



## Learning from Japan's Experience in Integrated Urban Flood Risk Management: A Series of Knowledge Notes

### Knowledge Note 1: Assessing and Communicating Urban Flood Risk

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Cover Image: Shiga Prefecture’s Disaster Information Map accessed from a smart phone. The map disseminates information on various natural disaster risks, including of floods, landslides, and earthquakes. The platform is used to enhance disaster risk awareness, preparedness, and evacuation and as a key urban flood risk management strategy.

(Shiga Prefecture. n.d.[a])

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## 1. Summary

**Understanding the causes of flood disasters, and ways to mitigate them, is an essential first step toward the integrated management of flood risk in cities.** This can help decision makers guide investments out of hazardous zones, save lives and property, as well as ensure that investments take into account both expected and unprecedented disaster events. Careful disaster planning is critical in complex urban environments that are home to large populations as well as multiple infrastructure and service networks. Though risk assessments are of various types, depending on the needs and objectives of the stakeholders involved, all share the objective of enhancing the knowledge and management of risk. To this end, it is also important to consider how assessment results are communicated to stakeholders, as well as to the wider public.

**In Japan, risk assessments are generally used to inform flood risk management plans and investments, as well as to communicate flood risk information to enhance preparedness and evacuation plans.** This Knowledge Note examines the different types of urban flood risk, and the roles of specific sectors and stakeholders in conducting flood risk assessments in Japan. It provides an overview of the various objectives and methodologies used. Examples include risk assessments conducted to inform the design of structural flood management measures and the planning of nonstructural flood evacuation, as well as to raise community awareness and integrate climate change considerations in risk management efforts. These examples showcase how and why various risk assessments are conducted, and how they are used to enhance decisions and actions. The note also considers the effectiveness of risk communication measures in Japan, and analyzes the prevalent methods and technologies used to strengthen flood risk mitigation, preparedness, and evacuation plans in Japanese cities.

**Key questions that may guide Japanese cities in understanding and assessing flood risk include the following:**

- What types of flood risk affect urban areas?
- How can cities use information on the risks and impacts relevant to key sectors and stakeholders to enhance flood risk mitigation and preparedness?
- How can the potential risks of climate change be considered within the flood risk assessment process? How can cities deal with uncertainty?
- How can flood risk information be communicated in a timely and effective manner? How do communication content, means, and processes influence preparedness and response capacities, especially of citizens (and, specifically, vulnerable groups) and the private sector?

**Japan's rich history and experience in managing urban flood risk offer the following lessons:**

- **Consider the context.** The risks and impacts of urban floods are complex and diverse, depending on flood type and the geographical and other characteristics of urban areas. Different stakeholders are affected by floods in different ways. For this reason, Japan pursues several approaches to risk assessment and risk communication, with different purposes and different target users. Choosing the right approach requires a careful examination of the variables involved. Regardless of location, flood risks are assessed using simulations and analytical models. In Japan, river administrators, sewerage system administrators, and mayors of municipalities at risk of inundation are responsible for risk assessments.
- **Consider the purpose.** Risk assessments can serve many purposes, such as designing and examining flood control infrastructure, establishing and revising land use plans and standards, planning and developing evacuation methods, examining disaster insurance and financing methods, and considering climate change adaptation measures. The scope of the risk assessment must match its purpose.
- **Think ahead.** In light of climate change impacts, flood risk assessments should consider various scenarios to deal with climate uncertainty. Many cities in Japan face limitations in the information and resources needed to conduct their own climate change risk and impact assessments. Often, assessment results are too uncertain to support evidence-based decision making. However, urban planners across Japan see the need for and value of integrating climate change impacts within their flood risk assessment processes. Japan promotes ways to integrate climate change considerations into the risk assessments guiding both structural and nonstructural investments.
- **Work together.** At the central level, the Ministry of Land, Infrastructure, and Transport and Tourism (MLIT) formulates and revises laws and guidelines related to investment in the management of various types of flood risk (related to rivers, sewerage systems, watersheds, coastal protection, and disaster mitigation). As the

number of urban floods increases in Japan, many cities are stepping up their efforts to better understand, define, and implement their own assessments to inform city-level flood management policies and action plans, as well as to enhance preparedness and evacuation plans (such as by improving hazard maps). Additionally, the Government's Cabinet Office, which is the key coordinating agency for disaster risk management in Japan, monitors and reviews urban flood disasters and risk management measures on an annual basis, and updates relevant laws, policies, and institutional frameworks to ensure lessons learned are scaled through a coordinated approach. Scientific knowledge underpins the new policies and approaches, which were reviewed by researchers and academic experts. Regarding risk communication, local governments, in partnership with private sector and community members, are improving what, when, and how risk information is communicated by developing more targeted approaches. For example, efforts to improve the communication of flood risk to railway and metro operators in Japan can greatly enhance the capacity of their large passenger bases to effectively evacuate.

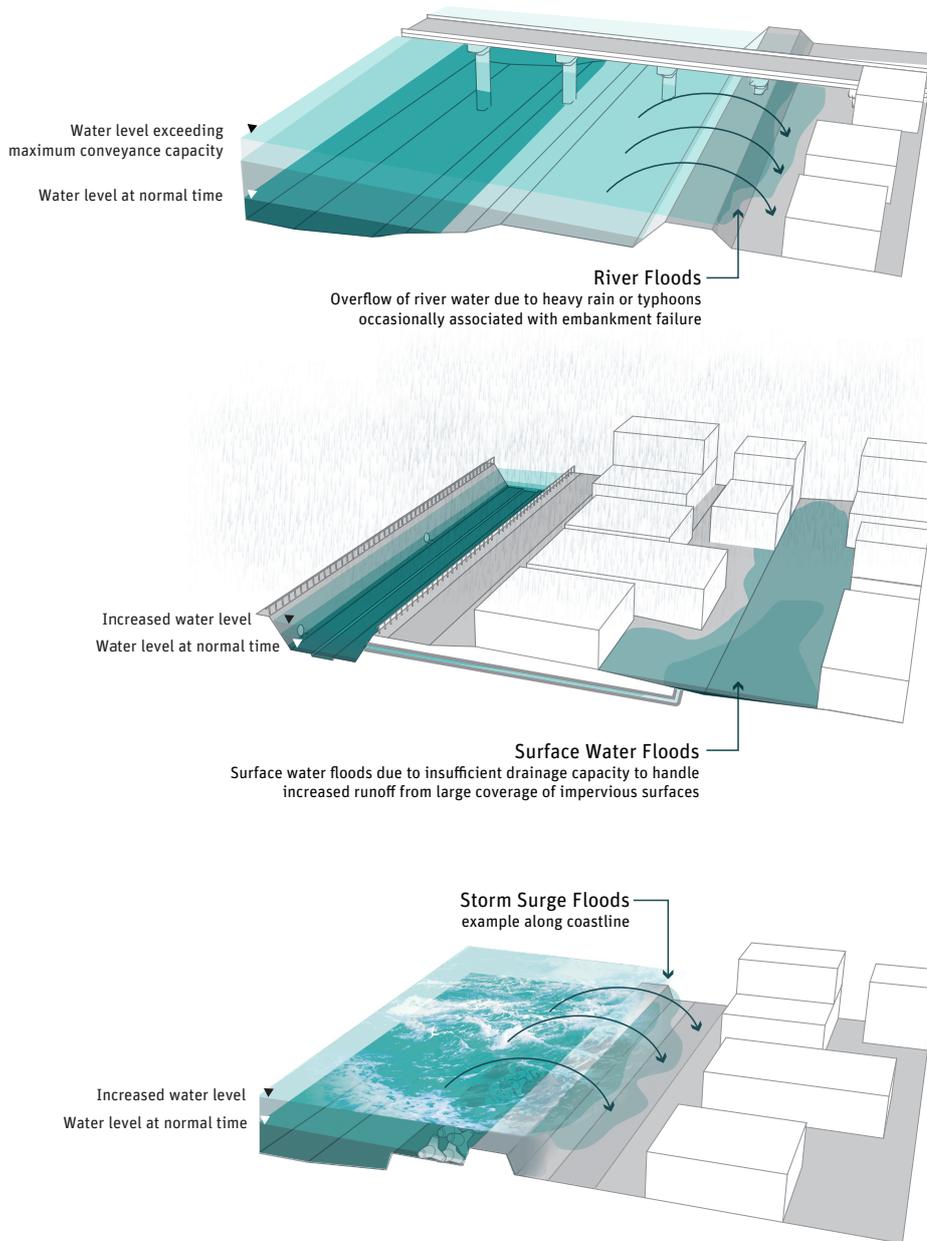
- **Learn by doing.** Japan has accumulated vast experience and know-how in different approaches and methods of urban flood risk assessment and related communication. Over the years, decision makers have increasingly focused on the objective of saving lives through risk assessment and risk communication. This is particularly critical when a flood's severity far exceeds the capacity of existing flood risk management infrastructure and facilities. In line with this, making flood risk information publicly available promotes individual-level investments. Reflecting lessons learnt, flood risk assessments need to be continuously reviewed and enhanced through research and new data, including the most recent information on inundation events, and changes in urban and infrastructure development processes, such as land use and sewerage systems.

## 2. Types of Urban Flood Risk

**Urban floods in Japan are divided by causal factors into three categories; river, surface water, and storm surge floods** (see **figure 1**). These may occur concurrently. All are generally caused by weather, such as heavy rain or typhoons. In the case of river floods, risk factors include: the location of the river and the distance between the river and the city, the river's water level compared to the ground level, and the status of flood risk mitigation measures for the river. Surface water floods generally occur when the drainage of stormwater is not managed properly during heavy rainfall in urban areas, and inundates roads and buildings. These floods typically occur in urban areas because the ground surface is covered with concrete and asphalt, which limits the capacity for infiltration and storage of storm/rainwater (see **Knowledge Note 2**). The factors that influence the risk of surface water floods in urban areas include: the capacity and development status of a city's stormwater drainage network, land use patterns, geographical characteristics, and the flow capacity of urban rivers and runnels. Factors particularly related to storm surges include the position and the distance between a city and the sea, the sea level and the ground level of the city, local topography, and the maintenance of seawalls.

**Flood risks and vulnerabilities depend on key urban characteristics.** These include the density of the population and assets, level of urbanization, age of the city and its infrastructure, urban development status and plans, and the capacity and development status of stormwater drainage systems, such as sewerage and river improvement systems. Geographical characteristics that affect flood risks include the position and distance of the city from rivers and/or coasts, the river water level and sea level, and the use of land. Some of the factors that influence the exposure, vulnerability, and flood risks of urban areas are listed in **table 1**.

**Figure 1: Diagram of Three Types of Urban Floods**



Source: Authors' compilation.

**Table 1:** Three Types of Urban Floods and Factors That Affect Their Risk

Factors Influencing Urban Flood Risk		River Flood	Surface Water Flood	Storm Surge Flood
<b>Urban Characteristics</b>				
Density (high density)		+	+	+
Maturity (age of cities, age of infrastructure, future development plans, etc.)		+	+	+
Sewerage and drainage system types / capacity (high flow capacity)			-	
Small rivers, canals (high flow capacity)			-	
Urban rivers (high flow capacity)		-	-	
Large, medium-sized rivers (high flow capacity)		-		
Tide embankment (high resilience)				-
<b>Geographic Characteristics</b>				
River	Proximity to rivers	+		
	Relative elevation (higher)	-		
Coast	Proximity to coasts			+
	Relative elevation (higher)			-
Topography	Flat and low elevation	+	+	+
	Gradient (not gentle)	-	-	-
	Depression	+	+	+
Land use, including soil and vegetation condition (infiltration capacity)		-	-	-

Source: Authors' compilation.

Note: Relationship of urban, geographic, and flood typologies: (+) direct relation; (-) inverse relation.

## 2.1 Urban Flood Risk in Japan

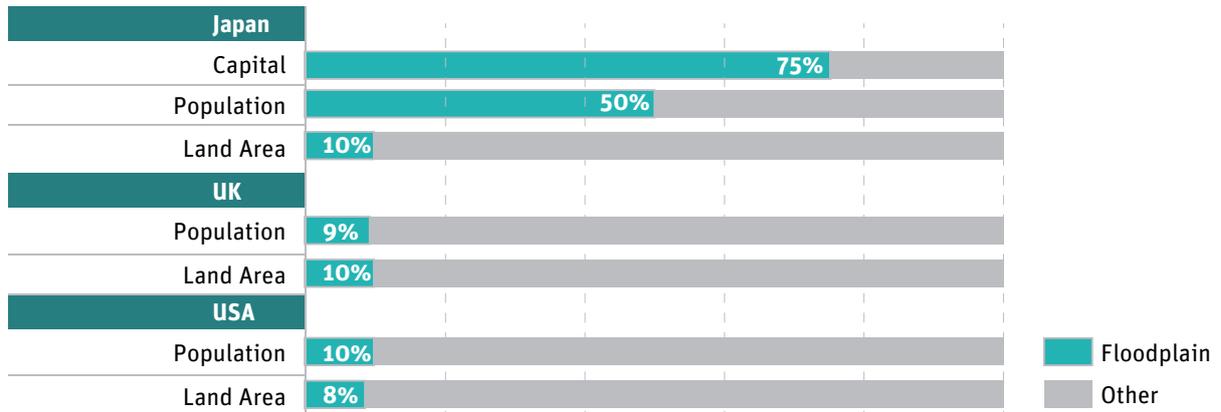
**Japan's cities are at high risk of flooding due to Japan's climate, exposure to hazards, geography, history, urban and economic development context, and other conditions.**<sup>1</sup> Japan is located at the eastern end of that part of Asia characterized by a monsoon season, and its annual average rainfall is approximately double the global average of 880 millimeters (mm). Average monthly rainfall fluctuates significantly between the rainy season and typhoon season. For example, in Tokyo, the average monthly rainfall in the wettest month of the year—September—is about five times that of December (Ministry of Internal Affairs and Communications 2017). As the frequency of localized heavy rain in Japan has increased in recent years, seemingly because of climate change, so has the occurrence of urban floods (MLIT 2015b).

