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CSNI Status Report and Perspectives

Advances in the Analysis and Management of External Hazards

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Advances in the Analysis and Management of External Hazards

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The mission of the NEA is:

- to assist its member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for the safe, environmentally sound and economical use of nuclear energy for peaceful purposes.
- to provide authoritative assessments and to forge common understandings on key issues as input to government decisions on nuclear energy policy and to broader OECD analyses in areas such as energy and the sustainable development of low-carbon economies.

Specific areas of NEA competence include the safety and regulation of nuclear activities, radioactive waste management, radiological protection, nuclear science, economic and technical analyses of the nuclear fuel cycle, nuclear law and liability, and public information. The NEA Data Bank provides nuclear data and computer program services for participating countries.

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Foreword

The Nuclear Energy Agency (NEA) Working Group on External Events (WGEV) was established in 2014 to improve the understanding and treatment of external hazards that would support the continued safety performance of nuclear installations and improve the effectiveness of regulatory practices in NEA member countries.

The WGEV is a forum for experts to exchange information and experience on external events in member countries, thereby promoting co-operation and maintaining an effective and efficient network of professionals.

This report aims to facilitate communication between reactor safety stakeholders by summarising the main aspects of the WGEV's activities: the context and key safety topics related to the analysis and management of external events; the approach and methodologies to cope with reactor safety issues; and a discussion of potential future activities. This report was approved by the CSNI in June 2024.

Acknowledgements

The Nuclear Energy Agency (NEA) Committee on the Safety of Nuclear Installations (CSNI) and the Working Group on External Events (WGEV) acknowledge the significant contributions of those individuals who had a key role in the conduct and success of the activities described in this report, including past chairs, bureau members, task leaders, contributors and members, as well as secretaries, for their selfless contributions.

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List of abbreviations and acronyms

CAPS	Committee on the Safety of Nuclear Installations Activity Proposal Sheet (NEA)
CNRA	Committee on Nuclear Regulatory Activities (NEA)
CSNI	Committee on the Safety of Nuclear Installations (NEA)
FHA	Flood hazard assessment
IAEA	International Atomic Energy Agency
IE	Initiating event
LIP	Local intense precipitation
MCMC	Markov Chain Monte Carlo
NEA	Nuclear Energy Agency
OECD	Organisation for Economic Co-operation and Development
PFHA	Probabilistic flooding hazard assessment
PSA	Probabilistic safety analysis
SMR	Small modular reactors
SSC	Structures, systems and components
TGNEV	Task Group on Natural External Events (NEA)
TSO	Technical and scientific support organisations
WGEV	Working Group on External Events (NEA)
WGHOF	Working Group on Human and Organisational Factors (NEA)
WGIAGE	Working Group on Integrity and Ageing of Components and Structures (NEA)
WGOE	Working Group on Operational Experience (NEA)
WGRISK	Working Group on Risk Assessment (NEA)
WGRNR	Working Group on the Regulation of New Reactors (NEA)
WPNEM	Working Party on Nuclear Emergency Matters (NEA)
WMO	World Meteorological Organisation

Chapter 1. **Introduction**

The March 2011 accident at the Fukushima Daiichi Nuclear Power Plant triggered discussions about natural external events that are of low frequency but of high consequence. To address these issues and determine which events would benefit from international co-operative work, the Task Group on Natural External Events (TGNEV) was established by the NEA Committee on the Safety of Nuclear Installations (CSNI) at its June 2013 meeting. In June 2014, the CSNI decided to reorganise the TGNEV into the Working Group on External Events (WGEV) to improve the understanding and treatment of external hazards and support the continued safety performance of nuclear installations, as well as improve the effectiveness of regulatory practices in NEA member countries. The WGEV is a forum for experts to exchange information and experience on external events in member countries, thereby promoting co-operation and maintenance of an effective and efficient network of experts.

The WGEV currently has 40 active members from 18 countries and the International Atomic Energy Agency (IAEA). In addition to an observer from the IAEA, members are from Austria, Belgium, Bulgaria, Canada, Czechia, Finland, France, Germany, Japan, Korea, the Netherlands, Poland, Romania, Spain, Sweden, Switzerland, Türkiye and the United States. The World Meteorological Organisation (WMO) also participates periodically. The group includes representatives from regulators, technical support organisations and utilities.

The role of the WGEV is to ensure collaboration among NEA member countries on the phenomena of external hazards (it interacts with the NEA Working Group on Integrity and Ageing of Components and Structures [WGIAGE] on seismic events), in particular:

1. Identifying sources of, and the application of, phenomenological information and data related to external hazards supporting regulatory decision making and event response.
2. Interacting with non-nuclear organisations on activities related to understanding the phenomena of external hazards and impacts on national and regional infrastructure.
3. Identifying commendable practices in the assessment of the phenomena of external hazards (hazards characterisation) related to impacts on nuclear facilities (deterministic aspects of external hazard effects on nuclear facilities).
4. Comparing and benchmarking practices and methodologies applied by member countries in the characterisation of external hazards. Collaborating with WGRISK in those areas where the understanding of the phenomena of external hazards interfaces with the application of probabilistic safety assessment modelling, assumptions, and methodologies.
5. Supporting NEA committees and working groups when requested in understanding the effects of external hazards (hazards characterisation) on nuclear facilities.

This report provides an overview of the activities of the WGEV since its inception in 2013 through the end of 2024.

Chapter 2. Objectives, issues and priorities

2.1. Objectives

The overall objective of the Working Group on External Events (WGEV) is to identify best practices for characterising external hazards and combinations of external hazards; assessing their consequences; and providing effective protective features and strategies. The working group has identified the following six goals to govern the work scope and to provide the technical basis required to properly characterise the risks associated with external events. The WGEV will also identify any gaps where additional R&D is needed.

- Goal 1: **Regulation of external hazards** – Identify the requirements and best practices in addressing external hazards to ensure nuclear safety.
- Goal 2: **Technical basis for external hazards, data collection, quantification and addressing uncertainty** – Identify best practices for characterising external hazards in terms of frequency, magnitude and duration.
- Goal 3: **Combinations of interrelated hazards** – Identify best practices for assessing combinations of hazards, either simultaneous or sequential, that are otherwise independently and individually assessed may not be challenging but, when combined within scenarios of interrelated events, can pose a significant risk.
- Goal 4: **Probabilistic methods to characterise external hazards** – Identify best practices for determining hazard curves for the evaluation of the impacts of external hazards on the safety of nuclear installations.
- Goal 5: **Challenges and impacts** – Identify best practices to ensure potential consequences and common-mode impacts, including direct and indirect effects, from the hazard have been considered.
- Goal 6: **Effective protection and mitigation concepts** – Identify best practices for evaluating the effectiveness of protection features and mitigation strategies.

