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Site Evaluation and The Experience in Korea

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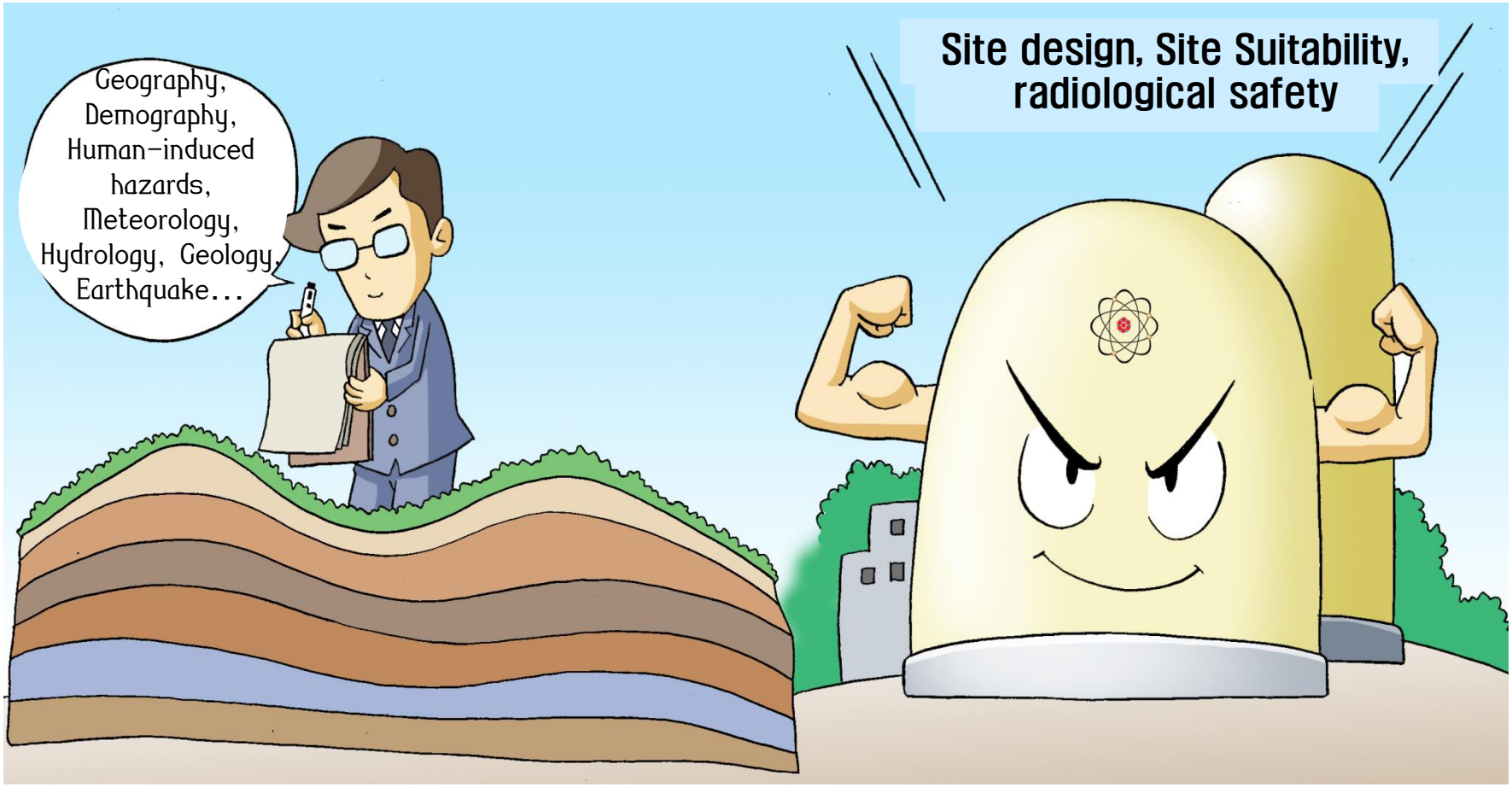
I. Introduction

Why the Site's Safety Evaluation?

Site safety evaluation for NPPs concerns
1. Site suitability for planed NPPs
2. Input data of the NPP site for the design



Introduction

☐ Siting

- ❍ **The process of selecting a suitable site for a facility** including appropriate assessment and definition of the related design basis (IAEA, NS-R-3)
- ❍ The siting process for a nuclear installation **generally consists of an investigation of a large region** to select one or more candidate sites (site survey), **followed by a detailed evaluation** of those candidate sites (IAEA, NS-R-3)
- ❍ Siting **covers** the general safety requirements and criteria for site related **evaluation of external natural and human induced hazards** to the nuclear installations

Introduction

- **Siting Factors and Criteria are important to assure that:**
  - **Radiological doses** from normal operation and postulated accidents will be **acceptably low**,
  - **Natural phenomena and potential man-made hazards** will be appropriately **accounted for in the design** of the plant,
  - Site characteristics are such that **adequate security measures** to protect the plant **can be developed**,
  - And that **physical characteristics** unique to the proposed site that could pose a significant impediment to the **development of emergency plans are identified**.
- KINS staffs tend to carry out **a traditional defense-in-depth approach** with regard to reactor siting to ensure public safety.
- **Siting away from densely populated centers** has been and will continue to be an **important factor** in evaluating applications for site approval.

Introduction

☐ Major Subjects Related to Siting(1)

❍ Geography and Demography

- The effects of the nuclear installation on the region and matters relating to **population and emergency planning**
- **Population density** and use characteristics of the site environs, including the exclusion area, **the population distribution**, and site-related characteristics must be evaluated to determine whether individual as well as societal risk of potential plant accidents is low, and that physical characteristics unique to the proposed site that could pose a significant impediment to the development of **emergency plans** are identified

❍ Man-related Hazard

- Nearby industrial, transportation, and military facilities
- The nature and proximity of man-related hazards (e.g., airports, dams, transportation routes, military and chemical facilities) must be evaluated to establish site parameters for use in determining whether a plant design can accommodate commonly occurring hazards, and whether the risk of other hazards is very low.

Introduction

☐ Major Subjects Related to Siting(2)

❍ Meteorology

- Meteorological characteristics of the site that are necessary for safety analysis or that may have an impact upon plant design (such as maximum probable wind speed and precipitation) must be identified and characterized.
- **Design** against the severe meteorological condition
- Strong wind, heavy rainfall or precipitation, tornadoes
- **Atmospheric diffusion characteristics** for the calculation of the transport and dilution of **radioactive materials**

❍ Hydrology

- Factors important to hydrological radionuclide transport (such as soil, sediment, and rock characteristics, adsorption and retention coefficients, ground water velocity, and distances to the nearest surface body of water) must be obtained from on-site measurements.
- The maximum probable flood along with the potential for seismically induced floods must be estimated using historical data.
- Protection from flooding, radioactive material diffusion through ground/ surface water, water use

Introduction

☐ Major Subjects Related to Siting(3)

❍ Geology, Seismology, and Geotechnical Engineering

- Geological hazards, design earthquake, site layout, stability of foundation materials and slopes

☐ **Where unfavorable physical characteristics of the site exist**, the proposed site may nevertheless be found to be acceptable if the design of the facility includes appropriate and adequate compensating engineering safeguards.

Legal Requirments and Technical Standards

Law	Articles 11 (Acceptance Criteria for Construction Permit), 21 (Acceptance Criteria for Operating License), 89 (Establishment of Exclusion Area) & 90 (Restriction of Installment of Dangerous Facility) of AESA
Ordinance of the Nuclear Safety and Security Commission (NSSC)	Regulation on Technical Standards for Nuclear Power Plants, Etc. Article 4 Geological Features and Earthquakes Article 5 Limitations on Location Article 6 Meteorological Condition Article 7 Hydrologic and Oceanographic Conditions Article 8 Impact of Human-induced Accident Article 51 Measures regarding Radiation Control Area, etc.
Notice of the NSSC	● No. 2017-15, "Technical Standards for Locations of Nuclear Reactor Facilities" • Technical Applications: 10CFR 100.11, 10CFR Part 100 App. A, R.G. 1.60, etc. ● No. 2017-26, "Technical Standards for Meteorological Evaluations for the Reactor Facility Site" ● No. 2017-27, "Technical Standards for Hydrological and Marine Environment Evaluation for the Reactor Facility Site" ● No. 2017-30, "Objects of Consultations due to Installation of Industrial Facilities, etc. around the Nuclear Facilities"
Regulatory Guidance	▪ KINS/RS-01 Regulatory Standards for PWR (Chapter 1. Site) ▪ KINS/RG-01 Regulatory Guidelines for PWR (Chapter 1. Site) ▪ KINS/GE-001 Safety Review Guideline (SRG) for PWR (Chapter 2. Site) ▪ KINS/GI-N03 Guideline on Pre-Operational Inspection

Legal Requirments and Technical Standards

Regulatory Guidance	▪ **KINS/RS-N01.00** Regulatory Standards for PWR (Chapter 1. Site) ▪ **KINS/RG-01** Regulatory Guidelines for PWR (Chapter 1. Site) ▪ **KINS/GE-001** Safety Review Guideline (SRG) for PWR (Chapter 2. Site) ▪ **KINS/GI-N03** Guideline on Pre-Operational Inspection ▪ **KINS/RG-N01.01** Specific Considerations on The Limitation of Site for Nuclear Facilities ▪ **KINS/RG-N01.02** Evaluation for the Nearby Human-induced Events ▪ **KINS/RG-N01.03** Investigation and Evaluation for meteorological and Atmospheric Dispersion Characteristics for Nuclear Facilities ▪ **KINS/RG-N01.04** Investigation and Evaluation for Flooding and Cooling Water Supply for Nuclear Facilities ▪ **KINS/RG-N01.05** Investigation and Evaluation for the Groundwater and the Liquidus Radioactive Effluent on the Site and It's Vicinity ▪ **KINS/RG-N01.06** Geologic, Seismological and Geotechnical Engineering Characteristics for Nuclear Facilities ▪ **KINS/RG-N01.07** Determination on the Site Design Earthquake ▪ **KINS/RG-N01.08** Determination of the Affected Zone from Surface Faulting ▪ **KINS/RG-N01.09** Investigation and Evaluation for the Slope Stability for Nuclear Facilities ▪ **KINS/RG-N01.10** Quality Assurance Program for the Geological and Geotechnical Investigation and Testing

II. Geography and Demography

Regulation and Guidance

☐ Regulations on Technical Standards for NRF and etc.

❍ Article 5 (Limitation on Location)

(1) Reactor facilities should be **located away from very densely populated areas**.

(2) Reactor facilities shall be installed at a place where the total radiation dose to public **in the event of an accidental release** of radioactive materials **does not exceed the acceptable value** determined and publicly notified by the Nuclear Safety and Security Commission

☐ Regulatory Standards for PWR

❍ Basic Requirements

- Nuclear site should be located in which the reactor and the related facilities can be operated safely and control authority be established in radiological accident
- The evaluation of natural and human-induced events in the site and its environs for safe operation shall be conducted

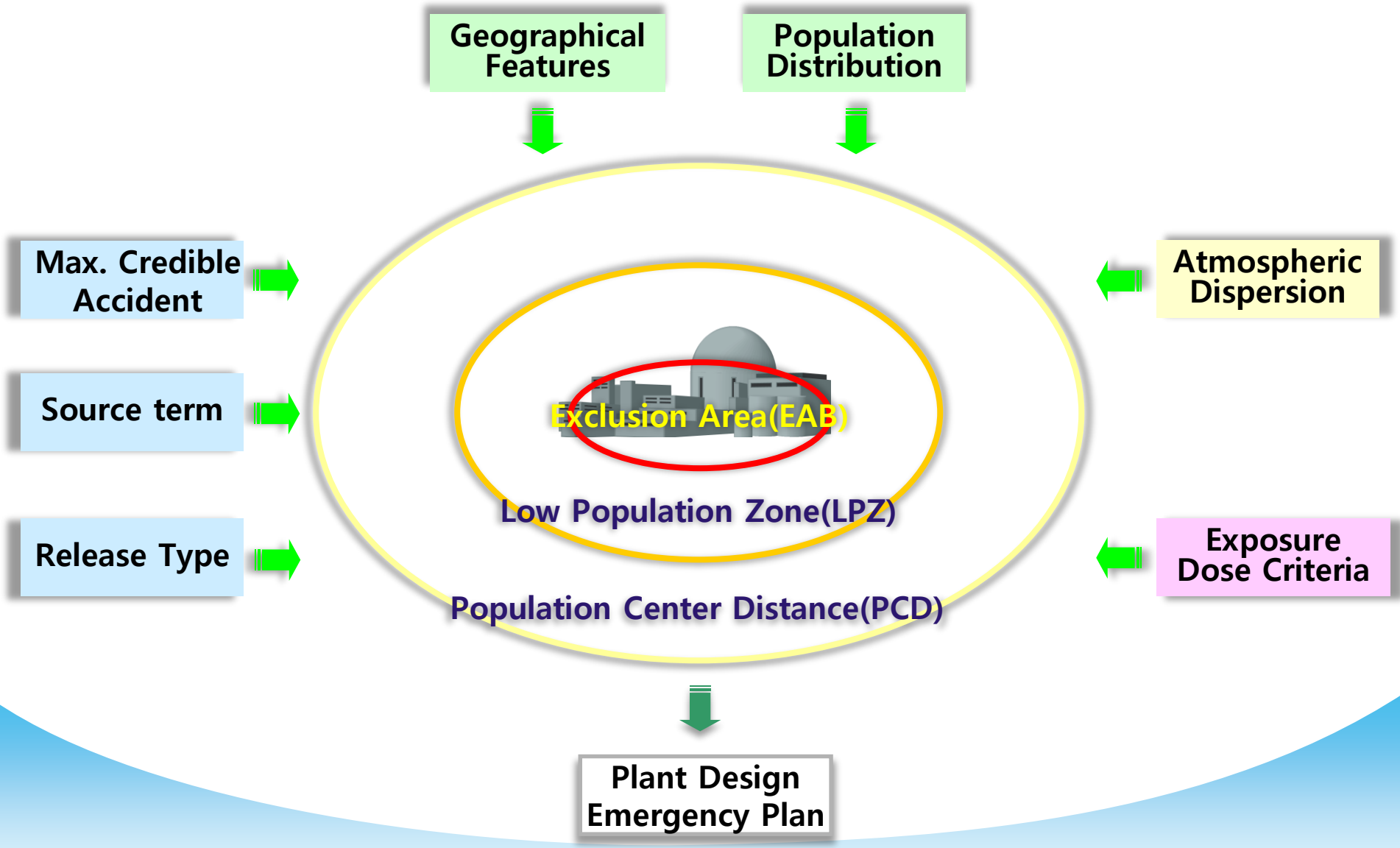
❍ Basic Information: The followings for the site and its vicinity should be provided;

- Site location and the geographic features
- Population distribution
- Exclusion area authority and control

Specific Criteria

☐ The proposed site meets the following criteria:

- ❍ Every site must have an exclusion area and a low population zone
- ❍ The population center distance must be at least one and one-third times the distance from the reactor to the outer boundary of the low population zone.
- ❍ In applying this guide, the boundary of the population center shall be determined upon consideration of population distribution. Political boundaries are not controlling in the application of this guide;


Geographical Features
Population Distribution
Max. Credible Accident
Source term
Release Type
Atmospheric Dispersion
Exposure Dose Criteria
Exclusion Area(EAB)
Low Population Zone(LPZ)
Population Center Distance(PCD)
Plant Design
Emergency Plan

Site Location

☐ Location of Reactor in

- ❍ Latitude & longitude
- ❍ Universal Transverse Mercator (UTM) coordinates

☐ Site Area Map showing

- ❍ Plant property lines
  - Area of plant property
- ❍ Location and Orientation of principal plant structures
  - Functional identification: reactor bldg., aux. bldg., turbine bldg., etc.
- ❍ Exclusion Area Boundary
- ❍ True North
- ❍ Natural and man-made features
  - Mountains, rivers, lakes, sea, valleys, etc.
  - Highways, railways, and waterways that traverse or are adjacent to the site

Population

☐ Population of Age Groups within 80 km of the Site

- ❍ in 16 azimuthal sectors
- ❍ in 10 distance intervals

☐ Transient Population

- ❍ Seasonal and monthly variation of transient population **within 20 km** from the reactor

☐ Population Projection

- ❍ For every **10 years**
- ❍ **From the expected first year of plant to the end of plant life**

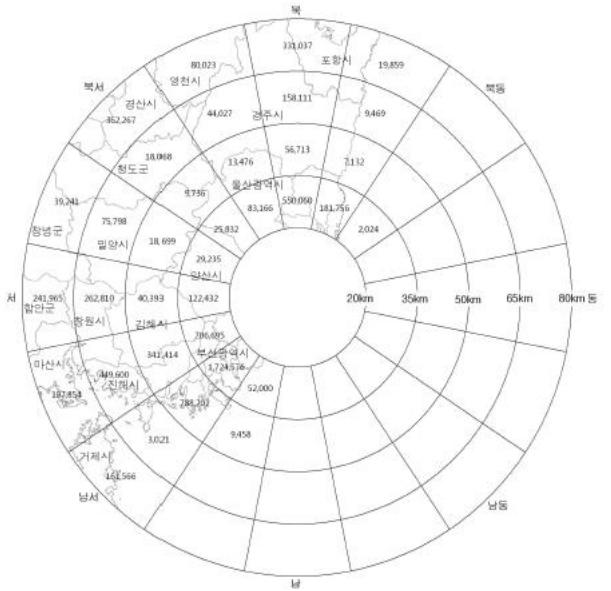
☐ Population Density

- ❖ Population density **within 50 km** should be lower than that of national average
  - Otherwise, it should be shown that the site has the superiority in the other aspects

Population

구간(km)	0~2	2~4	4~6	6~8	8~10	10~20	합계
인구수(명)	1,884	6,814	5,491	12,598	16,984	362,839	404,610

구간(km)	20~35	35~50	50~65	65~80	합계
인구수(명)	3,477,776	1,285,223	1,020,904	1,433,812	7,217,715



Population Distribution within 20km and between 20~80km of the Site

Exclusion Area

☐ Purposes

- ❍ To protect the resident from radiation exposure
  - **Residence within the exclusion area shall normally be prohibited**. In any event, residents shall be subject to ready removal in case of necessity.
- ❍ To protect the plant from activities not related to the plant operation
  - **Activities unrelated to operation of the reactor may be permitted in an exclusion area under appropriate limitations**, provided that no significant hazards to the public health and safety will result.

