Natural Disaster Risk Assessment and Area Business Continuity Plan Formulation for Industrial Agglomerated Areas in the ASEAN Region

Risk Profile Report
- Hai Phong of Vietnam -

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AHA CENTRE

Japan International Cooperation Agency

OYO International Corporation

Mitsubishi Research Institute, Inc.

CTI Engineering International Co., Ltd.

Outline of the Pilot Area

<table>
<tr><td>Country name</td><td>Vietnam</td></tr>
<tr><td>Pilot areas</td><td>Industrial clusters and surrounding areas in Hai Phong City</td></tr>
<tr><td>Location of pilot areas</td><td>Pilot areas are located in Hai Phong City. Industrial clusters are scattered across Hai Phong City. (The approximate area where industrial parks are scattered is indicated by a red broken line.)

</td></tr>
<tr><td>Local administrative agencies in pilot areas</td><td>Local administrative divisions of Vietnam consist of three levels: the first administrative division (Provinces), the second administrative division (Rural Districts), and the third administrative division (Towns and Communes). Hai Phong City is a centrally controlled city that does not belong to a province, but is directly controlled by the national government.</td></tr>
<tr><td>Area and population of pilot areas</td><td>

Local administrative agencies	Area (km^2)	Population*
Hai Phong City	1,523,4	1,878,500

* 2011, General Statistics Office of Viet Nam
</td></tr>
<tr><td>Natural conditions of pilot areas</td><td>Tropical monsoon climate with four seasons. Monthly average rainfall in Hai Phong is 299 mm. It rains heavily from June to September. The highest volume of rain tends to be recorded in August.</td></tr>
<tr><td>Hazards (disasters) in pilot areas: Flood</td><td>Hai Phong is located at the northeast end of the Red River Delta. Hai Phong City is affected by flooding of the Red River; however, the risk of flood damage is low in the town of Hai Phong. Major flood damage may include inundation caused by high tides due to tropical cyclone or typhoon, and inland flooding due to local torrential rain. Examination of inundation areas should be considered since Hai Phong town is a low-lying area.</td></tr>
</table>

Hazards (disasters) in pilot areas: Earthquake	There is no record in the disaster database of earthquakes with casualties around Hai Phong. Although an active fault is assumed to exist near Hai Phong, there is no record of its activities in the past. The rate of activity is unknown. IGP-VAST analyzed seismic activities statistically regarding a possible active fault around the city, as well as the seismic activities in the past at the border of the northwest area near China and Laos. Consequently, they estimate that the seismic acceleration in 500 years around Hai Phong would be 40 to 50 gal, which is the value on bedrock. According to a geological map prepared by the Bureau of Mines and Geology, the ground around Hai Phong is covered by sediment from the Quaternary period, which would amplify earthquake motion. Taking this fact into consideration, the acceleration on the earth's surface is assumed to be 50 to 80 gal (about 4 on the JMA intensity scale).
Hazards (disasters) in pilot areas: Tsunami	There is no record of tsunami damage in the disaster database. It is possible that a tsunami generated at the Philippine Trench west of the Philippines could reach Vietnam.
Hazards (disasters) in pilot areas: Volcanoes	There are no active volcanoes in the vicinity. There is no record of volcano damage in the disaster database.
Industrial clusters in pilot areas	There are six industrial parks in Hai Phong City, where 76 Japanese-affiliated companies are located. The Nomura Hai Phong Industrial Zone has the largest number of Japanese-affiliated companies, with 54 of 61 tenants being Japanese companies. The Nomura Hai Phong Industrial Zone has been selected as the representative industrial park in the pilot areas. Its outline is as follows. ✓ Constructed in 1997 as the first Japanese-affiliated industrial park in north Vietnam. Occupied by 54 Japanese-affiliated companies. ✓ Land transportation by Route 5 is the main means of transport to Hanoi. Route 5 has two lanes each way, but has frequent traffic congestion. Route 18 may be chosen in case Route 5 cannot be used, but this is not practical. ✓ The natural disaster risk in Hai Phong is inundation caused by torrential rain. However, this risk is very low since the industrial park is in a good location. ✓ If the roads of the residential areas of employees are flooded, commuting would be hindered, affecting business operations. However, recovery will take only one day. ✓ Companies occupying the industrial park vary in terms of type of business, e.g., distribution, manufacturing and insurance.
General economic conditions of pilot areas	Large-scale companies including Canon, Brother, Honda and Yamaha form production bases with their Japanese-affiliated suppliers in Vietnam. The flow of goods and materials of general manufactures is: import materials from Japan to Vietnam; suppliers process and deliver them to large manufacturers; and they assemble them into finished products. Currently, most of the large companies are trying to increase local procurement in order to reduce procurement costs and lead time. These efforts lead to an increase in production by local suppliers (Japanese-affiliated). "Export processing" is included in the business operation categories of the manufacturing industry in Vietnam. There is a preferential treatment for this category in that import taxes for materials are exempted when imported materials are processed and exported within nine months. (Finished products cannot be marketed in Vietnam if this preferential treatment is applied.) This system is referred to as the EPZ (Export Processing Zone), which was introduced to give incentives to foreign companies, with the additional aim of raising employment and transferring technology. Pioneer, Yazaki Corporation, Toyota Boshoku Corporation and others are based in the Nomura Hai Phong Industrial Zone. They all focus on export processing in their production activities. Consequently, they mostly process materials purchased from Japan and other countries in the industrial park, and export finished products (to advanced countries such as the U.S.A.). In contrast, Tang Long Industrial Park (developer: Sumitomo Corporation) mainly ships their products within Vietnam.
BCP	The concept of the BCP is generally unknown in Vietnam, and thus has not yet been

dissemination in Vietnam	recognized by many companies and corporate managers. Administrative agencies and private organizations that support companies do not understand the actual items of the BCP. They seem not to distinguish between the BCP and disaster prevention plans. The northern region of Vietnam, in particular, is rarely affected by national disasters. Companies in that region are not aware of the risk of disasters, especially in the industrial regions including Hai Phong. However, tidal waves caused by recent climate change are generally noticed. Companies dealing with dangerous substances such as oil, as well as organizations involved in lifeline utilities have developed emergency response plans concerning risk management. However, no case has been observed in which the BCP is clearly specified as a plan.

Contents

Chapter 1 Disaster Risks of the Pilot Area

1.1 Overview

The disaster risks of the pilot area were assessed by the distribution of facilities that are mentioned in Chapter 4 overlaid on the hazard maps for seismic intensity or inundation depth, among others. (See Appendix) The main subjects of the assessment are traffic infrastructures and lifeline facilities, which are important for the continuation of businesses.

For tsunamis, floods and storm surges, the facilities in areas that will be inundated and/or are projected to be submerged under are generally expected to receive damage. Past disaster records for the pilot area are the most valuable data for the assessment, because the extent of damage varies depending on the type and structure of the facilities, as well as their location. However, as past disaster records for the pilot area are not available for this study, disaster risk was assessed by referencing the disaster records from other areas.

For earthquakes, the extent of damage extent is determined by the intensity of seismic vibration at the location of the facility and their seismic performance. Several relationships between seismic intensity and the extent of damage of typical facilities have been proposed based on past earthquake disasters as the damage functions. The notable examples of functions are ATC-13[1], ATC-25[2] and Hazus[3], which were based on damage that occurred in the U.S.A. For this study, the extent of damage and the time needed to recover are assessed based on these damage functions. Therefore, it should be noted that the assessed results in this study can be improved by referring to the local situation of the facilities.

1.2 Identification of Predominant Hazards

Impacts to the business continuity were assessed and are shown in Figure 1.2.1. The hazard that will most likely interrupt business in Hai Phong is storm surges and flooding due to typhoons. This assessment is based on the overlaid maps of hazards and important facilities shown in Figure 1.2.2 – Figure 1.2.6.

The hazards in the pilot area with a probability of occurring once in 200 years are as follows.

- Earthquake: Seismic intensity of 5 to 6 of the MMI Scale.
- Tsunami: Maximum wave height is 1 to 2 m for the model with a return period of over 1,000 years.
- Flood: Maximum inundation depth is less than 1 m and the duration is several days or less.
- Storm surge: Maximum inundation depth is 5 m.

1 ATC, 1985, ATC-13: Earthquake Damage Evaluation Data for California, Federal Emergency Management Agency, Applied Technology Council, California, U.S.A.
2 ATC, 1991, ATC-25: Seismic Vulnerability and Impact of Disruption on Lifelines in the Conterminous United States, Federal Emergency Management Agency, Applied Technology Council, California, U.S.A.
3 FEMA, 2011, Hazus -MH 2.1, Multi-hazard Loss Estimation Methodology, Earthquake Model.

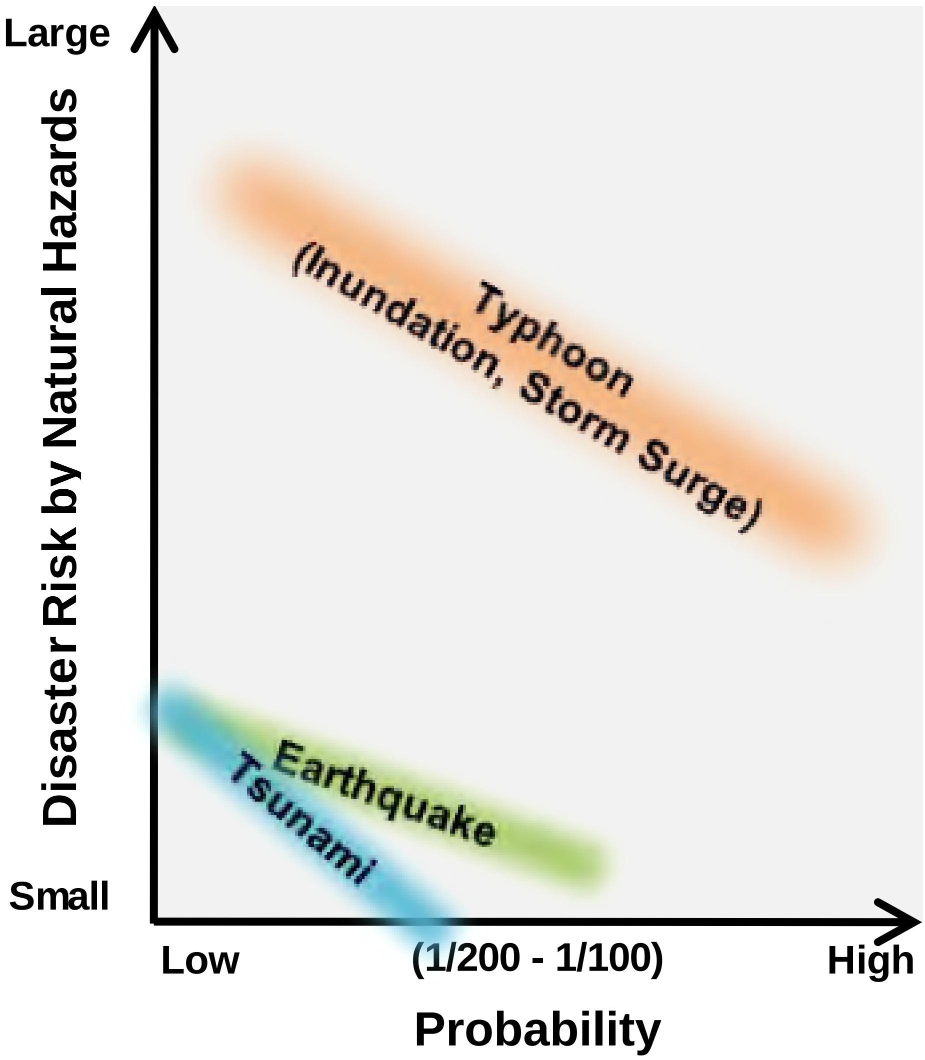


Figure 1.2.1 Identification of Predominant Hazards

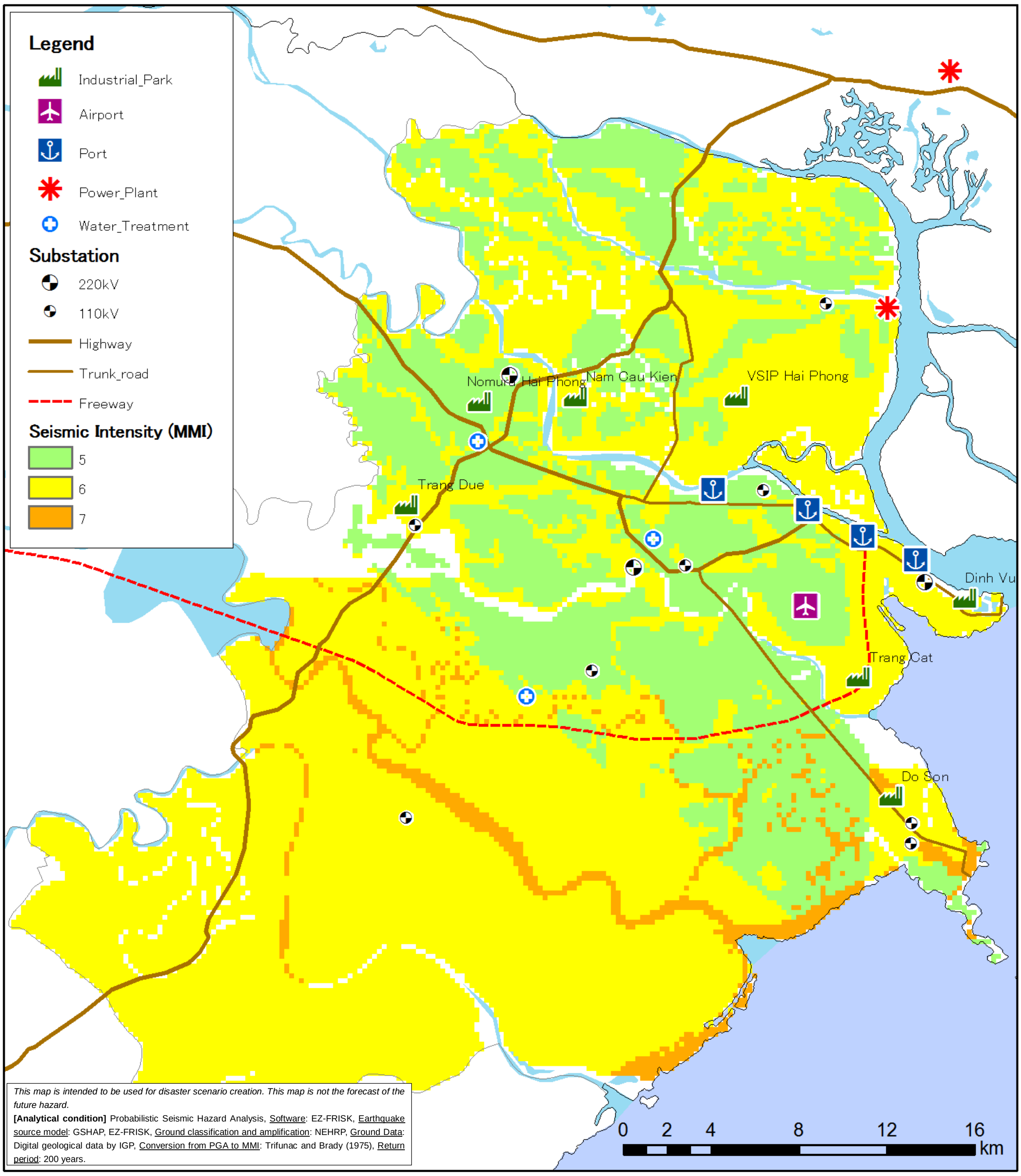


Figure 1.2.2 Seismic intensity expected with a 200-year probability and the distribution of important facilities

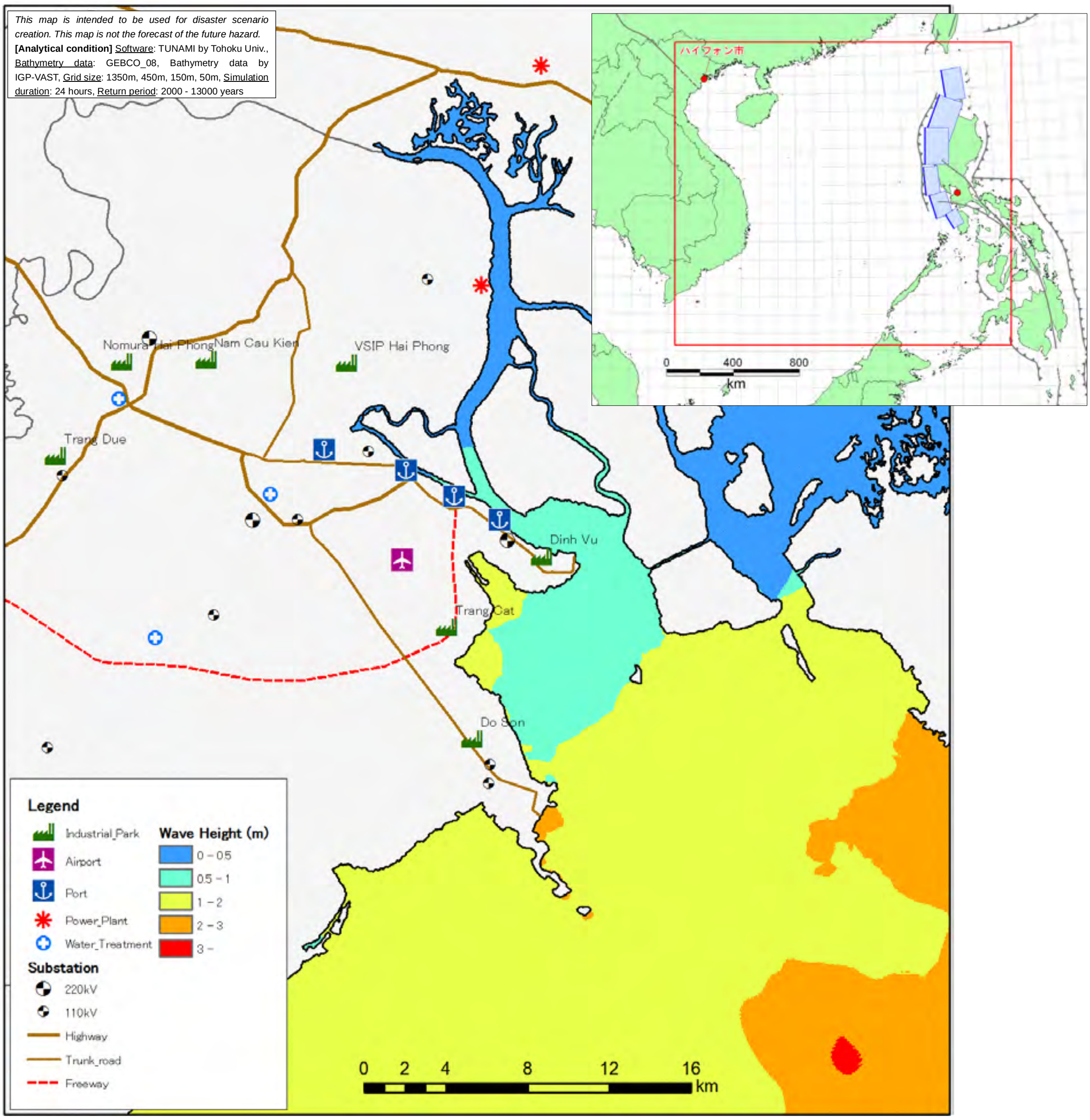


Figure 1.2.3 Maximum tsunami wave height for most severe case (return period is over 1,000 years)

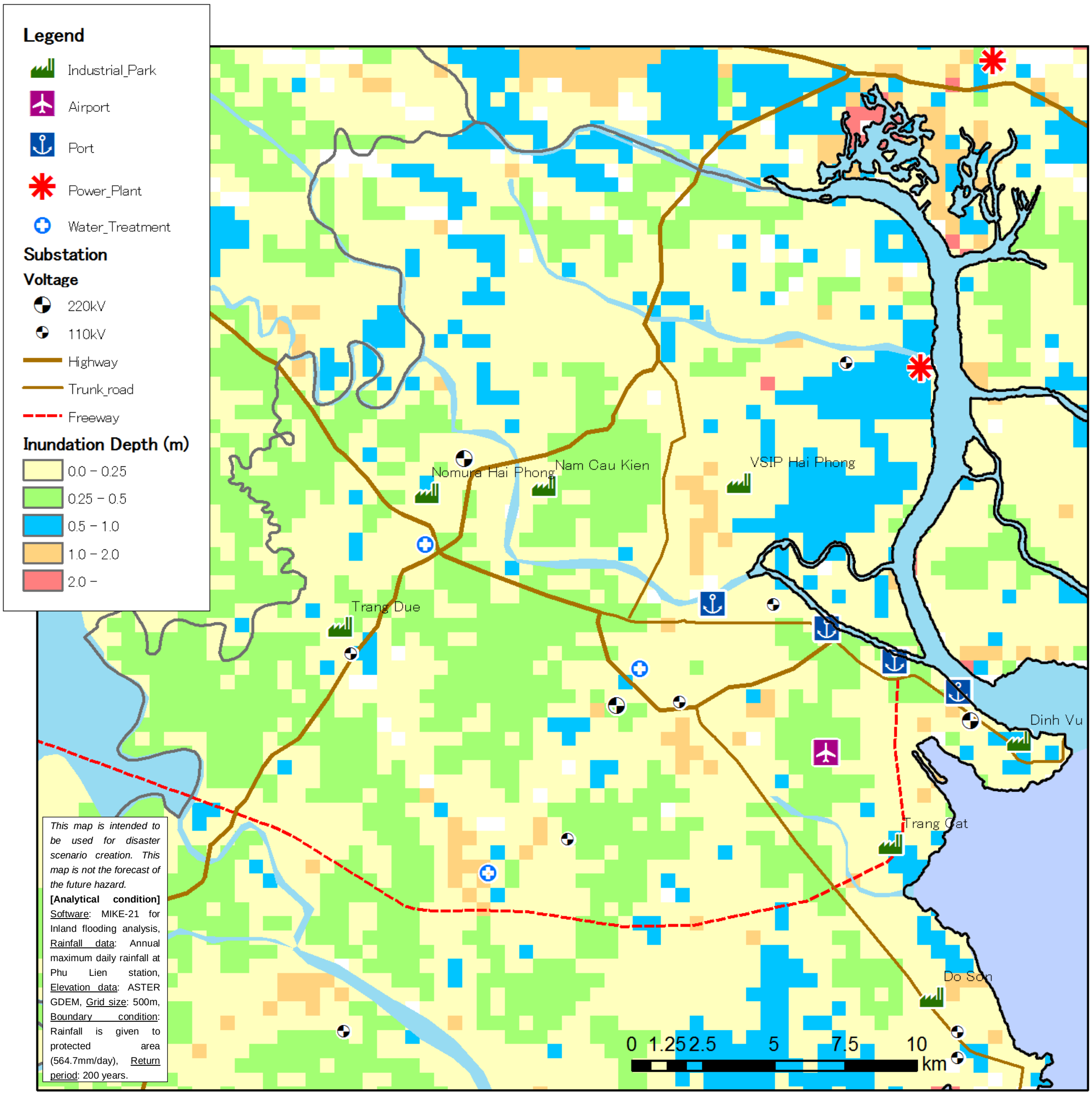


Figure 1.2.4 Maximum inundation depth expected with a 200-year probability and the distribution of important facilities

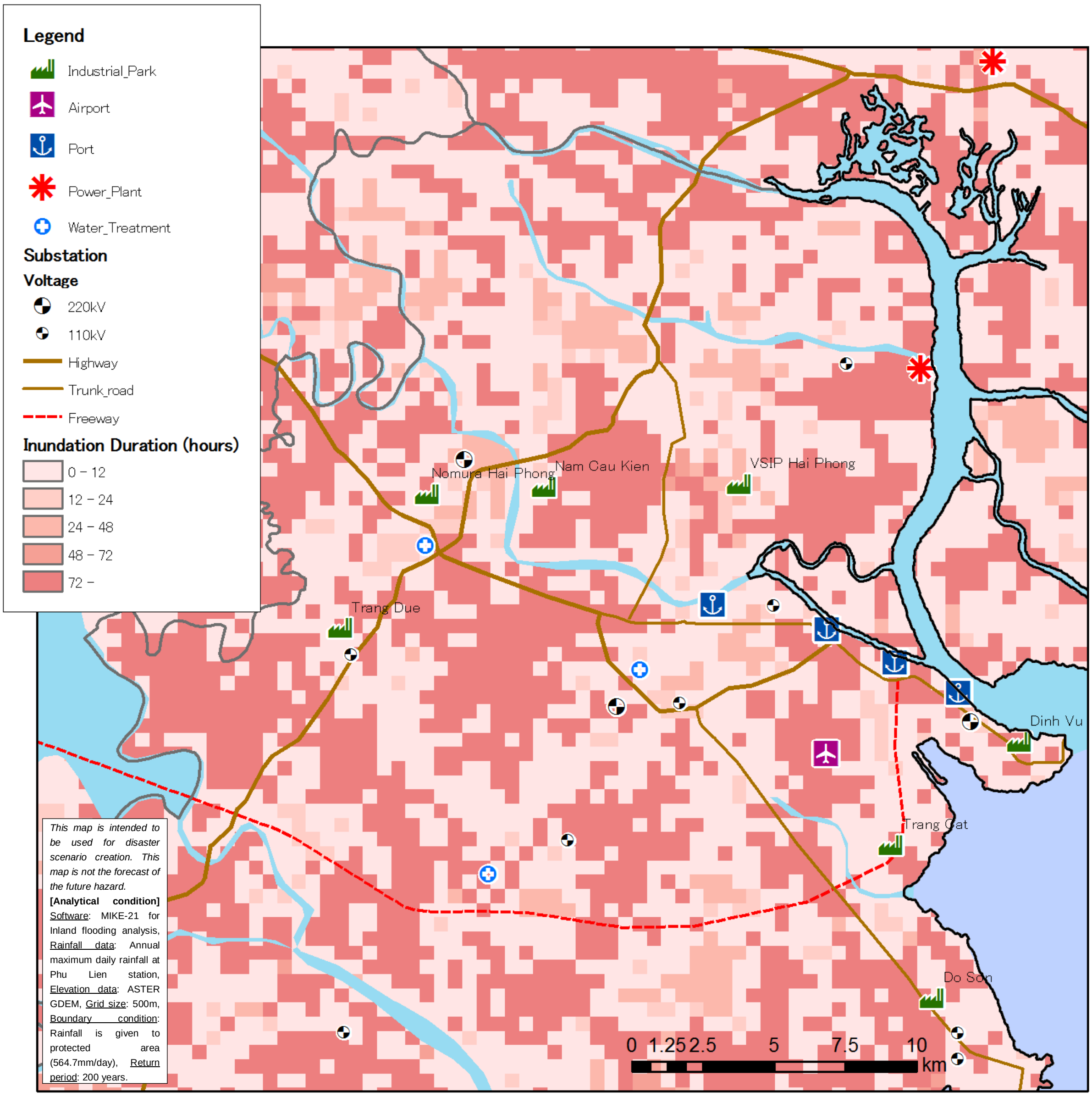


Figure 1.2.5 Maximum inundation duration expected with a 200-year probability and the distribution of important facilities

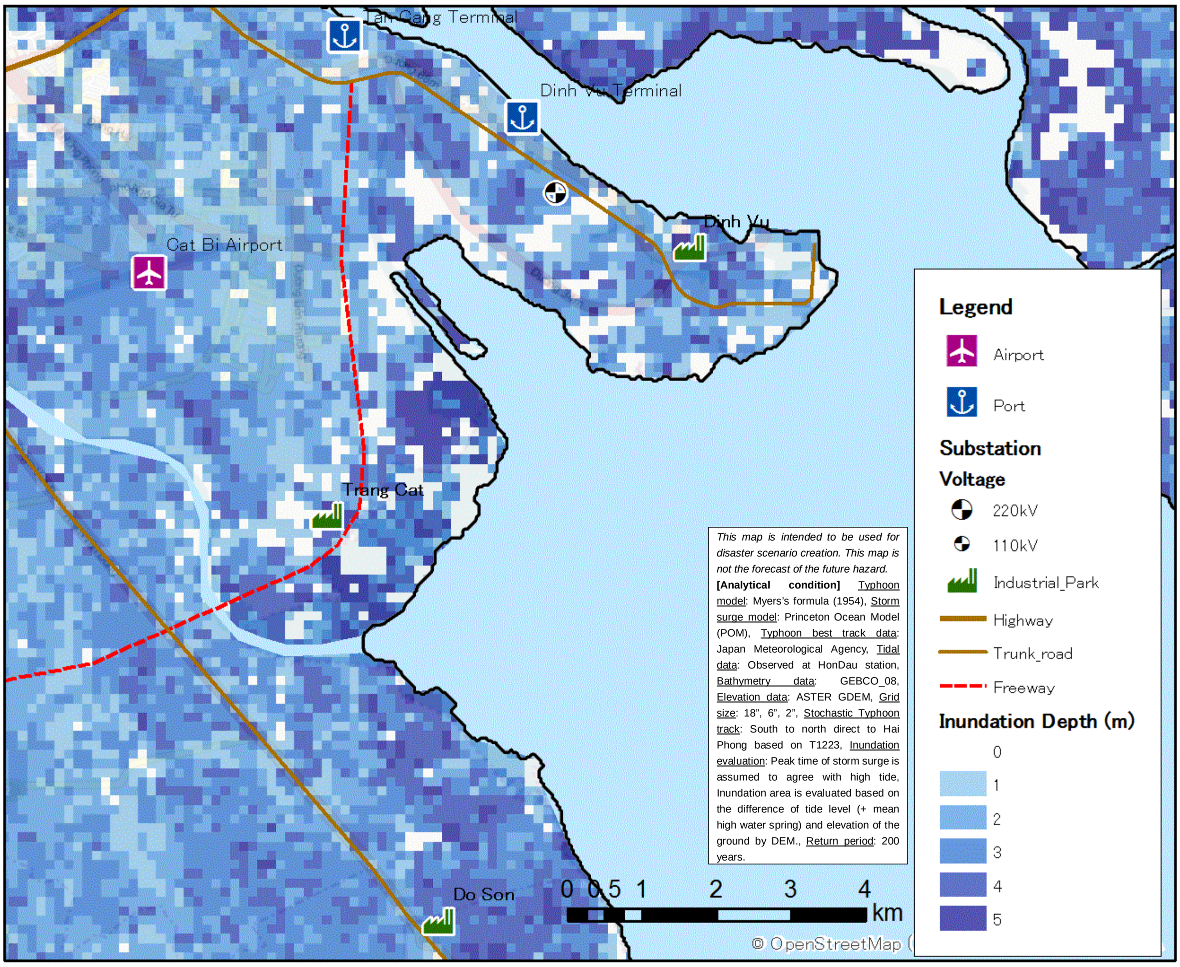


Figure 1.2.6 Inundation depth by storm surge due to typhoons expected with a 200-year probability and the distribution of important facilities

1.3 Disaster Risk by Storm Surge and Flood

The disaster risk for storm surges and floods due to typhoons, which has been identified as the predominant hazard for business interruption with a 200-year probability, was assessed and is shown in Table 1.3.1.

Table 1.3.1 Disaster Risk for Storm Surges and Floods

Buildings in Industrial Parks	● Buildings of factories in industrial parks along the coast suffer inundation due to storm surges.
Lifeline Facilities	● Hai Phong Power Plant will be inundated at a depth of 0.5 m to 1 m. Transmission of electricity to Hai Phong is limited. ● 220kV substation in Dinh Vu will be severely damaged by seawater. ● 110kV substation near the coast will be damaged by seawater. ● Electric power supply to the Hai Phong area will be limited. ● Some telephone/mobile phone base stations will cease operations because of the shortage of electric power.

Traffic Infrastructures	● Highway No. 5 will be closed for several days. ● Some of the roads in the city will be closed for several days. ● Dinh Vu Port will be affected by storm surges. Cargo handling equipment will be damaged by seawater. ● Container yard in Dinh Vu area will cease operations. ● Other ports will be crowded due to the transfer from Hai Phong Port and loading times will become longer.
Industrial Park Workers	● Some employees will be absent from work because of the inundation of their homes. ● Traffic conditions will become worse and many workers will be late for their shifts.

1.4 Hazard and Risk Information Sources

■ **Earthquakes, Tsunamis, Volcanoes**

[IGP-VAST] Institute of Geophysics, Vietnam Academy of Science and Technology
http://www.igp-vast.vn/
[VAST] Vietnam Academy of Science and Technology
http://www.vast.ac.vn/

■ **Meteorological Hazards, Flood**

[MARD] Ministry of Agriculture and Rural Development
http://www.agroviet.gov.vn/en/Pages/default.aspx
[CCFSC] Central Committee for Flood and Storm Control
http://www.ccfsc.gov.vn/KW367A21/Trang-chu.aspx
[CFSC] Committee for Flood and Storm Control
http://www.ccfsc.gov.vn/KW367A21/Trang-chu.aspx
[NHMS] National Hydro-Meteorological Services of Vietnam
http://www.nchmf.gov.vn/web/en-US/43/Default.aspx/
[VAST] Vietnam Academy of Science and Technology
http://www.vast.ac.vn/
[HUST] Hanoi University of Science and Technology
http://en.hust.edu.vn/home;jsessionid=3B761135553EC65597E3EA1F1D2C6F2C
Ho Chi Minh City - University of Technology
http://www.hcmut.edu.vn/en
[NCHMF] National Center for Hydro-meteorological Forecasting
http://www.nchmf.gov.vn/web/en-US/43/Default.aspx

Chapter 2 Natural Hazards in the Pilot Area

2.1 Floods

(1) Hai Phong City is located at the north-east end of the coastal area of the Red River and Thai Binh River Delta. It is a flat, low-lying area. The area is affected by three (3) to five (5) tropical storms and typhoons per year and has been impacted by serious damage and losses in terms of people and properties. Currently, the river overflow risk is low, but inundation risk caused by storm waters and storm surges is high. There are habitual inundation areas in the urban area and the maximum daily rainfall was 490 mm (22/09/1927) with maximum three-day rainfalls at 800 mm (6-8/08/1995). Hai Phong City is vulnerable to drainage problems. As for the industrial estates, the inundation risks are low, but their surrounding areas are vulnerable to drainage problems. Therefore the estates will incur indirect damage from these drainage problems.

(2) The disaster risk reduction and management organizations are the Ministry of Agriculture and Rural Development (MARD) and the Department of Dike Management and Flood Control (DDMFC) of MARD, who have developed a Master Plan for the Red River Basin. The current M/P was formulated in 2007 and is now under review. In March 2012, a new M/P was formulated and has been under review by the provincial governments. The flood control standards are: (1) for the 2007-2010 stage, the plan is to ensure control of 250-year probable flood and flood discharge at Son Tay of 42,600 m^3/sec, and (2) for the 2010-2015 stage, the plan is to ensure control of 500-year probable flood and flood discharge at Son Tay of 48,500 m^3/s.

For Hai Phong ,the Provincial People's Committee is responsible for the disaster risk reduction and management plan and the DDMFC is responsible for implementation of the dyke system and maintenance of safety levels.

(3) The basic policy for flood control of the Red River Basin is composed of (1) Control through dams: Hoa Binh, Tuyen Quang, Thac Ba and Son La Dams in the upper basin, and (2) Control through the dyke system in the Red River Delta area, and (3) Control of excessive flooding by diversion to floodways (the Day river and Luong Phu), retention areas, and spillways.

The dyke system for the Red River Delta was planned based on the historical flood of August 1971 (100-year or 125-year probable flood). Flood water levels are set as 13.4 m at Hanoi and 4.34 m at Hai Phong. At Hanoi, the Red River must have a flood discharge capacity of larger than 20,000 m^3/s at Long Bien Station.

(4) The Hai Phong Sewerage Co. is responsible for drainage improvement measures in Hai Phong City. They have improved the drainage system and installed 11 tidal gates. The city has requested that Kita Kyushu City provide technical assistance for the formulation of a drainage and sewerage improvement plan for Hai Phong City, and also in the preparation of an inundation map.

However, Kita Kyushu City still has no implementation schedule for the request. The formulation and implemention of improvement plans for storm water drainage facilities is an urgent task for Hai Phong City.

2.2 Typhoons/ Meteorological Hazard

Vietnam is subject to the Southeast Asian Monsoon. Hai Phong is affected by three (3) to five (5) storms or tropical low pressure systems per year on average, and one or two of which hit this area. In particular, Hai Phong was severly affected by three (3) typhoons (No.2, No.6 and No.7) in 2005.

2.3 Storm Surges

The average height of the tides is about 3 m - 4 m while the maximum height is 4 m - 4.5 m in spring water periods. Of the storms that hit the region, 17.8-50% caused storm surges of over 1.5 m, and 33% caused surges of over 2 m. Maximum surges are often delayed about 1 hour after the storms land. Surge duration is about 12 - 30 hours on average. Maximum surges often continue for 2 - 3 hours. There are six types of storm surge protection dykes and the crest level of the storm surge protection dykes are set at 5.1 m - 5.8 m.

DDMFC is responsible for the implementation and maintenance of tide embankments for the protection of Hai Phong from storm surges. Hai Phong Sewerage Co. is responsible for the construction and maintenance of 11 tidal gates as a part of urban drainage measures.

There are 18 marine stations along the coast, of which 5 are located at Hai Phong area as part of the observation network for tide levels. There is no automatic observation station, and they are all manually operated. The density of present observation stations is still low, and observation tools have deteriorated due to age, as they have been used since the era of the former Soviet Union. It is necessary to improve the observation system including the observation network, tools, and human resources in order to upgrade their work. NCHMF (National Center for Hydro-Meteorological Forecasting) prepared an improvement plan, which was approved by the government in 2007. However, the plan has not yet been implemented because of budget constraints.

NCHMF conducts storm surge analysis and reports to 1) the National Center for Hydro Meteorological Forecasting of the Ministry of Natural Resources and Environment, 2) the Local Council, and 3) the local press, as well as to important registered organizations.

2.4 Earthquakes

There is no record of earthquakes with casualties in or around Hai Phong in the disaster database. The existence of active faults is estimated, but there is no record of activity. Therefore, seismic activity is not clear.

IGV-VAST has performed statistical seismic analyses based on the estimated active faults and seismic activity in the northwest area of Vietnam near the border with China and Lao PDR. It estimates 40 to 50 gal as the expected PGA in a 500-year return period on bedrock areas of Hai Phong. However, according to geological maps created by governmental organizations, the pilot area is covered by soft sediment from the Quaternary period, and some amplification of seismic motion is expected.

PGA on the ground surface, considering surface ground amplification, has been estimated as 55 - 170 gal (MMI 6 - 7) in a 500-year return period in an analysis conducted by the Study Team. However, when a 100-year return period is adopted for BCP, PGA on the ground surface is estimated as 25 - 80 gal (MMI 5 - 6).

2.5 Tsunamis

There is no record of tsunamis with casualites in or around Hai Phong in the disaster database. There is some concern about the impact of tsunamis caused by earthquakes occuring along the Manila Trench.

IGP-VAST conducted a tsunami simulation assuming the occurrence of 9.3M earthquake after the 2011.3.11 Tohoku Earthquake in Japan. The results show that a 3 m tsunami may strike the coast of Hai Phong 8 hours after the earthquake. However, there is no record of a tsunami-generating earthquake along the Manila Trench causing damage in the Philippines. The occurrence probability of a 9M earthquake is low, according to a statistical analysis using small and medium sized earthquakes.

2.6 Volcanoes

There are no volcanoes around the pilot area and no damage or loss by volcanic eruption has been recorded in the disaster database.

Chapter 3 Outline of Natural Hazard Assessments

3.1 Seismic Hazard Assessment

The basic procedure of earthquake hazard assessment is shown in Figure 3.1.1. The details of each item are stated below.

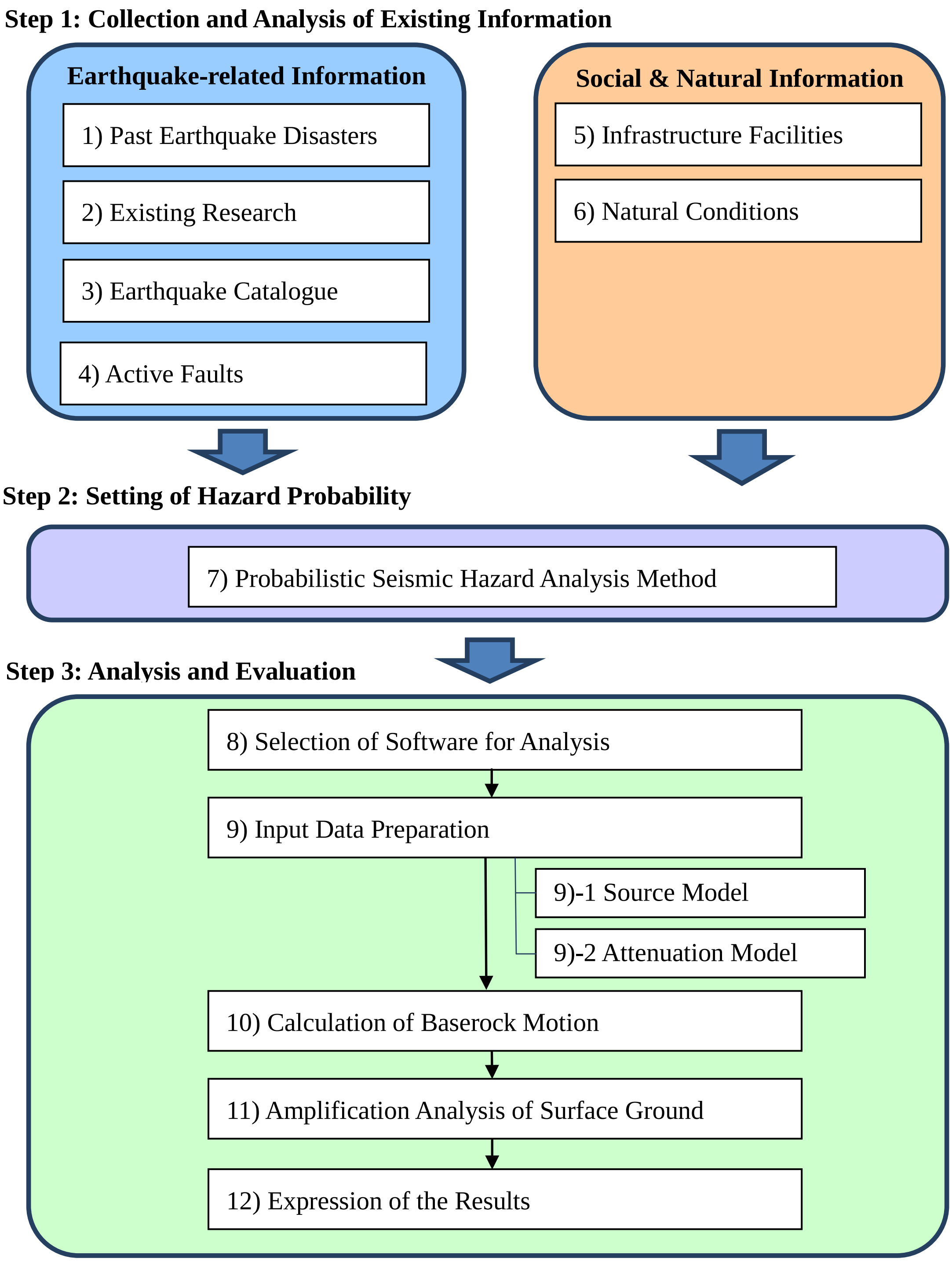


Figure 3.1.1 Basic Procedure of Earthquake Hazard Assessment

Step 1: Collection and Analysis of Existing Information

Earthquake-related Information

1) Past earthquake disaster records

Seismic intensity distribution data and disaster records of past earthquakes in the study area are collected. The frequency and the extent of earthquake disasters can be understood by analyzing the year of occurrence, earthquake magnitude, seismic intensity distribution and damage distribution.

2) Existing research and study

Existing research and study results of earthquake hazards in the area are collected. The information collected focuses on historical earthquake research, seismic hazard maps and studies on ground amplification of earthquake motion.

3) Earthquake catalogue

The earthquake catalogue is a list of past earthquakes including origin, depth, year/month/day/time of occurrence, seismic magnitude and so on. As the earthquake catalogue is a base for earthquake hazard analysis, a catalogue that covers a longer period is preferable. The catalogue should include the earthquakes that occurred within a 100 km range of the study area.

4) Active faults

An active fault is a fault which may generate earthquakes in the future. Data on active faults such as location, length and activity are necessary for earthquake hazard assessment.

Social and Natural Information

5) Infrastructure facilities

The distribution of infrastructure facilities on which industrial agglomerated areas are dependent is studied. Transportation facilities and lifeline facilities are the main target for study. The actual region where earthquake hazard is to be assessed is decided based on the distribution of infrastructure facilities. As infrastructure facilities are widely spread outside of industrial agglomerated areas, the region of hazard analysis is not limited to industrial agglomerated areas.

6) Natural conditions

Topography maps or DEM are collected as the basic information of the study area. Geological, geomorphological and land use maps are also collected to assess the amplification of earthquake motion caused by subsurface ground.

Step 2: Setting of Hazard Probability

7) Methodology of probabilistic seismic hazard analysis

Probabilistic methodology is used in the seismic hazard assessment because the probability of hazards is important for the Area BCP. Using the probabilistic method, the expected earthquake ground motion within a certain period at the study point is calculated, considering all the earthquake sources around the study point to reflect the possibilities of each source. Any hazard that has a high possibility of occurring during the lifetime of the industrial facilities is taken into account for the Area BCP. Therefore, estimating the probability of hazards is an essential component of the analysis.

Step 3: Analysis and Evaluation

8) Selection of software for analysis

As the probabilistic seismic hazard analysis involves complicated numerical calculations, many computing programs have been developed for this purpose and some of them are freely available. However, they are intended to be used by researchers or engineers with expert knowledge. EZ-FRISK is commercial software offered by Risk Engineering Inc. Analysis using EZ-FRISK is comparatively easy because the earthquake source model and attenuation formula are provided with the program.

9) Input data preparation

9)-1 Source model

The earthquake source model should include all the active faults within several 100 km of the study point. The earthquakes for which sources are unknown and for which it is difficult to make a definite estimation of the magnitude/location of future events are modeled as background seismic activities.

9)-2 Attenuation formula

The empirical attenuation formula is used to calculate earthquake ground motion based on the magnitude of the earthquake and the distance between epicenter and the study point. It is desirable to use an attenuation formula that was created for use on the study site. It is generally more desirable to use a new proposed attenuation formula because this newer formula is derived from precise, recent earthquake observation records.

