LEM/TEK/64
22 MAC 2011

GUIDELINE FOR SITE EVALUATION FOR NUCLEAR POWER PLANT

Atomic Energy Licencing Board
Ministry of Science, Technology and Innovation
Batu 24, Jalan Dengkil, 43800 Dengkil
Selangor Darul Ehsan

Tel : +603-8922 5888
Fax : +603-8922 3685
Website: www.aelb.gov.my

CONTENT **PAGE NUMBER**

CONTENT	PAGE NUMBER

1. INTRODUCTION

Background

1.1 An important stage in the development of a nuclear power project is the site evaluation of a suitable site. The evaluation of this site is to establish the site-related design input to the Nuclear Power Plant (NPP). The evaluation of suitable site is to ensure adequate protection of site personnel, the public and the environment from the effect of the development and operation of NPP. The information gathered during the site evaluation process may be used during the Environmental Impact Assessment (EIA) process, and will be reviewed by the appropriate authority during evaluation of all license applications. Site evaluation information may also feed into the NPP design process. As the first step in establishing a new NPP, site evaluation takes into account all phases of the NPP lifecycle, from site preparation to release from regulatory control.

Purpose

1.2 The purpose of this guideline is:

a) to assist applicants in evaluating site characteristic following regulatory requirements in terms of nuclear safety to protect the public and the environment from the radiological consequences of radioactive releases due to normal operation and accidents; and

b) to provide recommendations and guidance for the examination of the region considered for a plant in order to identify associated hazardous phenomena, such as natural external events and human-induced events.

Structure

1.3 Chapter 2 of this guideline provides detailed regulatory requirements for conducting site evaluation process. Lastly, Chapter 3 provides general recommendation in fulfilling quality assurance objectives for site evaluation of NPPs.

2. SITE EVALUATION FOR NUCLEAR POWER PLANT

General Consideration for Site Evaluation

2.1 Generally, the evaluation of the siting of NPPs shall consider the following aspects:

a) Evaluation of site characteristics affecting the plant safety;
b) Consideration of evolving natural and human-induced factors for a projected lifetime of NPPs;
c) Consideration of potential impacts by nearby hazard associated with land uses;
d) Evaluation of the hazards associated with external natural and human-induced events;
e) Determination of the potential impact of the NPPs to the environment;
f) Consideration of projected population growth in the vicinity of the site, and emergency planning that takes those projections into account; and
g) Consideration of total nuclear capacity in the proposed site.

2.2 If the site evaluation for the aspects cited above indicates that the site is unacceptable and the deficiencies cannot be compensated for by means of design features, measures for site protection or administrative procedures, the site shall be deemed unsuitable.

2.3 *Evaluation of site characteristics affecting the plant safety*: Proposed NPP designs are evaluated against applicable safety goals, taking into account the characteristics of the site, the risks associated with external hazards, and the potential impact of the NPP on the environment. If necessary, appropriate measures shall be taken to ensure that the overall risk remains acceptably low. There are three means available to ensure that risks are acceptably low: design features, measures for site protection (e.g. dykes for flood control) and administrative procedures. Design features and protective measures are the preferred means of ensuring that risks are kept acceptably low.

2.4 *Consideration of evolving natural and human-induced factors for a projected lifetime of NPP:* The evolution of natural and human-induced factors in the region that may have a bearing on safety and security are evaluated across a time period that encompasses the projected lifetime of the NPP, with the understanding that different levels of evaluation and monitoring apply to the various phases of the plant lifetime.

2.5 *Consideration of potential impacts by nearby hazard associated with land uses:* The possible non-radiological impact of the plant, due to chemical or thermal releases, and the potential for explosion and the dispersion of chemical products shall be taken into account in the site evaluation process. The potential for interactions between nuclear and non-nuclear effluents, such as the combination of heat or chemicals with radioactive material in liquid effluents, should be considered.

2.6 *Evaluation of hazards associated with external natural and human-induced Events:* The proposed site is examined with regard to the frequency and severity of external natural and human-induced events that could affect the safety and security of the proposed NPP. A systematic approach for identifying and assessing the hazards associated with external events, including underlying rationale, is developed, documented and implemented. Each external natural and human-induced event is identified and assessed with the following considerations:

a) The potential direct[1] and indirect[2] effects of the event on the proposed NPP structures, systems and components (SSCs), including those that could affect the safe operation of the NPP in both normal and abnormal operating states.

b) The potential combined effects of external and human-induced events with normal and accidental releases from the proposed NPP that would exceed environmental limits or cause a significant adverse effect to occur; and

[1] direct effect—an earthquake resulting in a mainsteam line break.
[2] indirect effect—a corrosive gas release from a nearby chemical plant degrading NPPs safety system trip circuits via ventilation intakes.

c) Effects that would influence the ability to successfully implement emergency plans.

2.7 *Determining the potential impact of the NPPs on the environment*: 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 plant. The pathways analyses take specific environmental and site characteristics into account, with special attention paid to the function of the biosphere in the accumulation and transport of radionuclide and hazardous substances. To determine the potential contaminant impact on the environment, assessments of all releases are made under normal and abnormal conditions for all phases of the NPPs life cycle. Bounding scenarios involving modeling of potential effects from maximum possible releases are completed to establish the outer boundaries or worst-case scenarios for the NPPs.

2.8 *Consideration of projected population growth in the vicinity of the site and emergency planning that takes those projections into account:* For each proposed site, the potential radiological impacts in operational states and in accident conditions on people in the region, including impacts that could lead to emergency measures, shall be evaluated with due consideration of the relevant factors, including population distribution in the vicinity of the site.

2.9 *Consideration of total nuclear capacity in the proposed site:* For NPPs, the total nuclear capacity to be installed on the site should be determined as far as possible at the first stages of the siting process. If it is proposed that the installed nuclear capacity be significantly increased to a level greater than that previously determined to be acceptable, the suitability of the site shall be re-evaluated, as appropriate.

Regulatory Requirement for Evaluation of External Natural Events

2.10 Appendix A provides a summary of regulatory site evaluation criteria discussed in this section.

Meteorological Events

2.11 The extreme values of meteorological variables and rare meteorological phenomena listed below shall be investigated for the site. The meteorological and climatological characteristics for the region around the site shall also be investigated.

(A) Extreme Values of Meteorological Phenomena

2.12 In order to evaluate their possible extreme values, the following meteorological phenomena shall be documented for at least 30 years, where appropriate: wind speed, rainfall, temperature and storm surges.

2.13 Meteorological parameters like wind speed, rainfall intensity, as well as total rainfall, storm, monsoon rainfall maximum and minimum temperature play a major role in the design of the NPPs from safety view point. Rainfall forms an important input to other process like estimation of maximum flood water level at the NPPs site whereas wind speed is necessary to study structural safety particularly for tall structures like cooling tower, stacks, transmission line tower, etc. Structures important to safety are to be designed so as to withstand the extreme value of these parameters that are likely to occur during the lifetime of the facility’s ability to maintain its integrity and functional capacity.

2.14 The output of the site evaluation shall be described in a way that is suitable for design purposes for the plant, such as the probability of exceedance values relevant to design parameters. Uncertainties in the data shall be taken into account in this evaluation.

(B) Rare Meteorological Events

2.15 *Lightning:* The potential for the occurrence and the frequency and severity of lightning shall be evaluated for the site, including the influence of lightning events on the risks of natural fire hazards.

2.16 *Tropical Storm:* The potential for tropical storm in the region of the site shall be evaluated. If this evaluation shows that there is evidence of tropical storms or a potential for tropical storms, related data shall be collected. The following potential factors are included in the assessment:

(a) Wind speed and pressure effects;
(b) Wind-propelled missiles that could have an impact on structures, systems and components or that could render off-site power supplies unavailable;
(c) Effect on implementing of emergency plan;
(d) Possibility affecting releases from the NPPs into the environment; and
(e) Rainfall.

2.17 On the basis of the available data and the appropriate physical models, the hazards associated with tropical storms shall be determined in relation to the site. Hazards for tropical storms include factors such as extreme wind speed, pressure and rainfall.

2.18 *Temperature and Humidity:* The following potential factors are included in the assessment of temperature and humidity:

a) Effects of sudden or prolonged extreme temperatures on proposed future plant's system and components (SSCs) that will be important to safety (e.g. cooling air intakes);
b) Effects of condensation and evaporation on proposed plant's SSCs that will be important to safety (e.g. electronic components); and

c) Potential for temperature and humidity to affect releases from the NPPs into the environment.

Flooding

(A) Floods due to Rainfall and Other Causes

2.19 The site shall be assessed to determine the potential for flooding due to one or more natural causes such as run-off resulting from rainfall, high tide, storm surge, seiche and wind waves that may affect the safety of the NPPs. The parameters used to characterize the hazards due to flooding shall include the height of the water, the height and period of the waves, the warning time for the flood, the duration of the flood and the flow conditions. All pertinent data, including historical data, both on-site meteorological and hydrological data, shall be collected and critically examined.

2.20 The potential for instability of the coastal area or river channel due to erosion or sedimentation shall be investigated.

2.21 A suitable meteorological and hydrological model shall be developed with account taken of the limits on the accuracy and quantity of the data, the length of the historical period at least 30 years, where applicable, and all known past changes in relevant characteristics of the region. The hazards for the site due to flooding shall be derived from the model.

(B) Tsunami or Water Waves Induced by Earthquakes or Other Geological Phenomena

2.22 The site shall be evaluated to determine the potential for tsunamis or seiches that could affect the safety of a NPP on the site. If there is found to be such a potential historical data relating to tsunamis or seiches affecting the shore region around the site, the data shall be collected and critically evaluated for their relevance to the evaluation of the site and their reliability. The evaluation includes determination of the frequency of occurrence, magnitude and height of regional tsunamis or seiches, with account taken of any amplification due to the coastal configuration at the site.