☐ Nature

- ❍ Means the area immediately surrounds the reactor, in which **the reactor licensee has the authority to determine all activities** including exclusion or removal of personnel and property from the area in case of radiological accident.
- ❍ May be traversed by a highway, railroad, or waterway, provided these are **not so close to the facility as to interfere with normal operations** of the facility and provided appropriate and effective arrangements are made **to control traffic** on the highway, railroad, or waterway, in case of emergency, to protect the public health and safety.

Exclusion Area (cont.)

- Factors considered for EAB & LPZ determination
  - Assumption of maximum credible (**design basis) accident**
  - Type and amount of fission product release **from the reactor core into the containment building**
  - Removal mechanism of the released fission product **within the containment building**
    - By natural and engineered safeguard features
  - An expected **leak rate from the containment to the atmosphere**
  - Pertinent meteorological conditions (**Atmospheric Dispersion**)
  - **Radiation dose guidelines**

Exclusion Area (cont.)

☐ Technical Criteria for Establishment of EAB

❍ At any point on the Exclusion Area Boundary (EAB), the radiation exposure **during 2 hours after a postulated accident shall be**

- Whole body radiation exposure: ≤ 25 rem (0.25 Sv) (individual)
- Thyroid radiation exposure: ≤ 300 rem (3 Sv) (individual)

(USNRC, 10CFR100 Subpart A, §100.11)

❍ Method to establish the EAB

- Purchase of land or creation of superficies

☐ Exemption of the EAB

❍ EAB need not be established for the research Reactor of which the thermal power is less than 10Mw

Exclusion Area (cont.)

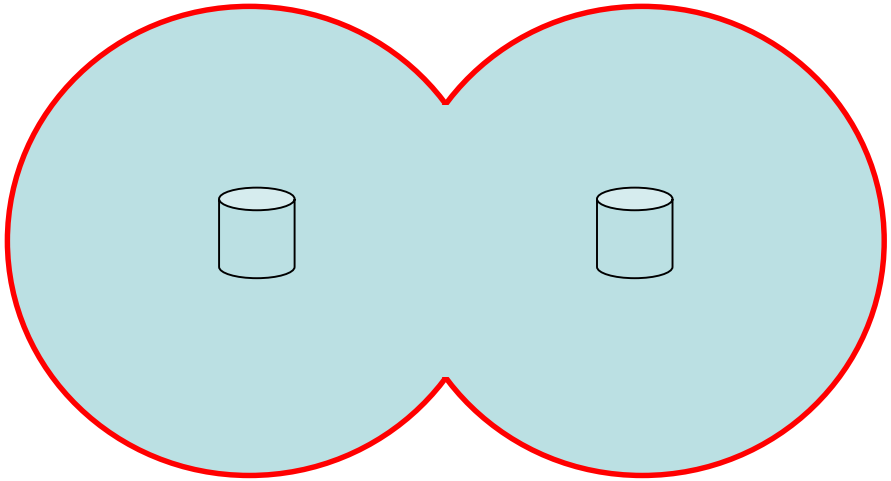
☐ Exclusion Area Boundary(EAB) for Multi-units

❍ First Step

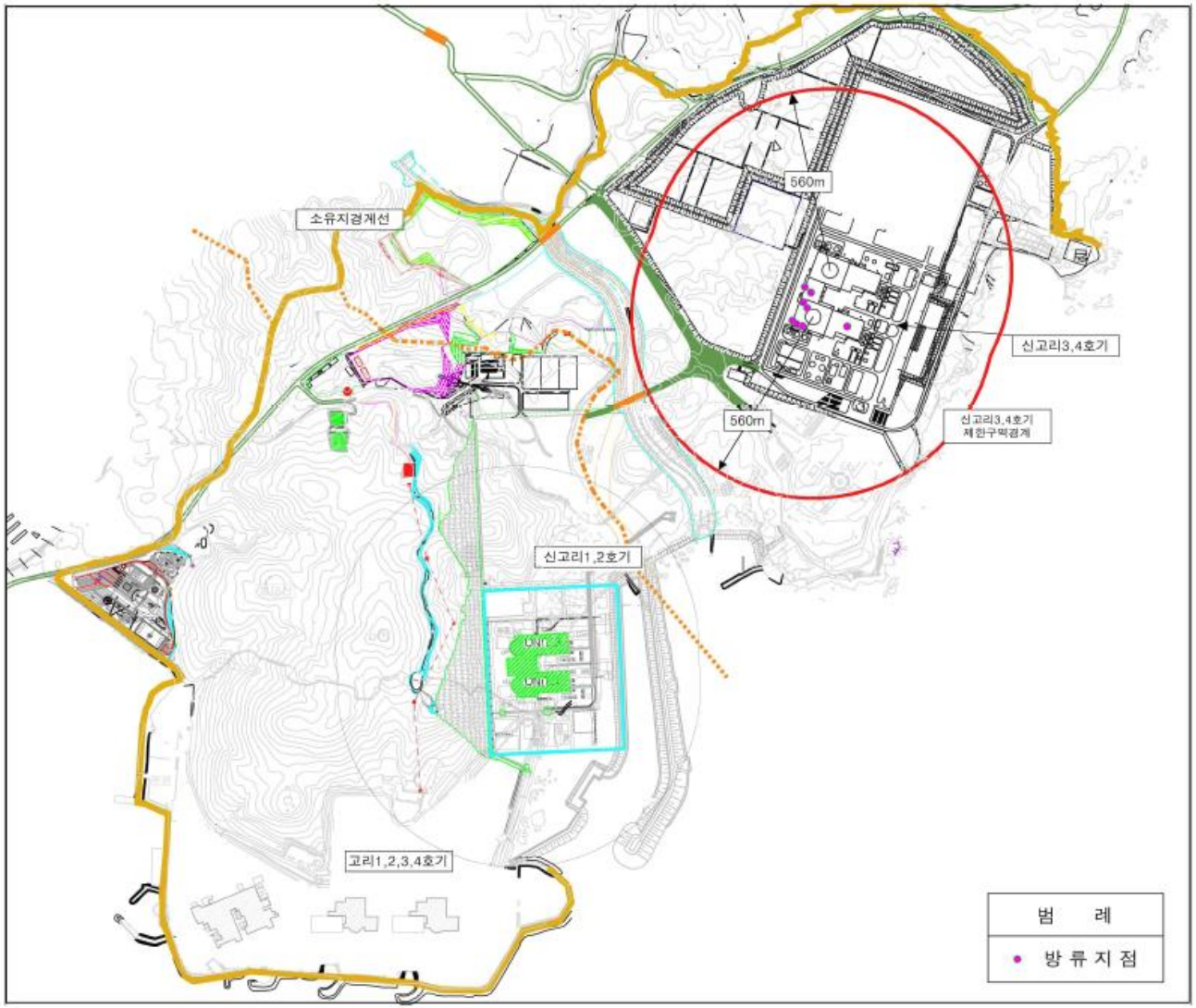
- Determine EABs for Individual Units

❍ Second Step

- Envelop all EABs
- Assumption:
  - The probability of simultaneous occurrence of the accident at multiple units is negligible.



Example of Exclusion Area Boundary



Low Population Zone

☐ Low Population Zone (LPZ)

- **Means the area immediately surrounding the exclusion area** which **contains residents**, the total number and density of which are such that there is **a reasonable probability that appropriate protective measures could be taken** in their behalf **in the event of a serious accident.**
- Determination of Boundary
  - An individual located at any point on the LPZ boundary, the radiation exposure **during the entire period after an accident** would not receive a total radiation dose to the
    - Whole body radiation exposure ≤ 25 rem (individual)
    - Thyroid radiation exposure ≤ 300 rem (individual)

Population Center Distance(PCD)

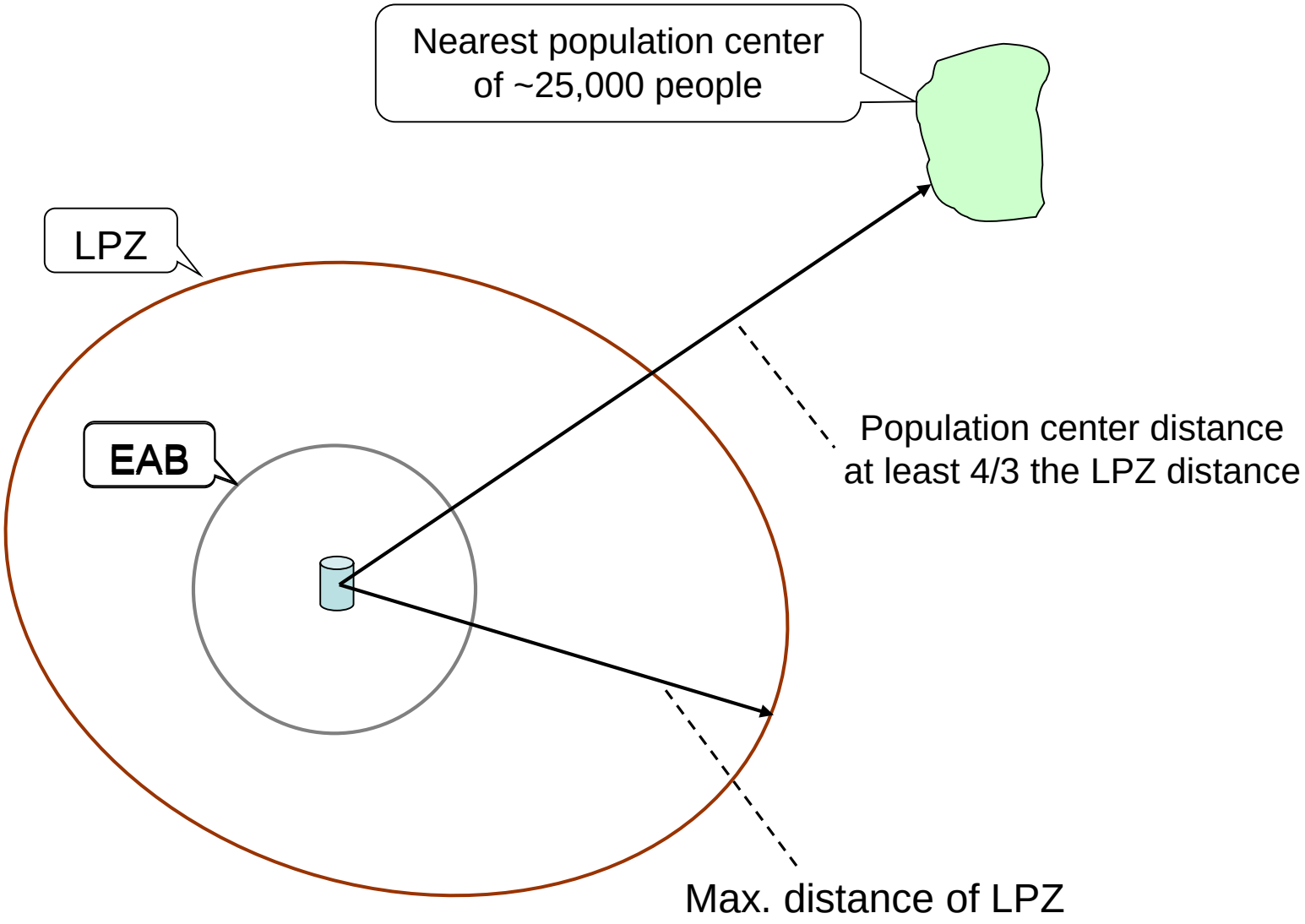
☐ Population Center

- ❍ An area with the resident more than 25,000

☐ Population Center Distance requirement

- ❍ At least 4/3 times the distance of LPZ boundary from the reactor

EAB, LPZ, and PCD



III. Human-Induced Hazard

Overview

☐ Purposes

- ❍ **Accidents at present or projected** nearby **industrial, military, and transportation facilities** may affect the safety of nuclear stations
- ❍ **Potential hazards associated with these nearby facilities must be evaluated** and site parameters are established such that potential hazards from such routes and facilities will **pose no undue risk to nuclear stations**

☐ Hazards to be evaluated (KINS/RS-N01.00, Sec. 1.3)

- ❍ Aircraft crash
- ❍ Explosion
  - Stationary and mobile sources
- ❍ Release of hazardous materials
  - To evaluate the control room habitability
- ❍ Fire, collision of ships, etc.
  - Loss of off-site power, loss of ultimate heat sink, etc.

Regulation and Guidance

☐ Regulations on Technical Standards for NRF and etc.

❍ Article 8 (Effects from Man-induced Events)

(1) Reactor facilities shall be installed at a place that is acknowledged to have no potential of hazard, based on detailed investigation and assessment of the impact of an accident at nearby industrial facilities manufacturing or handling hazardous materials, transportation means and so forth.

(2) Detailed standards as regards the investigation and assessment of the effects from an accident on reactor facilities as provided in the foregoing paragraph (1) shall be determined and publicly notified by the Nuclear Safety and Security Commission.

Regulation and Guidance

☐ Facilities to be considered (KINS/RS-N01.00, Sec. 1.3)

- ❍ Industrial facilities
  - Chemical plants, refineries, mining and quarrying operations, oil or gas wells, oil or gas storages, etc.
- ❍ Military facilities
  - Munitions storage areas, ordnance test ranges, bombing training ground, etc.
- ❍ Transportation routes
  - Air routes, waterways, railroad, highways, gas pipes
- ❍ Airports
  - Civil & military airports
- ❍ The future possible development of above facilities

Investigation

☐ Extent to be investigated

❍ Within 8km radius of the site

- Industrial facilities, transportation route and facilities including the activities in them
- Even the facility or activity are located beyond 8km radius of the site, they can be investigated according to the importance to the nuclear facility

❍ Within 32km of the site

- All civil & military airports
- Military facilities

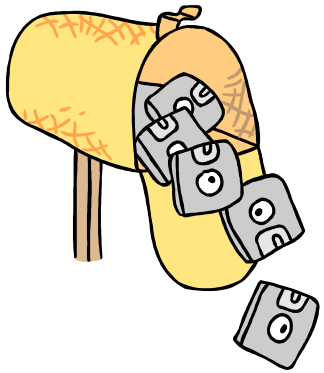
☐ Screening distance value(SDV)

❍ The distance from a facility beyond which, for screening purpose, potential sources of a particular type of external event can be ignored (IAEA, SG No. NS-G-3.1)

Information

☐ Information to be collected

- ❍ A list of potential sources
  - The source is divided into stationary and mobile
  - The type, quantity, and condition of the hazardous material involved
- ❍ The distance between the potential source and the nuclear site
- ❍ Source display map
- ❍ Statistical (probability) data of occurrence of accidents at the source
- ❍ Information about present and planned facilities and activities in the region
- ❍ Meteorology, topography, sea current, etc.



Evaluation - Preliminary

☐ Screening out

- ❍ Using the definition of the SDV and SPL

☐ Screening-out the source using the SDV

- ❍ The sources outside the Screening Distance Value (SDV) can be ignored and need not be considered as an potential hazardous source to plant
- ❍ If the site is outside the SDV for a particular source under consideration, the source need not be considered any more

☐ Screening-out the source using the SPL

- ❍ If the site is not outside the SDV for any accident source, the probability of occurrence of such an accident should be determined and compare with the specified SPL
- ❍ Screening Probability Level (SPL) means a value of the annual probability of occurrence of a particular type of event below which, for screening purpose, such an event can be ignored (IAEA SG No. NS-G-3.1)
- ❍ Generally, the SPL value is adapted as 10E-7/yr

Evaluation - in Detail

☐ Selection of candidate design basis accident

- ❍ **Potential events**, not eliminated at preliminary evaluation, **are evaluated whether they can be considered as an design basis accident**
- ❍ The probability of an accident occurrence with **equal or more than 10E-7/yr is considered as design basis accident**

☐ Design against the design basis accident

- ❍ Consideration of interacting events
- ❍ If the probability of occurrence of an accident at a particular source is above 10E-6/yr, then the results of the accident should be considered in the design of nuclear facilities.
- ❍ The value of 10E-6/yr is considered as design basis probability

Acceptance Criteria

- **The site is considered to be suitable for NF(nuclear facilities), if the following criteria are met**
  - Even if an external events causes an accident at nuclear facility, the radiation to the public do not exceed the dose limit specified by the law
  - The occurrence of an accident for a particular source is as low as SPL (1.0E-7/yr) and is considered to have little effect on the NF
  - Other design features (e.g., Reinforcement of facility, fire protection, etc.) can mitigate or reduce the effects on nuclear facility arose by particular accident source

* If evaluated results do not satisfy the above conditions, the events should be reflected in the plant design

IV.Meteorology

Purposes

☐ Evaluation of the meteorological date for design & safe operation

- ❍ Plant design
  - Wind speed, precipitation (rain, snow), freezing, etc.
- ❍ Plant operation
  - Habitability of control room: humidity, temperature, wind speed & direction, etc.
  - Exposure dose limits: atmospheric diffusion information

☐ Evaluation of radioactive material concentration

- ❍ During normal operation and accident condition
- ❍ Meteorological parameter

☐ Data Collection necessary for Proper emergency planning

- ❍ Wind speed and direction
- ❍ Atmospheric dispersion characteristics

Regulation and Guidance

☐ Regulations on Technical Standards for NRF and etc.

