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FRENCH PRACTICE OF SITE EVALUATION FOR NUCLEAR INSTALLATIONS

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INTRODUCTION

The nuclear safety approach in France is based on:

- the prime responsibility of the licensee for the safety of its facilities, under the oversight of ASN ;
- continuous improvement of nuclear safety and radiation protection.

The safety principles and approaches presented in the paper were implemented gradually. They included experience feedback from accidents. Safety can never be totally obtained and, despite the precautions taken in the design, construction and operation of nuclear facilities, an accident always remains possible. There must thus be a constant desire to move forwards and to implement a continuous improvement approach in order to reduce the risks.

In France all of the nuclear installations such as nuclear power plants, research reactors, fuel cycle installations, research laboratories, and radioactive waste disposal facilities are "Basic Nuclear Installations" (BNI). A BNI is a facility subject, by its nature or because of the quantity or the activity of radioactive substances contained in it, to the Act of June 13, 2006 and the Order of February 7, 2012. These facilities shall be authorized by decree after public inquiry and opinion of the French nuclear safety authority (ASN). One or several BNI(s) are located on a nuclear site which is the area under effective control of the operator of the BNI(s).

To ensure the safety of BNIs, the French regulations require that they be designed, built and operated to deal with a certain level of risks. These risks comprise natural hazards. The regulations also require the implementation of arrangements according to the "defence in depth" principle which is twofold: first, to prevent accidents and, second, if prevention fails, to limit their potential consequences and prevent any evolution to more serious conditions. These arrangements are regularly checked and systematically reviewed on the occasion of the ten-yearly periodic safety reviews.

The French nuclear sites have been selected from the 1950s up to the 1980s (for example the last new site for Nuclear Power Plant - NPP - is Civaux site where construction began in 1988). The sites of construction of new NPPs in the course or envisaged are sites where NPP are already operated. In effect, the 19 sites historically chosen allowed accommodating 4 units and on several of these sites 2 units have been built. As well the EPR in construction on Flamanville site is the third unit of the site.

The situation is similar for the other BNIs. During the past 30 years, new BNIs such as, research reactors/laboratories, fuel cycle facilities and industrial irradiators have been created on or in the immediate proximity of exiting sites, and in particular the sites of La Hague, Marcoule, Pierrelatte and Cadarache. In this period, a specific approach was developed for site selection for permanent disposal of radioactive waste in deep geological repositories. The ASN Guide no.1 (ASN, 2008) defines objectives to be adopted for a radioactive waste disposal in deep geological repository when the site investigation phase begins.

In this context, it has not been developed in France a specific approach for site selection for BNI. Typically, a site is selected by the applicant. Nevertheless, in the set of files accompanying the application for creation, commissioning, and modification of the BNI, the applicant shall justify that the design of the BNI is compliant with the specific hazards of the site and that the impact on the environment of the BNI is acceptable. These two key topics are addressed in site evaluation during the lifetime of BNI.

The paper provides an overview of the French practice for site evaluation addressing: in a first part effect of nuclear installations on public and environment, in a second part effect of site characteristics on nuclear installations with particular emphasis on external hazards, and in a third part the regulatory framework.

EFFECT OF NUCLEAR INSTALLATIONS ON PUBLIC AND ENVIRONMENT

Impact assessment

Pursuant to decree 2007-1557 of 2 November 2007, the Environmental impact assessment (EIA) is one of the items that accompanied the BNI creation authorisation application and further applications. The article 9 of this decree details the content of the impact assessment. The impact assessment comprises:

> 1) An analysis of the state of the site and its environment before the siting of the BNI. This analysis in particular concerns the natural resources and natural agricultural, forestry, maritime or leisure spaces, as well as the property and the cultural heritage liable to be affected by the project; it includes a radiological inventory of the environment, concerning the site and its vicinity.
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> 2) An analysis of the direct and indirect, temporary and permanent effects of the BNI on the environment, in particular on public health, on the climate, on the quality of life in the neighbourhood, as a result of noise, vibration, odours or light emissions, on the sites, landscapes and natural environment, on the fauna, flora and biological balance, on agricultural production and on the protection of property and the cultural heritage. As necessary, this analysis will differentiate between the various phases of construction and operation of the installation.
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> This analysis presents the water intake and liquid effluent discharges envisaged; it specifies the various types of effluent to be processed and their respective origins, their quantity, their physical characteristics, their composition, both radioactive and chemical, the treatment processes used, the conditions in which discharges are to be made into the host environment and the composition of the effluent to be discharged. It states the effect of the installation on the water resource, the aquatic environment, the flow, level and quality of water.
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> It also presents the envisaged atmospheric discharge of the effluent, including fall-out and settling of aerosols and dust. It states the impact of the installation on the quality of the air and of the soil.
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> It assesses public exposure to ionising radiation as a result of the installation, in particular taking account of the irradiation caused directly by the installation and the transfer of radionuclides by various means, including through the food chains.
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> Finally, it presents the waste that is to be produced by the installation, whether or not radioactive. It mentions its volume, nature, harmfulness and envisaged means of disposal.
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> The impacts of the installation on the environment are assessed in particular with respect to the atmosphere protection plans defined in article L. 222-5 of the Environmental Code as well as the

