



IAEA

60 Years

Atoms for Peace and Development

SITE SURVEY AND SITE SELECTION FOR NUCLEAR INSTALLATIONS, SAFETY ASPECTS: SSG-35

*Interregional Workshop on Graded Approach for Site Evaluation for SMRs
in Haikou, China*

06-11 November, 2023

Mazhar Mahmood

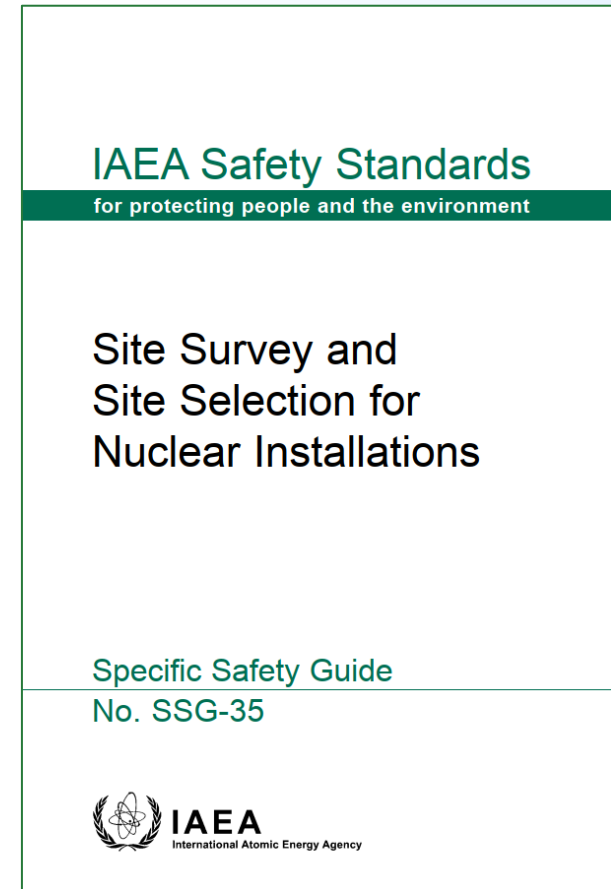
External Events Safety Section

Division of Nuclear Installation Safety (NSNI)

International Atomic Energy Agency (IAEA)

Safety Standard SSG-35

- Bibliography record
 - Published in 2015
 - Prepared between 2010 and 2013
 - Revision of IAEA 50-SG-S9 (published in 1984)



Learning Objectives

1. Understand the safety relevance of site selection
2. Identify the main steps in the siting process and the site evaluation process, and the resulting products of each step
3. Identify the typical tasks within each of the stages of the siting process and the necessary data
4. Understand the different types of siting criteria and their roles in the siting process

Contents of the presentation

1. Introduction

- Background of SSG-35
- Requirements in IAEA SSR-1
- Scope of SSG-35
- Workflow of SSG-35
- Related IAEA Safety Guides

2. Overview of the Siting Process and Site Evaluation Process

- Siting (definition of terms)
- Site evaluation (definition of terms)
- Stages in site selection and site evaluation
- Implications for safety – Regulated and non-regulated activities
- Outcome of the process
- Role of the future nuclear operator

Contents of the Lecture

3. Recommendations for the Siting Process

- Workflow of the process
- Tasks to be considered within each of the stages of the process
- Siting criteria to govern the process

4. Classification of Siting Criteria

- Safety related criteria
- Criteria relating to nuclear security
- Non-safety-related criteria

5. Summary of Main Points

Introduction (1/12)

Background of SSG-35

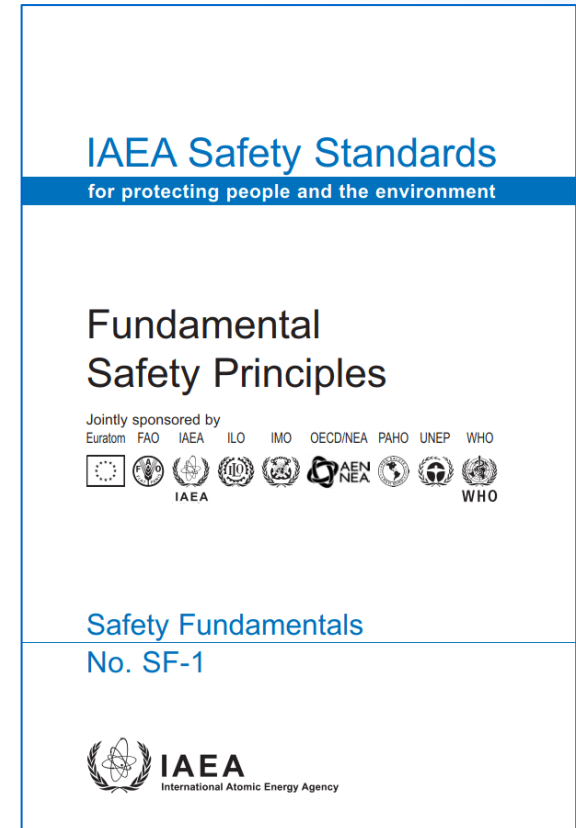
- IAEA Safety Fundamentals SF-1:

All practical efforts must be made to prevent and mitigate nuclear or radiation accidents (Principle 8)

The primary means of preventing and mitigating the consequences of accidents is 'defense in depth' (Para. 3.31)

Defense in depth (IAEA INSAG-10) is provided by a 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)



Introduction (2/12)

- IAEA Safety Requirements are intended to implement Safety Principles.

Safety Requirements must always be met.

- IAEA Safety Guides provide guidance on how to meet the requirements.

Guidance is consistent with international practice. The safety guides are consensus documents among Member States.

Background of SSG-35

Safety Standards Series hierarchy



Introduction (3/12)

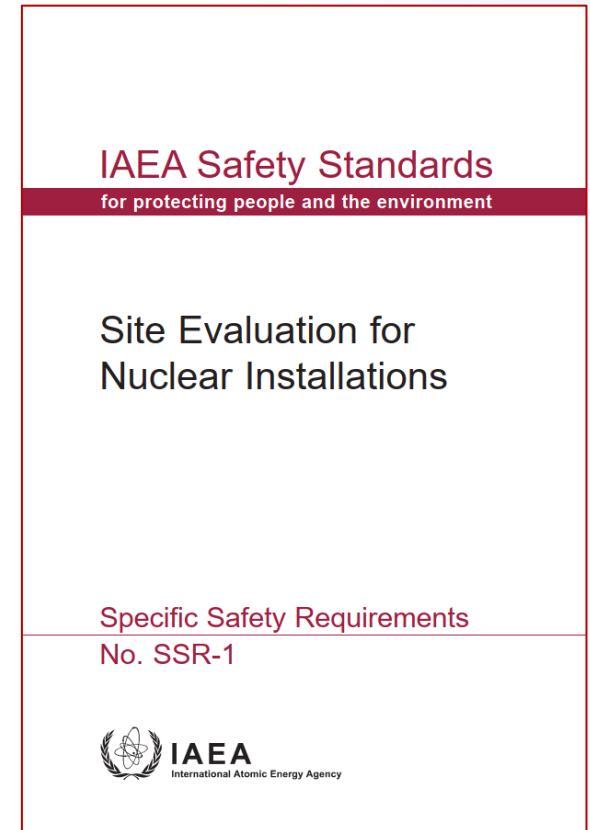
Background of SSG-35

- IAEA Safety Requirements SSR-1:

The siting process for a nuclear installation is divided into two stages:

(a) Site survey, in which candidate sites are identified after the investigation of a large region and the rejection of unsuitable sites;

(b) Site selection, in which the candidate sites are assessed by screening, evaluation, comparison and ranking on the basis of safety and other considerations to select one or more preferred candidate sites. (Para. 1.15)



Introduction (4/12)

Background of SSG-35

- IAEA Safety Requirements SSR-1:

The suitability of the site is then confirmed in the site evaluation process. The site evaluation process starts with the second stage of the siting process (i.e. site selection), and continues throughout the entire lifetime of the nuclear installation. (Para. 1.6)

IAEA Safety Standards

for protecting people and the environment

Site Evaluation for Nuclear Installations

Specific Safety Requirements

No. SSR-1



IAEA
International Atomic Energy Agency

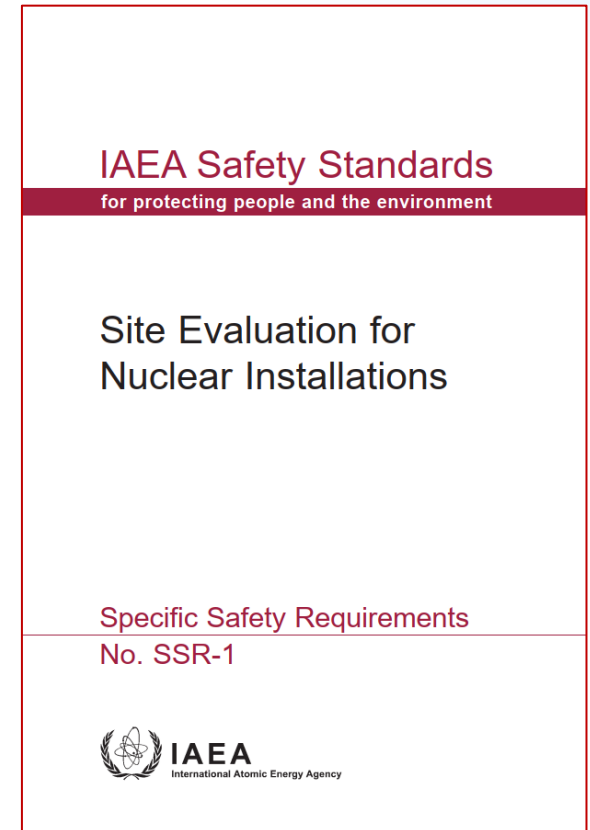
Introduction (5/12)

To apply the fundamental safety principle 8, it is required that (Requirement 4):

4.6 In the **assessment** of the **suitability** of a **site** for a nuclear installation, the following aspects shall be addressed at an early stage of the site evaluation:

- (a) The effects of natural and human induced external events occurring in the region that might affect the site;
- (b) The characteristics of the site and its environment that could influence the transfer of radioactive material released from the nuclear installation to people and to the environment;
- (c) The population density, population distribution and other characteristics of the external zone, in so far as these could affect the feasibility of planning effective emergency response actions, and the need to evaluate the risk to individuals and to the population.

