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IAEA SAFETY STANDARDS

for protecting people and the environment

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Draft with 32 NUSSC and 32 WASSC comments implemented

Safety Aspects in Siting for Nuclear Installations

DRAFT SPECIFIC SAFETY GUIDE No. SSG No. *x*??

DS433

Revision of Safety Guide No. SG-S9

IAEA

International Atomic Energy Agency

(Front inside cover)

IAEA SAFETY RELATED PUBLICATIONS

(to be included later)

FOREWORD

by Yukiya Amano

Director General

The IAEA's Statute authorizes the Agency to "establish or adopt… standards of safety for protection of health and minimization of danger to life and property" — standards that the IAEA must use in its own operations, and which States can apply by means of their regulatory provisions for nuclear and radiation safety. The IAEA does this in consultation with the competent organizations of the United Nations and with the specialized agencies concerned. A comprehensive set of high quality standards under regular review is a key element of a stable and sustainable global safety regime, as is the IAEA's assistance in their application.

The IAEA commenced its safety standards program in 1958. The emphasis placed on quality, fitness for purpose and continuous improvement has led to the widespread use of the IAEA standards throughout the world. The Safety Standards Series now includes unified Fundamental Safety Principles, which represent an international consensus on what must constitute a high level of protection and safety. With the strong support of the Commission on Safety Standards, the IAEA is working to promote the global acceptance and use of its standards.

Standards are only effective if they are properly applied in practice. The IAEA's safety services encompass design, siting and engineering safety, operational safety, radiation safety, safe transport of radioactive material and safe management of radioactive waste, as well as governmental organization, regulatory matters and safety culture in organizations. These safety services assist Member States in the application of the standards and enable valuable experience and insights to be shared.

Regulating safety is a national responsibility, and many States have decided to adopt the IAEA's standards for use in their national regulations. For parties to the various international safety conventions, IAEA standards provide a consistent, reliable means of ensuring the effective fulfilment of obligations under the conventions. The standards are also applied by regulatory bodies and operators around the world to enhance safety in nuclear power generation and in nuclear applications in medicine, industry, agriculture and research.

Safety is not an end in itself but a prerequisite for the purpose of the protection of people in all States and of the environment — now and in the future. The risks associated with ionizing radiation must be assessed and controlled without unduly limiting the contribution of nuclear energy to equitable and sustainable development. Governments, regulatory bodies and operators everywhere must ensure that nuclear material and radiation sources are used beneficially, safely and ethically. The IAEA safety standards are designed to facilitate this, and I encourage all Member States to make use of them.

PROMOTIONAL TEXT FOR THE BACK COVER:

Safety through international standards

“Governments, regulatory bodies and operators everywhere must ensure that nuclear material and radiation sources are used beneficially, safely and ethically. The IAEA safety standards are designed to facilitate this, and I encourage all Member States to make use of them.”

Yukiya Amano

IAEA Director General

THE IAEA SAFETY STANDARDS

(to be included later)

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1. INTRODUCTION

BACKGROUND

1.1. This Safety Guide was prepared under the IAEA's program for safety standards. It supplements and provides recommendations on meeting the requirements for nuclear installations established in the Safety Requirements publication on Site Evaluation for Nuclear Installations [1] with respect to the safety aspects to be considered during the stages of the selection process of a site for a nuclear installation. This Safety Guide complements the other Safety Guides that deal with all safety aspects of the site evaluation in respect to the effects of the external events occurring in the region of the particular site, the characteristics of the site and its environment that could influence the transfer to persons and the environment of radioactive material that may be released during the life time of the installation. The guide also deals with the population density and population distribution and other characteristics of the external zone in so far as they may affect the feasibility of implementing emergency measures.

1.2. The IAEA Safety Fundamentals publication on Fundamental Safety Principles [2] establishes that "The fundamental safety objective is to protect people and the environment from harmful effects of ionizing radiation" (Para. 2.1). Principle 8 of Reference-2 specifies that the prevention of accidents and it~~'~~s mitigation are the way to meet this objective; and establishes that "The primary means of preventing and mitigating the consequences of accidents is 'defence in depth'" (Para. 3.31). Defence in depth is provided by an appropriate combination of measures, one of which is "Adequate site selection and the incorporation of good design and engineering features providing safety margins, diversity and redundancy…" (Para. 3.32). To apply this principle, it is required (Ref. [1], Para. 2.1) that the suitability of a site for a nuclear installation be evaluated with regard to: (a) the effects of external events, which could be of natural origin or human induced, (b) the characteristics of the site and its environment that could influence the transfer to persons and the environment of radioactive material that has been released, and (c) the population density and the population distribution and other characteristics of the external zone that may affect the implementation of emergency measures.

1.3. The selection and the evaluation of a site suitable for the nuclear installation are crucial. The task at this early stage of program can significantly affect the costs, public acceptance and safety of the installation during its complete lifecycle. The~~,~~ outcome of this task may even affect the final success of the program. Poor planning and execution, lack of information and knowledge on applicable international safety standards and recognized practices could lead to faulty decision making and major delays either at the construction or at the operational stages of a nuclear installation *and to loss of public acceptance*. Faulty decisions in the site selection stage might also require major resource commitments at a much later phase of the project, if the site related design parameters are changed during the plant operation stage and, consequently, re-evaluation and upgrades would be required for plants during operation, with eventually extended shutdown periods.

1.4. The selection process of a suitable site, termed as “siting”, for a nuclear installation is a multi-faceted process where safety considerations largely dominate. A properly selected site provides two distinct levels of defence in depth. The first level is prevention and aims at decreasing the exposure to external hazards. It involves a comprehensive process of screening out sites where external hazards are dominant and designed safety measures would be necessary for site utilization. The second level is mitigation and aims at decreasing the impact of an accident on the people and environment. It involves the selection of a site with favourable dispersion characteristics of radionuclides in the air, surface as well as sub-surface water, and also terrain, population and infrastructure that would facilitate the implementation of an emergency plan.

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1.5. The siting process, from its very beginning, needs to be guided by a clearly established set of criteria or regulatory requirements. This is of particular importance for those aspects that can exclude sites. A global balance should be established between the characteristics of a site on the one hand, and specific design features, site protection measures and administrative procedures on the other hand.

1.6. In 2003, the Safety Requirements publication, “Site Evaluation for Nuclear Installations”, NS-R-3 [1] was published. This safety standard deals with the requirements for the full characterization of the site for a nuclear installation from the safety point of view, covering the entire process of the site evaluation, i.e. from the selection stage, to the assessment, the pre-operational and operational stages. Thus, Ref. [1] does not cover the initial stage of the siting process, i.e. the site survey, when studies and investigations at regional scale are performed to identify potential sites from which candidate sites are chosen.

1.7. There is now the need to update the previous IAEA Safety Guide, “Site Survey for Nuclear Power Plants”, 50-SG-S9, published in 1984 [16]~~.~~ in view of an increasing interest from Member States. The revision is necessary to streamline the Safety Guide with respect to Ref. [1] and [15] for covering the first stage of the siting process taking into account the safety requirements, especially in relation to the exclusion criteria to be applied and all the complete set of current safety guides providing recommendations to comply with such requirements during the stages of site evaluation, Refs. [3, 4, 5, 6, 7 and 8].

OBJECTIVE

1.8. The objective of this Safety Guide is to provide guidance on the siting of a nuclear installation meeting the safety objectives of the safety fundamentals [2] and in compliance with the safety requirements [1]. Recommendations on criteria and approaches are provided in order to identify suitable sites for nuclear installations complying with established safety requirements. The Safety Guide also has the objective of providing guidance on establishing a logical process for siting and establishing a suite of preferred sites any of which could be selected for the construction and operation of a nuclear installation.

1.9. This Safety Guide is intended for use by the organizations related to siting, such as regulatory bodies, government bodies, future licensees (generally the operating organizations) and their contractors.

SCOPE

1.10. This Safety Guide explicitly addresses the safety aspects of the siting process of nuclear installations. It is recognized and acknowledged that there are other aspects that play an important role in the siting process, such as security aspects, technology, economics, land use planning, cooling water availability, non-radiological environmental impact, and socio-economic aspects including public opinion.

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1.11. As the siting process progresses to screen out more and more sites (and therefore retain only a few sites), the importance of safety aspects becomes more pronounced. The data collected and the methods used for these few sites should be treated with similar care and scrutiny as for the finally selected site because this data could eventually be used in ranking process and finally in detailed site evaluation for the selected site.

1.12. The border line between the investigation processes of site survey and site evaluation may not be very distinct and this line depends on the methodology used. There is a transition between these two stages of work and this Safety Guide addresses the process that eventually terminates with the selection of site(s) for one or more nuclear installation.

1.13. This Safety Guide includes considerations for the siting of a new nuclear installation at a new site and provides recommendations for the siting of new nuclear installations that are to be collocated with other installation(s) at existing sites.

1.14. This Safety Guide addresses an extended range of nuclear installations as defined in Ref. [1]: land based stationary nuclear power plants, research reactors, nuclear fuel fabrication plants, enrichment plants, reprocessing facilities and spent fuel storage facilities. The methodologies recommended for nuclear power plants are applicable to other nuclear installations through a graded approach, whereby these recommendations can be tailored to suit the needs of different types of nuclear installations in accordance with the potential radiological consequences of their failure when subjected to external loads. The recommended direction of grading is to start with attributes relating to nuclear power plants and if possible to grade down to installations with which lesser radiological consequences are associated[1]. Therefore, if no grading is performed, the recommendations relating to nuclear power plants (chapters 2-5) are applicable to other nuclear installations.

1.15. This Safety Guide does not provide guidance on the final evaluation or characterization of a site nor establish an assessment of the site hazard for use in the design evaluation for licensing purpose. –The guide lines for final site evaluation are given in Re. [3,4,5,6,7 and 8].

STRUCTURE

1.16. Section 2 addresses the siting and site evaluation process. Section 3 provides general recommendations for the site selection of nuclear installations. Section 4 describes classification of criteria for siting process. Section 5 provides information and investigations necessary for the different stages of the site survey and site selection process (database). Section 6 deals with site survey and site selection process for nuclear installations other than nuclear power plants providing a graded approach for dealing with these installations. Section 7 provides recommendations for management systems and quality assurance requirements. Appendix A provides the database for the siting process. Annex I presents tables to be used in the siting process, including screening and ranking criteria. Annex II provides example of criteria for the siting process of nuclear power plants. Annex III provides an example of a procedure for comparing different factors for ranking the candidate sites. The numerical values provided in the annexures are examples only and used in some member states.

[1] For sites at which nuclear installations of different types are collocated, particular consideration should be given to the use of a graded approach so that siting evaluation is commensurate to the most hazardous nuclear installations.

2. GENERAL DESCRIPTION OF SITING AND SITE EVALUATION PROCESS

2.1. There are two processes related to the safety aspect of a nuclear installation site – siting and site evaluation. Further these two processes spread over five stages;

- site survey,
- site selection,
- site assessment,
- pre-operational, and
- operational.

The framework for the site survey and site evaluation stages is elaborated in the schematic representation shown in Fig.1.

2.2. Siting is the process of selecting a suitable site for a nuclear installation using adequate criteria. The selection of a suitable site is one of the elements of the concept of defence in depth for preventing accidents as set out in Principle 8 of Fundamental Safety Principles [2].

2.3. The siting process for a nuclear installation consists of the first two stages, i.e. site survey and site selection, Fig.1. In the site survey stage, large regions are investigated to identify potential available sites and to choose one or more candidate sites. The second stage of siting process is site selection during which the candidate sites are evaluated to arrive at the preferred sites.

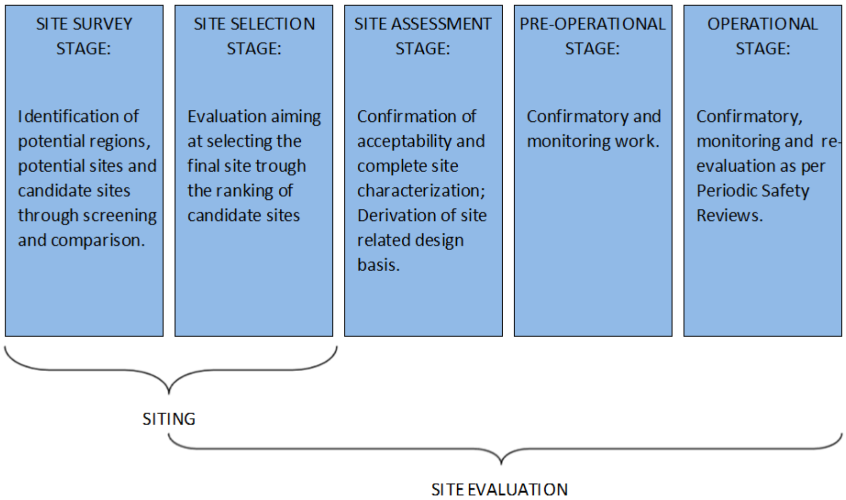

Figure 1: Siting and Site Evaluation Process in the Lifecycle of Nuclear Installation

2.4. Site evaluation is the process that extends from (a) the last stage of the siting process (i.e. the phase of evaluation of the candidate sites in order to arrive at the preferred site (s)); to (b) the detailed assessment of the selected site to confirm its suitability, its characterisation and derivation of the site related design bases for the installation; to (c) the confirmation and completion of the assessment during the pre-operational stage of the installation (i.e. during the design, construction, assembly and commissioning stages); and finally to (d) the operational stage of the installation (see Para 1.8 and 1.14 of Ref. [1]).~~ Thus, site evaluation continues throughout the entire lifetime of the installation to take into account the changes in site characteristics, availability of data and information, operational records, regulatory approaches, evaluation methodologies and safety standards [1,3,4,5,6,7,8].~~ Thus, site evaluation continues throughout the entire operating lifetime of the installation with applicable components captured in the Final Safety Analysis Report (FSAR) to take into account the changes in site characteristics, availability of data and information, operational records, regulatory approaches, evaluation methodologies and safety standards [1,3,4,5,6,7,8].