quality standards and objectives and the limit values defined pursuant to articles L. 211-2, L. 211-4 and L. 221-2 of the same code.

3) The reasons for which, in particular from the viewpoint of the environmental concerns, the project was selected over the other options envisaged;

4) The measures envisaged by the operator to prevent, limit and if possible compensate for the inconveniences created by the installation, along with an estimate of the corresponding expenses.

5) An analysis of the methods used for assessing the effects of the installation on the environment, mentioning any technical or scientific difficulties encountered in drawing up this assessment.

6) A non-technical summary of the study, such as to ensure easier understanding by the public of the information contained therein.

Monitoring

The Order of 7 February 2012 sets the general rules concerning basic nuclear installations (BNI). The Article 4.2.1 of the Order states that the licensee defines and implements systems for monitoring water intakes and consumption, emissions, and the environment that could be affected by the installation. The environmental monitoring aims at:

- contributing to the knowledge of the radiological and radio-ecological state of the environment of the installation, and its evolution;
- helping verify that the impact of the installation on health and the environment, particularly foodstuffs, is in conformity with the impact assessment (described above);
- detecting any abnormal increase in radioactivity as early as possible;
- ensuring there are no installation malfunctions, by analysing the ground water among other things.

The Article 4.4.4 of the Order states that each year the licensee draws up a report presenting the impact of its installation during the past calendar year. This report characterises the water intakes, the effluent discharges, the environmental monitoring measures and the impacts and detrimental effects caused by the installation.

Considerations for Emergency Planning

An on-site emergency plan (PUI) is drawn up by the licensee. The PUI defines the organisational measures, the response methods and the necessary resources implemented by the operator in the event of an emergency situation, to protect the workers, the public and the environment from ionising radiation, and preserve or restore the safety of the installation. It is based on studies of the accidents which require protective measures on or off the site, or which are likely to affect people and environment, including multi-facility common cause failures due to external events. Pursuant to decree 2007-1557 of 2nd November 2007, the PUI is one of the items to be included in the file sent by the licensee to ASN prior to commissioning of its facility.

An off-site emergency plan (PPI) is drawn up by the Prefect of the département concerned, who is the local representative of the State, pursuant to decree 2005-1158 of 13th September 2005, "to protect the populations, property and the environment, and to cope with the specific risks associated with the existence of structures and facilities whose coverage area is localised and fixed. The PPI implements the orientations of the policy of emergency preparedness and civil protection in terms of mobilisation of resources, information, alert, exercises and training". PPI planning makes provision for civil protection of the population residing within a radius up to 10 km around the affected BNI in the initial hours of the accident. The PPI falls within the framework of the ORSEC system, which specifies the protection measures implemented in large-scale emergencies. Consequently, beyond the perimeter established by the PPI, the modular and progressive département or zone ORSEC plan applies in full.

The PPI specifies population centres and distribution, including permanent residents and transient population; population in each educational, medical, social and touristic institutions. It also specifies the natural and economical significant areas (e.g. environmental protected areas, water resources). Finally it presents the list of means of relief and medical facilities which can be implemented, infrastructure (road, rail, maritime, river and air), enterprises of transport of persons, and networks/resources in electrical power.

EFFECT OF SITE CHARACTERISTICS ON NUCLEAR INSTALLATIONS - EXTERNAL HAZARDS

General considerations

The Order of 7 February 2012 sets the general rules concerning basic nuclear installations (BNI). The external hazards are specific to the site where the installation is located and can affect consecutively or concurrently all or part of facilities at the site. Applying the principle of defence in depth, attention shall be paid to the choice of the site, with particular consideration for the natural or industrial risks weighing on the installation (in Art 3.1).