Background of SSG-35

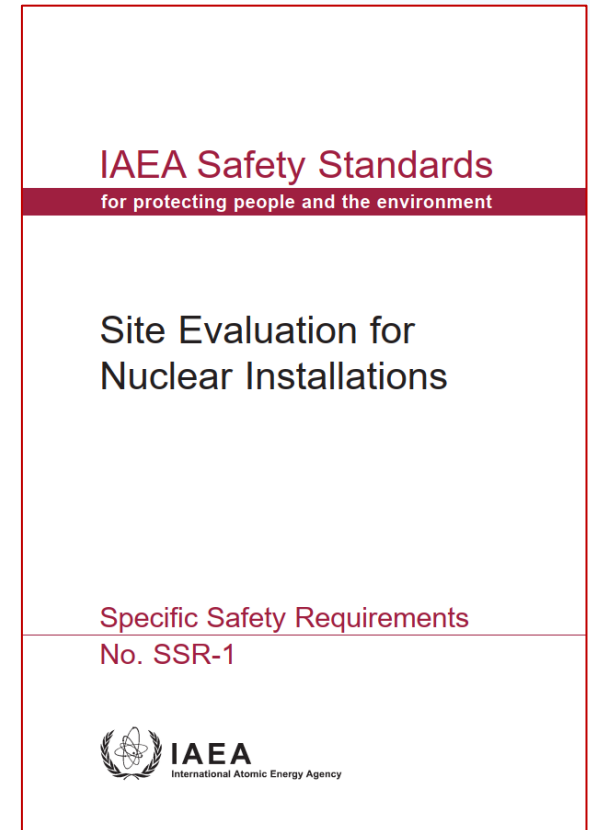


Introduction (6/12)

To apply the fundamental safety principle 8, it is required that (Requirement 4):

*4.67 The site shall be deemed **unsuitable** for a nuclear installation if one or more of the three aspects listed in para. 4.6 indicates that the site is unacceptable and the deficiencies cannot be compensated for by means of a combination of measures for **site protection**, **design features** of the nuclear installation and **administrative procedures***

Background of SSG-35



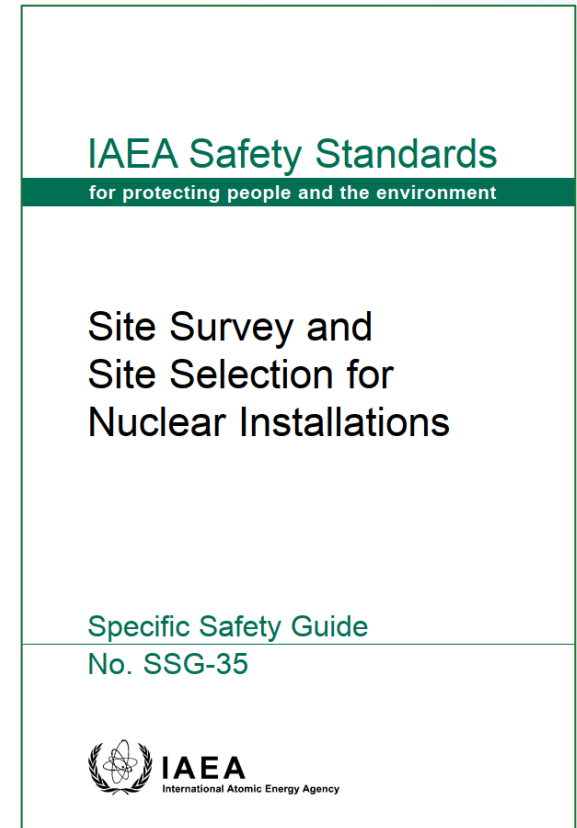
Introduction (7/12)

- IAEA Safety Guide SSG-35:

Provides guidance to address requirements in SSR-1 in relation with:

- ✓ Establishing a systematic process for site survey and site selection for a number of candidate sites (siting process)
- ✓ Consideration of safety in the siting process (i.e. in the selection of a site)
 - Criteria and approaches for identifying suitable sites that comply with established safety requirements are provided

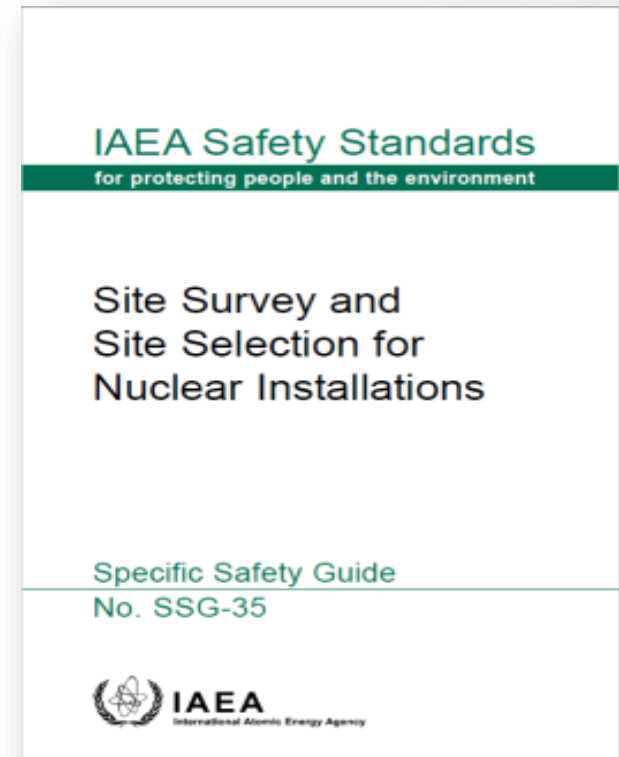
Scope of SSG-35



Introduction (8/12)

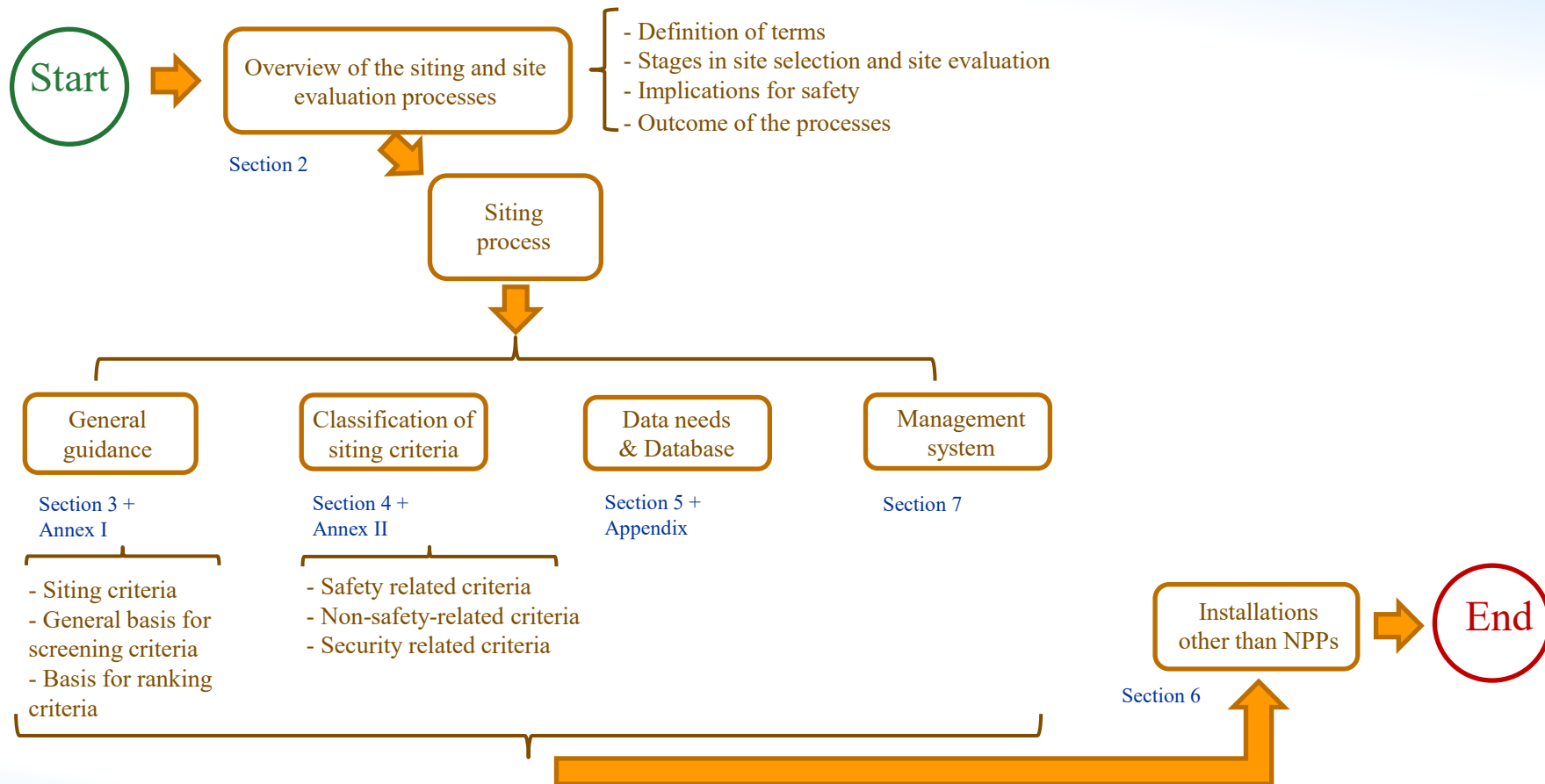
1. Introduction
2. General Description of the Siting Process and the Site Evaluation Process
3. General Recommendations for the Siting Process
 - Siting Process
 - Siting Criteria
 - General basis for screening criteria
 - Specific screening criteria
 - Basis for ranking criteria
 - Siting of new nuclear installations at existing sites
4. Classification of Siting Criteria
 - Safety related criteria
 - Criteria relating to nuclear security
 - Non-safety-related criteria
5. Data Necessary at Different Stages of the Siting Process
6. Siting for Nuclear Installations other than NPPs
7. Application of the Management Systems