10) Calculation of baserock motion

The earthquake ground motion calculated with a probabilistic method is expressed as follows.

a) The probability that the study site experiences a certain earthquake ground motion.

e.g. The probability of experiencing 100 gal or more is 10% in 50 years.

b) The earthquake ground motion value for a certain probability.

e.g. 100 gal or more will be experienced with a probability of 10% in 50 years.

11) Amplification analysis of surface ground

Seismic waves are amplified by the surface ground. There are several methodologies to evaluate the amplification characteristics of surface ground; for example, evaluation can be based on the surface soil, the average S wave velocity of surface soil layers, and numerical response analysis using the ground structure model. The most suitable method is selected by considering the available data, necessary work and budget.

12) Expression of the results

Calculated values for ground movement are physical quantities, such as peak ground acceleration or velocity. Seismic intensity is another way to express the strength of the ground vibration caused by earthquakes and is a more popularly understandable way of expressing values. Seismic intensity is also used to estimate damage based on past earthquake disasters. Though the relationship between PGA or PGV and seismic intensity is not a one-to-one ratio, empirical formulas are used to convert the former to the latter.

3.2 Tsunami Hazard Assessment

The basic procedure of hazard assessment for tsunamis generated by earthquakes is shown in Figure 3.2.1. The details of each item are stated below.

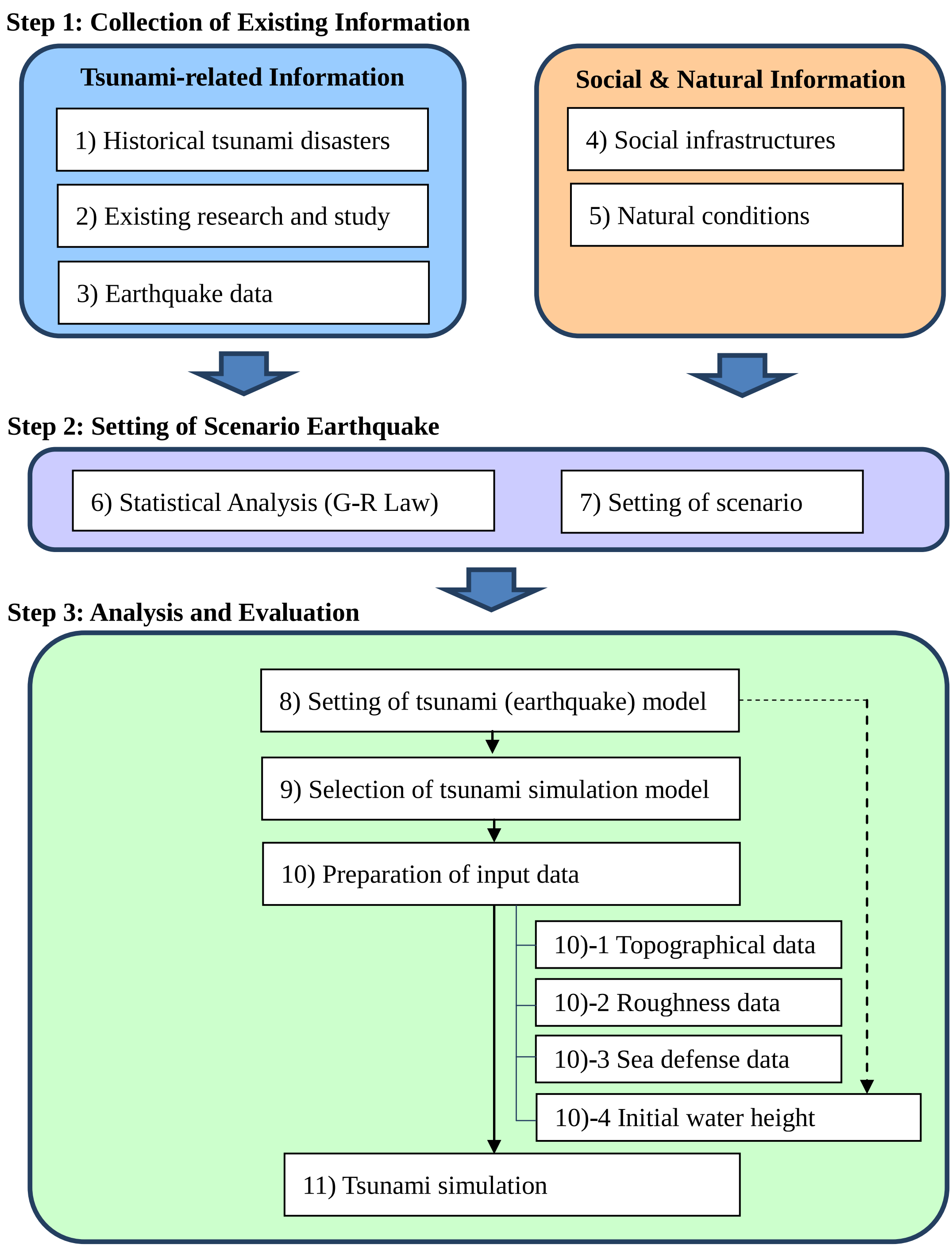


Figure 3.2.1 Basic Procedure of Tsunami Hazard Assessment

Step 1: Collection of Existing Information

Tsunami-related Information

1) Records of historical tsunami disasters

Inundation data and disaster records of past tsunamis in the study area are collected. The frequency and the extent of tsunami disaster can be understood by analyzing the year of occurrence, tsunami wave height, inundation and damage distribution.

2) Existing research and study

Existing research and study results of tsunami hazards in the area are collected. The information collected focuses on historical tsunami research and tsunami hazard maps.

3) Earthquake data (earthquake catalogue)

Data on earthquakes that have caused tsunamis is collected. The earthquake catalogue is the list of past earthquakes including the origin, depth, year/month/day/time of occurrence, seismic magnitude and so on. Earthquakes which generated tsunami are selected.

Social and Natural Information

4) Social infrastructures

Information on industrial agglomerated areas and social infrastructure that would be potentially affected by tsunami will be collected. Social infrastructures are categorized into transportation infrastructures and lifelines. The actual region where tsunami hazard is to be assessed is decided based on the distribution of infrastructure facilities. As infrastructure facilities are widely spread outside of industrial agglomerated areas, the region of hazard analysis is not limited to industrial agglomerated areas.

5) Natural conditions

Topography maps, bathymetry maps or DEM are collected as the basic information of the study area. Land use maps and geological maps are also useful for more precise analysis.

Step 2: Setting of Scenario Earthquake

A scale of tsunami disaster for risk assessment is decided based on the collected data. The scale of tsunamis is defined as the scale of the earthquake which generates the tsunami.

6) Statistical analysis of earthquake (Gutenberg-Richter Law)

The recurrence interval of scenario earthquakes that generate tsunami is decided based on the earthquake catalogue around the source area of scenario earthquakes. The relationship of earthquake magnitude and the frequency of earthquake occurrence, which is known as the Gutenberg-Richter Law is used. The annual probability or recurrence interval of the scenario earthquake of arbitrary magnitude can be estimated.

7) Setting of scenario earthquake

A scenario earthquake and its magnitude should be set for the Area BCP. If a larger magnitude is assumed, the components of the Area BCP increase and the process to formulate it becomes more complicated. However, business continuity after a disaster will be more stable. Conversely, if a smaller magnitude is assumed, the Area BCP can be more easily formulated. However if the disaster is larger than the estimated scenario, business continuity may become difficult. Therefore, it is desirable to decide the magnitude of the scenario earthquake by holding discussions with stakeholders, including citizens, on local disaster management planning, governmental policy and feasibility of the plan.

Step 3: Analysis and Evaluation

8) Setting of tsunami (earthquake) model

The fault parameters of the scenario earthquake such as location, size, slip, etc. are decided for numerical simulation.

9) Selection of tsunami simulation model

Tsunami propagation simulations require complicated numerical calculations. There are several theories to describe tsunami propagation, depending on the relationship between wavelength and depth of water or distance to the tsunami source area. Several computing programs have been developed in for these theories; however, most of them are intended to be used by researchers or engineers with expert knowledge.

10) Preparation of input data

The general input data for tsunami simulation is as follows. This data is given to each grid, which is explained below.

10)-1 Topographical data

For the simulation, it is necessary to create a topographical model for the area that includes the source area of the scenario earthquake, the objective area, and the route of tsunami propagation. The topographical model includes the topography of the sea floor, the topography of the land surface where tsunami might run up, and the sea defense structures.

The simulation area is divided and covered by a square grid, and altitude and roughness data are allotted to each grid. The size of grid is appropriate defined, taking into account the complexity of the topography and the wave length of the tsunami. The grid size is usually defined from larger to smaller according to the distance from coast, considering that the topography becomes more complex and shorter wave components become dominant near the coast. This methodology is called "nesting." The grid size is defined as, for instance, 1350 m → 450 m → 150 m → 50 m from the tsunami source region to the coast.

10)-2 Roughness data

The effect of friction for tsunami wave propagation is expressed by Manning's roughness coefficient (n). The roughness coefficient usually adopted for marine areas is n=0.025.

10)-3 Sea defense data

Embankments and other sea defense structures are modeled as height data in the grid.

10)-4 Initial water height data (= deformation of sea floor)

Changes of water heights caused by fault movement are given as initial conditions for tsunami simulations. Changes of water height are assumed to be same as the vertical components of sea floor deformation.

11) Tsunami simulation

The general output of the tsunami simulation is as follows. Output items are obtained for each grid.

1. Maximum water height or maximum inundation height
2. Maximum velocity
3. Elapsed time of maximum water height
4. Elapsed time of given water height (x cm, for instance)

3.3 Flood Hazard Assessment

The basic procedure of Flood Hazard Assessment is shown in Figure 3.3.1. The detailed procedure is described below.

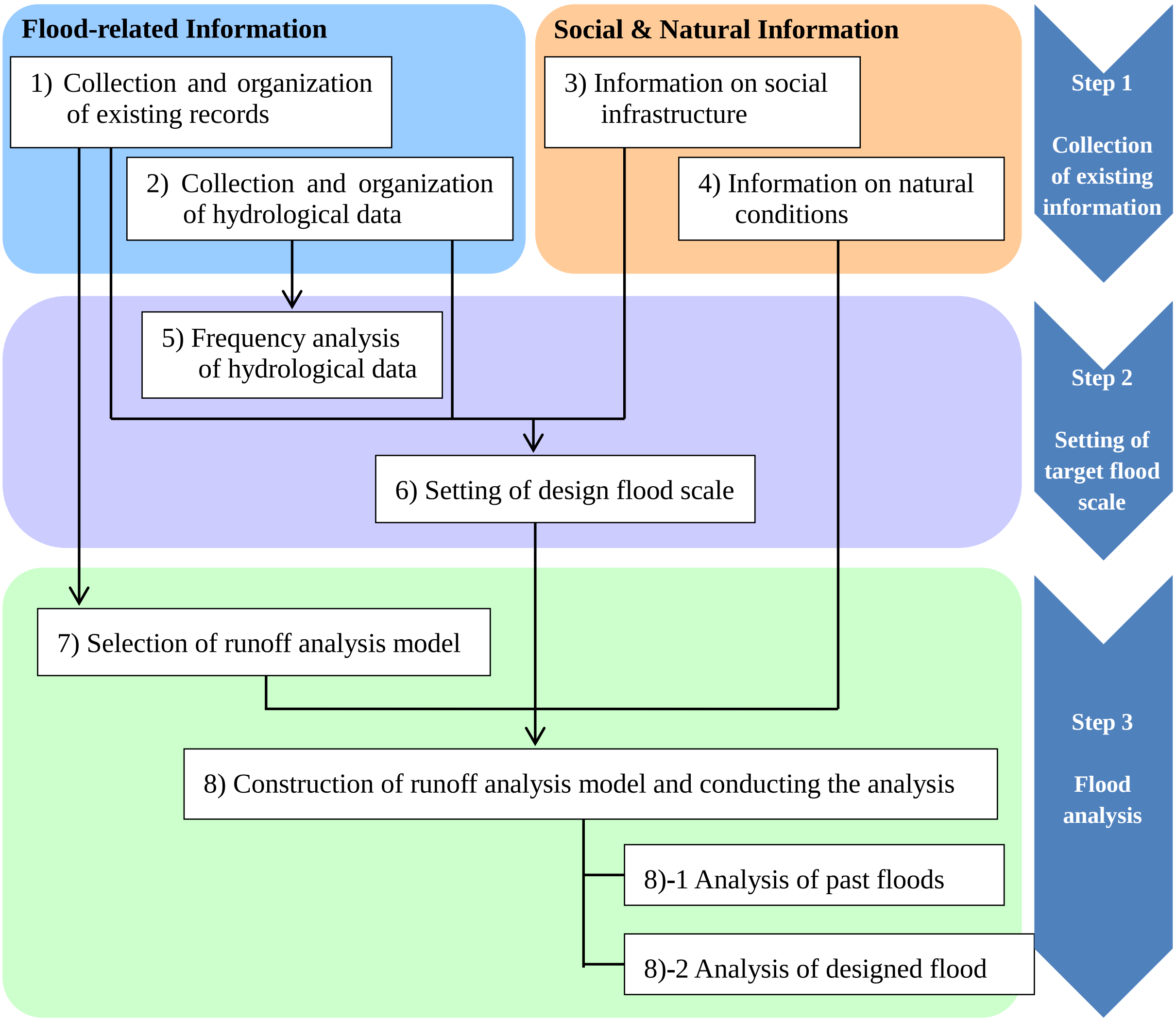


Figure 3.3.1 Basic Procedure of Flood Hazard Assessment

Step 1: Collection of existing information

Flood-related Information

1) Collection and organization of existing flood record

Flood-related information in the target area for flood risk evaluation is collected. Collecting data such as rainfall during floods, water level, and river discharge makes it possible to grasp the characteristics of floods. Inundation areas, duration time, water depth, and the cause of the flood as indicated in damage reports or photographs are also helpful in understanding the phenomena of inundation. If a flood hazard map is available in the target area, the information (inundation area, duration time and depth) shown in the map will be utilized.

2) Collection and organization of hydrological data

Existing hydrological data in target area is collected. Data on rainfall (hourly data or daily data), river water level, river discharge and tidal level should be collected. If there are river facilities such as dams or gates, it is advisable to collect the operational reports of these facilities during floods. Before organizing this data, confirm if there is incorrect or missing data.

Based on the collected hydrological data, flood duration, probability of flood occurrence, and situation when the largest recorded flood occurred will be analyzed. Cross-cutting profile data is also helpful in this step of model construction.

Information on Social Infrastructure and Natural Conditions

3) Collection and organization of information on social infrastructure

Information on industrial estates and social infrastructure that would be affected by flooding is collected. Social infrastructure can be divided into two categories: the transportation infrastructure related to transport to and from industrial estates and the lifeline infrastructures necessary to maintain business operations.

The actual region where flood hazard is to be assessed is decided based on the distribution of infrastructure facilities. As infrastructure facilities are widely spread outside of industrial agglomerated areas, the region of hazard analysis is not limited to industrial agglomerated areas.

4) Collection and organization of information on natural conditions

Topographic maps are collected, and data relating to natural conditions such as altitude, land use pattern and geology is organized. From the aspect of data accuracy, it is advisable to use a detailed map with a scale of 1/5,000 or more.

Step 2: Setting of target flood scale

Based on the data collected in Step 1, the target flood scale for formulating the Area BCP is set. The basic flood scale set as the largest recorded flood, 50-year return period, 100-year return period and 200-year return period.

5) Frequency analysis on hydrological data

Probable hydrological value is calculated using collected hydrological data. The procedure for processing statistics will involve applying probability density functions such as exponential distribution, evaluating the probability density function, and then determining the appropriate probability density function. For reliable probability density function results, samples for at least 50 years are needed.

6) Setting of design flood scale

The design flood scale for formulating the Area BCP is set. If the designed flood is large in scale, there are more components for formulating the Area BCP. In this case, a considerable amount of work is necessary to formulate the Area BCP, but level of safety in the plan is high. Conversely, if the designed flood scale is small, the target scope of the Area BCP becomes limited, which makes it easier to formulate the Area BCP. In this case, there is a possibility the Area BCP will not be effective. Hence, design flood scale should be set in accordance with regional city plans, administrative strategy, and feasibility of plan, and upon discussions with stakeholders, including local residents.

Step 3: Runoff analysis/evaluation

7) Selection of runoff analysis model

The appropriate model for analyzing the characteristics of floods in target area is selected. The appropriate analysis model should be selected from the viewpoint of runoff characteristics, required resolution, and financial capacity for purchasing software. At first, it is preferable to use free software like IFAS for formulating the Area BCP.

8) Construction of flood analysis model and conducting the analysis

8)-1 Analysis of past floods

Flood analysis with the selected model and past rainfall data is conducted. After that, simulation accuracy is confirmed by comparing the results of the simulation with actual discharge records. If the precision of the simulation is not satisfactory, attempts to improve the accuracy will be made by modifying parameters.

8)-2 Analysis of designed scale flood

Runoff analysis on the designed flood is conducted.

3.4 Storm Surge Assessment

Figure 3.4.1 shows the basic procedure of the methodology for the hazard assessment of storm surges. The details of each step are indicated below.

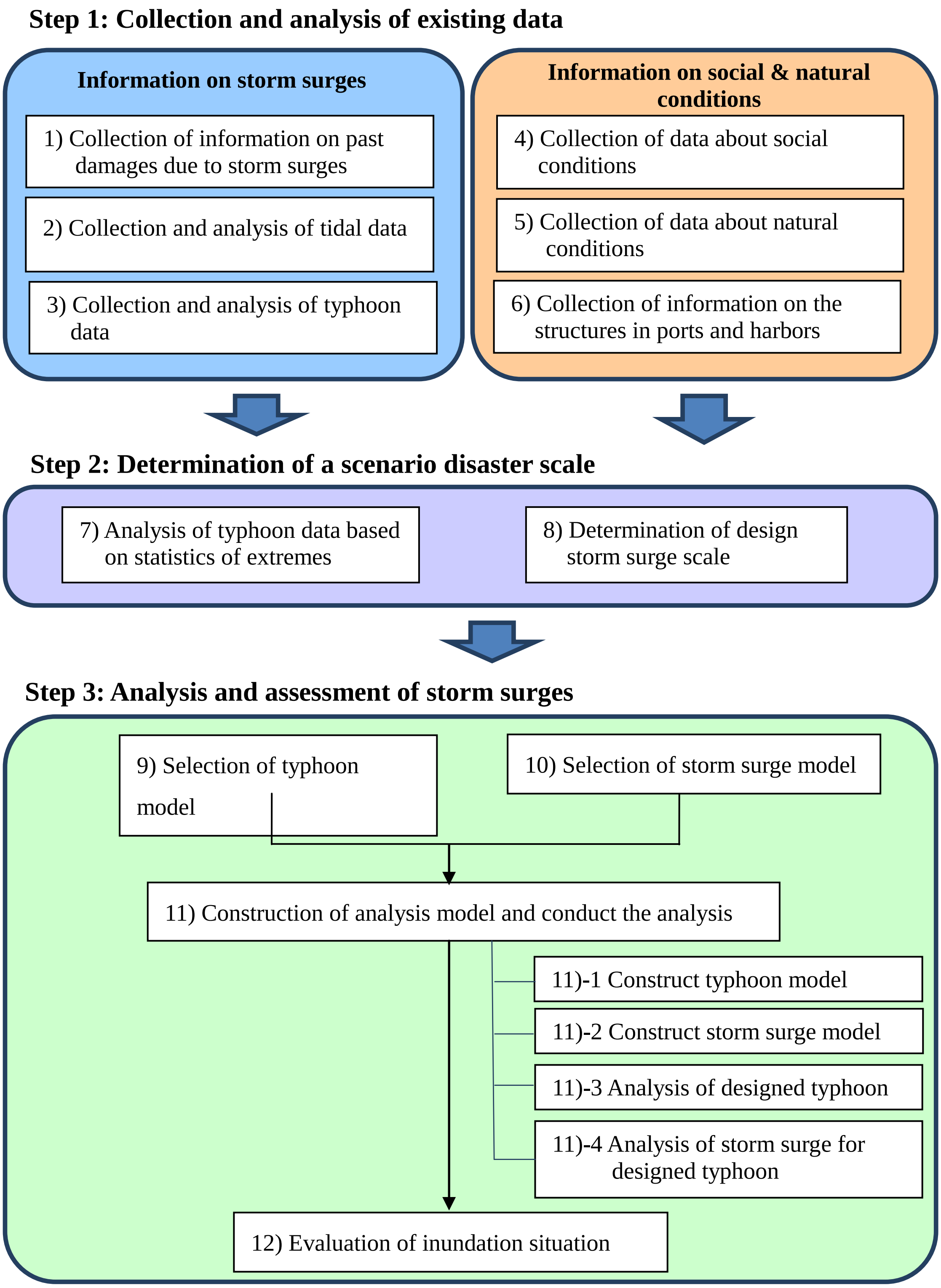


Figure 3.4.1 Basic Procedure of Storm Surge Hazard Assessment

Step 1: Collection and analysis of existing data

Information on Storm Surges

1) Collection of information on past damages due to storm surges

Records of past storm surges in the study area are collected. The necessary information includes: time and tidal data when large storm surges occurred, damage records and pictures, and inundation area and its depth. Characteristics of storm surges in the study area are comprehended by organizing and analyzing this data.

2) Collection and analysis of observed tidal data

Continuous tidal data for the study area is collected. This data is used to estimate the astronomical tides in the study area. The level of storm surges is assessed by adding sea level variations caused by typhoons to the astronomical tide level.

3) Collection and analysis of typhoon data

Records of typhoons in the study area are collected. The necessary data includes: atmospheric pressure, wind direction and speed, center position and time, and radius of maximum wind. The characteristics of typhoons in the study area are comprehended by organizing and analyzing this data.

Information on Social and Natural Conditions

4) Collection of data on social conditions

Information on industrial agglomerations and social infrastructure in the study area which would be affected by storm surges are collected and organized. Social infrastructures can be divided into two categories: transportation infrastructures and lifelines. The actual region where storm surge hazard is to be assessed is decided based on the distribution of infrastructure facilities. As infrastructure facilities are widely spread outside of industrial agglomerated areas, the region of hazard analysis is not limited to industrial agglomerated areas.

5) Collection of data on natural conditions

Topography maps, bathymetry maps or DEM are collected as the basic information of the study area. Land use maps and geological maps are also useful for more precise analysis. It is desirable to use data with the equivalent of 1 km or lower resolution to secure accuracy.

6) Collection of information on the structures in ports and harbors

Information on the artificial structures such as breakwaters and seawalls are not included in the elevation data. As these structures are important factors in assessing storm surges, the location and the function of the structures are collected.

Step 2: Determination of a scenario disaster scale

7) Analysis of typhoon data based on statistics of extreme

The relationship of typhoon scale in the study area and the return period is calculated using the analysis of statistics on extremes. It is desirable to collect the annual maximum values at least for 50 years to perform a reliable analysis.

8) Determination of a design storm surge scale

The design storm surge scale for formulating the Area BCP is set. If the designed scale is large, there are more components for formulating the Area BCP. In this case, a considerable amount of work is necessary to formulate the Area BCP, but the level of safety in the plan is high. Conversely, if the designed storm surge scale is small, the target scope of the Area BCP becomes limited, which makes it easier to formulate the Area BCP. In this case, there is a possibility the Area BCP will not be effective. Hence, the design hazard scale should be set in accordance with regional city plans, administrative strategy, and feasibility of plan, and upon discussions with stakeholders, including local residents.

Step 3: Analysis and assessment of storm surges

9) Selection of typhoon model

The appropriate typhoon model to create the fields of surface wind and air pressure caused by typhoon is selected. To simulate a storm surge by a stochastic typhoon, the typhoon model will reproduce the fields of surface wind and atmospheric pressure, which are the external forces in the storm surge simulation. The two-dimensional typhoon model based on the Myers' formula is normally used.

10) Selection of storm surge model

The appropriate storm surge model to calculate sea level variations using surface wind and pressure estimated by the typhoon model is selected. The appropriate analysis model should be selected among several general storm surge models created by universities or NOAA from the viewpoint of the characteristics of the study area, the degree of required accuracy and the available computer resources.

11) Construction of analysis model and conduct the analysis

11)-1 Construction of typhoon model

A past typical typhoon is selected from collected typhoon data. The fields of surface wind and air pressure are calculated using the selected typhoon model. The reproducibility of the typhoon is confirmed by comparing the analyzed and the observed wind and air pressure. If reproducibility is insufficient, the parameters of the model are modified.

11)-2 Construction of storm surge model

The tide level for the selected typhoon is calculated using the selected storm surge model and the calculated surface wind and air pressure distribution. The reproducibility of the tide level is confirmed by comparing the analyzed and the observed tide level. If reproducibility is insufficient, the parameters of the model are modified.

11)-3 Analysis of designed typhoon

The conditions of the designed typhoon are decided. As the storm surge is not only determined by the scale of typhoon, but is also strongly affected by its course and velocity, it is desirable to study several courses for the designed typhoon.

11)-4 Analysis of storm surge for designed typhoon

The tide level for the designed typhoon is studied based on the calculated wind and atmospheric pressure. The magnitude and range of hazard varies depending on the specified scale, radius, course and speed of typhoon. The course of the typhoon is selected, referring to the inundation area and depths caused by storm surges and the effect on important facilities.

12) Evaluation of the inundation situation

The inundation area and depths are calculated from the results of the storm surge analysis. The appropriate method for inundation evaluation is selected from static or dynamic procedures, considering the required accuracy, available computational resource, etc.

Chapter 4 Profile of the Pilot Area

4.1 Outline of the Pilot Area

In Vietnam, the city of Hai Phong was selected as a pilot area (Figure 4.1.1). The city of Hai Phong is located about 100 km east of the capital of Hanoi and is also known as one of the main port cities in Vietnam facing the West China Sea. As of 2011, the city population is 1,878,500 with an area of 1,523.4 km^2. The region belongs to the tropical monsoon climate, and has four seasons including the rainy season from June to September. The monthly average rainfall of Hai Phong is 299 mm and the peak rainfalls are observed in August. A description of the city is summarized in Table 4.1.1

Figure 4.1.1 Location Map of Pilot Area

Table 4.1.1 Description of Pilot Area (Hai Phong City, Vietnam)

Area[1]	City of Hai Phong: 1,523.4 km^2
Population[1]	City of Hai Phong: 1,878,500 persons
Natural Conditions[2]	It belongs to the tropical monsoon climate with two distinct seasons including the rainy season from May to October. Its average annual precipitation is 1,600 – 1,800 mm
Other Characteristics	Located in the Vietnam China Economic Cooperation Belt, Hai Phong City has an active relationship with China (particularly southern China).

[1] General Statistic Office of Vietnam: http://www.gso.gov.vn/default_en.aspx?tabid=467&idmid=3&ItemID=12941
[2] Vietnam Trade Promotion Agency: http://www.vietrade.gov.vn/en/

There are seven industrial parks (including those currently operating and those under construction and/or planning) in Hai Phong, where many Japanese companies have established businesses. Among the industrial parks in operation, the Nomura Hai Phong Industrial Zone has a particularly high occupancy rate of Japanese companies, with 46 out of 54 tenants being Japanese companies that manufacture machinery, auto parts and electronic parts.

4.2 Outline of the Local Authorities

Administrative divisions in Vietnam are divided into three levels: provinces, districts, and rural commune. The Hai Phong is a municipality which is under the direct jurisdiction of the national government, without belonging to a province. The organizational structure of Hai Phong is shown in Figure 4.2.1.

Disaster Prevention System: Storms and Floods

In Vietnam, the Disaster Management Center (DMC) is responsible for the establishment and management of disaster prevention systems (for storms and flood) such as the Disaster Monitoring System and Early Warning System. In order for DMC to release timely warnings, the National Hydro-Meteorological Service (NHMS) monitors the hydrometeorological data. This data is also disseminated to the public through the mass media (television and radio) and their websites[3].

In order to respond to the warnings announced by the national government, the local governments have formed Committees for Flood and Storm Control (CFF & SC), whose mandate is to provide prevention measures and issue evacuation advisories, disseminate flood/storm information, and conduct damage evaluations after natural disasters. The organizational structure of CFF & SC in Hai Phong is shown in Figure 4.2.2. Hai Phong CFF & SC members are required to take initiative in carrying out their assigned tasks, as stipulated in the Hai Phong People's Committee's Order Announcement No. 02/TB-PCLB&TKCN (See Table 4.2.1).

Based on information gathered from a national government report[4] and field interviews held with local residents regarding Typhoon Jebi (August 2013), it was concluded that the warnings issued by national and local governments reached local residents in a timely manner. In contrast, the foreign-affiliated companies located in industrial parks reported that they prepared for the typhoon based on the information provided by the embassy of their country and the industrial park management office, as the government's official warnings were not available in a timely manner. It is recommended that information dissemination methods are improved so that timely information will be available for all concerned stakeholders, including foreign-affiliated companies.

[3] JICA: Study on ASEAN Regional Cooperation for Disaster Reduction, Final Report, Country Report of Vietnam, December 2012.
[4] Hai Phong CFF & SC Report: Prevention, control, and recovery work response to Tropical Storm Jebi, August 2013.

People's Committee of Hai Phong

DEPARTMENTS, DIVISIONS AND UNITS:

1. Hai Phong Committee Office
2. Provincial Inspection
3. Religion Committee
4. Financial Dept.
5. Transportation Dept.
6. Natural Resource & Environmental Dept.
7. Science & Technology Dept.
8. Land Acquisition Committee
9. Ethnic Minority Committee
10. Education & Training dept.
11. Labor, Ward Invalid & Social Welfare Dept.
12. Population, Family and Children Committee
13. Interior Affairs Dept.
14. Justice Dept.
15. Planning & Investment Dept.
16. Industry & Trade Dept.
17. Construction Dept.
18. Agriculture & Rural Development Dept.
19. Steering Committee for Flood, Storm Control
20. Industrial Zone Management Agent
21. Culture, Sport and Tourism Dept.
22. Medical Dept.
23. Exterior Dept.
24. Forest Inspection
25. Information & Communication Dept.
26. Hai Phong Police (Hai Phong Public Security Dept.)
27. Hai Phong Firefighting Dept.
28. Television and Voice Agent
29. Hai Phong State Bank
30. Hai Phong Customer Dept.
31. Hai Phong Tax Dept.
32. Hai Phong Treasury
33. Hai Phong Statistic Dept.

DISTRICTS:

1. Duong Kinh District
2. Do Son District
3. Hai An District
4. Hong Bang District
5. Kien An District
6. Le Chan District
7. Ngo Quyen District
8. An Duong District
9. An Lao District
10. Bach Long Vi District
11. Cat Hai District
12. Kien Thuy District
13. Thuy Nguyen District
14. Tien Lang District
15. Vinh Bao District

Remarks:
Departments in red are members of the Steering Committee for Flood and Storm Control and Search Rescue of Hai Phong City.

Reference: JICA Study Team

Figure 4.2.1 Structure of Local Government

Members of the Steering Committee for Flood and Storm Control and Search & Rescue of Hai Phong City

Chief of the Committee:
1. Vice Chairman of Hai Phong People's Committee

On Duty Deputy Chief of the Committee:
2. Director of Agricultural and Rural Development Department

Deputy Chief of the Committee
3. Chief of Staff of City Military Department
4. Deputy Chief of City Military Border Defending Department

Members:
5. Chief of Administration of City People's Committee
6. Deputy Director of Agricultural and Rural Development Department
7. Deputy Director of Financial Department
8. Deputy Director of Planning and Investment Department
9. Deputy Director of Transportation Department
10. Deputy Director of Public Security Department
11. Deputy Director of Firefighting Department
12. Chief of Staff of Marine Command Zone 1
13. Deputy Director of Industry and Trade Department
14. Deputy Director of Construction Department
15. Deputy Director of Natural resources and Environment Department
16. Deputy Director of Medical Department
17. Deputy Director of Information and Communication Department
18. Deputy Director of Hai Phong Voice and Television
19. Deputy Director of Labor, War Invalids and Social Welfare Department
20. Deputy Director of Hydrometeorology Center in Northern East Zone
21. Chief of Technical Battalion of Kien An Cat Bi Airport
22. Deputy Director of Cat Bi Airport
23. Deputy Director of State Reservation Department in Northern East Zone
24. Director of Haiphong Port
25. Director of Zone 1 Marine Search and Rescue Center
26. Secretary of Hai Phong Youth
27. Deputy Director of Northern Oil Spills Control Center
28. Director of Hai Phong Coastal Information Voice
29. Deputy Director of Hai Phong Electric One Member Limited Company

Chief of Administration:
30. Chief of Dyke and Flood & Storm Control Department

Reference: Hai Phong People's Committee, "Decision No. 643/QD-UBND: ref. Nomination members for Steering Committee for Flood and Storm control and Search & Rescue of Hai Phong City, April 2013.

Figure 4.2.2 Members of Steering Committee for Flood and Storm Control and Search & Rescue of Hai Phong City

Table 4.2.2 Task List of Steering Committee for Flood and Storm Control and Search & Rescue of Hai Phong City

No.	Name	Office position	SC position	Section in charge
1	Do Trung Thoai	Vice Chairman of People's Committee	Chief of Steering Committee	- General control.
2	Bui Trong Tuan	Director of Agricultural and Rural Development Department (DARD)	On-duty Deputy Chief; Chief of Flood & Storm Control Sub-Division	- Control the work of the steering committee when the Chief is out; - Directly control and coordinate with divisions in assigned work.
3	Nguyen Van My	Chief of Staff of City Military Department	Deputy Chief; Chief of Search and Rescue Sub-Division	- Provide guidance to set up plans to mobilize military force for flood, storm control, search and rescue activities; - Directly control and coordinate with search and rescue, earthquake, tsunami.
4	Pham Quang Dao	Deputy Chief of City Military Border Defending Department	Deputy Chief	- Control, manage safety for human life and facilities in sea, islands region; - Provide guidance to set up plans to mobilize defense force for flood, storm control, search and rescue activities; oil spill accidents.
5	Pham Huu Thu	Chief of Administration of City People's Committee	Member	- Advise and assist Communist party, PPC, People's council in their management activities relating to flood, storm control, search and rescue activities; oil spill accidents.
6	Dao Viet Thuan	Deputy Director of Agricultural and Rural Development (DARD)	Member	- Provide guidance to set up plans and methods to ensure safety for fishermen, aquaculture firms and their properties; - Assist and supervise activities on flood, storm control, search and rescue for Cat Hai District.
7	Nguyen Thi Thuong Huyen	Deputy Director of Financial Department	Member	- In charge of financial resources to maintain dyke system, flood, storm control, search and rescue activities; to cope with oil spill accidents; to overcome natural disaster damages; - Assist and supervise activities on flood, storm control, search and rescue for An Duong District and financial sector.
8	Nguyen Thanh Long	Deputy Director of Planning and Investment Department	Member	- In charge of planning and investment to maintain dyke system, flood, storm control, search and rescue activities; to overcome natural disaster damages; - Assist and supervise activities on flood, storm control, search and rescue for Thuy Nguyen District.
9	Vu Duy Tung	Deputy Director of Transportation Department	Member	- Provide guidance to set up transportation plan and assist activities to maintain transportation system in case of natural disaster, to mobilize transportation means to rescue the dyke in emergency cases, to coordinate for flood, storm control, search and rescue activities; to cope with oil spill accidents; - Assist and supervise activities on flood, storm control, search and rescue for Do Son District and transportation sector.
10	Tran Dinh Vang	Deputy Director of Public Security Department	Member	- Provide guidance to set up plan to maintain security and safety for people before and after natural disaster; to mobilize police force for flood, storm control, search and rescue activities; - Assist and supervise activities on flood, storm control, search and rescue for Hong Bang District and police sector.
11	Pham Viet Dung	Deputy Director of Firefighting Department	Member	- Provide guidance to set up plan for firefighting and rescue in case of natural disaster.
12	Tran Ngoc Quyet	Chief of Staff of Marine Command Zone 1	Member	- Provide guidance to set up plan, to mobilize human resources from Marine Command Zone 1 in emergency cases for flood, storm control, and search and rescue activities.
13	Le Minh Son	Deputy Director of Industry and Trade Department	Member	- Provide guidance to set up plan, to mobilize material, fuel, consumer goods for flood, storm control, search and rescue activities; - Assist and supervise activities on flood, storm control, search and rescue for Tien Lang District and Industry-Trade sector.
14	Vu Huu Thanh	Deputy Director of Construction Department	Member	- Provide guidance to set up plan, to mobilize material, facilities of construction sector to rescue damaged houses and for flood, storm control, search and rescue activities; - Assist and supervise activities on flood, storm control, search and rescue for Le Chan District and construction sector.
15	Nguyen Tu Trong	Deputy Director of Natural Resources and	Member	- Provide guidance to set up plan, to maintain environmental safety in damaged area; take part in setting up plan and to

		Environment Department		cope with oil spill activities; - Assist and supervise activities on flood, storm control, search and rescue for Kien Thuy District and Environmental sector.
16	Nguyen Tien Son	Deputy Director of Medical Department	Member	- Provide guidance to set up plan for medical sector in damaged areas; emergency actions and disease prevention; - Assist and supervise activities on flood, storm control, search and rescue for An Lao District and medical sector.
17	Pham Van Tuan	Deputy Director of Information and Communication Department	Member	- Provide guidance to set up plan to maintain communication for natural disaster damaged area and oil spills; - Assist and supervise activities on flood, storm control, search and rescue for Bach Long Vy District and communication sector, communication and post offices.
18	Bui Thanh Long	Deputy Director of Hai Phong Voice and Television	Member	- Provide guidance to set up plan for information and communication on flood, storm control, search and rescue as well as oil spills accident; - Assist and supervise activities on flood, storm control, search and rescue for Ngo Quyen District.
19	Do Van Binh	Deputy Director of Labor, War Invalids and Social Welfare Department	Member	- Provide guidance to setup plan for rescue and humanity social policies in damaged regions; - Assist and supervise activities on flood, storm control, search and rescue for Duong Kinh District and Labor, Invalids and Social sector.
20	Nguyen Vu Thang	Deputy Director of Hydrometeorology Center in Northern East Zone	Member	- Provide guidance to set up plan and act as implementing agency for weather forecast and warnings concerning natural disasters; - Assist and supervise activities on flood, storm control, search and rescue for Kien An District.
21	Nguyen Thai Thinh	Chief of Technical Battalion of Kien An Cat Bi Airport	Member	- Provide guidance to set up plan, to mobilize human resources from the airport in emergency cases for flood, storm control, search and rescue activities, airlines accidents and oil spills.
22	Nguyen Quoc Tuan	Deputy Director of Cat Bi Airport	Member	- Provide guidance to set up plan, to mobilize human resources from the airport in emergency cases for flood, storm control, search and rescue activities, airlines accidents and oil spills.
23	Vu Nhat Le	Deputy Director of State Reserves Department in Northern East Zone	Member	- Provide guidance to set up plan to mobilize the state reserves for flood, storm control, search and rescue activities; - Assist and supervise activities on flood, storm control, search and rescue for Hai An District and State Reserves Department in Northern East Zone – Hai Phong region.
24	Bui Van Minh	Director of Hai Phong Port	Member	- Coordinate setting up plan and take part in flood, storm control, search and rescue activities; oil spill accidents in Hai Phong area; - Assist and supervise activities on flood, storm control, search and rescue in Hai Phong Port area.
25	Tran Van Do	Director of Zone 1 Marine Search and Rescue Center	Member	- Provide guidance to set up plan, to mobilize human resources from the Center in emergency cases for flood, storm control, search and rescue activities in rivers and sea in Hai Phong region.
26	Tran Quang Truong	Secretary of Hai Phong Youth	Member	- Provide guidance to set up plan, to mobilize human resources from Hai Phong Youth in emergency cases for dyke prevention, flood, storm control, search and rescue activities; - Assist and supervise activities on flood, storm control, search and rescue in Vinh Bao District.
27	Dinh Bang Sat	Deputy Director of Northern Oil Spills Control Center	Member	- Head in setting up plan to mobilize human resources from the Center in emergency cases of oil spill accidents.
28	Nguyen Ba Huy	Director of Hai Phong Coastal Information Voice	Member	- Lead in carrying out communication activities in The Voice of Hai Phong Coastal Zone; - To ensure VHF audio frequency for flood, storm control, search and rescue activities.
29	Nguyen Thanh Hung	Deputy Director of Hai Phong Electric One Member Limited Company	Member	- Lead in setting up plan for power sustainment, set priority order for power supply for flood, storm control, and search and rescue activities; - Assist and supervise activities on flood, storm control, search and rescue in electric sector.
30	Nguyen Ba Tien	Chief of Dyke and Flood & Storm Control Department	Chief of Administration	- Operate activities of the office of City Steering Committees for Flood & Storm Control and Search & Rescue; - Administration activities and reports.

Reference: Hai Phong People's Committee, "Announcement No. 02/TB-PCLB&TKCN: Ref. Task assignment for members of Steering Committee for Flood and Storm Control and Search & Rescue of Hai Phong City", April 2013

4.3 Present State of Industrial Agglomerated Area

For the formulation of the Area Business Continuity Plan, the Nomura Hai Phong Industrial Zone was selected as the industrial park representing the others in the Industrial Agglomerated Areas. The six industrial parks in Hai Phong targeted for this survey are as follows.

1) Dinh Vu Industrial Zone
2) Do Son Industrial Zone
3) Nam Cau Kien Industrial Zone
4) Nomura Hai Pohong Industrial Zone
5) Trang Due Industrial Zone
6) VSIP Hai Phong Industrial Zone

With the 'doi moi' measures, the liberalization in 1987 of Foreign Direct Investment (FDI) laws permitted foreign investment. As of February 2012, 80% of projects and 85% of capital came from Chinese or Southeast Asian investors. In Hai Phong, are more than 170 tenants in the six industrial parks, more than 40% of which are from Japan. There is only one park, i.e. Nam Cau Kien Industrial Zone that has no Japanese tenants.

4.3.1 Industrial Parks in the Industrial Agglomerated Area

In Hai Phong, the Nomura Hai Phong Industrial Zone has 46 Japanese tenants out of 54 in total. Another industrial park, the VSIP Hai Phong Industrial Zone, there are six Japanese tenants as detailed below.

<u>Nomura Hai Phong (NHIZ)</u>

In the north of Vietnam, NHIZ was the first industrial zone, constructed in 1997. This was a joint venture industrial zone between Hai Phong city and the Nomura Finance Group of Japan, with the strategic aim to attract famous and powerful investors in technology from Japan. NHIZ has an area of 153 hectares, of which 123 hectares is for factories and 30 hectares is for public utilities. With well-developed infrastructure facilities, including an independent electric power supply station with a capacity of 50 MW, a 13,500 cubic meter per day water supply plant, a 2,000-line telephone service, and modern wastewater treatment system, as well as roads and many other services, NHIZ is considered one of the most modern industrial zones in Vietnam.

Figure 4.3.1 Nomura Hai Phong Industrial Zone (NHIZ)

Source: NHIZ

1) Nearest main road: 1km from National Road No. 5
2) Nearest seaport: 15km from Hai Phong port
3) Nearest airport: 20 km from Cat Bi airport
4) Nearest railway station: 2 km from Hai Phong railway station
5) Current status:

- ✓ Occupancy rate: 100%
- ✓ Tenants: NHIZ currently has 54 investors, 46 of which are from Japan. Others are from the EU, US, and the Republic of Korea, with a total registered capital of nearly US$ 1 billion.
- ✓ Main industrial sectors:
  - Manufacture of machinery and equipment: 14 companies
  - Manufacture of rubber and plastic products: 7 companies
  - Manufacture of electrical equipment: 5 companies

VSIP Hai Phong

VSIP Hai Phong has an urban area, industrial park and service center on an area of 1,600 ha. It is situated on the north banks of the Cam River, a strategically important location in the city. VSIP Hai Phong allocates 1,100 ha to urban area development and 500 ha to industrial development and related services. VSIP Hai Phong has been operating since 2009.

Figure 4.3.2 VSIP Hai Phong

Source: VSIP Hai Phong

1) Nearest seaport: 16 km from Hai Phong Port
2) Nearest airport: 15 km from Cat Bi Airport, 120km from Noi Bai International Airport
3) Nearest railway station: 14 km from Hai Phong railway station
4) Current status:

- ✓ Occupancy rate: NA
- ✓ Tenants: 18 in total (including those have leased the land but are not yet operating), all of which are Japanese.
- ✓ Main industrial sectors:
  - Light industry, hi-tech & clean industry: 16 companies
  - Urban development: 2 companies
  - Heavy industry is not promoted because of possible environmental pollution.

VSIP Hai Phong was developed by a joint venture between Vietnam and Singapore. Becamex is a Vietnamese government corporation and Sembcorp is Singaporean, which is invested in by the Mitsubishi Corporation.

4.3.2 Tenant Companies in Nomura Hai Phong Industrial Zone

The following is the state of inventory control as implemented by tenants of the Nomura Hai Phong Industrial Zone.

1) Alternative Production Facilities

Only two companies out of 23 have alternative production facilities. One is a car parts manufacturer, who will use the production facility of a branch factory of Thai Binh, 50 km away from the company in the Nomura Hai Phong Industrial Zone, as their alternative production facility in an emergency.

The other is the manufacturer of “airbag handles” for automobiles. The company will use the production facility in a factory in Thailand or China as their alternative production facility in an emergency.

2) Product Stocks

Products are reserved as stock within the organization by 15 companies out of 23, which is 65%. The remaining 8 companies do not have product stocks.

3) Raw Material Stocks

Raw materials are reserved as stock within the organization by 16 companies out of 23, which is 70%. The remaining 7 companies do not have raw material stocks.

4.4 Transport Infrastructure Conditions

4.4.1 Roads

(1) Outline

The main roads in Hai Phong are National Route No. 5 and National Route No. 10.

National Route No. 5 connects Hanoi and Hai Phong - it mainly runs in an east-west direction. The level is two (2). The length is 102 km in total and the width is 23.5m with six lanes. This road links to National Route No. 1 at Hanoi. National Route No. 1 is the most important highway in Vietnam, and is said to be most modern road in Vietnam, as well as the most important trunk road in the northern part of the country. The traffic volume of National Route No. 5 shows a high rate of increase at 16% yearly. In particular, a steep increase in trucks is assumed, and the importance of the road is increasing as a transportation route for import/export goods from the harbor and the industrial complex in Hai Phong.

The transport volume of National Route No. 5 was initially estimated as 15 million tons/year, but is now 38.4 million tons/year. Since this cargo is mainly handled by 5,600 container cars, the transport load and congestion have been increasing significantly every year.

