

IAEA ANSN / ISSC - REGIONAL WORKSHOP ON

Unregistered version, please register. www.word-pdf-converter.com
“Volcanic, Seismic, and Tsunami Hazard Assessment Related
to NPP Siting Activities and Requirements”
Jakarta, Indonesia, 13-17 June 2011

“Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations”

Prof. Dr. Ahmet Cevdet YALCINER
INTERNATIONAL SEISMIC SAFETY CENTRE, NSNI/IAEA



IAEA

International Atomic Energy Agency

Lecture XX

1 – INTRODUCTION

- This Safety Guide was prepared under the IAEA's programme for safety standards. . It supplements and provides recommendations on meeting the requirements for nuclear installations established in the IAEA Safety Requirements publication on Site Evaluation for Nuclear Installations in respect of the assessment of meteorological and hydrological hazards.
- The present Safety Guide supersedes and replaces two earlier Safety Guides: No. NS-G-3.4 on Meteorological Events in Site Evaluation for Nuclear Power Plants (2003) and No. NS-G-3.5 on Flood Hazard for Nuclear Power Plants on Coastal and River Sites (2003).



- Significant new knowledge and experience has been gained of the meteorological and hydrological topics covered in the two earlier Safety Guides.
- There is also a need to integrate the approaches used for evaluating meteorological and hydrological hazards for all types of nuclear installations, not only nuclear power plants. Some States are already developing such an integrated approach.

OBJECTIVE

- to provide recommendations and guidance on how to comply with the safety requirements on assessing such hazards associated with meteorological and hydrological phenomena.
- to provide recommendations on how to determine the corresponding design bases for these natural hazards and it recommends measures for protection of the site against hazards of this type.

SCOPE

- Providing guidance for the assessment of hazards associated with meteorological and hydrological phenomena external to nuclear installations over their entire lifetime, from the detailed site investigation phase during the site selection process, from which the design bases are derived, up until the end of the operational period..
- Site selection process:
 - Site survey
 - Actual determination of the preferred site.

STRUCTURE

- Section 2: general recommendations on the assessment of hazards associated with meteorological and hydrological phenomena for nuclear installations.
- Section 3: describes data requirements.
- Section 4: provides recommendations for the assessment of meteorological hazards.
- Section 5: details the implementation of the assessment of hydrological hazards.
- Section 6: presents considerations in the determination of design basis parameters.

STRUCTURE

- Section 7: provides recommendations for measures to protect sites.
- Section 8: deals with changes in hazards with time.
- Section 9: provides recommendations on meeting requirements for monitoring and warning for purposes of plant protection
- Section 10: provides recommendations on applying a graded approach to the evaluation of nuclear installations other than nuclear power plants.
- Section 11: provides recommendations on management systems to be put in place for the performance of all activities.



2- GENERAL CONSIDERATIONS AND RECOMMENDATIONS

- GENERAL CONSIDERATIONS

2.1 Meteorological and hydrological phenomena can cause several hazards that singly or in combination could affect the safety of nuclear installations.

Hazards considered in the guide include those associated with

- wind, water, snow, ice or hail,
- wind driven materials;
- extreme water levels (high and/or low) around or at the site;
- dynamic effects of water (e.g. waves, tsunamis, flash flooding); extreme air temperature and humidity; extreme water temperature; and extreme groundwater levels.

2.2 Meteorological and hydrological phenomena may simultaneously affect all the structures, systems and components important to safety on a nuclear installation site .

2.3 Meteorological and hydrological phenomena may also affect the communication networks and transport networks around the site area of a nuclear installation.

2.4 Hazards associated with high water temperature and low water level conditions and drawdown are considered in this Safety Guide, to address conditions that could affect the ability of safety related systems, and in particular the ultimate heat sink, to perform their function adequately.

2.5 Meteorological aspects of external hazards to be considered include extreme values of meteorological parameters, as well as rarely occurring hazardous meteorological phenomena. The rarely occurring hazardous phenomena may produce extreme values of some important parameters.

2.5 Meteorological aspects of external hazards to be considered include extreme values of meteorological parameters, as well as rarely occurring hazardous meteorological phenomena. The rarely occurring hazardous phenomena may produce extreme values of some important parameters.

2.5 Meteorological aspects of external hazards to be considered include extreme values of meteorological parameters, as well as rarely occurring hazardous meteorological phenomena. The rarely occurring hazardous phenomena may produce extreme values of some important parameters.

Meteorological Hazards

2.6 The following meteorological variables are specifically addressed in this Safety Guide:

- Air temperature;
- Wind speed;
- Precipitation;
- Snow pack.

2.7 The hazardous, rarely occurring meteorological phenomena considered for the purposes of this Safety Guide are the following:

- Lightning;
- Tropical cyclones, typhoons and hurricanes;
- Tornadoes;
- Waterspouts.

2.8 Other potential phenomena

- Dust storms and sandstorms;
- Hail;
- Freezing precipitation and frost related phenomena;

2.9 In the context of this Safety Guide, extreme values of meteorological parameters are identified by means of statistical analysis of recorded parameters that are measured periodically on an ongoing basis (e.g. extreme temperature).

2.10 High intensity winds may have a major bearing on the safety of a nuclear installation and may lead to an initiating event that is to be included in the safety analysis for the installation. Wind may be a common cause for failure. High intensity winds, in particular in the case of tropical storms and tornadoes, may generate flying debris and projectiles.

Hydrological Hazards

2.11 Hydrological phenomena that are generated at relevant bodies of water and which may cause flooding or low water conditions are considered in this Safety Guide.

- Storm surges
- Waves
- Tsunamis
- Seiches
- Extreme Precipitation
- Sudden releases of water from natural or artificial storage.

Hydrological Hazards

2.12 Other hydrological phenomena

- Water level rising upstream or falling downstream
- Landslides or avalanches into water bodies
- Waterspouts
- Variation of groundwater levels
- Subsurface freezing of supercooled water

2.13 Considerable damage can be caused to safety related structures, systems and components by the infiltration of water into internal areas of the installation. Water pressure on walls and foundations may challenge their structural capacity or stability. Groundwater may affect the stability of soil or backfill.



Hydrological Hazards: Hurricanes, Cyclones, Typhoons

Unregistered version, please register. www.word-pdf-convert.com

- Few things in nature can compare to the destructive force of a hurricane. In fact, during its life cycle a hurricane can expend as much energy as 10,000 nuclear bombs! Hurricane winds blow in a large spiral around a relative calm centre known as the "eye." The term hurricane is derived from Huracan, a god of evil recognized by the Tainos, an ancient aborigines Central American tribe.