Table of Contents of SSG-35



Introduction (9/12)

General Workflow of SSG-35



Introduction (10/12)

General

Remarks

- From a nuclear safety perspective, a properly selected site provides **two** distinct **levels** of ‘defense in depth’:
 - The first level is prevention of accidents: it aims at decreasing the exposure to external hazards.

It involves a comprehensive process of screening out sites where hazards are dominant and complex design safety measures would be necessary.
 - The second level is mitigation: it aims at decreasing the impact of an accident on the environment.

It involves the selection of a site with good dispersion characteristics of radionuclides (air, surface and sub-surface water, terrain), population and infrastructure that are conducive for the implementation of an emergency plan

Introduction (11/12)

General Remarks

- The siting process is a multi-faceted process (nuclear safety, politics, social acceptance, environmental issues... see IAEA NG-T-3.7)
- Site survey and site selection are multidisciplinary efforts:

Power Engineering

Civil Engineering

Nuclear Engineering

Geology

Radiological protection

Seismology

Ecology

Hydrology

Demography / Geography

Meteorology

Emergency planning

Security

... ..

3.6.2. Disciplines required for the project

The siting team must include disciplines which will be available according to the needs of carrying out the specific activities of each stage. In principle, a division between technical disciplines specific to site related aspects and other disciplines can be indicated as follows:

Technical disciplines

- Geography and topography,
- Geology and tectonics,
- Seismology,
- External hazards specialists,
- Volcanology,
- Geotechnics, earthwork & foundation engineering,
- Oceanography,
- Meteorology,
- Hydrology and hydrogeology,
- Human activities and external human induced event assessment,
- Land and water use,
- Socioeconomics,
- Demography and population distribution,
- Analysis of feasibility of emergency planning,
- Environmental assessment, monitoring and environmental impact assessment (radiological and non-radiological),
- Archaeology and historical monuments,
- Grid infrastructure.

Other supporting disciplines

- Nuclear technology,
- Nuclear safety and nuclear security,
- Human resource, training and capacity building,
- Stakeholder involvement,
- Community development/sociology,
- Physical layout planners,
- Procurement of goods and services for executing the Project,
- Legal,
- Project management,
- Quality management,
- Geographical information systems specialists,
- Permitting & licensing, in conventional and nuclear facilities,
- Sustainability.

Managing Siting Activities for
NPPs, NG-T 3.7 (Rev. 1)

Introduction (12/12) Guides

Related IAEA Safety

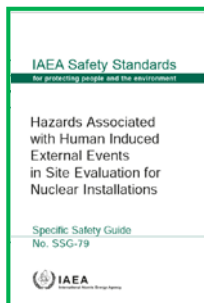
Group 1 Site safety evaluation / Site characterization



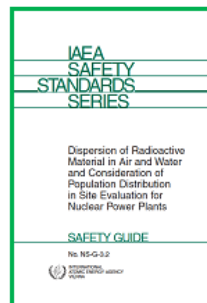
SSR-1 Site Evaluation
for Nuclear Installations

Site Evaluation

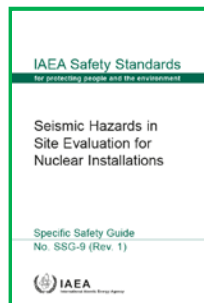
Under Revision



SSG-79, Hazards
Associated with Human
Induced External Events

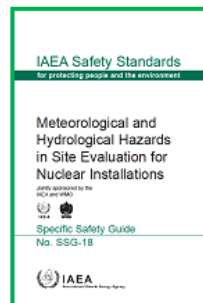


NS-G-3.2 Dispersion of
Radioactive Material in Air
and Water and Consideration
of Population Distribution
in Site Evaluation for
Nuclear Power Plants



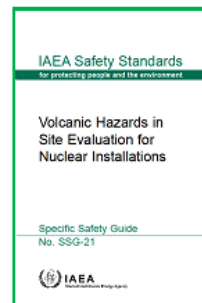
SSG-9 (Rev. 1) Seismic
Hazards in Site Evaluation
for Nuclear Installations

Under Revision

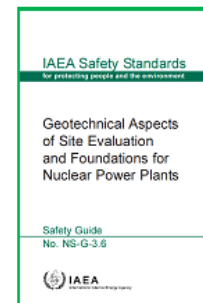


SSG-18 Meteorological and
Hydrological Hazards
in Site Evaluation for
Nuclear Installations

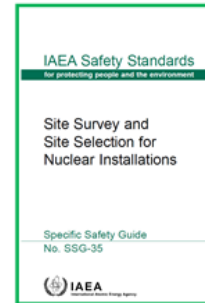
Under Revision



SSG-21 Volcanic Hazards in
Site Evaluation for Nuclear
Installations



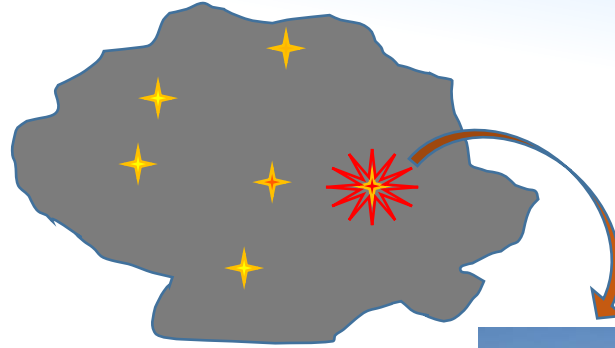
NS-G-3.6 Geotechnical
Aspects of Site Evaluation
and Foundations for Nuclear
Power Plants



SSG-35 Site Survey and Site
Selection for Nuclear
Installations

Actions - Siting and Site Evaluation

- Site selection



- Site Acquisition



- Site Characterisation



- Site preparation



Siting and Site Evaluation Processes

There are two processes relating to the safety considerations for the site of a nuclear installation:

- i. siting process
- ii. site evaluation process

These two processes are further split into five stages:

- site survey stage;
- site selection stage;
- site characterization stage;
- pre-operational stage; and
- operational stage

siting process (SSG35)

site evaluation process

- SSR-1
- Other safety guides covering all hazards

Siting and Site Evaluation Processes

The “Siting Process” = Site Survey + Selection

- **Siting** is the process of surveying and selecting a **suitable site**
- In the **site survey** stage, large regions are investigated to find **potential sites** and to identify **candidate sites**
- In the **site selection** stage, **unsuitable sites** are rejected and the remaining candidate sites are assessed by **comparing and ranking** them on the basis of safety and other considerations to arrive at the **preferred candidate sites**

Siting and Site Evaluation Processes

The “Site Evaluation Process”

= Site Selection + Characterization + Pre-operational + Operational stage

- **Site selection stage** is the overlapping stage between the siting process and the site evaluation process. A final site is selected through the ranking of candidate sites.
- The **suitability** of the site is **confirmed** according to predefined **site exclusion criteria** and a **complete site characterization** is performed, together with finalizing the derivation of site-specific design parameters during the site characterization stage. This process eventually leads to the preparation of the **site evaluation report**.
- All the site related activities involving **confirmatory** and **monitoring** work are taken up in the **pre-operational stage**.
- The site evaluation at the **operational stage** includes all **confirmatory**, **monitoring** and **re-evaluation** work conducted throughout the operational stage.

