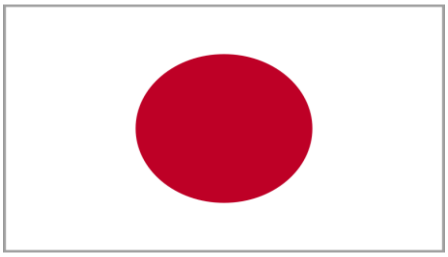
ASIAN DISASTER REDUCTION CENTER

Visiting Researcher Program
(FY2023)

RESEARCH REPORT

Flood Disaster Risk Management



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CONTENTS

OVERALL OF THE RESEARCH

The actuality of the research topic. Floods, which are among the most advanced natural disasters that occur in Azerbaijan and the world in terms of percentage, cause great damage to the country's economy, as well as human casualties and material losses. The inundation that occurred in the country was mainly manifested as a result of the overflow of the river in Azerbaijan.

Japan has a big experience in disaster reduction for almost all types of disasters, such as earthquakes, floods, typhoons, etc. So, this research will identify Japan's experience in flood risk management (countermeasures that Japan takes, technologies they use in flood management, simulation models of inundated areas, etc.). For this reason, the topic of the research is actual and appropriate for both countries. The study also examined both countries' experiences with flood risk management.

The purpose of the research. The purpose of the research work is to learn about Japan's experience in flood risk disaster management and to make an appropriate proposal and recommendations for the purpose of reducing and partially preventing the damage that floods can cause to the life activities of the population living there. Moreover, to identify the new technologies that are being used for flood management in Japan. Additionally, to learn simulation models for making hazard maps of the inundation areas.

Research place. The area of Japan, which is frequently exposed to the threat of flooding, was taken as the study area for research.

Research methodology. Statistical, comparative analysis, territorial historiography, systematic approach, cartography, zoning, field studies, application of new technologies, simulation models, and other methods were used in the research work.

Scientific innovations:

- The economic and socio-geographic risk of floods in Japan and Azerbaijan was studied, and their scientific-theoretical and methodological bases, conditions of occurrence, and distribution areas were determined.
- Early warning technologies were studied in flood management in Japan.
- Equations were studied for the simulation of flood-inundation areas in Japan.
- Building Back Better approach was studied to improve resilience to disasters.

Practical significance. The theoretical and practical significance of the obtained results are as follows:

In Japan, the materials of the research work and the obtained results, suggestions, and recommendations can be used in the protection and proper management of our country's population and agricultural areas from the effects of floods;

Studying the experience of Japan in the regularities of the occurrence of floods can be used as the main theoretical and methodological basis for reducing the dependence of the population on the influence of floods on the life and economic activity of our country.

The methodology developed for the purpose of reducing damages to the minimum level in the areas where there is a risk of flooding can be applied to the settlement of the population, the development of economic areas, as well as to different areas;

- To use the obtained results and maps (flood hazard map) in the relevant institutions of the country, including structural divisions of the Ministry of Emergency Situations, executive authorities of administrative regions and municipalities, as well as in the project planning works, construction, and operation of transport roads in regions and settlements with a high risk of flooding;

Equations studied for the simulation of flood-inundation areas could be innovative to use in our country.

Structure and scope of the research. The research paper consists of an introduction, 4 chapters, a conclusion, acknowledgement and a list of references. It consists of 63 pages with computer writing, 79 pictures (map, table, diagram, equations), and a reference with 50 names.

INTRODUCTION

Azerbaijan, bordered by the Caspian Sea, is a country known for its diverse relief, including mountains, valleys, and plains. Azerbaijan has a total land area of approximately 86,600 km^2 and a population of over 10 million, Azerbaijan has faced various natural disasters due to its geographic location and diverse climatic conditions. The main natural disasters are earthquakes, floods, landslides, droughts, etc.

Based on statistics and historical facts about disasters, we can say that the majority of territories of Azerbaijan are often exposed to the threat of floods. Especially from Yevlakh region to Neftchala region zones along the downstream of the Kura River Basin, floods are more evident there.

Japan is located in the Circum-Pacific Volcanic Belt, sometimes known as the Ring of Fire, which is characterized by persistent seismic and volcanic activity. Japan and its surrounding territories encounter nearly one-tenth of all earthquakes that occur worldwide. Japan is home to 7%[*] of the world's active volcanoes.

Furthermore, due to geographical, geological, and climatic characteristics, the nation is prone to regular natural catastrophes like typhoons, torrential rains, severe snowfalls, earthquakes, and tsunamis. Based on statistics and historical facts, it is obvious that there were numerous flood disasters in Japan as well. So, this is a great opportunity to learn Japan experience on disaster management during Asian Disaster Reduction Center (ADRC) Visiting Researcher Program FY2023.

I. PHYSICAL-GEOGRAPHICAL, ECONOMIC, SOCIO-DEMOGRAPHIC CONDITIONS, DISASTER RELATED REGULATIONS AND LAWS, THE CHARACTERISTICS OF DISASTERS, THE CONSEQUENCES OF FLOODS IN AZERBAIJAN AND JAPAN

1.1. Physical-geographical, economic, socio-demographic conditions of Azerbaijan and Japan

Azerbaijan is a country located at the crossroads of Eastern Europe and Western Asia, bordered by the Caspian Sea to the east. Comprehensive overview of the physical-geographical, economic, socio-demographic conditions, climate, natural resources, industries, population, ethnic composition, as well as education, health, and social welfare in Azerbaijan are shown in the following sub-sections:

Physical-Geographical Conditions. Azerbaijan's physical geography is diverse, encompassing the Greater Caucasus mountain range to the north and the Caspian Sea coastal plains to the east. The country is also home to vast semi-arid steppes and plateaus. The landscape provides a rich tapestry of natural beauty, showcasing stunning mountain vistas and unique ecosystems.

- The Greater Caucasus Range
- The Caspian Sea Coast
- Semi-arid Steppes and Plateaus

Economic Conditions. Azerbaijan has experienced significant economic growth due to its oil reserves, making it a key player in the global energy market. The oil and gas industry, alongside agriculture and manufacturing, form the backbone of Azerbaijan's economy. Additionally, the country has been focusing on diversifying its economy into non-oil sectors, such as tourism and technology. With its strategic location and significant natural resources, Azerbaijan has become an important hub for regional economic activities.

Socio-Demographic Conditions. Azerbaijan's socio-demographic landscape is characterized by a rich cultural heritage and diverse population. The country has a blend of ethnic groups, each contributing to the vibrant tapestry of traditions and customs. Moreover, the socio-demographic structure continues to evolve, reflecting a balance between modernization and preservation of traditional values.

1. Ethnic Diversity
2. Cultural Heritage
3. Social Evolution

Climate and Weather Patterns. Azerbaijan experiences a varied climate, with distinct seasonal changes. The country has a diverse range of microclimates, from humid subtropical in the eastern coastal areas to continental in the central regions. The climate, influenced by the Caspian Sea, fosters diverse ecosystems and agricultural opportunities.

Notable weather patterns include hot summers and mild winters, contributing to the agricultural productivity and ecological richness of the region.

Natural Resources and Industries. Azerbaijan's natural resources play a significant role in shaping the country's industrial landscape. The exploration and extraction of oil and gas have been central to the economy, with recent efforts focused on sustainable management of these resources. Additionally, the country boasts rich mineral deposits and fertile agricultural land supporting a variety of industries (Fig. 1.1).

Oil and Gas	Mining
Agriculture	Manufacturing

Figure 1.1. Natural Resources and Industries of Azerbaijan

Population and Ethnic Composition. The population of Azerbaijani is ethnically diverse, with Azerbaijani Turks forming the majority. The presence of various ethnic communities contributes to the cultural mosaic, enriching the social fabric with a tapestry of languages, traditional attire, and culinary arts. The population structure reflects a harmonious coexistence amid diversity.

- Azerbaijani Turks
- Ethnic Minorities
- Social Harmony

Education, Health, and Social Welfare. Educational, healthcare, and social welfare systems form critical components of Azerbaijan's societal framework. The country has made significant strides in advancing educational standards and healthcare facilities. Social welfare programs have been designed to ensure sustainable development and equitable access to essential services for all segments of society.

Azerbaijan's commitment to building a knowledge-driven society reflects the emphasis on human capital development and the well-being of its citizens.

Japan. *Physical-Geographical Conditions of Japan.* Japan's physical-geographical conditions are diverse and unique. The country is an archipelago consisting of over 6,800 islands, with four main islands: Honshu, Hokkaido, Kyushu, and Shikoku. The terrain is mountainous, characterized by numerous active and dormant volcanoes. The Pacific Ring of Fire significantly influences the country's geological features, leading to frequent seismic activities and volcanic eruptions. Additionally, Japan benefits from rich biodiversity, featuring various forest types and unique ecosystems.

Economic Conditions of Japan. Japan possesses a robust and advanced economy, being the third-largest in the world by nominal GDP. The country is renowned for innovation, technological advancement, and a strong industrial base. Moreover, Japan has a highly skilled workforce, efficient infrastructure, and a formidable export-oriented manufacturing sector. The economy is globally influential, with a focus on industries such as automotive, electronics, robotics, and high-tech machinery.

Socio-Demographic Conditions of Japan. Japan's socio-demographic landscape is characterized by a unique blend of ancient tradition and modernity. The population is highly urbanized, with Tokyo is the most populous metropolitan areas globally. The society is marked by a strong emphasis on cultural values, social harmony, and respect for traditions. Moreover, Japan has one of the highest life expectancies in the world, maintaining a rapidly aging population with a declining birth rate, leading to significant demographic challenges.

1.2. Disaster Management Regulations, Laws and Acts in Azerbaijan and Japan

Azerbaijan. *Law on Civil Defense* provides a legal framework for disaster management and outlines the responsibilities of relevant authorities and organizations.

The Ministry of Emergency Situations. Established by the Decree of the President of the Republic of Azerbaijan, in 16 December 2005, Ministry of Emergency Situations of the Republic of Azerbaijan is the central executive body of the government, which is responsible for emergency management within the entire territory of the country. According to the decree "for the purpose of providing prevention of natural and man-made disasters and fires, elimination of their consequences, management of activities of the relevant bodies responsible for rescue and rehabilitation works by one centralized system, organization and realization of civil defense work in the country, the Ministry of Emergency Situations of the Republic of Azerbaijan is established."

Outline of the main activities:

The Ministry is involved in drafting and implementation of the government policy in the following fields:

- civil defense,
- protection of population and property from emergency situations,
- fire security,
- individual protection in water areas,
- safety measures in industry, mining and construction,
- prevention of emergency situations and consequence management in cases of spills of crude oil and oil products as a result of incidents,
- formation of the state reserve funds (stocks).

In the framework of solid national system of emergency management, the Ministry provides coordination with national and local executive authorities in the fields of civil defense, protection of population and property from emergency situations, fire security, individual security in water areas, as well as in prevention of emergency situations and consequence management.

The Ministry implements normative regulations and exercises control and inspections within the scope of its authorities.

The Ministry is responsible for arranging and implementing civil defense functions, protecting population and territories in cases of emergency situations and fires, preventing emergency situations and managing their consequences, safeguarding human lives in water areas, monitoring technical safety of industrial activities, mining and construction works, establishing the state reserve stocks (funds), securing strategic facilities affected by natural and anthropogenic disasters or terrorist attacks, as well as providing prompt response and administering humanitarian assistance in cases of emergency situations.

The Ministry shall develop the areas attributed to the scope of its authorities [1].

The Ministry shall be also involved in other activities specified in the legislation.

Japan. It is a national priority to protect national land as well as citizens' lives, livelihoods, and property from natural disasters. The turning point for strengthening the disaster management system came into effect in response to the immense damage caused by the Typhoon Ise-wan in 1959, and led to the enactment of the Disaster Countermeasures Basic Act in 1961, which formulates a comprehensive and strategic disaster management system. Thereafter, the disaster management system has been continuously reviewed and revised following the lessons learned from large-scale disasters.

Japan's legislation for disaster management system, including the Disaster Countermeasures Basic Act, addresses all of the disaster phases of prevention, mitigation and preparedness, emergency response as well as recovery and reconstruction with roles and responsibilities among the national and local governments clearly defined, it is stipulated that the relevant entities of the public and private sectors are to cooperate in implementing various disaster countermeasures. The Disaster Countermeasures Basic Act has constantly been reviewed and amended since its first enactment, and with lessons learned from the Great East Japan Earthquake, provisions were added including enhancement of the measures concerning support activities mutually done by local governments in 2012 and the measures for ensuring smooth and safe evacuation of residents and improving protection of affected people in 2013. In 2014, provisions were added for strengthening measures against unattended cars in order to promptly clear them from the roads for emergency vehicles.

Mission of the Cabinet Office. Along with a series of reforms of the central government system in 2001, the post of Minister of State for Disaster Management was newly established to integrate and coordinate disaster risk reduction policies and measures of ministries and agencies. In the Cabinet Office, which is responsible for securing cooperation and collaboration among related government organizations in wide-ranging issues, the Director-General for Disaster Management is mandated to undertake the planning of basic disaster management policies and response to large-scale disasters, as well as conduct overall coordination (Fig. 1.2). To prepare for disasters, the Central Disaster Management Council with the Prime Minister as the Chief and all Cabinet members decides the national government's disaster management measures. Such decisions are carried out by respective ministries and agencies, accordingly. In the event of a large-scale disaster, the Cabinet Office is engaged in collection and dissemination of accurate information, reporting to the Prime Minister, establishment of the emergency activities system including the Government's Disaster Management Headquarters, overall wide area coordination concerning disaster response measures [2].

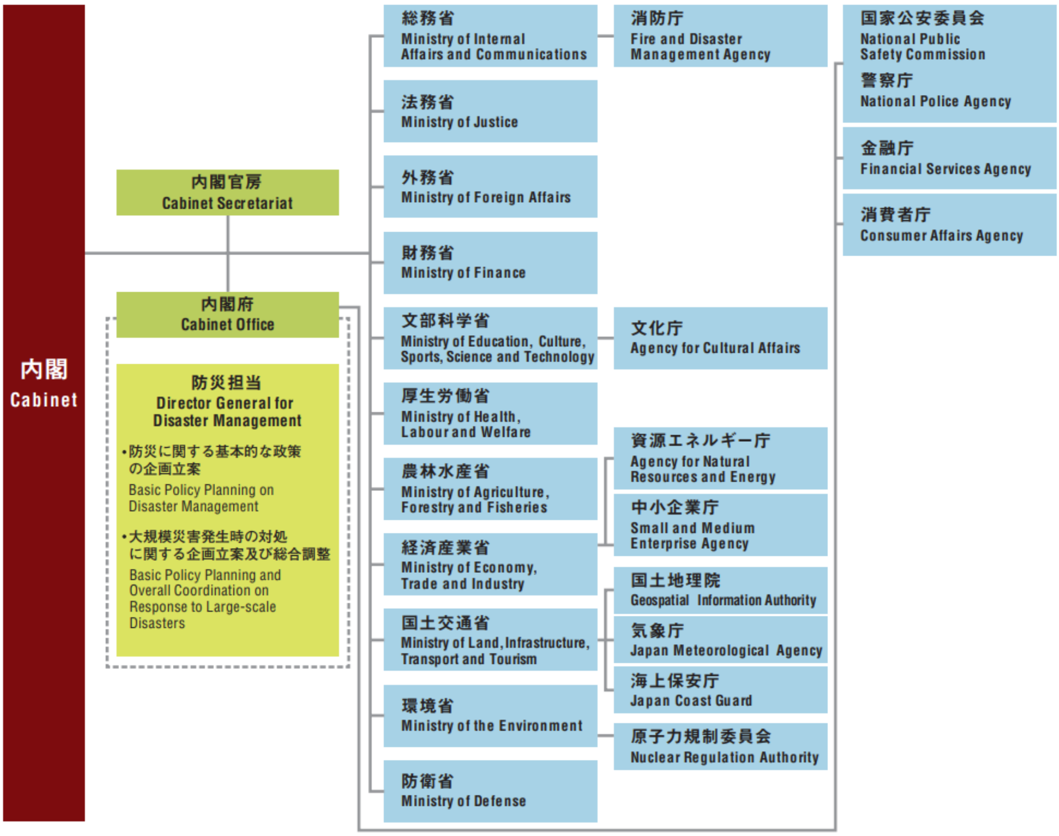

Figure 1.2. Cabinet Office and related Ministries and Agencies, this chart conceptually represents the relationship of ministries and agencies related to disaster management.

1.3. The causes and characteristics of disasters in Azerbaijan and Japan

Natural Hazard Statistics in Azerbaijan. Azerbaijan's population is vulnerable to earthquakes, drought and flooding. The GFDRR Disaster Risk Profile for the country estimated that an earthquake with a 250-year return period would affect $40 billion (71%) of Azerbaijan's GDP and 3 million (34%) of its population (GFDRR, 2016). Droughts are of frequent occurrence, and can lead to forest fires such as those experienced in 2014, when 59 hectares of forest were damaged by 12 fires (Ministry of Ecology and Natural Resources, 2015). Flooding is a regular issue in the country, denuding the land and damaging soil (Fig.

1.3). It is estimated to cause the Azerbaijan economy a total damage of $18-25 million each year (Ministry of Ecology and Natural Resources, 2010).

Country disasters	AZERBAIJAN	
Type of Disaster	*Date*	*Affected people*
Flood	June 1995	1,650,000
Earthquake (seismic activity)	July 1998	700,010
Flood	June 1997	75,000
Flood	April 2003	31,500
Earthquake (seismic activity)	June 1999	9,170
Flood	October 1995	6,000
Earthquake (seismic activity)	November 2000	3,294
Flood	June 1995	2,800
Source: *EM-DAT: The OFDA/CRED International Disaster Database*		

Figure 1.3. Natural disasters in Azerbaijan for 1990-2009, including dates and number of people affected

Figure 1.3 and 1.4 provide overview of the most frequent natural disaster in a given country and understand the impacts of those disasters on human populations [3].

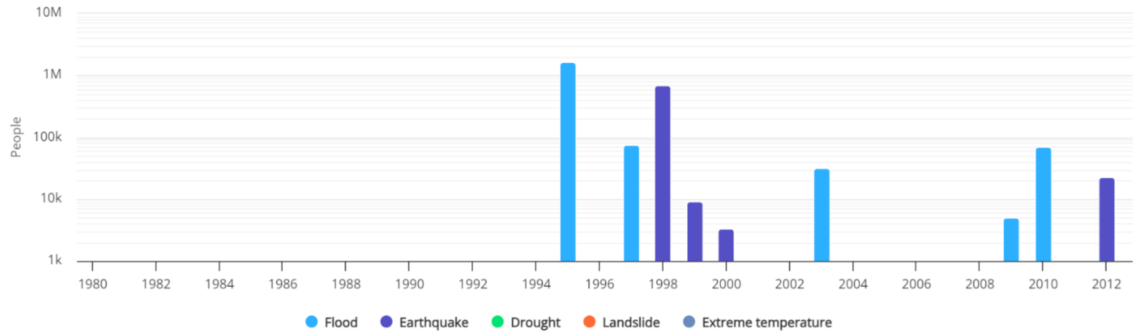

Figure 1.4. Key Natural Hazard Statistic for 1980-2020

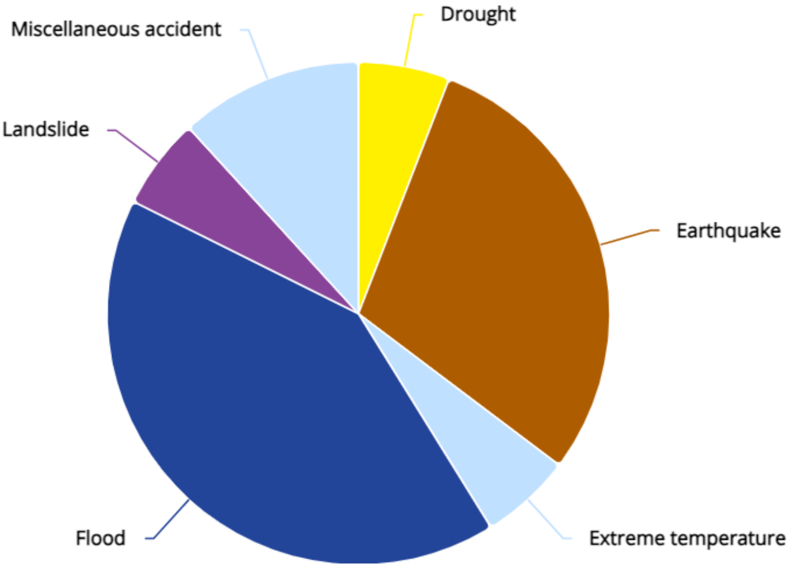

Figure 1.5. Average Annual Natural Hazard Occurrence for 1980-2020

Characteristics of Natural Disasters in Japan. Japan is located in the Circum-Pacific Mobile Belt where seismic and volcanic activities occur constantly. Although the country covers only 0.25% of the land area on the planet, the number of earthquakes and active volcanoes is quite high. In addition, because of geographical, topographical and meteorological conditions, the country is subject to frequent natural disaster such as typhoons, torrential rains and heavy snowfalls, as well as earthquakes and tsunami.