The external hazards to be considered in the demonstration of nuclear safety include (Art 3.6):

- the risks induced by the industrial activities and communication routes, including explosions, hazardous substance emissions and airplane crashes;
- earthquakes;
- lightning and electromagnetic interference;
- extreme meteorological or climatic conditions;
- fire;
- floods originating outside the perimeter of the basic nuclear installation, including their dynamic effect;
- malevolent acts;
- any other external hazard identified by the licensee or, if appropriate, that ASN considers must be taken into account;
- plausible combinations of the above hazards.

Definition of plausible combinations should in particular take into account any dependencies between the trigger events and a special attention should be paid to external hazards presenting a common origin. Considerations on the hazards related to malevolent acts are not treated in the present paper.

The exclusion of external hazards among those in the above list shall be accepted only with a justification based on a conservative approach that concludes, with a high degree of confidence, that the hazard cannot affect the installation or that the hazard has a very low frequency of occurrence. No mandatory criterion defines the frequency limit for the whole external hazards. However, in the established practice for hazards due to industrial activities and communication routes, such criterion is defined: for each type of hazard sources, the order of magnitude for the probability of occurrence of unacceptable releases is set at 10^{-7} per year per installation, for each safety function.

Definition of design basis events for external hazards. The Order of 7 February 2012 states, in Article 3.2, that nuclear safety is demonstrated by a prudent deterministic procedure, and in Article 3.8, that the demonstration of nuclear safety is based on:

- up-to-date and referenced data;
- appropriate, clearly explained and validated methods, integrating assumptions and rules adapted to the uncertainties and limits of knowledge of the phenomena in play;
- calculation and modelling tools qualified for the areas in which they are used.

For hazards due to industrial activities and communication routes, the approaches established long time ago are deterministic and use a probabilistic target for screening the events to be considered. For natural hazards, the historically established approaches were deterministic, but a probabilistic target used for defining design basis events was recently implemented for flood hazards. In the European context, the Western European Nuclear Regulators' Association (WENRA) has revised in 2014 a report presenting a set of safety reference levels for operating NPPs, in order to include a safety issue (set of reference levels dealing with a topic) dedicated to natural hazards (WENRA, 2014). In line with the requirements defined in that report, and the experience gained through works on flood hazards, the French practice on natural hazards is currently changing, in order to complete the classical deterministic approach with probabilistic approach as described below.

The design basis events shall be characterized using deterministic methods and, where possible and relevant, probabilistic methods. These methods shall take into account all the available data (including data from measures or based on historical facts recounted or recorded) and, where possible, shall make it possible to determine a relationship between the severity of the external hazard and its frequency of exceedance.

To determine design basis events, a target of 10^{-4}/year in terms of frequency of exceedance shall be covered. This target value was established considering the current limited capability to extrapolate to extremely low frequency of exceedance for many natural hazards.

However, for some external natural hazards of reference, when the frequency of exceedance of the hazard cannot be calculated or when the uncertainties on the value are too high, an "event" must nevertheless be retained and justified by aiming at a safety objective equivalent to that which shall be referred to pursuant to the preceding paragraph.

The design basis events shall be justified; in particular, their severity shall be increased as compared with that of relevant historical events.

Definition of events for design extension conditions. The lessons of the 2011 accident at the Fukushima Dai-ichi site and complementary safety assessments that were carried out have led to taken into account natural hazards in design extension conditions. The aim is to consider in the safety demonstration hazards of greater severity than the ones considered in the domain of reference design and to ensure the availability of sufficient margins to limit the risk of loss of fundamental safety functions to avoid cliff-hedge effects.
For the identification of events to be considered in the design extension conditions, the severity of the hazard in function of its annual frequency of exceedance shall be established, where possible.
For the natural hazards which annual frequency of exceedance cannot be calculated, or when the uncertainties on the value are too high, an event of greater severity than the one considered in the reference domain shall nevertheless be defined and justified.
These requirements have been declined in the definition of events to be used for the design of safety hardened core for BNI, in a set of ASN decisions. Methods used for the definition of these events for earthquake flooding and weather events are presented in the following paragraphs dedicated to each hazards.