2.5. The second stage of the siting process includes a part of the "site evaluation" and is the overlapping stage between the siting and site evaluation processes (see Figure 1). After the site selection stage, the confirmation of site suitability and a complete site characterization are performed along with derivation of the design bases due to external events during the site assessment stage. This process eventually leads to the preparation of the Site Evaluation Report (SER) as a basis to the Site Chapter of the Preliminary Safety Analysis Report (PSAR) of the nuclear installation. All the site related activities, involving confirmatory and monitoring work, are taken up in the pre-operational stage~~, after the approval of the SER by the regulatory authority~~. With the approval of the Final Safety Analysis Report (FSAR) of the nuclear installation, the site evaluation during the operational stage starts. This includes all confirmatory, monitoring and re-evaluation work throughout operational stage and, especially, during periodic safety reviews of the installation. This portion of work is generally reported in Periodic Safety Review (PSR) reports. Outcome vis-à-vis stages of siting and site evaluation processes are described in Fig.2.

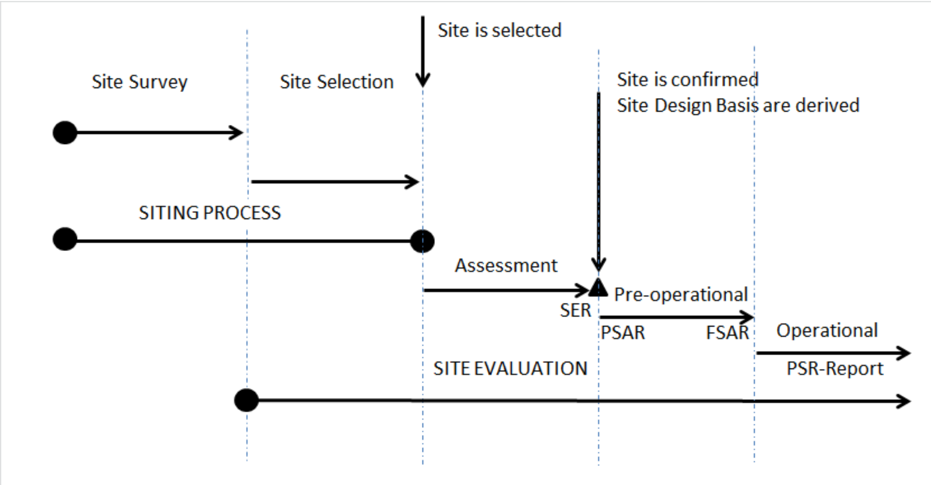

Figure 2: Outcome of Siting and Site Evaluation Process for Nuclear Installation

2.6. The siting and site evaluation processes should comply with the licensing process defined by the Regulatory Body~~Authority~~ and be consistent with IAEA Safety Standards on this topic [9, 10].

2.7. There are three important steps that will receive input from the site survey, site selection and the site evaluation process before construction starts. These are:

(a) Decision regarding the 'suitability' of the preferred site, i.e. confirmation that the site has no characteristics that would preclude the safe operation of a nuclear installation.

(b) The definition of the site related design basis parameters based on the Site Evaluation Report.

(c) The review of the PSAR or preliminary safety case which, inter alia, demonstrates that the site related design basis parameters have been appropriately accounted for through design features, measures for site protection.~~, and administrative procedures~~.

3. GENERAL RECOMMENDATIONS FOR THE SITING PROCESS OF NUCLEAR INSTALLATIONS

SITING PROCESS

3.1. Siting should be a process of selecting suitable locations for a nuclear installation such that ~~its~~site characteristics inherently makes its exposure to natural and human induced hazards of external events as low as practicable. Further, the surrounding demographic setting and dispersion characteristics should be conducive to the implementation of mitigation measures in the case of radiological release.

3.2. The siting process consists of a series of related activities with the objective of selecting the suitable site(s) for the new nuclear installation. The process should systematically ~~should~~ apply a series of screening criteria to screen out those sites with less favourable attributes that contribute to the safety and viability aspect of the site. Details of a siting process for a nuclear installation are~~is~~ described in Fig.3.

3.3. The siting process has three distinct steps starting with given region(s) of interest.

(1) Regional analysis: This is the first step, in which region(s) of interest are analysed to identify potential sites. It is important to consider all the potential sites in this phase and not to discard any without appropriate justification.

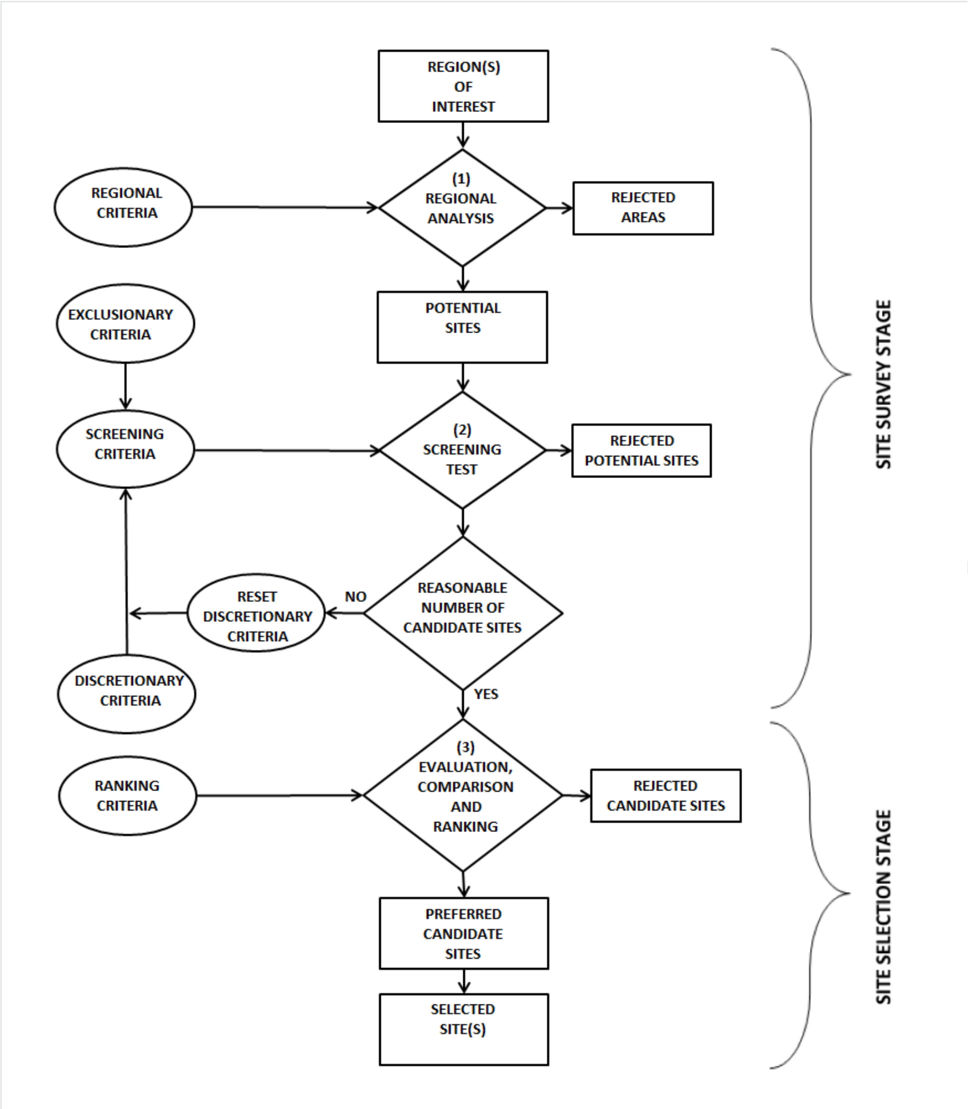

Figure 3: Flow Diagram for Siting Process for Nuclear Installations

(2) Screening test: In the second step, the potential sites are screened to choose the candidate sites. The principal objective of this step is to exclude the unfavourable sites from safety as well as non-safety considerations.

(3) Evaluation, comparison and ranking: Purpose of the third step is twofold: (i) to evaluate the site in order to assure there are no features at the sites that would preclude the construction and operation of the~~a~~ nuclear installation, and (ii) to compare the candidate sites and rank them in the order of their attractiveness as a nuclear installation site.

~~The first two steps fall into the first stage, while the third one in the second stage of siting process. Each step should refine the exercise of selection by removing from subsequent considerations those sites, which has less favourable attributes than the others.~~

3.4. Since most of the siting process is conducted using existing data, it is possible that some exclusionary considerations may emerge during the site assessment stage that may lead to site~~its~~ exclusion. To accommodate such a situation, a set of preferred candidate sites should be arrived at from the candidate sites. This allows the selection of alternative sites in the event that the first selected site later encounters serious safety or other issues that are discovered as a result of information from site specific investigation during the site assessment stage.

3.5. Finally the siting process is completed once the site on which the nuclear installation will be located is selected from the preferred candidate sites. The final selection is generally done by the owner organization of the nuclear installation taking input from~~-~~ all the stake holders.

SITING CRITERIA

3.6. Siting criteria are the bases (or the principles) by which decisions are made, on the site attributes during the different steps of the siting process. Siting~~e~~ criteria are used to evaluate site related specific issues, events, phenomena, hazards and other considerations after the site has been investigated and analysed. It is apparent from Fig.3 that there should be three categories of siting criteria,~~;~~ regional~~-~~ criteria, screening criteria and ranking criteria.

3.7. The regional analysis should be done to identify potential sites using well established "Regional-criteria". Regional criteria are generally related to national domestic policy, national economic policy or other related policies of the Member State. Technical constraints and the availability of resources (e.g. Water, infrastructure, etc.) on a regional basis are also important considerations for regional analysis. The important aspect of the regional criteria is that these criteria should identify all possible potential sites and not to discard any without appropriate justification.

3.8. The screening of potential sites should be conducted using two types of screening criteria:

- Exclusion criteria: the exclusion criteria is used to discard sites that are unacceptable from those attributes related to issues, or events or phenomena or hazards for which engineering solutions are not generally practicable.

- Discretionary criteria: the discretionary criteria are associated with those attributes related to issues, or events, or phenomena, or hazards, or considerations for which protective engineering solutions are available.. These criteria, listed in Table I-1 of Annexe 1, are used to facilitate the selection process through iterative screening to eliminate less favourable sites when a large number of possible candidate sites exist.

3.9. The preferred sites are arrived at through an exercise of comparison and ranking of the candidate sites after their evaluation. The exercise of comparison and ranking should be conducted applying ranking criteria.

3.10. The screening and ranking criteria consist of both safety related as well as non-safety related criteria. Screening and ranking criteria are further elaborated in Annex I.

GENERAL BASIS FOR SCREENING CRITERIA

3.11. Exclusion criteria should be established and used as part of the screening in the site survey stage. Screening by exclusion criteria enables indicates that sites with unfavourable characteristics should to be excluded from further consideration ~~Screening by exclusion criteria indicates that sites with unfavourable characteristics should be excluded from consideration at an early stage of the site survey stage.~~

3.12. Exclusion criteria should be selected for the negative attribute of a site characteristic, or any site related issue, event, phenomena and hazard for which engineering, site protection or administrative measures are not available or are excessively demanding.

3.13. Exclusion criteria that are used in screening out unfavourable potential sites are generally related not only to weaknesses related to site conditions but also to the feasibility of engineering solutions to compensate for these weaknesses either through design or site protection measures. Therefore, existence of a certain hazard or even the high likelihood of its occurrence should not constitute the sole basis upon which an exclusion criterion is based.