Table 4.4.1 Transport Volume on National Route No. 5（PCU/day）

Description	Passenger Cars	Vans	Buses	Trucks	Total
Standard Value (28 km in 1993)	1,034	291	281	1,306	2,912
Plan Value (28 km in 2008)	4,319	1,215	1,381	12,289	19,204
Actual Measurement (9 km in 2006)	4,788	1,499	4,539	8,955	19,781
Planned annual rate of increase	10%	10%	11%	16%	13%
Actual annual rate of increase	13%	13%	24%	16%	16%

Source: Vietnamese and Japanese joint evaluation team of 2007 for improvement work of National Route No.5

Moreover, National Route No. 10 is a road of 157 km with two lanes in each direction, which is located on the east side of Hai Phong. It is linked to National Route No. 1 at the major city of Ninh Binh in the south in the direction of northeast from southwest. It is also linked to National Route No. 18 connecting Ha Long Bay (Vinh Ha Long) in the north.

These national roads serve as important trunk roads connecting Hai Phong and the exterior for physical distribution. Its level is three (3). The new Highway No. 5 (total length: 105.5 km, width: 35 m) between Hanoi and Hai Phong is under construction and will be completed this fiscal year.

(2) Roads in Hai Phong City

The total road length in Hai Phong city is 324 km, and the roads fundamentally consist of semi-circle beltways centered around Hai Phong Port and radial roads from the port. There are 33 roads in total.

(3) Number of Vehicles

The number of vehicles in Hai Phong are as follows. Due to recovery from the economic recession from 2010 to 2011, the number of vehicles is clearly increasing.

Table 4.4.2 Transitions of the Number of Vehicles

Type	2008	2009	2010	2011	2012
Small Car	2,493	2,794	2,847	3,989	3,801
Light Lorry	3,483	3,787	3,835	5,493	6,381
Middle Van	1,606	1,587	1,570	2,948	3,077
Heavy Truck	5,247	5,729	5,474	13,278	11,222
Passenger Car	2,450	2,498	2,680	5,459	4,797
Total	15,279	16,395	16,406	31,167	29,278
Motorbike	40,144	38,058	33,842	26,142	34,368
Bicycle	12,500	12,701	13,571	11,058	11,821

Source: Interview by local consultants

4.4.2 Ports

(1) Outline

The representative ports in Hai Phong are Hai Phong Port and Dinh Vu Port.

The Hai Phong Port is a river port, and the depth of the access river channel is as shallow as 5.7 m to 7.8 m. Thus, large vessels are not able to enter this port. 40,000 tons is the maximum weight allowed. Small feeder boats of 500~700 TEU product class are allocated.

The Dinh Vu Port is located in the area furthest downstream on the Cam River. Sandbars are being used for land reclamation and development. Maintenance work is also being conducted in conjunction with the development of an industrial complex. If dredging work at the front of the river progresses, feeder boats of a 1,000 TEU stacking class will be able to make port calls.

If the Hai Phong International Gateway Port is developed at the offing of Hai Phong, large-sized feeder boats of a 3,000~4,000 TEU stacking class will be able to make port calls.

(2) Cargo

Table 4.4.3 Cargo Throughput

Breakdown	2006	2008	2009	2010	2011
Total million tons	11,151,000	13,900,000	14,370,000	15,688,689	17,891,568
Import million ton	5,199,000	7,635,000	8,226,000	7,815,129	7,861,456
Export million ton	2,825,000	3,231,001	2,376,000	2,858,577	3,989,431
Domestic million ton	3,127,000	3,103,000	3,768,000	5,014,983	6,040,681
Container TEUs	464,000	808,000	816,000	953,646	1,018,794
Ship Calls	2,056	4,779	4,779	5,298	2,470

Source: Vietnam Seaport Association, Shipping Times, Hai Phong Port

(3) Port Facility

The port is divided into three main areas (terminals).

Figure 4.4.1 Central Terminal Berth Plan

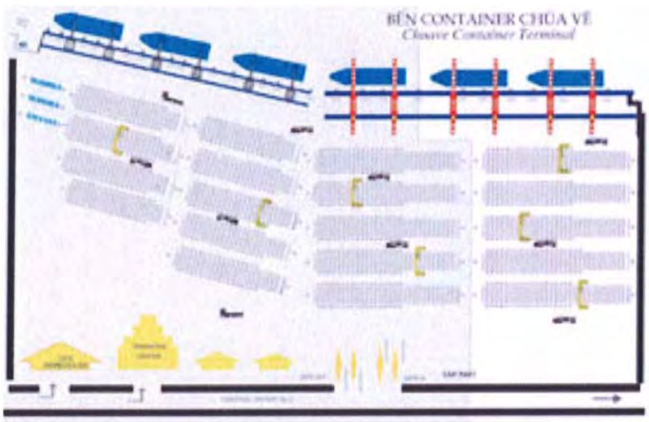


Figure 4.4.2 Chua Ve Terminal Berth Drawing

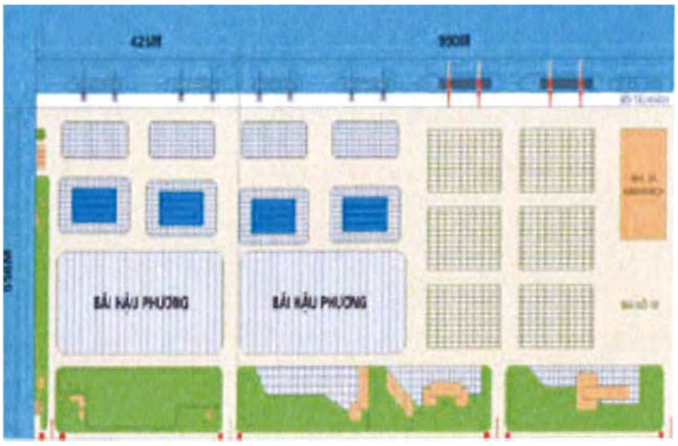


Figure 4.4.3 Dinh Vu Port Area Berth Drawing

Source: Unison Shipping Services/Starline Shipping Agencies (Vietnam)

The port facilities are as follows.

Table 4.4.4 Port Facilities

Berth No./ Qt'y	Length	Depth	Facilities	Ship/Cargo
Central Terminal				
M1~M11, 11	1,717 m	-8.4 m	Shore cranes 5MT, 10MT, 16MT, 32MT Floating Cranes, 10~80MT Forklift Automatic bagging line Electronic scale 80~120MT	General cargo, container, bag, bulk vessels
Chua Vu Terminal				
C1~C5, 5	714 m	-8.4 m	Shore crane 40MT Gantry crane 32MT Dedicated forklifts 2~42MT Elect. scale 80MT	Container, general cargo vessel
Dinh Vu Terminal				
DV3~DV7, 5	1,135 m	-10.5 m	Jb/Slewing crane 40MT Quayside gantry crane	Container, general cargo vessels 20,000DWT/ 1,200TEUs

Source: Vietnam Seaport Association, Shipping Times, Hai Phong Port

(4) Access Channels

Table 4.4.5 Access Channels

Name	Length (km)	Width (m)	Critical Depth (m)
Lach Huyen	17.5	100	-7.8
Ha Nam	6.3	70	-5.7
Bach Dang	9.2	70	-6.1
Song Cam	9.8	70	-6.1
Total	42.8		

Source: Unison Shipping Services/Starline Shipping Agencies (Vietnam)

4.4.3 Railways

(1) Outline

The Hai Phong - Hanoi - Lao Chai railway is connected to Kunming station in southern China, and serves as an arterial route for cargo transport to southern China. The train only makes as few as two or three round trips a day. The railway is a single track and there are four (4) river crossings (bridges) and 211 road intersections.

Table 4.4.6 Hanoi-Hai Phong Railway

Route	Start Year	Length	No. of Stations	Traveling Time	Gauge
Hanoi-Hai Phong	1902	102 km	18, (4 in Hai Phong)	2.5 hours	1,000 mm

Source: Wikipedia, Rail transport in Vietnam

Figure 4.4.4 Railway Network in the Hai Phong Vicinity

There are more than 40 industrial estates located along the railway and also many industrial estates being planning and under construction. Industrial estates are most concentrated along National Road No. 5. However, most of the raw materials that are delivered to these industrial estates and the products that they ship are mostly transported by trucks, so the contribution of the railway is very small.

Containers, passengers, and freight are also transported, but only on a small scale. Standardization of the rail gauge and electrification has not been conducted. The Vietnam National Railways (VNR) manages the railway.

(2) Cargo Transport

Cargo transport between Hanoi and Hai Phong is shown in the Table 5.5.7. The increase in the volume of down direction shows an increase in exports and industrial commodities. Apart from container transport, railways have become specialized in the transport of heavy loads such as coal, ore, stone, etc. The number of cars connected at one time is 28 or less.

Table 4.4.7 Freight Transport between Hanoi and Hai Phong

Description	Unit	2001		2010	
		Figure	Share %	Figure	Share %
Freight Volume	ton / year	496,289		1,385,300	
	ton / day	1,360	100	3,795	100
Down Direction	ton / day	653	48	2,467	65
Up Direction	ton / day	707	52	1,328	35

Source: Japan Railway Technical Service, Improvement Study of the Northern Vietnam Railway including Hanoi and Hai Phong cities, and its Logistics, Report summary

(3) Passengers

The annual numbers of passengers travelling to other districts from Hai Phong Station are as follows.

Table 4.4.8 Passengers in Hai Phong Station 2010

No.	Travel Route	Total
1	Hai Phong – Hon Gai	62,212
2	Hai Phong – MongCai	28,7132
3	Hai Phong – Cat Ba	401,066
4	Hai Phong – Thai Binh – Nam Dinh	112,424
5	International passengers	200,000

Source: Interview by local consultant

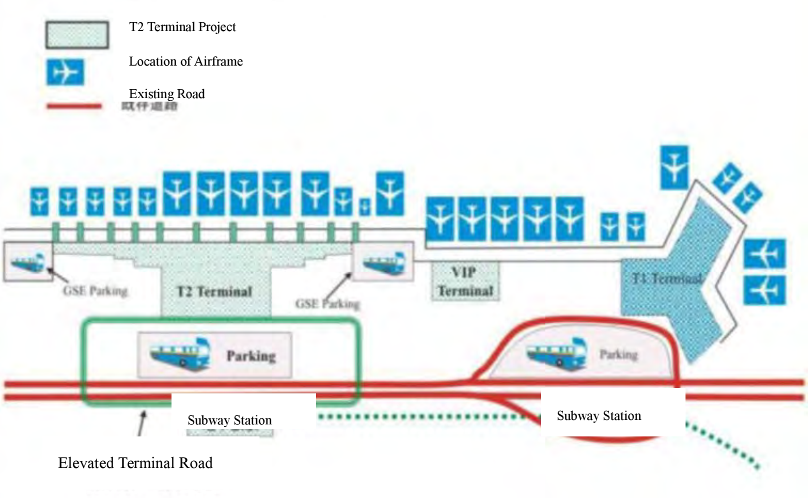
4.4.4 Airports

(1) Outline

In the Hai Phong area, the Noi Bai International Airport in located in Hanoi and the Cat Bi Airport in Hai Phong. Almost all air cargo and domestic/international passengers use Noi Bai International Airport. Cat Bi Airport in Hai Phong handles a small amount of air cargo and passengers going to Ho Chi Minh City and Da Nang. These airports are managed by the Northern Airports Authority.

(2) Noi Bai International Airport

Noi Bai international airport is located 45 km north of central Hanoi. Although only Terminal 1 is currently operating, there is an expansion project underway. After its completion, Terminal 2 and the cargo terminal can be used.



Source: JETRO, Infrastructure Map 2011

Figure 4.4.5 Noi Bai International Airport Drawing

The airport is a joint-use airport for the military and the general public. It is equipped with two runways (3,800 m x 45 m). The lobby is composed of Lobby A and B for international flights and Lobby C and D for domestic flights.

Table 4.4.9 No. of Arrivals and Departure at Noi Bai International Airport in August 2013

Departing planes	141 / day
Arriving planes	139 / day
Total	280 / day

Source: Interview by local consultant

Table 4.4.10 Air Cargo at Noi Bai International Airport

Year	Handling Cargo (tons)	One-day Average (tons)
2010	324,214	888
2011	249,046	682
2012	281,807	772
2013 up to May	285,841	783

Source: Interview by local consultant

The number of passengers is as follows. An increase rate of 10% or more per year is shown.

Table 4.4.11 Number of Passengers

Year	Passenger
2010	9,519,839
2011	10,797,923
2012	11,314,902
2013 up to May	11,556,600

Source: Interview by local consultant

(3) Cat Bi Airport

This airport has one runway (2,400 m x 50 m) and is used only for domestic flights. Only aircraft equivalent or smaller than B737 and A320 airplanes can be used. The runway will be expanded to 3,050 m by 2015, after which the airport is planned to be upgraded to an international airport.

During a 5-month period in 2013, there were 2,448 arrivals and departures. This shows a 16.8% increase in flights over the same period in 2012. There were 316,600 passengers in that period, which shows an increase of 23.29% over the same period of the last year.

Source: JETRO, Infrastructure Map 2011

Figure 4.4.6 Cat Bi Airport Location Map

4.4.5 Buses

There are five (5) bus stations in Hai Phong (Cau Rao, Niem Nghia, Tam Bac, Lac Long and Vinh Bao). The total land area of all the bus centers is 37,130 m^2. As for buses used for public transportation, six (6) companies operate 113 buses on 13 routes. In addition, there is also a wagon-type minibus that runs in Hai Phong. For this, there are 103 inter-province routes and 23 local routes. 47 companies operate 570 vehicles. For taxis, 27 companies operate 1,700 vehicles.

4.4.6 Waterways

Water transportation through rivers is well-developed. Seven (7) companies are operating 16 boats with 1,400 total seats.

4.5 Lifeline Facilities and Public Services

4.5.1 Electricity

(1) Outline

Electric power amounting to about 8 - 9.5 million kW/day is supplied to the Hai Phong Power Company from the Electricity of Vietnam (EVN).

Generally from there, electricity is supplied to residents through three 220kV substations and 25 110kV substations.

Table 4.5.1 TBA220kV Substations

Sub Station	Code	Spec	Location
Vat Cach	1T	125MVA	An Hong commune, An Duong district
	2T	125MVA	
Dong Hoa	1T	125MVA	Dong Hoa commune, Kien An district
	2T	250MVA	
Dinh Vu	1T	250MVA	Dinh Vu industrial, Dong Hai commune

Source: Interview by local consultant

Table 4.5.2 220kV Power Lines

Power Line	Cable	Distance	Location	
220kV Phai Lai-Dong Hoa	AC400	55km	From	Hai Dong
			Via	Dong Hoa Kien-An
			To	Hai Phong
HP1 electricity-Dinh Vu	2x400mm^2	16km	From	Tam Hung Thuy Nguyen
			To	Dong Hai
Dong Hoa-Dinf Vu	2x500mm^2	17.7km	From	Tam Hung Thuy Nguyen
			To	Dong Hai
Trang Bach-Vat Cach- Dong Hoa	ACK-450	22km	From	Trang Bach Quang Ninh
			Via	Hong An Duong
			From	Dong Hoa

Source: Interview by local consultant

Table 4.5.3 110kV Power Lines Managed by Hai Phong Power Company

No.	Items	Quantity
1	Number of TBA 110kV	24 TBA
2	Number of MBA 110kV	39 MBA
3	Capacity of MBA	1,468 MVA
4	110kV Lines	377.18 km

Source: Interview by local consultant

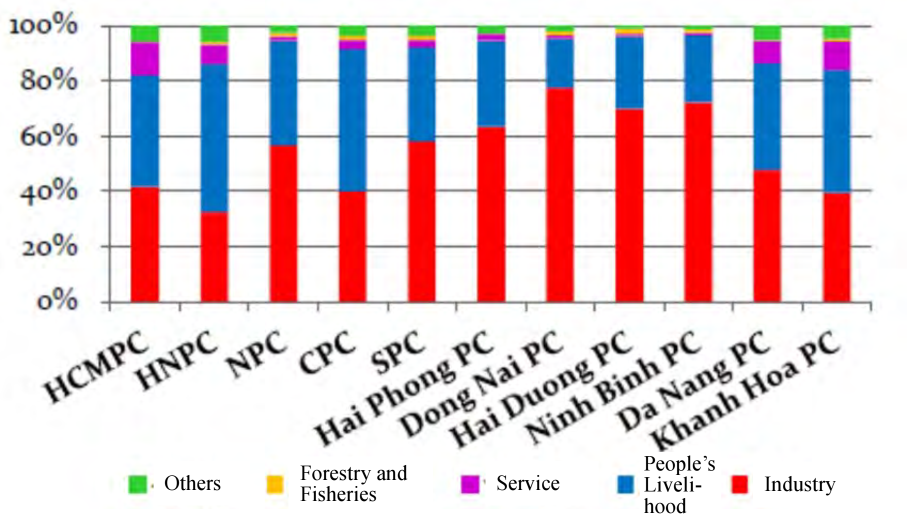
Moreover, the stable electric power supply became possible when the Hai Phong Thermal Power Joint Stock Company, which is a group company of EVN, began operating the Hai Phong Thermal Power Plant Phase I (600 MW=300 MWx2 dynamo).

The percentage of the industrial use is 62% in Hai Phong, which is comparatively high proportion for industrial electricity use.

(2) Distribution and Retail

Eleven electricity distribution companies manage distribution and retail sales. (Hanoi: HPC/HNPC, Ho Chin Minh: HCMPC, Hai Phong: HPPC/NPC, Dong Nai: DNPC/SPC, Hai Duong: HDPC, Ninh Binh: NBPC, Da Nang: CPC (Da Nang North: PC1, Da Nang South: PC2, Da Nang Central: PC3), Khanh Hoa: Khanh Hoa)

Ten of these companies are subsidiaries of the public corporation EVN (independent accounting), but Khanh Hoa is incorporated.



Source: JETRO, Vietnam Electric Power Study 2011

Figure 4.5.1 Power consumption percentage of each power distribution public corporation

4.5.2 Water

(1) Outline of Water Supply

The categorical division for water services in the urban areas of Vietnam is as follows. Hai Phong is classified as Category 1.

Table 4.5.4 Categories in Urban Areas

Category of Urban Area	Configuration	Population	Urban Area
Special Municipality	Large City	1,500,000 or more	Hanoi, Ho Chin Minh
Category I	National City	500,000 to 1,500,000	Hai Phong, Da Nang, Can Tho

Category II	Local City	250,000 to 500,000	Hue, Nha Trang, other 10 cities
Category III	Province City	100,000 to 250,000	16 cities
Category IV	Local Government Unit	50,000 to 100,000	58 LGU
Category V	LGU	4,000 to 50,000	612 LGU

Source: Ministry of Health, Labour and Welfare, International Water Promotion Report 2012.3

The performance targets of the city water service sector are determined by the following classifications.

Table 4.5.5 Category I in New Development Indicator Targets 2009 (Hai Phong City)

Item	Category of City	2015	2025
Water Supply	Category I	120 L/Man/day (90%)	120 L/Man/day (100%)
Rate of non-revenue water (%)	Category I	<25%	<15%
Water Supply Time	Category I	24hr	24hr

Source: Ministry of Health, Labor and Welfare, International Water Promotion Report 2012.3

The outline of water services in Hai Phong is as follows.

Table 4.5.6 Summary of Water Services in Hai Phong

Area	Hai Phong City		
Name of water service utility	Hai Phong Water Supply Company		
Year	2006	2007	2008
Population	804,669	836,635	876,809
Population in service area	764,669	836,635	876,809
Water supply population	658,248	700,352	795,096
Water service diffusion rate (%)	81.8	83.7	90.7
Rate of non-revenue water (%)	22.1	20.9	20.4
Average water charges (VND/m^3)	3,842	3,882	3,897

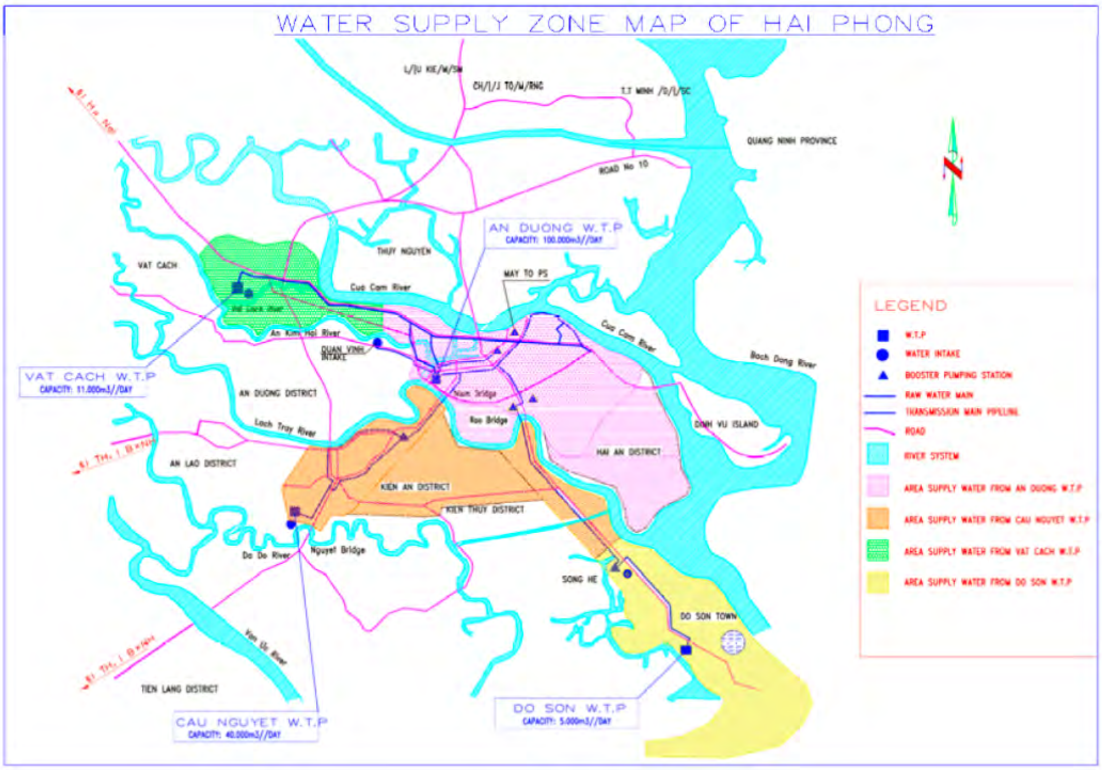
Source: Ministry of Health, Labor and Welfare, International Water Promotion Report 2012.3

(2) Water-purifying System

Seven water purification plants and water supply zones are located in Hai Phong, and the total water supply capacity is 125,000m^3/day. Purifying capacity is 100,000m^3/day, and water-purifying sludge is removed after it is dried in the sun.

(3) Water Supply System

Water supply is performed via six water purification plants in addition to the An Duong water purification plant described above. There are six relay pump locations, from which water is supplied to the city center. The water supply pipe is about 2,000 km in length.



Source: Matsuo Sekkei, Overseas Business PPP Project for Water Supply, Study Report 2012.3

Figure 4.5.2 Water Supply Zones

(4) Sewerage

Sewage treatment in Hai Phong is conducted by the Sewerage and Drainage Company (SADCO), which provides septic tanks. The World Bank purchased and supplied sucking trucks for SADCO, which provides services for all homes connected with a combined sewer system.

There are 86,501 septic tanks, which are cleaned free of charge every five years. There are 19,048 manholes.

(5) Drainage

Rainfalls below 500 mm no longer cause flooding in Hai Phong due to the regulating ponds that were installed in various locations in the city. However, in the city, there are several hot spots where are inundated with 50 to 100 mm rain. Nguyen Binh Street (Dong Quoc Binh Ward People's Committee), Binh Dong Street, the T-junction, the former road No. 5, and other areas are examples of such. Although the depth of this standing water in these areas is 15 to 20 cm, it drains within 1 to 3 hours. Current drainage facilities in Hai Phong are as follows.

Table 4.5.7 Drainage System in Hai Phong City

Item	Quantities
Regulating pond system	72.1 ha (11 ponds)
Canals and ditches of all types	57.6 km (6 canals)
Pump stations	2 storm water pump stations
	17 waste water pump stations
Tide blocking sewers of all types	14
Sewer network	450 km
Gas pits of all types	19,048
Check valve at sluice gates to the lakes or rivers	157

Source: Seawun, Hai Phong Wastewater Project

(6) Dyke

In Hai Phong City, 24 lines of dykes and embankments (416.97 km in total) have been constructed along rivers and seashores.

Table 4.5.8 Length of Dykes

Dyke level	Length (km)
Dyke Level 2	105.881
Dyke level 3	264.757
Dyke Level 4	46.332
Total	416.970

Source: Interview by local consultant

(7) Land Use

The state of land use in Hai Phong City is as follows.

Table 4.5.9 State of Land Use in 2010

No.	Forms of use	Area (ha)	(%)
1	Land for Agricultural Use (Farm, Forest, Culture etc.)	83,754	55.0
2	Land for Non-Agricultural Use (Public facility, Security Area, Industrial Estate, Faith Institution etc.)	64,864	42.6
3	Unused land	3,720	2.4
Total		152,338	100.0
4	Residents	33,958	22.3
5	National Protection Area	5,000	3.3
6	Sight Seeing Area	19,894	13.1

Source: Interview by local consultant

4.5.3 Communications

(1) Outline

Six fixed-line communication companies provide internet services including fixed-line telephone service and IP phone service.

Table 4.5.10 Fixed-Line Communication Providers in Vietnam

System	Company Name
Postal Administration Communication System	Vietnam Post & Telecommunications (VNPT)
National Ministry of Defense System	Vietnam Telephone. (Viettel)
National Power Corporation System	EVN Telecom
Government Joint Venture (JV)	Saigon Postel (SPT)
	Hanoi Telecom
Private Sector System	FPT Telecom

Source: Hanoi Telecom 2007

The following six companies offer mobile phone services. As of June 2011, about 29 million people are using the internet in Vietnam.

Table 4.5.11 Mobile Phone Companies in Vietnam

System	Company Name
VNPT System	VinaPhone : GSM/GPRS
	MobiFne : GSM/GPRS
Viettel System	Viettel Mobile: GSM/GPRS
EVN Telecom System	VP Telecom : CDMA2000 1x
Saigon Post System	S-Telecom (S-Fone) : CDMA2000 1x
Hanoi Telecom System	HT Mobile：CDMA2000 1x

Source: Hanoi Telecom 2007

(2) Communication in Hai Phong City

In Hai Phong, 1,800 Base Transceiver Stations (BTS) for 2G and 3G types have been installed and cover the wireless communications of all areas in the city. For mobile phones, there are 1.5 million prepaid subscribers and 180,000 postpaid subscribers. In contrast, there are 250,000 subscribers for fixed-line telephones.

There are 40,000 mobile internet subscribers and 180,000 fixed-line internet subscribers. Internet coverage is available in all areas of the city.

4.5.4 Gas

There is no gas facility in Hai Phong.

4.5.5 Waste

(1) Control System

Collection and transport of waste in Hai Phong is carried out by three public corporations under the Hai Phong People’s Committee (HPPC).

Table 4.5.12 Waste Management System

Management Corporation	Object Area
Hai Phong Urban Environmental Company (URENCO)	Hong Bang, Le Chan, Ngo Quyen / 3 Central City Areas
Kien An Public Works State Limited Company	Kien An District
Dong Son Public Works State Limited Company	Dong Son District

Source: Kajima Corporation, Vietnam, Study of 3R Promotion and Stabilizing treatment of Urban Waste 2008.3

(2) Collection Situation

Individual collection of waste in central city areas is carried out using handcarts every day. From there, it is taken to the final disposal site compactor trucks, where it is subsequently incinerated. Separate collection is not carried out and waste is collected in a mixed state.

The waste transport equipment owned by Hai Phong URENCO includes 700 handcarts, five trucks, and 40 compactors.

Table 4.5.13 Total Waste Generation in Hai Phong

Year	Amount Generated (ton/day)	Recovery Rate (%)
2005	767	82
2010	1,104 (Estimate)	93
2020	1,496 (Estimate)	95

Source: Kajima Corporation, Vietnam, Study of 3R Promotion and Stabilizing treatment of Urban Waste 2008.3

Table 4.5.14 Composition of Waste

Type	Share (%)
General Waste	46
Business System Waste	29
Street Waste	12
Industrial Waste	10
Medical Waste	1
Construction Waste	2
Total	100

Source: Kajima Corporation, Vietnam, Study of 3R Promotion and Stabilizing treatment of Urban Waste 2008.3

(3) Final Disposal Site

There are three main final disposal sites, over which Hai Phong URENCO has jurisdiction. They are the Tran Cat disposal site (I, II), Do Son disposal plant, and Dinh Vu disposal plant. These are landfill disposal sites and do not have sufficient facilities for accumulating and processing exudation water. The two main disposal sites are shown below.

Table 4.5.15 Major Final Disposal Site

Item	Tran Cat Disposal Site Section II	Dinh Vu Disposal Site
Place	11 km from center of city	17 km from center of city

Area	60 ha (treatment division=10 ha)	30 ha (treatment division=6 ha)
Start year	2003	October 2004
Amount of waste brought in	Daily waste: 350 ton/day	250 ton/day
Hours operated	365 days in a year	365 days in a year
Facility	With Leachate treatment equipment	With Leachate treatment equipment

Source: Kajima Corporation, Vietnam, Study of 3R Promotion and Stabilizing treatment of Urban Waste 2008.3

4.5.6 Schools

The schools in Hai Phong are as follows.

Table 4.5.16 Number of Schools in Hai Phong

Classification	No.
University	4
College	16
Senior High School	175
Secondary School	350
Primary School	229
Kindergarten School	261

Source: Interview by local consultant

4.5.7 Hospitals

The hospitals in Hai Phong are as follows.

Table 4.5.17 Hospitals

Classification	No.
Hospital	17
Health Center of the Region	14
Total	31
Total Number of Beds	5,626

Source: Interview by local consultant

4.6 Economic Relations with Neighboring Regions and Japan

4.6.1 Overview of the Economy of Target Region

Major Japanese machinery and electronics companies such as Canon, Brother Industries, Honda Motor Co., Ltd., Yamaha Corporation are establishing production bases in Vietnam, bringing their Japanese suppliers with them. Typically, the flow of goods in a manufacturing company starts from the point where the necessary parts are imported from Japan to Vietnam. The suppliers will then process the parts and deliver them to major companies, which will assemble the parts and complete the products. In the present situation, many major companies are trying to increase the local supply rate in order to curb the sourcing cost and minimize lead time. This trend has resulted in the increased production volume of local suppliers (Japanese companies).

In Vietnam, there is a category of manufacturing known as "Export Processing," and under this category, exemptions from import customs duties will be applicable if imported parts are processed and then exported within a period of nine months. (Finished products which benefited from this exemption cannot be sold in the domestic market). This system is called the Export Processing Zone (EPZ), and in general, is introduced to provide incentives to foreign companies, with the additional purpose of increasing job opportunities and promoting technical transfer.

Major tenants of the Nomura-Hai Phong Industrial Zone include Pioneer Corporation, Yazaki Corporation and Toyota Boshoku Corporation, all of which are engaged in the manufacturing business focusing on Export Processing. Therefore, for most of these companies, parts imported from countries such as Japan are processed inside the industrial zone and finished products are directly exported to other countries (to developed countries such as U.S.A.). In contrast, industrial parks such as Thang Long Industrial Park (developer: Sumitomo Corporation) mainly handle products for the domestic market.

4.6.2 Major Economic Policy

At the Eleventh National Congress of the Communist Party of Vietnam held in January 2011, the 9th five-year plan (2011-2015) was newly adopted. The plan sets goals for achieving the following objectives: increase the average annual economic growth rates by approximately 7 to 8%; increase exports by an average of 12%; decrease budget deficit to about 4 to 5% from the current deficit of 6.2% of the GDP; and to reach a GDP per capita of USD 2,100 by the year 2015.

4.6.3 Economic Ties with Japan

Looking at the trade partners of Vietnam, trade with ASEAN countries and China is increasing. Exports to the U.S.A. are also sharply increasing. Vietnam's top three trade partners as of 2009 (provisional value) are China, U.S.A. and Japan; these top three countries accounted for about 40% of the total trade. Asian countries such as South Korea, Taiwan and Singapore accounted for more than 50% of the total trade volume.

As for foreign direct investment (FDI) (on approval basis) by country, Singapore was at the top of the list, followed by the Netherlands and Japan, according to the preliminary figures announced in December 2010.

Licensed foreign direct investment projects listed by main counterparts are shown below. Looking at the accumulation of projects having effect as of 31/12/2011, Japan (US$ 24.4 billion) is on the top, followed by Korea (US$ 23.7 billion), Taiwan (US$ 23.6 billion) and Singapore (US$ 23.0 billion).

Table 4.6.1 Foreign Direct Investment Projects Licensed by Main Counterparts

(Accumulation of projects having effect as of 31/12/2011)

Country	Number of projects		Total registered capital *(Mill. USD)*	
TOTAL	**13,440**	*100%*	**199,078.9**	*100%*
Japan	1,555	*11.6%*	24,381.7	*12.2%*
Korea Rep. of	2,960	*22.0%*	23,695.9	*11.9%*
Taiwan	2,223	*16.5%*	23,638.5	*11.9%*
Singapore	1,008	*7.5%*	22,960.2	*11.5%*
British Virgin Islands	503	*3.7%*	15,456.0	*7.8%*
Hong Kong SAR (China)	658	*4.9%*	11,311.1	*5.7%*
Malaysia	398	*3.0%*	11,074.7	*5.6%*
United States	609	*4.5%*	10,431.6	*5.2%*
Cayman Islands	53	*0.4%*	7,501.8	*3.8%*
Thailand	274	*2.0%*	5,853.3	*2.9%*
Netherlands	160	*1.2%*	5,817.5	*2.9%*
Brunei	123	*0.9%*	4,844.1	*2.4%*
Canada	114	*0.8%*	4,666.2	*2.3%*
China, PR	833	*6.2%*	4,338.4	*2.2%*
France	343	*2.6%*	3,020.5	*1.5%*
Samoa	90	*0.7%*	2,989.8	*1.5%*
United Kingdom	152	*1.1%*	2,678.2	*1.3%*
Cyprus	11	*0.1%*	2,357.9	*1.2%*
Switzerland	87	*0.6%*	1,994.6	*1.0%*
Luxembourg	22	*0.2%*	1,498.8	*0.8%*
Australia	261	*1.9%*	1,316.9	*0.7%*
British West Indies	6	*0.0%*	987.0	*0.5%*
Fed. Russian	77	*0.6%*	919.1	*0.5%*
F.R Germany	177	*1.3%*	900.2	*0.5%*
Denmark	92	*0.7%*	621.5	*0.3%*
Finland	7	*0.1%*	335.4	*0.2%*
The Philippines	61	*0.5%*	302.3	*0.2%*
India	61	*0.5%*	233.8	*0.1%*
Mauritius	34	*0.3%*	229.2	*0.1%*
Indonesia	30	*0.2%*	219.7	*0.1%*
Bermuda	5	*0.0%*	211.6	*0.1%*
Italy	40	*0.3%*	191.9	*0.1%*
Slovakia	4	*0.0%*	147.9	*0.1%*
Cook Islands	3	*0.0%*	142.0	*0.1%*
United Arab Emirates	4	*0.0%*	128.4	*0.1%*
Chanel Islands	15	*0.1%*	114.4	*0.1%*
Bahama	3	*0.0%*	108.6	*0.1%*
Belgium	40	*0.3%*	106.7	*0.1%*
Norway	28	*0.2%*	102.4	*0.1%*
Poland	9	*0.1%*	98.7	*0.0%*
New Zealand	18	*0.1%*	76.4	*0.0%*
Sweden	28	*0.2%*	71.7	*0.0%*

Source: General Statistics Office of Vietnam

Licensed foreign direct investment projects listed by type of economic activity are shown below. Looking at the projects having effect as of 31/12/2011, manufacturing (US$ 94.7 billion) accounts for about half of the total, followed by real estate activities (US$ 48.2 billion).

Table 4.6.2 Licensed Foreign Direct Investment Projects by Type of Economic Activity

(Accumulation of projects having effect as of 31/12/2011)

Economic activity	Number of projects		Total registered capital *(Mil.USD)*	
TOTAL	**13,440**	***100.0%***	**199,079**	***100.0%***
Agriculture, forestry and fishing	495	*3.7%*	3,265	*1.6%*
Mining and quarrying	71	*0.5%*	3,016	*1.5%*
Manufacturing	7,661	*57.0%*	94,676	*47.6%*
Electricity, gas, stream and air conditioning supply	72	*0.5%*	7,392	*3.7%*
Water supply, sewerage, waste management and remediation activities	27	*0.2%*	2,402	*1.2%*
Construction	852	*6.3%*	10,324	*5.2%*
Wholesale and retail trade; Repair of motor vehicles and motorcycles	690	*5.1%*	2,119	*1.1%*
Transportation and storage	321	*2.4%*	3,257	*1.6%*
Accommodation and food service activities	319	*2.4%*	10,523	*5.3%*
Information and communication	736	*5.5%*	5,710	*2.9%*
Financial, banking and insurance activities	75	*0.6%*	1,322	*0.7%*
Real estate activities	377	*2.8%*	48,156	*24.2%*
Professional, scientific and technical activities	1,162	*8.6%*	976	*0.5%*
Administrative and support service activities	107	*0.8%*	188	*0.1%*
Education and training	154	*1.1%*	359	*0.2%*
Human health and social work activities	76	*0.6%*	1,082	*0.5%*
Arts, entertainment and recreation	131	*1.0%*	3,603	*1.8%*
Other activities	114	*0.8%*	712	*0.4%*

Source: General Statistics Office of Vietnam

Licensed foreign direct investment projects listed by province are shown below. Looking at the accumulation of projects having effect as of 31/12/2011, South East (US$ 93.7 billion) including Ho Chi Minh is the top region, followed by Red River Delta (US$ 47.4 billion) including Hanoi and Hai Phong.

Table 4.6.3 Licensed Foreign Direct Investment Projects by Province

(Accumulation of projects having effect as of 31/12/2011)

Region/Province	Number of projects		Total registered capital *(Mill. USD)*	
WHOLE COUNTRY	**13,440**	***100%***	**199,079**	***100%***
Red River Delta	***3,682***	***27.4%***	***47,443***	***23.8%***
Hà Nội	2,253	*16.8%*	23,596	*11.9%*
Vĩnh Phúc	143	*1.1%*	2,274	*1.1%*
Bắc Ninh	251	*1.9%*	2,957	*1.5%*
Quảng Ninh	95	*0.7%*	3,794	*1.9%*
Hải Dương	253	*1.9%*	5,286	*2.7%*
Hải Phòng	338	*2.5%*	6,133	*3.1%*
Hưng Yên	214	*1.6%*	1,785	*0.9%*
Thái Bình	32	*0.2%*	254	*0.1%*

Hà Nam	42	*0.3%*	408	*0.2%*
Nam Định	38	*0.3%*	209	*0.1%*
Ninh Bình	23	*0.2%*	747	*0.4%*
Northern midlands and mountain areas	***345***	***2.6%***	***2,857***	***1.4%***
North Central area and Central coastal area	***809***	***6.0%***	***41,458***	***20.8%***
Central Highlands	***135***	***1.0%***	***773***	***0.4%***
South East	**7,746**	***57.6%***	**93,694**	***47.1%***
Mekong River Delta	***678***	***5.0%***	***10,258***	***5.2%***
Petroleum & Gas	**45**	***0.3%***	**2,597**	***1.3%***

Source: General Statistics Office of Vietnam

The number of licensed foreign direct investment projects in Hai Phong, which is the target project area for the study, is listed by counterparts below.

Looking at the accumulation of projects having effect as of 31/12/2011, the Japanese share (US$ 563.4 billion) is exceptionally large, followed by Singapore (US$ 22.6 billion).

Table 4.6.4 Licensed Foreign Direct Investment Projects in Hai Phong by Counterparts

(As of 31/12/2011)

	Number of projects		Total registered capital *(Mill. USD)*	
Total	**30**	*100%*	**611,655**	*100%*
Japan	10	*33.3%*	563,426	*92.1%*
Singapore	2	*6.7%*	22,600	*3.7%*
Hong Kong	2	*6.7%*	8,400	*1.4%*
Taiwan	2	*6.7%*	3,584	*0.6%*
Korea	3	*10.0%*	2,200	*0.4%*
China	5	*16.7%*	2,200	*0.4%*
Holland	1	*3.3%*	715	*0.1%*
Thailand	1	*3.3%*	330	*0.1%*
Others	4	*13.3%*	8,200	*1.3%*

Source: Hai Phong Statistical Yearbook 2011

Similarly, licensed foreign direct investment projects in Hai Phong, which is the target project area for the study, are listed below by type of economic activity.

Looking at the accumulation of projects having effect as of 31/12/2011, construction (US$ 321.0 billion) is on the top, followed by manufacturing (US$ 266.6 billion).

Table 4.6.5 Licensed Foreign Direct Investment Projects in Hai Phong by Type of Economic Activity

(Accumulation of projects having effect as of 31/12/2011)

Economic activity	Number of projects		Total registered capital *(Mill. USD)*	
TOTAL	**30**	***100.0%***	**611,655**	***100.0%***
Manufacturing	22	*73.3%*	266,575	*43.6%*

Electricity and water supply				
Construction	1	*3.3%*	321,000	*52.5%*
Trade	5	*16.7%*	1,480	*0.2%*
Hotel and restaurant	1	*3.3%*	20,600	*3.4%*
Transportation and storage	1	*3.3%*	2,000	*0.3%*
Real estate; renting business activities				
Education and training				
Culture and sport				
Health				

Source: Hai Phong Statistical Yearbook 2011

4.7 BCP Implementation Conditions in Vietnam

4.7.1 Major Natural Disasters and Disaster Management Awareness

In Vietnam, the government and enterprises consider typhoons, floods and storm surges as natural disaster risks. Committees handling climate change and sea level rise have been established at governmental ministries in charge of disaster management such as Ministry of Agriculture and Rural Development (MARD) and the Ministry of Industry and Trade (MOIT). These committeess deal with the improvement of regulations for disaster risk control.

Since the disasters that cause damage to business activities are rarely observed in the northern part of Vietnam near Hanoi and Hai-Phong, business people are not concerned with natural disaster risk in business situations, and the necessity of disaster management systems is barely understood. Local administrative agencies do not recognize the value of BCM/BCP.

The Vietnam Chamber of Commerce and Industry (VCCI) can support SMEs in establishing activities for business continuity in time of emergency in conjunction with a contingency response system. They assume that the concepts of BCM and Disaster Risk Management (DRM) are not distinct.

4.7.2 Implementation of BCP

(1) Implementation of BCP by Enterprises

In Vietnam, enterprises are generally not making efforts for disaster risk mitigation in business situations, and corporate disaster management is not valued among most business managers. Individual enterprises have less concern about disaster risk mitigation, since they have had little experience with large disasters in northern Vietnam, especially in the industrial parks of Hai Phong or other provinces.

As an example of DRM implementation, large-scale enterprises and foreign capital companies conduct disaster risk assessment or establish disaster risk management systems. However, most

SMEs cannot afford to consider DRM in their present circumstances. Enterprises that established DRM are mainly engaged in emergency response or contingency management, but not disaster preparedness.

(2) Implementation of BCP by Utility Suppliers and Distributors

Enterprises that handle hazardous materials such as oil, coal or minerals, and enterprises in charge of utilities such as electricity companies have developed contingency plans or crisis management plans. These enterprises and corporations are obligated by law to establish a crisis management system. Though corporate response in times of emergency caused by flooding or storms, and policies for quick recovery of business activities are defined in these contingency or management plans, cases where specific BCP have been established have not ascertained.

(3) Implementation of BCP by Foreign Capital Companies and Japanese Companies

Although BCP is not yet well known, even among foreign capital companies in Vietnam, there has been a gradual increase of cases in which the head office or related customers require a BCP. Moreover, Japanese enterprises have become increasingly concerned about BCP implementation, and the Japan Business Association in Vietnam (JBAV) has made an effort to educate member companies on BCP.

Even foreign capital companies are generally not concerned about natural disaster risk. With the exception of some large-scale companies, most enterprises do not conduct BCM/BCP.

4.7.3 Efforts for Implementing BCP

(1) Regulations or Guidelines for the Implementation of BCP

In the present legislative system, Decree No. 168-HDBT outlines the role of the Central Committee of Storm and Flood Control (CCSFC), and the committees and sectors at every local level. In this decree, cooperation by the private sectors in disaster damage assessment and rehabilitation activities is defined as a corporate obligation. However, there are no laws defining corporate efforts in developing BCP or Disaster Risk Management Plans.

The new Law of Disaster Risk Management went into effect in 2014. This new law obligates all enterprises and agencies to develop Disaster Risk Management Plans. However, the development of contingency plans or BCP is still not regulated.

Disaster management policy in Vietnam has focused on mitigating human suffering, as opposed to reducing business loss. Concern regarding the implementation of BCP has increased as the impact of disaster damage on the economy and foreign investment is being considered. A symposium was held for ASEAN countries in order to discuss BCP.

(2) Private Sector Efforts in BCP Education and Dissemination

Efforts for the dissemination of DRM to SMEs are being made by private sectors such as the VCCI. Though the establishment of emergency response plans and disaster preparedness should be higher priority than BCP, symposiums on corporate DRM have been held, and enterprises are becoming more concerned with business continuity during disasters.

VCCI is strongly motivated in disseminating corporate disaster management to SMEs, and they are currently studying certification standards for disaster management as part of CSR.

(3) BCP Implementation Problems

In Vietnam, most enterprises and state administrations think that DRM in business is not important. They have placed weight on business growth instead of the implementation of BCP. As a part of corporate risk management, DRMs should be conducted first.

Due to the shortage of resources using DRM or disaster risk assessment, improvement of social infrastructures such as electricity, water, and traffic networks has not been achieved. Private enterprises assume that they cannot afford to develop disaster management systems and BCM.

The lack of knowledge or technical know-how on risk assessment and in developing BCP is also regarded as a problem.

4.8 Current State of Disaster Risk Management

In order to review the current state of the disaster risk management, questionnaire surveys were conducted by the local consultant.

4.8.1 Questionnaire Surveys

Questionnaires were prepared for five organizations deeply or markedly involved with Area Business Continuity Plans (A-BCP). The purpose of the questionnaires was to analyze the current practices and readiness of both A-BCP and individual BCP. A review of these questionnaires review will be used as a basis for formulating the framework of the JICA's Area Business Continuity Plan.

Focuses of the questionnaires are:

- ✓ assessment of the six industrial parks in Hai Phong;
- ✓ disaster risk management applied by 54 business enterprises as tenants of the Hai Phong Industrial Zone;
- ✓ assessment of lifeline utilities services;
- ✓ assessment of traffic infrastructure operators;
- ✓ disaster risk management applied by various levels of governments.