Hydrological Hazards: Storm Waves



Hydrological Hazards: Storm Waves

Unregistered version, please register. www.word-pdf-converter.com



IAEA

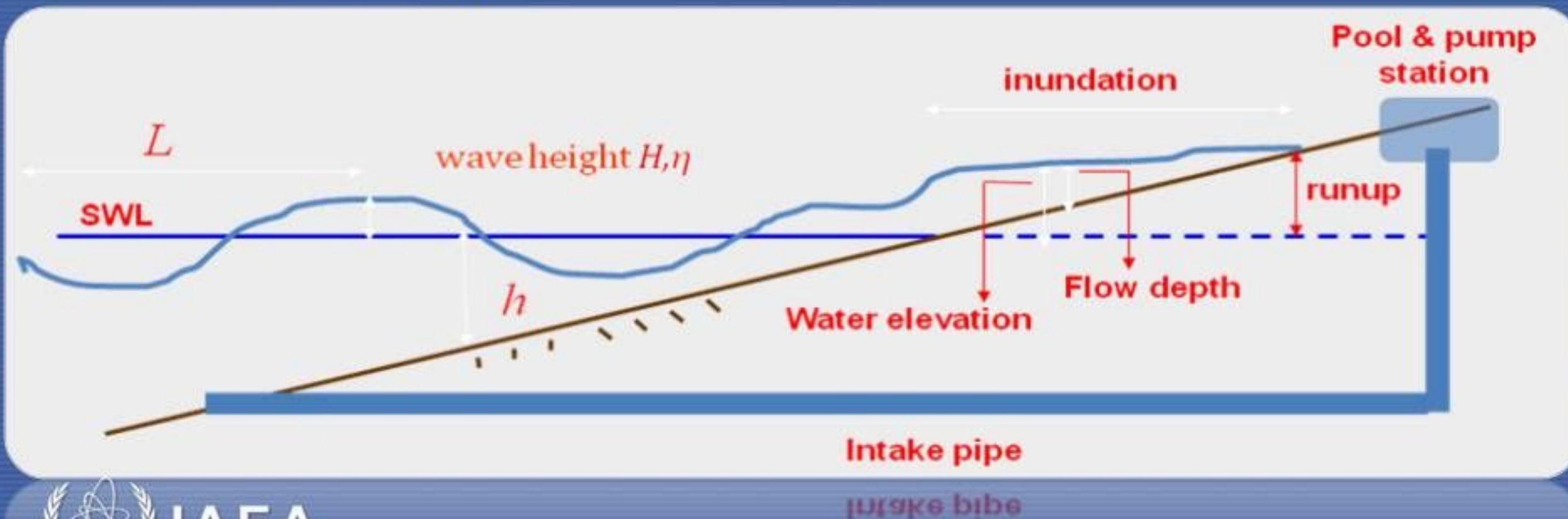
Hydrological Hazards: Storm surges

Wind setup

Wave setup

Tidal amplitude

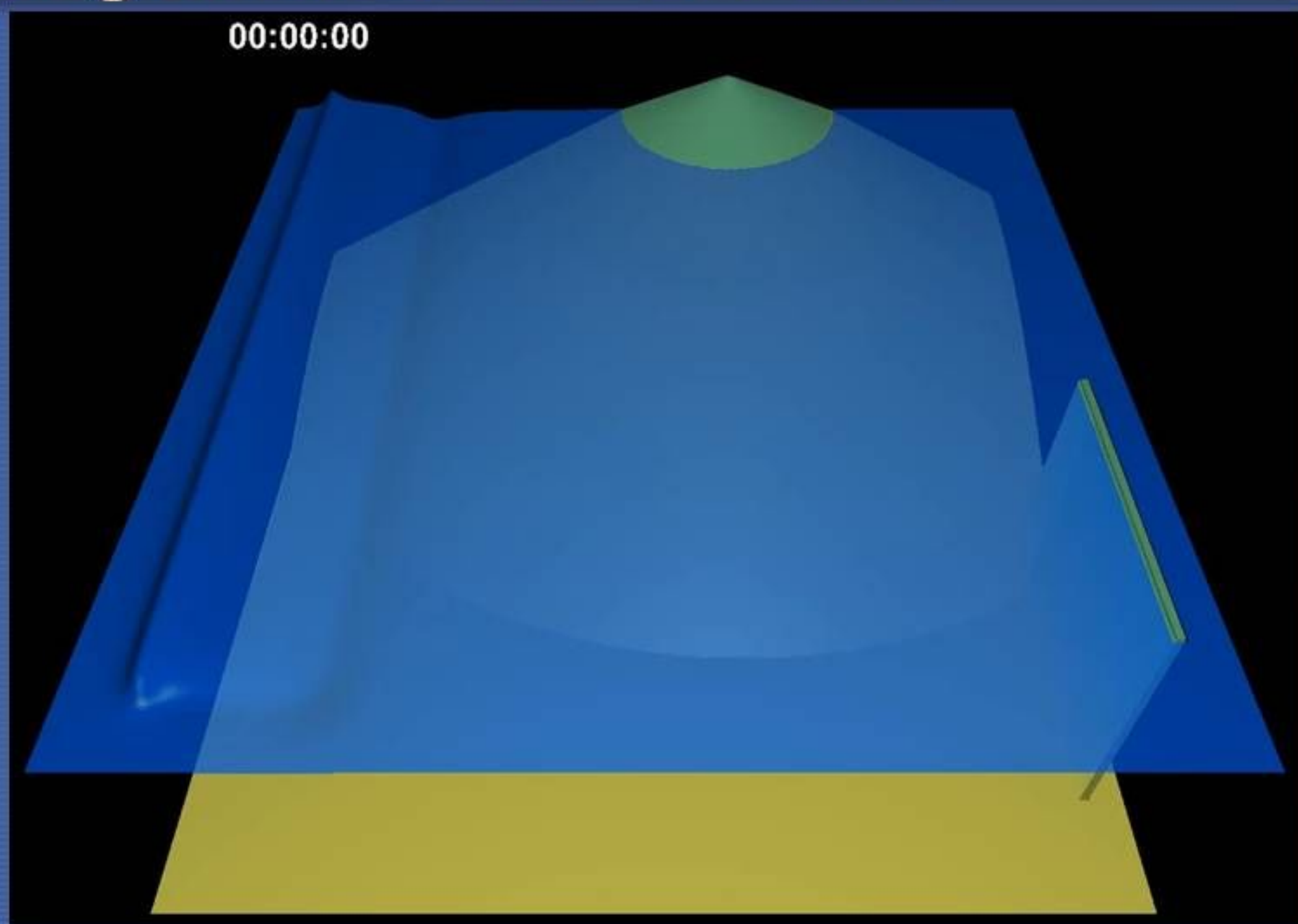
Wave runup



IAEA

Unregistered version, please register. www.word-pdf-convert.com

Hydrological Hazards: Tsunamis



Hydrological Hazards: Seiches

Unregistered version, please register. www.word-pdf-convert.com

- **TIDAL WAVES**
- **SWELL WAVES**
- **SEICHES (RESONANCE OF BASINS)**
- **FREAK WAVES**

Tides

Unregistered version, please register. www.word-pdf-convert.com

- Tides are the alternating rise and fall of the surface of the seas and oceans.
- They are due mainly to the gravitational attraction (pull) of the moon and sun on the rotating earth.
- Two high and two low tides occur daily and, with average weather conditions, their movements can be predicted with considerable accuracy.

Tides

Unregistered version, please register. www.word-pdf-convert.com



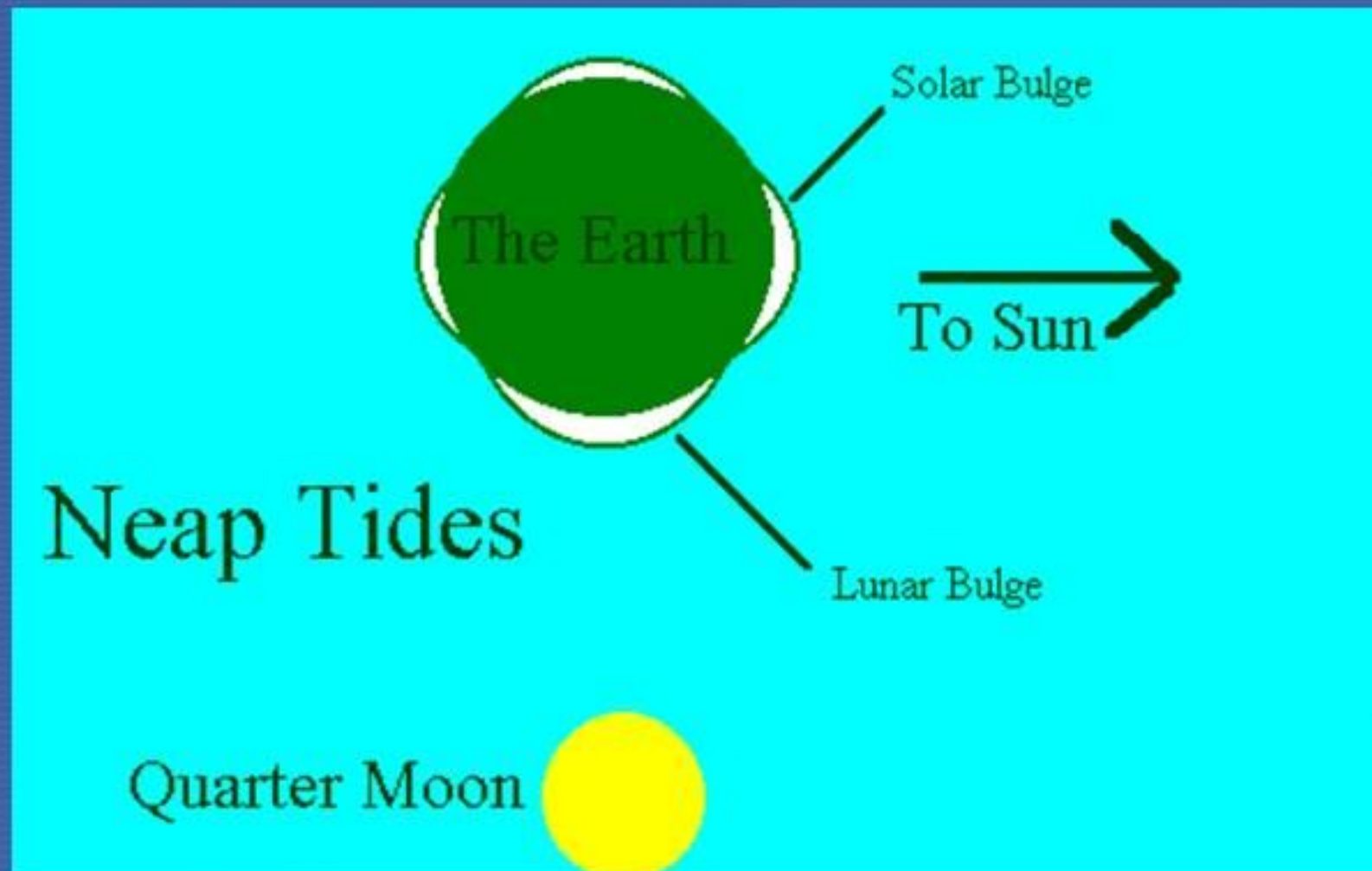
When the moon is new or full, the gravitational forces of the sun and moon are pulling at the same side of the earth → extra large "spring" tides occur.