❍ Article 6 (Meteorological Conditions)

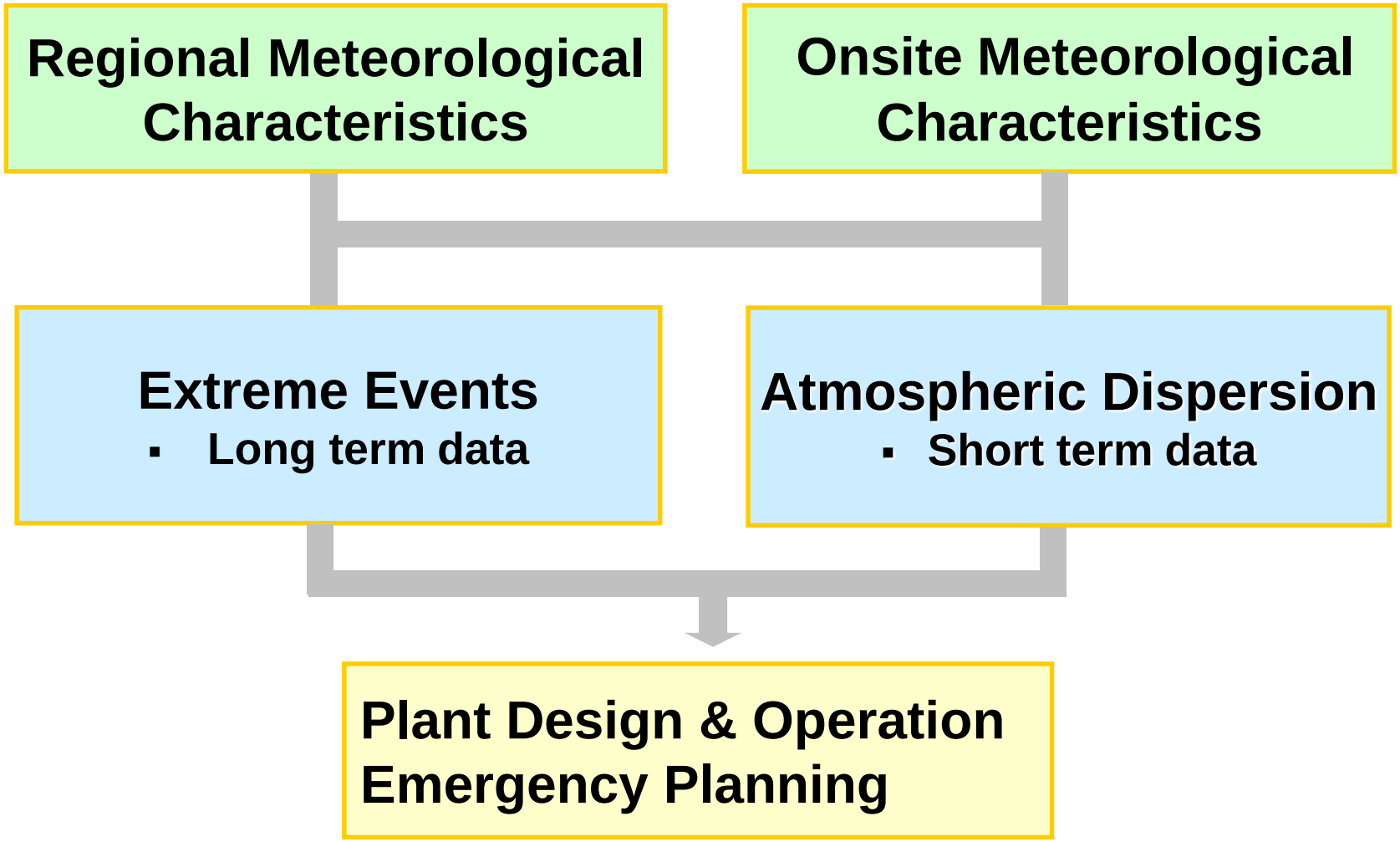
(1) Reactor facilities shall be installed at a place that is acknowledged to have little chance of any serious accidents, based on investigation and assessment of meteorological conditions including hurricanes, heavy snow and rainfall, or tornados.

(2) Reactor facilities shall be installed at a place that is acknowledged to have no radiation hazard, based on investigation and assessment of the diffusion and dilution characteristics of radioactive materials in case that such materials are released into the air from the facilities.

(3) Detailed standards as regards investigation and assessment of the meteorological conditions as provided in the foregoing Paragraph (1) and the diffusion and dilution characteristics of radioactive materials in the air as provided in the foregoing Paragraph (2) shall be determined and publicly notified by the Nuclear Safety and Security Commission

Specific Criteria

- **Site atmospheric dispersion characteristics must be evaluated and dispersion parameters established such that:**
  - Radiological effluent release limits associated with normal operation from the type of facility proposed to be located at the site can be met for any individual located offsite; and
  - Radiological dose consequences of postulated accidents shall meet the criteria for the type of facility proposed to be located at the site;
- **The meteorological characteristics of the site must be evaluated and site parameters established such that potential threats from such characteristics will pose no undue risk to the type of facility proposed to be located at the site**


Regional Meteorological Characteristics
Onsite Meteorological Characteristics
Extreme Events
▪ Long term data
Atmospheric Dispersion
▪ Short term data
Plant Design & Operation
Emergency Planning

Regional Climatology

☐ General climate

- ❍ Temperature, humidity, precipitation(rain, snow, and sleet)
- ❍ Types of air masses
- ❍ Synoptic features: high- and low-pressure systems, frontal systems
- ❍ Relationships between synoptic-scale atmospheric processes and local (site) meteorological conditions

☐ Seasonal and annual frequencies of severe weather phenomena

- ❍ Hurricanes, waterspouts, and tornados
- ❍ Thunderstorms and lightning, hail, air pollution potential

☐ Topographical information

- ❍ Information of the site and its environs, as modified by the plant structures, including
- ❍ Site boundary, exclusion area boundary(EAB), and low population zone(LPZ)

Regional Climatology (cont.)

☐ Meteorological conditions for design & operating basis

- **Max. snow and ice load** (water equivalent) that roofs of safety-related structures must be capable of withstanding during plant operation
- **Ultimate heat sink (UHS) meteorological conditions** resulting in the max. evaporation and drift loss of water and min. water cooling, if applicable
- **Tornado parameters**, including translational speed, rotational speed, and Max. pressure differential with the associated time interval
- **100-year return period of wind**, including vertical velocity distribution and gust factor
- Probable annual frequency of occurrence & time duration of freezing rain (ice storms) and dust (sand) storms where applicable
- **Max. rainfall rate**
- Other regional meteorological and air quality conditions used for design and operating basis considerations

Local Meteorology

☐ Description of local (site) meteorology

- ❍ Airflow, temperature, atmospheric water vapor, precipitation, fog
- ❍ Atmospheric stability
- ❍ Air quality

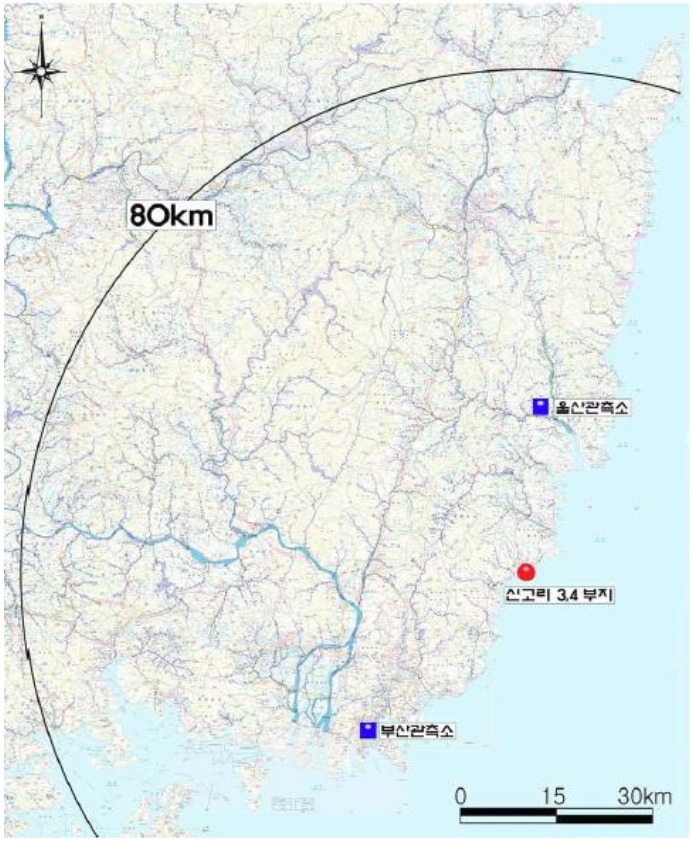
☐ Assessment of the influence of the plant on the above factors

- ❍ Effects of plant structures
- ❍ Effects of terrain modification
- ❍ Effects of heat and moisture sources due to plant operation

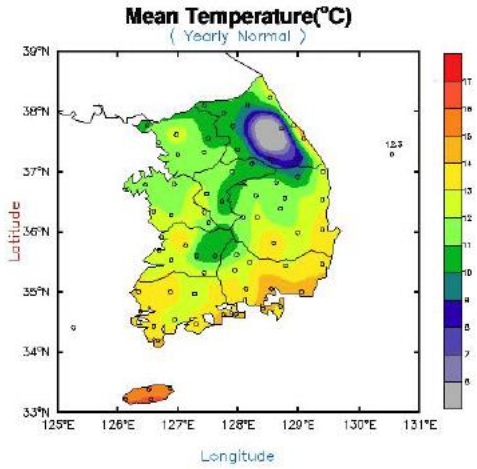
☐ Topographical information

- ❍ Information of the site and its environs, as modified by the plant structures, including
  - Site boundary, exclusion area boundary(EAB), and low population zone(LPZ)

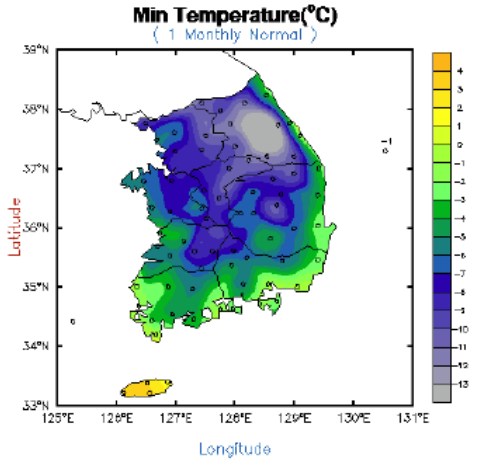
Example of meteorological information



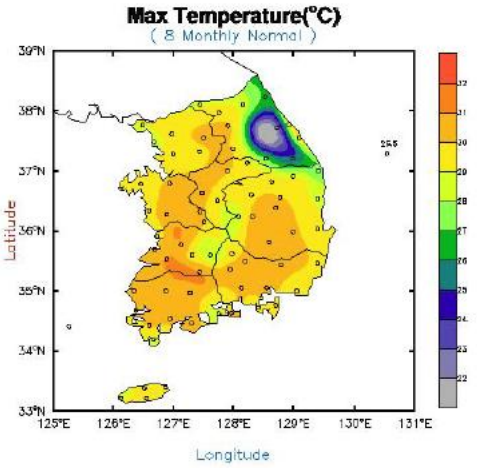
Location of site and meteorological observation station



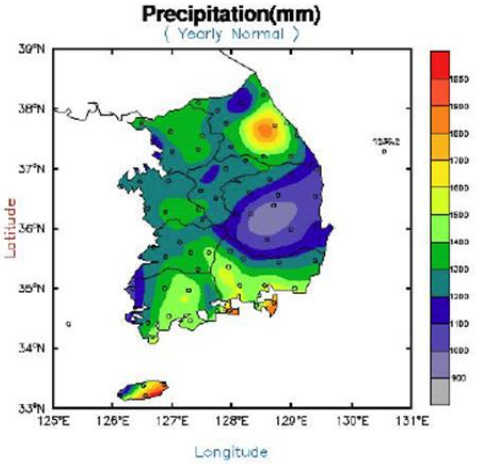
Annual mean temperature



Lowest day temperature distribution during January

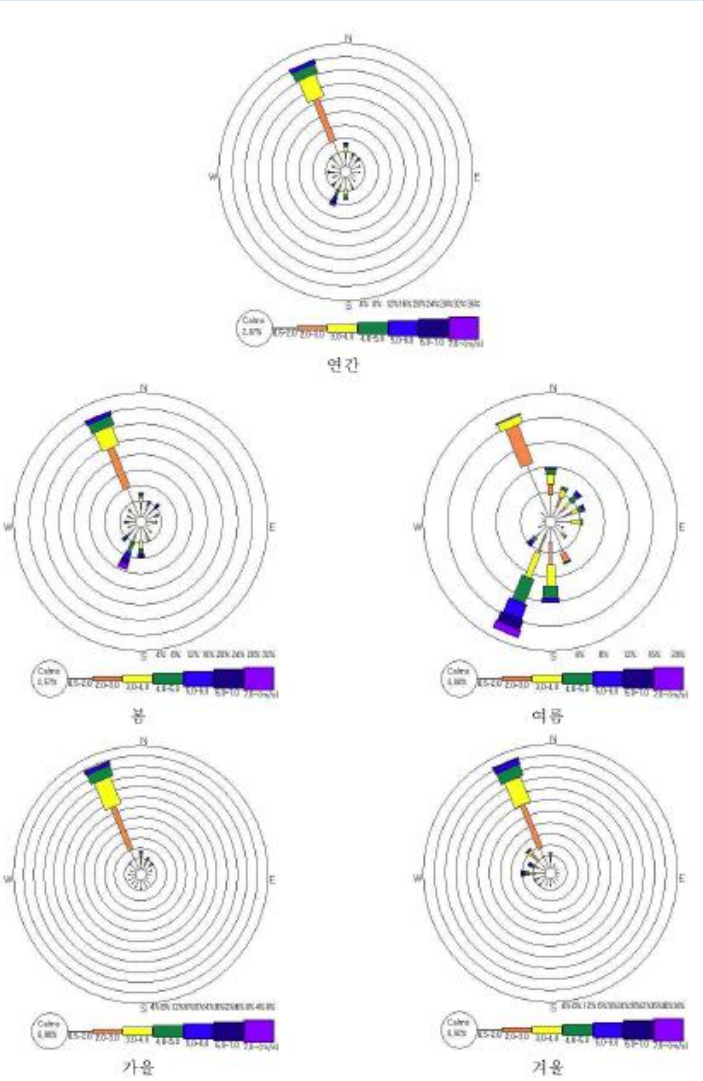


Highest day temperature distribution during August

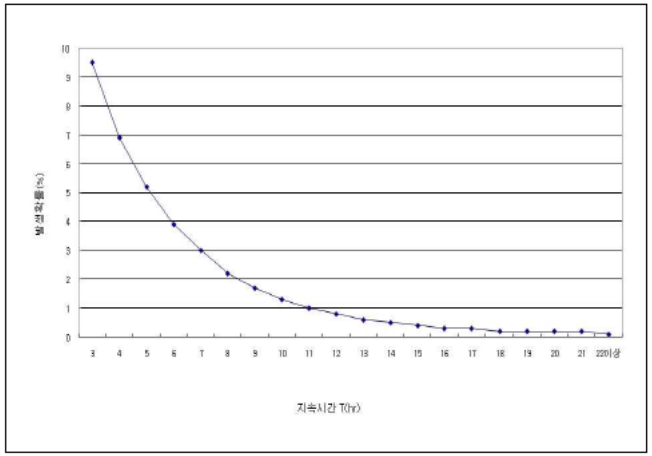


Annual mean precipitation

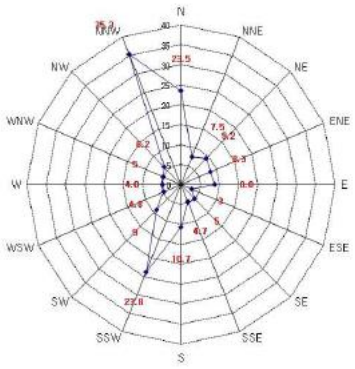
Example of meteorological information



Seasonal wind rose of site



Probability (%) of wind direction with time (hr)