Changes of hazard with time. The Order of 7 February 2012 states, in Article 3.10, that the licensee keeps himself informed about any changes made or planned in the vicinity of his installation that could alter the nature, the extent or the probability of an external hazard. If necessary, the licensee shall update the safety demonstration of its installation.
The current practice regarding external hazards is to include in the design basis events their foreseeable developments during the period of operation of the BNI, particularly the climatic conditions and hydrology. Periodic safety review process is considered as the more efficient way to cope with uncertainties related to changes of hazards with time.
ASN decision n° 2015-DC-0532 (ASN, 2015) states, in Article 4.12, that the safety analysis report (SAR) shall include information concerning hazards of natural origin and of human origin, with due consideration to their foreseeable developments during the period of operation of the installation. More specific guidance has been developed for flooding hazards (see below).

Graded approach. Articles 9, 10 and 11 of the Decree 2007-1557 of 2 November 2007 specify for the impact assessment, the safety report and the risk control study that their content "must be commensurate with the scale of the hazards due to the installation and, in the case of an incident, their foreseeable effects on the interests mentioned in I of article 28 of the Act of 13 June 2006".

Moreover, Article 1.1 of the Order of 7 February 2012 specifies that the application of its requirements is based on an approach that is proportional to the extent of the risks or drawbacks inherent to the installation. It takes into consideration all the technical aspects and relevant organizational and human factors.

For external hazards the graded approached applies on the BNI's protections against the hazards which are defined in the same way for all BNIs (e.g. Safe Shutdown Earthquakes and Reference Flooding Situations).

Seismic hazards

Basic safety rule 2001-01 (ASN, 2001) defines an acceptable method for determining the seismic movements to be taken into account when designing a BNI against seismic hazard. The method is deterministic (deterministic seismic hazard analysis - DSHA).

It is based first on a definition of the characteristics (magnitude and depth of the hypocenter) of "Maximum Historically Probable Earthquakes" (*Séismes Maximaux Historiquement Vraisemblables* -

SMHV) considered to be the most penalising earthquakes liable to occur over a period comparable to the historical period, or about 1000 years. In this first step, reference earthquakes (with highest intensity) are selected among observed events (through instrumental records and, mainly, historical records in archives which cover up to 1000 years). Seismotectonic zones are defined based on up-to-date geological and seismotectonic studies. These zones are volumes of the earth's crust with homogeneous seismogenic potential (an earthquake which occurred at one point in a zone is able to occur at any point in it). Having determined the seismotectonic zones, the SMHV is then defined as being the historically known earthquake(s) which, if considered at a particular location within the zone, would produce the highest intensities on the site, that is:

- reference earthquake in the zone containing the site is considered as being able to occur below the site,
- reference earthquakes of other zones are considered as being able to occur at the point of the site nearest to the zone to which they belong.

In the second step the response spectra of the "Safe Shutdown Earthquakes" at the site are defined. On one hand, Séismes Majorés de Sécurité (SMS) are defined by addition of a degree of intensity on the SMHV. On the other hand, potential earthquakes associated with active fault in the site region are defined; paleoseismic indicators showing events separated by a return time less than or equal to several tens of thousands of years must be taken into account. For both categories of earthquakes, response spectra at the site are calculated with specified relationship regarding: intensity, magnitude, modification of the seismic waves between the earthquake source and the site. Site effects due geological conditions of the site are considered as they could amplify the seismic motion.

The response spectrum used for the design or reassessment of a BNI shall encompass the response spectra associated with the Safe Shutdown Earthquakes, the paleoseismic events and a minimum standard response spectrum with peak ground acceleration (PGA) of 0.10g.

Some significant changes occurred in techniques and knowledge about seismic hazard assessment described by the safety rule. In particular, the use of the intensity criterion for SMHV definition appears unappropriated for some sites, methods for assessment of specific site effects were developed and additional efforts in the domain are undergoing, probabilistic seismic hazard analysis (PSHA) are used as complementary approach to the deterministic one and for probabilistic safety analysis (PSA).

Definition of seismic events for design extension conditions. The general approach to characterize seismic events for design extension conditions was to add a significant margin on the Safe Shutdown Earthquakes (derive from a DSHA) and to consider also seismic hazard derived from PSHA. Seismic hazard to be used for the design of safety hardened core for BNI is defined by a response spectrum which shall:

- encompass the site response spectrum of SMS plus 50 %;
- encompass the site response spectrum with a return period of 20,000 years, derived from PSHA;
- take into account in its characterization site effects due geological conditions of the site.

Geological/Geotechnical hazards

Basic safety rule I.3.c (ASN, 1985) specifies the soil characteristics to be determined and the soil response studies to be performed as part of geological and geotechnical studies. It applies first for NPP, but it's also used for other BNI. Because the characteristics specific to each site vary widely, the rule indicates that the type, scope and depth of the investigations, the methods used in studies shall be adapted to suit each individual case.