2.23 The hazards associated with tsunamis or seiches shall be derived from known seismic records and seismotectonic characteristics as well as from physical and/or analytical modeling. These include potential draw-down and run-up[3] that may result in physical effects on the site.

(C) Floods and Waves Caused by Failure of Water Control Structures

2.24 Information relating to upstream water control structures shall be analyzed to determine whether the NPP would be able to withstand the effects resulting from the failure of one or more of the upstream structures.

2.25 If a preliminary examination of the NPP indicates that it might not be able to withstand safely all the effects of the massive failure of one or more of the upstream structures, then the hazards associated with the NPP shall be assessed with the inclusion of all such effects.

2.26 The possibility of storage of water as a result of the temporary blockage of rivers upstream or downstream (e.g. caused by landslides) so as to cause flooding and associated phenomena at the proposed site shall be examined.

Geo-technical Hazards

2.27 The site and its vicinity shall be evaluated to determine the potential for geo-technical failure (such as ground settlement, slope failure, etc) that could affect the safety of the NPP. The evaluation shall include the use of accepted methods of soil investigation and analytical methods to determine engineering parameter of the soil (such as shear strength, bearing capacity, settlement prediction, etc).

---

[3] Draw-down is a falling of the water level at a coastal site. Run-up is a sudden surge of water up a beach or a structure.

2.28 The geo-technical characteristics of the sub-surface materials, including the uncertainties in them, shall be investigated and a soil profile for design purposes shall be determined.

2.29 The stability of the foundation under static and seismic loading shall be assessed.

2.30 If the detail evaluation shows that there is a potential for geo-technical failure that could affect the safety of the NPP, practicable engineering solutions shall be provided or otherwise the site shall be deemed unsuitable.

2.31 The groundwater table and the chemical compositions of the groundwater should be studied, as groundwater can greatly influence the engineering properties of soil.

2.32 If there do seem to be practicable engineering solutions available, a detailed description of sub-surface conditions obtained by reliable methods of investigation shall be developed for the purposes of determination of the hazards.

Earthquakes and Surface Faulting

(A) Earthquakes

2.33 Information on pre-historical, historical and instrumentally recorded earthquakes in the region shall be collected and critically examined.

2.34 In particular, the hazards associated with earthquakes and ground motion shall be evaluated with appropriate methods. A thorough uncertainty analysis shall be performed as part of the evaluation of seismic hazards.

2.35 Typically, two levels of ground motion hazard are evaluated. The SL-2 level corresponds directly to ultimate safety requirements. This level of ground motion shall have a very low probability[4] of being exceeded during the lifetime of the plant and represents the maximum level of ground motion to be assumed for design purposes. Its determination shall be based on the seismotectonic evaluation and a detailed knowledge of the geology and engineering parameters of the strata beneath the site area.

2.36 The SL-1[5] level corresponds to a less severe, more likely earthquake which has different safety implications from those of SL-2. The factors which may influence decisions on the level of ground motion chosen to represent SL-1 are:

a) Seismotectonic evaluation: the relative exposure of the site to multiple sources of seismicity; the frequency of earthquakes from each such source with respect to the lifetime of the plant.
b) Design considerations: the safety implications of the required loading combinations and stress limits; the plant type.
c) The post-earthquake situation: the implications of the agreed required action following SL-1; the regional need for the plant to continue to operate safely after an earthquake which may have damaged other electricity-generating plants.
d) Plant inspection considerations: the cost and safety implications of designing and/or constructing the plant to a higher level of SL-1, compared with the possibility of more frequent inspections for a lower level of SL-1.

2.37 Evaluation of earthquakes may involve probabilistic and deterministic approach.

2.38 *Probabilistic approach*: Application of the probabilistic method includes the following steps:

[4] SL-2 corresponds to a level in excess of a mean frequency of 10^{-3} to 10^{-4} per year.
[5] SL-1 corresponds to a level in excess of a mean frequency of 1×10^{-2} per year.

a) Evaluation of the seismotectonic model for the site region in terms of seismic sources, including uncertainty in source boundaries.

b) For each source, evaluation of the maximum earthquake magnitude, rate of earthquake recurrence and earthquake recurrence model, together with the uncertainty associated with each evaluation.

c) Evaluation of the attenuation of earthquake ground motion for the site region, and assessment of the uncertainty in both the mean attenuation and the variability of the motion about the mean as a function of earthquake magnitude and source distance.

2.39 Results of ground motion hazard analyses are typically displayed as the mean annual frequency of exceedance, often referred to as annual probability, of measures of ground shaking that represent the range of periods important for plant structures (for example, peak acceleration and an appropriate range of response spectral accelerations for both horizontal and vertical motions). The mean, 15^{th}, 50^{th} and 85^{th} percentile hazard curves are typically presented to display the hazard uncertainty for each measure of ground motion. With these hazard results, uniform hazard spectra (that is, spectral amplitudes that have the same annual exceedance frequency for the range of structural periods of interest) can be constructed for any selected target hazard level (annual frequency of exceedance). To assist in determining the ground motion characteristics at a site, it is often useful to de-aggregate the probabilistic seismic hazard analysis. Such de-aggregation should be carried out for a target annual frequency of exceedance, typically the value selected for determining the design basis ground motion at the site. The de-aggregation should be performed for at least two response spectral frequencies, normally 1 Hz and 10 Hz. The de-aggregation may be used to identify the mean magnitude and distance of earthquakes that control the ground motions at these response spectral frequencies.

2.40 *Deterministic approach*: The assessment of SL-2 by deterministic methods includes:

a) Dividing the seismotectonic model into seismotectonic provinces corresponding to zones of diffuse seismicity and seismogenic structures.

b) Identifying the maximum potential earthquake associated with each seismogenic structure and with each seismotectonic province.

c) Performing the evaluation as follows:

   (i) For each seismogenic structure, the maximum potential earthquake should be assumed to occur at the point of the structure closest to the site area, with account taken of the physical dimensions of the source. When the site is within the boundaries of a seismogenic structure, the maximum potential earthquake should be assumed to occur beneath the site. In this case, special care should be taken to demonstrate that the seismogenic structure is not capable.

   (ii) The maximum potential earthquake in a zone of diffuse seismicity which includes the site should be assumed to occur at some identified specific distance from the site, on the basis of investigations which ensure that there are no seismogenic structures within this distance and that therefore the related probability of earthquakes occurring therein is negligibly low. This distance may be in the range of a few to about 20 kilometers and will depend on the best estimate of the focal depth of the earthquakes in that seismotectonic province. In selecting a suitable distance, the physical dimensions of the source should be taken into account.

   (iii) The maximum potential earthquake associated with zones of diffuse seismicity in each adjoining seismotectonic province should be assumed to occur at the point of the province boundary closest to the site.

   (iv) An appropriate attenuation relation should be used to determine the ground motion that each of these earthquakes would cause at the site, with account taken of local conditions at the site.

(B) Surface Faulting

2.41 The potential for surface faulting (i.e. the fault capability) shall be assessed for the site. A fault shall be considered capable if, on the basis of geological, geophysical, geodetic or seismological data, one or more of the following conditions applies:

a) It shows evidence of past movement or movements (significant deformations and/or dislocations) of a recurring nature within such a period that it is reasonable to infer that further movements at or near the surface could occur.
b) A structural relationship with a known capable fault has been demonstrated such that movement of the one may cause movement of the other at or near the surface.
c) The maximum potential earthquake associated with a seismogenic structure is sufficiently large and at such a depth that it is reasonable to infer that, in the geo-dynamic setting of the site, movement at or near the surface could occur.

2.42 When faulting is known or suspected to be present, investigations of site vicinity scale and type should be made which include very detailed geological–geomorphological mapping, topographical analyses, geophysical surveys (including geodesy, if necessary), trenching, boreholes, age dating of sediments or fault rocks, local seismological investigations and any other appropriate techniques to ascertain when movement last occurred. Consideration should be given to the possibility that faults that have not demonstrated recent near surface movement, may be reactivated by large reservoir loading, fluid injection, fluid withdrawal or other phenomena.

2.43 Where reliable evidence shows that there may be a capable fault with the potential to affect the safety of a plant at the site, the feasibility of construction and safe operation of a plant at this site should be re-evaluated and, if necessary, an alternative site should be considered.

Regulatory Requirement for Evaluation of Human-induced External Events

2.44 Appendix C provides general flow diagram that applies to evaluation procedure for human-induced external event which provides relation to Screening Distance Value (SDV), Screening Probability Level (SPL), Conditional Probability Value (CPV) and Design Basis Probability Value (DBPV).

Aircraft Crashes

2.45 The potential for aircraft crashes on the site shall be assessed with account taken, to the extent practicable, of characteristics of future air traffic and aircraft. The site is considered unsuitable for NPP if the airport is located within 16km radius unless detailed evaluation is conducted to compensate with NPP design.

2.46 Generally, the potential will result from the contributions to the probability of occurrence of an aircraft crash of one or more of Type 1, Type 2 or Type 3 crash rate event:

a) *Type 1 event*: A crash occurs at the site deriving from the general air traffic in the region. To evaluate the probability of occurrence of such crashes, the site is considered as a tract or circular area of 0.1–1 km^2 and the region as a circular area of 100–200 km in radius.

b) *Type 2 event*: A crash occurs at the site as a result of a takeoff or a landing operation at a nearby airport.

c) *Type 3 event*: A crash occurs at the site owing to air traffic in the main civil traffic corridors and the military flight zones.