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~~Screening out based on an arbitrary safety criterion may discard a site having otherwise favourable safety qualities and finally result in the choice of a site that may be less 'safe' than the one that has been discarded.~~ Screening out based on an arbitrary safety criterion may discard a site having otherwise favourable safety qualities ~~and finally result in the choice of a site that may be less 'safe' than the one that has been discarded~~. Screening out based on an arbitrary safety criterion may discard a site having otherwise favourable safety qualities and finally result in the choice of a site that may be less 'safe' than the one that has been discarded.

3.14. Discretionary criteria should be redefined to:

- decrease the number of possible candidate sites if the number of these is too large to conduct the exercise of comparison and ranking.
- increase the number of candidate sites if this number is too small or none.~~It should also be used in the reverse case in which the number of candidate sites is too small or none~~.

~~3.14.~~ This is generally an iterative process in which criteria may be made more or less strict depending on the desired number of potential sites for further consideration. Attributes related to these criteria are also used for preliminary evaluation of site in the site selection stage of siting process.

3.15. As a result of the iterative screening of potential sites, a number of candidate sites are identified. ~~It is generally advantageous~~ ~~I~~if candidate sites are dispersed to two or more regions with different attributes. This would prevent the eventual elimination of all the candidate sites due to a common and regional shortcoming.

3.16. Siting process of a nuclear installation is expected to be completed using existing data. However, at early stage, especially the site survey stage, it may not always be possible to collect sufficient amount of good quality data on which such a decision could be based with adequate certainty. In such case, data should be collected to confirm the site suitability in the subsequent site selection stage. Some preliminary field investigation, if required, may be conducted in this stage.

3.17. Data collection related to potential and candidate sites should focus on attributes of these sites that may play a significant role as exclusion criteria to the extent possible.

SPECIFIC SCREENING CRITERIA

3.18. The site safety requirements cited in Ref~~.~~ [1] ar~~e~~es the primary source for establishing the screening criteria to the siting process~~. The site safety requirements~~ are reproduced below.

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~~(Following paragraphs, 1-8, are excerpt from reference - 1 will be edited as per IAEA standard practice)~~

1 In relation to the characteristics and distribution of the population, the combined effects of the site and the installation should be such that:

(a) *For operational states of the installation the radiological exposure of the population remains as low as reasonably achievable and in any case is in compliance with national requirements, with account taken of international recommendations.*

(b) *The radiological risk to the population associated with accident conditions, including those that could lead to emergency measures being taken, is acceptably low. If the design of the nuclear installation is not known a bounding analysis that would envelope envisaged technologies should be performed to estimate the radiological risks. If, after thorough evaluation, it is shown that no appropriate measures can be developed to meet the above mentioned requirements, the site shall be deemed unsuitable for the location of a nuclear installation of the type proposed.*

2 Before a construction license or permit is granted, it shall be confirmed that there will be no insurmountable difficulties in establishing an emergency plan for the external zone before the start of operation of the plant.

3 Where reliable evidence shows the existence of a capable fault that has the potential to affect the safety of the nuclear installation, an alternative site shall be considered.

4 If *the evaluation shows that there is a potential for collapse, subsidence or uplift of the surface that could affect the safety of the nuclear installation, practicable engineering solutions shall be provided or otherwise the site should be deemed unsuitable.*

5 If *the potential for soil liquefaction is found to be unacceptable, the site shall be deemed unsuitable unless practicable engineering solutions are demonstrated to be available.*

6 The *hazards associated with an airplane crash to be considered shall include impact, fire and explosions. If the assessment indicates that the hazards are unacceptable and if no practicable solutions are available, then the site should be deemed unsuitable. The airplane crash event mentioned here is considered to be of accidental origin.*

7 The region should be investigated for installations (including installations within the site boundary) in which flammable, explosive, asphyxiate, toxic, corrosive or radioactive materials are stored, processed, transported and otherwise dealt with that, *if released under normal or accident conditions, could jeopardize the safety of the installation. Hazards associated with chemical explosions should be expressed in terms of overpressure and toxicity (if applicable), with account taken of the effect of distance. If the effects of such phenomena and occurrences would produce an unacceptable hazard and if no practicable solution is available, the site shall be deemed unsuitable.*

8 Potential *natural and human induced events*[2] *that could cause a loss of function of systems required for the long term removal of heat from the core should be identified, such as the blockage or diversion of a river, the depletion of a reservoir, an excessive amount of marine organisms, the blockage of a reservoir or cooling tower by freezing or the formation of ice, ship collisions, oil spills and fires. If the hazards for the nuclear installation are unacceptable and no practicable solution is available, the site shall be deemed unsuitable.*

BASIS FOR RANKING CRITERIA

3.19. Ranking criteria are necessary to provide bases for comparison among the candidate sites to arrive at a list of preferred sites. For safety related issues, comparison within topics is generally quite straightforward. For example, sites with relatively higher seismic hazard would be penalized in comparison with those in more stable areas. What is more difficult is comparison across the topics, in other words comparing a site with higher seismic hazard but lower flood hazard with another site having the opposite characteristics. There are various ways of dealing with this type of situation as illustrated in Annex III.

3.20. Ranking criteria are~~is~~ generally developed using the considerations related to discretionary criteria along with relevant non safety related issues and considerations.

3.21. A sufficient amount of data should be collected before a comparison is made between two (or more) sites regarding the same topic. To the extent possible the amount and quality of the data upon which the comparison is based should be similar for the regions or sites being compared.

3.22. The candidate sites are ranked in order to arrive at the preferred site or several preferred sites. Ranking involves cross comparison of sites with respect to all their attributes, both safety related and non-safety related. This may involve weighting of various attributes in a matrix form. It is also possible to quantify the differences of each site with respect to a

[2] This term had been used in earlier safety standards [1, 3], to which the draft safety guide 433 is referred to.

reference site/installation combination. For many of the attributes, there exists more than one quantification parameter (e.g. the differential cost with respect to a reference site/plant combination) as the basis of comparison and ranking.

3.23. One preference criterion between candidate sites may be the likelihood that the specific site parameters are within the standard plant parameter envelope of potential nuclear installation suppliers. Suppliers of nuclear installation technologies typically offer non-site specific generic design information for consideration in bounding envelope cases being used for a siting exercise. This information identifies some of the design bases for site related load cases. ~~The siting organization can then use this~~ Such information can be used to either screen out candidate sites or decide where design changes may need to be made to bring the design into the site bounding envelope. When considering a vendor's generic information~~,~~ ~~the siting organization~~ should examine the bases and credibility of the vendors' generic information, particularly in first-of-a-kind designs.

SITING OF NEW NUCLEAR INSTALLATIONS AT EXISTING SITES

3.24. The siting process, as discussed above, is for construction of new nuclear installation in new sites. Similar process should be used for siting of a new installation in an existing site with certain special considerations, which are discussed below. The existence of a nuclear installation should not lead to an automatic assumption that the site is suitable for a new nuclear installation. The site evaluation process should be conducted at the same level of rigor as that for a new site.

3.25. There are several issues which need special attention, when sites:

- that have been selected in the context of an earlier nuclear installation project and are to be re-assessed to confirm up-to-date safety requirements
- ~~or that~~ have been discontinued are re-considered for a new nuclear installation project.

~~3.25.~~ These include the completion of data, considerations for new regulations and standards, considerations for new methods of analyses and lessons learned from recent external hazards, if relevant.

3.26. If the new site being considered is close to or adjacent to an existing nuclear installation site, the impact of existing site on the new site, and vice versa, should be considered. The impact of a new installation in an existing site should be assessed in a composite manner. Considerations for such cases should include:

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(a) Any design/operational restrictions arising from the way the existing site is operated. For example, the heat sink requirements of the operation of existing facilities may have significant bearing on the design of heat sink system of the new one.

(b) The nuclear hazards arising from accidental events on the existing site involving release of nuclear materials and/or radiation shine. The nature of accidental events will depend on the type ~~of activities taking place,~~ where they occur, e.g. nuclear power reactor, nuclear spent fuel storage, or~~and~~ nuclear fuel reprocessing plant~~facility~~.

(c) Conventional hazards arising from accidents on the existing site involving e.g. release of toxic chemicals, explosions, missiles, flooding, etc.

(d) Interactions between the emergency arrangements for both new and existing sites.

(e) Some hazardous events, e.g. loss of grid supplies, and most external hazards can initiate common cause faults, on all the nuclear installations at the site and the effects of these~~is~~ should be accounted for.

(f) Compliance with dose and risk criteria from the combined sites under both normal operations and accident conditions :

- *Normal operational doses to members of the public and environment*: It is to be expected that normal operations doses to members of the public may increase since the new facility will form an additional source term. Whether this new contribution ~~is significant and~~ requires additional protection over what would be expected if the new facility was on an isolated site should be established.

- *~~A~~Accident condition doses and risks*: ~~The new facility provides its own contribution to accident condition doses and risks to members of the public. Where the accidents from each facility are independent, then although the net combined contribution to risk should be established it is likely to be small. However, where the accident initiator is a common cause event, such as earthquake (in fact most external hazards would likely fall into this category), then both risks and doses to members of the public outside the site may be significantly higher for the combined site.~~ The new facility provides its own contribution to accident condition doses and risks to members of the public. Where the accidents from each facility are independent, then although the net combined contribution to risk should be established it is likely to be small. However, where the accident initiator is a common cause event then both risks and doses to members of the public should be assessed considering that all facilities at the site are simultaneously challenged outside the site may be

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higher for the combined site. This may warrant additional protection measures being applied to the new or both nuclear facilities to meet site wide dose and risk criteria, and in order to keep doses and risks as low as reasonably achievable.

- ~~Local regulatory requirements should be followed in determining site boundary and dose acceptance criteria~~
- ~~Emergency preparedness planning~~

(ii) Where the new facility forms a separate site immediately adjacent, or very close to, an existing site, then it is to be expected that the physical effects to people outside the combined sites will be similar to those noted above. Additional protective measures may still be required from one or both sites to keep doses and risks as low as reasonably achievable.

(iii) Doses and risks to workers on the site(s) should also be considered in terms of the combinations effects of the~~both~~ installations, and additional precautions taken if appropriate to keep doses and risks as low as reasonably achievable.

3.27. Information exchange between site operators: The developers of the new site should expect the operators of the exiting site to seek information from them on the issues identified above. Similarly, the developers of the new site will need information from the existing site operator to inform their own safety judgments. It is therefore beneficial for both parties to establish a working relationship early on in the development of the new site, so that information on these issues can be made available to either party as and when needed.

4. CLASSIFICATION OF SITING CRITERIA

4.1. Criteria used in siting process of a nuclear installation are classified as follows

- Safety related criteria,
- Criteria related to protection against ~~sabotage~~ malevolent acts, and
- Non-safety related criteria.

Criteria falling under any of the above class may be screening (exclusionary, or discretionary) criteria, or ranking criteria.

SAFETY RELATED CRITERIA

4.2. Safety related criteria to be considered in the siting process should be consistent with the requirements in IAEA NS-R-3 [1] and the associated safety guides related to the site evaluation of nuclear installations. In Section 3, the tasks during site survey and site selection stages are presented. These should be done through the use of screening (exclusionary or discretionary) and ranking criteria.

4.3. From a thematic perspective, these criteria are classified in four sets that should be complied with during siting process of a nuclear installation.

4.4. The first set of criteria is related to the potential impact of natural hazards on the safety of the nuclear installation. In this context, the following natural hazards should be considered:

(a) Capable faults (i.e. faults that may cause surface displacement near the nuclear installation)

(b) Vibratory ground motion due to earthquakes

(c) Volcanic hazards

(d) Coastal flooding or low water intake level (due to wave action, storm surges, seiches, ~~tsunamis, combinations with tides – sea water level variations and extremes)~~

~~(d)~~(e) Tsunamis in combinations with tides – sea water level variations and extremes,

~~(e)~~(f) River flooding or low water intake level (overtopping of banks, failure of water retaining structures such as dykes or dams)

~~(f)~~(g) Combination of coastal and river flooding (in estuaries, e.g.), flash floods due to intense precipitation or downburst

~~(g)~~(h) High winds, both straight winds such as hurricanes, tropical storms and rotational winds such as tornadoes, local phenomena such as sand dust and storms.

~~(h)~~(i) Other extreme meteorological events such as droughts, extreme precipitation, including snow pack; extreme hail; extreme temperatures, including the temperature of the source of the cooling water~~;~~ and lightning.

