be used in isolation.	The horizontal free field Peak Ground Acceleration (PGA) for all site conditions shall be 0,3 g. The higher PGA value of 0.3 g is used instead of 0.25 g in the EUR. This PGA has been selected for design purposes only and does not relate to the level of seismic hazard at any specific site	minimum	no	EUR Vol. 2 [11] NEI-ESP-PPE Worksheet [17] N-REP-01200-1000 [21] US NRC Reg Guide 1.208 [28] UKP-GW-GL-793NP [34]
1.3.3 Time History	The plot of earthquake ground motion as a function of time used to establish the plant's seismic design	The floor time history responses shall be converted into response spectra and combined with the response spectra obtained from the other directions of input if applicable.	minimum	no	EUR Vol. 2 [11] NEI-ESP-PPE Worksheet [17]
1.3.4 Capable Tectonic Structures or Sources	Assumption made in a plant design about the presence of capable faults or earth quake sources in the vicinity of site (e.g. no fault displacement potential within the investigative area	No displacement permitted within the site area.	minimum	no	EUR Vol. 2 [11] NEI-ESP-PPE Worksheet [17] UKP-GW-GL-793NP [34]
1.3.5 Volcanism	Volcanism is a process whereby liquid	History and/or evidence of volcanic		no	IAEA SSG-21 [14]

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PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
	lava/ash/gases from the mantle/deep interior of the earth erupts into the atmosphere and/or flows onto the surface. Apart from the destructive power of a volcanic eruption, volcanoes can also precipitate various consequential events including: lahars, earthquakes, floods, missiles, lightning, tsunamis and pyroclastic flows.	activity in recent geologic times (< 10 000 000 years) in the site region (R ≤ 50 km) are unacceptable. A generic screening distance value of 100 km for basaltic lava is required.			
1.4 Site Water Level (Allowable)					
1.4.1 Maximum Flood or Tsunami (Terrace height) (i.e. lowest elevation))	Design assumption regarding the difference in elevation between finished plant grade and the water level due to the probable maximum flood (or tsunami).	The terrace height must be such that the NNI terrace is elevated above design basis flooding hazards.	minimum	no	IAEA SSG-18 [13] EUR Vol.2 [11]
1.4.2 Maximum Groundwater Level (i.e. lowest elevation))	Design assumption regarding the difference in elevation between finished plant grade and the maximum site ground water level used in plant design	The extreme groundwater levels at the site and the associated pressures on structures should be characterized. If groundwater levels are expected to reach the ground surface or the levels of groundwater drains, the expected discharge rate should be characterized, together with the ways in which the water would be discharged. The potential need for dewatering should be identified where appropriate.	minimum	no	IAEA SSG-18 [13]
1.5 Soil Properties Design Bases					

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PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
1.5.1 Liquefaction (minimum)	Design assumption regarding the presence of potentially liquefying soils at a site (e.g., none at Site-Specific SSE).	No liquefaction is permitted for site specific SSE. If evaluations of the site investigations indicate the presence of potentially liquefiable soils, the resistance of these soils to liquefaction must be evaluated. It should also be determined whether the potentially liquefiable soils should be removed, whether remedial action should be undertaken, whether further field and laboratory investigations are needed or whether detailed stability and deformation analysis could demonstrate that an acceptable margin of safety is maintained for the design structures even if liquefaction is assumed to occur. Where no acceptable margin of safety can be maintained (where liquefaction is assumed to occur) then no liquefaction shall be permitted on the site, unless practicable engineering solutions are demonstrated to be available.	minimum	no	IAEA SSR-1 [15]
1.5.2 Minimum Bearing Capacity (Static)	Design assumption regarding the capacity of the competent load-bearing layer required to support the loads exerted by plant structures used in the plant design.	718.2 kPa over the footprint of the nuclear island at its excavation depth The potential for failure of the bearing capacity of the subsurface materials for a NPP under static loading should be low so that there are high margins of safety under static loading. These margins should be sufficient to meet SL-2 seismic loading conditions with	maximum	no	EUR Vol. 2 [11] IAEA NS-G-3.6 [12] NEI-ESP-PPE Worksheet [17] N-REP-01200-1000 [21]