The results of the questionnaire survey as summarized as follows:

1) Collection ratio (= Collected numbers divided by the total number of requests)

- Industrial Parks: 6/7 or 86%
- Business Enterprises: 46/77 or 60% (both emails and telephone interviews)
- Lifeline Utility Companies: 4/4 or 100%
- Traffic Infrastructure Companies: 4/5 or 80%
- Local Governments: 3/4 or 75%

2) Reasons for the low collection ratio

Industrial Parks:

- ✓ Questionnaires were sent out to seven industrial parks in Hai Phong including Nomura, VSIP, Trang Due, Dinh Vu, Nam Cau Kien and Trang Cat.
- ✓ All gave feedback except for Trang Cat. This IZ organized a ground-breaking ceremony, but has no office or staff on site. Therefore, it was impossible to conduct follow-up.

Business Enterprises:

- ✓ Questionnaires were emailed to 54 tenants of Nomura Hai Phong Industrial Zone (NHIZ) through its Management Authority.
- ✓ 23/ 54 enterprises answered; 17/54 refused to answer; others could not be contacted.

Lifeline Utility Companies:

- ✓ Questionnaires were sent to the main service providers in the four lifeline utility sectors including telecom, sewage, water supply and electricity supply
- ✓ All responded.

Traffic Infrastructure Companies:

- ✓ Questionnaires were sent to Hai Phong Railway Station, Hai Phong Port, Cat Bi Airport, Hai Phong Department of Transport and the Association of Transport Enterprises. Four responded. The Association of Transport Enterprises refused to answer because they found the questions not relevant to them.

Local Governments:

- ✓ Questionnaires were sent to five local government agencies in Hai Phong including the Department of Dyke and Flood and Storm Management, Department of Transport, Department of Industry and Trade, Department of Information and Communication, and Department of Planning and Investment.
- ✓ Four responded.
- ✓ The Steering Committee for Flood and Storm Management and Search and Rescue is in charge of comprehensive disaster management in Hai Phong City, but it is only an ad-hoc

organization. Meanwhile, the Secretary General of this Committee is also the Director of the Department of Dykes and Flood and Storm Management. Therefore, the questionnaire was sent to him with the request for reply on behalf of both organizations.

- ✓ The Department of Planning and Investment refused to answer because they found the questions not relevant to them.

The reply from the Department of Industry and Trade was submitted and summarized together with the group of traffic infrastructure companies because it relates closely to traffic infrastructure.

4.8.2 Review of the Questionnaire Surveys for Industrial Parks

The list of respondents is as follows:

- Nomura Hai Phong (NHIZ)
- VSIP
- Trang Due
- Dinh Vu
- Nam Cau Kien
- Do Son

The following are the results from the questionnaire survey given to the industrial parks.

1) Lifeline utility service interruptions and the causes of interruption are summarized as follows.

<u>Electricity supply:</u>

Nomura Hai Phong Industrial Zone (NHIZ): Regarding the electricity supply from PC Hai Phong (or EVN Hai Phong) to NHIZ, in 2010, there were 12 interruptions. However, since 2011, there has been only outage. The average length of the outages is 45 minutes. The interruptions are usually caused by problems at the EVN substation. However, NHIZ confirmed that there is no interruption in the power supply to their tenants since they have a backup power source.

<u>Water supply:</u>

Nomura Hai Phong Industrial Zone: NHIZ confirmed that there are many interruptions per year in the water supply from the city's system to NHIZ, but each of them lasts just for a short time and does not affect operations. Such interruptions are often due to broken water pipes. NHIZ also admitted that there was an interruption in their internal water supply system that lasted for 4 hours.

<u>Sewerage:</u>

According to NHIZ's records, there has been no interruption in sewage services. Three other industrial parks responded with the same answer. Others provided no information on this.

Telecommunication:

According to NHIZ's records, there has been no interruption in telecom services.

City gas:

No city gas supply.

2) Damages to roads and other traffic infrastructure caused by natural disasters are summarized as follows.

- ✓ All respondents confirmed that they have not experienced a situation in which in all direct roads to the industrial parks flooded simultaneously.

- ✓ When asked whether incidents and natural disasters caused serious damages to industrial parks, 33% of them answered "Yes" while 67% of them answered "No." Amongst other kinds of damage, there has been internal inundation and fallen trees on the roads inside the industrial parks.

3) The following are the results on business continuity in disasters.

- ✓ When asked about difficulties in business continuity during incidents or disasters, their concerns mainly focus on electricity interruptions and limited access to roads. They have no problems with the availability of their employees in case of disasters.

4) Main requests with respect to disaster control measures

✓ Requests to either the local government or lifeline utility/traffic infrastructure operators focus mainly on better quality of service and improved infrastructure.

4.8.3 Review of the Questionnaire Surveys for Business Enterprises

The respondents from Nomura Hai Phong (NHIZ) are listed in the following table.

Table 4.8.1 Tenant in NHIZ

No.	Name of tenants/ business firm
1	Synztec Vietnam
2	Tetsugen Vietnam
3	Tohoku Pioneer Vietnam
4	Toyota Boshoku Hai Phong
5	Vietnam Arai Co. Ltd
6	Vina-Bingo Co. Ltd.
7	Yanagawa Seiko Vietnam
8	Yoneda Vietnam
9	Johuku Hai Phong
10	PV Hai Phong
11	Korg Vietnam
12	EBA Machinery
13	Fuji Mold Vietnam
14	Fuji Seiko Vietnam
15	Toyoda Gossei Hai Phong
16	Iko Thompson Vietnam
17	Lihit Lab Vietnam Inc.
18	Nichias Hai Phong
19	Nishishiba Vietnam
20	Sougou Vietnam
21	Sumibubber Vietnam
22	Yazaki Hai Phong
23	Kokuyo Vietnam Co. Ltd.
	Source: VIETBID (Local consultant in Vietnam)

The following are results of the questionnaire survey given to business enterprises in NHIZ.

1) Lifeline utility service interruptions and the causes of interruption are summarized as follows.

- ✓ Interruption of lifeline utility services

  No comments because the questionnaires did not ask about this issue.
- ✓ Normally used traffic infrastructure and roads

  Most of the respondents use National Road No. 5, Hai Phong Port and Noi Bai Airport as their usual traffic infrastructures. Cat Bi Airport is also a popular choice. Only one of them uses railway as the first choice for logistics.
- ✓ Alternative traffic infrastructures

  None of the respondents specified the names of alternative roads, but they specified many alternative ports in Hai Phong and surrounding areas.

Although railway is not their normally used traffic infrastructure, 50% choose it as the alternative for logistics.

2) Disaster Prevention Plans, Business Continuity Plans and concerns

Half of the respondents do not have long term or even annual disaster management plans or business continuity plans. They only make decisions on prevention measures on a case by case basis before disasters, depending on the warnings on the weather forecasts. Recovery measures are decided after they see the actual damages.

With regard to BCPs, some respondents, 13%, answered "NA" instead of "No," because in their minds, BCPs are integral parts of disaster management plans and, conversely, disaster management plans are set up for business continuity purposes. In fact, they do not have disaster management plans, and this fact implies that BCPs are not available in their organizations either.

The concerns and difficulties with respect to the implementation of BCPs are varied, but unstable human resources and interruption of infrastructure services are the notable ones. Some enterprises are concerned about the interruption of the supply of materials. This, in turn, is also partly caused by the latter of the above.

The reason why there were many “NA” or “No” or “No ideas” answers may be due to the 48% of respondents with no disaster risk management plans or BCPs, as seen in the above charts.

3) Requests with respect to disaster control measures

A significant number of respondents did not have any requests.

The requests, if any, were various, but mainly emphasize more efficient preventive measures and quicker reactions from the local governments and infrastructure service providers.

4.8.4 Review of the Questionnaire Surveys for Lifeline Utility Companies

The list of respondents is as follows:

- VNPT Hai Phong
- Hai Phong Sewage Company
- Hai Phong Water Supply
- Hai Phong Power company (PC Hai Phong or EVN Hai Phong)

The following are the results from the questionnaire survey given to the lifeline utility companies.

1) Target and typical disasters for their disaster mitigation plans

- ✓ Water supplier: flood, storm and pollution of water resources
- ✓ Sewage operator: earthquake, flood, storm and storm surge
- ✓ Electricity supplier: flood, storm and storm surge
- ✓ Communication operator: flood, storm and storm surge

2) Emergency supply

- ✓ Electricity: All the respondents, except for the water supplier, have generators for emergency electricity supply.
- ✓ Communication: All the respondents have their own emergency communication solutions.

3) Interruption of supply and the causes of the interruption

- ✓ Water supplier: No interruption.
- ✓ Sewage operator: No interruption.
- ✓ Electricity supplier: Power was interrupted over large areas due to tornados or typhoons.
  - · Typhoon No. 2 on 25 June 2011, Typhoon No. 3 on 30 July 2011 and No. 5 on 30 Sep in 2011
  - · Typhoon No. 5 and No. 8 in 2012
  - · Typhoon No. 5 in 2013

  The reasons for the interruptions were strong winds and floods. In most cases, the power supply was resumed very soon after the incidents. In some cases, the power supply was resumed after 24 to 48 hours.

✓ Communication operator: There was an interruption during a typhoon.

- Typhoon No. 8 in 2012 due to strong wind and heavy rain.
  However, the interruption did not last for a long time or occur over a large area. It only happened with wire-line services in limited village areas only. Mobile telecommunication services were still ensured, and thus there were no effects on businesses.

4) Requests with respect to disaster control measures

To the local governments:

- ✓ Water supplier:
  - Improve infrastructures, especially pumping stations, to prevent floods and inundation.
- ✓ Water sewage operator:
  - Construct additional pumping stations.
- ✓ Electricity supplier:
  - No information
- ✓ Communication operator:
  - Improve capabilities for sea dykes and islands to prevent high waves and storm surge

To lifeline utility services:

- ✓ Water supplier:
  - Improve infrastructures, especially pumping stations, to prevent flood and inundation.
  - Construct sea dikes to prevent the overflow of sea water due to sea level rises during typhoons.
  - Ensure 24 hours/ 7 day electricity supply.
- ✓ Water sewage operator:
  - Ensure 24h power supply to the pumping stations
- ✓ Electricity supplier:
  - No information
- ✓ Communication operator:
  - Ensure safety of the power grid
  - Strengthen the power supply capability during storms and heavy rains
  - Proper layout of power supply system/ transmission routes
  - No power cut-off on large areas at the same time
  - Quick restoration of communication cables when they are broken down by fallen trees.

To traffic infrastructure services:

- ✓ Water supplier:
  - Quicker licensing procedures for digging roads and pavements so that the repair of broken pipelines and recovery of water supply services can be completed as soon as possible after the incidents.
- ✓ Water sewage operator:

  No information
- ✓ Electricity supplier:
  - No information
- ✓ Communication operator:
  - Ensure the safety of travelers during floods and inundations
  - Quick response to traffic congestion due to fallen trees

4.8.5 Traffic Infrastructure Companies

The list of respondents is as follows:

- Hai Phong Railway Station
- Hai Phong Port
- Cat Bi Airport
- Hai Phong Department of Transport

The following are the results from the questionnaire survey given to the traffic infrastructure companies.

1) Target and typical disasters for the disaster mitigation plan

✓ Road operator: Earthquake, flood, storm

✓ Port operator: Earthquake, flood, storm and others (tornados, heavy rains, inundations, etc.)

✓ Airport operator: Storm

✓ Railway operator: Earthquake, flood, storm, storm surge and others, e.g. terrorism

2) Emergency supply

✓ Electricity: All the respondents, except for the railway operator, have their own generators for emergency electricity supply.

✓ Communication: All the respondents have their own emergency communication solutions.

3) Interruption of supply and the causes of the interruption

✓ Road operator: There was an interruption during Typhoon No. 5 in 2013 when all offices on the ground floors of DOT's buildings were flooded. The standing water did not drain for 2 days due to the rising tides.

✓ Port operator: No interruption.

✓ Airport operator: No interruption.

✓ Railway operator: There were interruptions during the following disasters:

Typhoon No. 5 on 18 Aug. 2012

- Reason: Trees fell onto the railway section between Hai Phong and Thuong Ly.
- Duration: From 0.40 am to 2.50 am, 18 Aug 2012

The Typhoon on 28 and 29 Oct. 2012

- Reason: Trees fell onto the railway section between Hai Phong and Thuong Ly.
- Duration: From 2.15 am to 7.20 am, 29 Oct. 2012.

The heavy and prolonged rain on 29 and 30 Jun. 2013

- Hazard: Rainfall=over 200 mm, rain duration=10 hours
- Reason: The railways in Hai Phong Railway Station were heavily inundated.
- Duration: From 3.00 am to 7.30 am, 30 Jun 2013

4) Requests with respect to disaster control measures

To the local governments

✓ Road operator:

- Funds for raising the base course of the yard and the ground floors of office buildings
- Investments to prevent impacts of climate changes

- ✓ Port operator:
  - No information
- ✓ Airport operator:
  - Further support and assistance in terms of technical equipment and human resources for disaster recovery.
- ✓ Railway operator:
  - More active support and assistance to help Hai Phong Railway Station overcome disaster effects and return to normal operations in the shortest period of time.

To the lifeline utility services

- ✓ Road operator:
  - Subterraneanize the lines and cables
- ✓ Port operator:
  - No information
- ✓ Airport operator:
  - Ensure an uninterrupted supply so that Cat Bi Airport and other entities can return to normal operations quickly after disasters.
- ✓ Railway operator:
  - Quick responses in environmental and electricity supply recovery

To the traffic infrastructure services

- ✓ Road operator:
  - Regulations on coordination amongst local authorities and lifeline utility companies when natural disasters occur
- ✓ Port operator:
  - No information
- ✓ Airport operator:
  - Active and immediate support and assistance in the transport of passengers and staff members after disasters occur.
- ✓ Railway operator:
  - When train congestion occurs on the railway due to natural disaster, there should be support and coordination from other operators of transportation means such as busses and trucks to ensure the transportation of passengers and cargo.

4.8.6 Review of the Questionnaire Surveys for Local Governments

The list of respondents is as follows:

- Steering Committee for Flood and Storm Management and Search and Rescue of the city/ Hai Phong Department of Dyke and Flood and Storm Management
- Hai Phong Department of Industry and Trade
- Hai Phong Department of Information and Communication

The following are the results from the questionnaire survey.

1) Target and typical disasters for the disaster mitigation plan

All the respondents answered that floods, storms/storm surges and tsunamis are covered in their disaster mitigation plans. Earthquakes are considered in two-thirds of the plans. Some other disasters such as tornados, low tropical pressure systems, and oil spills are also covered.

2) Target and typical disaster for damage predictions

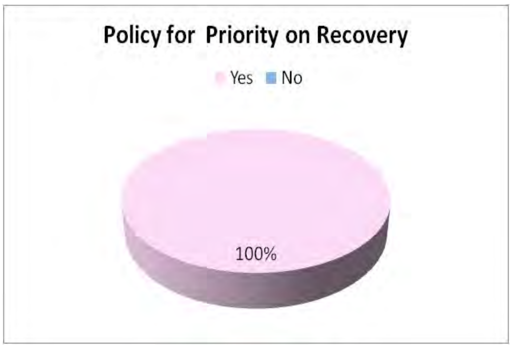
Similar to the above, earthquakes, floods, storms/storm surges and other disasters such as low tropical pressure systems, tsunamis, tornados, etc. are covered in their damage predictions.

3) Disaster response for residents

- ✓ Educate and improve residents' awareness on the possible effects of natural disasters and how to prevent and mitigate them ------- 1
- ✓ Provide warnings on areas which are in danger of being hit by natural disasters-----1
- ✓ Evacuate residents and protect evacuated houses-----3
- ✓ Provide temporary shelters/toilets-----3
- ✓ Search and rescue ----- 1
- ✓ Provide financial support to effected households ----- 1

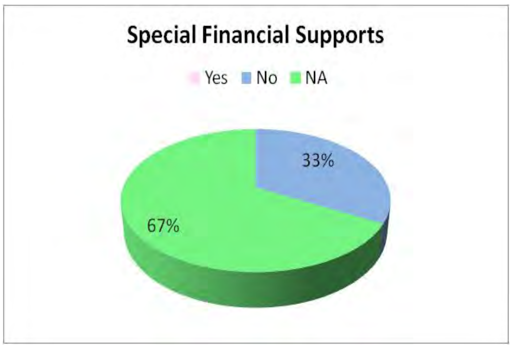
4) Disaster response for companies in terms of the recovery of lifeline utilities or traffic infrastructure.

All the respondents answered that they have policies to place priority on companies for the recovery of lifeline utilities and traffic infrastructure.



5) Financial support during disasters

According to the survey results, no financial support from the central governments or other authorities is provided to enterprises for disaster recovery.



6) Impacts of disaster to local government operations

The only damage on record is the interruption of services due to infrastructure damage.

7) Public disclosure of information on hazards/risks

According to the respondents, information on hazards/risks open to the public should include deaths, injuries and damages to infrastructures, production and trading, etc.

8) Requests with respect to disaster control measures

To the local governments

Two-thirds of the respondents expressed that they would like to be provided with more dedicated search and rescue forces and more equipment to facilitate their work.

More investments and budgets are other main requests.

To lifeline utility services

For lifeline utility services, as with other service users, local government agencies also emphasize better service quality and quicker reactions for disaster recovery. This is especially the case for the continuity of the electricity supply to facilitate local government operations in the case of emergency.

Regular training for their staff and workers is also strongly requested.

To traffic infrastructure services

50% of the responding local government bodies requested that traffic infrastructure operators be well-prepared for efficient and quick recovery after disasters to ensure that their services are not interrupted.

50% of did not have any requests.

Appendix Details of Natural Hazard Assessments

A.1 Seismic Hazard Assessment

The methodology of seismic hazard simulation is roughly divided into deterministic methodology and probabilistic methodology. By the deterministic methodology, earthquake ground motion is calculated if the specific earthquake source fault has been activated. The earthquake ground motion distribution by the future possible earthquake can be calculated precisely, but to estimate when the calculated earthquake ground motion will be realized is difficult because it is impossible to predict the future earthquake by current technology. By the probabilistic method, the expected earthquake ground motion within a certain period at the study point is calculated considering all the earthquake sources around the study point reflecting the possibility of each sources. Therefore, the earthquake motion distribution by probabilistic method is not the estimation of the earthquake motion distribution by future probable earthquake but the ensemble of independent expected earthquake motion at each point. The deterministic method is commonly used for disaster management purpose and the probabilistic methodology is usually used for zoning in the building seismic code or earthquake insurance system etc.

The probabilistic method is adopted in the seismic hazard analysis for area BCP because the probability of the hazard is important. The hazard that has high possibility to occur in the lifetime of the industrial facilities is considered in area BCP, therefore to estimate the probability of the hazard is essential component in the analysis.

A.1.1 Methodology of Probabilistic Seismic Hazard Analysis

(1) Summary

The combination of earthquake ground motion at a certain point and the probability to experience at least the ground motion in a certain period is calculated by the probabilistic seismic hazard analysis method. The flow of the analysis is shown in Figure A.1.1.

The general steps of the analysis are as follows.

1) Set up the model of seismic activity around the study point. Not only the earthquakes that the source faults are clearly known but the earthquakes that the earthquake sources are not known and definite estimation of the magnitude and the location of future event is difficult should be included.

2) Estimate the probability of the magnitude, probability of the distance from the study point and the probability of the occurrence of the modeled earthquakes.

3) Set up the probability model to estimate the earthquake ground motion if the magnitude of the earthquake and the distance from the study point are given. The empirical attenuation equation and the dispersion of the equation are usually used.

4) Calculate the probability that the earthquake ground motion at the study point by modeled earthquake become larger than a certain value in a certain period.

5) Steps 1) to 4) are carried out for each modeled earthquake and all the probabilities are aggregated. The probability to experience a certain earthquake ground motion at least once in a certain period at the study point is calculated as a result.

McGuire, R. K. (2004)[1] is recommended as a textbook of probabilistic seismic hazard analysis.

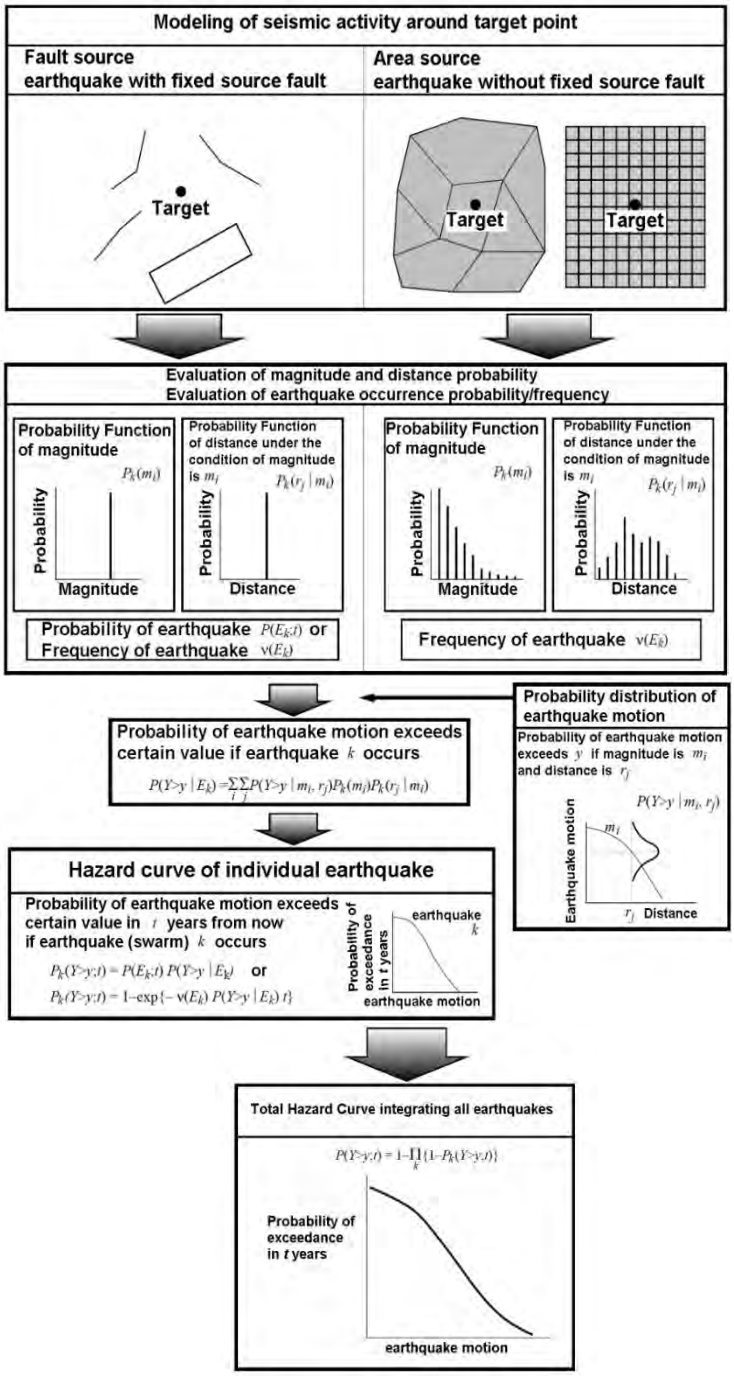


Figure A.1.1 Flowchart of probabilistic seismic hazard analysis (NIED (2005)[2], original in Japanese)

(2) Software for analysis

As the probabilistic seismic hazard analysis involves complicated numerical calculation, many computing programs are developed and some of them are freely available. Among them, SEISRISK, FRISK, CRISIS, NSHMP and OpenSHA are famous but they are intended to be used by the researchers or the engineer with expert knowledge. Danciu et al. (2010)[3] compiled the precise information about the probabilistic seismic hazard analysis programs. Table A.1.1 is the general information of the major software for probabilistic seismic hazard analysis by Danciu et al. (2010).

Table A.1.1 Major software for probabilistic seismic hazard analysis

Software Name	Version	Developer	Availability	Documentation	GUI	Program Language
CRISIS	6.0 (2007)	Ordaz, M., et al	Free upon Request	User Manual	Yes	Visual Basic
EQRM	3.2 (2009)	Robinson, D. et al.	Open Source	User Manual	No	Python
FRISK88M	1.8	R. McGuire	Proprietary	User Manual	No	Fortran
MoCaHAZ	2004	S. Wiemer	Free upon Request	Self-Explained	No	MATLAB
MRS	3.0	R. Laforge	Free upon Request	User Manual	No	C
NSHMP	2008	Frankel et al.	Free-Download	Self-Explained	No	Fortran, C
OHAZ	2.1	B. Zabikovic	Free upon Request	User Manual	Yes	Java
OpenSHA	2009	E. H. Field et al.	Open Source	Self-Explained	No	Java
SEISRISK IIIM	1996	Bender , B Perkins, D.M, R. LaForge	Free-Download	User Manual	No	Fortran
SeisHaz	2005	M. Stirling et al	Proprietary	Self-Explained	No	Fortran

EZ-FRISK is the expanded commercial version of FRISK and offered by Risk Engineering Inc. The analysis by EZ-FRISK is comparatively easy because the earthquake source model and attenuation formula are provided with computing program. EZ-FRISK Ver. 7.62 was used in this study.

(3) Source model

The earthquake source model should include all the seismic activities within several 100km from the study point. The active faults in the area are modeled at first because earthquake basically occurs by the activity of the fault. However, not all the active faults are known or studied of the properties, the earthquakes that the earthquake sources are not known and definite estimation of the magnitude and the location of future event is difficult are modeled as the background seismic activities also. As the creation of the earthquake source model needs high grade capacity and expert knowledge, earthquake modeling is usually conducted in university or public research institute. Therefore, to conduct originally new probabilistic seismic hazard analysis, the earthquake source model should be given from academic organization.

As mentioned above, the source models provided with EZ-FRISK are used in this study.

(4) Attenuation formula

The so-called empirical attenuation formula is used to calculate the earthquake ground motion from the magnitude of the earthquake and the distance between epicenter and the study point. Many researchers proposed various attenuation formulas for several decades. They have different features based on the database and the algorithm that were used to create the formula, and they also have the limitation of applicability. It is desirable to use the attenuation formula that was intended to use the study site. The newer proposed attenuation formula is generally desirable to use because newer formula is derived based on the more precise recent earthquake observation records.

The empirical attenuation formula for ASEAN region is not known. In this study, following formula based on the world wide earthquake observation records are adopted.

[for shallow crustal earthquake]

- ✓ Abrahamson and Silva (2008)[4)]
- ✓ Boore and Atkinson (2008)[5)]
- ✓ Campbell and Bozorgnia (2008)[6)]
- ✓ Chiou and Youngs (2008)[7)]

[for deep plate boundary earthquake]

- ✓ Atkinson and Boore (2003)[8)]
- ✓ Youngs et al. (1997)[9)]

A.1.2 Amplification Analysis of the Surface Ground

(1) Summary

The earthquake ground motion is affected by not only the magnitude and the distance but by the ground condition around the study area. The seismic wave is amplified by the surface grounds and the extent of amplification is different depending on the structure of the surface ground. Some of the empirical attenuation formula includes the effect of surface ground amplification but another method is usually used to evaluate the wide area. At first, the earthquake motion at the bedrock is calculated by the empirical attenuation formula and the amplification of the surface ground is multiplied to get the surface ground motion.

There are several methodology to evaluate the amplification characteristics of surface grounds; for example, based on the surface soil, based on the average S wave velocity of surface soil layers and numerical response analysis using the ground structure model. The suitable method is selected considering the available data, necessary work and budget.

In this study, the method based on the surface soil is used.

(2) Ground classification and amplification factor

The classification of the ground and the amplification factor by FEMA (1995)[10)] is adopted in this study (see Table A.1.2 and Table A.1.3). They are developed in U.S.A. and used in many countries recently. The soil profile, average S wave velocity of upper 30 meters and N value are used to define the site class.

Followings are the adopted ground classification based on the geologic time read from collected geologic maps.

- ✓ Class B: Tertiary and before
- ✓ Class C: Pleistocene
- ✓ Class D: Holocene
- ✓ Class E: River deposit and marine deposit in Holocene

Table A.1.2 NEHRP Classification

Site Class	Profile	Average S-wave velocity of the upper 30 meters	N value
A	Hard rock	> 1500 m/sec	
B	Rock	1500 ≥ Vs > 760 m/sec	
C	Very dense soil and soft rock	760 ≥ Vs > 360 m/sec	N > 50
D	Stiff soil	360 ≥ Vs > 180 m/sec	50 ≥ N ≥ 15
E	Soil	180 m/sec ≥ Vs	15 > N

Table A.1.3 NEHRP Amplification

Site Class B Spectral Acceleration	Site Class				
	A	B	C	D	E
Short-Period, S_{AS} (g)	Short-Period Amplification Factor, F_A				
≤ 0.25	0.8	1.0	1.2	1.6	2.5
0.50	0.8	1.0	1.2	1.4	1.7
0.75	0.8	1.0	1.1	1.2	1.2
1.0	0.8	1.0	1.0	1.1	0.9
≥ 1.25	0.8	1.0	1.0	1.0	0.9

A.1.3 Expression of the Results

(1) Methodology of expression

The calculated earthquake ground motion by the probabilistic method is expressed as follows.

a) The probability that the study site experiences a certain earthquake ground motion.

ex. The probability is 10% in 50 years to experience 100 gals or more.

b) The earthquake ground motion value for a certain probability.

ex. 100 gals or more will be experienced on the probability of 10% in 50 years.

The probability is expressed as the combination of the period and the probability in the period. If the seismic activity is uniform not depending on the year, probability can be expressed by annual probability.

In this study, the calculated results are expressed by the method b) above. It should be noticed that the earthquake motion distribution by probabilistic method is the ensemble of independent expected earthquake motion at each point and it is not related to the activity of a certain fault.

(2) Seismic Intensity

The calculated value is a physical quantity, such as peak ground acceleration or velocity. The seismic intensity is another expression of the strength of the ground vibration by the earthquake and more popularly understandable. The seismic intensity is also used to estimate the damage based on the past earthquake disaster experiences. In this study, peak ground acceleration is converted to seismic intensity in MMI scale following empirical formula by Trifunac and Brady (1975)[11)].

$\log PGA = 0.014 + 0.30*I$ PGA: peak ground acceleration (gal), I: seismic intensity (MMI)

A.1.4 Simulation and Results

(1) Source model

The source model for the Vietnam is shown in Figure A.1.2. The surface projection of source models is shown in rectangular shape or folded lines. The seismic activities that the location and the magnitudes are not identified in advance are modeled as the comparatively broad area sources.

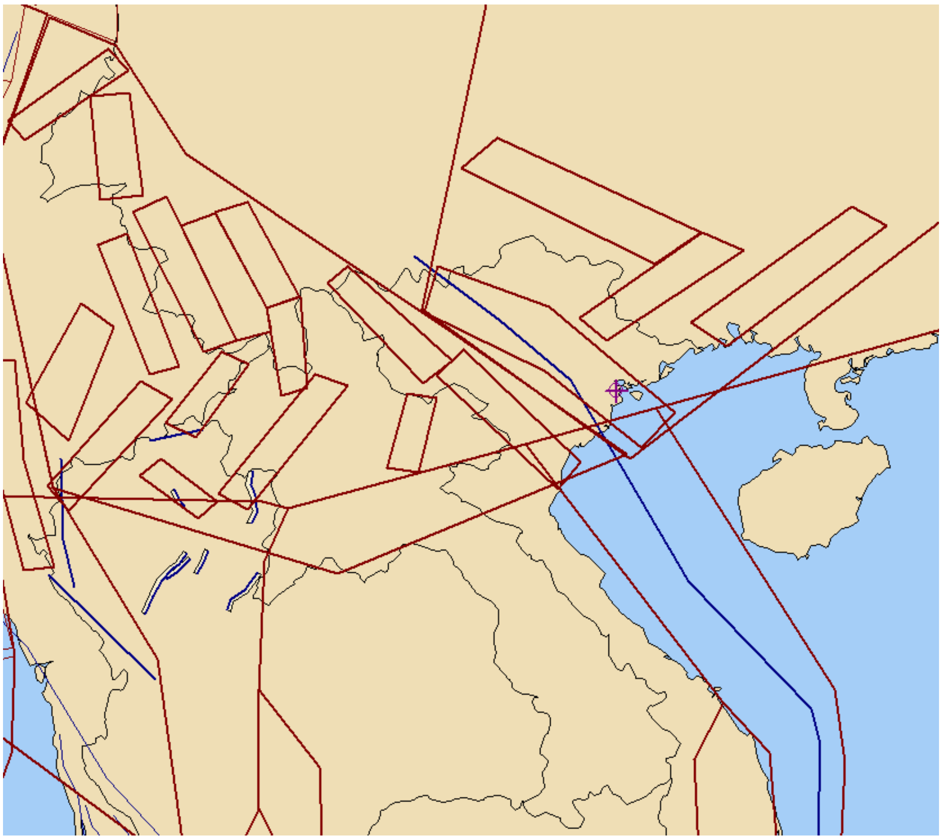


Figure A.1.2 Source model for Vietnam

(2) Baserock motion

The acceleration distribution on the ground with Vs=760 m/sec is shown in Figure A.1.3 to Figure A.1.6. The expected probability of occurrence is at least once in 50, 100, 200 or 500 years (50, 100, 200 or 500 years probability). The calculated acceleration is larger in south.

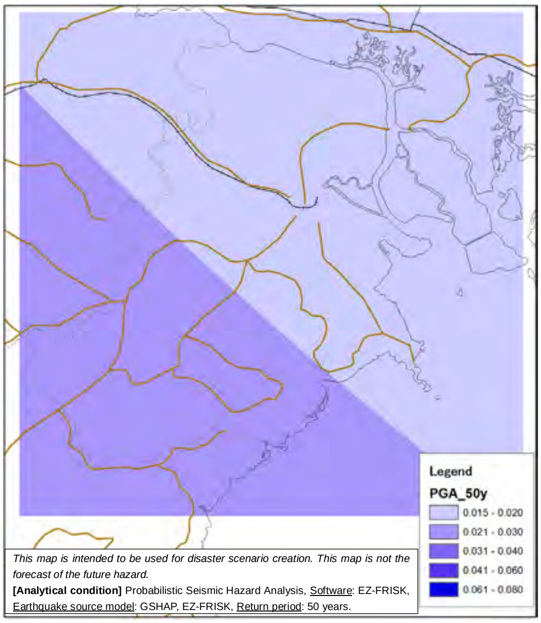


Figure A.1.3 Baserock acceleration distribution (expected for 50 years, unit: g)

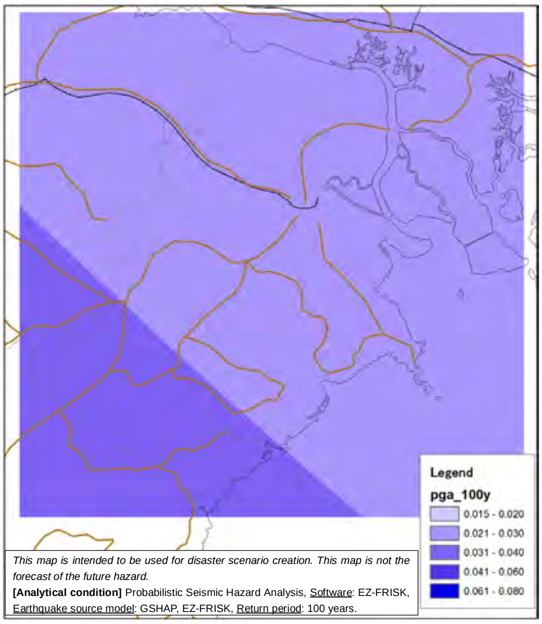


Figure A.1.4 Baserock acceleration distribution (expected for 100 years, unit: g)

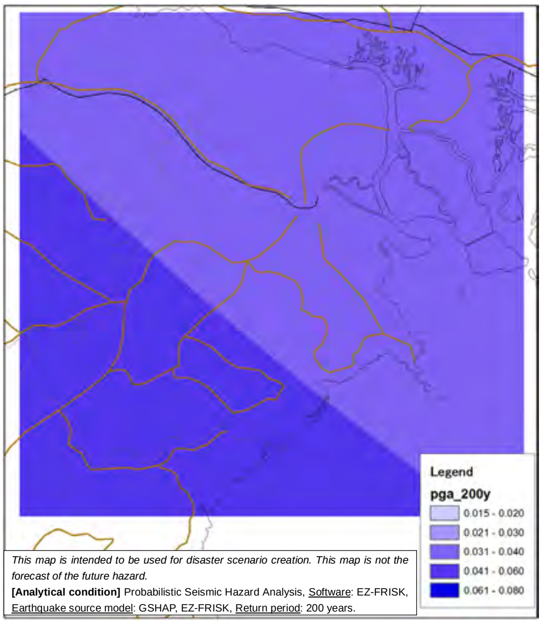


Figure A.1.5 Baserock acceleration distribution (expected for 200 years, unit: g)

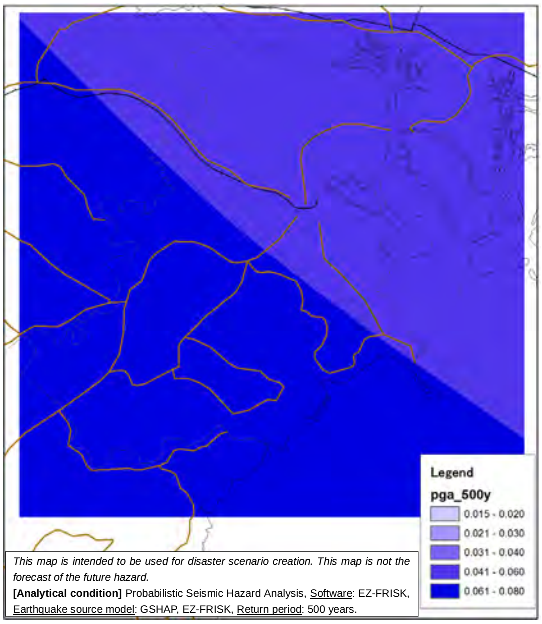


Figure A.1.6 Baserock acceleration distribution (expected for 500 years, unit: g)

(3) Ground classification

The digital geological map offered by Dr. Phuong of the Institute of Geophysics (IGP) is used for the ground classification. The ground of study area is classified based on the geological time. The ground classification map is shown in Figure A.1.7.

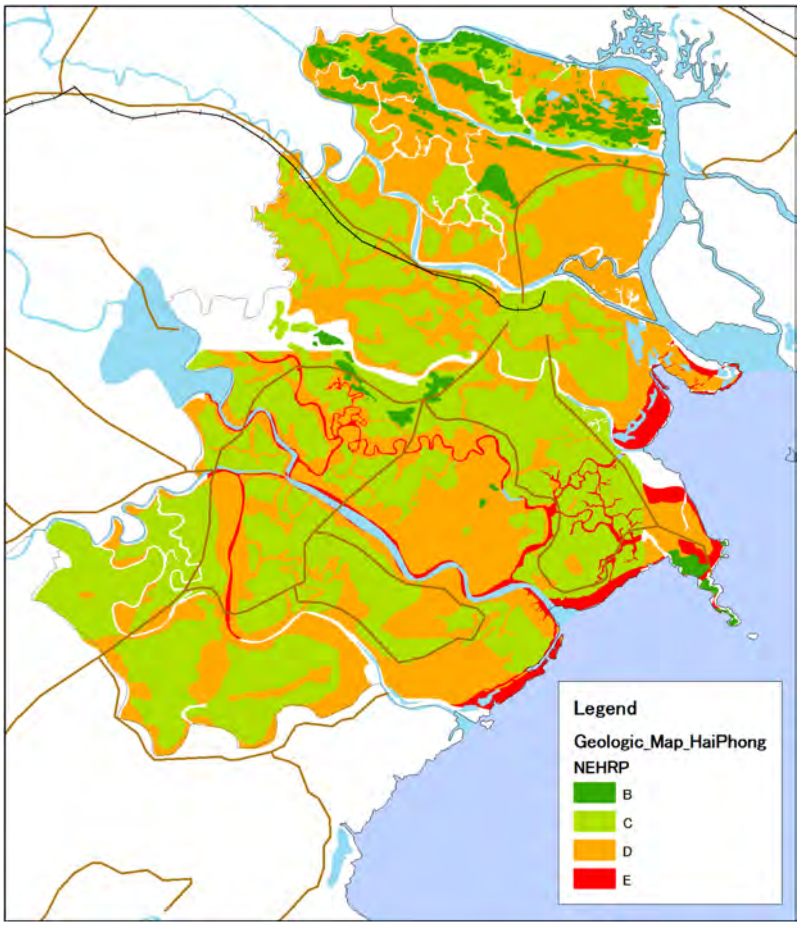


Figure A.1.7 Ground classification

(4) Surface motion

The acceleration at the ground surface is calculated multiplying the amplification factor to the acceleration value at the baserock. The results are shown in Figure A.1.8 to Figure A.1.11. The acceleration value is converted to seismic intensity in MMI scale by empirical equation and shown in Figure A.1.12 to Figure A.1.15.

