Nuclear Regulation
NEA/CNRA/R(2015)5
November 2015

www.oecd-nea.org

Report on the Survey of the Design Review of New Reactor Applications

Volume 2: Civil Engineering Works and Structures

Working Group on the Regulation of New Reactors

OECD
BETTER POLICIES FOR BETTER LIVES

NEA
NUCLEAR ENERGY AGENCY

Unclassified **NEA/CNRA/R(2015)5**

Organisation de Coopération et de Développement Économiques
Organisation for Economic Co-operation and Development

02-Dec-2015

English text only

NUCLEAR ENERGY AGENCY
COMMITTEE ON NUCLEAR REGULATORY ACTIVITIES

NEA/CNRA/R(2015)5
Unclassified

Working Group on the Regulation of New Reactors

Report on the Survey of the Design Review of New Reactor Applications
Volume 2:
Civil Engineering Works and Structures

JT03387636

Complete document available on OLIS in its original format

English text only

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

The OECD is a unique forum where the governments of 34 democracies work together to address the economic, social and environmental challenges of globalisation. The OECD is also at the forefront of efforts to understand and to help governments respond to new developments and concerns, such as corporate governance, the information economy and the challenges of an ageing population. The Organisation provides a setting where governments can compare policy experiences, seek answers to common problems, identify good practice and work to co-ordinate domestic and international policies.

The OECD member countries are: Australia, Austria, Belgium, Canada, Chile, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, , the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The European Commission takes part in the work of the OECD.

OECD Publishing disseminates widely the results of the Organisation’s statistics gathering and research on economic, social and environmental issues, as well as the conventions, guidelines and standards agreed by its members.

NUCLEAR ENERGY AGENCY

The Nuclear Energy Agency (NEA) was established on 1 February 1958. Current NEA membership consists of 31 countries: Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, Norway, Poland, Portugal, Russia, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The European Commission also takes part in the work of the Agency.

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 a safe, environmentally friendly 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 policy analyses in areas such as energy and sustainable development.

Specific areas of competence of the NEA 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. In these and related tasks, the NEA works in close collaboration with the International Atomic Energy Agency in Vienna, with which it has a Co-operation Agreement, as well as with other international organisations in the nuclear field.

COMMITTEE ON NUCLEAR REGULATORY ACTIVITIES

The Committee on Nuclear Regulatory Activities (CNRA) shall be responsible for the programme of the Agency concerning the regulation, licencing and inspection of nuclear installations with regard to safety. The Committee shall constitute a forum for the effective exchange of safety-relevant information and experience among regulatory organisations. To the extent appropriate, the Committee shall review developments which could affect regulatory requirements with the objective of providing members with an understanding of the motivation for new regulatory requirements under consideration and an opportunity to offer suggestions that might improve them and assist in the development of a common understanding among member countries. In particular it shall review current management strategies and safety management practices and operating experiences at nuclear facilities with a view to disseminating lessons learnt. In accordance with the NEA Strategic Plan for 2011-2016 and the Joint CSNI/CNRA Strategic Plan and Mandates for 2011-2016, the Committee shall promote co-operation among member countries to use the feedback from experience to develop measures to ensure high standards of safety, to further enhance efficiency and effectiveness in the regulatory process and to maintain adequate infrastructure and competence in the nuclear safety field.

The Committee shall promote transparency of nuclear safety work and open public communication. The Committee shall maintain an oversight of all NEA work that may impinge on the development of effective and efficient regulation.

The Committee shall focus primarily on the regulatory aspects of existing power reactors, other nuclear installations and the construction of new power reactors; it may also consider the regulatory implications of new designs of power reactors and other types of nuclear installations. Furthermore it shall examine any other matters referred to it by the Steering Committee. The Committee shall collaborate with, and assist, as appropriate, other international organisations for co-operation among regulators and consider, upon request, issues raised by these organisations. The Committee shall organise its own activities. It may sponsor specialist meetings and working groups to further its objectives.

In implementing its programme the Committee shall establish co-operative mechanisms with the Committee on the Safety of Nuclear Installations in order to work with that Committee on matters of common interest, avoiding unnecessary duplications. The Committee shall also co-operate with the Committee on Radiation Protection and Public Health and the Radioactive Waste Management Committee on matters of common interest.

FOREWORD

The Committee on Nuclear Regulatory Activities (CNRA) of the Nuclear Energy Agency (NEA) is an international committee composed primarily of senior nuclear regulators. It was set up in 1989 as a forum for the exchange of information and experience among regulatory organisations and for the review of developments which could affect regulatory requirements. The Committee is responsible for the NEA programme concerning the regulation, licencing and inspection of nuclear installations. In particular, the Committee reviews current practices and operating experience.

The CNRA created the Working Group on the Regulation of New Reactors (WGRNR) at the Bureau meeting of December 2007. Its mandate was to "be responsible for the programme of work in the CNRA dealing with regulatory activities in the primary programme areas of siting, licencing and oversight for new commercial nuclear power reactors (Generation III+ and Generation IV)".

At its second meeting in 2008, the Working Group agreed on the development of a report based on recent regulatory experiences describing; 1) the licencing structures, 2) the number of regulatory personnel and the skill sets needed to perform reviews, assessments and construction oversight, and 3) types of training needed for these activities. Also the Working Group agreed on the development of a comparison report on the licencing processes for each member country. Following a discussion at its third meeting in March 2009, the Working Group agreed on combining the reports into one, and developing a survey where each member would provide their input to the completion of the report.

During the fourth meeting of the WGRNR in September 2009, the Working Group discussed a draft survey containing an extensive variety of questions related to the member countries' licencing processes, design reviews and regulatory structures. At the fifth meeting, it was decided to divide the workload into three phases; General, Design and Construction. The General section of the survey was sent to the group at the end of the meeting with a request to the member countries to provide their response by the next meeting. The *Report on the Survey of the Review of New Reactor Applications* NEA/CNRA/R(2011)13[1] which covers the members' responses to the General section of the survey was issued in March 2012.

At the tenth meeting of the WGRNR in March 2013, the members agreed that the report on responses to the Design section of the survey should be presented as a multi-volume text. As such, each volume will focus on one of the eleven general technical categories covered in the survey. It was also agreed that only those countries with design review experience related to the technical category being reported are expected to respond to that section of the survey. The *Report on the Survey of the Design Review of New Reactor Applications – Volume 1: Instrumentation and Control* NEA/CNRA/R(2014)7[2] was issued in July 2014.

The reports of the survey on the design review of new reactor applications are to serve as guides for regulatory bodies to understand how technical design reviews are performed by member countries. It therefore follows that the audience for these reports are primarily nuclear regulatory organisations, although the information and ideas may also be of interest to other nuclear industry organisations and interested members of the public.

1. To download the report, see www.oecd-nea.org/nsd/docs/2011/cnra-r2011-13.pdf
2. To download the report, see www.oecd-nea.org/nsd/docs/2014/cnra-r2014-7.pdf

ACKNOWLEDGEMENTS

This report, prepared by Dr Steven Downey (NRC, United States), is based on discussions and input provided by members of the CNRA Working Group on the Regulations of New Reactors, listed below. Mr Janne Nevalainen (STUK, Finland) and Ms Aurélie Lorin (NEA Secretariat) chaired the meetings and supervised the work carried out by the group.

Philip Webster,	CNSC, Canada
Ken Lafrenière,	CNSC, Canada
Janne Nevalainen,	STUK, Finland
Philippe Joyer,	ASN, France
Thomas Houdré,	ASN, France
Jaharlal Koley,	AERB, India
Hiroshi Yamagata,	NRA, Japan
Tomonori Kawamura,	NRA, Japan
Walter Kim,	KINS, Korea
Mikhail Lankin,	SEC NRS, Russia
Sergei Nefedov,	SEC NRS, Russia
Jozef Kubanyi,	UJD, Slovak Republic
Ladislav Haluska,	UJD, Slovak Republic
Andreja Persic,	SNSA, Slovenia
Craig Reierson,	ONR, United Kingdom
Andrea Valentin,	NRC, United States
Steven Downey,	NRC, United States

TABLE OF CONTENTS

EXECUTIVE SUMMARY

At the tenth meeting of the CNRA Working Group on the Regulation of New Reactors (WGRNR) in March 2013, the Working Group agreed to present the responses to the Second Phase, or Design Phase, of the Licensing Process Survey as a multi-volume text. As such, each report will focus on one of the eleven general technical categories covered in the survey. The general technical categories were selected to conform to the topics covered in the International Atomic Energy Agency (IAEA) Safety Guide GS-G-4.1. This report, which is the second volume, provides a discussion of the survey responses related to Civil Engineering Works and Structures.

The Civil Engineering Works and Structures category includes the five following technical topics: containment design and other safety-related design, external natural event loadings, external man-made hazards, internal hazards, and aircraft impact assessment (AIA). For each technical topic, the member countries described the information provided by the applicant, the scope and level of detail of the technical review, the technical basis for granting regulatory authorisation, the skill sets required and the level of effort needed to perform the review. Based on a comparison of the information provided in response to the survey, the following observations were made:

- Among the regulatory organisations that responded to the survey, there are similarities in the design information provided by an applicant for each technical topic.
- All of the technical topics covered in the survey are reviewed in some manner by all of the regulatory organisations that provided responses.
- In addition to the regulations and guidance documents, member countries commonly refer to country-specific building codes as well as internationally recognised consensus standards to provide the technical basis of regulatory authorisation.
- It is common to consider emerging issues, operating experience and lessons learnt from the current fleet during the review process.
- Design review strategies most commonly used to confirm that the regulatory requirements have been met include document review and independent verification of analyses performed by the applicant. Confirmatory analyses are commonly performed in this technical area.
- The most commonly and consistently identified technical expertise needed to perform design reviews related to this category is Civil or Structural engineering. Other technical disciplines are identified on a less consistent basis.

The complete survey inputs are available in the appendices.

INTRODUCTION

During the five decades of commercial nuclear power operation, nuclear programmes in NEA countries have grown significantly. Over the years, communication among member countries has been a major reason for the steady improvements to nuclear plant safety and performance around the world. Member countries continue to learn from each other, incorporating past experience and lessons learnt in their regulatory programmes. They consult each other when reviewing applications and maintain bilateral agreements to keep the communication channels open. This has been vital and will continue to be extremely important to the success of the new fleet of reactors being built.

The Design Phase Survey Reports continue along these lines by providing detailed information on the design-related technical topics that are reviewed by the regulatory organisation as part of the regulatory authorisation process. This document, which is the second report on the results of the Design Phase Survey, focuses on Civil Engineering Works and Structures.

SURVEY

The Second Phase, or Design Phase, of the licencing process survey conducted by the CNRA Working Group on the Regulation of New Reactors (WGRNR) covers eleven general technical categories that are based on IAEA Safety Guide GS-G-4.1. Under these eleven general categories, there are a total of 69 specific technical topics to be addressed. For each topic, a member country is asked to answer seven survey questions. At the March 2013 meeting, the working group agreed that the report of the responses to the design section of the survey should be presented as a multi-volume text. As such, each volume will focus on one of the eleven general technical categories covered in the survey. This volume, which focuses on Civil Engineering Works and Structures, is the second of several reports that will present the results of the Design Phase Survey.

The following pages present high level summaries provided by the members and a discussion of the survey results. Complete survey responses are presented in the appendices.

HIGH LEVEL SUMMARIES

Canada

Since 2006, the Canadian Nuclear Safety Commission (CNSC) has been involved in revising its safety standards and guides to make them technology-neutral with respect to water-cooled reactors and to bring them up-to-date with international standards and best modern practices. This was in the expectation that any new nuclear power plant (NPP) build proposed for Canada may not be of the canada deuterium uranium (CANDU) design.

REGDOC-2.5.2, *Design of Reactor Facilities: Nuclear Power Plants* sets out requirements and guidance for new licence applications for water-cooled nuclear power plants. It establishes a set of comprehensive design requirements and guidance that are risk-informed and align with accepted international codes and practices. To a large degree, this regulatory document represents the CNSC's adoption of the requirements in the IAEA’s Safety Requirements document SSR-2/1 *Safety of Nuclear Power Plants: Design*, adapted to the Canadian situation. This regulatory document considers all licencing phases, as information from the design stage is also used when reviewing an application for a licence to construct an NPP, and other licence applications.

Regulatory requirements and expectations for containments have been part of this revision and updating; see section 8.6 of REGDOC-2.5.2. This requires that the containment include at least the following subsystems: the containment structure and related components, equipment required to isolate the containment envelope and maintain its completeness and continuity following an accident, equipment required to reduce the pressure and temperature of the containment and reduce the concentration of free radioactive material within the containment envelope and equipment required for limiting the release of radioactive material from the containment envelope following an accident.

The expectation is that the design stage should establish acceptance criteria for inspection, testing and maintenance provisions including: containment penetration isolation times, containment spray performance, filtered venting capability, vacuum building actuation, hydrogen mitigation system capability (e.g. recombiners), systems and equipment used for containment heat removal and concrete condition and possible concrete degradation.

The containment structure is required to provide sufficient margins of safety based on potential internal over-pressures, under-pressures, temperatures, dynamic effects such as missile generation, and reaction-forces anticipated to result in the event of design basis accidents (DBAs). The containment structure is required to protect systems and equipment important to safety in order to preserve the safety functions of the plant. The design shall support full functionality following a design basis earthquake (DBE) for all the parts of the containment system credited in the safety analysis. The concrete containment structure shall have an elastic response when subjected to seismic ground motions. The structure shall possess ductility and energy-absorbing capacity, which permits inelastic deformation without failure.

In addition to REGDOC-2.5.2, various documents issued by the Canadian Standards Association refer to containment structures. CSA-N285.0 gives general requirements for pressure-retaining systems and components in CANDU nuclear power plants, CSA-N287 gives requirements for concrete containment structures and CSA-N289 gives requirements for seismic design and qualification for nuclear power plants.

Finland

In Finland, the high level binding safety requirements for NPP Civil Engineering Works and Structures, such as the containment integrity requirements, are stated in the Government Decree on the Safety of Nuclear Power Plants. The high level requirements include conditions such as “the possibility of failure of the reactor pressure vessel in a severe accident so that the leak tightness of the containment would be endangered shall be extremely small” and “external events shall include exceptional weather conditions, seismic events, impact of accidents taking place in the plant’s vicinity and other factors resulting from the environment or human activity”. The design shall also consider unlawful actions with the aim of damaging the plant and a large commercial aircraft crash (APC).

The Finnish regulatory body STUK has specified detailed safety requirements concerning the implication of the safety level in accordance with the Decree. These requirements are presented in regulatory guides, which are called YVL Guides. Specific YVL Guides used for the civil structure review in Finland are detailed in each survey response (see appendices). Building norms in Finland and the Eurocode (2 and 3) shall be followed so that they also fulfil the Finnish building code (RakMK) requirements. Also standards, such as, the Nuclear Safety Standards Commission (Kerntechnischer Ausschuss – KTA), International Electrotechnical Commission (IEC) and Institute of Electrical and Electronics Engineers (IEEE) were used in well-defined and substantiated cases.

It should be noted that since the submittal of the Finnish response to the civil engineering works and structures survey, the regulatory YVL Guides have been under development and new set of YVL Guides were published at the end of 2013. The new guide for Buildings and structures of a nuclear facility is Guide YVL E.6 (covering the requirements of old YVL Guides 4.1, 4.2 and partly 4.3 mentioned in the Finnish response).

During the construction licence review and assessment, STUK’s main tasks are to review the preliminary safety assessment report (PSAR) documentation with topical reports, the classification documentation, and the design phase probabilistic risk assessment (PRA).

To carry out the construction licence review and write the regulatory safety assessment, STUK also used external support to review the civil design and structures. Finnish technical support organisation (TSO), VTT, carried out the analyses of the structural behaviour of the nuclear island, including containment structures, and the linear/non-linear analyses of structural responses against different kind of fire and explosions. Also, due to limited internal staff resources, STUK used private engineering company, Pontek Oy, to assist in review of detail level design documents. STUK also used external support to review the APC design.

In should be noted that it has been about twenty years since STUK last performed a full scope construction licence review of a NPP. The Finnish safety requirements and regulatory guides have been under constant development since the 70’s in Finland following the latest knowledge of nuclear safety.

The information provided in response to the survey is based on the construction licence review and assessment of the Olkiluoto 3 NPP. Olkiluoto 3 is based on the French-German European Pressurised water Reactor (EPR) concept. The thermal output of the reactor is 4 300 MW with a net electric power output of approximately 1 600 MW. The design has special provisions in containment design for a severe reactor accident (core meltdown) and provisions for large aircraft crash.

France

In France, the containment building of NPPs was initially made of a single wall for 900 Megawatt electric (MWe) reactors. The evolution of the designs has led to build a double wall for the next series of reactors (1 300 MWe, 1 450 MWe and 1 650 MWe (EPR)). These containment buildings are regarded as the main level of defence against external hazards. Therefore, special attention is given to this element and the regulatory review is mainly focused on the containment structure, the identification of external hazards, and the level of protection against these hazards.

Over the years, several documents (doctrine, basic safety rules, etc.) have been written to specify the French Nuclear Safety Authority (ASN)’s requirements and recommendations for the design and construction of the buildings and for the identification of the internal and external hazards – including external man-made hazards and aircraft impact assessment – to be considered.

- Regarding the containment structure review, the analysis is performed considering ETC-C (EPR Technical Code for Civil works) and RCC-G construction rules (Design and construction rules for civil engineering).
- Regarding external and internal hazards, the review is performed considering the hazards completeness, combinations of hazards and the protection designs for safety functions. It is mainly based on the French basic safety rules and technical guidelines in the case of the EPR. Probabilistic analyses are performed for some external hazards (e.g. aircraft impacts and industrial hazards) according to French fundamental safety rules, while other external and internal hazards are only considered through deterministic assessments.

The level of effort for these reviews is very important and is difficult to evaluate as such reviews have been performed for many years and are reassessed periodically.

India

The requirements for providing necessary information for consenting a nuclear power plant are elaborated in the Atomic Energy Regulatory Body (AERB) document on “Consenting Process for Nuclear Power Plants and Research Reactors” AERB/NPP&RR/SG/G-1. For regulatory review of containment design and other safety related structures, the following documents are to be submitted: Design Basis Reports (DBR), Dynamic Analysis Reports (DAR), Design Reports (DR), Design Basis Report on Shielding (DBRS), Documents on Industrial Safety during Construction, Construction Methodology Document and Report on Concrete Mix Design, and a quality assurance (QA) plan. These reports should present input parameters for analysis and design, calculation of design forces from analysis results, sample design calculations and specific design features, if any. All the inputs and calculations for estimation of design basis parameters (e.g. seismic data, wind loads, flood levels, meteorological, geological and hydrological characteristics, and stability of founding strata) are included in review and assessment.

An analysis of postulated initiating events (PIEs) to establish all those internal events which may affect the safety of the plant shall be carried out. The events will include equipment failures or mal-operation. The information must be provided by the Utility on human activities relating to industry, military, mining, transportation, etc. in the region of the proposed site that may have the potential to challenge the safety of NPP.

As a good practice, independent proof checking (i.e. finite element modelling, analysis and design) of important safety related concrete structures is carried out. The structures that undergo proof checking are Inner containment building, outer containment building, reactor building internal structure, and spent fuel pool. Related analysis and design reports from designer as well as independent proof checking are reviewed by regulatory body. Confirmatory analyses are also performed, if necessary, on a case-by-case basis by the technical service organisation or at the designated division of AERB.

Skill sets required to perform the review include civil, structural and geotechnical engineers having experience in system development, static and dynamic analysis and modelling, system review, construction, and the regulatory process. Other skill sets needed include experts capable of assessment of external hazards, structural analysis and design, development of software for analysis and design, etc.

In depth review is done by the specialist working group constituted by the Civil Engineering Safety Committee (CESC) and Project Design Safety Committee (PDSC) of AERB. The second level of review is done by CESC or PDSC, which looked in detail at the unresolved issues of the specialist group as well as related generic/policy issues on analysis, design and construction. The final level of safety review is done by the Advisory Committee on Project Safety Review (ACPSR) before the recommendations are forwarded to the Chairman AERB. The depth and schedule of a review should depend on whether the project is of new, evolved or repeat design.

Japan

The information provided is based on the new regulatory requirements for commercial nuclear power plants that went into force on 8 July 2013. In the sense of "back-fit", the new regulations are applied to the existing nuclear power plants. After the Fukushima Daiichi nuclear power plant accident, all nuclear power plants were stopped and only the nuclear power plant that conform to the new regulatory requirements could restart. The Nuclear Regulation Authority (NRA) that was established to improve its nuclear safety management and regulation in 2012 reviews application to restart. The application to restart Sendai NPP Unit 1 was approved in February 2015.

The new regulatory requirements significantly enhance design basis and strengthen protective measures against natural phenomena which may lead to common cause failure, for example strict evaluation of earthquakes, tsunamis, volcanic eruptions, tornadoes and forest fires, and countermeasures against tsunami inundation. They also enhance countermeasures against events other than natural phenomena that may trigger common cause failures, for example strict and thorough measures for fire protection, countermeasures against internal flooding.

The new regulatory requirements newly require preventing containment vessel failure under postulated severe accident conditions. Applicants should provide information including PRA report and safety analysis reports.

Before the Fukushima Daiichi nuclear power plant accident, if the aircraft crash probability onto nuclear power facilities was lower than the criteria, aircraft impact assessment was not requested. The new regulatory requirements require measures against intentional aircraft crashes.

The NRA has issued lots of requirements, standards, and guidelines on the above since its establishment. The NRA staff reviews accident progression, civil engineering works and structures in terms of design-basis events and severe accident conditions.

Korea

To ensure that the design of containment buildings and safety related structures complies with the regulations, the Korea Institute of Nuclear Safety (KINS) staff carefully review the applicant's safety analysis report (SAR) and site evaluation report, and assess the suitability of the proposed documents submitted for approval. The regulatory activity is performed under the Nuclear Safety Act, the nuclear law of Korea. The KINS regulatory documents involve Safety Review Guidelines for Light Water Reactors

(KINS/GE-N001), KINS regulatory standards (KINS/RSs), and KINS regulatory guidelines (KINS/RGs). United States Nuclear Regulatory Commission (US NRC) regulatory guides (RGs) are referenced as necessary. The specific and detailed review of the SAR is conducted by KINS staff mainly with the guidelines of Safety Review Guidelines (SRGs) and Korea Electric Power Industry Codes (KEPIC).

For a new nuclear power plant, the applicant provides the site information and detailed information for structural design in the SAR. The following site information should be included in the SAR: geographical and geological information of the site, meteorological information, demographical information, hydrological information, seismological and geotechnical information. The key information for structural design that should be described in the SAR includes, but is not limited to, design philosophy, design codes and specifications, general layout of structures, classification of structures, design loads such as wind loads, generated missile loads and seismic loads, etc., and analysis models and methods including soil structure interaction analysis method. In addition, quality assurance programmes for materials, design, fabrication and construction are included in the SAR.

Currently, the regulatory guides for aircraft impact assessment (AIA) are being developed for the possible event that the containment building and safety related structures are struck intentionally by a large commercial aircraft. Legal framework for AIA is currently being processed. The current review of AIA is based on the international practices. The effects of structural impact of an aircraft and induced vibration by the impact on the structures are to be properly taken into account in the design phase.

Extensive knowledge and understanding of regulatory requirements, regulatory guidelines, structural codes/standards and civil/structural engineering are required for the safety review of the applicant’s design packages (e.g. SAR, design reports, seismic analysis reports, etc.) Also, expertise on geology, seismology, hydrology and other related areas is necessary to evaluate the site characteristics and determine the site design parameters. If necessary, technical consultations and research on major issues may be conducted by external experts to assure the safety of containment buildings and safety related structures. Research outcomes are incorporated into the regulatory guidelines when necessary.

Russia

An applicant in Russia should carry out research, experiments and calculations, and develop safety cases for nuclear facilities in compliance with the federal regulations in the field of atomic energy use. In accordance with the requirements established for the licencing procedure, the applicant should develop and submit to Rostechnadzor a package of documents substantiating safety of a nuclear facility (including a safety analysis report, a probabilistic safety analysis report and others) to obtain licences for siting, construction and operation of a nuclear facility unit. The applicant should submit all the necessary justifications (including references to calculations and experimental research, if necessary) required by regulations in the field of atomic energy use, and demonstrate the compliance of the chosen solutions with the state of the art science and technology. Based on the applicant’s data, the regulatory body should also evaluate the sufficiency of the justifications for siting, construction and operation of a nuclear facility unit by organising an expert review of the documents submitted by the applicant. The expert review will include Rostechnadzor’s scientific and technical support organisations that have specialists of the adequate competence.

Slovak Republic

The information provided is based on the Slovak legal framework which accommodates Western European Nuclear Regulators Association (WENRA) reference levels and IAEA standards. The fulfilment of these requirements is reported via safety analysis report, technical and quality documentation.

The applicant has to demonstrate that all needed analysis and assessment of possible external and internal hazards were performed and that their results were taken into account during the planning and realisation of the civil engineering works and structures, especially those which are safety related. In this case, it must also be demonstrated that works and structures will be able to fulfil their functions during all life-cycles in normal, transient and accident conditions. The main goal of all submitted documentation is to ensure that all the legislative requirements are fulfiled, the nuclear facility will be operated safely, and the public will be protected against undesirable effects of nuclear facility.

Review of the applicants' submitted documentation is usually performed by regulatory body employees with the support of a TSO. When using support services from a TSO, there is a condition of TSO independence. This condition results from the fact that the Slovak Republic is small and there are not many organisations with relevant skills in this field. Therefore, possibility that the same organisation will provide support services for a nuclear facility and for the regulatory body has to be prevented.

Slovenia

The information provided is based on the review of a licencing process for civil engineering works and structures design approval. The most extensive review of civil engineering works and structures is performed at the design certification stage. During the operation stage or in case of changes, the licencing system is carried out in the same way, only less intensive. A description of civil engineering works and structures and their functions is given in the Safety Analysis Report.

The design basis requirements are set in the Regulation, entitled *Rules on Radiation and Nuclear Safety Factors*, which was prepared according to the WENRA Reference Levels. Annex 1 defines NPP design bases including also containment and external initiating events requirements. The design basis of civil engineering structures shall take into account the special environmental loads and conditions to which the structures may be exposed due to external and internal events, including natural events characteristics for the site region, as well as events associated with human activities. As a minimum, the following external initiating events shall be treated in accordance with the site conditions:

- extreme winds;
- extreme outside temperatures;
- extreme rainfall, extreme snowfall, flooding, extreme cooling-water temperatures and freezing;
- earthquakes;
- aircraft crashes;
- other events on nearby transport routes, in industrial facilities or within the site region that might lead to fire, explosion or other hazards to the safety of the nuclear power plant.

A nuclear power plant shall be fitted with a containment that shall ensure that any releases of radioactive substances during a design basis event into the environment remain below the statutory limits. The containment building shall retain its functionality even in an event of a direct crash of a large commercial aircraft.

The information provided by the applicant is based on a detailed system description and design bases. The safety analyses are normal part of applications. Additionally, during the licencing process the Slovenian Nuclear Safety Administration (SNSA) verifies that the applicant has provided complete information to demonstrate that the design, materials, fabrication methods, and inspection techniques used conform to all applicable regulations, industrial codes, and standards. The review of the results of testing, inspection and surveillance is also performed.

Civil engineer, geologist, structural and mechanical engineer are the primary expertise needed to successfully perform design reviews. In some areas probabilistic safety assessment (PSA) and PHA experts are needed to completely review the technical topic. Additionally, experiences including seismology, geotechnical engineering, hydraulic engineering, fire hazard are also needed for the review and assessment.

The level of effort (hours) needed for a review of submitted documentation was estimated on the basis of a special analysis, which was prepared in order to assess the resources needed in case of construction of a new build.

United Kingdom

The United Kingdom (UK) approach for new build prefers applicants to put their design through the generic design assessment (GDA) process, which determines the acceptability of a design for application on a generic UK site. Following a successful review, any licence application for a specific site would then need to examine the delta between the GDA design and that which is to be applied at the site as well as ensuring that the design reviewed under GDA envelopes the site under consideration. However, an applicant may apply directly for a site licence without previously having gone through the GDA process. The following description of regulatory activity covers that which would be done in GDA and/or in the licencing phase.