~~(i)~~(j) Geotechnical hazards such as slope instability, soil liquefaction, landslides, rock fall, avalanche, permafrost, erosion processes, subsidence, uplift and collapse

~~(j)~~(k) Forest fire

~~(k)~~(l) Credible Combinations of events

4.5. The second set of criteria is related to the potential impact of human induced hazards on the safety of the nuclear installation. In this context and in accordance with recommendations presented in Ref. [3], the following sources for human induced hazards should be considered:

(a) Stationary sources

(i) Oil ~~refineries~~and Gas operations, chemical plants, hazardous material processing or storage facilities, broadcasting and communication networks, mining or quarrying operations~~, forests~~, other nuclear facilities, high energy rotating equipment, hydraulic engineering structures

(ii) Military facilities (permanent or temporary) especially shooting ranges, arsenals

(iii) Electromagnetic interference

~~(iii)~~(iv) Commercial munitions plants

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(b) Mobile sources

(i) Railway trains and wagons, road vehicles, ships, barges, pipelines

(ii) Airport zones (civil and military)

(iii) Air traffic corridors and flight zones (both military and civilian)

4.6. The third set of criteria is related to the characteristics of the site and its environment that could influence the transfer to persons and the environment of radioactive material that has been released from the nuclear installation. In this context, the following phenomena should be considered:

(a) Atmospheric dispersion of radioactive material

(b) Dispersion of radioactive material in surface water

(c) Dispersion of radioactive material in ground water

(d) Population density and population distribution and distance to centres of population including projections for the lifetime of the nuclear installation.

(e) Common cause failure due to external hazards for multi-unit sites.

4.7. The fourth set of criteria is linked to the third set but it relates mainly to the demonstration of the feasibility of emergency plan implementation for the nuclear installation. In this context, the following phenomena should be considered:

(a) Physical site characteristics that may hinder emergency plans (particular geographical features such as islands, mountains and rivers)

(b) Infrastructure characteristics related to the implementation of emergency plans (especially local transport and communications network)

(c) Population land and water use considerations (e.g. special groups of the population who are difficult to evacuate or shelter)

(d) Special considerations prescribed by the Regulatory Body for special zones, such as the exclusion area boundary, low population zone, etc.

(e) Industrial facilities which may entail potentially hazardous activities.

(f) Agricultural activities that~~ose~~ are sensitive to possible discharges of radionuclides.

(g) Impact of concurrent external hazards on infrastructure.

4.8. Examples of criteria for the siting process are presented in Annex II.

CRITERIA RELATED TO PROTECTION AGAINST ~~S~~MALEVOLENT ACTS ~~ABOTAGE~~

4.9. Following criteria should be considered to site a nuclear installation in a location from the consideration of protection against ~~sabotage~~ malevolent acts.

~~(a) A site of nuclear installation is not preferably located near to an area or a facility with high potential threat.~~

~~(b) It is preferable to locate a site not having clear view of sight from all directions.~~

~~(c) The access to the site should be restricted to a minimum number required for safety and operational considerations.~~

~~(d) Site characteristics should be such that the ultimate heat sink, if any is not readily accessible to unauthorized personnel.~~

(a) ~~The site should be away from the population centres and public transportation routes.~~The site is sufficient in size for the establishment of security boundaries (e.g. owner controlled area, protected area and vital areas) having enough spatial distance between each boundary to ensure adequate separation for the implementation of associated security measures.

(b) The site is also sufficient in size to accommodate the installation of security equipment and measures such as physical barriers, protected area perimeter isolation zones, protected area perimeter intrusion detection and assessment equipment, vehicle search areas (sally ports), and the implementation of a physical protection program and protective strategy.

(c) The site characteristics that may require measures in order to control approaches to the facility (e.g., barge slips within the OCA, main access road from OCA to PA, transportation routes, cliffs, depressions, hills, mounds, open waterways, and roadway or railroad that penetrate the OCA boundary).

(d) The evaluation of site characteristics (location, size and proposed site layout) for potential negative impacts between safety and security, “Safety/Security Interface.” This criterion should address the identification of any potential conflicts that the proposed physical protection program and plant operational programs may pose to each other (including the installation, location, and configuration of proposed structures systems and components).

(e) Identifying and addressing (re-routing, eliminating, or protecting) existing culverts or unattended openings such as underground pathways (e.g. irrigation ditches, water

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4.10. The criteria related to protection against sabotage used in the siting process are generally discretionary and are also used for ranking purposes.

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~~4.10.~~ NON-SAFETY RELATED CRITERIA

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4.11. ~~OTHER CRITERIA~~ In the site survey and site selection process another set of criteria are concerned with considerations that are not directly related to nuclear safety or protection against maleviolent acts~~sabotage~~. They need to be considered together with the nuclear safety related aspects related to protection against malevolent acts ~~sabotage~~ in an interactive manner especially in the ranking of the candidate sites. See document [11].

4.12. Some examples of aspects to be considered that are not directly safety related include (but is not necessarily limited to) the following:

~~(a) Topography~~

~~(b) Availability and access conditions to condenser cooling water~~

~~(c) Transport routes and communication networks~~

~~(d) Proximity to load centres~~

~~(e) Non-radiological environmental impact including ecological considerations~~

~~(f) Socio-economic aspects including public acceptance~~

~~(g) Land use planning~~

~~(h) Aboriginal considerations~~

(a) ~~Power Supply~~ Terrorist threat environment for proposed site location

(b)) Law enforcement capabilities for proposed site location

~~(i)~~(c)

5. DATA NECESSARY AT DIFFERENT STAGES OF SITING PROCESS

5.1. The whole site selection should rely upon a grading data process. In particular, the site survey phase should be based on information and data principally collected from existing sources such as available records, satellite imageries, topographic sheets, and information available from local authorities and other institutions. If a potential site could not satisfy all the screening criteria based on collected information during site survey stage but is likely to satisfy these criteria with the help of additional study/investigation, such investigation / study and the related screening test should be initiated as soon as possible so that their results are available in the next stage, i.e. site selection stage. The input information/data collected during site survey are important for all site related activities prior to construction.

5.2. The siting process for a nuclear installation starts on a regional basis and with each step focuses more and more on potential sites and candidate sites. The data acquisition and processing for these stages should be in line with the purpose and accordingly should generally start with regional data presented in large~~small~~ scales (coarser data; data of low resolution) to local data presented in small~~larger and larger~~ scales (f~~iner and~~ finer data; data of ~~higher and~~ higher resolution) .

5.3. For each subject under consideration, the data should be collected in a coordinated manner with other subjects. The detail of different sets of data should be consistent with the aims of the specific steps of the siting process and should be similar across different topics.

5.4. The analyses performed based on the collected data should consider the total operating lifetime of the nuclear installation. Appropriate projections should be made especially in relation to parameters that may show significant variation with time. Data that may change more slowly should also be considered. In this context the potential impact of climate change ~~global warming~~ to site related hazards should be considered, as presented in [6], especially in terms of the possibility of increased rate and intensity of extreme meteorological and hydrological phenomena.

5.5. The general approach to site surveys and site selection should be directed towards reducing the uncertainties at various steps of the siting process in order to obtain reliable results driven by data. Experience shows that the most effective way of achieving this is to collect a sufficient amount of reliable and relevant data. There is generally a trade-off between the time and effort necessary to compile a detailed, reliable and relevant database and the degree of uncertainty that the analyst should take into consideration at each step of the process.

5.6. The acquisition and processing of data to be used in relation to siting criteria should be performed with the quality requirements needed for this purpose, as recommended in Section ~~7.~~

5.7. All site data should be collected in a systematic, transparent, retrievable or traceable manner. The use of tools such as Geographical Information System (GIS) should be considered especially for the data collected in relation to the preferred candidate sites.

5.8. The following databases should be established for the siting process and are~~is~~ further elaborated in detail in Appendix-A:

(a) Geological database

~~(a)~~(b) Hydrogeologic database.

~~(b)~~(c) Seismological database

~~(c)~~(d) Fault displacement database

~~(d)~~(e) Volcanological database

~~(e)~~(f) Geotechnical database

~~(f)~~(g) Coastal flooding database

~~(g)~~(h) River flooding database

~~(h)~~(i) Meteorological extreme events and rare events database

~~(i)~~(j) Human induced events database

~~(j)~~(k) Population and environmental aspects database

5.9. For each of the siting criteria, especially the screening and ranking criteria, one or more of these databases will be needed to inform a judgment as to whether the site should be kept or screened in or out, and if kept, how it should be ranked with respect to other candidate sites. Not all databases need to be considered for every criterion.~~.~~ Each of the databases is described in Appendix A, and criteria associated with the databases are listed in Table I-1.

5.10. A two-stage process has been described for siting in Sections 2 and 3. It is intended that a graded approach is adopted for this process. The initial Site Survey Stage should collect readily available data from relevant national and local authorities and other organizations, including contextual maps to undertake a qualitative desk-top study in order to establish relatively quickly whether the site can be screened in with respect to exclusionary criteria, and their likely impacts on the site for discretionary and ranking criteria. The extent of data collection and analysis cannot be defined explicitly in this guide since they are likely to be country and site specific.

5.11. In the second stage, it is intended to conduct a more detailed examination of how the site fares against the ranking criteria. The objective of this stage is to provide sufficient information and analysis to enable confident judgments to be made using the ranking criteria. It is anticipated that at the end of this stage, a firm decision and reasoning on site selection should be made by the site owner/operator.

5.12. To enable activities of the second stage, it is anticipated that more data will need to be collected and analysis work to be undertaken. For example, comprehensive relevant literature surveys and in some cases, bespoke field-work will be required, e.g. to identify local sub-map scale topographical features of significance, and confirm geological features from local rock exposures, etc.

5.13. Since the data on many external hazards is likely to be limited and of variable quality, it is anticipated that some quantitative analyses will be required, e.g. for:

(a) Accidental aircraft crash hazard

(b) Effects at the proposed site of nearby industrial facilities, for example impact of fires and chemical explosions, dispersion analysis for hazardous~~toxic~~air borne releases ~~plumes~~ that could affect the site.

(c) More detailed analysis of local fault displacement capability

(d) ~~Possibly an e~~Estimate of seismically induced soil liquefaction potential at the site.

(e) Generating a set of hazard curves for extreme meteorological and flooding events, e.g. wind, precipitation, temperature, sea and river flooding, etc., covering return periods applicable to the nuclear installation in question.

5.14. ~~The judgments made at this stage should be sufficiently robust so that there is a high degree of confidence that they will not be undermined by further work. There should be high confidence therefore that new data will not be discovered that would overturn site selection judgments, and more refined analyses should not expect to cast doubt on them~~. The judgments made at this stage should be sufficiently robust so that there is a high degree of confidence that they will not be undermined by further work. There should be high confidence therefore, i.e; that new data will not be discovered that would overturn site selection judgments, and more refined analyses should are not expected to cast doubt on them

~~5.15. A detailed deliberation of data base relevant for different stage of siting process is presented in Appendix A.~~

6. SITE SURVEY AND SITE SELECTION FOR NUCLEAR INSTALLATIONS OTHER THAN NUCLEAR POWER PLANTS

6.1. The graded approach as mentioned in Para. 1.14 provides guidance for the site survey and site selection of a broad range of nuclear installations other than nuclear power plants. These installations include:

(a) Research reactors and laboratories in which nuclear material is handled;

(b) Installations for storage of spent nuclear fuel (collocated with either nuclear power plants or independent installations), including:

  (i) Installations for spent fuel storage for which active cooling is required;

  (ii) Installations for spent fuel storage that require only passive or natural convection cooling.

(c) Processing facilities for nuclear material in the nuclear fuel cycle, e.g. conversion facilities, uranium enrichment facilities, fuel fabrication facilities and reprocessing plants.

6.2. For the purpose of site survey and site selection, these installations should be graded on the basis of their complexity, potential radiological hazards, and hazards due to other materials present.

6.3. Prior to categorizing an installation for the purpose of adopting a graded approach, a conservative process may be applied to estimate the consequences of a radiological release in which it is assumed that the entire radioactive inventory of the installation is released by ~~the potential external hazard initiated~~ an accident. The analysis should use the worst case radioactive inventory expected during the life of the installation and should not include any mitigating factors associated with siting (e.g., atmospheric dispersion), unless those factors are included in the final site selection acceptance criteria~~"~~.

~~6.4. If the results of the above conservative process show that the potential consequences of such releases would be 'significant', an appropriate site selection of the installation should be carried out using the recommendations of this safety guide~~.

6.5. The possibility that an external event will give rise to radiological consequences will depend on characteristics of the nuclear installation (e.g. its purpose, layout, design, construction and operation) and on the event itself. Such characteristics should include the following factors:

(a) The amount, type and status of the radioactive inventory at the site (e.g. whether solid or fluid, processed or only stored);

(b) The intrinsic hazard associated with the physical processes (e.g. nuclear chain reactions) and chemical processes (e.g. for fuel processing purposes) that take place at the installation;

(c) The thermal power of the nuclear installation, if applicable;

(d) The configuration of the installation for activities of different kinds;

(e) The concentration of radioactive sources in the installation (e.g. for research reactors, most of the radioactive inventory will be in the reactor core and the fuel storage pool, whereas in fuel processing and storage facilities it may be distributed throughout the installation);

(f) The changing nature of the configuration and layout for installations designed for experiments (activities at which may be unpredictable);

(g) ~~The need for active safety systems and/or operator actions for the prevention of accidents and for mitigation of the consequences of accidents;~~ characteristics of engineered safety features for the prevention ~~of accidents~~ and for mitigation of the consequences of accidents ~~(e.g. the containment and containment systems)~~;

(h) The characteristics of the process or of the ~~engineering~~ safety features that might show a cliff edge effect[3] in the event of an accident;

(i) The characteristics of the site relevant to the consequences of the dispersion of radioactive material to the atmosphere and the hydrosphere (e.g. size, demographics of the region);

(j) The potential for on-site and off-site contamination.