Every year there is a great loss of people's lives and property in Japan due to natural disasters. Until the second half of 1950s, large-scale typhoons with earthquakes caused extensive damage and thousands of casualties. Thereafter, with the progress of society's capabilities to respond to disasters and mitigate vulnerabilities to disasters by developing disaster management systems, promoting national land conservation, improving weather forecasting technologies, and upgrading disaster information communications systems, disaster damage has shown a declining tendency.

In spite of such efforts, in 1995, more than 6,400 people died of the Great Hanshin-Awaji Earthquake. Also, in 2011, more than 18,000 people died or went missing due to the Great East Japan Earthquake. There is also a high probability of the occurrence of large-scale earthquakes in the near future including impending possibilities of Nankai Trough Earthquake and Tokyo Inland Earthquake. As such, natural disasters remain a menacing threat to the safety and security of the country [4].

Introduction to Disasters in Japan. Japan is prone to a variety of natural and man-made disasters. The country's geographic location makes it susceptible to earthquakes, tsunamis, typhoons, and volcanic eruptions. Moreover, Japan has faced challenges like nuclear, industrial, and environmental disasters.

Natural Disasters in Japan. Japan experiences numerous natural disasters which pose significant risks to its population and infrastructure.

- Earthquakes
- Tsunamis
- Typhoons
- Volcanic eruptions

Earthquakes are a common occurrence in Japan due to its location along the Pacific Ring of Fire. The country has a history of devastating earthquakes caused by the movement of tectonic plates beneath the earth's surface.

Tsunamis, triggered by undersea earthquakes and volcanic eruptions, are a significant hazard for Japan’s coastal regions. These massive waves have caused tremendous destruction in the past.

Japan is regularly affected by typhoons, particularly during the summer and autumn months. These tropical cyclones bring strong winds, heavy rainfall, and often lead to widespread flooding and landslides.

Due to the presence of several active volcanoes, Japan faces the constant threat of volcanic eruptions. These eruptions have the potential to cause significant damage to nearby communities and infrastructure.

Aside from natural disasters, Japan has also experienced a number of man-made disasters, posing serious threats to public health and the environment.

- Nuclear accidents
- Industrial accidents
- Environmental disasters

Japan’s history includes significant nuclear accidents, emphasizing the severe consequences that can befall a nation from such incidents. The Fukushima Daiichi nuclear disaster in 2011 continues to have a lasting impact on the region.

Industrial accidents, such as chemical leaks and factory explosions, have led to casualties and environmental contamination in some instances, warranting increased focus on industrial safety regulations.

Environmental disasters, including oil spills and pollution incidents, have challenged Japan’s environmental sustainability efforts, emphasizing the need for robust measures to protect the natural ecosystem and public health (Fig. 1.6).

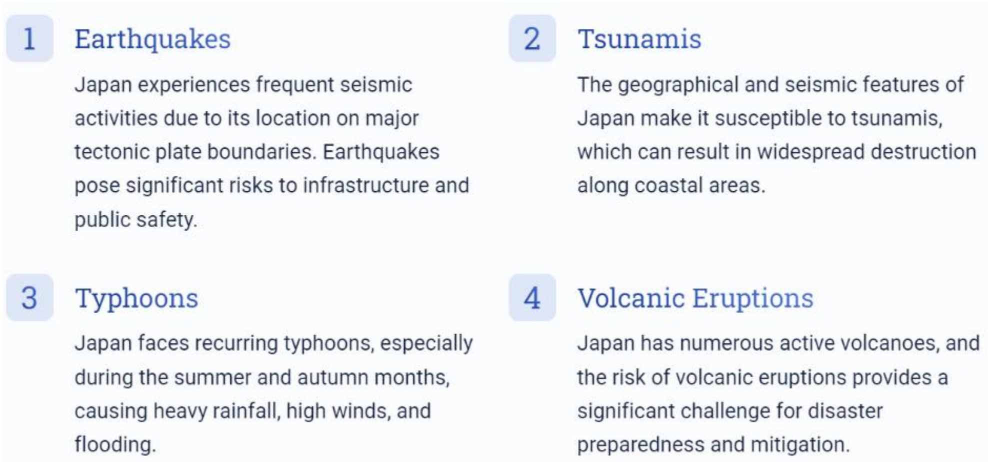

Figure 1.6. Environmental disasters

Typhoons, rainstorms and geological disasters caused by floods are referred to as “wind and water disasters” in Japan. Wind and water disasters are natural hazards with a strong destructive power, leading to hundreds of deaths each year. Figure 1.7 presents the summary of deaths due to natural hazards from 1993 to 2018 in Japan; the number of deaths caused by catastrophic floods in 2018 was the highest of all flood hazards. This indicates the insufficiency and vulnerability of the hazard prevention and management system in Japan. Besides, death comparisons are conducted for different hazards, and flood hazards should be given equal emphasis. In Figure 1.7, the Hanshin-Awaji earthquake in 1995 (6437 deaths) and the 2011 earthquake off the Pacific coast of Tohoku in 2011 (22, 203 deaths) are classified as “Major Disasters” in Japan. The flood in 2018 was the first time that a rainstorm disaster had been designated as a “Special Emergency Disaster” in Japanese history [5].

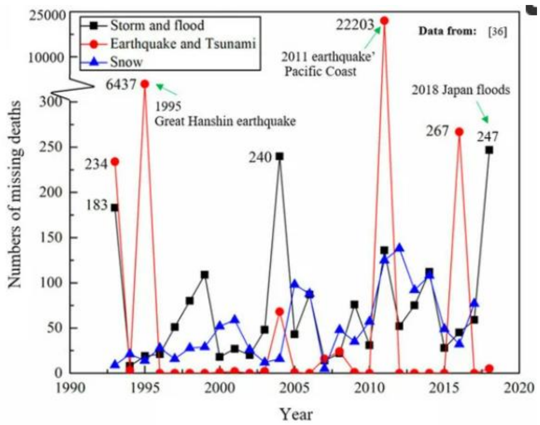

Figure 1.7. Summary of missing deaths due to natural hazards from 1993 to 2018 in Japan.

1.4. Statistics of flood disasters, economic, social, ecological consequences of catastrophic floods in Azerbaijan and Japan

Azerbaijan. Based on historical facts, we can say that the territory of our country is often exposed to the threat of floods. In Azerbaijan, especially in the Yevlakh-Neftchala zone along the Kura River coast, this emergency is more evident. In general, the Yevlakh-Neftchala zone along the Kura River coast is known as the area most affected by floods and overflows. The population of this area is more than 1.8 million people. There is a constant threat of overflow and flood in these areas with more than 700 settlements [6].

Flood modeling estimates losses and impacts on the basis of flood maps for river (fluvial) and surface water (pluvial) flooding generated at 30-meter spatial resolution. These maps use observed river and rainfall data to generate extreme rainfall and river flow volumes. Maps are generated for different return periods. The 1 in 200-year return period river flood map in Figure 1.8 highlights the main rivers of Azerbaijan. This event severity is often used for planning purposes as a plausible extreme event [7].

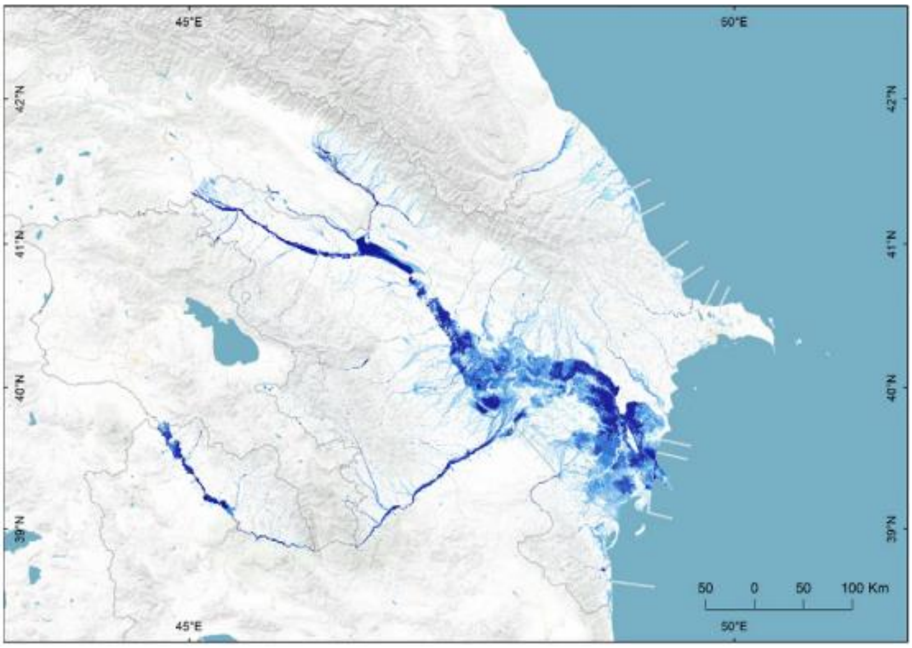

Figure 1.8. Map of river (fluvial) flooding (areas in blue) at the 200-year return period level

Japan. Japanese natural conditions, such as its topography and climate, are severe. Besides, about 50 % of its total population and about 75% of its assets are concentrated in flood vulnerable areas in the alluvial plains, which account for only 10% of its total land area.

Furthermore, as a result of the recent trend of the nuclear family and the increasing urban population, more people, even those who live in a flood-prone area, have no past experience of floods. As the people's memories of floods fade over time, the awareness to the potential flood risks is also fading away. Consequently, there now is a higher risk that, once a levee breaks during a massive flood, not only many lives and assets will be lost but also an unimaginable scale of social and economic confusion will occur. In recent years, torrential rainfall frequently causes flood disasters, and a quite a few of them cause tremendous damage to the areas, such as inundation in a large urban area and in underground facilities [8].

Japan flood disaster statistics. The Infrastructure Development Institute of Japan and Japan River Association estimates about 49% of the population and 75% real estate in Japan are located in alluvial plains exposed to flooding risk. The annual damage amount caused by water-related disasters in Japan from 1966 to 2010 is shown in Figure 1.9. During 1966-1985, the total flood flooded area ranged between 100 and 200 thousand hectares. It has been falling since 1982, owing to years of flood control initiatives. In 1977, the yearly flood flooded area (mainly developed or residential) was slightly more than 50,000 hectares (ha). It has diminished throughout time as a result of different flood damage control methods, including expanded channels and embankments, detention basins, floodways, and dams. However, the density of property damage (the total number of destroyed general assets) in flooded regions is growing. The key factors include ongoing population and general asset expansion, as well as rising urbanization and suburbanization in flood-prone areas. To prevent future flood damage in various ways, understanding the determinants of flood risk is critical, as is developing flood control methods ahead of time to avoid projected harm.

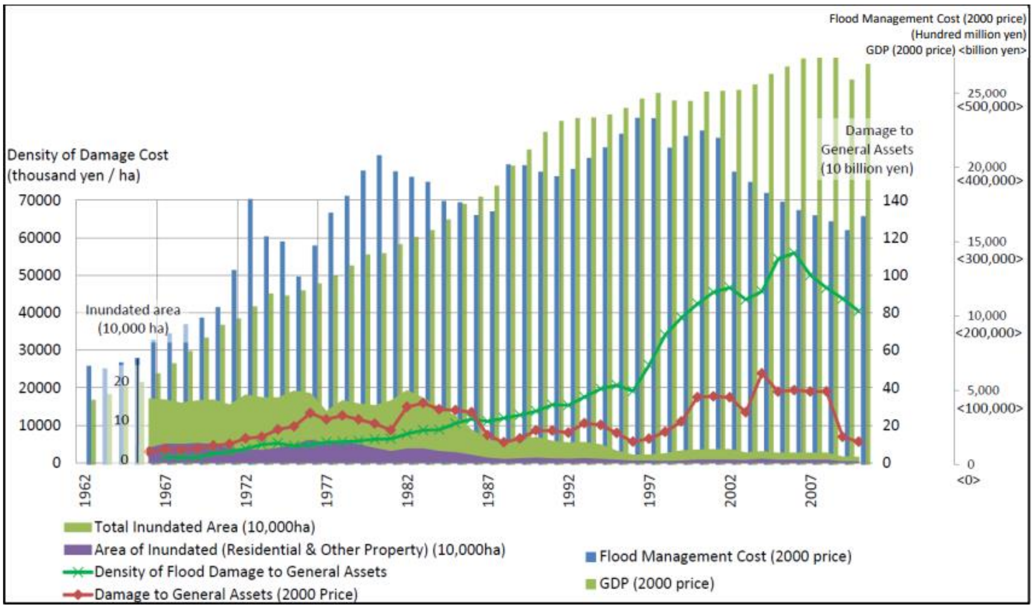

Figure 1.9. The annual damage caused by water-related disasters in Japan

Economic, social, ecological consequences of catastrophic floods. *Azerbaijan.* Referring to historical sources, there have been many floods and landslides in the Kura River in the last 150 years. One of the most dangerous floods was in May 1915. After 100 years, in 2010, a catastrophic flood of the same nature occurred.

The flood that occurred in Kur in May 1915 was caused by the collapse of dams in Garadeyin (Aghdash r.), Qakhay (Aghdash r.), Mollakend (Kurdemir r.) and other riverside settlements. Most of the Shirvan plain is under water. The flood, which covers an area of more than 200,000 ha, moved along the left bank of Kur and poured into the river again near the Shirvan station.

In May of the same year, the Araz river overflowed near the village of Mursalli and flooded an area of 70,000 hectares.

As a result of the floods that occurred in 1921 in the Kura and Araz rivers, many settlements and farmlands in the Mugan and Shirvan plains were flooded and resulted in material losses.

One of the causes of the floods is that despite the daily water release from the Shamkir, Yenikend, Mingachevir and Araz reservoirs being planned for 200-300 m^3 per second, in May 2006, on the eve of danger, the water was released from the norm without coordination with the Ministry of Emergency Situations or prompt warning. several times more (1.97 and 3.3 times, respectively) there were cases of water release, although there were objective reasons for this, but the water consumption released from existing reservoirs was not regulated accordingly. Despite the winter months in 2008, from January 31 to February 20, the volume of water released from the Mingachevir reservoir was increased by 1.47-1.62 times compared to the volume of incoming (flow) water, as a result of which, in Banke settlement of Neftchala district, 50 until a private residential house was subjected to subasma.

As a result of the floods that occurred in 2003, 2006, 2010, settlements and agricultural fields along the Kura coast of Shirvan city, Hajigabul, Sabirabad, Salyan, Neftchala, Imishli, Saatli, and Zardab regions were flooded. Both banks of the Kura river basin are under the influence of the flood. In the agricultural and economic areas affected by the catastrophic drought, the productivity has decreased significantly (90%). If we take into account the possibility of salinization of those areas and the future damage, then the damage is measured in billions of manats.

One of the areas most affected by floods is the transport sector. As a result of the floods that occurred in 2003, 2006 and 2010 in the research area, 366 km of republican and 305 km of local roads and 2317.5 km of dirt roads were damaged. Figure 1.10 below shows the distribution of locally important highways under subasma by administrative regions [9].

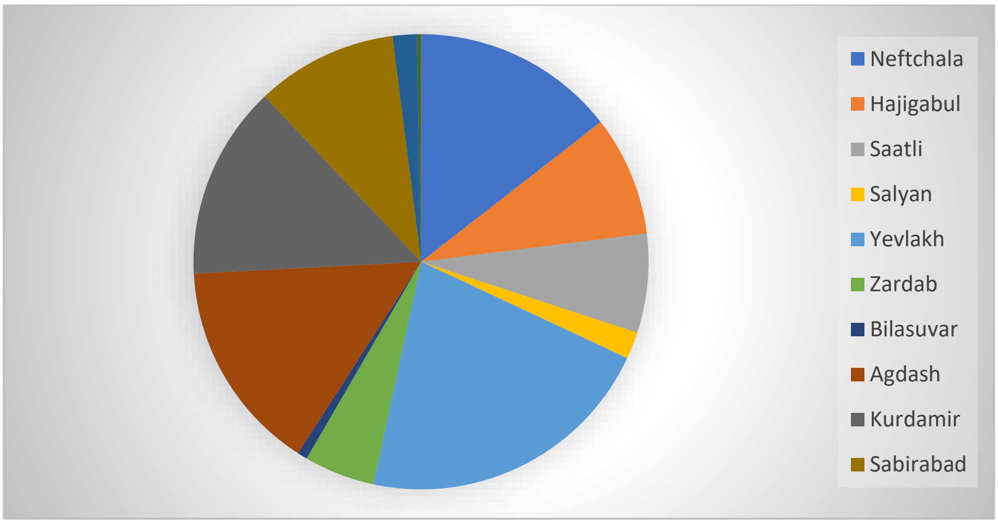

Figure 1.10. Distribution of locally important highways under inundation by administrative regions

Japan. In Japan, in terms of the number of past natural disasters, flood-related disasters such as typhoons, floods, and landslides account for more than 70% of the total number of natural disasters and are considered to be non-negligible and important risks [10].

There are many factors that contribute to flood hazards. These factors are justified based on the preliminary investigations of catastrophic floods in western Japan and can be classified into direct and indirect factors. The extreme level of accumulated rainfall and rainfall intensity were the direct factors affecting the catastrophic flood in 2018 in western Japan [11].

Since 1949 in Japan, annual toll of dead and missing because of flood and typhoon disasters shown in Figure 1.11. The toll of dead and missing was calculated with reference to Ushiyama (2017), National Police Agency (1968-2019) and Ministry of Land, Infrastructure, Transport and Tourism (2021).

The flood-based damages to agriculture have been increasing, especially in the last four years. Annual agricultural damage caused by flood disasters has mostly exceeded approximately 200 billion JP¥ (equivalent to 1,893 million US dollars at the exchange rate of 105.6 JP¥ per USD as on February 20, 2021), and in 2018 and 2019, it was over 400 billion JP¥. While economic damage to agricultural crop production, which used to be high, has decreased, the damage to agricultural infrastructure, such as ponds, headworks, irrigation-drainage canals, and farm roads, is still high. Such infrastructure plays a key role in water circulation and contribute to disaster risk reduction. Therefore, policies and research and development pertaining to disaster risk management must be strengthened.

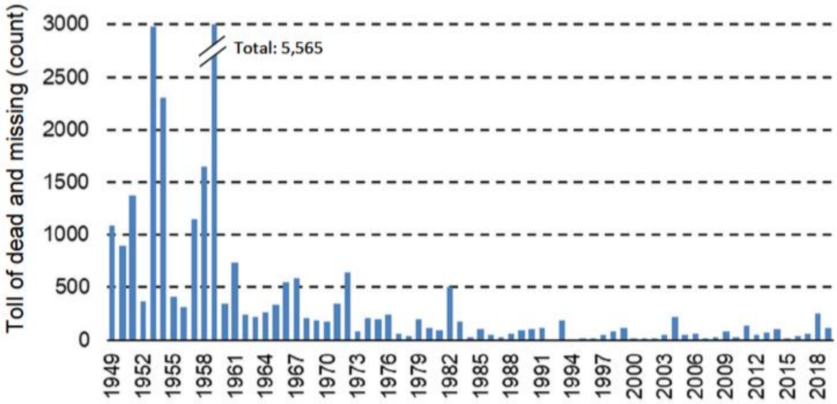

Figure 1.11. Annual toll of dead and missing because of flood and typhoon disasters since 1949 in Japan.