Within the UK, a non-prescriptive regime for the regulation of nuclear installations is operated. The UK Office for Nuclear Inspectorate (ONR) publishes its safety assessment principles which provide a framework to articulate our expectations. Key aspects for this are our expectations that designs are in line with relevant good practice, and that they demonstrate that the risks are driven to as low as reasonably practicable (ALARP). The key areas of focus from a civil engineering perspective are on ensuring that the appropriate classification and categorisation is applied to structures and their component parts. This in turn drives the requirements for aligned codes and standards to deliver the associated reliability. The design is also examined for its consideration of buildability, durability, maintainability, inspectability, robustness against internal and external hazards, and ease of decommissioning. Safety justifications are often balances of individual components detailed above – what are often referred to as multi-legged safety cases. In addition, there are requirements for the design to consider certain malicious threat scenarios including aircraft impact.

The detailed design review will examine the following key inputs to the process:

- codes and standards used;
- analysis methods and codes used;
- interfaces between analysis and design;
- loading schedule and development of the design basis;
- design tools;
- methods of construction.

The process itself will be examined in terms of the capability of the designer, design interfaces, quality requirements and change management.

The following key outputs from the process will be examined:

- site-specific pre-construction safety report;
- site-specific hazard studies;
- site layout.

United States

The information provided is based on the technical review of a new reactor design certification application, but is also applicable to the review of applications for new reactor design approvals and combined licences issued under 10 CFR Part 52. Typically, the most extensive review of Civil Engineering Works and Structures is performed at the design certification stage. New reactor combined licence (COL) applicants prefer to incorporate most, if not all, of the information related to civil engineering works and structures by reference to a certified standard plant design. COL applicants also conduct site-specific analyses associated with certain design parameters, such as environmental and seismic evaluations, to confirm that the standard plant design is suitable for the proposed plant site. If the COL applicant identifies parameters that are not bounded by the standard design, additional analyses are performed to demonstrate that the structures are able to perform their safety related function. Otherwise, the COL applicant may propose a departure from the standard design in order to provide an alternative. In addition to departures, a COL application may also include site-specific structures that are not part of the standard design. As such, the staff's review of this technical category at the COL application stage would focus on site-specific information and departures from the standard plant design.

Regardless of the type of application, the fundamental purpose is for the applicant to demonstrate that the facility and equipment, the operating procedures, the processes to be performed, and other technical requirements described in the SAR offer reasonable assurance that the plant will comply with the regulations and that public health and safety will be protected. Design information provided by the applicant in this technical category should show that structures are designed to withstand the design basis and beyond design basis conditions, normal and abnormal operating conditions, severe and extreme environmental loads, and severe accidents, including aircraft impact. To accomplish this, the applicant should provide a complete description of the design and analysis procedures followed to demonstrate that structures can withstand appropriate loads with sufficient margin of safety. The applicant should also provide provisions for construction and operational maintenance.

The regulations related to this technical category require that structures be designed and located to either minimise or withstand the effects of natural phenomena, fires and explosions, internally and externally generated missiles, and environmental conditions associated with operation, maintenance, testing, and postulated accidents. Several regulatory guides have been developed to provide guidance to applicants and licensees on acceptable approaches to meet the regulatory requirements. The United States Nuclear Regulatory Commission (NRC) staff has endorsed codes and consensus standards related to containment design and external natural event loadings as well as industry guidance in the area of Aircraft Impact.

Once an application has been formally accepted, the NRC staff reviews the information provided for compliance with the regulatory requirements and performs confirmatory analyses, as necessary, to make a reasonable assurance finding. The scope and level of detail of the staff's safety review of Civil Engineering Works and Structures is based on the guidance provided in the applicable sections of the Standard Review Plan (SRP), NUREG-0800. As part of the review, the staff also considers emerging issues, operating experience, and lessons learnt from the current fleet.

Structural engineering are the primary expertise needed to successfully perform reviews in the area of containment design and other safety related structural design. Reviews of all other technical topics in the civil engineering works and structures category are performed by a team composed of multiple skill sets. For example, the review of external natural event loadings, which requires the broadest range of technical expertise, is typically performed by a team composed of geologists, geotechnical engineers, hydrologists, PRA analysts, seismologists, and structural engineers.

DISCUSSION

Under the category of Civil Engineering Works and Structures, there were five technical topics to be addressed in the survey. These topics were selected to conform to the topics covered in IAEA Safety Guide No. GS-G-4.1. For each of the five technical topics under this category, the members were asked seven questions in order to gather some insights on the level of detail needed for regulatory authorisation. In responding to these questions, each member country described the following:

- the design information provided by the applicant;
- the analysis, reviews, and/or research performed by the regulatory authority's reviewer(s) and the scope of the review;
- the types of confirmatory analyses performed (if any) by the regulatory authority;
- the technical basis (standards, codes, acceptance criteria) for regulatory authorisation;
- the skill sets required to perform the review;
- the specialised training, experience, education, and/or tools needed to perform the regulatory review;
- the level of effort needed for the regulatory authority to perform the review.

Design information provided by the applicant.

Among the regulatory organisations that responded to the survey, there are similarities in the design information provided by an applicant. In the area of containment design and other safety-related structural design, all countries responded that the applicant provides a description of the design and analysis of the containment and other applicable structures. Most countries also responded that the applicant is to provide information on aspects of construction, testing, and inspection of the containment and other structures. In Canada, India, Japan, Korea Russia and the United States, quality control and quality assurance programmes are also provided by the applicant.

In the area of external natural event loadings, most countries responded that the applicant provides a description of the how protection against natural phenomena is considered in the design of the facility. Commonly mentioned natural events include earthquake, flooding, snow, fire, weather, tsunami, ice, wind, and extreme temperatures. Most countries also mentioned that the applicant provides the characteristics of the proposed plant site. Geological, geophysical, geotechnical, hydrological, meteorological, and seismic site characteristic were mentioned. All countries responded that the applicant provides an analysis of the effects of natural event loadings on the facility. The submittal of a seismic-related analysis was most commonly mentioned.

In the area of external man-made hazards, most countries responded that the applicant provides some type of description of how the facility is protected against man-made hazards, such as those associated with military facilities, industrial facilities, and transportation routes. Commonly mentioned man-made hazards include explosions, dam failures, missiles, toxic gases and aircraft.

In the area of internal hazards, most countries responded that the applicant describes how internal hazards and their effects are considered in the facility design. The most commonly mentioned internal hazards to be considered were fire, explosions, and internally generated missiles. Other internal hazards that were mentioned less frequently include flooding and pipe whip.

In the area of aircraft impact assessment, most countries responded the applicant provides some type of analysis of the probability and effects of aircraft impacts on the plant site.

Analysis, reviews and/or research performed.

All of the technical topics covered in the survey are reviewed in some manner by all of the regulatory organisations that provided responses. While the responses show that most regulatory organisations have the framework in place to perform separate design reviews related to each survey topic, the responses also indicates that some survey topics may be reviewed concurrently. All countries review the information provided by the applicant for compliance with the applicable regulatory requirements and guidelines. In addition to document reviews, many countries responded that design reviews related to this technical category require the review of some type of structural or seismic analysis provided by the applicant. Several countries also responded that some form of comparative or confirmatory analysis is performed as part of the design review.

Technical basis.

In all cases, the technical basis for regulatory authorisation is provided by a combination of regulations and regulatory guidance. In addition to the regulations and guidance documents, most countries make use of country-specific building codes as well as national or international consensus standards related to Civil Engineering Works and Structures. Commonly identified consensus standards are described below.

Russia, Slovenia and Canada identified IAEA standards as part of the technical basis for regulatory authorisation. In Russia, IAEA standards were identified as part of the technical basis for the review of three of the technical topics covered in the survey. In Slovenia, IAEA standards are used in the review of each technical topic covered in this survey, while in Canada the IAEA standards are used only as part of the technical basis for external man-made hazards and aircraft impact assessment. Canada, Korea, Slovenia, the United Kingdom and the United States refer to the American Society of Civil Engineers (ASCE) standards as part of the technical basis for regulatory authorisation. For example, Canada, Slovenia, the United Kingdom and the United States identified ASCE standards as part of the technical basis for external natural event loadings. Also, Korea, Slovenia and the United States identified the ASCE standard when describing the review of Containment Design and Safety Related Structural Design, while the United Kingdom identified the standard as part of the technical basis for the review of aircraft impact assessments. The most commonly identified ASCE Standards were ASCE 7 *Minimum Design Loads for Buildings and Other Structures*, and ASCE 4-98 *Seismic Analysis of Safety-Related Nuclear Structures*.

Canada, Korea, Slovenia and the United States refer to the American Concrete Institute (ACI) standards as part of the technical basis for regulatory authorisation. For example, in Canada, Slovenia and the United States, the ACI standards were identified as part of the technical basis for external natural event loadings. Also, Korea, Slovenia and the United States identified ACI 349 *Code Requirements for Nuclear Safety Related Concrete Structures* as part of the technical basis for granting regulatory authorisation for Containment Design and Safety-Related Structural Design.

American National Standards Institute (ANSI) standards were identified as part of the technical basis for granting authorisation in four of the five technical topics. For example, Korea, Slovenia and the United States identified ANSI/AISC N690 *Specification for the Design, Fabrication and Erection of Steel Safety-*

Related Structures for Nuclear Facilities as part of the technical basis for granting regulatory authorisation for Containment Design and Safety-Related Structural Design. Other ANSI standards that were identified include ANSI/ANS-2.8-1992 *Determining Design Basis Flooding at Power Reactor Sites*, which Slovenia and the United States listed as part of the technical basis for Containment Design and external natural event loadings, and ANSI/ANS-58.21-2003 *External Events in PRA Methodology*, which Slovenia identified as part of the technical basis for external man-made hazards and aircraft impact assessment.

Korea, Slovenia and the United States identified several ASTM International (formerly known as the American Society for Testing and Materials) standards as part of the technical basis for granting regulatory authorisation for external natural event loadings. The standards that were identified by all three countries include ASTM D 1586, *Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils*, ASTM D 1587, *Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes*, ASTM D 4044, *Standard Test Method (Field Procedure) for Instantaneous Change in Head (Slug) Tests for Determining Hydraulic Properties of Aquifers*, and ASTM D 6913, *Standard Test Method for Particle Size Distribution (Gradation) of Soils Using Sieve Analysis*.

Skill sets required to perform review.

Civil and structural engineers were the most consistently identified technical expertise needed to perform the reviews related to Civil Engineering Works and Structures. Other technical disciplines that were identified on a less consistent basis by the member countries were geologists, geophysicists, geotechnical engineers, hydrologists, meteorologists, mechanical engineers, fire protection engineers, reactor systems engineers, physical scientists, process engineers, and risk assessment experts.

Fire protection engineers are used in Canada, Finland, Korea, Russia and the United States for the review of internal hazards. The United States also uses fire protection experts in the review of aircraft impact assessments.

France and Japan identified the need for mechanical engineers in the review of all technical topics in the Civil Engineering Works and Structures category. Mechanical engineers are also used in Finland and Slovenia for the review of external man-made hazards and aircraft impact assessments. In addition, Slovenia also listed the need for this expertise in the review of containment design and internal hazards while Russia identified the need for mechanical engineers in the review of internal hazards and aircraft impact assessments.

Geologists, geophysicists and/or hydrologists are used in Japan, Korea, Russia, Slovenia and the Unites States for the review of external natural event loadings. Japan and Slovenia also identified the need for geophysicists in the review of containment design and safety-related structural design.

Specific skill sets needed to review each technical topic are provided in the summary tables located on the first page of each appendix.

Specialised training.

Although the specific training requirements may vary, all countries have indicated that experience related to the technical review topic is important. Finland, India, Japan, Korea and the United States offer formal training programmes for technical reviewers responsible for Civil Engineering Works and Structures.

Level of effort.

The total Level of effort required for each member country to review the Civil Engineering Works and Structures category is provided in the table below. It is noted that, in France, Japan and India, resources (hours) are not set up for each individual review area. Also, in the Slovak Republic, the level of effort allotted for the review of submitted documentation is defined by regulation and dependent upon the activity to be approved.

Country	Total level of effort for Civil Engineering Work and Structures	Basis for estimate
Canada	10 900 hours.	Construction licence application review.
Finland	1 970 working days (15 760 hours).	Construction licence review and assessment of the Olkiluoto 3 NPP.
France	–	Hours not estimated for each review area.
India	–	Resources (hours) are not set up for each individual review area.
Japan	–	Resources (hours) are not set up for each individual review area.
Korea	12 200 hours.	New nuclear power plant review.
Russia	–	Resources (hours) are not set up for each individual review area.
Slovakia	–	Level of effort defined by regulation and dependent upon the activity to be approved.
Slovenia	8 200 hours.	Review of a licencing process for Civil Engineering Works and Structures design approval.
United Kingdom	–	Generic design assessment and/or site licencing process.
United States	26 750 hours.	Standard design certification review.

Table 1: Total level of effort for the Civil Engineering Works and Structures category

Note:

The total level of effort is only listed for those countries that provided hours for all technical topics. The level of effort for each specific technical topic is located in the summary table of the corresponding appendix.

CONCLUSION

This report focused on the results of the design survey related to Civil Engineering Works and Structures. Based on a comparison of the information provided in response to the survey, the following observations were made:

- Among the regulatory organisations that responded to the survey, there are similarities in the design information provided by an applicant for each technical topic.
- All of the technical topics covered in the survey are reviewed in some manner by all of the regulatory organisations that provided responses.
- In addition to the regulations and guidance documents, member countries commonly refer to country-specific building codes as well as internationally recognised consensus standards to provide the technical basis of regulatory authorisation.
- It is common to consider emerging issues, operating experience and lessons learnt from the current fleet during the review process.
- Design review strategies most commonly used to confirm that the regulatory requirements have been met include document review and independent verification of analyses performed by the applicant. Confirmatory analyses are commonly performed in this technical area.
- The most commonly and consistently identified technical expertise needed to perform design reviews related to this category is Civil or Structural engineering. Other technical disciplines are identified on a less consistent basis.

Additional reports will be issued by the working group in order to discuss the results of the Design Phase survey in other technical areas. In addition to the design phase reports, the working group is also issuing a report that will deal with a survey on the review of new reactor applications, focusing on questions related to the construction stage.

APPENDIX A: CONTAINMENT DESIGN AND OTHER SAFETY RELATED STRUCTURAL DESIGN

Summary table

Country	Is this area reviewed?	Are confirmatory analyses performed?	Expertise of reviewers	Level of effort
Canada	Yes.	Yes.	Structural engineer.	3 000 hours.
Finland	Yes.	Yes.	Civil engineer.	1 150 working days (9 200 hours).
France	Yes.	Yes.	Civil works engineers, mechanical engineers.	–[1]
India	Yes.	Yes.	Civil, structural and geotechnical engineers.	–[1]
Japan	Yes.	Yes.	Civil, structural and mechanical engineers, geophysicists. Generally, staff that have more than 10 year- experience are taken on the task.	–[1]
Korea	Yes.	Yes.	Structural engineer.	3 800 hours.
Russia	Yes	Yes	Civil Engineer with in-depth experience in nuclear civil structures designing.	–[1]
Slovakia	Yes.	No.	Civil engineer.	–[2]
Slovenia	Yes.	Yes.	Structural engineer, civil engineer, geophysicist, mechanical engineer.	3 600 hours[3].
United Kingdom	Yes.	Yes.	Chartered engineer, typically over ten year-experienced in the area.	4 man-years (5 250 hours).
United States	Yes.	Yes.	Structural engineer.	3 500 hours.

Notes:

1. The level of effort is not estimated for each review area.
2. In the Slovak Republic, the standard level of effort for the review of submitted documentation is defined by regulation and dependent upon the activity to be approved.
3. In Slovenia, the level of effort (hours) estimated on the basis of analysis, which was prepared in order to assess the resources needed in case of construction of new nuclear power plants.

Containment design and other safety related structural design	Canada CNSC
Design information provided by applicant.	Structural analysis, design and construction information including the description of structures, applicable codes and standards, analysis and design methodology, and construction methods: – General arrangement and layout of foundations and structures including plan, elevation and sectional views; – Technical specifications related to design, fabrication, installation, construction as well as examination and testing; – Quality assurance and quality control programmes for the construction phase.
Analysis, reviews and/or research performed by the reviewer and scope of review.	In general, 3-D finite element analysis/design are required for containment structure. The design review will include the follow-up of the related loading evaluation and its application into the design, such as assessment and the results of the external/internal natural/manmade events. In addition, review of a soil-structure interaction analysis is also required.
What type of confirmatory analysis (if any) is performed?	For new design and construction methodologies a confirmatory test/analysis should be requested to justify it.
Technical basis • **standards** • **codes** • **acceptance criteria** **(e.g. can come from accident analysis, regulatory guidance).**	The main technical basis are: CNSC REGDOC 2.5.2 (RD 337) and CNSC Staff Review Procedures with the following Canadian Standards: – CSA N287 series for concrete Containment design; – CSA N291 for safety related structures; – CSA N289 series for seismic qualification; – CSA A23 series for concrete design and construction; – CSA S16 for structural steel design, fabrication and installation.
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	Structural engineer with expertise in design and analysis of concrete and steel structures of nuclear power plants.
Specialised training, experience and/or education needed for the review of this topic.	All technical reviewers are required to have sufficient knowledge and experience in the review area such as the regulatory requirements, codes and standards, and structural design/construction methods.
Level of effort in each review area.	3 000 hours.

Containment design and other safety related structural design	Finland STUK
Design information provided by applicant.	– Preliminary safety report, chapters for containment design; – Project specification and design guide for SC 2 (incl. containment) structures; – Containment specific construction plan including design bases, construction materials, coatings, structural analysis and dimensioning, drawings, inspection programme, type test results and type-approved products plus products in accordance with certified product declarations, procedure qualification and work tests, manufacturing procedures, description of manufacturer and testing organisations.
Analysis, reviews and/or research performed by the reviewer and scope of review.	– Comparative linear analyses of structural behaviour of nuclear island including containment structures by VTT (TSO); – Comparative linear/non-linear analyses of main steam pipeline breakage effects to containment penetration structures by VTT (TSO); – Detail level review of design documents by STUK assisted by specialists from VTT and Pontek (TSO); – Comparative linear/non-linear analysis of inner containment by licensee; – Separate comparative non-linear analysis of ultimate capacity of containment under severe accident situations required from the designer.
What type of confirmatory analysis (if any) is performed?	– Linear and non-linear 3D finite element method (FEM) analyses; – Floor response spectra analyses, dynamic structural analyses for equipment; – Modal superposition based and direct integration based methods.
Technical basis • **standards** • **codes** • **acceptance criteria (e.g. can come from accident analysis, regulatory guidance).**	– Eurocode 2 and 3 so, that they fulfil also Finnish Building Code requirements; – YVL 4.1, Concrete structures for nuclear facilities; – YVL 4.2, Steel structures for nuclear facilities; – YVL 4.3, Fire protection at nuclear facilities; – KTA, IEC/IEEE standards for qualification against external vibrations; – LOCA and severe accident related load analyses based structural design for isolation between nuclear facilities and external area, eurocode based factorised requirements for ultimate capacity, earthquake peak ground acceleration (PGA) 0.1 g.
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	– No official requirements, but in practice; – Senior Inspectors: university degree in civil engineering, adequate working experience in design/research; – TSO specialists: as above, but more concentrated in corresponding technical domain.
Specialised training, experience and/or education needed for the review of this topic.	– Altogether 5 week training course on nuclear safety; – Site training: one day for common issues and first days under senior guidance; – After first observations on civil engineering at the construction period: joint seminar/workshop between civil engineering inspectors.
Level of effort in each review area.	– Regulatory review: 700 working days; – Consultants: 300 working days; – TSO (VTT): 150 working days.

Containment design and other safety related structural design	France ASN
Design information provided by applicant.	As part of the section 3.1 of the safety analysis report, the French electricity supplier Electricité De France (EDF) should provide the followings: – Assumptions and calculation notes; – Formwork and wiring guide drawings; – Reinforcement guide drawings; – Metal structures guide drawings; – Documents interface design incorporating the technical constraints of the other trades; – Technical specifications; – Civil engineering standards.
Analysis, reviews and/or research performed by the reviewer and scope of review.	The French TSO Institut de radioprotection et de sûreté nucléaire (IRSN) evaluates the global model and calculation of the nuclear island carried out by EDF. For example, according to behaviour requirements, hypothesis, input data and load cases introduced in the model are checked. The global results which are used for basement and structures design are analysed in terms of coherence with hypothesis and existence of margins. After that, a detailed assessment of a selection of safety related structures is carried out: – nuclear island basement; – reactor building: steel liner, inner pre-stressed containment, outer containment (airplane shell), internal structures, pool; – fuel building: internal structures, pool; – safeguard auxiliary building; – pumping station. At this step, IRSN analyses detailed calculation notes and drawings in order to ensure that results are coherent with design methodology, criteria and construction rules defined in ETC-C and also with “Art Rules” and the Book of Technical Specifications (RST). Detailed safety assessments do not consist in a technical control but in an analysis which objectives are to ensure that design and demonstrations are robust, according to safety and regulatory rules. At the end of most of its assessments, IRSN asked EDF to carry out some additional justifications which led sometimes to significant modifications. Accounting those complementary justifications and modifications, IRSN concludes that evaluations carried out on design studies are globally satisfactory.

What type of confirmatory analysis (if any) is performed?	IRSN identified items whose construction should be inspected, because of their importance for safety or because of special execution difficulties encountered during the past construction of NPPs. If it is necessary to aid IRSN, confirmatory analyses may be performed.
Technical basis • **standards** • **codes** • **acceptance criteria** **(e.g. can come from accident analysis, regulatory guidance).**	The following requirements are applicable to this technical area: – Technical guidelines for the design and construction of the next generation of nuclear power plants with pressurised water reactors; – DAC (authorisation decree to create an INB); – Fundamental Safety Rules (RFS); – Technical Code for Civil works in which are defined design criteria and construction rules (ETC-C); – Eurocodes; – French standards in addition to European standards; – Professional recommendations.
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	The review requires a team of: – Civil works engineers; – Mechanical engineers.
Specialised training, experience and/or education needed for the review of this topic.	Experience and knowledge that are needed to perform review in this technical area include: – Reinforced concrete, pre-stressed concrete and steel structures; – Sealing devices (water-stop, membranes ...); – Anchors, supports, inserts; – Welding and non-destructive examination.
Level of effort in each review area.	The level of effort is very important but is not estimated.

Containment design and other safety related structural design	India AERB
Design information provided by applicant.	The requirements are elaborated in AERB document on “Consenting Process For Nuclear Power Plants And Research Reactors” AERB/NPP&RR/SG/G-1. The design description part of safety analysis report should bring out design criteria/bases and functional requirements and how these are met in the detailed design. Following documents are necessary for regulatory review as per the above mentioned guide. a. Design Basis Reports (DBR): (a) General description: Functional and physical description of the structure, safety requirements, safety and seismic classification, layout; (b) Applicable design codes, standards and specifications; (c) Materials of construction, material properties; (d) Loads and load combinations; (e) Design and analysis procedures: Analysis methodology, mathematical model, design for strength and serviceability, important assumptions in analysis and design, seismic analysis methodology, soil structure interaction, structure-structure interaction, hydrodynamic aspects, design requirements pertaining to geotechnical safety and foundation design, structural acceptance criteria; (f) Construction and maintenance aspects, provisions for in-service inspection; (g) Special requirements, if any, such as tests, structural instrumentation, fire protection, decommissioning, special construction techniques. b. Dynamic Analysis Reports (DAR): These reports should cover in detail all aspects of dynamic analysis including modelling aspects, input parameters, dynamic characteristics of the structure, generation of floor response spectra and important results (i.e. output), spatial interaction aspects of lower seismic category structures. c. Design Reports (DR): These reports should present input parameters for analysis and design, calculation of design forces from analysis results, sample design calculations and specific design features, if any. d. Design Basis Report on Shielding (DBRS): DBR on shielding should cover in detail the bulk shielding aspects of concrete structures used as shielding for radioactive systems, components and structures. It should also cover layout and shielding of penetrations through these shielding structures. Layout of areas/rooms containing active systems/equipment requiring shielding should also be covered in detail with respect to structures (walls and slabs) used for

	shielding. e. Documents on industrial safety during construction: – Job Hazard Analysis Report; – Construction Safety Management Manual; – Supporting documents for Industrial Safety during Construction. f. Construction methodology document and report on concrete mix design: The construction methodology document should cover specific construction/erection aspects of various structures vis-à-vis design intent and quality requirements, general descriptions of various structures, materials of construction, sequence of construction, pour size and sequence, construction joints, form work and shuttering, handling of concrete (viz. production, delivery, placement, compaction, curing), control of concrete temperature, adequacy of construction machinery and manpower, sections identified for mock-ups, etc. The report on concrete mix design should cover qualification of concrete ingredients, trial mix details, laboratory tests, field trials including all tests necessary for qualification, acceptance of the mix design and its suitability under field conditions. The construction methodology should also address the qualification, testing and acceptance of embedded parts within the concrete structures designed for shielding purpose. g. Details of construction colony (for existing sites). h. Emergency preparedness plan covering the project construction personnel (for existing sites). i. Nuclear security aspects relevant to construction phase. j. Quality Assurance (QA) plan of the designer: QA plan of contractor including organisation chart, inspection/test/rectification procedures, formats, inspection frequency by contractor’s and utility’s personnel, sampling frequency for material testing, etc.
Analysis, reviews and/or research performed by the reviewer and scope of review.	Layout of plant bringing out location of all buildings and structures and general description of the layout requirements and functional requirements of all buildings and structures important to safety are reviewed. Layout of equipment of safety systems and safety related systems including, amongst other aspects, requirements of ISI, nuclear security, operational surveillance, fire safety, radiation zoning, internal events, maintainability and life extensions are assessed. With respect to each of the buildings and structures important to safety the review cover the following: (i) Functional and safety requirements. It should include shielding aspects for bulk shielding and penetrations through shielding; (ii) Design basis and design requirements to satisfy functional and safety requirements; (iii) Design requirements pertaining to geotechnical aspects and foundation design; (iv) Layout and considerations for layout. It should include layout of

	bulk shielding structures, penetrations through shielding structures and areas/rooms containing radioactive systems/components/ equipment; (v) Analysis methodology, mathematical modelling, codes, guides and standards used for analysis/design, validation of computer codes for analysis and design, design for strength, serviceability and shielding requirements, seismic design, description of loads, design values of loads and load combinations, materials and material properties, important assumptions in analysis and design; (vi) Construction and maintenance aspects, provision for in-service inspection; (vii) Special requirements such as tests, structural instrumentation, fire protection, decommissioning, as applicable. With respect to reactor building (RB) the review covers containment structures, internal structure, calandria vault and air lock barrels. The following aspects are covered: (i) Containment pressure, leak tightness, containment penetrations, provisions for meeting leak tightness requirements, provision for conducting proof test and leakage rate tests including instrumentation for structural monitoring and leakage rate tests; (ii) Containment pressure suppression system, separation of high enthalpy volume to low enthalpy volume, vent system and suppression pool, provisions for pressure equalisation within RB, operational aspects of airlocks and interlock logics. The review of service building covers radiation zoning aspects and shielding aspects for rooms/areas handling radioactive jobs. Review of spent fuel storage building covers fuel transfer duct, spent fuel pool and spent fuel bay, test requirements of the pool and bay and shielding aspects associated with these areas/structures.
What type of confirmatory analysis (if any) is performed?	As a good practice, independent proof checking (i.e. finite element modelling, analysis and design) of important safety related concrete is carried out. The structures that undergo proof checking are Inner containment building, outer containment building, reactor building internal structure and spent fuel pool Related analysis and design reports from designer as well as independent proof checking are reviewed by regulatory body. Confirmatory analyses are performed, if necessary, on a case-by-case basis by the technical service organisation or at the designated division of AERB.

Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g. can come from accident analysis, regulatory guidance).**	a. Design of Pressurised Heavy Water Reactor Based Nuclear Power Plants (AERB/NPP-PHWR/SC/D (Rev. 1)). The relevant sections are: – 5.3 Design for Reliability of Structures, Systems and Components; – 5.9 Other Design Considerations; – 5.9.1 Sharing of Structures, Systems and Components in Multi-reactor Nuclear Power Plants; – 6.5 Civil Structures and Containment System. b. Quality Assurance In Nuclear Power Plants (AERB/NPP/SC/QA (Rev.1)). The relevant sections are: – 3.2.2.3 Site Construction. c. Quality Assurance During Construction Of Civil Engineering Structures Important To Safety Of Nuclear Facilities (AERB/NF/SM/CSE-3). d. Materials of construction for civil engineering structures Important to safety of nuclear facilities (AERB/NF/SG/CSE-4). e. Containment System Design For Pressurised Heavy Water Reactors (AERB/NPP-PHWR/SG/D-21). f. Safety Classification And Seismic Categorisation For Structures, Systems And Components Of Pressurised Heavy Water Reactors (AERB/NPP-PHWR/SG/D-1). g. Seismic Qualification of Structures, Systems and Components of Pressurised Heavy Water Reactor (AERB/SG/D-23). h. Civil Engineering Structures Important To Safety Of Nuclear Facilities (AERB SAFETY STANDARD NO. AERB/SS/CSE). i. Design Of Concrete Structures Important To Safety Of Nuclear Facilities (AERB/SS/CSE-1). j. AERB/SS/CSE-2: Steel. k. AERB/SS/CSE-4: EPs. l. AERB/SG/CSE-2: Geotechnical Aspects And Safety Of Foundation For Buildings And Structures Important To Safety Of Nuclear Power Plants. m. Regulatory Inspection During Construction Of Civil Engineering Structures Important to Safety Of Nuclear Facilities (AERB/NF/SM/CSE-4).
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	– Civil, structural and geotechnical engineers having experience in system development, static and dynamic analysis and modelling, system review, construction, regulatory experience. – Exposure to nuclear reactor engineering, reactor systems. – Engineers with reactor operation and maintenance background especially civil structures. – Experts capable of assessment of external hazards, seismic structural analysis, probabilistic assessments, development of software for analysis and design, etc.
Specialised training, experience and/or education needed for the review of this topic.	Reviewers are from regulatory staff undergone formal training in relevant areas and subsequently in regulatory/safety review. Many have additional specialisation (e.g. Master's degree in structural/geotechnical engineering, construction experience). Further, the regulatory staff is trained in various

	review areas through participation in the safety review and regulatory inspection process. The other members of the review team are from the premier academic institutes, TSO's who are working in specialised areas.
Level of effort in each review area.	In depth review is done by the specialist working group constituted by the Civil Engineering Safety Committee and Project Design Safety Committee of AERB. The second level of review at CESC or PDSC, which specially looked at the unresolved issues of the specialist group. The final level of safety review is done at ACPSR before the recommendations are forwarded to the AERB Chairman. The depth and schedule of a review should depend on whether the project is of new, evolved or repeat design. As an example, some recent data with respect to man-days spent are given below: – The standard design lead plant – 804 hours; – Standard design (repeat) – 664 hours; – New design – 2175 hours; – New design (imported plant) – 3 916 hours.

Containment design and other safety related structural design	Japan NRA
Design information provided by applicant.	In the establishment permit application stage, the following information is provided regarding the containment vessel: – Structure; – Design pressure and design temperature as well as leakage rate against DBAs; – Limiting pressure and limiting temperature against severe accidents; – Other main systems (e.g. reactor containment ventilation air conditioner system, annulus air cleaning system, containment vessel spray system, ignitors and PARs); – PRA report and safety analysis report of DBAs and severe accidents; – Load combination for short-term and long-term; – Codes and standards. In addition, in construction work approval application stage, the following information of the containment vessel is provided: – Design policy; – Plan, section view, structural drawing, system diagram; – Design conditions; – Design description of strength calculation, system integrity under DBAs and severe accidents; – Test and inspection programme; – Quality control and assurance programme.
Analysis, reviews and/or research performed by the reviewer and scope of review.	These activities are to conform to the requirements, standards, criteria and are like described below.
What type of confirmatory analysis (if any) is performed?	In the establishment permit application stage, adequacy of an applicant's analytic method and the analysis results are verified. Independent evaluation is also performed to comprehend the uncertainties of the analytic method, if needed.
Technical basis • **standards;** • **codes;** • **acceptance criteria.** **(e.g. can come from accident analysis, regulatory guidance).**	The following regulatory requirements and guides are applicable to this technical area: Requirements: – Requirement of SCCs of commercial NPPs (H25 #5); – Interpretation of Requirement of SCCs of commercial NPPs (#1306193); – Standard of technical ability of severe accident management of commercial NPPs (#1306197); – Technical standard of SCCs of commercial NPPs (H25 #6); – Interpretation of Technical standard of SCCs of commercial NPPs (#1306194). Guides: – Guide for evaluation of effectiveness of preventive measures against core damage and containment vessel failure (#13061915);

	– Guide for procedure of construction work approval (#13061920).
Skill sets required by (Education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	– Senior: manager and engineer; – Junior: engineer; – TSO**:** researcher. Generally the staffs who have more than 10 year-experience are taken on the task.
Specialised training, experience and/or education needed for the review of this topic.	– Basic training for the examiner for nuclear safety; – Practical application training for the examiner for nuclear safety.
Level of effort in each review area.	Resources (hours) is not set up for the individual review area. Regarding the standard processing duration, 2 years is set up for establishment permit of an entire plant, and 3 months per one application is set up for construction work approval. Divided application is granted for construction work approval.

Containment design and other safety related structural design	Korea KINS
Design information provided by applicant.	The applicant should provide the following information and technical requirements applied in the design of containment buildings and other safety related structures (i.e. seismic Category I structures): – Seismic category of structures: seismic Category I, seismic Category II and non-seismic Category; – General description of structures: general arrangement of structures, structural configuration of each structure (plan, elevation and section view) and structural function description; – Structural analysis and design information: design philosophy, design loads and load combinations, structural material, analysis method, design criteria, design codes, standards and specifications; – Quality assurance programmes and quality control for fabrication and construction works.
Analysis, reviews and/or research performed by the reviewer and scope of review.	The design of containment buildings and other safety related structures is reviewed in accordance with the nuclear laws of the republic of Korea (i.e. Nuclear Safety Act, Enforcement Decree of the Nuclear Safety Act, Enforcement Regulation of the Nuclear Safety Act and Regulations on Technical Standards for Nuclear Reactor Facilities, etc.), KINS safety review guidelines (SRGs), KINS regulation standards (KINS/RSs series), KINS regulation guidelines (KINS/RGs series). US NRC RGs series can be referenced if necessary. Currently, the detail review of the Safety Analysis Report is performed on the basis of the guidelines of “Safety Review Guidelines for Light Water Reactors (Revision 3, KINS/GE-N001)”. The relevant sections of the SRGs are listed below. In addition, the KINS staff may have technical consultation or research projects to review specific issues from external experts: – KINS SRG 3.2.1 Seismic Classification; – KINS SRG 3.3.1 Wind Loadings; – KINS SRG 3.3.2 Tornado Loadings; – KINS SRG 3.4.2 Hydraulic Analysis Procedures; – KINS SRG 3.5.1.4 Missiles Generated by Tornadoes and Extreme Winds; – KINS SRG 3.5.1.5 Site Proximity Missiles (except Aircraft); – KINS SRG 3.5.1.6 Aircraft Hazards; – KINS SRG 3.5.3 Barrier Design Procedures; – KINS SRG 3.7.1 Seismic Design Parameters; – KINS SRG 3.7.2 Seismic System Analysis; – KINS SRG 3.7.3 Seismic Subsystem Analysis; – KINS SRG 3.7.4 Seismic Instrumentation; – KINS SRG 3.8.1 Concrete Containment; – KINS SRG 3.8.2 Steel Containment; – KINS SRG 3.8.3 Concrete and Steel Internal Structures of Steel or Concrete Containments; – KINS SRG 3.8.4 Other Seismic Category I Structures; – KINS SRG 3.8.5 Foundations;

	– KINS SRG 3.10 Seismic and Dynamic Qualification of Mechanical and Electrical Equipment; – KINS SRG Appendix 3.7.1-1 Minimum Requirement of Power Spectral Density; – KINS SRG Appendix 3.7.1-2 Review Procedure of Design Response Spectra; – KINS SRG Appendix 3.8.4-1 Requirements for Safety Related Concrete Masonry Structures; – KINS SRG Appendix 3.8.4-2 Structural Design Audit; – KINS SRG Appendix 3.8.4-3 Design Report; KINS SRG Appendix 3.8.4-4 Spent Fuel Storage Racks.
What type of confirmatory analysis (if any) is performed?	– Verification of design response spectra and power spectral density of ground motions. – Soil-structure interaction analysis for the design of safety related structures if needed.
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g. can come from accident analysis, regulatory guidance).**	The applicable KINS regulatory requirements are listed below: – Nuclear Safety Act, Article 10 Construction Permit; – Nuclear Safety Act, Article 20 Operating License; – Enforcement Regulation of the Nuclear Safety Act, Article 4 Application for Construction Permit, etc.; – Enforcement Regulation of the Nuclear Safety Act, Article 5 Preparation of Attached Documents for Construction Permit; – Enforcement Regulation of the Nuclear Safety Act, Article 11 Application for Standard Design Approval, etc; – Enforcement Regulation of the Nuclear Safety Act, Article 12 Preparation of Attached Documents for Standard Design Approval; – Enforcement Decree of the Nuclear Safety Act, Article 17 Application for Construction Permit; – Regulations on Technical Standards for Nuclear Reactor Facilities, etc., Article 4 Geological Features and Earthquakes; – Regulations on Technical Standards for Nuclear Reactor Facilities, etc., Article 12 Safety Classes and Standards; – Regulations on Technical Standards for Nuclear Reactor Facilities, etc., Article 13 External Events Design Bases; – Regulations on Technical Standards for Nuclear Reactor Facilities, etc., Article 15 Environmental Effects Design Bases, etc; – Nuclear Safety and Security Commission Notice No 6. (2012-06), Provisions on Safety-Related Facilities of Nuclear Reactor – Nuclear Safety and Security Commission Notice No 9. (2012-09), Provisions on Safety Classification and Standards of Each Class; – Nuclear Safety and Security Commission Notice No 13. (2012-13), Guidelines on Application of Korea Electric Power Industry Code on; – Technical Standards of Nuclear Facilities. The KINS staff reviews the Safety Analysis Report based on the KINS/RSs series, KINS/RGs series and US NRC RGs series. Some relevant regulation standards and guidelines are listed below: – KINS/RS-N03.00 3.2 Classification; – KINS/RS-N03.00 3.3 Applicable Standards and Criteria; – KINS/RS-N03.00 3.4 External Hazard; – KINS/RS-N03.00 3.5 Equipment Qualification;

	– KINS/RS-N03.00 3.8 Materials; – KINS/RS-N03.00 3.10 Arrangement of Building and Room; – KINS/RS-N04.00 4.2 Geotechnical Property; – KINS/RS-N04.00 4.3 Wind Loadings and Tornado Loadings; – KINS/RS-N04.00 4.4 Flooding Protection; – KINS/RS-N04.00 4.5 Missile Protection; – KINS/RS-N04.00 4.7 Seismic Design; – KINS/RS-N04.00 4.8 Containment Building Design; – KINS/RS-N04.00 4.9 Seismic Category I Structures; – KINS/RG-N03.01 Codes and Standards; – KINS/RG-N03.02 Seismic Qualification of Mechanical and Electric Equipment; – KINS/RG-N04.06 Seismic Instrumentation; – KINS/RG-N04.07 In-service Inspection of Ungrouted Tendons in Prestressed Concrete Containments; – KINS/RG-N04.08 Design Response Spectrum; – KINS/RG-N04.09 Protection Coating of Reactor Facilities; – KINS/RG-N04.10 In-service Inspection of Prestressed Concrete Containment Structures with Grouted Tendons; – KINS/RG-N04.11 Combination of Modal Response; – KINS/RG-N04.12 Flood Protection; – KINS/RG-N04.13 Development of Floor Design Response Spectra for Seismic Design of Floor-Supported Equipment or Components; – KINS/RG-N04.16 Determining Prestressing Forces for Inspection of Prestressed Concrete Containments; – KINS/RG-N04.17 Qualifications for Cement Grouting for Prestressing Tendons in Containment Structures; – KINS/RG-N04.18 Pre-Earthquake Planning and Immediate Nuclear Power Plant Operator Post-earthquake Actions; – KINS/RG-N04.19 Restart of a Nuclear Power Plant Shut Down by a Seismic Event; – KINS/RG-N04.20 Design Report; – KINS/RG-N04.21 Structural Design Audit; – KINS/RG-N04.22 Design of Spent Fuel Pool; – KINS/RG-N04.23 Design of Concrete Masonry Wall; – KINS/RG-N04.25 Design of Spent Fuel Pool Racks; – KINS/RG-N04.26 Load Combinations for Containment Building and Design Criteria; – KINS/RG-N04.27 Load Combinations for Seismic Category I Structures and Design Criteria; – RG 1.12 Nuclear Power Plant Instrumentation for Earthquakes; – RG 1.13 Spent Fuel Storage Facility Design Basis; – RG 1.29 Seismic Design Classification; – RG 1.35 In-service Inspection of Ungrouted Tendons in Prestressed Concrete Containments; – RG 1.35.1 Determining Prestressing Forces for Inspection of Prestressed Concrete Containments; – RG 1.54 Service Level I, II, and III Protective Coatings Applied to Nuclear Power Plants; – RG 1.57 Design Limits and Loading Combinations for Metal Primary Reactor Containment System Components;

	– RG 1.59 Design Basis Floods for Nuclear Power Plants; – RG 1.60 Design Response Spectra for Seismic Design of Nuclear Power Plants; – RG 1.61 Damping Values for Seismic Design of Nuclear Power Plants; – RG 1.69 Concrete Radiation Shields and Generic Shield Testing for Nuclear Power Plants; – RG 1.76 Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants; – RG 1.90 In-service Inspection of Prestressed Concrete Containment Structures with Grouted Tendons; – RG 1.92 Combining Modal Responses and Spatial Components in Seismic Response Analysis; – RG 1.100 Seismic Qualification of Electric and Mechanical Equipment for Nuclear Power Plants; – RG 1.102 Flood Protection for Nuclear Power Plants; – RG 1.107 Qualifications for Cement Grouting for Prestressing Tendons in Containment Structures; – RG 1.117 Tornado Design Classification; – RG 1.122 Development of Floor Design Response Spectra for Seismic Design of Floor-Supported Equipment or Components; – RG 1.127 Inspection of Water-Control Structures Associated with Nuclear Power Plants; – RG 1.136 Design Limits, Loading Combinations, Materials, Construction, and Testing of Concrete Containments; – RG 1.142 Safety-Related Concrete Structures for Nuclear Power Plants (Other than Reactor Vessels and Containments); – RG 1.166 Pre-Earthquake Planning and Immediate Nuclear Power Plant Operator Post-earthquake Actions; – RG 1.167 Restart of a Nuclear Power Plant Shut Down by a Seismic Event; – RG 1.199 Anchoring Components and Structural Supports in Concrete; – RG 1.216 Containment Structural Integrity Evaluation for Internal Pressure Loadings Above Design-Basis Pressure. In addition, the following codes and standards are applicable for safety review: – Korea Electric Power Industry Code (KEPIC): KEPIC Nuclear Safety Related Structures (SN), KEPIC General Structural Provisions (ST), KEPIC Structural Welding (SW), KEPIC Material (MD), KEPIC Non-destructive Examination (ME), KEPIC Nuclear Mechanical (MN) and KEPIC Welding (MQ); – ACI 349 Code Requirements for Nuclear safety Related concrete structures and Commentary; – ANSI/AISC N690 Specification for the Design, Fabrication and Erection of Steel Safety-Related Structures for Nuclear Facilities; – ASME (American Society of Mechanical Engineers) Boiler and Pressure Vessel Code, Section III, Division 2; – Concrete Reactor Vessels and Containments, American Society of Mechanical Engineers; – ASCE 7 Minimum Design Loads for Buildings and Other Structures.

Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	– Structural engineer with extensive knowledge in the following area: o structural design of post-tensioned structures, reinforced concrete structures and steel structures; o structural dynamics and earthquake engineering; o regulatory guides and industrial codes/standards related to nuclear power plant structures.
Specialised training, experience and/or education needed for the review of this topic.	– Education: regulatory requirements, guidelines, codes and standards. – Experience: structural analysis and design of nuclear power plant structures.
Level of effort in each review area.	Approximately 3 800 hours.

Containment design and other safety related structural design	Russia SEC NRS
Design information provided by applicant.	– Chapters 1, 3 and 12 chapters of PSAR (final safety analysis report, FSAR); – Reports of analyses of containment and other safety related structures; – Quality assurance programme for the NPP construction phase.
Analysis, reviews and/or research performed by the reviewer and scope of review.	– Review of NPP general plan; – Review of soil basis and foundation stability of category I buildings and structures; – Review of strength of constructions of reactor building (against inner and external loading); – Review of containment; – Review of strength of constructions of category I buildings and structures other that reactor building; – Review of procedure of testing of containment.
What type of confirmatory analysis (if any) is performed?	Confirmatory analyses for reactor building, containment structure and other safety related buildings shall be listed in PSAR and presented to regulatory body for review. Regulatory body checks the sufficiency of the analyses list and fulfil the Review of the most important analyses.
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g. can come from accident analysis, regulatory guidance).**	The following regulatory documents are applicable to the technical sphere under consideration: – Federal law “On the Use of Atomic Energy” No. 170-FZ dated of November 21, 1995; – Federal law “Technical Regulations on the Safety of Buildings and Building Structures” No. 384-FZ dated of December 30, 2009; – NP-001-97, “General Safety Provisions for Nuclear Power Plants” (OPB-88/97); – NP-006-98, “Requirements to the Contents of Safety Analysis Report for a Nuclear Power Plant with VVER-type Reactor” (PNAE G- 01-036-95); – NP-031-01, “Design Standards for Aseismic Nuclear Power Plants”; – NP-010-98, “Design Standards for Reinforced Structures of NPP Safety Localizing Systems”; – NP-064-05, “Accounting of External Natural and Man-Induced Impacts on Nuclear Facilities”; – NP-082-07, “Nuclear Safety Rules for Reactor Installations of Nuclear Power Plants”; – PiN AE-5.6, “Construction Design Standards for NPP with Different Reactors Types”; – PiN AE-5.10.87, “Foundations of NPP Reactor Buildings”; – SP 2.6.1. 758-99, “Radiation Safety Standards” (NRB-99); – NP-090-1, “Requirements to Nuclear Installations Quality Assurance Programme”. Besides that the requirements and recommendations of the following documents are taken into account: – SNiP 52-01-2003, “Concrete and Reinforced Structures”; – SNiP 2.01.07-85*, “Loads and Impacts”; – Quality Management Systems. Requirements. GOST R ISO 9001-2001; – IAEA Safety Guides No. NS-G-1.5, NS-G-1.6, NS-G-1.10 and others.

Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	– Civil engineers, geotechnical and environmental engineers with in-depth experience in nuclear civil structures designing; – Senior TSO staff with more than 10 year-experience in nuclear civil structures designing, as a rule with scientific degree; – Junior TSO staff with more than 3 year-experience in nuclear civil structures designing; – Also Laboratories of Academy of Sciences and Civil Engineering university are invited.
Specialised training, experience and/or education needed for the review of this topic.	All technical reviewers are required to have knowledge of federal norms and regulations and safety guides. Knowledge of Civil Engineering norms and rules is also required. Training is needed for junior staff. Such training in different forms (lectures, professional contests etc.) is organised by SEC NRS (Scientific and Engineering Centre for Nuclear and Radiation Safety, the TSO of the regulatory body).
Level of effort in each review area.	The level of effort is not estimated.

Containment design and other safety related structural design	Slovakia UJD
Design information provided by applicant.	– Technical description; – Construction documentation (scheme, drawings, references on the detailed information if it is needed); – Demonstrate the containment ability performs its functions during all life-cycle in normal, transient and accident condition; – Demonstrate that containment fulfils all requirements arising from regulation No. 430/2011 Coll; – Extent of expected strength load together with the requirements on defined response of buildings and civil structures considering in the project; – Buildings and civil structures ability to resist required combination of loads during fulfilment their safety function; – Methodology description and criteria using on the seismic evaluation and seismic classification of buildings and civil constructions.
Analysis, reviews and/or research performed by the reviewer and scope of review.	Review of the submitted documentation, if it conforms to atomic act and regulations. Evaluate if the systems, structures and components are in compliance with all requirements arising from applicable regulations, codes and standards. Confirm that the containment and other civil structures: – Are able to manage their roles in the condition of working environment; – That the structures have been properly classified to identify their importance to safety.
What type of confirmatory analysis (if any) is performed?	
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g. can come from accident analysis, regulatory guidance).**	
Skill sets required by (Education); • **senior (regulator);** • **junior (regulator);** • **TSO.**	– Senior: civil engineer; – Junior: civil engineer; – TSO: civil engineer.
Specialised training, experience and/or education needed for the review of this topic.	Experience with building and civil structures evaluation.

Level of effort in each review area.	Review of the submitted design information is a part of approval process which is performed as an administrative procedure based on administrative proceeding code. Based on this act 60 days are scheduled for approval of the submitted documentation. In case more time is needed (for example if a review from TSO or the other support organisation is needed) the chairperson can be asked to extend the period for approval. In some cases, which are strictly defined in the atomic act the time period for reviewing is longer. These cases are as follows: – Four months if siting of nuclear installation, except repository is concerned; – Six months if nuclear installation commissioning or decommissioning stage is concerned; One year if building authorisation, siting and closure of repository or repeated authorisation for operation of a nuclear installation are concerned.

Containment design and other safety related structural design	Slovenia SNSA
Design information provided by applicant.	– Technical description, analysis and design information of concrete containment including information on testing and in-service inspection; – Technical description, analysis and design information for steel containments or class MC steel portions of steel/concrete containments including information on testing and in-service inspections; – Technical description, analysis and design information of steel and concrete internal structures inside steel or concrete containments; – Technical description, analysis and design information of all seismic category I structures and other safety related structures that may not be classified as seismic category I, other than the containment and its interior structures; – Technical description, analysis and design information of foundations of all seismic category I structures including assessment of stability of these structures.
Analysis, reviews and/or research performed by the reviewer and scope of review.	Detailed review and determination that the design information included in the application meet regulatory requirements, guidance and applicable codes for demonstrating reasonable assurance of safety.
What type of confirmatory analysis (if any) is performed?	– Floor response spectra analyses, dynamic structural analyses for equipment; – Verification of design response spectra and power spectral density of ground motions; – Soil-structure interaction analysis for the design of safety related structures if needed.
Technical basis: • **standards;** • **codes;** • **acceptance criteria (e.g. can come from accident analysis, regulatory guidance).**	General aspects of design standards including: – IAEA, “Safety of Nuclear Power Plants: Design”, Safety Standards Series No. SSR-2/1, IAEA, Vienna (2012); – IAEA, “Site Evaluation for Nuclear Installations”, Safety Standards Series No. NS-R-3, IAEA, Vienna (2003); – IAEA, “Format and Content of the Safety Analysis Report for Nuclear Power Plants” – Safety Guide, Safety Standards Series No. GS-G-4.1, IAEA, Vienna (2004); – IAEA, “Safety Assessment and Verification for Nuclear Power Plants”, Safety Standards Series No. NS-G-1.2, IAEA, Vienna (2001); – IAEA, “Engineering Safety Aspects of the Protection of Nuclear Power Plants against Sabotage”, Nuclear Security Series No. 4, IAEA, Vienna (2007); – IAEA, “Design of Reactor Containment Systems for Nuclear Power Plants” – Safety Guide, Safety Standards Series No. NS-G-1.10, IAEA, Vienna (2004); – IAEA, “Seismic Design and Qualification for Nuclear Power Plants” – Safety Guide, Safety Standards Series No. NS-G-1.6, IAEA, Vienna (2003). The main technical basis are Eurocodes and Regulation JV5 (Rules on radiation and nuclear safety factors). JV5 requires that a nuclear power plant shall be fitted with a containment that shall ensure any releases of radioactive substances during a design-basis event into the environment remain below

	statutory limits. The containment system shall comprise: – Leak-tight structures enclosing all the essential components of the primary reactor-coolant system; – Containment temperature- and pressure-controlling systems; – Devices for isolation, containment and removal of radionuclides, hydrogen, oxygen and other substances that may be released into the containment atmosphere; – Any line that penetrates the containment and forms a part of the reactor coolant-pressure boundary or is in direct contact with the containment atmosphere shall be isolated automatically and reliably upon any event that leads to a design-basis event. Each such line shall be fitted with at least two appropriate isolation valves in series. Isolation valves shall be located as close to the containment as practicable; – Any line that penetrates the containment and does not form a part of the reactor coolant-pressure boundary and is not in direct contact with the containment atmosphere shall be fitted with at least one appropriate isolation valve. The isolation valve shall be located outside the containment, as close to the containment as practicable; – The containment building shall retain its functionality even in an event of a direct crash of a large commercial aircraft. In additional, the following codes and standards are applicable for safety: – ASME Boiler and Pressure Vessel Code, Section III; – ASME Boiler and Pressure Vessel Code, Section XI; – ACI 349, "Code Requirements for Nuclear Safety Related Concrete Structures"; – ANSI/AISC N690-1994, "Specification for the Design, Fabrication and Erection of Steel Safety-Related Structures for Nuclear Facilities"; – ACI 318, "Building Code Requirements for Structural Concrete"; – ASCE 7, "Minimum Design Loads for Buildings and Other Structures"; – AISC, "Steel Construction Manual"; – ANSI/ANS-2.8-1992, "Determining Design Basis Flooding at Power Reactor Sites." – ASCE 4-98, Seismic Analysis of safety-Related Nuclear Structures and Commentary; – ASCE/SEI 43-05, Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities.
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	– Senior: structural engineer, civil engineer, geophysicist; – Junior: structural engineer, civil engineer, geophysicist; – TSO: structural engineer, mechanical engineer, civil engineer, geophysicist.
Specialised training, experience and/or education needed for the review of this topic.	– Background in earthquake engineering; – Experience in structural analysis, dynamics and design of nuclear category I structures; – Understanding of integrated nuclear plant operations and systems interaction; – Knowledge and experience with steel and concrete codes for design of containments and other seismic category I structures, and other industry standards.

Level of effort in each review area.	– Regulator: 1 600 hours; – TSO' review time: 2 000 hours.

Containment design and other safety related structural design	United Kingdom ONR
Design information provided by applicant.	– Basis of design documents; – Design codes; – Analysis inputs/outputs; – Reliability calculations; – Supporting research and test results.
Analysis, reviews and/or research performed by the reviewer and scope of review.	Detailed review of all design information.
What type of confirmatory analysis (if any) is performed?	Independent reliability estimates.
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g. can come from accident analysis, regulatory guidance).**	Basis of our decision on Safety Assessment Principles (SAPs) and Technical Assessment Guides (TAGs).
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	– Honours degree in relevant subject; – Chartered engineer; – Typically over 10 year-experience in related areas.
Specialised training, experience and/or education needed for the review of this topic.	– Training in design codes used; – Experience in the development of fragility data; – Experience in the construction of large pre-stressed concrete structures.
Level of effort in each review area.	Containment review: 4 man-years of effort.

Containment design and other safety related structural design	United States US NRC
Design information provided by applicant.	In the SAR, the applicant should provide the following information on concrete containments; steel containments; internal structures of the containment; all seismic Category I structures; and foundations of seismic Category I structures: – General arrangement of structures and foundations, including plan and section views; – Identification and description of those structural elements or sections considered to be critical to maintain the integrity of the structure or building during a design basis event; – A functional description of each building; – Design parameters for winds, tornadoes, hurricanes, floods, earthquakes and other credible environmental phenomena and respective selection criteria; – Applicable design codes, standards and specifications; – Loading criteria, including loads and load combinations; – Design and analysis procedures; – Design acceptance criteria; – Materials, quality control and quality assurance programmes, and special construction techniques (if applicable); – Testing and in-service inspection programmes.
Analysis, reviews and/or research performed by the reviewer and scope of review.	The Nuclear Regulatory Commission (NRC) staff (1) reviews the information provided in the SAR for compliance with the regulations, (2) issues requests for additional information (RAIs) as necessary, (3) reviews RAI responses, (4) resolves technical issues with applicants or licensees and (5) develops a safety evaluation report (SER) documenting its findings. The scope and level of detail of the staff's safety review is based on the guidance of NUREG-0800, Standard Review Plan (SRP). The sections of the SRP that are applicable to this technical area are as follows: – SRP 3.3.1, "Wind Loadings"; – SRP 3.3.2, "Tornado Loading"; – SRP 3.4.2, "Analysis Procedures"; – SRP 3.5.3, "Barrier Design Procedures"; – SRP 3.7.1, "Seismic Design Parameters"; – SRP 3.7.2, "Seismic System Analysis"; – SRP 3.7.3, "Seismic Subsystem Analysis"; – SRP 3.8.1, "Concrete Containment"; – SRP 3.8.2, "Steel Containment"; – SRP 3.8.3, "Concrete and Steel Internal Structures of Steel or Concrete Containments"; – SRP 3.8.4, "Other Seismic Category I Structures"; – SRP 3.8.5, "Foundations"; – SRP 14.3.2, "Structural and System Engineering – Inspections, Tests, Analysis, and Acceptance Criteria". As part of the review, the NRC staff also considers emerging technical and construction issues, operating experience and lessons learnt related to this technical area.