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PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
		reasonable safety margins. (In some states SL-2 corresponds to a level with a probability of being exceeded in the range of 1x10-3 to 1x10-4 (mean values) or 1x10-4 to 1x10-5 (median) per reactor per year.)			
1.5.3 Minimum Shear Wave Velocity	The assumed limiting propagation velocity of shear waves through the foundation materials used in the plant design.	304.8 m/s Generally, the soil/rocks on which the nuclear and conventional islands are founded will be engineered so that Vs > 300m/s Competent material is defined as in-situ material having a minimum shear wave velocity of ≥ 300 m/s. If the minimum shear wave velocity of the supporting foundation material is less than 300 m/s, additional studies need to be performed which consider the average shear wave velocity and its degree of variability addressing potential impact on soil-structure interaction, potential settlements and design of foundation elements.	maximum	no	N-REP-01200-1000 [21] EPR SAR [24] AP1000 DCD [33] UKP-GW-GL-793NP [34]
1.5.4 Dynamic Bearing Capacity	Design assumption regarding the capacity of the founding soil/rock to resist loads imposed by the structures in the event of an earthquake.	≥2 872.8 kPa at the edge of the nuclear island at its excavation depth. OR Site-specific analyses should demonstrate a factor of safety appropriate for normal plus safe shutdown earthquake loads.	maximum	no	EPR SAR [24] APR1400 DCD [16]

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PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
1.5.5 Minimum Soil Angle of Internal Friction	Design assumption for the minimum value of the internal friction angle of foundation soils, fill soil, or excavation slopes that would provide a safe design of plant through soil structure interaction analyses including sliding along the base	≥35° below footprint of nuclear island at its excavation depth. If a minimum soil angle of internal friction is below 35 degrees, a site-specific analysis shall be performed using the site-specific soil properties to demonstrate stability	maximum	no	EUR Vol. 2 [11] UKP-GW-GL-793NP [34] APR1400 DCD [16]
1.5.6 Slope Instability	Slope instability is a phenomenon resulting from steep slopes, high ground water, and/or vibratory ground motion but not related to surface faulting. The movements encompass avalanches, landslides and general earth movements.	Slope instability which could affect the safe operation of the NPP or which could hinder emergency response is not permitted. If there is found to be a potential for slope instability that could affect the safety of the nuclear installation, the hazard shall be evaluated by using parameters and values for the site specific ground motion.		no	IAEA SSR-1 [15] APR1400 DCD [16] EPR SAR [24] UKP-GW-GL-793NP [34]
1.6 Tornado (Design Bases)					
1.6.1 Maximum Pressure Drop	The design assumption for the decrease in ambient pressure from normal atmospheric pressure due to the passage of the tornado.	4 kPa	minimum	no	US NRC 1.76 [27]
1.6.2 Maximum Rotational Speed	The design assumption for the component of tornado wind speed due to the rotation within the tornado.	57 m/s	minimum	no	US NRC 1.76 [27]
1.6.3 Maximum Translational Speed	The design assumption for the component of tornado wind speed due to the movement of the tornado over the ground.	14 m/s	minimum	no	US NRC 1.76 [27]

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PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
1.6.4 Maximum Wind Speed	The design assumption for the sum of maximum rotational and maximum translational wind speed components.	72 m/s	minimum	no	US NRC 1.76 [27]
1.6.5 Missile Spectra	The design assumptions regarding missiles that could be ejected either horizontally or vertically from a tornado. The spectra identify mass, dimensions and velocity of credible missiles.	130 kg (0.168 m dia x 4.58 m long) steel pipe having a velocity of 24 m/s 1 178 - 1814.4 kg automobile at a velocity of 24 horizontal and 33.1 m/s vertical 0.0669 kg solid steel sphere, 2.54 cm dia, having a velocity of 6 m/s horizontal and 5.2 m/s vertical.	range provided	no	US NRC 1.76 [27] NEI-ESP-PPE Worksheet [17]
1.6.6 Radius of Maximum Rotational Speed	The design assumption for distance from the centre of the tornado at which the maximum rotational wind speed occurs.	45.7 m	maximum	no	US NRC 1.76 [27]
1.6.7 Rate of Pressure Drop	The assumed design rate at which the pressure drops due to the passage of the tornado.	13 mbar/s	minimum	no	US NRC 1.76 [27]
1.7 Wind (Non Tornado)					
1.7.1 Wind Speed (3 second gust)	The design wind for which the facility is designed – basic wind speed 3 second gust velocity associated with a 100-year return period (straight line) at 10 m above ground level in the site area	43 m/s 70 m/s The revised SANS 10160 code of practice gives a maximum basic wind speed of 52 m/s for the whole country.	minimum	no	EUR Vol. 2 [11] EIA Consistency Data Set [5]
1.7.2 Importance Factors	Multiplication factors applied to basic wind speed to develop the plant design.	1.15 safety related 1.0 non safety related	minimum	no	EUR Vol. 2 [11] N-REP-01200-10000 [21]

