RESILIENT WATER SUPPLY AND SANITATION SERVICES

THE CASE OF JAPAN

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ABBREVIATIONS

AM	asset management
BCM	business continuity management
BCP	business continuity plan
DRM	disaster risk management
EPC	engineering, procurement, and construction
FRSB	Fukuoka City Road and Sewerage Bureau
FWB	Fukuoka City Waterworks Bureau
GEJE	Great East Japan Earthquake
GIS	geographic information system
HCWB	Hiroshima City Waterworks Bureau
JSWA	Japan Sewage Works Association
JWWA	Japan Water Works Association
KCWB	Kobe City Waterworks Bureau
KWSB	Kumamoto City Waterworks and Sewerage Bureau
LMICs	low- and middle-income countries
MHLW	Ministry of Health, Labour and Welfare
MLIT	Ministry of Land, Infrastructure, Transport and Tourism
MoU	memorandum of understanding
O&M	operation and maintenance
SCB	Sendai City Construction Bureau
SWB	Sendai City Waterworks Bureau
TEC-FORCE	Technical Emergency Control Force
TMBS	Tokyo Metropolitan Government Bureau of Sewerage
TMBW	Tokyo Metropolitan Government Bureau of Waterworks
UPS	uninterruptible power supply
WSS	water supply and sanitation
WTP	water treatment plant
WwTP	wastewater treatment plant

EXECUTIVE SUMMARY

Japan has built the resilience of its water supply and sanitation (WSS) services through an adaptive management approach based on lessons learned from past natural disasters. This experience offers key insights for low- and middle-income countries (LMICs) seeking to sustain and build resilience of WSS services.

Sustainability of Essential WSS Services at Risk

Natural disasters have increasingly damaged WSS facilities and infrastructure, leaving entire communities without safe and reliable drinking water and the appropriate disposal of wastewater. These emergency events could arise from inundation of facilities, loss of electricity, and exposure and disruption of infrastructures. Less-severe impacts can arise from increased siltation of reservoirs and slow-onset events such as droughts, thus having longer-term effects on the resilience and reliability of services. These WSS service failures or interruptions could set off a cascading effect across interconnected infrastructure systems including public health and fire services, which in turn could pose both direct and indirect economic impacts.

For example, recent natural disasters that affected the utilities in Japan include the following:

- In 1978 and 1994, Fukuoka City experienced severe droughts that necessitated water rationing for approximately 300 days each.
- The 1995 Hanshin-Awaji Earthquake (magnitude 7.3) took the lives of 4,571 people and severely damaged the infrastructure; it took 10 weeks to restore piped water supply.
- The 2011 Great East Japan Earthquake (GEJE) of magnitude 9.0 led to a loss of water access among up to 500,000 residents in Sendai City, and the city's primary wastewater treatment plant was completely submerged by tsunami.
- The GEJE had a seismic intensity at the upper-5 level in Tokyo, and led to a temporary service disruption to 42,000 residents. 12 kilometers of sewerage pipelines were adversely affected by cracks and sand clogging owing to earthquake-induced soil liquefaction.
- Multiple precipitation-induced landslides in 2014 in Hiroshima City extensively damaged the water distribution networks and other facilities, causing approximately 3,500 households to lose access to water.
- In 2016, two earthquakes of magnitudes 6.5 and 7.3 caused all residents in Kumamoto City (up to 326,000 households) to lose access to water.

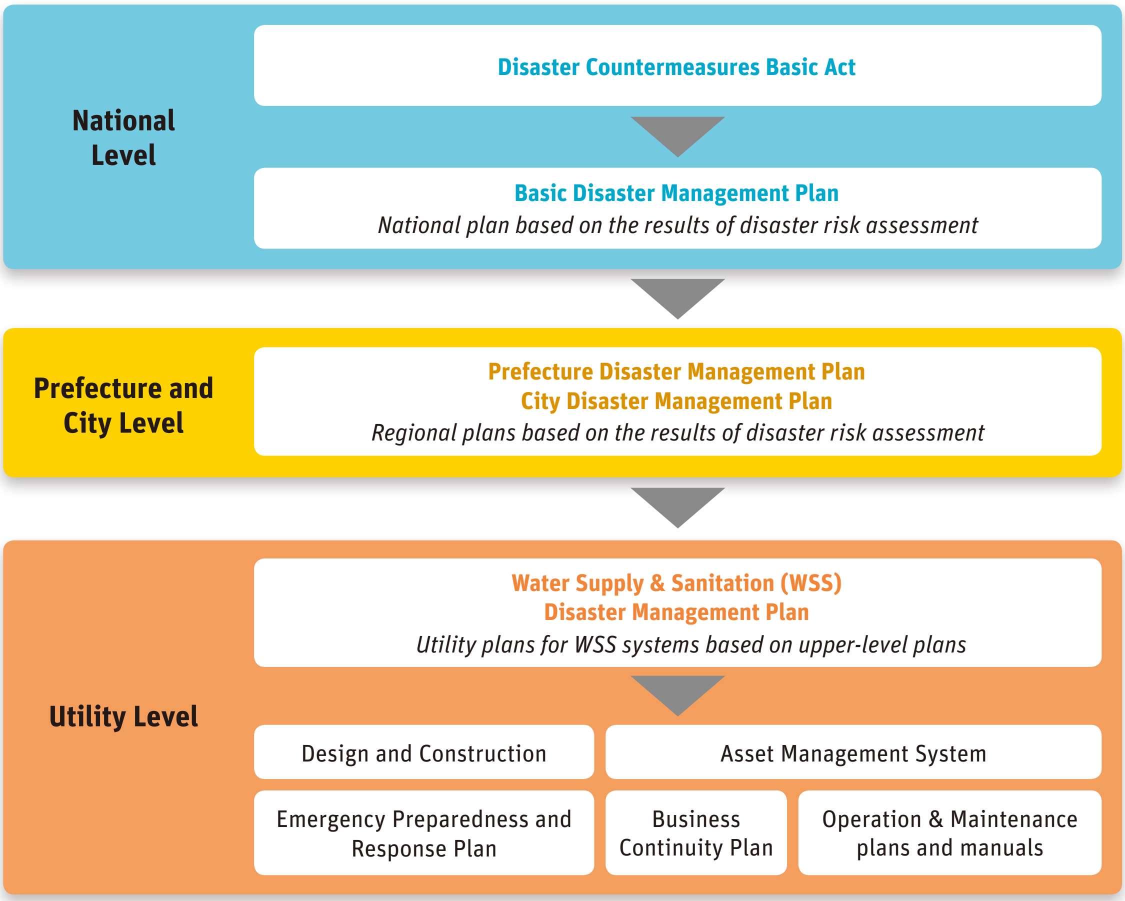
Although more investment is urgently needed to improve basic water and sanitation access in LMICs, maintaining or enhancing the disaster resilience of both new and existing (particularly aging) infrastructure—especially in the context of climate change and variability—is also critical for sustainable development.

Legal and Institutional Frameworks for Resilient WSS Services in Japan

As chapter 2 discusses, rapid urbanization and population growth during the 1960s–80s as well as a cholera outbreak led Japan to rapidly develop water resources and wastewater services under the 1957 Waterworks Act and 1958 Sewerage Act. The water supply coverage has increased from 26 percent in 1950 to 98 percent in 2015, while wastewater services have increased from 6 percent in 1961 to 90 percent in 2016. WSS services are delegated from the Ministry of Health, Labour and Welfare (for water supply) and from the Ministry of Land, Infrastructure, Transport and Tourism (for sewerage) to the municipalities.

Based on the 1961 Disaster Countermeasures Basic Act, WSS utilities develop and implement disaster risk management (DRM) planning and measures, which are iteratively improved based on lessons learned from past natural disasters (figure ES.1). As a guide to design, construct, and operate WSS systems in accordance with the laws, the Japan Water Works Association and the Japan Sewage Works Association develop guidelines and establish a mutual support network of member utilities in case of disasters.

Figure ES.1 **Development of Disaster Management Plans at National and Local Levels**

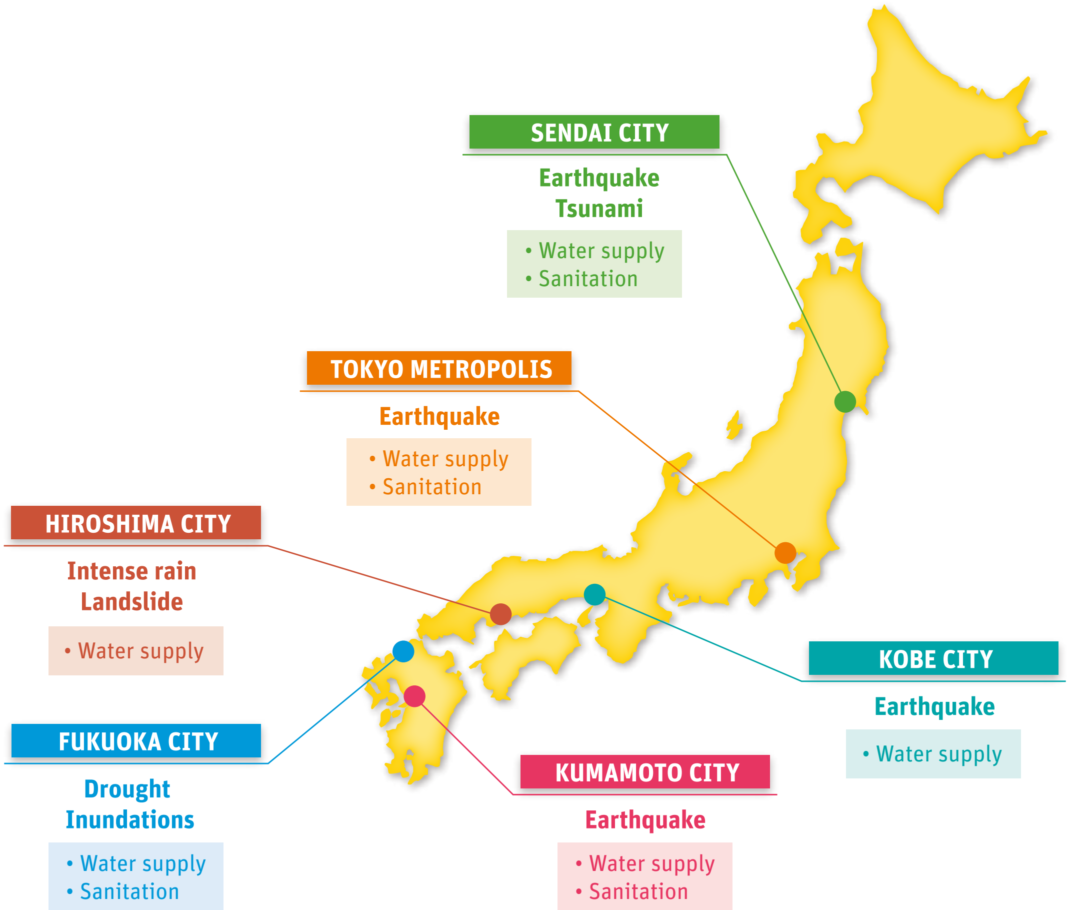


Given the aging infrastructure and limited financial resources, the utilities have improved asset management practices to extend the lifetime of assets and to enhance system resilience. To incentivize utilities to develop or upgrade the WSS facilities that are critical for building resilient and inclusive communities, the Japanese central government prepares contingency funds and provides a range of subsidy programs.

Urban WSS Utility Best Practices and Lessons Learned

Utilities in Japan offer insightful lessons based on their accumulated experience of natural disasters, which include earthquakes, landslides, cyclones, floods, drought, and tsunamis (chapter 3). Map ES.1 shows the location of utilities and the types of natural hazards addressed in the report.

Map ES.1 **Case Study WSS Utilities, Services Covered, and Natural Hazards Faced**



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Some measures implemented by Japanese utilities are capital-intensive and could be challenging to implement depending on the financial and technical capacities of countries and utilities. Therefore, it is recommended to conduct risk assessment and cost-benefit analysis to prioritize and implement financially- and technically-viable DRM practices.

As discussed in chapter 4, recommendations for policy makers and utilities seeking to sustain and build resilience of WSS services are summarized as follows:

Legal and Institutional Frameworks

- Incorporate DRM into WSS regulations, including performance objectives, engineering design, operation and maintenance (O&M), emergency response, and recovery.
- Prepare contingency funds and subsidy programs for WSS assets that are critical for building system resilience and inclusive communities.

- Ensure there is a clear legal structure or entity responsible for coordination and enforcement of provisions for DRM in order to integrate DRM measures in utility operations management.

Systems Planning

- Develop a WSS system master plan for building resilience of WSS systems in accordance with a citywide master plan.
- Create system redundancy to increase availability and reliability of safe drinking water after disasters.
- "Build back better" by incorporating lessons learned from natural disasters into postdisaster reconstruction plans.

Engineering Designs and Materials

- Plan and prioritize reinforcement of WSS assets based on the risk assessment for critical infrastructure.
- Internalize DRM investments as part of regular maintenance works given the limited budgets.
- Conduct iterative planning to optimize stormwater drainage capacity and protect against high impact of recurrent flooding.
- Design topography-oriented sewer networks to continue effective treatment when pump stations are damaged from a natural hazard.

Asset Management

- Integrate DRM into a system of improved asset management that allows for the continuous review and re-evaluation of the system performance, investment plans, financial plans, investments prioritization, and maintenance decision making.
- Integrate DRM into daily O&M to enable timely identification of vulnerable assets and implementation of preventive measures.
- Develop a geographic information system (GIS) database of assets to enable visualization, efficient risk estimation, and construction planning.
- Develop efficient water distribution management systems to effectively control water quality and leakage and to function as effective early warning systems that can inform emergency response needs and contingency planning.

Contingency Programming

- Develop and institutionalize business continuity management (BCM) and business continuity planning (BCP) to maintain and quickly restore essential WSS services.
- Incorporate business continuity into water safety planning and develop an emergency operations manual for water treatment plants and headquarters operations.
- Store materials and equipment required for restoring water supply in critical municipal buildings and functions.
- Mutually reinforce and integrate a BCP and asset management system.
- Prepare mutual aid agreements and framework contracts with external entities for timely emergency response and recovery.
- Prepare plans and protocols to efficiently receive external assistance as part of BCM and BCP.
- Build early warning and emergency water storage systems to secure distribution of water via pipelines to complement emergency water tanker trucks.
- Train the local communities and facilitate community-driven emergency water supply.
- Establish an emergency communication system to disseminate disaster-related information to the public in a timely manner through use of media and hotlines.

01

Introduction

1.1 Background

Natural disasters such as earthquakes, floods, cyclones, and landslides could physically damage water supply and sanitation (WSS) facilities and suspend operations because of emergencies such as inundation of facilities, sedimentation of reservoirs, and loss of electricity. These WSS service failures or interruptions could set off a cascading effect across interconnected infrastructure systems including public health and fire services, which in turn could pose both direct and indirect economic impacts. Although more investment is urgently needed to improve basic water and sanitation access in low- and middle-income countries (LMICs), maintaining or enhancing the disaster resilience of both new and existing (particularly aging) infrastructure—especially in the context of climate change and variability—is also critical for sustainable development.