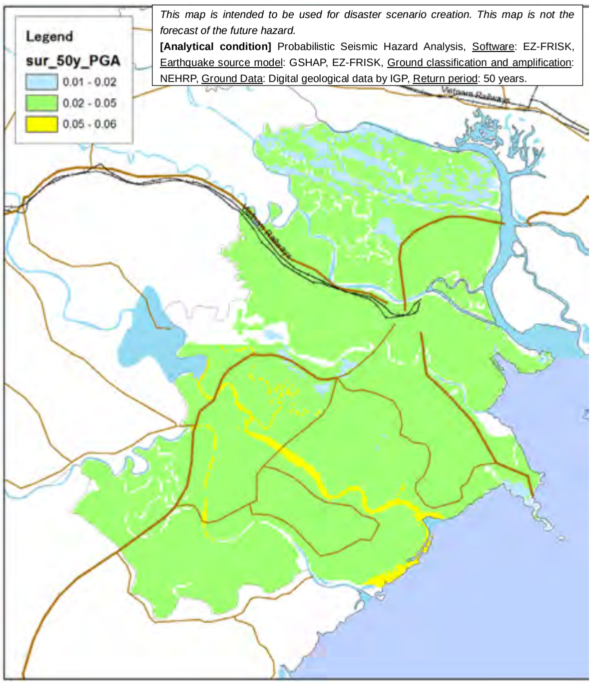


Figure A.1.8 Surface acceleration distribution (expected for 50 years, unit: g)

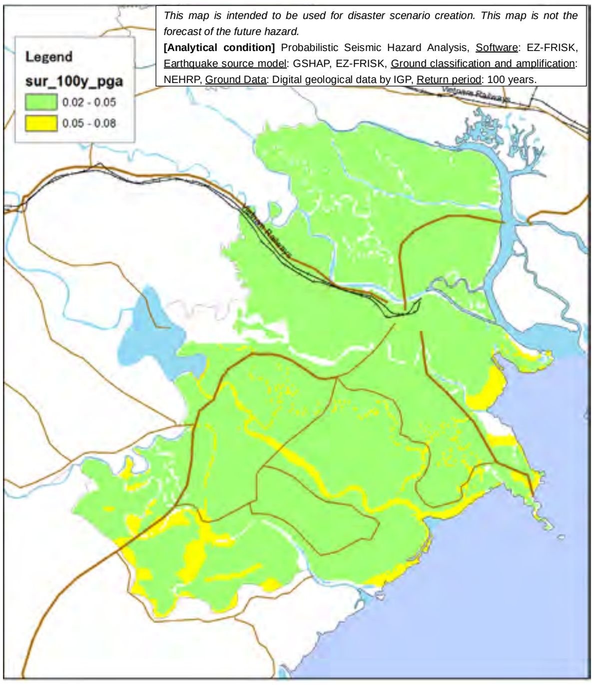


Figure A.1.9 Surface acceleration distribution (expected for 100 years, unit: g)

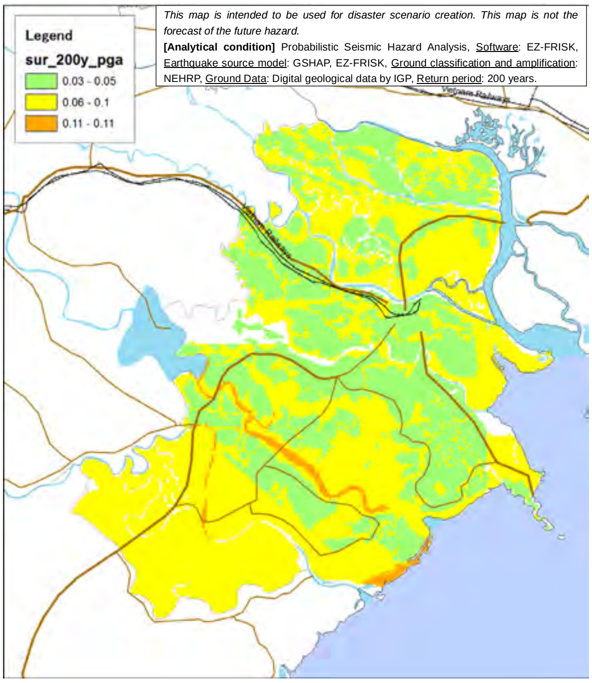


Figure A.1.10 Surface acceleration distribution (expected for 200 years, unit: g)

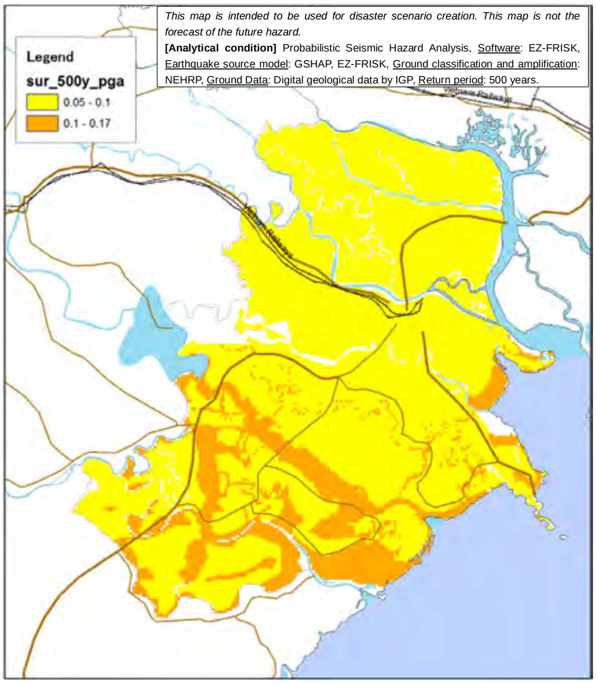


Figure A.1.11 Surface acceleration distribution (expected for 500 years, unit: g)

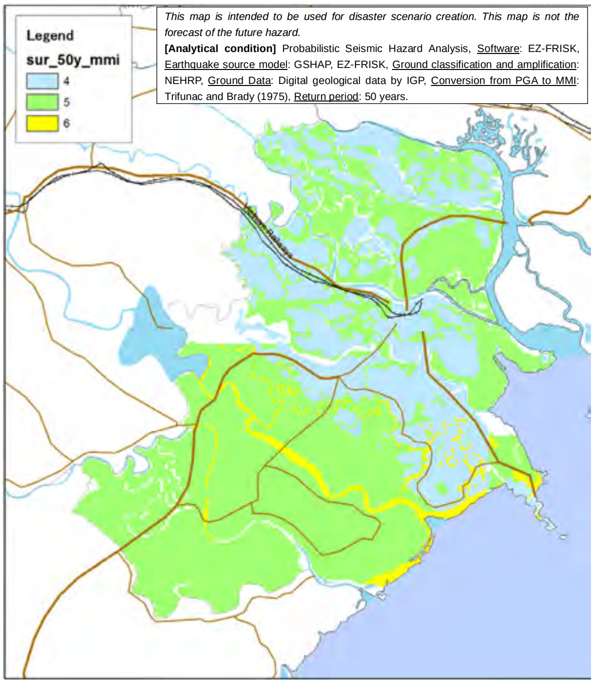


Figure A.1.12 Seismic intensity distribution (expected for 50 years in MMI scale)

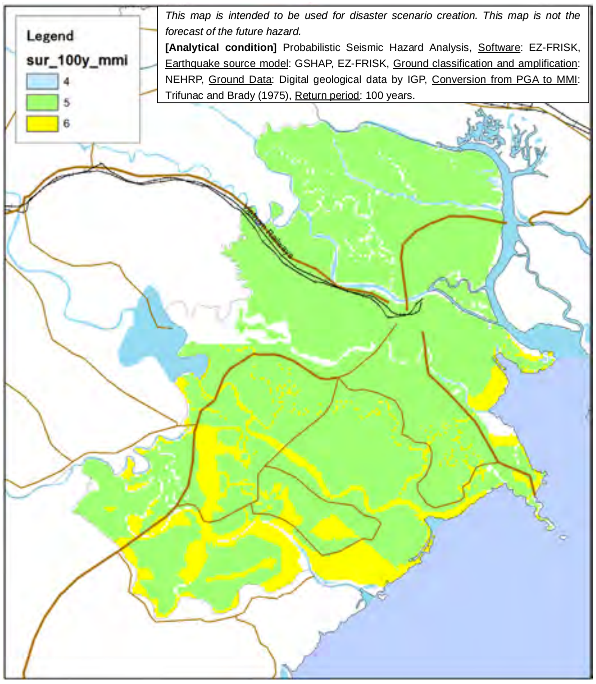


Figure A.1.13 Seismic intensity distribution (expected for 100 years in MMI scale)

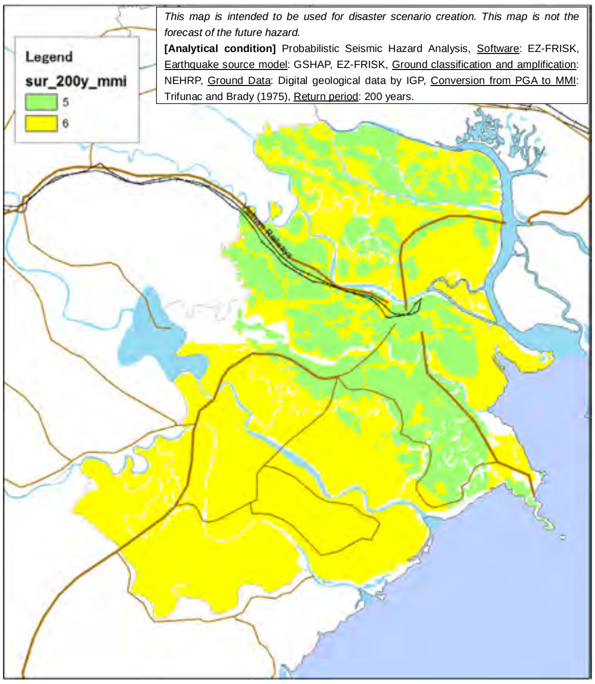


Figure A.1.14 Seismic intensity distribution (expected for 200 years in MMI scale)

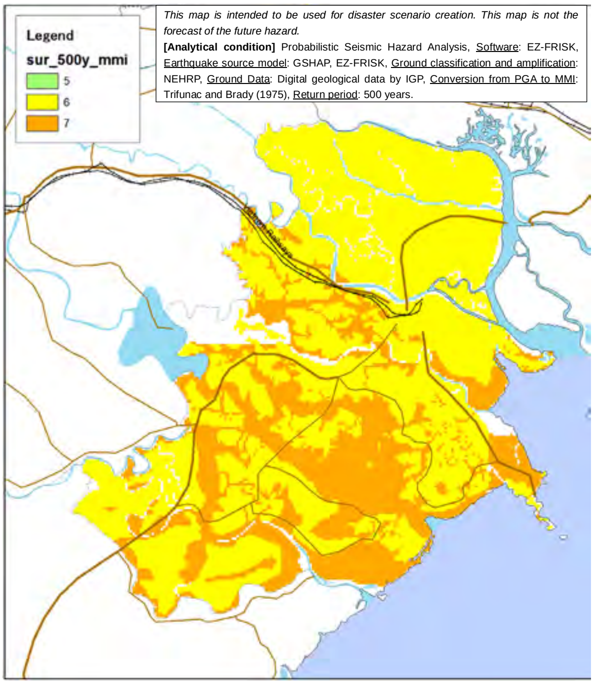


Figure A.1.15 Seismic intensity distribution (expected for 500 years in MMI scale)

A.1.5 Evaluation of the Results

(1) Probabilistic seismic hazard analysis

As the most software for probabilistic seismic hazard analysis is made based on the same theorem, there is no big difference between them except user interface. The largest component that may affect to the result is the earthquake source model. Not only the earthquake catalogue of recorded events and historical earthquakes, the active faults with no record of earthquakes in the history or the area source model should be considered. In this study, the earthquake source model included in the commercial analysis package is used. This source model was made based on the existing documents in the world and the accuracy is enough for the hazard assessment of the pilot study site in this project. However, the opinions about the active faults by the researchers are not usually same and the consensus between them is difficult in many cases. To consult the local researcher and reflect the opinion to the analysis may be necessary to assess the seismic hazard in smaller area.

(2) Amplification analysis of the surface ground

There are plenty of analysis methods for amplification by the surface ground. The methodology that is adopted in this study is the comparatively easy to use. Basically, the structure of the soil layers of underground is necessary to know the amplification characteristics. In this study, the amplification factor is estimated based on the information that is available from geological maps. As the local researcher in the Philippines studied the ground condition of Cavite and presented in the scientific papers, the amplification in part of study area can be evaluated more precisely. The similar scientific research may has been conducted or will be conducted in other region in ASEAN. The research such information is effective for the assessment.

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A.2 Tsunami Hazard Assessment

The flowchart of tsunami simulation is shown in Figure A.2.1. The detailed procedure is described hereinafter and the results of simulation for three pilot areas are shown next.

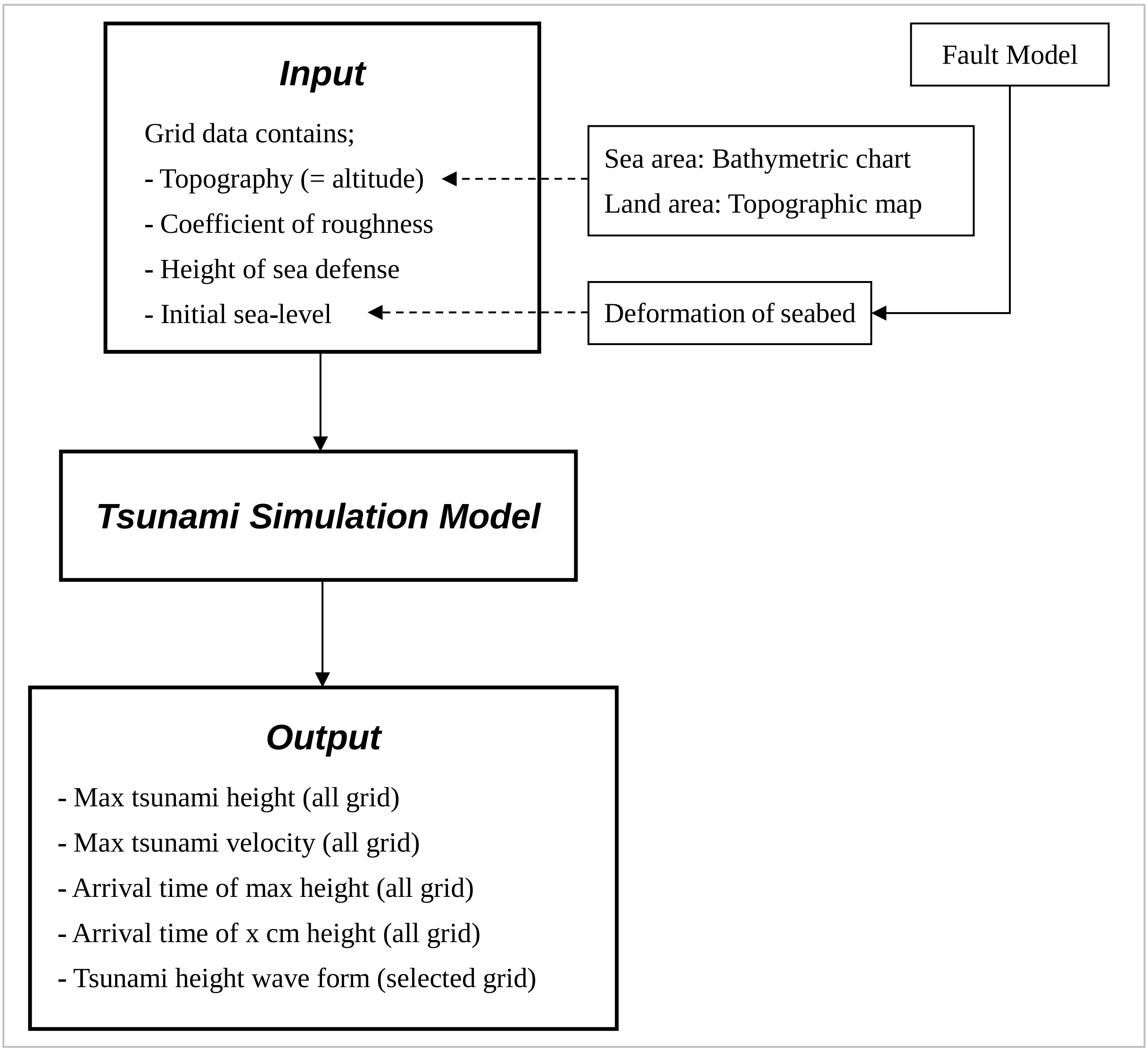

Figure A.2.1 Flowchart of tsunami simulation

A.2.1 Theory of Tsunami Propagation and Selection of Simulation Model

There are several theories to describe the behavior of tsunami such as linear long-wave theory, non-linear long-wave theory, linear disperse wave theory and non-linear disperse wave theory. Each of them is a theory based on the long-wave approximation which can be applied to the wave which wave length is long enough to the depth of water. The wave length of tsunami is generally from several 10 km to 100 km relative to the average depth of the ocean is 4 km. That is the reason why the long-wave approximation can be proper for tsunami.

Linear long-wave theory can be applied to the deep water area, over around 50 m in depth, where the amplitude of the wave is small enough to the depth of water and the friction on the sea floor can be neglected. On the other hand, non-linear long-wave theory can be applied to the shallow water area where the amplitude of the wave is no so small to the depth of water and the friction on the sea floor cannot be neglected and the case of tsunami runs up on the land.

The velocity of shorter wave is slower than longer wave. Therefore, when tsunami wave consists of several waves of different length, dispersion of short wave and long wave is observed. This difference in velocity by the wavelength is called dispersibility and the theory considering this dispersibility is the disperse wave theory. The simulation on the disperse wave theory is not so common at present, however in case of distant tsunami which occurs over 1,000 km far from the object site, linear disperse wave theory is to be applied. And when the effect of dispersibility is concerned at shallow water area, non-linear disperse wave theory is to be applied. Please see reference 1) and 2) when more detailed explanation of those theories are required.

Table A.2.1 shows the sample tsunami simulation models based on the long-wave theory and the disperse wave theory introduced above. Tsunami simulation program "TUNAMI" which is developed by Tohoku University based on the non-linear long wave theory is used in this study.

Table A.2.1 Tsunami simulation model

Program Name	Organization	Source	URL
Long Wave Theory			
TUNAMI	Tohoku University, Japan	Open	https://code.google.com/p/tunami/
STOC	The Port and Airport Research Institute, Japan	Open	http://www.pari.go.jp/cgi-bin/search-en/detail.cgi?id=2005060440205
COMCOT	Cornell University, USA	Open	http://ceeserver.cee.cornell.edu/pll-group/comcot.htm
GeoClaw	Washington University, USA	Open	http://depts.washington.edu/clawpack/geoclaw/
MOST	NOAA, USA	Closed	http://nctr.pmel.noaa.gov/model.html
ComMIT	NOAA, USA	Closed	http://nctr.pmel.noaa.gov/ComMIT/
Disperse Wave Theory			
Disperse Potential Model	National Defense Academy, Japan	Open	http://www.nda.ac.jp/cc/kensetsu/index-e.html
FUNWAVE	University of Delaware, USA	Open	http://chinacat.coastal.udel.edu/programs/funwave/funwave.html
NEOWAVE	University of Hawaii, USA	Open	http://www.ore.hawaii.edu/OE/index.htm
COULWAVE	Cornell University, USA	Closed	http://ceeserver.cee.cornell.edu/pll-group/doc/COULWAVE_manual.pdf

A.2.2 Input Data

General input data for tsunami simulation is as follows. These data is given to each grid which is explained below.

1) Topographical data
2) Roughness data

3) Sea defense data
4) Initial water height data (= deformation of sea-floor)

(1) Topographical Data

Topographical model for the area which includes the source region of the scenario earthquake, the objective area and the route of tsunami between them is required for tsunami simulation. Topographical model includes the topography of sea-floor, the topography of the land surface where tsunami might run up and sea defense structures. Orthogonal coordinate system is usually used for the modeled area of less than 1,000 km x 1,000 km and polar coordinate system is used for the wider area. The orthogonal UTM coordinate system is used for this analysis.

The simulation area is divided and covered by square grid and altitude and roughness data are given to each grid. Altitude describes topographic features and roughness is used for considering friction between water and sea-floor or land surface. The size of grid is properly defined considering the complexity of topography and the wavelength of tsunami. The grid size is usually defined from bigger to smaller according to the distance from coastlines, considering the condition that is the topography becomes more complex and shorter wave component becomes dominant at the nearer area to the coastlines. This methodology is called "nesting". The grid size is defined as, for instance, 1350m -> 450m -> 150m -> 50m from tsunami source region to the coast. Grid is connected with 1/3 size grid step by step in this case and this 1/3 connection is the most general way, however 1/2 connection and 1/5 connection is also used for nesting.

Topographical data is obtained from bathymetry chart and topographical map. Nowadays, digital data of those maps are often available. However, if there is no digital data, it is required to generate digital data by digitizing those maps. Table A.2.2 shows digital topographical data provided by international organization for free. Those data can be also used for the modeling. Following shows a case study preparing topographical model from source region to coastal area by GEBCO_08 data (Figure A.2.2) and from coastal area to the coastline and inland area by more detailed bathymetry chart (Figure A.2.3).

Table A.2.2 Open-source Data of Bathymetric Chart

Name	Explanation
GEBCO_08 Grid	- Organization: British Oceanographic Data Centre (BODC) - Topographic data of 30 sec grid covering sea-floor and land surface - URL: http://www.gebco.net/data_and_products/gridded_bathymetry_data/
SRTM30_PLUS	- Organization: Scripps Institution of Oceanography, University of California San Diego - Topographic data of 30 sec grid covering sea-floor and land surface - URL: http://topex.ucsd.edu/

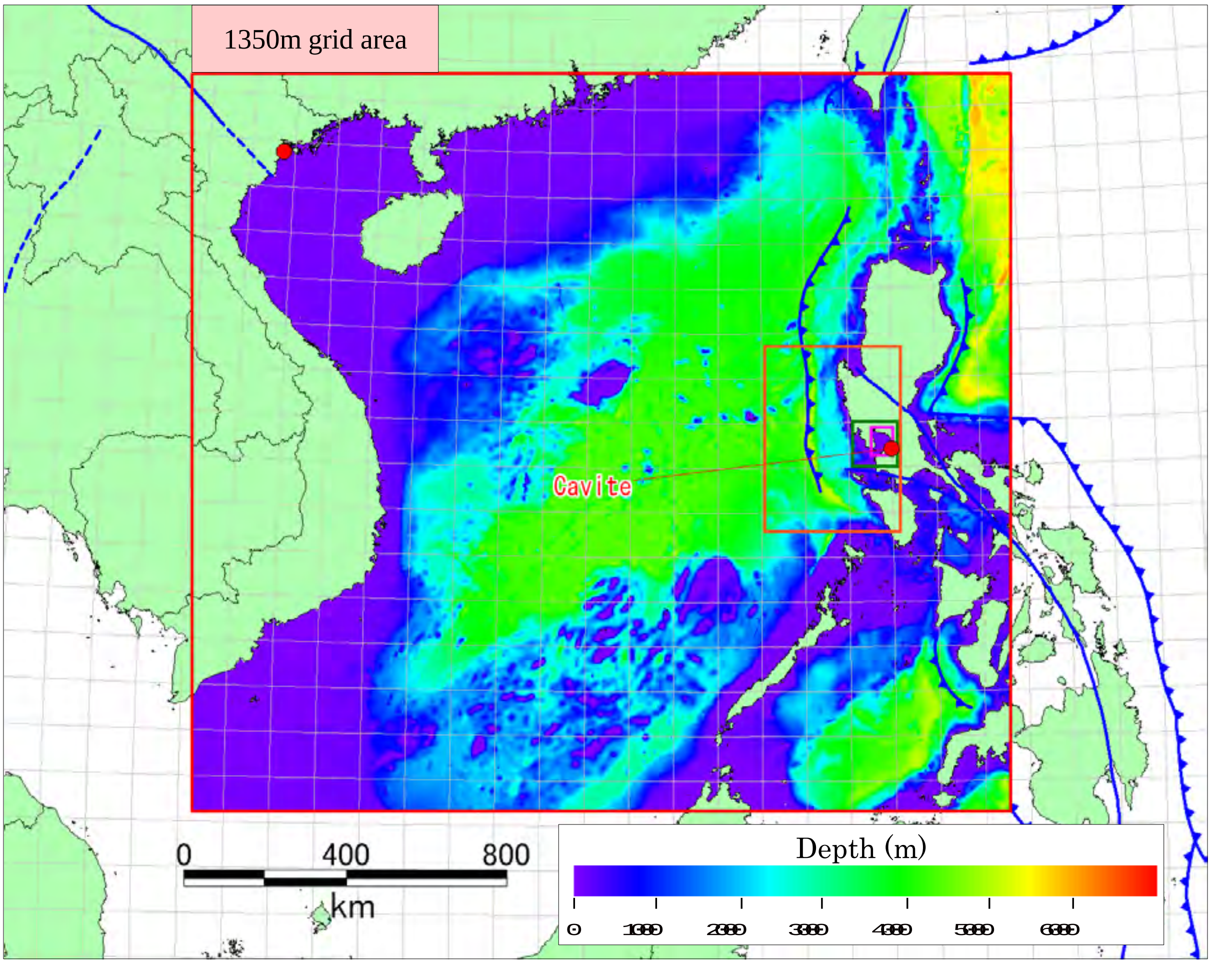

Figure A.2.2 Wide Area Topography Model by GEBCO Data (South China Sea Area)

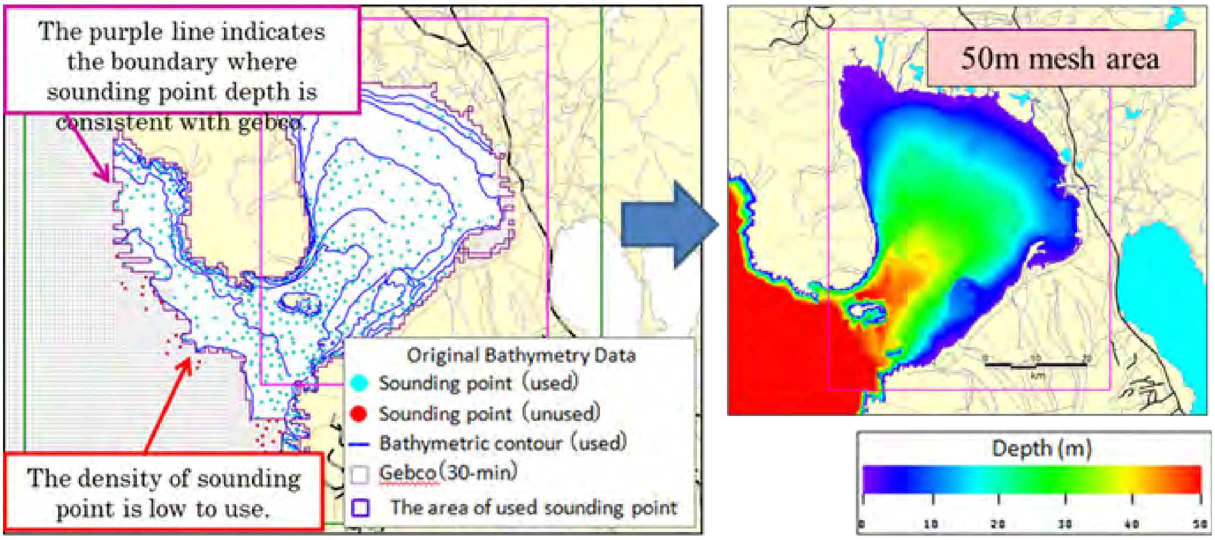

Figure A.2.3 Topography Model of Coast Area by Bathymetry Data (Manila Bay area)

(2) Roughness Data

The effect of friction for tsunami wave propagation is considered by Manning's roughness coefficient (n). "0.025" is often used as roughness coefficient for marine area. Table A.2.3[3)] and Table A.2.4[4)] show Manning's roughness coefficients for different types of ground surfaces.

Table A.2.3 Comparison of Manning's roughness coefficients [3)]

Fukuoka et al. (1994)		Aida (1977)		Goto and Shuto (1983)		Kotani et al. (1998)	
category	estimated roughness coefficient	category	equivalent roughness coefficient	category	estimated coefficient	category	setup roughness coefficient
80%	0.1			high density	0.01		
50 ～8	0.096	dense zone	0.07			high density residential zone	0.080
20 ～5	0.084	rather high density zone	0.05	mid density	0.05	mid density residential zone	0.060
0 ～2	0.056			low density	0.03	low density residential zone	0.040
road	0.043	other land zone	0.02			forest zone (inc. garden, tide protection forest)	0.030
						field zone (inc. waste land)	0.020
		Shoreline (inc. tide protection forest)	0.04			sea and river zone (w/o tide protection forest)	0.025

Table A.2.4 Manning values for land cover classes [4)]

Land cover class	Mannings n	Manning M in $m^{1/3}\ s^{-1}$	Source
Barren land/mud, sand, beach, roads	0.0310	32	b
Grassland	0.0360	28	b
Young Plantation	0.0370	27	b
Scrubland	0.0380	26	b
Cashew Plantation	0.0430	23	b
Other plantation	0.0430	23	b
Coconut plantation	0.0458	22	a
Semi open landscape	0.0550	18	b
Oil plantation	0.0573	17	a
Middle density urban area	0.0600	17	c,d
Melaleuca forest	0.0550	18	b
Rubber plantation	0.0609	16	a
Casuarina forest	0.0731	14	a
Inner beach forest	0.0744	13	a
High density urban area	0.0800	12.5	c,d
Other forest/rainforest	0.0850	12	c,e
Outer beach forest	0.0870	12	a
Mangrove forest	0.0951	11	a
Buildings non-resistant	0.0900	11	c,f
Buildings resistant	0.4000	2.5	c,f
Mangrove area 2005 (post-tsunami)			
Mangrove → water	0.0110	90	a,b,g
Mangrove → mud	0.0310	32	a,b,g
Mangrove → damaged understory	0.0310	32	a,b,g
Mangrove → sand	0.0310	32	a,b,g
Mangrove → inclined, roots remaining	0.0360	28	a,b,g
Mangrove → no damage	0.0951	11	a,b,g
Mangrove → indirect damage	0.0951	11	a,b,g

Values are derived from [a] measurement of tree stand parameters in the field followed by calculation of Manning's n according to Eq. (1); [b] measurement of stand parameters for different land cover classes in the field and subsequent estimation of Manning's n; [c] literature; [d] Kotani (1998) in Latief and Hadi (2007); [e] Arcement and Schneider (1989); [f] Gayer et al. (2010), Leschka et al. (2009); [g] + change detection/Ikonos

(3) Sea defense data

Embankment and other sea defense structures are modeled as a grid height data.

(4) Initial Water Height Data (=deformation of sea-floor)

Change of water height caused by fault movement should be prepared as an initial condition for tsunami simulation. Change of water height is assumed to be same as vertical component of sea-floor deformation. The sea-floor deformation is calculated as a displacement caused by a slip on the fault in the semi-finite elastic body using fault parameters shown in Table A.2.5.

The theory of above calculation is described in the following references like Mansinha and Smilie (1971) [5] or Okada (1992) [6] and others. The website of Cornell University[7] and National Research Institute for Earth Science and Disaster Prevention (NIED) [8] are also informative.

Figure A.2.4 shows a calculated deformation of sea-floor by the program named DC3D0 / DC3D [8] developed by Okada.

Table A.2.5 Example of fault parameters

Fault Parameter	Sample Value (corresponding to Figure A.2.4)
Depth (km)	18
Strike angle (degree)	177
Dip angle (degree)	24
Rake angle (degree)	90
Length (km)	313
Width (km)	70
Slip (m)	9.6

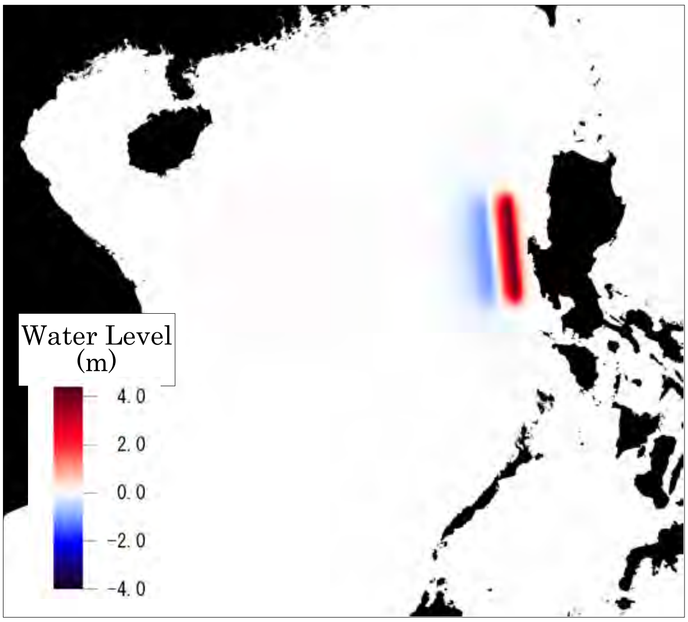

Figure A.2.4 Example of calculated vertical deformation

A.2.3 Output Data

The general output of the tsunami simulation is as follows. Output items are obtained for each grid.

1) Maximum water height or maximum inundation height (for all grid)
2) Maximum velocity (for all grid)
3) Elapsed time of maximum water height (for all grid)
4) Elapsed time of given water height (x cm, for instance) (for all grid)
5) Time history of water height (selected grid)
6) Time history of water velocity (selected grid)

Figure A.2.5 shows a sample result of tsunami simulation by the program "TUNAMI" developed by Tohoku University in Japan. The left side of Figure A.2.5 shows maximum water height distribution map and the right side of Figure A.2.5 shows time history of water height at the selected grid.

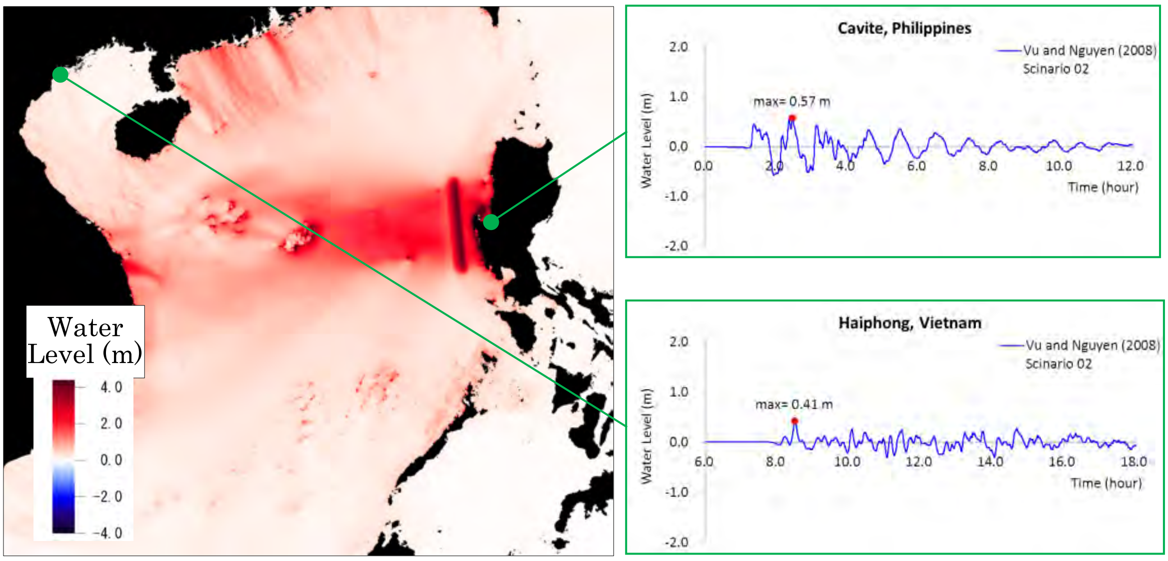

Figure A.2.5 example of tsunami simulation results

A.2.4 Return Period of Scenario Earthquake

The relationship of earthquake magnitude and return period is estimated by Gutenberg-Richter Low using earthquake data, often called earthquake catalog, around the targeted earthquake zone. It is well known that larger earthquake occurs less frequently. It was Gutenberg and Richter who formulate this relation as the following equation in 1941. It is the reason why this relation is called as Gutenberg-Richter Low or G-R Low.

$$\log n(M) = a - b M$$

or

$$\log N(M) = A - b M$$

The relation between occurrence frequency, n(M) dM, and cumulative frequency which is magnitude M and over, N(M), and 0.1 interval magnitude, dM = 0.1, is arranged in Table A.2.6 for the earthquake data which occurred during 1965 to 1999 in and around Japan area. Figure A.2.6 is the plot of the data with magnitude on x-axis and frequency on y- axis. The formula on the figure is a regression curve of M and N relation derived by the least square method.

M = 7.5 corresponds to N = 6.8 on the formula, for instance. It means that the occurrence frequency of the earthquake with magnitude 7.5 and over is 6.8 times on average in 35 years, during 1965 to 1999. And its annual probability is calculated as 6.8 / 35 = 0.19 / year. It is recognized that the earthquake with magnitude 7.5 and over is expected to occur 0.19 time on average in and around Japan area. On the other hand, inverse number of the annual probability, 1 /0.19 = 5.1 years in this case, is called recurrence time. Then it is expressed that the recurrence time of the earthquake with magnitude 7.5 and over is 5.1 years.

As described above, an annual probability or a recurrence time of the scenario earthquake can be estimated using G-R Low in and around the scenario earthquake area.

Table A.2.6 Number of Shallow Earthquakes Occurred in and around Japan (1965 - 1999) [9)]

M	$n(M)dM$	$N(M)$	M	$n(M)dM$	$N(M)$	M	$n(M)dM$	$N(M)$
8.2	0	0	7.1	5	18	6.0	52	224
8.1	1	1	7.0	5	23	5.9	56	280
8.0	0	1	6.9	4	27	5.8	79	359
7.9	1	2	6.8	2	29	5.7	91	450
7.8	2	4	6.7	9	38	5.6	94	544
7.7	1	5	6.6	14	52	5.5	134	678
7.6	0	5	6.5	14	66	5.4	138	816
7.5	3	8	6.4	18	84	5.3	199	1015
7.4	2	10	6.3	18	102	5.2	256	1271
7.3	0	10	6.2	30	132	5.1	343	1614
7.2	3	13	6.1	40	172	5.0	407	2021

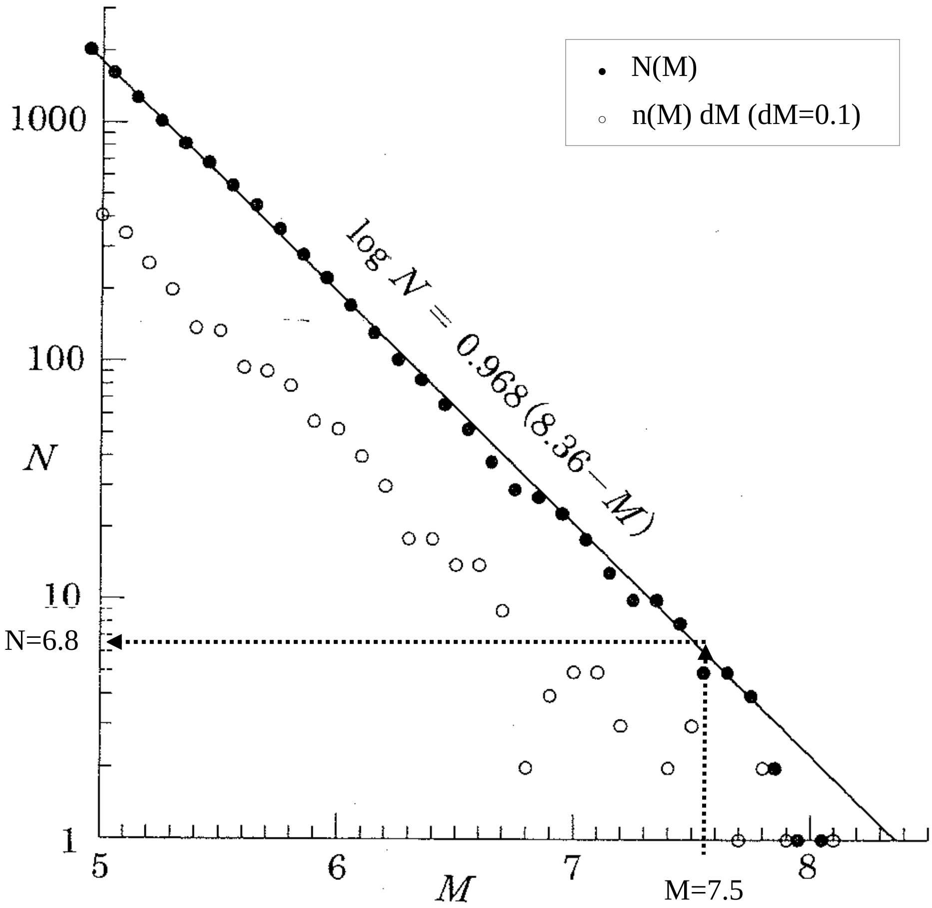

Figure A.2.6 Data Plot of Table A.2.6 [9)]

A.2.5 Results of Simulation

(1) Collection of Existing Information

The following information and data are collected for setting scenario earthquake and conducting tsunami simulation.

<u>Literatures related to scenario earthquakes</u>

- EMILE A. OKAL et al. (2011) [10)]: Tsunami Simulations for Regional Sources in the South China and Adjoining Seas
- Vu Thanh Ca1 et al. (2008)[11)]: Tsunami risk along Vietnamese coast
- Nguyen Hong Phuong et al. (2013)[12)]: Simulation of a Worst Case Tsunami Scenario from the Manila Trench to Vietnam

<u>Literatures related to earthquake environment</u>

- Earthquake catalog prepared by IGP-VAST (Institute of Geophysics, Vietnam Academy of Science and Technology)

<u>Data related to bathymetric feature</u>

- Wide area: GEBCO_08 Grid
- Vicinity of objective area: Digital bathymetry data prepared by IGP-VAST

(2) Setting of Scenario Earthquake

1) Statistical analysis of earthquake (Gutenberg-Richter Law)

The earthquake data along the Manila trench is picked up from the data[13)] as shown in Figure A.2.7 and the return period of the earthquake is estimated by statistical analysis based on the Gutenberg-Richter Law. The estimated result is shown in Figure A.2.8. Followings are the results obtained by the analysis.

- ✓ Formula-1: G-R Law parameters are derived from the data during 1980 to 2002 as "b = 1.0" and "a = 5.2".
- ✓ Formula-2: In case of drawing envelope assuming "b = 1.0", "a = 6.0" is estimated.
- ✓ Formula-3 (reference): In case of drawing envelope for all data, "b = 0.9" and "a = 5.2" are estimated.

Magnitude of the earthquake along the Manila Trench with 100 years return period is estimated to be 7.2 to 8.0 from Formula-1 and Formula-2.

On the other hand, the return period of the earthquake with magnitude 8.0 is estimated to be 100 to 630 years and 1,000 to 6,300 years for magnitude 9.0.

2) Setting of scenario earthquake

Hai Phong faces the South China Sea where fewer earthquakes occur and there is almost no record of large tsunami disaster around the area. In this study, the possible tsunami that may cause impact to the study area, though the possibility is very low, is simulated considering that the result will be used in the future.

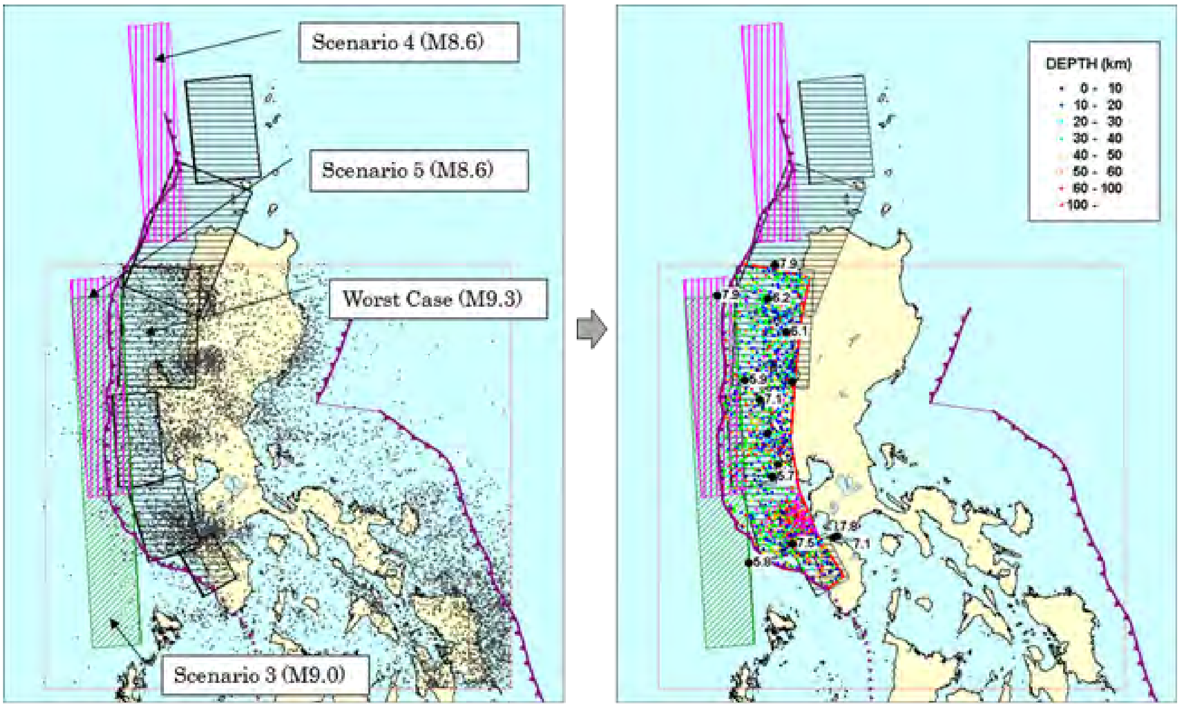

Figure A.2.7 Epicenter Data along Manila Trench used for Statistical Analysis

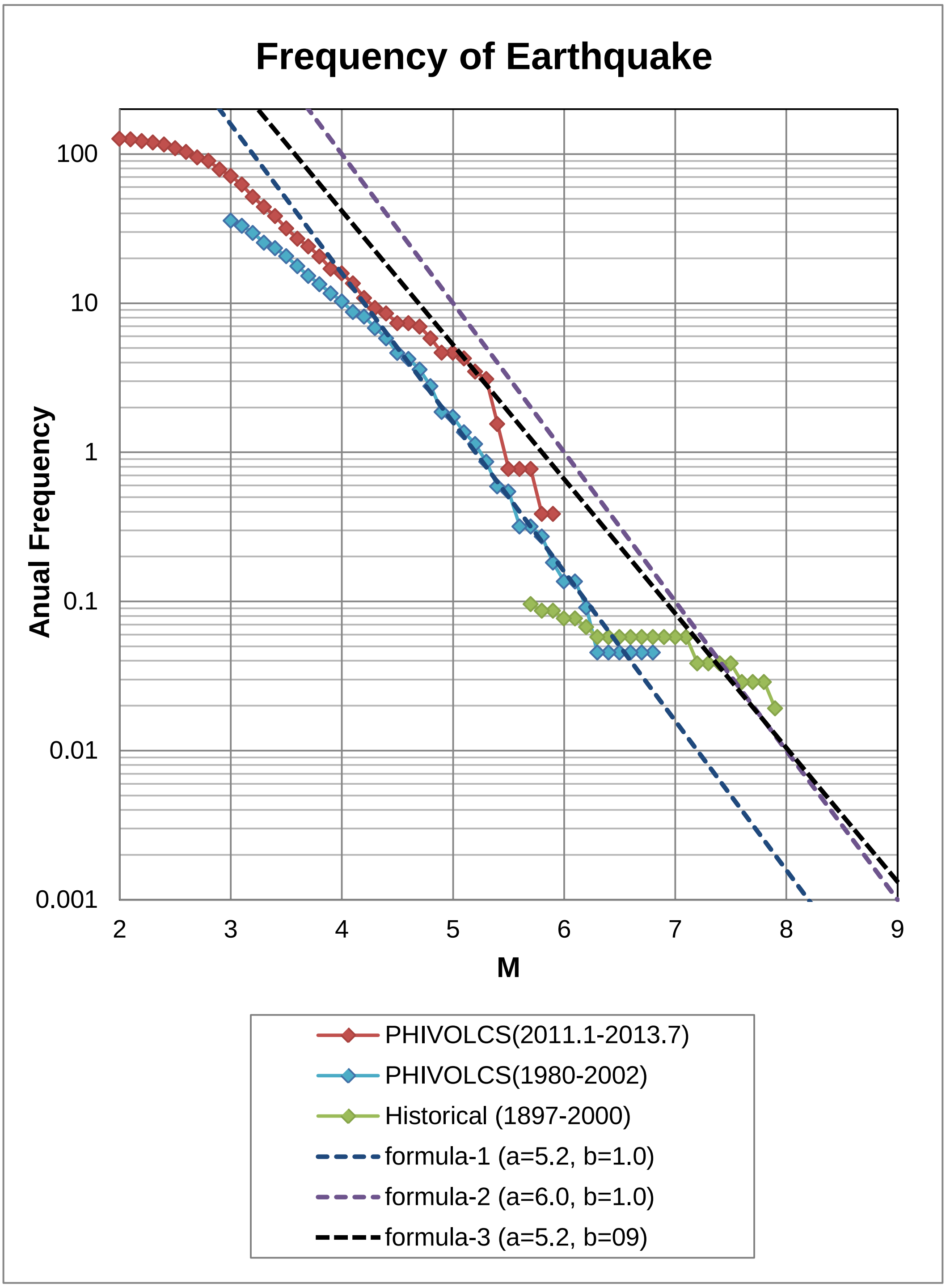

Figure A.2.8 Return Period of the Earthquakes along Manila Trench (Gutenberg–Richter law)

(3) Analysis and Results

1) Setting of tsunami (earthquake) model

Scenario earthquakes which is considered to affect to the objective area are selected from the existing researches [10)11)12)]. Table A.2.7 shows fault parameters of scenario earthquakes. The locations of the scenario earthquakes are shown in Figure A.2.9 to Figure A.2.11.