Past heavy rainfall events causing major damage. Isewan Typhoon, 1959

The 15th typhoon (commonly known as Isewan Typhoon) made landfall at Shionomisaki shortly after 6 pm on September 26, 1959, with a pressure of 929 hPa. A maximum instantaneous wind speed of 45.7 m/s and a maximum tide level of 5.31 m (Nagoya port) were recorded in Nagoya city. The typhoon caused major storm surge damage from Nagoya city to the coast of Mie prefecture. The daily rainfall from September 26 to 27 was approximately 160 mm in Tsu city, Mie prefecture, equivalent to once in 80 years. Of the 5,098 people reported dead or missing, over 90% were in the three prefectures of Aichi, Mie, and Gifu around the Ise Bay, and 70% of these casualties were due to the storm surge. Over 5,000 people were reported dead or missing, approximately 149,000 homes were destroyed, 158,000 homes flooded, and 5760 levees breached, making it Japan’s largest flood disaster of the 20th century (Fig. 1.12). The damage to agricultural land in Aichi prefecture included approximately 1,800 ha of rice paddies covered in debris, approximately 35,000 ha of rice paddies flooded, approximately 1,300 ha of crop fields covered in debris, and approximately 7,700 ha of crop fields flooded (Yamauchi, 1959). The enormous destruction caused by this typhoon prompted the Japanese government to legislate the Disaster Countermeasures Basic Act. Hence, this typhoon is said to be the disaster that shaped Japan’s disaster prevention policy.

Figure 1.12. The photo of Isewan typhoon

Nagasaki Flood, July 1982

On July 23, 1982, torrential rainfall exceeding 100 mm/h fell for approximately three hours in Nagasaki, causing flooding, landslides, and avalanches of rocks and earth. The daily rainfall in Nagasaki city was 448 mm, equivalent to once in 200 years (Ota, 1983). Nagasaki is a hilly city, and approximately 90% of the 299 casualties died in landslides due to the collapse of slopes. The damage to agriculture and forestry land in Nagasaki prefecture included approximately 2700 ha of agricultural land flooded, buried, or covered in debris; and approximately 20,000 agricultural and forestry facilities damaged. The cost of damage to agricultural facilities, produce, and livestock was approximately 8.4 billion yen (Tanaka et al.1983, Fig. 1.13).

Figure 10.13. The photo of Nagasaki flood

Kagoshima Flood, 1993

In the afternoon of August 6, 1993, heavy rainfall of up to 99.5 mm/h fell for several hours in the area around Kagoshima city. The banks of three rivers flowing through Kagoshima city burst, flooding approximately 11,000 buildings. The daily rainfall in Kagoshima city was 259 mm, equivalent to once in 200 years (Iwamatsu, 1994). Cliffs alongside the national highway collapsed at 22 points along a 4 km stretch. The death toll was 71, and about 2,500 people who were in cars, buses and trains were saved by fishing boats and ferries which carried them to Kagoshima through the Kagoshima Bay. The soil in this area is known as Shirasu, which is made up of fine volcanic rock and ash; hence, it is susceptible to erosion by rainfall. This is believed to have resulted in the collapse of several slopes (Fig. 1.14). Approximately 800 locations of agricultural land and 1500 agricultural facilities were damaged in Kagoshima prefecture [12].

Figure 1.14. The photo of Kagoshima heavy rain (Ministry of Land, Infrastructure, Transport and Tourism Kyusyu Regional Development Bureau, 2003b)

Flooding in Western Japan in 2018

The western regions of Japan experienced catastrophic flooding from 5 to 9 July 2018. Of the 1300 rainfall observation stations across Japan, precipitation at 119 stations reached its highest level within 72 h and 123 stations received the highest amount of rainfall within 48 h compared to all historical recordings [13,14]. The water depth in some areas was up to 3 m, and numerous residual houses were immersed in the flood. Figure 1.15 presents the flooded areas in western Japan. Kochi, Gifu, Ehime and Saga were the most seriously flooded areas in this catastrophic flood. The cumulative rainfall of these four prefectures was over 600 mm. The flooded area of Ehime Prefecture was 970 hm^2, and about 720 houses were flooded [15]. As shown in Figure 1.15 the maximum accumulative rainfall occurred in Malu village, Anji-gun, Kochi Prefecture, reaching 1425.12 mm in four days. The amount of rainfall in many places reached its highest level in recorded history. Residents in Okayama County reported that floodwaters arrived and immersed their houses in a very short time, leaving them without sufficient time for evacuation at midnight.

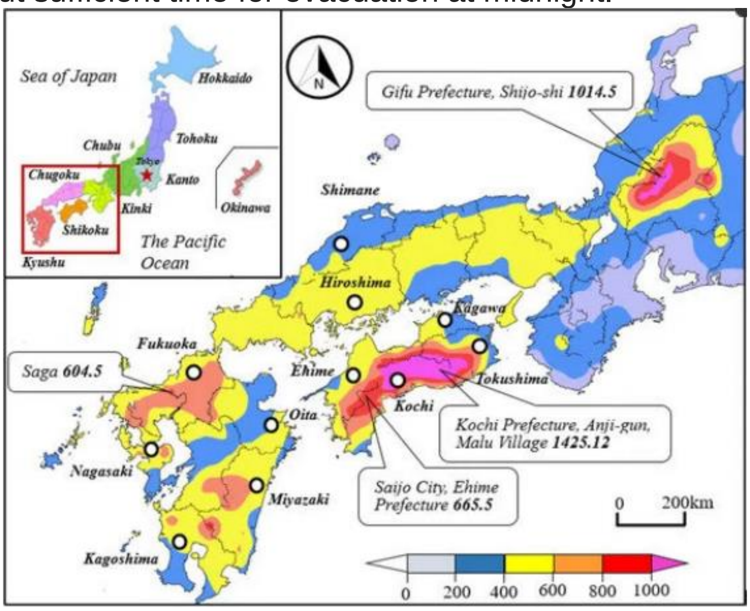

Figure 1.15. Cumulative rainfall distribution during 5–8 July 2018

Serious disasters were caused by heavy rainfall during 5–9 July 2018, leading to numerous casualties and a huge economic loss. According to the work presented in [16], the rainfall disasters resulted in 212 deaths in total, and nearly 50% of the deaths were from Hiroshima Prefecture (Fig 1.16). As shown in Figure 1.16, the death toll in Hiroshima was the highest, at 101 within five days, followed by Okayama, where the death toll was 61. The majority of deaths were suffered by elderly people (70% of the total deaths), who were not capable of rescuing themselves. The economic loss to agriculture related to flooding was 16.1 billion JPY, and Hiroshima Prefecture accounted for the biggest loss of 2.5 billion JPY. Besides, according to the work presented in [16], small- and medium-sized enterprises also suffered from huge economic losses, which were estimated at 473.8 billion JPY (Okayama prefecture accounted for 281 billion JPY). It is noted that the economic loss could have been greatly underestimated, because many affected areas were not accessible. The casualties, shelters and affected areas resulting from the catastrophic flood are displayed in Figure 1.16.

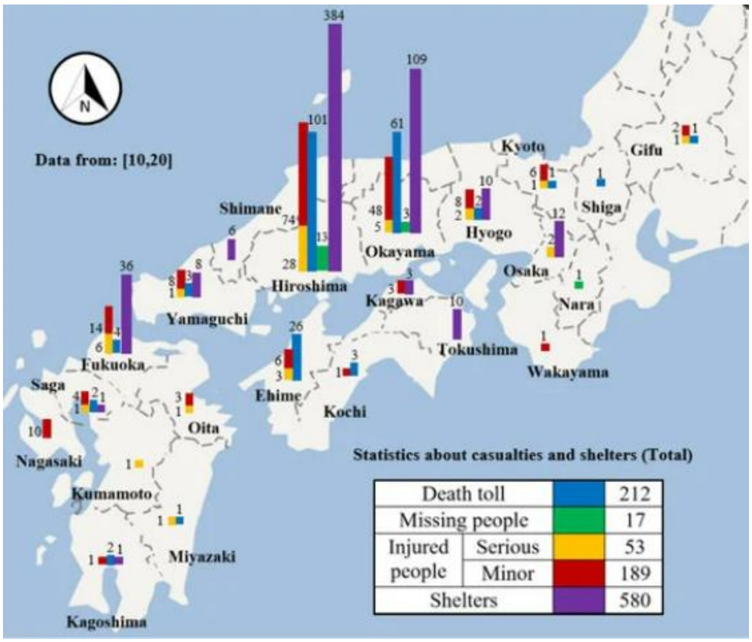

Figure 1.16. The distribution of casualties and shelters during 4–9 July 2018

2020 Kyushu Floods

At the beginning of July, continuous rainfall hit several parts of southern Japan, particularly in Kyushu, causing flooding and extreme damage.

As a result of flooding and landslides, 77 people were confirmed dead (includes 1 death due to cardiopulmonary arrest) and approximately seven are missing. Fourteen of the victims were residents of an old age home in Kuma, Kumamoto that was flooded. Approximately 15,335 buildings were destroyed, damaged or flooded (Fig. 1.17) [17].

Figure 1.17. Kyushu Flood

II. THE EXISTENCE OF EARLY WARNING AND MONITORING SYSTEMS AND THE LATEST TECHNOLOGIES IN FLOOD MANAGEMENT IN AZERBAIJAN AND IN JAPAN

2.1. Establishment of early warning and monitoring systems

Azerbaijan. The project financed the installation of two key monitoring stations in the Turyanchay basin. One is the "high altitude" station located in the mountains above the town of Gabala, at the top of a ski resort (Fig. 2.1). This station is technically qualified to cover an area with a radius of 50 km, so although it is one station is covering a significant of the project's original focus area. The second is a river hydrology monitoring station downstream of the town of Gabala. The installation of the first hydro-meteorological stations for flood forecasting in the Turyanchay basin will benefit approximately 211,000 people over an area of 3,000 sq. km.

Figure 2.1. High altitude hydrometeorological station

In the Kura basin, the project was later able to install a hydro-met station on the dam of the Mingachevir reservoir, which includes an evaporation estimation tool (Fig. 2.1), which is the first in use in Azerbaijan. The tenders for the provision and installation of these three stations were won by European companies, and cost approximately $250,000 USD in total. Once the project focus extended to the Kura basin, six additional hydrological monitoring stations were supported and installed by the project (Fig. 2.1). The hydrological-only monitoring stations are significantly cheaper than the full hydro-meteorological stations. The system of monitoring stations is linked to and reporting to a central database in Baku at the MES through the cellular network (via a GSM modem for each station). This remote-monitoring capacity of the network does depend on some maintenance and consistent payment to the cellular network operating company. However, if there is any problem with the remote transmission of data, the data can be downloaded directly from the monitoring station.

Figure 2.2. Monitoring station on Mingachevir Dam

As part of the monitoring station network the project developed the centralized database that aggregates the data from all of the monitoring stations. This is the first such database in the country, and it is now used by multiple stakeholders to monitor the amount of water resources.

Based on the estimation of the project team and project experts, the monitoring network in place now in Azerbaijan (partially supported from the project, partially from the government, and partially from other external donors) covers approximately 50% of the urgent need for total operation of water planning and management in Azerbaijan. The monitoring stations established by the project cover some of the highest priority areas, such as the Kura basin downstream from the Mingachevir reservoir (Fig. 2.3).

Figure 2.3. Kura Basin Hydrological Monitoring Stations

The project worked with the communities in the Turyanchay river basin to set up an early warning system for flooding. Floods mainly occur in the summer months, when there are long periods without rain followed by a heavy rainstorm. According to one project participant, the local communities have a saying in the local language that floods occur when the dust in the mountains is up to your knees. The Early Warning System provides advance notice of a likely flood with a 1-2+ hour warning. The high-altitude monitoring station established by the project collects rainfall data and sends it to the central database managed by the MES. If a certain intensity of rainfall is recorded then a warning text message is sent to two to five focal point individuals in each village, who then activate the wider person-to-person text message communication network. The project also procured and installed emergency sirens in two locations (Fig. 2.4).

Figure 2.4. Emergency Sirens for Flood and Landslide Disasters and Early Warning System

The project also procured "First Responder Emergency Tool Kits" as a part of set up of Early Warning Systems and distributed these in the target communities. These include items such as chainsaws and safety equipment that can be used for clearing roads of downed trees, and other debris (Fig. 2.5).

Figure 2.5. First Responder Emergency Equipment

The Early Warning System faced its first real-life test on June 8th, 2017 in the Gabala region, and the First Responder Emergency Tool Kits provided by the project proved their worth [18]. As described by one local project participant, there was a short, but severe summer storm:

"…it was short, only 5 minutes, but many houses were damaged by trees falling on them, up to 200 trees fell. And even elderly people said they hadn't seen such a thing in their lifetime. Equipment provided by the project helped us to eliminate the consequences of this storm. It was such a storm that my phone was wet and I couldn't contact anybody. We had consulted and planned that in the case of such a storm we would organize. So, we put on our rubber boots, and got equipment, and called MES and they said they couldn't

come, the road was blocked, and within 4 hours we managed to unblock the road and restore traffic. And thank goodness there was no loss of life. Therefore, would like to extend my gratitude to the project on behalf of our villagers."

Japan. The Ministry of Land, Infrastructure, Transport and Tourism provides river information in real time, 24 hours a day, 365 days a year throughout Japan to help protect lives and property from rainfall-induced river and land-based hazards [19].

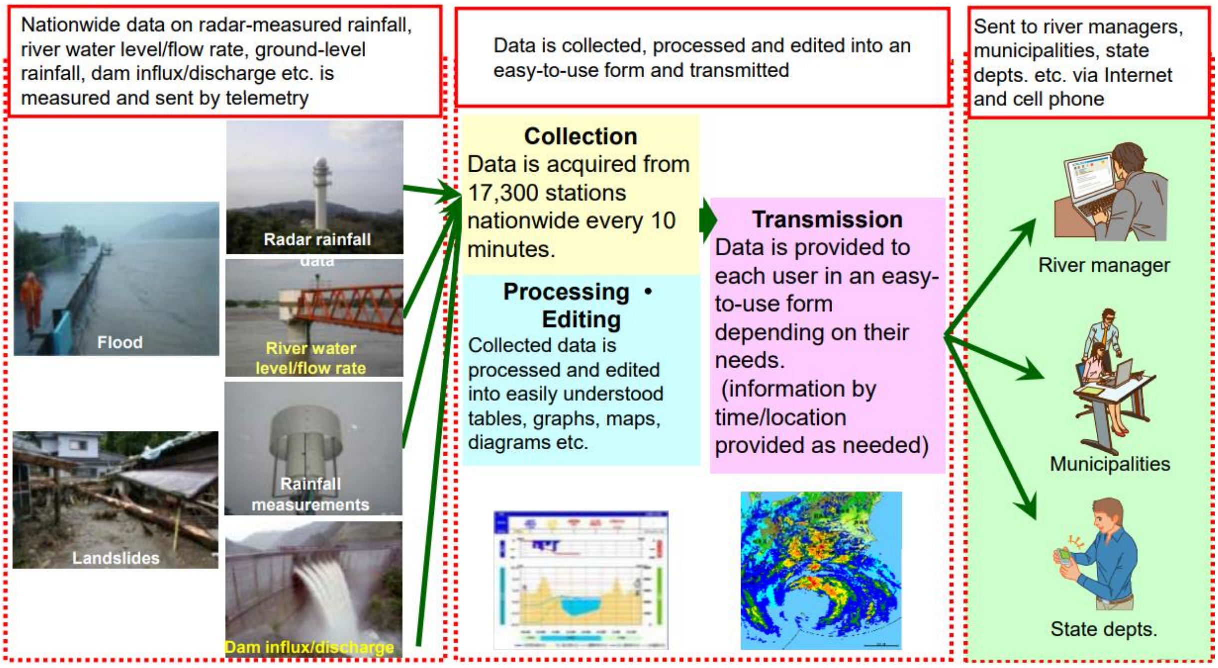

Figure 2.6. Routinely measured river information is provided in real-time (24hours a day, 365 days a year) to river managers, municipal supervisors, and other state departments. *Includes various data from radar, rainfall measurement stations, river water level meter stations, dams

If hazardous weather conditions are expected, the Japan Meteorological Agency (JMA) issues a variety of messages including Emergency Warnings, Warnings, Advisories and Bulletins so that appropriate measures can be taken to mitigate possible disasters (Fig. 2.6).

These messages are issued by Local Meteorological Offices (LMOs) to their respective prefectures.

Emergency Warnings are issued if there is significant likelihood of catastrophes by a natural phenomenon expected to be of a scale that will far exceed the warning criteria. Warnings are issued if there is a chance of catastrophe by weather conditions that meet relevant warning criteria. Advisories are issued if there is possible development of serious adverse conditions by weather conditions that meet advisory criteria but remain below the warning criteria.

Bulletins provide information to supplement Emergency Warnings, Warnings, Advisories. They are also issued by Regional Headquarters (RHs) of JMA or JMA Headquarters according to the scale or severity of the related disturbance, and include information not only on severe weather but also on possible disasters. For example, Landslide Alert Information are issued jointly with municipalities in particular when landslides* caused by heavy rain are expected with a high possibility in the next few hours. Serious damage caused by severe storms including tornadoes in 2006 induced requirements for alerts for hazardous winds. To address this requirement, JMA started to issue the Hazardous Wind Watch from March 2008 based on the discussion in advisory meetings.

All such messages are disseminated to the public through administrative organs and wide variety of media.

Weather alerts from different organizations have been combined to give people a clearer understanding of the situation (Fig. 2.7, 2.8) [20].

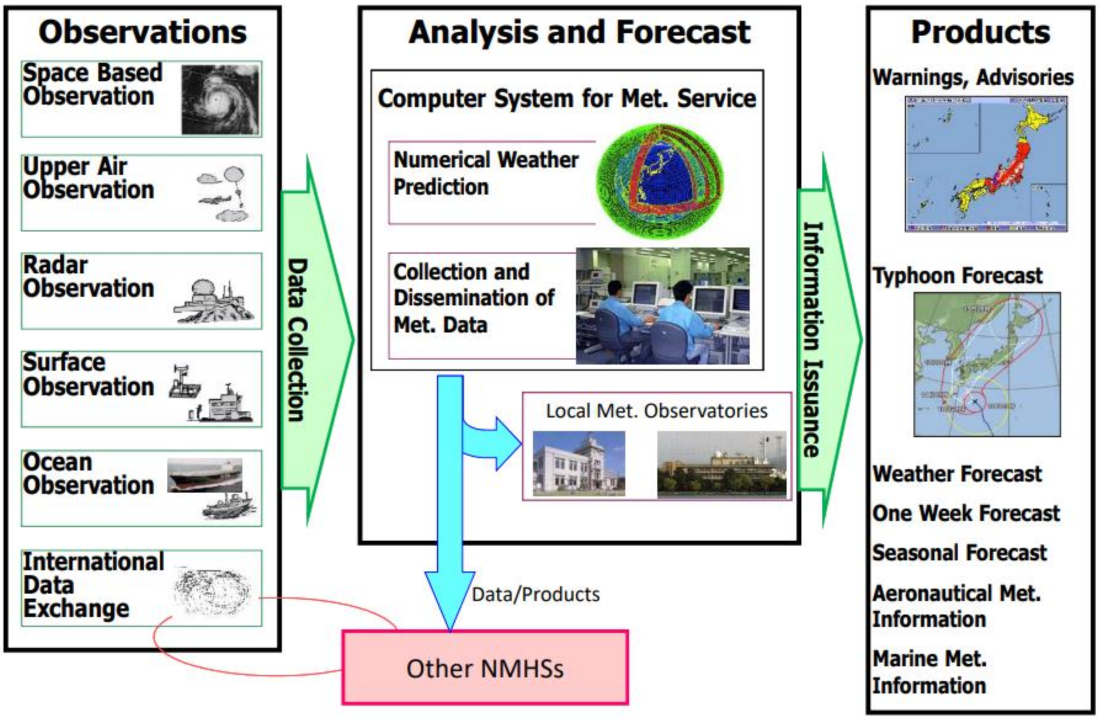

Figure 2.7. JMA's Operational Service

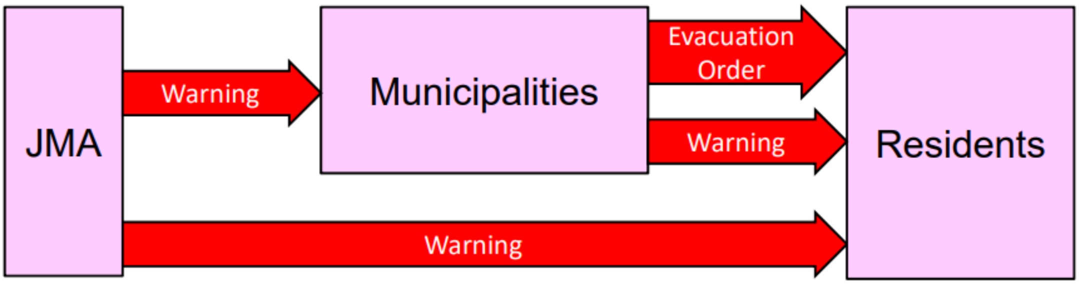

Figure 2.8. Improvement of Warning

In order that JMA's warnings help mayors' decision:

1. Warnings should be issued to city / town / village respectively.
2. Warning criteria should be consistent with the criteria for evacuation advisory and order.