**Many major cities, including Tokyo, Osaka, and Nagoya, are located in flood-prone lowland areas.** Because of Japan's small land mass, its population is one of the most densely concentrated in the world. The largest metropolitan areas include those of Tokyo and Yokohama (with a combined population of 39 million), Osaka (17 million), and Nagoya (10 million) (City Population 2018), all of which include low-lying areas vulnerable to river floods. In fact, Japan's population, assets, and houses are concentrated in cities with rivers flowing through them (**figure 2**) (MLIT 2002, 2007b). While so-called flood plains account for 10 percent of land in Japan, they are home to 50 percent of the total population and 75 percent of assets (Japan Institute of Country-ology and Engineering 2015).

**Urban areas are also vulnerable to localized heavy rains as asphalt-paved roads and dense concrete buildings decrease the amount of storm water that infiltrates the ground,** causing it to flow into the sewerage system. Approximately 80 percent of the 23 wards of Tokyo<sup>2</sup> have confluent sewerage systems (Bureau of Sewerage, Tokyo Metropolitan Government 2017). When a flood occurs, nearby rivers swell, increasing the risk of both surface water and river floods. As **figure 3** shows, coastal regions and cities, such as Osaka Bay, Setouchi Inland Sea, Shikoku, eastern Tokyo, and Nagoya have relatively low elevation and thus are at high risk for storm surge floods. Cities in Japan are thus vulnerable to various forms of flood risk, especially Tokyo, Nagoya, and Osaka, which have the three largest bay areas in Japan and are flat and at or near sea level.

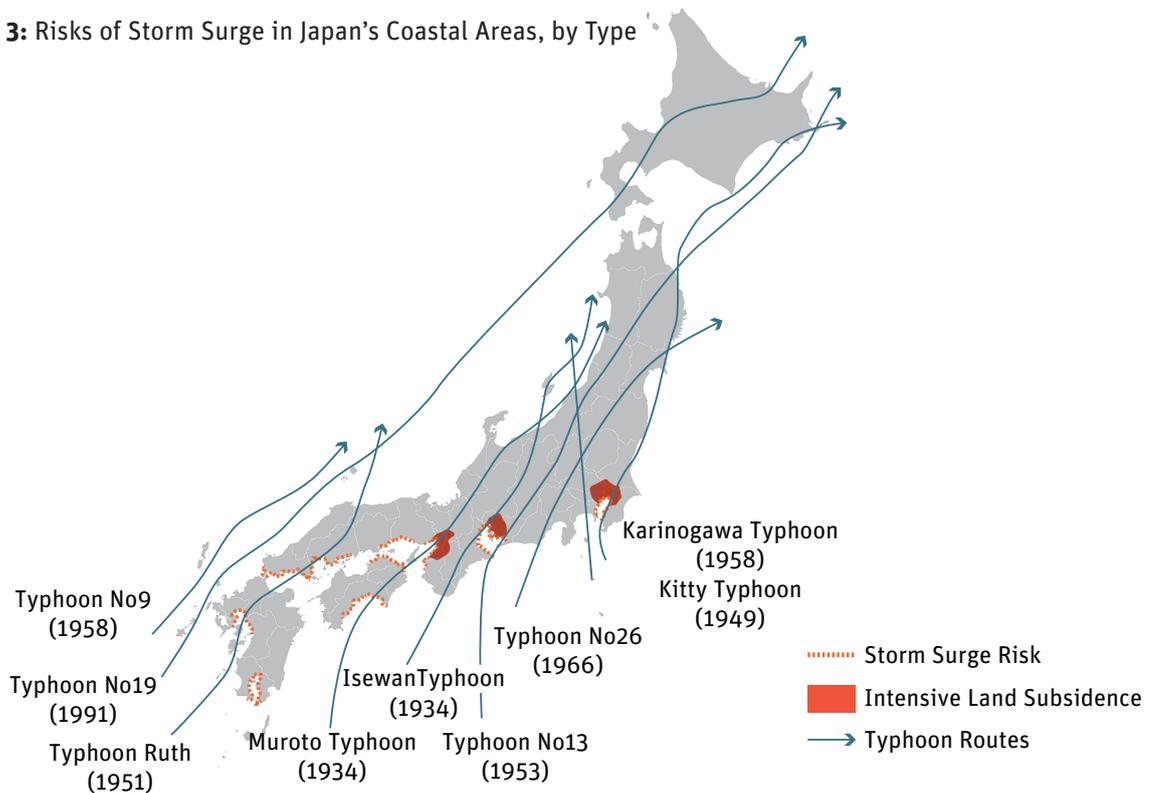
<sup>1</sup> This series of notes understands disaster risk as the potential loss of life, injury, or destroyed or damaged assets that could occur in a system, society, or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability, and capacity, in line with the definition of the United Nations Office for Disaster Risk Reduction (UNISDR).

**Figure 2: Percentage of Capital, Population, and Land Area Located in Floodplains: Japan, the United Kingdom, and the United States**



Source: Modified based on information from MLIT (2007a).

**Figure 3: Risks of Storm Surge in Japan’s Coastal Areas, by Type**



Source: Modified based on information from MLIT (2006).

2 Tokyo is a regional government encompassing 23 special wards, 26 cities, 5 towns, and 8 villages. However, reflecting the dense population, urban contiguity, and other realities of the 23 special ward area, a unique administrative system exists between the metropolitan government and the wards, which differs from the typical relationship between prefectures and municipalities. This system balances the need to maintain unified administration and control across the whole of the ward area and the need to have the local ward governments, which are nearer to the residents, handle everyday affairs. Specifically, in the 23 wards, the metropolitan government takes on some of the administrative responsibilities of a “city,” such as water supply and sewerage services, and firefighting, to ensure the provision of uniform, efficient services, while the wards have the autonomy to independently handle affairs close to the lives of the residents such as welfare, education, and housing (Tokyo Metropolitan Government n.d.).

## 2.2 Risk Assessment and Communication Objectives/Stakeholders

In general, risk assessments in Japan are conducted to support: (i) the planning and reviewing of structural flood risk mitigation and management measures, such as building embankments and other facilities; and (ii) the reviewing and adjusting of nonstructural flood risk mitigation and management measures, such as land use plans and evacuation plans. Specific objectives are listed in table 2.

**Table 2:** Objectives of Risk Assessment and Risk Communication

Risk Assessment & Risk Communication Objectives	Developed by	Used / Received by
Plan and design flood protection measures (differentiated risks / risk per flood type)	National (infrastructure / construction) government; academia; local government	National (infrastructure / construction) government; local government
Review and adjust land use plans, zoning, and building codes (combined and differentiated risks)	National (infrastructure / construction) government; academia; local government	National (infrastructure / construction) government; local government
Understand and communicate who, when, where, and how to evacuate (combined risk of inundation)	Local government; academia; civil society organizations	Local government; citizens; elderly
Develop and implement ex ante financial protection measures (combined risks)	Academia; insurance companies	Insurance companies; citizens
Integrate climate change risks into flood modeling and forecasting (combined risk and future risks)	Academia; national and local government	National and local government

Source: Authors' compilation.

**There are multiple stakeholders involved in various flood risk assessments in Japan.** Risk assessments are generally conducted by organizations and/or group(s) of experts and academics, who own, manage, and are responsible for developing and managing the structural facilities for flood management or areas susceptible to flood disasters. They are led by policy makers, practitioners, and city officials responsible for developing and implementing flood risk mitigation, management, and evacuation plans. The results of risk assessments are provided to organizations, institutions, and other governmental bodies that need the information.

**Methodologies used in risk assessments differ based on flood types and objectives.** In general, flood risk assessments are conducted according to flood type because interactions between the natural and built environments create different risks for each type of flood. In some cases, the risk assessment assumes that multiple flood incidents will happen simultaneously. **Table 3** summarizes responsible authorities, risk assessment methodologies typically employed, and assessment goals.

**Table 3: Common Risk Assessment Methods, Stakeholders, and Aims**

Urban Floods		Flood Management	Risk Assessment		Risk Communication
		Responsible Authority	Responsible Authority	Assessment Method	Objective
River (fluvial) floods (overflow of rivers under government jurisdiction)	Class A rivers	River, construction, and infrastructure sections under the jurisdiction of the MLIT; governors of prefectural governments	River administrators (national government)	Hydrological analysis, flood analysis / forecast	Infrastructure development and design; Evacuation warning (to local governments and community)
	Class B rivers	Governors of prefectural governments	River administrators (prefectural governments)		
Surface water (pluvial) floods (stormwater and/or sewerage system overflow)		Municipal and prefectural governments	Municipal and prefectural governments	Inland (surface water) flood analysis / forecast	Infrastructure development and design; Evacuation warning (to local governments and community – short lead time)
Storm surge floods		Prefectural governments	MLIT and prefectural governments	Storm surge simulation / forecast	Infrastructure development and design; Evacuation warning (to local governments and community)

Source: Authors' compilation.

Note: Class A river systems are those designated by the MLIT minister as important for national land conservation or economic activities. Most Class A rivers have basin areas of 1,000 km<sup>2</sup> or more and are used for water supply and power generation. Class B rivers are related to important public benefits and designated by prefectural governors.

### 3. Conducting Urban Flood Risk Assessments and Communicating Their Results

#### 3.1 Japan's Experience with Urban Flood Risk Assessments

##### Methodology

**Regardless of location, flood risks are assessed using simulations and analytical models.** These may include the U.S. Hydrologic Engineering Center's River Analysis System (HEC-RAS) or MIKE11 from the Danish DHI (Institute for Water and Environment) (Jha, Bloch, and Lamond 2012; Rudari 2017). Essentially, analyses based on scientific evidence use hydrometeorological, hydrographical, land use, and geographical data. The methodology for conducting disaster risk assessments will be explained in more detail below, but the fundamental ideas are common: risks are assessed based on the external force of the disaster; which entities will suffer from losses and damages (as described by the urban characteristics defined in **table 1**, including population, assets, and social infrastructure); and how vulnerable or resilient these entities are.

**In Japan, river administrators, sewerage system administrators, and mayors of municipalities at risk of inundation are responsible for risk assessments.** These assessments in turn inform the design of urban flood management infrastructure, evacuation plans, and land use plans as per relevant laws.

**Japan's river administrators determine basic policies and plans for river management, which include considering and designing infrastructure for flood measures in accordance with the River Law.**

Based on the results of risk assessment simulations, river administrators determine the goals for flood measures as per the guidelines set by the national government, including the “Technical Criteria for River Works Practical Guide for Planning” (MLIT 2014). Japanese mayors of municipalities that are likely to experience river floods are required under the 2005 revision of the Flood Prevention Act to create flood hazard maps and related resources and distribute them to local residents (Ministry of Internal Affairs and Communications 2017). MLIT has published guidelines and manuals, such as the “Guidelines and Manuals for Developing River Flood Hazard Maps” (2005) and “Guidelines and Manuals for Flood Disasters Hazard Maps” (2016) to help municipal governments create their own hazard maps. Additionally, the national government supports local governments with flood risk management by providing financial subsidies, risk information, and technical support.

**The time and budget constraints involved in implementing structural measures, the limits of structural measures in saving lives, and the need to advance nonstructural measures are now acutely recognized (MLIT 2009).** In line with this, the development of surface water flood hazard maps became a requirement when the Flood Prevention Act was revised in 2015. The published guidelines and manuals indicate the need for the hazard maps to indicate risks from the most severe flood incident in the mapped region’s history. To determine the potential inundation areas to be noted on hazard maps, simulations should be conducted if appropriate data are available; if not, historical information on inundation and geographical characteristics can be used (MLIT 2009). To assist each local government in developing hazard maps, MLIT hosts conferences and capacity-building sessions for experts and has published guidelines and manuals that local governments and cities must follow. These are regularly updated based on lessons learned from each disaster. Because a thorough PDCA cycle<sup>3</sup> is followed in Japan, the Flood Prevention Act was revised 19 times between 1949 and 2015, and the River Law was revised 37 times between 1964 and 2017.

**Assessments inform land use plans based on the probability of occurrence (per year) and predicted level of damage (inundation depth and its extent).** City governments determine land use plans, zoning, and levels and types of design requirements and standards (such as installation of rain/stormwater harvesting, infiltration and storage facilities) required for new and renovated building construction, based on forecasts of direct and indirect damage risk. For example, Shiga Prefecture utilizes flood risk assessments to demarcate “restricted urban development areas” so as to avoid critical damage to assets and the burden of recovery.