2.47 If the assessment shows that there is a potential for an aircraft crash on the site that could affect the safety of the plant, then an assessment of the hazards shall be made. Assessment should primarily cover the following:

a) Design Basis Event that takes into account the physical separation and the redundancy of items important to safety, especially for vulnerable part of the NPP;

b) Primary Impact and Secondary Projectile, including analysis of the potential for:

(i) Structural failure due to shearing and bending force;

(ii) Perforation of structure and spalling of concrete within structure; and

(iii) Propagation of shock wave that affect items important to safety.

c) Effect caused by aircraft fuel, which covers:

(i) burning of aircraft fuel outdoors causing damage to exterior plant components important to safety;

(ii) the explosion of part or all of the fuel outside buildings;

(iii) entry of combustion products into ventilation or air supply systems; and

(iv) entry of fuel into buildings through normal openings, through holes caused by the crash or as vapor or an aerosol through air intake ducts, leading to subsequent fires, explosions or side effects.

d) Design Basis Parameter, including:

(i) Direct impact of aircraft to NPP, as follows:

— Distribution of mass and stiffness along the aircraft concerned (one or more), nose shape, area of impact, velocity and angle of incidence — when the structural evaluation includes detailed local analyses of the potential for structural failure due to shearing and bending forces, for spalling and scabbing of concrete within the structures, and for perforation of the structures.

— A load–time function, which may be independent of the specific aircraft and representative of a class of aircraft, with associated mass, velocity and application area when the structural evaluation includes only a preliminary screening of local effects in comparison with other design events, or for a generic evaluation of the induced vibration effects on structures and components.

(ii) Type of fuel and the maximum amount of fuel potentially involved in an accident.

(iii) Estimation of the same quantities for parts of an aircraft that have become separated to form secondary projectiles.

2.48 If the assessment indicates that the hazards are unacceptable (probability of occurring more than 10^{-6}) and if no practicable solutions are available, then the site shall be deemed unsuitable.

Releases of Hazardous Fluids

2.49 In evaluation of releases of hazardous fluids, particular attention in view of the potential release of the following substances should be given:

a) Flammable gases and vapors which can form explosive clouds and can enter ventilation system intakes and burn or explode;
b) Asphyxiant and toxic gases which can threaten human life and impair crucial safety functions; and
c) Corrosive and radioactive gases and liquids which can threaten human life and impair the functionality of equipment.

2.50 Preliminary evaluation includes identification of any activities and facilities involving the processing, handling, storage or transport of flammable, toxic or corrosive liquids within the SDV. The SDV selected will depend on a number of factors, such as the physical properties of the substance, the regional topography and the type and extent of industrialization. If the potential hazard within the SDV to items important to safety arising from these activities and facilities is less than that due to similar materials to be stored on the site and against which protection has been provided, then no further investigation should be carried out. Otherwise, the potential hazards due to off-site activities should be evaluated using in the first instance a conservative and simple deterministic approach.

2.51 Detail evaluation includes the following:

a) Potential hazards of hazardous fluids that have not been eliminated in preliminary evaluation;
b) Identification of location of the liquid sources, as well as maximum inventory, quantity in store and/or amount otherwise contained;
c) Determination of maximum quantity of hazardous fluids that could be released, the rate of release and the related probability of release;
d) Potential of rupture of a container or of any leak from the facility store;
e) Probability of release of hazardous fluid from mobile source in transit within the SDV, on the assumption that maximum quantity being transported is released; and
f) Potential hazardous fluid interaction with nearby water intake.

2.52 The important parameters and properties that should be established for inclusion in the design basis for protection of the NPP against hazardous fluids are as follows:

a) amount of fluid;
b) surface area of the pool;
c) chemical composition;
d) concentration (corrosion potential);
e) partial pressure of vapors;
f) boiling temperature;
g) ignition temperature; and
h) toxicity.

Releases of Hazardous Gases, Vapors and Aerosols

2.53 Gases, vapors and aerosols from volatile liquids or liquefied gases may, upon release, form a cloud and drift. The drifting cloud may affect the nuclear power plant in the following two ways:

a) When the cloud remains external to the plant (either near the source or after drifting), it is a potential hazard similar to some of the other external human-induced events (fires, explosions and related effects).

b) The cloud can permeate plant buildings, posing a hazard to personnel and items important to safety, particularly for a cloud of toxic, asphyxiant or explosive gas. It can also affect the habitability of the control room and other important plant areas.

2.54 Meteorological information should be taken into account in estimating the danger due to a drifting cloud as local meteorological conditions will affect dispersion. In particular, dispersion studies based on probability distributions of wind direction, wind speed and atmospheric stability class should be made. For the postulated event of an underground release of hazardous gases or vapors, consideration should be given to escape routes and to seepage effects which may result in high concentrations of hazardous gases in buildings or the formation of hazardous gas clouds within the SDV.

2.55 The preliminary evaluation requires examining the surroundings of NPP for the purpose of identifying all possible sources of hazardous cloud within SDV[6]. Particular attention should be given to the following:

a) chemical plants;

b) refineries;

c) above ground and underground storage systems;

d) pipelines for volatile liquids, gases and liquefied gases; and

e) transport routes and their associated potential sources external to the SDV on which hazardous clouds may be generated.

[6] an SDV in the range of 8–10 km is used for the sources of hazardous clouds.

2.56 In the detailed evaluation, the probability of occurrence of an interacting event due to gas clouds — that is, the probability that flammability or toxicity limits are exceeded — should be assessed and the following factors should be taken into consideration:

a) the probability of occurrence of the initiating event (for example, pipe rupture);
b) the quantity of material released and the release rate;
c) the probability that a cloud will drift towards the nuclear power plant;
d) the dilution due to atmospheric dispersion; and
e) the probability of ignition for explosive clouds.

2.57 Hazard evaluation for gases, vapors and aerosols includes the following:

a) Generation of drifting cloud of hazardous gases, vapors or aerosols, with clear distinction between sub-cooled liquefied gases and gases liquefied by pressure and non-condensable compressed gas; and

b) Design Basis Parameter, including:
   (i) Chemical composition;
   (ii) Concentration with time and distance;
   (iii) Toxicity limit and asphyxiant properties; and
   (iv) Flammability limit.

Explosion[7]

2.58 This section deals with evaluation of explosions of explosive solid, liquid or gaseous substances at or near the source. Moving clouds of explosive gases and vapors are also considered.

2.59 In evaluating the potential for explosions, all potential sources lying within the SDV should be taken into consideration, with the following parameters:

a) The nature and maximum amount of the material that may simultaneously explode; and

b) The distance and orientation from the explosion centre to the site, where the explosive mass is usually expressed in terms of *trinitrotoluene* (TNT) equivalent mass for generic explosive substances.

(A) Stationary Sources

2.60 Preliminary evaluation requires applicant to determine SDV for any initiating event by calculating the scaled distance corresponding to that overpressure[8].

2.61 If the site is located within the SDV, an evaluation of the probability of occurrence of the explosion should be undertaken. The probability of an explosion occurring at hazardous industrial plants, refineries and storage depots is usually higher than the SPL. Unless there is adequate justification, a conservative assumption should be made that the maximum amount of explosive material usually stored at the source will explode, and an analysis should then be made of the effects of interacting events (incidence of pressure waves, ground shock and projectiles) on

[7] Explosion: any chemical reaction between solids, liquids, vapors or gases which may cause a substantial rise in pressure, possibly owing to impulse loads, drag loads, fire or heat. An explosion can take the form of a deflagration, which generates moderate pressures, heat or fire, or a detonation, which generates high near-field pressures and associated drag loading but usually without significant thermal effects. Whether or not the ignition of a particular chemical vapor or gas causes a deflagration or a detonation in air depends primarily on the concentration of the chemical vapor or gas. At concentrations two to three times the deflagration limit, detonation can occur. The deflagration limit and therefore the related effects are in general related to the burning velocity.

[8] It is assumed that a typical plant does not need any analysis for reflected overpressures of less that 0.07 bar, for which SDV = $18W^{1/3}$ (W in kg, SDV in m). An SDV adopted for explosions is in the range of 5–10 km.

items important to safety. The secondary effects of fires resulting from explosions should also be considered.

2.62 If facilities exist or activities take place within the SDV in which the amount of explosive material is large enough to affect safety and the probability of occurrence of an explosion is higher than the SPL value, then a more detailed evaluation should be made in order to establish a design basis event. If as a result of the detailed evaluation using more specific data the calculated probability of occurrence of a postulated explosion exceeds the DBPV, a design basis explosion should be determined. For the purposes of evaluating the importance of the interacting event, the protection necessary against the design basis explosion should be compared with that already provided against overpressures from other external events such as extreme winds and tornadoes.

(B) Mobile Sources

2.63 If there is a potential for explosions within the SDV on transport routes, the potential effects should be estimated. If these effects are significant, the frequency of shipments of explosive cargoes should be determined. The probability of occurrence of an explosion within the SDV should be derived from this, and if it is less than the SPL no further consideration should be given. Particular attention should be paid to the potential hazards associated with large explosive loads such as those transported on railway freight trains or in ships.

2.64 The pressure waves, drag level and local thermal effects at the plant would differ according to the nature and amount of the explosive material, the configuration of the explosive, meteorological conditions, the plant layout and the topography. Certain assumptions are usually made to develop the design basis for explosions, with data on the amounts and properties of the chemicals involved taken into account. TNT equivalents are commonly used to estimate safe distances for given amounts of explosive chemicals and for a given pressure resistance of the structures concerned. For certain explosive chemicals, the pressure–distance relationship has been determined experimentally and should be used directly.

2.65 Projectiles that may be generated by an explosion should be identified by using engineering judgment and taking into account the source of these projectiles. In particular, the properties of the explosive material concerned and the characteristics of the facility in which the explosion is assumed to occur should be considered. Consideration should also be given to possible ground motion and to other secondary effects such as the outbreak of fire, the release or production of toxic gases and the generation of dust.