In Japan, earthquakes have been among the most damaging and frequent natural disasters. Hence, regulatory pressure on disaster risk management (DRM) for water and sanitation utilities is mostly focused on seismic risk mitigation and response. In addition, attention to extreme precipitation events is on the rise because of their increasing frequency and intensity in recent years under conditions of changing climate and variability. For example, recent natural disasters that affected the utilities in Japan include the following:

- In 1978 and 1994, Fukuoka City experienced severe droughts that necessitated water rationing for approximately 300 days each.
- The 1995 Hanshin-Awaji Earthquake (magnitude 7.3) took the lives of 4,571 people and severely damaged the infrastructure; it took 10 weeks to restore piped water supply.
- The 2011 Great East Japan Earthquake (GEJE) of magnitude 9.0 led to a loss of water access among up to 500,000 residents in Sendai City, and the city's primary wastewater treatment plant was completely submerged by tsunami.
- The GEJE had a seismic intensity at the upper-5 level in Tokyo, and led to a temporary service disruption to 42,000 residents. 12 kilometers of sewerage pipelines were adversely affected by cracks and sand clogging owing to earthquake-induced soil liquefaction.
- Multiple precipitation-induced landslides in 2014 in Hiroshima City extensively damaged the water distribution networks and other facilities, causing approximately 3,500 households to lose access to water.
- In 2016, two earthquakes of magnitudes 6.5 and 7.3 caused all residents in Kumamoto City (up to 326,000 households) to lose access to water.

Annex 1 comprehensively lists major earthquakes and extreme rain and inundation events since 1995 and their impacts on WSS services.

1.2 Objective of the Report

The objective of this report is to share an overarching policy framework on resilient WSS services in Japan as well as best practices and lessons learned from urban utilities in terms of managing natural disaster risks and impacts (such as from earthquakes, floods, drought, extreme rains, and landslides). The case studies of six urban WSS utilities provide concrete examples of how the utilities have enhanced resilience of their services through a range of structural and nonstructural measures as well as lessons learned from recent natural disasters experienced by the utilities. The target audience of this report includes WSS utilities and the associated ministries in LMICs that plan to mainstream DRM into WSS services.

1.3 Case Study Selection

To present recent as well as representative DRM practices in Japan, the report showcases six urban utilities that have been affected by large natural disasters since the 1970s and have been enhancing their disaster preparedness: Fukuoka, Hiroshima, Kobe, Kumamoto, Sendai, and Tokyo. Table 1.2 summarizes the basics about the utilities in terms of service coverage and non-revenue water (NRW) levels (the difference between the volume of water put into a water distribution system and the volume that is billed to customers).

Notably, although Tokyo has not been severely affected by a natural disaster in recent years, this report explores Tokyo's long-term planning to enhance resilience and sustainability of its WSS services while maintaining significantly low NRW for a population exceeding 13 million.

Table 1.2 Overview of WSS Utilities for Case Studies, FY2014

City	Water and sanitation utility	Population served (millions) and coverage (%)	Share of non-revenue water (%)
Fukuoka City	Fukuoka City Waterworks Bureau Fukuoka City Road and Sewerage Bureau	Water: 1.48 (99.4%) Sanitation: 1.48 (99.6%)	3.8
Hiroshima City	Hiroshima City Waterworks Bureau	Water: 1.22 (97.6%)	6.9
Kobe City	Kobe City Waterworks Bureau	Water: 1.53 (99.8%)	7.4
Kumamoto City	Kumamoto City Waterworks and Sewerage Bureau	Water: 0.69 (94.3%) Sanitation: 0.65 (87.9%)	10.3
Sendai City	Sendai City Waterworks Bureau Sendai City Construction Bureau	Water: 1.05 (99.6%) Sanitation: 1.03 (97.6%)	5.8
Tokyo Metropolis	Tokyo Metropolitan Government Bureau of Waterworks Tokyo Metropolitan Government Bureau of Sewerage	Water: 13.09 (100%) Sanitation: 9.13 (99.9%)	4.1

Source: MIC 2015.
Note: WSS = water supply and sanitation. "Sanitation" means piped sewer service. "Non-revenue water" (NRW) refers to the difference between the volume of water put into a water distribution system and the volume that is billed to customers.

1.4 Organization of the Report

The rest of the report is structured as follows:

- *Chapter 2, "Legal and Institutional Frameworks for Resilient Water Supply and Sanitation Services in Japan,"* presents DRM- and WSS-related laws and regulations pertaining to the four stages of infrastructure life cycle: systems planning, engineering design and materials, asset management, and contingency programming.
- *Chapter 3, "Best Practices and Lessons Learned from Urban WSS Utilities,"* presents case studies of six WSS utilities, summarizing the most recent natural disasters they have experienced, best practices, and lessons learned.
- *Chapter 4, "Recommendations for Policy Makers and Utilities,"* summarizes the policy implications of the case study findings and provides recommendations for policy makers and utilities to mainstream DRM into WSS services.

References

MIC (Ministry of Internal Affairs and Communications), 2015. "2014–15 Yearbook of Local Public Enterprises." [In Japanese.] Statistical data, MIC, Tokyo. http://www.soumu.go.jp/main_sosiki/c-zaisei/kouei26/index.html.

02

Legal and Institutional Frameworks for Resilient Water Supply and Sanitation Services in Japan

2.1 Overview

Based on the 1961 Disaster Countermeasures Basic Act, water supply and sanitation (WSS) utilities in Japan develop and implement disaster risk management (DRM) planning and measures, which are iteratively improved based on lessons learned from the past natural disasters. As a guide to design, construct, and operate WSS systems in accordance with the laws, the Japan Water Works Association (JWWA) and the Japan Sewage Works Association (JSWA) develop guidelines and establish a mutual support network of member utilities in case of disasters. Given the aging infrastructure and limited financial resources, the utilities have improved asset management practices to extend the lifetime of assets and to enhance resilience. Also, to help utilities prepare for or recover from disasters, the Japanese central government provides a range of subsidy programs.

This chapter presents an overview of legal and institutional frameworks that underpin resilient WSS practices implemented by the Japanese utilities as presented in chapter 3.

2.2 Historical Development of Water Supply and Sanitation Services in Japan

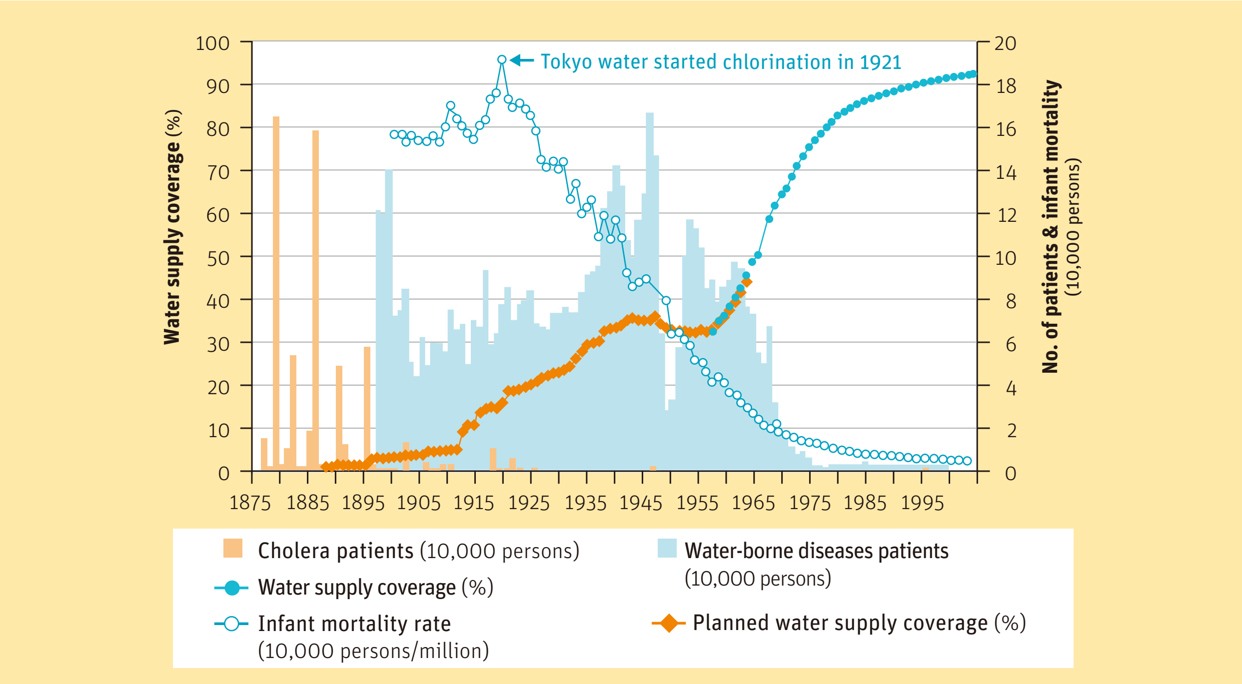
In the late 1800s, increasing trade with foreign countries led to waterborne disease epidemics in Japan. The patients of cholera, typhus, and other diseases numbered approximately 410,000 from 1868 to 1888. To ameliorate the situation, authorities started building pressurized water supply systems, first at major port cities and large cities that were particularly vulnerable to outbreaks. The first water supply system was built in 1887 in Yokohama City, followed by Hakodate City (1889), Nagasaki City (1891), Osaka City (1895), Tokyo (1898), Hiroshima City (1899), Kobe City (1900), and later across Japan.

Japan's piped water supply coverage increased from 26 percent in 1950 to approximately 98 percent in 2015,[1] while wastewater services increased from 6 percent in 1961 (Jagannathan, Mohamed, and Kremer 2009) to approximately 90 percent in 2016.[2] As water supply coverage expanded, waterborne diseases and infant mortality have dropped dramatically to almost nil (figure 2.1).

1 Water supply coverage data from Ministry of Health, Labour and Welfare (MHLW): http://www.mhlw.go.jp/file/06-Seisakujouhou-10900000-Kenkoukyoku/0000164506.pdf.

2 Wastewater service coverage data since 1995 from Ministry of Land, Infrastructure, Transport and Tourism (MLIT): http://www.mlit.go.jp/common/001197825.pdf.

Figure 2.1 Urban Water Supply Trends and Benefits in Japan, 1875–1995



Source: Jagannathan, Mohamed, and Kremer 2009.

In line with the country's population and economic growth after World War II, the annual domestic and commercial water consumption in Japan almost tripled, from 4.2 billion cubic meters in 1965 to 14.4 billion cubic meters in 2000 (excluding industrial and agricultural water use). In turn, the rapidly increasing water consumption led to further water resources development, water conservation efforts, and water loss management by the utilities. As a result, the non-revenue water (NRW) ratio decreased gradually, with the national average reaching 10.2 percent as of 2014 (JWRC 2016).

2.3 Overarching Legislation and Key Institutions

Almost all WSS services in Japan are operated by public utilities. At the national level, the Ministry of Health, Labour and Welfare (MHLW) is responsible for developing national policies for water supply, and the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) is responsible for sewerage. As the administrative agencies of the Waterworks Act and the Sewerage Act, respectively, both ministries issue various ministerial ordinances and notices based on the Acts.

Each time a major disaster has occurred, the Japanese government iteratively developed or amended laws and regulations based on the experiences and lessons learned. One of the fundamental DRM-related laws is the 1961 Disaster Countermeasures Basic Act, which was enacted after a 1959 typhoon ravaged Ise Bay (between Mie and Aichi prefectures), claiming approximately 4,700 lives.

The Disaster Countermeasures Basic Act stipulates provisions to address all phases of DRM: risk identification, risk reduction, preparedness, response, and recovery. It also mandates that the national, prefectural, and municipal governments develop disaster management plans. Other laws are specific to various hazards including earthquake, tsunami, flood, and sediment disaster. These DRM laws, the Waterworks Act, and the Sewerage Act complement one another to increase the preparedness and resilience of Japan's WSS services against natural disasters and climate variability.

Table 2.1 shows the scope of some of the key legislation and national financial assistance programs and laws per disaster type and DRM phase (risk identification, risk reduction, preparedness, emergency response, and recovery). Annex 2 summarizes the relevant laws and notices.

Table 2.1 Overview of Primary WSS and DRM Legislation in Japan since 1949, by Disaster Type and DRM Phase

<table>
<tr><th></th><th>Risk Identification, Reduction, and Preparedness</th><th>Emergency Response</th><th>Resilient Recovery</th></tr>
<tr><td rowspan="5">Fundamental WSS and DRM Legislation</td><td colspan="3">City Planning Act</td></tr>
<tr><td colspan="3">Disaster Countermeasures Basic Act</td></tr>
<tr><td colspan="2">Waterworks Act</td><td>Extremely Severe Disasters Act</td></tr>
<tr><td colspan="2">Sewerage Act</td><td>National Financial Assistance Program for Disaster Affected Water Supply Facilities (MHLW)</td></tr>
<tr><td></td><td></td><td>Act on National Treasury’s Sharing of Expenses for Project to Recover Public Works Damaged by Disaster (MLIT)</td></tr>
<tr><td rowspan="3">Earthquake & Tsunami</td><td colspan="3">Act on Special Measures Concerning Countermeasures for Large-Scale Earthquakes</td></tr>
<tr><td>Act on Special Measures for Earthquake Disaster Countermeasures</td><td></td><td></td></tr>
<tr><td colspan="3">Act on Promotion of Tsunami Countermeasures</td></tr>
<tr><td rowspan="3">Floods</td><td>River Act</td><td></td><td></td></tr>
<tr><td>Flood Control Act</td><td></td><td></td></tr>
<tr><td>Specified Urban River Inundation Countermeasures Act</td><td></td><td></td></tr>
<tr><td>Landslides</td><td>Sediment Disaster Prevention Act</td><td></td><td></td></tr>
</table>

Source: Cabinet Office 2011.
Note: DRM = disaster risk management. WSS = water supply and sanitation. MHLW = Ministry of Health, Labour, and Welfare. MLIT = Ministry of Land, Infrastructure, Transport, and Tourism.