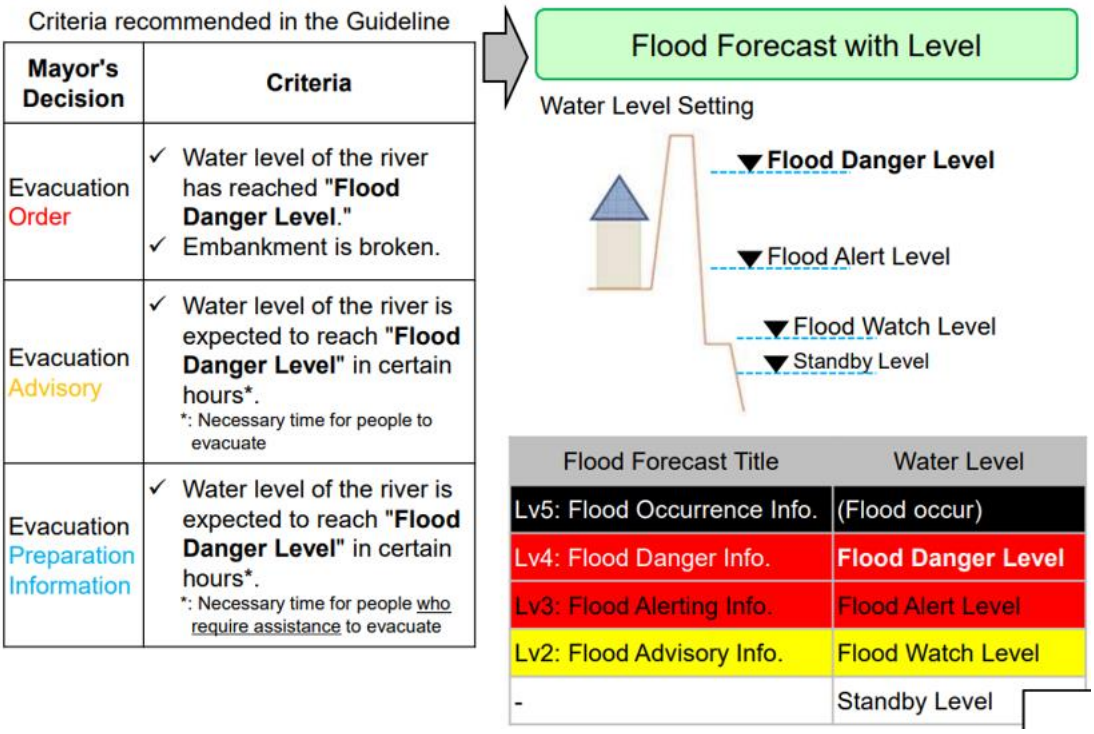

Figure 2.9. Improvement of the Criteria for Flood Forecast

Emergency Warnings are intended for extraordinary phenomena expected to be of a scale that will far exceed the warning criteria. Warnings and Advisories continue to be issued in their current form even after the introduction of Emergency Warnings.

Residents should not let down their guard even if no Emergency Warning is currently in effect in the area. It is important to take action early wherever possible with reference to relevant weather bulletins, Advisories and Warnings, which are updated in response to the latest phenomenon observations or predictions [21, 22].

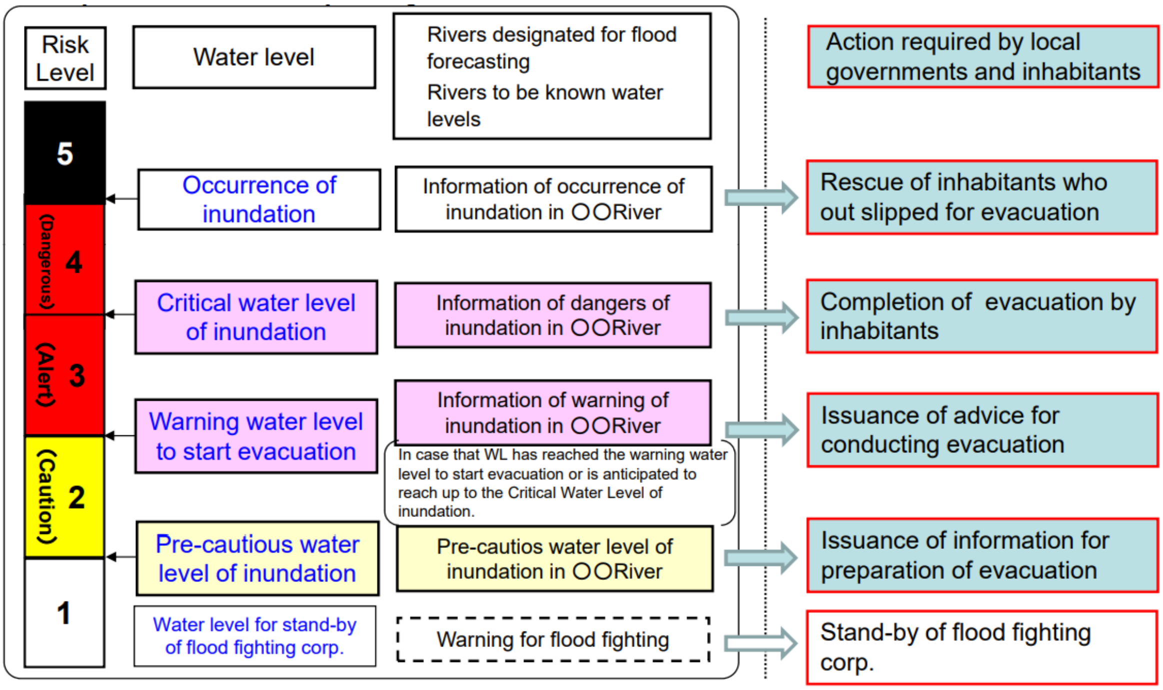

Figure 2.10. Risk levels, *to unify the color over the country to recognize the risk level

Level 1 corresponds to “early warning information” issued by the JMA. It indicates that people should be alert for weather updates.

Level 2 means “heavy rain/flood/storm surge advisories” have been issued by the JMA. People are required to take concrete action, such as avoiding areas where a disaster is likely to occur or reviewing the evacuation routes and meeting points on disaster hazard maps.

Level 3 indicates “heavy rain/flood warnings” from the JMA or “evacuation preparation information” issued by local governments. The elderly and people who need assistance must start evacuating at this stage.

Level 4 corresponds to “landslide alert information” issued by the JMA or an “evacuation order” issued by local governments. All residents are required to evacuate to safe places immediately.

Level 5 is the most severe warning. It corresponds to the JMA’s “heavy rain emergency warning.” At this stage, it is likely that severe disasters have already occurred. People should make every effort to save themselves (Fig. 2.9, 2.10) [21, 23].

Japan Bosai Platform (JBP) is an association of private companies with leading bosai solutions. Their goal is to make society disaster resilient and sustainable by sharing Japanese bosai solutions with the world.

JBP’s strength lies in the cooperation and wide-ranging technologies of its more than 100 member companies and organizations. Unlike a private company, their neutrality enables them to respond rapidly with optimized solutions. They are helping countries around the world to invest before disasters to save lives and strengthen their economies.

Public-Private-Academic Partnership JBP is the focal point of disaster risk reduction (DRR) technology in Japan. They are founded on strong support from and collaboration with the Japanese government, academia and the private sector. Asian Disaster Reduction Center (ADRC) where I am visiting researcher right now (FY2023) is a supporting member of JBP [24].

Takuwa Corporation Japan is a leading company in flood control and disaster prevention in Japan. The flood control and the disaster countermeasure technology and solution based on "water measurement technologies to measure water" including water level gauge are supporting the country resistant to water disasters (Fig. 2.11).

Water Level Observation System:

Quartz Type Water Level Gauge QS Series | Quartz Type Water Level Gauge(RS485) QSM Series | Quartz Type Water Level Gauge Optical Fiber Transmission type OPQS Series

Figure 2.11. Sensors (Water level gauge)

Quartz-type is a pressure type water level gauge by using Quartz oscillator which has high accuracy, high durability, and wide measuring range. It is suitable for accurate water level observation for river, irrigation, and dam (Fig. 2.12).

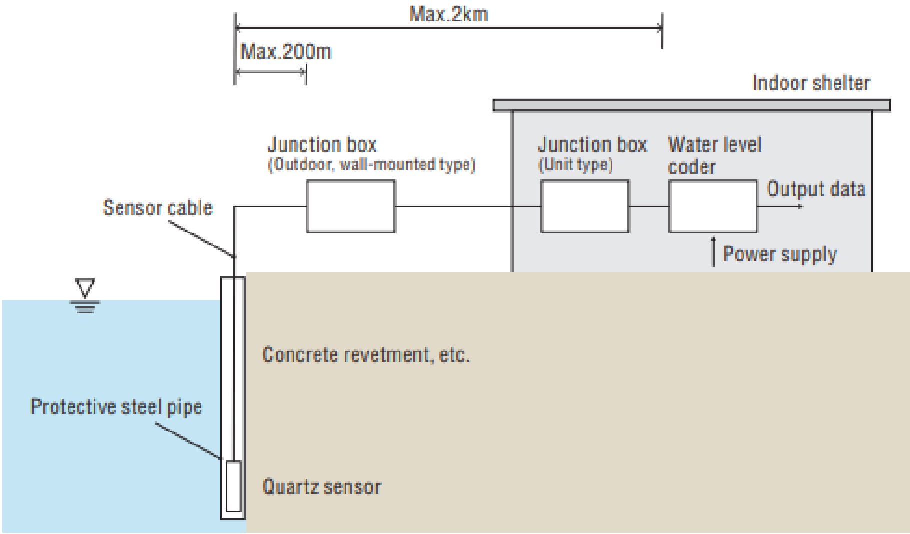

Figure 2.12. Configuration diagram

Quartz-type water level gauge (QS series) has high accuracy (≤± 1 cm), wide measuring range (0-70 m), high durability (>10 years) and easy maintenance (cleaning and electrical check once per year). Specifications are showed following table:

Model	QS-10(measuring range 0 to 10m) QS-20(measuring range 0 to 20m) QS-30(measuring range 0 to 30m) QS-50(measuring range 0 to 50m) QS-70(measuring range 0 to 70m)
Accuracy	±0.05%FS ±0.02%FS:QS-H□□ ±0.01%FS:QS-S□□(QS-70 not allowed)
Temperature coefficient at 0 point	±0.0007% FS/℃
Temperature sensitivity coefficient	±0.0049% FS/℃
Overload resistance	120%FS
Power supply	DC12V(10.5 to 16.5V)(supplied from the Water level coder)
Operating condition (temperature, humidity)	-10°C to +70°C (No freezing)
Material	SUS316L or Titanium(for sea)
Dimensions	240 x φ60 mm
Weight	Approx.3kg
Cable	Dedicated cable(Sensor to Junction box) Max.200m

Figure 2.13. Quartz Sensor Specifications

OPQS Series is, a kind of "Quartz pressure type", for enhancing the lightning protection. It using only optical fiber for cable of data transmission and electrical power supply by mounting the "very small optical-electric convertor" inside of the sensor. Recently in Japan, this type has been used for dam control and flood forecasting and warning systems (Fig. 2.14).

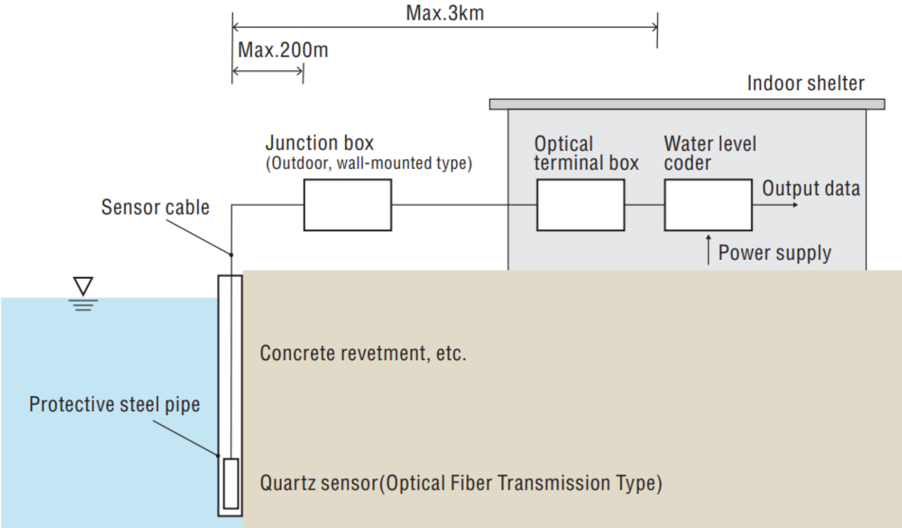

Figure 2.14. Configuration diagram

Quartz-type water level gauge optical-fiber version (OPQS series) has lightning protection by optical fiber cable: strong against lightning and operation power generated by O/E converter in the sensor.

- ■ Lightning protection measure (with a wireless cable);
- ■ High accuracy measurement with a quartz oscillator;
- ■ Optical power supply (sensor power generated with the light);
- ■ Wide measuring range.

Model	OPQS2-10(measuring range 0 to 10m) OPQS2-20(measuring range 0 to 20m) OPQS2-30(measuring range 0 to 30m) OPQS2-50(measuring range 0 to 50m) OPQS2-70(measuring range 0 to 70m)
Accuracy	±0.05%FS ±0.02%FS ±0.01%FS(OPQS2-70 not allowed)
Temperature coefficient at 0 point	±0.0007% FS/°C
Temperature sensitivity coefficient	±0.0049% FS/°C
Overload resistance	120%FS
Power supply	Optical power feeding uni t : DC9V
Optical fiber	SM Type Optical Fiber(10/125μm) 2-core cable
Operating condition (temperature, humidity)	-10°C to +60°C (No freezing)
Material	SUS316L or Titanium(for sea)
Dimensions	280 x φ60 mm
Weight	Approx.3kg
Cable	Dedicated cable(Sensor to Junction box) Max.200m

Figure 2.15. Optical Quartz Sensor Specifications

Pressure-type Water Level Gauge (Fig. 2.16) is a pressure-type sensor that measures the water level from the water pressure using a ceramic resonator. It outputs measurements in the form of DC signals at 4 to 20 mA.

Figure 2.16. Pressure-type Water Level Gauge

Specifications:
■ Small and light, easy operation;
■ Built-in arrester;
■ Durable stainless steel.

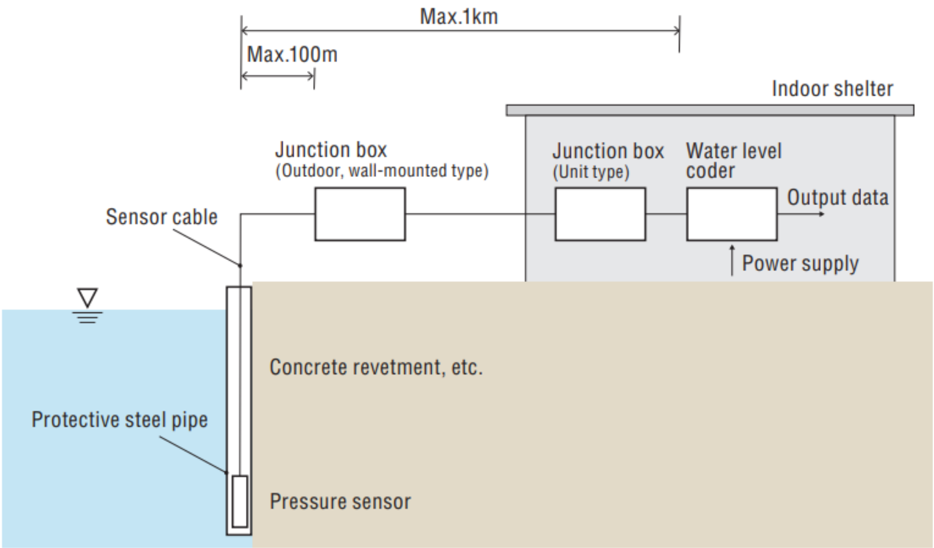

Figure 2.17. Configuration diagram

A capacitance type water level gauge that detects the water pressure, varied as the water level changes, with the semiconductor (ceramic), whose electric signals are calculated to the water level.

Model	CPS-04-A(measuring range 0 to 4m) CPS-10-A(measuring range 0 to 10m) CPS-20-A(measuring range 0 to 20m)
Accuracy	±0.2%FS(CPS-04-A) ±0.1%FS(CPS-10-A, CPS-20-A)
Overload resistance	200%FS
Output signal	DC4 to 20mA
Power supply	DC24V(11 to 26V)(supplied from the water level coder)
Operating condition (temperature, humidity)	-10°C to +60°C (No freezing)
Material	SUS316L or Titanium(for sea)
Dimensions	160 x φ42.3 mm
Weight	Approx.1kg
Cable	Dedicated cable(Sensor to Junction box) Max.100m

Figure 2.18. Pressure sensor specifications

The ceramic features excellent temperature characteristics, anti-vibration, and environment resistance. The compact and light design also allows easy installation and maintenance. And other sensors are being using for Flood Forecasting [25].

Overview of Sentinel Asia. The Asia-Pacific Regional Space Agency Forum in 2005 proposed an initiative called "Sentinel Asia", to showcase the value and impact of Earth observation technologies, combined with near-real-time internet dissemination methods and Web-GIS mapping tools for disaster management support in the Asia-Pacific region.

Sentinel Asia aims to:

- improve safety in society through the application of information and communication technologies (ICT) combined with space technologies;
- improve the speed and accuracy of disaster preparedness and early warning;
- minimize the number of victims and social/economic losses resulting from disasters;
- contribute to the establishment of rehabilitation plans.

Many of these goals are possible only through the wide-area and fast response collection of images and other data which can be acquired by Earth observing satellites.

Sentinel Asia is a voluntary and best-efforts-basis initiative led by The Asia-Pacific Regional Space Agency Forum (APRSAF) to share disaster information in near-real-time across the Asia-Pacific region, using primarily the Web-GIS technology. Its architecture is designed to operate initially as an internet-based, node-distributed information distribution backbone, eventually distributing relevant satellite and in situ spatial information on multiple hazards in the Asia-Pacific region.

Main activities:

- *Emergency observation by earth observation satellites in case of major disasters:* Joint Project Team members or Asian Disaster Reduction Center (ADRC) are entitled to make emergency observation requests (EORs) to Sentinel Asia.