2.66 For the established design basis explosion, the following parameters should be determined:

a) the properties of the exploding substance;
b) the properties of the pressure waves (maximum side-on or incident and reflected overpressures and evolution with time of the pressure wave);
c) the properties of the projectiles generated (material, size, impact velocity); and
d) the ground shock, especially for buried items.

Other External Human-induced Events

(A) Fire

2.67 An assessment should be made at and around the site[9] to identify potential sources of fire, such as forests, peat, storage areas for low volatility flammable materials (especially hydrocarbon storage tanks), wood or plastics, factories that produce or store such materials, their transport lines, and vegetation.

2.68 The main fire-related hazard to the NPP site is the burning of parts of the plant and the resulting damage. Local structural collapse may occur. Smoke and toxic gases may affect plant operators and certain plant systems. Particular attention should be paid to sources causing possible common mode failures. For instance, the off-site emergency power supply could be interrupted by fire, while the emergency

[9] The area to be examined for the possible occurrence of fires that may affect items important to safety should have a radius equal to the SDV for this type of hazard, which in radius of 1-2 km from NPP.

diesel generators may fail to function owing to smoke being drawn into their air intakes.

2.69 Parameters and properties that define the magnitude of a fire are:

a) the maximum heat flux;

b) the magnitude of hazards from burning fragments and smoke; and

c) the duration of the fire.

(B) Ship Collision

2.70 Ship collision may constitute a particular hazard to the water intake structures of a nuclear power plant. If the ship collision probability is found to be greater than the SPL, a detailed analysis should be conducted to assess the consequences of such an impact. In such an analysis, the simulation of uncontrolled drifting of ships and recreational boats (especially sailing vessels) should be conducted, according to the direction of dominant winds and currents. The collision of large ships in normal cruising can usually be screened out by the implementation of administrative measures and safeguards.

2.71 Important parameters that should be analyzed are:

a) impact velocity;

b) impact area;

c) mass and stiffness of the ship;

d) substances transported; and

e) potential secondary effects, such as oil spills and explosions.

Electromagnetic Interference

2.72 Electromagnetic interference can affect the functionality of electronic devices. It can be initiated by both on-site (high voltage switchgear, portable telephones, portable electronic devices, computers) and off-site sources (radio interference and telephone network). The presence of central telephone installations close to the site could give rise to specific provisions for the design stage, but usually such high frequency waves do not represent exclusion criteria for sites since specific engineering measures for the qualification of equipment should be taken in the design stage and administrative procedures should be adopted on site to avoid local interference.

2.73 In the site evaluation stage, potential sources of interference should be identified and quantified (for example, intensity and frequency). They should be monitored over the lifetime of the plant for the purpose of ensuring the proper qualification of plant components.

Atmospheric Dispersion of Radioactive Material

2.74 A meteorological description of the region shall be developed, including descriptions of the basic meteorological parameters, regional topography and phenomena, as follows:

a) wind speed and direction;
b) air temperature and humidity;
c) rainfall;
d) atmospheric stability parameters; and
e) prolonged inversions.

2.75 A program for meteorological measurements shall be prepared and carried out at or near the site with the use of instrumentation capable of measuring and recording the main meteorological parameters at appropriate elevations and locations. Data from at least one full year shall be collected, together with any other relevant data that may be available from other sources.

2.76 On the basis of the data obtained from the investigation of the region, the atmospheric dispersion of radioactive material released shall be assessed with the use of appropriate models. These models shall include all significant site specific and regional topographic features and characteristics of the plant that may affect atmospheric dispersion.

2.77 The following properties and parameters should be estimated for dispersion of radioactive sources in atmosphere:

a) Radioactivity, including the rate of discharge of each important nuclide and the total activity of each important nuclide released in a specified period and variation of the rate of discharge of each important nuclide;
b) Chemical characteristics of the material released;
c) Physical properties of the material released; and
d) Geometry and mechanics of the discharge.

2.78 Information should be collected on the background levels of activity in air due to natural and artificial sources.

Dispersion of Radioactive Material through Surface and Groundwater

2.79 A detailed evaluation of the hydrosphere in the region should be carried out. Calculations of dispersion and concentrations of radionuclide should be made to show whether the radiological consequences of routine discharges, uncontrolled releases during normal operation and potential accidental releases of radioactive materials into the hydrosphere are acceptable. The results of these calculations may be used to demonstrate compliance with the national authorized limits for discharges of radioactive effluents.

Surface Water

2.80 The information necessary to perform dose assessment relating to exposure pathways in the hydrosphere includes:

a) the source term for the discharge of radioactive material to the environment;
b) hydrological, physical, physicochemical and biological characteristics governing the transport, diffusion and retention of radioactive materials;
c) relevant food-chains leading to humans;
d) locations and amounts of water used for drinking and for industrial, agricultural and recreational purposes; and

e) dietary and other relevant habits of the population, including special occupational activities, such as the handling of fishing gear and recreational pursuits, such as water sports and fishing.

2.81 The following properties and parameters should be estimated for radioactive discharges:

a) Radioactivity:

(i) the rate of discharge of each important nuclide, and an estimate of the total activity discharged in a specific period and its fixation capacity on soils; and

(ii) Absorption and retention co-efficient for radioactive material;

b) Chemical properties, including:

(i) important anion and cation concentrations, and their oxidation states and complexing states (e.g. Ca^{2+}, K^{+}, Mg^{2+}, Na^{+}, NH_4^{+}, HCO_3^{-}, Cl^{-}, SO_4^{-}, NO_2^{-}, NO_3^{-}, PO_4^{-});

(ii) organic content;

(iii) pH; and

(iv) the concentration of dissolved oxygen and conductivity, and concentrations of associated pollutants;

c) Physical properties of the liquid effluents discharged, including:

(i) temperature;

(ii) density; and

(iii) loads and granulometry of suspended solids;

d) Flow rates for continuous discharges, or volume and frequency for batch discharges;

e) Distance to nearest body of surface water;

f) The variation of the source term over the duration of the discharge, which is necessary to evaluate the concentrations due to long-term releases; and

g) The geometry and mechanics of discharges.

2.82 Necessary consideration to surface water dispersion should be given to the preferred site located at rivers, estuaries, open shore of lake and sea and human-made impoundment. Consideration for this case is provided in Appendix D.

Groundwater

2.83 Evaluation of groundwater contamination releases from normal and abnormal nuclear power plant operation shall be conducted. A discharge of radioactive material from a NPP may contaminate the groundwater system in the region either directly or indirectly, via earth, atmosphere or surface water, in the following three ways:

a) Indirect discharge to the groundwater through seepage and infiltration of surface water that has been contaminated by radioactive material discharged from the nuclear power plant;
b) Infiltration into the groundwater of radioactive liquids from a storage tank or reservoir; and
c) Direct release from a nuclear power plant; an accident at the plant may induce such an event, and radioactive material could penetrate into the groundwater system. The protection of aquifers from such events should be considered in the safety analysis for postulated accident conditions, and a geological barrier to provide protection should be considered.

2.84 Groundwater condition of the site, such as groundwater level, thickness of aquifers, and confining beds, groundwater flow patterns, groundwater quality, transmissiveness, and storage co-efficient are to be determined.

2.85 The evaluation of hydro-geological characteristics should determine the following:

a) the estimated concentration of radioactive material in groundwater at the nearest point in the region where groundwater is drawn for human consumption;
b) radionuclide retention characteristic of the soil;
c) the transport paths and travel times for radioactive material to reach the source of consumption from the point of release;
d) the transport capacity of the surface flow, interflow and groundwater recharge;
e) the susceptibility to contamination of the aquifers at different levels; and
f) time and space distributions of the concentrations in the groundwater of radioactive material resulting from accidental releases from the plant.

Population Density and Distribution

2.86 The distribution of the population within the region shall be determined. The purposes of the population studies should be:

a) to evaluate the potential radiological impacts of normal radioactive discharges and accidental releases; and
b) to assist in the demonstration of the feasibility of the emergency plan.

2.87 In particular, information on existing and projected population[10] distributions in the region, including resident populations and to the extent possible transient populations, shall be collected and kept up to date over the lifetime of the NPP. The radius within which data are to be collected shall be 80km from the NPP, with

---

[10] A projection of the present population in the region should be made for:

a) the expected year of commissioning of the plant; and
b) selected years (e.g. every tenth year) over the lifetime of the plant.

Projections should be made on the basis of population growth rate, migration trends and plans for possible development in the region. The projected figures for the two categories of permanent population and temporary population should be extrapolated separately if data are available.

account taken of special situations. Special attention shall be paid to the population living in the immediate vicinity of the plant, to densely populated areas and population centers in the region, and to residential institutions, such as schools, hospitals and prisons.

2.88 Information on the permanent population of the region and its distribution should include information on occupation, places of work, means of communication and typical diet of the inhabitants. If a city or town in the region is associated with a major industrial facility, this should be considered.

2.89 The information on the temporary population should cover:

a) the short-term transient population, such as tourists and nomads; and
b) the long-term transient population, such as seasonal inhabitants and students.

2.90 The data shall be analysed to give the population distribution in terms of the direction and distance from the plant. An evaluation shall be performed of the potential radiological impacts of normal discharges and accidental releases of radioactive material, including reasonable consideration of releases due to severe accidents, with the use of site specific parameters as appropriate.

2.91 The critical group[11] associated with each NPP should be identified. Critical groups of the population with particular dietary habits and specific locations for particular types of activity in the region should be considered.

[11] The critical group is a group of members of the public which is reasonably homogeneous with respect to its exposure for a given radiation source and given exposure pathway and is typical of individuals receiving the highest effective dose or equivalent dose (as applicable) by the given exposure pathway from the given source.