IAEA

Tides

Unregistered version, please register. www.word-pdf-convert.com



When the moon is at first or third quarter, the gravitational forces of the sun and moon are pulling at 90 degrees from each other → little net tides called "neap" tides occur.



IAEA

Tides

Unregistered version, please register. www.word-pdf-convert.com

- The General characteristics of tides in different locations are shown below:

Wind waves: $T < 20 \text{ sec}$, $H < 20 \text{ m}$

Tidal waves: $T = 24 \text{ hours}$, diurnal type

$T = 12 \text{ hours}$, semidiurnal type

$H = 1\text{-}6 \text{ m.}$ in Pacific Ocean
1.6 m.

Mombasa:Kenya 6 m. Rio:

Tokyo: 1.6 m.

England: 6 m. La Haye (Den Haag)=2.5 m.

Black Sea: $H < 0.20 \text{ m.}$

The Sea of Marmara: $H < 0.30 \text{ m.}$

The Mediterranean Sea: $H < 0.40 \text{ m.}$

Swell Waves

Unregistered version, please register. www.word-pdf-convert.com

- a wave system not raised by the local wind blowing at the time of observation, but raised at some distance away due to winds blowing there, towards the site,
- travel out of a stormy or windy area and continue on in the direction of the winds that originally formed them as sea waves
- may travel for thousands of miles before dying away
- The long period waves remain and smaller ones disappear during long distance propagation.
- Normally come from a direction different from the direction of the prevailing wind and sea waves at the time of observation

Swell Waves

Unregistered version, please register. www.word-pdf-convert.com



IAEA

Hydrological Hazards: Seiches

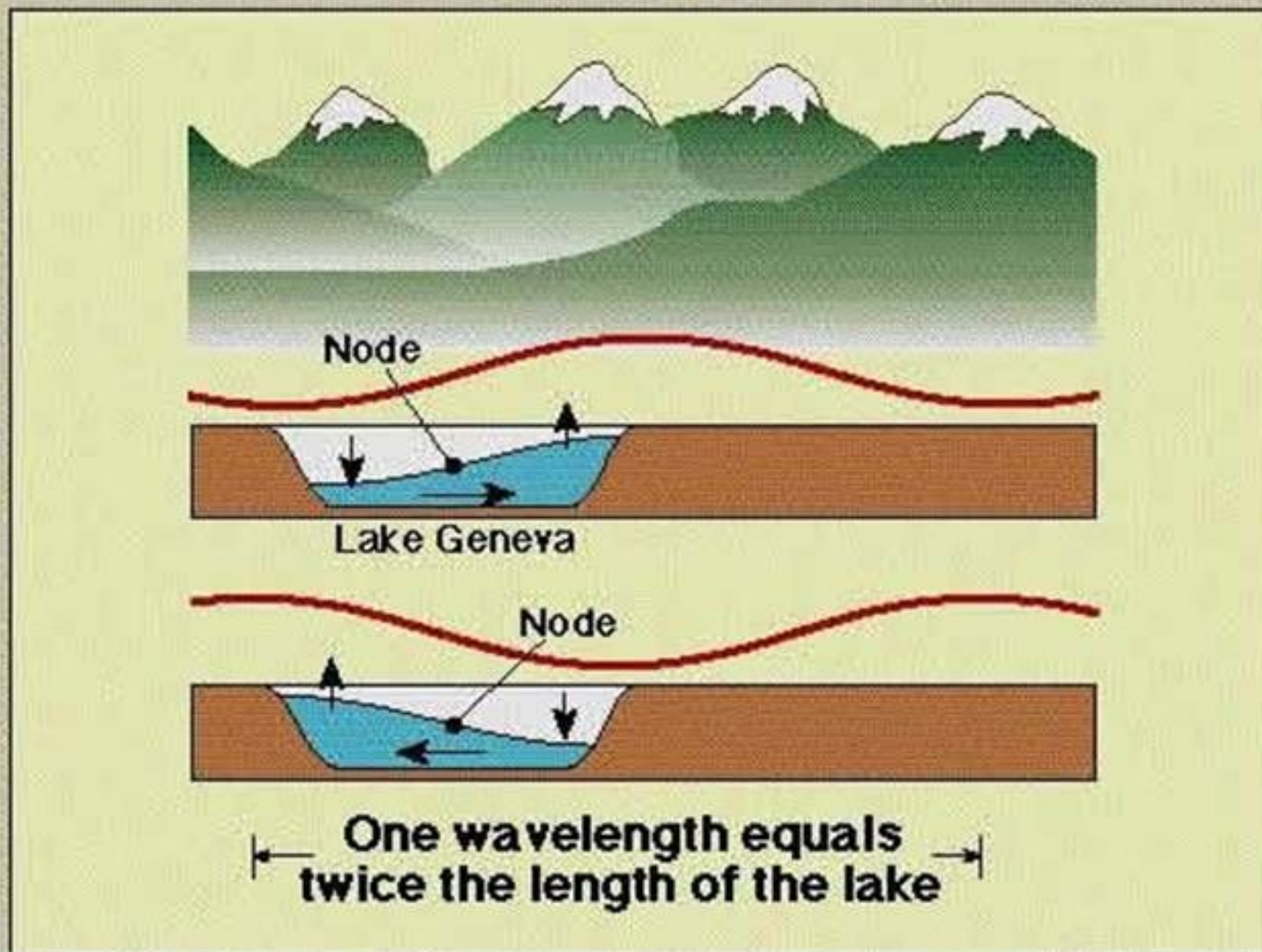
Unregistered version, please register. www.word-pdf-convert.com

- Seiches are periodic oscillations of water level set in motion by some atmospheric disturbance passing over a Great Lake.
- The disturbances that cause seiches include the rapid changes in atmospheric pressure with the passage of low or high pressure weather systems, rapidly-moving weather fronts, and major shifts in the directions of strong winds.
- Seiches exist on the Great Lakes, other large, confined water bodies, and on partially-enclosed arms of the sea. The intervals (or periods) between seiche peaks on the Great Lakes range from minutes to more than eight hours.
- The term was first promoted by the Swiss hydrologist François-Alphonse Forel in 1890, who had observed the effect in Lake Geneva, Switzerland. The word originates in a Swiss French dialect word that means "to sway back and forth", which had apparently long been used in the region to describe oscillations in alpine lakes.

Resonance of Basins: Seiches

Unregistered version, please register. www.word-pdf-converter.com

Seiche in Lake Geneva (Switzerland)



Resonance of Basins: Seiches

Unregistered version, please register. www.word-pdf-converter.com

- Resonance may be described as the coincidence of natural period of oscillatory motion of a system with the period of external effect on this motion and the resultant increase in the magnitude of motion.
- From coastal engineering point of view, every closed basin also has its own free oscillation period. Determination of these oscillation periods is considerable since incoming waves with this oscillation periods make effect within basin higher than expected.
- When a wave enters a closed basin (harbor, bay etc.), surface fluctuations occur within the basin which affects coastal infrastructure, navigation of marine vehicles, public safety etc.
- Thus, magnitudes of these fluctuations are significantly important and they depend on 2 basic parameters: Boundary conditions of the basin and incoming wave properties.

Hydrological Hazards: Freak Waves

Unregistered version, please register. www.word-pdf-converter.com

- Freak, rogue, or giant waves correspond to large-amplitude waves surprisingly appearing on the sea surface ("wave from nowhere").
- Such waves can be accompanied by deep troughs (holes), which occur before and/or after the largest crest.
- Very often the term "extreme waves" is used to specify the tail of some typical statistical distribution of wave heights (generally a Rayleigh distribution); meanwhile the term "freak waves" describes the large-amplitude waves occurring more often than would be expected from the background probability distribution.
- Its height should exceed the significant wave height in 2–2.2 times.
- In particular, twenty-two super-carriers were lost due to collisions with rogue waves for 1969–1994 in the Pacific and Atlantic causing 525 fatalities. At least, the twelve events of the ship collisions with freak waves were recorded after 1952 in the Indian Ocean, near the Agulhas Current, coast of South Africa.

Unregistered version, please register. www.word-pdf-convert.com

Hydrological Hazards: Extreme Precipitations

- Extreme precipitation causes floods, dam break, excess water flow towards rivers and lowland areas and coastal areas

Hydrological Hazards: Sudden release of water

Sudden releases of water from natural or artificial storage (dam break, release of excess water from reservoirs, etc.)

Hydrological Hazards: Floods

Unregistered version, please register. www.word-pdf-convert.com

- Floods are one of the most common and widespread of all natural disasters. Floods have been an integral part of the human experience ever since the start of the agricultural revolution when people built the first permanent settlements on the great riverbanks.