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PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
1.8 Lightning	An atmospheric electrostatic discharge accompanied by thunder, which typically occurs during thunderstorms, and sometimes during volcanic eruptions or dust storms.	First stroke: 200 kA, 10/350 µs Second stroke: 50 kA, 0,25/100 µs		no	EUR Vol. 2 [11]
2. Plant Heat Sink					
2.1 Ambient Air Requirements and Humidity Conditions					
2.1.1 Normal Shutdown Max Ambient Temperature (1% exceedance)	Assumption used for the maximum ambient temperature that will be exceeded no more than 1% of the time, to design plant systems capable of effecting normal shutdown under the assumed temperature condition	37.8°C DB / 25°C WB coincident	minimum	no	AP1000 DCD [33]
2.1.2 Normal Shutdown Max Wet Bulb Temperature (1% exceedance)	Assumption used for the maximum wet bulb temperature that will be exceeded no more than 1% of the time – used in design of plant systems that must be capable of effecting normal shutdown under the assumed temperature condition.	26.7°C WB on-coincident	minimum	no	AP1000 DCD [33]
2.1.3 Normal Shutdown Min Ambient Temperature (1% exceedance)	Assumption used for the minimum ambient temperature that will be exceeded no more than 1% of the time to design of plant systems that must be capable of effecting normal shutdown under the assumed temperature condition.	-23.3°C	maximum	no	AP1000 DCD [33]
2.1.4Maximum Air Design Temperature (0% exceedance)	Assumption used for the maximum ambient temperature that will never be exceeded – used in design of plant	Long term base (> 7 days) = 42°C, Short term daily (6hours to 7 days) =	minimum	no	NSIP0321 [8]

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PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
	systems that must be capable of supporting full power operation under the assumed temperature condition.	46°C, Instantaneous (6 hours) = 50°C			
2.1.5 Maximum Wet Bulb Temperature (0% exceedance)	Assumption used for the maximum wet bulb temperature that will never be exceeded – used in design of plant systems that must be capable of supporting full power operation under the assumed temperature condition.	30.1°C WB non-coincident	minimum	no	AP1000 DCD [33]
2.1.2 Minimum Air Design Temperature (0% exceedance	Assumption used for the minimum ambient temperature that will never be exceeded – used in the design of plant systems that must be capable of supporting full power operation under the assumed temperature condition.	Long term base (> 7 days) = 2.8°C, Short term daily (6 hours to 7 days) = 0 °C, Instantaneous (6 hours) = -1.3°C	maximum	no	NSIP0321 [8][7]
2.1.3 Design Basis Maximum External Humidity	Assumption used for the maximum external humidity that the standard design shall be able to deal with (Relative humidity)	Winter: ≥20% (reaching as high as 100% for the Western Cape) Summer: 100%	minimum	no	EIA Consistency Data Set [5] NSIP03251 [8]
2.2 Condenser					
2.2.1 Max Inlet Temp Condenser/Heat Exchanger	Design assumption for the maximum acceptable circulating water temperature at the inlet to the condenser or cooling water system heat exchangers	13°C	minimum	no	Koeberg Safety Analysis Report [9]

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2.2.2 Condenser/Heat Exchanger Duty	Design value for the waste heat rejected to the circulating water system across the condenser	3 400 MW	maximum	yes	N-REP-1200-10000 [21]
2.3 Once-Through Cooling					
2.3.1 Cooling Water Discharge Temperature	Expected temperature of the cooling water at the exit of the condenser/heat exchangers	45.6°C	maximum	no	N-REP-01200-10000 [21]
2.3.2 Cooling Water Flow Rate	Total cooling water flow rate through the condenser (also the rate of withdrawal from and return to the water source)	76 000 l/s	maximum	yes	EIA Consistency Data Set [5]
2.3.3 Cooling Water Temperature Rise	Temperature rise across the condenser (temperature of water out minus temperature of water in)	12°C	maximum	no	KNPS Coastal Water Discharge Permit Application [7]
2.3.4 Evaporation Rate	The expected (and maximum) rate at which water is lost by evaporation from the receiving water body as a result of heating in the condenser	915 l/s	maximum	yes	N-REP-01200-10000 [21]
2.3.5 Heat Rejection Rate	The expected heat rejection to a receiving water body	3 397 MW/hr	maximum	yes	N-REP-01200-10000 [21]
2.3.6 Cooling Water Temperature Range	The range of water temperatures at the intake	-0.5°C - 30°C	range	no	EIA Consistency Data Set [5]
2.3.7 Maximum increase in the cooling water source	Design value for the maximum temperature increase in the cooling water source	The intake and the outfall configuration should not result in a net rise in CW. The maximum increase in the temperature of the recirculated water should be < 1.5°C.	minimum	yes	EIA Consistency Data Set [5]