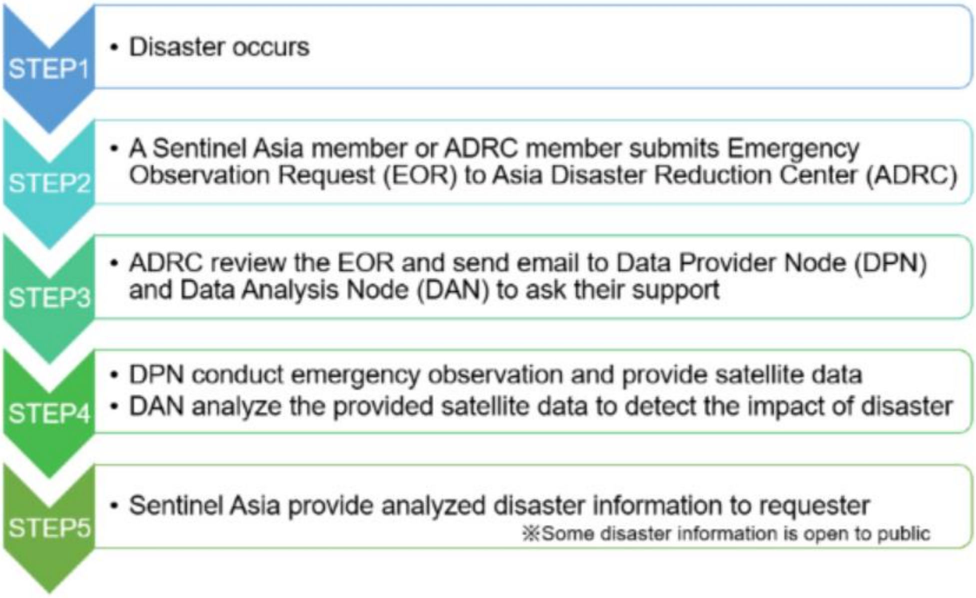

Figure 2.19. Emergency Observation Flow

- *Water related disaster Working Group:* Water related disaster Working Group works for exchanging ideas with regards to water related disasters reduction by using aerospace technology together with ground survey and GIS/Mapping technology especially in the field of flood, land slide, flash flood, drought, storm surge and so on caused by heavy rain, typhoon, tropical cyclone, monsoon and climate change.

114 Organizations are the member of Sentinel Asia.

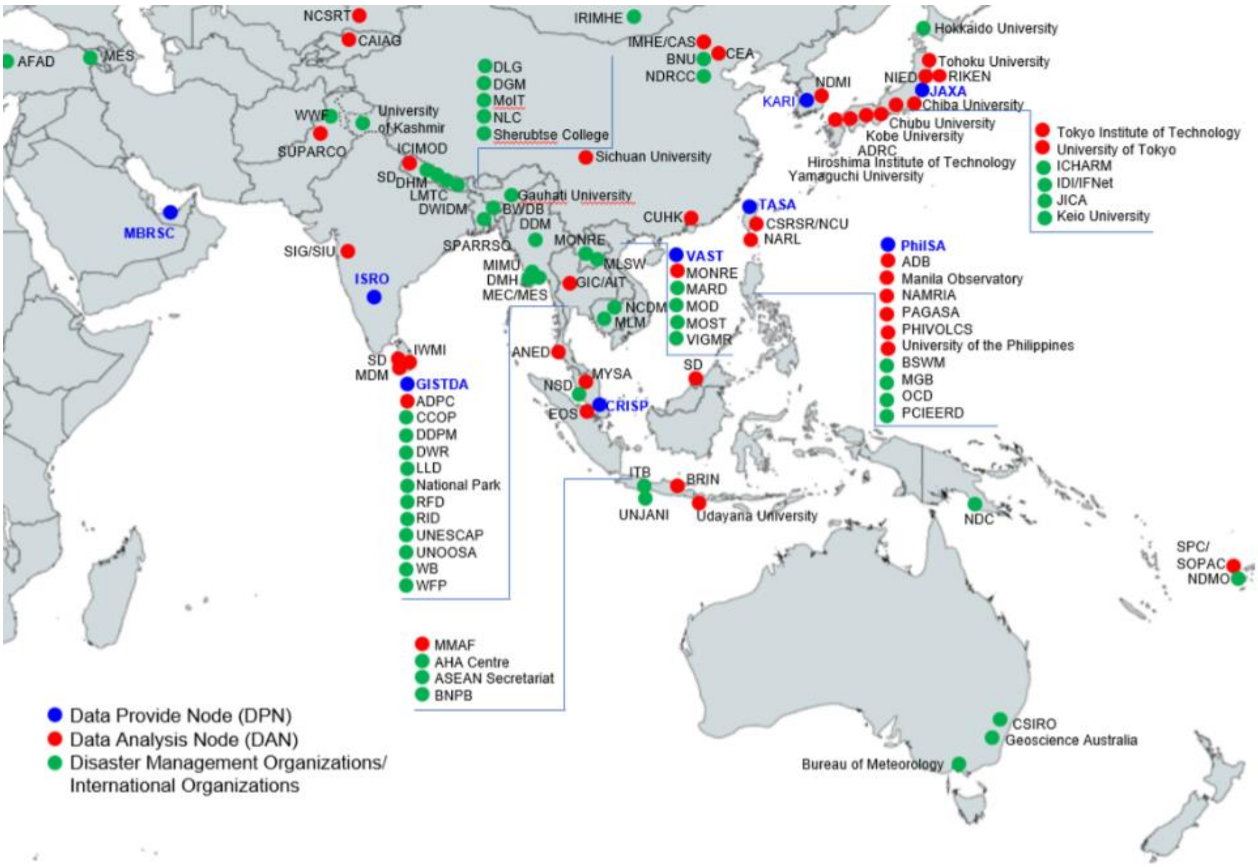

Figure 2.20. Membership status of Sentinel Asia (As of September 2023)

Data Provider Node (DPN) provides their own satellite imagery and/or data to Sentinel Asia upon the emergency observation request to the extent permitted by the data policy of each DPN when disaster happens.

When emergency observation requests are accepted, subject to each DPN availability, the following satellite data will be acquired and provided:

ALOS-2 (JAXA), Resourcesat-2, Cartosat-3 (ISRO), Thaichote (GISTDA), VNREDSat-1A (VAST), TeLEOS-1 (CRISP), KhalifaSat (MBRSC), and FORMOSAT-5 (TASA), and DIWATA-2, NovaSAR-1 (PhilSA).

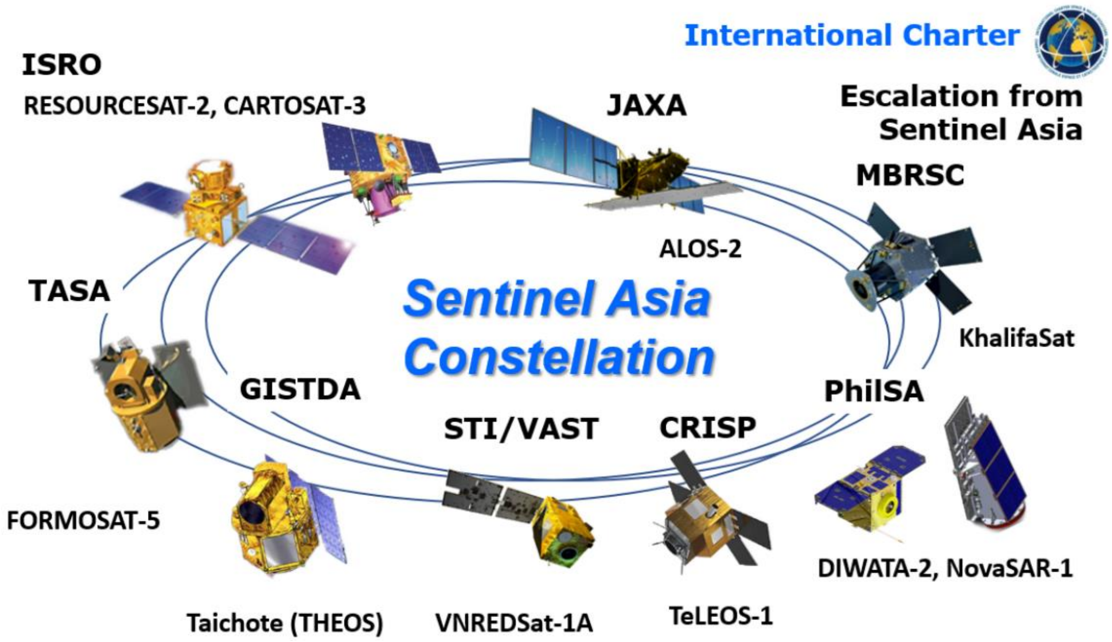

Figure 2.21. Data Provider Node that currently contributing to Emergency Observation

Data Analysis Node analyzes the satellite data provided by DPN, makes damage assessment maps and discloses the result through the Sentinel Asia System within the domestic legislation of each DAN permits.

Sentinel Asia provides various kinds of disaster Assessment Maps.

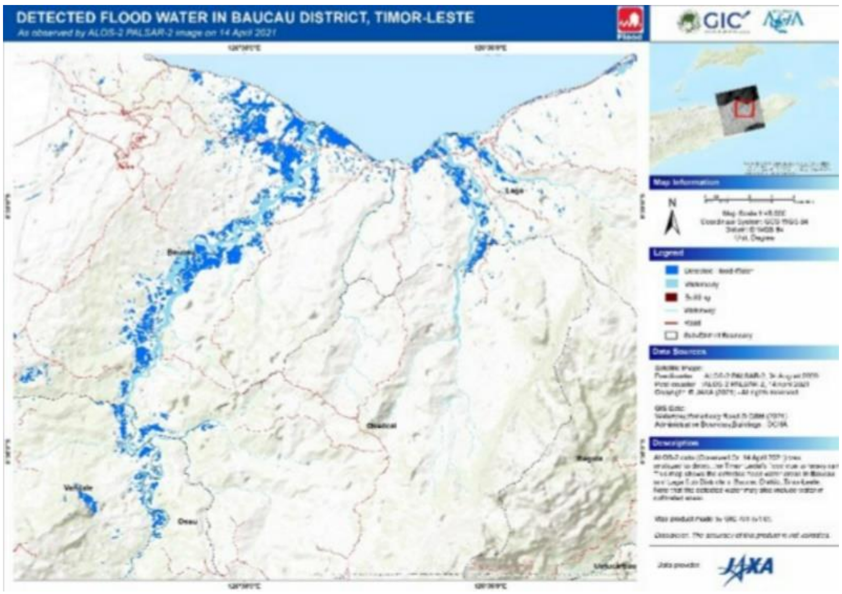

Figure 2.22. Flood-detected areas in Timor-Leste in April 2021

Especially, Sentinel Asia provides Web-GIS. Web-GIS is a web-based tool for easy browsing of satellite observation data or processed products with your own web browser, requiring only an internet connection. Sentinel Asia Secretariat launched the Web-GIS service for its Joint Project Team (JPT) members in November 2019 and continues to operate the service. When we receive Emergency Observation Requests (EORs), most of the satellite observation data from Data Provider Node (DPN) and all the processed products from Data Analysis Node (DAN) are displayed on Web-GIS. This service has been developed primarily for the benefit of visitors who are not accustomed to satellite imageries or who want to brows Sentinel Asia data at a glance.

Following section introduces some examples by disaster types.

Flood detected areas:

- Blue indicates the detected flood-water;
- Through this kind of product, an overview of the flood-affected area can be monitored;
- This kind of product will be available within around 1 to 7 days (excluding holidays) of EOR activation.

Flood detected areas on Web-GIS:

- Web-GIS enables zoom in and out flood-detected areas;
- By overlaying potentially damaged areas and maps, it may be possible to determine whether main social infrastructures such as main roads, hospitals, and evacuation shelters are potentially affected or not [26].

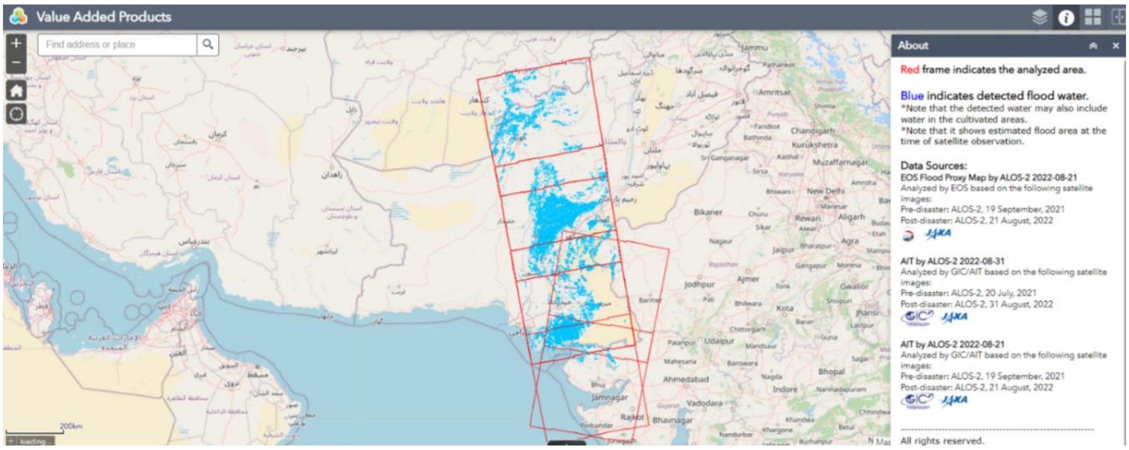

Figure 2.23. Flood in Pakistan in August 2022

Figure 2.24. Emergency observation review by geographical Distribution (As of January 2024)

Sentinel Asia is expected to implement not only emergency observation but also activities covering entire disaster management cycle including mitigation, preparedness and recovery phase after a disaster [27].

Figure 2.25. Concept of Sentinel Asia Strategic Plan (Challenges for Disaster Risk Reduction by a Collaboration between Space and Disaster Management Agencies)

2.2. Best practices and the latest technology in flood management, prevention and response

"Town Watching for Disaster Prevention" is the program that people who are living or going to school in the area such as residents and students etc., walk around, see, and understand facilities, activities for the safety and dangerous places in the local area, and after that, those people think and make solutions against danger.

"Town Watching for Disaster Prevention" consists of 4 parts below.

- **Field survey**

We walk around and observe the dangerous places and facilities by ourselves, and also, we see, hear and record about the facilities, organization, and solutions for the safety in the local area.

Figure 2.26. Field survey

For the examples of the dangerous places, there are the places where flood or landslide may occur, the houses that may break down easily by earthquake, and very narrow road that fire engine cannot enter easily. Facilities and activities for the safety in the local area would be fire station, hydrant, extinguisher, the road and field for the evacuation, organization for disaster prevention by residents, and an evacuation drill.

- **Develop a map of observation.** About the observation we learned by field survey, write or draw into the map and make a hand-made local area map for disaster prevention.

Figure 2.27. Develop a map for disaster prevention

- **Discussion to solve the problem**

As for dangerous places and problems regarding disaster that we learned from observation, we think how those problems can be solved, and draw up a list.

Figure 2.28. Discussion

- **Presentation**

Make presentations about the results to the participants. Presentation makes us aware that what we see is not all, and we will learn other people's thinking and some points that we missed out. We understand disaster prevention better by hearing other people's thinking. That is why presentation is the important part of this program.

Figure 2.29. Presentation

It is basic that we have to protect us by ourselves at any era. When we are in danger, we can avoid danger by judging from various situations around and conducting appropriate actions.

However, when large scale of disaster such as big earthquake, big tsunami, flood, landslide etc. occurs, it may be difficult to protect ourselves only by our actions. So, for example, as for buildings, the Building Standards Law is established, and it is ruled that the buildings should be built according to a certain standard. As for fire, material etc. is specified by the law, and organization for fire, as a public agency, undertakes a role of fire extinction.

In this way, it is basic that we protect us by ourselves, and as for some parts that are not covered, rules that are constituted by the law or regulation and organization for disaster prevention are prepared. However, though rules and organization are provided, it is not always safe in any situation and they will not always come to help us in case of emergency. Especially, when a large scale of disaster occurs, fire station and police station cannot dispatch enough human resources. If we fully depend on other people, it would be too late in many cases.

Therefore, it is necessary to understand what kind of danger is lurking in our town or local area, what we should do, and where we should evacuate when a disaster occurs. To decrease danger in our town, it is necessary that we have to make our town better by ourselves without expecting other people would do for us.

"Town Watching for Disaster Prevention" is the program that we understand dangerous places in the local area regarding disaster, and on the contrary, also learn where are useful places and know-how when a disaster occurs by observing our town in the view of disaster prevention.

"Town Watching for Disaster Prevention" includes some parts that we think how we can solve the problems found by field survey of our town. Some solutions we thought may be carried out only by administrative institution or the law. However, some solutions can be done by us, by family, and by a group in the local area such as neighborhood association.

If we wait for other people's effort for our town's safety, it makes slow progress. But, if we start and go ahead with those activities, it sometimes makes a big impact.

If our town is not safe, we may lose someone precious. We understand danger regarding disaster in our town and take the first step to solve those problems. This is "Town Watching for Disaster Prevention" [28].

While we were making hazard map of the study area, we were using **Geobingan** app system. This is an app that can be made reports from affected area by users. With the help of this app we can see real situation of disaster zones by taking photos by users via using WhatsApp app.

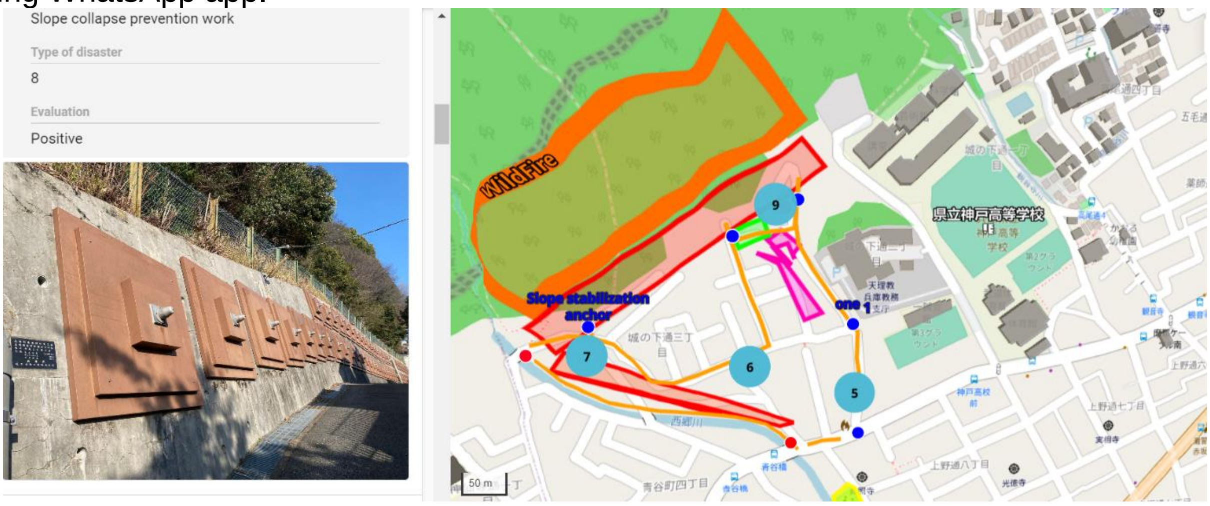

Figure 2.30. Making Hazard map by using Geogingan app

The Metropolitan Outer Area Underground Discharge Channel provides safety and security for the Tokyo Metropolitan Area.

Figure 2.31. Location of the Metropolitan Outer Area Underground Discharge Channel

The Metropolitan Outer Area Underground Discharge Channel, one of the world's largest, takes in overflow from small to mid-size rivers, such as the Kuramatsu and Oootoshifurutone, and directs it to the Edogawa River through a 6.3 km tunnel running 50m below ground. Construction was started in March 1993 utilizing world-class Japanese civil engineering technologies. Following a construction period of 13 years, in June 2006 it became possible to direct water from the Oootoshifurutone River into the Edogawa River.