Floods



Hydrological Hazards: Drought

Unregistered version, please register. www.word-pdf-convert.com

- ***Meteorological*** drought is usually based on long-term precipitation departures from normal, but there is no consensus regarding the threshold of the deficit or the minimum duration of the lack of precipitation that make a dry spell an official drought.
- ***Hydrological*** drought refers to deficiencies in surface and subsurface water supplies. It's measured as stream flow, and as lake, reservoir, and ground water levels.
- ***Agricultural*** drought occurs when there is insufficient soil moisture to meet the needs of a particular crop at a particular time. A deficit of rainfall over cropped areas during critical periods of the growth cycle can result in destroyed or underdeveloped crops with greatly depleted yields. Agricultural drought is typically evident after meteorological drought but before a hydrological drought.

Hydrological Hazards: Drought

Unregistered version, please register. www.word-pdf-convert.com

-
- **Hydrological drought** refers to deficiencies in surface and subsurface water supplies. It's measured as stream flow, and as lake, reservoir, and ground water levels.
-

Hydrological Hazards: Others

- Water level rising upstream or falling downstream
- Landslides or avalanches into water bodies
 - tsunami generation
 - discharge flow prevention
- Waterspouts
- Variation of groundwater levels
- Subsurface freezing of super cooled water

Hydrological Hazards: Volcano induced

Effects of volcanic eruptions:

- 1) pyroclastic eruptions can smother large areas of landscape with hot ash, dust, and smoke within a span of minutes to hours;
- 2) red hot rocks spewed from the mouth of a volcano can ignite fires in nearby forests and towns, while rivers of molten lava can consume almost anything in their path as they reshape the landscape;
- 3) heavy rains or a rapidly melting summit snowpack can trigger lahars-slurries of mud that can flow for miles, overrunning roads and villages; and
- 4) large plumes of ash and gas ejected high into the atmosphere can influence climate, sometimes on a global scale.

Unregistered version, please register. www.word-pdf-convert.com



Unregistered version, please register. www.word-pdf-convert.com



2.14 Deficiencies or blockages in site drainage systems also could cause flooding of the site.

2.15 The dynamic effect of water can be damaging to the structures and foundations of a nuclear installation as well as to the many systems and components located on the site.

2.16 Flooding may also contribute to the dispersion of radioactive material to the environment in an accident

2.17 Recommendations relating to the causes and effects of flood related phenomena are provided in other Safety Guides discussing, respectively, earthquakes, volcanoes, and dispersion of radioactive material in air, surface water and groundwater

Changes in hazards with time

2.18 Climatic variability and climate change may have effects on the occurrence of extreme meteorological and hydrological conditions. Over the lifetime of an installation, it is possible that the climate at the site will undergo significant changes.

Methods for the assessment of hazards

2.19 Methods for the assessment of hazards are often divided into two broad approaches: deterministic methods and probabilistic methods.

2.20 In spite of the accepted terminology, events such as the probable maximum seiche or the probable maximum storm surge are not characterized in a probabilistic framework

2.21 The assessment of the hazards implies the need for treatment of the uncertainties in the process. The overall uncertainty will involve both aleatory uncertainty, as well as epistemic uncertainty.

Deterministic Methods

2.22 Deterministic methods are based on the use of physical or empirical models to characterize the impact of an event in a specific scenario on a system.

2.23 In some cases in which a physical limit exists), deterministic methods may provide rational limits to the statistical extrapolation by means of the concept of the 'physical limit': an upper limit on the variable of interest, such as flooding level or wind velocity, irrespective of the frequency of occurrence.

Statistical and Probabilistic Methods

2.24 When a statistical analysis is performed, it is typically based on time series analysis and synthesis. It is assumed that the series represents both deterministic components and an unknown number of random components, and that the random components are reasonably independent. A time series in this context is a chronological tabulation of values of a given variable measured continuously or at stated time intervals.

2.25 Two different statistical methods of analysing the data series are commonly used. When using these methods, the extreme values corresponding to various frequencies of exceedance are derived from these data as well as the associated confidence intervals

Statistical and Probabilistic Methods

2.26 The non-stationary characteristics of the data set due to long term variation of variables (e.g. due to climate change) can be dealt with by allowing parameters of the extreme value distribution (generalized extreme value, peak over threshold) to vary over time throughout the data record.

2.27 Probabilistic hazard assessment makes use of the probabilistic descriptions of all involved phenomena to determine the frequency of exceedance of any parameter, such as tsunami wave height. It explicitly accounts for aleatory uncertainties and epistemic uncertainties.

GENERAL RECOMMENDATIONS

2.28 As established by the Safety Requirements publication on Site Evaluation for Nuclear Installations:

- "Site characteristics that may affect the safety of the nuclear installation shall be investigated and assessed.

Characteristics of the natural environment in the region that may be affected by potential radiological impacts in operational states and accident conditions shall be investigated.

All these characteristics shall be observed and monitored throughout the lifetime of the installation." (Ref. [1], para. 2.4.)

GENERAL RECOMMENDATIONS

- “Proposed sites for nuclear installations shall be examined with regard to the frequency and severity of external natural and human induced events and phenomena that could affect the safety of the installation.”
- “The hazards associated with external events that are to be considered in the design of the nuclear installation shall be determined. For an external event (or a combination of events) the parameters and the values of those parameters that are used to characterize the hazards should be chosen so that they can be used easily in the design of the installation.”

2.29 The meteorological and hydrological characteristics of the region around the site of the installation should be investigated as described in this Safety Guide.

2.30 When the region to be investigated extends beyond national borders or when the site is located on the coastline, the database should include data from the entire region.

2.31 When a statistical analysis is performed, jumps, trends, gaps and missing data and outliers of the data set should be duly taken into account.

2.32 In probabilistic hazard assessment, when several models are proposed, they should be formally included in the probabilistic computation of hazards. The results of probabilistic methods should be checked for consistency with the results of a simplified deterministic analysis.

2.33 The general approach to meteorological and hydrological evaluations should be directed towards reducing the uncertainties at various stages of the evaluation process so as to obtain reliable results driven by data.

2.34 In all cases, whether a deterministic approach, a statistical approach or a probabilistic approach is used, a quantitative estimate of the uncertainties in the results of the hazard assessment should be determined.

2.35 In deterministic and statistical approaches, uncertainties should be determined by conducting a sensitivity study.

2.36 In probabilistic hazard analysis, the consideration of uncertainties should be explicitly included in the procedure.

2.37 Climate change is adding further uncertainty to the meteorological and hydrological analyses that should be considered.

2.38 With the exception of Section 10, the remainder of this Safety Guide is devoted to data collection, methods and criteria for hazard assessment for nuclear power plants. The information to be collected, the methods to be used and the criteria to be applied should be scaled (or graded) down for other nuclear installations by using the guidance provided in Section 10.

2.39 The assessment of the meteorological and hydrological hazards should be made through a specific project for which clear and detailed objectives are defined, and in accordance with a work plan as recommended in Section 11 of this Safety Guide.

3- NECESSARY INFORMATION AND INVESTIGATIONS (DATABASES)

- GENERAL RECOMMENDATIONS FOR DATA COLLECTION

3.1 When site investigation and data collection are undertaken, care should be taken to include all the information necessary for analysing and estimating site specific values of meteorological and hydrological hazard parameters.

3.2 Detailed studies and investigations should be undertaken to collect all the required and necessary meteorological and hydrological data and information relating to the hazards discussed in this Safety Guide.

3.3 The detailed data collected should be used to determine the relevant design basis parameters for the plant

3.4 In all cases, the size of the region to be investigated, the scope and detail of the information to be collected, and the investigations to be undertaken should be sufficient to determine the design bases for protection of the nuclear power plant against meteorological and hydrological hazards.

3.5 The collection of data and information should be continued throughout the lifetime of the nuclear power plant and up until the completion of the safety related tasks of the decommissioning phase, in order to permit the performance of periodic safety reviews.



3.6 Data should be presented clearly, using maps of an appropriate scale, graphs and tables. In general, all available data that have been collected during the site evaluation stage should be organized from the beginning by means of a geographic information system

3.7 The long term data used to evaluate extreme values of meteorological and hydrological variables should cover a period commensurate with the return period used for assessing the corresponding design basis

3.8 For the hazard assessment for tsunamis, the available observation periods are generally not sufficient. Other approaches, such as palaeoflood (paletsunami) analysis of the site area, should therefore be considered

3.9 Historical and anecdotal accounts often provide important and otherwise unavailable information that is necessary for improving the comprehensiveness and the reliability of hazard assessments.

3.10 A required action in response to the observed effects of climate change is the continuous long term monitoring of environmental data and the correlation of the data with regional trends.

Meteorological Data – General Recommendations

3.11 For assessing the extreme values of meteorological variables and rarely occurring hazardous meteorological phenomena, specific and detailed information should be collected. In this regard, the following should be taken into consideration:

- a) Climate normal and extreme values of parameters
 - i) Annual extreme values of wind speed, precipitation (liquid equivalent), and snow pack
 - ii) The frequency with which certain air temperature conditions occur
 - iii) Historic worst case meteorological conditions
- b) Rarely occurring hazardous meteorological phenomena are best assessed on the basis of regional meteorological data and information sources.