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

6.7. The grading process should be based on the following information:

(a) The generic preliminary safety analysis report for the installation, if one is available, which should be the primary source of information;

(b) The results of a preliminary~~generic~~ probabilistic safety assessment[4], if ~~one is~~ available;

(c) The characteristics specified in Para. 6.5.

6.8. As a result of this process, three or more categories of installation may be defined on the basis of national practice and criteria. As an example, the following categories may be defined:

(a) The lowest hazard category includes those nuclear installations for which national building codes for conventional facilities (e.g. essential facilities such as hospitals) or

[3] A cliff edge effect in a nuclear installation is an instance of severely abnormal system behaviour caused by an abrupt transition from one system status to another following a small deviation in a system parameter, and thus a sudden large variation in system conditions in response to a small variation in an input.

[4] ~~Generic PSA means the PSA of the designed unit with generic database without considering site specific and plant specific data base information~~.

for hazardous facilities (e.g. petrochemical or chemical plants), as a minimum, should be applied.

(b) The highest hazard category includes installations for which standards and codes for nuclear power plants should be applied.

(c) There are often one or more intermediate categories of nuclear installation.

6.9. The graded approach is generally applied to the extent and detail for the data to be collected and analysed at each step. Furthermore, depending on the consequences of the external hazards considered as screening criteria, the protection feasibility and method for the installation may vary. These aspects should be considered when setting up the screening criteria for nuclear installations other than NPPs.

6.10. Criteria not directly associated with safety (Paragraphs 4.11 and 4.12) may be very different for other nuclear installations. This should be taken into consideration.

7. MANAGEMENT SYSTEMS AND QUALITY MANAGEMENT

GENERAL RECOMMENDATIONS

7.1. As a function of the management system, the quality assurance program should be established by the organizations, and their contractors directly responsible for investigating and selecting the site of a nuclear installation. ~~This is necessary to control the effectiveness of the execution of the siting process.~~

7.2. The management system should cover the organization, planning, work control, personnel qualification and training, verification and documentation for the activities to ensure ensure adequate performance of these tasks ~~that the required quality is achieved~~.

7.3. The management system program for the siting process is a part of the overall management system program for the nuclear installation project. The management system for siting should be established at the earliest possible time consistent with its implementation in the conduct of activities for site survey and selection stages of the nuclear installation.

7.4. The results of the activities for site investigation should be compiled in a report that documents the results of all in situ work, laboratory tests and geotechnical analyses and more generally safety related evaluations.

7.5. The studies and investigations should be documented in sufficient detail to permit an independent review.

7.6. Records should be kept of the work carried out in the activities for site selection for the nuclear installation.

7.7~~8~~. When developing the part of the management system dealing with the siting process, the following should be considered to have it proportionate to the safety significance of process and studies/investigations:

(a) The intended end use of the knowledge and data that result from the activities of the siting process, in particular, in terms of their consequences for safety;

(b) The capability to demonstrate, test or repeat results;

(c) The scale and technical complexity of the activities of the siting process, whether it is a new or proven concept or a model that is being applied or an extension of a new application;

(d) The managerial complexity of the activity and the involvement and coordination of multiple disciplines, work units or internal or external organizations, with divided or contingent objectives and responsibilities;

(e) The extent to which other site evaluation work, or later work, depends on the results of the siting activities;

(f) The expectation for, or the desired use or application of the results.

SPECIFIC RECOMMENDATIONS ~~FOR A SITING PROJECT ORGANIZATION~~

7.8~~9~~. A project work plan should be prepared prior to, and as a basis for, the execution of the siting project, i.e. project related to site survey and site selection. The work plan should convey the complete set of general requirements for the nuclear installation (such as total power generation of the nuclear power plant (NPP) project), including applicable regulatory requirements. In addition to general requirements, the work plan should delineate the following specific elements: personnel and their responsibilities; work breakdown and project tasks; schedule and milestones; and deliverables and reports.

7.9~~10~~. A program should be established and implemented under the management system to cover all activities for data collection and data processing, field and laboratory investigations, analyses and evaluations that are within the scope of this Safety Guide. See Refs [12, 13] for requirements, recommendations and guidance on management systems.

7.10~~1~~. Results of the activities during the site survey and site selection stages should include all outputs indicated in the work plan. The reporting of the site survey and site selection should be specified in sufficient detail in the work plan.

7.11~~2~~. To make the activities of site selection process traceable and transparent to the public, users and reviewers, the related documentation should provide the following:

- description of all elements of the process;
- identification of the study participants and their roles; and
- background material that comprises the analysis documentation, including raw and processed data, computer software and input and output files, reference documents, results of intermediate calculations and sensitivity studies.

7.1~~3~~2. This material should be maintained in an accessible, usable and auditable form by the responsible organization. Documentation or references that are readily available elsewhere should be cited where appropriate. All elements of the site survey and site selection should be addressed in the documentation.

7.1~~4~~3. The documentation should identify all sources of information used in the site survey and site selection, including information on where to find important citations that may be difficult to obtain. Unpublished data that are used in the analysis should be included in the documentation in an appropriately accessible and usable form.

7.14~~5~~ If earlier studies for site survey and site selection for the same region are available, studies should be made to demonstrate how different approaches or different data affect the earlier conclusions. These should be documented in a way that allows review.

7.15~~6~~. Considering that a variety of investigations are carried out (in field, laboratory and office) and, if there is a need for expert judgment in the decision making process, technical procedures that are specific to the activity should be developed to facilitate the execution and verification of these tasks, and a peer review of the process should be conducted.

7.16~~7~~ Requirements for implementing a management system program should be established by the responsible organizations to ensure appropriate process and input from their contractors. The responsible organization for siting should identify the quality assurance standards that should be met. Applicable requirements, recommendations and guidance on the management system are provided in Refs [12,13]. Special provisions should be specified to address document control, analysis control, software, validation and verification, procurement and audits, and non-conformance and corrective actions. Work related documents should be prepared to cover all the activities for data collection and data processing, field and laboratory investigations, analyses and evaluations that are within the scope of this Safety Guide.

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APPENDIX – A

DATABASE FOR SITING PROCESS

1. The extent of work required to develop appropriate database will depend on the nature of the site, how easy to meet the site selection criteria (especially the exclusion criteria) and the extent of effort for comparison and ranking among the candidate sites.

2. The database should be comprehensive, up-to-date and compiled to support the evaluation and judgment of relevant number of thematic sets given in Section .0.

GEOLOGICAL DATABASE

3. The objective is to collect all the geological data necessary to enable judgments of site suitability using the criteria above to be confidently made. Detailed data requirements (for the final site selection process) are the same as those required for nuclear safety and are specified in the relevant Safety Guide [5] and [8]. The extent and quality of data collection may vary depending on the stage in the site survey and site selection process for which it is used. The ~~size~~ radius of the relevant region to be studied is typically 150 – 300 km and depends on the length of the regional faults. The following summarizes the data necessary at different stages:

Site Survey Stage

4. Make use of existing data available from national and local archives, e.g.:

(a) Regional geological maps, including those which contain data on stratigraphy, i.e. with appropriate cross-sections

(b) Tectonic maps

(c) Regional geophysical maps, indicating gravity and magnetic anomalies

(d) Satellite imagery

Site Selection Stage

5. At this stage the data indicated above should be augmented with more detailed information. This may require more detailed and site specific available information as well as site studies to be undertaken to confirm geological characteristics, such as existing bore-hole logs, seismic reflection surveys, and geological fieldwork.

SEISMOLOGICAL DATABASE

6. The ground motion to be considered during the site evaluation should be determined appropriate to the installation under consideration postulating the ground motion to occur with very low probability over its service period. Geological, seismological and geotechnical, characteristics of the potential and candidate sites should be considered. Detailed data requirements (for the final site selection process) are the same as those required for nuclear safety and are specified in the relevant Safety Guide [5].

Site Survey Stage

7. Using available earthquake catalogues, major earthquakes which may have had significant impacts on the proposed site should be selected taking account of the characteristics of causative faults. This preliminary information will be used for identification of the seismic active zones and preliminary estimation of seismicity for the potential sites to be used in the screening process.

Site Selection Stage

8. Available information on pre-historical, historical and instrumentally recorded earthquakes in the region should be collected and documented. A catalogue should be compiled that includes all earthquake information developed for the project covering all those temporal scales. In particular, all available 'pre-instrumental' historical earthquake data (that is, events for which no instrumental recording was possible) should be collected, extending as far back in time as possible.

DATABASE RELATED TO FAULT DISPLACMENT

9. The fault displacement hazard arises when an earthquake event on a fault close to or beneath safety related nuclear installation structures causes displacement to occur that may directly affect plant safety. This hazard is also referred to as capable fault hazard. A clear definition of capable faults is given in the Safety Guide [5] together with recommended site investigations in relation to potential capable faults.

Site Survey Stage

10. The capable faults should be thoroughly investigated by integrating geomorphological, geological, geodetic and geophysical methods to make clear their locations, shapes, activity, characteristics, and also considering their distance from the proposed site. At this stage sufficient site specific data may not be available and literature survey related to the suspect features would be a reasonable source of information.

Site Selection Stage

11. An in-depth investigation should be made on the capable faults combining the survey of existing reference materials, tectonic geomorphologic investigation, the earth's surface geological feature investigation, and geophysical investigation, etc. depending on the distance from the proposed site. Especially the area near the proposed site (e.g. 8 km) should be investigated precisely and in detail.

VOLCANOLOGICAL DATABASE

12. Volcanic products such as lava flows, pyroclastic flows, lahars and ash fall (among many others) may affect the safe operation of nuclear installations. These ~~these~~ should be evaluated for potential and candidate sites if they are in volcanic regions.

Site Survey Stage

13. The database should include descriptions of any volcanic products at the site. For Holocene and younger volcanoes, including those that are known to be currently active, the entire geologic history of the volcano should be investigated if the volcanic products may have an impact on the safe operation of the nuclear installation under consideration.

Site Selection Stage

14. An evaluation of the uncertainty in age determinations should be included in this assessment. For example, the stratigraphy of pyroclastic units commonly is complex and incomplete. Assessment of the completeness of the geologic record should be attempted, even if all volcanic deposits cannot be mapped. The ages of volcanic deposits should be quantified if possible to describe the history of volcanic activity. Detailed data requirements are similar to those recommended in the Safety Guide [7].

DATABASE ON GEOTECHNICAL HAZARDS

15. Investigation of the subsurface conditions at a nuclear installation site is important at all stages of the site selection and evaluation process. The purpose of this investigation is to provide information or basic data for decisions on the nature and suitability of the subsurface materials. At each stage of the process, the investigation program should provide the data necessary for an appropriate characterization of the subsurface. The specific requirements will vary greatly from stage to stage.

Site Survey Stage

16. The various methods of investigation - that is, the use of current and historical documents, geophysical and geotechnical exploration in situ and laboratory testing – are applicable to all stages of the site evaluation process, but to varying extents.

Site Selection Stage

17. The purpose of an investigation at the site selection stage is to determine the suitability of sites and identify issues that may be used in comparing the site with other potential or candidate sites. Subsurface information for this stage is usually obtained from current and historical documents and by means of field reconnaissance, including geological and geomorphological surveys and a limited amount of site specific field investigations in order to understand:

(a) Unacceptable subsurface conditions
(b) Classification of sites
(c) Groundwater regime
(d) Foundation conditions

Detailed data requirements are similar to those recommended in the relevant Safety Guide [8].

DATABASE ON COASTAL FLOODING

18. The coastal flooding database provides information describing the sea flooding characteristics of the candidate site. The extent and quality of data collection can vary depending on the stage in the site survey and site selection process for which it is used, as discussed above. This section includes all forms of flooding, including tsunami hazard.

19. At both the site survey and site selection stages, the suitability of the site is not solely determined by whether the site is inundated or not at particular return frequency events. Engineered solutions can be effected that can safeguard the site in many cases. For example, the installation grade could be built at a sufficiently elevated platform level to support the safety related structures and equipment for protection against these extreme events. The site can also be protected from flooding by sea walls and dykes. The practicality of employing these flood defensive measures should be considered along with the flood level predictions when deciding whether the coastal flooding is acceptable according to the criteria noted above.