Soil characteristics are derived from geological, hydrogeological and geotechnical surveys. The surveys should enable the parameters used for soil/foundation calculations to be determined.

The geological survey aims to define the different soils and/or rocks and their geometric layout, and mapping of significant discontinuities and variations within the different formations. To this end, the site geological survey shall include geophysical tests. In addition, the bottom of the excavation shall be geologically surveyed before permission for concreting is granted.

The hydrogeological survey includes an examination of initial conditions and shall take into account any changes to the aquifer which may affect soil characteristics. To this end, a program to monitor the aquifer shall be implemented during construction and during the plant's lifetime if soil subsidence or uplift are anticipated. The main hydrogeological characteristics studied are: groundwater levels and variations, permeability and porosity of the different layers, the chemical properties of the water.

The geotechnical survey shall enable all useful soil mechanical properties to be determined, in particular, those relating to deformations, strength, dynamics and statics. The survey comprises drilling and the collecting of samples for laboratory testing and on-site mechanical tests (penetration and pressure meter tests) used to reveal soil variations with depth. The soil study shall accompany foundation design and construction and be re-examined, where necessary, in accordance with observations made during construction and operation (subsidence or swelling, water level, etc.).

Soil response studies concern foundation soils, any site earthworks and soil located in the vicinity of nuclear facilities. The extent of the soils studied shall ensure that the uncertainties with regards to measurements taken have a negligible effect on response study results. Typical hazards related to soil response are:

- Subsidence or uplift of foundation soil that shall be evaluated and monitored from the time construction begins and throughout the entire life of the plant;
- Liquefaction caused by high-intensity seismic movement is a risk specific to certain soils. Where the permeability coefficient of these soils is less than 10-2 m/s, liquefaction risk analysis shall be performed. The potential for soil liquefaction at the site is evaluated using Safe Shutdown Earthquakes parameters. Where the evaluation results in an inadequate safety factor, deformation calculations shall be performed. The operating utility shall propose an acceptable deformation criterion. Where the calculations do not meet this criterion, soil strength shall be increased;
- The stability of all slopes (earth, rock, snow or ice), be they natural or the result of human activity (e.g. cliffs, dykes, dams, earthworks, etc.), including site work, shall be examined since their rupture may jeopardize facility safety;
- Capable fault, even if available seismo-tectonic data indicates that surface fault slippage is an exceptional event in France, shall be investigated in order to be able to discount the possibility of fault slippage during plant life.

Few significant changes occurred in techniques and knowledge about geotechnical hazard assessment described by the safety rule. The main change is the development of approaches dedicated to foundation rock collapse due to underground cavities.

Flooding hazards

The ASN guide n°13 (ASN, 2013) have been published in January 2013 and supersedes the basic safety rule I.2.e of 1984 relative to external flooding hazards for NPPs. The ASN guide n°13 applies to all the BNI. With regard to radioactive waste disposal installations, this guide only applies to above-ground facilities.

The considered external flooding hazards are whose origins are external to the structures, areas or buildings of the BNI accommodating systems or components to be protected, whatever the cause(s) of that flooding. An external flood therefore means any flood originating outside the BNI site and certain floods originating within the BNI site.

The purpose of this guide is to:

- define the situations to consider when assessing the flood hazard;
- propose an acceptable method of quantifying them;
- list recommendations for defining means of protection adapted to the specifics of the flooding hazard.

The guide defines eleven “Reference Flooding Situations” (RFS) to consider when assessing reference flood hazard for the site. All the RFS have been defined on the basis of engineering judgment and using a probabilistic target (annual exceedance probability of 10^{-4}, in order of magnitude, and covering associated uncertainties). RFS is an event or a combination of events whose characteristics are increased if necessary (unfavorable combination or margin to compensate for the limits of current knowledge). The RFSs are expressed either on the basis of a statistical analysis of the available data or deterministically. The RFSs shall at least encompass all the situations corresponding to the experience feedback which is relevant for the site (e.g. extreme recorded values in the site region, experience feedback from other BNIs).

Five RFSs shall be considered for all sites:

- “Local rainfall”,
- “Small watershed flooding”, which addresses flood due to precipitation on watershed with surface area between 10 and 5,000 km^2,
- “Deterioration or failure or structures or equipment”, which addresses reservoirs, ponds, tanks, circuits, pipes, filling and discharge structures, dykes close to or on the site,
- “Mechanically induced wave”, which addresses waves resulting from a rapid change in flow rate in channel generally due to malfunctioning of hydraulic structures (e.g. hydroelectric power plant),
- “High groundwater level”.