3.12 Climatological statistics, including extreme values, should to the extent possible be determined from records of observations made under standard conditions and by following standard procedures.

3.13 Other sources of relevant meteorological data and information could be available; for example, historical analyses (or meteorological reanalysis data sets), or descriptions from local or regional development projects that include relevant meteorological information.

Off-Site Sources of Data and Information

- 3.14** For evaluating the extreme values of meteorological variables, data should be collected at appropriate intervals uninterrupted over a long period of time.
- 3.15** In general, it is preferable to choose the beginning date for the yearly time interval for data analysis to be at a time of year when the meteorological variable concerned is not at the peak or valley of a cycle.
- 3.16** Field measurements made by different organizations for meeting different requirements do not necessarily follow the same standards.

3.17 A report on the results of the analyses should include a description of each meteorological station and the monitoring programme.

3.18 Numerical mesoscale models with spatial resolution adequate to resolve the regional and local geophysical features of the site are useful for simulating the atmospheric circulation and other local meteorological parameters at regional and local scales.

On-Site Observation Programme

3.19 As early as possible after selecting the candidate site for a nuclear installation, an on-site meteorological observation programme should be established.

3.20 The on-site meteorological observation programme should be used as part of an on-site surface based programme for vertical profile monitoring for evaluating the atmospheric dispersion at the site

3.21 There may be indirect evidence that long term measurements made at nearby meteorological stations can be considered representative of the site.

Rare meteorological phenomena

3.22 Events characterized as rarely occurring hazardous meteorological phenomena are unlikely to be recorded at any single location or by a standard instrumented network owing to their low frequency of occurrence.

3.23 Two types of data, which are generally available from national meteorological services, should be collected for rare meteorological phenomena:

a) Data and information systematically collected, processed and analysed in recent years may include more occurrences of events of lower intensity and may be more reliable than historical (anecdotal) data.

b) Historical data

3.24 On occasion a comprehensive collection of data and information obtained soon after the occurrence of a rare meteorological event may be available and the use of this data will be efficient.

3.25 Following the collection of data on rare meteorological phenomena, a specific dedicated catalogue should be compiled with an appropriate check for completeness.

Remote Sensing

3.26 In many States, national meteorological services operate networks of weather radars, or have arrangements for acquiring space based observations of surface meteorological parameters. Appropriate use should be made of this data.

Hydrological Data – General Recommendations

3.27 Hydrological data should include the following, as appropriate for the site:

- The hydrological characteristics of groundwater and all relevant bodies of water and the locations of surface water bodies.

- The locations of and descriptions of existing and proposed water control structures, both upstream and downstream of the site, that may influence site conditions.

3.28 The tidal water level range should be determined for those sites located in coastal areas affected by ocean and sea tides.

3.29 The water level range for non-tidal phenomena should be obtained, subject to the following considerations:

- Water level records should be obtained for all relevant bodies of water
- Wave characteristics should be reported.
- Field surveys following significant inundation events should include the necessary data.
- Water levels for significant historical events near to the site should be obtained
- Special consideration should be given to bore observations

3.30 Discharge related measurements and related information from the following sources should be obtained:

- Discharge records
- Rating curves, which relate water level to discharge, for gauges near the site

3.31 Hydrogeological data derived from geological media and backfills, such as data on permeability and porosity, should be collected in the vicinity of the site.

3.32 Other measurements and information should be collected from the following sources:

- The historical occurrence of ice floes
- Measurements of near-shore and along-shore currents induced by tides and winds

Geophysical, geological and seismological data

- 3.33** Two different sets of geophysical and geological data should be considered with regard to: (a) specific site geology and (b) sources of the tsunami phenomena
- 3.34** The tsunami source parameters and data on the tsunamigenic potential should be collected for the relevant body of water where the nuclear power plant site is located
- 3.35** All data relevant for assessing the potential for tsunami hazards and for determining the parameters of tsunami hazards should be compiled in a tsunami catalogue specific to the site.

Topographic and bathymetric data

3.36 Information about the reference vertical datum and horizontal datum, General topography, Detailed topography, Boundaries of the watershed, Flood plain characteristics, Historical phenomena , Elevations, Recent modifications of the topography should be collected.

3.37 The index of bathymetric data to be assembled for the nuclear power plant site

Data on anthropogenic activities

3.38 Relevant data should be collected to assess the potential for anthropogenic activities to affect the hydrological hazards.

3.39 In a river basin, anthropogenic activities interfere with hydrological processes primarily owing to two types of change in activity

3.40 Necessary information for the relevant hydraulic structures

4- ASSESSMENT OF THE METEOROLOGICAL HAZARDS

- GENERAL PROCEDURE

4.1 The general procedure for assessing the hazard associated with an extreme value of a meteorological parameter or the occurrence of rare hazardous phenomena comprises the following steps:

- A study of the representative data series available for the region under analysis and an evaluation of its quality**
- Selection of the most appropriate statistical distribution for the data set**
- Processing of the data to evaluate moments of the probability distribution function of the parameter under consideration**

4.2 Extreme annual values of meteorological parameters constitute samples of random variables, which may be characterized by specific probability distributions.

4.3 Caution should be exercised in attempting to fit an extreme value distribution to a data set representing only a few years of records

Extreme Meteorological Phenomena

4.4 The meteorological variables for which extreme values should be determined are :

- Air temperature
- Wind speed
- Precipitation
- Snow pack

4.5 In data processing account should be taken of the possible non-stationary behaviour of the stochastic process under consideration, which may reflect climatic variability and climate change, among other phenomena.

Air Temperature – Hazard Assessment

4.6 The specific site data should be collected from the on-site measurements and a comparison with data from existing off-site meteorological stations in the region should be performed.

4.7 The data set of daily maximum and minimum air temperatures collected in the off-site monitoring programmes should be used to identify the extreme annual values.

4.8 In data processing account should be taken of the possible non-stationary behaviour of the stochastic process under consideration, which may reflect climatic variability and climate change, among other phenomena.

Air Temperature – Hazard Assessment

4.6 The specific site data should be collected from the on-site measurements and a comparison with data from existing off-site meteorological stations in the region should be performed.

4.7 The data set of daily maximum and minimum air temperatures collected in the off-site monitoring programmes should be used to identify the extreme annual values.

4.8-4.9 The data set of hourly ambient dry bulb and wet bulb temperature values collected in the off-site monitoring programme should be used

4.10 A description of each meteorological station from which data are obtained and its geographical setting should be included in the report on the analysis performed for assessing the hazard.

4.11 The persistence of very high or very low temperatures may also be a factor that should be considered.

Wind Speed

4.12-4.17 The occurring winds should be inspected, data should be taken from a specific height and be standardized. The results should be used in design purposes.

Precipitation

4.18-4.25 A regional assessment of precipitation should be made. The hazard assessment for extreme maximum precipitation should preferably use data from a continuously recording rain gauge. where there is no continuously recording network similarity concepts may be employed. The results of a hazard assessment for extreme minimum precipitation should include an identification of the worst drought considered reasonably possible in the region.

Snow Pack

4.26-4.31 The load on a structure due to the snow pack will depend on both snow depth and packing density. If significant snowfall occurs in the region, an assessment should be made of the snowfall distribution. In cold regions where snow on the ground may persist for long periods, caution should be exercised in estimating the design basis snow pack since snow depth and compaction will vary from place to place. The results of a hazard assessment for extreme snow pack should include the determination of the water equivalent and the annual frequency of exceedance

RARE METEOROLOGICAL PHENOMENA

4.32 Lightning, Tropical cyclones, tornadoes, waterspouts, hurricanes

4.33-4.37 Lightning

4.38-4.51 Tropical cyclones, typhoons and hurricanes

4.52-4.58 Tornadoes

4.59-4.62 Waterspouts

OTHER METEOROLOGICAL PHENOMENA

4.63 Dust storms and sandstorms, Hail, Freezing precipitation and frost related phenomena

4.64-4.66 Dust storms and sandstorms

4.67-4.69 Hail

4.70-4.73 Freezing precipitation and frost related phenomena

5- ASSESSMENT OF HYDROLOGICAL HAZARDS

- STORM SURGES – General Recommendations

5.1-5.3 The hazard assessment is generally split into three different typologies: open coastal area, semi-enclosed body of water and enclosed body of water.

When computing the storm surge hazard, a reference water level such as the high tide or high lake level should be assumed to occur coincidently with the storm surge.

The potential for storm surges at a site should be assessed on the basis of meteorological and hydrological information.

Hazard Assessment

Probabilistic Methods

5.4-5.6 Probabilistic methods should be used to estimate the still water elevation for the hazard assessment for a storm surge.

In this case, time series from several locations should be correlated, providing a basis for developing a synthetic time series that is valid over a longer interval than the time span of the local observations.

By working with actual surge levels as basic parameters, the different factors relating to the intensity, path and duration of storms are implicitly taken into account if the records cover sufficiently long periods of time.