What type of confirmatory analysis (if any) is performed?	The staff commonly performs confirmatory analyses to verify the adequacy of the following submittal(s) related to this technical area: – Soil Structure Interaction (SSI) Analysis; For new and novel construction approaches, the applicant may be requested to perform confirmatory tests.
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g. can come from accident analysis, regulatory guidance).**	The following NRC regulatory requirements are applicable to this technical area: – 10 CFR Part 50, Appendix A, General Design Criteria: o GDC 1, "Quality Standards and Records"; o GDC 2, "Design Bases for Protection Against Natural Phenomena"; o GDC 4, "Environmental and Dynamic Effects Design Bases"; o GDC 5, "Sharing of Structures, Systems, and Components; o GDC 16, "Containment Design"; o GDC 44, "Cooling Water"; o GDC 50, "Containment Design Bases". – 10 CFR Part 50, Appendix B as it relates to the quality assurance criteria for nuclear power plants; – 10 CFR Part 50, Appendix J, "Primary Reactor Containment Leakage testing for Water-Cooled Power Reactors"; – 10 CFR Part 50, Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants"; – 10 CFR 50.34(f), "Additional TMI-related requirements"; – 10 CFR 50.44, "Combustible Gas Control for Nuclear Power Plants"; – 10 CFR 50.55a, "Codes and Standards"; – 10 CFR 52.47 (b)(1), "Requirement for DC application to contain the proposed inspection, tests, analyses, and acceptance criteria (ITAAC); – 10 CFR 52.80(a), "Requirement for COL application to contain the proposed inspection, tests, analyses, and acceptance criteria (ITAAC); – 10 CFR 100 Subpart A, "Evaluation Factors for Stationary Power Reactor Site Applications Before January 10, 1997 and for Testing Reactors"; – 10 CFR 100 Subpart B, "Evaluation Factors for Stationary Power Reactor Site Applications on or After January 10, 1997"; – 10 CFR Part 100, Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants". The NRC guidance documents that provide an acceptable basis for meeting the regulations and are applicable to this technical area are as follows: – RG 1.7, "Control of Combustible Gas Concentrations in Containment Following a Loss-of-Coolant Accident"; – RG 1.29, "Seismic Design Classification;" – RG 1.35, "Inservice Inspection of Ungrouted Tendons in Prestressed Concrete Containments"; – RG 1.35.1, "Determining Prestressing Forces for Inspection of Prestressed Concrete Containments"; – RG 1.57, "Design Limits and Loading Combinations for Metal Primary Reactor Containment System Components"; – RG 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants"; – RG 1.61, "Damping Values for Seismic Design of Nuclear Power Plants";

	– RG 1.69, "Concrete Radiation Shields for Nuclear Power Plants"; – RG 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants (LWR Edition.)"; – RG 1.76, "Design basis Tornado and Tornado Missiles for Nuclear Power Plants"; – RG 1.90, "Inservice Inspection of Prestressed Concrete Containment Structures with Grouted Tendons"; – RG 1.91, "Evaluations of Explosions Postulated to Occur on Transportation Routes Near Nuclear Power Plants"; – RG 1.92, "Combining Modal Responses and Spatial Components in Seismic Response Analysis"; – RG 1.94, "Quality Assurance Requirements for Installation, Inspection, and testing of Structural Concrete and Structural Steel during the Construction of Nuclear Power Plants"; – RG 1.102, "Flood Protection for Nuclear Power Plants"; – RG 1.107, "Qualifications for Cement Grouting for Prestressing Tendons in Containment Structures"; – RG 1.115, "Protection Against Low Trajectory Turbine Missiles"; – RG 1.117, "Tornado Design Classification"; – RG 1.122, "Development of Floor Design Response Spectra for Seismic Design of Floor-Supported equipment or Components"; – RG 1.127, "Inspection of Water-Control Structures Associated with Nuclear Power Plants"; – RG 1.136, "Materials, Construction, and Testing of Concrete Containments"; – RG 1.142, "Safety-Related Concrete Structures for Nuclear Power Plants (Other than Reactor Vessels and Containments); – RG 1.143, "Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in LWR Plants"; – RG 1.160, "Monitoring the Effectiveness of Maintenance at Nuclear Power Plants"; – RG 1.163, "Performance-Based Containment Leak-Test Program"; – RG 1.199, "Anchoring Components and Structural Supports in Concrete"; – RG 1.206, "Combined License Applications for Nuclear Power Plants"; – RG 1.208, "A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion"; – RG 1.221, "Design-Basis Hurricane and Hurricane Missiles for Nuclear Power Plants"; Note: Guidance documents are not a substitute for regulations, and compliance with guidance documents is not required. The Codes and Standards related to this technical area are as follows: – ASME Boiler and Pressure Vessel Code, Section III; – ASME Boiler and Pressure Vessel Code, Section XI; – ACI 349, "Code Requirements for Nuclear Safety Related Concrete Structures"; – ANSI/AISC N690-1994, "Specification for the Design, Fabrication and Erection of Steel Safety-Related Structures for Nuclear Facilities";

	– ACI 318, "Building Code Requirements for Structural Concrete"; – ASCE 7, "Minimum Design Loads for Buildings and Other Structures"; – AISC, "Steel Construction Manual"; – ANSI/ANS-2.8-1992, "Determining Design Basis Flooding at Power Reactor Sites".
Skill sets required to perform review.	– Structural engineer with expertise in the design, analysis, construction, inspection, and testing of concrete, steel structures and related materials.
Specialised training, experience and/or education needed for review.	Technical reviewers are required to complete a formal training and qualification programme prior to performing safety reviews independently. Other specialised training, experience and education that is needed to successfully perform reviews in this technical area include: – Knowledge in regulatory requirements, regulatory guides, and codes and standards; – Knowledge and experience in structural analysis and design of nuclear containment structures and other seismic Category I structures; – Knowledge and experience with steel and concrete codes for the design of containment structures and other seismic Category I structures, and industry standards; – Experience in structural dynamics, structural analysis and structural design; – Experience in construction, inspection and testing of nuclear structures; – Experience in operation and maintenance of nuclear structures; – Basic knowledge on hydrology and meteorology; – Basic knowledge on geotechnical and earthquake engineering; – A minimum of Bachelor of Science (B.S.) degree in civil engineering; preferably higher education in structural engineering.
Level of effort in each review area.	3 500 hours (this estimate includes NRC staff and technical support for all technical disciplines involved in the review of an application for design certification application).

APPENDIX B: EXTERNAL NATURAL EVENT LOADINGS (E.G. EARTHQUAKE, WEATHER, FLOODING, FIRE)

Summary table

Country	Is this area reviewed?	Are confirmatory analyses performed?	Expertise of reviewers	Level of effort
Canada	Yes.	Yes.	Structural engineer.	600 hours.
Finland	Yes.	No.	Civil engineer.	130 working days (1 040 hours).
France	Yes.	No.	Civil works engineers, mechanical engineers.	–[1]
India	Yes.	Yes.	Civil, structural and geotechnical engineers.	–[1]
Japan	Yes.	Yes.	Civil, structural and mechanical engineers, geophysicists. Generally, staff that has more than 10 year-experience is taken on the task.	–[1]
Korea	Yes.	Yes.	Seismologist, geophysicist, geologist, geotechnical/rock mechanics engineer, meteorologist.	3 000 hours.
Russia	Yes	Yes	Civil Engineer, structural engineer, geotechnical and environmental engineers with in-depth experience in design and analysis of external natural event protection in NPP.	–[1]
Slovakia	Yes.	No.	Technical engineer.	–[2]
Slovenia	Yes.	Yes.	Hydrologist, geologist, civil engineer, geophysicist.	2 200 hours[3].
United Kingdom	Yes.	No.	Chartered engineer, typically over ten year-experienced in the area.	–[4]
United States	Yes.	Yes.	Structural engineer, geotechnical engineer, geophysicist, meteorologist, geologist, hydrologist, PRA analyst.	16 500 hours.

Notes:

1. The level of effort is not estimated for each review area.
2. In the Slovak Republic, the standard level of effort for the review of submitted documentation is defined by regulation and dependent upon the activity to be approved.
3. In Slovenia, the level of effort (hours) estimated on the basis of analysis, which was prepared in order to assess the resources needed in case of construction of new nuclear power plants.
4. Insufficient information available to estimate level of effort for full review in the area.

External natural event loadings	Canada CNSC
Design information provided by applicant.	3D-analysis as well as simplified “Stick” models simplified methods.
Analysis, reviews and/or research performed by the reviewer and scope of review.	Research programmes performed to: – Determine the serviceability and ultimate seismic capacity of reinforced concrete walls; – Assess the effect soil structure interaction using non-linear techniques.
What type of confirmatory analysis (if any) is performed?	Structural dynamic analysis along with seismic soil-structure interaction analysis. Verification of design criteria based on test results.
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g. can come from accident analysis, regulatory guidance).**	The main technical basis are: CNSC REGDOC 2.5.2 and CNSC Staff Review Procedures supported by Canadian National Building Code as well as CSA (Canadian Standards Association), ASCE and ACI standards.
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	Structural engineer with extensive experience in the design, analysis and testing of structures under seismic, wind, rain and snow loadings as well as in the review of licencing submissions related to structural analysis and designs of nuclear facilities to withstand these loadings.
Specialised training, experience and/or education needed for the review of this topic.	Extensive experience in the behaviour of reinforced concrete structures gained in analysis, design, testing or review of licensees’ submission related to earthquake, wind, rain and snow resisting design of nuclear facilities.
Level of effort in each review area.	CNSC staff: 600 hours.

External natural event loadings	Finland STUK
Design information provided by applicant.	PSAR, seismic hazard analysis for the site.
Analysis, reviews and/or research performed by the reviewer and scope of review.	CFD analyses of fire dynamics.
What type of confirmatory analysis (if any) is performed?	
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g. can come from accident analysis, regulatory guidance).**	YVL 2.6, YVL 2.8, YVL 4.3, Finnish building code.
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	No official requirements, but in practice: – Senior Inspectors: university degree in civil engineering, adequate working experience in design/research.
Specialised training, experience and/or education needed for the review of this topic.	– Altogether 5 week training course on nuclear safety; – Site training: one day for common issues and first days under senior guidance. After first observations on civil engineering at the construction period: joint seminar/workshop between civil engineering inspectors.
Level of effort in each review area.	– Regulatory review: 30 working days; – Consultants: 0; – TSO (VTT): TSO statements: 100 working days.

External natural event loadings	France ASN
Design information provided by applicant.	EDF should provide the followings: Safety analysis report: – Section 3.3.4: Risks linked to industrial environment -explosion-pressure wave; – Section 3.3.2: Earthquake; – Section 3.3.5: External flooding; – Section 3.3.6: Extreme climatic conditions; – Section 3.3.7: Lightning and electro-magnetic interferences; – Section 3.2: Classification of construction work; – Section 15.0.2: Accident analysis rules; – Section 1.7: Applicable regulatory documents. Technical guideline: – ELPES000011A: External explosion Doctrine; – ENSNDR030011B: Earthquake Doctrine REX Blayais; – ENSN000850C: External flooding Doctrine; – ENSNDR030031A: External flooding Doctrine; – EN5N8787F: Extreme climatic conditions Doctrine; – ELGGC970088B: Extreme climatic conditions Doctrine; – ENSNEA0040103A: Extreme climatic conditions Doctrine; – ENITSF040050A: Extreme climatic conditions Doctrine; – ENSEMS030303A: Lightning and electro-magnetic interferences.
Analysis, reviews and/or research performed by the reviewer and scope of review.	IRSN evaluates in addition to: "Containment design and other safety related structural design": – Rules and methods used for the dynamic analysis of buildings; – Building modelling; – Loading combination in relation with External Natural Events.
What type of confirmatory analysis (if any) is performed?	
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g. can come from accident analysis, regulatory guidance).**	The following requirements are applicable to this technical area: – Technical guidelines*; – Fundamental safety rule 2001 01 (RFS): Earthquake; – ASN Earthquake design guideline; – Fundamental safety rule 1.2.d (RFS): External explosion; – Fundamental safety rule 1.2.e (RFS): External flooding; – Eurocode. *Technical guidelines for the design and construction of the next generation of nuclear power plants with pressurised water reactors
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	The review requires a team of: – Civil works Engineers; – Mechanical Engineers.

Specialised training, experience and/or education needed for the review of this topic.	Other specialised training, experience and education that are needed to successfully perform reviews is this technical area include: – Experience in External hazard assessment; – Methodology and inspection programme.
Level of effort in each review area.	The level of effort is very important but is not estimated.

<table>
<tr><th>External natural event loadings</th><th>India
AERB</th></tr>
<tr><td>Design information provided by applicant.</td><td>The requirements are elaborated in AERB document on “Consenting Process For Nuclear Power Plants And Research Reactors” AERB/NPP&RR/SG/G-1. Among other requirement for submission of information the following reports can be mentioned:
A. Report on Design Basis Ground Motion:
The report should cover geological and seismological investigations including site seismicity based on historical earthquake data, recorded earthquakes, site-specific instrumentation and other geological investigations on faults and ground failure aspects. Derivation of design basis ground motion should cover in detail seismotectonics and lineaments map of the site, design basis earthquake levels, peak ground accelerations, response spectra and time histories in two orthogonal horizontal and vertical directions. The report should contain all information as required by AERB safety guide titled Seismic Studies and Design Basis Ground Motion for Nuclear Power Plant Sites AERB/SG/S-11.
B. Report on Geotechnical Investigations and Foundation Parameters:
The report should cover topology and geology of the site, sub surface condition and profiles, boreholes, trial pits, water table, various field tests for determination of foundation parameters including geophysical tests permeability tests and load tests, soil/rock sampling and laboratory tests related to geotechnical characterisation and strength parameters. The report should also cover evaluation of suitability of the soil/rock as foundation medium and evaluation of foundation design parameters.
Confirmatory geotechnical and geological investigations are required to be carried out after foundation excavation. The report on confirmatory investigation should include geological mapping of the excavated foundation pits of RB, results of confirmatory geotechnical and geological investigations, and confirmation of the foundation parameters.
C. Report on Design Parameters for Meteorological Events:
This report should cover data collection, data analysis and evaluation of design parameters for structural design with regard to wind, rainfall, flooding, temperature, humidity and any other site-specific meteorological event.
D. Report on Site Grading and Surface Drainage:
This report should cover derivation of finished grade levels of the main plant complex and design of plant drainage.</td></tr>
<tr><td>Analysis, reviews and/or research performed by the reviewer and scope of review.</td><td>Those related to environmental conditions and aspects which will influence the design basis of the plant/facility, will be review in detail, namely:
(i) Geology and soil mechanics;
(ii) Topography;
(iii) Hydrology and hydro-geology;
(iv) Meteorology;
(v) Natural phenomena such as earthquakes, floods and tornadoes.
Data which have formed inputs for design basis parameters, e.g. seismic data, wind loads, flood levels, meteorological, geological and hydrological</td></tr>
</table>

	characteristics, population distribution and land use are included. The extent of the evaluation by the applicant and the amount and detail of information provided on any particular factor should be commensurate with the importance of that factor to safety. The review will cover the following: – Site location: Geographical location indicating latitude longitude, distance/direction with respect to major towns/landmarks, location map, access roads/routes covering at least 50 km from the facility; – Geological setting and tectonic set up; effect on design of foundation and structures; – Seismic design basis, parameters covering the data base used, regional geology and tectonic, earthquake occurrence history; – Applicable attenuation law for PGA. PGAs for S1 (OBE) and S2 (SSE) levels, PGA response spectra and spectrum compatible accelerograms; – Topography and ground-water conditions of the site area; – Geotechnical investigation and evaluation of foundation parameters; – River, lake, other water bodies, water retaining structures, etc.; – Nearest military and civilian airports; – Meteorological and environmental data which affect plant design and gaseous radioactive effluents, viz., wind speed, direction and duration (wind roses), data for design basis wind loads, precipitation, peculiarities of local meteorological conditions including effect of terrain, which could have impact on diffusion of radioactive releases; – Flood & Shore line erosion.
What type of confirmatory analysis (if any) is performed?	Confirmatory analyses are performed, if necessary, on a case-by-case basis by the technical service organisation or at the designated division of AERB. The commonly performed confirmatory analyses are to verify the adequacy of the submissions related to Failure Modes and Effects Analysis. As best **practice**, expert elicitation is conducted on key areas of seismo-tectonics and hydrology, with respect to specific cases.
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g. can come from accident analysis, regulatory guidance).**	– Code of Practice on Safety in Nuclear Power Plant Siting, AERB/SC/S; – Extreme Values of Meteorological Parameters, AERB/NF/SG/S-3; – AERB/SG/S-11 Seismic Studies and Design Basis Ground Motion for Nuclear Power Plant Sites; – AERB/SG/S-6A Design Basis Flood for Nuclear Power Plants on Inland Sites; – AERB/SG/S-6B Design Basis Flood for Nuclear Power Plants at Coastal Sites; – AERB/SG/S-7 (Draft); – AERB/SG/CSE-2, Geotechnical Aspects And Safety Of Foundation For Buildings And Structures Important To Safety Of Nuclear Power Plants.
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	– Civil, structural and geotechnical Engineers having experience in system development, static and dynamic analysis and modelling, system review, construction, regulatory experience; – Exposure to nuclear reactor engineering, Reactor Systems; – Engineers with reactor operation and maintenance background especially civil structures; – Expertise on derivation of ground motion parameters, hydrology, flood routing, extreme value analysis, probabilistic assessments, etc.

Specialised training, experience and/or education needed for the review of this topic.	Reviewers are from regulatory staff undergone formal training in relevant areas and subsequently in regulatory/safety review. Many have additional specialisation e.g. Master’s degree in structural/geotechnical engineering, construction experience. Further, the regulatory staff is trained in various review areas through participation in the safety review and regulatory inspection process. The other members of the review team are from the premier academic institutes, TSO’s who are working in specialised areas. Reviewers also undertake specialised training courses on a case by case basis.
Level of effort in each review area.	In depth review is done by the specialist working group constituted by the Civil Engineering Safety Committee and Project Design Safety Committee of AERB. The second level of review at CESC or PDSC, which specially looked at the unresolved issues of the specialist group. The final level of safety review is done at ACPSR before the recommendations are forwarded to Chairman AERB. The depth and schedule of a review should depend on whether the project is of new, evolved or repeat design. As an example, some recent data with respect to man-days spent are given below: – The standard design lead plant – 397 hours; – Standard design(Repeat) – 109 hours; – New design – 626 hours; – New design (Imported Plant) – 660 hours.

External natural event loadings	Japan NRA
Design information provided by applicant.	In the establishment permit application stage, the following information is provided: – Circumstances, such as weather, ground, forest, hydrology, earthquake, volcano, and social environment, at the site for installing a nuclear reactor facility; – Design conditions, such as design basis of ground motion, tsunami, wind speed of tornado, external fire, volcanic ash accumulation, and combination of these; – Earthquake PRA and Tsunami PRA; – Basic design policy. In addition, in construction work approval application stage, the following information is provided: – Design policy; – Plan, section view, structural drawing, system diagram; – Design conditions; – Design description of strength calculation, system integrity under design basis of external natural events; – Test and inspection programme; – Quality control and assurance programme.
Analysis, reviews and/or research performed by the reviewer and scope of review.	These activities are to conform to the standards, criteria, and are like described below.
What type of confirmatory analysis (if any) is performed?	
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g. can come from accident analysis, regulatory guidance).**	The following regulatory requirements and guides are applicable to this technical area. Requirements: – Requirement of SCCs of commercial NPPs (H25 #5); – Interpretation of Requirement of SCCs of commercial NPPs (#1306193); – Standard of technical ability of severe accident management of commercial NPPs (#1306197); – Technical standard of SCCs of commercial NPPs (H25 #6); – Interpretation of Technical standard of SCCs of commercial NPPs (#1306194). Guides: – Guide for procedure of construction work approval (#13061920); – Guide for design basis ground motion and design policy of earthquake resistant (#1306192); – Guide for foundation ground and stability of slope (#1306194); – Guide for survey of geology and geological structure (#1306191); – Guide for construction work approval of earthquake resistant (#1306195); – Guide for design basis tsunami and design policy of tsunami resistant

	(#1306193); – Guide for construction work approval of tsunami resistant (#1306196); – Guide for evaluation of tornado (#13061911); – Guide for evaluation of volcano (#13061910); – Guide for evaluation of external fire (#13061912).
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	– Senior: Manager and engineer; – Junior: Engineer; – TSO**:** Researcher. Generally the staffs who have more than 10 year-experience are taken on the task.
Specialised training, experience and/or education needed for the review of this topic.	– Basic training for the examiner for nuclear safety; – Practical application training for the examiner for nuclear safety.
Level of effort in each review area.	Resources (hours) is not set up for the individual review area. Regarding the standard processing duration, 2 years is set up for establishment permit of an entire plant, and 3 months per one application is set up for construction work approval. Divided application is granted for construction work approval.

External natural event loadings	Korea KINS
Design information provided by applicant.	The applicant should provide the following information and technical requirements: – Seismicity, earthquake catalogue; – Geological characteristics and tectonic activity; – Seismic source model; – Seismic wave attenuation; – Seismic wave transmission characteristics of the site; – Seismic hazard analysis; – Simulation of strong ground motion by a finite fault; – Geotechnical site characteristics; – Hydrological site characteristics; – Meteorological site-characteristics; – Major historical flood events in the site region including stream floods, surges, seiches, tsunami, dam failures, ice jams, floods induced by landslides and similar events; – Identify measures to address potential flooding; – Identify measures to address potential external fire; – Assessment of the risks associated with external flooding.
Analysis, reviews and/or research performed by the reviewer and scope of review.	The Safety Analysis Report is reviewed in accordance with the nuclear laws of the republic of Korea (i.e. Nuclear Safety Act, Enforcement Decree of the Nuclear Safety Act, Enforcement Regulation of the Nuclear Safety Act and Regulations on Technical Standards for Nuclear Reactor Facilities, etc.), KINS safety review guidelines (SRGs), KINS regulation standards (KINS/RSs series), KINS regulation guidelines (KINS/RGs series) and US NRC RGs series). Currently, the detail review of the Safety Analysis Report is performed on the basis of the guidelines of “Safety Review Guidelines for Light Water Reactors (Revision 3, KINS/GE-N001)”. The relevant sections of the SRGs are listed below. In addition, the KINS staff may have technical consultation or research projects to review specific issues from external experts: – KINS SRG 2.3.1 Regional Climatology; – KINS SRG 2.3.2 Local Meteorology; – KINS SRG 2.4.2 Floods; – KINS SRG 2.4.3 Probable Maximum Flood (PMF) on Streams and Rivers; – KINS SRG 2.4.5 Probably Maximum Surge and Seiche; – KINS SRG 2.4.6 Probable Maximum Tsunami; – KINS SRG 2.4.7 Ice Effects; – KINS SRG 2.4.10 Flood Protection Requirements; – KINS SRG 2.4.12 Groundwater; – KINS SRG 2.5.1 Basic Geologic and Seismic Information; – KINS SRG 2.5.2 Vibratory ground motion; – KINS SRG 2.5.3 Surface Faulting”; – KINS SRG 2.5.4 Stability of Subsurface Materials; – KINS SRG 2.5.5 Slope Stability; – KINS SRG 3.2.1 Seismic Classification;

	– KINS SRG 3.3.1 Wind Loadings; – KINS SRG 3.3.2 Tornado Loadings; – KINS SRG 3.4.2 Hydraulic Analysis Procedures; – KINS SRG 3.5.1.4 Missiles Generated by Tornadoes and Extreme Winds; – KINS SRG 3.7.1 Seismic Design Parameters; – KINS SRG 3.7.2 Seismic System Analysis; – KINS SRG 3.7.3 Seismic Subsystem Analysis; – KINS SRG 3.7.4 Seismic Instrumentation.
What type of confirmatory analysis (if any) is performed?	For safety review, KINS staff performs a routine confirmatory analyses including literature review, site visit and expert consultation in general.
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g. can come from accident analysis, regulatory guidance).**	The applicable KINS regulatory requirements are listed below: – Nuclear Safety Act, Article 10 Construction Permit; – Nuclear Safety Act, Article 20 Operating License; – Enforcement Regulation of the Nuclear Safety Act, Article 4 Application for Construction Permit, etc; – Enforcement Regulation of the Nuclear Safety Act, Article 5 Preparation of Attached Documents for Construction Permit; – Enforcement Regulation of the Nuclear Safety Act, Article 9 Application for Standard Design Approval, etc; – Regulations on Technical Standards for Nuclear Reactor Facilities, Etc., Article 4, Geological Features and Earthquakes – Regulations on Technical Standards for Nuclear Reactor Facilities, Etc., Article 6, Meteorological Conditions – Regulations on Technical Standards for Nuclear Reactor Facilities, Etc., Article 7, Hydrology and Oceanographic Conditions – Regulations on Technical Standards for Nuclear Reactor Facilities, Etc., Article 12 Safety Classes and Standards – Regulations on Technical Standards for Nuclear Reactor Facilities, Etc., Article 13 External Events Design Bases – Regulations on Technical Standards for Nuclear Reactor Facilities, Etc., Article 15 Environmental Effects Design Bases, etc. – Regulations on Technical Standards for Nuclear Reactor Facilities, Etc., Article 39, Protection Against Collapse of Steep Slope; – Nuclear Safety and Security Commission Notice No 03. (2012-03), Technical Standards for Locations of Nuclear Reactor Facilities; – Nuclear Safety and Security Commission Notice No 19. (2012-19), Technical Standards for Investigation and Evaluation of Meteorological Conditions of Nuclear Reactor Facility Sites; – Nuclear Safety and Security Commission Notice No 20. (2012-20), Technical Standards for Investigation and Evaluation of Hydrological and Oceanographic Characteristics of Nuclear Reactor Facility Sites. The KINS staff reviews the Safety Analysis Report based on the KINS/RSs series, KINS/RGs series. US NRC RGs series can be referenced if necessary. Some relevant regulation standards and guidelines are listed below: – KINS/RS-N01.00 1.2, Location of Site; – KINS/RS-N01.00 1.4, Meteorology; – KINS/RS-N01.00 1.5, Hydrology;

	– KINS/RS-N01.00 1.6, Features of Geology, Earthquake, and Subsurface Materials; – KINS/RS-N03.00 3.4 External Hazard; – KINS/RS-N04.00 4.3 Wind Loadings and Tornado Loadings; – KINS/RS-N04.00 4.5 Missile Protection; – KINS/RS-N04.00 4.7 Seismic Design; – KINS/RG-N01.00 1.3, Survey and Evaluation of the Characteristics of Meteorology and Atmospheric Diffusion in a Reactor Facility Site; – KINS/RG-N01.00 1.4, Survey and Assessment of a Flood and the Water Supply of the Site of a Reactor Facility and its Adjacent Areas; – KINS/RG-N01.00 1.5, Survey and Assessment of Underwater Properties and Liquid Radioactive Material Leakage at The Site of Reactor Facility and its Adjacent Areas; – KINS/RG-N01.00 1.6, Assessment of Features of Geology, Earthquake and Subsurface Materials for Reactor Facility Sites; – KINS/RG-N01.00 1.7, Determination of Design Earthquake for Nuclear Power Facility Site; – KINS/RG-N01.00 1.8, Determination on the Extent of Influence of Surface Faulting; – KINS/RG-N01.00 1.9, Investigation and Evaluation for the Slope Stability for Nuclear facility Site; – KINS/RG-N03.02 Seismic Qualification of Mechanical and Electric Equipment; – KINS/RG-N04.06 Seismic Instrumentation; – KINS/RG-N04.08 Design Response Spectrum; – KINS/RG-N04.12 Flood Protection; – KINS/RG-N04.13 Development of Floor Design Response Spectra for Seismic Design of Floor-Supported Equipment or Components; – RG 1.27, Ultimate Heat Sink for Nuclear Power Plants; – RG 1.59, Flood Design Basis for Nuclear Power Plants; – RG 1.60, Design Response Spectra for Seismic Design of Nuclear Power Plants; – RG 1.102, Flood Protection for Nuclear Power Plants; – RG 1.122, Development of Floor Design Response Spectra for Seismic Design of Floor-Supported Equipment and Components; – RG 1.132, Site Investigations for Foundations of Nuclear Power Plants; – RG 1.138, Laboratory Investigations of Soils and Rocks for Engineering Analysis and Design of Nuclear Power Plants; – RG 1.208, A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion; – RG 1.29 Seismic Design Classification; – RG 1.59 Design Basis Floods for Nuclear Power Plants; – RG 1.60 Design Response Spectra for Seismic Design of Nuclear Power Plants; – RG 1.61 Damping Values for Seismic Design of Nuclear Power Plants; – RG 1.76 Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants; – RG 1.100 Seismic Qualification of Electric and Mechanical Equipment for Nuclear Power Plants; – RG 1.102 Flood Protection for Nuclear Power Plants; – RG 1.117 Tornado Design Classification.