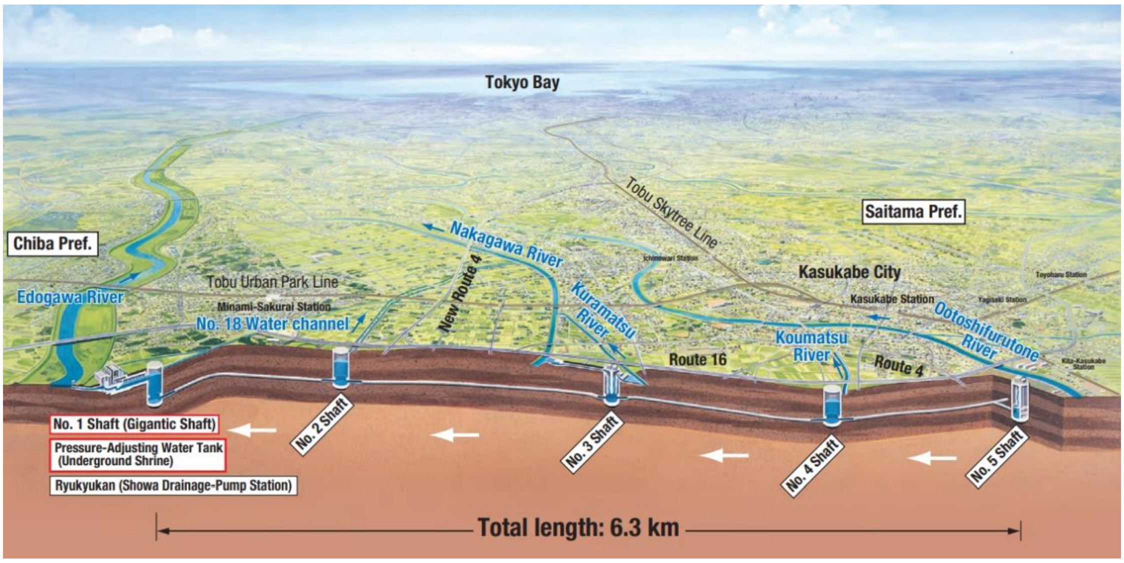

Figure 2.32. Structure of the Metropolitan Outer Area Underground Discharge Channel

Water is taken into the Metropolitan Outer Area Underground Discharge Channel about seven times a year, with the largest amount of water discharged approximately 19 million m^3 (during Typhoons No. 17 and No. 18 in September 2015). The flood control effect from this water system was remarkable, serving to greatly reduce flood damage in the Nakagawa/Ayase River basin.

Figure 2.33. Comparison

Year	Annual Amount Regulated		Year	Annual Amount Regulated	
	Times	Water Volume (x 10,000 m^3)		Times	Water Volume (x 10,000 m^3)
FY 2006	7	2,021	FY 2013	12	1,864
FY 2007	6	879	FY 2014	6	2,229
FY 2008	10	1,592	FY 2015	9	2,698
FY 2009	5	742	FY 2016	5	630
FY 2010	7	586	FY 2017	5	1,717
FY 2011	9	1,494	FY 2018	4	61
FY 2012	4	839	FY 2019	7	1,948

Figure 2.34. Operating Statistics of the Metropolitan Outer Area Underground Discharge Channel

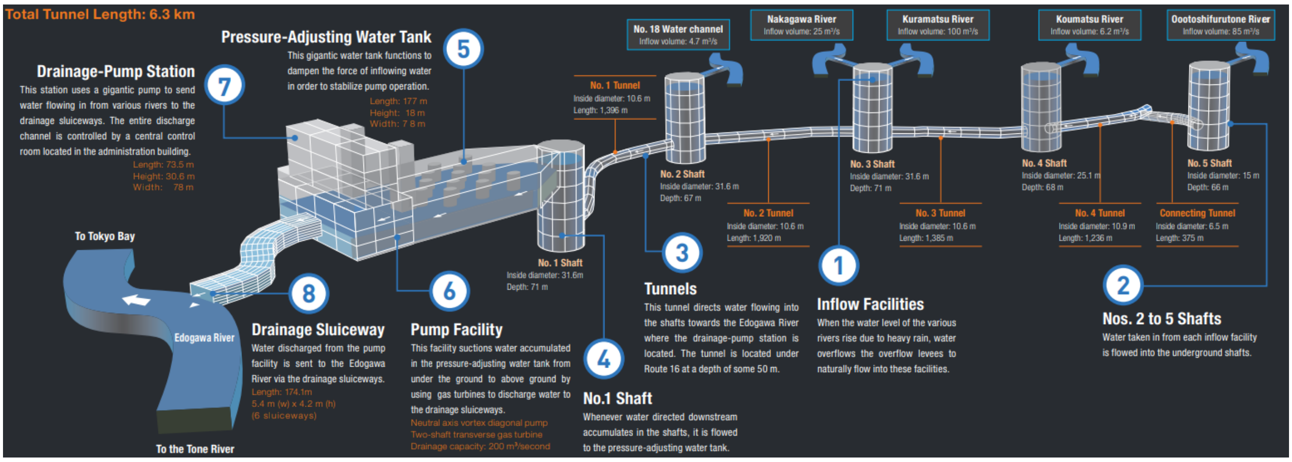

Figure 2.35. Mechanisms of the Metropolitan Outer Area Underground Discharge Channel

Flood Control Effects of the Metropolitan Outer Area Underground Discharge Channel. The Metropolitan Outer Area Underground Discharge Channel is making a significant contribution to reducing damage due to flooding of the Nakagawa/Ayase River basin.

Figure 2.36. Pictures were taken at the Metropolitan Outer Area Underground Discharge Channel

The effects of constructing the Metropolitan Outer Area Underground Discharge Channel have been studied by using a flood analysis simulation to calculate the possible damage that would occur if these facilities were not present, and then preliminary calculations are made to estimate how much flood damage has been reduced due to these facilities. The flood damage mitigation effects of the Metropolitan Outer Area Underground Discharge Channel have been calculated for major flooding from after the start of partial water flow in June 2002, with the results showing a total reduction of approximately 148.4 billion yen in flood damage over the approximately 18 years since this partial water flow started. During the season's 19th typhoon (East Japan Typhoon) in October 2019, the average rainfall of the Nakagawa/Ayase River basin was 216 mm/48 hours (preliminary value), resulting in an outflow that surpassed the “flood risk water level” at the Yoshikawa Water Level Observation Station on the Nakagawa River. The Edogawa River Office operated all the drainage facilities to reduce the river water levels to regulate some 12.18 million m^3 of flood water, the third highest ever, in the Metropolitan Outer Area Underground Discharge Channel. As a result, the number of flooded houses in the Nakagawa/Ayase River basin for 1.1 times the rainfall amount of the flooding in September 1982 was reduced by some 90%, and the amount of damage was decreased by approximately 26.4 billion yen [29].

Ohkouzu Diversion Channel. The Ohkouzu Diversion Channel is a 10-km man-made river constructed to allow floodwaters of the Shinano River to escape to the Sea of Japan before entering the Echigo Plain. The water was connected to the river on August 25, 1922.

There were repeated citizen’s petition activities for the measures. After construction work finally began and the Ohkouzu Diversion Channel was opened, the weir collapsed. After overcoming many difficulties, making numerous repair works, reconstructions, and expansions, the Ohkouzu Diversion Channel becomes what it is today.

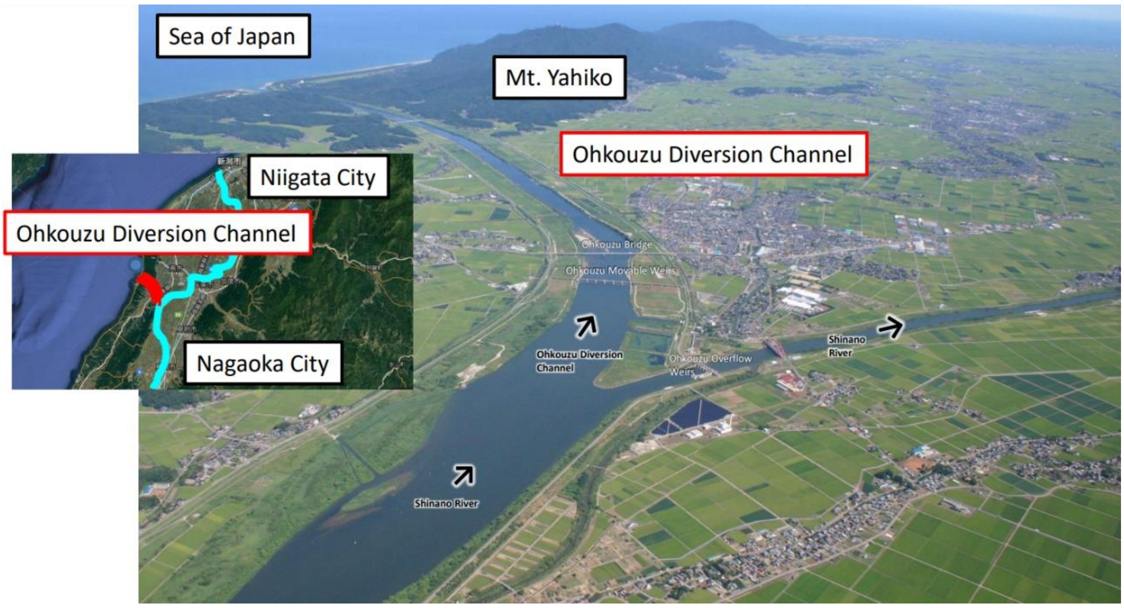

Figure 2.37. Ohkouzu Diversion Channel

Recommendation for Disaster Prevention, Mitigation and Realization of a New Era of National Resilience. Working Group on Digitalization and Technologies for DRM Currently, much of the data that could be useful for reducing disaster risk in advance or for rescuing lives after a disaster is scattered and buried. It is necessary to support decision-making, which is worthwhile taking the initiative, with promoting the digitization of such data, and detecting and eliminating problems by analyzing the data. The Cabinet Office has convened a “Digitalization and Disaster Management Technology Working Group” to study these issues. In this working group, two types of teams have been set up: one is called the "Future Vision Team,” which focuses on discussing the future concepts of digitalization and disaster management technology by assuming future technological innovations in the mid to long term (10 years or more) even if it is difficult to achieve with the current technology. The other is known as the "Social Implementation Team," which aims at figuring out the direction to improve and issues about technologies that are already being used from both perspectives of technology and institution by assuming implementation in the medium to short term period (within about 5 years).

Main Content of Recommendations

The Future Vision Team recommended setting goals that could be achieved by digitalization for the case of reducing disaster risk in advance and rescuing lives. The specific points are as follows.

・Making use of digital twin technology to simulate disaster and response to each case of disaster.

・Collecting and sharing information about spaces and infrastructures on real-time basis by using drones or sensors.

・Shifting administrative functions such as meetings and administrative procedures into the digital space so that those functions can be completed by online.

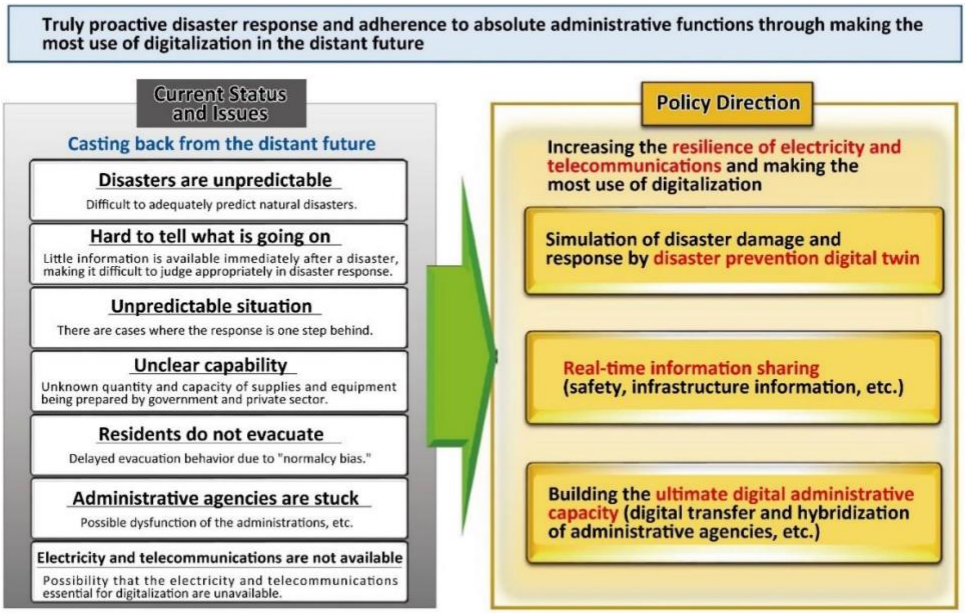

Figure 2.38. Summary of Recommendations from Digital and Disaster Management Technology Working Group

Other recommendations were given by the Social Implementation Team, focusing on the issues raised by digitalization in the disaster management field and the plans to make the current systems user-friendly or more advanced as follows.

・Standardizing information items and acquisition time required in the event of a disaster.

・Organizing the way for local governments to handle personal information related to disaster response.

・Developing networks that allow related organizations to collect, analyze, process and share necessary information without using the human resources [30].

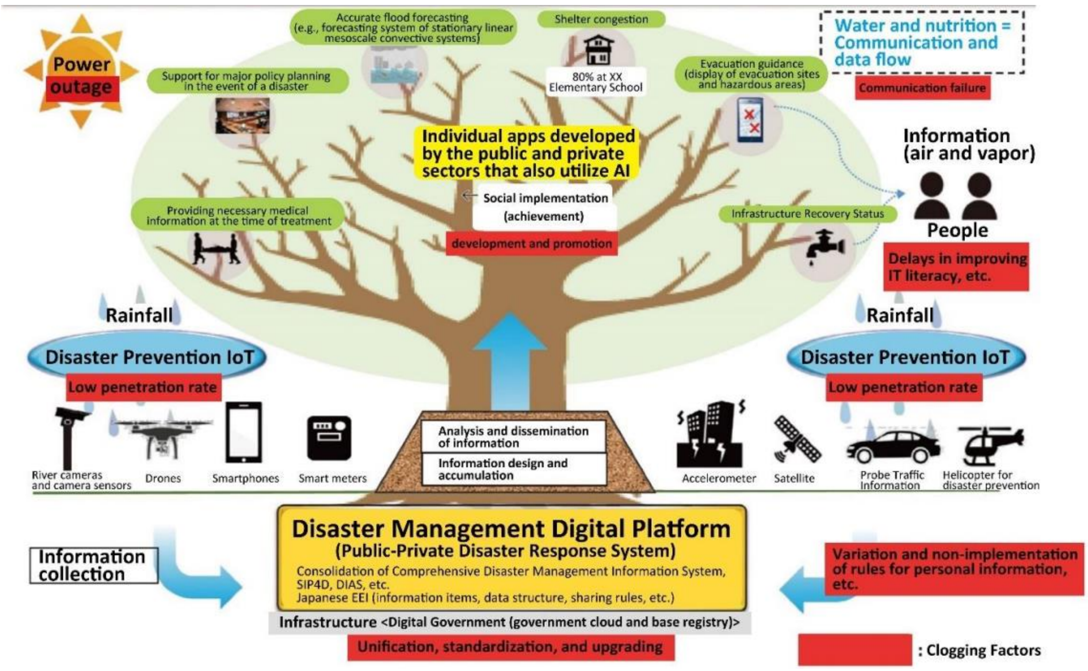

Figure 2.39. Disaster Management Digital Information and Data Flow Chart

III. SHELTER MANAGEMENT, DISASTER RISK REDUCTION AWARENESS AMONGST PUBLIC, BUILDING BACK BETTER SYSTEM IN JAPAN

3.1. Shelter Management and the locations of evacuation centers in case of disasters in Japan

"Shelter Management Guidelines" (April 2016) (Revised April 2022)

In each stage of disaster response (preparation, initial response, emergency response and recovery), the report emphasizes the importance of establishing a cooperative system of coordination in and out of the government in ordinal times and maintaining evacuees' health. The report also identifies detailed tasks that are often forgotten, such as toilets, sleeping quarters, bathing and pets, with a specific checklist of 19 tasks to perform.

"Guidelines for Securing and Managing Toilets at Shelters" (April 2016) (revised April 2022)

More of affected people feel uncomfortable since restrooms at shelters are insanitary in times of disaster. As they hold back on relieving themselves and refrain from consuming water and foods with hesitation to use restrooms, this can lead them to worsen their health or, in the worst case, life-threatening consequences. Therefore, the guideline emphasizes the importance of securing restroom provision and management.

"Guidelines for Securing and Managing Welfare Shelters" (April 2016) (revised May 2021)

Considering the lessons from the Great East Japan Earthquake, the "Guidelines for Welfare Shelters' Establishment and Management" (June 2008) were revised and amended substantively. Furthermore, based on the recognition that it is impossible to provide emergency response in times of disaster without efforts in ordinary times, the Guidelines emphasize that municipalities should also take the lead in promoting welfare shelters from ordinary times [31].

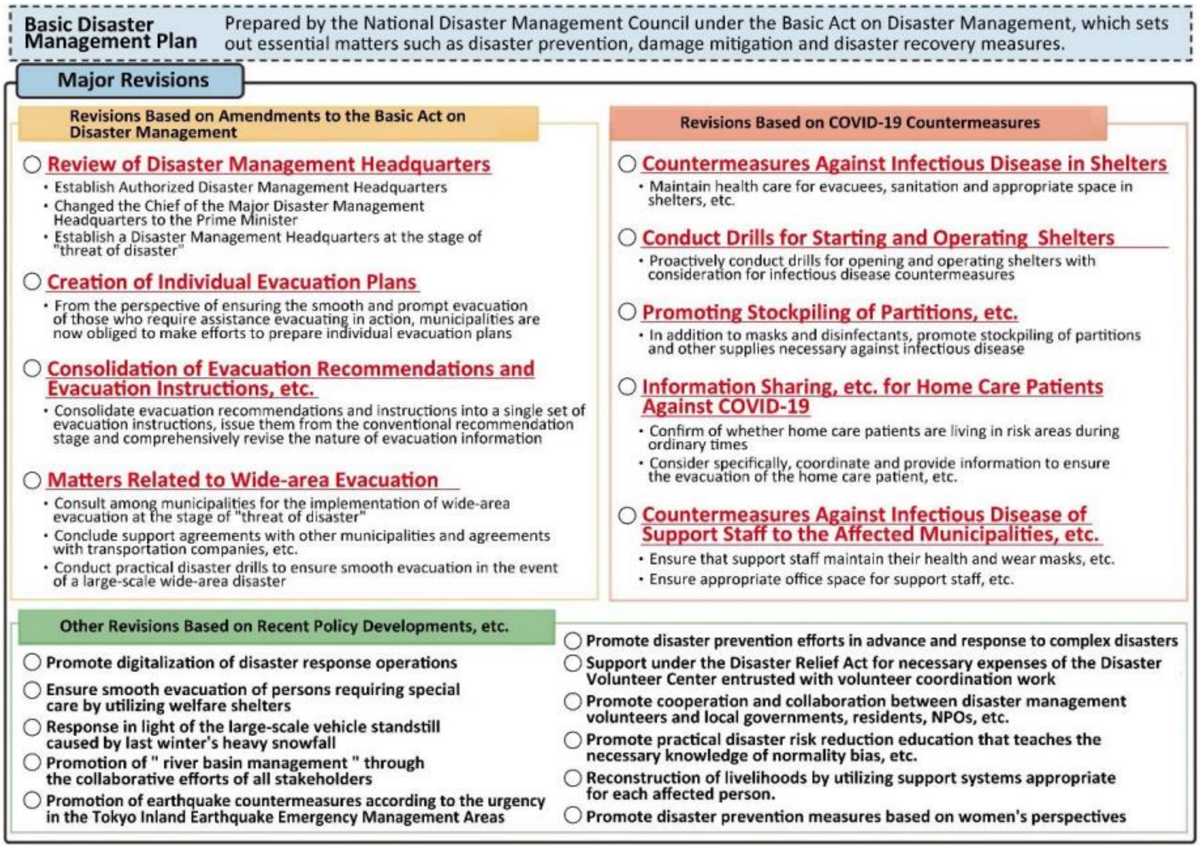

Figure 3.1. Outline of the Revised Basic Disaster Management Plan (May 2021)

At the time of the Great East Japan Earthquake, evacuation sites and shelters were not always clearly distinguished, which unfortunately became a factor in the spread of damage. Therefore, the Cabinet Office amended the "Basic Act on Disaster Management" in 2013, requiring the mayors of municipalities to designate designated emergency evacuation sites and designated shelters separately in advance and to inform (publicly notify) residents of these details. The status of the designated emergency evacuation sites as of April 1, 2021, is shown in Fig. 3.2.