Three additional RFSs shall be considered for river sites:

- “Large watershed flooding”, which addresses flood due to precipitation on watershed with surface area larger than 5,000 km^2,
- “Failure of a water-retaining structure” (dams),
- “Local wind waves”, which addresses wind waves propagated over large watershed flooding.

Three additional RFSs shall be considered for coastal sites:

- “Sea level”, which addresses theoretical tide, storm surge, and the long term change in mean sea water level,

- “Waves”, which addresses ocean waves and local wind waves propagated over the reference sea level,
- “Seiches”, which addresses stationary wave that can occur in a closed or semi-closed area of water (e.g. pond, lake or bay).

The above RFSs have been defined in the light of current knowledge of the existing French BNI sites. It has been determined for French BNI sites that tsunami flood hazard is encompassed by “Sea level” and “Waves” RFSs.

Changes of flooding Hazard with Time. The guide has taken climate change into account when the state of knowledge so allows. It is necessary to take into account – on the basis of current knowledge – the predictable climate changes for a period representative of the installations' foreseeable life times, and until the next safety review. According to the present knowledge of climate change impacts in France, it is considered that sea level rise is the main impact of climate change. Other effects of climate changes in the domain of flooding hazard still uncertain and the periodic safety review process is considered as the more efficient way to cope with such uncertainties. Moreover, major change (in land use, river regulation, land slope, new water management facilities, etc.) may conduct to anticipate the periodic review if the impact of this change is significant according to experts.

Definition of flooding events for design extension conditions. The general approach to characterize external flooding events for design extension conditions was to add a significant margin on the keys RFSs for the site. For example, for “Large watershed flooding”, the added margin is an increase of 30% of the flowrate in the river; for “Failure of a water-retaining structure”, the added margin is related to additional failure(s) of dam(s) that could occur on tributaries of the stream where failure of dam(s) is considered for design basis.

No significant changes occurred in techniques and knowledge about flooding hazard assessment described by the guide. However IRSN engaged a research program on probabilistic flood hazard assessment (PFHA).

Meteorological hazards

The established practice for definition and characterization of meteorological hazards relies historically first on industrial codes, and, progressively more and more, on baseline requirements that supplement these codes. Baseline requirements are initially proposed by the licensees and possibly modified after being reviewed by IRSN and ASN. However, ASN guides on meteorological hazards will be developed in the near future.

Meteorological hazards that are considered for safety demonstration regarding design basis and design extension conditions (complementary to precipitations that are considered in flooding hazard characterization) are the following:

- Snow,
- Wind,
- Tornadoes,
- Lightning,
- Low and High Temperatures (air and water cooling sources).

As an example of the approach for meteorological hazards, the case of wind hazard and tornadoes are further developed.

The basis for wind hazard characterization is a French code for snow and wind loads edited first in 1965 and several times revised up to Règles « Neige et Vent », 2009 (CSTB, 2009), and Eurocode 1 national annex (Eurocode 1, 2008). These codes define wind hazards due to storms. Design basis wind speed and dynamic pressure are defined with consideration of the site specificities such as roughness and topography. Additional baseline requirements address experience feedback on extreme recorded values in the site region and wind induced missiles.

Different approaches to define wind events for design extension conditions were developed by the licensees (additional margin (x2) on the design basis wind speed, more conservative combination of loads). Some licensees defined tornado hazards that encompass such wind hazards.

More attention was paid in France on tornado hazards in the follow-up of Fukushima-Daiichi accident. The licensees were required to develop or update baseline requirements to define design basis tornadoes and tornado events for and design extension conditions. These baseline requirements were reviewed in 2016 by IRSN, which proposed a set of parameters for both domains (Enhance Fujita scale intensity, wind speed, maximum pressure variation, pressure drop rate, and missiles). ASN decisions on tornado hazards will be edited in the near future.