Deterministic Methods

5.7-5.9 Deterministic methods may also be used to estimate the maximum still water elevation for the hazard assessment for storm surge.

The analysis consists in selecting those appropriate storm parameters and other relevant parameters to be used as inputs to a one dimensional or two dimensional storm surge model that maximizes the flooding potential.

The storm surge analysis should provide:

- Over-water wind field and pressure gradients for the initial position of each storm and for specified later times.
- Summary of storm surge calculations
- Summary tables and plots of the total storm surge hydrographs for specified locations.

Open Coastal Regions

5.10 An appropriate validated model should be selected for calculating the storm surge elevation. The outcome of the meteorological analysis is an extreme wind field and pressure gradient. This should then be transposed along various tracks with an optimum forward speed for surge generation to determine the most extreme surge for a particular location.

5.11 Cyclones or storms other than those generating the peak open coast surge, but that could produce effects such as those just described, should be considered.

Semi Enclosed Bodies of Water

5.12-5.14 The open coast surge is usually evaluated first, and then it is routed through the entrance and up the bay or river to the plant site using a numerical model.

For sites located on bays with low beach berms and low marshes, overtopping of the beach berms together with flooding is possible. Open coast surges with longer duration, but lower than maximum peaks, may generate the highest surge elevations at such sites. The erosion of beach berms and bay entrances, which might worsen flood conditions, should also be taken into consideration for semi-enclosed bodies of water.

The results of the surge analysis for a semi-enclosed body of water should include many parameters.

Enclosed Bodies of Water

5.15 For enclosed bodies of water the storm surge is generally associated with oscillations of the water surface (i.e. seiche). The methods described in paras 5.70–5.77 (seiche) should be used to compute both the surge hazard and seiche in enclosed bodies of water.

Values of parameters derived from the hazard assessment

5.16 Results from the surge analysis should include estimates of the maximum still water elevation (deterministic methods) or a distribution of still water elevations with a corresponding annual frequency of exceedance (probabilistic methods).

- STORM SURGES – General Recommendations

5.17 General description of the phenomenon

5.18 General Recommendations

5.19-5.21 Hazard Assessment

To determine the wind wave effects near the plant site, the offshore wave spectra should first be determined on the basis of the generating wind field or a probabilistic study of observed offshore waves.

In computing the wind wave hazard, a reference water level such as the high tide or high lake level should be assumed to occur coincidentally with the wind wave event

The effects of wind waves at the site should include both the force associated with the waves as well as any local flooding that may occur.

Windfield

5.22-5.25 To evaluate wind waves, the wind field generating the waves should first be characterized in terms of wind speed, wind direction and duration.

The wind speed should be evaluated using the probabilistic methods

When using a deterministic approach to establish the critical wind field, wind vectors along the critical wind fetch should be calculated for various times during the movement of the storm in the proximity of the plant site.

For some coastal locations, wind wave hazards are the dominant consideration in relation to flooding.

Generation of offshore waves

5.26 The offshore wave characteristics can be deterministically computed from the wind field selected.

5.27 Offshore wave characteristics should be probabilistically computed if reliable offshore wave data are available and cover a sufficiently long period of time.

Near-shore waves and interactions with structures

5.28 The transformation and propagation of these offshore waves to the near shore area should be evaluated. For situations with more complex geometry, a two dimensional numerical model or a physical model should be employed

5.29 *The* wave phenomena that are relevant to this evaluation and which should be considered include friction, shoaling, refraction, diffraction, reflection, breaking and regeneration.

5.30 The near-shore waves critical for the design of the plant should be identified by comparing the histories of various wave heights of incident deep water waves, transition water waves and shallow water waves and limiting breaking waves, with account taken of the still water hydrograph for the storm surge.

5.31 Available historical data on observed extreme waves for the region should be reviewed to verify the results of the analysis of near shore waves.

5.32 For each structure, system or component important to safety that is potentially exposed to wave action, the characteristics of the design wave should be evaluated for the base of the structure. A two dimensional model should be used for the analysis

5.33 Wind wave effects that should be considered in the hazard assessment process include wave runup along the structures, overtopping of embankments and wave spray.

5.34 The hydrostatic and hydrodynamic loading on structures important to safety should be evaluated.

Values of parameters derived from the hazard assessment

5.35 Results from the wind wave analysis should include estimates of the increases in water level due to wind wave activity that are to be superimposed on the still water level. Wave runup height along the beach and/or structure related estimates should be computed as part of the hazard assessment.

TSUNAMIS

5.36-5.42 General description of the phenomenon

General Recommendations

5.44-5.46 Initial assessment

As an initial assessment, a simplified screening criterion is recommended evidence of past occurrences of tsunamis should be reviewed for the site region.

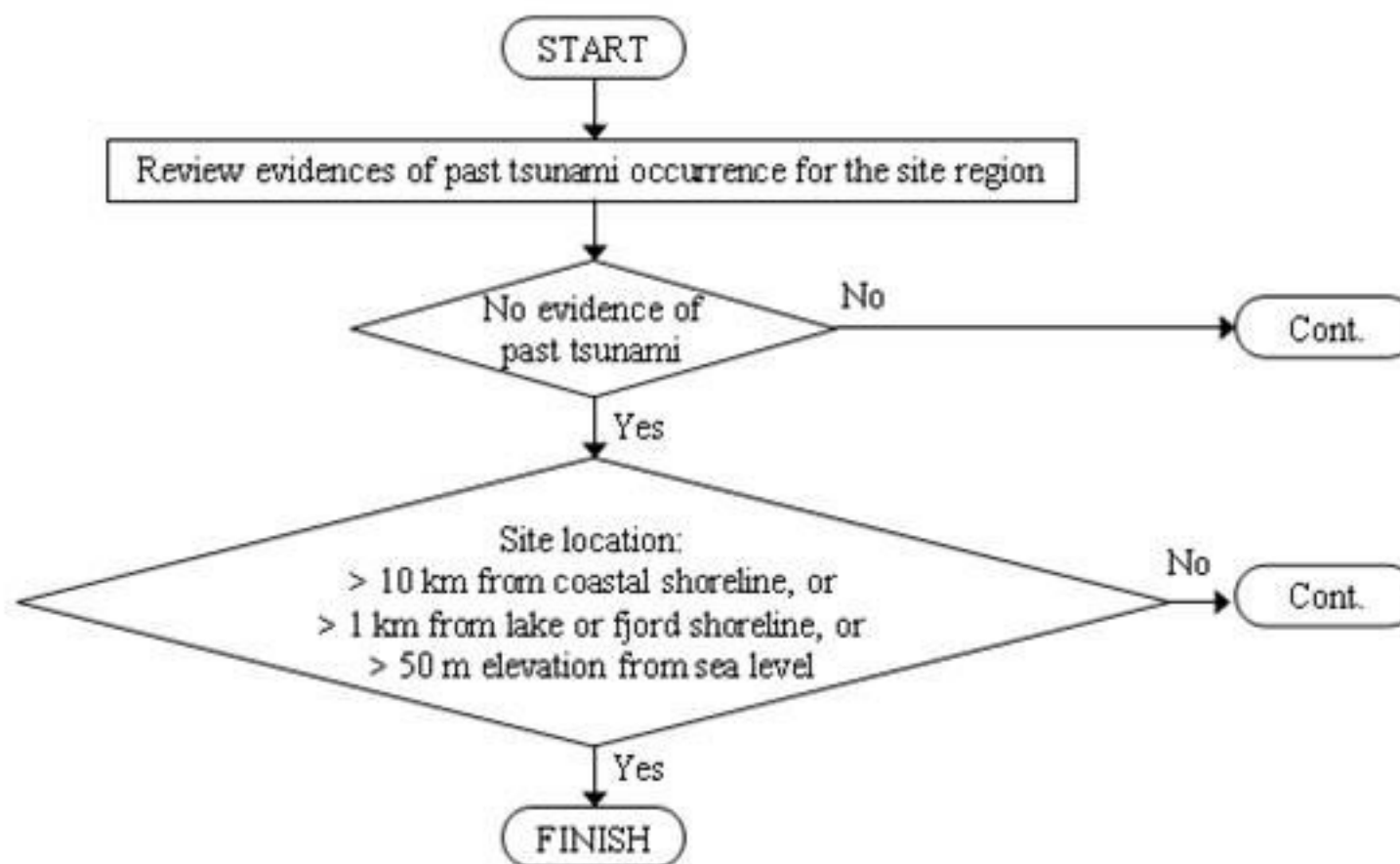
In all cases, the required volume of cooling water should be secured in case of the occurrence of a tsunami, because of the potential for high and low water level to affect the intake water system for several hours.

In all situations other than those described in para. 5.44, a detailed hazard assessment for tsunamis should be performed as outlined in the following paragraphs.