풍향	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
최대 지속 시간	25.6	7.6	9.2	8.8	8.8	8.0	6.0	4.7	10.7	23.8	9.0	4.8	4.8	6.0	6.2	35.8

Maximum duration time with wind direction

Onsite Meteorological Measurement Program

☐ Purpose

❍ To provide meteorological conditions for safe design and operation, and proper emergency planning

☐ Onsite Meteorological Observation Tower

❍ Open-lattice steel framed tower

❍ Height of the tower: 58 m

❍ Heights of observation points: at 10 m and 58 m

❍ Data to be observed:

- Temperature, precipitation, and relative humidity
- Wind direction and speed
- Atmospheric stability

Long-Term Atmospheric Diffusion

☐ Guidance(KINS/RG-01.03)

- ❍ Radionuclide concentration during normal operation shall be evaluate using the meteorological data measured during **at least one year** and **at the level representative of the site**
- ❍ **Transportation and diffusion characteristics in air** shall be estimated **using suitable models**

☐ Criteria

- ❍ **Long-term atmospheric diffusion** applies to normal operation.
- ❍ The transport and dilution of radioactive materials are a function of:
  - **State of the atmosphere** along the plume path
  - **Topography** of the region
  - **Characteristics of the effluents** themselves

Short-Term Atmospheric Diffusion

☐ Guidance(KINS/RG-01.03)

- ❍ Atmospheric diffusion characteristics during accident condition shall be evaluated with the data measured **during at least one year**, and measured **at the level of 10m above ground surface for ground release** and **at the release height for the elevated release**
- ❍ Transportation and diffusion characteristics in air shall be estimated using suitable models
- ❍ Short-term atmospheric dispersion estimate applies to **accidental conditions**
- ❍ For an accidental airborne release (2 hrs. basis), the concentration of radioactive material in the surrounding region depends on
  - the amount of effluent released
  - the height of the release
  - the momentum and buoyancy of the emitted plume
  - the wind speed, atmospheric stability, and airflow patterns of the site
  - and various effluent removal mechanisms

V.Hydrology

Purposes

☐ Flooding

- ❍ To protect the plant from **seismically and non-seismically induced** flooding
- ❍ To protect **safety-related** structures, systems, and component
- ❍ To evaluate **the evacuation route** in case of radiological emergency

☐ Water availability

- ❍ NPP must have sufficient water available and acquirable for cooling during plant operation and normal shutdown, for the ultimate heat sink, and for fire protection

☐ Radionuclide retention and transport

- ❍ To assess the potential impact of the contamination of groundwater on the population
- ❍ To assess the dispersion characteristics of radioactive material through the water system

Regulation and Guidance

☐ Regulations on Technical Standards for NRF and etc.

❍ Article 7 (Hydrologic and Oceanographic Conditions)

(1) Reactor facilities shall be installed at a place that is **not affected by river flooding** caused by failure of upstream reservoirs or dams, rain and so forth.

(2) Reactor facilities shall be installed at a place that is acknowledged to pose **no risk to the safety thereof with regard to the influence of coastal flooding** caused by natural phenomena including tsunamis, seawater level and surges.

(3) Reactor facilities shall be installed at a place that is acknowledged to have **no radiation hazard**, based on investigation and assessment of the diffusion, dilution and adsorption characteristics of radioactive materials in case that such materials are **released into the surface water, ground water and seawater** from such facilities.

Regulation and Guidance

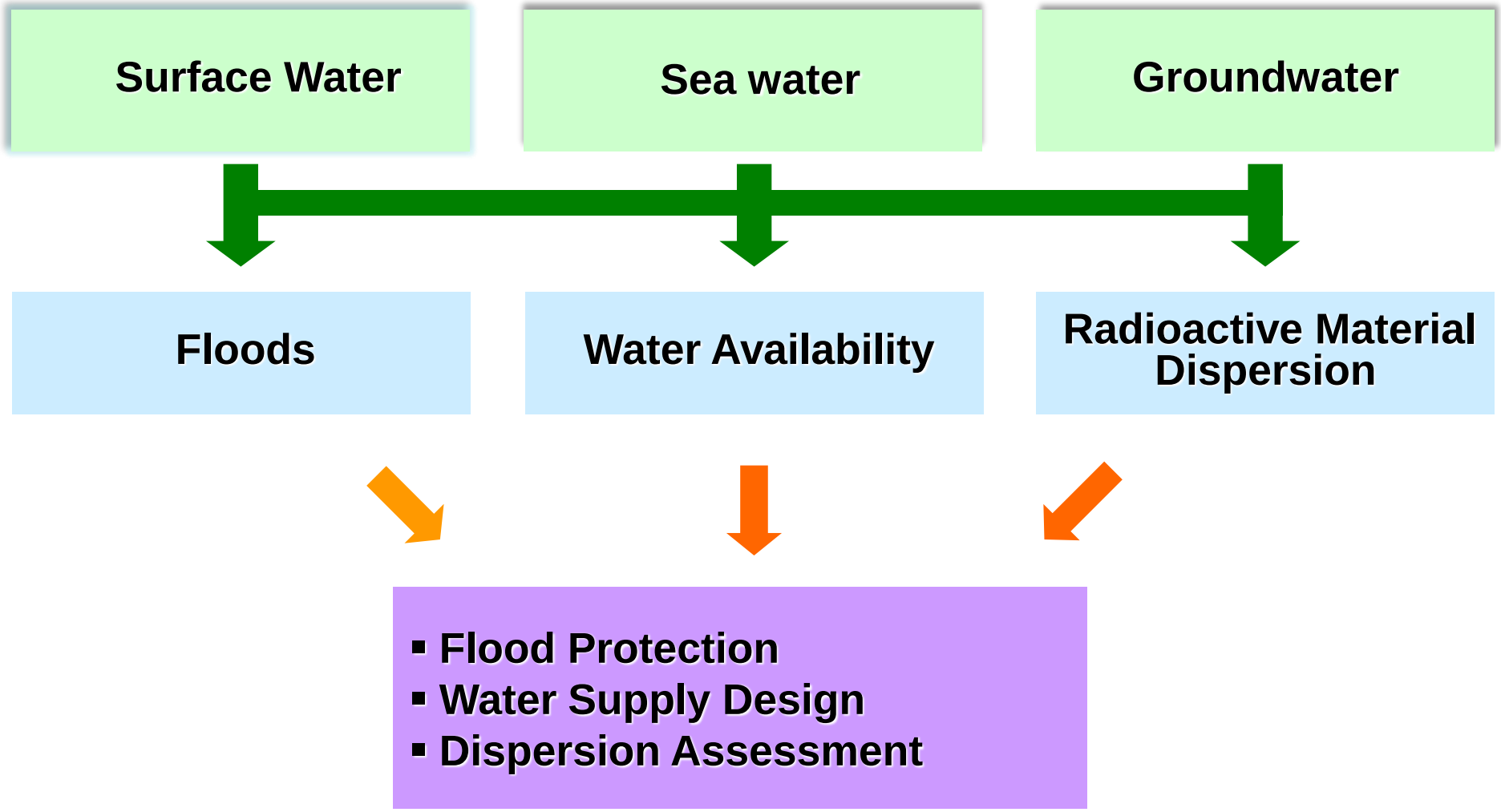
☐ Regulations on Technical Standards for NRF and etc.

❍ Article 7 (Hydrologic and Oceanographic Conditions)

(4) Reactor facilities shall be installed at a place to which **service and cooling water** necessary for operation thereof can be supplied.

(5) Detailed standards for the location of reactor facilities as provided in the foregoing Paragraphs (1) through (3) shall be determined and publicly notified by the Nuclear Safety and Security Commission.6 (Meteorological Conditions)

Purposes


Surface Water
Sea water
Groundwater
Floods
Water Availability
Radioactive Material Dispersion
▪ Flood Protection
▪ Water Supply Design
▪ Dispersion Assessment

Flooding

☐ Inland Flooding

- ❍ Due to precipitation
  - Flood of rivers or streams
  - Inundation of site due to localized heavy rain
- ❍ Due to earthquakes or landslides
  - Failure of up-stream dams or embankments
  - Waterway blockage

☐ Coastal Flooding

- ❍ Tidal waves
- ❍ High sea waves
- ❍ Storm surges
  - Uplift of sea surface
- ❍ Tsunamis
  - Due to sea floor earthquakes

Inland Flooding (River flooding)

Global warming inundation? In fact, this photo shows
Missouri River as it recedes from Nebraska's Cooper n

2011 Cooper Station

Coastal Flooding

☐ Information to be collected

- Historical flooding data, **bathymetry and coastal configuration**
- Storm surge: local surge data, Models
- **Tsunamis**: information about the seismic and geologic data in view of the behavior of oceanic crust, coastal and continental shelf landslide, volcanic activities, paleo-seismic tsunami data, tsunami wave transmission data and model.
- Tidal information: observatory and the historical data
- **Wave activities**
- Combination of all flood-causing factors

* Fukushima Daiich NPP

Flood Protection

☐ Determination of Design Basis Flood

- ❍ Calculate the height of flood from selected combinations of multiple events
  - Tide + wave + surge + wave run-up
- ❍ The probability of simultaneous occurrence is taken into account
  - In case of PMP, all up-stream fill dams are supposed to be failed
- ❍ Methods of event combination are prescribed

☐ Design against Flood

- ❍ All safety-related facilities and structures
- ❍ Essential safety systems are required
  - Complimentary measures (ex: technical specification)
- ❍ Engineered measures
  - To **make the site grade level higher than the flooding level**
  - To **protect the facilities using water-tightening doors**
- ❍ Administrative measures
  - **Establishment of emergency procedure** in response to the flooding

Water availability

☐ Water Supply Sources

- ❍ Service water
  - Fresh water (rivers, lakes)
  - Used in the plant (ex: internal-circulating water system)
- ❍ Cooling water
  - Sea water, river water, cooling tower.
  - Used as the Ultimate Heat Sink (ex: essential service water)

☐ Water Supply Capacity

- ❍ Service water
  - Water supply capacity is guaranteed during probable minimum water level in dry season
  - Capacity of additional water tanks if the service water supply capacity is not enough should be guaranteed to make up the deficiency
- ❍ Ultimate Heat Sink (UHS)
  - Water supply capacity at probable min. & max. sea levels
  - The temperature of cooling water should be lower the design sea-water temperature

Dispersion of Radioactive Materials

☐ Purpose

- ❍ To assess the **potential impact of the contamination of groundwater/surface water on the population**
- ❍ To evaluate **release patterns, expected amount, and migration and transport routes of radioactive materials** in hydrogeological units at or near the nuclear site

☐ Acceptance Criteria

- ❍ **Radionuclide transport characteristics of the groundwater environment** with respect to existing and future users **must be described**
  - Dispersion, adsorption, transportation velocity, etc.
- ❍ **Radionuclide transport characteristics of the surface water environment** with respect to existing and future users **must be described**
  - Worst-case release and source terms
- ❍ **Mathematical models** are acceptable, if
  - Models are verified by field data and
  - Conservative site-specific hydrologic parameters are used

Dispersion of Radioactive Materials(cont.)

☐ Information to be collected

- ❍ Soil and rock characteristics (grain size, hydraulic conductivity, etc.,)
- ❍ Direction and flow rate of groundwater
- ❍ Site specific adsorption coefficient
- ❍ Chemistry of subsurface materials

☐ Evaluation

- ❍ Potential migration and ground water transport pathways are identified using **a conceptual ground water site model**
  - The model should consider the ability of ground and subsurface water environment to delay, disperse, dilute, or concentrate accidentally released radioactive liquid effluent during its transport

VI. Geology and Seismology

Regulation and Guidance

☐ Regulations on Technical Standards for NRF and etc.

❍ Article 4 (Geological Features and Earthquakes)

(1) Reactor facilities shall be installed at a place acknowledged to have little chance of earthquakes or surface deformation.

(2) Reactor facilities shall be installed at a place with no possibility of collapse or sinking of the ground surface at the place of their installation and its vicinity and with a stable slope and ground.

(3) Detailed technical standards as regards investigation, analysis and assessment of geological and seismic characteristics, surface faulting, and ground surface and foundation characteristics as provided in the foregoing Paragraphs (1) and (2) shall be determined and publicly notified by the Nuclear Safety and Security Commission.

Regulation and Guidance

☐ NSSC Notice 2014-10, 10CFR100 App. A

- The geological, seismological, and engineering characteristics of a site and its environs **must be investigated in sufficient scope and detail**
  - To permit an **adequate evaluation of the proposed site**
  - To provide sufficient information to support evaluations performed to arrive at **estimates of the Safe Shutdown Earthquake Ground Motion(SSEGM)**
  - To permit adequate **engineering solutions** to actual or potential geologic and seismic effects at the proposed site.
- **The size of the region to be investigated** and **the type of data** pertinent to the investigations **must be determined based on the nature of the region** surrounding the proposed site.
- Data on the vibratory ground motion, tectonic surface deformation, nontectonic deformation, earthquake recurrence rates, fault geometry and slip rates, site foundation material, and seismically induced floods and water waves must be **obtained by reviewing pertinent literature and carrying out field investigations**. However, each applicant shall investigate all geologic and seismic factors (for example, volcanic activity) that may affect the design and operation of the proposed nuclear power plant

Regulation and Guidance

☐ NSSC Notice 2014-10, 10CFR100 App. A

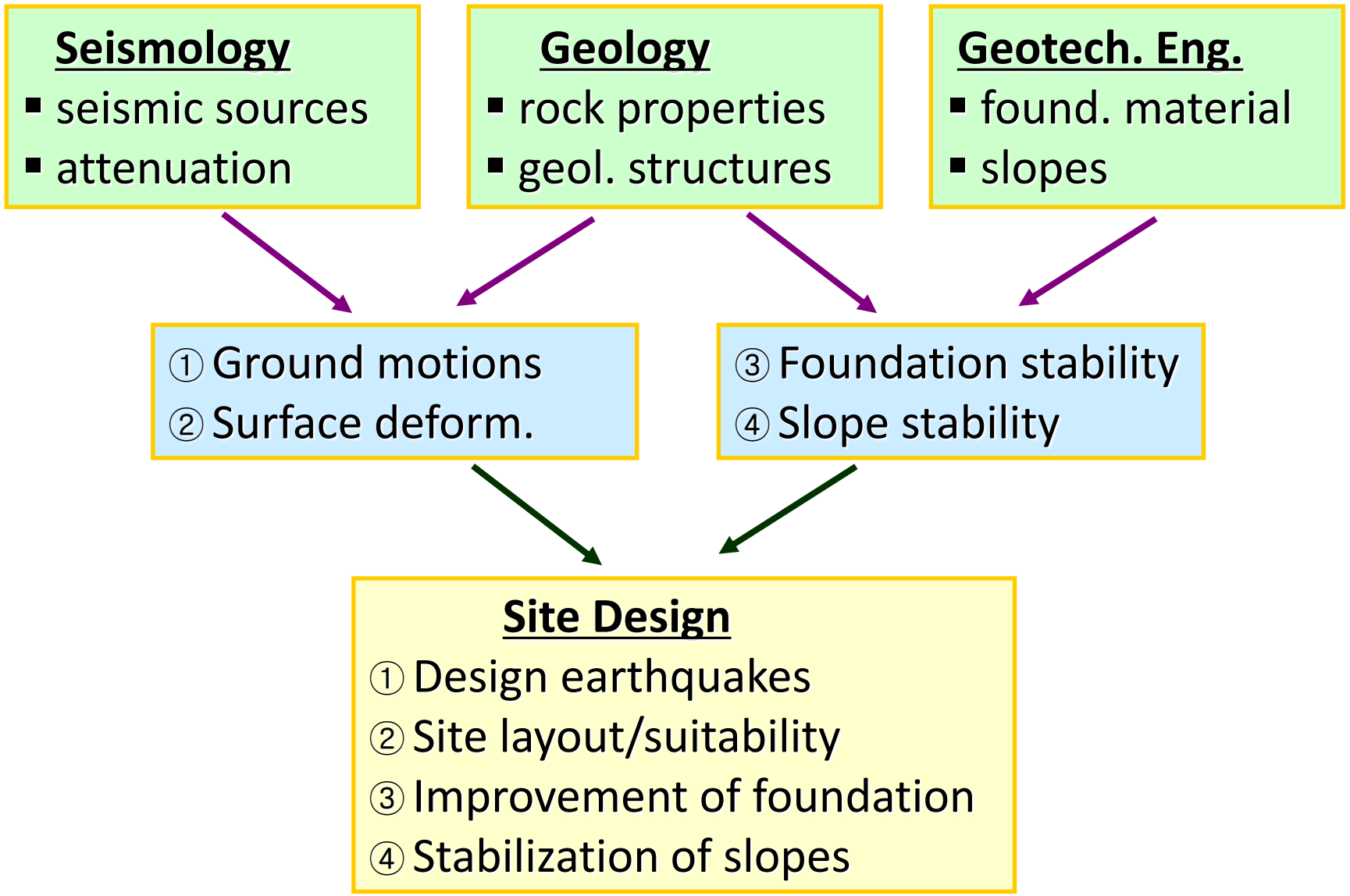
❍ Geologic and seismic siting factors for the design must include

- A determination of the Safe Shutdown Earthquake Ground Motion for the site,
- The potential for surface tectonic and nontectonic deformations
- The design bases for seismically induced floods and water waves
- Other design conditions such as slope stability, cooling water supply, distant structures, etc.