The WGEV defines its technical activities by focusing on: 1) high consequence/low frequency external events; 2) external hazards that could potentially result in an event of high safety significance, broad relevance, and interest (i.e. affect more than a few countries); 3) uncertainties and technical issues associated with external event hazard assessment methodologies practices that could benefit from the ongoing work and co-operative efforts; and 4) external hazards that could potentially result in operational challenges and affect all the units on a site, and different sites at the same time.

To achieve the goals, the WGEV will:

- Seek to understand the commonalities and differences in the state-of-the-practices of countries, whether they be regulatory or technical (e.g. use of probabilistic and/or deterministic methods).
- Focus on how various external hazard assessment parameters were used to establish the design-basis limits and associated margins (e.g. considerations given to beyond-design-basis cliff edge effects).
- Leverage subject matter experts (SMEs) from national institutes, agencies or universities to aid in defining the external events' characteristics (e.g. including complex hazards which may produce several interrelated hazards) that may have significant effects on a nuclear site and plant safety – in terms of frequency, magnitude and duration (e.g. wind speed, water volume) – particularly when historical records are relatively short term (e.g. less than 100 years) and may potentially not be representative of stationary normalities (e.g. rare and extreme regional weather patterns).
- Understand the current state-of-practise for assessing combinations of hazards (e.g. storm surge; high-tide level, plus very high winds) that are otherwise independent and, when assessed individually, may not be challenging but when combined within scenarios of interrelated events could pose a significant risk (e.g. 100-year flood and mild earthquake, or river flood with high winds, 100-year storm and high storm surge).
- Seek to understand and categorise the direct, indirect and common-cause effects on safety resulting from external events by engaging subject matter experts to assist with the identification of a full range of potential effects and consequences. For example, high winds can impose loads directly on a nuclear plant but can also indirectly affect supplies of power and cooling water. Alternatively, an earthquake may lead to a dam failure which can cause flooding and loss of power.
- Focus on understanding how changes to the environment and land use conditions can impact the dynamics and severity of weather-driven external events. Specifically, it is important to understand the practises of accounting for the effects of climate change and other environmental changes that can contribute to the severity of natural external hazards over the lifetime of a nuclear site.
- Work with SMEs to assist in defining the criteria and characteristics used to design protective measures for various external events. Additional insight will be sought from SMEs on how to assess the effectiveness of these criteria and characteristics (e.g. using hazard-specific fragility estimates, walkdowns, and exercises for procedures and strategies).
- Work with national SMEs who are responsible for forecasting, monitoring, alerting, and warning the public and critical facilities of the severity of a pending external event (e.g. weather monitoring and flood forecasting). Additionally, seek to understand the expected actions and resources needed to effectively mitigate potential risks with real-time predictive onset of impact information (e.g. pre-established time limits to reach safe-cold shutdown and implementing supplementary measures).

- Engage and collaborate with other NEA working groups, as appropriate, such as the Working Group on Integrity and Ageing of Components and Structures (seismic and structural), the Working Group on Risk Assessment (probabilistic and deterministic hazard assessment methods and outputs), the Working Group on Human and Organisational Factors (human factors and reliability support related to the implementation of mitigation measures), the Working Group on Operating Experience (operational experience), the Working Group on the Regulation of New Reactors (plant siting and external event considerations), and the Working Party on Nuclear Emergency Matters (external event emergency preparedness and mitigation).

2.2. **Priority areas**

Completed and ongoing activities

The WGEV has conducted multiple activities looking into external hazards including coastal storms and tsunamis, riverine flooding, high winds and tornadoes. Activities were also performed on the approaches to screening hazards and benchmarking statistical methods.

For the hazards addressed, the WGEV typically discussed regulatory requirements, assessment methods, protection and mitigation measures and the effects of climate change.

The activities of the working group are provided in Chapters 3 and 4, as well as in Appendix A.

Activities to be considered in the future

The working group is considering further activities on topics related to:

- tsunamis;
- water control structure failures (e.g. dam failure mechanisms for various dam types; dam failure breach modelling; safety assessment and maintenance);
- extreme temperatures (e.g. extreme prolonged heat or extreme prolonged cold);
- protection and mitigation strategies (e.g. protective measures, protection and mitigation strategies, mobile equipment location);
- other aspects of the assessment of external hazards (e.g. methods, benchmarking, data collection and analysis);
- external fires;
- volcanic hazards;
- seasonal hazards (e.g. snow loads, ice storms, other effects of snow, droughts, spring rains, eutrophication);
- biological hazards;
- climate change;
- unintentional human-induced hazards.

Chapter 3. Outline and main technical achievements

3.1. Understanding the impact of external hazards on nuclear facilities: Severe weather and storm surge

Severe weather and storm surge project overview

One of the priorities identified by the TGNEV was to share regulatory approaches and technical methods for assessing the hazards posed by severe weather events involving high winds and the potential for flooding. To address this, the group identified two tasks. The first task was to develop a comprehensive survey which could be used to gain insights into the current state of knowledge. The second task would then use the outcomes and insights from the survey and conduct a workshop to assist with the identification of knowledge gaps and/or identify collaborative activities to fill such gaps.

Accordingly, a survey of practices for severe weather events involving high winds and flooding was prepared and circulated to CSNI members in the summer of 2014. The responses to the questionnaire provided useful insight into how the contributing countries review and assess the adequacy of protection against tropical cyclones (including typhoons and hurricanes), and tropical and extra-tropical storm types and their associated storm surges. With respect to severe weather and storm surge assessment methodologies, data, and models used, benefits could be obtained by:

1. gaining an in-depth understanding of how a deterministic storm surge assessment methodology is conducted, including the data requirements and the assumptions used to determine the design-basis levels for storm surge events;
2. gaining an in-depth understanding of probabilistic and statistical analysis, including the treatment of uncertainties, the data requirements and the assumptions used to define the design-basis surge level; and
3. understanding the limitations of the historical record/data for a particular nuclear power plant site (both in time and number of events), and how methods are used to combine the outcomes and insights from deterministic and probabilistic approaches.

Following an initial assessment of the survey results, a workshop was held that involved experts identifying the activities required to address the knowledge gaps. In this context, the workshop "Severe Weather and Storm Surge" focused on the current national regulatory approaches for the assessment of severe weather events and protection as well as on technical methods for assessing hazards and on the effectiveness of preventive measures.

The workshop proceedings were published in April 2018 in the NEA report *Understanding the Impact of External Hazards on Nuclear Facilities: Severe Weather and Storm Surge* (NEA, 2018).

Severe weather and storm surge project key messages

The following points were highlighted by the participants as topics of concern that needed further consideration (NEA, 2018):

1. The reliability of information and boundary conditions for the performance of hazard evaluations (e.g. how to use a return frequency threshold for the design-basis hazards considerations) should be improved.