Uses of Land and Water in the Region

2.92 The uses of land and water shall be characterized in order to assess the potential effects of the NPP in the region and particularly for the purposes of preparing emergency plans. The investigation should cover land and water bodies that may be used by the population or may serve as a habitat for organisms in the food chain.

2.93 The operation of a NPP may affect the population in the surrounding area and the local and regional environment. As part of the assessment for the site, the uses of land and water should be investigated. The characteristics of the land and water utilized in the region should also be considered in demonstrating the feasibility of the emergency response plan.

2.94 The evaluation related to uses of land and water in the region should cover:

a) land devoted to agricultural uses, its extent, and the main crops and their yields;
b) land devoted to dairy farming, its extent and yields;
c) land devoted to industrial, institutional and recreational purposes, its extent and the characteristics of its use;
d) bodies of water used for commercial, individual and recreational fishing, including details of the aquatic species fished, their abundance and yield;
e) bodies of water used for commercial purposes, including navigation, community water supply, irrigation, and recreational purposes, such as bathing and sailing;
f) land and bodies of water supporting wildlife and livestock;
g) direct and indirect pathways for potential radioactive contamination of the food-chain;
h) products imported to or exported from the region which may form part of the food-chain; and
i) free foods, such as mushrooms, seaweed and forest produce.

2.95 Present uses of water which could be affected by changes in the water temperature and by radioactive material discharged from a NPP, together with the location, nature and extent of usage, should be identified. Changes in uses of water in the region, such as for irrigation, fishing and recreational activities, should also be considered.

2.96 Special consideration should be given to any population centers for which drinking water is obtained from water bodies that may be affected by a NPP. To the extent possible, future water flow and water uses should be projected over the lifetime of the plant. This may lead to a change in the critical group of the population.

2.97 For areas where drinking water is obtained from springs, wells or any other source of groundwater, the movement and quality of the groundwater should be studied.

2.98 The data on different water uses should include the following:

a) For water used for drinking by humans and animals, and for municipal and industrial purposes:
   - (i) average and maximum rates of water intake by users;
   - (ii) distance of the intake from the potential source of radioactive discharges;
   - (iii) mode of water consumption; and
   - (iv) number of water users.

b) For water used for irrigation:
   - (i) rate of water use;
   - (ii) area of irrigated land; and
   - (iii) types and yields of agricultural products, and their usual consumers.

c) For water used for fishing:

(i) the aquatic species fished, and their abundance and yields in water used for commercial, individual and recreational fishing.

d) For water used for recreational purposes:

(i) the number of persons engaging in swimming, boating and other recreational uses, and the time spent on these activities.

2.99 These investigations should cover a reasonably large area in the site region. If a NPP is located on a river bank, users downstream from the site should be identified. If the site is near a lake, all users of the lake should be identified. If a site is on an ocean coast, users of the sea out to tens of kilometers in all directions should be identified.

2.100 Information should be collected on levels of background activity for environmentally relevant substances, such as soils, and for vegetables and other foodstuffs.

3. QUALITY ASSURANCE FOR SITE SELECTION AND EVALUATION

3.1 An adequate quality assurance program should be established to control the effectiveness of the execution of investigations and assessments and engineering activities performed in the different stages of the site selection and evaluation for NPP.

3.2 The quality assurance program should cover the organization, planning, work control, personnel qualification and training, verification and documentation for the activities to ensure that the required quality of the work is achieved.

3.3 The quality assurance program for site selection and evaluation is a part of the overall quality assurance program for the NPP. However, since activities for site investigation are normally initiated long before the establishment of a nuclear project, the quality assurance program should be established at the earliest possible time consistent with its application in the conduct of selection and evaluation activities.

3.4 The results of the activities for investigation and assessment during site selection and evaluation of NPP should be compiled in a report that documents the results of all in-situ work, laboratory tests and geo-technical analyses and evaluations.

3.5 The results of studies and investigations shall be documented in sufficient detail to permit comprehensive regulatory review.

3.6 A quality assurance program should be implemented for all activities that may influence safety or the derivation of parameters for the design basis for the site. The quality assurance program may be graded in accordance with the importance to safety of the individual siting activity under consideration.

3.7 The process of establishing site-related parameters and evaluations involve technical and engineering analyses and judgments that require extensive experience and knowledge. In many cases, the parameters and analyses may not lend themselves to direct verification by inspections, tests or other techniques that can be precisely defined and controlled. These evaluations shall be reviewed and verified by individuals or groups (e.g. by peer review) who are separate from those who did the work.

3.8 In accordance with the importance of engineering judgment and expertise in geo-technical engineering, the feedback of experience is an important aspect. For the assessment of matters, such as the liquefaction potential, the stability of slopes and the safety in general of earth and of buried structures, information from the feedback of experience of failures in comparable situations shall be documented and analyzed in order to be able to provide evidence that similar failures will not occur.

3.9 Records of the work carried out in the activities for site selection and evaluation for NPP should be properly maintained and kept.

LIST OF IAEA DOCUMENTS TO BE USED IN SITE EVALUATION OF NPP

[1] External Human-induced Events in Site Evaluation for Nuclear Power Plants, NS-G-3.1

[2] Dispersion of Radioactive Material in Air and Water and Consideration of Population Distribution in Site Evaluation for Nuclear Power Plants, NS-G-3.2

[3] Evaluation of Seismic Hazards for Nuclear Power Plants, NS-G-3.3

[4] Meteorological Events in Site Evaluation for Nuclear Power Plants, NS-G-3.4

[5] Flood Hazard for Nuclear Power Plants on Coastal and River Sites, NS-G-3.5

[6] Geo-technical Aspects of Site Evaluation and Foundations for Nuclear Power Plants, NS-G-3.6

REFERENCES

[1] Atomic Energy Licensing Act 1984.

[2] Environmental Quality Act 1974.

[3] Environmental Quality (Industrial Effluent) Regulations 2009.

[4] Environmental Quality (Clean Air) Regulations 1978.

[5] KOREA ATOMIC ENERGY RESEARCH INSTITUTE. *Nuclear Power Project: Policy and Korean Experience*. First Edition (5th December 2007).

[6] UNITED STATES NUCLEAR REGULATORY COMMISSION. *Preparation of Environment Report for Nuclear Power Station* (Regulatory Guide 4.2, Revision 2) (July 1976).

[7] UNITED STATES NUCLEAR REGULATORY COMMISSION. Title 10 of Code of Federal Regulation (CFR), Part 100: *Reactor Site Criteria.*

[8] UNITED STATES NUCLEAR REGULATORY COMMISSION. *Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants* (Regulatory Guide 1.70).

[9] UNITED STATES NUCLEAR REGULATORY COMMISSION. *Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion* (Regulatory Guide 1.165) (March 1997).

[10] UNITED STATES NUCLEAR REGULATORY COMMISSION. *Design Basis Floods for Nuclear Power Plants* (Regulatory Guide 1.59, Revision 2) (August 1977).

[11] UNITED STATES NUCLEAR REGULATORY COMMISSION. *Onsite Meteorological Programs* (Regulatory Guide 1.23, Revision 1) (March 2007).

[12] UNITED STATES NUCLEAR REGULATORY COMMISSION. Title 10 of Code of Federal Regulation (CFR), Part 50: *Domestic Licensing of Production and Utilization Facilities.*

[13] UNITED STATES NUCLEAR REGULATORY COMMISSION. Title 10 of Code of Federal Regulation (CFR), Part 51: *Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions.*

[14] UNITED STATES NUCLEAR REGULATORY COMMISSION. Title 10 of Code of Federal Regulation (CFR), Part 73: *Physical Protection of Plants and Materials.*

[15] UNITED STATES NUCLEAR REGULATORY COMMISSION. *Seismic Design Classification* (Regulatory Guide 1.29, Revision 4) (March 2007).

[16] UNITED STATES NUCLEAR REGULATORY COMMISSION. *Ultimate Heat Sink for Nuclear Power Plants* (Regulatory Guide 1.27, Revision 2) (January 1976).

[17] UNITED STATES NUCLEAR REGULATORY COMMISSION. *Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants* (NUREG-0800).

[18] UNITED STATES NUCLEAR REGULATORY COMMISSION. *Assumptions for Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release* (Regulatory Guide 1.78, Revision 1) (December 2001).

[19] UNITED STATES NUCLEAR REGULATORY COMMISSION. *Evaluations of Explosions Postulated to Occur on Transportation Routes Near Nuclear Power Plants* (Regulatory Guide 1.91, Revision 2) (February 1978).

[20] UNITED STATES NUCLEAR REGULATORY COMMISSION. *Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants* (NUREG-0654, Revision 1) (November 1980).

[21] INTERNATIONAL ATOMIC ENERGY AGENCY, *Site Evaluation for Nuclear Installation*, Safety Standards Series No. NS-R-3, 2003.

[22] INTERNATIONAL ATOMIC ENERGY AGENCY, *Geo-technical Aspects of Site Evaluation and Foundations for Nuclear Power Plants*, Safety Standards Series No. NS-G-3.6.

[23] INTERNATIONAL ATOMIC ENERGY AGENCY, *Evaluation of Seismic Hazards for Nuclear Power Plants*, Safety Standards Series No. NS-G-3.3, 2002.

[24] INTERNATIONAL ATOMIC ENERGY AGENCY, *Meteorological Events in Site Evaluation for Nuclear Power Plants*, Safety Standards Series No. NS-G-3.4, 2003.

[25] INTERNATIONAL ATOMIC ENERGY AGENCY, *Flood Hazard for Nuclear Power Plants on Coastal and River Sites*, Safety Standards Series No. NS-G-3.5, 2003.

[26] INTERNATIONAL ATOMIC ENERGY AGENCY, *External Human-induced Events in Site Evaluation for Nuclear Power Plants*, Safety Standards Series No. NS-G-3.1, 2002.