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PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
		Increases in the water temperature will most likely be limited by environmental issues for each specific site.			
3 Potable Water/ Waste System					
3.1 Discharge					
3.1.1 Flow Rate (Effluent Normal)	Expected (normal) effluent flow rate from the potable/ water system to the Waste Water Treatment System (WWTW). 80% of sewerage directed to municipal WWTW. The rest (20% <100m3/day) to be treated on site before discharge into the sea.	0.0384 m^3/s Dependent upon chosen reactor technology		yes	331-301 [6] 240-129930970 [10] KNPS Coastal Water Discharge Permit Application [7]
3.1.2 Flow Rate (Effluent Maximum)	Expected (maximum) effluent discharge rate from on-site WWTW	7.8 l/s (Koeberg) 16.7 l/s (nuclear new build) Dependent upon chosen reactor technology	maximum	yes	KNPS Coastal Waters Discharge Permit Application [7]
3.2 Water Requirements					
3.2.1 Potable Water Requirements	Potable water is water of sufficiently high quality that can be consumed or used with low risk of immediate or long term harm. It is free from pollution, harmful organisms and impurities. Desalination plants may be	27.2 l/s (site establishment) 35.3 l/s(early site activities) 36.5 l/s (early construction activities)	maximum	yes	EIA Consistency Data Set [5] 331-301 [6]

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PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
	used to produce potable water in the NPP. The potable water system is designed to furnish water for human consumption in compliance with National Primary Drinking water standards bacteriological and chemical quality requirements.	31.6 l/s (construction) 15 l/s (operation)			240-129930970 [10]
3.2.2Maximum Use	The maximum short-term rate of withdrawal from the water source for potable water systems.	52 l/s	maximum	yes	331-301 [6]
3.2.3 Monthly Average Use	The average rate of withdrawal from the water source for the potable water systems.	15 l/s	maximum	yes	331-301 [6] 240-129930970 [10]
3.2.4 Stored Water Volume (potable water supply requirements)	Total capacity of on-site water storage tanks/reservoirs (operational phase)	Site water (SEP) – 37 492 m^3 Feed water (SER) – 6 210 m^3 Demineralised (SED) – 1 035 m^3 Condensate feed water (ASG) – 3 312 m^3 Demineralised primary make-up water (REA) – 35 190 m^3 Borated Refuelling Water (PTR) – 6 624 m^3	maximum	yes	240-129930970 [10]
4. Demineralised Water System					
4.1 Discharge to Site Water Bodies					

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PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
4.1.1 Flow Rate	The expected (and maximum) effluent flow rate from the demineralised processing system to the receiving water body.	4.42 l/s	maximum	yes	N-REP-01200-10000 [21]
4.2 Raw Water Requirements					
4.2.1 Capacity per unit		2 450 m^3/day	maximum	yes	Koeberg Safety Analysis Report [9]
4.2.2 Conductivity		<170 mS/m	maximum	yes	EIA Consistency Data Set [5]
4.2.3 Silica (SiO2)		<20 x 10^{-3} mg/l	maximum	yes	EIA Consistency Data Set [5]
4.2.4 Free bases (CaCO3)		<15 mg/l	maximum	yes	EIA Consistency Data Set [5]
4.2.4 Sodium		<200 mg/l	maximum	yes	EIA Consistency Data Set [5]
4.2.5 Suspended solids		5 x 10^{-3} mg/l	maximum	yes	EIA Consistency Data Set [5]
4.2.6 Maximum Use	The maximum short-term rate of withdrawal from the water source for the demineralised water system	34.07 l/s Dependent upon chosen reactor technology	maximum	yes	N-REP-01200-10000 [21]
4.2.7 Monthly Average Use	The average rate of withdrawal from the water source for the demineralised water system	5.1 l/s Dependent upon chosen reactor technology	maximum	yes	N-REP-01200-10000 [21]