Siting and Site Evaluation Processes

Stages

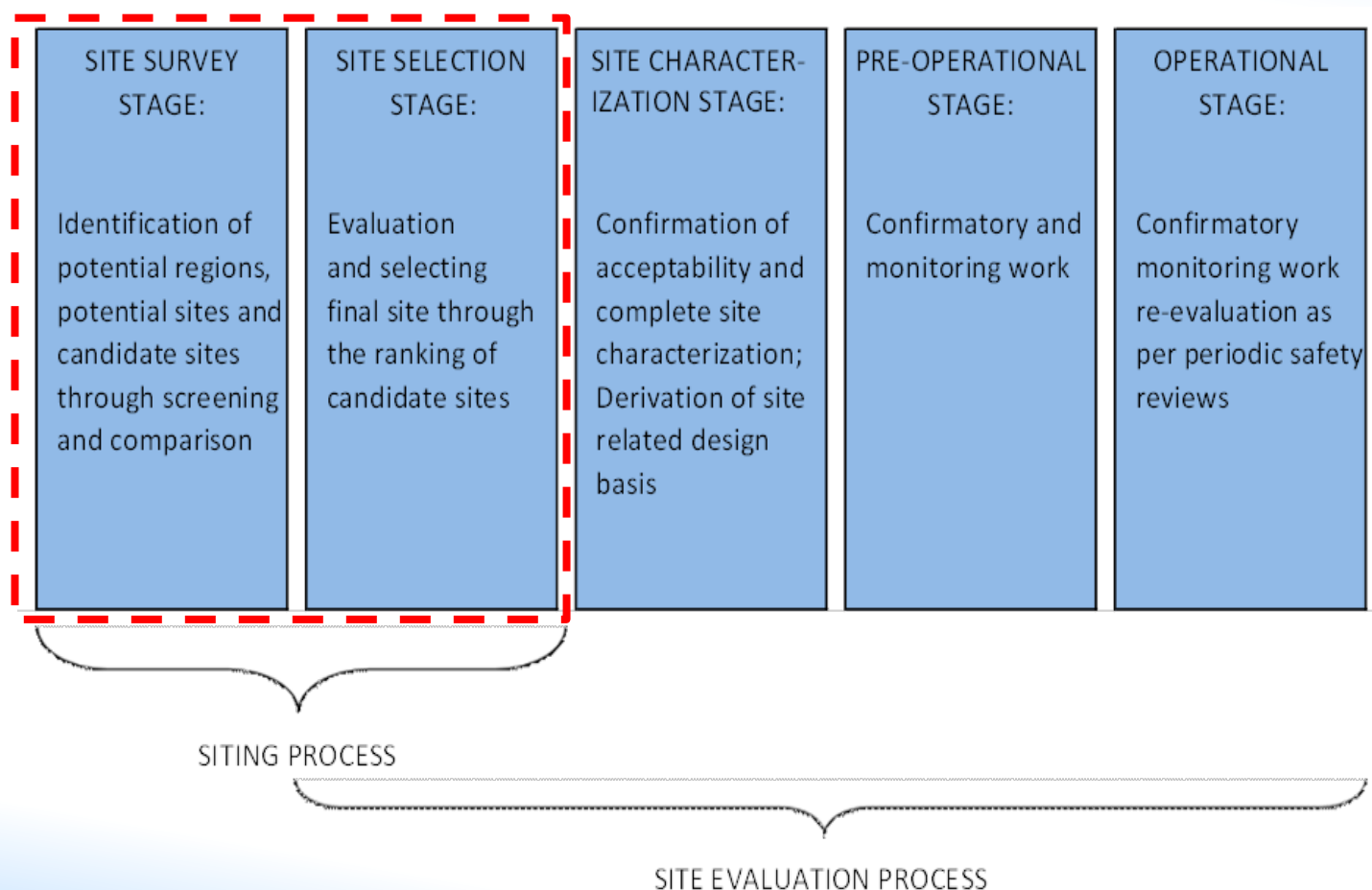


FIG. 1. Stages in the siting process and site evaluation process in the operating lifetime of a nuclear installation.

Siting and Site Evaluation Processes



Site Survey Stage

Identification of potential regions, potential sites and candidate sites through screening and comparison.

Site Selection Stage

Evaluation and selection of final site through the ranking of candidate sites

Site Characterization Stage

Confirmation of acceptability and complete site characterization; derivation of site-specific design parameters.

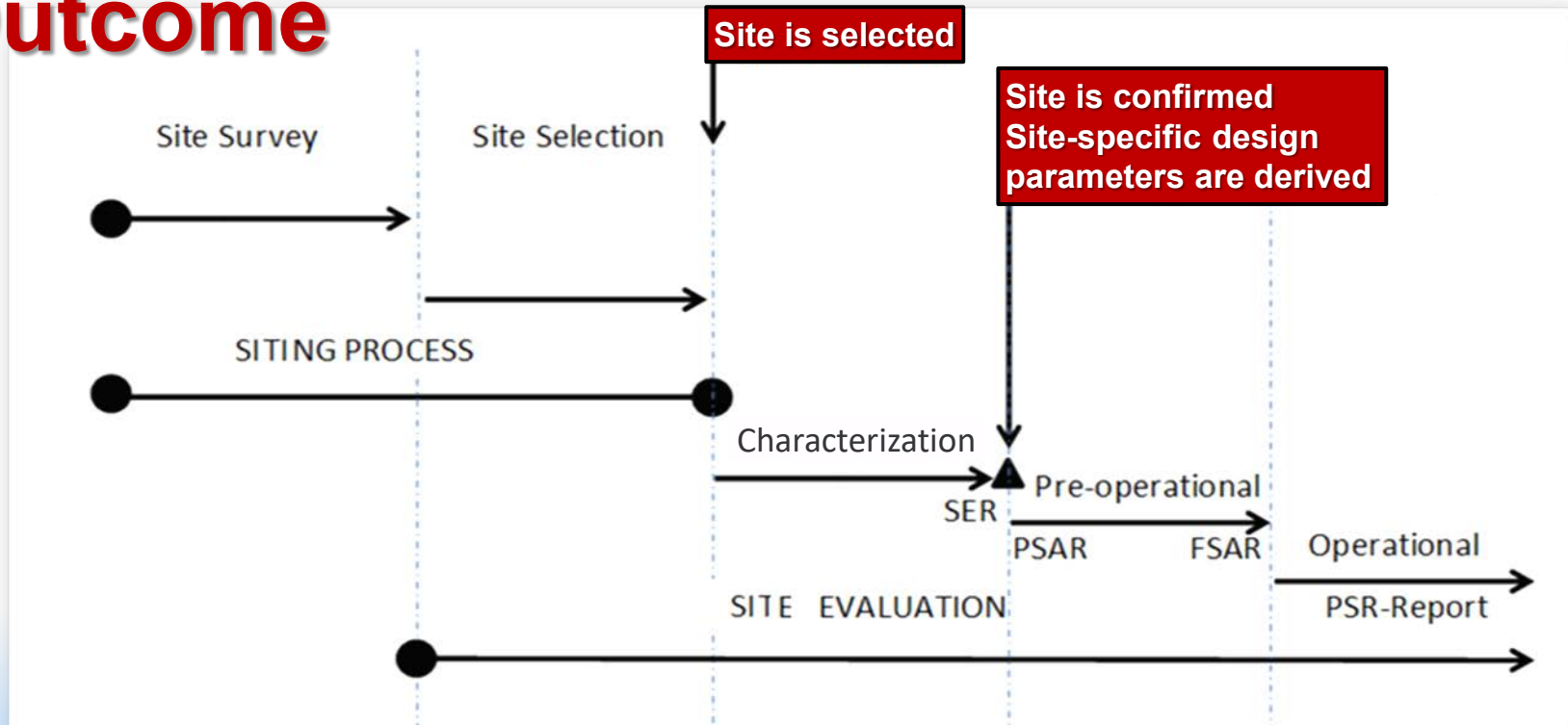
Pre-Operation Stage

Confirmatory and monitoring work.