❍ All the geologic and seismic data should permit

- The determination suitability of the proposed site for nuclear facilities
- The determination of the plant design bases relation to the earthquake and fault

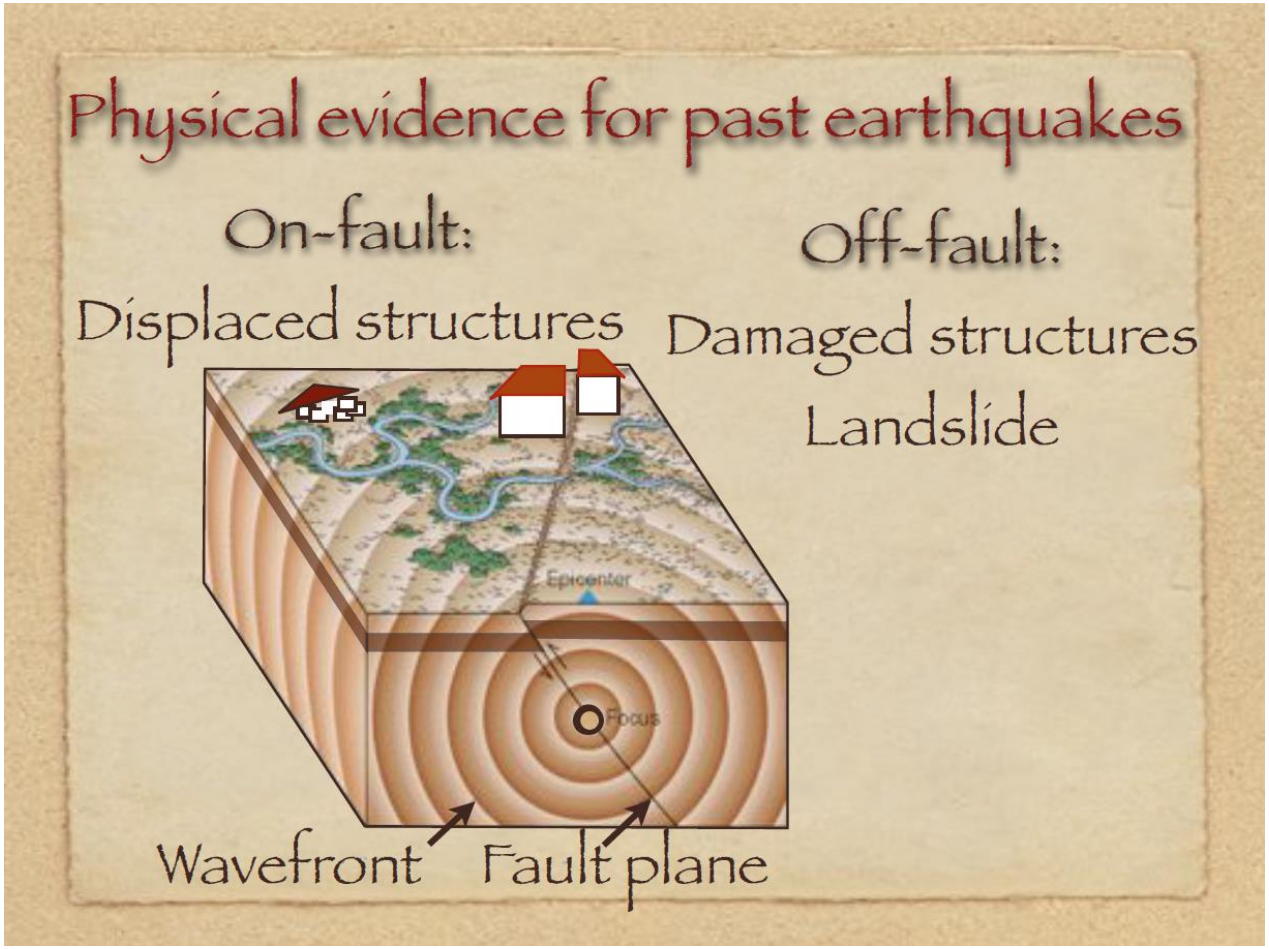
Overview


Seismology
seismic sources
attenuation
Geology
rock properties
geol. structures
Geotech. Eng.
found. material
slopes
① Ground motions
② Surface deform.
③ Foundation stability
④ Slope stability
Site Design
① Design earthquakes
② Site layout/suitability
③ Improvement of foundation
④ Stabilization of slopes

Surface Faulting

Surface faulting

is **differential ground displacement at or near the surface** caused **directly by fault movement** and is distinct from nontectonic types of ground disruptions, such as landslides, fissures, and craters.



Surface deformation is distortion of geologic strata at or near the ground surface by the processes of folding or faulting as a result of various earth forces. **Tectonic surface deformation is associated with earthquake processes**.

Capable Fault

- A fault that has a significant potential for relative displacement at or near the ground surface (earthquake & surface deformation).

- A fault shows one or more of following evidences
  - Movements at or near the ground surface **at least once in the past 35,000 years** or movement of a **recurring nature within the past 500,000 years**
  - Macro-seismicity instrumentally determined with records of sufficient precision to demonstrate a direct relationship with the fault
  - A structural relationship to a capable fault according to characteristics (1) or (2) of this paragraph such that movement on one could be reasonably expected to be accompanied by movement on the other.

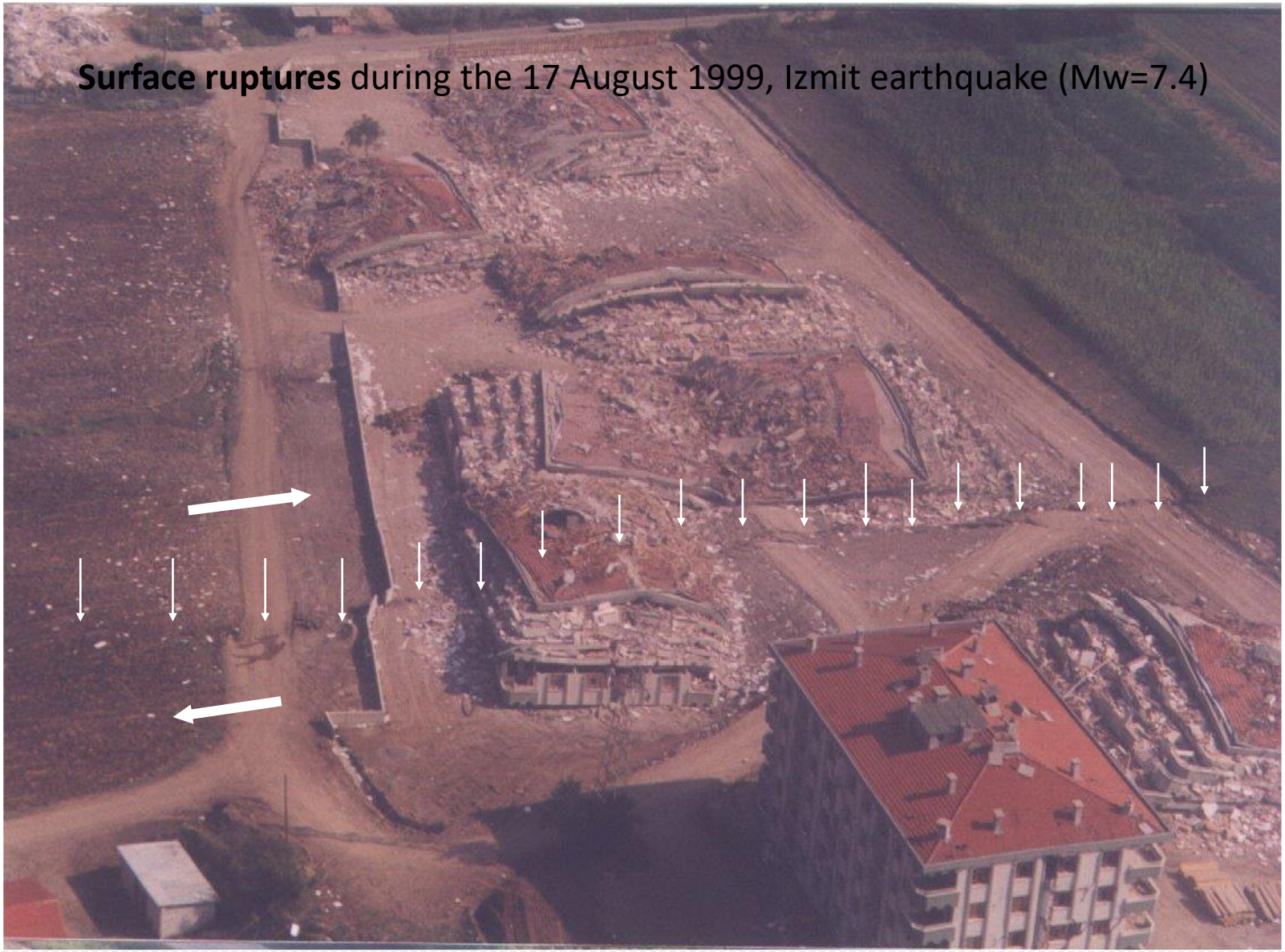
Capable Fault

- It can cause surface deformation in near future
- It is difficult to construct NPP on a site that surface deformation is occurring or potential for it exist
  - In some cases, the geologic evidence of past activity at or near the ground surface along a particular fault may be obscured at a particular site.
  - This might occur, for example, at a site having a deep overburden. For these cases, evidence may exist elsewhere along the fault from which an evaluation of its characteristics in the vicinity of the site can be reasonably based. Such evidence shall be used in determining whether the fault is a capable fault within this definition.