Table A.2.7 Source Model

Scenario No.	Mw	Depth (km)	Strike (degree)	Dip (degree)	Rake (degree)	Length (km)	Width (km)	Slope (m)
1[11)]	8.0	12	177	24	90	151	47	5.3
2[11)]	8.5	18	177	24	90	313	70	906
3[11)]	9.0	27	177	24	90	646	101	17.5
4[11)]	7.5	24	57	78	-45	89	25	3.0
5[11)]	7.5	17	172	78	-45	89	25	3.0
6[10)]	8.6	10	355	35	57	400	90	6.0
7[10)]	8.6	10	355	24	72	400	90	6.0
Worst Case [12)]	9.3	0	35.4	10	90	190	120	25.0
		0	22	20	90	250	160	40.0
		0	2	28	90	220	160	40.0
		0	356	20	90	170	90	28.0
		0	344	22	90	140	110	12.0
		0	331	26	90	95	80	5.0

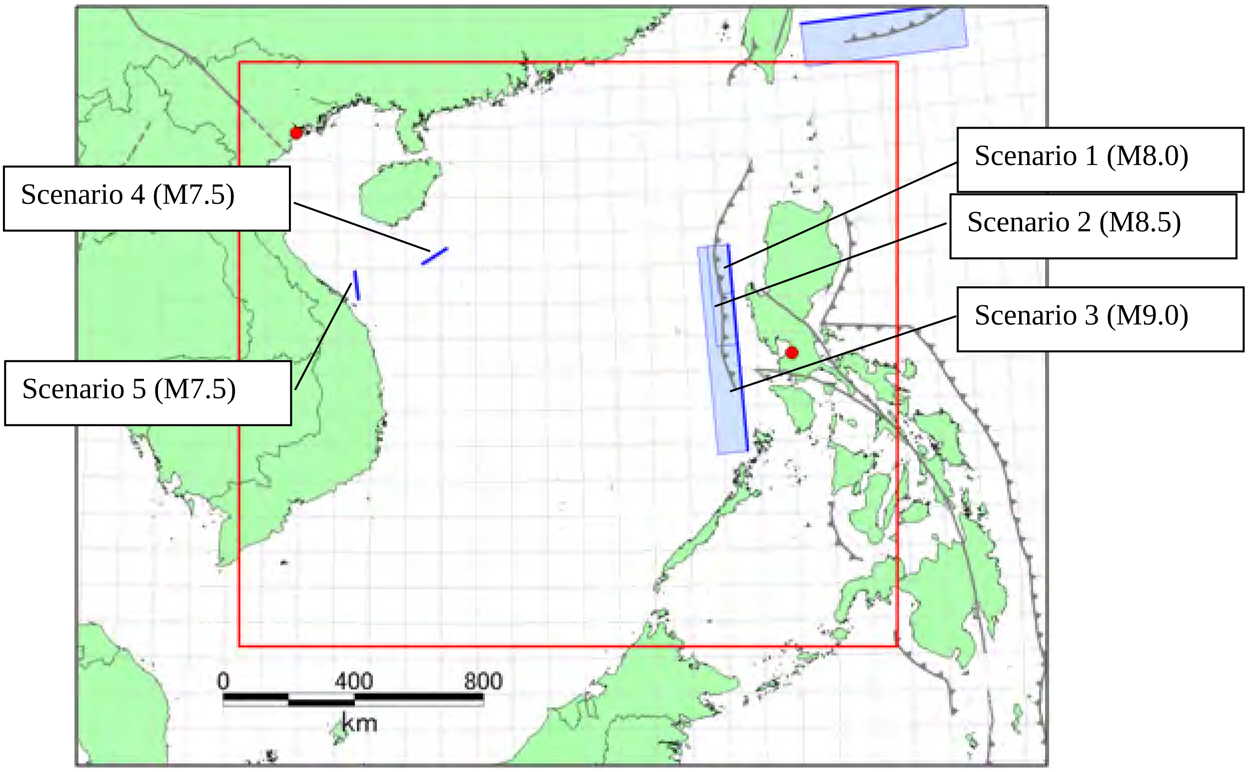

Figure A.2.9 Tsunami Source Model (Scenario 1 - 5)

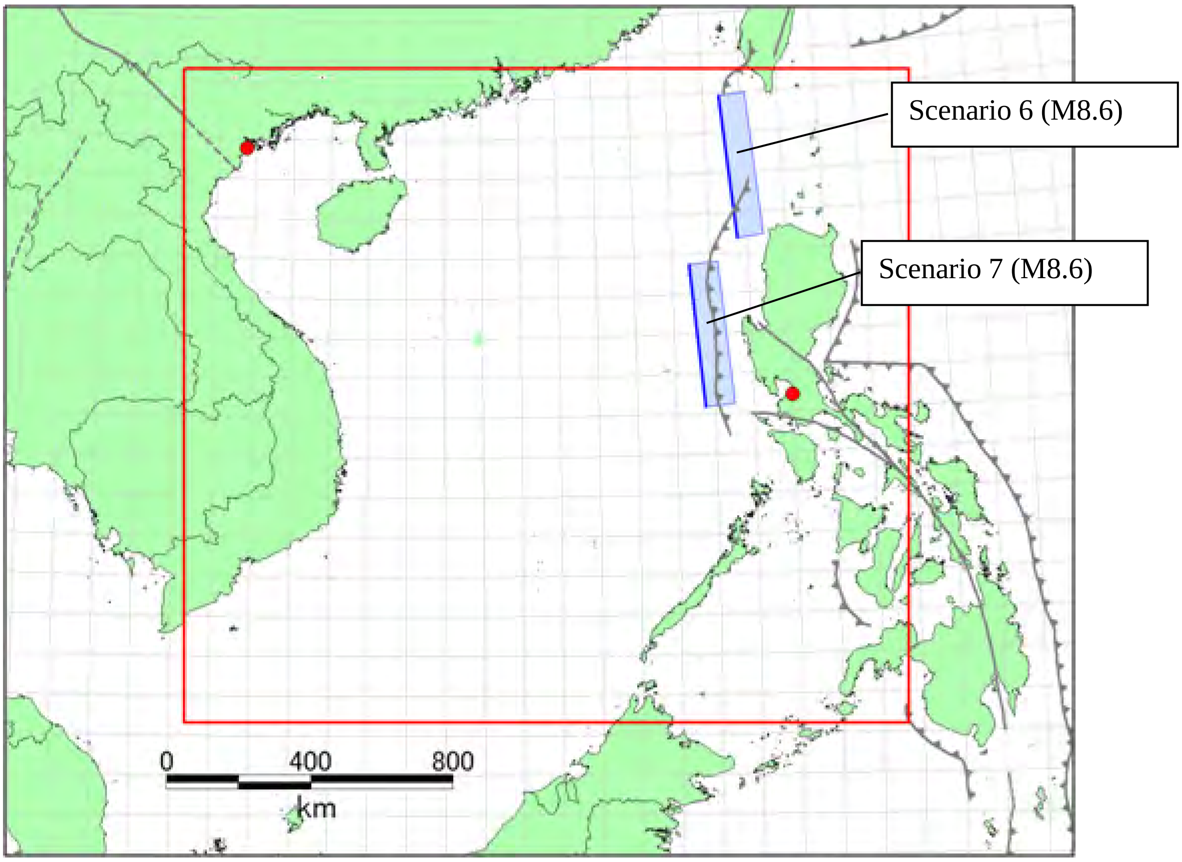

Figure A.2.10 Tsunami Source Model (Scenario 6 - 7)

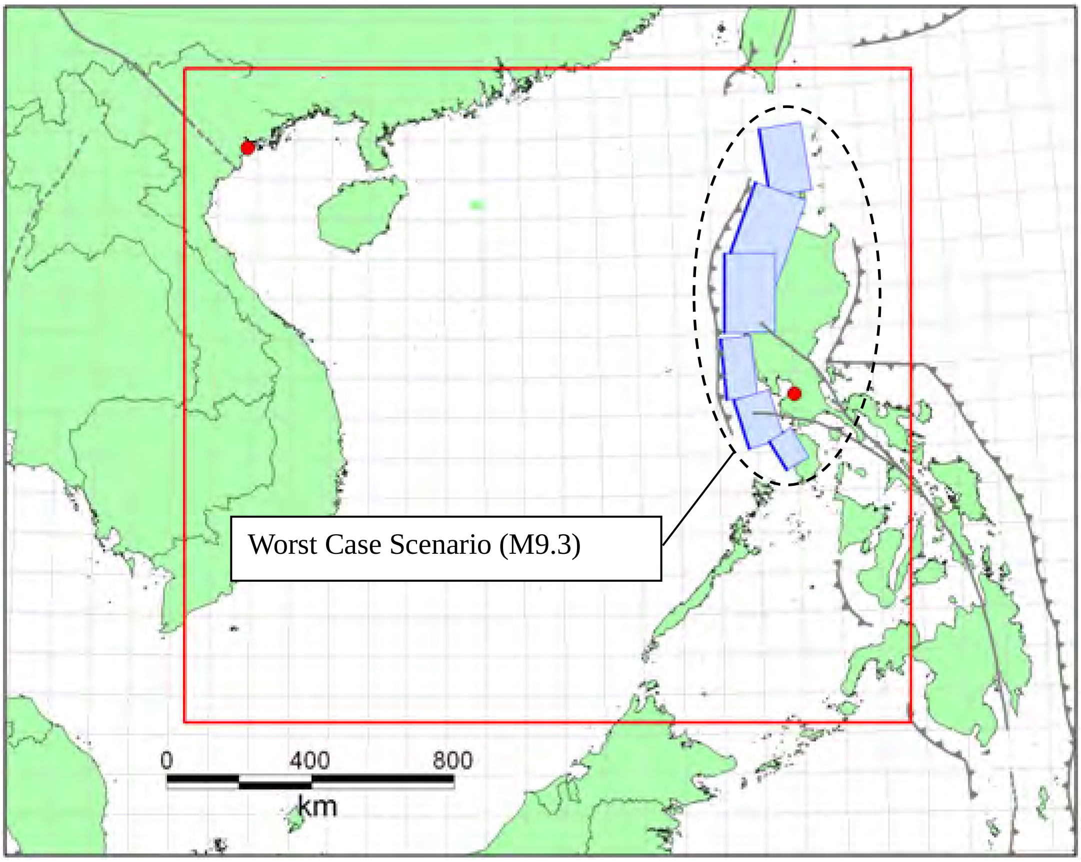

Figure A.2.11 Tsunami Source Model (Worst Case Scenario)

2) Selection of tsunami simulation model

Tsunami simulation program "TUNAMI" which is developed by Tohoku University based on the non-linear long wave theory is used for the analysis. Analysis period is set to be 24 hours after earthquake occurrence.

3) Preparation of Input data

UTM coordinate system is used. Square grids are adopted for topographical model. The size of grids are defined as 1350m, 450m, 150m and 50m, from tsunami source region to the coast based on the nesting method.

Topographical data

The depth of the grids in the ocean area with the size of 1350m, 450m and 150m and the inland 50m grids are generated based on "GEBCO_08 Grid" data prepared by BODC (British Oceanographic Data Centre).

The digital bathymetry data prepared by IGP-VAST (Institute of Geophysics, Vietnam Academy of Science and Technology) is used for creating the depth data of the 50m grids near the coast.

Figure A.2.12 shows wide area topographical model prepared from "GEBCO_08 Grid". Figure A.2.13 shows coast area topographical model prepared from the data by IGP-VAST.

Roughness data

Roughness coefficient "0.025" is used for ocean and land area.

Sea defense data

Embankment and other sea defense structures are not considered in this study.

Initial water height data (= deformation of sea-floor)

Deformation of sea-floor is calculated by Okada's program "DC3D0 / DC3D" with using fault parameters of scenario earthquakes and the vertical component of the deformation of sea-floor is given to corresponding grid as initial water height.

Calculated deformation of sea-floor is shown in Figure A.2.14, Figure A.2.17, Figure A.2.20, Figure A.2.23, Figure A.2.26, Figure A.2.29, Figure A.2.32 and Figure A.2.35.

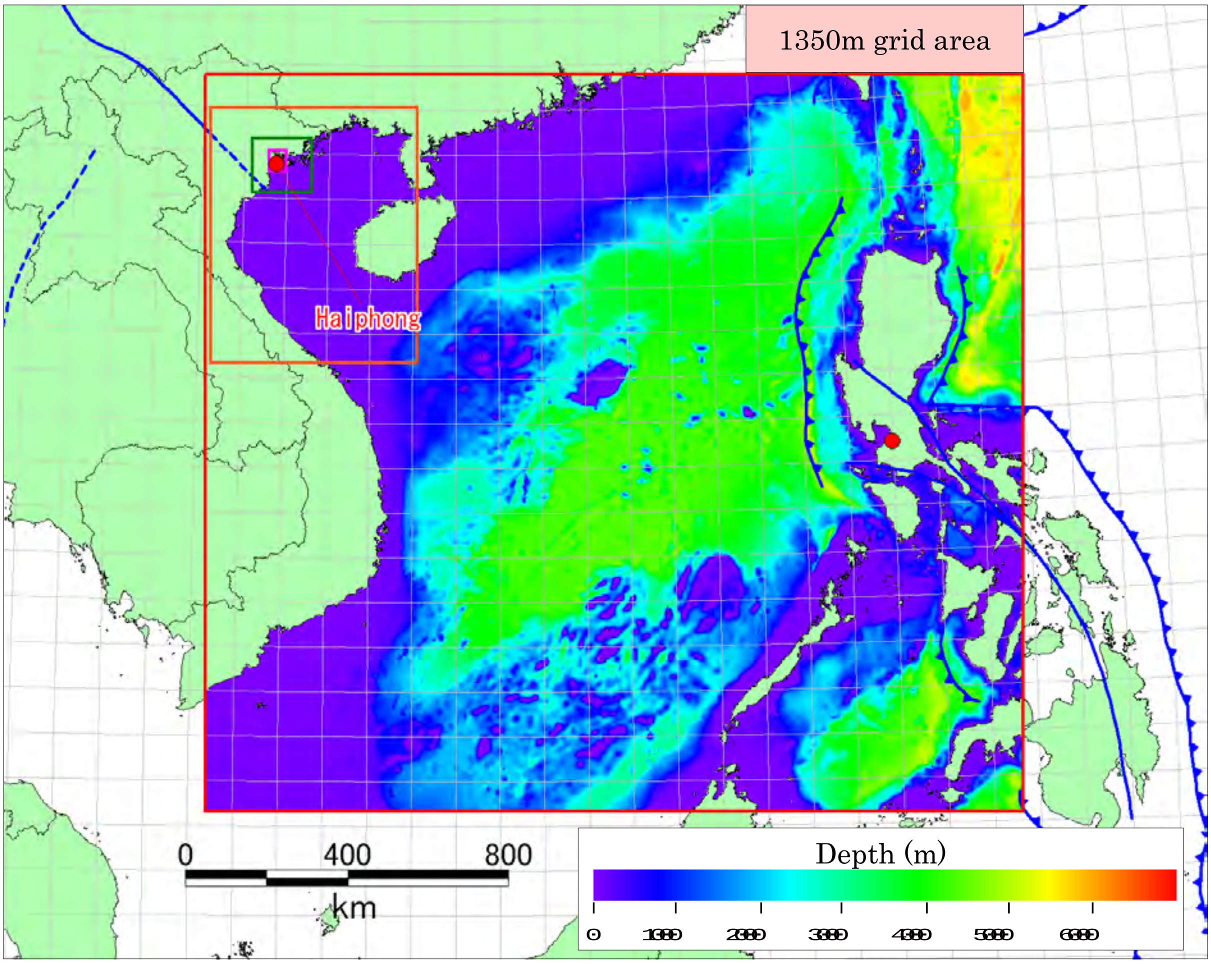

Figure A.2.12 Wide Area Topography Model by GEBCO Data (South China Sea Area)

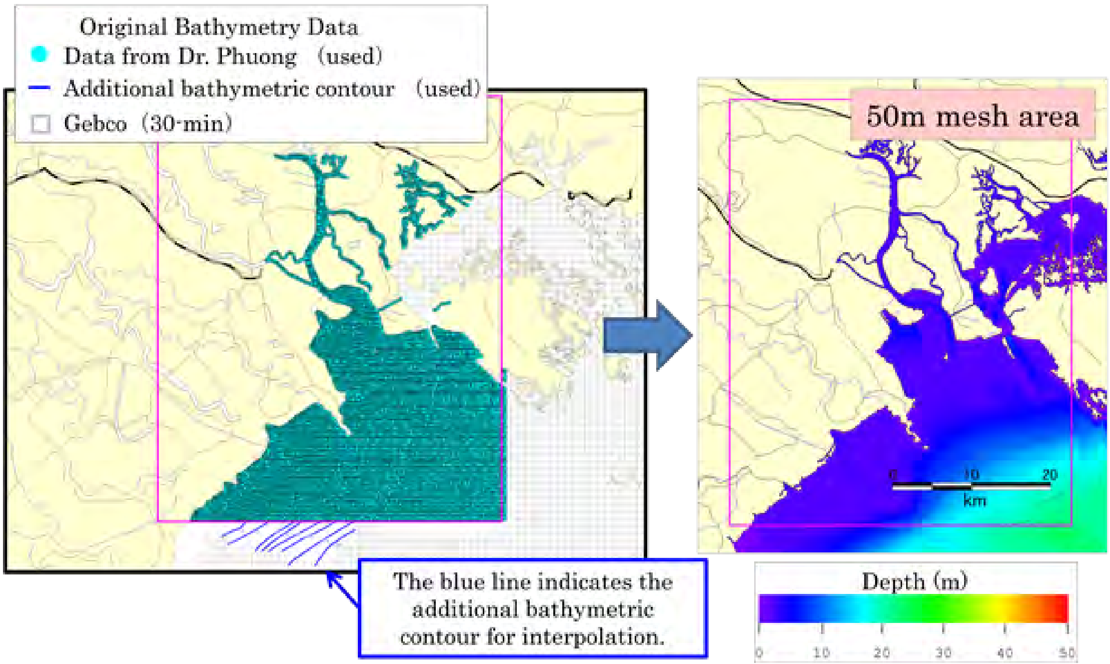

Figure A.2.13 Topography Model of Coast Area by Bathymetry Data (Hai Phong Area)

4) Tsunami simulation

Figure A.2.14 to Figure A.2.37 show the simulation results of Scenario 1 to 7 and the Worst Case Scenario. Table A.2.8 shows the maximum tsunami height at Hai Phong and the expected return period calculated from magnitude of each scenario earthquake.

The width of channel from the South China Sea to the coast of Hai Phong is reduced by the Hainan Island. Therefore, tsunami height along the coast of Hai Phong is not high compared with open ocean. The tsunami heights by the earthquakes with magnitude 7.5 which occur offshore of Hai Phong are estimated around 10 cm by the simulation (Scenario 4, 5). And the tsunami heights by the earthquakes with magnitude 8.5 which occur along the Manila Trench are estimated less than 1 m (Scenario 2, 6, 7). If earthquake of magnitude 9.0 occurs, the tsunami height may become 1 to 2 m around Hai Phong (Scenario 3 and Worst Case Scenario); however the probability of such a huge earthquake may be once in several thousand years.

Table A.2.8 Maximum Tsunami Height at Hai Phong for Each Scenario

Scenario No.	Mw	Return Period (year)	Max Tsunami Height (m)
1	8.0	100 ～63	0.11
2	8.5	300 ～20	0.41
3	9.0	1000 ～6	1.22
4	7.5	-	0.05
5	7.5	-	0.14
6	8.6	400 ～25	0.14
7	8.6	400 ～25	0.21
Worst Case	9.3	2000 ～	1.92

Simulation result of Scenario 1

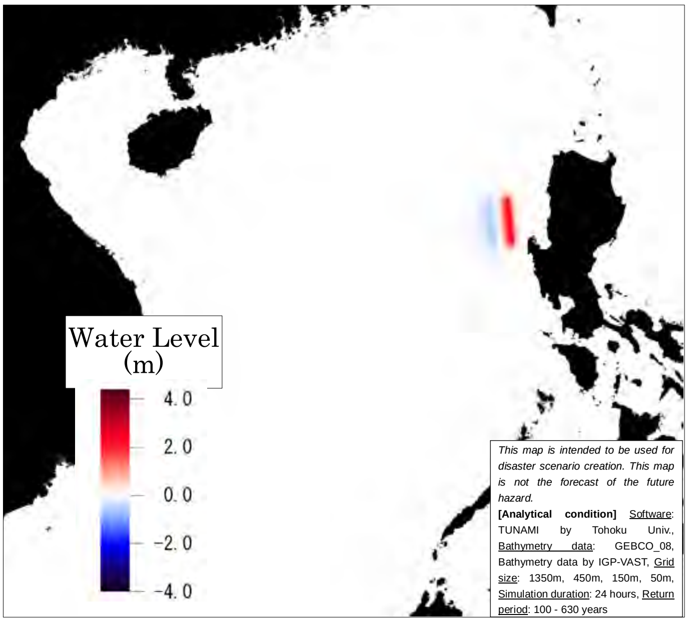

Figure A.2.14 Vertical deformation (Scenario 1)

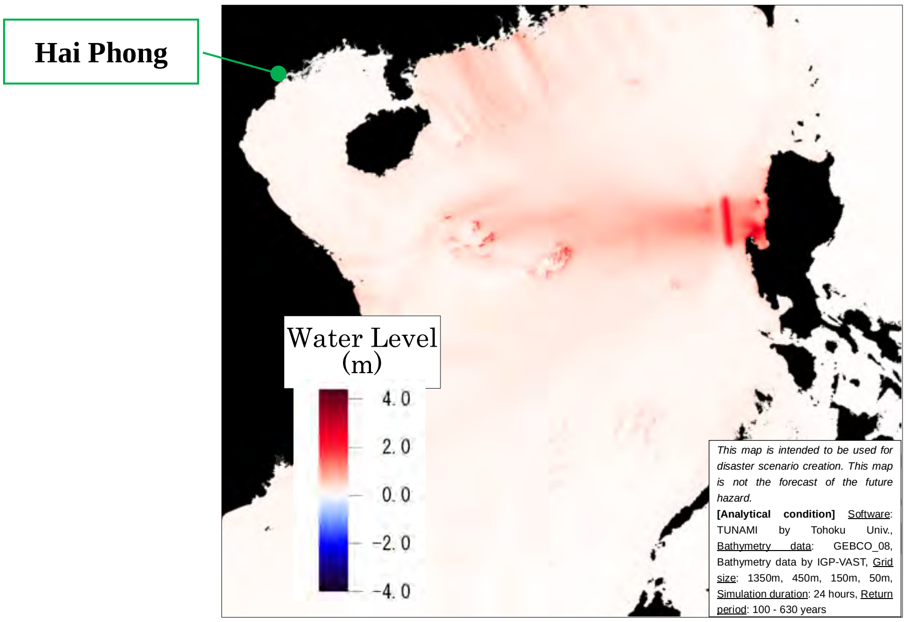

Figure A.2.15 Maximum Water Height (Scenario 1)

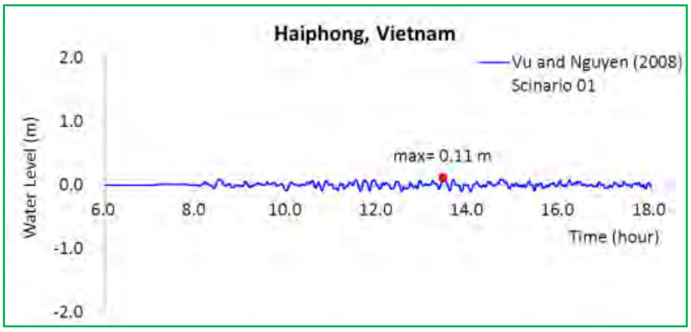

Figure A.2.16 Wave form of Tsunami Height at Hai Phong (Scenario 1)

Simulation result of Scenario 2

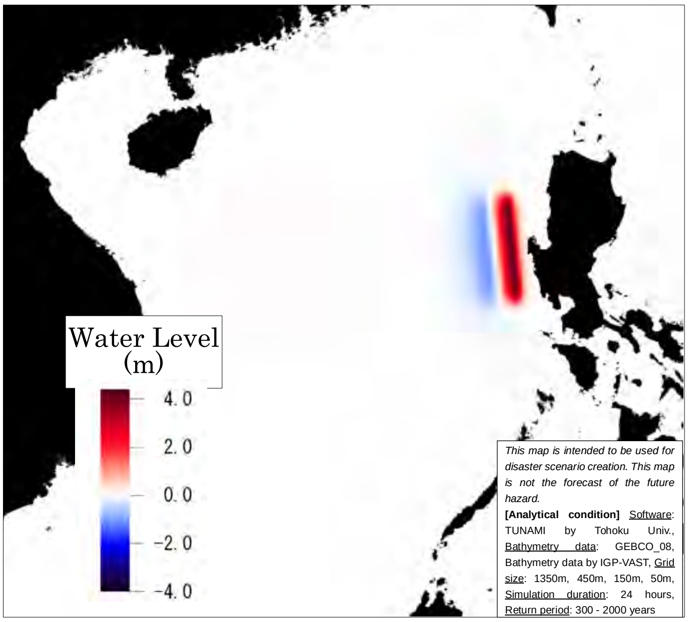

Figure A.2.17 Vertical deformation (Scenario 2)

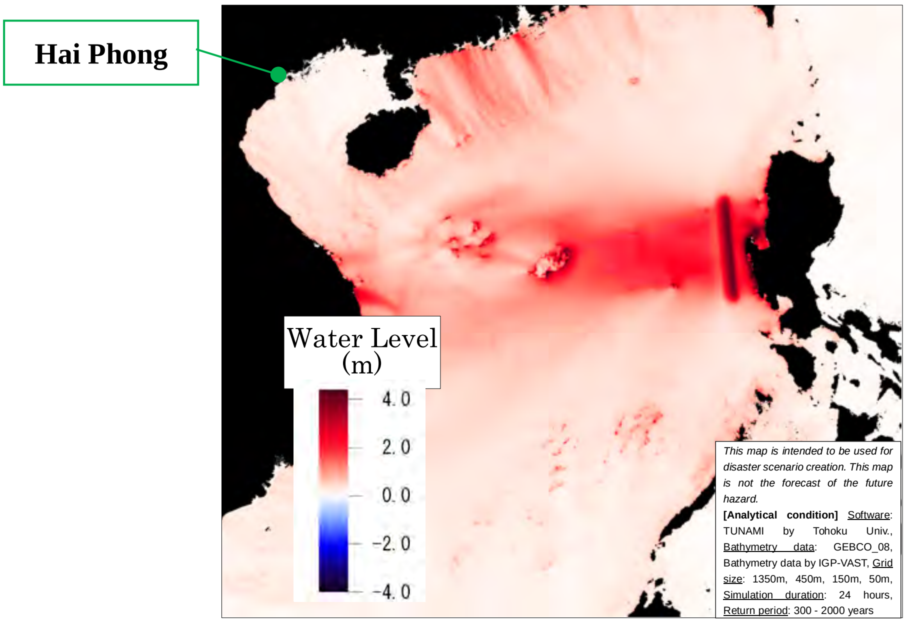

Figure A.2.18 Maximum Water Height (Scenario 2)

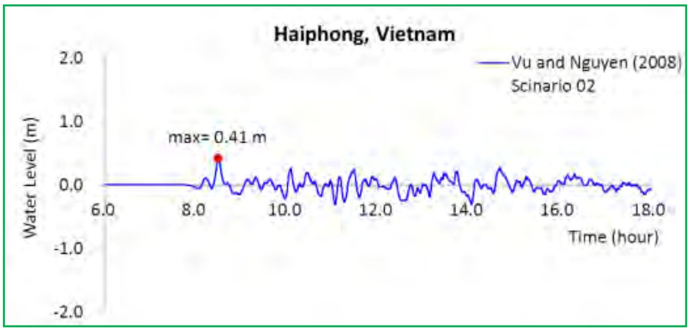

Figure A.2.19 Wave form of Tsunami Height at Hai Phong (Scenario 2)

Simulation result of Scenario 3

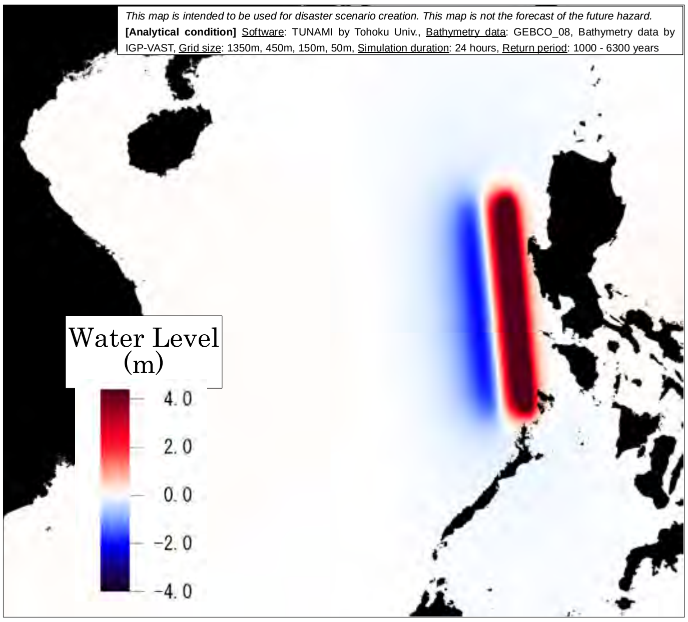

Figure A.2.20 Vertical deformation (Scenario 3)

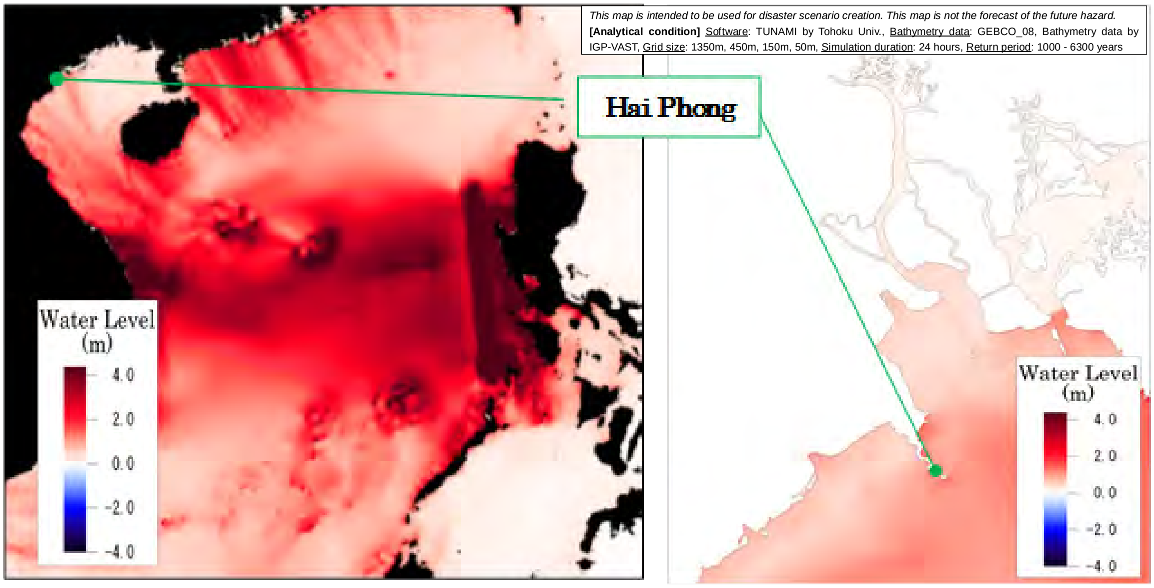

Figure A.2.21 Maximum Water Height (Scenario 3)

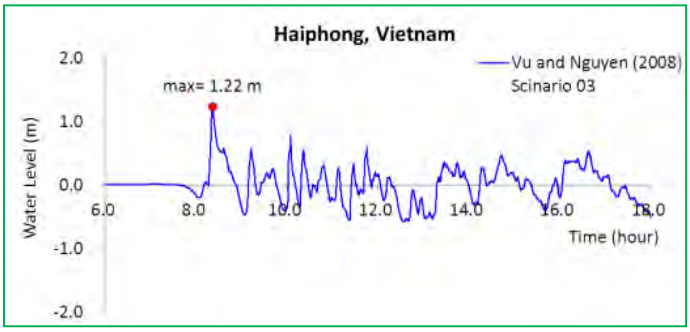

Figure A.2.22 Wave form of Tsunami Height at Hai Phong (Scenario 3)

Simulation result of Scenario 4

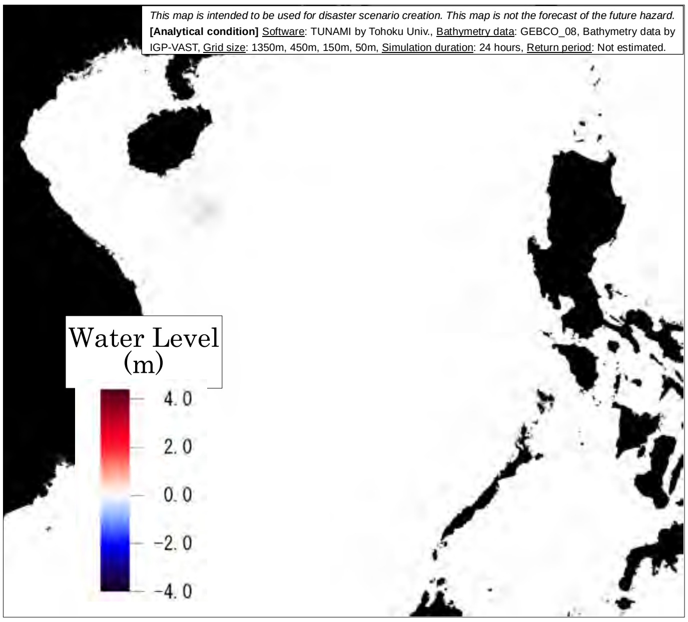

Figure A.2.23 Vertical deformation (Scenario 4)

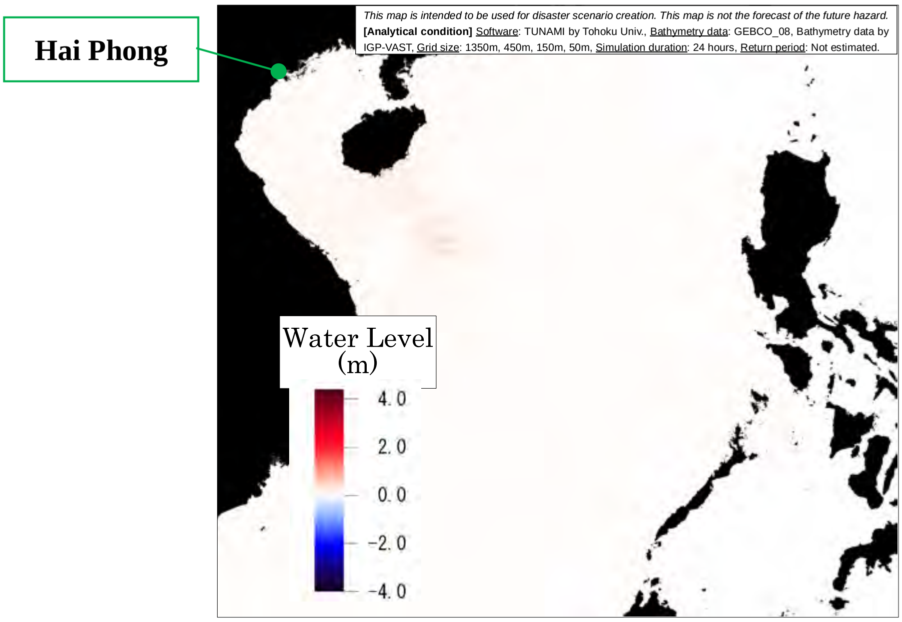

Figure A.2.24 Maximum Water Height (Scenario 4)

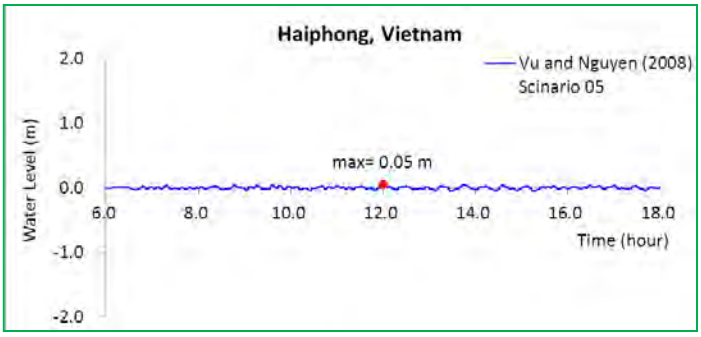

Figure A.2.25 Wave form of Tsunami Height at Hai Phong (Scenario 4)

Simulation result of Scenario 5

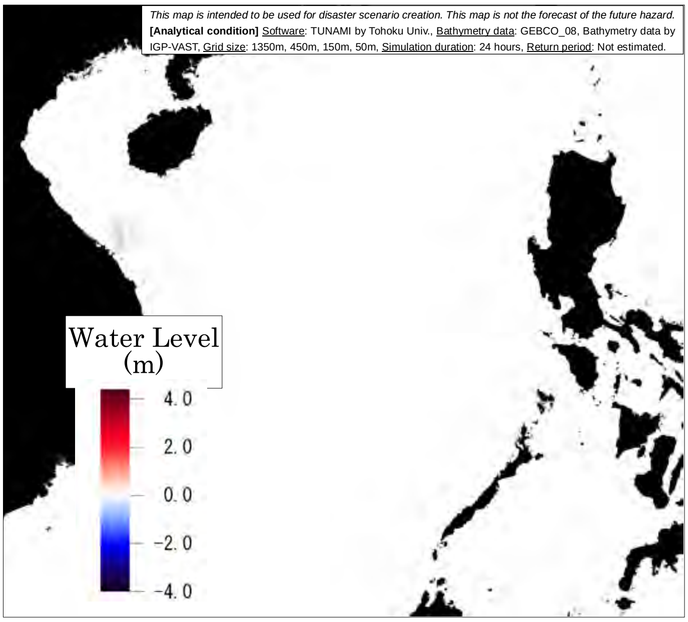

Figure A.2.26 Vertical deformation (Scenario 5)

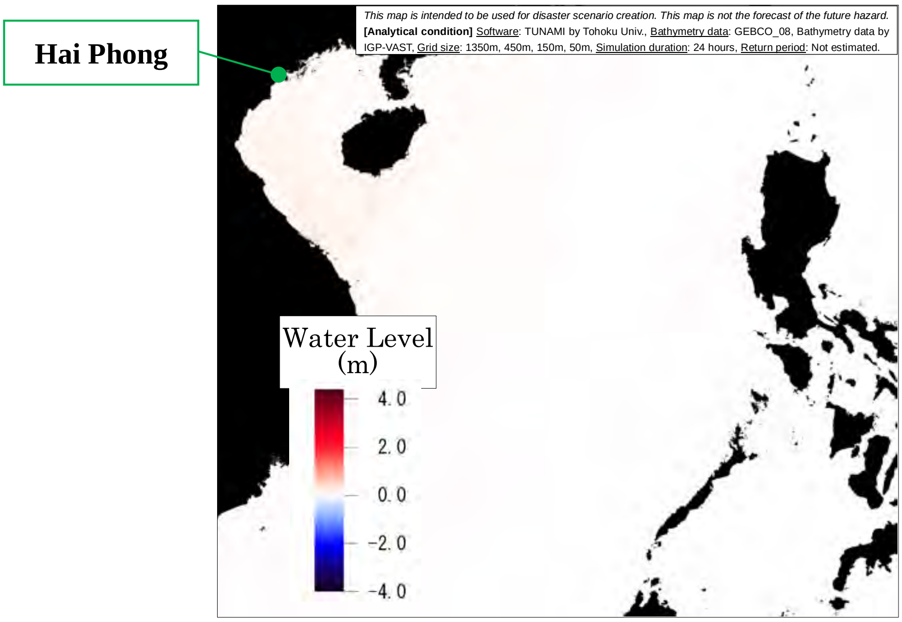

Figure A.2.27 Maximum Water Height (Scenario 5)

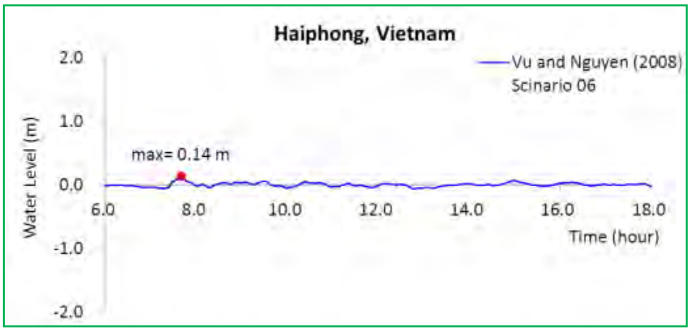

Figure A.2.28 Wave form of Tsunami Height at Hai Phong (Scenario 5)

<u>Simulation result of Scenario 6</u>

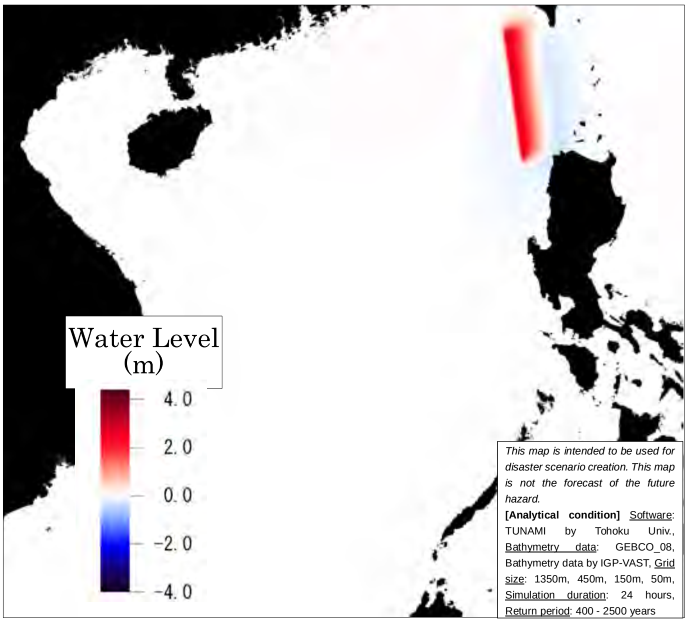

Figure A.2.29 Vertical deformation (Scenario 6)

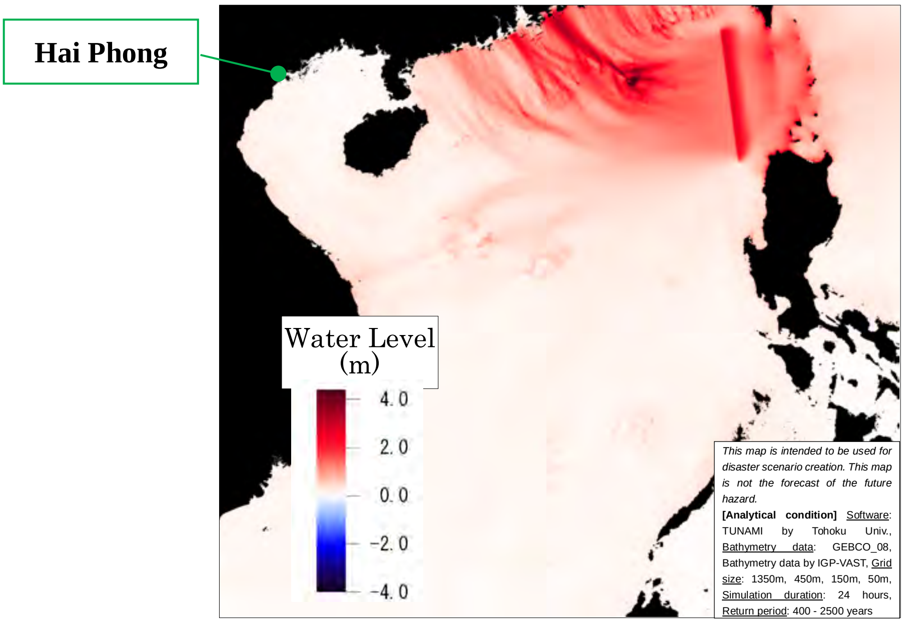

Figure A.2.30 Maximum Water Height (Scenario 6)

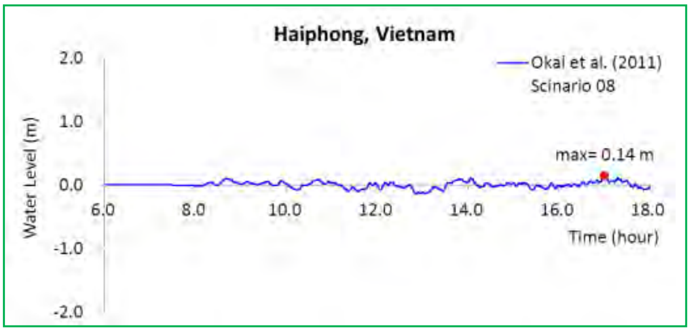

Figure A.2.31 Wave form of Tsunami Height at Hai Phong (Scenario 6)

<u>Simulation result of Scenario 7</u>

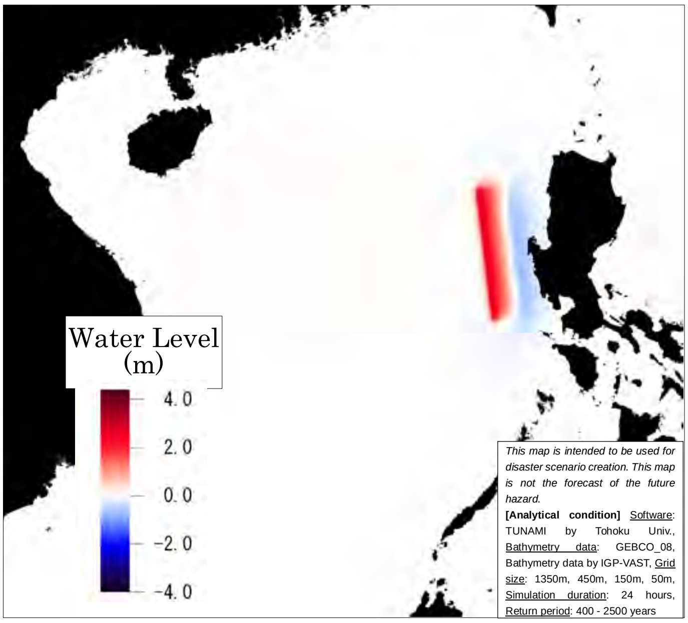

Figure A.2.32 Vertical deformation (Scenario 7)

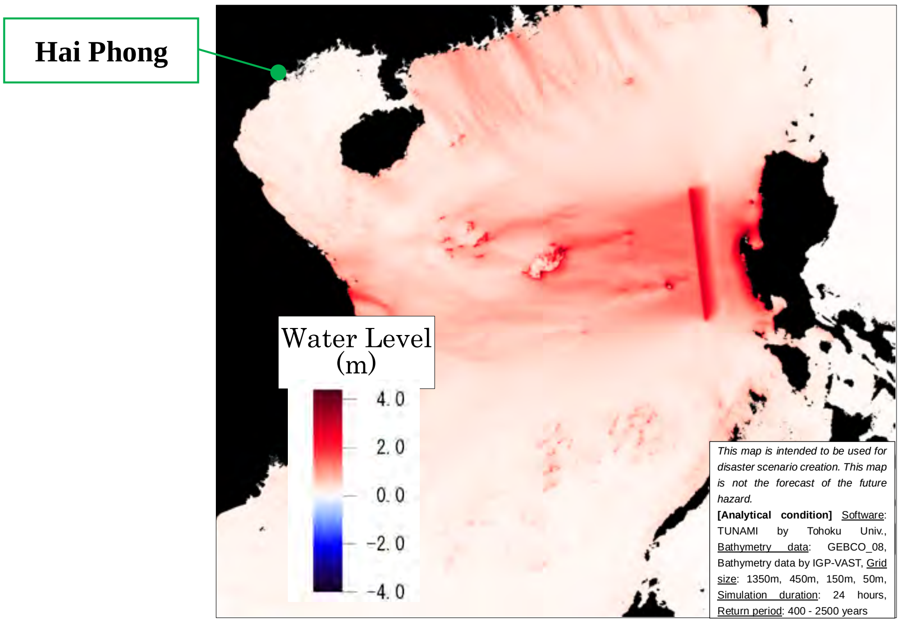

Figure A.2.33 Maximum Water Height (Scenario 7)

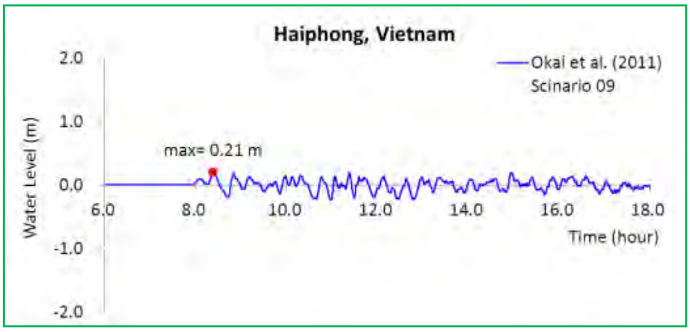

Figure A.2.34 Wave form of Tsunami Height at Hai Phong (Scenario 7)

<u>Simulation result of Worst Case Scenario</u>

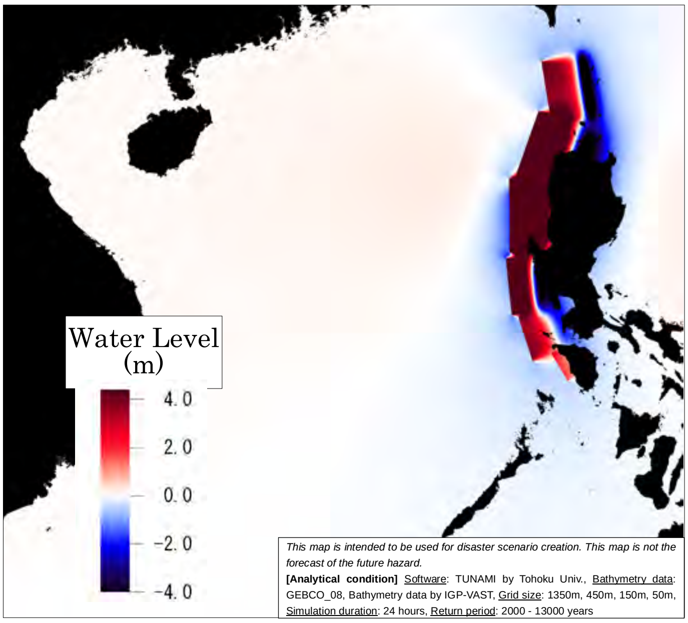

Figure A.2.35 Vertical deformation (Worst Case Scenario)

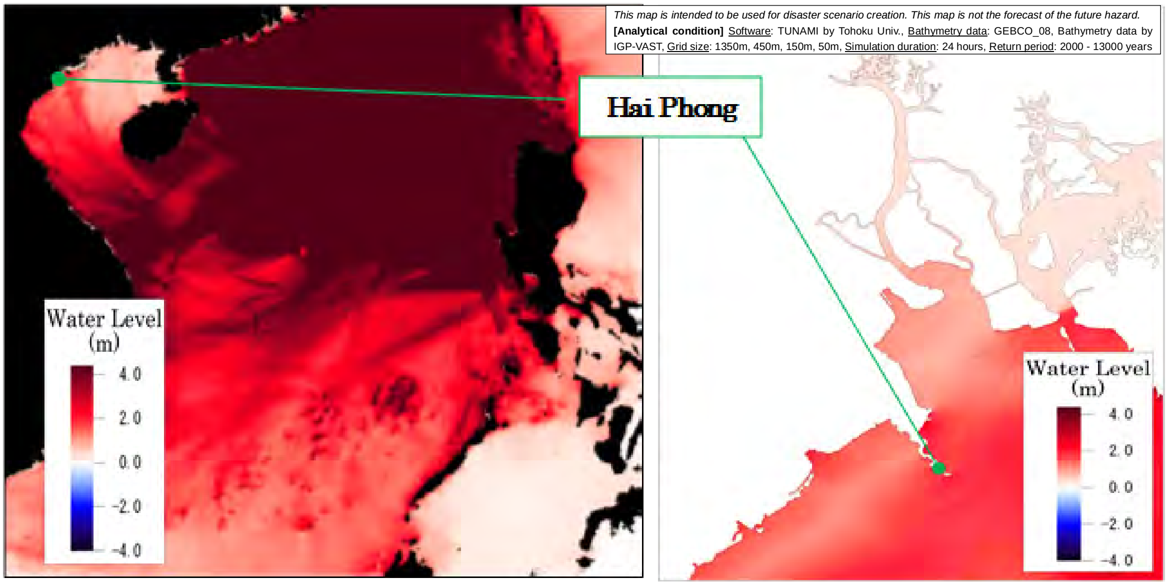

Figure A.2.36 Maximum Water Height (Worst Case Scenario)

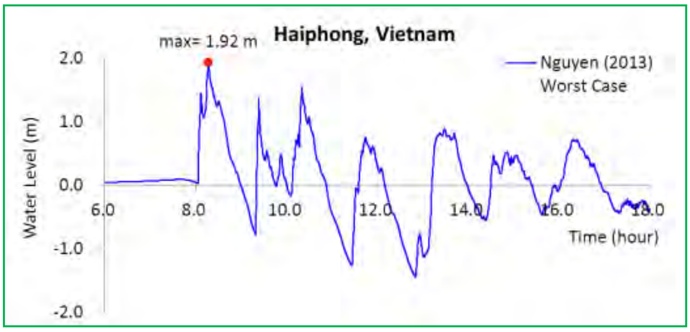

Figure A.2.37 Wave form of Tsunami Height at Hai Phong (Worst Case Scenario)

A.2.6 Evaluation of the Results

(1) Return period of the tsunami

The probabilistic analysis methodology for tsunami is not established as for the earthquake. The main reason is that there is no simple simulation method for tsunami compared to the earthquake. The earthquake motion can be evaluated by attenuation formula using only the magnitude of the earthquake and the distance from the epicenter to the study point; however simple formula to estimate tsunami is not exist because the influence of the bathymetry and the shape of the shore line have a great influence to the tsunami. Therefore, the tsunami simulation for the previously decided probability of occurrence like the other hazards is not possible. In this study, the tsunami was simulated based on the existing fault models in the existing scientific papers, and the probability of the occurrence of the earthquake at the fault was estimated based on the earthquake catalogue around the fault separately. The tsunami simulation in this study is not the probabilistic analysis but the simulation of tsunami by the existing fault model and the evaluation of the probability of fault activity.