**By understanding potential flood risks in each region and watershed, development plans can ensure that hard infrastructure investments are complemented by softer flood mitigation, preparedness, and evacuation measures—** such as establishing and implementing effective evacuation systems, flood emergency response plans and business continuity plans, flood-sensitive siting of housing development, education and drills on disaster risk management, and so on. In addition, making flood risk information publicly available promotes individual-level actions such as investments in roof drains and the careful use of basements in flood-prone areas. Flood risk assessments need to be continuously reviewed and enhanced through research and the collection of data on flood incidents (MLIT 2012).

## Assessing River Flood Risk

**Generally, river and surface water flood risks are defined based on their probability and the scale of possible damage.** Estimates of damage consider the external force of the disaster (hazard); damage to populations, assets, and socioeconomic activities (exposure); and the vulnerability of entities to the hazard. River flood risk assessments inform the development of river maintenance plans, evaluation of flood control projects, facility maintenance and operations, and development of evacuation directions and plans (MLIT 2012). The general process is illustrated in **figure 4**.

**The first step in this process is to collect and organize data on rainfall, watersheds, rivers, flood areas, and so on.** A hydrological analysis, hydraulic analysis of river flood flow, and inundation analysis consider variables such as the flow volume, water level, inundation area, transition of inundation depth over time, inundation duration, and so on. Statistics on population numbers, assets, and critical facilities are also gathered. These analyses help estimate and evaluate the event probability of floods, financial damage to general assets, potential casualties, economic damage,

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<sup>3</sup> The PDCA (Plan-Do-Check-Act) cycle is an improvement cycle based on the scientific method of proposing a change in a process, implementing the change, measuring the results, and taking appropriate action. The concept is closely linked to and developed together with the “Kaizen (good change)” concept (<https://www.kaizen.com.sg/pdca-cycle/>).

damage to crucial facilities, and so on, based on the “Manuals for Flood Control Survey” (MLIT 2005b) and the “Guidelines for Indicator Analysis on Flood Damages” (MLIT 2012, 2013b).

**In Japan, the standard methods of flood flow and inundation analysis use a hydraulic model of one-dimensional, quasi two-dimensional, and two-dimensional flow processes.** The two-dimensional model calculates variations. This model is effective for complex geography including spread-out flood plains, alluvial fans, and river mouths, but needs highly precise data and takes a long time to calculate (Jha, Bloch, and Lamond 2012).

### Assessing Surface Water Flood Risk

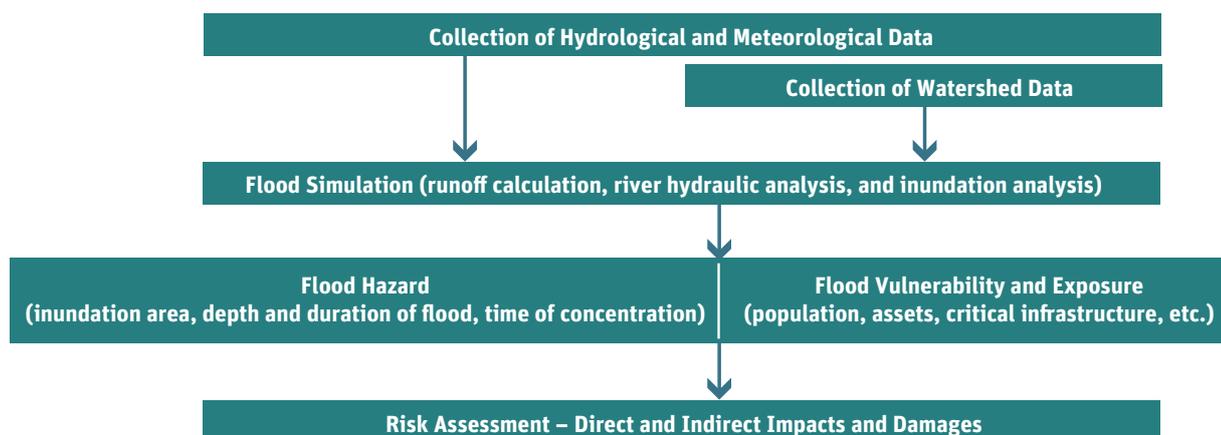
**There are several similarities and differences between risk assessments for river floods and surface water floods.** In general, surface water flood modelling is more complex than river modelling due to high data requirements and sensitivity to changes in the urban environment. River and surface water floods occur under different climate conditions, with varying time lags between the start of rainfall and inundation, and different frequencies of inundation. Therefore, separate risk assessments for river floods and surface water floods are needed. Despite various differences, the overall methodology is the same (described in **figure 4**). The risk assessment begins with collecting and organizing data on watershed surface water, followed by a hydrological analysis and a surface water flood analysis. The surface water flood analysis examines the level and event probability of hazards, including inundation areas in sewage watersheds, the transition of inundation depth over time, and the duration of inundation. Subsequently, population numbers, assets, and critical facilities are identified. The results of these analyses help estimate and evaluate the event probability of floods, the amount of financial damage to general assets, potential casualties, economic damages, and damages to crucial facilities.

**Whenever possible, it is recommended that surface water flood risk assessments be based on inundation simulations.** However, depending on local geographic contexts, needs, and limitations, assessments based on historical floods and analysis of geographic conditions (elevation data and so on) are also permitted. These general guidelines are included in the 2009 MLIT draft publication entitled “Guidelines for Creating Surface Water Flood Hazard Maps” (MLIT 2009). An alternate approach is mentioned because citywide simulations may not be required where national assessment results can be used directly, sufficient records of the flood management capacity of sewerage facilities may not be available, and municipal governments may not be able to afford preparing their own assessments. Regardless of the method, city officials must understand their local flood risks, develop hazard maps, and communicate flood risk information to citizens as quickly as possible. Additionally, flood risk assessments need to be updated regularly with the most recent information on inundation events, depth, and changes in urban and infrastructure development processes, such as land use and sewerage systems. These, along with rainfall data, may be used to predict future inundation areas.

### Assessing Storm Surge Flood Risk

**Risk assessments for storm surge floods are conducted by running simulations based on local natural hazard risks and conditions (e.g., high tides with strong winds).** Results are utilized in designing structural and nonstructural measures, including seawalls and raised-ground areas, as well as in preparing storm surge hazard maps, particularly for logistics facilities, marine-based businesses, and industrial zones that tend to be concentrated in coastal areas. However, risk assessments for storm surge floods are not as advanced in Japanese cities as they are for river and surface water floods. In Japan, only 18 percent of the 639 localities designated as being at risk for storm surge flooding had published storm surge hazard maps as of 2013 (Cabinet Office 2014). There have been several efforts to bring together diverse stakeholders to better understand and identify storm surge flood risks. For example, the national government, port and bay area authorities, disaster prevention departments of local governments, and members of the private sector (such as factories and businesses located in coastal areas) are cooperating to enhance storm surge risk mitigation measures and secure the safety of the people who work and visit Japan’s coastal areas (MLIT 2018c).

**Figure 4:** The Process of Assessing River, Surface Water, and Storm Surge Flood Risk



Source: Authors' compilation.

### Informing the Design of Structural Flood Management Measures

#### River Floods

**In Japan, river administrators set the goals for river development plans and design levels for flood management investments in accordance with the level of disaster management designated in the River Law.** All rivers in Japan are classified by their socioeconomic significance, possible extent and nature of flood damage, past flood history, and other factors (MLIT 2018f). In line with this process, the design level of flood management investments is set according to the significance of the river. As shown in **table 4**, rivers in Japan are classified into five categories from Grade A to Grade E (where Grade A is the most significant), and each river classification has a designated flood level which the river administrator has to consider when designing flood management measures.

**The design level is calculated through statistical analyses of past hydrological data and historical rainfall** (MLIT 2018e). For example, major rivers of substantial economic significance (such as the lower courses of the Tone, Yodo, and Kiso rivers) are categorized as Grade A. Grade A and Grade B rivers are required to have river improvement plans and associated measures to prevent flooding in case of rainfall levels that occur extremely rarely. The main sections of Grade A rivers are generally ranked as either Grade A or Grade B, while Grade C and lower is often applied to their subsidiary streams (MLIT 2018f).

**Table 4:** Classification of Rivers and Design Level of Flood Management Measures

Classification of Rivers	Design Level (probability of occurrence of predicted rainfall)
Grade A	>200 (1-in-200-year rainfall)
Grade B	100–200 (1-in-100- to 1-in-200-year rainfall)
Grade C	50–100 (1-in-50- to 1-in-100-year rainfall)
Grade D	10–50 (1-in-10- to 1-in-50-year rainfall)
Grade E	<10 (1-in-10-year rainfall)

Source: MLIT 2008.

**Flood simulations are conducted by river administrators to identify areas at risk of inundation.** In the simulations, flood plains are represented in two dimensions; computational mesh and river hydraulics are presented in one dimension, and cross-sections are made. The simulation predicts the area and depth of inundation, and the speed and direction of flood water flow driven by river overflow, rainfall, and stormwater runoff.

## Surface Water Flood

**Japan's national standard for flood risk management is to design and implement measures that can effectively manage a level of heavy rains likely to occur once in five years, and avoid or mitigate the inundation of assets at this level.** This target level is informed by reports from agencies such as MLIT's city planning commission. The standard is applied for both structural and nonstructural flood risk management measures. For example, critical infrastructure, such as roads, powerlines, and public schools, have been developed accordingly (MLIT 2016b). So has the Comprehensive Sewerage Inundation Management Plan. (The process is further elaborated in **Knowledge Note 2.**)

**As Tokyo's highly concentrated population and assets continue to grow, the city has developed one of the most ambitious urban flood risk management targets in the world.** Taking a long-term view (generally 30 years), the city's flood risk management targets include: preventing flood damage from rainfall up to 60 mm/hour; and preventing flooding above ground floor level (> 50 cm) during rainfall of up to 75 mm/hour (Tokyo Metropolitan Government 2014). Kyoto, with its high concentration of historical assets, has set a goal to eliminate damage-prone flood risks in a swift manner and to avoid damage from heavy rainfall intensity of 62 mm/hour or higher (probability of 1 in 10 years). In line with this, Kyoto will set higher goals in the future as necessary (Kyoto City 2000). Sendai, with a growing population of over 1 million as of 2019, has set a goal to develop stormwater drainage facilities to avoid damages during rainfall with an intensity of 52 mm/hour (probability of 1 in 10 years) (Sendai City 2019). As of 2015, the project covered only 33.5 percent of the total area to be developed with stormwater drainage facilities (Sendai City 2019).

**If appropriate rainfall data are not available, similar data for large-scale rainfall in other cities may be utilized to prepare flood plans.** However, given that the risks of surface floods depend on not only rainfall but also unique urban and geological conditions, the challenges of the application of standard design levels have been highlighted by recent urban flood experiences in Japan. With the frequency and intensity of concentrated heavy rain increasing, the approaches to setting the design level for surface flood management measures are being continuously reviewed and improved in Japan (MLIT 2016b).

## Storm Surge Floods

**Storm surge measures in Japan, such as coastal seawalls and embankments, are designed to withstand the highest-recorded tidal surge in history.** The height and design level of coastal protection infrastructure, such as seawalls, is also determined by average and record high tide levels. Predictions consider the increases in these levels due to climate change (Coastal Development Institute of Technology 2018). Each area sets its own levels based on observed data. See **box 1** for the case of a storm surge flood protection park in Kagawa Prefecture.

## Box 1: A Storm Surge Flood Protection Park in Kagawa Prefecture: Assessing Risk to Enhance Storm Barriers

### Takamatsu Port Shoreline, Kagawa Prefecture

Figure B1.1: Takamatsu Port Shoreline before and after the Enhancement of the Seawall



Source: Ichitanda 2008.

**Objective of the risk assessment:** To better protect coastal areas against storm surge floods and better predict the level of storm surges.

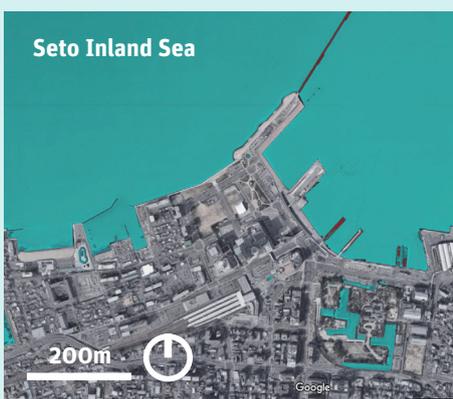
**Type of flood:** Storm surge.

**Urban characteristics:** Medium-sized city with a population over 331,000 (Ministry of Internal Affairs and Communications 2019).

**Responsible organization:** Ministry of Land, Infrastructure, Transport and Tourism (MLIT); Kagawa Prefecture.

**Success factors / takeaways:** Based on a reassessment of future storm surge levels, the wave breakers along the shoreline needed to be raised. A high-accuracy simulation was conducted based on an updated calibration model of wave heights. This information was also shared with citizens, whose responses informed a design that protected the scenic nature of the coastline by keeping the additional height added to wave breakers to a minimum.

Source: Coastal Development Institute of Technology 2018; Ichitanda 2008.



Source: Google Earth. Note: m = meter.

In 2004, Typhoon Cimaron (No. 16) made landfall in Kagawa Prefecture and wreaked unprecedented damage to the coastal areas of its capital, Takamatsu City. The level of the storm surge was far beyond the highest recorded, which led the prefectural government to reassess the level used for planning.