2. Risk-informed decisions are essential to regulatory oversight and communication, but data for external hazards are sparse temporally and spatially. Therefore, using simulations and incorporating other data sources (i.e. paleodata) are key to extending the currently available data, though simulations need to be validated with consideration of available data.

3. The use of paleodata and historical data is important, though interpreting and using such data properly is challenging.

4. The uncertainties associated with data and modelling need to be better understood and quantified, and decision makers should be aware of the uncertainties and take them into account in their decision-making processes.

5. More fragility information needs to be gathered to support the application of insights gained from hazard assessments in a probabilistic safety assessment (PSA).

6. Climate change is introducing new challenges into the decision-making process and new approaches and models will be needed to identify and address these challenges.

It was also noted that it would be beneficial to continue information sharing with several other NEA working groups and with the Working Group on Risk Assessment (WGRISK) on hazard quantification for risk assessments. The workshop demonstrated that it is important for the nuclear and meteorological communities to work together to take advantage of methods, models, data and experiences in the understanding of severe weather phenomenon and the impacts on local, national and regional infrastructure. Furthermore, co-operation with subject matter experts and regional co-sharing of experience and data are important.

3.2. **Examination of approaches for screening external hazards**

Screening external hazards project overview

At its 58th meeting, the CSNI approved a recommended task on a science-based screening approach for external hazards to be pursued by the WGEV. It has long been recognised that external hazards can present a potential common cause source of initiating events that could challenge nuclear power plant safety. Modelling of these hazards is a common practice in many countries. It is widely acknowledged that it is not practicable to model all possible hazards in a risk assessment, and a screening process is employed to focus the risk assessment on the events that possess the characteristics that may result in unacceptable consequences and that occur with a frequency that is sufficiently high to warrant the imposition of additional protective actions to reduce the likelihood of occurrence, reduce the resultant consequences, or both. However, current practice shows a wide variety of criteria are used to screen external hazards for further consideration in nuclear power plant risk assessments. The objective of this activity was to provide the results of a survey of current approaches to external hazard screening and to describe potential science-based screening of external hazards. This report identifies both best practices and gaps that exist in the specification of such screening processes based on the current state of the practice.

The report contains a summary of external hazard screening practices from several countries including Canada, Germany, Finland, Russia, Switzerland and the United States, as well as international organisations such as the International Atomic Energy Agency, the Western Europe Nuclear Regulators Association, the Advanced Safety Assessment Methodologies: extended PSA (ASAMPSA) project and the Nuclear Energy Agency.

The scope of work for this activity was focused primarily on absolute frequency (probabilistic) screening and investigated the potential to develop a science-based approach for screening. Ideas explored in the enhanced screening approach included looking at a risk-informed (frequency and/or consequence) mechanism to determine natural limits to modelling for certain types of initiating events. A second idea was to examine screening approaches that rely on physical conditions (e.g. maximum atmospheric precipitation concentration may provide a physical limit for rainfall events) that may limit the magnitude of external hazards. Included in the screening consideration was the idea of how uncertainty may be captured and how it impacts potential screening approaches. The purpose of having a science focus in the screening was to supplement the statistics-based approaches to screening that are found in many current guidance reports.

Work conducted under the scope of this activity surveyed the relevant technical literature and guidance documents to ascertain the current state of the practice in assessing hazards probabilistically and applying the results within a decision-making framework (i.e. setting of appropriate policy goals). The results of this assessment were used to identify best practices, technological gaps and probabilistic methods that may be potentially useful in screening approaches found in current nuclear power plant risk assessments.

The report “Examination of Approaches for Screening External Hazards for Nuclear Power Plants” (NEA, 2019) was published in April 2019.

Screening external hazards project key messages

The report “Examination of Approaches for Screening External Hazards for Nuclear Power Plants” (NEA, 2019) provides a broad overview of current approaches, guidelines, and quantitative metrics for screening of external hazards. In general, there are three types of screening processes used in practice:

1. Deterministic screening, usually dictated by standard practice, judgement or regulatory requirements. This type of screening process is typically used in cases where hazards are excluded when they are not applicable to a specific facility.

2. Absolute frequency (or probability) screening. In this approach a specific frequency is selected as a cutoff value and events that occur at a frequency below

the specified cutoff can be excluded from consideration. For example, if the probability of a very large meteorite (e.g. > 5 km in diameter) hitting the Earth is 5×10^{-8} per year, it may be possible to choose to exclude events less frequent than this.

3. Relative probabilistic considerations conditional upon the specifics of a particular plant design. For example, conditional core damage probabilities (CCDPs) could be calculated for potential initiating events and compared to predetermined thresholds. This approach is used by the US NRC as part of the significance determination process to screen out minor issues from the process.

One of the findings was that guidance exists internationally that documents best practices outlined in the risk analysis community. For example, many of the reports and papers mentioned the need to screen and group hazards where applicable. A couple of notable processes were mentioned in many of the reviewed sources, including generic hazard or initiating event lists. Different types of grouping processes were identified, including grouping based upon facility type, hazard frequency, impacts on the facility, and consequences.

The following potential issues with existing screening processes were identified:

1. Varying definitions: Given the varying ages of the reports and different points of origination (and applications), the collected reports and papers evaluated did have various interpretations of applicable terms.

2. Reliance on deterministic technical basis: Deterministic approaches tend to set “worst case” limits for screening. In some cases, extreme values might provide information on possible “physical upper limits”; however, for many hazards the recorded periods for which observational data are available are limited.

3. Lack of consideration of uncertainty in the screening process: Almost exclusively in the reviewed sources (there are exceptions), the concept of uncertainty is not present in the screening process.

4. Absence of physics-based information integrated into statistical models: Most of the quantitative models that focus on external hazards’ frequency estimation are statistically based (relying on a probabilistic model and associated data) and typically have not included the physics of the process.

5. Lack of supporting rationale behind screening criteria: Many of the existing documents that provide quantitative screening guidance do not supplement the guidance with the “why” (i.e. the technical basis) for the suggested guidance.

This research identified potential ideas to develop science-based approaches, such as including physics-based limits to support screening processes. This report noted the ability to enhance screening by looking at a risk-informed mechanism to determine natural limits for certain types of initiating events and it provided an example where science-based limits could be integrated into the quantitative screening process.

3.3. Riverine flooding – Hazard assessment and protection of nuclear power plants

Riverine flooding project overview

The WGEV task entitled "Riverine flooding – Hazard assessment and protection of nuclear power plants" was designed to share regulatory practices and technical approaches for riverine flood hazard assessment (both deterministic and probabilistic) and for flood protection of nuclear power plants. The first activity involved in this task was to survey CSNI members so that they could share information on such regulatory practices and technical approaches. Following an initial assessment of the survey results, an international workshop was organised to involve relevant experts in identifying the activities required to address knowledge gaps. In this context, the international workshop on "Riverine flooding: hazard assessment and protection of nuclear installations" focused on current national regulatory approaches and operating experience, technical methods for the assessment of riverine flooding events, protection of nuclear installations against river floods and promotion of the effectiveness of preventive measures.