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PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
4.2.8 Stored Water Volume	Capacity of demineralised water storage tanks/reservoirs.	1 035 m^3 {1 Demineralised water tank (SED) [500 m^3]} 35 190 m^3 {2 Demineralised primary make-up water tanks (REA) [8 500 m^3] 17 595 m^3}	maximum		331-301 [6] 240-129930970 [10]
5. Fire Protection System					
5.1 Raw Water Requirements					
5.1.1 Maximum Use	The maximum short term rate of withdrawal from the water source for the fire protection water system (does not include large area fire requirements).	39.4 l/s Dependent upon chosen reactor technology	maximum	yes	N-REP01200-10000 [21]
5.1.2 Monthly Average Use	The average rate of withdrawal from the water source for the fire protection system	0.315 l/s Dependent upon chosen reactor technology	maximum	yes	N-REP-01200-10000 [21]
5.1.3 Stored Water Volume	The capacity of fire water storage impoundments, basins, reservoirs or tanks.	1 water tank (SEP) = 1 730 m^3	maximum	yes	240-129930970[10]
6. Miscellaneous Drain					
6.1 Discharge to Site Water Bodies					
6.1.1 Flow Rate	The expected normal (and maximum) effluent flow rate from miscellaneous drains to the receiving water body.	3.2 l/s (Maximum) Dependent upon chosen reactor technology	maximum	yes	N-REP-01200-10000 [21]

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PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
7. Fuel					
7.1 Fuel Design					
7.1.1 Fuel Enrichment	Concentration of U-235 in the fuel uranium	4.95%	maximum	no	EIA Consistency Data Set [5]
7.1.2 Mass of fuel in core	The total mass of uranium dioxide in the core	187.98 T	maximum	yes	EIA Consistency Data Set [5]
7.1.3 Mass of Zirconium alloys in core	The total mass of all zirconium alloys in the core	c.43 T	maximum	yes	N-REP-01200-10000 [21]
7.2 Spent Fuel					
7.2.1 Total Mass of used fuel during Licensed Operation	The total mass of used fuel (per unit) during the operating license life of the plant.	c.2712 T	maximum	yes	N-REP-01200-10000 [21]
7.3. Spent Fuel Storage Pool					
7.3.1 Pool Capacity	The number of years of reactor operation that spent fuel storage can accommodate all used fuel from the core	10 years + full core offload (nominal) 18 years + full core offload (high density) Vendor dependent	minimum	no	N-REP-01200-10000 [21]
7.3.2 Pool Volume	Volume of spent fuel storage pool	1 481 m^3 total volume inside fuel pool below normal water level (without fuel assemblies or racks) 1 185 m^3 available for fuel storage Vendor dependent	maximum	yes	N-REP-1200-10000 [21]

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PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
7.3.3 Annual dose	Annual dose at the EAB due to operation of the spent fuel storage pool	The annual dose at the EAB solely due to the spent fuel pool is not explicitly calculated. The contribution of operation of the spent fuel pool is expected to be a small percentage of the total dose (negligible)	maximum	yes	N-REP-01200-10000 [21]
7.4 Spent Fuel Dry Storage					
7.4.1 Acreage	The land usage required to provide onsite dry storage of spent fuel for the expected plant lifetime, including the fenced off area necessary to provide an acceptable radiation protection and security zone.	c.6 ha	maximum	yes	NEI-ESP-PPE Worksheet [17] N-REP-01200-10000 [21]
7.4.2 Storage Capacity	The years of plant operation for which spent fuel dry storage should be provided without taking credit for capacity in the spent fuel pool,	60 years	maximum	no	NEI-ESP-PPE Worksheet [17] N-REP-01200-10000 [21]
7.4.3 Annual dose	Annual dose at the EAB due to operation of the spent fuel dry storage area	<2E-5 Sv/a <2 mrem/a	maximum	no	N-REP-01200-10000 [21]
8. Plant Characteristics					
8.1 Access Routes					
8.1.1 Heavy Haul Routes	The land usage required for permanent heavy haul routes to support normal operations and refuelling	3.64 ha	maximum	no	N-REP-01200-10000 [21] EPR SAR [24]
8.1.2 Maximum Shipment Weight	The weight of the heaviest expected shipment during normal plant operations and refuelling	c.300 T Vendor specific.	maximum	no	N-REP-01200-10000 [21] UKP-GW-GL-793NP [34]