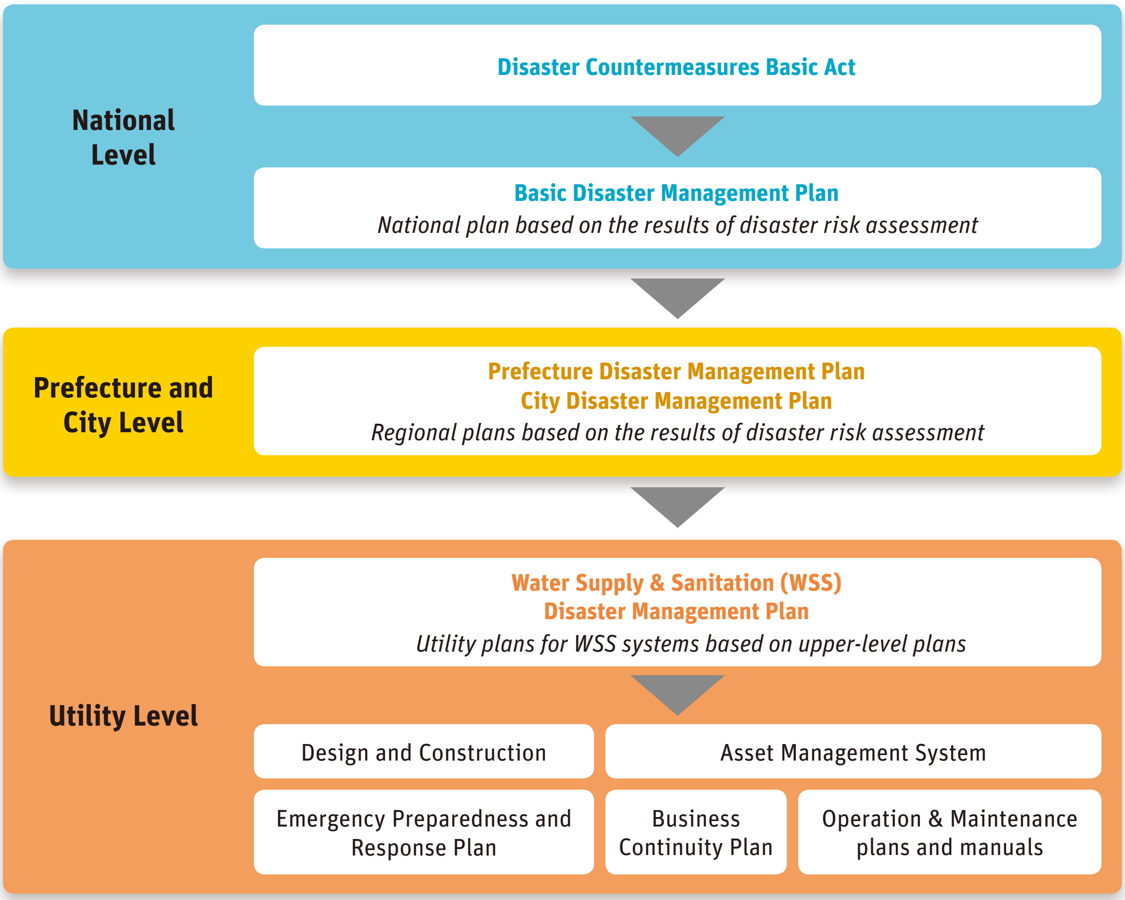
2.4 Systems Planning

WSS services in Japan are regulated by the 1957 Waterworks Act and the 1958 Sewerage Act. Together, these Acts provide for all aspects of WSS services, including an approval process for starting the service, performance criteria for facilities, water quality standards, and the structure of service management. If infrastructure works are planned in the designated urban areas, utilities design infrastructure in accordance with the 1968 City Planning Act.

In compliance with the Disaster Countermeasures Basic Act (1961) and its associated Basic Disaster Management Plan (developed also at the national level), all 47 prefectures in Japan have developed prefectural disaster management plans (figure 2.2). In most cases, the prefectural plans are translated into municipal disaster management plans by municipalities to further adapt to local conditions. The plans at all administrative levels are revised as necessary to reflect lessons learned from major natural disasters. Such revisions are usually made in a cascading manner, starting at the national level and ending at the municipal level.

In the municipal disaster management plans, each municipality's relevant DRM department analyzes local hydrometeorological and geotechnical conditions and historical records to assess the municipality's natural disaster risks, including earthquakes, floods, cyclones, landslides, and volcanic eruptions. When developing and revising WSS emergency preparedness and response plans, WSS utilities use the municipality's analysis as a basis for related policy development (for example, emergency operation procedures and business continuity planning) as well as for planning future investment (such as for design and construction of infrastructure, taking into account the site-specific conditions).

Figure 2.2 Development of Disaster Management Plans at National and Local Levels



2.5 Engineering Design and Materials for Resilience

2.5.1 Water Supply

Legislation for Resilient Design

Article 5 of the Waterworks Act specifies the following performance criteria for water supply facilities: "The structure and materials adopted for constructing water supply facilities shall resist the water pressure, earth pressure, seismic forces and other types of external loads, and minimize water pollution or leakage."

Key ministerial ordinances related to designs of the water supply assets include MHLW's 2000 Ministerial Ordinance for Technical Standards of Water Supply Facilities. The objectives were to (a) provide more concrete performance criteria than those of the 1957 Waterworks Act, (b) promote appropriate measures at utilities to increase water supply safety and reliability, and (c) establish criteria for facilities' performance against natural hazards.

In 2008, the ordinance was amended to further clarify the performance criteria required of water supply facilities against earthquakes because most water supply facilities had not been seismically retrofitted (Yamamura 2008). Key amendments included an introduction of Level 1 and Level 2 Earthquake Ground Motion concepts. Level 1 Earthquake Ground Motion refers to earthquake(s) likely to occur at the site of the facility within the lifetime of that facility. Level 2 Earthquake Ground Motion refers to the largest earthquake(s) that could occur at the site of the facility beyond its lifetime. The amendment required to design (Yamamura 2008):

- The primary water supply facilities (such as transmission pipelines, water treatment plants, and primary distribution pipelines) to function properly upon Level 1 Earthquake Ground Motion as well as to survive Level 2 Ground Motion with minor damage and without getting critically affected; and
- The nonprimary facilities (such as smaller distribution pipelines connected directly to service pipes) to survive Level 1 Ground Motion with minor damage and without getting critically affected.

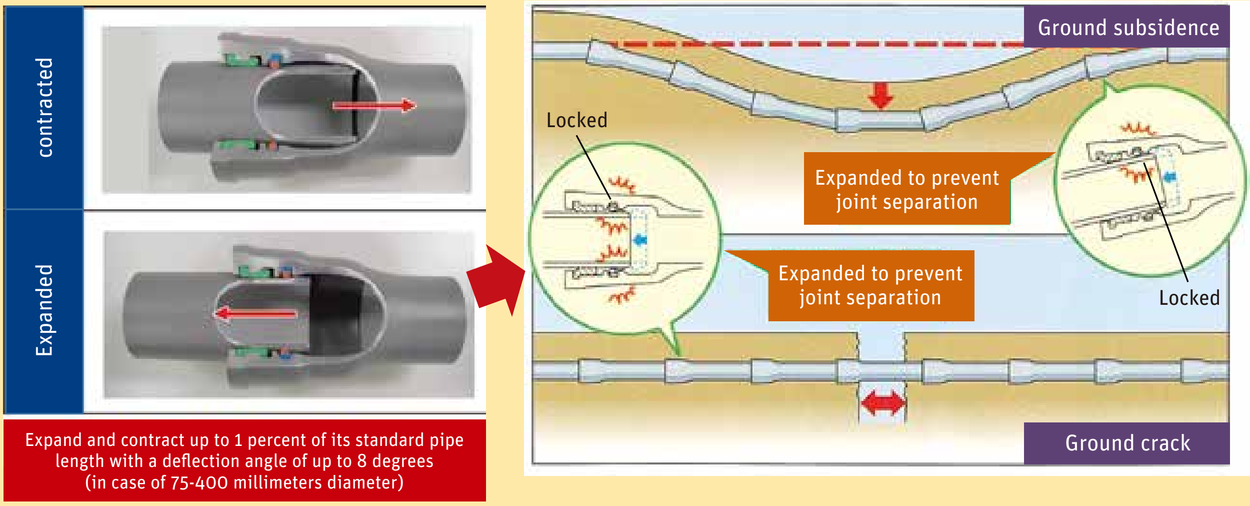
MHLW recommends that utilities implement appropriate seismic retrofitting at the time of renewal or replacement, including installation of earthquake-resistant pipes (box 2.1). The timing of retrofitting is determined by utilities depending on the age and criticality of facilities.

Box 2.1 Earthquake-Resistant Ductile Iron Pipe (ERDIP)

Because large earthquakes have been among the most damaging and frequent natural disasters for water supply services in Japan, the pipe manufacturing industry has continuously enhanced pipe resistance against seismic forces. The first earthquake-resistant pipe was developed in 1974 as a lesson learned from devastating 1968 Tokachi-Oki Earthquake (magnitude 8.2) that extensively damaged northern Japan.

The most common earthquake-resistant pipe is ductile iron pipe (DIP) equipped with a joint locking mechanism. Commonly known as earthquake-resistant ductile iron pipe (ERDIP), it has a unique segmented design that can endure the pressure of large ground displacement caused by natural hazards such as earthquakes and landslides (figure B2.1). The joint locking design enables the pipes to expand and contract up to 1 percent of their standard length, with a deflection angle of up to 8 degrees, to fully absorb ground displacement associated with an earthquake. When a joint lock is triggered, the pipe mobilizes the connecting pipe like a chain, allowing the pipes to move with ground motion to prevent it from breakage.

Figure B2.1 **Properties of Earthquake-Resistant Joint Ductile Iron Pipe**



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Before the 1995 Great Hanshin-Awaji Earthquake, the use of ERDIP was mostly limited to areas with vulnerable ground conditions (such as liquefaction or reclaimed land). The large utilities in Japan increasingly adopted ERDIP as a lesson learned from the 1995 earthquake, which had damaged all kinds of pipes in the affected municipalities except ERDIP that remained completely intact. As of April 2017, ERDIPs have not undergone any damage from the major earthquakes in Japan, including the 2011 Great East Japan Earthquake (magnitude 9.0)[3] and the 2016 Kumamoto Earthquake (magnitude 7.0).[4] A simulation analysis shows that ERDIP can maintain its resistance even to multiple consecutive earthquakes (JDPA 2014). ERDIP also has resistance to landslides and fire induced by earthquake.

Although ERDIP is the most common earthquake-resistant pipe, other types of earthquake-resistant pipes are also currently in service. Among the most representative are steel pipes with welded joints, which underwent relatively less damage in the major historical earthquakes. ERDIP and steel pipe with a welded joint are considered more resistant to earthquakes than other types of pipes based on the damage assessment (MHLW 2014c). Organizations such as Japanese Industrial Standards, JWWA, and JSWA establish performance standards and specifications of earthquake-resistant pipes.

Although the Waterworks Act and the associated ministerial ordinances determine the performance criteria required for water supply facilities, they do not stipulate how to meet the criteria. Therefore, to help utilities design and construct water supply systems in accordance with the performance criteria, the JWWA developed "Guidelines for Designing the Water Supply System," which is almost universally adopted by the utilities in Japan (JWWA 2000). Although aimed for the water supply system in general, the guidelines incorporate a DRM element (for example, development of multiple water sources and network redundancy including a backup water supply capacity).

3 "Questions on Ductile Iron Pipes." [In Japanese.] JDIPA (Japan Ductile Iron Pipe Association) website: http://www.jdpa.gr.jp/q_sonota.htm#1.

4 "Views on the Leakage of NS-type Pipe in the Kumamoto Earthquake." [In Japanese.] JDIPA website: http://www.jdpa.gr.jp/sp/kumamotojisin.html.

2.5.2 Sanitation Services

Legislation for Resilient Design

Article 5 of MLIT's Enforcement Order of the Sewerage Act mandates that the structural design of drainage and wastewater treatment plants (WwTP) be robust and durable. It also specifies necessary measures to prevent or minimize damage from earthquakes, including improvement of ground conditions and installation of flexible pipe joints. In 2005, MLIT issued Notification No. 1291, introducing the concept of Level 1 and Level 2 Earthquake Ground Motion for sanitation facilities. The Notification requires critical drainage and WwTPs to perform as follows in the event of earthquakes:

- Level 1 Ground Motion - ensure the stability of the required structure, and to ensure the sound drainage and treatment functions; and
- Level 2 Ground Motion - sustain only minor damage, and capable of restoring the drainage and treatment functions quickly after the earthquake as well as maintain the expected drainage and treatment functions.

To help utilities design and construct sanitation systems in accordance with the national performance criteria, the JSWA developed the "Guidelines for Designing the Sanitation System," which is almost universally adopted by sanitation utilities in Japan (JSWA 2009).

Also, in the contexts of increasing hydrometeorlogical risks, MLIT periodically reviews and amends the Sewage Act (box 2.2).

Box 2.2 Iterative Amendment of the Sewage Act in the contexts of Changing Climate and Variability

In the contexts of increasing hydrometeorlogical risks, Article 25 of the Sewage Act was updated in 2015 to enable the sanitation utilities to cooperate with private entities to increase their stormwater storage capacity.

By local ordinance, the municipalities can designate a part of their administrative area as an "inundation countermeasure zone" if a high level of urbanization or development in the area makes it difficult for the utility to install public sewers on public land despite potential inundation risks. In the designated zones, utilities can specify private entities such as building owners to install underground storage facilities on private land and contract with them to allow the utility to manage those facilities. The management contract can be made for storage facilities of 100 cubic meters or greater[5] that are either existing, under construction, or planned for construction. Stored water is drained to public sewers when a risk of inundation diminishes—after the rain stops, for instance.

A central government subsidy program is available to cover up to 30 percent of the cost for private entities to install underground storage facilities (MLIT 2015a).

5 Utilities can include storage facilities of less than 100 cubic meters by local ordinance if they consider it necessary, taking into account the local conditions.

2.6 Asset Management for Resilient Water Supply and Sanitation Services

The objectives of asset management (AM) are to assess and efficiently maximize the value of the assets through timely interventions including inspection, repair, and replacement. Integrating DRM into an AM system helps utilities enhance resilience of a WSS system and develop a targeted emergency preparedness and response plan based on a disaster risk profile of assets. It is important to internalize the costs of potential damage from a natural disaster into life-cycle costs and establish a risk-informed investment decision-making process. Identifying critical assets in the WSS system helps to evaluate the level of function of the WSS system as a whole and help prioritize targeted investments. During the emergency response and recovery phases, a geographic information system (GIS) developed as part of AM system can help utilities effectively and quickly identify and restore damaged pipelines and other assets.

2.6.1 Water Supply

Water Supply Vision and Asset Management

Most of the water supply systems in Japan were constructed in the 1960s to 1970s, and a vast majority of old assets require replacement, posing a challenge for many utilities, especially small utilities with limited financial resources. As the budget for water supply infrastructure investments has declined, MHLW estimated in 2008 that if the investment continued to decline by 1 percent from each preceding year, the demand for replacement would catch up with an annual budget by 2025 and exceed it afterward, making it even more difficult for small utilities to replace the old assets. In addition, a budget constraint for utilities is expected to be exacerbated owing to a shrinking population in Japan, which is forecasted to drop to 90 million in 2055 from the current 125 million. Because water supply utilities are required by law to recover operation and maintenance (O&M) costs from water tariffs, the population decline leads to a shrinking customer base and decreasing service revenue.