	Designation of designated emergency evacuation sites							
	Floods	Slope failure, debris flow and landslide	Storm surge	Earthquakes	Tsunami	Large-scale fire	Inundation by Heavy Rain	Volcanic Phenomenon
The number of designated sites	70,323	66,253	21,701	85,035	38,365	39,286	37,993	10,329
Estimated accommodation capacity (10,000 people)	11,808	13,236	5,874	22,970	8,569	16,753	7,208	2,279

Figure 3.2. Designation of Designated Emergency Evacuation Sites

The designated emergency evacuation sites are also available on the Geospatial Information Authority of Japan’s web map, "GSI Maps" (Fig. 3.3).

Figure 11.3. Example Map Showing Indications of Designated Emergency Evacuation Sites

The Cabinet Office, together with the Fire and Disaster Management Agency, is urging local governments to designate their designated emergency evacuation sites. In addition, since the designated emergency evacuation sites are to be designated for each type of disaster, the local governments nationwide are being called to begin work on a project to organize information boards with the “Hazard Specific Evacuation Guidance Sign System (JISZ 9098) (March, 2016)” as soon as possible (Fig. 3.4).

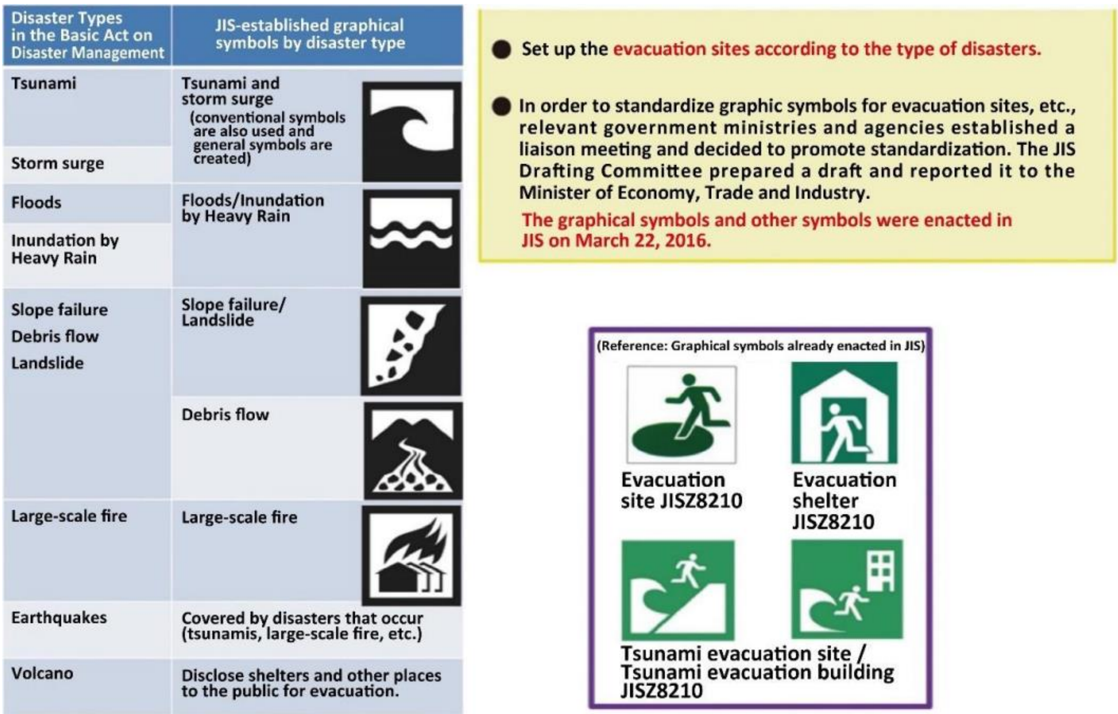

Figure 12. Example of Information Board Using Hazard Specific Evacuation Guidance Sign System

In response to the situation in recent disasters, various problems related to securing the living environment in shelters and issues related to improving the toilets in shelters were pointed out. It is considered important to improve the quality of life and ensure a good living environment even under conditions where people are forced to live inconveniently in shelters during a disaster.

3.2. Building Back Better as an aspect of Sustainable Development Goals

'Build back better' – a phrase first popularized in the United Nations Sendai Framework for Disaster Risk Reduction in 2015, and now ubiquitous.

To build back better, first we need to ensure that we protect the most vulnerable. To do so, it is essential to holistically integrate public health preparedness, universal health coverage, and healthy societies in a three-pronged approach to build back better.

The presence of an effective recovery framework is vital to the establishment of a clear structure and coordination for planning and operational activities. However, in the absence of necessary legal, technical, financial, and other support mechanisms, such conventions lack meaning. Stakeholders must work together to identify obstacles that prevent Build Back Better in RRR, including practices that unnecessarily increase the time between disaster onset and recovery operations, over-reliance on compensatory disaster risk management, misguided or weakly-enforced regulations, insufficient funding, poor coordination, or a lack of technical guidance and expertise.

Strong institutional mechanisms allow for adaptive legislative environments. Legislation can be used for Build Back Better compliance, where compliance entails using legislation to enforce recovery initiatives to conform to Build Back Better principles. The lack of enforcement of hazard-related laws and adequate risk-based building controls contributed to the large-scale devastation caused by the 2004 Indian Ocean tsunami. Enforcing updated risk-based building design standards through the use of compulsory construction codes and maintaining standards is an important regulatory requirement in Build Back Better. Legislation can also facilitate, simplify and guide recovery activities. Time-consuming procedures, insufficient resources to process permits and the lack of fast-tracked methods delay reconstruction and are some reasons for slow repair and rebuilding. Legislative suspensions and emergency powers can reduce reconstruction time and encourage Build Back Better [32].

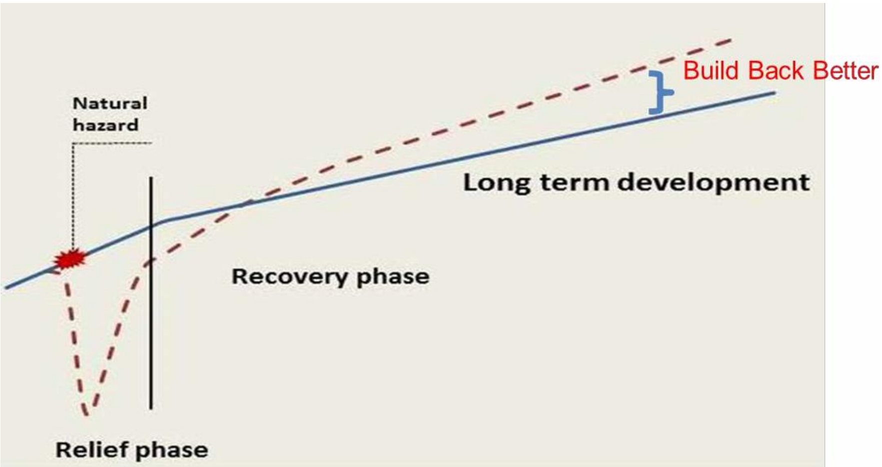

Figure 13. Build Back Better (BBB) Development approach

Building Back Better in post-disaster recovery. The frequency and scale of disasters are increasing. The asymmetry of rising technical capacities and the decreasing options of poor people may contribute to hazard exposure as the rate of urbanization accelerates and the environment changes, resulting in catastrophic effects. Efficient and successful post-disaster restoration and recovery can halt the destruction imposed on mankind and slow the descent of disadvantaged communities into cyclical poverty. Recovery and rebuilding, in its many stages, give the potential to rebuild beyond pre-disaster conditions for safer, more sustainable, and resilient communities. What does it mean to build back better? Building Back Better (BBB) is a post-disaster recovery strategy that minimizes susceptibility to future catastrophes while increasing community resilience to physical, social, environmental, and economic vulnerabilities and shocks [33].

During my stay in Japan, we attended at International Recovery Forum 2024 in Japan. Main topic was Accelerating Progress with Building Back Better Resilient Recovery in the Face of Rising Climate Risks.

Figure 14. International Recovery Forum 2024, Accelerating Progress with Building Back Better

Key Points:

- Needs to be a coordinated process;
- Should aim to restore emotional, social, financial and physical well-being as well as ensuring that physical reconstruction takes place;
- Should be treated as a developmental activity.

Principles. Recovery and rehabilitation are most effective:

❖ When communities and stakeholders recognize that it is a long process;
❖ When activities are integrated with risk management;
❖ When conducted with the participation of all affected persons;
❖ When services are provided in timely, fair and flexible manner.

What we **DO NOT** want. Actions taken in the aftermath of a disaster to:

- reconstruct same as before (Figure 3.7a, b);
- rebuilding the pre-existing vulnerabilities;
- community in the same state as before the disaster.

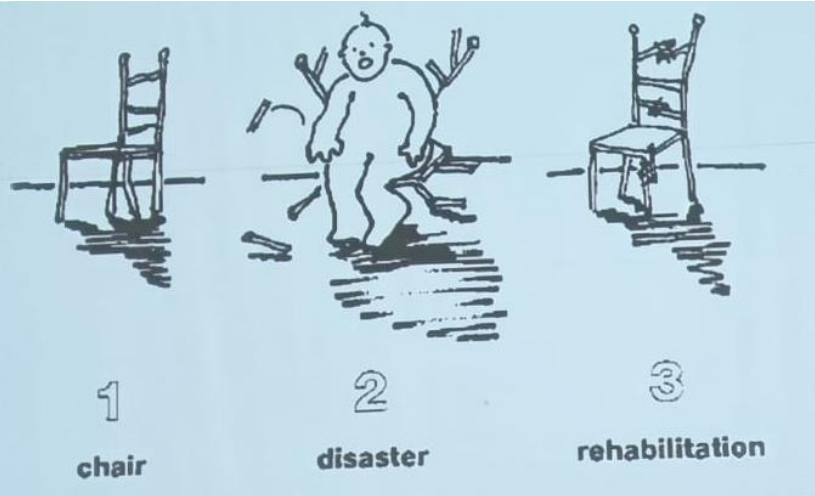

Figure 3.7a. United Nations Disaster Management Training Programme (DMTP)

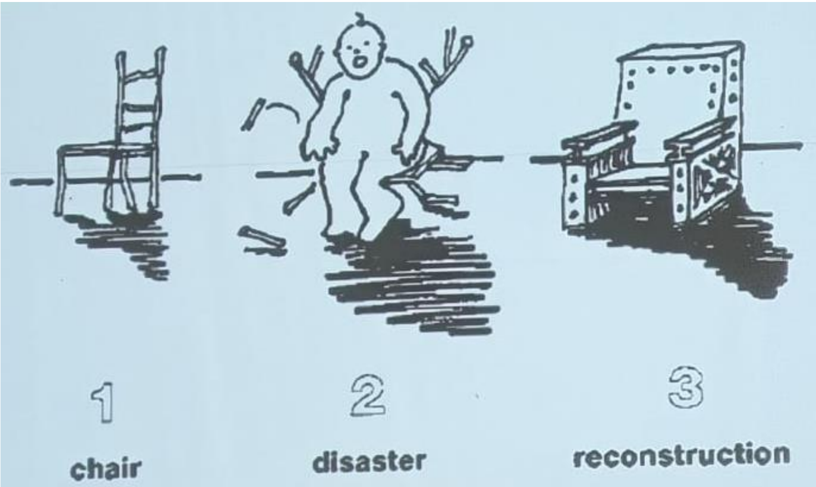

Figure 3.7b. United Nations Disaster Management Training Programme (DMTP)

Key Challenges and Gaps:

- Capacity for post-disaster assessment;
- Recovery planning does not always draw from damage, loss and needs assessment;
- M&E systems are critical but lacking lack of baseline data;
- DRR measures not adequately integrated into recovery;
- Implementation issues consistently plague recovery programs but do not have cookie-cutter solutions;
- Concept of "better" evolving and context specific;
- Extent to which recovery experiences deploy and benefit from BBB is not well known.

Key recommendations:

- Invest in targeted capacity building for recovery preparedness, planning and management;
- Guidance on monitoring and evaluation of recovery programs;
- Provide a one-stop shop of information on how to access, manage and track recovery finance, with a particular emphasis on measures for financial preparedness;
- Engage with climate adaptation programs to ensure that they are including resilience building in recovery as part of their portfolio;

- Develop, collect information on and analyze indicators of progress with the adoption of the BBB approach;
- Support countries to review their policies, laws and programs that concern post-disaster recovery to strengthen them in area of BBB;
- A “Readiness to Build Back Better” initiative to strengthen country capacity for preparedness for resilient recovery;
- Expand the use of business continuity planning in both the public and private sectors;
- Consistent after-action reviews of disaster recovery programs to assess performance, identify gaps, formulate lessons, and document good practices;
- Support the mainstreaming of disaster resilience in national planning and BBB in recovery planning;
- Develop and utilize policies as well as a checklist to ensure that adequate recovery policies are in place before the next disaster [34].

3.3. Disaster risk reduction awareness activities in Japan

Awareness Raising and Knowledge Promotion on Disaster Reduction.

1. Promotion of Efforts for Disaster Reduction - In order to improve the disaster resilience of the community and to reduce disaster damages, there must be close cooperation among individuals, families, local community, businesses and relevant entities, to build momentum for a nationwide movement. The Government has designated the 1st day of September as the "Disaster Preparedness Day" and the week including this day as the Disaster Preparedness Week and carries out various events to raise awareness and readiness about the disaster. Disaster drills and promoting events are held in various parts of Japan.

In 2011, the Act on Promotion of Tsunami Countermeasures was enacted, and November 5th was designated as the "Tsunami Preparedness Day." In the 70th UN General Assembly, November 5th was designated to be the "World Tsunami Awareness Day".

2. Education about Disaster Reduction - Education for disaster risk reduction is quite important for enabling individuals to have correct understanding about natural disasters and be able to act on their discretion to prevent and reduce damages from a disaster. In the Great East Japan Earthquake, a case of an elementary school was reported to have safely evacuated based on their daily education of the past disasters and training about evacuation. Thus, it is important to enhance education for disaster risk reduction at schools and in local communities so that people are nurtured to be equipped with correct understanding about disaster awareness.

The Cabinet Office implements "Disaster Reduction Education Challenge Plan" to nurture a positive environment for more proactive disaster reduction education by picking up active local groups, schools and individuals who demonstrated better disaster reduction plans and actions, give support to them, and publicize their achievements, through the web site, intending that such plans and programs be widely recognized and utilized throughout the nation. In addition, the Cabinet Office and the Council for Promoting Disaster Risk Reduction implement the award for posters with the aim of further raising awareness of disaster prevention and reducing disaster damage by soliciting poster designs related to disaster prevention from the general public.

Additionally, the Ministry of Education, Culture, Sports, Science and Technology has enhanced contents regarding disaster reduction in the new Curriculum Guidelines announced in 2017/2018. For example, during social studies for fourth grade in elementary schools, local natural disasters that happened in the past are introduced, and students learn to think about what they should do and what items should be prepared by imagining about a disaster that could happen locally. Further improvement with disaster management education is promoted through development of materials such as "Guide to Make a Disaster Reduction Manual for Schools (Earthquake and Tsunami)," and "Development of a Disaster Reduction Education to Nurture Power to Live On," providing guidance for disaster reduction at schools.

Moreover, Fire and Disaster Management Agency offers an online program called "Disaster Reduction / Crisis Management e-College" on the web, directed to local residents, professional / voluntary firefighters and local government employees, to enhance community disaster resilience. Also, a textbook for school teachers and leaders "Challenge! Disaster Prevention 48" has been compiled in order for school children to be able to learn and acquire knowledge and practical skills about disaster reduction. In these ways, An environment is being created to independently engage in disaster reduction education in each region and school.

3. Transmission of the lessons learned from generation to generation - in the Great East Japan Earthquake, a case of a village resident who escaped the tsunami disaster as the house was built in the area higher than a stone monument on which the inscription read "Do not build a house lower than this point", With such lesson in mind, the Basic Act on Disaster Management was revised to make it an obligation of local residents to record and transcend lessons from disasters experience.

Figure 3.8. Memorial Day of Great Hanshin-Awaji Earthquake on 17 January 2024

Further, in Kobe City, Hyogo Prefecture, "Disaster Reduction and Human Renovation Institution" was established in memory of the Great Hanshin-Awaji Earthquake (Figure 3.8), and is engaged in activities to pass the lessons from the Earthquake disaster on to the younger generations through reproduction of the big Earthquake by audio-visual and model construction [35].

IV. PREDICTION OF THE CONSEQUENCES OF FLOODS BY USING LOCATION-SPECIFIC FLOOD SCENARIOS AND SIMULATION EXERCISES IN JAPAN

4.1. Methods to develop flood hazard map

Methods to develop flood hazard map. In Japan, flood hazard maps are mainly prepared by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) and Prefectural governments (local municipalities) using inundation information. The steps being currently used by MLIT to prepare flood hazard maps in Japan are given in the following sub-sections.

Flood inundation model: Shallow Water Equations. MLIT uses the following shallow water equations (SWE) for the simulation of flood inundations areas [36]:

$$\gamma\frac{\partial Q_x}{\partial t}+\frac{\partial}{\partial x}\left(\gamma\frac{Q_x^2}{h}\right)+\frac{\partial}{\partial y}\left(\gamma\frac{Q_xQ_y}{h}\right)+g\gamma h\frac{\partial(h+z_b)}{\partial x}+g\gamma n^2\frac{Q_x\sqrt{Q_x^2+Q_y^2}}{h^{7/3}}$$
$$+\frac{1}{2}C_D{}'(1-\gamma)\frac{Q_x\sqrt{Q_x^2+Q_y^2}}{h}=0$$

$$\gamma\frac{\partial Q_y}{\partial t}+\frac{\partial}{\partial x}\left(\gamma\frac{Q_xQ_y}{h}\right)+\frac{\partial}{\partial y}\left(\gamma\frac{Q_y^2}{h}\right)+g\gamma h\frac{\partial(h+z_b)}{\partial y}+g\gamma n^2\frac{Q_y\sqrt{Q_x^2+Q_y^2}}{h^{7/3}}$$
$$+\frac{1}{2}C_D{}'(1-\gamma)\frac{Q_y\sqrt{Q_x^2+Q_y^2}}{h}=0$$

$$\frac{\partial h}{\partial t}+\frac{\partial(\gamma Q_x)}{\partial x}+\frac{\partial(\gamma Q_y)}{\partial y}=q$$

where, Q_x, Q_y are the discharges per unit width in x and y directions, h the water depth, z_b the bed elevation, γ the porosity, q the rainfall, inundation from the sewerage, etc., n the roughness coefficient according to the land use, C_D the drag coefficient. The spatial resolution (grid size) for the model simulation of the Yodogawa River Basin is 25 m x 25 m.

Levee breach conditions. The amount of the flow overtopped from the river is estimated using modified Honma's overflow formula (as used in Manual for Economic Evaluation for Flood Control Investment, 2005, MLIT) [37].

a. Honma's front-overflow formula:

For complete overflow (for $h_2/h_1 < 2/3$),

$$Q_0 = 0.35\,h_1\sqrt{2gh_1}B$$

For submerged overflow (for $h_2/h_1 \geq 2/3$),

$$Q_0 = 0.91h_2\sqrt{2g(h_1-h_2)}B$$

where Q is overflow discharge through structure and h_1, and h_2 are the water depth measured from the bed height of a breached levee.

b. Honma's side-overflow formula:

Inundation discharge (Q) following a levee breach is given by:
For I>1/1580,

$$\frac{Q}{Q_0} = \left(0.14 + 0.19 \times log_{10}\left(\frac{1}{I}\right)\right) \times cos\left(48 - 15 \times log_{10}\left(\frac{1}{I}\right)\right)$$

For 1/1580≥I>1/33600,

$$\frac{Q}{Q_0} = \left(0.14 + 0.19 \times log_{10}\left(\frac{1}{I}\right)\right)$$

For 1/33600≥I,

$$\frac{Q}{Q_0} = 1$$

where Q is inundation flow, Q_0 is flow volume calculated by Honma's formula, I - is bed slope of a river, and B is the width of the crest. The unit of "cos" in the parenthesis is "degree."