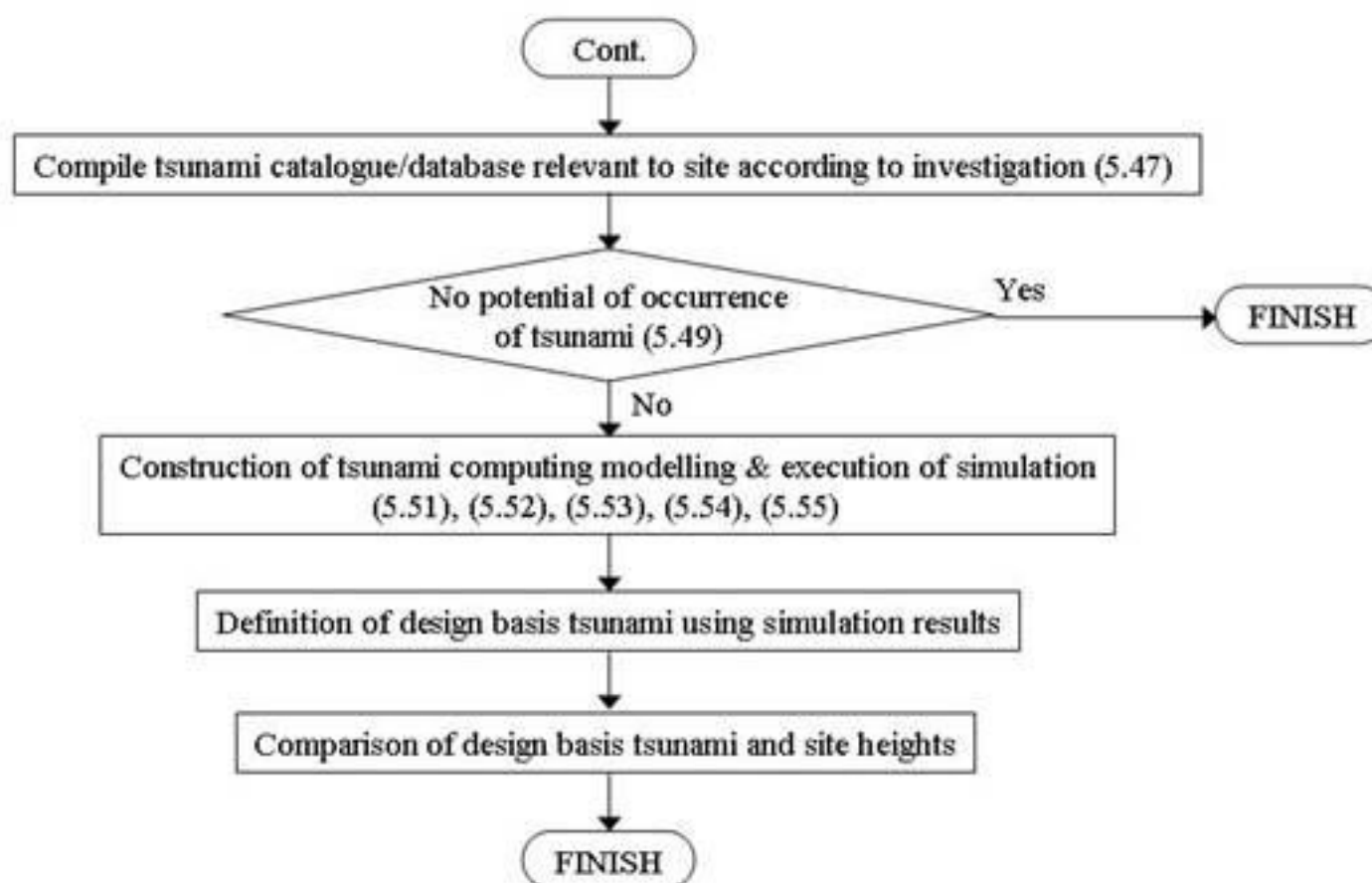
5.47-5.55 Detailed assessment

Initial Assessment Stage: Consideration of Publicly Available Information (5.44)



5.47-5.55 Detailed assessment

Detailed Assessment Stage: Consideration of Design Basis Tsunami



Hazard assessment

5.56-5.58 Methods for hazard assessment for earthquake induced tsunamis

For earthquake induced tsunamis, the hazard should be assessed by using either a deterministic hazard analysis or a probabilistic hazard analysis, or preferably both methods

The overall uncertainty will involve both aleatory uncertainty as well as epistemic uncertainty that arises owing to differences in interpretation of tsunami sources and runup heights by informed experts.

The collection of site specific data tends to reduce uncertainties

5.59-5.62 *Deterministic Methods*

The numerical simulation may be performed using a deterministic approach

The uncertainties should be taken into account; both the aleatory (by chance) and the epistemic (correct data) part should be estimated when relevant.

A parametric study of the dominant factors of the fault model should be carried out by considering the characteristics of earthquakes in each region

As the last step, it should be verified that the maximum and minimum runup heights should be bounding as compared with the runup heights that correspond to the historical tsunamis and the potential tsunamis examined

5.63-5.64 *Probabilistic Methods*

Probabilistic tsunami hazard assessment is analogous to probabilistic seismic hazard assessment, but it is not the current practice applied by States for assessing tsunami hazards

Results of the probabilistic tsunami hazard assessment are typically displayed as the mean or median annual frequency of exceedance of runup height values through a logic tree approach.

The general approach to the assessment of tsunami hazards should be directed towards reducing the uncertainties at various stages of the evaluation process to obtain reliable results driven by data.

5.65-5.67 Methods for hazard assessment for landslide induced tsunamis

Sources for landslide induced tsunamis should be characterized using the maximum volume parameter, as determined from sea floor mappings or geological age dating of historical landslides

Owing to the insufficiency of data for probabilistic analysis in most regions

Owing to the small size of a source in comparison with that for an earthquake induced tsunami, the impacts of a landslide induced tsunami are limited around the source and are generally not observed at more than several tens of kilometres from the source.

5.68 Methods for hazard assessment for tsunami induced by volcanic phenomena

Modelling of tsunamis due to volcanic phenomena is not the current practice applied by States for assessing the associated tsunami hazards. Methods for the modelling of tsunamis due to volcanic phenomena have been proposed, although standard evaluation procedures have not yet been developed.

Values of parameters deriving from the hazard assessment

5.69 The results of a hazard assessment for tsunami flooding should be the bounding values for the maximum water level at shoreline, runup height, inundation horizontal flood, maximum water level at the plant site, minimum water level at the shoreline, and the duration of the drawdown below the intake.

SEICHES

5.70 General recommendations

5.71-5.76 Hazard Assessment

For flooding by seiches, the hazard should be assessed by using either a deterministic hazard analysis or a probabilistic hazard analysis, or preferably both methods

The modes of oscillation will depend on the surface geometry and bathymetry of the water body, and the amplitudes of the oscillation will depend on the magnitude of the exciting force and on friction

The assessment of seiche should be conducted both separately and in conjunction with the other hazard assessments for site flooding

5.77 Values of parameters deriving from the hazard assessment

The maximum and minimum runup heights resulting from the assessment of seiche hazard should be evaluated.

EXTREME PRECIPITATION EVENTS

5.78 General recommendations

5.79-5.102 Hazard Assessment

5.79-5.81 *Local intense precipitation and associated site drainage*

5.82 *Computation of watershed discharge*

5.83-5.84 Probabilistic methods

Probabilistic methods may be suitable for estimating peak river discharges near the plant site.

5.85-5.91 Deterministic methods

Deterministic methods may be used to compute peak river discharges near the site.

5.92-5.99 Routing the flood to the site



EXTREME PRECIPITATION EVENTS

5.100-5.102 *Hydrodynamic forces, sedimentation and erosion*

5.103 Values of parameters deriving from the hazard assessment

FLOODS DUE TO THE SUDDEN RELEASE OF IMPOUNDED WATER

5.104-5.107 General recommendations

5.108-5.126 Hazard Assessment

5.113-5.117 Analysis of the stability and the survival of the water control structures

5.118-5.124 *Conditions at failure and downstream routing*

5.125-5.126 *Obstructions due to floating debris and ice conditions*

5.127 Values of parameters deriving from the hazard assessment.

BORES AND MECHANICALLY INDUCED WAVES

5.128-129 General recommendations

5.130-5.131 Hazard Assessment

5.132 Values of parameters deriving from the hazard assessment

HIGH GROUNDWATER LEVELS

5.133 General recommendations

5.134-5.136 Hazard Assessment

5.137 Values of parameters deriving from the hazard assessment

6- DETERMINATION OF DESIGN BASIS PARAMETERS

6.1-6.3 METEOROLOGICAL DESIGN BASIS PARAMETERS

In general, each of the meteorological hazards is determined individually, even if they occur simultaneously, unless they interfere and increase a given hazard

Meteorological events such as precipitation that drive hydrological events such as runoff should be addressed in conjunction

If relevant to the site, the design basis parameters for other site specific meteorological phenomena — such as dust storms and sandstorms, hail and freezing precipitation and frost related phenomena — that have been identified and assessed for the plant design basis as recommended are Dust storm and sandstorm, Hail, Freezing precipitation and frost related phenomena

6.4-6.16 HYDROLOGICAL DESIGN BASIS PARAMETERS

The design basis flood for a given site may result not from the occurrence of one extreme event but from the simultaneous occurrences of more than one severe event, each of which is in itself less severe than the resultant combined extreme event.