To maximize resource efficiency and return on investments, taking into account the future financial constraints, MHLW revised a national Water Supply Vision in 2008 and emphasized the importance of AM. Also, MHLW requires the utilities to inspect not only structural soundness of each facility but also its functional soundness (for example, quality of supplied water). To minimize the potential impacts from a disaster, utilities develop an ordinary and emergency inspection checklist based on the MHLW's guideline (MHLW 2011). For example, Hiroshima City Waterworks Bureau has developed emergency inspection checklists, taking into account the aging water supply assets.

To promote effective daily management of assets, JWWA developed "Guidelines for Operation and Maintenance of Water Supply Systems," which are widely adopted by utilities in Japan (JWWA 2016).

Financial Arrangements

The O&M budget for water supply utilities comes from a tariff charged to consumers. Given the utilities' limited budgets, they have internalized structural and nonstructural DRM practices into their regular O&M works. For example, the utilities take the opportunity to replace aged pipes to also install earthquake-resistant pipes. In addition, MHLW provides a subsidy program for utilities to replace, rehabilitate, or upgrade emergency water supply facilities and pipelines. To benefit from the program, applicant utilities must meet specific conditions (table 2.2).

Table 2.2 MHLW Subsidy Program for Water Supply Infrastructure Upgrades

Works eligible for subsidy	Subsidy rate
Emergency water supply facilities	
Distribution reservoir: Development of a distribution reservoir whose storage capacity is more than 10 hours of the planned maximum water supply volume per day	1/3–1/4
Backup water pipeline: Construction of pipelines to connect with different water sources to share water supply among wide regions, between local water utilities, or within a water utility	
Storage facilities: Construction of a transmission or distribution pipeline with emergency water storage capacity	
Emergency shutoff valve: Installation of shutoff valves to prevent water leakage from distribution reservoirs and other relevant facilities	
Large-capacity transmission pipeline: Construction of a large-capacity transmission pipeline with a water storage facility that can provide emergency water supply for approximately 10 days in the service area	
Distribution pipeline for high-priority facilities: Construction of earthquake-resistant distribution pipelines for water supply to critical facilities such as hospitals, shelters (for example, schools), and disaster management bases (for example, public parks)	
Seismic countermeasures for primary building structures: Reinforcement, retrofitting, or replacement of primary building structures for water supply such as intake and transmission facilities, distribution reservoirs, and WTPs, which need to be highly resistant to earthquakes	
Seismic retrofitting of water supply pipelines	
Replacement of aged pipes	1/3–1/4
Pipe modernization work: replacement of aged pipes to adopt direct water supply	1/3
Replacement of transmission, conveyance, and distribution pipelines made of lead	1/3
Seismic retrofitting of distribution pipelines	1/2

Source: Adapted from MHLW 2014a. Translation by Japan Water Research Center.
Note: MHLW = Ministry of Health, Labour and Welfare. WTP = water treatment plant. In addition to the criteria described in the table, a successful applicant must meet other criteria such as the size of the population served, financial status, and others.

2.6.2 Sanitation Services

Sewage Vision and Asset Management

In 2015, the sanitation service coverage (people with access to the centralized sewer system divided by total population) in Japan reached 77 percent of the population, and the sewage pipelines stretch approximately 460,000 kilometers while the WwTPs total 2,200. With this vast infrastructure now deteriorating from age, the O&M costs and needs for replacement are expected to significantly increase soon. Without proper O&M and replacement, risks of decreased system performance, malfunctioning, and road collapses associated with corroded pipe failures would increase. Today, approximately 4,000 road collapses occur every year, and only 20 percent of the utilities regularly inspect sewer pipes. Utilities also face budget constraints owing to internal and external pressures to minimize expenditures.

Given an increasing importance of planned maintenance of aging infrastructure assets in Japan, MLIT revised in 2014 a national Sewage Vision to promote AM implementation in the sanitation sector. In 2015, the Sewage Act was revised to:

- Incorporate new provisions on inspection and maintenance of sewer pipelines, requiring the utilities (through a related ministerial order) to inspect the pipelines at risk of corrosion at least every five years;
- Clarify the frequency and methods of pipeline inspection in their service management plans; and
- Develop mid- to long-term policies regarding construction and maintenance of pipelines.

Key challenges to implementing an AM system in the sanitation sector are summarized in box 2.3.

Box 2.3 Structural Challenges to Implementing an Asset Management System in the Sanitation Sector

Due to the following challenges, minimizing the total cost and synchronizing the timing of inspections and repairs for multiple subfacilities are required for efficient sanitation AM system (Hori, Kaito, and Kobyashi 2009):

- The sanitation sector is a systematic facility consisting of serial and parallel subfacilities: for example, pipe and culvert, pump station, plant, and so on.
- Suspension of subfacilities is needed to inspect and repair another subfacility. However, suspension of one subfacility causes suspension of the entire sanitation sector (that is, redundancy of the sanitation sector is not assured).
- Each unit of each subfacility has different durability, and deterioration mechanisms of a number of subfacilities are difficult to be clarified.

To help implement the amended Sewage Act, MLIT published “Guideline on Stock Management for Sewage Services” in 2015. The objective of the guideline is to help sanitation utilities optimize the long-term facility management through inspections, repair, and replacement of facilities based on their age and evaluations of associated risks (MLIT 2015a). To develop and prioritize risk-informed investments, MLIT requires data collection for defining each facility’s degree of influence by taking into account transfer routes, evacuation routes, and locations of evacuation shelters. In addition, to promote effective daily management of assets, JSWA developed the “Guidelines for Operation and Maintenance of Sanitation Systems,” which are widely adopted by utilities in Japan (JSWA 2014).

In addition, it is recommended that financial and human resource management be conducted in accordance with the ISO 55000:2014 standards for AM. As discussed in chapter 3, Sendai City’s Construction Bureau became the first ISO55001-certified sanitation utility in Japan in 2014.

Financial Arrangements

The sanitation utilities in Japan collect a tariff from consumers to recover the cost of sewage management, and they receive a municipal budget for stormwater collection and drainage because of its public nature. In addition, MLIT implements a subsidy program for utilities to develop or upgrade related facilities based on their needs. To benefit from the program, applicant utilities must meet specific conditions (table 2.3).

Table 2.3 MLIT Subsidy Program for Wastewater Infrastructure Upgrades

Type of work	Work eligible for national subsidy	Subsidized ratio
Inundation countermeasures	Development of the following facilities in the districts that have been inundated in the past and have a high need for anti-inundation measures: (a) *Stormwater storage and drainage facilities* of sewerage coverage ranging from 0.1 to over 1.0 hectares depending on the population of the municipality (b) *Rainwater infiltration facilities* that are economical and have comparable functions to (a) above (c) *Installation of permeable pavement* in the road surface upon a sewer construction (d) *Information provision facilities* to provide data on rainfall and stormwater discharge in real time to residents in areas of possible flooding	1/2
	(e) *Sewer facilities* with rainwater storage and infiltration functions	1/3
Earthquake resistance enhancement	Implementation or development of the following projects or facilities in areas with a high need for earthquake countermeasures (for example, cities with largely populated areas): • *Seismic retrofitting of pipelines from WwTPs* to disaster prevention bases, evacuation sites, and care facilities for elderly and persons with disabilities • *Seismic retrofitting of buried pipelines* beneath emergency transportation routes, evacuation routes, railways, and rivers • *Seismic retrofitting of stormwater storage and drainage facilities* near disaster prevention bases, evacuation areas, and care facilities for elderly and persons with disabilities • *Seismic retrofitting of pipelines in the urban areas* designated under the Urban Reformation Special Measures Act as well as the pipelines connecting these areas with WwTPs • *Installation of manhole toilet systems* at disaster prevention bases or evacuation sites	1/2

Source: MLIT 2017a, 2017b. Translation by Japan Water Research Center.
Note: MLIT = Ministry of Land, Infrastructure, Transport and Tourism. WwTP = wastewater treatment plant. Table shows only selected items and eligibility criteria.

2.7 Contingency Programming

2.7.1 Emergency Preparedness and Response Planning

The most important emergency preparedness and response plan (EPRP) at the municipal level is the municipal disaster management plan, developed under the Disaster Countermeasures Basic Act. The plan provides an overall framework for the municipality to deal with various types of disasters. In line with the municipal disaster management plan, WSS utilities formulate either their own EPRPs and standard operation procedures or more general service management plans incorporating DRM aspects.

A range of guidelines are available as a reference for the utilities to formulate their own crisis management manuals (box 2.4).

Box 2.4 Utility's Guidelines for Emergency Preparedness and Response Planning

Below is a list of the guidelines (in Japanese) currently available on the MHLW website:[6]

- Earthquake countermeasures
- Measures against wind and flood damage
- Measures against water pollution accidents
- Facility accident and power outage countermeasures
- Countermeasures against freezing accidents of pipelines and water supply equipment
- Counterterrorism measures
- Measures against drought
- Formulation of mutual assistance agreements for emergencies

Regarding sanitation services, the *Handbook to Develop Crisis Management Manual for Sewerage Services* (JSWA 2007) describes common approaches and preparations necessary to deal with all types of crises, including natural disasters and terrorism. Because the guidelines are not designed for specific types of disasters such as earthquake, it lists reference materials on seismic disaster management, water quality incidents, and so forth that are published by various organizations. In developing local manuals based on the guidelines and these references, utilities take into account their own service populations and other local conditions.

Rapid inspection and early repair works are crucial for recovering water supply services in the aftermath of a disaster. During the early emergency response period, water supply utilities normally check water leaks from road surfaces to see whether they contain a residual chlorine. If the result is positive, they dig out the dirt to expose the pipe and fix the leak (presence of chlorine shows the water comes from a water supply pipe, as the Waterworks Act requires a certain amount of residual chlorine to be maintained at the point of customer tap). Chlorine levels are not tested if it is obvious that the leak comes from a water supply pipe (for example, clear water gushing out like a fountain). After early repair works have been made to some degree, utilities switch to inspect wider areas by using leak detectors such as acoustic leak detectors. Because this requires much manpower, it is normally conducted when enough human resources are available (such as with assistance from external entities).

WSS Utility Disaster Simulation Drills

Many WSS utilities carry out disaster simulation drills on either September 1 (National Disaster Prevention Day) or somewhere during the week of August 30 to September 5 (Disaster Prevention Week). For example, in response to mock earthquakes and other threats, utilities mobilize water tanker trucks to practice emergency water provision at designated evacuation sites, exercise damage inspection and repair of WSS pipelines, and train to improve communications among relevant personnel or departments within the utility. Some utilities conduct drills with other utilities in the framework of mutual assistance agreements.

6 "Report on guideline development for crisis management of water supply services," Ministry of Health, Labour and Welfare website: http://www.mhlw.go.jp/topics/bukyoku/kenkou/suido/kikikanri/chosa-0603.html.

2.7.2 Business Continuity Planning

A business continuity plan (BCP) is developed as part of business continuity management (BCM) system to keep the service level above an allowable limit even when an emergency makes it difficult to continue normal service and to restore the operation to a certain level within a permissible period. BCM is highly related to other management systems (for example, AM, accounting, and training programs), and it is important to mutually reinforce and integrate BCM with other management systems for effective implementation.

The difference between a BCP and a conventional EPRP is that a BCP considers the limitations of resources. In formulating a BCP, therefore, utilities need to determine in advance which facilities and functions should have top priority for restoration, by when, and to what extent. Also, it is more efficient to add BCP elements to existing emergency response plans and manuals than to formulate a BCP from scratch. Advance preparation of a mutual assistance framework with external parties is critical for the affected utilities to implement the high-priority tasks upon a disaster.

Considering the limited manpower and time, Japanese utilities have built mutual support networks among utilities and the private sector as part of a BCP. During the 2011 Great East Japan Earthquake, WwTP operators that developed a BCP in advance were able to implement initial emergency response measures more quickly than those without a BCP (JIWET 2012).

Mutual Support Agreement in Coordination with JWWA and JSWA

In many Japanese municipalities, although the crisis management department formulates a mutual support agreement with other municipalities under the municipality-level BCP, utilities also formulate a WSS-specific mutual support framework with other utilities to secure business continuity. Typical emergency support activities include

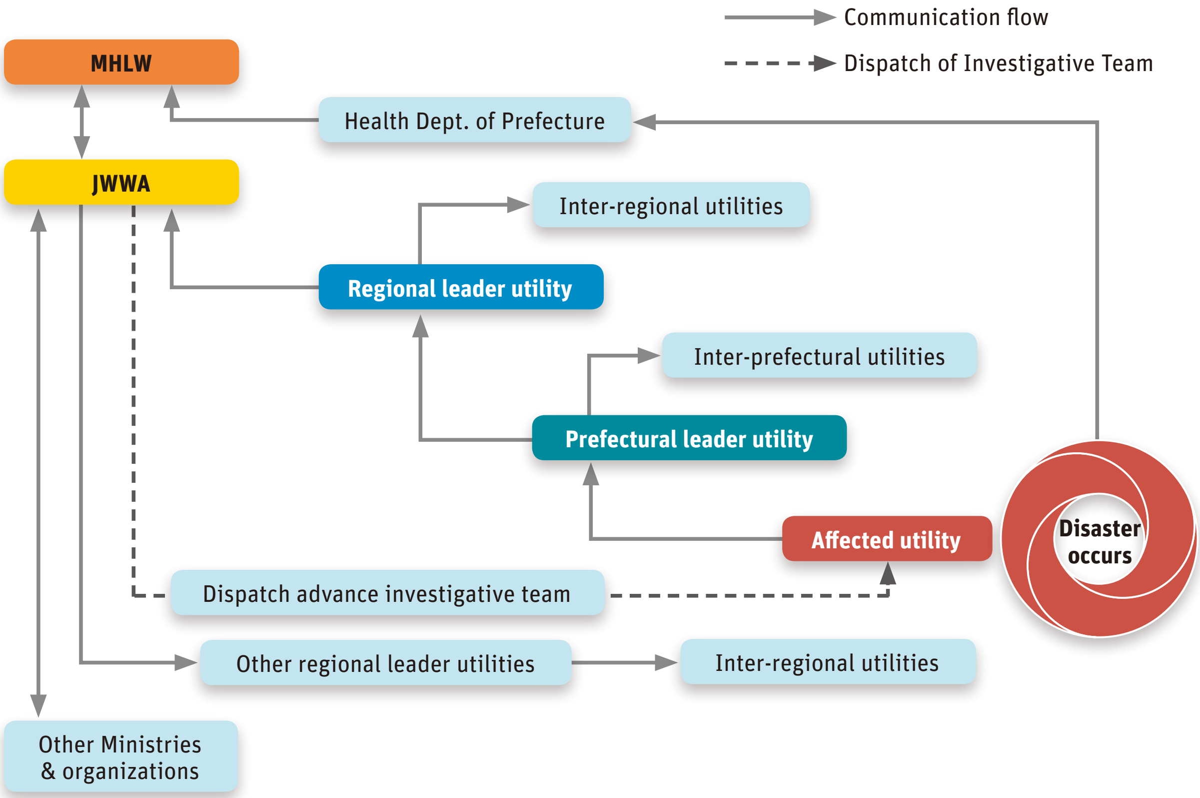
- Dispatch of field engineers to support various emergency response works;
- Provision of various supplies (such as bottled water) and equipment (such as water tanker trucks);
- Investigation of damaged pipes and repair works; and
- Assistance in setting up temporary sanitary facilities at evacuation sites.