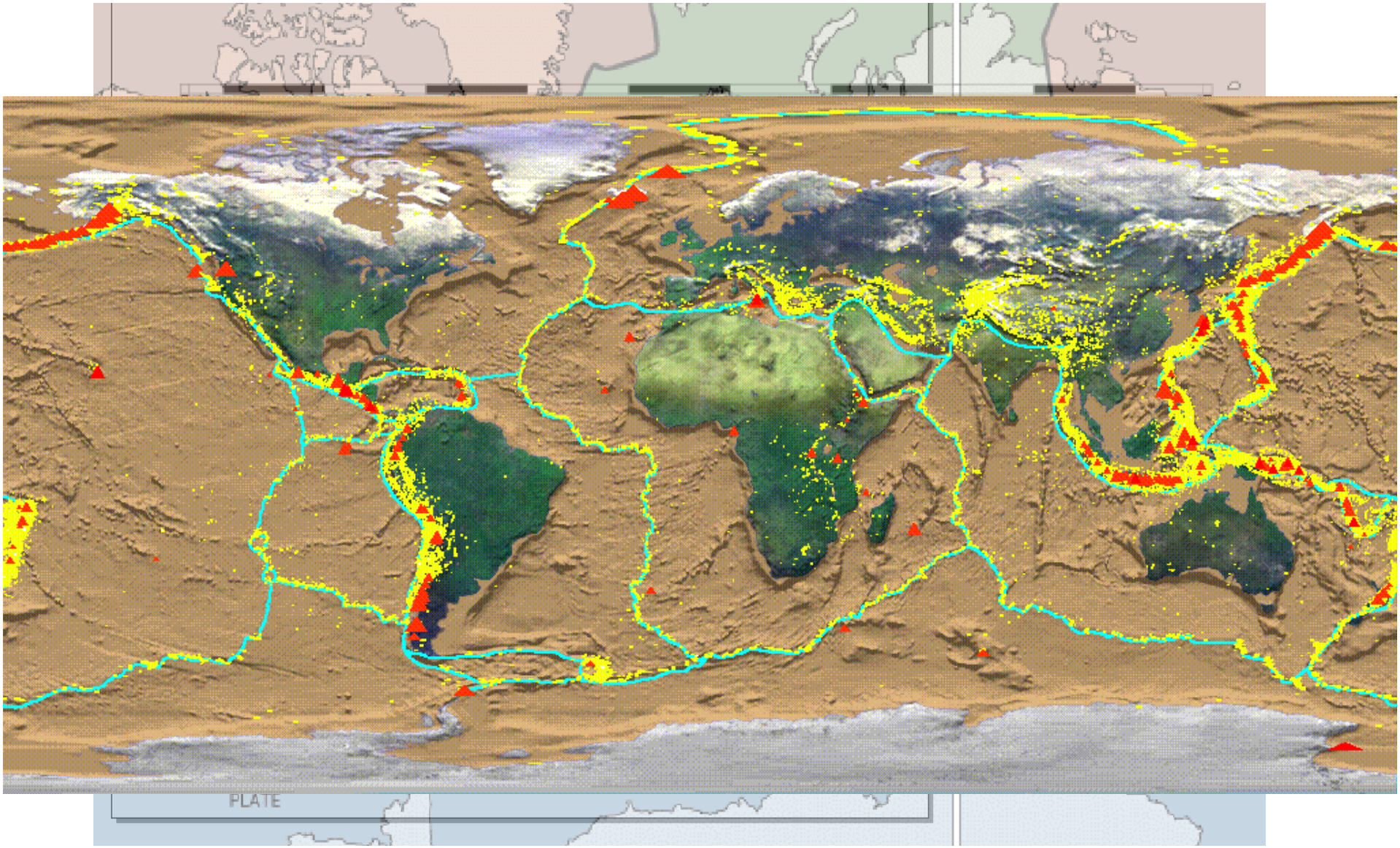
Surface Deformation

Surface rupture cutting
a village road near Arifiye

Surface Deformation



The Origin of Earthquake _ Plate Tectonics



Overview

Surface Deformation

Design for Surface Deformation

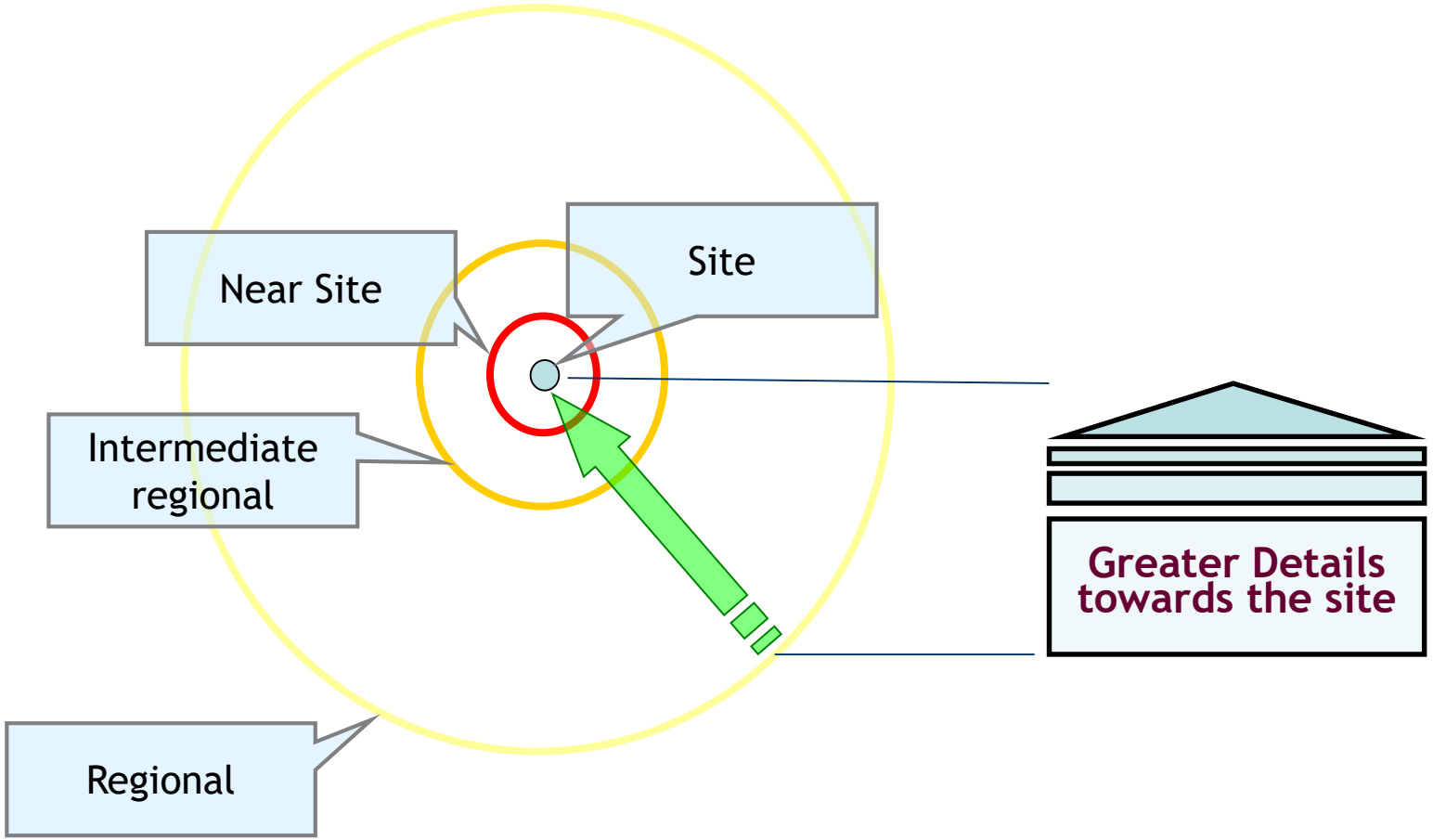
Faulting

FT Characteristics
- Length, Displacement
- Magnitude
- Historic Activity

Wave propagation
- Attenuation

Seismic Design
- Subsurface Material
- Response Spectrum

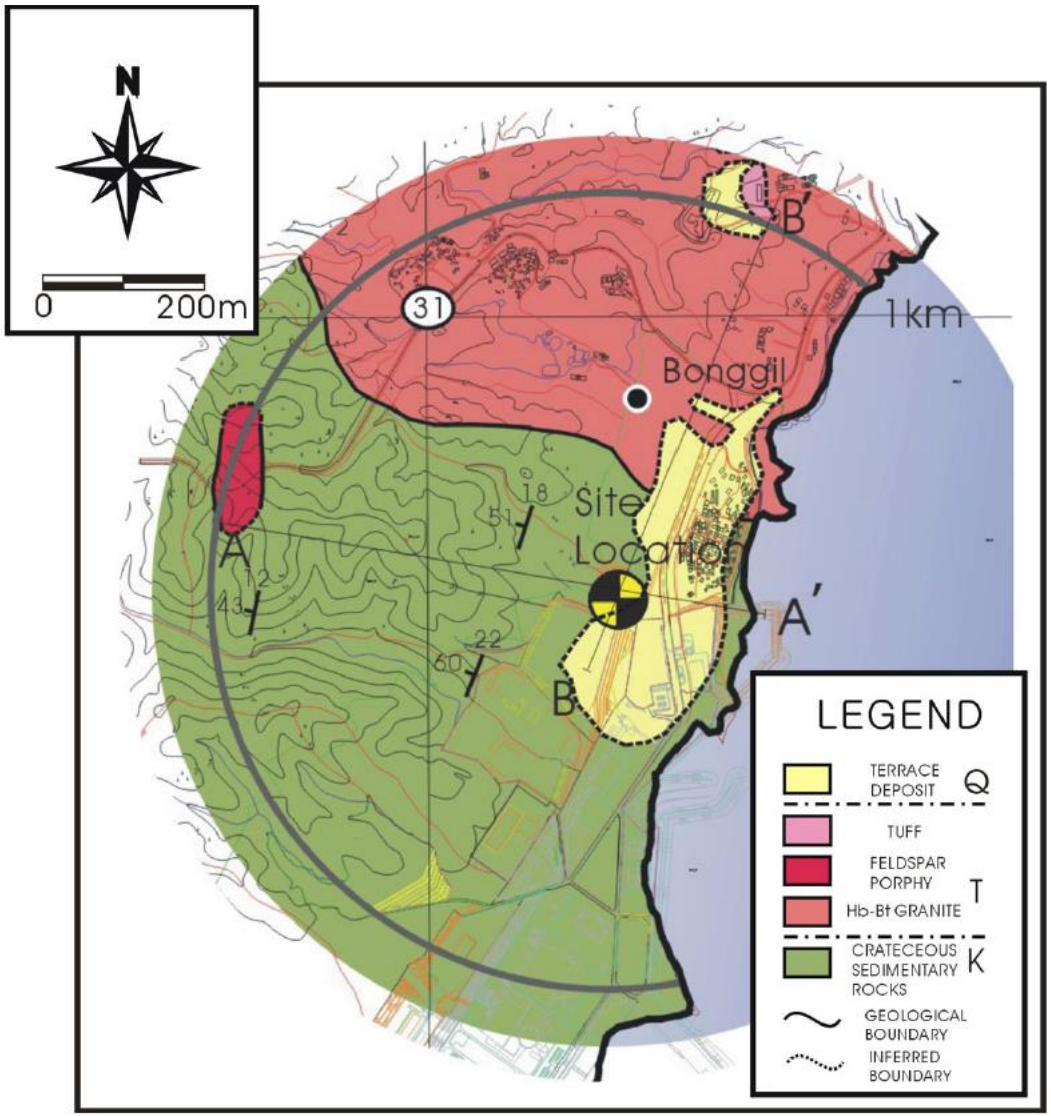
Extent of Investigation

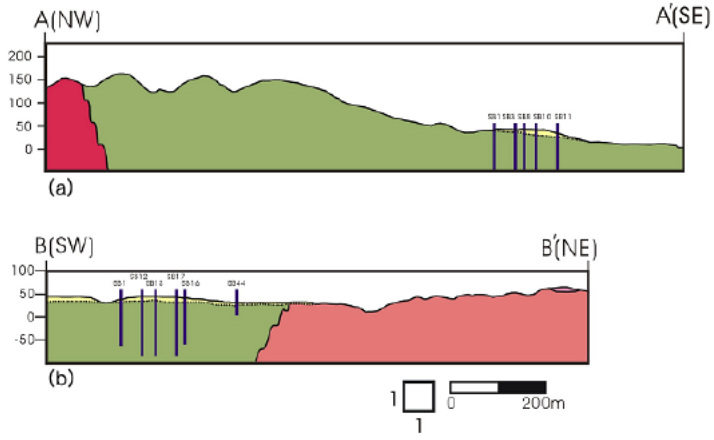


Extent of Investigation (cont.)

Step	Range	Investigation Method
Regional	320 km (200 mi)	• Comprehensive literature review supplemented by geological reconnaissances • Map scale - 1:500,000 or smaller
Intermediate Regional	40 km (24 mi)	• Reconnaissance-level investigation supplemented by explorations • Map scale – 1:50,000 or smaller
Near Site	8 km (5 mi)	• Detailed investigations to delineate the geology and the potential for tectonic deformation at or near surface • Map scale – 1:5,000 or smaller
Site	about 1 km	• Most detailed investigations including geotechnical engineering investigations • Mapping of excavations and logging of trenches for plant structures • Map scale – 1:500 or smaller

Geologic Map within1km from the site





(a) A-A′ 단면, (b) B-B′ 단면

Geologic map and cross sections within 1km of the site

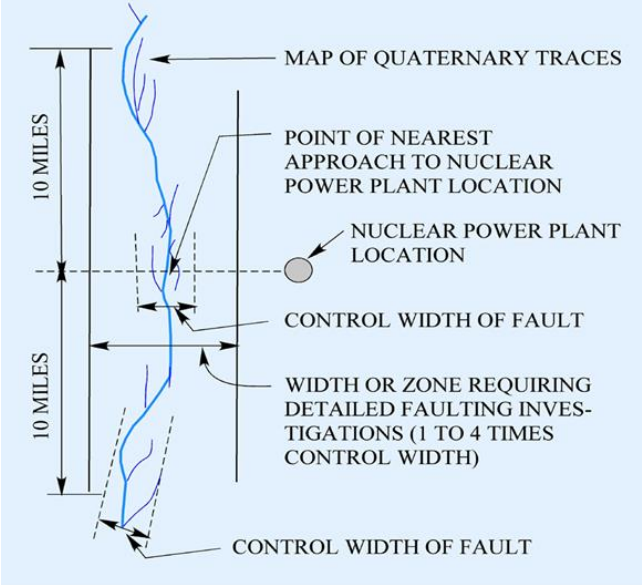
Surface Deformation

☐ Control width

- ❍ Maximum width of mapped Quaternary fault traces

☐ Zone of detailed investigation (ZDI)

EQ Magnitude	Width of zone requiring detailed faulting investigation
< 5.5	1 × control width
5.5 ~ 6.4	2 × control width
6.5 ~ 7.4	3 × control width
7.5 ≤	4 × control width



- ❍ ZDI is at least 0.5 mile.

☐ Recommendation

- ❍ Not to locate plant structures within the ZDI

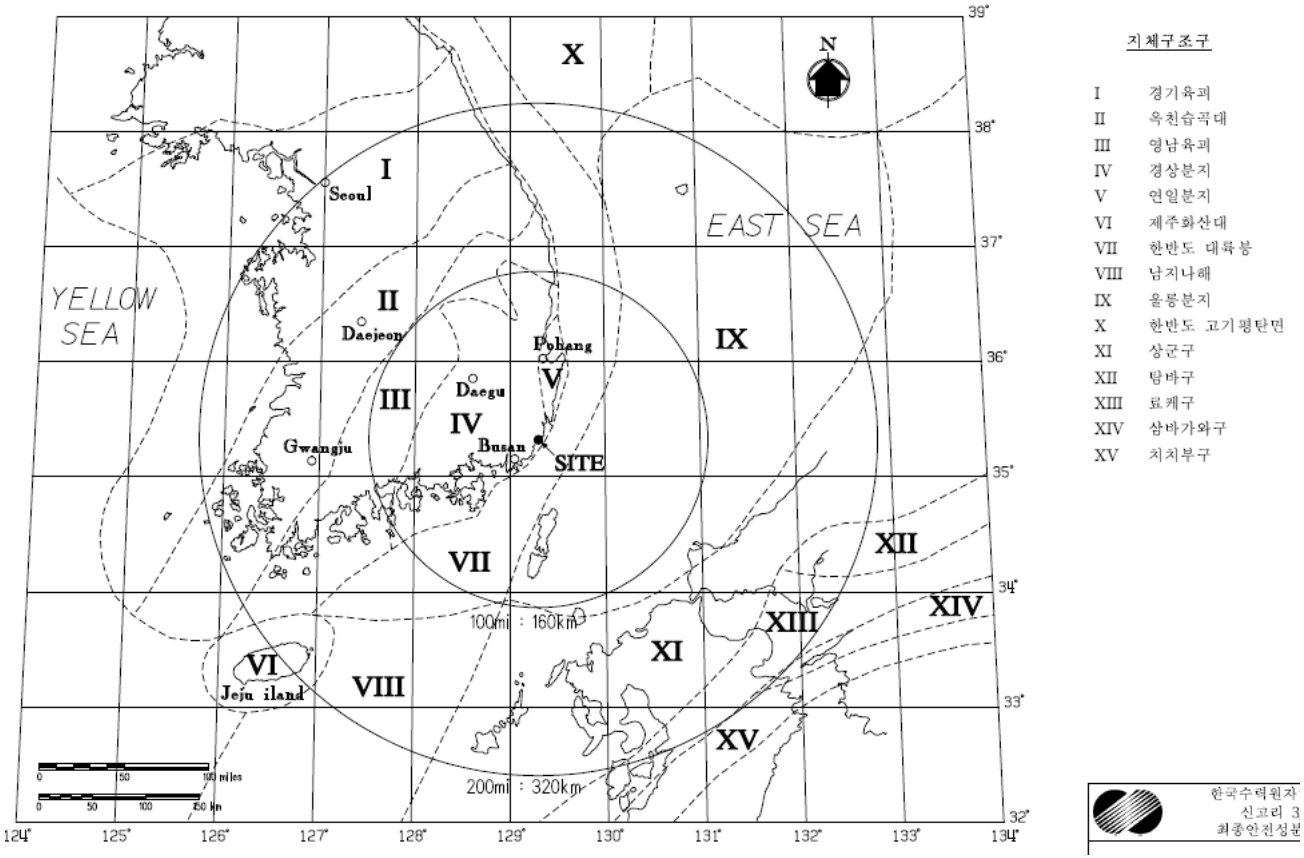
Design Earthquakes

☐ General considerations

❍ Seismic sources

- Capable tectonic structure(Fault)
  - Definition: a geological structure capable of generating earthquakes
  - Characterization: location & geometry of geological structure, maximum potential earthquake, earthquake recurrence rate, etc.
- Seismotectonic province
  - Definition: a region where earthquakes diffusely occur, but no specific geological structure is identified to be responsible for those earthquakes.
  - Characterization: similar to that of capable tectonic source

Example of Seismotectonic Province



Seismotectonic province within 320km of the site

Design Earthquakes (cont.)

☐ Seismic Hazard/Design Earthquakes

❍ Methods

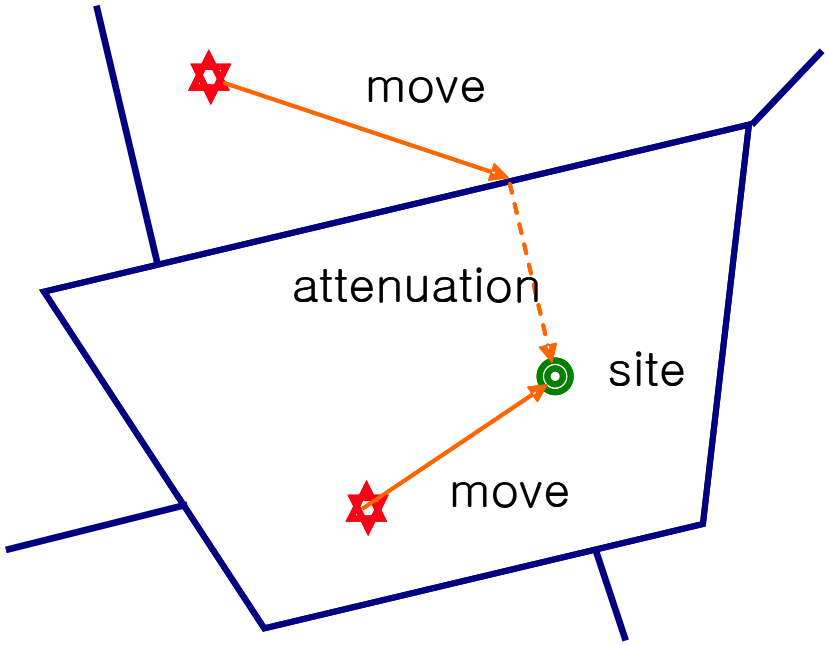
- Deterministic & probabilistic methods
- Korean regulation requires the deterministic method
  - Mean annual exceeding frequency of SSE should be less than 1.0E-3

❍ Deterministic method

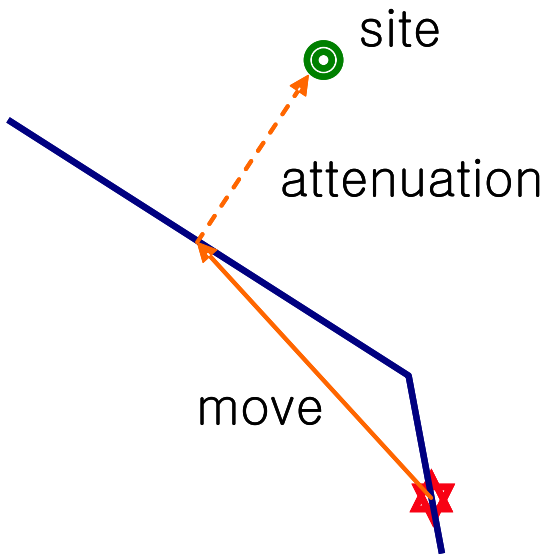
- Establish a seismotectonic model consisting of capable tectonic structures and seismotectonic provinces (i.e., seismic sources)
- Determine the max. potential earthquake (MPE) for each seismic source
- Locate each MPE at the closest point to site
- Calculate the site ground motion by each MPE by using proper attenuation equation
- Take the largest ground motion among all MPEs (max. site ground motion)

Design Earthquakes (cont.)

☐ Deterministic method (diagrammatic)



Seismotectonic Provinces



Capable Tectonic Structure

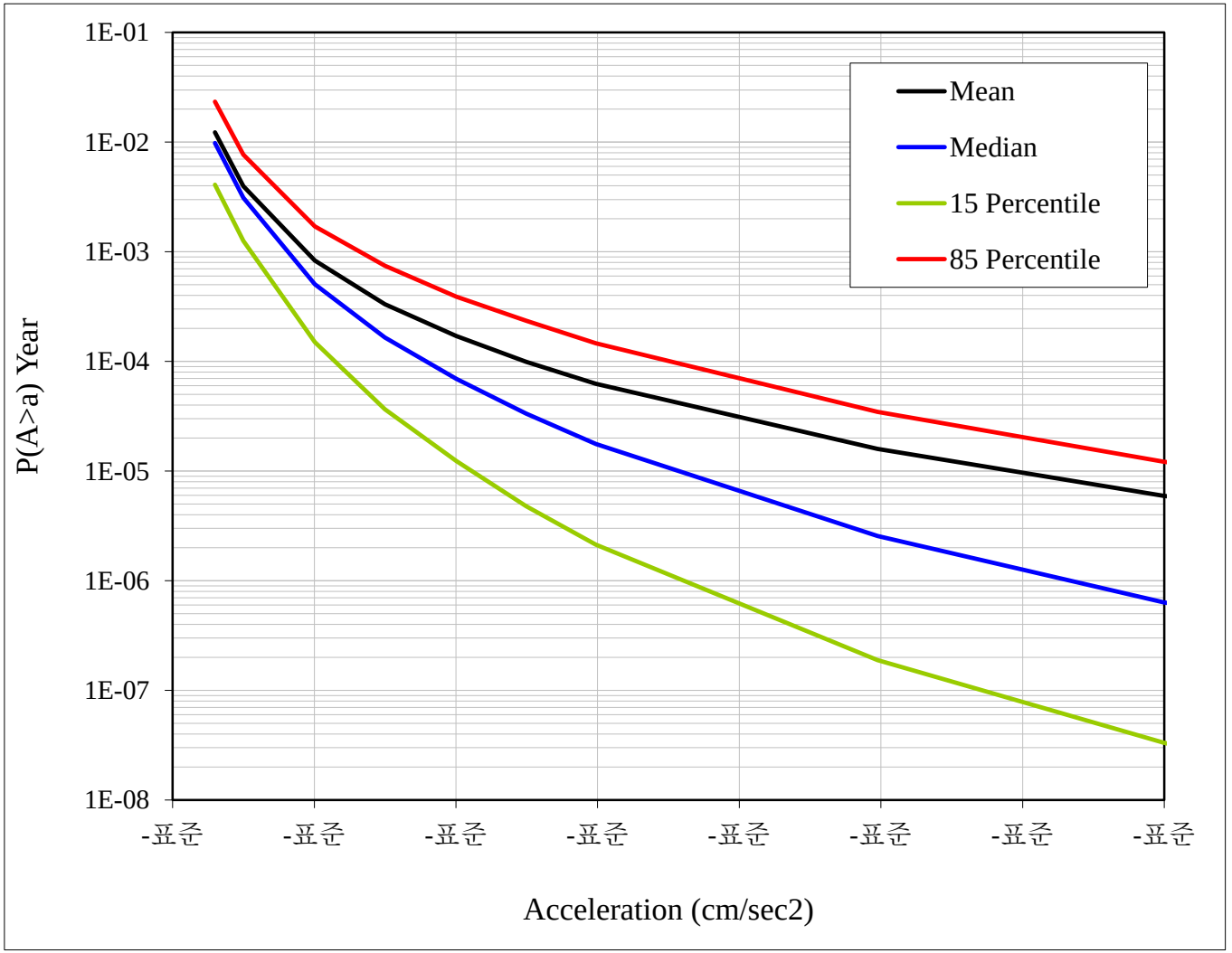
Design Earthquakes (cont.)