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PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
8.2 Acreage (To Support Plant Operations)					
8.2.1 Office Facilities	The land area required to provide space for office facilities.	10ha	maximum	Note 1	UKP-GW-GL-793NP [34]
8.2.2 Parking Lots	The land area required to provides space or parking lots	c.2.5 ha	maximum	Note 1	N-REP-01200-10000 [21]
8.2.3 Permanent Support Facilities	The land area required to provide space for permanent support facilities.	6.5 ha	maximum	Note 1	N-REP-01200-10000 [21]
8.2.4 Power Block	The land area required to provide space for power block facilities. Power block is defined as all structures, systems and components which perform a direct function in the production of, transport of, or storage of heat energy, electrical energy or radioactive wastes. Also included are structures, systems and components that monitor, control or protect the public health and safety.	6.9 ha	maximum	yes	N-REP-01200-10000 [21]
8.2.5 Protected Areas (maximum)	The land area required to provide space for Protected Area facilities. Provide list of structures and associated acreage of each.	19.02 ha	maximum	Note 1	N-REP-01200-10000 [21]
8.2.6 Switchyard (maximum)	The land usage required for the high voltage switchyard used to connect the plant to the transmission grid	9.7 ha	maximum	no	N-REP-01200-10000 [21]
8.3. Plant Population					

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PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
8.3.1 Construction	Maximum number of people on site during construction.	5 000 construction workers 2 200 vendor staff 180 Eskom Project Staff	maximum	no	EIA Consistency Data Set [5]
8.3.2 Operation	The estimated number of total permanent staff to support operations of the plant.	1 385 persons	maximum	Note 1	EIA Consistency Data Set [5]
8.3.3 Refuelling/Major Maintenance	The estimated number of total permanent staff required to conduct refuelling and major maintenance activities.	1 000 persons	maximum	no	N-REP-01200-10000 [21] UKP-GW-GL-793NP [34]
9. Construction					
9.1 Access Routes					
9.1.1 Construction Module Dimensions	The maximum expected length, width, and height of the largest construction modules or components and delivery vehicles to be transported to the site during construction	Reactor Vessel 6.71 D x 10.36 L Steam Generator 6.10 D x 24.38 L, Turbine Rotor 5.49 D x 8.84 L Generator Stator 5.49 D x 12.19 L Modules by barge: 27.43 (H) x 24.99 (W) x 28.35 (L) OR 39.62 (D) x 15.54 (H) (All dimensions in m)	maximum	no	N-REP-01200-10000 [21]
9.1.2 Heaviest Construction Shipment	The maximum expected weight of the heaviest construction shipment to the site.	861.8 T	maximum	no	N-REP-01200-10000 [21]
9.2 Acreage					

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PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
9.2.1 Laydown Areas	The area required to provide space for construction support facilities.	5.1 ha (for laydown only)	maximum	no	N-REP-01200-10000 [21]
9.2.2 Temporary Construction Facilities	The land area required to provide space for temporary construction support facilities.	4.9 ha (concrete batch plant)	maximum	no	N-REP-01200-10000 [21]
9.2.3 Construction Parking Lot	The land area required to provide space for parking lots.	16.2 ha (Construction parking with separate construction site access road)	maximum	no	N-REP-01200-10000 [21]
9.3 Construction					
9.3.1 Construction Noise	The maximum expected sound level due to construction activities, measured ≥15 m from the noise source	101 dB(A) at 15 m from noise source	maximum	no	N-REP-01200-10000 [21]
10. Decommissioning					
10.1 Access Routes					
10.1.1 Decommissioning Dimensions	The maximum expected length, width, and height of the largest components and delivery vehicles to be transported on or off site during decommissioning	See 9.1.2	maximum	no	N-REP-01200-10000 [21]
10.1.2 Heaviest Decommissioning Shipment	The maximum expected weight of the heaviest shipment on or off the site during decommissioning	See 9.1.2	maximum	no	N-REP-01200-10000 [21]
10.2 Acreage					
10.2.1 Laydown Area	The land area required to provide space	Unknown at this stage	maximum	no	

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PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
	for decommissioning support facilities				
10.2.2 Temporary Decommissioning Facilities	The land required to provide space for temporary decommissioning facilities	Unknown at this stage	maximum	no	
10.3 Decommissioning Noise	The maximum expected sound level due to decommissioning activities ≥15 m rom the noise source	80 -90 dB(A) at 15 m from noise source	maximum	no	N-REP-01200-10000 [21]
10.4 Plant Decommissioning Population	Peak employment during plant decommissioning.	100 – 200 persons	maximum	yes	N-REP-01200-10000 [21]
10.5 Site Preparation Duration	Length of time required to prepare the site for decommissioning.	Variable based on plant owner decommissioning strategy and plan. OR 1 to 2 years (Assuming preparation encompasses nuclear fuel (both new and spent) removal from site and removal of all radioactive wastes)	maximum	no	N-REP-01200-10000 [21]
10.6 Delay Time Prior to Decommissioning	Length of time required to allow radiation levels to decrease prior to commencing decommissioning.	If deferred dismantling is planned, then a wait time of 10 years is recommended to allow for short and intermediate lived nuclides to decay and Co-60 to reduce by a factor of four (half- life = 5.2 years)	maximum	no	N-REP-01200-10000 [21]
10.7 Mass of Plant Material and Components					
10.7.1 Mass of Highly Active Material	The total mass of plant components and materials that are highly active and require specially shielded handling techniques during, and/or significant time delays prior	800 T (steel and concrete)	maximum	yes	N-REP-01200-10000 [21]