Detailed protocols should be prepared in advance by relevant utilities so that such a framework works well during an emergency. Items to be considered include decision-making criteria for requesting external assistance, procedures to request assistance, the scope of assistance, coordination with prefectural governments, and so on. It is recommended that the supporting utilities develop and share a list with partnering utilities, in advance, of the equipment and materials they could provide.

For the recipient utility that requested assistance, it is important to provide a working space, parking lot, and repair materials to the supporting utilities so that their activities can be implemented efficiently. A point of contact within the recipient utility should also be clarified for the supporting utilities to communicate necessary information. Data handling would be easier if the related information could be provided or shared in a common format.

As a framework to support the affected utilities in the event of a natural disaster, JWWA and JSWA manage a network of WSS utilities to coordinate emergency support (JWWA 2013; JSWA 2016). For example, when a disaster strikes and affects the water supply service, the affected water supply utility requests emergency support from the leader utility in its own prefecture (figure 2.3). Upon the request, the prefectural leader evaluates the overall situation and decides whether the situation could be handled by interprefectural coordination with other water supply utilities. If it is deemed difficult to manage the situation within the prefecture, the leader utility contacts the regional leader utility, which normally represents multiple prefectures. If the situation could not be handled by the regional network of utilities, the regional leader could contact JWWA and ask for emergency support from other regions by coordinating with JWWA.

Figure 2.3 **Water Utility Emergency Communication Flow upon Disaster**



Source: Adapted from JWWA 2013. Translation by Japan Water Research Center.
Note: JWWA = Japan Water Works Association. MHLW = Ministry of Health, Labour and Welfare.

A similar mutual support framework exists for the sanitation sector as mentioned in the Sewerage Act. In 2015, the Act was amended to add an article on "Conclusion of Agreements for Maintenance and Repair in Times of Disaster". Based on the amendment, an agreement for support in times of disaster (which includes the agreement for maintenance and repair) was concluded between JSWA and Kawaminami City in Miyazaki Prefecture in December 2015 as the first case in Japan.

Under Article 92 of the Basic Disaster Countermeasures Act, the direct costs associated with external support (such as transportation of staff and materials, food, and daily staff allowances) must be borne by the recipient utility. The associated labor costs of the supporting utilities are borne by the supporting utilities.

Mutual Support Agreement among Utilities

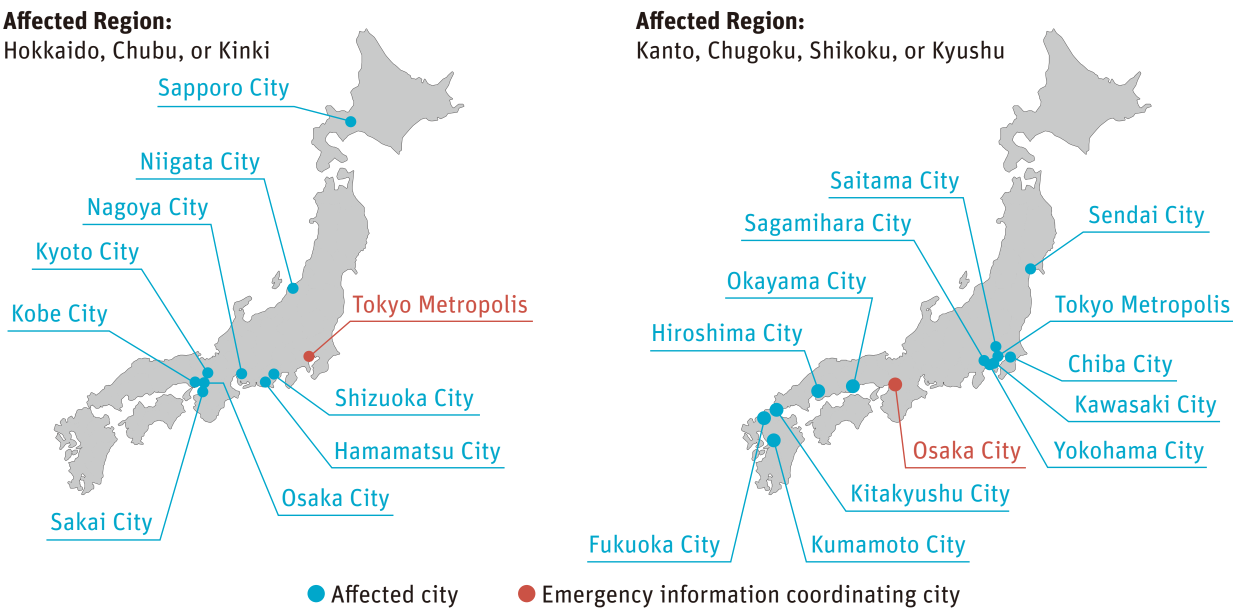
In 2012, 21 large municipalities have established a memorandum of understanding (MoU) for mutual assistance on disaster response.[7] Under the overarching MoU, the utilities also established a WSS-specific MoU that specifies protocols for WSS-related assistance. Because the needs of large utilities would usually be different from those of small utilities given their large customer bases and the complexities of WSS systems, this MoU allows the signed parties to receive the kind of support that is more appropriate to their urban context.

In the case of sanitation utilities, for instance, this MoU is used when either (a) an earthquake of intensity 6 or greater occurs; or (b) an earthquake with a seismic intensity of 5 or smaller or other types of disasters occur and the affected utility requests assistance through the MoU (TMBS 2017).[8]

An emergency operation center is set up in the affected city that requested assistance. If the setup is difficult because of disaster severity, the base is set up in a city near the affected city. To communicate related information in a unified manner and reduce the administrative burden on the affected utility, an emergency information-coordinating city (Tokyo or Osaka, depending on the region affected) is designated upon a disaster (figure 2.4). If Tokyo and Osaka are both affected and cannot play the role, Sapporo City becomes the information coordinating city. As the point of contact, the coordinating city communicates with the affected city regarding assistance and liaises closely with MLIT. Also, an onsite assistance coordinating city is appointed by Tokyo or Osaka from among the assisting cities.

Because these large WSS utilities also belong to the JWWA and JSWA networks for emergency assistance, the MoU specifies the utilities to coordinate with JWWA and JSWA in the event of an emergency.

Figure 2.4 **WSS Utility Disaster Communication and Coordination under the MoU**



Source: Information adapted from Liaison Conference on Postdisaster Support between Large Cities 2017. ©World Bank. Further permission required for reuse.

7 The 21 municipalities are (from the north to the south and west) Sapporo City, Sendai City, Saitama City, Chiba City, Tokyo Metropolitan Government, Kawasaki City, Yokohama City, Sagamihara City, Niigata City, Shizuoka City, Hamamatsu City, Nagoya City, Kyoto City, Osaka City, Sakai City, Kobe City, Okayama City, Hiroshima City, Kitakyushu City, Fukuoka City, and Kumamoto City.

8 "Seismic intensity" is measured on the Japan Meteorological Agency's seismic intensity scale (see http://www.jma.go.jp/jma/en/Activities/inttable.html). Seismic intensity is the value observed at a site where a seismic intensity meter is installed, and it may vary within the same city. The scale ranges from 1 to 7, with 5 and 6 each divided into "lower" and "upper."

As discussed in box 2.5, MLIT provides emergency assistance to municipalities through Technical Emergency Control Force (TEC-FORCE).

Box 2.5 Technical Emergency Control Force

In 2008, MLIT established a Technical Emergency Control Force (TEC-FORCE) to assist the affected municipalities in their emergency response and recovery efforts by implementing various emergency measures, including the following (MLIT 2017c):

- Damage investigations by helicopters
- Dispatch of liaison personnel to municipalities
- On-site damage investigation
- Satellite monitoring of affected areas
- Technical advice to local governments
- Emergency drainage by mobilizing drainage pump vehicles
- Technical advice for search and rescue activities

MLIT had been providing emergency assistance to municipalities before the founding of TEC-FORCE, but it was after a disaster occurred that they organized response teams. The creation of TEC-FORCE enables MLIT to appoint its staff as TEC-FORCE members in advance, so that the appointed staff can provide emergency assistance to municipalities more quickly upon a disaster owing to preparations, periodic trainings, and coordination with relevant parties. As of April 2017, approximately 9,000 people are appointed as TEC-FORCE members (MLIT 2017c), most of whom work for MLIT's regional branches across Japan as well as MLIT's affiliated organizations such as the National Institute for Land and Infrastructure Management (NILIM) and the Public Works Research Institute (PWRI).

Approximately 400 TEC-FORCE members were dispatched to disaster-stricken areas on the day after the Great East Japan Earthquake in 2011. For sanitation, a TEC-FORCE group comprising PWRI and NILIM personnel was dispatched to damaged areas in Miyagi Prefecture a month after the earthquake to conduct on-site damage investigation, interview the utility staff, and provide technical support to local managers of the damaged sanitation systems. For water supply systems, a mutual support network established by JWWA was mainly used to mobilize support teams organized by TMBW from a number of regions in Japan.

Framework Agreement with the Private Sector

Utilities and local engineering and construction companies often establish a framework agreement before a disaster to provide personnel, equipment, materials (such as pipes and valves), and assistance on emergency repair works in case of natural disaster. The companies are typically engaged in regular O&M works and therefore can provide effective, quick response based on their familiarity with the local conditions of WSS assets.

During the 2011 Great East Japan Earthquake, the utilities that established a framework agreement with the private pipe companies were able to inspect and restore the damaged pipes more quickly than those without such a framework agreement (JIWET 2012).

2.8 Contingency Funds for Resilient Recovery

National subsidies are available from both MHLW and MLIT for WSS systems to recover from natural hazards such as typhoons, floods, earthquakes, landslides, and volcanic eruptions. The eligibility criteria depend on the magnitude of hazard, size of utility, and the total cost of rehabilitation works.

2.8.1 Water Supply Services

The water supply utilities are eligible to apply for the MHLW national subsidy for reconstruction of (a) water supply service or water supply facilities administered by the local government; and (b) facilities for water intake, storage, conveyance, transmission, treatment, and distribution (table 2.4).

Table 2.4 **MHLW Subsidy Program for Reconstruction of Water Supply Services**

Eligibility criteria	Subsidy rate
A utility affected by earthquake of seismic intensity equal to or greater than 6.0, and the cost of recovery estimated by central government's inspector is • Equal to or greater than ¥10,000 (approximately US$88) per capita served; *and* • Equal to or greater than ▪ ¥100,000,000 (approximately US$880,000); *or* ▪ ¥50,000,000 (approximately US$440,000) if a small water utility.	2/3
A utility affected by volcanic activities and that meets the following two criteria: • The cost of recovery works estimated by central government's inspector is equal to or greater than ¥150,000 per capita served. • The disaster is designated by the central government as catastrophic under the Disaster Countermeasures Basic Act.	8/10
A utility affected by other types of hazards	1/2

Source: Based on MHLW 2014b. Translation by Japan Water Research Center.
Note: MHLW = Ministry of Health, Labour and Welfare. US$1 = ¥113.6.

In addition to the national subsidy programs, special financial assistance is arranged to support the water supply utilities affected by a catastrophic disaster. In the case of the 1995 Great Hanshin-Awaji Earthquake, MHLW covered up to 80 percent of the total cost to restore damaged distribution pipelines for the eligible utilities, and up to 90 percent was covered in the case of the 2011 Great East Japan Earthquake (MHLW 2012).

2.8.2 Sanitation Services

Table 2.5 summarizes MLIT's subsidy program for reconstruction of sanitation systems as regulated under the National Government Defrayment Act for Reconstruction of Disaster-Stricken Public Facilities. However, the subsidy does not apply under the following conditions:

- Reconstruction cost is less than ¥1,200,000 for prefectures and designated major cities.
- Reconstruction cost is less than ¥600,000 for small cities, towns, and villages.
- Reconstruction works are considered to be regular O&M works.
- Works required are because of a defect associated with the infrastructure, construction, or inadequate O&M.

Table 2.5 MLIT Subsidy Program for Reconstruction of Sanitation Services

Eligibility criteria	Subsidy rate
Disasters from abnormal natural phenomena: 1. *Rivers:* water level (a) exceeding the warning water level; (b) approximately 50 percent of the river bank (where the warning water level is not determined); or (c) snowmelt for a long period 2. *In facilities other than rivers:* (a) maximum rainfall of 80 millimeters or more in 24 hours; or (b) rainfall of 20 millimeters or more per hour 3. *Maximum wind speed* of 15 meters or more (average in 10 minutes) 4. *High tide, wave, or tsunami* causing nonminor disasters 5. *Disasters due to an earthquake, landslide, or lightning strike* 6. *Disasters due to snow depth* of 1 meter or more that exceeds the average of the maximum snow depth in the past 10 years	2/3 or more

Source: MLIT 2015b.