☐ Probabilistic method

- Construct seismotectonic models in terms of seismic sources including uncertainty in source boundary
- For each source, determine magnitude-frequency models and MPEs including the associated uncertainties
- Select proper attenuation equations including the uncertainties
- Evaluate annual frequency of exceedance for various levels of ground motions
- Mean, median, 15th-percentile, 85th-pertiles

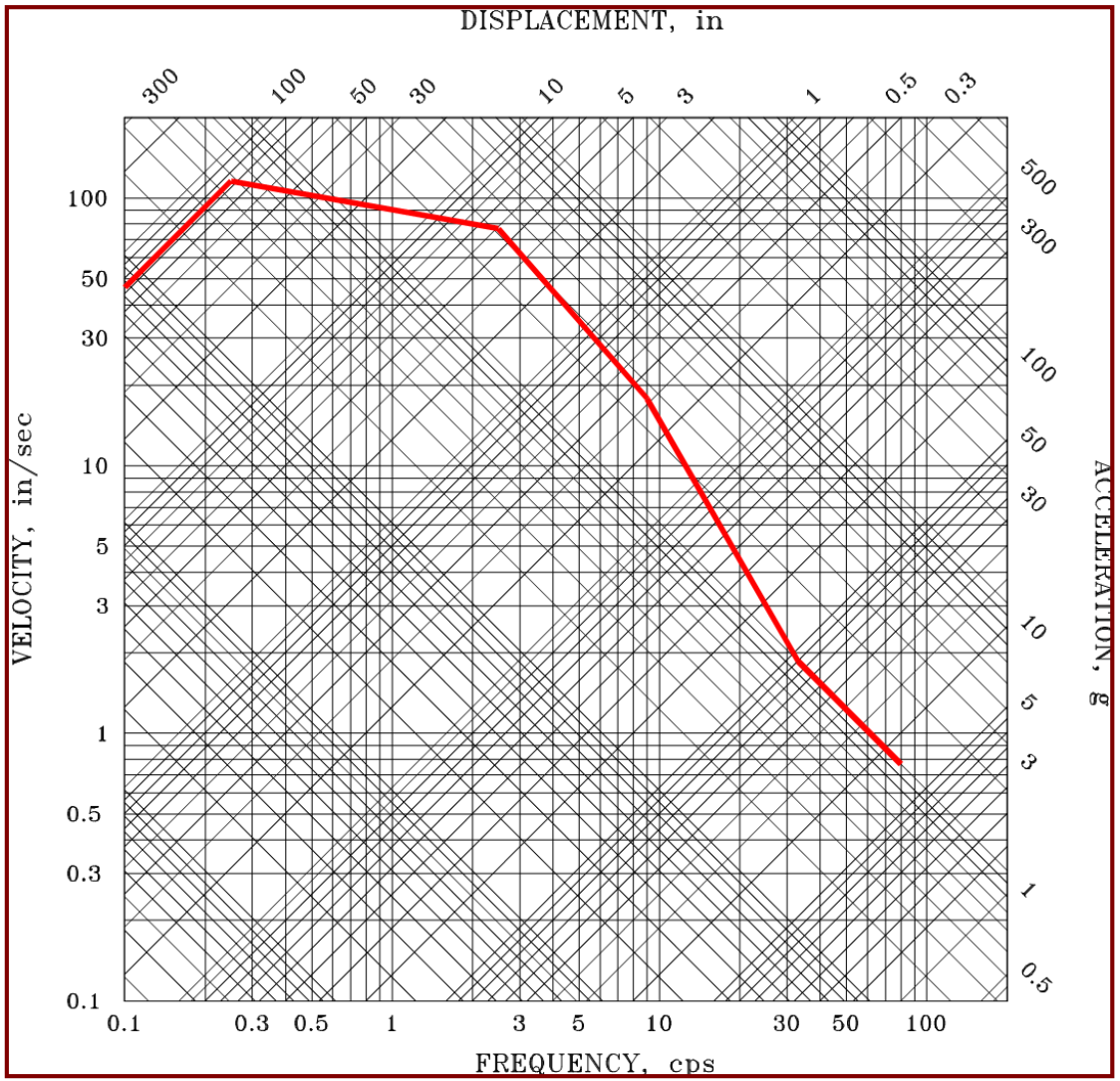
Design Earthquakes (cont.)

Example of PSHA



Design Earthquake _ Standard Response Spectrum

Reg. Guide 1.60
Horizontal Design
Response Spectrum
(Scaled to 1.0g
Horizontal Ground
Acceleration)



VII. Geotechnical Engineering

CONTENTS

- Design considerations of foundation
- Engineering properties of rocks and soils
- Investigation for engineering purposes
- Evaluation and Criteria

Overview

☐ Stability of subsurface materials

- ❍ Subsurface foundation material is assumed to be homogeneous and stable in terms of geological hazards
- ❍ Sufficient bearing capacity to sustain the load of structures

☐ Factors to be evaluated

- ❍ Bearing Capacity of foundation materials
  - BC is the capacity of the material to support the dynamic and static load of the upper structures or facilities
  - BC is calculated the different ways according to the supporting materials
  - If the BC is too low, the failure of the foundation can be imagined
- ❍ (Total) Settlement or differential settlement
  - The calculated settlement and the DS shall be the allowable limit
  - In general, I inch for TDS and 0.5” for DS is allowed

Overview

☐ Factors to be evaluated

- ❍ Liquefaction potential
  - The word “liquefaction” means a change in state from a solid to liquid.
  - As applied to a soil, the term refers to a change from a solid or stable assemblage of soil particles to a complete or substantially complete suspension of the solid particles in a fluid, such that the suspension has a very low shear strength.
- ❍ Velocity model for SSI
  - Vertical distribution of shear wave velocity (Vs) under the ground
- ❍ Slope stability
  - Man-made and natural slope
  - Permanent and temporal (excavated) slopes
  - Dynamic and static evaluation
- ❍ Possibility of reinforcement of local unsuitable materials or zones

IAEA NS-R-3: SPECIFIC REQUIREMENTS FOR EVALUATION OF EXTERNAL EVENTS

❖ GEOTECHNICAL HAZARDS

- Geological instability due to the mineral composition and weathering
- Dam failure, sea wall and breakwater in case that the nuclear installations will be constructed near sea, and using the sea water for ultimate heat sink(UHS).

Behaviour of foundation materials

- The geotechnical characteristics of the subsurface materials, including the uncertainties in them, shall be investigated and a soil profile for the site in a form suitable for design purposes shall be determined.
- The stability of the foundation material under static and seismic loading shall be assessed.
- The groundwater regime and the chemical properties of the groundwater shall be studied.

IAEA NS-R-3: SPECIFIC REQUIREMENTS FOR EVALUATION OF EXTERNAL EVENTS

Collapse, subsidence or uplift of the site surface

- The existence of natural features such as caverns, karstic formations and human made features such as mines, water wells and oil wells shall be examined using the geological maps and other appropriate information for the region. The potential for collapse, subsidence or uplift of the site surface shall be evaluated.
- 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 shall be deemed unsuitable.
- If there seems to be practicable engineering solutions available, a detailed description of subsurface conditions shall be developed for the purposes of determination of the hazards.

IAEA NS-R-3: SPECIFIC REQUIREMENTS FOR EVALUATION OF EXTERNAL EVENTS

Soil liquefaction

- The potential for liquefaction of the subsurface materials of the proposed site shall be evaluated by using parameters and values for the site specific ground motion.
- The evaluation shall include the use of accepted methods of soil investigation and analytical methods to determine the hazards.
- 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.

IAEA NS-R-3: SPECIFIC REQUIREMENTS FOR EVALUATION OF EXTERNAL EVENTS

Slope instability

- The potential for slope instability (such as land and rock slides and snow avalanches) that could affect the safety of the nuclear installation shall be determined.
- If potential for slope instability that could affect the safety of the nuclear installation exist, the hazard shall be evaluated by using parameters and values for the site specific ground motion.

Three categories of rocks (cont.)

Igneous	Metamorphic	Sedimentary
		
Igneous Rocks: Photos, descriptions and facts about intrusive and extrusive igneous rocks.	Metamorphic Rocks: Photos, descriptions and facts about foliated and non-foliated metamorphic rocks.	Sedimentary Rocks: Photos and facts about clastic, chemical and organic sedimentary rocks.

2 Types of Sedimentary Rocks

One type of sedimentary rock texture is **clastic**.

- Clastic rocks are made from pieces of sediments.
- You can tell where a rock has been based on the size and shape of its sediments.

Another type of sedimentary rock texture is **crystalline** or **bioclastic**.

- Crystalline sedimentary rocks are the result of solids left behind after water evaporates (like salt)
- Evaporite = precipitate= minerals left behind after water evaporates
- Bioclastic rocks are made by organic things, like shells from marine organisms.

What Type of Rock am I ?

How to tell an igneous rock from a sedimentary rock from a metamorphic rock.

Metamorphic rocks are recognized by:
- the interlocking texture of large grains
- foliation (layering)
- banded light and dark colors
- "ching" sound instead of a "chunk" sound when tapped

Igneous rocks are recognized by:
- the interlocking texture of the grains
- the presence of vesicules (holes) in extrusive igneous rocks
- may be dark-colored and heavy
- may display two grain sizes, one much larger than the other

Sedimentary rocks are recognized by:
- grains cemented together
- the presence of fossils
- light-colored and light weight
- may display interlocking grains but is very light weight

Design considerations

☐ Stable condition of foundation

- ❍ Stable geologic condition with homogeneous subsurface materials
- ❍ Suitable bearing capacity with limited (differential) settlement with no potential weak zone

☐ Major evaluation items

- ❍ Bearing capacity
- ❍ Settlement or differential settlement
- ❍ Liquefaction potential
- ❍ Seismic wave propagation characteristics
- ❍ Slope stability
- ❍ Possibility of improvement of unsuitable foundation materials

Design considerations (cont.)

☐ Basic data necessary to evaluate the foundation stability

- ❍ Geology and geological structure
- ❍ Static engineering properties
  - Unit weight, poisson's ratio, compressive strength, young's modulus, deformation modulus, etc.
- ❍ Dynamic engineering properties
  - Poisson's ratio, young's modulus, compressional/shear wave velocity, seismic wave velocity profile
- ❍ Ground water condition
  - Groundwater level, water quality, existence of artesian condition, etc.
  - Permanent dewatering
- ❍ Layout of the facilities and the nature of the structural foundation
- ❍ Characteristics of permanent or temporal cut slope

Engineering properties of rocks and soils

☐ Selection of representative value (RV)

- ❍ Direct measurement : in-situ test (rock mass deformation test, joint characteristics, groundwater level, etc.)
- ❍ Indirect measurement : correlation with related parameters (Rock Mass Rating, Rock Quality Designation, velocity index, etc.)
- ❍ Selection of RV : Consideration of test reliability and site condition

☐ Rock mass deformation modulus(E_d)

- ❍ Used for evaluation of deformation characteristics and settlement for foundation materials
- ❍ Direct measurement – using the stress-strain relationship
- ❍ Indirect measurement – correlation with related parameters

Engineering properties of rocks and soils

☐ Rock mass deformation modulus(E_d)

- ❍ Direct measurement
  - Jack test, elastometer test, etc.
- ❍ Indirect measurement
  - Correlation with related parameters such as RMR (Rock mass rating), RQD (Rock Quality Designation) and Velocity index

☐ Uniaxial compressive strength(Qu)

- ❍ Using for the bearing capacity of foundation material
- ❍ Trlaxial/Uniaxial compressive strength test
- ❍ Uniaxial compressive strength test : Direct measurement
- ❍ Point load test (PLT) : Indirect method using point load index
  - In general, Qu = 24 x $I_{s(50)(}$about 20-25 times) is applied

Engineering properties of rocks and soils

Core recovery and Rock Quality Designation(RQD)

- **Core recovery**
  - The ratio of recovered core length to total length drilled, expressed as a %.
- **RQD**
  - The sum of the lengths of rock core pieces longer than 10cm expressed as a percentage of a given total length drilled, usually a core run(Deere et al,1969)

Density, specific gravity, porosity and water content

- Density: mass / unit volume
- Unit weight: weight / unit volume
- Specific gravity (dimensionless): density of rock / unit weight of water
- Weight

Permeability

- The pore (void) space in soils and in most rocks is interconnected
- The rate of discharge flow of a fluid through the pore passages is given by *Darcy's equation(law)* relating flow, Q, per unit discharge area, A, to hydraulic gradient:

$$\frac{Q}{A} = v = ki$$

Investigation for Engineering Properties

☐ In-land investigation

- ❍ Surface geological investigation
- ❍ Borings, Trenches, Ground water condition
- ❍ Geophysical exploration
  - Reflection and refraction method
  - Cross-hole test, down-hole test, tomography
- ❍ In-situ test
  - Rock deformation test
  - Standard penetration test (SPT)
- ❍ Laboratory test (Index test, uniaxial and triaxial compressive test, sonic test, …)

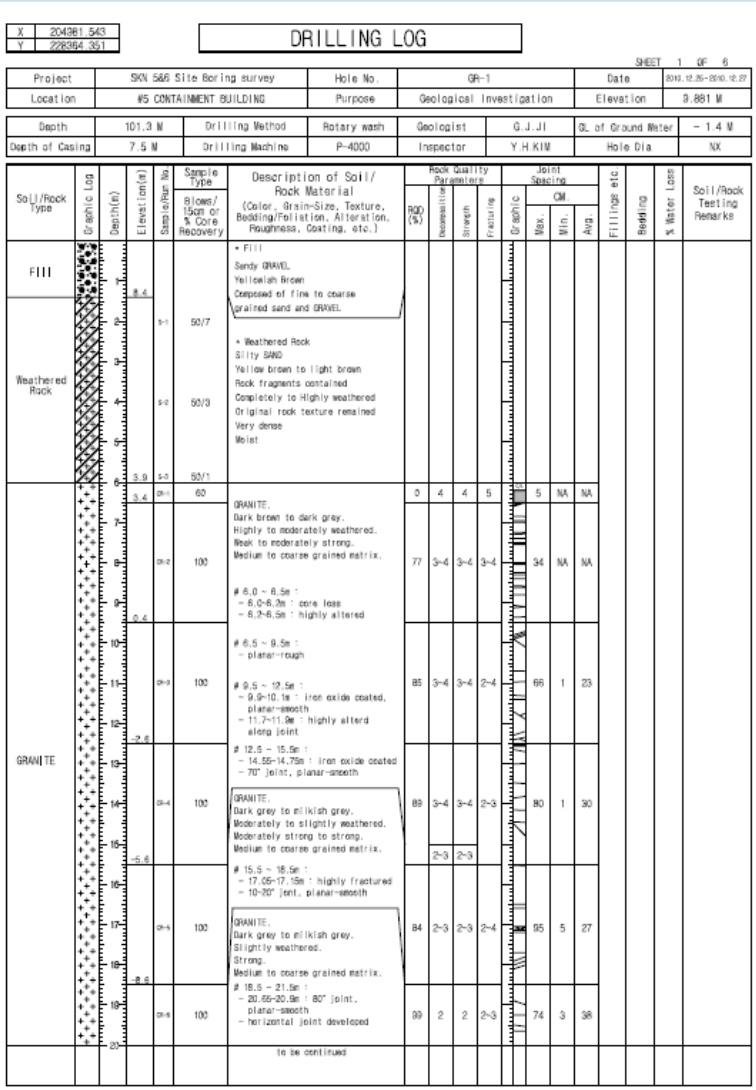
☐ Off-shore or marine investigation

- ❍ Marine physical exploration

☐ Determination of engineering properties of materials

- ❍ Direct measurement : In-situ test
- ❍ Indirect measurement : Correlation between parameters