Operation Stage

Confirmatory and monitoring work, re-evaluation as per Periodic Safety Reviews

Outcome



Siting and Site Evaluation Processes

Licensing and Site Suitability

- In most States, **siting is a non-regulated activity** and no licence is required
- The **site should be deemed unsuitable** if it is concluded that:
 - **no engineering solutions exist** to design against external hazards that challenge the safety of the nuclear installation,
or
 - **there are no adequate measures** to protect people against unacceptable radiological risks

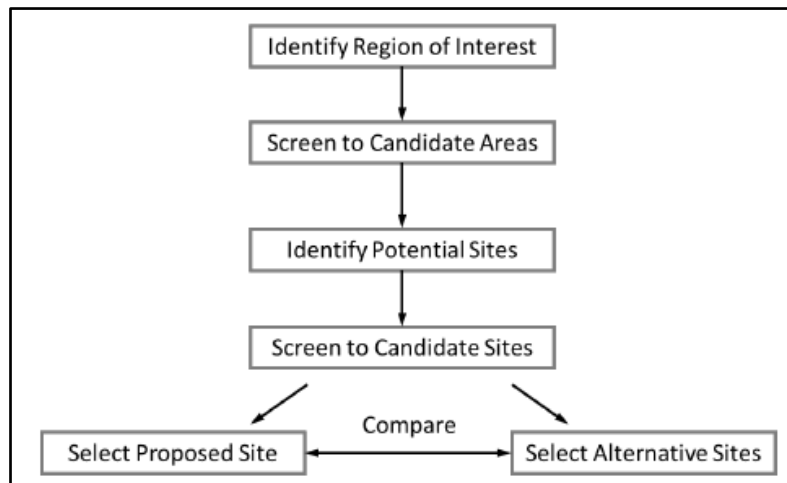
SSG-35 : General Recommendations

The “Siting Process”

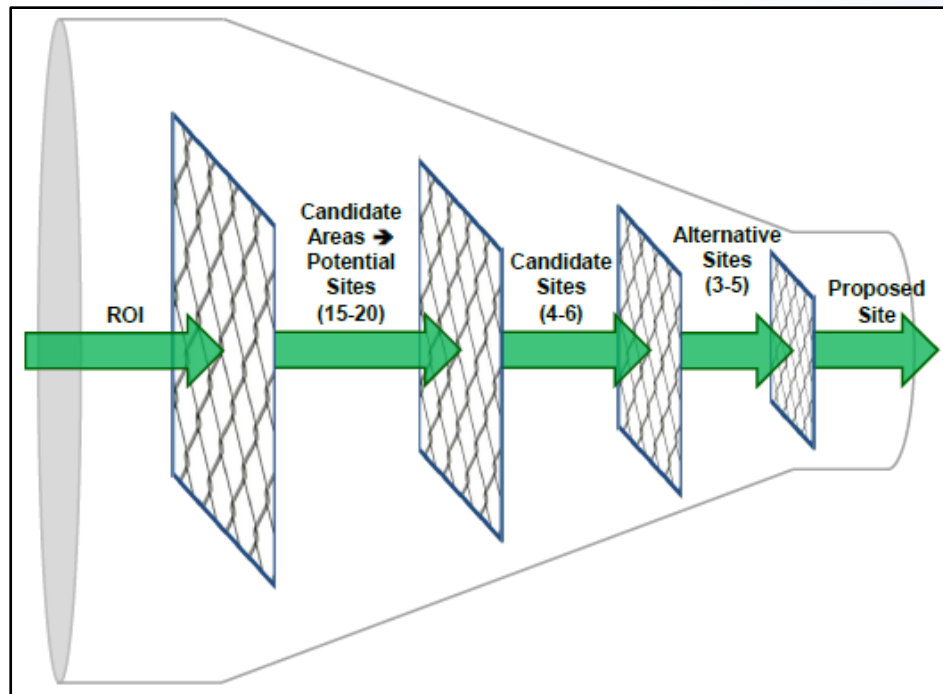
- ❑ is intended to select suitable location for nuclear installation
- ❑ has three distinct steps starting with the region(s) of interest as given;
 - Regional analysis
 - Screening
 - Evaluation, comparison and ranking

SSG-35 : General Recommendations

Remarks



Siting Process steps



Conceptual Siting Process

SSG-35 : General Recommendations

Regional analysis: potential sites

Screening of potential sites: candidate sites

Evaluation, comparison and ranking of candidate sites:

selected/preferred site(s)

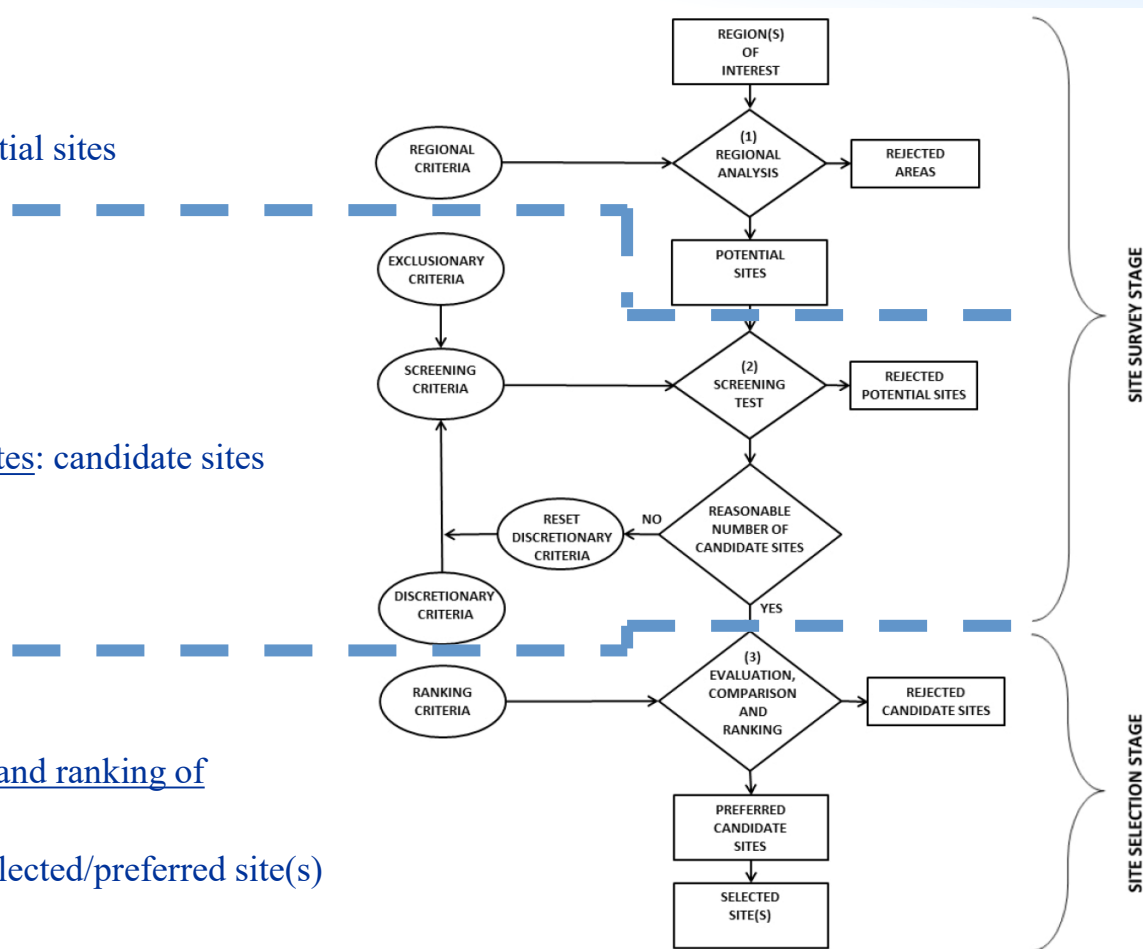


Figure 3, SSG-35

**A Schematic Flow Chart for
Siting Process**

SSG-35 : General Recommendations

Steps of the “Siting Process”

1. **Regional analysis:** region(s) of interest are analyzed to identify all potential sites
2. **Screening test:** potential sites are screened to exclude unfavorable sites using safety and non-safety considerations
3. **Evaluation, comparison and ranking:**
 - to ensure that there are no **features** that would **preclude** the construction and operation of a nuclear installation
 - to **compare** the candidate sites and **rank** them in order of their attractiveness

SSG-35 : General Recommendations

Remarks

- Potential sites (in case of nuclear power plants)
 - ✓ Close to the load centers
 - ✓ Close to transmission line
 - ✓ Heat sink available
- Candidate sites: apply safety and non-safety criteria
 - ✓ Geology & seismicity
 - ✓ Population centers
 - ✓ Potential natural/human-induced events
 - ✓ Economic aspects (site specific works, infrastructures)

SSG-35 : General Recommendations

Remarks

- Selected/preferred site(s)

Balance between **advantages** and **drawbacks**

The final choice is normally strategic or political

Detailed site characterization of the selected site in the following steps may lead to a selected site being found unsuitable from a safety point of view and, thus, excluded.

In order to cater for such situations, a preferred site and an **alternative-preferred site** need to be selected as a result of the process.

SSG-35 : General Recommendations

Remarks

- **Tasks** to be considered in the **regional analysis**:
 1. Review of previously performed studies
Methodology, data and criteria used
 2. Update previous studies
Check validity of previous results and whether or not other sites can be identified in the region.
 3. Identification of new potential sites
Identify potential sites using the updated criteria and methodology, if applicable.

SSG-35 : General Recommendations

Remarks

- Data requirements in the regional analysis:
 - Only available data, either from previous studies or from public sources
 - No site-specific investigations need to be made
 - Required data refer to topics such as:

Population density	Topography & Bathymetry
Proximity to towns and cities	Meteorology & Hydrology
Land use	Geology / Geotechnical
Access and transportation	Seismicity
Proximity to hazardous activities	Grid connection
Availability of cooling & industrial water	

SSG-35 : General Recommendations

Remarks

- Typical **tasks** in the **screening** of potential sites:

1. Establish screening criteria (discussed in upcoming slides)

2. Data collection and verification

Collect additional available data, associated to screening criteria

Visit sites. Collect a limited amount of new data through basic site investigations.