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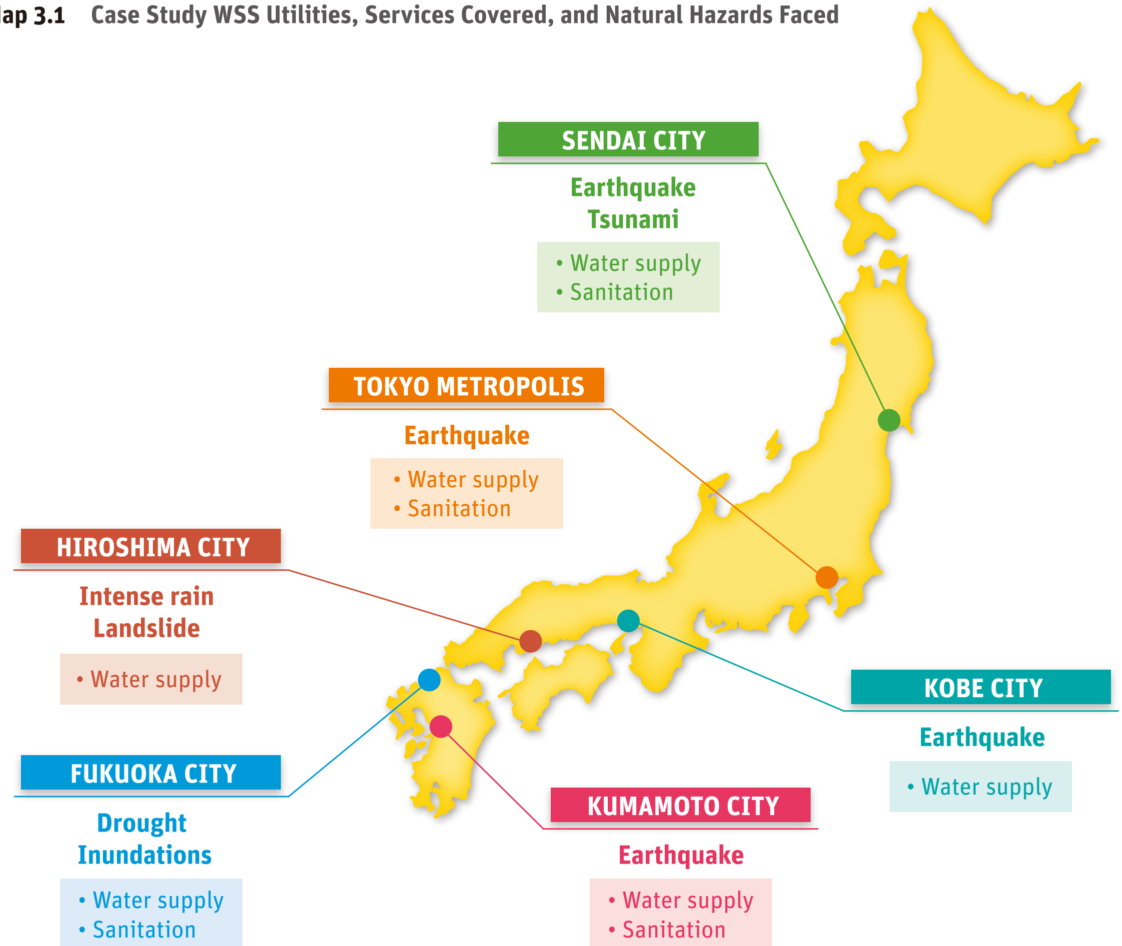
03

Best Practices and Lessons Learned from Urban WSS Utilities

3.1 Overview

This section summarizes the best practices of the WSS utilities covered within the individual case studies on Fukuoka (Section 3.2), Hiroshima (Section 3.3), Kobe (Section 3.4), Kumamoto (Section 3.5), Sendai (Section 3.6), and Tokyo (Section 3.7). Map 3.1 shows the location of these cities' public WSS utilities and the types of natural hazards addressed in the case studies.

Map 3.1 Case Study WSS Utilities, Services Covered, and Natural Hazards Faced



A summary is provided according to the relevant natural hazard types and water supply or santiation service processes in tables 3.1 and 3.2, respectively. High-level cost implications are provided for each measure for reference purposes only. It is of note that many of the practices are commonly implemented by all the utilities in Japan, and the case studies showcase recent and representative DRM practices.

Table 3.1 **Summary of Best Practices by Water Supply Utilities, by Hazard Type**

Hazard types	Relevant assets	Best practices and lessons learned	Cost implications	Relevant utility case study
Multihazards	All assets	Develop an emergency preparedness and response plan or a BCP, including an emergency operation manual for critical facilities such as WTPs	Low	Hiroshima (Section 3.3), Sendai (Section 3.6), Tokyo (Section 3.7)
Multihazards	All assets	Appropriately decentralize decision making for implementation of timely emergency response on the ground	Low	Sendai (Section 3.6)
Multihazards	All assets	Risk-informed water safety planning and integration with a BCP	Low	Hiroshima (Section 3.3)
Multihazards	Distribution	Identify critical customers (such as hospitals) and develop targeted emergency water supply plans	Low	Kobe (Section 3.4), Tokyo (Section 3.7)
Multihazards	All assets	Set up an internal emergency response team available 24/7 for swift system recovery for critical municipal functions (such as government buildings)	Low	Tokyo (Section 3.7)
Multihazards	Distribution	Outsource public emergency communication to maximize human resources for other critical emergency response and restoration works	Low	Kumamoto (Section 3.5)
Multihazards	Distribution	Train local communities for community-driven emergency water supply	Low	Hiroshima (Section 3.3), Kobe (Section 3.4), Kumamoto (Section 3.5), Tokyo (Section 3.7)
Multihazards	All assets	Develop a long-term infrastructure master plan to improve system resilience and to meet recovery-time-objectives	Low	Kobe (Section 3.4), Kumamoto (Section 3.5), Sendai (Section 3.6), Tokyo (Section 3.7)
Multihazards	Distribution	Establish a mutual support agreement with municipal, private, and other external organizations to bolster emergency response capacities	Low	Hiroshima (Section 3.3), Kobe (Section 3.4), Kumamoto (Section 3.5), Sendai (Section 3.6), Tokyo (Section 3.7)
Multihazards	All assets	Establish emergency communication protocols and conduct regular trainings or drills between relevant municipal and private sector entities for effective emergency cooperation	Low	Kobe (Section 3.4), Kumamoto (Section 3.5), Sendai (Section 3.6), Tokyo (Section 3.7)

Hazard types	Relevant assets	Best practices and lessons learned	Cost implications	Relevant utility case study
Multihazards	Pumping stations and WTPs	Backup power supply to key assets	Medium	Hiroshima (Section 3.3)
Multihazards	Distribution	Develop an emergency water storage system through capacity enhancement and emergency shutoff valves	High	Hiroshima (Section 3.3), Kobe (Section 3.4), Tokyo (Section 3.7)
Multihazards	Transmission and distribution	Improve redundancy and interconnections at transmission and distribution level between pipeline networks and WTPs	High	Hiroshima (Section 3.3), Kobe (Section 3.4), Kumamoto (Section 3.5), Sendai (Section 3.6), Tokyo (Section 3.7)
Multihazards	Distribution	Reduce leakage through efficient distribution control and systematic leakage detection and reduction systems	High	Fukuoka (Section 3.2)
Extreme rains or landslide	WTPs	Increased water quality monitoring and adapted WTP and chemical dosing to handle increased flows and turbidity	Low	Hiroshima (Section 3.3)
Drought	Sources	City regulations require gray water reuse systems installed on large developments	Low	Fukuoka (Section 3.2)
Drought	Policy	Public water saving awareness campaigns	Low	Fukuoka (Section 3.2)
Drought	Policy	Reduce water use though regulations on equipment and fittings—e.g. low-flush toilets	Medium	Fukuoka (Section 3.2)
Drought	Sources	Utilize reclaimed water to flush toilets and water trees	High	Fukuoka (Section 3.2)
Drought	Sources	Diversify water sources—e.g. dams, wholesale purchase, desalination plant	High	Fukuoka (Section 3.2)
Earthquake and landslide	Pipelines and WTPs	Seismic reinforcement of water supply facilities as part of long-term DRM planning	High	Hiroshima (Section 3.3), Kobe (Section 3.4), Kumamoto (Section 3.5), Sendai (Section 3.6), Tokyo (Section 3.7)

Note: DRM = disaster risk management. WTP = water treatment plant.

Table 3.2 Summary of Best Practices by Sanitation Utilities, by Hazard Type

Hazard types	Relevant assets	Best practices and lessons learned	Cost implications	Relevant utility case study
Multihazards	All assets	BCP development process enables swift emergency response	Low	Sendai (Section 3.6)
Multihazards	All assets	Mutual aid agreement with other utilities and framework agreements with private sector	Low	Kumamoto (Section 3.5), Sendai (Section 3.6), Tokyo (Section 3.7)
Multihazards	All assets	Risk-informed asset management system and integration with BCP	Medium	Sendai (Section 3.6)
Multihazards	Pipelines	Design topography-oriented sewer networks to continue effective treatment when pump stations are damaged	High	Sendai (Section 3.6)
Multihazards	Pipelines	Interconnect sewer pipelines to build a backup capacity	High	Tokyo (Section 3.7)
Multihazards	Disposal	Provision of more hygienic means for sanitary disposal by installing manhole toilets	High	Kumamoto (Section 3.5)
Floods	Drainage	Upgraded stormwater management capacities	High	Fukuoka (Section 3.2)
Floods	Drainage	Separation of stormwater and sewer drainage systems	High	Fukuoka (Section 3.2)
Earthquake and landslide	Pipelines and WwTPs	Seismic reinforcement of pipelines and facilities	High	Kumamoto (Section 3.5), Sendai (Section 3.6), Tokyo (Section 3.7)

Note: BCP = business continuity planning. WwTP = wastewater treatment plant.

3.2 Fukuoka City:

Building Drought Resilience and Enhancing Drainage Capacity against Urban Floods

Photo 3.1 **Aerial View of Fukuoka City**

Source: City of Fukuoka. ©City of Fukuoka. Reproduced, with permission, from Fukuoka City; further permission required for reuse.

Fukuoka City Waterworks Bureau (FWB) supplies water to the city's 1.48 million residents (photo 3.1), with a non-revenue water (NRW) rate of 3.8 percent in 2014. In 1978 and 1994, the utility experienced severe droughts that necessitated water rationing for approximately 300 days each (Fujino 2013). Based on the lessons learned, Fukuoka City developed a policy on efficient water usage in 1979, became the first city in Japan to enact a water conservation ordinance in 2003, and implemented numerous drought countermeasures over recent decades, including the following (FWB 2013):

- *Water resources development and conservation:* Diversification of water sources including development of an intake facility at Chikugo River in 1983 and a seawater desalination plant in 2005; enforcement of a regulation to use nonpotable water (for example, reclaimed water or rainwater) for buildings, sanitary facilities, and tree or plant watering; and annual water conservation campaigns to raise public awareness
- *Efficient water distribution control system:* Establishment of a Water Distribution Control Center in 1981 to monitor and remotely control water flows and pressures by operating 177 motor valves based on an analysis of data collected from the flow meters and pressure gauges installed in 21 blocks of the water distribution pipe network
- *Portfolio risk management for leakage prevention:* Regular leakage inspection and implementation of preventive or corrective measures (for example, replacement of aging service pipes) based on the results of risk assessment conducted every four years for 250 small grids

3.2.1 Basic Profile of Utilities

The FWB is responsible for water supply, while the Fukuoka City Road and Sewerage Bureau (FRSB) is responsible for sewage and stormwater collection and treatment (table 3.3).

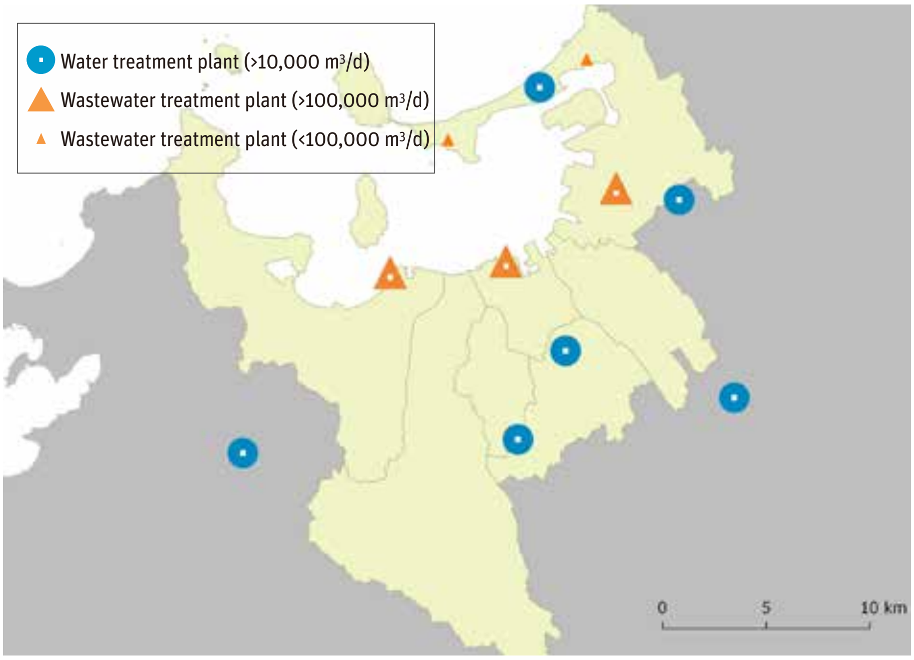
Table 3.3 Basic Profile of Fukuoka City Water Utilities, 2014–15

Descriptor	Fukuoka City Waterworks Bureau	Fukuoka City Road and Sewerage Bureau
Service coverage	1.48 million population (99.4%)	1.48 million population (99.6%)
Capacity	0.78 million m^3/day[a]	0.92 million m^3/day
Non-revenue water[b]	3.8%	n.a.
Operational income	¥31.0 billion (US$272 million)	¥43.0 billion (US$379 million)
Operational expenditure	¥27.1 billion (US$238 million)	¥40.8 billion (US$359 million)
Number of employees	520	266
Regulator	Ministry of Health, Labour and Welfare	Ministry of Land, Infrastructure, Transport, and Tourism

Sources: MIC 2015.
Note: US$1 = ¥113.6. m^3 = cubic meters. n.a. = not applicable.
a. Distribution capacity
b. “Non-revenue water” refers to the difference between the volume of water put into a water distribution system and the volume that is billed to customers.

The city has three types of water sources: eight dams (38 percent), three local rivers (27 percent), and a wholesale supply (35 percent) from the Fukuoka District Waterworks Agency (FWB 2013). Five of the dams are located outside the city. The city has seven wastewater treatment plants (WwTPs) with a total capacity of 0.92 million cubic meters per day. Some portions of the service area still use a combined stormwater and sewer drainage system. Map 3.1 shows the location of water treatment plants (WTPs) and WwTPs.