An approach to estimate maximum inundation depths. The steps to prepare flow inundation area map using SWE and levee breach conditions are shown in Fig. 4.1. In step 1, it is assumed that the levee breach has occurred at two or more locations simultaneously. It is assumed that inundation starts at or above the designed high-water level in the river. The levee breach is assumed at a point if the water level in the river is greater than the designed high-water level of the river. In step 2, inundation depths are simulated for individual levee breach points. Step 3 overlays the inundation maps (for two or more levee breaches) obtained in step 2 to estimate maximum inundation depths. Finally, in step 4, the maximum inundation depth maps are distributed to local governments, and other stakeholders, etc. [38].

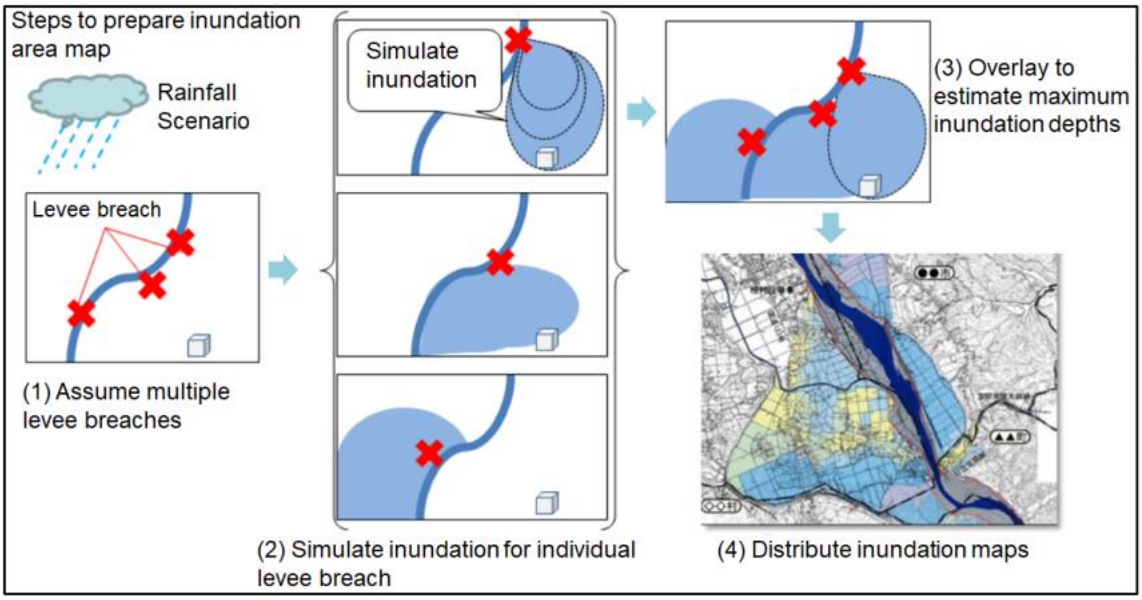

Figure 4.1. Steps to prepare the inundation area map

Scenarios of external force to develop flood hazard map. According to the Flood Fighting Act (FFA) amended in 2014 the river administrators, MLIT and prefectural governments should design the area that might be inundated during the flooding events. The act specifies that two rainfall scenarios should be considered as inputs to simulate flood hazard (inundation area) maps. The first scenario is to use the design-rainfall used for the river works as input to simulate flood inundation. In case of the Yodogawa River, the design rainfall is assumed equivalent to 200-year return period (261 mm in 24 hours) while the upstream tributaries assume comparatively smaller return periods (150-years): for the Uji River (164 mm in 9 hours), the Kizu River (253 mm in 12 hours) and the Katsura River (247 mm in 12 hours).

The second scenario is to use the largest-scale (worst case) rainfall as input to simulate flood inundation. Based on rainfall patterns, the whole Japan is divided into 15 regions, and DepthArea-Duration (DAD) analysis is conducted using recorded maximum rainfall in each region. Figure 4.2 shows the DAD relationship for the Kinki region [39]. The average basin rainfall can be estimated from DAD analysis and typically exceed or equivalent to 1000-year return period. If the historical maximum rainfall observed is less than the rainfall corresponding to the exceedance probability of 1/1,000 (360 mm/24 hr.), then the rainfall corresponding to that exceedance probability is used for the simulation as maximum rainfall in the worst-case scenario. The historical maximum rainfall observed in the Hirakata station (Yodogawa River Basin) is 314 mm in 24 hrs. which is less than 360 mm in 24 hrs. Hence the rainfall by DAD analysis for the Yodogawa River Basin is assumed to be 360 mm in 24 hours for the simulation, whereas for its major tributaries: for the Uji River is 356 mm in 9 hours; for the Kizu River is 358 mm in 12 hours; and for the Katsura River is 341 mm in 12 hours.

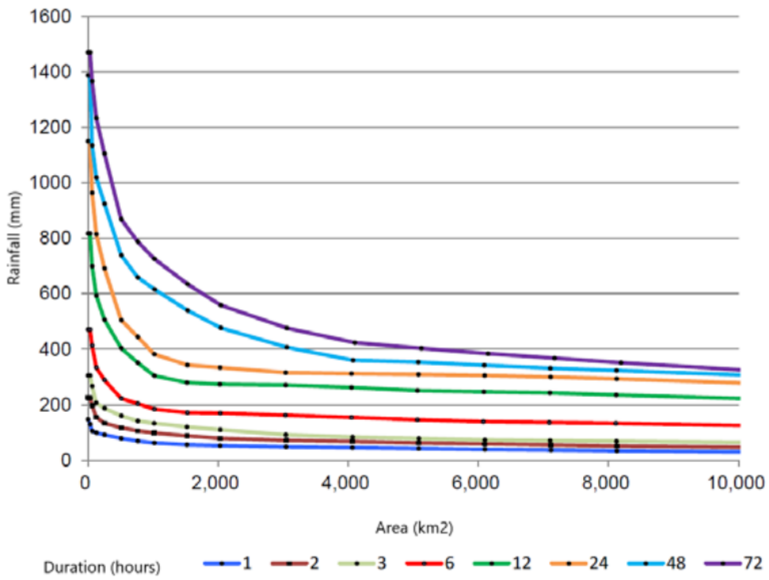

Figure 4.2. DAD analysis for the largest-scale scenario (e.g., Kinki Region)

The inundation simulation maps are prepared by MLIT using the second scenario in combination with steps in subsection “Flood Hazard Mapping in Japan” above. The prefectural government may use the flood inundation map (25 m x 25 m) prepared by MLIT to plan mitigation activities during flood events for decision making, planning, and implementation of flood management strategies. However, the prefectural governments can also develop their own inundation models using different tools. For example, the Shiga Prefectural government uses own model for flood inundation simulation (50 m x 50 m). In addition to MLIT and prefectural governments' flood simulation models, a list of commonly used flood inundation models in Japan is given in Appendix A.

4.2. Flood scenarios of Yodogawa River Basin

The Yodogawa River Basin located in the central part of Japan is shown in Figure 4.3. The length of the Yodogawa River is 75 km. It is the seventh largest river basin in Japan with a catchment area of 8,240 km^2 [40]. Flowing south out of Lake Biwa, the largest lake in Japan, first as the Seta River and then the Uji River, it merges the Kizu River and the Katsura River near the border between Kyoto and Osaka Prefectures. The Yodogawa River runs through the heartland of the Kinki region and flows into the Osaka Bay. The Yodogawa River basin consists of six subcatchments, which are the Lake Biwa basin (3,802 km^2), the Uji River basin (506 km^2), the Kizu River basin (1,647 km^2), the Katsura River basin (1,152 km^2), the lower Yodogawa River basin (521 km^2) and the Kanzaki River basin (612 km^2). It extends over six prefectures namely Shiga, Kyoto, Osaka, Hyogo, Nara, and Mie [41,42].

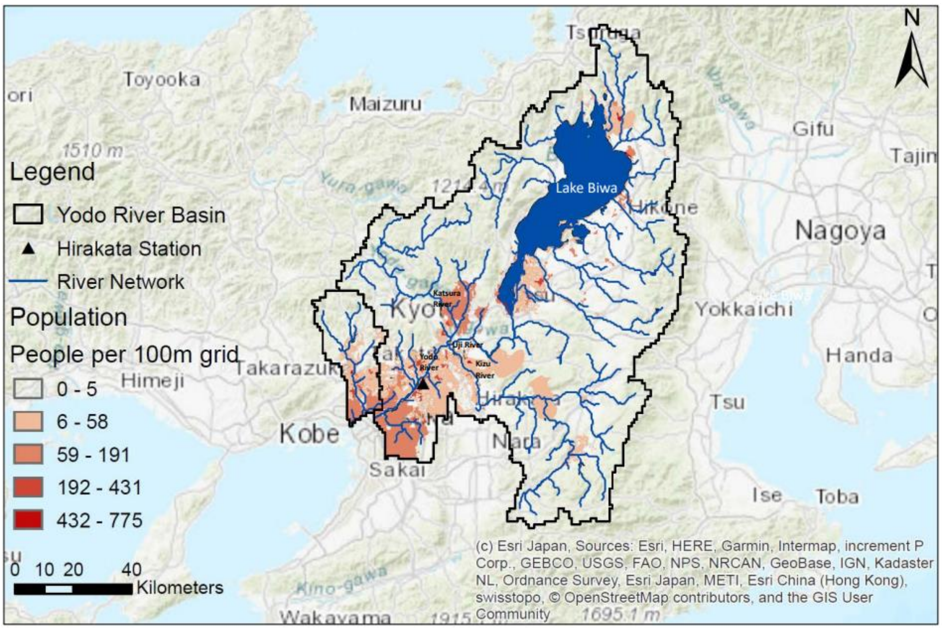

Figure 4.3. Location of Yodogawa River basin in Japan (The figure is prepared in ArcMap 10.6.1 using data from the Geospatial Information Authority of Japan (GSI), HydroSHEDS, WorldPop and ArcGIS online)

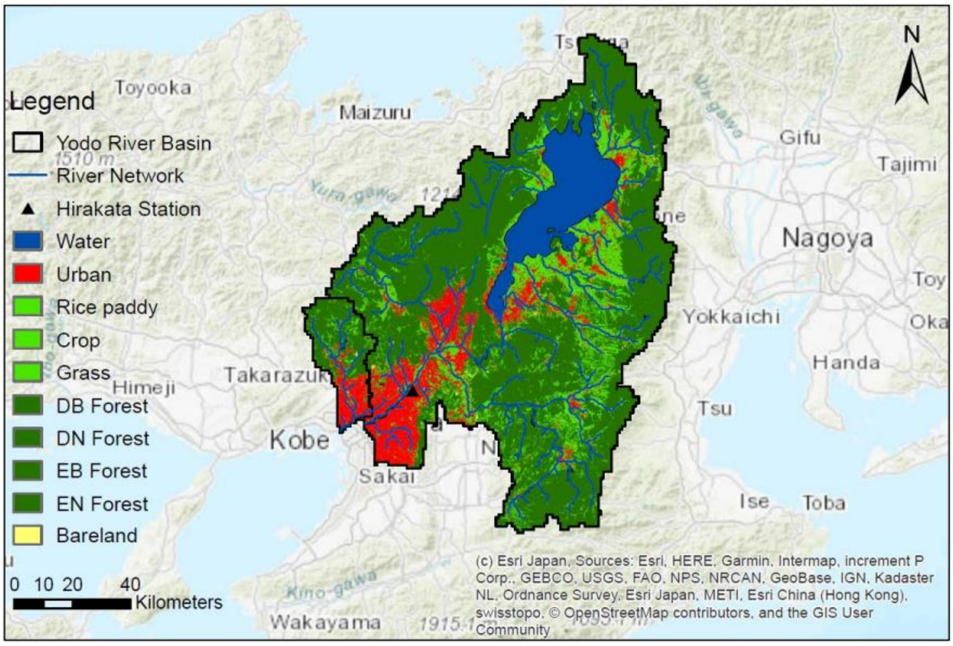

Figure 4.4. Land use map of the Yodogawa River Basin (The figure is prepared in ArcMap 10.6.1 using data from JAXA EORC and Geospatial Information Authority of Japan (GSI), HydroSHEDS, and ArcGIS online)

City areas spread throughout the basin as shown in Figure 4.4. Metropolitan areas such as Osaka, Kyoto, and Otsu are located along the rivers. The population in the basin is about 9.30 million in 2015 [42,43,44]. In the lower Yodogawa River basin, most of the highly populated urban developments are in areas lower than the river water level. In Osaka City, it is estimated that 94.9% of the total metropolitan area is in the flood-prone area [41].

The simulated flood hazard map of Yodogawa River Basin with 25 m x 25 m resolution is shown in Figure 4.5. The second scenario of the external force, i.e., the amount of rainfall 360 mm in 24 hours is used to simulate flood inundation depth. The estimated inundation areas cover approximately 144 km^2 in Osaka prefecture and 121 km^2 in Kyoto prefecture where Osaka City and Kyoto City are major urban areas, respectively. The maximum inundation area is anticipated in Osaka City is about 62 km^2 with an average inundation depth 2.4 m ranging from 2.6 to 7.2 m. The maximum inundation depth of 8 m is anticipated in Takatsuki City in the Osaka prefecture. The model simulated about 40.9 km^2 inundated area in Kyoto City around Katsura River (and its major tributary Kamo River) and Uji River. The average inundation depth of 2.7 m is anticipated in Kyoto City ranging from 1.9 to 7.4 m [45].

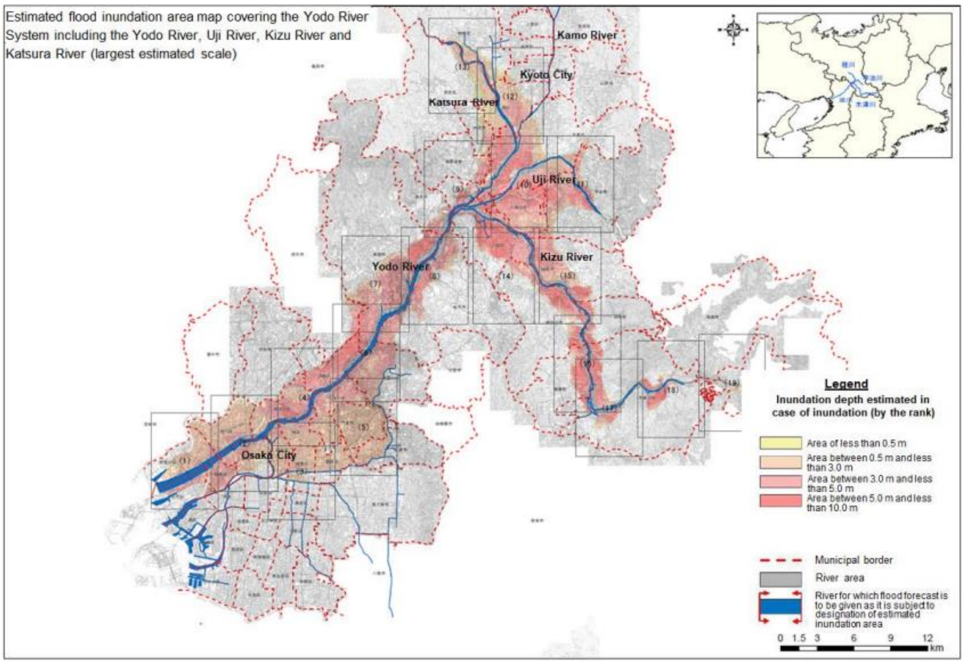

Figure 4.5. Estimated flood inundation area map of the largest estimated scale of the Yodogawa River Basin

Flood hazard maps prepared by MLIT are useful for the city and prefectural governments to design flood mitigation strategies as explained in the Introduction section. Following are the specific examples of usage of flood hazard maps. The example of a flood hazard map for the Kobe City in Hyogo Prefecture are shown in Figure 4.6 [46].

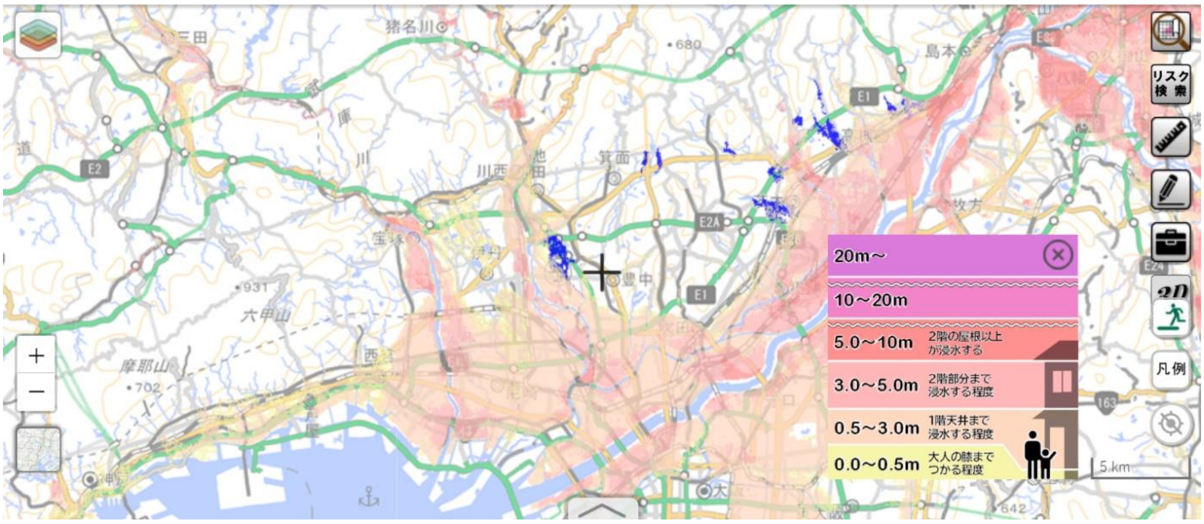

Figure 4.6. Flood Hazard Map for Kobe city, Hyogo Prefecture, Japan

Appendix A. Examples of software used for flood inundation simulation in Japan:

1. Rainfall-Runoff Inundation (RRI). The RRI model is a two-dimensional model capable of simulation the runoff and flood inundation using rainfall, digital elevation model (DEM), land cover, and river cross section [47, 48].

1. *Nays 2D Flood.* Nays 2D Flood is a two-dimensional flood flow simulation model [49].
2. *DioVISTA.* DioVISTA flood simulator developed by Hitachi Ltd. [50].

CONCLUSION

During the Program of Visiting Researcher FY2023 at the Asian Disaster Reduction Center, I have learned and gained lots of information related to disaster management systems and disaster risk reduction lessons in Japan. Based on historical records, we know that Japan faces numerous kinds of disasters. So, the disasters made Japan take serious countermeasures to reduce casualties and economic losses. During my stay in Japan, I learned about the countermeasures taken by the Japanese government.

Furthermore, Japan uses some apps that notify people about disasters beforehand. Sensors and other kinds of new technologies help them predict floods, landslides, and other disasters beforehand as well.

Additionally, I researched whether the flood simulation models that Japan uses for flood prediction could be useful in our country as well. I could compare these models to our models that we use for flood prediction and for making flood hazard maps.

Achieved Results:

- Got information about the disaster management system in Japan;
- Learned countermeasures can be taken to reduce casualties before floods happen in Japan;
- Learned about new technologies (early warning technologies) that can be used for flood prediction in Japan;
- Building Back Better approach was studied to improve resilience to disasters;
- Learned a simulation model to make a flood hazard map for the inundation areas in Japan.

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During my stay in Japan, I had a chance to see how Japan deals with disasters. By taking the program activities, I updated my knowledge, and skills and learned the best practices in disaster risk management. When I return to Azerbaijan, I am excited to share my new experiences with my colleagues, and as a teacher, I will teach students (cadets) for sure what I experienced during the program. Apart from that I also was enjoying while I was learning about Japan's national customs, cultures, and cuisine.

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