Based on the reassessment, the height of the existing wave breakers was to be increased by 70 centimeters (cm). However, local citizens were concerned that this would deter access to and recreational use of the shore and would disturb the scenic views. A wave-breaking shape design allowed this increase to be adjusted to 50 cm (**figure B1.1**).

This case demonstrates the importance of evaluating various solutions and approaches beyond the conventional measures for coastal flood protection. In the case of Kagawa, the objective of the risk assessment was not just to improve the design level of the existing storm surge infrastructure, but also to propose other potential structural and nonstructural options to manage the increased risks. This was made possible when technological innovation (in simulation models and creative infrastructure design) was integrated with community input.

## Cost-Benefit Analysis

**A cost-benefit analysis (CBA) is important to the process of assessing and designing flood risk management infrastructure.** The combination of a risk assessment and CBA allows planners to investigate different investment options, and how to prioritize and select investments. Flood risk information is typically used to calculate the benefits of (or damage to be avoided by) implementing the proposed structural measures. These benefits may include the avoidance of the loss of life, direct and indirect loss of assets, decrease of land value due to inundation and flood damage, and psychological trauma that may be caused by floods. The cost is often the construction cost of the flood management infrastructure. The time frame of the investment cost and its benefits are normally taken from project investment plans. In Japan, CBA methods for flood management facilities are defined by a national guideline (MLIT 2005a).

**The current CBA method includes only those benefits that are quantifiable in monetary terms, which may leave out some of the comprehensive benefits of flood management investment.** Future efforts are needed to consider and integrate qualitative information in the assessment of flood management investment benefits. Some related initiatives are ongoing in Japan, such as a “Draft Toolkit for Evaluating Flood Damage Indicators,” developed by MLIT in 2013. The toolkit includes methodologies for estimating qualitative flood damage parameters. Examples include: affected populations, damages to medical facilities and disaster response hub facilities, and transport and lifeline infrastructure disruptions, among others.

## Informing the Design of Nonstructural Flood Management Measures

**Flood risk assessments inform not only the design of hard infrastructure solutions but also the design and implementation of nonstructural measures to enhance people’s preparedness and response to floods.** In particular, these assessments are essential for developing flood risk scenarios that inform the design of lifesaving evacuation measures such as hazard maps, simulation training, and evacuation drills. These evacuation measures, informed by risk assessments, form a critical element of city-level disaster risk management plans.

## Improving Hospitals’ Preparedness

**The Ozu Memorial Hospital in Ozu City (see box 2) is a representative case of how flood risk information, together with continuous reflection, improvement, and training after each flood experience, can significantly improve the flood preparedness of critical facilities such as hospitals.** It is important to understand the inundation risks in advance and utilize this information to develop a business continuity plan that outlines the clear chain of command at times of emergency, enabling the swift evacuation of patients, as well as the moving of critical medical equipment and assets to avoid flood damage.

### **Box 2: Enhancing the Flood Preparedness of Ozu Memorial Hospital: Assessing Risk to Help Develop a Hazard Map and Business Continuity Plan** Ozu Memorial Hospital, Ozu City, Ehime Prefecture

**Objective of the risk assessment:** To improve the business continuity of a health-care facility for the elderly.

**Type of flood:** River.

**Urban characteristics:** Ozu is a medium-sized city located in the countryside. Its population has been decreasing since 1955 while the number of elderly people has been increasing (Ozu City 2018). As of 2015, 33.8 percent of the population were 65 years and above, or higher than the national average of 26.6 percent (Ozu City 2018).

**Responsible organization:** Ozu Memorial Hospital, with long-term health-care facilities for elderly people.

**Success factors / takeaways:** The medical facility enhanced its flood risk preparedness by utilizing hazard maps and the lessons learned from past floods to develop a business continuity plan. Through this process, flood risk assessment results were reviewed to inform evacuation methods as well as preliminary investments to mitigate potential damages. As a result, flood resilience was significantly improved.

**Figure B2.1:** Inundation by the Hiji River in 1995 **Figure B2.2:** Installation of Flash Flood Barriers by Hospital Staff

Source: Association of Medical Corporation, Jyofuukai, Ozu Memorial Hospital.



Source: Google Earth. Note: m = meter.

Ozu Memorial Hospital is a health-care facility for the elderly in Ozu City, Ehime Prefecture. In 1995, the hospital was inundated by flood waters from the Hiji River due to heavy rain. These cut off the building's water supply and electricity, and caused significant damage to medical devices. The hospital was again affected by Typhoon 16 in 2004, which caused inundation above the ground-floor level.

According to an Ozu City flood risk assessment conducted in 2013 and 2003, hazard maps show that Ozu Memorial Hospital is located in a flood hazard zone. The 2013 assessment indicates that if a bank of the Hiji River collapses, the hospital will be inundated by 3 or more meters of water. These results were consistent with the Hiji River Inundation Prediction Area Map published in 2003, which forecasted the area's inundation level to be between 2 and 5 meters (Ozu City

2003). Following the first flood, the hospital privately installed a power generator and water supply pumps to prevent the suspension of power or water on the second floor. This kept the damage during the 2004 typhoon to a minimum. Based on lessons learned from the 2004 typhoon, exterior water-sealing plates and waterproof doors were installed to protect rooms containing expensive medical devices such as CT scanners, MRI machines, and X-ray machines. In addition, a new hospital building that opened in 2016 was designed with car parks on the first floor and outpatient units on the second floor to minimize the effects of floods and help sustain regional health-care services (Chugoku Shimbun n.d.).

With these disaster preparedness measures, the hospital was able to minimize damages during a flood that occurred in July 2018 and resumed normal operations within three days (Ozu Memorial Hospital 2018).

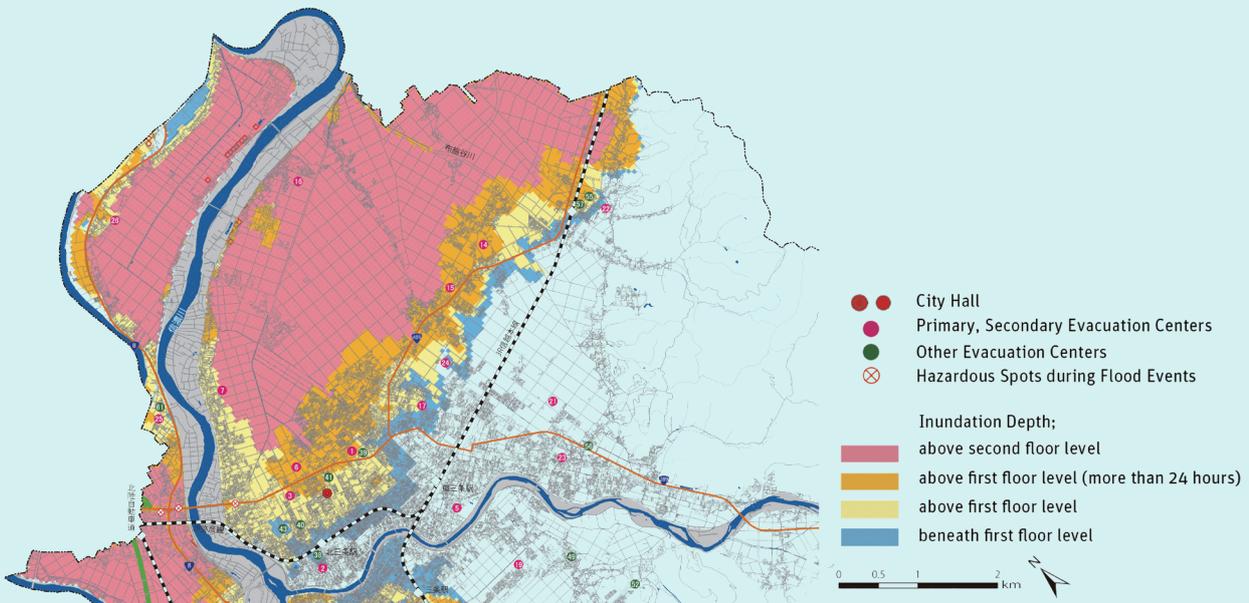
## Informing Plans for Evacuation

**Sanjo City, Niigata Prefecture, experienced extensive flooding in 2004, which compelled the city to enhance its nonstructural measures against urban floods to complement its structural measures.** As part of this effort, the city prepared a guidebook for citizens that gave them information needed to make key evacuation decisions. The city delivered a guidebook to every household in 2011 to promote flood preparedness at the household and individual levels (Sanjo City n.d.).

### Box 3: Flood Evacuation Plans in Sanjo City: Assessing Risk to Improve Citizens’ Decision-Making Processes

#### Sanjo City’s Flood Risk Evacuation Map

Figure B3.1: Sanjo City’s Flood Risk Evacuation Map



Source: Modified based on information from Sanjo City 2011.

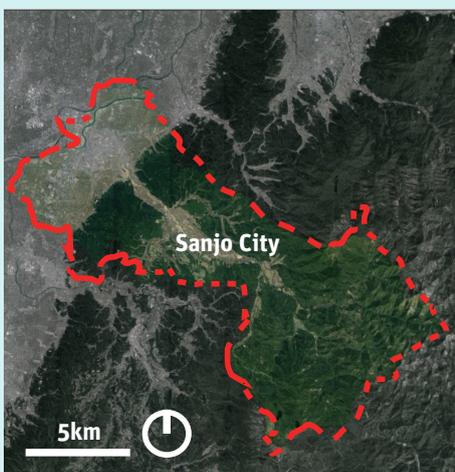
**Objective of the risk assessment:** To develop a decision-making guidebook for citizens that helps empower them to make quick and informed decisions on where (vulnerable locations), when (timing), and how (actions to be taken) to evacuate.

**Type of flood:** River.

**Urban characteristics:** Located near Niigata City, Sanjo City is an old, historic city located on the northwestern coast of Japan. Its population was estimated at around 98,000 in 2019, and has been declining significantly since 1985 (Sanjo City 2019, Ministry of Internal Affairs and Communications 2019).

**Responsible organization:** Sanjo City, Niigata Prefecture.

**Success factors / takeaways:** Based on lessons learned from a 2004 flood, the city government created an action-oriented flood evacuation guidebook, including various hazard maps for local residents to determine and prioritize flood evacuation actions based on their own unique contexts.



Source: Google Earth. Note: km = kilometer.

The *Guidebook for Heavy Rain Disaster Measures* consists of four hazard maps for flood risk awareness, estimated inundation levels, landslide hazard zones, and timetables for evacuation. Sanjo City developed maps independently based on the city’s existing flood risk assessment results. Sapporo City (Hokkaido) and Okazaki City (Aichi Prefecture) have also developed similar maps.

These maps are developed based on the same flood risk assessment results, in line with the standard national process for hazard map development. However, Sanjo City took one step forward to make this risk information accessible and usable for citizens by clarifying how various indicators relate to contextual specifics of timing, building structure, and location. Also featuring a decision tree, the guidebook is an action-oriented tool to help residents evacuate in a safe and timely manner.

The map in **figure B3.1** was created based on the lessons learned from a severe flood in eastern Japan in 2009, in which five people died from falling into irrigation channels during their attempts to escape the flood. As such, Sanjo City realized that citizens need to understand the importance of the timing of their evacuation. The map features a timetable and encourages citizens to evacuate prior to the occurrence of flooding. If the area where they are is already flooded, Sanjo City warns citizens to stay indoors and move to upper floors instead of taking escape routes as this could expose them to even greater danger. The map provides evacuation actions for residents depending on their location and residential structure.

Another map outlines the characteristics of potential inundation areas along the Shinano, Igarashi, and Kariyata rivers (Sanjo City n.d.). The map also indicates the flood risks faced by citizens' unique residential and workplace contexts, and helps them understand and adopt necessary evacuation measures depending on these characteristics. Using flood risk information to inform a combination of various tools allows for more customized evacuation instructions than do conventional hazard maps that simply show estimated damages and evacuation areas. By taking several steps beyond the status quo, Sanjo City demonstrates how risk information can be utilized to help citizens make their own decisions and be effectively prepared for evacuation during floods.