(2) Bathymetry data

The open source bathymetry data of around 1km grid is used to make the bathymetry model. The quality of the data is enough to be used to make offshore bathymetry model. The bathymetry data near the coast should be more precise, for example 50m grid data is necessary. The chart or bathymetry map are digitized and used in this study. The precise bathymetry data is sometimes unavailable or not exist at all. This limitation may become an obstacle to the tsunami simulation.

(3) Run-up

The run-up is not simulated in this study because the precise and accurate elevation model, height of dyke, land cover and distribution of the buildings are necessary. The high level of technique is also required for precise analysis. The hurdle to realize the run-up simulation for Area BCP is high.

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A.3 Flood Hazard Assessment

A.3.1 Overview

According to the past flood/inundation condition and the result of interview survey conducted in this study, it is said that inundation in Hai Phong City is caused by not overflow from the Red River water but inland flooding by local rainfall. Since the flood safety level of the Red River is relatively high and equal to around 100-year return period, inland flooding shall be examined in this study.

A.3.2 Design Flood Scale

Design disaster scale shall be determined considering central and/or local government policies, opinion of resident, feasibility of countermeasures and so on. Here, flood analysis under four cases including 50, 100, 200-year (probable rainfall) and record-high rainfall shall be conducted for reference. Other studies on natural disaster (earthquake, tsunami and storm surge) would be done for same flood scale.

A.3.3 Rainfall Analysis

In this study, daily rainfall data at three stations are available for probable analysis. The location of rainfall gauging stations is shown in the following map. Collected rainfall data is annual maximum daily rainfall and observed period is from 1961 to 2010. Since Phu Lien station is located at center of Hai Phong City, rainfall data observed at Phu Lien station is used for probable analysis.

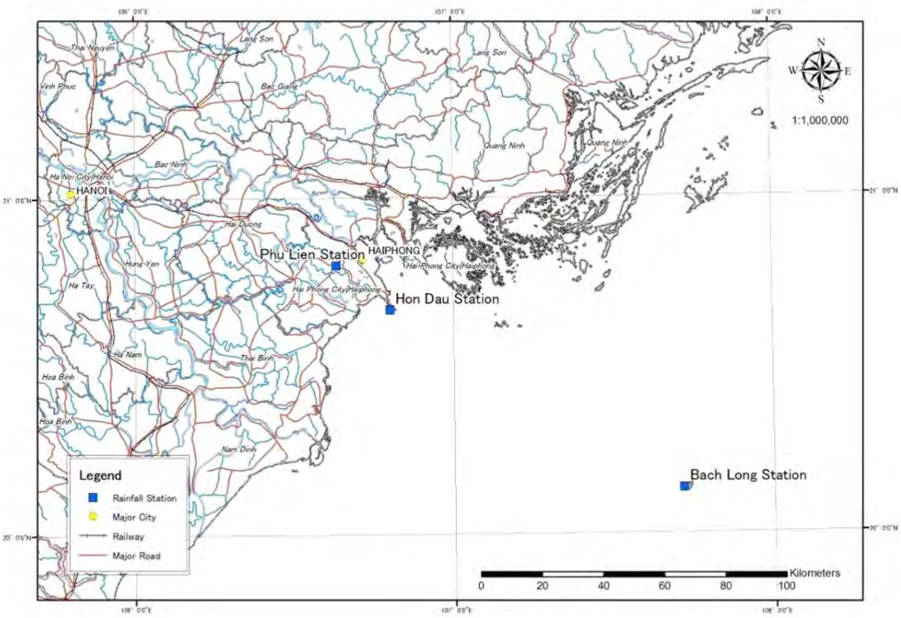
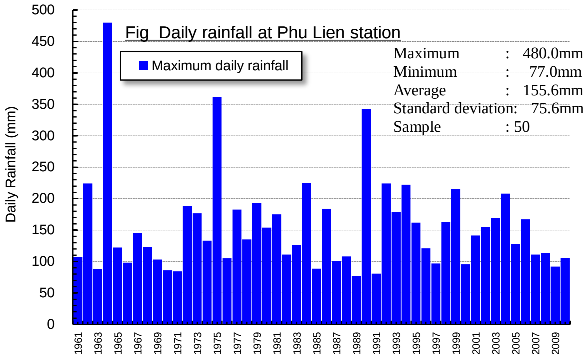


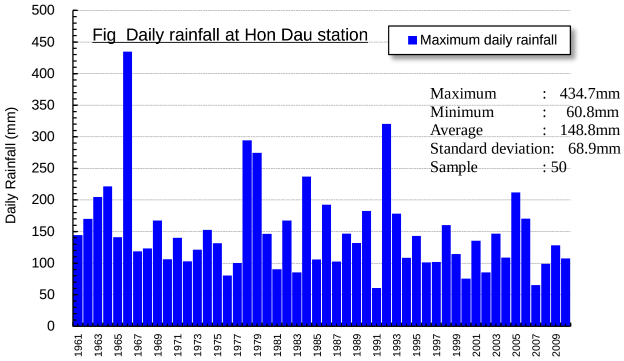
Figure A.3.1 Location of Rainfall Station (only available in this study)

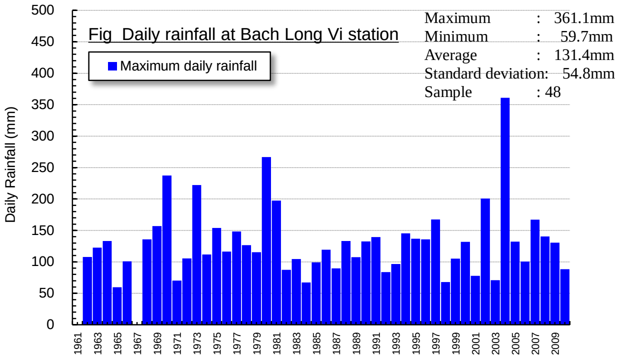
The calculation condition is shown in following table.

Table A.3.1 Conditions of Probable Analysis

No	Items	Description
1	Software	Hydrological statistical tool developed by JICE[1]
2	Sample	Annual maximum daily rainfall at <u>Phu Lien station</u> Number of samples is 50 (from 1961 to 2010)
3	Probability density function (PDF)	13 functions Exp: Exponential Distribution Gumbel: Gumbel Distribution SqrtET: Square-root Exponential Type (Maximum Distribution) Gev: Extreme Value Distribution LP3RS: Peason Type III Distribution (Real Space) LogP3: Peason Type III Distribution (Logarithmic Space) Iwai: Iwai Method Ishi Taka: Ishihara Takase Method LN3Q: Log-normal Distribution (Quantile Method) LN3PM: Log-normal Distribution 3 (Slade II) LN2LM: Log-normal Distribution 2 (Slade I, L-moment method) LN2PM: Log-normal Distribution 2 (Slade I, Product moment method) LN4PM: Log-normal Distribution 4 (Slade IV, Product moment method)
4	Plotting position	Cunnane plot (α = 0.4)
5	Evaluation criterion for selection of PDF	SLSC (Standard Least Squares Criterion) is less than 0.04. High-correlation between plotting position and probability density curve Jack-knife estimated error is as small as possible







Reference: Ministry of Natural Resource and Environment
National Hydro-Meteorological Service

Figure A.3.2 Daily Maximum Rainfall

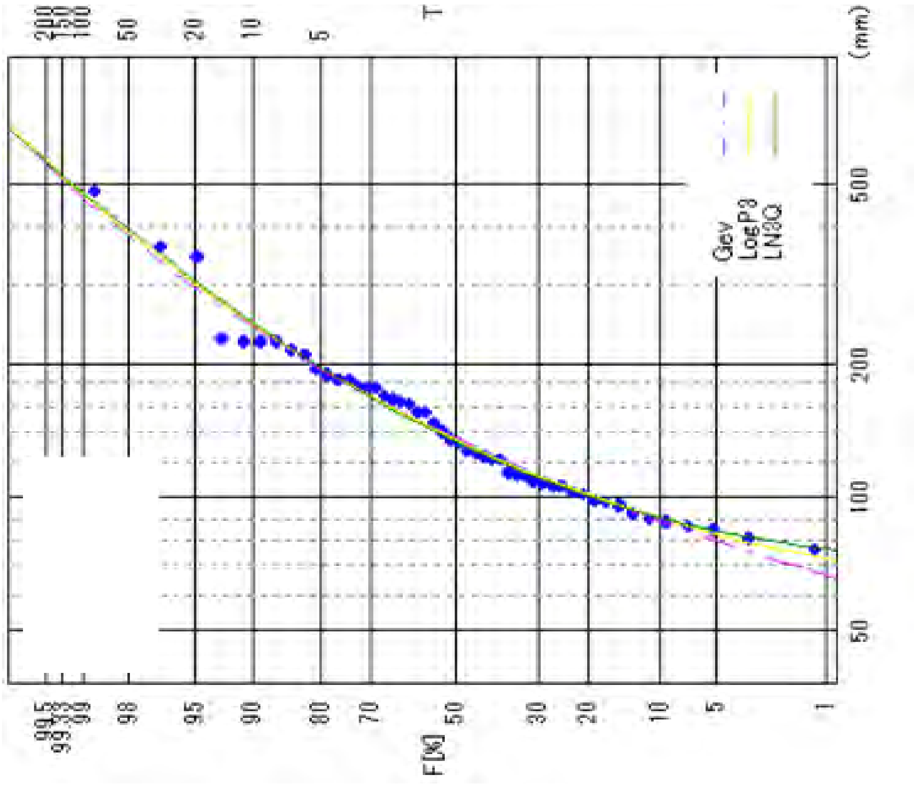
[1] Japan Institute of Country-ology and Engineering http://www.jice.or.jp/sim/t1/200608150.html

Table A.3.2 Result of Plobable Statistical Processing

Items		Probability density function (PDF)												
		Exp	Gumbel	SqrtEt	Gev	LP3Rs	LogP3	Iwai	IshiTaka	LN3Q	LN3PM	LN2LM	LN2PM	LN4PM
X-COR (99%)		0.979	0.955	0.976	0.988	–	0.988	–	–	0.988	–	–	–	–
P-COR (99%)		0.996	0.99	0.994	0.995	–	0.996	–	–	0.996	–	–	–	–
SLSC (99%)		0.046	0.071	0.056	0.028	–	0.027	–	–	0.022	–	–	–	–
Log likelihood		-265.7	-274.8	-270.8	-270.1	–	-269.1	–	–	-268.7	–	–	–	–
pAIC		535.4	553.6	545.7	546.2	–	544.3	–	–	543.3	–	–	–	–
X-COR (50%)		0.961	0.952	0.966	0.978	–	0.988	–	–	0.977	–	–	–	–
P-COR (50%)		0.981	0.987	0.986	0.984	–	0.996	–	–	0.983	–	–	–	–
SLSC (50%)		0.076	0.135	0.109	0.053	–	0.053	–	–	0.057	–	–	–	–
probable hydrological value	Return period	Exp	Gumbel	SqrtEt	Gev	LP3Rs	LogP3	Iwai	IshiTaka	LN3Q	LN3PM	LN2LM	LN2PM	LN4PM
	2	132.6	144.2	137.9	135.1	–	134.1	–	–	132.6	–	–	–	–
	3	163	173.1	162.3	160.6	–	160.1	–	–	159.3	–	–	–	–
	5	201.2	205.4	191.5	193.2	–	193.7	–	–	194.7	–	–	–	–
	10	253	245.8	231.2	241.4	–	243.8	–	–	247.5	–	–	–	–
	20	304.8	284.7	272.4	296.6	–	301	–	–	307	–	–	–	–
	30	335.1	307	297.5	332.9	–	338.5	–	–	345.4	–	–	–	–
	50	373.3	334.9	330.2	383.7	–	390.8	–	–	397.7	–	–	–	–
	80	408.5	360.5	361.6	436	–	444.5	–	–	450.1	–	–	–	–
	100	425.1	372.6	376.9	462.9	–	472	–	–	476.4	–	–	–	–
	150	455.5	394.5	405.5	515.7	–	525.7	–	–	526.8	–	–	–	–
	200	477	410.1	426.3	556.3	–	567	–	–	564.7	–	–	–	–
	400	528.8	447.5	478.3	666.5	–	678.4	–	–	663.3	–	–	–	–
Jack Knife Estimate value	Return period	Exp	Gumbel	SqrtEt	Gev	LP3Rs	LogP3	Iwai	IshiTaka	LN3Q	LN3PM	LN2LM	LN2PM	LN4PM
	2	132.6	144.2	137.7	134.8	–	134.1	–	–	131.9	–	–	–	–
	3	163	173.1	162.2	160.6	–	160.5	–	–	159.1	–	–	–	–
	5	201.2	205.4	191.5	193.9	–	194.4	–	–	195.2	–	–	–	–
	10	253	245.8	231.4	243	–	244.2	–	–	249.2	–	–	–	–
	20	304.8	284.7	272.9	298.8	–	300	–	–	309.8	–	–	–	–
	30	335.1	307	298.1	335.2	–	335.9	–	–	348.7	–	–	–	–
	50	373.3	334.9	331.1	385.3	–	384.9	–	–	401.6	–	–	–	–
	80	408.5	360.5	362.6	436.1	–	434.1	–	–	454.3	–	–	–	–
	100	425.1	372.6	378	461.9	–	458.8	–	–	480.7	–	–	–	–
	150	455.5	394.5	406.7	511.5	–	506.4	–	–	531	–	–	–	–
	200	477	410.1	427.6	549.1	–	542.1	–	–	568.7	–	–	–	–
	400	528.8	447.5	480	647.8	–	635.4	–	–	666.3	–	–	–	–
Jack Knife estimated error	Return period	Exp	Gumbel	SqrtEt	Gev	LP3Rs	LogP3	Iwai	IshiTaka	LN3Q	LN3PM	LN2LM	LN2PM	LN4PM
	2	7.5	9.1	8	8.5	–	8.3	–	–	7.7	–	–	–	–
	3	12	13.7	11.1	11.1	–	11	–	–	10.6	–	–	–	–
	5	18.5	19.3	15.1	15.1	–	15.6	–	–	15.9	–	–	–	–
	10	27.8	26.5	21	23.9	–	25.4	–	–	26.7	–	–	–	–
	20	37.2	33.5	27.5	38.7	–	40.8	–	–	42.2	–	–	–	–
	30	42.8	37.6	31.5	50.9	–	52.8	–	–	53.5	–	–	–	–
	50	49.8	42.7	36.8	70.7	–	71.7	–	–	70.3	–	–	–	–
	80	56.2	47.4	42	94	–	93.2	–	–	88.4	–	–	–	–
	100	59.3	49.6	44.6	107	–	105	–	–	97.9	–	–	–	–
	150	64.9	53.7	49.4	134.2	–	129.4	–	–	116.9	–	–	–	–
	200	68.8	56.5	52.9	156.6	–	149.1	–	–	131.6	–	–	–	–
	400	78.4	63.4	61.9	222.8	–	206.6	–	–	172.1	–	–	–	–

Note: "-" means that statistical processing does not converge.

Plotted in lognormal probability paper



Plotted in lognormal probability paper

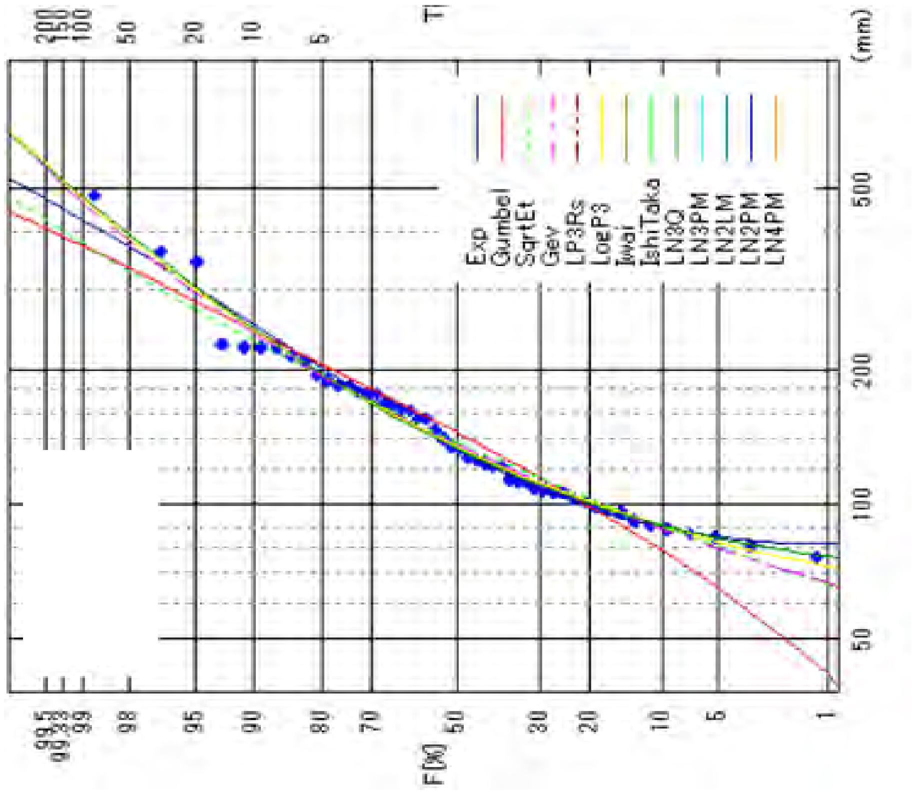


Figure A.3.3 Probable Annual Maximum Daily Rainfall

The result shows that three probability density functions namely Gev, LogP3 and LN3Q clear the evaluation criteria that SLSC is less than 0.04 and high correlation. Also, each Jack Knife estimate error is not so much of a difference. In this study, since LN3Q is better than other functions by visual judging of fitness between plotting and probability density curve (see Figure A**.3.3**), probable hydrological value estimated by LN3Q is employed for evaluation of flood scale at Phu Lien station. The following table shows the probable daily rainfall. Record-high daily rainfall is 480mm (1964), which is evaluated to be 100-year return period.

Table A.3.3 Probable Rainfall at Phu Lien Station

Return period (year)	Annual maximum daily rainfall (mm)
2	132.6
3	159.3
5	194.7
10	247.5
20	307
30	345.4
50	397.7
80	450.1
100	476.4
150	526.8
200	564.7
400	663.3

A.3.4 Inundation Analysis

Calculation condition of inland-flood analysis is shown in following table. Estimated inundation area/depth and inundated period are shown in next page.

Table A.3.4 Calculation Contidion for Inland flooding Analaysis in Hai Phong City

No	Items	Descriptions
1	Software	MIKE-21 (released by DHI[2])
2	Calculation method	Designed rainfall depth is given to calculation grids and behavior of flooded water shall be calculated with two-dimensional unsteady flow analysis. NOT considering spilled water from the Red River.
3	Grid size	500m
4	Elevation data	ASTER Data resolution :30m
5	Roughness coefficient in protected area	0.040 (constant)
6	Boundary condition	Rainfall depth given to protected area 50-year return period: 397.7mm/day 100-year return period: 476.4mm/day 200-year return period: 564.7mm/day Record-high: 480mm/day (1964) Since all rainfall depth does not contributes to inland flooding, runoff rate of 0.80 is employed for estimation of inland-flooding. On the assumption that rainfall given to mountain/hill area flows into river/canal, rainfall depth would not be given to mountain/hill area. According to the topographic feature and land use condition (by using Google Earth), elevation over 200m is assumed as mountain/hill area.
7	Evaporation	4mm/day
8	Infiltration to the ground	Not considering
9	Drainage	In Hai Phong City, drainage canals are raid widely and inundated water would be drained to the rivers through drainage canals. In this study, drainage capacity of $5m^3/s$ per km^2 is counted for consideration of decrease of inundation area/depth due to drainage.

[2] Danish Hydraulic Institute, DHI http://www.dhigroup.com/

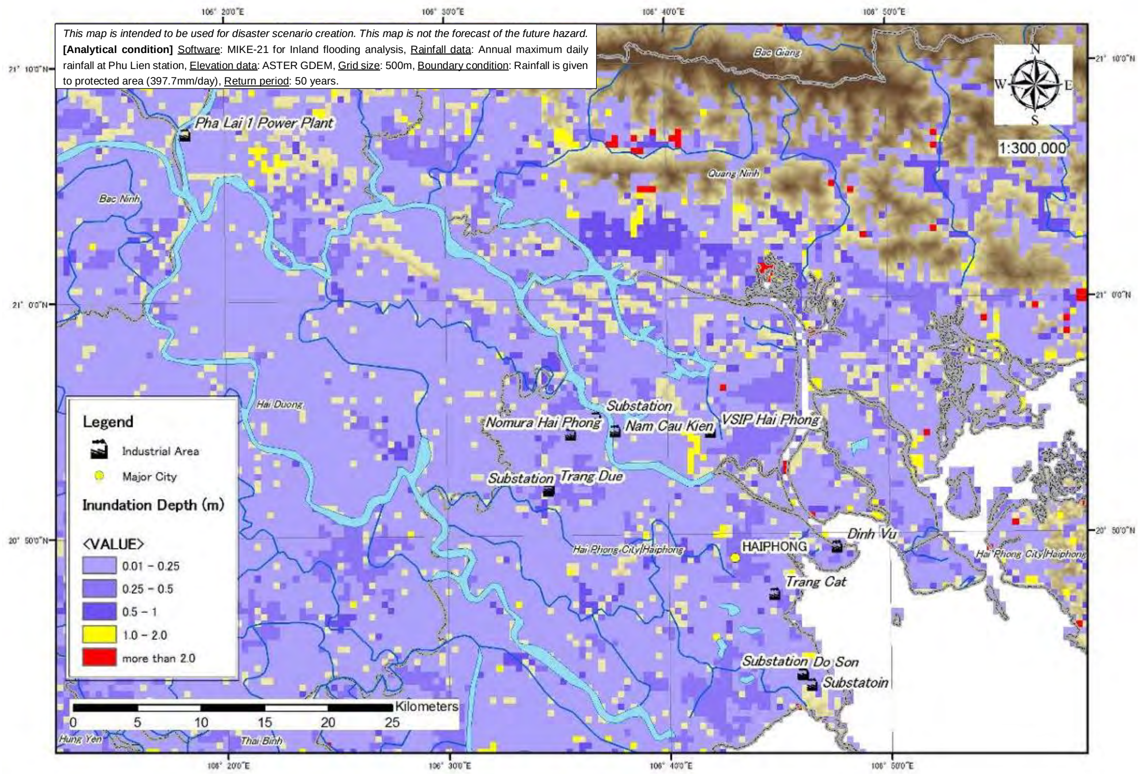


Figure A.3.4 Estimated Inundation Area/Depth (flood scale: 50-year)

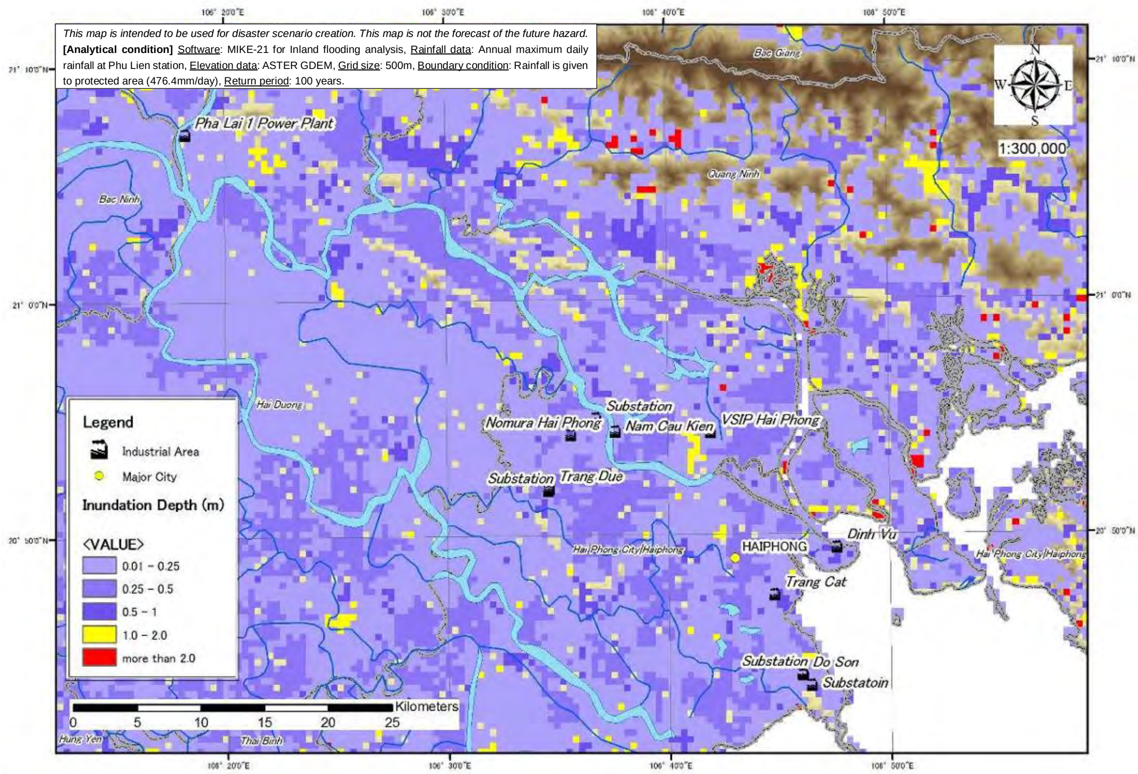


Figure A.3.5 Estimated Inundation Area/Depth (flood scale: 100-year)

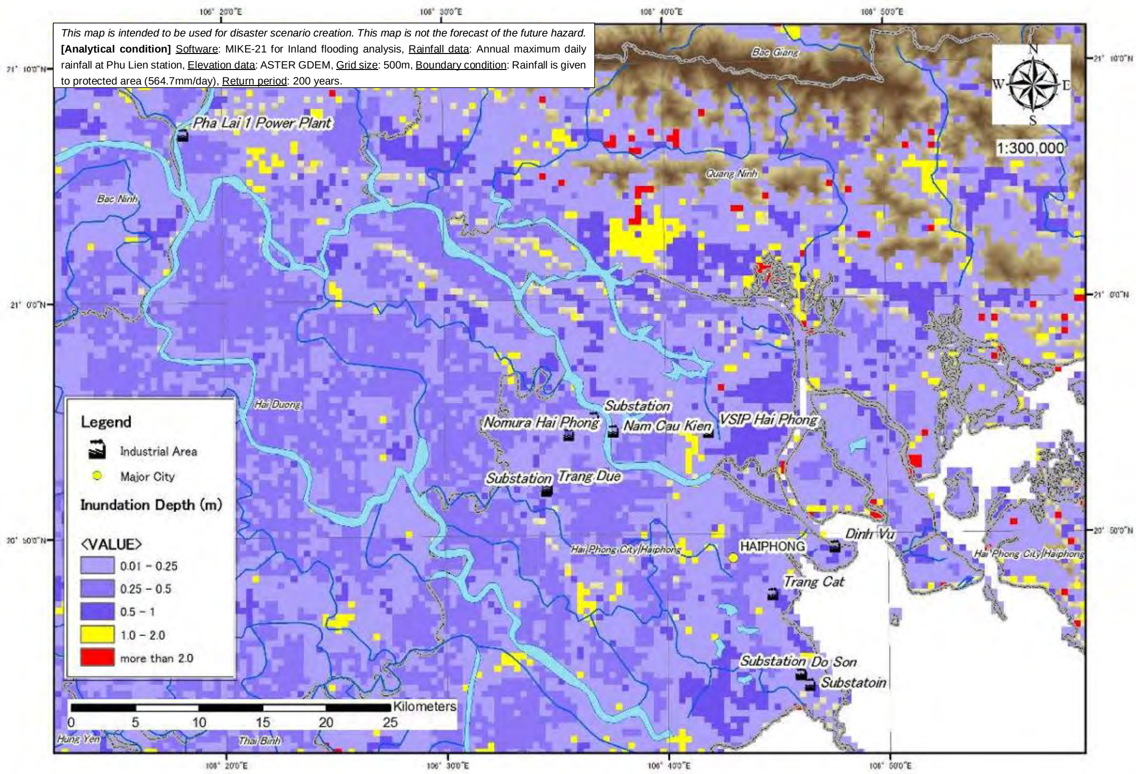


Figure A.3.6 Estimated Inundation Area/Depth (flood scale: 200-year)

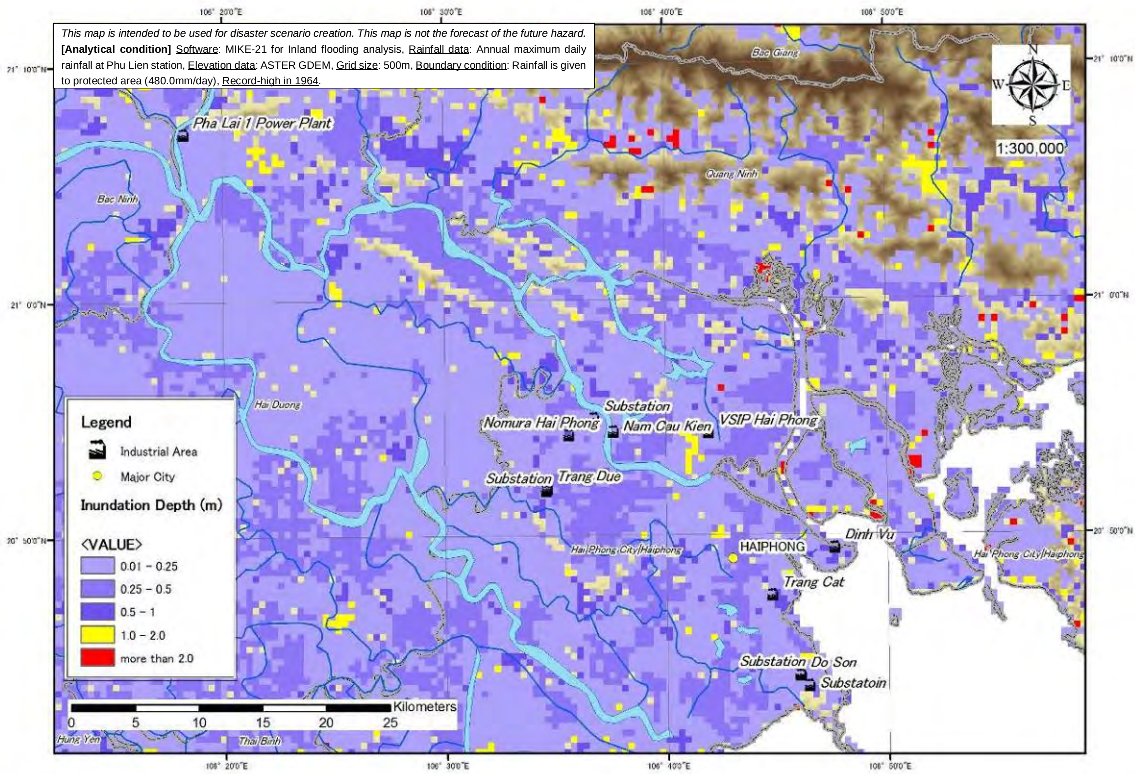
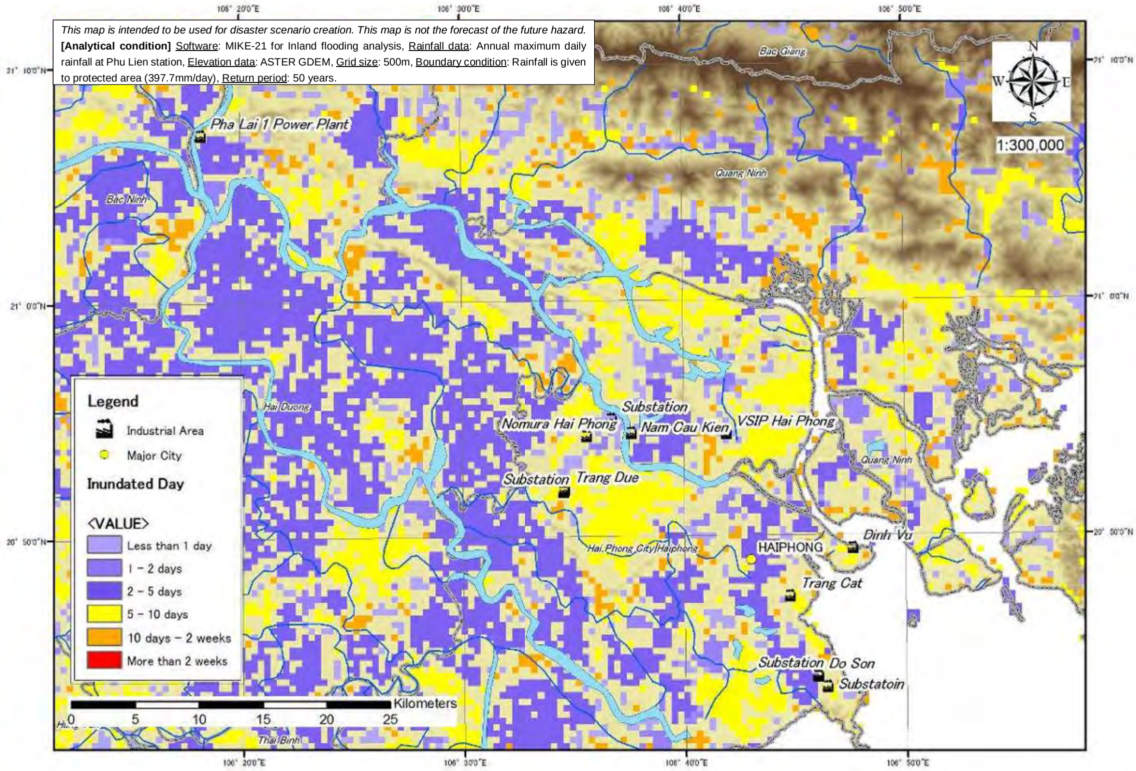
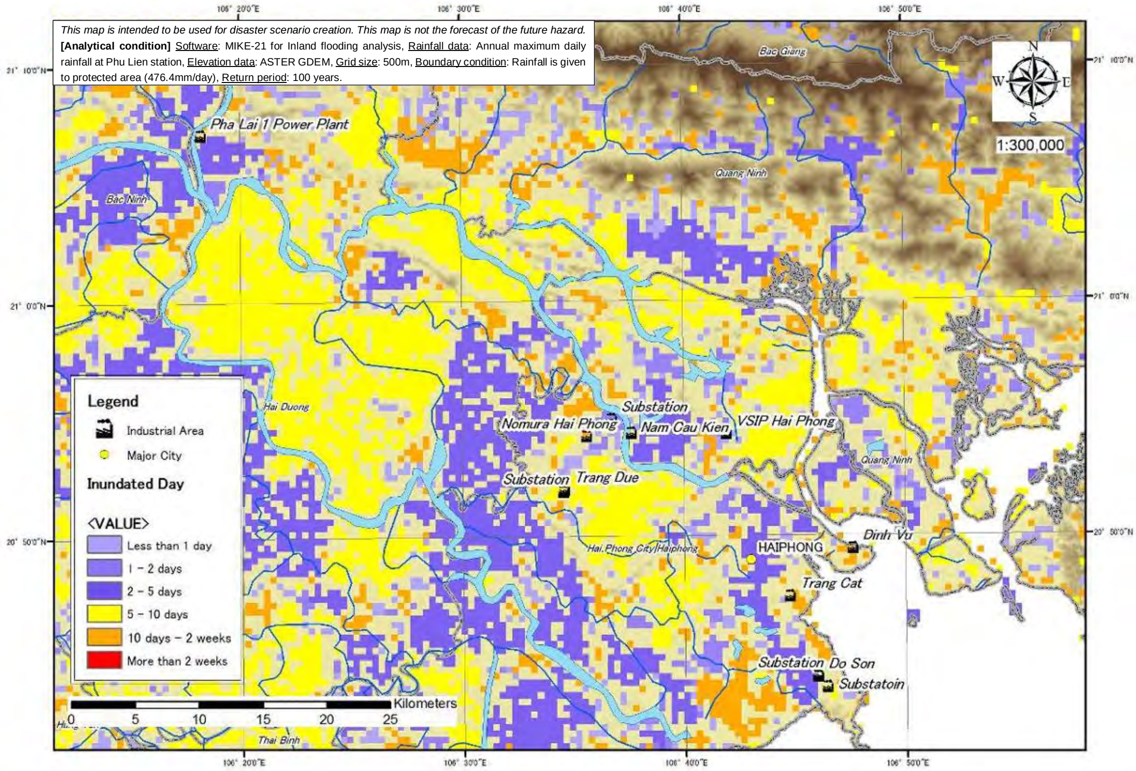


Figure A.3.7 Estimated Inundation Area/Depth (record-high: 1964yr)



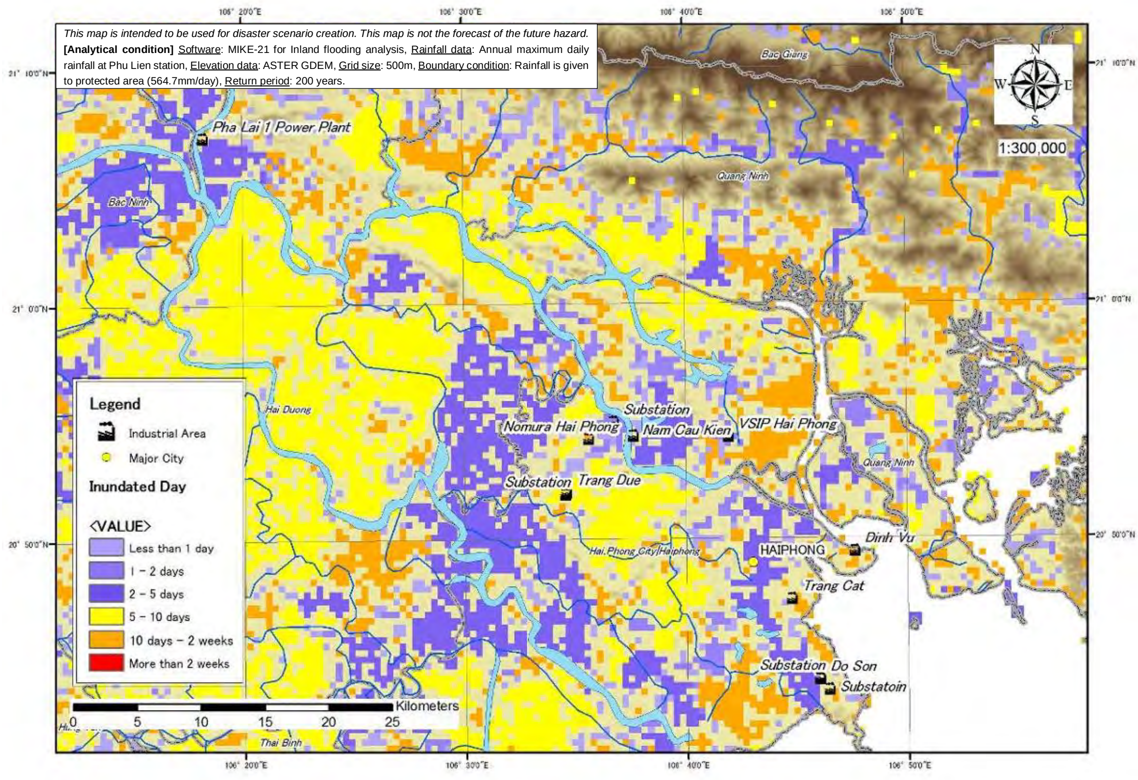
*Inundation depth less than 5cm is not displayed

Figure A.3.8 Estimated Inundation Period (flood scale: 50-year)



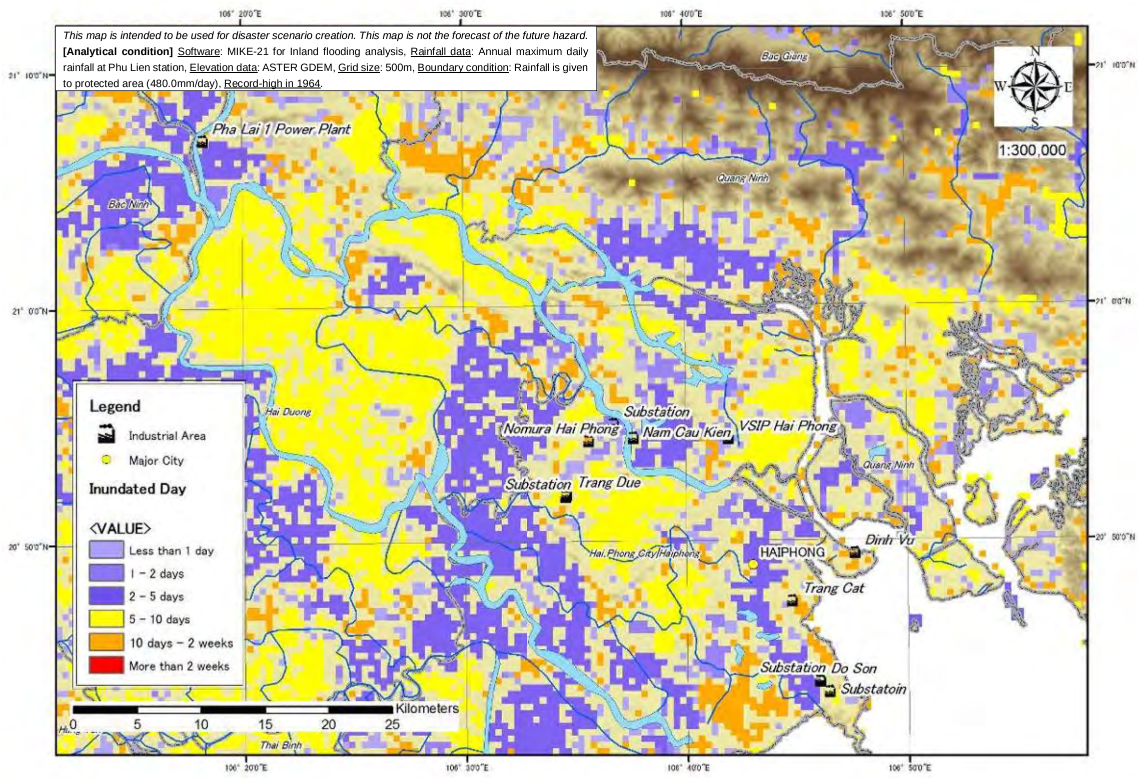
*Inundation depth less than 5cm is not displayed

Figure A.3.9 Estimated Inundation Period (flood scale: 100-year)



*Inundation depth less than 5cm is not displayed

Figure A.3.10 Estimated Inundation Period (flood scale: 200-year)



*Inundation depth less than 5cm is not displayed

Figure A.3.11 Estimated Inundation Period (record-high: 1964yr)

The result shows that maximum inundation depth around industrial estates is evaluated to be less than 50cm. Regarding inundated period, less than 10 days around "Trang Due" industrial estate is predicted at a maximum under flood scale of 200-year return period. According to the interview survey conducted in this study, it is reported that past maximum inundation depth is 50 to 60cm in Hai Phong City and record-high inundation time is 7 to 10 days before completion of countermeasures such as tidal gates and canal improvement works against inland flooding. Therefore it could be said that the simulation result does not so lose touch with the actual inundation condition, which proves the reasonability of this inundation model.