The workshop proceedings are available in the NEA report *Riverine Flooding: Hazard Assessment and Protection of Nuclear Installations* (NEA, 2020).

Riverine flooding project key messages

The workshop demonstrated that it is important for the nuclear and meteorological communities to work together to take advantage of methods, models, data and experiences in the understanding of flooding hazards and the impacts on local, national and regional infrastructure. Co-operation among experts, including non-nuclear experts, as well as regional co-operation will be key to share experience and data. Some of the issues that were highlighted by the participants are listed below.

1. There are various methods for flooding hazard assessment, from very simple approaches to highly complex and sophisticated models. Each method has its advantages, drawbacks and sources of uncertainty. These factors should be considered carefully when choosing the most suitable hazard assessment method for a given purpose.
2. For any hazard assessment, the availability of data is of paramount importance. Unfortunately, the database with respect to flooding is limited. Therefore, ways must be found to increase the relevant database and to supplement the data with additional information, e.g. from physics-based models/simulations.
3. Flooding can have many causes (e.g. rising water levels in adjacent waterbodies or heavy precipitation) and may affect an installation in many ways. Therefore, the hazard assessment should not focus on a particular flooding scenario but should try to cover all reasonable scenarios.
4. Both flooding hazard assessment and flooding protection measure reliability involve uncertainties. To account for the uncertainties and to increase the robustness of nuclear installations with respect to flooding risks, the flooding protection concept should comprise multiple layers, e.g. selection of an elevated site, augmented by a dyke and waterproofing of safety-related buildings as a third line of defence.

5. The demonstration of the effectiveness of flooding protection measures should consider ageing effects and should not be limited to the consideration of the water level (i.e. hydrostatic pressure) but should also include associated effects such as debris and dynamic loads.
6. As the protection against one hazard may also affect the protection measures against other hazards, the potential adverse effects of increasing the robustness with respect to a specific hazard should be considered carefully.
7. Sharing information regarding regulations, hazard assessment approaches and protective measures is an important element of understanding the impact of external hazards on nuclear facilities. The sharing of information needs to cross the boundary between the nuclear industry and other organisations that collect and analyse data on external hazards for use in assessing the impact of severe weather on society and its supporting infrastructure. Sharing includes reaching out to organisations responsible for modelling and predicting weather (i.e. national weather services, universities) and international organisations, such as the World Meteorological Organisation, to facilitate a more integrated national and international response to external hazards.
8. Probabilistic safety assessment provides an important input for a traceable and reproducible risk-informed regulatory decision-making process, but as highlighted in work on PSA for natural hazards done by the Working Group on Risk Assessment (WGRISK) (see "Probabilistic Safety Assessment (PSA) of Natural External Hazards Including Earthquakes" [NEA, 2014]), challenges remain for areas such as fragility analysis for non-seismic hazards, including external flooding, as discussed during this workshop. Within this context, research results related to external flooding, including the PFHA (Probabilistic Flooding Hazard Assessment), being conducted by universities, regulators, the nuclear energy industry and other organisations should be shared to the extent practical to develop a common data set for use in assessing the impact on nuclear power plants and other nuclear installations.

The following conclusions and recommendations were made based on the workshop presentations and the discussions during the technical sessions (NEA, 2020):

1. Sharing of information between the nuclear industry and non-nuclear organisations regarding regulations, hazard assessment approaches and protective measures is important to successfully understanding the impact of external hazards on nuclear power plants and other nuclear installations. Data received from neighbouring countries can also be used to broaden information on flooding phenomena.
2. Given the limited amount of available historical data, further work needs to be done to understand how metrics, such as a selected value for annual exceedance frequency, can be used in regulatory decision making and be clearly communicated to the public. It is necessary to augment temporally and spatially sparse historical data with simulations and other information to be able to make decisions associated with rare events. Simulation and modelling should be validated with consideration of available empirical data.
3. In the treatment of uncertainty, there are two important aspects: from a scientific perspective, there are uncertainties with data and modelling that need to be better understood and quantified; from a regulatory perspective, decision makers should be aware of the uncertainties in the scientific results and take them appropriately into account in their decision-making process.

4. Co-ordination of the work of the Working Group on External Events (WGEV) with other NEA working groups, primarily with the Working Group on Risk Assessment (WGRISK), is important to understand how better data and a better understanding of the phenomena associated with external events can be used to better assess the risk to public health and safety from nuclear power plants and other nuclear installations. Building on the results of this research will support the balance needed in risk-informed decision making between the use of deterministic and probabilistic methods.

5. Climate change is introducing new challenges into the decision-making process that will need to be considered. New approaches and models will need to be developed to identify and address these challenges.

3.4. Concepts and definitions for flooding protective measures

Concepts and definitions for flooding protective measures project overview

At its December 2017 meeting, the CSNI approved the task on concepts and definitions for protective measures in response to external flooding hazards. Operating experience has shown that external flooding can have an adverse impact on nuclear installations. Protection against these impacts is an important part of the regulatory framework of NEA member countries, with each regulatory authority establishing its own regulations, requirements, guidance and practices to ensure that adequate measures are put into place. To improve information sharing, the WGEV decided to prepare a report on the common concepts and terminology that can be used to describe the approaches to protecting nuclear installations from external floods.

This report was developed based on the responses to a WGEV survey on the requirements, concepts and terminology as applied within individual regulatory frameworks. The report provides a summary of concepts and terminology used in establishing measures to prevent, mitigate or recover from external flooding hazards (protective measures) based on feedback from Belgium, Canada, Czechia, Germany, Finland, France, Japan, the Netherlands, Korea, Sweden, Switzerland, and the United States.

The NEA report *Concepts and Terminology for Protecting Nuclear Installations from Flood Hazards* (NEA, 2022) was published in October 2022.

Concepts and definitions for flooding protective measures project key messages

Several recommendations, as listed below, can be made related to protective measures being used for external flooding hazards (NEA, 2022):

1. The primary layer of defence against external floods that could reasonably be expected to occur at a nuclear installation should consist of permanently installed, passive protective measures that are designed to prevent adverse impacts on safe operations (flooding preventive measures).

2. A key factor that should be considered in establishing this primary layer of defence is site elevation. The ground level of the site should be above the level of external floods that could be expected to occur, with a margin to account for uncertainty, based on the established frequency (dry site concept).