[27] INTERNATIONAL ATOMIC ENERGY AGENCY, *External Events Excluding Earthquakes in the Design of Nuclear Power Plants*, Safety Standards Series No. NS-G-1.5, 2003.

[28] INTERNATIONAL ATOMIC ENERGY AGENCY, *Dispersion of Radioactive Material in Air and Water and Consideration of Population Distribution in Site Evaluation for Nuclear Power Plants*, Safety Standards Series No. NS-G-3.2, 2002.

[29] INTERNATIONAL ATOMIC ENERGY AGENCY, *Quality Assurance for Safety in Nuclear Power Plants and Other NPPs*: Code and Safety Guides Q1–Q14, Safety Series No. 50-C/SG-Q, 2001.

[30] CANADIAN NUCLEAR SAFETY COMMISSION. *Site Evaluation for New Nuclear Power Plants*, Regulatory Document No. 346, November 2008.

GLOSSARY

design basis external events means the external event(s) or combination(s) of external events considered in the design basis of all or any part of a facility.

external events means events unconnected with the operation of a facility or activity which could have an effect on the safety of the facility or activity.

external zone means the area immediately surrounding a proposed site area in which population distribution and density, and land and water uses, are considered with respect to their effects on the possible implementation of emergency measures.

site area means a geographical area that contains an authorized facility, and within which the management of the authorized facility may directly initiate emergency actions.

site personnel means all persons working in the site area of an authorized facility, either permanently or temporarily.

siting means the process of selecting a suitable site for a facility, including appropriate assessment and definition of the related design bases.

conditional probability value (CPV). The upper bound for the conditional probability that a particular type of event will cause unacceptable radiological consequences. The term is used in the detailed event screening process for site evaluation.

design basis probability value (DBPV). A value of the annual probability for a particular type of event to cause unacceptable radiological consequences. It is the ratio between the SPL and the CPV. The term is used in the detailed event screening process for site evaluation.

initiating event. An identified event that leads to anticipated operational occurrences or accident conditions and challenges safety functions.

interacting event. An event or a sequence of associated events that, interacting with a facility, affect site personnel or items important to safety in a manner which could adversely influence safety.

postulated initiating events. An event identified during design as capable of leading to anticipated operational occurrences or accident conditions. The primary causes of postulated initiating events may be credible equipment failures and operator errors (both within and external to the facility), human-induced or natural events.

screening distance value (SDV). The distance from a facility beyond which, for screening purposes, potential sources of a particular type of external event can be ignored.

screening probability level (SPL). A value of the annual probability of occurrence of a particular type of event below which, for screening purposes, such an event can be ignored.

CONTRIBUTORS TO DRAFTING AND REVIEW

Members of National Working Group on NPP Siting:

Atomic Energy Licensing Board
Mrs. Azlina Mohammad Jais
Mr. Mohd Pauzi Sobari
Mr. Ibrahim Muhamad
Mr. Zainal Abidin Husain
Mr. Mahyudin Abu Bakar
Mr. Fedrick Charlie Matthew Brayon
Ms. Lydia Ilaiza Saleh
Mr. Ridha Roslan
Mr. Abd. Aziz Sadri

Department of Environment
Mrs. Halimah Hassan
Mrs. Norlin Jaafar

Mineral & Geosciences Department Malaysia
Mrs. Habibah Tahir

Department of Town & Country Planning Peninsular Malaysia
Dr. Dahlia Rosly
Dr. Noor Yazan Zainol
Mrs. Tee Szu Fong

Department of Irrigation and Drainage
Dr. Mohamed Roseli Zainal Abidin
Ms. Devi a/p Peechmani

Department of Public Works

Mr. Ezuan Jamadon

Mr. Nicholas T. Jacob

Malaysian Meteorological Department

Mr. Alui Bahari

Dr. Mohd Rosaidi Che Abbas

Malaysian Nuclear Agency

Mr. Mohamad Yusof Mohamad Ali

Dr. Abdul Khalik Wood

Mrs. Azlinda Aziz

APPENDIX A

SUMMARY OF GUIDELINE FOR SITE EVALUATION CRITERIA OF NUCLEAR POWER PLANT

<table>
<tr><th>SCOPE</th><th>ASPECT</th><th>CRITERIA</th><th>REFERENCE</th><th>REMARKS</th></tr>
<tr><td rowspan="2">EVALUATION OF NATURAL EXTERNAL EVENTS</td><td rowspan="2">Meteorological Events</td><td>Extreme Meteorological Events:

Possible extreme values should be evaluated based on the following meteorological phenomena for at least 30 years, where appropriate: wind speed, rainfall intensity, and temperature and storm surges.</td><td>IAEA NS-R-3, NS-G-3.4</td><td></td></tr>
<tr><td>Rare Meteorological Events

The following rare meteorological events should be evaluated:

a) <u>Lightning</u>: The potential for the occurrence and the frequency and severity of lightning shall be evaluated for the site, including the influence of lightning events on the risks of natural fire hazards.

b) <u>Tropical Storm</u>: The potential for tropical storm in the region of the site shall be evaluated. The following potential factors are included in the assessment:
i) Wind speed and pressure effects;
ii) Wind-propelled missiles that could have impact on structures, systems and components or that could render off-site power supplies unavailable;
iii) Effect on emergency plan execution; and
iv) Possibility of affecting releases from the NPP into the environment.

c) <u>Temperature and Humidity</u>: The following potential factors are included in the assessment of temperature and humidity:
i) Effects of sudden or prolonged extreme temperatures on future plant SSCs that will be important to safety (e.g. cooling</td><td></td><td></td></tr>
</table>

SCOPE	ASPECT	CRITERIA	REFERENCE	REMARKS
		air intakes); ii) Effects of condensation and evaporation on future plant SSCs that will be important to safety (e.g. electronic components); and iii) Potential for temperature and humidity to affect releases from the NPP into the environment.		
	Flooding Events	**Floods due to rainfall and other causes** The following should be evaluated: a) The potential of flood, based on the following: i) the height of the water; ii) the height and period of the waves; iii) the warning time for the flood; iv) the duration of the flood; and v) the flow conditions. b) Potential for instability of the coastal area or river channel due to erosion or sedimentation.	IAEA NS-R-3, NS-G-3.5	
		Tsunami or water waves induced by earthquakes or other geological phenomena Determine the potential for tsunamis or seiches that could affect the safety of a NPP on the site based on historical data relating to tsunamis or seiches affecting the shore region around the site. The evaluation includes: a) determination of the frequency of occurrence; b) magnitude; and c) height of regional tsunamis or seiches, with account taken of any amplification due to the coastal configuration at the site.	IAEA NS-R-3, NS-G-3.5	The hazards associated with tsunamis or seiches shall be derived from known seismic records and seismotectonic characteristics as well as from physical and/or analytical modeling. These include potential draw-down and run-up that may result in physical effects on the site.

SCOPE	ASPECT	CRITERIA	REFERENCE	REMARKS
		Floods and waves caused by failure of water control structures Determine the following: a) ability of NPP to withstand safely all the effects of the massive failure of one or more of the upstream structures; and b) the possibility of storage of water as a result of the temporary blockage of rivers upstream or downstream (e.g. caused by landslides).	IAEA NS-R-3, NS-G-3.5	
	Geo-technical Hazards	The following should be evaluated: a) the potential for geo-technical failure (such as settlement, slope failure, etc) include the use of accepted methods of soil investigation and analytical methods to determine engineering parameter of the soil (such as shear strength, bearing capacity, settlement prediction, etc); b) the geo-technical characteristics of the sub-surface materials, including the uncertainties in them and a soil profile for design purposes; and c) the stability of the foundation material under static and seismic loading.	IAEA NS-R-3, NS-G-3.6	If there do seem to be practicable engineering solutions available, a detailed description of sub-surface conditions obtained by reliable methods of investigation shall be developed for the purposes of determination of the hazards.
	Earthquakes And Surface Faulting	**Earthquakes** The <u>hazards associated with earthquakes and ground motion</u> should be evaluated with appropriate method. *<u>Probabilistic approach</u>*: Application of the probabilistic method includes the following steps: a) Evaluation of the seismotectonic model for the site region in terms of seismic sources, including uncertainty in source boundaries. b) For each source, evaluation of the maximum earthquake magnitude, rate of earthquake recurrence and earthquake recurrence model, together with the uncertainty associated with each evaluation.	IAEA NS-R-3, NS-G-3.3	Evaluation of earthquakes may involve probabilistic and deterministic approach.

SCOPE	ASPECT	CRITERIA	REFERENCE	REMARKS
		c) Evaluation of the attenuation of earthquake ground motion for the site region, and assessment of the uncertainty in both the mean attenuation and the variability of the motion about the mean as a function of earthquake magnitude and source distance. *Deterministic approach*: The assessment of SL-2 by deterministic methods includes: a) Dividing the seismotectonic model into seismotectonic provinces corresponding to zones of diffuse seismicity and seismogenic structures. b) Identifying the maximum potential earthquake associated with each seismogenic structure and with each seismotectonic province. c) Performing the evaluation as follows: i) For each seismogenic structure, the maximum potential earthquake should be assumed to occur at the point of the structure closest to the site area, with account taken of the physical dimensions of the source. When the site is within the boundaries of a seismogenic structure, the maximum potential earthquake should be assumed to occur beneath the site. In this case, special care should be taken to demonstrate that the seismogenic structure is not capable. ii) The maximum potential earthquake in a zone of diffuse seismicity which includes the site should be assumed to occur at some identified specific distance from the site, on the basis of investigations which ensure that there are no seismogenic structures within this distance and that therefore the related probability of earthquakes occurring therein is negligibly low. This distance may be in the range of a few to about 20 kilometers and will depend on the best estimate of the focal depth of the earthquakes in that seismotectonic province. In selecting a suitable distance, the physical dimensions of the source should be taken into account. iii) The maximum potential earthquake associated with zones of diffuse seismicity in each adjoining seismotectonic province		

SCOPE	ASPECT	CRITERIA	REFERENCE	REMARKS
		should be assumed to occur at the point of the province boundary closest to the site. iv) An appropriate attenuation relation should be used to determine the ground motion that each of these earthquakes would cause at the site, with account taken of local conditions at the site.		
		Surface Faulting When capable fault[23] is known or suspected to be present, evaluation of site vicinity scale and type should be made which include: a) detailed geological– geo-morphological mapping; b) topographical analyses; c) geo-physical surveys (including geodesy, if necessary); d) trenching; e) boreholes; f) age dating of sediments or fault rocks; g) local seismological investigations; and h) any other appropriate techniques to ascertain when movement last occurred.	IAEA NS-R-3, NS-G-3.6	Consideration should be given to the possibility that faults that have not demonstrated recent near surface movement may be re-activated by large reservoir loading, fluid injection, fluid withdrawal or other phenomena.