Investigation to be conducted



DRILLING LOG

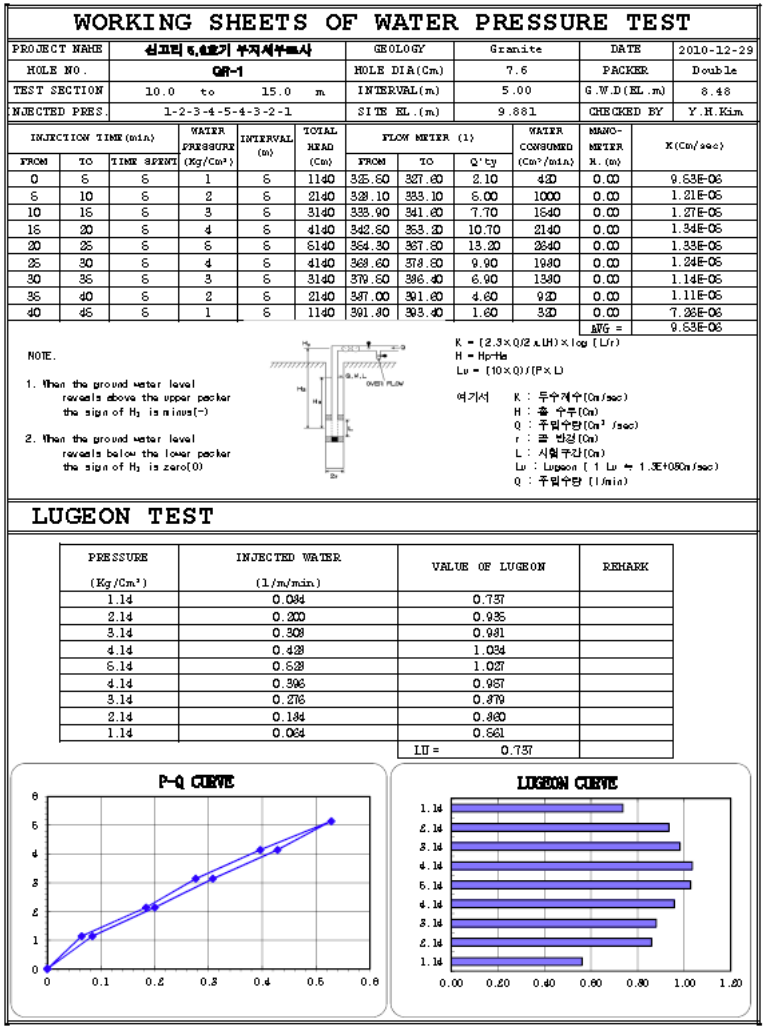
X	204361.543
Y	228354.351

SHEET 1 OF 6

Project	SKN 5&6 Site Boring survey	Hole No.	GR-1	Date	2010.12.25~2010.12.27
Location	#5 CONTAINMENT BUILDING	Purpose	Geological Investigation	Elevation	9.881 M
Depth	101.3 M	Drilling Method	Rotary wash	Geologist	G.J.JI	GL of Ground Water	- 1.4 M
Depth of Casing	7.5 M	Drilling Machine	P-4000	Inspector	Y.H.KIM	Hole Dia	NX

Soil/Rock Type	Graphic Log	Depth(m)	Elevation(m)	Sample/Run No.	Sample Type / Blows/15cm or % Core Recovery	Description of Soil/Rock Material (Color, Grain-Size, Texture, Bedding/Foliation, Alteration, Roughness, Coating, etc.)	Rock Quality Parameters: RQD (%)	Decomposition	Strength	Fracturing	Joint Spacing: Graphic	Max.	Min.	Avg.	Fillings etc	Bedding	% Water Loss	Soil/Rock Testing Remarks
FIII		1	-0.4			* FIII Sandy GRAVEL Yellowish Brown Composed of fine to coarse grained sand and GRAVEL.												
		2		S-1	50/7													
Weathered Rock		3				* Weathered Rock Silty SAND Yellow brown to light brown Rock fragments contained Completely to Highly weathered Original rock texture remained Very dense Moist												
		4		S-2	50/3													
		5																
		6	-5.9	S-3	50/1													
			-6.4	R-1	60		0	4	4	5		5	NA	NA				
GRANITE		7				GRANITE, Dark brown to dark grey, Highly to moderately weathered. Weak to moderately strong. Medium to coarse grained matrix.												
		8		R-2	100		77	3~4	3~4	3~4		34	NA	NA				
		9				# 8.0 ~ 8.5m : - 8.0~8.2m : core loss - 8.2~8.5m : highly altered												
			-9.4															
		10				# 8.5 ~ 9.5m : - planar-rough												
		11		R-3	100		85	3~4	3~4	2~4		66	1	23				
		12	-12.6			# 9.5 ~ 12.5m : - 9.9~10.1m : iron oxide coated, planar-smooth - 11.7~11.9m : highly altered along joint												
		13				# 12.5 ~ 15.5m : - 14.55~14.75m : iron oxide coated - 70° joint, planar-smooth												
		14		R-4	100	GRANITE, Dark grey to milkish grey, Moderately to slightly weathered, Moderately strong to strong, Medium to coarse grained matrix.	89	3~4	3~4	2~3		80	1	30				
		15	-15.6					2~3	2~3									
		16				# 15.5 ~ 18.5m : - 17.05~17.15m : highly fractured - 10~20° joint, planar-smooth												
		17		R-5	100	GRANITE, Dark grey to milkish grey, Slightly weathered, Strong, Medium to coarse grained matrix.	84	2~3	2~3	2~4		95	5	27				
		18	-18.6															
		19		R-6	100	# 18.5 ~ 21.5m : - 20.65~20.9m : 80° joint, planar-smooth - horizontal joint developed	99	2	2	2~3		74	3	38				
		20																
						to be continued												

Drilling Log for Rock Site



WORKING SHEETS OF WATER PRESSURE TEST

PROJECT NAME	신고리 5,6호기 부지세부조사	GEOLOGY	Granite	DATE	2010-12-29
HOLE NO.	GR-1	HOLE DIA(Cm)	7.6	PACKER	Double
TEST SECTION	10.0 to 15.0 m	INTERVAL(m)	5.00	G.W.D(EL.m)	8.48
INJECTED PRES.	1-2-3-4-5-4-3-2-1	SITE EL.(m)	9.881	CHECKED BY	Y.H.Kim

INJECTION TIME(min) FROM	TO	TIME SPENT	WATER PRESSURE (Kg/Cm²)	INTERVAL (m)	TOTAL HEAD (Cm)	FLOW METER (1) FROM	TO	Q'ty	WATER CONSUMED (Cm³/min)	MANO-METER H.(m)	K(Cm/sec)
0	5	5	1	5	1140	325.60	327.60	2.10	420	0.00	9.63E-06
5	10	5	2	5	2140	328.10	333.10	5.00	1000	0.00	1.21E-05
10	15	5	3	5	3140	335.90	341.60	7.70	1540	0.00	1.27E-05
15	20	5	4	5	4140	342.60	353.20	10.70	2140	0.00	1.34E-05
20	25	5	5	5	5140	354.30	367.50	13.20	2640	0.00	1.33E-05
25	30	5	4	5	4140	368.60	378.50	9.90	1980	0.00	1.24E-05
30	35	5	3	5	3140	379.50	386.40	6.90	1380	0.00	1.14E-05
35	40	5	2	5	2140	387.00	391.60	4.60	920	0.00	1.11E-05
40	45	5	1	5	1140	391.80	393.40	1.60	320	0.00	7.38E-06
										AVG =	9.63E-06

NOTE.

1. When the ground water level reveals above the upper packer the sign of H_2 is minus(-)
2. When the ground water level reveals below the lower packer the sign of H_2 is zero(0)

$K = (2.3 \times Q / 2\pi LH) \times \log(L/r)$

$H = Hp - Hs$

$Lu = (10 \times Q) / (P \times L)$

여기서 K : 투수계수(Cm/sec)
H : 총 수두(Cm)
Q : 주입수량(Cm³/sec)
r : 공 반경(Cm)
L : 시험구간(Cm)
Lu : Lugeon (1 Lu = 1.3E-05Cm/sec)
Q : 주입수량 (l/min)

LUGEON TEST

PRESSURE (Kg/Cm²)	INJECTED WATER (l/m/min)	VALUE OF LUGEON	REMARK
1.1d	0.084	0.737	
2.1d	0.200	0.935	
3.1d	0.308	0.981	
4.1d	0.428	1.034	
5.1d	0.628	1.027	
4.1d	0.398	0.987	
3.1d	0.276	0.879	
2.1d	0.184	0.860	
1.1d	0.084	0.561	
		LU = 0.737	

Working Sheet of Water Pressure Test

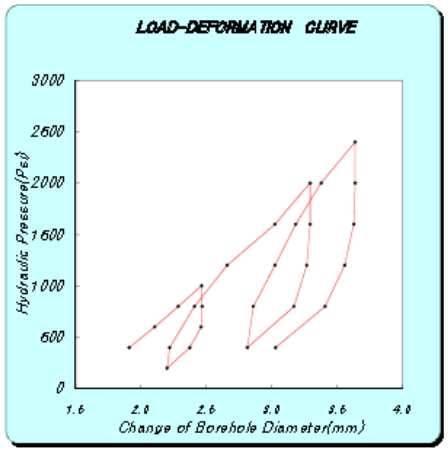
Investigation to be conducted

GOODMAN-JACK TEST SHEET

Project Name : 신고리 5,6호기 부지 세부조사

Hole No. :	GR-1	Rock Name :	GRANITE	Test Date :	2010.12.30
Depth :	8.0m	Rock Weathering :	HW	Record By :	S.H. Lee
G.W.L(-) :	1.4m	TCR/RQD(%) :	100/77	Checked By :	Y.H. Kim

PRESSURE	LVDT DISPLACEMENT READING (mm)		
(Psi)	NEAR	FAR	ΔAVG
200	2.47	0.93	1.700
400	2.46	1.56	1.810
600	2.48	1.73	2.105
800	2.54	2.05	2.295
1000	2.63	2.30	2.465
800	2.63	2.31	2.470
600	2.61	2.31	2.460
400	2.62	2.23	2.575
200	2.40	2.00	2.200
400	2.43	2.01	2.220
800	2.59	2.23	2.410
1200	2.73	2.59	2.660
1600	2.97	3.08	3.025
2000	3.17	3.42	3.295
1600	3.17	3.42	3.295
1200	3.10	3.44	3.270
800	2.97	3.37	3.170
400	2.76	2.87	2.815
800	2.82	2.90	2.860
1200	2.97	3.08	3.025
1600	3.08	3.29	3.185
2000	3.23	3.53	3.380
2400	3.46	3.83	3.640
2000	3.46	3.83	3.640
1600	3.43	3.83	3.630
1200	3.33	3.79	3.560
800	3.17	3.65	3.410
400	2.91	3.15	3.030



$$Ec = 0.86 \times e \times D \times (\Delta P/\Delta D) \times T^*$$

e : efficiency of jack's hydraulic system — 0.93

D : jack operating point — 76.2 (mm)

[coefficient dependent on poission's ratio]

Poisson's ratio	0.1	0.2	0.25	0.3	0.33	0.4	0.5
T*	1519	1474	1438	1397	1366	1289	1151

ν(Poisson's ratio) : 0.25 T* = 1.438

[보정루틴을 이용한 보정표 (Ec>1E+06, correction data (Et-Ec graph) use)]

Ec	0	1	2	3	4	5	6	7	8	9
0	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1	1.2	1.3	1.5	1.7	1.9	2.1	2.4	2.6	2.9	3.1
2	3.4	3.7	4.0	4.3	4.7	5.1	5.5	6.0	6.5	7.0
3	7.6	8.2	9.0	9.7	10.6	11.5	12.5	13.4	14.3	15.3

ΔP : P_1 (Psi) 1000 — P_2 (Psi) 2400

ΔD : D_1 (mm) 2.465 — D_2 (mm) 3.640

Dc (psi) = 1.04E+05 — Dt = 1.04E+05 psi

7.34E+03 kgf/㎠

ΔP : P_1 (Psi) 800 — P_2 (Psi) 2000

ΔD : D_1 (mm) 2.860 — D_2 (mm) 3.380

Ec (psi) = 2.02E+05 — Et = 2.02E+05 psi

1.42E+04 kgf/㎠

* Et : Calculation Elastic Modulus, Et : True Elastic Modulus

Dc : Calculation Deformation Modulus, Dt : True Deformation Modulus

* If Ec > 1E+06, correction data (Et-Ec graph) use!

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KNU 강원대학교

시험결과 (Test Result)

2011-073

Specimen	
Borehole ID	GR-21
Depth	48.0~49.0 m
Lithology	
Diameter / Length	5.05 / 11.15 cm
Condition	Normal

Test Condition	
Test Date	2011. 6. 14.
Testing Machine	KDU-100 / UCAM20-PC
Stress Rate	0.5 MPa/sec

Test Method

ASTM C97 / C97M - 09 Standard Test Methods for Absorption and Bulk Specific Gravity of Dimension Stone

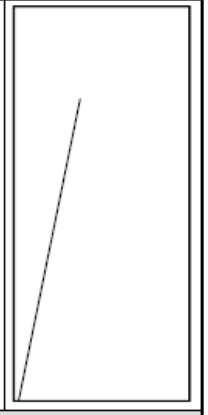
ASTM D2845-08 Standard Test Method for Laboratory Determination of Pulse Velocities and Ultrasonic Elastic Constants of Rock

ASTM D7012-10 Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens under Varying States of Stress and Temperatures

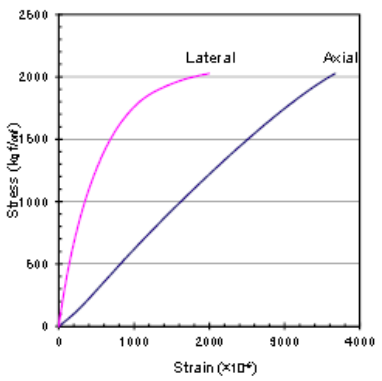
Test Result (Reliability)		
Dry Density	2.68 g/㎤	(Medium)
Specific Gravity	2.68	(High)
Porosity	0.52 %	(High)
Absorption	0.19 %	(High)
P-wave Velocity	5,353 m/s	(High)
S-wave Velocity	2,753 m/s	(Medium)
Young's Modulus	5.89 $\times 10^5$ kgf/㎠	
Poisson's Ratio	0.31	(Medium)
Uni. Comp. Strength	2,027 kgf/㎠	(High)
Rock Strength Classification (ISRM)	Very strong rock	
Remark		

Pictures of Specimen

Failure Description



Stress vs. Strain Curve



Affirmation	
Tested by	홍 보 현
Technical Manager	장 원 식

Rock Physical Properties and UCS Test

페이지 (99) / (총 66)

KOREA INSTITUTE OF NUCLEAR SAFETY
Global Safety Infrastructure Group

Foundation stability criteria

☐ Bearing capacity (Qa) evaluation (CGS)

❍ For rock site

- **Qa = Ksp X Qu-core**

Qa: allowable bearing pressure,

Qu-core: average unconfined compressive strength of rock cores(ASTM D2938),

Ksp : an empirical coefficient, which include safety factor of 3 and ranges from 0.1 to 0.4

Spacing of discontinuities	Ksp	Spacing width (m)
Moderately close	0.1	0.3 - 1
Wide	0.25	1 - 3
Very Wide	0.4	> 3

Foundation stability criteria

☐ Settlement evaluation for rock site

$$\rho = \frac{P(1-\nu_m^{\,2})}{\beta_Z E_m A^{0.5}} \qquad \rho = \frac{0.9P}{E_m A^{0.5}} = \frac{0.9P}{\alpha_E E_r A^{0.5}} \qquad \alpha_E = \frac{Ei}{Er}$$

- ρ : amount of settlement, P: load, V_m : poisson's ratio of rock, E_m: young's modulus of rock, A: foundation area, β_Z: foundation shape coefficient
- For rock site, the settlement may negligible
- Computer simulation, 1.0 inch is allowable criteria
- In case of differential settlement, pipes between Structures should be considered

Foundation stability criteria

☐ Velocity structure model

- ❍ Development of the seismic response characteristics of foundation materials : site-specific response spectrum
- ❍ If the s-wave velocity is equal or more than 8,000ft/sec, then the foundation assumed to be a fixed base
- ❍ If the s-wave velocity is less than 8,000ft/sec, then the soil structure interaction (SSI) analysis should be conducted
- ❍ The material with s-wave velocity less than 8,000ft/s does not mean unsuitable for foundation materials

Foundation stability evaluation

☐ Liquefaction

- Liquefaction susceptibility can be expressed in terms of a factor of safety against the occurrence of liquefaction as:

$$FS = \left(\frac{CRR_{7.5}}{CSR}\right) MSF$$

$$CSR = \frac{T_{av}}{\sigma'_{vo}} = 0.65\left(\frac{a_{max}}{g}\right)\left(\frac{\sigma_{vo}}{\sigma'_{v0}}\right)\gamma_d \qquad CRR_{7.5} = \frac{1}{34-N} + \frac{N}{135} + 50/(10N+45)^2\text{-}1/200$$

- CRR (cyclic resistance ratio) is the available soil resistance to liquefaction, expressed in terms of the cyclic stresses required to cause liquefaction
- CSR (cyclic stress ratio) is the cyclic stress generated by the design earthquake.

Always we keep watching our Atomic Power