3. If the dry site concept cannot be achieved, it is recommended that an alternative concept that provides an equivalent level of protection be considered, including the use of exterior/peripheral barriers or a watertight volume.
4. It is also recommended that additional protective measures be used to account for flood sources, such as local intense precipitation, which due to their nature bypass some of the barriers traditionally used to protect the site from external flooding (site elevation, dams, dikes, levees, etc.).
5. Flooding mitigative measures should be used to avert facility impacts in the event of the failure of the flooding preventive measures or when external flood levels and loads exceed the conditions that the structure, systems and components were designed to be protected against.
6. The impacts on the facility structures, systems and components (facility impacts) should include all consequences caused by relevant hazards coming from different scenarios and their resulting flooding mechanisms.
7. Flood scenarios should include all site-relevant interdependent and independent combinations of hydrological and meteorological conditions, as well as structural failures. This should include flooding mechanisms related to parameters like flooding water level and flow rates; flood duration; static and dynamic forces from water, waves, and debris; and deposits.

In conclusion, the representatives of the WGEV found that the concepts discussed in this report represent commendable practices that NEA member countries are applying when assessing and understanding protections of nuclear installations against the impacts of external flooding.

3.5. Benchmark exercise to validate hazard frequency and magnitude for external events risk assessment

Benchmark exercise – Hazard frequency and magnitude project overview

As an input into risk analysis modelling and simulation, a hazard initiating event (IE) is typically considered as the starting point for risk models. Since the IE both contributes to the risk quantification results and provides the boundary conditions for the rest of the hazard scenarios, effective modelling of the frequency and magnitude for different external events using data-driven methods can be applied. However, current practice has shown a variety of technical approaches, models and limitations in validation of these approaches. Consequently, this benchmark study is intended to demonstrate and capture commendable practices in formulating and assessing the quantification of external event IEs when using statistical models. This benchmark was open to a variety of technical communities including academia, government agencies, industry, research institutes, and technical and scientific support organisations (TSOs).

The objective of this benchmark study was to facilitate an exercise on statistical modelling to better understand the quantitative technical analysis steps and processes used for assessing hazard frequency and magnitude for external events risk assessment. The overall scope of the benchmark exercise for external events risk assessment covers topics of describing probabilistic hazard modelling, its associated uncertainty characterisation, and the process used for analysis and assessment. The information that was asked for and provided by the benchmark participants is described below.

- Hypothetical observational data represent an external hazard which has been created from synthetic models (this type of model is used to create synthetic data that have been generated from a computer). Two cases were described: (1) a fully revealed "open" case where both the synthetic data and the synthetic model producing the data were provided and (2) a "blind-test case" where only the synthetic data were provided.
- Participants were asked to describe the assumptions made to create the hazard frequency/magnitude model(s), the qualitative and quantitative results of the model(s), the process used to assess the adequacy of the model(s), and the results of the model adequacy assessment. For this benchmark, phenomenological-based evaluation and modelling will not be considered since only "observational-type" data (derived from a synthetic model) are provided, resulting in statistical-types of models to be considered.

The specific choice of model(s) to be considered by benchmark participants was not limited a priori but needed to be able to incorporate the data and ideally be able to provide a consideration of prediction uncertainty.

The report "Benchmark on External Events Hazard Frequency and Magnitude Statistical Modelling" (NEA, 2024) was published in June 2024.

Benchmark exercise – Hazard frequency and magnitude project key messages

The results for Case 1 of all the participants tended to track well with the exact results and were consistent across all groups. The approach and models used by the different groups ranged from curve fitting logarithm models to performing Markov Chain Monte Carlo (MCMC) calculations using the GEV model. For Case 1, five of the groups used a regression-based approach while two used a MCMC calculation.

The study for Case 2 was much more complicated since the underlying model was not provided. From the results it was shown that the predictions for long periods (> 10 000 years) started to become problematic due to the underlying synthetic model (based upon an exponential function that was proposed as a strong challenge).

Focusing on just the 50 000-year magnitude predictions, it was noted that the predictions were consistent but were too low by about 40%. Again, this underprediction is likely a result of the use of the exponential function for the underlying synthetic model for Case 2. While the models used by the submitters (e.g. GEV, Generalised Pareto, regression) can represent exponential types of behaviour, the data that were provided may represent too short of a period to reliably predict long return periods (i.e. for periods much longer than the data set provided). In Case 2, the "longest" data point provided was for 10 000 years, or five time shorter than the 50 000-year prediction.

A second set of data were also provided for Case 2. This Case 2b included 26 data points instead of the original 10 data points provided in Case 2a. However, in both cases, the longest period represented was 10 000 years. Looking at the 50 000-year predictions, it was shown that increasing the data points (from 10 to 26) resulted in only slightly better predictions (but they were still low by approximately 40%). It appears that having additional data within the "observed" time frame did not lead to much of an improvement in the predictions. It was surmised that if the participants had been provided "paleo-data" for a period longer than 10 000 years, these data would have likely resulted in better predictions.

The participants that submitted information for Case 2 used two basic approaches to the analysis, Bayesian analysis via MCMC or regression to a curve. It appears that the quantity of data and the quantification had little impact on the results. However, it did appear that the Bayesian approach was able to quantify the uncertainty on the predictions in a straight-forward fashion.

Focusing on just the 500 000-year magnitude predictions, it was noted that the predictions again were consistent but were very low by more than a factor of ten. This extreme underprediction is (again) likely a result of the use of the exponential function for the underlying synthetic model for Case 2. While these types of predictions tend to be increasingly uncertain as the period increases, this error in the prediction is quite large.

A concern here would be if return periods are being predicted that are much greater than what has been experienced (> 10 times the period) and the underlying phenomena that drive the magnitude of the external hazard are unbounded upward like an exponential function, then the predictions for the hazard may be underestimated. Fortunately, most (if not all) natural external hazards would have upper bounds to the magnitude – it would not make sense to assume infinitely large floods, temperatures, rain, snow, earthquakes, etc.

The difficulty in the predictions for long return periods does indicate that knowledge of the underlying phenomena or knowledge of upper bounds (e.g. physical limits) could help to greatly improve predictions.

3.6. High wind and tornado – Hazards assessment and protection of nuclear installations

High wind and tornado project overview

At its June 2019 meeting, the CSNI approved the task on "high winds and tornadoes – hazard assessment and protection of nuclear installations" to be pursued by the WGEV. The objectives of this task are the collection of information from the CSNI participating countries with respect to current regulatory practices and technical approaches used to confirm the adequacy of protection of nuclear installations against high wind and tornadoes, and the identification of key issues regarding high wind and tornado hazard assessment (both deterministic and probabilistic) and dedicated protection.