	In addition, the following codes and standards are applicable for safety review: – ASTM International (formerly known as the American Society for Testing and Materials), ASTM D 1586, "Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils", 1999; – ASTM International (formerly known as the American Society for Testing and Materials), ASTM D 1587, "Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes", 2000; – ASTM International (formerly known as the American Society for Testing and Materials), ASTM D 4220, "Standard Practices for Preserving and Transporting Soil Samples", 2000; – ASTM International (formerly known as the American Society for Testing and Materials), ASTM D 4044, "Standard Test Method (Field Procedure) for Instantaneous Change in Head (Slug) Tests for Determining Hydraulic Properties of Aquifers", 2002; – ASTM International (formerly known as the American Society for Testing and Materials), ASTM D 6913, "Standard Test Method for Particle Size Distribution (Gradation) of Soils Using Sieve Analysis", 2004.
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	– Seismologist; – Geophysicist; – Geologist; – Geotechnical/Rock Mechanics Engineer.
Specialised training, experience and/or education needed for the review of this topic.	– Overall plant system knowledge; – Possession of concepts in seismology, specifically to evaluate seismic hazard analysis; – Possession of principles in hydrology, specifically to evaluate flood and groundwater loads; – Understanding of the meteorological dispersion of radioactive materials; – Experience in analysing the geophysical exploration results; – Knowledge of the subsurface and slope condition modelling; – Knowledge of in-situ and laboratory experiment for rock and soil possession of geological background (understanding of the various rocks and geological process).
Level of effort in each review area.	– Meteorologist (KINS): 400 hours; – Geo-hydrologist (KINS): 600 hours; – Geologist (KINS): 600 hours; – Seismologist (KINS): 400 hours; – Geophysicist (KINS): 400 hours; – Geotechnical engineer (KINS): 600 hours.

External natural event loadings	Russia SEC NRS
Design information provided by applicant.	– Chapters 1, 2, 3 of PSAR (FSAR); – Reports of analyses of Containment and other safety related structures; – Quality assurance programme for the construction phase.
Analysis, reviews and/or research performed by the reviewer and scope of review.	Review of strength and stability analyses presented by Applicant: – against maximum design earthquake (once per 10000 years); – against extreme wind (once per 10000 years); – against extreme snow (once per 10000 years); – against extreme temperature(once per 10000 years); – against extreme floods (once per 10000 years); – against tornado; – against tsunami (for sea coast sites).
What type of confirmatory analysis (if any) is performed?	Confirmatory analyses of Reactor building, Containment structure and other safety related buildings should be listed in PSAR and presented to regulatory body for review. Regulatory body checks the sufficiency of the list of analyses and fulfil the Review of the most important analyses.
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g. can come from accident analysis, regulatory guidance).**	The following regulatory documents are applicable to the technical sphere under consideration**:** – Federal law "On the Use of Atomic Energy" No. 170-FZ dated of November 21, 1995; – Federal law "Technical Regulations on the Safety of Buildings and Building Structures" No. 384-FZ dated of December 30, 2009; – NP-001-97, "General Safety Provisions for Nuclear Power Plants" (OPB-88/97); – NP-006-98, "Requirements to the Contents of Safety Analysis Report for a Nuclear Power Plant with VVER-type Reactor". (PNAE G- 01-036-95); – NP-032-01, "Nuclear Power Plant Siting. Basic Safety Criteria and Requirements"; – NP-031-01, "Design Standards for Aseismic Nuclear Power Plants"; – NP-064-05, "Accounting of External Natural and Man-Induced Impacts on Nuclear Facilities"; – NP-082-07, Nuclear Safety Rules for Reactor Installations of Nuclear Power Plants; – PiN AE-5.6, Construction Design Standards for NPP with Different Reactors Types; Besides that the requirements and recommendations of the following documents are taken into account: – RB-022-01, "Recommendations to Assessment of Tornado Characteristics in Respect to Nuclear Facilities"; – "Meteorological Events in Site Evaluation for Nuclear Power Plants" – Safety Guide, Safety Standards Series No. NS-G-3.4, IAEA, Vienna, 2005; – SPPNAE-87, par. 4.1. Requirements to the Contents and Scope of Engineering Survey and Research for Nuclear Power Plants Design. 1989; – SP 11-104-97, Engineering and Geodetic Surveys for Construction. 1997;

	– SNiP 11-02-96, Engineering Surveys for Construction. General Provisions. 1997; – SNiP 2.01.07-85□, Loads and Impacts; – GOST 19912-2001, Soils. Methods of Field Tests by Static and Dynamic Sounding; – RB-006-98, “Determination of Initial Seismic Soils Vibrations for Design Bases”. Moscow, 1999; – SNiP II-7-81*. Construction in Seismic Areas. Gosstroy of Russia, 2000; – RB-019-01, “Seismic Hazard Evaluation for Sites of Nuclear and Radiation Hazardous Facilities Based on Geodynamic Data”; – IAEA, “External Events Excluding Earthquakes in the Design of Nuclear Power Plants” – Safety Guide, Standards Series No. NS-G-1.5, IAEA, Vienna, 2003; – IAEA, “Seismic Design and Qualification for Nuclear Power Plants” – Safety Guide, Safety Standards Series No. NS-G-1.6, IAEA, Vienna, 2003.
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	– Civil Engineers, geotechnical and environmental engineers with in-depth experience in nuclear civil structures designing; – Senior staff has more than 10 year-experience in nuclear civil structures designing, as a rule with scientific degree; – civil structures designing; – Also Laboratories of Academy of Sciences and Civil Engineering university are invited.
Specialised training, experience and/or education needed for the review of this topic.	All technical reviewers are required to have knowledge of federal norms and rules in using of atomic energy and safety guides. Knowledge of Civil Engineering norms and rules is also required. Knowledge of safety guides and good practice of IAEA and NEA in analyses of external events is necessary.
Level of effort in each review area.	The level of effort is not estimated.

External natural event loadings	Slovakia UJD
Design information provided by applicant.	A geological and seismic loading assessment for the selected site for a nuclear facility, which has to contain: – A probabilistic seismic hazard analysis for the site; – An assessment of seismic and geological conditions in the area, and the geo-engineering and geotechnical aspects of the proposed site; – Designation of earthquake-related hazard through a seismo-tectonic assessment of the area using; – The greatest possible scope of collected information; – An assessment of the risk due to movement caused by earthquakes, taking into account the Seismo-tectonic nature of the area and site-specific conditions; – An uncertainty analysis as part of the seismic hazard analysis; – An assessment of the impact of potential surface shift at a fault on the site; – A review of the geological, geophysical and seismic characteristics of the region, regardless of state borders and the site's geotechnical characteristics, in accordance with international practice, performed in such a manner that the resultant set of data is homogenous for the entire area or at least permits sufficient determination of the nature of seismo-tectonic structures relevant for the site and the size of the region that was reviewed, the type of information analysed and the scope and details of the analysis that were specified according to the nature and complexity of seismo-tectonic conditions; – Proof of the adequacy of the scope and detail of information analysed and research performed to determine danger resulting from seismic movement and shift at a fault; Assessment results which proved, that the following requirements are fulfilled: – Selected facilities must be designed so that during natural disasters that can be realistically expected, such as earthquakes, windstorms, flooding, deluge, extreme outdoor temperatures, extreme cooling water temperatures, rain of all forms, moisture, frost, the effects of flora, fauna and so on, it is possible to; a) safely shut down the nuclear facility and maintain it in a subcritical state. b) remove residual heat from spent nuclear fuel or radioactive waste. c) maintain leaks of radioactive substances below specified levels. – The design must also take into account; d) the most serious natural phenomena historically recorded in the area around the site of the nuclear facility and extrapolated taking into account limited accuracy as far as size and time of occurrence are concerned. e) a combination of effects of phenomena caused by natural conditions and human activity. f) maximum expected acceleration given for the site's location, based on an assessment of the location's seismic loading performed during the

	siting of the nuclear facility, specified as seismic level 1 and seismic level 2. g) requirements for earthquake-resistant nuclear facility systems, components and structures or parts thereof that must correspond to their safety function and presumed effects of an earthquake according to specified seismic level 1 and seismic level 2. – Response analyses for the proposed facility for at least the following postulated external trigger events. 1. extreme wind load. 2. extreme outdoor temperatures. 3. extreme rain and local flooding. 4. extreme cooling water temperatures and icing. 5. earthquakes.
Analysis, reviews and/or research performed by the reviewer and scope of review.	Review of the submitted documentation, if it conforms to atomic act and regulations. Evaluate if the systems, structures and components are in compliance with all requirements arising from applicable regulations, codes and standards. Confirm that the nuclear facility is able to manage hazard arising from external natural events.
What type of confirmatory analysis (if any) is performed?	
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g. can come from accident analysis, regulatory guidance).**	
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	– Senior: technical engineer; – Junior: technical engineer; – TSO: technical engineer.
Specialised training, experience and/or education needed for the review of this topic.	– Experience with evaluation; – Knowledge about nuclear facilities and safety analysis.
Level of effort in each review area.	Review of the submitted design information is a part of approval process which is performed as an administrative procedure based on administrative proceeding code. Based on this act 60 days are scheduled for approval of the submitted documentation. In case more time is needed (for example if a review from TSO or the other support organisation is needed) the chairperson can be asked to extend the period for approval. In some cases, which are strictly defined in the atomic act the time period for reviewing is longer. These cases

	are as follows: – Four months if siting of nuclear installation, except repository is concerned; – Six months if nuclear installation commissioning or decommissioning stage is concerned; – One year if building authorisation, siting and closure of repository or repeated authorisation for operation of a nuclear installation are concerned.

External natural event loadings	Slovenia SNSA
Design information provided by applicant.	The design information shall provide enough information of the adequacy of protection against external natural phenomena hazards with taken into account the actual plant design, actual site characteristic and the actual condition of SSC. <u>The basic information for seismicity:</u> – geological and geotechnical site characteristic and investigations; – seismicity of the region, including seismic sources and investigations; – ground motion response spectra and safe shutdown earthquake; – non-tectonic deformation; – conditions caused by human activities (e. g., fluid injection or withdrawal, mineral extraction); – tectonic surface deformation; – stability of subsurface materials and foundations; – fault displacement potential; – minimum static bearing capacity; – minimum shear wave velocity; – liquefaction potential; – maximum settlement; – slope characteristics (including design criteria, design analyses and results of the investigations including borings, shafts, pits, trenches and laboratory tests); – slope failure potential; – probability seismic hazard analysis, assessment of risk; – design parameters;. <u>The basic information for flooding:</u> – hydrological site characteristic; – data of historical flood events; – interface of the plant with the hydrosphere; – hydrological causal mechanism; – local flooding on the site and drainage design; – stream flooding; – floods cause by dam failures, surges, seiches and landslides; – maximum flood elevation; – maximum precipitation rate; – potential for water freezing in the UHS water storage facility; – hydraulic design bases for protection of structures; – maximum elevation of groundwater; – travel time for groundwater flow; – travel time for radionuclide transport in the groundwater; – inventory of radionuclide which could potentially seep into the groundwater; – bases for emergency actions due to hydrological events; – design features to address flooding hazard. <u>The basic information for severe weather:</u> – meteorological site characteristic; – assessment of risk from severe weather events; – design features to address severe weather hazard.

Analysis, reviews and/or research performed by the reviewer and scope of review.	– Ensure that adverse environmental conditions will not preclude the safety function of the SSCs; – Ensure that the information provided is complete; compares well with data from other studies carried out in the same areas; and is supported by detailed investigations conducted by the applicant.
What type of confirmatory analysis (if any) is performed?	The hazards analysis must be performed to establish whether the plant design can accommodate commonly occurring hazards, and whether the risk of other hazards is very low.
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g. can come from accident analysis, regulatory guidance).**	General aspects of design standards including: – IAEA, "Safety of Nuclear Power Plants: Design", Safety Standards Series No. SSR-2/1, IAEA, Vienna (2012); – IAEA, "Site Evaluation for Nuclear Installations", Safety Standards Series No. NS-R-3, IAEA, Vienna (2003); – IAEA, "Format and Content of the Safety Analysis Report for Nuclear Power Plants" – Safety Guide, Safety Standards Series No. GS-G-4.1, IAEA, Vienna (2004); – IAEA, "Safety Assessment and Verification for Nuclear Power Plants", Safety Standards Series No. NS-G-1.2, IAEA, Vienna (2001); – IAEA, "Engineering Safety Aspects of the Protection of Nuclear Power Plants against Sabotage", Nuclear Security Series No. 4, IAEA, Vienna (2007); – IAEA, "Design of the Reactor Coolant System and Associated Systems in Nuclear Power Plants" – Safety Guide, Safety Standards Series No. NS-G-1.9, IAEA, Vienna (2004); – IAEA, Safety Standards Series No. NS-G-1.5, "External Events Excluding Earthquakes in the Design of Nuclear Power Plants – Safety Guide. The main technical basis are Eurocodes and JV5 (Rules on radiation and nuclear safety factors); JV5 requires that the design bases shall take into account the internal initiating events characteristic for the power plant and, as a minimum, the following external initiating events, which shall be treated in accordance with the site conditions: – extreme winds; – extreme outside temperatures; – extreme rainfall, extreme snowfall, flooding, extreme cooling-water temperatures and freezing; – earthquakes; – aircraft crashes. In addition, the following codes and standards are applicable for safety review: – ANSI/ANS-2.8-1992, "Determining Design Basis Flooding at Power Reactor Sites"; – ASCE/SEI 7, "Minimum Design Loads for Buildings and Other Structures"; – ASME Boiler and Pressure Vessel Code, Section III; – ANSI/AISC N690-1994, "Specification for the Design, Fabrication and Erection of Steel Safety-Related Structures for Nuclear Facilities"; – ACI 318, "Building Code Requirements for Structural Concrete"; – ACI 349-01, "Code Requirements for Nuclear Safety-Related Concrete

	Structures"; – AISC 325-05, "Steel Construction Manual", Thirteenth Edition; – ASTM International (formerly known as the American Society for Testing and Materials), ASTM D 5778, "Standard Test Method for Performing Electronic Friction Cone and Piezocone Penetration Testing of Soils" 1995; – ASTM International (formerly known as the American Society for Testing and Materials), ASTM D 1586, "Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils" 1999; – ASTM International (formerly known as the American Society for Testing and Materials), ASTM D 1587, "Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes" 2000; – ASTM International (formerly known as the American Society for Testing and Materials), ASTM D 4220, "Standard Practices for Preserving and Transporting Soil Samples" 2000; – ASTM International (formerly known as the American Society for Testing and Materials), ASTM D 1557, "Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 feet-lbf/feet3 [2,700 kN-m/m3])" 2002; – ASTM International (formerly known as the American Society for Testing and Materials), ASTM D 4044, "Standard Test Method (Field Procedure) for Instantaneous Change in Head (Slug) Tests for Determining Hydraulic Properties of Aquifers" 2002; – ASTM International (formerly known as the American Society for Testing and Materials), ASTM D 2850, "Standard Test Method for Unconsolidated Undrained Triaxial Compression Test on Cohesive Soils" 2003; – ASTM International (formerly known as the American Society for Testing and Materials), ASTM D 4767, "Standard Test Method for Consolidated Undrained Triaxial Compression Test for Cohesive Soils" 2004; – ASTM International (formerly known as the American Society for Testing and Materials), ASTM D 6913, "Standard Test Method for Particle Size Distribution (Gradation) of Soils Using Sieve Analysis" 2004. – ASTM International (formerly known as the American Society for Testing and Materials), ASTM D 2435, "Standard Test Method for One-Dimensional Consolidation Properties of Soils Using Incremental Loading" 2004. – ASTM International (formerly known as the American Society for Testing and Materials), ASTM D 3080, "Standard Test Method for Direct Shear Test of Soil Under Consolidated Drained Conditions" 2004. – ASTM International (formerly known as the American Society for Testing and Materials), ASTM D 2166, "Standard Test Method for Unconfined Compressive Strength of Cohesive Soils" 2006; – American Society of Civil Engineers, ASCE 4-98, "Seismic Analysis of Safety-Related Nuclear Structures and Commentary" 2000; – American Society of Civil Engineers (ASCE), Editing Board and Task Groups of the Committee on Nuclear Structures and Materials of the Structural Division, "Structural Analysis and Design of Nuclear Plant Structures" ASCE 1980; – ASME/ANS-RA-Sa-2009, "Standard for Level 1/Large Early Release Frequency PRA for Nuclear Power Plant Applications".

Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	– Senior: hydrologist, geologist, civil engineer, geophysicist; – Junior: geologist, civil engineer; – TSO: hydrologist, geologist, civil engineer, geophysicist.
Specialised training, experience and/or education needed for the review of this topic.	– Training in design codes used; – Experience in water resources, hydraulic engineering; PSA basis from external events, seismology, geotechnical engineering.
Level of effort in each review area.	– Regulator: 600 hours; – TSO' review time: 1600 hours.

External natural event loadings	United Kingdom ONR
Design information provided by applicant.	– Basis of Design documents; – Design codes; – Analysis inputs/outputs; – Generic design envelope.
Analysis, reviews and/or research performed by the reviewer and scope of review.	Detailed review of all design information.
What type of confirmatory analysis (if any) is performed?	None.
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g. can come from accident analysis, regulatory guidance).**	– Safety Assessment Principles (SAPs); – Technical Assessment Guides (TAGs); – ASCE 4-98.
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	– Honours degree in relevant subject; – Chartered engineer; – Typically 10+ years experience in related areas.
Specialised training, experience and/or education needed for the review of this topic.	– Training in design codes used; – Experience in the development of fragility data; – Experience in the construction of nuclear facilities.
Level of effort in each review area.	Review for EPR was only partial, as insufficient information available for a full design review.

External natural event loadings	United States US NRC
Design information provided by applicant.	As part of the SAR, the applicant should describe the following: – Seismicity of the immediate and surrounding region; – Applicable seismic sources; – Seismic analysis, subsystem analysis, design parameters and instrumentation; – Design parameters for winds, tornadoes, hurricanes, floods, earthquakes, tsunamis, liquefaction potential, icing and other natural phenomena hazards; – Applicable design codes and standards Loading criteria for weather related credible environmental phenomena; – Design and analysis methods to address natural phenomena hazards; – Structural acceptance criteria related to natural phenomena hazards; – Design features to address natural phenomena hazards; – Geological site characteristics; – Geotechnical site characteristics; – Hydrological site characteristics; – Meteorological site characteristics; – Major historical flood events in the site region including stream floods, surges, seiches, tsunami, dam failures, ice jams, floods induced by landslides and similar events; – Identify measures to address potential flooding; – Assessment of risk from events initiated by high winds (e.g. hurricanes and Tornados); – Assessment of the risks associated with external flooding; – Assessment of the risks associated with external fires; – PRA-based Seismic Margins Analysis; – COL applicants provide site-specific information for the purpose of confirming the applicability the seismic margins analysis to their site.
Analysis, reviews and/or research performed by the reviewer and scope of review.	The Nuclear Regulatory Commission (NRC) staff (1) reviews the information provided in the SAR for compliance with the regulations, (2) issues requests for additional information (RAIs) as necessary, (3) reviews RAI responses, (4) resolves technical issues with applicants or licensees and (5) produces a safety evaluation report (SER) documenting its findings. The scope and level of detail of the staff's safety review is based on the guidance of NUREG-0800, Standard Review Plan (SRP). The sections of the SRP that are applicable to this area are as follows: – SRP 2.3.1, "Regional Climatology"; – SRP 2.3.2, "Local Meteorology"; – SRP 2.4.2, "Floods"; – SRP 2.4.3, "Probable Maximum Flood (PMF) on Streams and Rivers"; – SRP 2.4.5, "Probably Maximum Surge and Seiche Flooding"; – SRP 2.4.6, "Probable Maximum Tsunami Hazards"; – SRP 2.4.7, "Ice Effects"; – SRP 2.4.10, "Flood Protection Requirements"; – SRP 2.4.12, "Groundwater"; – SRP 2.5.1, "Geological Characterization Information"; – SRP 2.5.2, "Seismic Ground Motion"; – SRP 2.5.3, "Surface Deformation";

	– SRP 2.5.4, "Stability of Subsurface Materials and Foundations"; – SRP 2.5.5, "Stability of Slopes"; – SRP 3.3.1, "Wind Loadings"; – SRP 3.3.2, "Tornado Loadings"; – SRP 3.4.1, "Internal Flood Protection for Onsite Equipment Failures"; – SRP 3.4.2, "Analyses Procedures"; – SRP 3.5.1.4 "Missiles Generated by Tornados and Extreme Winds"; – SRP 3.5.2 "Structures, systems and components to be protected from externally generated missiles"; – SRP 3.5.3, "Barrier Design Procedures"; – SRP 3.8.4, "Other Seismic Category I Structures"; – SRP 3.8.5, "Foundations"; – SRP 3.7.1, "Seismic Design Parameters"; – SRP 3.7.2, "Seismic System Analysis"; – SRP 3.7.3, "Seismic Subsystem Analysis"; – SRP 3.7.4, "Seismic Instrumentation"; – SRP 19.0, "Probabilistic Risk Assessment and Severe Accident Evaluation for New Reactors". The staff also considers emerging technical and construction issues, operating experience and lessons learnt related to this category.
What type of confirmatory analysis (if any) is performed?	The staff commonly performs the following confirmatory analyses to verify the adequacy of the application in this technical area: – Input used for environmental loads such as winds, floods and icing is verified to ensure consistency with acceptable codes, standards or regulatory guidance; – Analyse procedures used for translating external natural events into structural loads are evaluated to be consistent with acceptable practice; – Liquefaction potential of subsurface materials; – Dynamic slope stability; – Seismic site response; – Seismic hazard. The NRC is in a process of developing the capability of performing seismic hazard confirmatory calculations. When that capability is established, the NRC staff will routinely perform seismic hazard confirmatory analyses. Confirmatory seismic structural analysis is sometimes performed to verify the applicant's analysis assumptions. This is usually in the case of a unique site condition or a first-of-a kind seismic Category I structural system.
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g. can come from accident analysis, regulatory guidance).**	The applicable NRC Regulatory Requirements are listed below: 1. 10 CFR Part 20, "Standards for Protection Against Radiation"; 2. 10 CFR Part 50, Appendix A, GDC 1, "Quality Standards and Records"; 3. 10 CFR Part 50, Appendix A, GDC 2, "Design Bases for Protection Against Natural Phenomena"; 4. 10 CFR Part 50, Appendix A, GDC 4, "Environmental and Dynamic Effects Design Bases"; 5. 10 CFR Part 50, Appendix A, GDC 44, "Cooling Water"; 6. 10 CFR Part 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Processing Plants"; 7. 10 CFR Part 50 Appendix S, "Earthquake Engineering Criteria for

	Nuclear Power Plants"; 8. 10 CFR 50.55a, "Codes and standards"; 9. 10 CFR Part 100, "Reactor Site Criteria"; 10. 10 CFR Part 100, Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants"; 11. 10 CFR 100.20, "Factors to be Considered When Evaluating Sites"; 12. 10 CFR 100.23, "Geologic and Seismic Siting Criteria"; 13. Regulatory requirements pertaining to assessment of risk are listed in SRP 19.0, "Probabilistic Risk Assessment and Severe Accident Evaluation for New Reactors", Revision 3. The NRC guidance documents that provide an acceptable approach for satisfying the applicable regulatory requirements are listed as follows: 1. RG 1.12, "Nuclear Power Plant Instrumentation for Earthquakes"; 2. RG 1.27, "Ultimate Heat Sink for Nuclear Power Plants"; 3. RG 1.28, "Quality Assurance Program Requirements (Design and Construction)" 4. RG 1.29, "Seismic Design Classification"; 5. RG 1.59, "Flood Design Basis for Nuclear Power Plants"; 6. RG 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants"; 7. RG 1.61, "Damping Values for Seismic Design of Nuclear Power Plants." 8. RG 1.76, "Design Basis Tornado and Tornado Missiles for Nuclear Power Plants" 9. RG 1.92, "Combining Modal Responses and Spatial Components in Seismic Response Analysis." 10. RG 1.102, "Flood Protection for Nuclear Power Plants." 11. RG 1.122, "Development of Floor Design Response Spectra for Seismic Design of Floor-Supported Equipment and Components"; 12. RG 1.132, "Site Investigations for Foundations of Nuclear Power Plants"; 13. RG 1.138, "Laboratory Investigations of Soils and Rocks for Engineering Analysis and Design of Nuclear Power Plants"; 14. RG 1.165, "Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion"; 15. RG 1.166, "Pre-Earthquake Planning and Immediate Nuclear Power Plant Operator Post-Earthquake Actions"; 16. RG 1.198, "Procedures and Criteria for Assessing Seismic Soil Liquefaction at Nuclear Power Plant Sites"; 17. RG 1.206, "Combined License Applications for Nuclear Power Plants"; 18. RG 1.208, "A Performance-Based Approach to Define Site-Specific Earthquake Ground Motion"; 19. RG 1.221, "Design Basis Hurricane and Hurricane Missiles for Nuclear Power Plants"; 20. RG 4.7, "General Site Suitability Criteria for Nuclear Power Stations";

21. Applicable Guidance documents pertaining to assessment of risk are listed in SRP 19.0, “Probabilistic Risk Assessment and Severe Accident Evaluation for New Reactors”, Revision 3.