Initiate a systematic, consistent and uniform database for each potential site and regarding each considered topic

3. Screening and identification of candidate sites

Using the established criteria and the collected data, identify a reasonable number of candidate sites (for example, 3 to 6)

Visit each candidate site once again to confirm the results

SSG-35 : General Recommendations

Remarks

- Data requirements in the screening of potential sites

Data used in previous phase need to be enhanced in two ways:

1. Data related to topics not covered in previous phase should be collected
2. The data need to be uniform for all sites, if a reasonably comparative basis is to be established. For this reason, further collection of data may be needed for sites where information is lacking.

SSG-35 : General Recommendations

Remarks

- Typical **tasks** in the **ranking** of candidate sites:
 1. Confirmation of the suitability of the sites (no exclusion factors)
Identify the potential weakness of each site that may be the basis for excluding it from further consideration.
Conduct appropriate **site-specific investigations** and analyses to decide whether or not the site is confirmed (i.e. it does not possess any negative features to be considered as a suitable site).
 2. Establish criteria for comparison and ranking (discussed in upcoming slides)
 3. Identify the preferred candidate site(s)
Using the established criteria quantify the selected attributes of each site.
Select the site(s) that ranks highest as the preferred candidate site(s).

SSG-35 : General Recommendations

Remarks

- Data requirements in the **ranking** of potential sites:

For Task 1 (confirmation of suitability), it is possible that detailed data is required for some sites.

Specific site investigations (boreholes, pits, trenches, geophysical) will be required in that case

Data about construction and operation costs is required

Design details are not required, since ranking is made in relative terms

Data needed for simplified assessment of external hazards and other design parameters related to the site should be collected

This will allow performance of quantitative comparisons from site to site

SSG-35 : General Recommendations

Siting Criteria

There are **three** categories of **siting criteria**:

1. regional criteria;
2. screening criteria; and
3. ranking criteria.

SSG-35 : General Recommendations

1. Regional Criteria

- The regional analysis should be carried out to identify potential sites using well established regional criteria.
- No site should be discarded without appropriate justification
- Regional criteria are generally related to:
 - national domestic policy,
 - national economic policy,
 - national and international environmental protection or other related policies of the State
- Technical and infrastructure constraints and availability of resources (e.g. water) are also important considerations

SSG-35 : General Recommendations

2. Screening Criteria - are of two types:

- ***Exclusion criteria:*** used to discard unacceptable sites based on site attributes for which there are no generally practicable engineering solutions.
- ***Discretionary criteria:*** associated with attributes for which protective engineering solutions are available. Used to eliminate less favourable sites from a large number of sites

Table I-1 can be used as screening criteria.

SSG-35 : General Recommendations

2. Screening Criteria – Availability of Data

- Siting process is expected to be completed using **existing data**,
 - However, good quality data may not always be available, at the early site survey stage, to make certain decisions

In such a case, **additional data should be collected** to confirm the suitability of the site

SSG-35 : General Recommendations

3. Ranking Criteria

- provide bases for **comparing and ranking** the candidate sites to arrive at a list of **preferred candidate sites**
- are generally developed by using considerations relating to **discretionary criteria** together with relevant non-safety-related consideration
- sufficient **amount and quality of data** should be collected before a comparison between two (or more) sites
- **Limited field investigation**, if required, should also be conducted at this stage

Classification of siting criteria

- *Screening criteria or Ranking criteria* used within the siting process fall into one of three types
 - Safety related criteria
 - Criteria relating to nuclear security
 - Non-safety-related criteria

Classification of siting criteria

Safety related criteria

- Safety related criteria to be considered in the siting process should be consistent with the safety requirements established in IAEA **SSR-1**
- These criteria are classified into four thematic sets:
 - Potential impact of natural hazards on the safety of the nuclear installation (Para. 4.3, SSG-35)
 - Potential impact of human-induced events on the safety of the nuclear installation (Para. 4.4, SSG-35)
 - Characteristics of the site that could influence the transfer of radioactive material to people and environment (Para. 4.5, SSG-35)
 - Feasibility of implementation of the emergency plan (Para. 4.6, SSG-35)

Classification of siting criteria

Criteria relating to nuclear security

- Nuclear security aspects should also be considered in siting nuclear installations, taking account of the guidance provided in the IAEA Nuclear Security Series Nos. 10, 13 and 19.
- Typically, this includes consideration of site characteristics that could affect:
 - The ability to implement **physical protection** measures
 - The capability to **deter, detect, delay** and **respond** to nuclear security events

Classification of siting criteria

Non-safety-related criteria

- Non-safety-related criteria are concerned with aspects that are not directly related to nuclear safety, such as:
 - Availability of cooling water
 - Topography
 - Access to electrical grid
 - Non-radiological environmental impacts
 - Socioeconomic impacts
- Such criteria should be considered together with the considerations relating to nuclear safety, especially in the **ranking** of the candidate sites.

Managing Siting Activities for
Nuclear Power Plants (NG-T-3.7
(Rev. 1): 19 Infrastructure
Issues



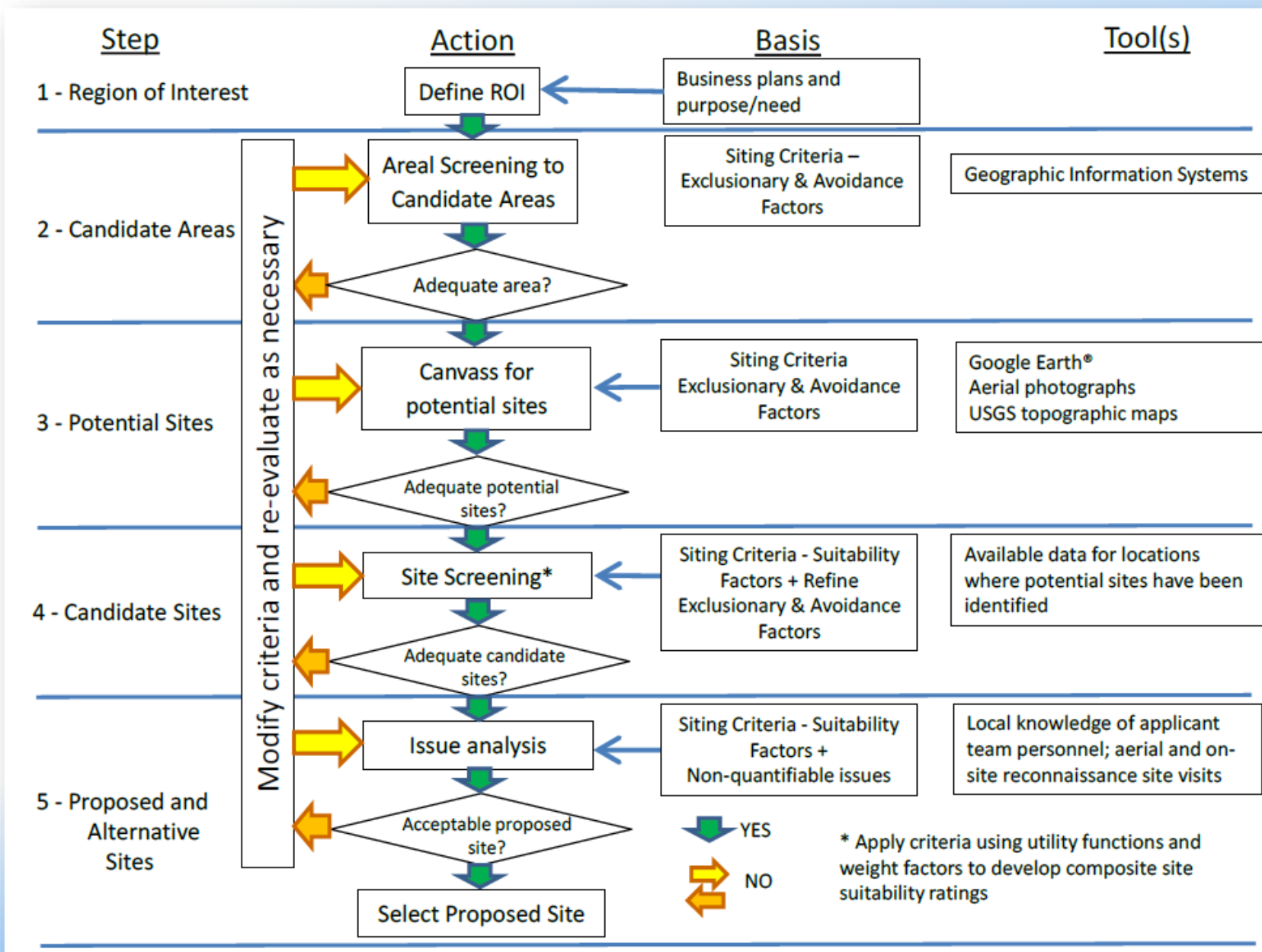
Table I-1. Screening and Ranking Criteria for the Purpose of Site Selection