Appropriate combinations of extreme events with wind waves and reference water levels should be taken into consideration

The events to be combined should be selected appropriately, with account taken not only of the resultant annual frequency of occurrence but also of the relative effect of each secondary event on the resultant severity of the flood event.

7- MEASURES FOR SITE PROTECTION

7.1-7.4 GENERAL

7.5-7.7 TYPES OF PROTECTION OF THE SITE

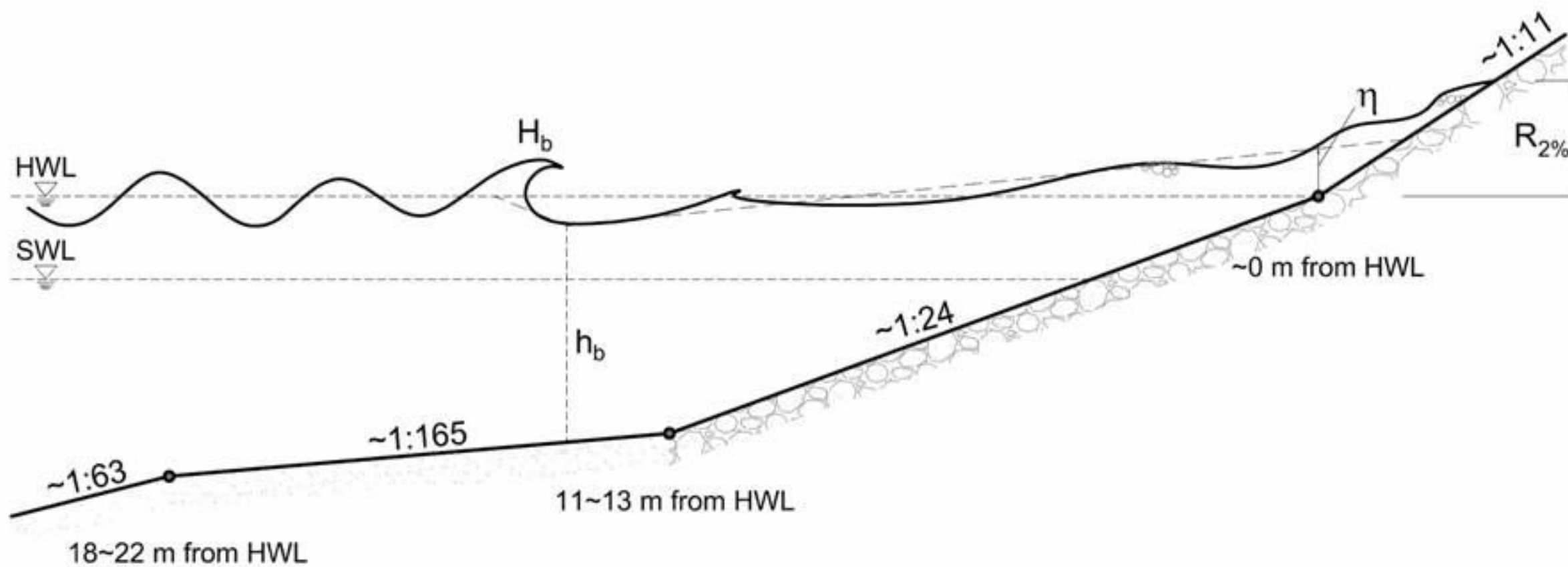
Dry Site Concept

Artificial protection structures (dykes, levees, walls, breakwaters etc.

7.8-7.12 ANALYSIS OF THE PROTECTION OF THE SITE

- **Sedimentation of the material transported by the flow;**
- **Erosion;**
- **Blockage of intakes by ice and debris;**
- **Biological fouling by animals (e.g. fish, jellyfish, mussels and clams);**
- **Salt corrosion (in the marine environment, after heavy sprays).**





7.13-7.21 STABILITY OF THE SHORELINE

7.18 Analysis of shoreline stability

7.19 Evaluation of longshore transport

Aim is to determine the long term stability of the shoreline and its stability against severe storms.

7.22-7.23 SITE DRAINAGE

- Overtopping of the structures used to protect the site;
- Sheet flow on areas adjacent to safety related structures, systems and components;
- Excessive drainage from upland areas running towards the plant;
- Overflowing of streams or canals in the site area;
- Accumulation of water in the plant area (i.e. ponding) due to the topography of the site area and inadequate infiltration capacity, and the lack of an efficient drainage system;

7.24-7.25 TRANSPORT AND COMMUNICATION ROUTES

8- CHANGES OF HAZARDS WITH TIME

8.1 GENERAL

Hydrological and meteorological hazards may change over time as a result of various causes

8.2-8.5 CHANGES DUE TO CLIMATIC EVOLUTION

Due attention should be paid to the implications of climatic variability and change, and in particular, to the possible consequences in relation to meteorological and hydrological extremes and hazards that should be considered for the planned operating lifetime of the plant.

To take account of future climatic change, an additional safety margin should be taken into consideration in the design of nuclear power plants

•8.6-8.11 OTHER CHANGES OF HAZARDS WITH TIME

- Regional climate change associated with global climate change;
- Changes in the physical geography of a drainage basin, including the estuaries, and changes to the offshore bathymetry, coastal profile and catchment areas; or changes in the surface roughness of the area around the site, which may influence the effects of wind on the plant;
- Changes of land use in the area around the site.

9- CHANGES OF HAZARDS WITH TIME

9.1-9.7 GENERAL RECOMMENDATIONS

Hydrological and meteorological hazards may change over time as a result of various causes

9.8-9.21 MONITORING AND WARNING SYSTEMS FOR METEOROLOGICAL HAZARDS AND HYDROLOGICAL HAZARDS

9.8-9.10 Meteorological monitoring systems

9.11-9.17 Tsunami warning systems

9.18-9.19 Monitoring systems and warning systems for dams and reservoirs

9.20-9.21 Monitoring systems and warning systems for lakes and rivers

10- NUCLEAR INSTALLATIONS OTHER THAN NUCLEAR POWER PLANTS

The likelihood that a meteorological or hydrological event would give rise to radiological consequences will depend on characteristics of the nuclear installation (e.g. its use, design, construction, operation and layout) and on the event itself.

Depending on the criteria of the regulatory body, some or all of the above factors should be considered. For example, fuel damage, radioactive releases or doses may be the conditions or metrics of interest.

11- MANAGEMENT SYSTEM FOR HAZARD ASSESSMENTS

11.1-11.13 SPECIFIC ASPECTS OF PROJECT ORGANIZATION

11.14 ENGINEERING USAGE AND OUTPUT SPECIFICATION

11.15-11.17 INDEPENDENT PEER REVIEW

- **INTRODUCTION**
-
- **2. DATA MANAGEMENT**
- **2.1 Existing Data**
- **2.2 Collected Data**
- **3. FIELD SURVEY**

- **4. FLOOD ANALYSES**
- **4.1 Introduction**
- **4.2 Geographical Characteristics of the Basin**
- **4.3 Climatic and Meteorologic Characteristics**
- **4.4 Geologic and Hydrologic Information**
- **4.5 Isohyetal Maps**
- **4.6 Flood Frequency Analysis**
- **4.7 Water Surface Profile Computations**
- **Conclusions**

- 5. STORM SURGE
- 5.1 Wind Statistics
 - 5.1.1 Long Term Wind Statistics
 - 5.1.2 Extreme Wind Statistics
- 5.2 Wave Hindcasting and Statistics
 - 5.2.1 Effective Fetch Study
 - 5.2.2 Wave Steepness
 - 5.2.3 Long Term Wave Statistics
 - 5.2.4 Extreme Wave Statistics
 - 5.2.5 Wave Transformation
- 5.3 Water Level Variations
- 5.4 Extreme Water Levels and Wave Run-up Computations
- 5.4 Extreme Swell Wave Statistics
- 5.4 Discussion on Effects of Long Period Waves and Determination of Free Oscillation Periods

- **6. TSUNAMI ANALYSES**
- **6.1 Historical Tsunamis**
- **6.2. Seismic and Non Seismic Sources**
- **6.3. Numerical Model**
- **6.3.1 Tsunami Modeling**
- **6.3.2 Brief History and Capabilities of Tsunami Model**
- **6.4 Applications of Tsunami Model**
- **6.5. Results, Comparison and Discussion**
- **Conclusions**

- **7. PALEOTSUNAMI**
- **7.1 Studay Area and Data**
 - 7.2. Results
- **8. UNCERTAINTY ANALYSIS**
- **9. REVIEW OF COMPLETED WORKS AND ONGOING STUDIES**
- **APPENDICES**

International Atomic Energy Agency

Unregistered version, please register. www.word-pdf-convert.com



Thank you for your attention
[yalciner@metu.edu.tr]



IAEA