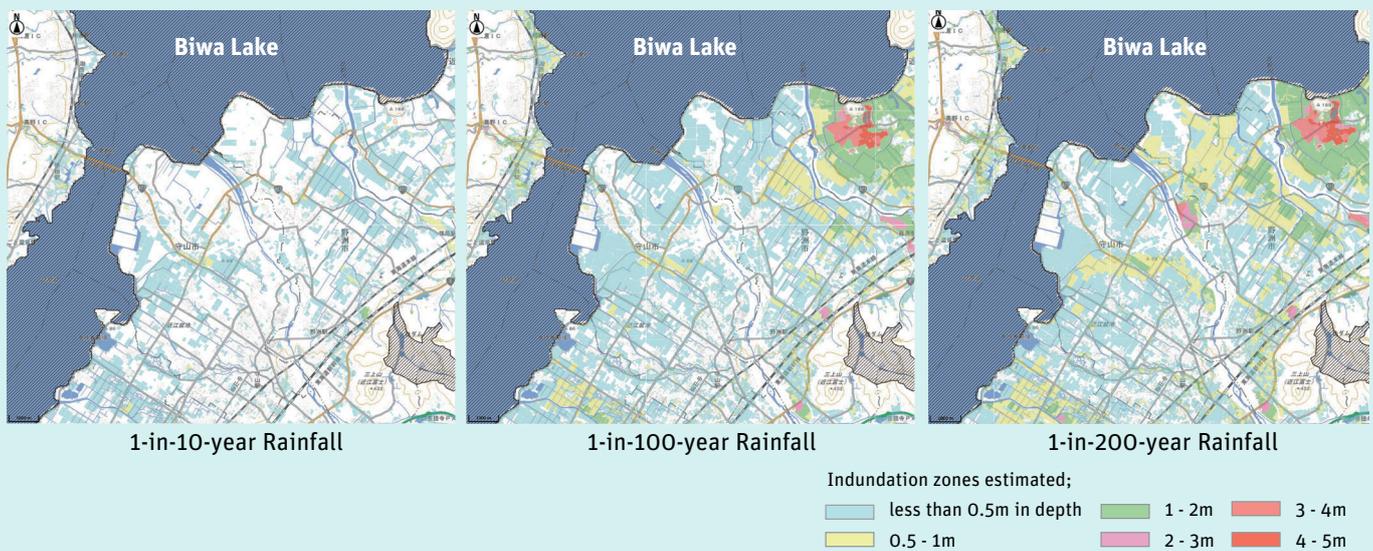
### Raising Awareness of Flood Risk and Safety Measures

**With unprecedented extreme weather events becoming a norm around the world, many cities are recognizing the critical importance of supporting citizens' capacities to protect their own lives and livelihoods in the face of flooding.** Shiga Prefecture embarked on an effort to enhance citizens' awareness of flood risk and related safety information. Similar to flood risk hazard maps, Neighborhood Flood Safety Maps note possible areas of inundation from the overflow of small, medium, and large rivers. Each neighborhood's "safety level" is categorized by its susceptibility to surface water floods and river floods, and by how regularly these are forecasted to occur (for example, once in 10, 100, or 200 years).

## Box 4: Neighborhood Safety Maps in Shiga Prefecture: Using Risk Assessments to Raise Awareness

### Shiga Prefecture

**Figure B4.1:** Flood Depth Map by Likely Frequency of Rainfall Level



Source: Modified based on information from Shiga Prefecture (n.d.a).

**Objective of the risk assessment:** To promote citizens' understanding of the risks of streams and rivers overflowing into neighborhoods, and to enhance voluntary evacuation.

**Type of flood:** River, surface water.

**Urban setting:** Shiga Prefecture has a total population of approximately 1.4 million (Government of Japan 2017). Given its proximity to major cities such as Kyoto and Osaka, it is historically significant both culturally and economically. However, its population is declining and has been aging rapidly in recent years.

**Responsible organization:** Shiga Prefecture.

**Success factors / takeaways:**

- Given its rich water resources, combined with increasing heavy rains, Shiga Prefecture is exposed to high flood risks. Since infrastructure projects for flood risk mitigation and management require a long time to be completed, the prefecture has embarked on noninfrastructural measures to improve flood risk preparedness and response actions that could minimize flood impacts.
- As part of this effort, the Basic Policy for Watershed Flood Management was prepared by the prefectural government in 2012.
- Shiga Prefecture created Neighborhood Flood Safety Maps that indicate potential inundation areas from both river and surface water floods.
- By assessing various flood risks comprehensively (large and small rivers, river and storm surge floods) as well as the likely frequency of their occurrence, the assessment gathered a wide spectrum of information to share with local households and businesses.



Source: Google Earth. Note: km = kilometer.

Shiga Prefecture has 504 rivers, with a combined length exceeding 2,000 kilometers (km). The share of major rivers governed by the prefecture is the largest among all prefectures in Japan (Kada 2018), and therefore requires a more effective system of flood risk communication with stakeholders in the region. After an eight-year discussion with academics and local residents, the prefecture enacted the Shiga Prefecture Basin Flood Management Basic Policy (2012) (Tsuji 2014). The policy mandated that information on possible floods and inundation caused by various rainfall patterns be open to the public, which led to the introduction of Neighborhood Flood Safety Maps and increased the variety of flood risk assessment results shared with citizens. (Shiga Prefecture's urban flood risk management planning and prioritization efforts are further elaborated in **Knowledge Note 2**.) Shiga Prefecture has a high flood risk because 81 of Japan's 240 elevated-bed rivers (or about one-third) run through it. Over the past decade, the prefecture has

also experienced heavily concentrated rain. Therefore, many flood risk mitigation structures and systems such as levees (ridges of earth that prevent rivers from overflowing) have been established across the prefecture. In recent years, there has been a move to utilize historical information and flood risk mitigation structures to mitigate flood risk while raising awareness of it among citizens (Shiga Prefecture n.d.[b]).

In 2012, Shiga Prefecture published neighborhood safety maps for all cities and towns in the prefecture to share information on the risks of flood damages and inform efforts to stay safe (**figure B4.1**). These new maps were different from previous versions, which focused on large rivers only. Shiga Prefecture developed its own method to translate risk assessment results into more user-friendly hazard maps illustrating the combined risks of river and surface floods, and outlining the likely occurrence of floods (once in 10, 100, or 200 years) in specific locations. This more nuanced and wide range of flood risk information at the neighborhood level was communicated to local citizens to enable evacuation plans and related community development (Shiga Prefecture 2017).

A flood inundation area map assumes a 1-in-100-year flood (approximately 109 millimeters [mm]/hour) but also shares the possible level of inundation depth of each neighborhood for floods due to rainfall levels likely to occur between once in 10 years (approximately 50 mm/hour) and once in 200 years (approximately 131 mm/hour). The flood hazard maps are updated every five years based on the status of river improvements and changes in land use (Shiga Prefecture 2017).

The example of Shiga Prefecture illustrates how sharing various types of flood risk assessment results can enhance citizens' awareness and capacity for flood risk preparedness and response. However, these must be accompanied by various educational and communication efforts to help citizens understand and interpret the information, and translate their knowledge into effective action.

## Integrating Climate Change Considerations into Assessments of Urban Flood Risk

### Importance and Challenges

**Amid climate change, Japan's maximum annual precipitation level is expected to increase by a factor of between 1.1 and 1.3 by the end of the 21st century, compared with today's levels (MLIT 2015g).** At the same time, it is estimated that the frequency of floods exceeding the design level of flood management measures in place will increase between 1.8 and 4.4 times, possibly causing devastating flood damage. Low-lying lands and areas below sea level, often in urban areas, are expected to be inundated for extended periods by river, surface water, and storm surge floods. For instance, areas below sea level along the bays of Tokyo, Nagoya, and Osaka, the three largest metropolitan areas in Japan, are likely to face much higher flood risk. Based on the assumption that sea level will increase by 80 cm by the year 2100, the size of areas below sea level will increase by 60 percent, and the population at risk in these areas will increase by 40 percent. Integrating these and related estimates into flood risk assessments, especially for urban areas, is critical in order to mitigate and respond to floods effectively.

**The effects of climate change are predicted to vary from place to place, based on unique geographic and urban contexts. Therefore, location-specific estimates of how climate change might affect flood risk are quite important.** But the quality and detail of existing forecasts are limited by the current state of spatial resolution technology. To counter this, Japan's Ministry of Education, Culture, Sports, Science and Technology (MEXT) has launched an initiative to conduct 12 research programs on climate change adaptation. These include supporting the research and development of a management system for river and water resource areas to address climate change, technological solutions that facilitate the application of global climate change forecasts to regional and local assessments, and climate change simulation technology (Ministry of Education, Culture, Sports, Science and Technology 2010). Few cities to date have conducted their own climate change impact assessments or applied these to flood management plans.<sup>4</sup>

### Current Approach

**After Japan saw unprecedented flood levels across many regions in 2015, the national government initiated efforts to integrate climate change risks into flood risk management efforts.** These highlight the importance of planning for both manageable and unmanageable flood risks, and using both structural and nonstructural measures (MLIT 2015a). Several committees<sup>5</sup> and working groups convened by MLIT have been discussing measures to address flood disasters caused by climate change. In 2015, MLIT published an interim report that outlined Japan's policies and guidelines based on a review of various climate-smart flood management approaches trialed in the European Union and United States (MLIT 2015c).

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<sup>4</sup> The Tokyo Metropolitan Government conducted a climate change impact assessment in partnership with the National Institute of Environmental Science (NIES) and MEXT for 2009–12 ([https://www.iges.or.jp/files/research/natural-resource/PDF/20140326/2-3\\_shirai.pdf](https://www.iges.or.jp/files/research/natural-resource/PDF/20140326/2-3_shirai.pdf)).

<sup>5</sup> For example, in April 2018, the MLIT established a committee called the "Flood Risk Management Review with Climate Change Consideration" to discuss risk assessment methodologies to reflect changes in risk due to climate change (MLIT 2017b).

To make flood measures resilient to climate change risks, the report highlights the importance of: (i) designing and implementing flood management measures with the assumption that unprecedented levels of hazards will occur, and facility managers may have to cope with both manageable and unmanageable levels of rainfall; and (ii) helping citizens understand that public sector initiatives alone may not be sufficient to protect their lives and livelihoods, and so they must strengthen their knowledge of risks and safety measures. While these efforts are still in their nascent stage, some legal frameworks such as the Flood Control Act (updated in 2015) have integrated these principles, such as the need to prepare for not only the highest watermark in recorded history but also for unprecedented events.

**While the flood risk level considered for structural measures remains the same (that is, high-frequency rainfall levels), a different approach is proposed for nonstructural measures.** Differences between the current flood risk management approach and the proposed climate adaptive approach are elaborated in the “Interim Report on Flood Disaster Measures Resulting from the Climate Change” (MLIT 2015c, 2017a) and summarized in **table 5**.

**Table 5:** Approaches to Flood Risk Assessments with and without Climate Change Considerations

	Current Approach (without climate change consideration)	Proposed Approach (with climate change considerations)
Design of flood management infrastructure (structural measures)	<ul style="list-style-type: none"> <li>• Design of infrastructure investment is based on flood management of sewerage facility development plans and river improvements plans.</li> <li>• Based on these plans, the infrastructure facilities are designed to manage <b>high-frequency flood events (i.e., floods from rainfall that occur once every few decades to every few centuries)</b>.</li> </ul>	<ul style="list-style-type: none"> <li>• Given that flood management infrastructure development has not yet met the planned level, <b>the design level remains the same with climate change considerations.</b></li> <li>• Therefore, infrastructure facilities are designed to manage <b>high-frequency floods (i.e., due to rainfall levels expected every few decades to every few centuries)</b>.</li> </ul>
Preparing for floods beyond the capacity of existing flood management infrastructure (nonstructural measures)	<ul style="list-style-type: none"> <li>• Enhance preparedness, mitigation, and response actions by diverse stakeholders by developing and disseminating flood hazard maps and business continuity plans.</li> <li>• Hazard maps are informed by risk assessments based on <b>high frequency floods (i.e., due to rainfall levels expected once in every few decades to every few centuries)</b>.</li> </ul>	<ul style="list-style-type: none"> <li>• The general approach toward enhancing flood preparedness, mitigation, and response actions remains the same, such as developing and disseminating flood hazard maps, preparing business continuity plans, and enhancing evacuation.</li> <li>• However, the risk assessment differs, as it considers <b>floods that may occur with maximum precipitation (a probability of approximately 1-in-1,000-years)</b>.</li> </ul>

Source: Authors’ compilation based on MLIT (2015c).

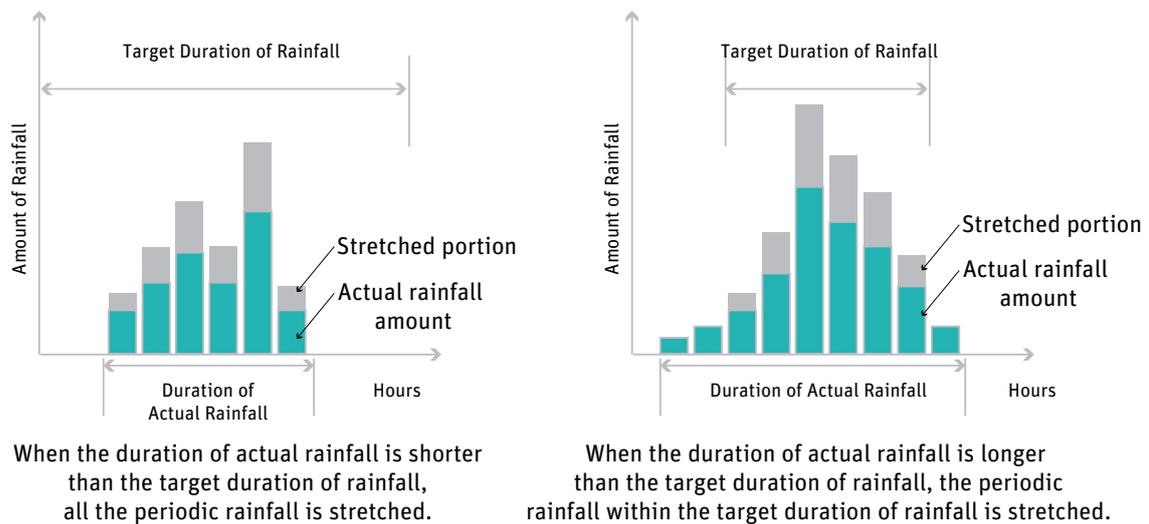
**Building on these overall approaches to promoting climate resilience, climate change risks are integrated in flood risk assessments by considering two key parameters:** (i) river and surface water floods at historically high levels, and (ii) storm surge floods with a 1-in-1,000-year probability (MLIT 2015d).