Primary	Criteria	Category		
		Screening	Discretionary	Ranking
Earthquake	Ground vibration		✓	✓
	Surface rupture	✓		
Geotechnical	Slope instability (massive landslide)	✓		
	Slope instability (minor)		✓	✓
	Subsidence		✓	✓
	Massive liquefaction	✓		
	Liquefaction		✓	✓
	Karst (massive)	✓		
Volcanism	Lava flow	✓		
	Pyroclastic flow	✓		
	Ground deformation	✓		
	Tephra fall		✓	✓
	Volcanic gases		✓	✓
	Lahars(massive)	✓		
Flooding	River		✓	✓
	Dam break		✓	✓
	Coastal(storm surges, waves, etc.)		✓	✓
	Tsunami		✓	✓
Extreme meteorological events	High straight winds		✓	✓
	Tomados		✓	✓
	Tropical storms		✓	✓
	Precipitation		✓	✓
	Sand storms and dust storms		✓	✓
Human induced events	Aircraft crashes		✓	✓
	Explosions		✓	✓
	Gas releases		✓	✓
	External fires		✓	✓
	Electromagnetic interference		✓	✓
Nuclear security			✓	✓
Dispersion			✓	✓
Feasibility of implementation of emergency plan	In air and water	✓		
Implementation of emergency plan			✓	✓
Non-safety	Topography		✓	✓
	Availability of cooling water	✓		
	Access to water		✓	✓
	Availability of transport		✓	✓
	Access to national or regional grid		✓	✓
	Non-radiological environmental impacts	✓		
	Socio-economic impacts		✓	✓
	Land-use planning		✓	✓

Table I-2. Site Selection Issues Crossed-Referenced to IAEA Safety Standards

Site selection issue		Safety Requirements	Safety Guides relevant to site evaluation						Safety Guides relevant to design	
Primary	Effect	NS-R-3	NS-G-3.1	NS-G-3.2	SSG-9	SSG-18	SSG-21	NS-G-3.6	NS-G-1.5	NS-G-1.6
Earthquake	Ground vibration	✓			✓					✓
	Surface rupture	✓			✓					
Geotechnical	Slope instability	✓						✓		
	Subsidence	✓						✓		
	Soil Liquefaction	✓						✓		
	Extensive oil and gas extraction history	✓						✓		
Volcanism		✓					✓			
Flooding	River	✓				✓			✓	
	Dam break	✓				✓			✓	
	Coastal	✓				✓			✓	
	Tsunami	✓				✓			✓	
Extreme meteorological events	High straight winds	✓				✓				
	Tomadoes	✓				✓			✓	
	Precipitation	✓				✓			✓	
Human induced events	Aircraft crashes	✓	✓						✓	
	Explosions	✓	✓						✓	
	Gas releases	✓	✓						✓	
	External fires	✓	✓						✓	
Population	Density	✓		✓						
	Distance from centres	✓		✓						
Dispersion	In air	✓		✓						
	In water	✓		✓						
Feasibility of the emergency plan		✓		✓						

Example of Functional Application of Site Selection Process



Example Results of Screening Criteria used in Candidate site identifications

Site Name	Seismic	Cooling Water Supply	Flooding	Population	Hazardous Land Uses	Ecology	Wetlands	Heavy Haul Access	Transmission Access	Land Acquisition	Site Rating
	Weight Factor of Criterion										
	8.2	9.5	4.6	8.1	6	5.7	6.2	5.1	7.8	3.3	
Site 1	3	4	5	4	2	1	1	5	1	5	191.7
Site 2	3	5	1	5	2	1	1	5	2	5	198.7
Site 3	2	2	1	4	2	2	2	5	2	5	165.8
Site 4	5	1	5	4	4	1	3	5	2	5	211.8
Site 5	5	5	4	5	3	2	5	4	3	5	268.1
Site 6	4	3	5	4	2	4	3	3	3	5	225.3
Site 7	3	3	4	3	2	2	4	3	3	5	199.2
Site 8	1	5	4	4	2	2	4	3	4	5	217.7
Site 9	1	5	3	4	1	2	4	3	4	4	203.8
Site 10	2	3	5	5	2	3	4	2	3	4	209.1
Site 11	3	3	4	4	2	2	5	2	3	5	208.4
Site 12	4	5	2	5	2	2	4	4	4	5	246.3
Site 13	5	5	4	1	2	2	5	4	4	4	234.2
Site 14	3	2	4	3	2	1	5	1	4	4	184.5
Site 15	4	2	5	2	3	2	5	5	5	4	229.1

Detailed Siting Criteria (Ranking and Scoring) – Sample Results

Criterion*	Weight	Site 5		Site 12		Site 8		Site 9		Site 15		Site 13		Site 10		Site 6	
	Factor	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score
Cooling system requirements	9.6	2.5	24	3	28.8	3.25	31.2	3	28.8	3	28.8	3.25	31.2	2.75	26.4	3	28.8
Flooding	3.9	5	19.5	1	3.9	3	11.7	2	7.8	3	11.7	3	11.7	5	19.5	3	11.7
Nearby hazardous land uses	4.2	4	16.8	3	12.6	4	16.8	4	16.8	3	12.6	3	12.6	4	16.8	3	12.6
Extreme weather conditions	4.6	3	13.8	3	13.8	3	13.8	3	13.8	3	13.8	3	13.8	3	13.8	3	13.8
Air radionuclide pathway	7.4	4	29.6	4	29.6	4	29.6	4	29.6	4	29.6	4	29.6	4	29.6	4	29.6
Disruption of important species/habitats	6.4	4	25.6	4	25.6	4	25.6	4	25.6	4	25.6	4	25.6	4	25.6	4	25.6
Dewatering effects on adjacent wetlands	5.6	4	22.4	3	16.8	4	22.4	2	11.2	4	22.4	4	22.4	3	16.8	4	22.4
Socioeconomics: construction-related effects	5.2	3	15.6	2	10.4	2	10.4	3	15.6	5	26	4	20.8	3	15.6	3	15.6
Civil works	4.8	3	14.4	2	9.6	3	14.4	2	9.6	5	24	3	14.4	3	14.4	2	9.6
Railroad access	6.7	3	20.1	4	26.8	3	20.1	3	20.1	5	33.5	4	26.8	3	20.1	4	26.8
COMPOSITE RATING			202		178		196		179		228		209		199		197

Scoring Example for Flooding

Area Flooding Potential	Rating
Site is not located within a 100-year floodplain, and no potential upstream flooding concerns (such as dam failure) exist.	5
Site is not located within 100-year floodplain, but potential upstream flooding concerns exist.	4
Site borders a 100-year floodplain, and potential upstream flooding concerns might exist.	3
Site is located within 100-year floodplain, but no potential upstream flooding concerns exist.	2
Site is located within 100-year floodplain, and potential upstream flooding concerns exist.	1

Scoring Example for Population Density and proximity

Host County Population Density	Rating
Fewer than 50 persons per square mile (psm)	5
Between 50 psm and < 100 psm	4
Between 100 psm and < 250 psm	3
Between 250 psm and < 500 psm	2
500 psm or more	1

Distance to Nearest Populated Area	Rating
No populated area within 20 miles*	5
Populated areas between 15 miles and < 20 miles	4
Populated areas between 10 miles and < 15 miles	3
Populated areas between 5 miles and < 10 miles	2
Populated areas less than 5 miles	1

Screening of Hazards during Site Selection process for SMRs

- Screening for
 - ✓ Population
 - ✓ Capable faulting
 - ✓ Volcano Hazard
 - ✓ Floods
 - ✓ Human Induced Events
 - ✓ UHS

Screening of Hazards during Site Selection process for SMRs

Screening for Population

- The population data to be collected and processed for an SMR depends on the **external zone** to be considered necessary;
- External zone would be smaller than that for a large NPP, depending on the **number of modules** planned and whether or not the extent of the external zone is determined conditional to the failure of a single module;
- In case if external zone is determined conditional to failure of a **single module**, it is necessary to ensure that all **common cause** scenarios have been taken into account;
- Screening values for the population data should be selected following a **performance-based** criteria commensurate with specific SMR design;
- In case specific design is not yet selected, an enveloping criteria may be selected.
- The consideration **for 5th level of DiD** for SMRs is under debates.

Screening of Hazards during Site Selection process for SMRs

Screening for Population

- The **type** of **data** to be collected regarding population is not different from one type of facility to another;
- **Size** of the **region** (the radius) has to be adjusted according to the source term and the engineered safety features of the SMRs.

Screening of Hazards during Site Selection process for SMRs

Screening for Feasibility of Emergency Response Action

- Regardless of the size of the external zone, following three major potential **impediments** need to be taken into account:
 1. **Geographic** and/or **topographic** conditions of the site that may cause hindrance to transportation and communication within and outside the site;
 2. **External hazards** which may have played a role in the **severe accident**, and which may also **destroy infrastructure** needed for **transportation** and **communication** within and outside the site;
 3. **Collocated** nuclear **installations** that may also have concurrent severe accidents due to a **common cause**.
- All these points have to be considered for site selection even if the external zone for the SMR is reduced (or even within the site area of the SMR)

Screening of Hazards during Site Selection process for SMRs

Screening for Capable Faults

- Fault capability is an **exclusionary** external hazard, **no grading** for application of the requirements is recommended;
- Even though if the size of the footprint of an SMR is smaller in comparison to a large NPP, screening distance for fault displacement should be considered similar to that of large NPPs.