The first activity involved in this task was a survey to acquire an informed understanding of the regulatory requirements as well as the scientific and technical approaches in the CSNI participating countries to deal with high winds and tornadoes. Besides the pertinent regulatory requirements, the survey addressed relevant aspects of hazard assessment (e.g. availability of data, assessment methods), the definition of wind and tornado loadings for structures, system and components (SSC) design, and protection measures. The results of this survey were presented in the "Technical Note on High Wind and Tornado – Hazard Assessment and Protection of Nuclear Installations".

Following the evaluation of the survey, a workshop was held online in March 2022 that brought together a broad range of engineers, meteorologists and other experts in this subject – including from non-nuclear fields – to address key issues and identified technology gaps. About 82 participants from 16 countries as well as representatives from international organisations attended the workshop. A total of 20 technical presentations were given in four sessions devoted to: (1) phenomenological aspects of high winds and tornadoes, (2) data sources and the translation of data from the nuclear installation site region to the site itself, (3) how the impacts from the high winds and tornadoes are reflected in the design and operation of nuclear installations and other installations, and (4) safety cases approaches.

At the end of each session, a panel session was held allowing for more detailed discussions on any of the presentations in that session. On the last day, a wrap-up session concluded the workshop. Based on the discussions, the participants expressed a strong interest in continuing efforts after the WGEV workshop.

The workshop proceedings "High Wind and Tornadoes – Hazard Assessment and Protection of Nuclear Installations" (NEA, forthcoming a) include as an annex the technical note that documented the results of the survey, and were approved by CSNI in June 2023.

High wind and tornado project key message

The following points were highlighted by the participants as needing further consideration:

1. Sharing of information between the nuclear industry and non-nuclear organisations regarding regulations, hazard assessment approaches, and protective measures is an important element to successfully understanding the impact of wind-related hazards on nuclear facilities.
2. Given the limited amount of available instrumentally recorded wind speed data, current works aiming to capture additional information from other sources are essential for regulatory decision making and clear communication to the public. It is necessary to augment temporally and spatially sparse recorded data with simulations and other information to be able to make decisions associated with rare events. Simulation and modelling should be validated with consideration of available empirical data. In the treatment of uncertainty there are two aspects that are important to address. From a scientific perspective, there are uncertainties with data and modelling that need to be better understood and quantified. These aspects are further addressed and discussed in the framework of ongoing WGEV activity on uncertainties in the assessment of natural hazards (excluding earthquakes). From a regulatory perspective, decision makers should be aware of the uncertainties in the scientific results and take them appropriately into account in their decision-making process.
3. Climate change's impact on the frequency and severity of high wind events is an emerging issue and needs to be considered in detail as it introduces new challenges in the decision-making process.
4. Co-ordination of the work of the WGEV with other NEA working groups, primarily with WGRISK, is important to understand how better data and a better understanding of the phenomena associated with external events can be used to better understand the risk to public health and safety from nuclear facilities. Building on the results of this research will support the balance needed in risk-informed decision making between the use of deterministic and probabilistic methods.

Chapter 4. Current and future activities and applications

4.1. Combined external hazards

This task is a joint project between the Working Group on External Events (WGEV) and the Working Group on Risk Assessment (WGRISK). From the perspectives of the WGEV, the main objectives of this CAPS are the collection of information from participating countries with respect to current regulatory practices as well as technical approaches and methods applied in hazard assessments for nuclear installations with respect to combinations of (independent as well as correlated) external hazards and integrated hazard impacts, i.e. the loads and conditions resulting directly or indirectly from a hazard. Based on the evaluation of the obtained information, key issues regarding such hazard combinations and integrated hazard impacts will be identified. In support of WGRISK activities, the objective of the task is to provide an overview of the current state of the art of risk analysis of combinations of external hazards and to review the methods applied for these analyses to provide a basis for advances in this area. Inasmuch as the task will be solved by two groups of experts, the introduction of the research will harmonise the terminology used by both parties for full understanding.

A survey was performed that led to an informed understanding of the regulatory requirements and the technical approaches in WGEV members to deal with combinations of types of external hazards (e.g. high winds and flooding) and integrated hazard impacts (e.g. wind pressure and missile impacts due to high winds). Besides the corresponding regulatory requirements, the survey will address relevant aspects of hazard assessment (e.g. availability of data, deterministic/statistical/probabilistic criteria and approaches for combinations of different hazards) and of the determination of the resulting integrated impacts on nuclear installations.

As to risk assessment, the survey helped to recognise and characterise the methods and approaches used in participating countries to include combinations of external hazards in the scope of PSA. Over and above selection, screening and hazard assessment for combinations of hazards, the scope covered methodologies for plant response and fragility analysis, development of event sequence models including the role of plant personnel, and risk quantification along with the treatment of uncertainties. As internal events and hazards that are consequential to external hazards or combinations of external hazards are typically considered in plant response and fragility analysis and in the associated accident sequence modelling, this aspect was also addressed in the survey. The survey task report [NEA/CSNI/R(2023)13] was approved by the CSNI in June 2023 (NEA, forthcoming b).

The "International Workshop on the Safety Assessment of Nuclear Installations for Combinations of External Hazards" was held in September 2023, including participants from a broader range of engineers, scientists, risk analysts and other experts in this subject – also from non-nuclear fields – to address key issues and identify technology gaps. The discussions will help to identify and characterise important hazard combinations, understand the state of the art in assessing the integrated impacts of hazard combinations as well as in developing PSA for hazard combinations, and specify further R&D needs and potential for improvements in the assessment of external hazards, nuclear installations design and safety assessment approaches including probabilistic safety assessment.

4.2. Uncertainties in the assessment of natural hazards (excluding earthquakes)

The activity on "uncertainties in the assessment of natural hazards (excluding earthquakes)" originally consisted of two phases, one on sources of uncertainties and one on methods to deal with uncertainties, which were in 2023 merged into one combined activity. The overall objective of this combined activity is to develop an understanding of the state of practice with respect to the consideration of uncertainties in natural hazards assessments. The results will serve as a basis for the identification of areas that could benefit from future collaborative efforts and as an input to the work of the Committee on Nuclear Regulatory Activities (CNRA).

This activity will provide an overview of the various types of uncertainties that need to be considered depending on the type of natural hazard, the data sources and the assessment approaches as well as an outline of suitable methods to deal with them.

To ensure a consistent approach, the types of natural hazards to be included in the discussion were selected and specified. The selection process focused on the natural hazards previously addressed by the WGEV, i.e. storm surges, tsunamis, riverine flooding, high winds and local precipitation. For the selected natural hazards, factors that contribute to the uncertainty of the corresponding hazard assessments are being identified. As the sources of uncertainty may vary depending on the type of natural hazard under consideration as well as on the data and methods used in the assessment process, a review of the available literature on uncertainties is being performed. To facilitate the identification of relevant literature, a workshop with experts in hazard assessment (with nuclear and non-nuclear background) was held in April 2022. The result of these studies and the workshop will be a compilation of the major contributors (including their relevant characteristics) to the uncertainty of hazard assessments for the selected natural hazards and a bibliography to support experts performing such hazard assessments. The workshop proceedings were published in 2025 (NEA, 2025).