Integrating Climate Change Considerations into Risk Assessments for River and Surface Water Floods

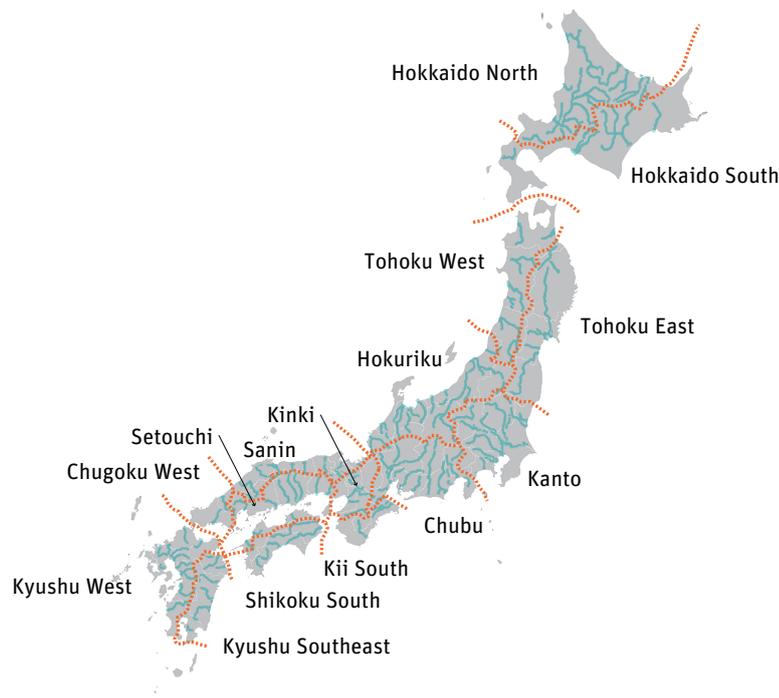
**Drawing upon experiences and lessons learned in Europe and the United States, the Flood Risk Assessment Guidelines developed by the second Technical Committee for Flood Management Plans Taking into Consideration Climate Change Risks and Impacts suggests that, to consider climate change risks, flood risk assessments should review multiple rainfall scenarios (MLIT 2018b).** The guidelines recommend that risk assessments be conducted using precipitation scenarios for: (i) targeted flow volume defined in river improvement plans; (ii) scale as per the Basic Policy of river development plans; (iii) the probability that an annual event will be of the magnitude of a 1-in-200-year or even a 1-in-500 year event; and (iv) the probable maximum precipitation (or probability of 1 in 1,000 years) (MLIT 2018b). Additionally, risk assessment results are to be cross-checked with hyetographs, where rainfall must not exceed 220 mm/hour or 60 mm/10 minutes, which is the theoretical maximum level of rainfall that is used to define an “extreme event” (MLIT 2018b).

**Risk assessments require information from hydraulic, hydrological, and meteorological observations,** such as the rainfall depth, water level, and flow rate of rivers and sewerage systems, capacity of river and sewerage facilities, and past recorded flood levels. These data include two key parameters: rainfall depth and hyetographs. Hyetographs show the spatial distribution of rainfall intensity over time. Floods due to maximum precipitation levels are forecasted based on the maximum rainfall volume affecting not only the target river but also neighboring rivers. The probable maximum hyetograph is set based on the hyetograph used for the river improvement basic policy and/or the hyetograph of recent major floods. The probable maximum hyetograph is stretched to the level equal to the probable maximum precipitation of each geographical area in order to consider extreme weather events that may be induced by climate change (see **figure 5**). Flood risk assessments that integrate climate change risks are conducted regionally in Japan. Fifteen geographic areas are identified for the risk assessment, grouped based on similar levels of probable maximum precipitation (see **figure 6**). The maximum rainfall volume for each geographic area is set based upon the highest level of probable maximum precipitation, also called the local maximum rainfall (MLIT 2016a).

**Figure 5:** Estimating Maximum Rainfall Considering the Effects of Climate Change



Source: Authors’ compilation based on MLIT 2015d.

**Figure 6:** Regional Flood Risk Assessment, by Probable Maximum Precipitation Levels

Source: Authors' compilation based on MLIT 2015d.

### Integrating Climate Change Considerations into Risk Assessments for Storm Surge Floods

**In the case of storm surge floods, the current method of integrating climate change risk is to use the largest typhoons that Japan has ever experienced (approximately 1-in-1,000-year events) to identify high-risk inundation areas based on the simulation of multiple routes with the highest sea-level departure.**<sup>6</sup> Estimates center on the Muroto and Isewan typhoons. The maximum strength of central atmospheric pressure is based on the Muroto Typhoon, which was categorized as a 1-in-1,000-year event. The simulation is calculated by adjusting the typhoon's central atmospheric pressure to the latitude of the coastline in question. A storm's predicted maximum radius and travel velocity are based on the Isewan Typhoon, which was larger and faster than the Muroto Typhoon. In addition, combined flooding scenarios are prepared by predicting the worst-case scenarios related to excessive river flow volume, high tide level, and levee failure (Ministry of Agriculture, Forestry and Fisheries and MLIT 2015).

### Integrating Climate Change into Hazard Maps

**To prepare for climate change risks and to inform evacuation plans, cities are developing hazard maps based on flood risks and impacts from probable maximum flood strength, as in five neighboring low-lying wards of Tokyo.** Hazard maps created by some cities and wards in Tokyo set a target flood management level equivalent to a 1-in-1,000-year flood. This is in accordance with Tokyo Metropolitan Government's Basic Policy for Heavy Rain Measures, revised in 2014, which is further introduced in **Knowledge Note 2** (Bureau of Construction, Tokyo Metropolitan Government 2018).

<sup>6</sup> Tide-level departure refers to the difference between the astronomical tide level and high tide caused by typhoons and tropical depressions (<https://www.jma.go.jp/jma/kishou/now/typhoon/4-1.html>).

**To make sure hazard maps stay responsive to climate change, it is important to update them with the latest lessons learned.** Large-scale floods in the Kanto region (surrounding Tokyo) and Tohoku region (the northern part of Japan's main island) in 2015 revealed that traditional hazard maps did not indicate the risks of buildings being washed away or the possibility of long durations of inundation, but focused more on inundation area and depth. As a result, citizens could not utilize the hazard maps effectively to plan for an effective mitigation or response strategy. Lessons should be integrated into risk assessments and hazard maps at the local level, as well as within the national guidelines. For example, based on 2015 flood experiences, in 2016, MLIT published new hazard map guidelines integrating river, surface water, and storm surge floods (Nihon Suiko Sekkei Company Limited 2016).

**Enhancing the usability of hazard maps to improve citizens' flood preparedness and evacuation plans is a vital step.** User-friendly maps that integrate climate change considerations include the following characteristics:

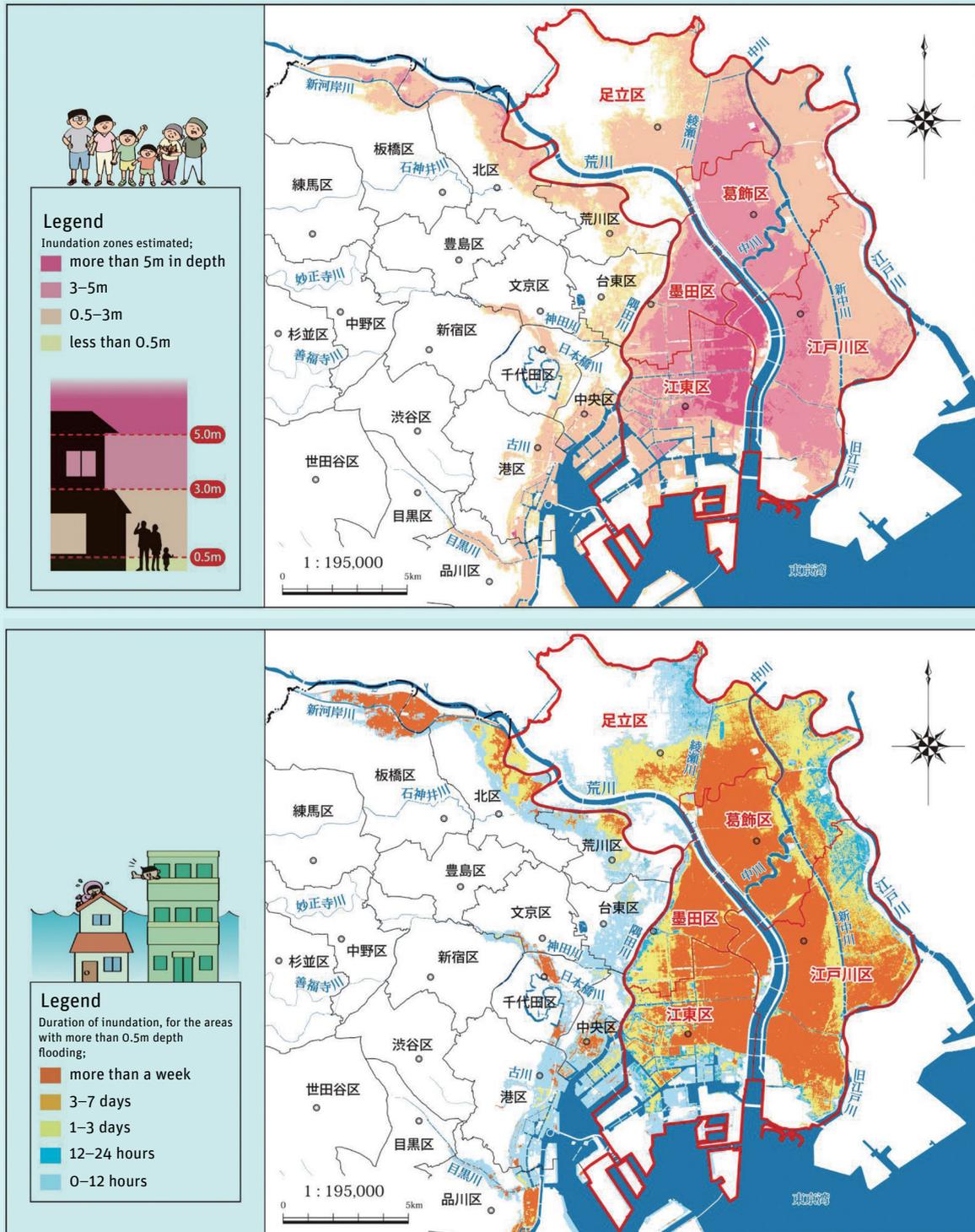
1. **Climate change risks are clearly noted**—maximum flood strength is set as a baseline.
2. **Information is local and detailed**—maps are customized to each community and by flood type and local geographic and economic conditions.
3. **Evacuation decisions are supported**—maps inform users *who*, *when*, and *where* to evacuate.
4. **Actions to be taken before and after floods, to enhance preparedness and response are recommended**—two sets of information are provided: one for normal (nondisaster) times, to understand the risk, and the other to refer to during evacuation in times of disaster.

See **box 5** for examples of enhanced hazard maps made by a consortium of five Tokyo wards.

## Box 5: Integrating Climate Change into Hazard Maps: Regional Evacuation Plans for Large-Scale Floods in Tokyo

Five neighboring wards (Sumida, Koto, Adachi, Katsushika, and Edogawa), Tokyo

**Figure B5.1:** Flood Hazard Maps for the Public: Projected Inundation Depth Map (above) and Inundation Duration Map (below) of Five Wards in Tokyo



Source: Council for Koto 5 Wards Wide Area Disaster Evacuation 2018a.

**Objective of the risk assessment:** To understand likely inundation areas and their depths, duration of inundation, and effects on buildings in five wards of Tokyo and to develop a regionwide evacuation strategy for citizens to ensure safe evacuation locations, methods, and timing in case of extreme flood events.

**Type of flood:** River, surface water, storm surge.

**Urban characteristics:** East of Tokyo with dense population and businesses located in wide coastal areas below sea level.

**Responsible organization:** Wards of Tokyo Metropolitan Government.

**Success factors / takeaways:** Five neighboring wards that have vast areas below sea level and share the same flood risks collaborated to conduct a risk assessment of probable maximum floods, considering climate change impacts. The assessment revealed the need to promote awareness among citizens of the potential for widespread, long-lasting floods and voluntary evacuation at an early stage.

Five neighboring wards in Tokyo (Sumida, Koto, Adachi, Katsushika, and Edogawa) offer an example of how vulnerable cities can collaborate to understand the potential devastating risks of extreme floods from climate change, and develop a joint solution to ensure safe evacuation. These wards include three major rivers (the Sumida, Arakawa, and Edogawa) as well as many smaller rivers. In addition, the area is located below sea level, making it particularly vulnerable to flood damage, and is densely populated with many residential zones and high-value assets. Historically, it has repeatedly suffered damage from devastating typhoons such as Typhoon Kathleen (1947) and Typhoon Kitty (1949). Significant damage was caused by not only the wide area of inundation but also the long duration of the floods due to difficulty draining flood waters. For example, some districts of this area may stay inundated for more than two weeks if large-scale floods destroy the embankments along the Arakawa and Edogawa rivers. As climate change brings about more extreme events, the approximately 2.5 million people living in the five wards are exposed to significantly greater flood hazards.