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PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
	to, decommissioning				
10.7.2 Mass of Moderately Active Material	Total mass of plant components and materials that are moderately active and require some shielded handling techniques during, and/or some time delays prior to, decommissioning	900 T (concrete)	maximum	yes	N-REP-01200-10000 [21]
10.7.3 Mass of Low Activity Material	Total mass of plant components and materials that are slightly active but require no shielded handling techniques during, and/or no time delays prior to, decommissioning	15 000 T	maximum	yes	N-REP-01200-10000 [21]
10.7.4 Mass of Non-Active Material	Total mass of plant components and materials that are not active but must be transported and/or handled during decommissioning	180 000 T	maximum	yes	N-REP-01200-10000 [21]
10.8 Decommissioning Materials					
10.8.1 Concrete	Total mass of concrete to be used in decommissioning	Not available	maximum	yes	N-REP-01200-10000 [21]
10.8.2 Land fill	Total mass of landfill to be used in decommissioning	Not available	maximum	yes	N-REP-01200-10000 [21]

Note 1: Prorated parameter value for multiple units on site will be greater than the single unit value but no greater by number of units on site.

Note 2: * Source Term Tables and Solid Activity Tables are not contained in this document.

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	External Event	Plant Parameter Envelope Reference Values
1	External natural fire	SDV: 1 to 2 km depending on the land vegetation cover. Vegetation that can result in severe fires (e.g. dense forests) will require a larger distance.
	Human Induced Events	
2	Aircraft crash	Distance from commercial airports and runway orientation not to be controlling factors. Design basis to include aircraft in the general, military and commercial categories. Impact to be calculated separately for the mass of the aircraft engine and/or landing gear as well as the mass of the aircraft. Generally the engine impact will govern the minimum thickness of the structural element i.e. local effects and the aircraft impact, the global structural damage. Impact to be defined in terms of force time histories .Functional damage to SSC as a result of shock loads/vibratory effects to be checked. Fire damage to be checked in the crash zone. Aircraft crash analyses to be performed for general aircraft such as the Cessna 210 and the Lear Jet 23, military aircraft such as the Phantom RF-4E, and commercial aircraft such as the Boeing 777.The site specific aircraft crash hazard study will dictate whether other aircraft should be included.
3	Hazards from nearby land-based Installations	
3.1	External missiles in general (from tornadoes, high-energy rotating machinery, etc.)	Missile parameters for rotating machinery to be defined for each postulated missile.
3.2	External explosion (*pressure, fire, projectiles, smoke, vibrations, etc.*), solid, liquid or gaseous	$P_{wave} = 10^4$ Pa Duration = 300 ms Velocity = 4 500-7 000 m/s
3.3	Industrial facility incident	The effects of a rupture of pressure vessels, fluid pipelines and so forth that serve industrial facilities located near a nuclear power plant. Pressure and heat loads resulting from chemical energy dissipated Distance to pipelines to be limited such that they do not constitute controlling events for transient pressure waves. Pressure wave to be less than stated in item 18.2. Mitigating action to be taken to protect the safe operation of the nuclear installation(s) against the potential discharge of toxic liquids/gases.