Hazards to be considered for the heat sinks

Specifically for NPPs, baseline requirements have gradually been developed since the years 2000 in order to strengthen the ability of systems of the pumping station to respond to external hazards that can compromise the quality or quantity of cooling water for safety systems. Considered hazards are the followings:

- **Low water level** in the intake structure due to natural hazards (e.g. drought, low sea level) or degradation of works (e.g. , rupture or erasure or malfunction of a retention work…);
- **Silting** in the intake structures, that decrease the storage volume in basins, or reduce the water flowrate;
- **Ice cover** on the water in the intake structures, that reduce the water flowrate;
- **Frazil** corresponding to ice crystals formed in a turbulent flow when the water temperature falls below its melting point. These ice crystals can stick and form ice blocks on metallic surfaces such as the ones of the filters;
- **Massive arrival of clogging agents** on filters corresponding to items originate from the fauna (fish, jellyfish, shellfish, etc.), or the flora (algae, trees and leaves, other plants, etc.) or mineral origin (sediment, sludge, etc.), or anthropogenic (oil spills, etc.).

For the design extension conditions, EDF (the operator of all the NPPs in France) is implementing an ultimate back-up make-up means specific to each reactor and robust to the hazards considered in that domain, which will draw water from the water table or large-capacity ponds using a stand-alone motor-driven pump or an electric pump backed by the ultimate back-up diesel generator.

Hazards induced by the industrial activities and communication routes

Basic safety rule I.1.a (ASN, 1992) and I.2.a (ASN, 1980) define acceptable methods for determining aircraft crash hazards (respectively for BNI others than NPPs, and for NPPs) to be taken into account when designing a BNI, and performing periodical safety reviews.

Basic safety rule I.1.b (ASN, 1992) and I.2.d (ASN, 1982) define acceptable methods for determining potential hazards due industrial activities and communication routes in the site vicinity (respectively for BNI others than NPPs, and for NPPs) to be taken into account when designing a BNI and performing periodical safety reviews.

The human activities account for six types of hazard sources:

- permanent industrial facilities, i.e. manufacturing and storage plants,
- pipelines such as gas pipelines,
- highway, railroad, river and sea traffic,
- general purpose aircraft (lighter than 5,700 kg),
- commercial aircraft,
- military aircraft.

The related hazards fall into four categories:

- abnormal increases in temperature due to a fire,
- pressure waves and seismic waves caused by an explosion,
- drifting blankets or clouds of toxic or corrosive gases and of gases and smoke released from a fire,
- missile impact generated by the explosion of rotating machines or an aircraft crash.

The hazard assessment approach is first based on a probabilistic screening criterion: to ensure that the overall probability of occurrence of unacceptable radioactive releases from the BNI could not exceed 10^{-6} per year, the criterion for each type of hazard sources is set at 10^{-7} per year. All the hazards with lower probability don't need further consideration. All the hazards that are not screening out shall be addressed as design basis.

Some significant changes occurred in techniques and knowledge about hazards induced by the industrial activities and communication routes assessment described by the safety rules. In particular, these changes took into account changes in aircraft (the A380 wide-body aircraft, civil defense water-bombers used in fighting forest fires).

REGULATORY FRAMEWORK

Main actors

Operators ensure the prime responsibility of the safety of their nuclear installations. They must demonstrate to the public authorities relevance of technical and organisational solutions applied for this purpose. Every 10 years a thorough safety review has to be performed. The main French operators are EDF (single NPP operator), Areva (fuel cycle installations), and CEA (research organisation).

ASN duties and responsibilities entail that the Authority draws up the regulations, authorizes the creation of the BNI, controls their activities through inspections and enforcement actions, contributes to the emergency situations response and informs the public. ASN is responsible for reviewing the applications, jointly with the ministers responsible for nuclear safety and with the support of IRSN and of its Advisory Committees.

IRSN is the French technical support organisation and provides technical assistance to ASN in preparing regulations, standards and rules, assessing authorisation applications (creation, commissioning, etc.) for the safety, radiation protection and environmental protection viewpoints, and providing technical support for checks and inspections. The safety assessment involves the collaboration of many specialists (including those of site characterization and external hazards) and effective coordination in order to identify the essential safety issues. IRSN's assessment relies on research and development programmes and is based on in-depth technical exchanges with the licensee teams. The results of IRSN's assessment are presented in a publically available report.

For the main decisions, Advisory Committees are requested by ASN, for instance, for the review of SARs. The Advisory Committees examine the reports produced by IRSN, by a special working group or by one of the ASN departments. They issue an opinion backed up by recommendations and report to the ASN Director-General.

Local Information Committees (CLI) and the High Committee for Nuclear Transparency (HCTISN) gather stakeholders concerned by nuclear installations and constitute leading bodies for access to information and monitoring of safety, health and environmental protection issues. Every actor communicates and explains its position to the public.