[23] A fault shall be considered capable if, on the basis of geological, geo-physical, geodetic or seismological data, one or more of the following conditions applies:

a) It shows evidence of past movement or movements (significant deformations and/or dislocations) of a recurring nature within such a period that it is reasonable to infer that further movements at or near the surface could occur.
b) A structural relationship with a known capable fault has been demonstrated such that movement of the one may cause movement of the other at or near the surface.
c) The maximum potential earthquake associated with a seismogenic structure is sufficiently large and at such a depth that it is reasonable to infer that, in the geo-dynamic setting of the site, movement at or near the surface could occur.

EVALUATION OF HUMAN-INDUCED EXTERNAL EVENTS	Aircraft Crashes	The following should be evaluated for Type 1, 2, 3 crash rate event: a) Design Basis Event, which takes into account the physical separation and the redundancy of items important to safety, especially for vulnerable part of the NPP; b) Primary Impact and Secondary Projectile, including: i) Analysis of potential structure failure due to shearing and bending force; ii) Perforation of structure for spalling of concrete within structure; and iii) Propagation of shock wave that affect items important to safety. c) Effect caused by aircraft fuel, which covers: i) burning of aircraft fuel outdoors causing damage to exterior plant components important to safety; ii) the explosion of part or all of the fuel outside buildings; iii) entry of combustion products into ventilation or air supply systems; and iv) entry of fuel into buildings through normal openings, through holes caused by the crash or as vapor or an aerosol through air intake ducts, leading to subsequent fires, explosions or side effects. d) Design Basis Parameter, including: i) Direct impact of aircraft to NPP, including: - Distribution of mass and stiffness along the aircraft concerned (one or more), nose shape, area of impact, velocity and angle of incidence; - A load–time function; ii) Type of fuel and the maximum amount of fuel potentially involved in an accident; and iii) Estimation of the same quantities for parts of an aircraft that have become separated to form secondary projectiles.	IAEA NS-R-3, NS-G-3.1	

	Releases of Hazardous Fluids	The following should be evaluated: a) Potential hazards of hazardous liquids that have not been eliminated in primary evaluation; b) Identification of location of the liquid sources, as well as maximum inventory, quantity in-store amount otherwise contained; c) Determination of maximum quantity of hazardous that could be released, the rate of release and the related probability of release; d) Potential of rupture of a container or of any leak facility store; e) Probability of releases of hazardous liquid from mobile sources in transit, on the assumption that maximum quantity being transported is released; and f) Potential hazardous liquid interaction with nearby water intake.	IAEA NS-R-3, NS-G-3.1	The important parameters and properties for protection of the NPP against hazardous liquids are as follows: a) amount of liquid; b) surface area of the pool; c) chemical composition; d) concentration (corrosion potential); e) partial pressure of vapors; f) boiling temperature; g) ignition temperature; and h) toxicity.
	Releases of Hazardous Gases, Vapors and Aerosols	The following should be evaluated: a) The probability of occurrence of the initiating event (for example, pipe rupture); b) The quantity of material released and the release rate; c) The probability that a cloud will drift towards the NPP; d) The dilution due to atmospheric dispersion; and e) The probability of ignition for explosive clouds.	IAEA NS-R-3, NS-G-3.1	Design Basis Parameter for hazardous gases, vapors and aerosols include: a) Chemical composition; b) Concentration with time and distance; c) Toxicity limit and asphyxiant properties; and d) Flammability limit.
	Explosion	**Stationary Sources** Evaluation should be made by calculating the distance (5-10km) corresponding to the overpressure (~0.07bar).	IAEA NS-R-3, NS-G-3.1	
		Mobile Sources The following should be evaluated: a) The properties of the exploding substance; b) The properties of the pressure waves (maximum side-on or incident and reflected overpressures and evolution with time of the pressure wave); c) The properties of the projectiles generated (material, size, impact velocity); and d) The ground shock, especially for buried items.	IAEA NS-R-3, NS-G-3.1	

	Other Human-induced Events	**Fire** Parameters and properties that define the magnitude of a fire are: a) the maximum heat flux; b) the magnitude of hazards from burning fragments and smoke; and c) the duration of the fire.	IAEA NS-R-3, NS-G-3.1	
		Ship Collision The following should be evaluated: a) Impact velocity; b) Impact area; c) Mass and stiffness of the ship; d) Substances transported; and e) Potential secondary effects, such as oil spills and explosions.	IAEA NS-R-3, NS-G-3.1	
		Electro-magnetic Interferences The following should be evaluated: a) Potential sources of interference; b) Intensity; and c) Frequency.	IAEA NS-R-3, NS-G-3.1	
ATMOSPHERIC DISPERSION OF RADIOACTIVE MATERIAL		The evaluation of radioactive material dispersion in the atmosphere should cover the following: a) Radioactivity, including the rate of discharge of each important nuclide and the total activity of each important nuclide released in a specified period and variation of the rate of discharge of each important nuclide; b) Chemical characteristics of the material released; c) Physical properties of the material released; and d) Geometry and mechanics of the discharge.	IAEA NS-R-3, NS-G-3.2	Information should be collected on the background levels of activity in air due to natural and artificial sources.

DISPERSION OF RADIOACTIVE MATERIAL THROUGH SURFACE AND GROUNDWATER	Surface Water	The evaluation should cover the dose assessment related to exposure pathways in hydrosphere: a) the source term for the discharge of radioactive material to the environment; b) hydrological, physical, physicochemical and biological characteristics governing the transport, diffusion and retention of radioactive materials; c) relevant food-chains leading to humans; d) locations and amounts of water used for drinking and for industrial, agricultural and recreational purposes; and e) dietary and other relevant habits of the population, including special occupational activities, such as the handling of fishing gear and recreational pursuits, such as water sports and fishing. The following properties and parameters should be estimated for radioactive discharges: a) Radioactivity: i) the rate of discharge of each important nuclide, and an estimate of the total activity discharged in a specific period and its fixation capacity on soils; and ii) absorption and retention co-efficient for radioactive material. b) Chemical properties, including: i) important anion and cation concentrations, and their oxidation states and complexing states (e.g. Ca^{2+}, K^{+}, Mg^{2+}, Na^{+}, NH_4^{+}, HCO_3^{-}, Cl^{-}, SO_4^{-}, NO_2^{-}, NO_3^{-}, PO_4^{-}); ii) organic content; iii) pH; and iv) the concentration of dissolved oxygen, and conductivity and concentrations of associated pollutants. c) Physical properties of the liquid effluents discharged, including: i) temperature; ii) density; and iii) loads and granulometry of suspended solids. d) Flow rates for continuous discharges, or volume and frequency for batch discharges; e) Distance to nearest body of surface water;	IAEA NS-R-3, NS-G-3.2	