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	External Event	Plant Parameter Envelope Reference Values
3.4	Military facility incident	Distance to military facilities to be limited such that they do not constitute controlling events. Preventative actions to be taken such that missile and heat loads may not originate from such installations. Pressure wave to be less than stated in item 3.2.
3.5	Pipeline accident	Pressure and heat loads, toxic/flammable vapour clouds or liquids - distance to pipelines to be limited such that they do not constitute controlling events for transient pressure waves. Pressure wave to be less than stated in PPE item 3.2. Mitigating action to be taken to protect the safe operation of the nuclear installation(s) against the potential discharge of toxic liquids/gases.
3.6	Transportation accident	
3.7	Electromagnetic interference from off-site and/ or on-site activated sources. The process in which external signals are emitted and super-imposed on fundamental signals controlling critical plant instrumentation resulting in false, erroneous, inaccurate and/ or unwanted operation of equipment.	Hazard to be mitigated. Preventative action to be taken in the design phase to prevent an impact on the safe operation of the nuclear installation(s).
3.8	Release of asphyxiant and toxic gases	Distance to potential sources to be limited such that they do not constitute controlling events. Preventative action to be taken in the design phase to prevent an impact on the safe operation of the nuclear installation(s).
3.9	Release of corrosive gases and liquids, including atmospheric attack (salt) and aerosols.	
4	Extra-terrestrial objects: meteorites; satellite re-entry	Generally not considered in the design. Impact resistance of safety related structures designed for aircraft crash.

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Appendix 6-D: Example of an External Event Interaction Matrix

There are various possible approaches to screen the potential combinations of EE's but the basis of any approach consists of an 'interaction' matrix. The matrix lists the set of EEs to be assessed in terms of their potential interaction in the first column and first row. It facilitates a systematic and iterative process to either screen out combinations or to identify combinations of events for further assessment. Each combination has to be interrogated in a systematic manner, using expert opinion, published literature and studies on EEs and prior assessments of individual EE. It is important that a team representing different engineering and scientific disciplines participate in the EE Matrix exercise to question the plausibility and credibility of combinations. Screening out combinations must be substantiated and documented. An EE screening matrix may require multiple reviews or passes.

Annotation of the Matrix cell of the EE combinations is carried as follows:

First pass:

(Note: Column/Row colour – Red; Green)

X = Event individually or in combination Screened Out; event cannot occur (e.g. dam failure since no dam in the region) or events combinations impossible (e.g. high sea water temperature and low sea water temperature).

0 = Combination not considered further based on the subjective concept of plausibility/expert opinion, e.g. tornado and extreme snow. Individually the events are plausible but in combination not.

1 = Further consideration of combination

E = Overlap of the EE sets of hazard parameters and the one event envelops the other

Second/subsequent pass(es):

1 in shaded block = More detailed consideration and assessment of combination

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Comments on the combinations can be documented by using a unique identifier, by using a (row, column) number. For example (strong winds and surface ice) is comment

(1;8): Screened out because ……(site specific justification then follows).

Events initially screened out on assessment of single event considerations have to be considered in the EE screening matrix since they may be a consequence of another EE when combinations are considered. ***Table 6E.1*** illustrates sections, as an example, of a large EE interaction matrix.

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Table 6E.1: Illustration of subsections of an EE interaction matrix

EE Combination Matrix				Flooding					Extra-terrestrial	
			35	36	37	38	39	40	41	42
			Site instability by erosion from the sea	Tsunami	Sea water level - tides, seiches, storm surge, waves, landslide into sea	Dams	Rivers	Groundwater related effects	Astroids and satellites	Solar flares (CME)
Human induced events	21	Chemcial release on-site	0	1	E	X	X	0	X	0
	22	Chemical release off-site	0	1	0	X	X	0	X	0
	23	Electromagnetic interference	0	0	0	X	X	0	X	E
	24	Aircraft crash	0	0	0	X	X	0	X	1
	25	Missiles	0	1	0	X	X	0	X	0
	26	Heavy transport on-site - direct impact	0	0	0	X	X	0	X	0
	27	Ship release- solid or fluid	0	1	1	X	X	0	X	0
	28	Ship collision - direct impact	0	1	1	X	X	0	X	0

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EE Combination Matrix			Geological and seismotectonic events					Flooding			
			31	32	33	34	35	36	37	38	39
			Seismic (includes soil liquefaction)	Other geological phenomena - subsistence, uplift, mining, quarrying	Slope instability - avalanches, land slides	Volcanism and related phenomena - Lava, ash, gases, lahars, missiles, lightning,, flood	Site instability by erosion from the sea	Tsunami	Sea water level - tides, seiches, storm surge, waves, landslide into sea	Dams	Rivers
	34	Volcanism and related phenomena: Lava, ash, gases, lahars, missiles, lightning,, flood					X	1	X	X	X
	35	Site instability by erosion from the sea						1	1	X	X
Flooding (External)	36	Tsunami							E	X	X
	37	Sea water level - tides, seiches, storm surge, waves, landslide into sea								X	X
	38	Dams									X
	39	Rivers									
	40	Groundwater related effects									
	41	Astroids and satellites									

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