Site evaluation assessment in the licensing process

The environment code provides for a creation authorisation procedure, which may be followed by other authorisations during the operation of a BNI, from its commissioning to its final shutdown and decommissioning, including any changes made to the facility.

The global process to build and operate a BNI includes:

- the authorization decree for NPP "creation" delivered by Government on the basis of ASN's official advice. The process linked with other administrative authorization (construction code…), especially a construction permit, as well as national public debate process;
- the commissioning and operation authorization delivered by ASN.

The preliminary SAR, incorporated into the authorisation application file, informs ASN of and substantiates the measures taken at each step in the life of the facility to comply with the regulations and guarantee safety. It contains all information able to verify that all risks (whether or not nuclear) and all possible hazards (internal or external) have indeed been taken into account and that in the event of an accident, the personnel, the population and the environment are adequately protected by the means put into place. This report presents the specific characteristics of the site and its environment (meteorology, geology, hydrology, industrial environment, etc.).

During this administrative technical review and assessment procedure, ASN and IRSN have to perform the safety assessment of the installation, mainly on the basis of the preliminary SAR, and the EIA. The site characteristics, the external hazards and the impact on the environment are reviewed against the regulatory framework. This procedure can include some Advisory Committee meetings. The national environmental authority has to give its opinion on the environmental impact assessment prior to the public inquiry. Local state services (firefighters, local environmental agencies) review the application for the related specific issues. A public review procedure named "public inquiry" is carried out in parallel (see below).

In preparation for commissioning authorisation, the licensee sends ASN a file comprising the updated safety analysis report for the facility "as-built", the general operating rules, a waste management study, the on-site emergency plan, the impact analysis and the decommissioning plan. These aspects are reviewed by ASN with the support of IRSN and the Advisory Committees.

Once the nuclear installation has started operating, all safety-related modifications proposed by the operator are subject to ASN approval. In addition to these checks necessitated by changes in installations or their operating procedures, ASN requires the operators to conduct periodic safety reviews, to reinforce safety requirements according to changes in techniques and doctrine on the one hand and to experience feedback on the other. This may include issues related to the site evaluation, for instance due to the scientific knowledge development, the acquisition of new data of the occurrence of a severe event. Examination of these files may lead ASN to accept or reject the licensee's proposals, or to ask for additional information, studies or works to ensure conformity. ASN issues its requirements in the form of an authorisation or a resolution.

Public consultation

The authorization to create a nuclear installation can only be given after a local public inquiry as provided for in L593-8 of Environmental Code. It aims at informing the public and collecting opinions, suggestions and counter-proposals, in such a way as to provide the competent authority with all the elements necessary for its own information before any decisions are made. The Prefect (local representative of the State) opens the public inquiry at least in each of the communes which is located, at least in part, less than 5 km from the perimeter of the installation. Most of the dossier submitted by the licensee in support of its authorization application is made available in the public inquiry dossier. A risk control study supplements the safety analysis report which is a large document, difficult for non-specialists to understand.

In application of article 37 of the treaty instituting the European Atomic Energy Community and the Act of 13 June 2006, the authorization decree for an installation that could discharge radioactive effluents into the environment can only be granted after consulting the Commission of the European Communities in application of article 37 of the treaty instituting the European Atomic Energy Community.

Additional consultations are held if a foreign State is less than 5 km away from the nuclear installation (article R.122-11 of Environmental Code).

SUMMARY

The paper provides an overview of the French practice for site evaluation addressing effect of nuclear installations on public and environment, effect of site characteristics on nuclear installations with particular emphasis on external hazards, and the regulatory framework.

TABLE OF ABBREVIATIONS

ASN	Autorité de sûreté nucléaire (French nuclear safety authority)
BNI	Basic Nuclear Installations
DSHA	Deterministic seismic hazard analysis
EIA	Environmental impact assessment
IRSN	Institut de Radioprotection et de Sûreté Nucléaire (French public expert for research and technical support on radiation protection and nuclear safety)
ORSEC	Organisation de la réponse de sécurité civile (national emergency plan)

PPI	Plan particulier d’intervention (off-site emergency plan)
PSHA	Probabilistic seismic hazard analysis
PUI	Plan d’urgence interne (on-site emergency plan)
RFS	Reference Flooding Situations
SAR	Safety analysis report
SMHV	Séisme maximal historiquement vraisemblable (maximum historically probable earthquakes)
WENRA	Western European Nuclear Regulators’ Association

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