In light of this concern, in 2016, the five wards collaborated to establish the Council for Koto 5 Wards Wide Area Evacuation. The council invited academics to advise plans for large-scale evacuations that would require complex coordination among many stakeholders. The Ministry of Land, Infrastructure, Transport and Tourism (MLIT), the Tokyo Metropolitan Government, and transportation operators were invited to observe the council's discussions. The council developed two evacuation maps in 2018: "Wide Area Evacuation Plans for Large Scale Floods in Koto Five Wards" and "Floods Hazard Maps for Large Scale Floods in Koto Five Wards." Through a collective effort, the wards are working to create a regional evacuation plan that would define the collaboration of neighboring municipalities and enhance residents' capacity to voluntarily evacuate when needed to safe sites located outside their neighborhoods (Council for Koto 5 Wards Wide Area Disaster Evacuation 2018b).

**Figure B5.1** shows the projected inundation areas of the five wards. The image at the top shows the depth of inundation, while the image below this shows the duration. These maps were created by combining the inundation data from the Arakawa and the Edogawa rivers from a scenario that requires both rivers to be flooded from three consecutive days of rain—a 1-in-1,000-year occurrence, with a total rainfall of 632 millimeters (mm) and 491 mm for the Arakawa River and Edogawa River, respectively.

The extent of possible damage was also discussed at meetings on the impacts of climate change in the area. According to the MLIT's Office of Water Management and Homeland Protection, if probable maximum rainfall occurs along the Arakawa River and causes a failure of one section of the levee, there would be a maximum of \$250 billion in economic damages (14-month accumulative damage) and \$360 billion in asset damages over the course of a year.

### 3.2 Japan's Experience in Urban Flood Risk Communication

**The overall objective of flood risk communication is to encourage and guide actions that mitigate and prevent flood risk by disseminating the right information, to the right stakeholders, at the right time, through the right channels.** Methods of flood risk communication differ according to the goals and phases of a flood incident, such as before, during, and after floods, as well as during recovery.

#### Enhancing Preparedness

**Risk assessments, if communicated effectively before disasters, can support the preparedness and mitigation efforts of citizens and other stakeholders. This can significantly reduce losses and damages to lives and livelihoods.** Strengthening the capacity of individuals and communities to prepare for, mitigate, and respond to floods through their own efforts is extremely critical, especially since structural measures have their limits. Floods may occur before enhancements to existing infrastructure are complete, as construction generally spans long periods of time. Therefore, it is important to effectively communicate information needed to prepare for a flood beyond the level that existing or planned infrastructure enhancements can handle.

**In order to trigger swift evacuation and response when flood events are detected, cities are making accurate and real-time risk information available to citizens through “push” and “pull” methods.** Technological advancement has drastically improved last-mile flood risk communication and early warnings throughout the world. In Japan's case, local governments have been utilizing information and communication infrastructure and devices to enhance flood and other disaster risk communications. Many municipalities make local flood risk information available online so citizens and stakeholders can “pull” almost real-time information from these platforms anytime. Also, in recent years, national and local governments can increasingly “push” information on early flood warnings, a rise in forecasted levels, and evacuation plans directly to mobile devices, televisions, radio signals, and so on.

For example, in 1988, the Tokyo Metropolitan Government's Sewerage System Management Division introduced a rainfall information broadcasting system called Tokyo Amesh. The MLIT also uses a highly accurate (the smallest observation unit is 250 square meters) and real-time (data are renewed every minute) radar system (MLIT 2013a). The Tokyo Metropolitan Government has started using the cutting-edge Multi Parameter (MP) radar, which enables detection of very subtle rainfall of 1 mm/hour. This highly accurate information is delivered to personal computers and mobile devices so that residents can prepare for floods (Bureau of Sewerage, Tokyo Metropolitan Government n.d.).

**Enhancing the communication of flood risk to operators of critical infrastructure, such as roads and rails, and water supply, sanitation, and power companies can significantly improve flood risk management and response in cities.** Boxes 6 and 7 outline communication and response measures implemented by railway and metro operators.

#### Box 6: Disseminating Flood Risk Information: The “Timeline” Method Used by Urban Railways

**Objective of the risk assessment:** To mitigate chaos during a flood by providing companies and schools early notice of suspended train operations by major railway companies, well in advance of the expected heavy rain and/or associated flood event.

**Type of flood:** River, surface water, storm surge.

**Urban setting:** In the Tokyo Metropolitan Area and Kansai Metropolitan Area (including Osaka and Kyoto) alone, Japan's railways carry more than 21 million passengers a day (JR East n.d.; JR West n.d.).

**Responsible organization:** Ministry of Land, Infrastructure, Transport and Tourism (MLIT), private railway companies, including JR West.

**Success factors / takeaways:** The MLIT led the initiative to create “Timeline-Based Disaster Prevention Action Plans” outlining a detailed list of actions to be implemented by railway companies in metropolitan areas to ensure the continuation and/or quick recovery of operations after a flood event. Given the importance of rail transport in Japan, the Japanese government encouraged the adoption of the measures within specified time frames by railway companies, local governments, and other relevant stakeholders.

The concept of timelines drew attention when Hurricane Sandy struck New Jersey in the United States in October 2012. Swift disaster prevention actions were taken according to a prepared timeline that set the hurricane’s predicted landfall as the “zero” hour. The governor of New Jersey published evacuation recommendations 36 hours before this and called for emergency evacuation 12 hours before the zero hour for those who remained behind. Plans outlining who was to do what and when were decided before the disaster and shared with all stakeholders (MLIT 2015e).

Based on the U.S. experience with Hurricane Sandy, in 2014 MLIT established a working group to tailor the timeline-based approach to Japan’s context; the group published “Timeline-Based Disaster Prevention Action Plans” and other guidelines in 2016. By 2017, all 730 of the municipal governments located in flood-prone areas completed timelines for early evacuation advisories.

Benefits of the timeline-based action plans included clarifying the responsibilities of disaster prevention authorities, outlining appropriate actions for disaster prevention, and verifying and improving disaster measures. During the devastating floods caused by heavy rain in 2015, 72 percent of municipal governments with timeline-based action plans were able to swiftly warn citizens to evacuate, whereas only 33 percent of those without the timelines were able to do this. These statistics clearly show how such plans help city authorities make timely and effective evacuation announcements, and as a result save lives and assets in the face of floods (MLIT 2015f).

In 2014, JR West started issuing advance notice of the suspension of train operations due to typhoons and/or heavy rain. The company’s action plan includes the following: issuing advance notice of the suspension of train operations two days before a typhoon’s arrival, through various means such as in-train announcements and the Internet; partial suspension of train operations during heavy rain and publication of timetables on websites and other outlets; specific actions around the disruption of train services, facility protection, and evacuation during a typhoon; and the announcement of resumed train services after a typhoon passes (Yahoo Japan 2014).

In a 2018 review of action plans conducted by MLIT and railway companies, an interim recommendation was that the suspension of train service be announced earlier, more widely, and in multiple languages. The review also noted that information provision to local governments and collaboration among railway companies were essential to streamline the resumption of services (MLIT 2018d).

### Box 7: Disseminating Key Information through Multiple Means: The Case of Tokyo Metro

**Figure B7.1:** Signboard Indicating the Elevation of the Station Entrance Compared with Sea Level



Source: Economic Research Association (2018).

**Figure B7.2:** Handy Safety Guide (Evacuation Handbook for Subway Passengers)



Source: Tokyo Metro (2018).

**Objective of the risk communication:** To disseminate updated information on heavy rains, flood warnings, and evacuation procedures via announcements and displays at subway ticket gates, with the aim of helping metro users make informed decisions, evacuate safely and quickly, and mitigate their personal risk.

**Type of flood:** River, surface water, storm surge.

**Urban setting:** Capital with dense population and assets.

**Responsible organization:** Tokyo Metro.

**Success factors / takeaways:** Tokyo Metro has been implementing various flood-related measures in subway facilities. As part of its communication efforts, the company distributes Handy Safety Guides in multiple languages to subway passengers and displays disaster information at ticket gates. An online meteorological information system disseminates updated data to subway employees so that they can swiftly share precise information with passengers and decide when to resume operations.

Tokyo Metro operates nine subway lines mainly in the Tokyo Metropolitan Area. The lines cover a total of 195.1 kilometers (km), service 179 stations, and accommodate 7.24 million passengers daily. As of 2018, 168.6 km (86.4 percent of the total service distance) and 158 stations (88.2 percent of all stations) were underground. Tokyo Metro has been addressing the disaster resilience of underground metro systems for a long time by focusing on measures to mitigate and manage underground inundation caused by the overflow of small rivers. The company is also considering the risks of underground inundation due to extreme weather events, such as concentrated heavy rain as well as a possible major flood of the Arakawa River due to changing rainfall patterns (Economic Research Association 2018).

Tokyo Metro has been implementing various new flood measures, including installing flood prevention equipment on the ceilings of subway tunnels and waterproof sealing plates at subway entrances. These measures consider a worst-case scenario with deeper inundation depths than those listed on the MLIT's inundation maps of Grade A rivers or the Tokyo Metropolitan Government's inundation maps of small- and medium-sized rivers. Other existing flood measures include constructing entrances higher than street level and installing waterproof doors and sealing plates at ground-level entrances. In case of immense water flow into underground tunnels, flood prevention gates are installed at various points to close tunnels, and pumps are installed to help get water out (Tokyo Metro n.d.).

In accordance with the Flood Prevention Act, 40 Tokyo Metro stations have prepared evacuation and flood prevention plans. The plans require Tokyo Metro employees to lead subway passengers in the event of an evacuation and indicate the evacuation routes and places where water sealing plates are installed (Tokyo Metro 2015). In addition, the municipal government has conducted emergency drills in collaboration with various stakeholders (local citizens, fire and police departments, and other transport operators) to simulate emergency exercises (Tokyo Metro 2016).

To effectively communicate risk and inform subway passengers of proper actions to take during a flood, the Handy Safety Guide (Tokyo Metro 2018) was prepared in multiple languages and has been distributed at all Tokyo Metro stations since 2012. Screen monitors have also been installed at the fare gates of every station to provide weather, train operation, and disaster emergency information from the NHK public TV station. Risk and weather forecast information from the Meteorological Agency is disseminated through the Tokyo Metro Online Climate System to subway employees. This information allows employees to make informed decisions regarding the operation and regulation of train services. In addition, signboards are displayed at station entrances; they indicate the relative elevation of the station compared with sea level, and promote awareness of evacuation procedures (Economic Research Association 2018).

**Improving the communication of flood risk and safety measures to vulnerable people such the elderly, people with disabilities, and children is extremely critical to enable their safe evacuation. Box 8** outlines flood risk communication and response measures implemented in Sanjo City to support the evacuation of those needing assistance.

## Box 8: Evacuation Measures for Those in Need of Assistance in Sanjo City

**Objective of the risk communication:** To share flood risk information and secure the effective evacuation of vulnerable citizens in need of assistance during a disaster.

**Type of flood:** River, surface water.

**Urban setting:** Located near Niigata City on the Sea of Japan coast, Sanjo has a population of 98,000. This population is aging and has been decreasing since 1985.

**Responsible organization:** Sanjo City, Niigata Prefecture.

**Success factors / takeaways:** The municipal government recognized: (i) the limited capacity of communities to provide assistance to those in need during an emergency; and (ii) the privacy concerns of individuals who refused to be listed on a roster of people needing assistance. The city revised the registration criteria to limit the number of listed citizens and target assistance to those most in need.

Those in need of special consideration during evacuation include the elderly, those with disabilities, infants, and anyone with difficulty moving independently (Sakai City 2014).

Sanjo City experienced nine casualties, of which seven were elderly citizens, during a river flood in 2004. This incident highlighted the need for evacuation measures that enlisted community help to assist those in need. The city started listing those in need of assistance in 2005 and continuously updated the list every six months with the help of community leaders (Ebina 2014). Until 2017 the city used data from long-term care insurance providers to identify those who could not evacuate on their own or with their families. However, the 4,842 citizens who needed assistance according to these criteria were too many for local communities to manage. Also, due to privacy concerns, some of these individuals did not want to register and be identified as people in need.

The municipal government therefore applied new criteria to narrow down the number of those in need of assistance by focusing on households inhabited by the elderly and those with disabilities. Eventually 2,216 individuals were identified as those in need of community assistance during an emergency. Prioritizing saving lives during an emergency over privacy concerns, the city adopted a new rule that all citizens in need must register, but once registered they can apply to be removed. Under this new system, the number of those who chose not to be registered decreased to 5 percent by 2014, compared with 18 percent in 2007 (Sanjo City n.d.).

**Since flood risks, city contexts, and technological advancements evolve rapidly, it is very important to monitor, evaluate, and improve flood risk communication methods after each flood event.** Another example from Sanjo City (box 9) highlights how evaluating flood risk communication after each disaster event, and making improvements based on those findings, can be instrumental in improving flood risk communications and minimizing the impacts of future flood events.

## Box 9: Assessing and Improving Risk Communications after Floods in Sanjo City

**Objective of the assessment:** To review and evaluate the risk communication implemented after flood events to determine areas for modification and improvement

**Type of flood:** River.

**Urban characteristics:** The population of Sanjo City is approximately 98,000, and has been decreasing since 1985. It is located near Niigata City, a city with an aging population of 800,000 on the coast of the Sea of Japan.