In addition, an overview of recommendable methods to account – either qualitatively or quantitatively – for uncertainties in assessments for natural hazards will be published. This serves to develop a better understanding of the benefits and drawbacks of the various methods currently available. To achieve this, the literature review will be extended to include publications in other fields addressing uncertainties (e.g. internal hazards and earthquakes). This extension of the study aims at identifying suitable approaches not yet established in the assessment of natural hazards. The various methods will be discussed with respect to the advantages and disadvantages of their application to the major sources of uncertainties affecting the assessment of natural hazards.

Although this activity focuses on scientific/technical aspects of uncertainties in natural hazard assessments, benefits and challenges related to different ways of presenting information on uncertainties to regulators will be discussed. These considerations might serve as an input for further discussion of the issue of uncertainties with respect to natural hazards in the CNRA.

4.3. Local intense precipitation

The concept of local intense precipitation (LIP) has been widely used in flood risk assessments for nuclear installations, but it is not well defined in the literature. The objective of this activity is the collection of information from WGEV participating countries with respect to current regulatory guidance and operators' practices as well as the best available technical approaches and methods in assessing and characterising LIP for use in flood hazard assessment (FHA) for nuclear installations. Based on the evaluation of the obtained information, best practice and knowledge gaps will be identified.

LIP is often considered to be a rainfall event, but it could be rainfall combined with snow melt or hail if there is a physical basis for it to be combined with rainfall to generate a larger magnitude precipitation event. Heavy snow or hail could itself have safety implications for a nuclear installation but, for the scope of this activity, heavy snow and hail are not included, except in cases where there is a physical basis to combine them to generate a larger magnitude precipitation event.

A survey will be performed that is intended to lead to an informed understanding of the regulatory requirements and the technical approaches used in the WGEV participating countries to deal with assessing and characterising LIP. Following the evaluation of the survey, a workshop was held in September 2024 to involve a broader range of engineers, scientists, risk analysts and other experts in this subject – also from non-nuclear fields – to address key issues and knowledge gaps. The discussions will help to specify further research and development needs and the potential for improvements in the assessment and characterisation of LIP for flood hazard assessment for nuclear installations.

4.4. External event effects on small modular reactors

The WGEV has been addressing a broad spectrum of external hazards in the operation of large nuclear power plants. With the future deployment of small modular reactors (SMRs), new issues related to external hazards might arise. This has also been recognised by the Expert Group on Small Modular Reactors (EGSMR) which identified cross-cutting safety issues for SMRs – some of them related to external hazards. Therefore, WGEV members discussed the need for a new project to review external hazards issues and practices as they pertain to the licensing, siting and transportation of SMRs. The objective of this future activity will be to identify best practices and technical gaps or limitations in the siting and transportation of SMRs.

4.5. Climate change effects on nuclear power plants

Natural disasters are increasing in frequency and intensity due to global climate change. Climate change is a global issue, not just a problem for one country. The NEA has already published a report on assessing the vulnerability of nuclear power plants to climate change, which summarises climate change trends and impacts on nuclear power plants and recent climate change events (NEA, 2021). However, the published reports do not reflect the climate change phenomena and impacts on nuclear power plants in all countries. Therefore, the WGEV is interested in the impact of climate change on the safety of nuclear power plants and is working to prepare a report that includes climate change phenomena in each country, institutional and regulatory standards for considering climate change, and the latest research status. This report will provide an overview of the status and efforts of NEA member countries to address the impacts of climate change on nuclear power plants.

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Appendix A. **WGEV activities**

The list of possible WGEV activities is reviewed periodically and will be updated according to the interest of the group and the gaps identified from completed work.

Reference CSNI technical goals	Activity/objectives/results
Preventing and mitigating severe accidents, including internal and external events Safety margin quantification Safety issues specific to new designs, including Fukushima Daiichi lessons learnt Analytical tools and risk assessment approaches and their applicability to new designs Safety issues specific to advanced designs, including Fukushima Daiichi lessons learnt	***Severe weather events with high winds and flooding*** Objectives and results: Summary of regulatory approaches to hazard assessment and protection and of technical methods for assessing risk and effectiveness of preventive measures. A survey of current regulatory practises for severe weather events, and of knowledge gaps, undertaken in 2014. A workshop, with invited experts, to determine activities to address knowledge gaps.
Preventing and mitigating severe accidents, including internal and external events Safety margin quantification Safety issues specific to new designs, including Fukushima Daiichi lessons learnt Analytical tools and risk assessment approaches and their applicability to new designs Safety issues specific to advanced designs, including Fukushima Daiichi lessons learnt	***Examination of approaches for screening external hazards*** Objectives and results: To provide the technical basis behind an approach for science-based screening of external hazards. A technical report summarising the current state of the art/practice and identifying best practices and gaps found in application of existing screening approaches for external hazards currently employed for nuclear power plant risk assessment (NEA, 2019).
Preventing and mitigating severe accidents, including internal and external events Safety margin quantification Safety issues specific to new designs, including Fukushima Daiichi lessons learnt Analytical tools and risk assessment approaches and their applicability to new designs Safety issues specific to advanced designs, including Fukushima Daiichi lessons learnt	***Riverine flooding – Hazard assessment and protection of nuclear power plants*** Objectives and results: Summary of regulatory approaches to hazard assessment and protection and of technical methods for assessing risk and effectiveness of preventive measures. A survey of current regulatory practises for riverine flooding, and of knowledge gaps. A workshop, with invited experts, to determine activities to address knowledge gaps ("International Workshop on Riverine Flooding: Hazard Assessment and Protection of Nuclear Installations", 21-23 March 2018 in Paris, France).