The applicable Standards related to this area are:

1. ANSI/ANS-2.8-1992, “Determining Design Basis Flooding at Power Reactor Sites”;
2. ASCE/SEI 7, “Minimum Design Loads for Buildings and Other Structures”;
3. ASME Boiler and Pressure Vessel Code, Section III;
4. ANSI/AISC N690-1994, “Specification for the Design, Fabrication and Erection of Steel Safety-Related Structures for Nuclear Facilities”;
5. ACI 318, “Building Code Requirements for Structural Concrete”;
6. ACI 349-01, “Code Requirements for Nuclear Safety-Related Concrete Structures”;
7. AISC 325-05, “Steel Construction Manual”, Thirteenth Edition;
8. ASTM International (formerly known as the American Society of Testing and materials), ASTM D 5778, “Standard Test Method for Performing Electronic Friction Cone and Piezocone Penetration Testing of Soils,” 1995;
9. ASTM International (formerly known as the American Society for Testing and Materials), ASTM D 1586, “Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils,” 1999;
10. ASTM International (formerly known as the American Society for Testing and Materials), ASTM D 1587, “Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes,” 2000;
11. ASTM International (formerly known as the American Society for Testing and Materials), ASTM D 4220, “Standard Practices for Preserving and Transporting Soil Samples,” 2000;
12. ASTM International (formerly known as the American Society for Testing and Materials), ASTM D 1557, “Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 feet-lbf/feet3 [2,700 kN-m/m3]),” 2002;
13. ASTM International (formerly known as the American Society for Testing and Materials), ASTM D 4044, “Standard Test Method (Field Procedure) for Instantaneous Change in Head (Slug) Tests for Determining Hydraulic Properties of Aquifers,” 2002;
14. ASTM International (formerly known as the American Society for Testing and Materials), ASTM D 2850, “Standard Test Method for Unconsolidated Undrained Triaxial Compression Test on Cohesive Soils,” 2003;
15. ASTM International (formerly known as the American Society for Testing and Materials), ASTM D 4767, “Standard Test Method for Consolidated Undrained Triaxial Compression Test for Cohesive Soils,” 2004;
16. ASTM International (formerly known as the American Society for Testing and Materials), ASTM D 6913, “Standard Test Method for Particle Size Distribution (Gradation) of Soils Using Sieve Analysis,” 2004;

	17. ASTM International (formerly known as the American Society for Testing and Materials), ASTM D 2435, "Standard Test Method for One-Dimensional Consolidation Properties of Soils Using Incremental Loading," 2004; 18. ASTM International (formerly known as the American Society for Testing and Materials), ASTM D 3080, "Standard Test Method for Direct Shear Test of Soil Under Consolidated Drained Conditions," 2004; 19. ASTM International (formerly known as the American Society for Testing and Materials), ASTM D 2166, "Standard Test Method for Unconfined Compressive Strength of Cohesive Soils," 2006; 20. American Society of Civil Engineers, ASCE 4-98, "Seismic Analysis of Safety-Related Nuclear Structures and Commentary," 2000; 21. American Society of Civil Engineers (ASCE), Editing Board and Task Groups of the Committee on Nuclear Structures and Materials of the Structural Division, "Structural Analysis and Design of Nuclear Plant Structures," ASCE 1980; 22. ASME/ANS-RA-Sa-2009, "Standard for Level 1/Large Early Release Frequency PRA for Nuclear Power Plant Applications".
Skill sets required to perform review.	– Structural Engineer with design and analysis experience in external natural event loading on reinforced concrete and steel structures; – Geotechnical Engineer; – Seismologist/Geophysicist; – Meteorologist; – Hydrologist; – Geologist; – PRA analyst.
Specialised training, experience and/or education needed for review.	Technical reviewers in this area are required to complete a formal qualification programme prior to performing safety reviews independently. Other specialised training, experience and education that is needed to successfully perform reviews in this technical area include: – Experience in developing seismic analysis models incorporating the effects of soil-structure interaction; – Knowledge in industry codes and standards related to steel and concrete structures; – Overall plant systems knowledge; – Experience designing protective barriers against wind-borne missiles; – Experience with wind/tornado/hurricane/icing loadings on structures; – Understanding of basic concepts in hydrology, specifically to evaluate flood and groundwater loads; – A minimum of B.S. degree in civil engineering; preferably higher education in structural engineering; – Expertise in the review and/or performance of external event PRA; – Expertise in the review and/or performance of PRA-based Seismic Margins Analysis.
Level of effort in each review area	16,500 hours (this estimate includes NRC Staff and technical support for all technical disciplines involved in the review of an application for Design Certification application).

APPENDIX C: EXTERNAL MAN-MADE HAZARDS

Summary table

Country	Is this area reviewed?	Are confirmatory analyses performed?	Expertise of reviewers	Level of effort
Canada	Yes.	Yes.	Structural engineer.	600 hours.
Finland	Yes.	Yes.	Civil engineer, mechanical engineer.	250 working days (2 000 hours).
France	Yes.	Yes.	Civil works engineers, mechanical engineers, process engineers.	–[1]
India	Yes.	Yes.	Civil, structural and geotechnical engineers.	–[1]
Japan	Yes.	Yes.	Civil, structural and mechanical engineers. Generally, staff that has more than 10 year-experience are taken on the task.	–[1]
Korea	Yes.	Yes.	Industrial safety engineer, chemical engineer.	600 hours.
Russia	Yes	Yes	Civil engineer, process engineer, automatic control engineer with in-depth experience in design and analysis of external man-made hazards protection in NPP.	–[1]
Slovakia	Yes.	No.	Technical engineer.	–[2]
Slovenia	Yes.	Yes.	Civil engineer, mechanical engineer.	600 hours[3].
United Kingdom	Yes.	Yes.	Chartered engineer, typically over 10 year-experience in the area.	1.5 FTE plus £2.2M TSO Costs (20301 hours).
United States	Yes.	Yes.	Physical scientist, structural engineer, chemical engineer, geotechnical engineer.	2 400 hours.

Notes:

1. The level of effort is not estimated for each review area.
2. In the Slovak Republic, the standard level of effort for the review of submitted documentation is defined by regulation and dependent upon the activity to be approved.
3. In Slovenia, the level of effort (hours) estimated on the basis of analysis, which was prepared in order to assess the resources needed in case of construction of new nuclear power plants.

External man-made hazards	Canada CNSC
Design information provided by applicant.	3D-analysis or simplified methods for global behaviour. Simplified methods (using SDOF or empirical formulas) for local behaviour.
Analysis, reviews and/or research performed by the reviewer and scope of review.	Extensive research programme performed under International testing programme IMPACT and international NEA simulation benchmark IRIS.
What type of confirmatory analysis (if any) is performed?	Impact analysis using LS-Dyna software and performing extensive sensitivity studies. The LS-Dyna models were calibrated using IMPACT test results.
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g. can come from accident analysis, regulatory guidance).**	The main technical basis are: CNSC REGDOC 2.5.2 and CNSC staff review procedures supported by the new IAEA Safety report related to human induced external hazards and supported by test results and recommendation of NEA report on IRIS_2012.
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	Structural Engineer with extensive experience in the design, analysis and testing of structures under impulsive and impactive loading due to human induced hazards.
Specialised training, experience and/or education needed for the review of this topic.	Extensive experience in the behaviour of reinforced concrete structures gained in multiyear testing programmes. Extensive training in non-linear analysis using LS-Dyna software and calibrating constitutive models using test results.
Level of effort in each review area.	CNSC staff: 600 hours.

External man-made hazards	Finland STUK
Design information provided by applicant.	PSAR, First structural design documents.
Analysis, reviews and/or research performed by the reviewer and scope of review.	Comparative linear/non-linear analyses of structural response against different kind of missiles and other impacts as explosion pressure waves by VTT (TSO).
What type of confirmatory analysis (if any) is performed?	Please see above.
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g. can come from accident analysis, regulatory guidance).**	KTA (incl. acceptance criteria), YVL 2.6, IEC/IEEE, Finnish building code (RakMK).
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	– No official requirements, but in practice; – Senior Inspectors: university degree in civil and mechanical engineering, adequate working experience in design/research; – TSO specialists: as above, but more concentrated in corresponding technical domain.
Specialised Training, Experience and/or Education Needed for the Review of this topic.	Altogether 5 week training course on nuclear safety.
Level of effort in each review area.	– Regulatory review: 50 working days; – Consultants: 100 working days; – TSO (VTT): TSO statements: 100 working days.

External man-made hazards	France ASN
Design information provided by applicant.	EDF should provide the followings: Safety analysis report: – Section 3.3.4: Risks linked to industrial environment; – Section 3.3.8: probabilistic results; – Section 1.6: References.
Analysis, reviews and/or research performed by the reviewer and scope of review.	Scope of the review: According to Basic safety rule I.2.d, different potential effects of industrial environment are taken into account: High temperatures because of a fire outside the site, pressure wave, seismic wave and missiles following an external explosion, toxic gas clouds.
What type of confirmatory analysis (if any) is performed?	Probabilistic analysis according to the fundamental safety rule 1.2.d has to be performed.
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g. can come from accident analysis, regulatory guidance).**	The following requirements are applicable to this technical area: – Fundamental safety rule I.2.d (RFS); – Technical guidelines* § A.2.5 (contribution of external hazards in the global risk) and § F2.2.3 (protection against external explosion); – All applicable technical guidelines identified in section 1.6 of the safety analysis report; – The ETC-C applicable for the design of civil work structures. *Technical guidelines for the design and construction of the next generation of nuclear power plants with pressurised reactors
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	The review requires a team of: – Civil works engineers; – Mechanical engineers; – Process engineers.
Specialised training, experience and/or education needed for the review of this topic.	
Level of effort in each review area.	The level of effort is very important but is not estimated.

External man-made hazards	India AERB
Design information provided by applicant.	The information provided by the Utility shall cover human activities relating to industry, military, mining, transportation, etc. in the region of the proposed site may have the potential to challenge the safety of NPP. **1) Aircraft crash:** The location of site with respect to the distance to major and minor air fields, including military airports is identified. If these distances are greater than SDVs as defined in the AERB siting code SC/S, for respective types of airports, the location of site is considered as acceptable. **2) Chemical explosions:** Plants in the site region involved in handling, processing and storage of chemicals having potential for explosion or for production of gas clouds capable of deflagration/detonation, and the transportation routes for such chemicals are identified and associated hazards in terms of over-pressure and toxicity are assessed. A site is considered unacceptable if such activities take place in its vicinity and no practical solutions are available to mitigate their effects. **3) Other important human-induced events:** Information on blasting operations in the site vicinity and activities related to mining, drilling and sub-surface extraction/injection of fluids are carefully studied to assess their impact on safety of the installation. The region is also investigated for plants/activities either within or outside the installation boundary in which flammable, explosive, asphyxiate, toxic, corrosive or radioactive materials are stored, processed, handled or transported such that if released under normal or accident conditions, could jeopardise safety of the installation. The plants that could give rise to missiles are also assessed with respect to the plant safety. Potential natural and human induced events that could result in loss of cooling water are to be identified. These events include blockage or diversion of a river, depletion of a reservoir, blockage of a reservoir or cooling water intake structure by ship collisions, oil spills and fires. If the probabilities and consequences of such events cannot be reduced to acceptable levels, then the hazards for the nuclear power plant associated with such events are to be established.
Analysis, reviews and/or research performed by the reviewer and scope of review.	It is necessary to collect and analyse information regarding all human activities in the region of interest at siting stage of the nuclear power plant and evaluate their impact on the proposed plant under various postulated worst-case scenarios and design the NPP to withstand the effect. AERB guide, AERB/SG/S-7 covers in detail various human induced events and procedures for estimation of corresponding design bases. The following areas need to be reviewed: – Potential external man-induced events such as plane crashes, fires and explosions; – Failure of man-made structures such as dams and sea walls; – Availability of water for plant cooling and requirement of ultimate heat sink; – Reliability of off-site electrical power.

	Chemical Explosions and Toxic Gas Releases: Activities in the region involving the handling, processing, transporting and storing of chemicals and explosives having potential for significant explosions and toxic gas releases shall be identified. **Oil Slick:** Information regarding proximity of movement of oil tankers in the nearby shipping channels in case of coastal sites shall be obtained and potential for oil slick formation checked. **Blasting Operation:** Information regarding blasting operations including those during site excavation in the site vicinity (less than 5 km) shall be assessed. **Mining, Drilling and Water Extraction:** All activities related to mining, drilling and subsurface extraction and injection of water and other fluids shall be carefully studied in order to assess their impact on plant safety. If the hazards for the nuclear power plant are unacceptable and no practicable solution is available, the site is deemed unsuitable.
What type of confirmatory analysis (if any) is performed?	Confirmatory analyses are performed, if necessary, on a case-by-case basis by the technical service organisation or at the designated division of AERB. The commonly performed confirmatory analyses are to verify the adequacy of the submissions related to Failure Modes and Effects Analysis.
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g. can come from accident analysis, regulatory guidance).**	– Code of Practice on Safety in Nuclear Power Plant Siting, AERB/SC/S; – AERB/SG/S-7 Human-Induced Events and Establishment of Design Basis Events.
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	– Civil, structural and geotechnical Engineers having experience in system development, static and dynamic analysis and modelling, system review, construction, regulatory experience; – Exposure to nuclear reactor engineering, Reactor Systems; – Engineers with reactor operation and maintenance background especially civil structures; – Experts capable of dynamic structural analysis, probabilistic assessments, development of software for analysis and design, etc.
Specialised training, experience and/or education needed for the review of this topic.	Reviewers are from regulatory staff undergone formal training in relevant areas and subsequently in regulatory/safety review. Many have additional specialisation e.g. Master's degree in structural/geotechnical engineering, construction experience. Further, the regulatory staffs are trained in various review areas through participation in the safety review and regulatory inspection process. The other members of the review team are from the premier academic institutes, TSO's who are working in specialised areas.

Level of effort in each review area.	In depth review is done by the specialist working group constituted by the Civil Engineering Safety Committee and Project Design Safety Committee of AERB. The second level of review at CESC or PDSC, which specially looked at the unresolved issues of the specialist group. The final level of safety review is done at ACPSR before the recommendations are forwarded to Chairman AERB. The depth and schedule of a review should depend on whether the project is of new, evolved or repeat design.

External man-made hazards	Japan NRA
Design information provided by applicant.	In the establishment permit application stage, the following information is provided: – Circumstances, such as location of dams, oil reservoirs and refineries, roads, rails, courses of ships and aircrafts; – Evaluation of external man-made hazards (e.g. aircraft crash, collapse of dam, explosion, illegal access of the third party); – Basic design policy; In addition, in construction work approval application stage, the following information is provided: – Design policy; – Plan, section view, structural drawing, system diagram; – Design conditions; – Design description of strength calculation, system integrity under design basis of External man-made hazards; – Test and inspection programme; – Quality control and assurance programme.
Analysis, reviews and/or research performed by the reviewer and scope of review.	These activities are to conform to the requirements, standards, criteria, and are like described below.
What type of confirmatory analysis (if any) is performed?	
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g., can come from accident analysis, regulatory guidance).**	The following regulatory requirements and guides are applicable to this technical area. Requirements: – Requirement of SCCs of commercial NPPs (H25 #5); – Interpretation of Requirement of SCCs of commercial NPPs (#1306193); – Standard of technical ability of severe accident management of commercial NPPs (#1306197); – Technical standard of SCCs of commercial NPPs (H25 #6); – Interpretation of Technical standard of SCCs of commercial NPPs (#1306194). Guides: – Guide for procedure of construction work approval (#13061920); – Guide for evaluation of external fire (#13061912); – Evaluation basis for aircraft crash probability onto nuclear power reactor facilities (H21-6-25 #1).
Skill sets required by (Education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	– Senior: Manager and engineer; – Junior: Engineer; – TSO: Researcher. Generally the staffs who have more than 10 year-experience are taken on the task.

Specialised training, experience and/or education needed for the review of this topic.	– Basic training for the examiner for nuclear safety; – Practical application training for the examiner for nuclear safety.
Level of effort in each review area.	Resources (hours) is not set up for the individual review area. Regarding the standard processing duration, 2 years is set up for establishment permit of an entire plant, and 3 months per one application is set up for construction work approval. Divided application is granted for construction work approval.

External man-made hazards	Korea KINS
Design information provided by applicant.	– The identifications of nearby industrial, transportation and military facilities; – Projection of industrial growth; – Evaluations of hazards associated with nearby industrial activities, transportation routes and military activities including aircraft hazards.
Analysis, reviews and/or research performed by the reviewer and scope of review.	The Safety Analysis Report is reviewed in accordance with the nuclear laws of the republic of Korea (i.e. Nuclear Safety Act, Enforcement Decree of the Nuclear Safety Act, Enforcement Regulation of the Nuclear Safety Act and Regulations on Technical Standards for Nuclear Reactor Facilities, etc.), KINS safety review guidelines (SRGs), KINS regulation standards (KINS/RSs series), KINS regulation guidelines (KINS/RGs series). US NRC RGs series can be referenced if necessary. Currently, the detail review of the Safety Analysis Report is performed on the basis of the guidelines of "Safety Review Guidelines for Light Water Reactors (Revision 3, KINS/GE-N001)". The relevant sections of the SRGs are listed below. In addition, the KINS staff may have technical consultation or research projects to review specific issues from external experts. – KINS/SRG 2.2.1-2.2.2, Identification of potential hazards in site vicinity; – KINS/SRG 2.2.3, Evaluation of potential accidents; – KINS SRG 3.5.1.5 Site Proximity Missiles (except Aircraft); – KINS SRG 3.5.1.6 Aircraft Hazards; – KINS SRG 3.5.3 Barrier Design Procedures.
What type of confirmatory analysis (if any) is performed?	For safety review, the KINS staff performs a routine confirmatory analysis including literature review, site visit and conversation with nearby villagers in general.
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g., can come from accident analysis, regulatory guidance).**	The applicable KINS regulatory requirements are listed below: – Nuclear Safety Act, Article 10 Construction Permit; – Nuclear Safety Act, Article 20 Operating License; – Enforcement Regulation of the Nuclear Safety Act, Article 4 Application for Construction Permit, etc; – Enforcement Regulation of the Nuclear Safety Act, Article 5 Preparation of Attached Documents for Construction Permit; – Enforcement Regulation of the Nuclear Safety Act, Article 9 Application for Standard Design Approval, etc. – Regulations on Technical Standards for Nuclear Reactor Facilities, etc., Article 8, Impacts of Man-made Accidents; – Regulations on Technical Standards for Nuclear Reactor Facilities, etc., Article 13, External Events Design Basis; – Nuclear Safety and Security Commission Notice No 03. (2012-03), Technical Standards for Locations of Nuclear Reactor Facilities; – Nuclear Safety and Security Commission Notice No 26. (2012-26), Objects of Consultations due to Installation of Industrial Facilities, etc. around the Nuclear Facilities. The KINS staff reviews the Safety Analysis Report based on the KINS/RSs series, KINS/RGs series). US NRC RG series can be referenced if necessary. Some relevant regulation standards and guidelines are listed below: – KINS/RS-N01.00 1.3, Nearby Industrial, Transportation, and Military

	Facilities; – KINS/RG-N01.00 1.2, Assessment of Man-made Accidents at a Nuclear Power Plant; – KINS/RG-N01.00.4.24, Assessment of a Virtual Explosion on the Transportation Routes near Nuclear Facilities; – RG 1.79, Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release; – RG 1.91, Evaluation of Explosion Postulated to Occur on Transportation Routes near Nuclear Power Plants.
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	Industrial Safety engineering/Chemical engineering.
Specialised training, experience and/or education needed for the review of this topic.	Technical reviewers in this area are required to complete a formal qualification programme prior to performing safety reviews independently. – Knowledge of industrial safety law and standard; – Knowledge of the geographic, demographic and industrial situation around NPPs.
Level of effort in each review area.	600 hours.

External man-made hazards	Russia SEC NRS
Design information provided by applicant.	– Chapters 1, 3, 7 of PSAR (FSAR); – Reports of analyses of Containment and other safety related structures; Quality Assurance programme for the construction phase.
Analysis, reviews and/or research performed by the reviewer and scope of review.	Review of strength and stability analyses presented by Applicant: – against accidental extreme explosions; – against other hazards in accordance with IAEA Safety Guide NS-G-1.5.
What type of confirmatory analysis (if any) is performed?	Confirmatory analyses of Reactor building, Containment structure and other safety related buildings should be listed in PSAR and presented to regulatory body for review. Regulatory body checks the sufficiency of the list of analyses and fulfil the Review of the most important analyses.
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g. can come from accident analysis, regulatory guidance).**	
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	– Civil engineer, Process engineer, Automatic control engineer with in-depth experience in design and analysis of external man-made hazards protection in NPP; – Senior staff has more than 10 year-experience in nuclear civil structures designing, as a rule with scientific degree; – Junior staff has more than 3 year-experience in nuclear civil structures designing; – Also Laboratories of Academy of Sciences and Civil Engineering university are invited.
Specialised training, experience and/or education needed for the review of this topic.	All technical reviewers are required to have knowledge of federal norms and rules in using of atomic energy and safety guides. Knowledge of Civil Engineering norms and rules is also required; Knowledge of safety guides and good practice of IAEA and NEA in analyses of external events is necessary; Special knowledge is needed in the field of: – wave loading of civil engineering constructions; – response spectra approach.
Level of effort in each review area.	The Level of effort is not estimated.

External man-made hazards	Slovakia UJD
Design information provided by applicant.	– Describing of methodology using for assessment; – Assessment which proved, that the following requirements are fulfilled; – Selected facilities must be designed so that during events caused by human activity outside the nuclear facility, it is possible to: a) safely shut down the nuclear facility and maintain it in a subcritical state; b) remove residual heat from spent nuclear fuel or radioactive waste; c) maintain leaks of radioactive substances below specified levels. – Response safety analyses for the proposed facility for the effect of human activity and industrial activity near the nuclear facility.
Analysis, reviews and/or research performed by the reviewer and scope of review.	Review of the submitted documentation, if it conforms to atomic act and regulations. Evaluate if the systems, structures and components are in compliance with all requirements arising from applicable regulations, codes and standards. Confirm that the nuclear facility is able to manage hazard arising from external man-activities.
What type of confirmatory analysis (if any) is performed?	
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g., can come from accident analysis, regulatory guidance).**	
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	– Senior: technical engineer; – Junior: technical engineer; – TSO: technical engineer.
Specialised training, experience and/or education needed for the review of this topic.	– Experience with evaluation; – Knowledge about nuclear facilities and safety analysis.
Level of effort in each review area.	Review of the submitted design information is a part of approval process which is performed as an administrative procedure based on administrative proceeding code. Based on this act 60 days are scheduled for approval of the submitted documentation. In case more time is needed (for example if a review from TSO or the other support organisation is needed) the chairperson can be asked to extend the period for approval. In some cases, which are strictly defined in the atomic act the time period for reviewing is longer. These cases are as follows: – Four months if siting of nuclear installation, except repository is

	concerned; – Six months if nuclear installation commissioning or decommissioning stage is concerned; – One year if building authorisation, siting and closure of repository or repeated authorisation for operation of a nuclear installation are concerned.

External man-made hazards	Slovenia SNSA
Design information provided by applicant.	– Technical description of location of military and industrial facilities, transport routes; – Hazard analyses of associated to industrial activities, military activities and transportation routes (this includes toxic vapours or gases; explosions or detonations; missile effects and thermal effects attributable to fires); – Assessment of aircraft hazards.
Analysis, reviews and/or research performed by the reviewer and scope of review.	Detailed review and determination that the information provided is complete; compares well with data from other studies carried out in the same areas; and is supported by detailed investigations conducted by the applicant. Ensure that external man-made events will not preclude the safety function of the SSCs.
What type of confirmatory analysis (if any) is performed?	The hazards analysis must be performed to establish whether the plant design can accommodate commonly occurring hazards, and whether the risk of other hazards is very low.
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g., can come from accident analysis, regulatory guidance).**	General aspects of design standards including: – IAEA, "Safety of Nuclear Power Plants: Design", Safety Standards Series No. SSR-2/1, IAEA, Vienna (2012); – IAEA, "Site Evaluation for Nuclear Installations", Safety Standards Series No. NS-R-3, IAEA, Vienna (2003); – IAEA, "Format and Content of the Safety Analysis Report for Nuclear Power Plants" – Safety Guide, Safety Standards Series No. GS-G-4.1, IAEA, Vienna (2004); – IAEA, "Safety Assessment and Verification for Nuclear Power Plants", Safety Standards Series No. NS-G-1.2, IAEA, Vienna (2001); – IAEA, "Engineering Safety Aspects of the Protection of Nuclear Power Plants against Sabotage", Nuclear Security Series No. 4, IAEA, Vienna (2007); – IAEA, "Design of the Reactor Coolant System and Associated Systems in Nuclear Power Plants" – Safety Guide, Safety Standards Series No. NS-G-1.9, IAEA, Vienna (2004). Hazard analysis: – IAEA, External Human Induced Events in Site Evaluation for Nuclear Power Plants, Safety Standards Series No. NS-G-3.1, IAEA, Vienna (2002); – IAEA, External Events Excluding Earthquakes in the Design of Nuclear Power Plants – Safety Guide, Safety Standards Series No. NS-G-1.5, IAEA, Vienna (2004); – ANSI/ANS-58.21-2003 "External-events PRA Methodology, An American National Standard", American Nuclear Society, March 2003; – US NRC, Appendix C "NRC Staff Regulatory Position on ANS External Hazards PRA Standard" to Regulatory Guide 1.200 "An Approach for Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk Informed Activities", August 2004. The main technical basis are Eurocodes and Regulation JV5 (Rules on radiation and nuclear safety factors). JV5 requires that the design bases shall take into

	account the following external initiating events, which shall be treated in accordance with the site conditions: – Events on nearby transport routes, in industrial facilities or within the site region that might lead to fire, explosion or other hazards to the safety of the nuclear power plant.
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	– Senior: Civil engineer, mechanical engineer; – Junior: Civil engineer, mechanical engineer; – TSO: Civil engineer, mechanical engineer.
Specialised training, experience and/or education needed for the review of this topic.	– PSA expert, experience with hazards analysis.
Level of effort in each review area.	– Regulator: 200 hours; – TSO' review time: 400 hours.

External man-made hazards	United Kingdom ONR
Design information provided by applicant.	Not applicable at generic level.
Analysis, reviews and/or research performed by the reviewer and scope of review.	Review of PCSR and supporting documentation by regulatory organisation and TSO. Review against relevant good practice and SAP/TAG expectations. No confirmatory analysis undertaken, but a review of the QA validation/verification of the software used was undertaken.
What type of confirmatory analysis (if any) is performed?	Some reliability analysis was undertaken.
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g., can come from accident analysis, regulatory guidance).**	SAPs, TAGs.
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	All degree qualified in a relevant subject and professionally qualified through a relevant institution.
Specialised training, experience and/or education needed for the review of this topic.	– Training in the ETC-C design code; – Training in Eurocodes.
Level of effort in each review area.	Total review for EPR, 1.5 full time equivalent in regulatory organisation for 4.5 years. £2.2 million in TSO costs.

External man-made hazards	United States US NRC
Design information provided by applicant.	As part of the SAR, the applicant should describe the following: – The locations and distances from the plant of nearby industrial, military and transportation facilities and routes; – The nature and extent of activities conducted, materials and products handled at the site and in its vicinity; – Hazards associated with nearby industrial activities, including mining and gas/oil exploration activities, such as manufacturing, processing and storage facilities; – Hazards associated with potential release of toxic chemicals due to industrial activities and on-site storage of chemicals on control room habitability; – Hazards associated with military activities, such as military bases, training areas or aircraft flights; – Hazards associated with nearby transportation routes (aircraft routes, highways, railways, navigable waters and pipelines); – Identification and description of on-site/off-site activities that could potentially generate missiles and the effect of those missiles on the plant; – Potential turbine missiles from co-located facilities/units; – Assessment of aircraft hazards; – Assessment of dam failure.
Analysis, reviews and/or research performed by the reviewer and scope of review.	The Nuclear Regulatory Commission (NRC) staff (1) reviews the information provided in the SAR for compliance with the regulations, (2) issues requests for additional information (RAIs) as necessary, (3) reviews RAI responses, (4) resolves technical issues with applicants or licensees and (5) produces a safety evaluation report (SER) documenting its findings. The scope and level of detail of the staff's safety review is based on the guidance of NUREG-0800, Standard Review Plan (SRP). The sections of the SRP that are applicable to this area are as follows: – SRP 2.2.1-2.2.2, "Identification of Potential Hazards in Site Vicinity"; – SRP 2.2.3, "Evaluation of Potential Accidents"; – SRP 2.4.4, "Potential Dam Failures"; – SRP 3.5.1.5, "Site Proximity Missiles(Except Aircraft)"; – SRP 3.5.1.6, "Aircraft Hazards". The staff also considers emerging technical and construction issues, operating experience and lessons learnt related to this category.
What type of confirmatory analysis (if any) is performed?	The staff commonly performs confirmatory analyses to verify the adequacy of the following submittal(s) related to this technical area: – Confirmatory analysis for dam failure. Confirmatory analyses and testing are performed by the staff, as needed, to verify the information and conclusions provided in the FSAR and to aid the staff in making its safety finding.

Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g. can come from accident analysis, regulatory guidance).**	The applicable NRC Regulatory Requirements are listed below: 1. 10 CFR Part 50, Appendix A, GDC 3, "Fire Protection"; 2. 10 CFR Part 50, Appendix A, GDC 4, "Environmental and Dynamic Effects Design Bases"; 3. 10 CFR 50.34, " Contents of Application, Technical Information"; 4. 10 CFR Part 100, "Reactor Site Criteria"; 5. 10 CFR Part 100.10, "Factors to be Considered When Evaluating Sites"; 6. 10 CFR Part 100.20, "Factors to be Considered When Evaluating Sites"; 7. 10 CFR Part 100.21, "Non-seismic Site Criteria". The NRC guidance documents that provide an acceptable approach for satisfying the applicable regulatory requirements are listed as follows: 1. RG 1.78, "Evaluating the Habitability of a Nuclear Power Plant Control Room During A Postulated Hazardous Chemical Release"; 2. RG 1.91, "Evaluation of Explosions Postulated to Occur on Transportation Routes near Nuclear Power Plant Sites"; 3. RG 1.117, "Tornado Design Classification".
Skill sets required to perform review.	– Physical scientist; – Hydraulic/geotechnical engineer; – Structural engineer; – Chemical engineer.
Specialised training, experience and/or education needed for review.	Technical reviewers in this area are required to complete a formal qualification programme prior to performing safety reviews independently: Other specialised training, experience and education that is needed to successfully perform reviews in this technical area include: – Experience with environmental, chemical and radiological impact assessments; – Experience with siting and external hazard evaluations; – Understanding of missile production and impacts; – Computer modelling experience with dispersion and accident impact computer models.
Level of effort in each review area.	2 400 hours (this estimate includes NRC staff and technical support for all technical disciplines involved in the review of an application for design certification application).

APPENDIX D: INTERNAL HAZARDS (E.G. FIRE, FLOODING, EXPLOSION)

Summary table

Country	Is this area reviewed?	Are confirmatory analyses performed?	Expertise of reviewers	Level of effort
Canada	Yes.	Yes.	Fire protection.	6 000 hours.
Finland	Yes.	Yes.	Civil engineer, fire protection, risk assessment.	190 working days (1 520 hours).
France	Yes.	No.	Civil works engineers, mechanical engineers.	–[1]
India	Yes.	Yes.	Civil, structural and geotechnical engineers.	–[1]
Japan	Yes.	Yes.	Civil, structural and mechanical engineers. Generally, staff that has more than 10-year experience are taken on the task.	–[1]
Korea	Yes.	No.	Structural engineering, fire protection engineering, reactor systems engineering.	4 000 hours.
Russia	Yes	Yes	Civil engineer, fire protection engineer, processing engineer, mechanical engineer, hydraulic engineer with in-depth experience in analysis of internal hazards in NPP.	–[1]
Slovakia	Yes.	No.	Technical engineer.	–[2]
Slovenia	Yes.	Yes.	Civil engineer, mechanical engineer.	1 200 hours[3].
United Kingdom	No.	–	–	–
United States	Yes.	No.	Structural engineer, reactor systems engineer, fire protection engineer, PRA analyst.	3 000 hours.

Notes:

1. The level of effort is not estimated for each review area.
2. In the Slovak Republic, the standard level of effort for the review of submitted documentation is defined by regulation and dependent upon the activity to be approved.
3. In Slovenia, the level of effort (hours) estimated on the basis of analysis, which was prepared in order to assess the resources needed in case of construction of new nuclear power plants.

Internal hazards	Canada CNSC
Design information provided by applicant.	Code Compliance Review (CCR) – an assessment for compliance with the applicable sections of the Codes of construction (e.g. the NBCC, NFCC and CSA N293) and the Codes and Standards referenced therein. The code compliance review includes documentation of any deviations from the prescriptive requirements of the applicable Codes and Standards, and how the intent of the requirements is met using equivalent or alternative means. Fire Hazard Assessment (FHA) – a set of analyses and assessments for evaluating potential fire hazards as well as the appropriate fire protection systems and features used to mitigate the effects of a fire. Fire Safe Shutdown Analysis (FSSA) – an analysis to demonstrate that at least one means of achieving nuclear safety objectives and performance criteria is available in the event of a fire. The CRR, FHA and FSSA may include fire modelling and alternative solutions to demonstrate the fire protection objectives of the codes and standards identified below are met. A Fire Protection Program – a set of planned and coordinated activities by various contributing disciplines and organisations that is intended to ensure adequate protection against fires.
Analysis, reviews and/or research performed by the reviewer and scope of review.	An in-depth review of the above information.
What type of confirmatory analysis (if any) is performed?	The above information is reviewed for compliance with the codes and standards identified in the Technical Basis row below. Fire dynamics equation spreadsheets, CFAST or FDS modelling is used as required to confirm assumptions, compare modelling results and to assess uncertainties and sensitivities.
Technical basis: • **standards;** • **codes;** • **acceptance criteria;** **(e.g., can come from accident analysis, regulatory guidance).**	CSA N293 Fire Protection for Nuclear Power Plants is the main technical basis and CNSC Staff Review Procedures. CSA N293 references additional codes and standards including but not limited to: – National Building Code of Canada; – National Fire Code of Canada; – CAN/ULC-S524 Installation of fire alarm systems; – NFPA 13: Installation of Sprinkler systems; – NFPA 14: Standard for the Installation of Standpipe and Hose Systems; – NFPA 24: Standard for the Installation of Private Fire Service Mains and Their Appurtenances.

Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	An extensive knowledge in: – Fire protection codes and standards requirements; – Fire Hazard Assessment and Fire Safe Shutdown Analysis; – Fire detection and suppression means and design; – Fire containment and control; – Fire prevention; – NPP safety systems; – Probability Risk Assessment.
Specialised training, experience and/or education needed for the review of this topic.	Fire Protection training and experience in fire dynamics and fire protection as well as extensive experience in fire protection design and analysis and the review of licencing submissions related to fire protection in nuclear facilities.
Level of effort in each review area.	CNSC staff: 6 000 hours.

Internal hazards	Finland STUK
Design information provided by applicant.	PSAR and Topical reports: fire compartments, fire protection solutions, fire protection of transformers.
Analysis, reviews and/or research performed by the reviewer and scope of review.	– Comparative linear/non-linear analyses of structural response against different kind of fire and explosions by VTT (TSO); – Review of plant layout against selected flooding hazards such as ESWS system rupture.
What type of confirmatory analysis (if any) is performed?	Please see above.
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g., can come from accident analysis, regulatory guidance).**	– Governmental degree 733; – regulatory guides YVL 2.0, YVL 2.1, YVL 2.8, YVL 4.3.
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	No official requirements, but in practice. – Senior inspectors: university degree in civil, fire protection, risk assessment engineering, adequate working experience in design/ research. TSO specialists: as above, but more concentrated in corresponding hazard and technical domain.
Specialised training, experience and/or education needed for the review of this topic.	
Level of effort in each review area.	– Regulatory review: 50 working days (RAKista); – Consultants: 40 working days; – TSO (VTT): 100 working days.

Internal hazards	France ASN
Design information provided by applicant	EDF should provide the followings sections of the Safety analysis report: – 3.4.2 Pipes leaks and breaks; – 3.4.3 Failure of vessels, tanks, pumps and valves; – 3.4.4 Missiles; – 3.4.5 Load drop; – 3.4.6 Internal explosion; – 3.4.7 Fire; – 3.4.8 Internal flooding.
Analysis, reviews and/or research performed by the reviewer and scope of review	IRSN evaluates in addition to: "Containment design and other safety related structural design": – Loading combination in relation with Internal hazards.
What type of confirmatory analysis (if any) is performed?	
Technical basis • **standards** • **codes** • **acceptance criteria** **(e.g., can come from accident analysis, regulatory guidance)**	The following requirements are applicable to this technical area: – Technical guidelines*; – DAC; – Eurocode; – Fundamental safety rule 1.2.b (RFS): projectiles. *Technical guidelines for the design and construction of the next generation of nuclear power plants with pressurised water reactors.
Skill sets required by (Education) • **senior (regulator)** • **junior (regulator)** • **TSO**	The review requires a team of: – Civil works engineers; – Mechanical engineers.
Specialised training, experience and/or education needed for the review of this topic.	Experience and knowledge that are needed to perform review in this technical area include: – Reinforced concrete, pre-stressed concrete and steel structures.
Level of effort in each review area.	The level of effort is very important but is not estimated.

<table>
<tr><th>Internal hazards</th><th>India
AERB</th></tr>
<tr><td>Design information provided by applicant.</td><td>Internal Events:
An analysis of PIEs to establish all those internal events which may affect the safety of the plant. The events will include equipment failures or maloperation.
Fire and Explosion:
(a) The capability for shutdown, residual heat removal, confinement of radioactive material and monitoring the state of plant in the case of fire and explosion shall be established and show that same can be maintained.
(b) The planning to be done for prevention and protection against fire and explosion at the plant design stage itself and carried through construction, commissioning and operation phases.
(c) A fire hazard analysis of the plant shall be presented to determine the required rating of the fire barriers, and the required capability of fire detection and firefighting systems shall be provided.
Other Internal Events:
The potential for internal hazards such as flooding, missile generation, pipe whip, jet impingement and fluid release from failed systems or other plant on the site shall be informed. Appropriate prevention and mitigation measures taken shall be reported which will ensure that nuclear safety is not compromised.
It should be noted that some external events may initiate internal fires or floods and may cause the generation of missiles. Such interaction of external and internal events shall also be considered in the design, wherever appropriate and reported.
Typical missiles postulated to be caused by the failure of high speed rotating equipment include:
(a) Fan blades;
(b) Turbine disc fragments or blades;
(c) Pump impellers;
(d) Flanges;
(e) Coupling bolts.
Low Trajectory Turbine Missiles: The following specific information is necessary in order to assess the protection against low trajectory turbine missiles:
(a) Dimensioned plant layout drawings, (b) Barriers (e.g. structural wall material strength properties, thickness), (c) Identification of safety-related structures, systems and components in terms of location, redundancy and independence, (d) Identification of all turbine-generator units (present and future) in the vicinity of the plant and quantitative description of TG sets.</td></tr>
</table>

Analysis, reviews and/or research performed by the reviewer and scope of review.	It is to be demonstrated that consistent with other safety requirements, structures, systems and components important to safety shall be designed and located to minimise the probability and effects of fire and explosions caused by external or internal events. These requirements with respect to internal fires shall be achieved by suitable incorporation of redundant parts, diverse systems, physical separation and design for fail-safe operation such that the following objectives are achieved: (i) preventing fires from starting; (ii) detecting and extinguishing quickly those fires which do start, thus limiting the damage; (iii) preventing the spread of those fires which have not been extinguished, thus minimising their effect on essential plant functions. Firefighting systems are automatically initiated where necessary, and systems shall be reviewed and analysed to ensure that their rupture or spurious or inadvertent operation does not significantly impair the capability of structures, systems and components important to safety, and does not simultaneously affect redundant safety chains, thereby challenging compliance with the single failure criterion. Review to check that non-combustible or fire retardant and heat resistant materials are used wherever practicable throughout the plant, particularly in locations such as the containment and control room. **Jet Impingement Analysis:** In addition to pipe restraints, barriers and layout are used to provide protection for vital equipment from pipe whip and blow down jet forces arising from postulated piping breaks. Some typical methods used to determine jet impingement loads on components and supports. **Pipe Whip Analysis:** For breaks where pipe whip protection is not provided by means of restraints, a detailed study shall be conducted to evaluate the effects of the whipping pipe on safety related SSC. When pipe whip restraints are provided, these shall be designed to withstand pipe rupture thrust load, which includes a dynamic load factor appropriate for the gap between the pipe and the restraint. Important cascading secondary effects which need to be considered following a primary missile effect are as follows: – (a) Radiation release, (b) Secondary missiles, (c) Fire, (d) Flooding, (e) Chemical reactions, (f) Electrical damage, (g) Damage to Instrumentation & Control lines, (h) High energy pipe failures and consequent effects of jets, whipping pipes, secondary missiles, pressure, temperature, humidity, flooding and radiation, as applicable, (i) Falling objects, (j) Personnel injury.
What type of confirmatory analysis (if any) is performed?	Confirmatory analyses are performed, if necessary, on a case-by-case basis by the technical service organisation or at the designated division of AERB. The commonly performed confirmatory analyses are to verify the adequacy of the submissions related to Failure Modes and Effects Analysis.
Technical basis: • **standards;** • **codes;** • **acceptance criteria.**	– Design of Pressurised Heavy Water Reactor based Nuclear Power Plants, AERB/NPP-PHWR/SC/D (Rev. 1) Section 5.2.4; – Protection against Internally Generated Missiles in Nuclear Power Plants, AERB/NPP-PHWR/SG/D-3;

(e.g., can come from accident analysis, regulatory guidance).	– Design Basis Events for Pressurised Heavy Water Reactors, AERB/NPP-PHWR/SG/D-5.
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	– Civil, structural and geotechnical Engineers having experience in system development, static and dynamic analysis and modelling, system review, construction, regulatory experience; – Exposure to nuclear reactor engineering, Reactor Systems; – Engineers with reactor operation and maintenance background especially civil structures; – Experts capable of seismic structural analysis, probabilistic assessments, development of software for analysis and design, etc.
Specialised training, experience and/or education needed for the review of this topic.	Reviewers are from regulatory staff undergone formal training in relevant areas and subsequently in regulatory/safety review. Many have additional specialisation e.g. Master's degree in structural/geotechnical engineering, construction experience. Further, the regulatory staff is trained in various review areas through participation in the safety review and regulatory inspection process. The other members of the review team are from the premier academic institutes, TSO's who are working in specialised areas.
Level of effort in each review area.	In depth review is done by the specialist working group constituted by the Civil Engineering Safety Committee and Project Design Safety Committee of AERB. The second level of review at CESC or PDSC, which specially looked at the unresolved issues of the specialist group. The final level of safety review is done at ACPSR before the recommendations are forwarded to Chairman AERB. The depth and schedule of a review should depend on whether the project is of new, evolved or repeat design.

Internal hazards	Japan NRA
Design information provided by applicant.	In the establishment permit application stage, the following information is provided: – Fire protection areas and sections; – Basic design policy of fire prevention, detection and extinguishing, mitigation; – Evaluation of system integrity under fire; – Sources, route and amount of flooding; – Basic design policy of flooding resistant. In addition, in construction work approval application stage, the following information is provided: – Design policy; – Plan, section view, structural drawing, system diagram; – Design conditions; – Design description of system integrity under flooding and fire; – Test and inspection programme; – Quality control and assurance programme.
Analysis, reviews and/or research performed by the reviewer and scope of review.	These activities are to conform to the requirements, standards, criteria, and are like described below.
What type of confirmatory analysis (if any) is performed?	
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g., can come from accident analysis, regulatory guidance).**	The following regulatory requirements and guides are applicable to this technical area: Requirements: – Requirement of SCCs of commercial NPPs (H25 #5); – Interpretation of Requirement of SCCs of commercial NPPs (#1306193); – Technical standard of SCCs of commercial NPPs (H25 #6); – Interpretation of Technical standard of SCCs of commercial NPPs (#1306194); Standard of fire protection of commercial NPPs (#1306195). Guides: – Guide for procedure of construction work approval (#13061920); – Guide for evaluation of internal fire (#13061914); – Guide for evaluation of internal flooding (#13061913).
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	– Senior: Manager and engineer; – Junior: Engineer; – TSO: Researcher. Generally the staffs who have more than 10 year-experience are taken on the task.
Specialised training, experience and/or education needed for the review of this topic.	– Basic training for the examiner for nuclear safety; – Practical application training for the examiner for nuclear safety.

Level of effort in each review area.	Resources (hours) is not set up for the individual review area. Regarding the standard processing duration, 2 years is set up for establishment permit of an entire plant, and 3 months per one application is set up for construction work approval. Divided application is granted for construction work approval.

Internal hazards	Korea KINS
Design information provided by applicant.	The applicant should provide the following information for the protection design of internally generated missiles, flooding and fire: – Identification of structures, systems and components (SSCs) for protection; – from internally generated missiles, flooding and fire; – Location of safety-related SSCs that should be protected from internally generated missiles, flooding and fire Possibility of pressurised components and systems for generating missiles; – Internal missile effects on safety-related or non-safety-related structures, systems and components; – Possibility of secondary missile generation from primary missile impact; – Analysis of fire and explosion hazards.
Analysis, reviews and/or research performed by the reviewer and scope of review.	The Safety Analysis Report provided by the applicant is reviewed in accordance with the nuclear laws of the republic of Korea (i.e. Nuclear Safety Act, Enforcement Decree of the Nuclear Safety Act, Enforcement Regulation of the Nuclear Safety Act and Regulations on Technical Standards for Nuclear Reactor Facilities, etc.), KINS safety review guidelines (SRGs), KINS regulation standards (KINS/RSs series), KINS regulation guidelines (KINS/RGs series). US NRC RG series can be referenced if necessary. Currently, the detail review of the Safety Analysis Report is performed on the basis of the guidelines of "Safety Review Guidelines for Light Water Reactors (Revision 3, KINS/GE-N001)". The relevant sections of the SRGs are listed below. In addition, the KINS staff may have technical consultation or research projects to review specific issues from external experts: – KINS SRG 3.4.1 Internal Flood Protection for Onsite Equipment Failures; – KINS SRG 3.4.2 Hydraulic Analysis Procedures; – KINS SRG 3.5.1.1 Internally Generated Missiles (Outside Containment); – KINS SRG 3.5.1.2 Internally Generated Missiles (Inside Containment); – KINS SRG 3.6.1 Plant Design for Protection Against Postulated Piping Failures in Fluid Systems Outside Containment; – KINS SRG 3.6.2 Determination of Rupture Locations and Dynamic Effects Associated with the Postulated Rupture of Piping; – KINS SRG 9.5.1 Fire Protection Program.
What type of confirmatory analysis (if any) is performed?	None.
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g., can come from accident analysis, regulatory guidance).**	The applicable KINS regulatory requirements are listed below: – Nuclear Safety Act, Article 10 Construction Permit; – Nuclear Safety Act, Article 20 Operating License; – Enforcement Regulation of the Nuclear Safety Act, Article 4 Application for Construction Permit, etc; – Enforcement Regulation of the Nuclear Safety Act, Article 5 Preparation of Attached Documents for Construction Permit; – Enforcement Regulation of the Nuclear Safety Act, Article 11 Application for Standard Design Approval, etc; – Enforcement Regulation of the Nuclear Safety Act, Article 12 Preparation

	of Attached Documents for Standard Design Approval; – Enforcement Decree of the Nuclear Safety Act, Article 17 Application for Construction Permit; – Regulations on Technical Standards for Nuclear Reactor Facilities, etc., Article 14 Protection against Fire Protection, etc; – Regulations on Technical Standards for Nuclear Reactor Facilities, etc., Article 15 Environmental Effects Design Bases, etc; – Regulations on Technical Standards for Nuclear Reactor Facilities, etc., Article 16 Sharing of Structures, Systems, and Components; – Regulations on Technical Standards for Nuclear Reactor Facilities, etc., Article 25 Control Room, etc; – Regulations on Technical Standards for Nuclear Reactor Facilities, etc., Article 26 Protection System; – Nuclear Safety and Security Commission Notice No 6. (2012-06), Provisions on Safety-Related Facilities of Nuclear Reactor; – Nuclear Safety and Security Commission Notice No 9. (2012-09), Provisions on Safety Classification and Standards of Each Class; – Nuclear Safety and Security Commission Notice No 21. (2012-21), Provisions on Establishment and Implementation of Fire Protection Plan; – Nuclear Safety and Security Commission Notice No 22. (2012-22), Guidelines on Technical Standards of Fire Rick Analysis. The KINS staff review the Safety Analysis Report based on the KINS/RSs series, KINS/RGs series. US NRC RG series can be referenced if necessary. Some relevant regulation standards and guidelines are listed below: – KINS/RS-N03.00 3.2 Classification; – KINS/RS-N04.00 4.4 Flooding Protection; – KINS/RS-N04.00 4.5 Missile Protection; – KINS/RS-N10.00 10.6 Fire Protection; – KINS/RG-N03.02 Seismic Qualification of Mechanical and Electric Equipment; – KINS/RG-N04.12 Flood Protection; – KINS/RG-N10.06 Fire Protection of Nuclear Power Plants; – RG 1.29 Seismic Design Classification; – RG 1.115 Protection Against Low-Trajectory Turbine Missiles; – RG 1.189 Fire Protection for Nuclear Power Plants; – RG 1.139 Guidance for Residual Heat Removal; – RG 1.191 Fire Protection Program for Nuclear Power Plants During Decommissioning and Permanent Shutdown.
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	– Engineers with extensive knowledge in the following area; – Structural & mechanical analysis and design; – Fire protection; – Reactor system; – regulatory guides and industrial codes/standards related to nuclear power plant structures.
Specialised training, experience and/or education needed for the review of this topic.	– Education: regulatory requirements, guidelines, codes and standards; – Training: protection design and analysis of internal flooding, explosion and fire.
Level of effort in each review area.	– Approximately 4 000 hrs.

Internal hazards	Russia SEC NRS
Design information provided by applicant.	– Chapters 1, 3, 7 and 12 of PSAR (FSAR); – Quality Assurance programme for the construction phase.
Analysis, reviews and/or research performed by the reviewer and scope of review.	Review of analyses presented by Applicant on: – LOCA accidents; – Impacts from jets, flying debris and other Internal hazards in accordance with IAEA Safety Guides NS-G-1.10, NS-G-1.11.
What type of confirmatory analysis (if any) is performed?	Confirmatory analyses of Reactor building, Containment structure and other safety related buildings should be listed in PSAR and presented to regulatory body for review. Regulators check the sufficiency of the list of analyses and fulfil the Review of the most important analyses.
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g. can come from accident analysis, regulatory guidance).**	The following regulatory documents are applicable to the technical sphere under consideration: – Federal law “On the Use of Atomic Energy” No. 170-FZ dated of November 21, 1995; – Federal law “On Radiation Safety of Public” No. 3-FZ dated of January 09, 1996; – NP-001-97, “General Safety Provisions for Nuclear Power Plants” (OPB-88/97); – NP-006-98, “Requirements to the Contents of Safety Analysis Report for a Nuclear Power Plant with VVER-type Reactor”, (PNAE G- 01-036-95); – NP-082-07, “Nuclear Safety Rules for Reactor Installations of Nuclear Power Plants”; – “Fire Protection of Nuclear Power Plants. Design Standards”, NPB 114-2002; – “Fire Safety of Nuclear Power Plants. General Requirements”, NPB 113-03; – “Fire Safety Rules in Operation of Nuclear Power Plants”, PPB AS-95*; – “Fire Safety Rules in the Russian Federation”, PPB 01-03; – “Fire Protection of the Enterprises. General Requirements”, NPB 201-96; – “Determination of the Categories of Premises, Buildings and Outdoor Installations Based on Explosion and Fire Hazard”, NPB 105-03; – “The List of Buildings, Building Structures, Premises and Equipment Subject to Protection by Automatic Fire Extinguishing Units and Automatic Fire Alarm”, NPB 110-03; – NP-044-03, “Rules for Design and Safe Operation of Pressure Vessels for Nuclear Facilities”; – NP-040-02, “Rules of Nuclear Power Plant Explosion Protection”; – “Fire Warning and Evacuation Management System in Buildings and Building Structures”, NPB 104-03.
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	– Civil engineers, geotechnical and environmental engineers with in-depth experience in nuclear civil structures designing; – Senior TSO staff has more than 10 year-experience in nuclear civil structures designing, as a rule with scientific degree; – Junior TSO staff has more than 3 year-experience in nuclear civil structures designing;

	– Also laboratories of academy of sciences and civil engineering university are invited.
Specialised training, experience and/or education needed for the review of this topic.	Fire protection training.
Level of effort in each review area.	The level of effort is not estimated.

Internal hazards	Slovakia UJD
Design information provided by applicant.	Response safety analyses for the proposed facility for the following initiating events: – internal flooding; – internal fire; – internal explosion; – internal systems and constructions failure; – pipe whipping; – false signals leading to the heat removal loss; – inside generated flying object.
Analysis, reviews and/or research performed by the reviewer and scope of review.	Review of the submitted documentation, if it conforms to atomic act and regulations. Evaluate if the systems, structures and components are in compliance with all requirements arising from applicable regulations, codes and standards. Confirm that the nuclear facility is able to manage hazard arising from internal events.
What type of confirmatory analysis (if any) is performed?	
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g., can come from accident analysis, regulatory guidance).**	
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	– Senior: technical engineer; – Junior: technical engineer; – TSO: technical engineer.
Specialised training, experience and/or education needed for the review of this topic.	– Experience with evaluation; – Knowledge about nuclear facilities and safety analysis.
Level of effort in each review area.	Review of the submitted design information is a part of approval process which is performed as an administrative procedure based on administrative proceeding code. Based on this act 60 days are scheduled for approval of the submitted documentation. In case more time is needed (for example if a review from TSO or the other support organisation is needed) the chairperson can be asked to extend the period for approval. In some cases, which are strictly defined in the atomic act the time period for reviewing is longer. These cases are as follows: – Four months if siting of nuclear installation, except repository is concerned; – Six months if nuclear installation commissioning or decommissioning stage is concerned;

	– One year if building authorisation, siting and closure of repository or repeated authorisation for operation of a nuclear installation are concerned.

Internal hazards	Slovenia SNSA
Design information provided by applicant.	Determination the adequacy of protection against Internal hazards with account taken of the actual plant design, actual site characteristic, the actual condition of SSC. The following hazards have to be taken into account in hazard analysis: internal fire (prevention, detection and suppression), flooding, pipe whip, steam release, cold gas release, deluge and spray, toxic gas, explosion, electromagnetic or radio frequency interference and internally generated missiles.
Analysis, reviews and/or research performed by the reviewer and scope of review.	Independent PSA analyses.
What type of confirmatory analysis (if any) is performed?	The hazards analysis must be performed to establish whether the plant design can accommodate commonly occurring hazards, and whether the risk of other hazards is very low.
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g., can come from accident analysis, regulatory guidance).**	<u>General aspects of design standards including</u>: – IAEA, “Safety of Nuclear Power Plants: Design”, Safety Standards Series No. SSR-2/1, IAEA, Vienna (2012); – IAEA, “Site Evaluation for Nuclear Installations”, Safety Standards Series No. NS-R-3, IAEA, Vienna (2003); – IAEA, “Format and Content of the Safety Analysis Report for Nuclear Power Plants” – Safety Guide, Safety Standards Series No. GS-G-4.1, IAEA, Vienna (2004); – IAEA, “Safety Assessment and Verification for Nuclear Power Plants”, Safety Standards Series No. NS-G-1.2, IAEA, Vienna (2001); – IAEA, “Engineering Safety Aspects of the Protection of Nuclear Power Plants against Sabotage”, Nuclear Security Series No. 4, IAEA, Vienna (2007); – IAEA, “Design of the Reactor Coolant System and Associated Systems in Nuclear Power Plants” – Safety Guide, Safety Standards Series No. NS-G-1.9, IAEA, Vienna (2004); – IAEA, “Protection against Internal Fires and Explosions in the Design of Nuclear Power Plants” – Safety Guide, Safety Standards Series No. NS-G-1.7, IAEA, Vienna (2004); – IAEA, Inspection of Fire Protection Measures and Fire Fighting Capability at Nuclear Power Plants, Safety Series No. 50-P-6, IAEA, Vienna (1994); – IAEA, Evaluation of Fire Hazard Analyses for Nuclear Power Plants, Safety Series No. 50-P-9, IAEA, Vienna (1995); – IAEA, Assessment of the Overall Fire Safety Arrangements at Nuclear Power Plants, Safety Series No. 50-P-11, IAEA, Vienna (1996); – IAEA, Protection against Internal Fires and Explosions in Nuclear Power Plants, *Safety Standards Series*, Vienna (in preparation). The main technical basis represents Regulation JV5 (Rules on radiation and nuclear safety factors) which requires that the design bases shall take into account the internal initiating events characteristic for the power plant. Additionally, fire-protection objectives require that:

	– Fire protection shall observe the defence-in-depth principle, to ensure: - measures to prevent occurrence of fire; - fast detection, containment and suppression of fires; - prevention of the spreading of fire and consequences in any area where they might compromise nuclear power plant safety, or of fire reaching such areas. – Fire-protection design bases. Safety related SSCs shall be designed and installed as to: – Minimise the risks of occurrence of fire and its consequences; – Ensure the capability of plant shutdown; – Ensure the capability of residual-heat removal; – Limit the spreading of radioactive substances; – Ensure control over the situation in the nuclear power plant during and following a fire. The buildings containing safety-related SSCs shall be protected against fire in compliance with the findings of the fire hazard analysis.
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	– Senior: Civil engineer, mechanical engineer; – Junior: Civil engineer, mechanical engineer; – TSO: Civil engineer, mechanical engineer, fire protection engineer.
Specialised training, experience and/or education needed for the review of this topic.	– Training in design codes used; – Experience performing and reviewing fire and flooding PSA.
Level of effort in each review area.	– Regulator: 200 hours; – TSO’ review time: 400 hours.