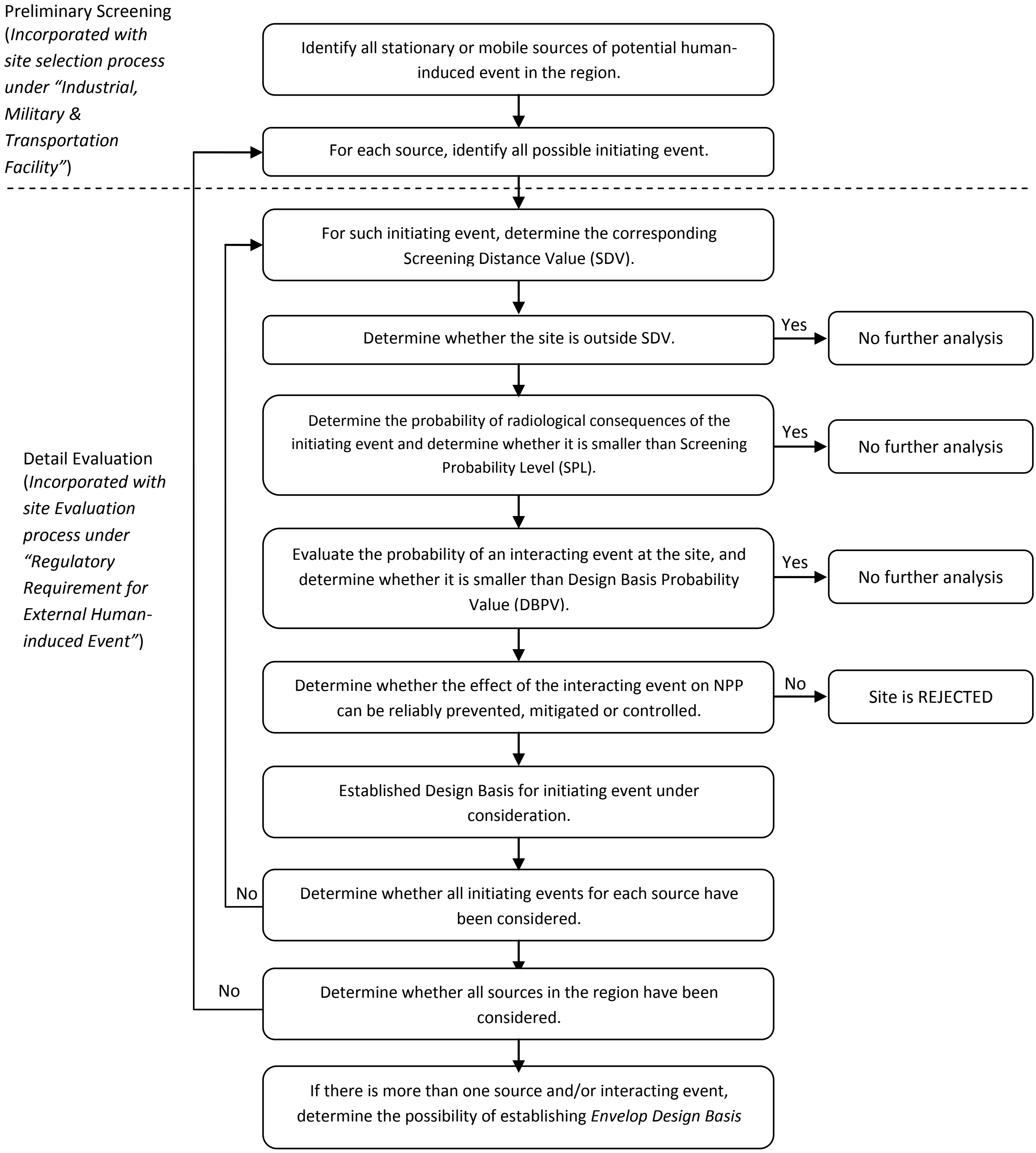
		f) The variation of the source term over the duration of the discharge, which is necessary to evaluate the concentrations due to long term releases; and g) The geometry and mechanics of discharges.		
	Groundwater	The evaluation should determine the following: a) the estimated concentration of radioactive material in groundwater at the nearest point in the region where groundwater is drawn for human consumption; b) radionuclide retention characteristic of the soil; c) the transport paths and travel times for radioactive material to reach the source of consumption from the point of release; d) the transport capacity of the surface flow, interflow and groundwater recharge; e) the susceptibility to contamination of the aquifers at different levels; and f) time and space distributions of the concentrations in the groundwater of radioactive material resulting from accidental releases from the plant.	IAEA NS-R-3, NS-G-3.2	
POPULATION DENSITY AND DISTRIBUTION		The evaluation should cover the following: a) Existing and projected population distributions in the region, and should include information on: i) Occupation; ii) Places of work; iii) Means of communication; iv) Typical diet of the inhabitants; and v) Major industrial facility associated with the town. b) Temporary population, and should cover: i) The short-term transient population, such as tourists and nomads; and ii) The long-term transient population, such as seasonal inhabitants and students.		

		c) The critical group[24] associated with each NPP with particular dietary habits and specific locations for particular types of activity in the region.		
USES OF LAND AND WATER IN THE REGION		The evaluation should cover: a) Land devoted to agricultural uses, its extent, and the main crops and their yields; b) Land devoted to dairy farming, its extent and yields; c) Land devoted to industrial, institutional and recreational purposes, its extent and the characteristics of its use; d) Bodies of water used for commercial, individual and recreational fishing, including details of the aquatic species fished, their abundance and yield; e) Bodies of water used for commercial purposes, including navigation, community water supply, irrigation, and recreational purposes, such as bathing and sailing; f) Land and bodies of water supporting wildlife and livestock; g) Direct and indirect pathways for potential radioactive contamination of the food-chain; h) Products imported to or exported from the region which may form part of the food-chain; and i) Free foods such as mushrooms, berries and seaweed. Special consideration should be given to any population centers for which drinking water is obtained from water bodies that may be affected by a NPP.	IAEA NS-R-3, NS-G-3.2	

[24] The critical group is a group of members of the public which is reasonably homogeneous with respect to its exposure for a given radiation source and given exposure pathway and is typical of individuals receiving the highest effective dose or equivalent dose (as applicable) by the given exposure pathway from the given source.

APPENDIX B

SCREENING AND EVALUATION PROCEDURE FOR EXTERNAL HUMAN-INDUCED EVENT



APPENDIX C

NECESSARY HYDROLOGICAL INFORMATION FOR SURFACE WATER DISPERSION

Sites on rivers

For sites on rivers, the hydrological and other information should cover the following:

a) The channel geometry, defined by the mean width, the mean cross-sectional area and the mean slope over the river reaches of interest (the water level can be computed from the channel geometry and the river flow rate). If there are important irregularities, such as dead zones or hydraulic equipment in the stream which could influence the dispersion of the plume, they should be described. Additional downstream measurements of channel geometry should be made as necessary to assess the dispersion process over the river reaches of interest.

b) The river flow rate, presented as monthly averages of the inverse of daily flows. The inverse rate of flow is used since the fully mixed concentration is proportional to the reciprocal of the flow rate if sediment sorption effects are not considered. The flow rates of other relevant and important water bodies (such as downstream tributaries of the river) should be measured if they affect dispersion.

c) Extremes in the flow rate evaluated from available historical data.

d) Temporal variation of the water level over the reaches of interest.

e) Tidal variations in water level and flow rate in the case of a tidal river.

f) Data to describe possible interactions between river water and groundwater, and the identification of those reaches of the channel where the river may gain water from or lose water to groundwater.

g) River temperature measured at a representative location over at least an entire year and expressed as monthly averages of daily temperatures.

h) The thickness of the top layer if thermal stratification of water in the river occurs.

i) Extreme temperatures evaluated from available historical data.

j) The concentrations of suspended matter measured:

  – at locations downstream – of sections where the river is slowed, depleted or fed by tributaries;
  – on discrete samples at appropriate intervals (such as every two months for at least an entire year); and
  – over a sufficient range of flows to establish curves of flow versus sedimentation and/or erosion rate;

k) The characteristics of deposited sediments, including mineral and/or organic compositions and size classification;

l) The distribution co-efficients for sediments and for suspended matter for the various radionuclides that may be discharged;

m) The background levels of activity in water, sediment and aquatic food due to natural and artificial sources;

n) Seasonal cycles of phytoplankton and zooplankton, with at least the periods of their presence and cyclical evolutions of their biomass; and

o) Spawning periods and feeding cycles of major fish species.

Sites on estuaries

For sites on estuaries, the following information should be collected:

a) The salinity distribution determined along several verticals covering different cross-sections of the salinity intrusion zone. The data should be sufficient to delineate the flow pattern, which is directed towards the estuary mouth in the upper layer and towards the inner reaches in the lower layer of a fully or partially mixed estuary;

b) Evaluations of sediment displacements, the load of suspended matter, the rate of build-up of deposited sediment layers and the movement of these sediments with the tide;

c) Channel characteristics sufficiently upstream of the site to model the maximum upstream travel of radioactive effluents if applicable;

d) The distribution co-efficients for sediments and for suspended matter for the various radionuclides that may be discharged;

e) The background levels of activity in water, sediment and aquatic food due to natural and artificial sources;

f) Seasonal cycles of phytoplankton and zooplankton, with at least the periods of their presence and cyclical evolutions of their biomass; and

g) Spawning periods and feeding cycles of major fish species.

Measurements of water temperature, salinity and other relevant water quality parameters in estuaries should be made at appropriate depths, distances and times, depending on the river flow, tidal levels and the configuration of the water body in different seasons.

Sites on the open shores of large lakes, seas and oceans

For sites located on the shores of large lakes, seas and oceans, the hydrological information should include the following:

a) The general shore and bottom configuration in the region, and unique features of the shoreline in the vicinity of the discharge. Data on bathymetry out to a distance of several kilometers, and data on the amount and character of sediments in the shallow shelf waters;

b) Speeds, temperatures and directions of any near shore currents that could affect the dispersion of discharged radioactive material. Measurements should be made at appropriate depths and distances, depending on the bottom profile and the location of the point of discharge;

c) The duration of stagnation and characteristics of current reversals. After a stagnation, a reversal in current usually leads to a large scale mass exchange between inshore and offshore waters that effectively removes pollutants from the shore zone;

d) The thermal stratification of water layers and its variation with time, including the position of the thermocline and its seasonal changes;

e) The load of suspended matter, sedimentation rates and sediment distribution co-efficients, including data on sediment movements characterized by defining at least the areas of high rates of sediment accumulation;

f) The background levels of activity in water, sediment and aquatic food due to natural and artificial sources;

g) Seasonal cycles of phytoplankton and zooplankton, with at least the periods of their presence and cyclical evolutions of their biomass; and

h) Spawning periods and feeding cycles of major fish species.

Sites on human-made impoundments

For sites on impoundments, the hydrological information should include the following:

a) Parameters of the impoundment geometry, including length, width and depth at different locations;

b) Rates of inflow and outflow;

c) Expected fluctuations in water level on a monthly basis;

d) The water quality at inflows, including temperature and suspended solids;

e) Data on thermal stratification and its seasonal variation for relevant water bodies;

f) Interaction with groundwater;

g) Characteristics of bottom sediments (type and quantity);

h) The distribution co-efficients for sediments and for suspended matter for the various radionuclides that may be discharged;

i) The rate of sediment deposition;

j) The background levels of activity in water, sediment and aquatic food due to natural and artificial sources;

k) Seasonal cycles of phytoplankton and zooplankton, with at least the periods of their presence and cyclical evolutions of their biomass; and

l) Spawning periods and feeding cycles of major fish species.