Reference CSNI technical goals	Activity/objectives/results
Preventing and mitigating severe accidents, including internal and external events Safety margin quantification Safety issues specific to new designs, including Fukushima Daiichi lessons learnt Analytical tools and risk assessment approaches and their applicability to new designs Safety issues specific to advanced designs, including Fukushima Daiichi lessons learnt	***Concepts and definitions for protective measures in response to external flooding hazards*** Objectives and results: To develop insights on the concepts used to establish effective protective measures to cope with flooding hazards and to develop a common understanding of the terminology used to discuss protective measures as they relate to flooding. Report documenting the common concepts for effective protective measures and a common set of terms and definitions for flood hazard assessment and related protective measures (NEA, 2022).
Preventing and mitigating severe accidents, including internal and external events Safety margin quantification Safety issues specific to new designs, including Fukushima Daiichi lessons learnt Analytical tools and risk assessment approaches and their applicability to new designs Safety issues specific to advanced designs, including Fukushima Daiichi lessons learnt	***Benchmark on external events hazard frequency and magnitude statistical modelling*** Objectives and results: To facilitate a benchmark exercise focused on the quantitative technical analysis steps and processes used for assessing hazard frequency and magnitude for external events risk assessment. Technical Report with the benchmark specification and summarising the results of the benchmarking exercise along with insights gained on assessing hazard frequency and magnitude of external events (NEA, 2024).
Preventing and mitigating severe accidents, including internal and external events Safety margin quantification Safety issues specific to new designs, including Fukushima Daiichi lessons learnt Analytical tools and risk assessment approaches and their applicability to new designs Safety issues specific to advanced designs, including Fukushima Daiichi lessons learnt	***High winds and tornadoes – Hazard assessment and protection of nuclear installations*** Objectives and results: The collection of information from WGEV members with respect to current regulatory practices and technical approaches, methods and models used to confirm the adequacy of protection of nuclear installations against high winds and tornadoes, and the identification of key issues regarding high wind and tornado hazard assessment (both deterministic and probabilistic) and dedicated protection. The output of the activity will consist of 1) a report summarising the survey results and the preliminary conclusions drawn from the evaluation of the survey and 2) the workshop proceedings, including final conclusions and recommendations for follow-up activities (if necessary).

Reference CSNI technical goals	Activity/objectives/results
Preventing and mitigating severe accidents, including internal and external events Safety margin quantification Safety issues specific to new designs, including Fukushima Daiichi lessons learnt Analytical tools and risk assessment approaches and their applicability to new designs Safety issues specific to advanced designs, including Fukushima Daiichi lessons learnt	***Combinations of external hazards – Hazard and impact assessment and probabilistic safety analysis (PSA) for nuclear installations*** Objectives and results: Collection of information on current regulatory practices as well as technical approaches and methods applied in hazard assessments for nuclear installations with respect to combinations of external hazards and integrated hazard impacts, i.e. the loads and conditions resulting directly or indirectly from a hazard. Based on the evaluation of this information, key issues impacts will be identified. A further objective of the task is to provide an overview of the current state of the art with respect to risk analysis of hazard combinations of external hazards and to review the methods applied for these analyses to provide a basis for advances in this area. A forthcoming joint WGEV and WGRISK task report (NEA, forthcoming b) summarising the survey results and the preliminary conclusions drawn from the evaluation of the survey. Forthcoming workshop proceedings (NEA, forthcoming c) including final conclusions and recommendations for follow-up activities.
2. Effectiveness and efficiency of activities related to safety 2c. To build and harmonise international approaches to safety issues using multi-national collaborative efforts and cost and resource sharing. 3. Safe operation of current nuclear installations 3f. To develop approaches and methods to quantify safety margins 4. Safety in new nuclear installations 4c. To review current analytical tools as well as risk assessment approaches regarding their applicability to safety assessments of new designs and further develop and validate them where needed.	***Uncertainties in the assessment of natural hazards (excluding earthquakes) – Phase 1 (sources of uncertainties)*** Objectives and results: The overall objective of the two phases is to develop an understanding of the state of practice with respect to the consideration of uncertainties in natural hazards assessments. The results will serve as a basis for the identification of areas that could benefit from future collaborative efforts and as an input to the work of the NEA Committee on Nuclear Regulatory Activities (CNRA). Phase 1 will provide an overview of the various types of uncertainties that need to be considered depending on the type of natural hazard*, the data sources and the assessment approaches. The output of Phase 1 will consist of the workshop proceedings (NEA, 2025) and a forthcoming report that (i) outlines the spectrum of uncertainties to be considered, (ii) summarises the relevant characteristics of these uncertainties and (iii) provides a bibliography of the pertinent literature. The report will serve as an input for Phase 2 of the activity.

Reference CSNI technical goals	Activity/objectives/results
2. Effectiveness and efficiency of activities related to safety 2c. To build and harmonise international approaches to safety issues using multi-national collaborative efforts and cost and resource sharing. 3. Safe operation of current nuclear installations 3f. To develop approaches and methods to quantify safety margins 4. Safety in new nuclear installations 4c. To review current analytical tools as well as risk assessment approaches regarding their applicability to safety assessments of new designs and further develop and validate them where needed.	***Uncertainties in the assessment of natural hazards (excluding earthquakes) – Phase 2 (methods to deal with uncertainties)*** Objectives and results: Phase 2 will provide an overview of recommendable methods to account – either qualitatively or quantitatively – for uncertainties in assessments for a set of natural hazards* as specified in Phase 1 of the activity. The output of Phase 2 will consist of (i) a forthcoming report summarising the insights of the literature review (i.e. a compilation of suitable methods for consideration of uncertainties) and (ii) the proceedings of the workshop. The proceedings will include recommendations with respect to the consideration of uncertainties in natural hazard assessments and an identification of areas requiring further research.
2. Effectiveness and efficiency of activities related to safety. 2c. To build and harmonise international approaches to safety issues using multi-national collaborative efforts CSNI, and cost and resources sharing. 3. Safe operation of current nuclear installations 3f. To develop approaches and methods to quantify safety margins. 4.Safety in new nuclear installations 4c. To review current analytical tools as well as risk assessment approaches regarding their applicability to safety assessments of new designs and further develop and validate them where needed.	***Characterisation of local intense precipitation*** Objective and results: The objective of this CAPS is the collection of information from WGEV members with respect to current regulatory guidance and operators' practices as well as best available technical approaches and methods in assessing and characterising LIP for use in flood hazard assessment (FHA) for nuclear installations. Based on the evaluation of the obtained information, best practice and knowledge gaps will be identified. The output of the activity will consist of 1) a forthcoming task report (technical note) summarising the survey results and the preliminary conclusion drawn from the evaluation of the survey and 2) the workshop proceedings (CSNI report) including final conclusions and recommendations for follow-up activities (if necessary)

* In this CAPS the term "natural hazards" refers to hazards posed by all external events excluding human-induced events and earthquakes.

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CSNI Status Report and Perspectives: Advances in the Analysis and Management of External Hazards

The NEA Working Group on External Events (WGEV) aims to improve the understanding and treatment of external hazards to support the continued safety performance of nuclear installations and heighten the effectiveness of regulatory practices in NEA member countries. This report provides an overview of the activities of the WGEV from its inception in 2013 through the end of 2024. It seeks to facilitate communication between reactor safety stakeholders by summarising the main aspects of the WGEV's activities: the context and key safety topics related to the analysis and management of external events; the approach and methodologies used to cope with reactor safety issues; and a discussion of potential future activities.

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