20. Similar investigation on shore line stability should be conducted.

Site Survey Stage

21. Flooding due to storm surges, seiches, tides and wind waves: To determine the flooding potential of the site in these cases, it is necessary to know the extreme sea levels from storm surges, seiches, tidal and wind waves and the topography of the land around the proposed site. At the site survey stage a good approximation to evaluate flood levels can be

done using tidal data usually available at national or local authorities and/or institutions, although frequently this data is not sufficient by itself to assess the highest astronomical tides or the combined effects of storm surge, seiche and wind wave effects because only a few decades of data may be available.

22. Once an estimate of extreme sea levels has been made, an approximate flood level at the site can be determined from the local topology of the land in and around the site. It may be possible to screen out the site at this stage if the flood level is too high. However, if the possibility of coastal flooding is not clear, especially at longer return periods, then more detailed work is required and the judgment of site suitability should be carried to the next stage.

23. Consideration should also be given to the potentially detrimental effects of extreme low water levels.

24. Flooding from Tsunami: Tsunami hazard arises because of the effects of earthquakes, volcanic activity or landslides on the ocean floor. Relevant data should be collected from national authorities if this is available. There may also be historical records of large scale flooding in the region that can be associated with one of the initiators above. The Safety Guide [6] provides simple screening criteria that can be employed and that need only minimal data. If the proposed site does not satisfy the conditions for applying the screening criteria in [6], then a situation may exist where there is too little reliable data upon which a simple desk-top study can be made, and consideration of this issue should be carried to the next stage.

Site Selection Stage

25. Flooding from storm surges, seiches, tidal and wind waves: More detailed work is required to provide better estimates for flood levels at the site. A preliminary analytical technique may be used at this stage to determine the extreme sea levels for longer return periods and appropriate to the nuclear installation under consideration.

26. Flooding from Tsunami: A preliminary evaluation of tsunami hazard should be undertaken at this stage. A preliminary analytical technique may be used at this stage to determine the extreme sea levels for longer return periods and appropriate to the nuclear installation under consideration. Information provided in the Safety Guide [6] will be useful for further work on this area.

DATABASE ON RIVER FLOODING

27. This database provides information describing the river flooding and storm water flash floods characteristics of the proposed site including river course changes, river bank stability and upstream land use changes. The extent and quality of data collection can vary depending on the stage in the site selection process for which it is used. The flood level data by itself is not sufficient for screening a site from further consideration since it may be possible to provide flood defences to protect the site, and this aspect should be considered when making site selection judgments.

Site Survey Stage

28. River flooding can arise directly from rivers that have overtopped their banks or flood defences following heavy precipitation and snow melt upstream of the site. The following data should be obtained and is normally available from national or local authorities:

(a) Regional and local maps of watercourses, rivers, lakes, streams, wadis etc. and local site topographic maps. All watercourses that could credibly flood the site should be identified. Topographic features such a flood plain characteristics and the location and size of existing flood protection systems should be established, e.g. dykes and levees.

(b) For major rivers, data on discharge rates v. river level should be obtained. The possibility of ice hazard, including frazil ice should be considered. Historical data on river levels, extent of flooding etc. should be obtained.

(c) Information on water retaining structures especially upstream of the site should be collected.

(d) Low river levels: The potentially detrimental effects of low river water levels should also be considered.

Site Selection Stage

29. For this stage it may be necessary to undertake preliminary flood hazard analysis to estimate flood water levels at the site and the potential for interfering with safety related equipment. Simple dam-break scenarios should be considered for upstream water retaining structures. A statistical analysis of flood data to determine flood levels at longer return periods will also be required if not previously available. Information provided in the Safety Guide [6] will be useful for further work on this area.

METEOROLOGICAL DATABASE (on extreme and rare events)

30. This database provides information describing extreme and rare meteorological events that could affect the potential or candidate sites. The extent and quality of data collection can vary depending on the stage in the site selection process for which it is used. The

meteorological data by itself is not sufficient for screening a site from further consideration since it is often possible to provide defences to protect safety related equipment at the site.

Site Survey Stage

31. Meteorological data is usually collected on a regional basis by national authorities, although local authorities and in some cases, particular industrial sectors, may collect specific data for special reasons. The following data should be obtained:

(a) Regional and local history of extreme values, both extreme highs and extreme lows of meteorological parameters like Temperature, humidity, atmospheric pressure, wind speed, precipitation, icing, ice-storms, sandy/dust storms~~, ice- storms~~ etc. Similar regional and local data on rare meteorological events, such as storms, tornado, cyclone, lightning should be collected.

(b) The site drainage characteristics should be ascertained, e.g. natural drainage routes for surface water, height of water table, ability of water to flow onto the site. Consideration should be given to the fact that in-ground works of the nuclear facility can have a significant effect on the site drainage characteristics.

Site Selection Stage

32. For this stage it may be necessary to undertake a preliminary analytical exercise to determine historical meteorological data to establish hazard/frequency curves for the various meteorological variables. The suitability of the site will also depend on the extent that protection measures can be put in place to protect safety related SSC(s). In particular the drainage requirements for the site should be evaluated in detail, and the geotechnical features of the site will need to be determined, at least approximately, and their sensitivity to extremes of precipitation, temperature and drought established. Information provided in the Safety Guide [6] will be useful for further work on this area.

DATABASE ON HUMAN INDUCED EVENTS

33. The human induced events database provides information describing the type, severity and frequency of past events in the vicinity of the site and their relationship to the potential and candidate sites. The extent and quality of data collection can vary depending on the stage in the site selection process for which it is used. At both the site survey and site selection stages, the suitability of the site is not solely determined by the site's proximity to human induced events, but should also consider the credible protection measures that can be put in place as well. For example, protection barriers can usually be erected to protect safety related equipment against vehicle impacts.

Site Survey Stage

34. To determine the potential of human induced events to affect the site, it is necessary to collect information about the human activities around the site. There are a large number of potentially hazardous human activities that could affect a site. The following general categories should be considered for their hazardous potential:

(a) Co-located nuclear facilities

(b) Nearby industries, especially those using quantities of toxic/explosive chemicals, or involving exothermic reactions or high pressure/temperature processes. Also industries that provide strong sources of ionizing or electro-magnetic fields~~radiation~~.

(c) Nearby military facilities

(d) Transport systems, including road, rail, air, shipping and pipeline transport.

(e) Land use activities such as those that influence water courses or slope stability affecting the site, e.g. upstream dams, major users of river abstraction, industries that could deposit large amounts of debris into a river upstream of the site etc.

These sites can present a range of hazardous events including:

(a) flooding hazards

(b) forest and other external fire

(c) missiles and impact hazards

(d) toxic clouds

(e) explosive pressure waves

(f) ground disturbance on or under the proposed site

Information on local industrial hazards and land use hazards should be available from local government/planning authorities. Data on the location and movement of air traffic and other forms of transport should be available from local and relevant national authorities. Information on military facilities will be available form relevant national government authorities.

35. This data can be used with local and regional maps showing transport routes and industrial locations etc., and local topographical maps to make an initial assessment of whether the candidate site should be screened out or not on the basis of screening distance values for the sources of human induced events. It is anticipated that many of the hazards listed above can be eliminated on the basis that their effects are very local to the source and unlikely to affect the site directly, e.g. missiles from small scale pressurized systems, or can easily be protected against, such as impacts from road traffic/rail vehicles. Other hazards may

require a more detailed analysis from the next stage before a judgment can be made in respect of site selection.

Site Selection Stage

36. In this stage, it will be necessary to provide more detailed estimates of the severity/frequency of human induced events affecting the site. For several hazards listed above, a simple analysis based on site survey data alone may be insufficient to make a site selection judgment. For example, it is anticipated that this will apply to the following:

(a) Aircraft crash (data collected for aircraft crash of accident origin can also be used to some extent~~d~~ for the evaluation of the site for aircraft crash of malevolent origin).

(b) Toxic/explosive hazards from nearby industries using or storing very large quantities of these materials, e.g. oil and gas operations, large petrochemical factories, local quarrying or mining activities under the site.

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For these situations it is likely that an expert analysis is required to determine the severity of the hazard, its likely impact at the site and the frequency with which the hazard is associated. Such analyses should be undertaken at this stage by a competent person or organization. Further guidance on undertaking these analyses is available in Safety Guide [3].

DATABASE ON POPULATION, LAND USE AND ENVIRONMENTAL ASPECTS

37. The criteria relate to the potential radiological impact of the nuclear installation on the workers, population and the environment due to normal operation and accident conditions. Furthermore, the feasibility of the implementation of emergency plans is also addressed through this database.

Site Survey Stage

38. One of the most common metrics considered at this stage is related to either population density in the site vicinity or distance of the potential or candidate sites to population centres (or both). This type of a metric is easy to use because most of the time such data is readily available. Care should be taken to use reasonable numbers for screening values. It should also be noted that these values are country dependent.

Site Selection Stage

39. Depending on the regulatory requirements of the country this process may be more or less involved. In regulatory regimes where exclusionary area boundary (EAB) and low population zones (LPZ) are not required, attention should be paid mainly to the feasibility of emergency plan implementation in terms of effectively sheltering and evacuating the

population in the external zone of the installation, i.e. emergency planning zone (EPZ). In countries where these additional measures (EAB and LPZ) are required more detailed work is needed to demonstrate compliance. This involves the collection of population data with more precision. Information provided in the Safety Guide [4] will be useful for further work on this area.

ANNEX I

TABLES TO BE USED IN SITING PROCESS

I.1. Table I-1 provides an indication of the type of criteria that is generally associated with various issues related to siting process. It should be pointed out that there may be cases which are not consistent with Table I-2~~1~~ due to the specific conditions of certain sites. Therefore, Table I-2~~1~~ should be used only as a first indication.

I.2. Table I-2 cross references applicable IAEA Safety Standards to the siting issues under consideration. Guidance provided in the Safety Standards is useful for issues related to evaluation of candidate sites. In some cases, explicit guidance may be provided for the site survey and site selection stages.

TABLE I-1. SCREENING AND RANKING CRITERIA FOR SITE SELECTION

Criteria		Category		
Primary	Type	Screening		Ranking
		Exclusionary	Discretionary	
Earthquake	Ground Vibration	✓	✓	✓
	Ground Rupture	✓		
Geotechnical	Slope Instability (Massive)	✓		
	Slope Instabilty (Minor)		✓	✓
	Subsidence	✓		
	Massive liquefaction	✓		
	Liquefaction			✓
	Karst (massive)	✓		
Volcanism	Lava Flow	✓		
	Pyroclastic Flow	✓		
	Ground deformation	✓		
	Tephra Fall		✓	✓
	Volcanic gases		✓	✓
	Lahars	✓		
Flooding	River		✓	✓
	Dam Break		✓	✓
	Coastal (storm surges, waves,		✓	✓
	Tsunami		✓	✓
Extreme Meteo Events	High Straight Winds		✓	✓
	Tornados		✓	✓
	Tropical Storms		✓	✓
	Precipitation		✓	✓
	Sand/Dust Storms		✓	✓
Human Induced Events	Aircraft Crash		✓	✓
	Explosions		✓	✓
	Gas Releases		✓	✓
	External Fires		✓	✓
	Electromagnetic interference		✓	✓
Sabotage			✓	✓
Dispersion	In air and water		✓	✓
Feasibility of emergency plan implementation		✓		
Implementation of emergency plan			✓	✓
Non-Safety	Topography			✓
	Availability of Cooling Water	✓		✓
	Accessibility of water			✓
	Transport availability			✓

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	Access to Grid			✓
	Non-radiological environmental	✓		✓
	Socio-economic impact			✓
	Land-use plan			✓

TABLE I-2. SITE SELECTION ISSUES CROSS REFERENCE TO SAFETY STANDARDS

Site Selection Issues		Site Evaluation Safety Requirements	Site Evaluation Safety Guides					Design Safety Guides		
Primary	Effect	NS-R-3 [1]	NS-G-3.1 [3]	NS-G-3.2 [4]	SSG-9 [5]	DS-417 [6]	DS-405 [7]	NS-G-3.6 [8]	NS-G-1.5	NS-G-1.6
Earthquake	Ground Vibration	✓			✓					✓
	Ground Rupture	✓			✓					
Geotechnical	Slope Instability	✓						✓		
	Subsidence erosion and permafrost	✓						✓		
	extensive oil and gas extraction history	✓						✓		
	Liquefaction	✓						✓		
Volcanism		✓					✓			
Flooding	River	✓				✓			✓	
	Dam Break	✓				✓			✓	
	Coastal	✓				✓			✓	
	Tsunami	✓				✓			✓	
Extreme	High straight	✓				✓			✓	

meteo events	winds									
	Tornados	✓				✓			✓	
	Precipitation	✓				✓			✓	
Human Induced Events	Aircraft Crash	✓	✓						✓	
	Explosions	✓	✓						✓	
	Gas releases	✓	✓						✓	
	External Fires	✓	✓						✓	
Population	Density	✓		✓						
	Distance from Centres	✓		✓						
Dispersion	In Air	✓		✓						
	In Water	✓		✓						
Emergency Plan Feasibility		✓		✓						

ANNEX II

EXAMPLE OF CRITERIA FOR SITING PROCESS OF NUCLEAR INSTALLATIONS

GENERAL CONSIDERATIONS

II.1. The objective of this annex is to provide certain information that could serve as examples of attributes and related criteria to be considered in the siting process of nuclear power plants (NPP). This annex is intended to be used by the stake~~-~~holders associated with the siting process of NPP.