Internal hazards	United States US NRC

Design information provided by applicant.	As part of the SAR, the applicant should describe the following:
	– All the safety-related structures, systems and components (SSCs) that must be protected against flooding from both external and internal causes;
	– The location of the safety-related SSCs relative to the internal flood level in various buildings, rooms and enclosures that house safety-related SSCs;
	– Possible flow paths from interconnected non-safety-related areas to buildings, rooms and enclosures that house safety-related SSCs (e.g. leakage through interconnecting doorways);
	– The adequacy of the isolation of safety-related systems and equipment between redundant trains and from non-safety systems that could be sources of internal flooding;
	– Provisions for protection against possible in-leakage sources, such as non-mechanistic cracks in structures and exterior openings and penetrations in structures located at a lower elevation than the internal flood level;
	– SSCs that could be a potential source of internal flooding (e.g. pipe breaks and cracks, tank and vessel failures, backflow through drains);
	– Design features that will be used to mitigate the effects of internal flooding (e.g. adequate drainage, sump pumps, etc.);
	– Safety-related structures that are protected from below-grade groundwater seepage by means of a permanent dewatering system;
	– Structures, systems and components that could be the potential source of internal flooding;
	– Design features that will mitigate the effects of internal flooding;
	– Highest flood and groundwater levels
	– Analysis of loads applied to seismic Category I structures due to flooding;
	– Potential sources and effects of internally generated missiles;
	– Identification and analysis of fire and explosion hazards:
	    – Description of Fire Protection Program;
	    – Fire detection and suppression systems;
	    – Post fire safe shutdown capability
	    – Special fire hazards.
	    – Enhanced fire protection criteria for new reactors;
	– Assessment of the risks associated with internal flooding;
	– Assessment of the risks associated with internal fires.

Analysis, reviews and/or research performed by the reviewer and scope of review.	The Nuclear Regulatory Commission (NRC) staff (1) reviews the information provided in the SAR for compliance with the regulations, (2) issues requests for additional information (RAIs) as necessary, (3) reviews RAI responses, (4) resolves technical issues with applicants or licensees and (5) produces a safety evaluation report (SER) documenting its findings. The scope and level of detail of the staff's safety review is based on the guidance of NUREG-0800, Standard Review Plan (SRP). The sections of the SRP that are applicable to this area are as follows: – SRP 3.4.1, "Internal Flood Protection for Onsite Equipment Failures"; – SRP 3.4.2, "Analysis Procedures"; – SRP 3.6.1, "Plant Design for Protection Against Postulated Piping Failures in Fluid Systems Outside Containment"; – SRP 3.6.2, "Determination of Rupture Locations and Dynamic Effects

	Associated with the Postulated Rupture of Piping"; – SRP 3.5.1.1, "Internally Generated Missiles (Outside Containment); – SRP 3.5.1.2, "Internally Generated Missiles (Inside Containment); – SRP 9.5.1, "Fire Protection Program"; – SRP 19.0, "Probabilistic Risk Assessment and Severe Accident Evaluation for New Reactors". The staff also considers emerging technical and construction issues, operating experience and lessons learnt related to this category.
What type of confirmatory analysis (if any) is performed?	None.
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g. can come from accident analysis, regulatory guidance).**	The applicable NRC Regulatory Requirements are listed below: 1. 10 CFR Part 50, Appendix A, GDC 2, "Design Bases for Protection Against Natural Phenomena; 2. 10 FRE Part 50 Appendix A, GDC 3, "Fire Protection"; 3. 10 CFR Part 50, Appendix A, GDC 4, "Environmental and Dynamic Effects Design Bases"; 4. 10 CFR 50.48, "Fire Protection"; 5. Regulatory requirements pertaining to assessment of risk are listed in SRP 19.0, "Probabilistic Risk Assessment and Severe Accident Evaluation for New Reactors", Revision 3. The NRC guidance documents that provide an acceptable approach for satisfying the applicable regulatory requirements are listed as follows: 1. RG 1.29, "Seismic Design Classification"; 2. RG 1.115, "Protection Against Low-Trajectory Turbine Missiles"; 3. RG 1.189 "Fire Protection for Nuclear Power Plants"; 4. Regulatory Guidance pertaining to assessment of risk are listed in SRP 19.0, "Probabilistic Risk Assessment and Severe Accident Evaluation for New Reactors", Revision 3.
Skill sets required to perform review.	– Structural Engineer; – Reactor systems engineer; – Fire Protection Engineer; – PRA Analyst.
Specialised training, experience and/or education needed for review.	Technical reviewers are required to complete a formal qualification programme prior to performing safety reviews independently. Other specialised training, experience and education that is needed to successfully perform reviews in this technical area include: – Experience in evaluation of internal hazards; – Knowledge of National Fire Protection Association (NFPA) codes and standards; – Experience performing and/or reviewing fire PRA developed with either the FIVE method or methods documented in NUREG/CR-6850; – Experience performing and/or reviewing internal flooding PRA.
Level of effort in each review area.	3000 hours (this estimate includes NRC Staff and technical support for all technical disciplines involved in the review of an application for Design Certification application).

APPENDIX E: AIRCRAFT IMPACT ASSESSMENT

Summary table

Country	Is this area reviewed?	Are confirmatory analyses performed?	Expertise of reviewers	Level of effort
Canada	Yes.	Yes.	Structural engineer.	700 hours.
Finland	Yes.	Yes.	Civil engineer, mechanical engineer.	250 working days (2 000 hours).
France	Yes.	No.	Civil works engineers, mechanical engineers.	–[1]
India	Yes.	Yes.	Civil, structural and geotechnical engineers.	–[1]
Japan	Yes	Yes.	Civil, structural and mechanical engineers. Generally, staff that has more than 10 year-experience are taken on the task.	–[1]
Korea	Yes.	Yes.	Structural engineer.	800 hours.
Russia	Yes.	No.	Architects, civil engineer, mechanical engineer.	–[1]
Slovakia	Yes.	No.	Technical engineer.	–[2]
Slovenia	Yes.	No.	Structural engineer, mechanical engineer.	600 hours[3].
United Kingdom	Yes.	No.	Chartered engineer, typically over 10 year-experience in the area.	0.1 FTE plus £250,000 TSO cost (2 214 hours).
United States	Yes.	No.	Structural engineer, fire protection engineer, reactor systems engineer.	1 350 hours.

Notes:

1. The level of effort is not estimated for each review area.
2. In the Slovak Republic, the standard level of effort for the review of submitted documentation is defined by regulation and dependent upon the activity to be approved.
3. In Slovenia, the level of effort (hours) estimated on the basis of analysis, which was prepared in order to assess the resources needed in case of construction of new nuclear power plants.

Aircraft impact assessment	Canada CNSC
Design information provided by applicant.	3D analysis for global behaviour and simplified methods, using empirical formulas, for local behaviour.
Analysis, reviews and/or research performed by the reviewer and scope of review.	Extensive research programme performed under International testing programme IMPACT and international NEA simulation benchmark IRIS.
What type of confirmatory analysis (if any) is performed?	Impact analysis using LS-Dyna software and performing extensive sensitivity studies. The LS-Dyna models were calibrated using IMPACT test results.
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g., can come from accident analysis, regulatory guidance).**	The main technical basis are: CNSC REGDOC 2.5.2 and CNSC Staff Review Procedures supported by new IAEA Safety report related to human induced external hazards and supported by test results and recommendation of NEA report on IRIS_2012.
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	Structural Engineer with extensive experience in the design, analysis and testing of structures under impulsive and impactive loading.
Specialised training, experience and/or education needed for the review of this topic.	Extensive experience in the behaviour of reinforced concrete structures gained in multiyear testing programmes. Extensive training in non-linear analysis using Ls-Dyna software and calibrating constitutive models using test results.
Level of effort in each review area.	CNSC staff: 700 hours.

Aircraft impact assessment	Finland STUK
Design information provided by applicant.	PSAR, First structural design documentation.
Analysis, reviews and/or research performed by the reviewer and scope of review.	Comparative linear/nonlinear analyses of structural response against different kind of missiles including large passage air plane by VTT (TSO).
What type of confirmatory analysis (if any) is performed?	Please see above, verification analyses ensured with testing.
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g., can come from accident analysis, regulatory guidance).**	KTA (incl. acceptance criteria), YVL 4.1-3, IEC/IEEE, Finnish building code (RakMK).
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	– No official requirements, but in practice; - Senior Inspectors: university degree in civil and mechanical engineering, adequate working experience in design/research; - TSO specialists: as above, but more concentrated in corresponding technical domain.
Specialised training, experience and/or education needed for the review of this topic.	– Altogether 5 week training course on nuclear safety; – research work within Finnish nuclear safety research programme (SAFIR).
Level of effort in each review area.	– Regulatory review: 150 working days; – Consultants: 0; – TSO (VTT): TSO statements: 100 working days.

Aircraft impact assessment	France ASN
Design information provided by applicant.	EDF should provide the followings: Safety analysis report: – Section 3.3.3: (Aircraft impact) and; – Section 3.4.7: (Fire) of the safety analysis report; – Section 1.6: References. Note ENSN9455A probabilistic analysis.
Analysis, reviews and/or research performed by the reviewer and scope of review.	Scope of the review: – According to Technical Guidelines § F2.2.2, different potential effects of aircraft impact are taken into account: perforation and scabbing of civil work structures and vibrations of equipment; – Analysis of loading combinations of aircraft impact.
What type of confirmatory analysis (if any) is performed?	
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g., can come from accident analysis, regulatory guidance).**	The following requirements are applicable to this technical area: – Fundamental safety rule I.2.a (RFS); – All applicable technical guidelines identified in section 1.6 of the safety analysis report; – Technical guidelines* §A.2.5 (contribution of external hazards in the global risk) and §F2.2.2 (protection against APC); – The ETC-C applicable for the design of civil work structures.. * Technical guidelines for the design and construction of the next generation of nuclear power plants with pressurised water reactors.
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	The review requires a team of: – Civil works engineers; – Mechanical engineers.
Specialised training, experience and/or education needed for the review of this topic.	
Level of effort in each review area.	The level of effort is very important but is not estimated.

Aircraft impact assessment	India AERB
Design information provided by applicant.	**Aircraft Crash**: A study on the probability of occurrence of an aircraft crashing on the nuclear power plant shall be made taking into account the flight frequencies at the nearest air field and its distance from site. If the study indicates that the probability is more than 10-7 per year, then the site shall be deemed unsuitable. Appropriate Screening Distance Value may be used to obtain the above probability value. In the absence of site-specific data, SDVs as specified in Annexure A of AERB siting code (AERB/SC/S) shall be used.
Analysis, reviews and/or research performed by the reviewer and scope of review.	**Protection against Man-made Events:** Structures, systems and components necessary to assure the capability for shutdown, residual heat removal and confinement of radioactive material shall be designed to remain functional despite man-made events that might occur due to aircraft crash or due to activities at or near the site as identified in AERB siting code (AERB/SC/S). SDVs typically: – Distance from small airfields Less than 5 km; – Distance from major airports Less than 8 km; – Distance from military airfields Less than 15 km.
What type of confirmatory analysis (if any) is performed?	Confirmatory analyses are performed, if necessary, on a case-by-case basis by the technical service organisation or at the designated division of AERB. The commonly performed confirmatory analyses are to verify the adequacy of the submissions related to Failure Modes and Effects Analysis.
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g., can come from accident analysis, regulatory guidance).**	– Code of Practice on Safety in Nuclear Power Plant Siting, AERB/SC/S; Protection against Internally Generated Missiles in Nuclear Power Plants, AERB/NPP-PHWR/SG/D-3.
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	– Civil, structural and geotechnical Engineers having experience in system development, static and dynamic analysis and modelling, system review, construction, regulatory experience; – Exposure to nuclear reactor engineering, Reactor Systems; Experts capable of structural analysis and design, development of software for analysis and design, etc.
Specialised training, experience and/or education needed for the review of this topic.	Reviewers are from regulatory staff undergone formal training in relevant areas and subsequently in regulatory/safety review. Many have additional specialisation e.g. Master's degree in structural/geotechnical engineering, construction experience. Further, the regulatory staff is trained in various review areas through participation in the safety review and regulatory inspection process. The other members of the review team are from the premier academic institutes, TSO's who are working in specialised areas.
Level of effort in each review area.	In depth review is done by the specialist working group constituted by the Civil Engineering Safety Committee and Project Design Safety Committee of AERB. The second level of review at CESC or PDSC, which specially looked at the unresolved issues of the specialist group. The final level of safety review is done

	at ACPSR before the recommendations are forwarded to Chairman AERB. The depth and schedule of a review should depend on whether the project is of new, evolved or repeat design.

Aircraft impact assessment	Japan NRA
Design information provided by applicant.	In the establishment permit application stage, the following information is provided: – Type, approaching route, speed, amount of loading kerosene of aircraft; – Basic design policy. In addition, in construction work approval application stage, the following information is provided: – Design policy; – Plan, section view, structural drawing, system diagram; – Design conditions; – Design description of system integrity under aircraft crash; – Test and inspection programme; – Quality control and assurance programme.
Analysis, reviews and/or research performed by the reviewer and scope of review.	These activities are to conform to the requirements, standards, criteria, and are like described below.
What type of confirmatory analysis (if any) is performed?	
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g., can come from accident analysis, regulatory guidance).**	The following regulatory requirements and guides are applicable to this technical area: Requirements: – Requirement of SCCs of commercial NPPs (H25 #5); – Interpretation of Requirement of SCCs of commercial NPPs (#1306193); – Standard of technical ability of severe accident management of commercial NPPs (#1306197); – Technical standard of SCCs of commercial NPPs (H25 #6); – Interpretation of Technical standard of SCCs of commercial NPPs (#1306194). Guides: – Guide for procedure of construction work approval (#13061920); – Guide for review of specialised safety facility of commercial NPPs (#1409177); – Guide for evaluation of aircraft crash (#1409178); – Evaluation basis for aircraft crash probability onto nuclear power reactor facilities (H21-6-25 #1).
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	– Senior: manager and engineer; – Junior: engineer; – TSO: researcher. Generally the staffs who have more than 10 year-experience are taken on the task.
Specialised training, experience and/or education needed for the review of this topic.	– Basic training for the examiner for nuclear safety; – Practical application training for the examiner for nuclear safety.

Level of effort in each review area.	Resources (hours) is not set up for the individual review area. Regarding the standard processing duration, 2 years is set up for establishment permit of an entire plant, and 3 months per one application is set up for construction work approval. Divided application is granted for construction work approval.

Aircraft impact assessment	Korea KINS
Design information provided by applicant.	The aircraft impact assessment (AIA) report should be provided to show that 1) the reactor core remains cool, or the containment remains intact by intentional aircraft impact; and 2) spent fuel cooling or spent fuel pool integrity is maintained. The report should include the methodology and assumptions adopted in the AIA, and the results of impact analysis and the levels of structural damage.
Analysis, reviews and/or research performed by the reviewer and scope of review.	The KINS staff performs the following activities to confirm that AIA by the applicant is reliable, and the safety of NPP is ensured for the aircraft impact occurrence: – Review all design and analysis parameters used in AIA; – Request additional or missing information in the AIA report; – Evaluate that the NPP design is safe for the aircraft impact.
What type of confirmatory analysis (if any) is performed?	– Develop force-time history for the aircraft impact analysis by conducting impact analyses with the large commercial aircraft; – Evaluate the appropriateness of the AIA results using force-time history by the applicant.
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g., can come from accident analysis, regulatory guidance).**	Now, the Korean domestic law for regulation is under developing, and the AIA is performed according to the international practice before the domestic law is officially announced: – 10 CFR 50.150, "Aircraft Impact Assessment" and RG 1.217, "Guidance for Assessment of Beyond-Design- Basis Aircraft Impacts"; – NEI 07-13, "Methodology for Performing Aircraft Impact Assessments for New Plant Designs". When a national regulation standard is issued, the review of AIA will be performed with the developed regulation standard with NRC materials.
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	– Structural engineer with extensive knowledge in the following area; – Structural analysis and design of reinforced concrete (RC) structures subjected to impact loading, and structural vibration due to impact; – Regulatory guides and industrial codes/standards related to nuclear power plant structures.
Specialised training, experience and/or education needed for the review of this topic.	– Education about regulatory requirements, guidelines, codes and standards; – Overall understanding of NPP structures; – Experience in structural engineering (pre-stressed structures, RC structures and impact analysis); – Experience in computer analysis tools which can analyse the impact effect.
Level of effort in each review area.	– KINS staff: more than 800 hours; – A sophisticate aircraft model for impact analysis has been developed, and verification analyses are performed for newly designed NPPs. In addition, design review is performed if needed.

Aircraft impact assessment	Russia SEC NRS
Design information provided by applicant.	– Chapters 1 and 3 of PSAR (FSAR); – Quality Assurance programme for the construction phase.
Analysis, reviews and/or research performed by the reviewer and scope of review	Review of analyses presented by Applicant on: – local behaviour of containment structure in response to aircraft shock; – vibration of reactor building at aircraft shock.
What type of confirmatory analysis (if any) is performed?	Confirmatory analyses of Reactor building, Containment structure and other safety related buildings should be listed in PSAR and presented to regulatory body for review. Regulators check the sufficiency of the list of analyses and fulfil the Review of the most important analyses.
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g. can come from accident analysis, regulatory guidance).**	Regulatory documents related to the technical sphere under consideration are listed below: – Federal law "On the Use of Atomic Energy" No. 170-FZ dated of November 21, 1995; – Federal law "On Radiation Safety of Public" No. 3-FZ dated of January 09, 1996; – NP-001-97, "General Safety Provisions for Nuclear Power Plants" (OPB-88/97); – NP-006-98, "Requirements to the Contents of Safety Analysis Report for a Nuclear Power Plant with VVER-type Reactor". (PNAE G- 01-036-95); – NP-032-01, "Nuclear Power Plant Siting. Basic Safety Criteria and Requirements"; – NP-064-05, "Accounting of External Natural and Man-Induced Impacts on Nuclear Facilities"; – NP-082-07, Nuclear Safety Rules for Reactor Installations of Nuclear Power Plants; – PiN AE-5.6, Construction Design Standards for NPP with Different Reactors Types; – NP-010-98, Design Standards for Reinforced Structures of NPP Safety Localizing Systems; – SNiP 2.01.07-85□, Loads and Impacts; – RD 95 10528-96, "Guideline on Shock Wave Determination in Case of Explosion and Loads on Building Structures of Nuclear Power Plants"; – IAEA, "External Events Excluding Earthquakes in the Design of Nuclear Power Plants" – Safety Guide, Standards Series No. NS-G-1.5, IAEA, Vienna, 2003.
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	– Civil engineers, geotechnical and environmental engineers with in-depth experience in nuclear civil structures designing; – Senior staff has more than 10 year-experience in nuclear civil structures designing, as a rule with scientific degree; – Junior staff has more than 3 year-experience in nuclear civil structures designing; – Also Laboratories of Academy of Sciences and Civil Engineering university are invited.

Specialised training, experience and/or education needed for the review of this topic.	All technical reviewers are required to have knowledge of federal norms and rules in using of atomic energy and safety guides. Knowledge of Civil Engineering norms and rules is also required. Knowledge of safety guides and good practice of IAEA and NEA in analyses of external events is necessary. Special knowledge is needed in the field of: – resistance of reinforced concrete to impact loads; – response spectra approach; – scenarios of aircraft impact (mechanical loads, fuel fire etc.).
Level of effort in each review area.	Level of effort not estimated for each review area.

Aircraft impact assessment	Slovakia UJD
Design information provided by applicant.	Aircraft type: – Safety analysis for the proposed facility for the aircraft impact.
Analysis, reviews and/or research performed by the reviewer and scope of review.	Review of the submitted documentation, if it conforms to atomic act and regulations. Evaluate if the systems, structures and components are in compliance with all requirements arising from applicable regulations, codes and standards. Confirm that the nuclear facility is able to manage hazard arising from aircraft impact.
What type of confirmatory analysis (if any) is performed?	
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g., can come from accident analysis, regulatory guidance).**	
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	– Senior: technical engineer; – Junior: technical engineer; – TSO: technical engineer**.**
Specialised training, experience and/or education needed for the review of this topic.	– Experience with safety analysis; – Knowledge about nuclear facilities.
Level of effort in each review area.	Review of the submitted design information is a part of approval process which is performed as an administrative procedure based on administrative proceeding code. Based on this act 60 days are scheduled for approval of the submitted documentation. In case more time is needed (for example if a review from TSO or the other support organisation is needed) the chairperson can be asked to extend the period for approval. In some cases, which are strictly defined in the atomic act the time period for reviewing is longer. These cases are as follows: – Four months if siting of nuclear installation, except repository is concerned; – Six months if nuclear installation commissioning or decommissioning stage is concerned; – One year if building authorisation, siting and closure of repository or repeated authorisation for operation of a nuclear installation are concerned.

Aircraft impact assessment	Slovenia SNSA
Design information provided by applicant.	Based on the number and the relevant types of aircrafts, crash frequencies for the airport shall be estimated. The subsequent analysis shall be performed. It comprises determination of impact frequencies, structural evaluation of buildings, evaluation of core damage risk and risk quantification.
Analysis, reviews and/or research performed by the reviewer and scope of review.	Evaluate that the applicant has provided complete information as required by applicable regulation, guides and industrial standards.
What type of confirmatory analysis (if any) is performed?	Independent evaluation is also performed to demonstrate the analysis results, if needed, (cross check analysis).
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g., can come from accident analysis, regulatory guidance).**	<u>General aspects of design standards including:</u> – IAEA, “Safety of Nuclear Power Plants: Design”, Safety Standards Series No. SSR-2/1, IAEA, Vienna (2012); – IAEA, “Site Evaluation for Nuclear Installations”, Safety Standards Series No. NS-R-3, IAEA, Vienna (2003); – IAEA, “Format and Content of the Safety Analysis Report for Nuclear Power Plants” – Safety Guide, Safety Standards Series No. GS-G-4.1, IAEA, Vienna (2004); – IAEA, “Safety Assessment and Verification for Nuclear Power Plants”, Safety Standards Series No. NS-G-1.2, IAEA, Vienna (2001); – IAEA, “Engineering Safety Aspects of the Protection of Nuclear Power Plants against Sabotage”, Nuclear Security Series No. 4, IAEA, Vienna (2007); – IAEA, “Design of the Reactor Coolant System and Associated Systems in Nuclear Power Plants” – Safety Guide, Safety Standards Series No. NS-G-1.9, IAEA, Vienna (2004); – IAEA, Safety Standards Series No. NS-G-3.1, “External Human Induced Events in Site Evaluation for Nuclear Power Plants” – Safety Guide; The main technical basis represents Regulation JV5 (Rules on radiation and nuclear safety factors) which requires that the containment building shall retain its functionality even in an event of a direct crash of a large commercial aircraft. <u>Standards and codes taken into account assessing aircraft impact:</u> – Standard Review plan for the Review of Safety Analysis Reports for Nuclear Power Plants, NUREG-0800, Revision 4, March 2010; – US NRC Regulatory Guide 1.70, “Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants, LWR Edition” (Sections 2.2 and 3.5.1.6), Revision 3, November 1978; – Accident analysis for aircraft crash into hazardous facilities DOE-STD-3014-2006 US DOE, Washington D.C., May 2006; – Evaluation of Aircraft Crash Hazards Analyses for Nuclear Power Plants, NUREG/CR-2859, ANL-GT-81-32, ANL, 1982; – Waste Handling System Frequency Analysis of Aircraft Hazards for License Application, 000-00C-WHS0-00200-000-00E; – “External Events PRA Methodology, An American National Standard”, ANSI/ANS-58.21-2003, American Nuclear Society, March 2003.

	Other references taken into account assessing aircraft impact: Test results and recommendation of NEA report on IRIS_2012.
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	– Senior: Structural, mechanical engineers; – Junior: Structural, mechanical engineers; – TSO: Structural, mechanical engineers.
Specialised training, experience and/or education needed for the review of this topic.	– Training in design code used; – Experience in impact analysis of reinforced concrete structures; – Experience in the development of fragility data; – Experience in risk hazard analyses.
Level of effort in each review area.	– Regulator: 200 hours; – TSO' review time: 400 hours.

Aircraft impact assessment	United Kingdom ONR
Design information provided by applicant.	– Basis of Design documents; – Design codes; – Analysis inputs/outputs; – Generic design envelope.
Analysis, reviews and/or research performed by the reviewer and scope of review.	Detailed review of all design information.
What type of confirmatory analysis (if any) is performed?	None.
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g., can come from accident analysis, regulatory guidance).**	– Safety Assessment Principles (SAPs); – Technical Assessment Guides (TAGs); – ASCE 4-98.
Skill sets required by (education): • **senior (regulator);** • **junior (regulator);** • **TSO.**	– Honours degree in relevant subject; – Chartered engineer; – Typically 10+ years experience in related areas.
Specialised training, experience and/or education needed for the review of this topic.	– Training in design codes used; – Experience in the development of fragility data; – Experience in the construction of nuclear facilities.
Level of effort in each review area.	– Full time equivalent over 2.5 years; – TSO effort £ 250,000.

Aircraft impact assessment	United States US NRC
Design information provided by applicant.	As part of the SAR pertaining to aircraft impact assessments (AIA), the applicant should describe the key design features and functional capabilities of the plant necessary to show, with reduced use of operator action, that the reactor core remains cooled or the containment remains intact and spent fuel cooling or spent fuel integrity is maintained. The supporting technical basis is typically categorised as Security-related and Safeguards Information, which is not submitted on the docket but can be inspected by the staff.
Analysis, reviews and/or research performed by the reviewer and scope of review.	The Nuclear Regulatory Commission (NRC) staff (1) reviews the information provided in the SAR for compliance with the regulations, (2) issues requests for additional information (RAIs) as necessary, (3) reviews RAI responses, (4) resolves technical issues with applicants or licensees and (5) produces a safety evaluation report (SER) documenting its findings. The scope and level of detail of the staff's safety review is based on the guidance of NUREG-0800, Standard Review Plan (SRP). The sections of the SRP that are applicable to this area are as follows: – SRP 19.5, "Adequacy of Design Features and Functional Capabilities Identified and Described for Withstanding Aircraft Impacts". The staff can also perform an inspection of the applicant or licensee's AIA for conformance to regulatory guidance. NRC Inspection Procedure 37804, "Aircraft impact assessment" provides guidance for performing such inspections. In addition, the staff considers emerging technical and construction issues, operating experience and lessons learnt related to this category.
What type of confirmatory analysis (if any) is performed?	Staff does not typically perform confirmatory analysis for this beyond-design-basis scenario. However, the applicant or licensee should ensure that structural analysis methods are benchmarked to representative experiments. Acceptable methods are described in NEI-07-13, "Methodology for Performing Aircraft impact assessment for New Plant Design", Revision 8, April 2011.
Technical basis: • **standards;** • **codes;** • **acceptance criteria.** **(e.g. can come from accident analysis, regulatory guidance).**	The applicable NRC Regulatory Requirements are listed below: 1. 10 CFR 50.150, "Aircraft impact assessment". The NRC guidance documents that provide an acceptable approach for satisfying the applicable regulatory requirements are listed as follows: 1. RG 1.217, "Guidance for Assessment of Beyond-Design-Basis Aircraft Impacts". The AIA parameters as required by 10 CFR 50.150 are based on realistic (or best-estimate) analyses. The AIA assessments are conducted using realistic aircraft parameters (provided by NRC), best-estimate material properties and failure limits with no conservative margin. Uncertainties in AIA assessments are recognised and are described in industry guidance NEI-07-13 (endorsed in RG 1.217).
Skill sets required to perform review.	– Structural engineer with understanding of relevant guidance and experience in impact analysis and shock and vibration effects; – Fire protection engineer with experience in fire modelling and analysing fire barriers; – Reactor systems engineer familiar with containment and spent fuel pool

	safe shutdown equipment and related support systems such as cooling water, electrical and HVAC.
Specialised training, experience and/or education needed for review.	Technical reviewers are required to complete a formal qualification programme prior to performing safety reviews independently. Other specialised training, experience and education that is needed to successfully perform reviews in this technical area include: – Knowledge in regulatory requirements and regulatory guides; – Experience in impact analysis of reinforced concrete structures; – Background in the analysis of large deformations of structures; – Overall plant systems knowledge.
Level of effort in each review area.	1 350 hours (this estimate includes NRC staff and technical support for all technical disciplines involved in the review of an application for design certification application).