**Responsible organization:** Sanjo City, Niigata Prefecture.

**Success factors / takeaways:** After a large-scale flood event in 2004, the city conducted a review of its risk communication and identified several bottlenecks. Based on a postdisaster survey conducted in collaboration with a university, areas for improvement were addressed, resulting in the enhancement of risk communication in Sanjo City.

In 2004, the Igarashi River flooded Sanjo City, causing severe damage. The year's total rainfall of 491 millimeters (mm) broke records. This experience exposed several problems in the city's communication of flood risk, including the chaotic management of disaster control headquarters; difficulties in deciding when to order evacuation;

inadequate information dissemination systems; and inadequate assistance of elderly citizens.

The city conducted a survey of its citizens to examine their behaviors and the status of risk communication at the time of the disaster. Based on the survey results, both structural and nonstructural measures were developed and implemented.

The city experienced another period of heavy rain in 2011 with a total rainfall of 959 mm, twice as much as in 2004. The rainfall caused damage, including a levee collapse in the upper course of the Igarashi River and landslides in the mountains. But as a result of improved risk communication measures developed after 2004, overall damages were limited. Changes included increased use of information dissemination systems and methods, updated flood disaster manuals, and publication of guidebooks for heavy rain disasters including Flood Risk Evacuation Maps (see **box 3**), and the enhancement of life-saving disaster measures (see **box 8**) (Sanjo City n.d.).

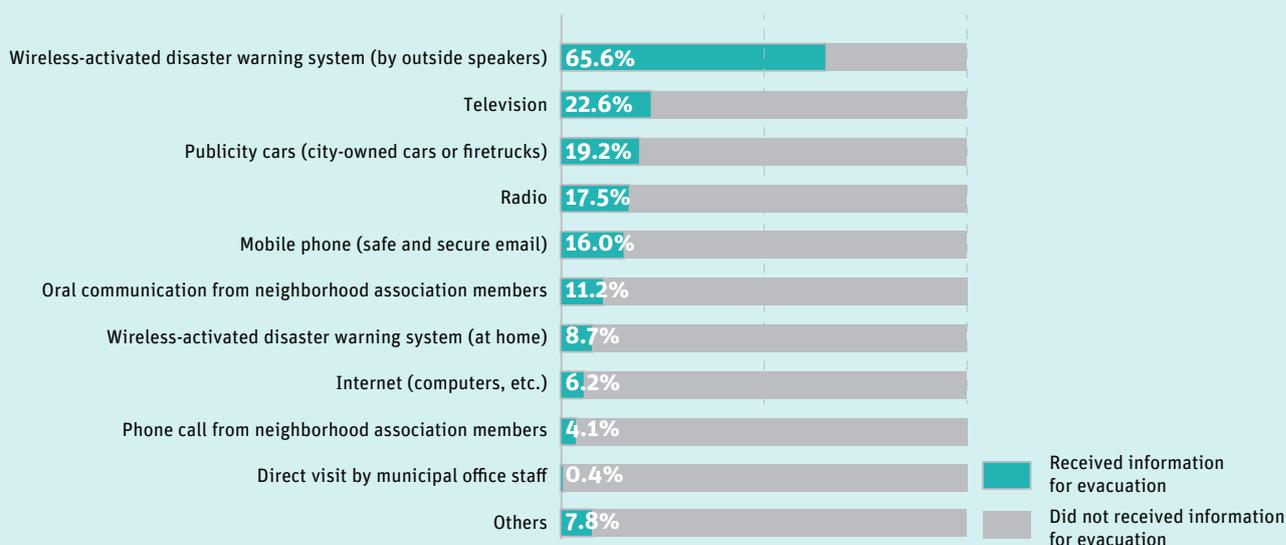
A survey conducted in 2011 found that most citizens (93.3 percent) had received evacuation information. The survey results suggest that the risk communication issues observed in 2004 had been adequately addressed (**table B9.1**).

**Table B9.1:** Overview of Flood Impacts in 2004 and 2011

	Total Rainfall	Casualties	Houses that Were Completely Destroyed	Houses that Required Repairs before They Were Habitable	Buildings Where Flood Reached Ground Floor	Buildings Where Flood Stayed below Ground Floor	Share of Citizens Who Received Evacuation Info (%)	# of Respondents
2004	491 mm	9	1	5,281	515	1,649	21.9	6,401
2011	959 mm	1	10	400	13	1,518	93.3	6,384

Source: Sanjo City n.d.; Sanjo City and Gumma University 2012.  
 Note: mm = millimeter.

**Figure B9.1:** Communication Channels Used to Obtain Evacuation Data—Results of Public Survey after 2011 Floods



Source: Authors' compilation based on information from Sanjo City (n.d.).

## 4. Lessons Learned and Key Takeaways

Over the years, Japan has developed a range of urban flood risk assessments, communication approaches, and methods that enable stakeholders to take timely and effective actions to mitigate and manage urban flood risks. Lessons learned and key takeaways from Japan's experience are as follows.

1. **Carefully consider the types and combinations of urban flood risk.** Urban flooding may involve river, surface water, and storm surge floods, singly or in combination. In Japan, many major cities, including Tokyo, Osaka, and Nagoya, are located in flood-prone lowland areas, and face a combination of flood types. The risks and impacts of urban flooding are complex and diverse, linked to key urban characteristics. Points of vulnerability depend on geographical and regional characteristics, locations and types of assets, populations' location and size, and the status of rainwater drainage facilities. Risk assessments in Japan take into account the typology and combinations of flood risk.
  - *Assessing river flood risk:* Generally, river and surface water flood risks are defined based on their probability and the scale of possible damage. A key step in this process is to collect and organize data on rainfall, watersheds, rivers, flood areas, etc. In Japan, the standard methods of flood flow and inundation analysis use a hydraulic model of one-dimensional, quasi-two-dimensional, and two-dimensional flow processes.
  - *Assessing surface water flood risk:* If possible, it is recommended that surface water flood risk assessments be based on inundation simulations. However, depending on local geographic contexts, needs, and limitations, assessments based on historical floods and analysis of geographic conditions (elevation data and so on) are also used in Japan.
  - *Assessing storm surge flood risk:* Risk assessments for storm surge floods are conducted by running simulations based on local natural hazard risks and conditions.
2. **Clarify urban flood risk assessment objectives and parameters.** Depending on the stakeholders involved, there are various approaches, objectives, and applications that can be used to mitigate urban flood risks. It is necessary to clarify the specific purpose of the assessment, as well as how and when various stakeholders can utilize it to enhance their capacities to prepare, mitigate, and respond to urban floods. In general, risk assessments in Japan are conducted to support: (i) the planning and reviewing of structural flood risk mitigation and management measures, such as building embankments and other facilities; and (ii) the reviewing and adjusting of nonstructural flood risk mitigation and management measures, such as land use plans and evacuation plans. For example, assessments may inform land use plans of the probability of an event's occurrence (per year) and predicted level of damage (inundation depth and its extent). In Shiga Prefecture, flood risk assessments demarcate "restricted urban development areas" in order to avoid critical damage to assets and the burden of recovery. The combination of a flood risk assessment and a CBA allows planners to investigate different investment options, and how to prioritize and select investments. Efforts are being made to integrate qualitative information in the assessment of flood management investment benefits
3. **Clarify institutional roles and modes of collaboration.** In Japan, the MLIT formulates laws and guidelines that are revised whenever major disasters occur. Scientific knowledge is utilized to formulate new policies by involving researchers and academic experts. River administrators, sewerage system administrators, and mayors of municipalities at risk of inundation are responsible for risk assessments. Municipalities are also responsible for creating hazard maps and developing disaster prevention plans, based on the laws and guidelines established by the government. In terms of risk communication, municipalities, often in close collaboration with the private sector and community members, develop plans to facilitate evacuation and prevent inundation.
4. **Consider how the assessment will inform the design of structural flood management measures.**
  - *River floods:* In Japan, river administrators set the goals for river development plans and design levels for flood management based on the concepts stipulated in the River Law. The design level is calculated through statistical analyses of past hydrological data and historical rainfall. Flood simulations are conducted by river administrators to identify areas at risk of inundation.

- *Surface water floods:* Japan's national standard for flood risk management is to design and implement measures that can effectively manage a level of heavy rains likely to occur once in five years, and avoid or mitigate the inundation of assets at this level. If appropriate rainfall data are not available, similar data for large-scale rainfall in other cities may be utilized to prepare flood plans.
- *Storm surge floods:* Storm surge measures in Japan, such as coastal seawalls and embankments, are designed to withstand the highest-recorded tidal surge in history.

**5. Consider how the assessment will inform the design of non-structural flood management measures.** Flood risk assessments also inform the design and implementation of nonstructural measures to enhance people's preparedness and response to floods. Examples of good practice in Japan include the following:

- *Critical infrastructure:* In Ozu City, flood risk communication and training demonstrate the opportunity to improve flood preparedness of critical facilities, in this case the Ozu Memorial Hospital.
- *Evacuation plans and awareness:* Sanjo City in Niigata Prefecture used risk assessments to inform city plans for evacuation. The city prepared a guidebook for citizens with information needed for key evacuation decisions. Every household received this guidebook in 2011 to promote flood preparedness at the household and individual levels.
- *Raising awareness of flood risk and safety measures:* In Shiga Prefecture, to enhance citizens' awareness of flood risk and safety, in addition to flood risk hazard maps, neighborhood flood safety maps were prepared to note possible areas of inundation from the overflow of small, medium, and large rivers.

**6. Prepare for predicted impacts of climate change.** There are ongoing efforts to integrate climate change considerations into flood risk assessments. Examples include the following:

- *At the policy level,* the updated Flood Control Act highlights the need to prepare for not only the highest watermark in recorded history but also for unprecedented events.
- *River and surface water floods:* The Floods Risk Assessment Guidelines developed by MLIT Technical Committee suggest that, to consider climate change risks, flood risk assessments should review multiple rainfall scenarios.
- *Storm surge floods:* The current method of integrating climate change risk is to use the largest typhoons that Japan has ever experienced (approximately 1-in-1,000-year events) to identify high-risk inundation areas based on the simulation of multiple routes with the highest tide-level departure.
- *Improving risk maps:* Cities in Japan are developing hazard maps based on flood risks and impacts from probable maximum flood strength. User-friendly maps that integrate climate change considerations include the following characteristics:
  - i) **Climate change risks are clearly noted**—maximum flood strength is set as a baseline.
  - ii) **Information is local and detailed**—maps are customized to each community and by flood type and local geographic and economic conditions.
  - iii) **Aids evacuation decisions**—maps inform users who, when, and where to evacuate.
  - iv) **Recommends actions to be taken before and after floods to enhance preparedness and response**—two sets of information are provided: one for normal (nondisaster) times, to understand the risk, and the other to refer to during evacuation in times of disaster.

**7. Improve communication efforts through various means.** In response to the extensive flood damage experienced in recent years, the country has started focusing on risk assessments and communication methods that prioritize saving lives, and thus is developing lessons and know-how to handle severe situations.

- *Access to information:* For hazards that greatly exceed the capabilities of facilities, Japan is focusing on improving risk communication to protect lives and avoid damage. New technologies can facilitate better access to risk information. For example, the Tokyo Metropolitan Government has started using the cutting-edge MP radar, which enables detection of very subtle rainfall of 1 mm/hour. This highly accurate information is delivered to personal computers and mobile devices so that residents can prepare for floods.
- *Risk maps and evacuation plans:* Lessons from recent floods have revealed that traditional hazard maps were underutilized by citizens during evacuation. MLIT and regional governments are improving these maps to integrate lessons learned to better help citizens decide how and when to evacuate. In addition, efforts are being made to improve the evacuation of vulnerable populations. Sanjo City, for example, supports the evacuation of those needing assistance by requiring people in need to register for additional support.

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### **UFCOP**

Urban Floods Community of Practice is an umbrella program to share operational and technical experience and solutions for advancing an integrated approach to urban flood risk management, and leveraging expertise and knowledge of different stakeholders and practice groups and across the WBG. The program supports the development of an interactive space for collaboration and exchange on the subject, facilitating users' access to information and adaptation of knowledge to local conditions, and bringing together different stakeholders to enhance collective knowledge on integrated urban flood risk management.

### **World Bank Tokyo DRM Hub**

The World Bank Tokyo Disaster Risk Management (DRM) Hub supports developing countries to mainstream DRM in national development planning and investment programs. As part of the Global Facility for Disaster Reduction and Recovery, the DRM Hub provides technical assistance grants and connects Japanese and global DRM expertise and solutions with World Bank teams and government officials. The DRM Hub was established in 2014 through the Japan-World Bank Program for Mainstreaming DRM in Developing Countries—a partnership between Japan's Ministry of Finance and the World Bank.

### **GFDRR**

The Global Facility for Disaster Reduction and Recovery (GFDRR) is a global partnership that helps developing countries better understand and reduce their vulnerabilities to natural hazards and adapt to climate change. Working with over 400 local, national, regional, and international partners, GFDRR provides grant financing, technical assistance, training, and knowledge sharing activities to mainstream disaster and climate risk management in policies and strategies. Managed by the World Bank, GFDRR is supported by 36 countries and 10 international organizations.

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