II.2 This annex is prepared by compiling information on the practices of different member states and also from the new version of relevant IAEA safety standards. Examples are given in this Annex on ~~the events of accidents and / or~~ external natural hazards~~phenomena~~as well as ~~including~~ external human induced events ~~of sabotage~~.

II.3. A number of attributes (issues, events, phenomena, hazards and specific considerations) are related to the siting process in addition to general information on the site. These attributes are grouped into five thematic sets in Section 4. These sets are,

- External natural hazards.
- External human-induced events.
- Radiological impact on public and environment.
- Emergency planning.
- Aspects not directly related to nuclear safety.

The last set, though not directly related to nuclear safety, is considered to have important bearing on the effectiveness of the siting process.

II.4. This annex further expands these five sets of attributes providing examples of issues, events, phenomena, hazard and considerations that are to be taken into account in siting process of an NPP. Screening values for some of these attributes serve as useful siting criteria. Examples on such screening values are provided. The candidate sites need to undergo preliminary evaluation which is useful for comparison and ranking in the second stage of siting process. Examples of discretionary criteria with respect to some of these issues, events, phenomena and hazards are also provided. Finally, the Annex provides example of content of emergency procedures, which would serve as useful information for examination of the feasibility of emergency planning.

EXAMPLE OF ATTRIBUTES CONSIDERED IN SITING

II.5 General Site information

1. Maps of site area at suitable scale

   ~~i) Plant property line with co-ordinate of reactor building~~

   ~~ii) Plant boundary~~

   ~~iii)~~i) Site boundary or exclusion zone; zones demarcating 5km, 16km, (>) 25 km, and 80km from centre of reactors [II-1, II-2, II-3].

   ~~iv)~~ii) Population distribution and location of existing industrial, commercial, institutional, recreational and residential facilities including projections for the operating lifetime of the nuclear power plant

   ~~v) Scale of map~~

   ~~vi) True North~~

II.6 External natural hazards

1. Geology

   i) Properties of sub-surface strata, depth of bed rock and type

   ii) Characteristics of sub-surface material

   iii) Ground water

2. Natural events

   i) Seismic and geological considerations

      a. Capable faults

      b. Vibratory ground motion due to earthquakes

      c. Failure of upstream or downstream water control structure

   ii) Meteorological events and variables

      a. High wind events, such as tropical cyclone, tornado and water spout

      b. Precipitation

      c. Storm

      d. Snow

      e. Lightning

      f. Dust storm and sand storm

      g. Hail

h. Freezing precipitation and frost related phenomena

i. Air temperature

iii) Coastal flooding

a. Storm surges

b. Seiches

c. Tsunamis

d. Tides

e. Wave action

f. Combinations of tides – sea water level variations and extremes

iv) Inland (river) flooding

a. Overtopping of banks

b. Failure of upstream or downstream water control structures such as dykes or dams

c. Blockage of river and other drainage channel

v) Combination of coastal and inland flooding for sites on estuary

vi) Geological hazards

a. Slope instability

b. Soil liquefaction

c. Rock fall

d. Permafrost

e. Soil erosion processes

f. Collapse, subsidence

g. Expansion, uplift

h. Karst

~~g.~~i. Avalanche

~~h.~~j. Stability of foundation

vii) Shoreline erosion

3. Ultimate heat sink

i) Availability of water

ii) Reliability of water supply

iii) Effect of failure of upstream and downstream water control structure

iv) Impact of flooding including run-up and draw down

v) cooling air characteristics (for cooling towers)

4. Change of hazard with time

i) Change due to climatic evolution: regional climatic change with global climatic change.

ii) Changes in physical geography of a drainage basin including estuaries, off shore bathymetry, coastal profile, catchment area etc.

iii) Changes in land and water use.

II.7 External human induced hazard

1 Stationary sources

i) Oil and Gas Operation (e.g. refineries)

ii) ~~Chemical~~ Industrial plants and operatiopns and other hazardous substances processing facilities

iii) Hazardous substances storage facilities

iv) Broadcasting and communication networks (for electromagnetic interfering hazard)

v) Mining or quarrying operations

~~vi) Forests~~

~~vii)~~vi) Other nuclear facilities

~~viii)~~vii) High energy rotating equipment

~~ix)~~viii) Military facilities (permanent or temporary) especially shooting ranges, arsenals

~~x)~~ix) Co-located facilities (like fuel reprocessing unit, storage of fresh and spent fuel)

2 Mobile sources

i) Railway trains and wagons

ii) Road vehicles

iii) Ships and barges

iv) Pipelines

v) Air traffic corridors and flight zones (both military and civilian)

vi) Transportation of fresh and spent fuel and other nuclear material

3 Other characteristics

i) Oil slick

ii) Transportation of over dimension consignment (ODC)

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II.8 Radiological Impact

1 Meteorology

i) Wind speed and direction
ii) Rain and other precipitation
iii) Atmospheric temperature
iv) Humidity
v) Atmospheric stability
~~v)~~vi) Sand/Dust storms

2 Use of land and water

3 Population consideration

4 Dispersion of radioactive material through

i) Atmosphere
ii) Sub-surface water
iii) Surface water

5 Management of radioactive waste during normal operation

i) Radioactive solid waste
   a. Characteristics of waste
   ~~a.~~b. Quantity
   ~~b.~~c. Level of activity
   ~~c.~~d. Management Strategy
ii) Radioactive liquid waste
   a. Characteristics of waste
   ~~a.~~b. Quantity
   ~~b.~~c. Level of activity
   ~~c.~~d. Management Strategy
iii) Radioactive gas release
   a. Characteristics of waste
   ~~a.~~b. Quantity
   ~~b.~~c. Level of activity
   ~~c.~~d. Management Strategy

6 M~~N~~anagement of the Radioactivity waste during accident conditions

i) Radioactive solid~~Liquid~~ waste

a. Characteristics of waste

~~a.~~b. Quantity

~~b.~~c. Level of activity

~~c.~~d. Method of disposal

ii) Radioactive liquid~~gas~~ release

a. Characteristics of waste

~~a.~~b. Quantity

~~b.~~c. Level of activity

~~c.~~d. Method of disposal

iii) Radioactive gas release

a. Characteristics of waste

b. Quantity

c. Level of activity

d. Method of disposal

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7 Co-located facilities like fuel reprocessing facility, storage of fresh and spent fuel

8 Ambient radiation

9 Monitoring

II.9 Emergency management

1 Physical and site characteristics that may hinder emergency plans

2 Emergency management procedures

3 Infrastructure characteristics related to the implementation of emergency plans

i) Evacuation routes

ii) Shelter

iii) Transportation

4 Special considerations prescribed by the regulatory authority for special zones, such as exclusion zone boundary, low population zone etc.

5 Population considerations within Emergency zones outside the nuclear installation boundary

~~i) Exclusion zone (population in this zone is plant personnel)~~

~~ii) Sterilized or low population zone~~

~~iii) Emergency planning zone~~

~~iv) Radiation monitoring Zone~~

6 Additional statutory requirements by the

i) Federal government

ii) State, provincial or territorial government

iii) Local government

II.10 Aspects not directly related to radiological safety

- Topography
  - i) Salient feature
  - ii) Contour maps for the region up to 30 km
- Accessibility
  - i) Nearest railway lines
  - ii) Nearest national highway and major road
  - iii) Nearest sea port
- Available industrial infrastructure and construction facilities
  - i) Construction materials
  - ii) Construction power
  - iii) Construction water
  - iv) Infrastructural facilities
- Availability of power supply sources and transmission lines
  - i) Start-up power
  - ii) Power evacuation scheme
- Availability and access conditions to cooling water
  - i) Condenser cooling
  - ii) Fresh water for consumptive use
- Township
  - i) Location
  - ii) Distance from NPP site
  - iii) Expected population
- Proximity to load centres

i) Power distribution grid lines

ii) Location of major power consuming units/facilities/population

- Non-radiological environmental impact including ecological considerations

i) Heat sinks – water bodies/atmosphere

ii) Presence of bio-sensitive areas adjacent to site

iii) Reserve forest or monuments or tourist spots

iv) Statutory bodies restriction on

- Thermal pollution
  - Differential temperature between the intake and outfall points of the condenser cooling water.
  - Effect of condenser water discharge on aquatic life.
- Chemical pollutant discharge

- Socio-economic aspects including public acceptance

i) Type of adjacent area – urban or rural

ii) General source of income for local population – large scale industry, small scale industry, agriculture and agro industries

iii) General economic condition of the surrounding population with respect to national averages (e.g. per–capita–income)

iv) Acceptance level of the plant by general public

EXAMPLE OF SCREENING VALUES

II.11 The screening values of different characteristics of a site could be used as exclusion criteria or discretionary criteria during site survey stage. Examples of such screening values are given in Table II-1. If a site does not satisfy any one or a combination of screening values, it can still be acceptable provided engineering solutions are available, i.e. design features, measures for site protection or administrative procedures, exist.

Table II-1 Example of the screening values

Sr. No.	Characteristics	Screening Values	Remarks
1.	Distance from capable fault	8.0 km#[II-3]	Exclusion criterion
2.	Distance from flight path	4.0 km [II-4]	Discretionary criterion

	approaching airport		
3.	Distance from airport with attributes of Type-2 event*	7.5 Km [II-4]	Discretionary criterion
4.	Distance from small airports	10.0 km [II-4]	Discretionary criterion
5.	Distance from large airport for yearly flight operations > 500d^2 for yearly flight operations > 1000d^2	< (d=)16.0 km > (d=)16.0 km [II-4]	Discretionary criterion
6.	Distance from military installations or air space usage such as practice, bombing and fire ranges	30.0 km [II-4]	Discretionary criterion
7.	Distance from military installations storing ammunitions etc.	8.0km [II-4]	Discretionary criterion
8.	Distance from facilities of storing handling flammable, toxic, corrosive or explosive material	5.0 km [II-4]	Discretionary criterion
9.	Sources of hazardous clouds	8.0 km [II-4]	Discretionary criterion
10.	Distance of places of architectural/ historical monuments, tourists interest	5.0 km [II-5]	Exclusion criterion
11.	Reserved bio sensitive region and forest	Exclusion zone	Exclusion criterion
12.	Sand dune		Location potential to sand dune should be avoided.
13.	Tsunami	10 km from sea or ocean shore line or 1 km from lake or fjord shoreline, or 50 m above mean water level [II-6]	Discretionary criteria

*~~Event of an~~Accidental aircraft crash at the site as due to take-off or landing operation at nearby airport.

Because of the uncertainties and difficulties in mitigating the effects of permanent ground displacement phenomena such as surface faulting, or folding, fault creep, subsidence or collapse, the NRC staff considers it prudent for permanent ground displacement exists at the site.

EXAMPLE OF DISCRETIONARY CRITERIA

II.12 The second stage of the siting process is the site selection stage, which involves a preliminary site evaluation. Examples of criteria for the site evaluation needed at this stage are given below. These criteria are of the discretionary type and can also be used for ranking purposes.

II.13 Size of exclusion zone (EZ)

The size of the exclusion zone around a nuclear power plant is such that the dose limits are met at the EZ boundary for the normal operating condition and governing design basis accident conditions (DBA) by considering all radiation exposure pathways including inhalation and ingestion doses and taking into account public emergency counter measures. The size of exclusion zone should satisfy the minimum requirements for safety against events of malevolent origin. Distances for sabotage scenarios included in the standoff design basis threat are considered in this context.

II.14 Dose limit

The dose received by an individual member of the public and population as a whole under normal and design basis accident condition is as low as reasonably achievable (ALARA) level subject to the limit imposed by the National Regulatory Authority of the MS.

II.15 Radiological risk

Total radiological risk due to NPP is assessed considering all design basis accident conditions initiated by internal as well as external events. For multi-unit sites, total radiological risk due to an external event is assessed taking into consideration the accident condition for all units of the site, since an external event can induce a common cause failure.

EXTERNAL NATURAL HAZARDS

II.16 Meteorological Variables

The design basis parameters corresponding to the meteorological variables (e.g. air temperature; wind speed and direction; precipitation (liquid equivalent)) and meteorological phenomena are derived for annual frequencies of exceedance appropriate to the extreme values to be established for each of them. For extreme values of meteorological variables, data collected during a minimum period of continuous observation of at least 30 years is needed for estimating their annual frequency of exceedance of 10^{-2} [II-6] since the estimate of the hazard cannot be assessed with enough accuracy for values above 3 to 4 times the length of the sample.