Map 3.1 Water and Wastewater Treatment Plants of Fukuoka City

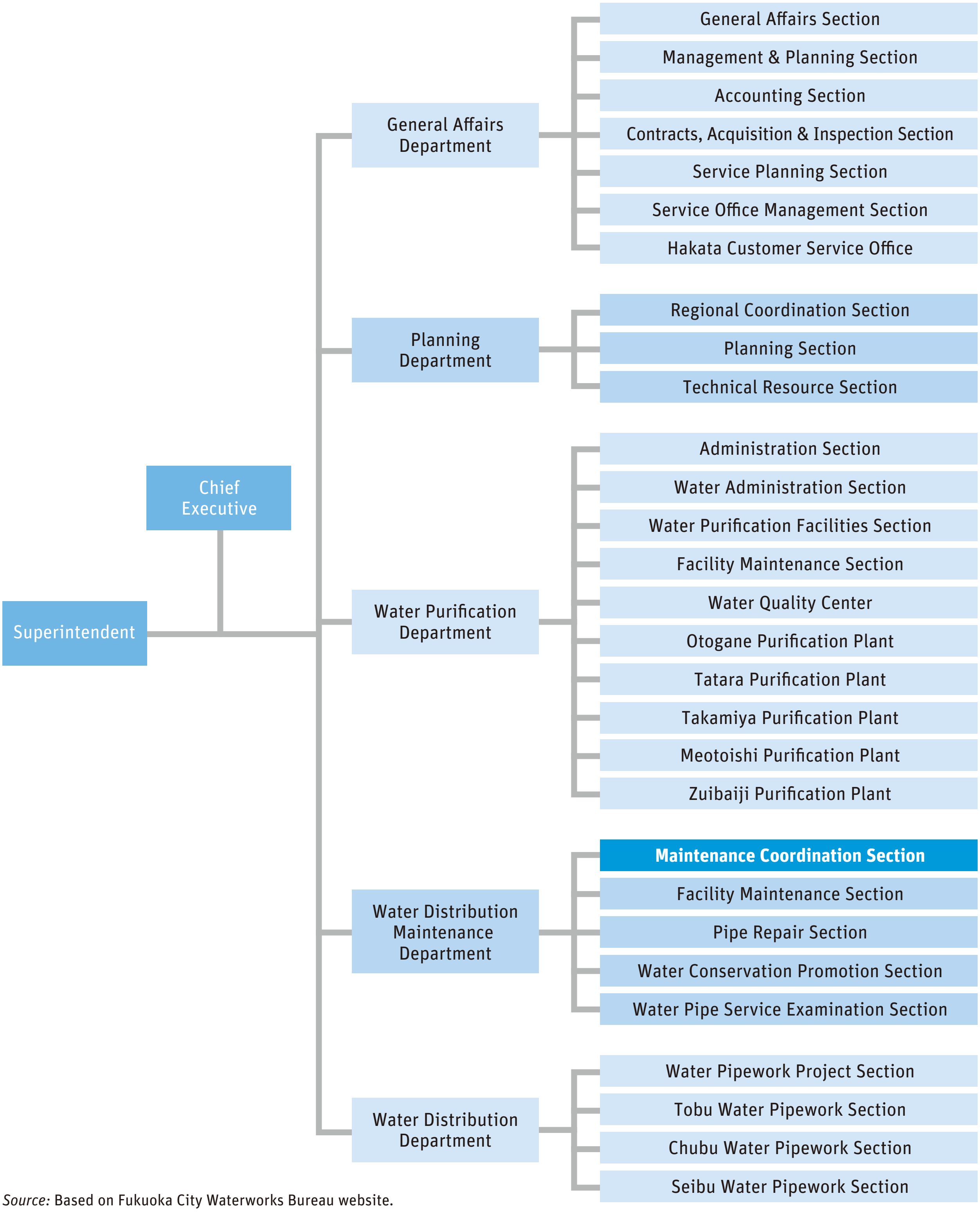


Source: Based on National Land Numerical Information database, Ministry of Land, Infrastructure, Transport and Tourism. ©World Bank. Permission required for reuse.
Note: m^3/d = cubic meters per day.

03 Fukuoka City

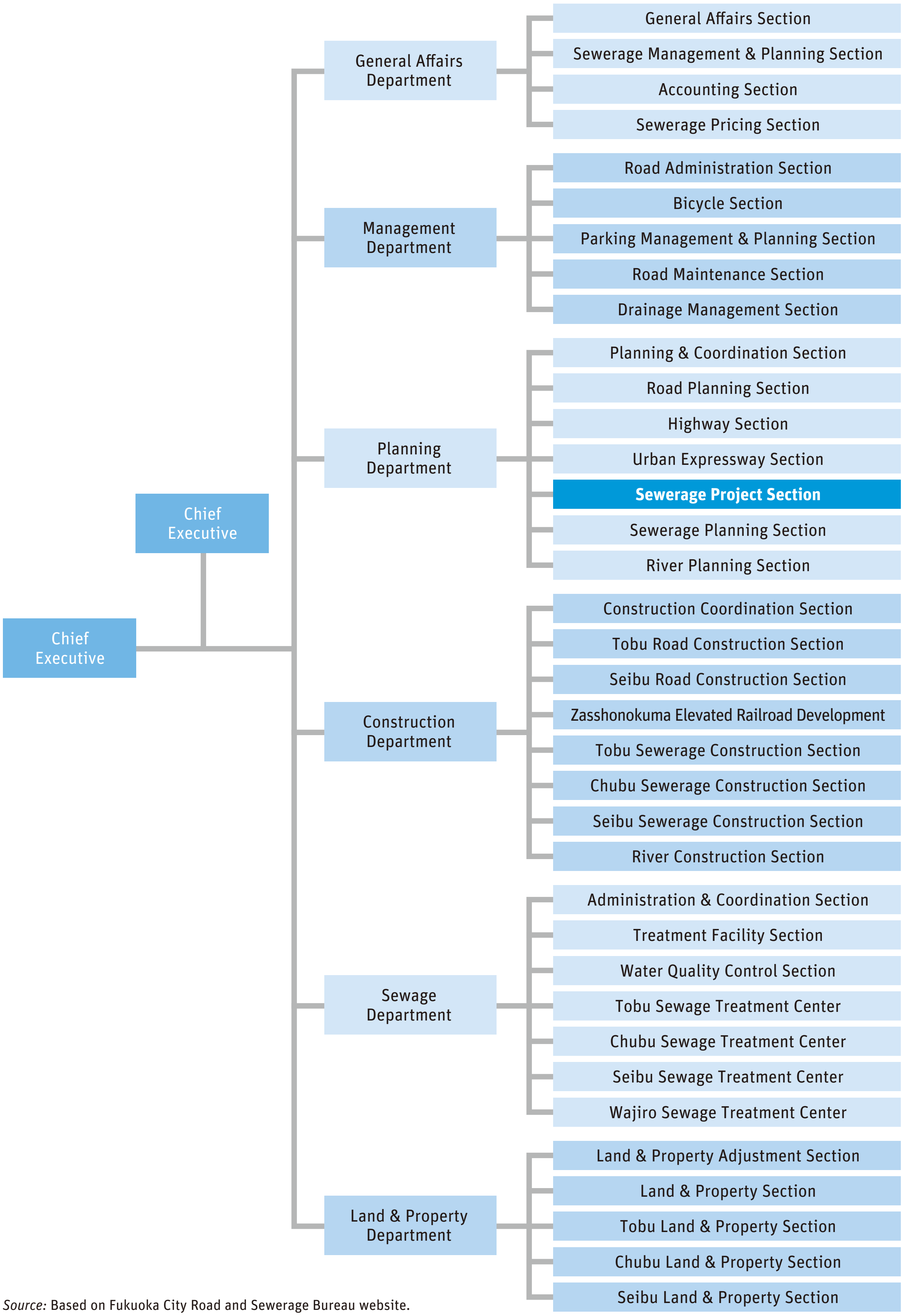
The organizational structures of the FWB and FRSB are shown in figures 3.1 and 3.2. In the FWB, the Technical Resource Section (within the Planning Department) is mainly responsible for DRM. Upon a disaster, the Maintenance Coordination Section (within the Water Distribution Maintenance Department) oversees the FWB's efforts for emergency restoration while the Water Pipework Project Section (within the Water Distribution Department) oversees emergency water supply. In the FRSB, the Sewerage Project Section (within the Planning Department) is mainly responsible for both DRM and emergency response.

Figure 3.1 **Organizational Structure of Fukuoka City Waterworks Bureau**



Source: Based on Fukuoka City Waterworks Bureau website.

Figure 3.2 **Organizational Structure of Fukuoka City Road and Sewerage Bureau**



Source: Based on Fukuoka City Road and Sewerage Bureau website.

3.2.2 Disaster Risk Profile

Fukuoka City, the capital of Fukuoka Prefecture, covers 341 square kilometers at the center of the Fukuoka Plain, opening into the Genkai Sea to the north and bordered by mountains. Several small and medium-size rivers originating from the mountains run through the city and feed into the Hakata Bay and Genkai Sea. The annual precipitation is around 1,600 millimeters. Although the total precipitation is comparatively high, the city's high population density makes its average per capita precipitation 400 cubic meters per year, which is significantly lower than the national average of 5,000 cubic meters per person per year (Fujino 2013).

The key risks to Fukuoka City from natural hazards include (a) drought because of the low per capita precipitation in the context of limited water resources, which increases the chance of water rationing; and (b) flash floods, which have increased in recent years as heavy precipitation has become more frequent.

Recent Natural Disasters

Two severe droughts—in 1978 (photo 3.2) and 1994—had a significant impact on the daily lives of city residents and on vital social functions such as those of hospitals and schools. The water rationing lasted for 287 days and 295 days, respectively. On certain days, the duration of daily water supply fell to as low as five hours.

Photo 3.2 Parched Minamihata Dam during 1978 Drought

Source: FWB 2013. ©Fukuoka City Waterworks Bureau (FWB). Reproduced, with permission, from FWB; further permission required for reuse.

In June 1999 and July 2003, large volumes of storm runoff surpassing the city's sewer capacity poured into the subway and underground shopping district in the city center (photo 3.3). In the 1999 event, one person was killed by being trapped in the underground shopping district.

Photo 3.3 Flash Flood around Hakata Station, Fukuoka City, 2003

Source: FRSB n.d.[b]. ©Fukuoka City Road and Sewerage Bureau (FRSB). Reproduced, with permission, from FRSB; further permission required for reuse.

3.2.3 Best Practices

Water Supply

Since the late 1970s, as mentioned above, two droughts and two floods have heavily affected Fukuoka City. In the context of changing precipitation patterns in recent years, these experiences have offered many lessons for the water supply and sanitation utilities to improve and develop a range of long-term countermeasures. Each category of countermeasure described below pertains to one or more stages of infrastructure life cycle—policy and legislation, systems planning, engineering design and materials, asset management, and contingency programming—as designated within brackets in the category headings.

The water rationing that continued twice for around 300 days in 1978 and 1994 became a crucial driver for the city to start planning and developing multiple drought countermeasures. In fact, the utility did not need to ration water during the 2005 drought (when the annual rainfall dropped to the third-lowest level) because it had implemented the following types of countermeasures based on lessons learned from the past droughts (table 3.4):

- Water resource development to diversify and increase water supply capacity
- Legislation and public awareness raising for water efficiency and conservation
- Establishment of a water distribution control system to control the water flow and pressure from WTPs to tap
- Portfolio risk management for systematic leakage reductions

Table 3.4 Drought Countermeasure Results in Fukuoka City since 1970s

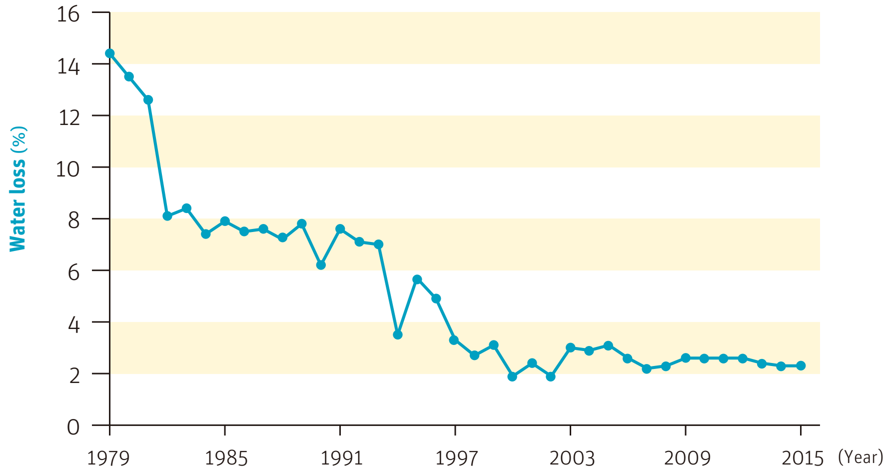
Statistic	1978 drought	1994 drought	2005 drought
Annual rainfall	1,138 mm/year	891 mm/year	1,020 mm/year
Service coverage (population)	1.03 million	1.25 million	1.39 million
Water supply capacity	478,000 m^3/d	704,800 m^3/d	764,500 m^3/d
Water rationing	287 days (average 14 hours/day)	295 days (average 8 hours/day)	None
Number of customer complaints	47,902	9,515	0

Source: Adapted from Fujino 2013.
Note: m^3/d = cubic meters per day. mm = millimeters.

Because of the efficient distribution network control and leakage reductions, coupled with replacement and improvement of distribution pipelines, the utility's water loss ratio in 2015 was 2.3 percent, less than 10 percentage points below the 1979 level (figure 3.3).[9]

9 "Water loss" denotes the water leaking from distribution pipelines and service pipes, as opposed to "non-revenue water," which takes into account the volume of water loss plus other nonbilled water consumption (for example, firefighting, toilet flushing at public facilities, inaccuracies of water meters, and pipe cleaning by utilities).

Figure 3.3 Utility's Water Loss in Fukuoka City, 1979–2015



Source: Based on data provided by Fukuoka City Waterworks Bureau.

Water Resource Development to Diversify Water Sources [systems planning]

The severe drought in 1978 made the city realize the importance of diversifying its water sources for resilient water supply, and it subsequently implemented the following measures (FWB 2013):

- *Establishment of the Fukuoka District Waterworks Agency*, a wholesale water supplier cofunded by Fukuoka City and other municipalities to draw water from the Chikugo River, a large river outside the Fukuoka metropolitan area
- *Development of eight dams*, of which two are pumped-storage dams
- *Construction of a piped water conveyance system* to minimize evaporation and infiltration of irrigation water
- *Operation of a seawater desalination plant* since 2005, with a capacity of 50,000 cubic meters per day, through the *Fukuoka District Waterworks Agency*

Policies and Regulations for Water Efficiency and Conservation [policy and legislation]

In 2003, Fukuoka City became the first municipality in Japan to enact an Ordinance on the Promotion of Water Conservation. Because of the city's efforts to build a water-conscious city, its average daily water consumption per capita was reduced to 272 liters in 2011—the lowest among major cities in Japan, which averages consumption of 313 liters per person per day (FWB 2013). For example, new buildings with a total floor area of over 3,000 square meters are required to use reclaimed water to flush toilets.[10] As of March 2015, the utility supplied 417 buildings with reclaimed water (FRSB n.d.[a]). The reclaimed water is also used to water trees in public places such as parks and streets. In the areas not supplied with reclaimed water, buildings with a total floor area of over 5,000 square meters must either use rainwater for their toilets or develop an internal wastewater treatment system to generate and use reclaimed water within the buildings. Further, the city specifies the type of water-efficient toilets to encourage their wider use in both residential and commercial buildings. It also offers subsidies for installation of nonpotable water systems (OECD 2015).

In addition, to raise public awareness, the city designated June 1 as Water Conservation Day in 1979. Since then, the utility has run water conservation campaigns every year from June to August, when the water consumption is the highest (FWB 2013). Other public relations efforts also take place throughout the year, including the delivery of the utility's newsletters to all the residents, production of educational materials for elementary schools, and organization of water supply facility tours to raise awareness about water conservation.

10 "Reclaimed wastewater" refers to treated wastewater that is of better water quality than ordinary effluents from wastewater treatment plants.