A.3.5 Evaluation of the Results

(1) Assumptions for the simulation

Only the effect of rainfall is considered in the analysis because the possibility of flooding due to the break of embankment is low. The rainfall to the hill is assumed to permeate to the ground or flow out to the river and the rainfall to the urban area is considered. The rainfall is supposed uniform in urban area because rainfall data at ground surface is available for only one station. The function of the aqueducts and drainage pumps are supposed to be maintained. The drainage capacity is set to agree the simulated results with the surveyed actual flooding situation.

(2) Used data and the accuracy of the analysis

As mentioned above, the simulation is done on many assumptions because of the shortage of information; hence the analysis is limited to the outline study level. However, the characteristics of the inundation in the study area can be evaluated properly and the analyzed results are adequate for the disaster scenario formulation. The consistency of the simulated results and the actual flooding is confirmed by the hearing survey of the actual duration period of the inundation in this area. The precise cross section of the river and channel, survey of elevation, information of drainage capacity, and so on, are necessary for more precise analysis. It may needs much resource.

A.4 Storm Surge Assessment

A.4.1 Abstract

The possible water height of storm surges in the region (Hai Phong) is simulated through a storm surge model. Figure A.4.1 shows the flow chart of risk assessment for storm surges.

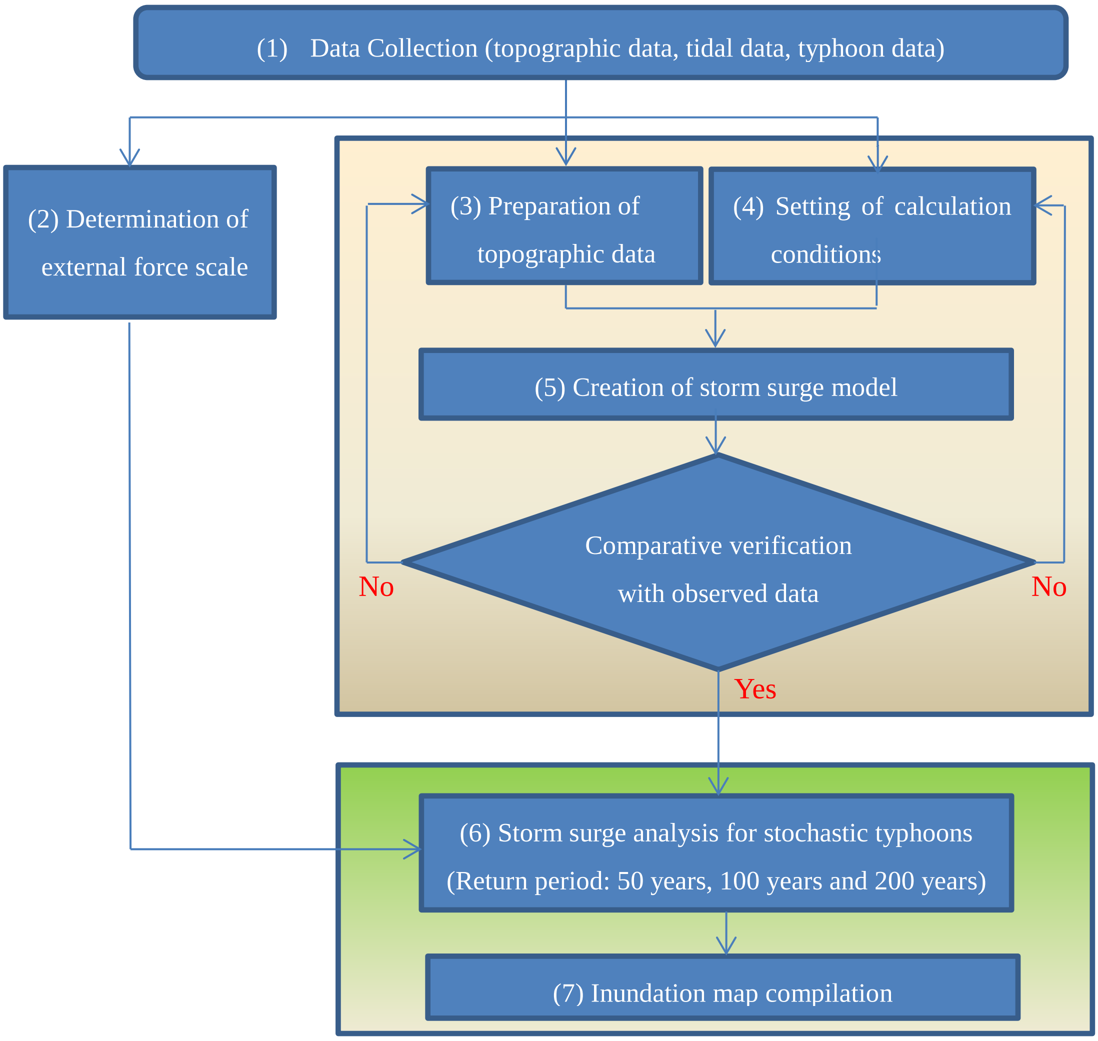


Figure A.4.1 Flow chart of storm surge simulation

A.4.2 Scale of External Force

As for the external force (probability scale) for storm surge simulation, 50-year return period typhoon, 100-year return period typhoon and 200-year return period typhoon models are set up.

A.4.3 Storm Surge Model

The storm surge analysis is conducted based on the Princeton Ocean Model (POM). Table A.4.1 shows the outline of the adopted models and input data for simulation.

Table A.4.1 Outline of models and data in the simulation

Model and data	Outline
Two Dimensional Typhoon Model Myers's Formula (1954)	The pressure fields are calculated using the location of the typhoon center, the minimum pressure at the typhoon center and the radius of the maximum wind. Based on these pressure fields, wind fields are created by the assumption of a gradient wind.
Storm Surge Model Princeton Ocean Model (POM)	The POM is a Hydrostatic model which uses the sigma coordinate model in that the vertical coordinate is scaled on the water column depth. It can be used to calculate efficiently the flow of sea of shallow water depth (less than 10 meters) and of deep water depth (more than several 1,000 meters) such as the Pacific Ocean.
Typhoon Best Track Data (Japan Meteorological Agency)	The "Best Track" analysis, which is different from the operational real time track analysis, is a re-analysis of fiscal data. JMA dataset include following information from 1951 to 2013: - Typhoon center position and pressure - Maximum winds (10 minute averages) - 50 knot and 30 knot wind radius
Tidal data (from Local Agency)	To build storm surge model and examine the performance of it, hourly tidal data are obtained when storm surges occur. As the storm surge model computes the deviation of water height, the astronomical tide level is also necessary. Tidal data of more than five years is required.
Topography data GEBCO_08, ASTER GDEM	The bathymetry and terrestrial topography gridded data are necessary. The threefold nested grid system with the size of 18", 6" and 2" is used.

A.4.4 Setting of the Extent of Typhoon (Stochastic Typhoon)

The data of typhoon, which came near to Hai Phong, are extracted from JMA best track dataset (1951-2013), including positions and intensities of typhoons. The typhoons that passed the area of Table A.4.2 are selected. Figure A.4.3 and Table A.4.2 show the return period for pressure dip of typhoons following the Weibull distribution fitting analysis.

Table A.4.3 shows the relationship between the typhoon central pressure and the radius of maximum wind.

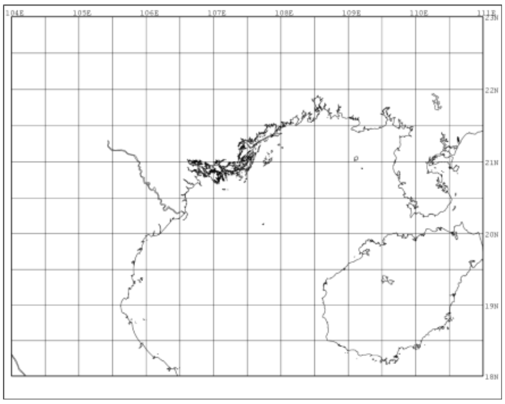
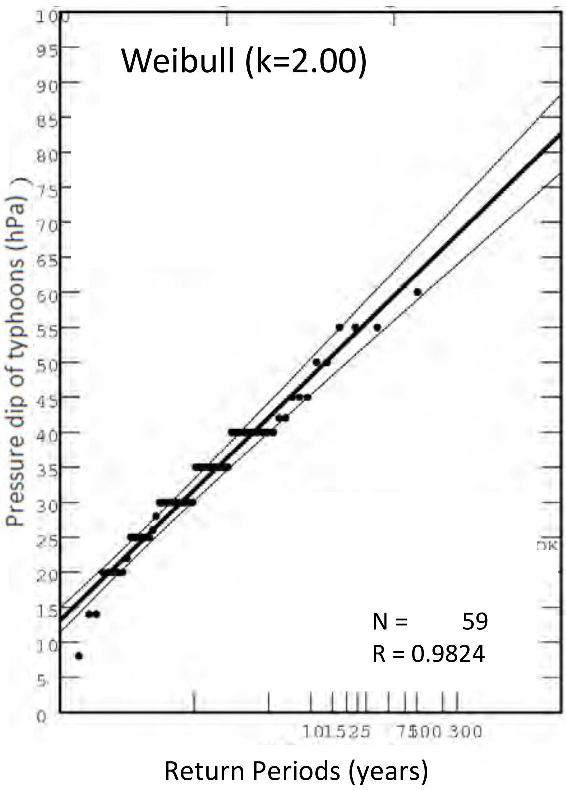


Figure A.4.2 Region for typhoon extraction (18.0°N - 23.0°N,   104.0° E- 111.0°E)



Return Periods (Year)	Pressure dip of typhoons (hPa)	Standard Deviation (hPa)
1	-	-
2	31.720	1.547
5	42.078	2.140
10	47.922	2.576
15	50.925	2.815
20	52.917	2.977
25	54.397	3.099
30	55.568	3.197
50	58.688	3.460
75	61.020	3.660
100	62.608	3.797
200	66.240	4.113
300	68.253	4.290

Figure A.4.3 Return period for pressure dip (differences of center pressure with 1,010hPa) of typhoons

Table A.4.2 Center pressure for 50, 100 and 200 years return period

Return periods (years)	Center pressure (hPa)
50	951.3
100	947.7
200	943.8

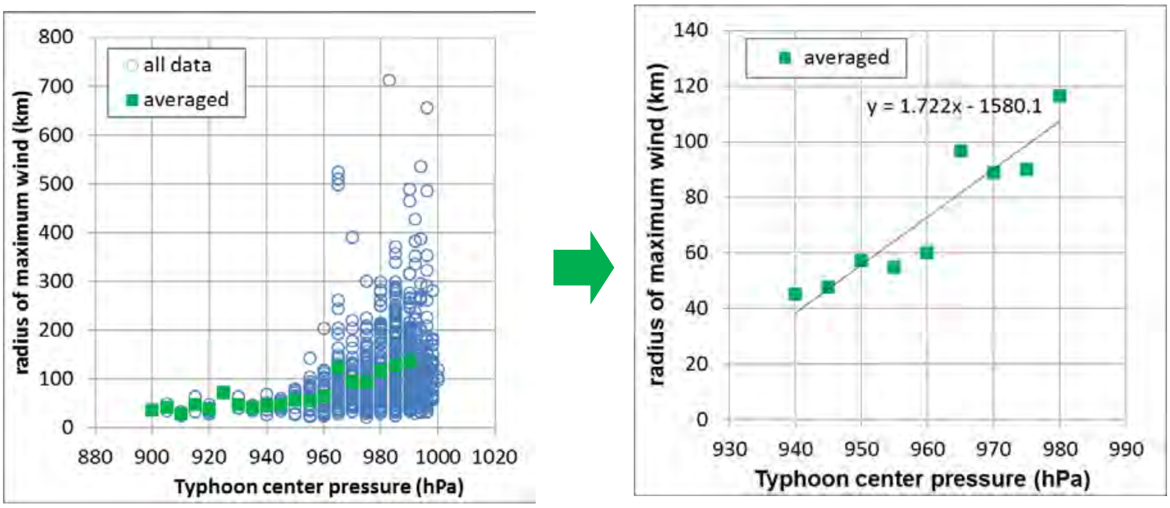


Figure A.4.4 Scatter diagram of typhoon center pressure and radius of maximum wind (left - all data (blue) and averaged (green); right - averaged at each pressure class 940 to 980hPa)

Table A.4.3 Typhoon center pressure and radius of maximum wind

Return periods (years)	Center pressure (hPa)	Radius of maximum wind (km)
50	951.3	58.1
100	947.7	51.3
200	943.8	45.1

A.4.5 Storm Surge Model (Comparative Verification)

Figure A.4.5 shows the calculation domain. Taking into account the computing time and the stability of the calculation, parent coarse mesh region 1 (grid size: 18”), and nest region 2 & 3 (6” and 2”) were set. Observation point (Hon Dau Station) is also plotted in this map (symbol:☆).

To examine the performance of the storm surge model, typhoon Son Tinh (T1223) that caused storm surge in Hai Phong was selected. Figure A.4.6 shows the track of T1223.

Figure A.4.7 shows the observed and estimated time series of tide level at Hon Dau Station (Hai Phong) on October 27 to 28 when typhoon Son Tinh (T1223) passed the northern part of Vietnam. Estimated tide level by the typhoon model (blue line) is smaller than actual observed data (green dots) because of the underestimated wind velocity. A correction factor was determined to align the estimated data with the observed data. As a result, the tide level using the corrected wind velocity (red line) becomes closer to the observed data.

This correction factor for wind velocity was used in all analysis for stochastic typhoon.

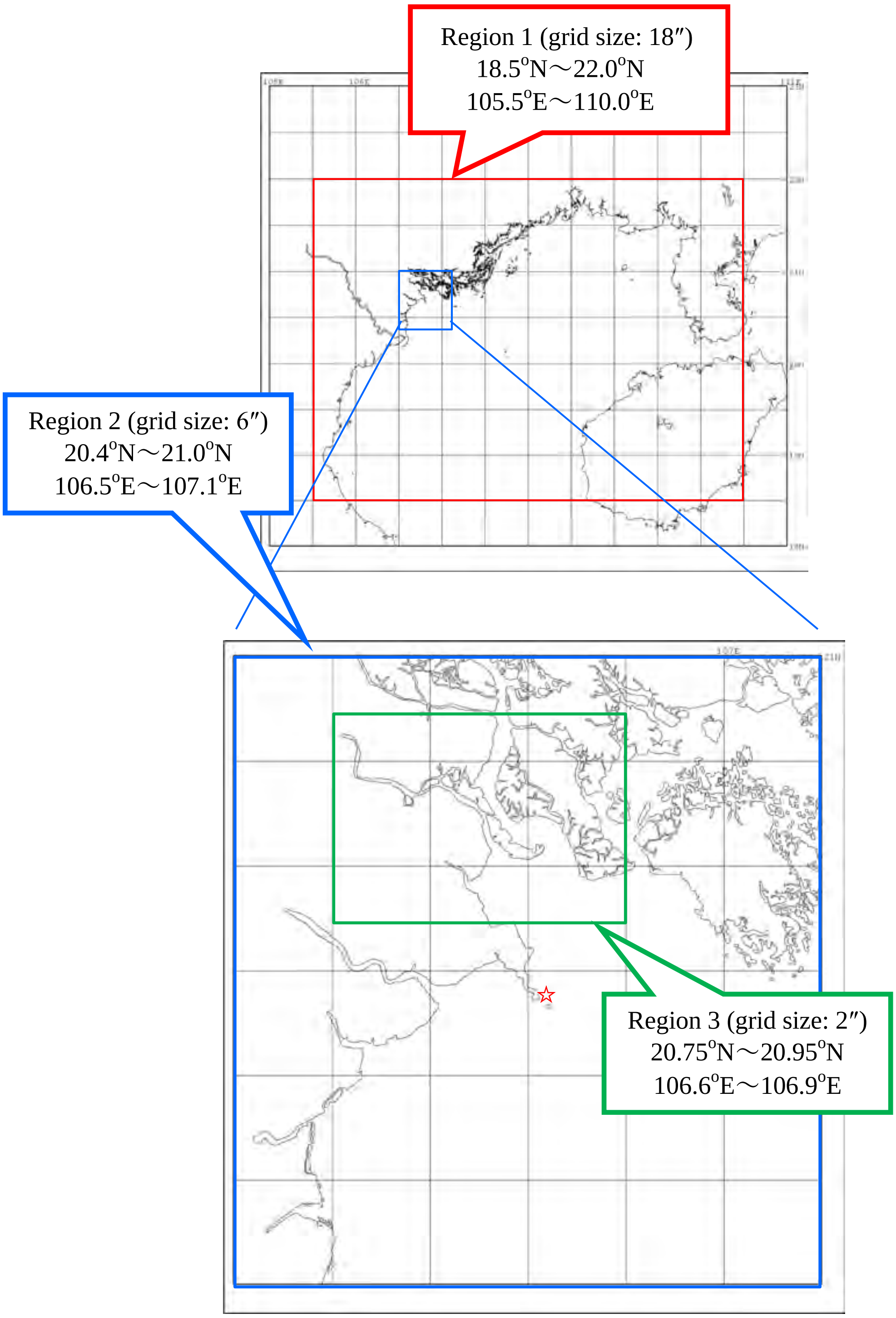


Figure A.4.5 The domain of the storm surge model

Date	Hour	Center latitude (°N)	Center longitude (°E)	Center pressure (hPa)	Max. wind speed (m/s)	Radius of 50kt winds (km)	Radius of 30kt winds (km)
10/26	18z	16.1	111.2	975	30	90	390
10/27	00z	16.5	111.0	975	30	90	390
	06z	17.0	109.7	965	35	110	390
	12z	17.5	108.9	945	45	110	390
	18z	18.1	107.8	955	40	110	390
10/28	00z	18.4	107.5	965	40	110	390
	06z	19.2	107.1	970	35	110	330
	12z	19.8	106.7	980	30	110	280
	18z	20.7	106.6	990	23	-	279
10/29	00z	21.3	107.0	1004	18	-	220

Figure A.4.6 Track of Typhoon Son Tinh (T1223)

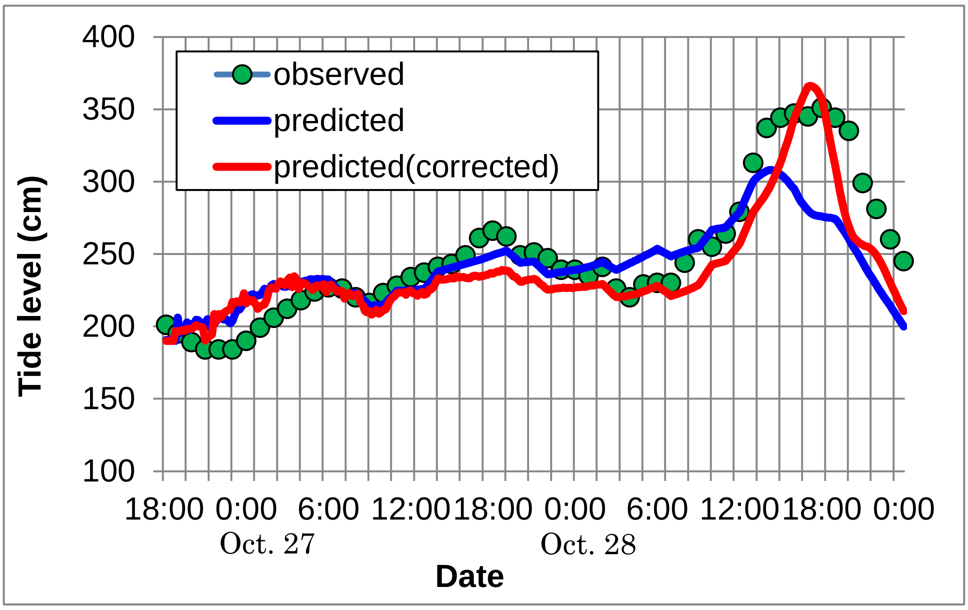


Figure A.4.7 Time series of storm surge (T1223) at Hon Dau Station (Hai Phong) observed (green dots), predicted (blue line) and predicted (corrected) (red line)

A.4.6 Storm Surge Estimation for Stochastic Typhoons

To calculate storm surge for stochastic typhoons, it is necessary to set the path of the typhoon (center positions and movement speeds). A typhoon becomes weak on land after landfall because of the lack of the water vapors and heat sources, and by the effect of friction with the ground surface. It is unlikely that a typhoon passes over Hainan Island from east to west and causes large storm surge damage to Hai Phong. Therefore, four different typhoon tracks from south to north were considered for the simulation as shown in Figure A.4.8. One of them was made based on the course of T1223 that affected Hai Phong in 2012 and the other three tracks were made by shifting the course to east or west by the radius of the maximum wind.

Figure A.4.9 to Figure A.4.11 show the results of tide level (water height of storm surge) for stochastic typhoons. It can be confirmed that the tide level by the typhoon that directly hit Hai Phong is higher than the other cases. In case of a typhoon for 200 years return period, the maximum tide level is estimated to be 2.6 meters along the coasts of Hai Phong.

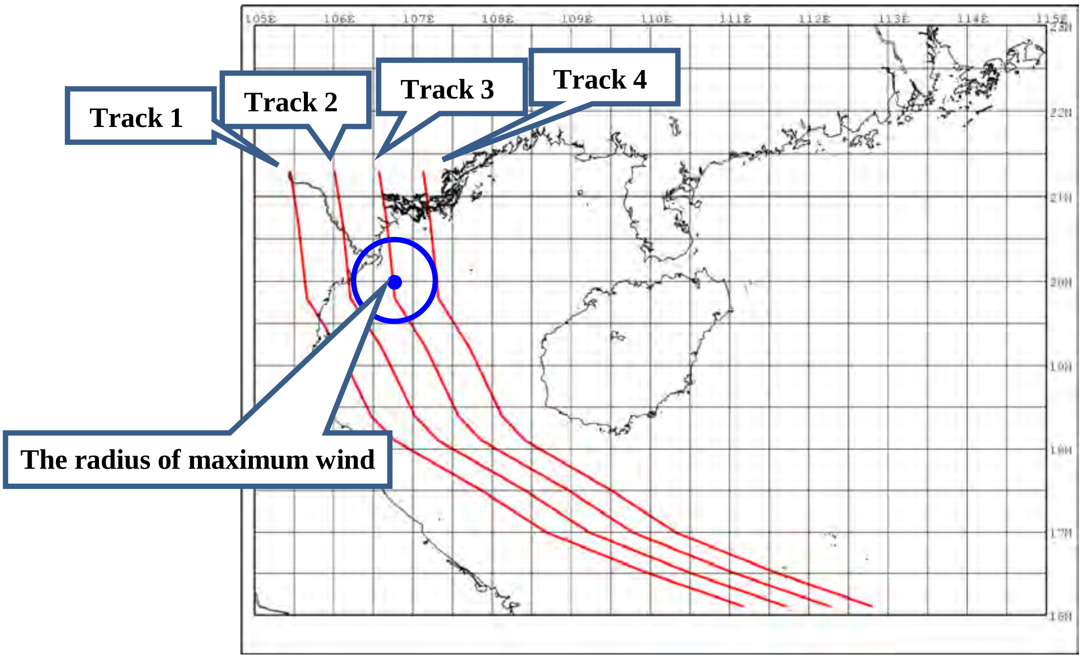


Figure A.4.8 Four different typhoon tracks for simulation

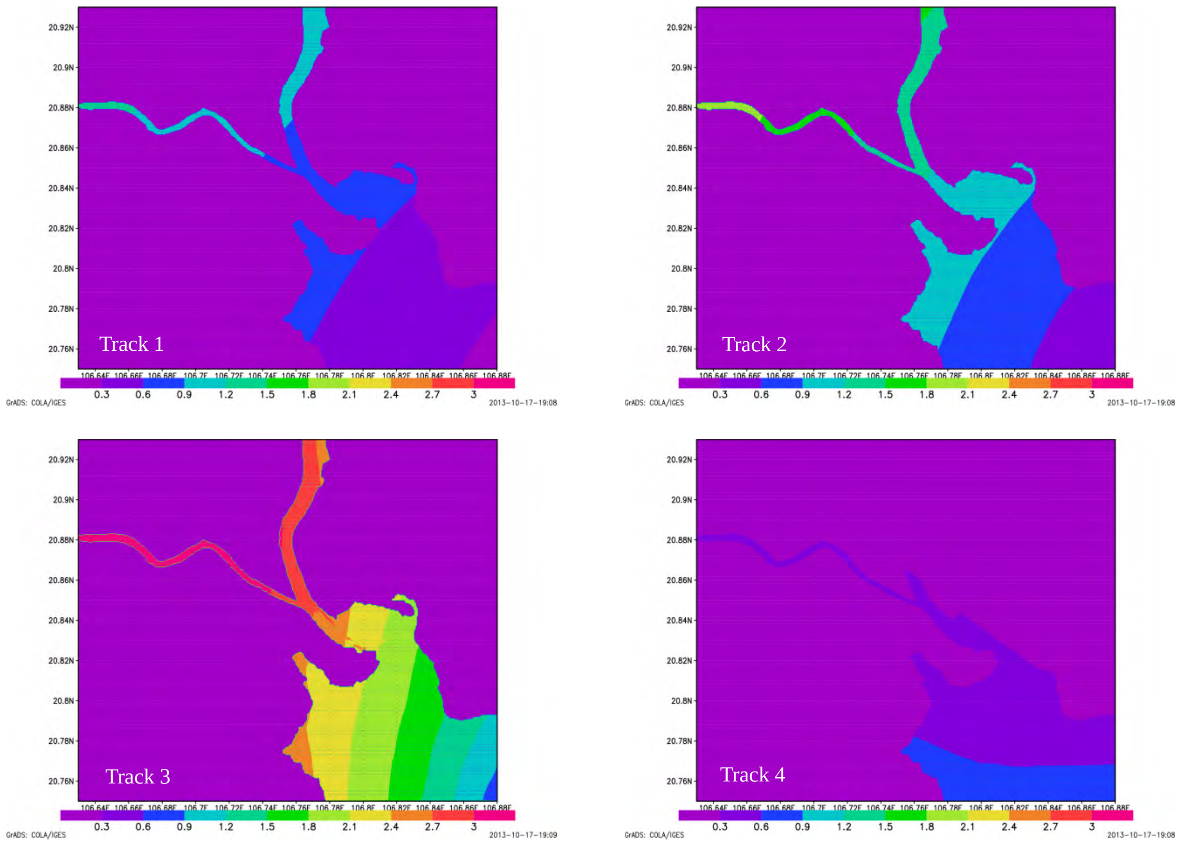


Figure A.4.9 Tide level (water height of storm surge) by a typhoon for 50 years return period

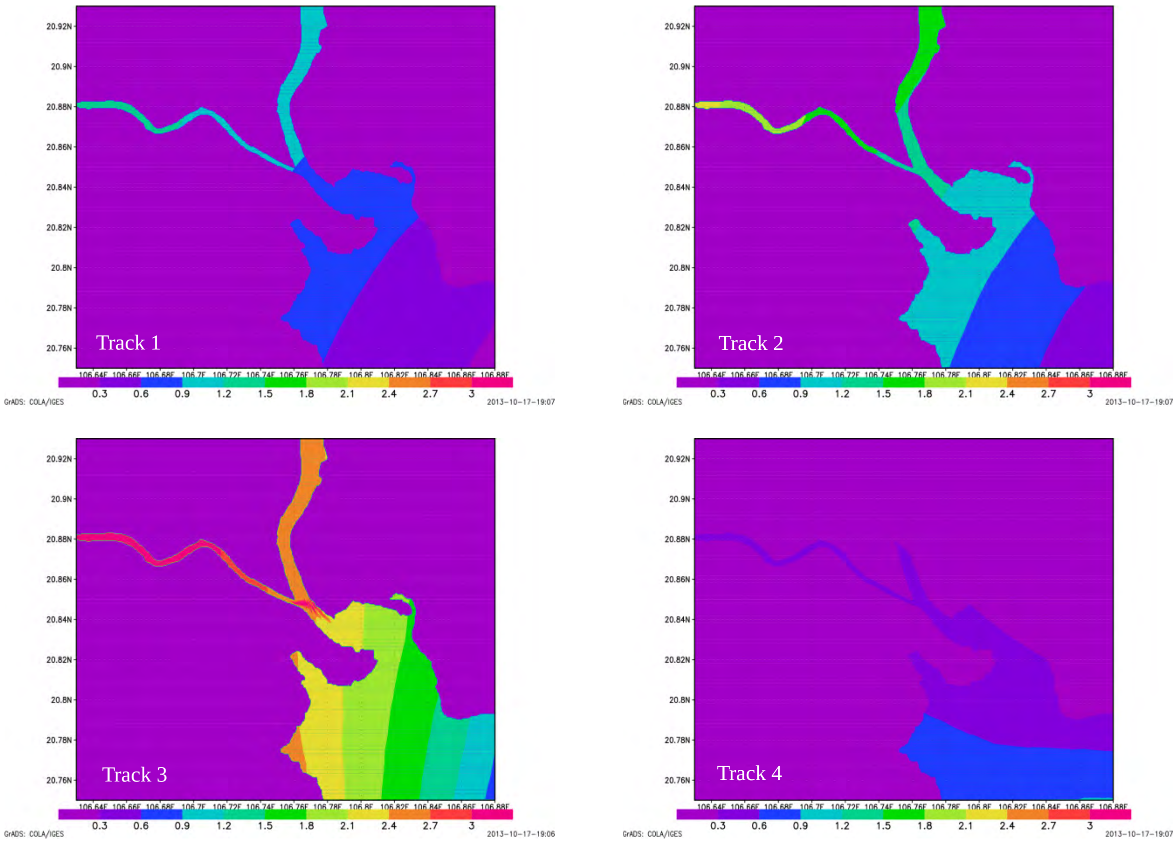


Figure A.4.10 Tide level (water height of storm surge) by a typhoon for 100 years return period

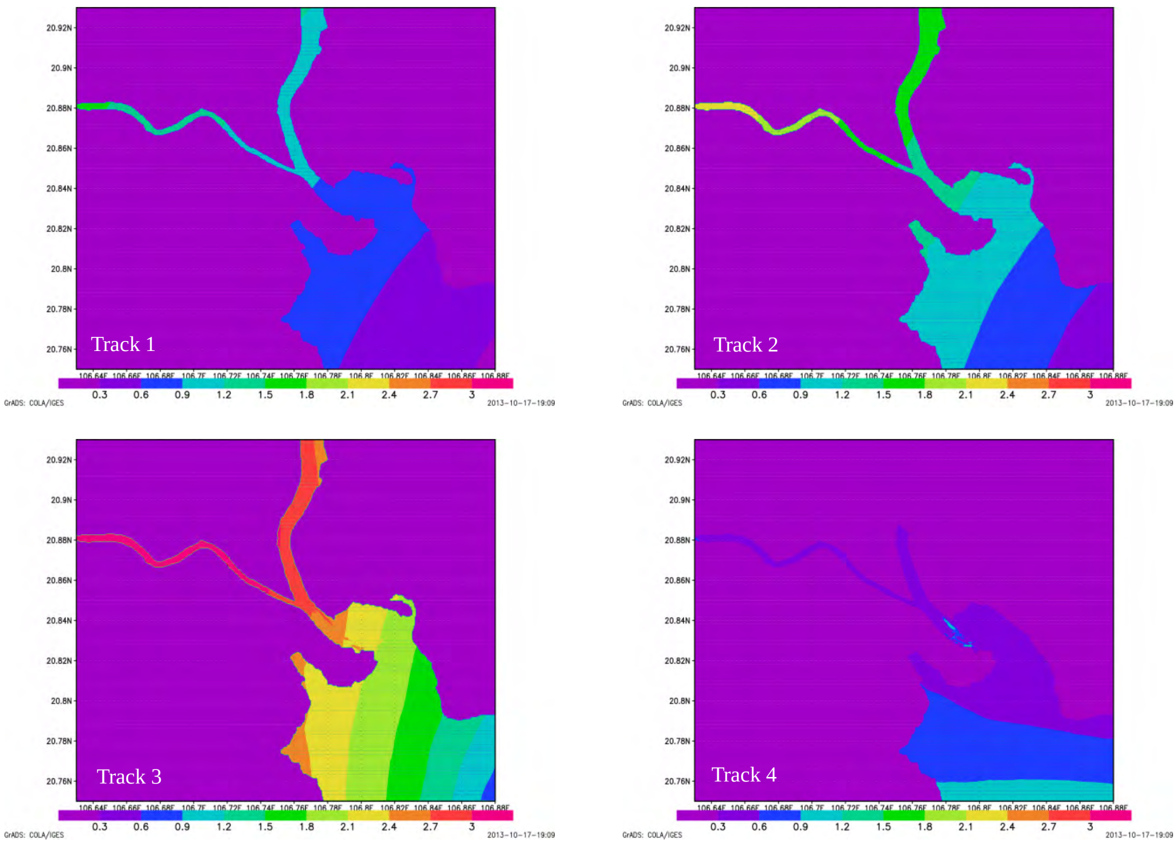


Figure A.4.11 Tide level (water height of storm surge) by a typhoon for 200 years return period

A.4.7 Inundation Mapping

The inundation by storm surge is evaluated based on the assumption that the peak time of storm surge agree with high tide. The tide level difference by typhoon is added to the mean high water spring. Figure A.4.12 to Figure A.4.14 show the inundation depth in reference to the maximum tide levels near the seacoast. Mean high tide at Hai Phong is 3.5 meters. The tide level in excess of 6m is estimated when the high tide and the peak of a storm surge occur at the same time.

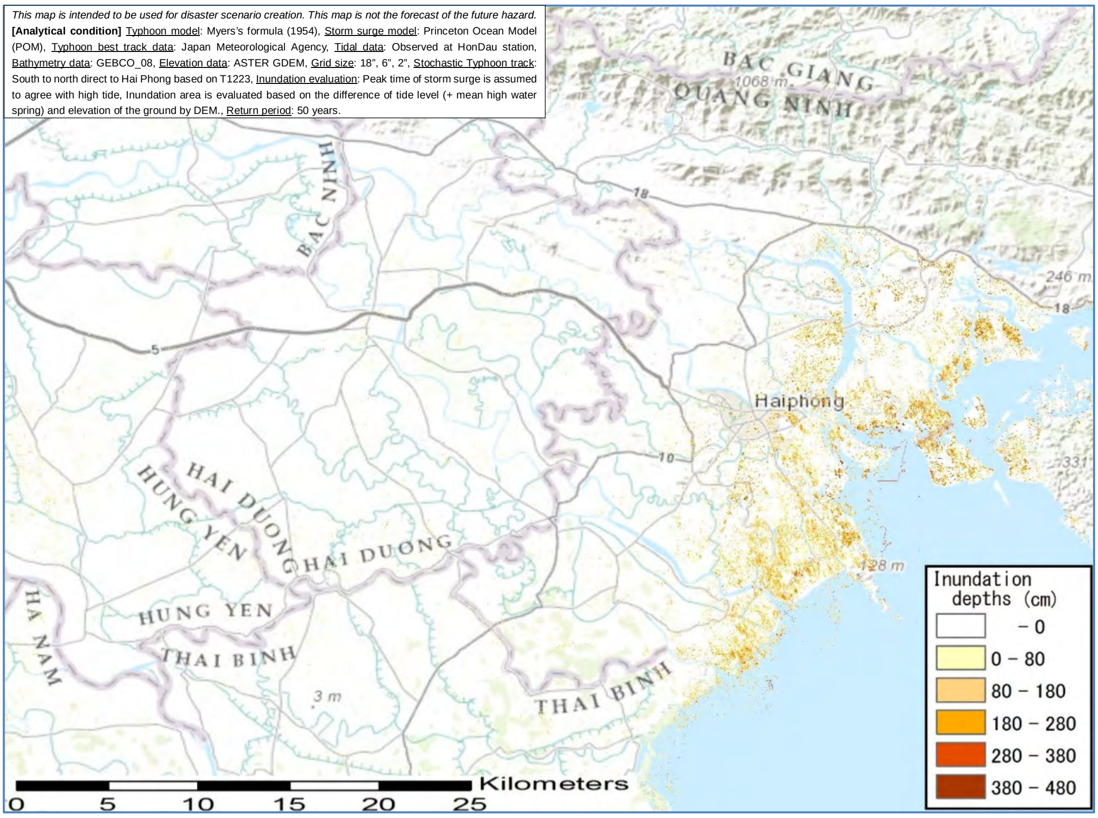


Figure A.4.12 Inundation map (Inundation depths for 50 years return period, Track 3)

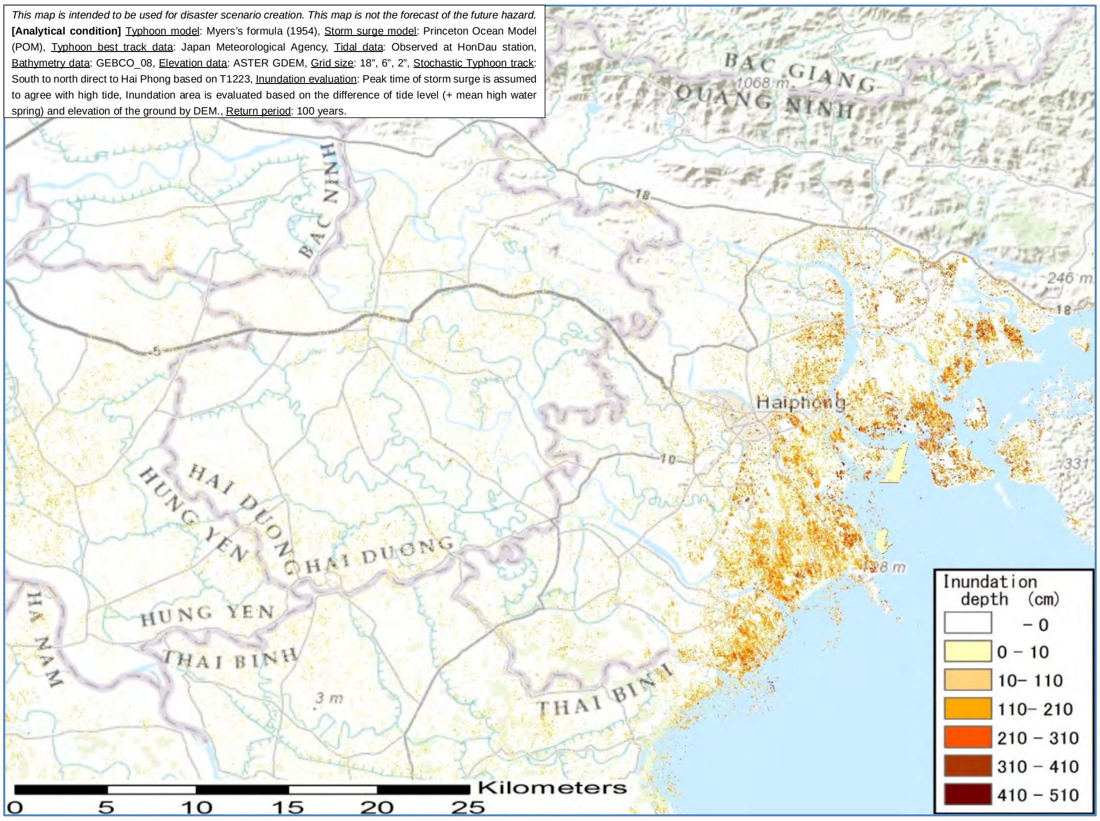


Figure A.4.13 Inundation map (Inundation depths for 100 years return period, Track 3)

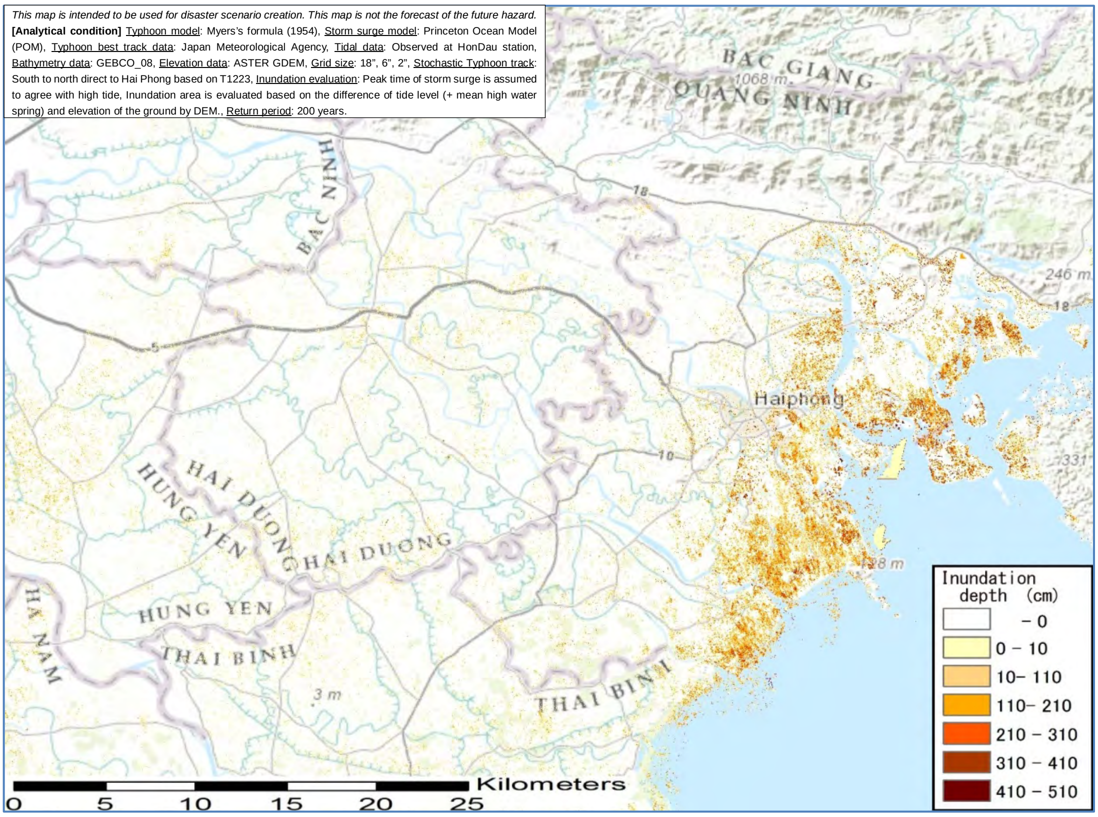


Figure A.4.14 Inundation map (Inundation depths for 200 years return period, Track 3)

A.4.8 Evaluation of the Results

(1) Effects by the climate change

According to the IPCC's 5th report, the global mean sea level will continue to rise during the 21st century. The rate of sea level rise will likely exceed the value which was previously observed during 1971 to 2010. In addition, the increased incidence and magnitude of extreme high sea levels is considered very likely. The risk of storm surges might increase in the future.

(2) Probabilistic model of typhoon

The stochastic typhoon model corresponding once in X years probability is created based on the database of past typhoon. The central pressure is used as the index. Several tracks are supposed for the stochastic typhoon in the simulation program and the worst course is selected as the result. Also it is assumed that the peak time of storm surge agree with high tide. Therefore, the expected typhoon may come to the pilot area once in X years but it cannot be said that the simulated storm surge will attack the pilot area once in X years. It should be noted that the worst condition is supposed.

(3) Inundation analysis

In this study, the inundation is evaluated by comparing the maximum tide levels near the seacoast and the elevation of the ground. If tide level is larger than elevation, the point is inundated by the difference of these values. The dyke along the seashore is not considered. Therefore, the inundation area by this method will reach to far from the seacoast if the lowland spread widely near the coast. The precise and accurate elevation model, height of dyke, land cover and distribution of the buildings are necessary to simulate the dynamic water movement. The high level of technique is also required for precise analysis. The hurdle to realize the dynamic inundation simulation for Area BCP is high.

(4) Digital Elevation Model (DEM)

The digital elevation model created from the satellite image, ASTER-GDEM is used in this study. This data is precise compared to the resemble data but it should be noted that it includes the effect of buildings fundamentally. As the data is about 30 meters gridded, one idea is grouping several point data using the larger grid and selecting the lowest data as the true elevation of the larger grid. If the inundation analysis is done using the same methodology of this study, the expression of the inundation map should be figured out considering the limitation of DEM data.