II.17 Rare Meteorological Phenomena

In case of rare meteorological phenomena (e.g. lightning; tropical cyclone, hurricane and typhoon; tornado, waterspout) annual frequency of exceedance of 10^{-4} is usually considered [II-6, II-7].

II.18 Flood

1) The design basis flood level at an NPP site is determined for annual frequency of exceedance of 10^{-4} [II-7, II-8].
2) For coastal site, design value of astronomical high tides is taken 10% above the maximum recorded high tides for a period of at least 50 years [II-6].

II.19 Effects of climatic change

To account for future climatic change, an additional safety margin is to be considered in the design of nuclear facility. Guidelines on such additional margin are given in the IAEA Safety Standard, "Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installation" DS417 [II-6].

II.20 Earthquake

Site specific Design Basise Ground Motion (DBGM) parameters for earthquakes are derived to meet a target performance goal. To achieve the recommended performance goal for the new build~~s~~, the DBGM ~~the~~ mean parameters for earthquakes should not have a frequency of exceedance higher than 10^{-4} [II-7].

II-21 Loss of ultimate heat sink

Availability of adequate quantity of water in alternate heat sink to maintain the reactor under safe shutdown state for at least 30 days is ensured under all circumstances [II-9]. The minimum period of 30 days may have to be revised to a higher value depending on site characteristics.

EXTERNAL HUMAN INDUCED HAZARDS

II.22 Aircraft crash

In case the screening value given in Table II-1~~2~~ is not satisfied, it is to be demonstrated that the annual frequency of occurrence of an aircraft crashing on the NPP is not more than 10^{-7}. ~~The site deems to be unsuitable if the annual frequency of aircraft crash at site is greater than 10^{-7} and there exists no practicable and reliable engineering solution to mitigate this hazard~~.

II.23 Chemical explosions and toxic gas releases

1) Design basis for chemical explosion events is expressed in terms of over-pressure and tolerance levels for toxic materials at the site. Further guidance is provided in [II-3].

2) Those human-induced activities (existing and proposed) at further distances (beyond 5 km) are looked into for their impact on the safety of the facility.

IMPACT OF NPP ON THE ENVIRONMENT

II.24 Radiological impact assessment

Minimum area to be covered from the centre of reactor for radiological impact assessment for design basis accidents is [II-3]:

1) For exposure pathway : 16km
2) For ingestion pathway : 80km

II.25 Thermal and non-radiological chemical pollution

1) The arrangement of intake and outfall structures is such that the temperature difference between the two legs at specified locations are within the limits specified by the competent authority of the MS taking into account of possibility of re-circulation.
2) Regarding the chemical effluents discharged to a water body appropriate limits as specified by competent authorities of MS are~~is~~ adhered to.

EMERGENCY MANAGEMENT PLAN~~PROCEDURE~~

II-26 Feasibility of emergency plan implementation is an important constituent of exclusion criteria. Emergency conditions arising out of both internal and external events are considered for planning. In addition, different considerations of emergency management planning with respect to population density and distance from population centre contribute significantly to the discretion as well as ranking criteria. The emergency management procedure includes both on-site emergency and off-site emergency. Off-site emergency management activity covers the area within radius not less than 16 km from the centre of NPP [II-3]. It is generally confirmed before starting of the plant construction that there will be no insurmountable difficulties in establishing an emergency plan for external zone prior to commencement of plant operation. The contents of the emergency procedures are suggested below.

II.27 Content of on-site emergency procedures

1) Description of NPP site
   i) Description of site
   ii) Site location
   iii) Site area maps
   iv) Site area
2) Emergency organization and responsibilities
   i) Organization details
   ii) Contact details
   iii) Responsibilities
   iv) Emergency response group
   v) Mutual aid
3) Guidelines for evaluation of emergencies
   i) Radiation doses
   ii) Emergency scenarios
   iii) Emergency classification
   iv) Counter measures
4) Communications
   i) System description
   ii) System requirements
   iii) System features
   iv) Testing of communication systems
   v) Redundancy in communication links
5) Resource and facilities
   i) Plant/site emergency control centre
   ii) Emergency equipment centre
   iii) Personnel decontamination/treatment facilities
   iv) Emergency shelters
   v) Emergency survey vehicle
   vi) Rescue and first aid facilities
   vii) Ambulance
   viii) Control of radiation emergency facilities
   ix) Assembly areas
6) Declaration/termination and notification of emergency
   i) Declaration of emergency
   ii) Termination of emergency

iii) Announcements and notifications during emergency exercise

7) Action plan for plant/site emergency

8) Maintenance, training and updating of emergency plan

i) Maintenance

ii) Training

iii) Exercise

iv) Records

II.28 Content of off-site emergency procedure

1) Description

i) Description of site

ii) Site location

iii) Site area maps

iv) Site area

v) Nature of land and produce

vi) Site area maps

vii) Site meteorology

2) Emergency organization and responsibilities

i) Emergency organization details

ii) Contact details of emergency functionaries

iii) Responsibilities of emergency functionaries

iv) Responsibilities of district sub committees

3) Evaluation of emergency conditions

i) Emergency classification

ii) Radiation doses (intervention levels and derived intervention levels), domain and counter measures

4) Emergency communications

i) Organization details

ii) Contact details

iii) Responsibilities

iv) Testing of communication systems

v) Redundancy in communication links

5) Resource and facilities

i) Plant/site emergency control centre

ii) Off-site emergency control centre

iii) Emergency equipment centre

iv) Personnel decontamination/treatment facilities

v) Emergency shelters

vi) Emergency survey vehicle

vii) Rescue and first aid facilities

viii) Ambulance

ix) Control of radiation emergency facilities

x) Assembly areas

6) Declaration/termination and notification of emergency

i) Declaration of emergency

ii) Emergency siren and announcements

iii) Notification of off-site emergency

iv) Termination of off-site emergency

v) Exercises

7) Action plan for off-site emergency

8) Maintenance, training and updating of off-site emergency plan

i) Maintenance

ii) Training

iii) Exercise

9) Records

REFERENCE

TO ANNEX_II~~I~~

II-1 INTERNATIONAL ATOMIC ENERGY AGENCY, Seismic Hazards in Site Evaluation for Nuclear Installations, Safety Standard Series No. SSG-9, IAEA (2010).

II-2 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 Series No. NS-G-3.23, IAEA (2002).

II-3 US NEUCLEAR REGULATORY COMMISSION, General Site Suitability Criteria for Nuclear Power Plants, Regulatory Guide 4.7 (rev-2), USNRC, Washington DC (1976).

II-4 INTERNATIONAL ATOMIC ENERGY AGENCY, External Human Induced Events in Site Evaluation for Nuclear Power Stations, Safety Standard Series NoNS-G-3.1, IAEA (1998).

II-5 AERB Code

II-6 INTERNATIONAL ATOMIC ENERGY AGENCY, Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations, Safety Standard Series, design Safety Guide No. DS417, IAEA (2011).

II-7 INTERNATIONAL ATOMIC ENERGY AGENCY, Extreme External Events in the Design and Assessment of Nuclear Power Plants, TECDOC No. 1341, IAEA (2003).

II-8 NUCLEAR SAFETY STANDARD COMMISSION (KTA), Flood Protection for Nuclear Power Plants, KTA 2207 (11/2004), KTA, Salzgitter (2004).

II-9 US NEUCLEAR REGULATORY COMMISSION, Ultimate Heat Sink for Nuclear Power Plants, Regulatory Guide 1.27 (rev-2), USNRC, Washington DC (1976).

ANNEX III

COMPARISON AND RANKING OF CANDIDATE SITE

GENERAL

III.1 The candidate sites are evaluated and the preferred sites are arrived at by comparing and ranking them in the second stage of the siting process. Safety and economic aspects will play the major role in the comparison and ranking exercise.

III.2 This Annex suggests an approach to arrive at the preferred site from the candidate ones by means of a comparison and ranking process.

III.3 Candidate sites are evaluated against those characteristics, issues, events, phenomena and hazards, negative attributes which can be compensated by means of engineering, site protection or administrative measures. No exclusionary consideration is taken into account in this exercise. However, to assure that the candidate sites passed all exclusion criteria, limited site specific investigation work such as geophysical profiles or boreholes (for example to demonstrate that there are no capable faults in the site area) may be required if the available information is found to be inadequate during the screening test.

III.4 Comparisons between the candidate sites are done on a reference parameter. One example of such parameter is cost-differential. Cost-differential is the difference in the cost of NPP of a standard design at different sites. Ideally, the lifecycle cost i.e. cost for construction (including that of engineering), operation, transmission including losses, and decommissioning is to be considered. However, consideration of construction, operating and transmission cost is sufficient.

III. 5 The cost-differential is calculated as follows.

1. A standard design of NPP for a reference site is assumed for which design basis parameters for different site characteristics, events, phenomena, and hazards are known. The cost-differential is worked out with respect to the reference plant.
2. Design parameters related to different candidate sites to be considered are p_{ij}. Where, p_{ij} is the design parameter related to i^{th} attributes (of site characteristics, issues, events, phenomena, and hazards; refer Annex-II) specific to j^{th} candidate site. The cost-differential may not be considered if p_{ij} is enveloped by the corresponding design

value of the same parameter considered in the design of the reference NPP; otherwise, the cost-differential is considered.

3. Some cost-differentials are one time only (e.g. infrastructure development and site cut and fill) and other continue for life time of the plant owing to operating cost (e.g. inspection, maintenance and monitoring of structure, system and component), and efficiency factor (e.g. transmission loss).

4. Cost-differential may be calculated in term of absolute and effective value as follows;

Absolute cost-differential: $C_j^a = \sum_{i=1}^{n}(IC_{ij} + OC_{ij})$ (F-1)

Effective cost-differential: $C_j^e = \sum_{i=1}^{n}\alpha_{ij}(IC_{ij} + OC_{ij})$ (F-2)

Where, C_j^a and C_j^e are the absolute and effective cost difference for j^{th} candidate site respectively. $IC_{i,j}, OC_{ij}$ and α_{ij} are initial cost-differential, operating and assigned weightage respectively with respect to i^{th} attribute of j^{th} candidate site. Table III-1 provides an arbitrary example of estimating cost-differential.

5. In some cases, the effective cost-differential may be more rational for comparison and ranking between the candidate sites. The weightage factor α_{ij}, is always greater than unity. It's value depends on a number of issues such as whether a change in a particular attribute of a given candidate site would have impact on project schedule, or attracts more elaborate regulatory requirements, or has impact on the operating life of the installation. For example, a differential cost due to change in non-safety related attribute, which could be taken care of by design measure without any significant activity during operation and does not fall in the critical path of the project schedule, can be assigned with the weightage factor of unity.

III.6 The candidate sites are ranked on the basis of associated cost differential. The most preferred site is the candidate site with least cost-differential. The list of preferred site is the list of candidate sites with increasing value of cost-differential.

Table III-1 Estimation of Cost-differential for 'Site – j' (Example)

No. (i)	Parameters	Cost-Differential		Weightage factor (α_{ij})
		Initial cost (IC_{ij})	**Operating cost (OC_{ij})***	
1	Seismic	x_{1j}	y_{1j}	a_{1j}
2	Aircraft impact	x_{2j}	-	1.0
3	High wind	-	-	
4	Soil improvement	x_{4j}	-	a_{4j}
5	Coast protection	x_{5j}	y_{5j}	a_{5j}
6	Water temperature	-	y_{6j}	1.0
7	Grid Loss	-	y_{7j}	1.0
8	Infrastructure development	x_{8j}	-	1.0
9	Required Stack Height	-	-	-
10	Need for Cooling Towers	-	-	-
11	Cooling Water Pumping	-	y_{11j}	$a_{11,j}$
12	Groundwater pumping	-	-	-
13	Site cut and fill	x_{13j}	-	1.0
14	Other	x_{14j}	y_{14j}	1.0

*Operating cost is estimated on the basis of design life of the plant.

The absolute cost-differential,

$C^a_j = (x_{1j}+y_{1j}) + x_{2j} + x_{4j} + (x_{5j}+y_{5j}) + y_{6j} + y_{7j} + x_{8j} + y_{11j} + x_{13j} + (x_{14j}+y_{14j})$

The effective cost-differential,

$C^e_j = a_{1j}(x_{1j}+y_{1j}) + x_{2j} + a_{4j}\, x_{4j} + a_{5j}(x_{5j}+y_{5j}) + y_{6j} + y_{7j} + x_{8j} + a_{11j}y_{11j} + x_{13j} + (x_{14j}+y_{14j})$

ABBREVIATIONS

ALARA	As low as reasonably achievable
DBA	Design basis accident
DBGM	Design basis ground motion
EPZ	Emergency planning zone
EZ	Exclusion zone
EAB	Exclusionary area boundary
FSAR	Final safety analysis report
GIS	Geographical information system
LPZ	Low population zone
MS	Member States
PSR	Periodic safety review
PSAR	Preliminary safety analysis report
SER	Site evaluation report

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