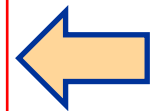
Screening of Hazards during Site Selection process for SMRs

Screening for Volcano Hazards

TABLE 1. VOLCANIC PHENOMENA AND ASSOCIATED CHARACTERISTICS THAT COULD AFFECT NUCLEAR INSTALLATIONS, WITH IMPLICATIONS FOR SITE SELECTION AND EVALUATION AND DESIGN

Phenomena	Potentially adverse characteristics for nuclear installations	Considered an exclusion condition at site selection stage?	Can effects be mitigated by measures for design ² and operation?
1. Tephra fallout	Static physical loads, abrasive and corrosive particles in air and water	No	Yes
2. Pyroclastic density currents: pyroclastic flows, surges and blasts	Dynamic physical loads, atmospheric overpressures, projectile impacts, temperatures >300°C, abrasive particles, toxic gases	Yes	No
3. Lava flows	Dynamic physical loads, floods and water impoundments, temperatures >700°C	Yes	No
4. Debris avalanches, landslides and slope failures	Dynamic physical loads, atmospheric overpressures, projectile impacts, water impoundments and floods	Yes	No
5. Volcanic debris flows, lahars and floods	Dynamic physical loads, water impoundments and floods, suspended particulates in water	Yes	Yes
6. Opening of new vents	Dynamic physical loads, ground deformation, volcanic earthquakes	Yes	No
7. Volcano generated missiles	Particle impacts, static physical loads, abrasive particles in water	Yes	Yes
8. Volcanic gases and aerosols	Toxic and corrosive gases, acid rain, gas charged lakes, water contamination	No	Yes

Grading is not possible



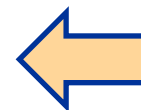
Screening of Hazards during Site Selection process for SMRs

Screening for Volcano Hazards

TABLE 1. VOLCANIC PHENOMENA AND ASSOCIATED CHARACTERISTICS THAT COULD AFFECT NUCLEAR INSTALLATIONS, WITH IMPLICATIONS FOR SITE SELECTION AND EVALUATION AND DESIGN (cont.)

Phenomena	Potentially adverse characteristics for nuclear installations	Considered an exclusion condition at site selection stage?	Can effects be mitigated by measures for design ² and operation?
9. Tsunamis, seiches, crater lake failure and glacial burst	Water inundation	Yes	Yes
10. Atmospheric phenomena	Dynamic overpressures, lightning strikes, downburst winds	No	Yes
11. Ground deformation	Ground displacements, subsidence or uplift, tilting, landslides	Yes	No
12. Volcanic earthquakes and related hazards	Continuous tremor, multiple shocks, usually earthquake magnitude $M < 5$	No	Yes
13. Hydrothermal systems and groundwater anomalies	Thermal water, corrosive water, water contamination, inundation or upwelling, hydrothermal alteration, landslides, modification of karst and thermokarst, abrupt change in hydraulic pressure	Yes	Yes

Grading is not possible



Note: A 'Yes' in the site selection stage column indicates that the presence of a significant hazard from this phenomenon in the site vicinity generally constitutes a site exclusion criterion, i.e. the site is not suitable for a nuclear installation. The design and operation column indicates the general practicality of mitigating the potential hazard associated with particular phenomena, by either facility design or operational planning. A 'Yes' in both columns indicates that, in principle, this phenomenon constitutes a site exclusion criterion, although for some cases a design basis may be achievable.

² Design also includes the design of site protection measures for some of the hazards.

Screening of Hazards during Site Selection process for SMRs

Screening for Volcano Hazards

- For the **exclusionary** volcano hazard, **no grading** for application of the requirements is recommended;
- Usually, large NPPs have more design robustness against impact and blast loads, therefore **screening distance values** for SMRs related to some volcano effects of may be **larger** than that for a large NPP;
- Theoretically, it is possible to apply a graded approach for non-exclusionary phenomena, however, there is **no significant advantage** in terms of human resources or time as these involve **standard engineering approaches**;
- **Tephra fall** out phenomena may be graded if SMR **design covers** this hazards.

Screening of Hazards during Site Selection process for SMRs

Screening for Floods

- Flooding events may not be screened out in general;
- One possibility of screening of floods is if the design of the SMR is such that it is not located near a river, lake or sea. However, flash flooding due to local intense precipitation has to be evaluated;
- Since flooding could lead to common cause failures involving more than one module, sufficient margins are needed for safety against flood hazards;
- Marine based SMRs are particularly vulnerable to coastal flooding.
- Even though protective measures be adopted against flood hazards caused by tsunami, seiches, storm surge, waves, rivers and precipitation etc, however may be not cost effective for SMRs.
- As flooding is a major safety issue for nuclear installations, it is recommended that flooding issues be avoided through the site selection process

Screening of Hazards during Site Selection process for SMRs

Screening for HIEEs

- Two types of screening including SDV and SPV are recommended in SSG-79 for screening of HIEEs;
- SDV for large NPPs is indicated for each HIEE with respect to the design of the NPP for loads such as impact, blast, thermal, and vibration. It is expected that in general, SMRs may not be as robust as large NPPs with respect to their design against these loads which may lead to larger values for the SDVs;
- On the other hand, the exposed profile of SMR structures may be significantly smaller than those of a large NPP, especially if the safety related parts of an SMR are embedded. This could be a consideration for the possibility of screening out of some missile impact scenarios including, for example, aircraft crash;
- This may not be a case for marine based SMRs where the plant is exposed, and the impact of a large aircraft would potentially result in unacceptable consequences.

Screening of Hazards during Site Selection process for SMRs

Screening for UHS

- Ultimate Heat Sink requirements for large NPPs and SMRs may differ significantly ;
- Accordingly, the data needed and the uncertainties involved may also be different;
- For example, some SMRs have passive means of extracting residual heat;
- In general, grading of data collection and protection of the UHS for SMRs is a possibility in comparison to large NPPs. However, potential for grading depends on specific UHS design that may be different for different SMRs.
- Screening for UHS during the site survey needs to consider the SMR technology. The water requirements for the UHS may vary from one type of SMR to the other.

Summary ^(1/7)

1. Adequate site selection is important for social, economical and nuclear safety reasons

- ✓ From a nuclear safety point of view, an adequate site selection belongs in Level 1 of the *Defence-In-Depth* principle ('prevention of abnormal operation and failures'), as defined in IAEA INSAG-10, and also in Level 5 ('mitigation of radiological consequences of releases').

Summary (2/7)

2. Site selection is performed by means of a **siting process**

- ✓ The siting process has two main steps: site survey and site selection.
- ✓ Site survey consists of a regional analysis, to identify potential sites, followed by a screening of potential sites, to identify candidate sites.
- ✓ Site selection is performed by evaluation, comparison and ranking of candidate sites.
- ✓ Balance between advantages and drawbacks (no site is perfect)
- ✓ Final choice is made with a strong strategical or political weight

Summary ^(3/7)

3. The main focus of Safety Guide **SSG-35** is on the **siting process**

- ✓ The siting process results in the selection of a site, for detailed characterization and safety evaluation.
- ✓ The siting process is normally a non-regulated process. However, the selected site must meet the site safety requirements in IAEA SSR-1.
- ✓ Detailed site characterization of the selected site in the following phases may lead to a selected site being found unsuitable from a safety point of view and, thus, excluded.
- ✓ A badly selected site can have serious consequences downstream, in terms of over-costs and delays in the nuclear programme.

Summary (4/7)

4. Siting process makes use of an increasingly detailed data collection and evaluation activity

- ✓ Site survey is based on information and data collected mainly from existing sources
- ✓ Site selection works mostly at the local scale of candidate sites and may require acquisition of new (i.e. non-available) data.
- ✓ Acquisition and processing of data should be performed according to the quality requirements of a Management System.
- ✓ All data should be collected in a systematic, transparent, retrievable and traceable manner.
- ✓ A database, containing all gathered data, should be established

Summary ^(5/7)

5. Pre-defined **siting criteria** provide the basis for a rational **decision-making process** in site selection
- ✓ There exist three types of criteria:
 - Safety related: intended to facilitate meeting SSR-1 requirements.
 - Security related: intended to facilitate physical protection measures, and capability to deter, detect and respond to threats
 - Non-safety related: technical, economical, environmental, etc.
 - ✓ The criteria are used in the different stages of the process.
 - Regional criteria: mainly, non-safety related criteria
 - Screening criteria: focus on safety-related criteria
 - Ranking criteria: mainly non-safety related discretionary criteria

Summary (6/7)

6. A management system for siting should be established at the earliest possible time

- ✓ The management system will need to cover:

Organization

Planning

Qualification of personnel

Work control / Verification

Required documentation

- ✓ The goal is to have a documented, traceable process, with reliable results
- ✓ The key management document is a Project Plan.

Summary ^(7/7)

7. Siting process may be **graded**, for installations other than nuclear power plants

- ✓ Site survey and site selection process, by their own nature, are difficult to grade.
- ✓ Considering deployment of potential SMRs technology in the siting process is helpful for screening of hazards.
- ✓ Possibility of grading depends on the radiological hazard category of the installation, which is determined by a consequence analysis.
- ✓ For high hazard installations, no grading is possible.
- ✓ For medium and low hazard installations, grading may be applied to the extent and level of detail of the data to be collected and analyzed for application of safety-related screening criteria.



IAEA

60 Years

Atoms for Peace and Development



Thank you!
Questions?

ma.mahmood@iaea.org



**Co-funded by
the European Union**