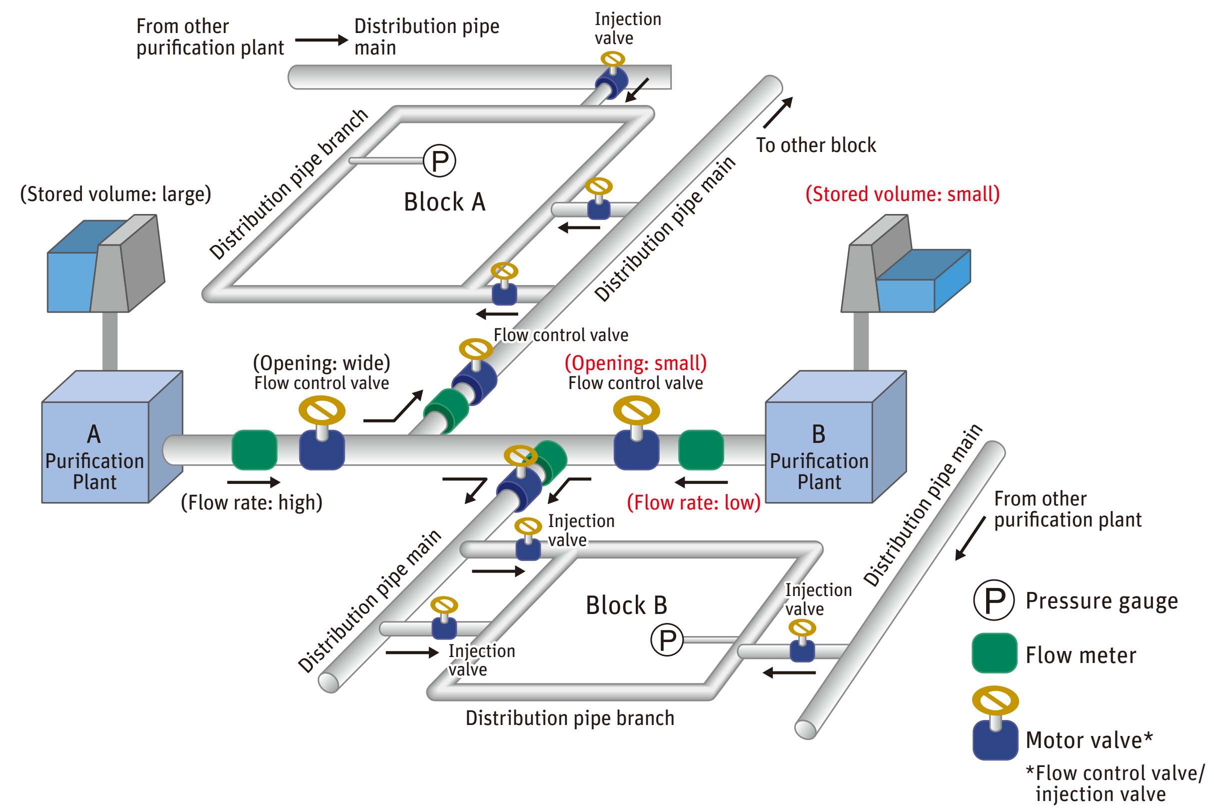
Efficient Distribution Control and Emergency Management [systems planning] [contingency programming]

In 1981, the utility established Japan's first Water Distribution Control Center to enable smooth, equal water supply to all customers regardless of topographical differences (figure 3.4). The city's water distribution network was divided into 21 distribution blocks, and the center monitors and remotely controls water flows and pressures in real time by operating 177 motor valves based on an analysis of data collected from the flow meters and pressure gauges installed in the 21 blocks (FWB 2013).

By controlling the water pressure in each distribution block in response to demand fluctuations, the utility has managed to reduce its water pressure by 0.1–0.2 megapascal (MPa) compared with the level before the operation of the center (FWB 2013). This pressure reduction is estimated to have saved water by 4,000–5,000 cubic meters per day while cutting the number of naturally occurring water leakages by 30 percent.

During an emergency that involves large-scale water supply disruptions, the center analyzes the damage to the network based on the data collected from the flow meters, pressure gauges, and water gauges at distribution reservoirs.[11] Based on the results of the analysis, the center develops an emergency distribution management plan, which provides instructions to the relevant departments of the utility. The center also contributes to emergency restoration of the affected water supply by identifying the locations of water leakage and providing advice to help prioritize where to allocate more resources for restoration.

Figure 3.4 Water Distribution Control System in Fukuoka City



Source: FWB 2013. ©Fukuoka City Waterworks Bureau (FWB). Reproduced, with permission, from FWB; further permission required for reuse.

11 Information about Water Distribution Control Center operations and backup functionality as well as FWB postdisaster water quality management from FWB, personal communication, October 23, 2017.

Building Redundancy and Controlling Water Transportation by Interconnecting Facilities
[systems planning] [contingency programming]

The utility's five WTPs and one distribution plant (which distributes water received from the Fukuoka District Waterworks Agency) are connected to each other via large distribution pipelines. Owing to this interconnectivity, the center can control water transportation between the plants to some degree, by remotely operating the electric valves and adjusting water flows and pressures. This function would alleviate the impact of drought, for example, by enabling water allocation to more drought-affected WTPs and distribution reservoirs. In addition, since four of the larger WTPs are connected to multiple sources, an unexpected incident at one source (for example, water pollution or damage to an intake station) would not force the WTPs to stop water supply, with the other sources feeding the plants.

Water Quality Management Upon a Disaster [asset management]

The FWB's Water Distribution Maintenance Department checks residual chlorine and turbidity levels of the distribution network as well as service pipes, while the Water Quality Center (not the Distribution Control Center) is responsible for further inspections and examinations. When the water quality of the sources (such as dams or rivers) is adversely affected, the staff at each WTP handles the issue by themselves, and the Water Quality Center provides assistance as necessary.

Portfolio Risk Management for Systematic Leakage Reductions [asset management]

FWB routinely inspects water distribution pipes (totaling 2,907 kilometers in length) by monitoring the underground sounds for early detection and quick repair of water leakage to prevent a water loss. For effective and efficient leak detection, the city prioritizes areas for inspections every four years based on historical pipe failures and leakages, length of aged pipes, the number of remaining lead service pipes, water pressures, and soil corrosiveness (FWB 2013). The results of analysis are used to assess and determine leakage risks on three scales: leakage inspection every year in the high-risk areas, every two years in the medium-risk areas, and every four years in the low-risk areas. Because 90 percent of all leaks occur in the service pipes, the city has also been replacing aged service pipes.

Sanitation

Iterative Planning to Upgrade Stormwater Management Capacity
[systems planning] [engineering design and materials]

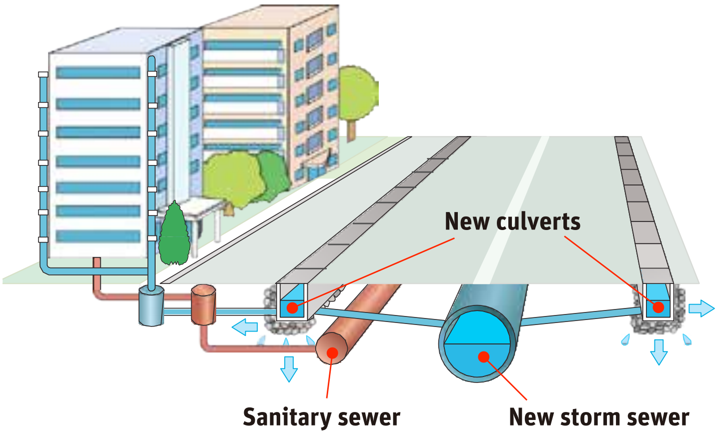
Heavy rains totaling up to 79.5 millimeters per hour caused a flash flood in Fukuoka City in 1999. In response, the city developed a master plan to reconstruct and upgrade storm sewer capacity for 138 districts (FRSB 2000; Tsuno 2016). Before all the work under the master plan was completed, however, another massive flood occurred in 2003 because of increased runoff upstream of the Mikasa River, which led to flooding of the Hakata district, the city's central business district. Based on the lessons learned from the two events, Fukuoka City upgraded the master plan and developed "Rainbow Plan Hakata" (FRSB n.d.[b]; Tsuno 2016). The Rainbow Plan, implemented from 2004 to 2012, increased the area's overall storm sewer capacity from 59.1 millimeters per hour to 79.5 millimeters per hour (the maximum precipitation intensity of the 1999 flash flood).

Rainbow Plan Hakata consisted of the following projects, with a total capital expenditure of approximately ¥35.3 billion (US$322 million)[12] (Tsuno 2016):

12 Conversion rate: US$1 = ¥113.6. Each project was subsidized in part by Ministry of Land, Infrastructure, Transport and Tourism.

- *Separation of stormwater and sewer drainage systems*. The plan brought a major transformation of Hakata Station area's sewer system, which was aging and still used a single set of pipes to collect both wastewater and stormwater. By installing new pipelines dedicated to stormwater collection, the entire system was converted into a separate sewer system for improved stormwater drainage capacity (figure 3.5).
- *Construction of stormwater culverts and drainage pipeline*. The city increased its drainage capacity to reduce urban runoff by constructing stormwater culverts with permeable road surfaces and a 5.7-kilometer drainage pipeline (figure 3.5).

Figure 3.5 **Upgrading Stormwater Drainage Capacity around Hakata Station, Fukuoka City**



Source: Adapted from FRSB, n.d.[b] (partially modified and translated). ©Fukuoka City Road and Sewerage Bureau (FRSB). Reproduced, with permission, from FRSB; further permission required for reuse.

- *Development of underground stormwater storage facilities and a pump station*. The primary objective was to enhance the stormwater storage capacity near the Sanno Channel because the area had been adversely affected by the channel's frequent overflows in the past. The utility installed two stormwater storage facilities with a total capacity of 30,000 cubic meters at the nearby Sanno Park. The first storage facility was built by digging out the existing baseball field and lowering the ground level by around 1.8 meters so that the excavated space can function as an additional storage when it rains. The second storage facility was constructed underground of the park, in which the stored water is pumped up and discharged to the adjacent rivers (photo 3.4).

While construction works were still ongoing, the Hakata Station area was not severely affected by a heavy precipitation event (maximum over 100 millimeters per hour) in July 2009 because of the partially completed works.

Photo 3.4 **Underground Stormwater Storage Facility Beneath Sanno Park, Fukuoka City**

Source: FRSB n.d.[c]. ©Fukuoka City Road and Sewerage Bureau (FRSB). Reproduced, with permission, from FRSB; further permission required for reuse.

3.2.4 Lessons Learned

Build resilience against drought by implementing risk reduction measures from source to tap
[systems planning] [asset management]

FWB successfully reflected the lessons learned from a series of drought events since the 1970s and became the most water-efficient utility in Japan. Its success is attributed to risk reduction measures implemented from source to tap: integrating regulatory frameworks for water efficiency, systems planning for diversifying water sources, and portfolio risk management through establishment of a systematic water distribution control system.

Adapt to changing hydrometeorological risks using iterative planning [systems planning]

Based on the historical hydrometeorological data, FRSB has prioritized areas that are susceptible to inundation, iteratively reviewed and upgraded the flood control master plan, and implemented large-scale storm sewer capacity upgrades.

3.3 Hiroshima City:

Enhancing Water Supply Continuity against Extreme Rainfalls and Landslides

Photo 3.5 **Aerial View of Hiroshima City**

Source: ©Hiroshima City Waterworks Bureau (HCWB). Reproduced, with permission, from HCWB; further permission required for reuse.

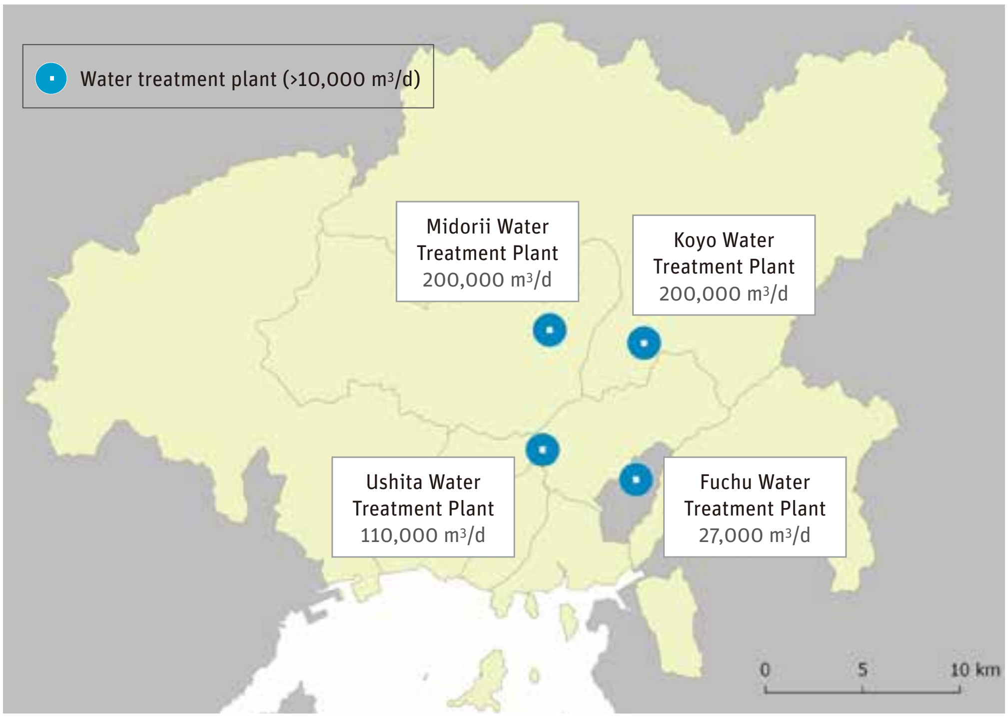
The Hiroshima City Waterworks Bureau (HCWB) supplies water to 1.2 million residents and two neighboring towns (photo 3.5), with a non-revenue water (NRW) level of 6.9 percent as of 2014. Multiple precipitation-induced landslides in August 2014 extensively damaged the city's water distribution networks and other facilities, causing approximately 3,500 households to lose access to water. The heavy rains also posed a challenge to water treatment because of an unprecedented increase in turbidity (Matsuoka 2016). The utility's rapid restoration of water supply was enabled by implementation of structural and nonstructural measures, including the following (HCWB 2009; Matsuoka 2016):

- *Building of redundant emergency water supply networks:* Installation in 2005 of a network of interconnecting pipelines to enhance the backup water supply capacity, which enabled 80 percent of the households to receive emergency water from another primary water treatment plant (WTP)
- *Emergency preparedness at pumping stations, reservoirs, and storage tanks:* Installation of emergency power generators and uninterruptible power supply (UPS) at pumping stations to prevent service disruption during a blackout; installation of emergency shutoff valves at the primary reservoirs; and, in cooperation with the city's Fire Services Bureau, installation of more than 30 underground, seismic-resistent emergency water storage tanks
- *Business continuity with external assistance:* Establishment of an internal emergency task force to address the unprecedented increase in turbidity

3.3.1 Basic Profile of Utility

HCWB supplies water to Hiroshima City and neighboring Fuchū Town and Saka Town through pipelines that are approximately 4,800 kilometers long. The city has two primary surface water sources, the Ohta River and Haji Dam, which supply four water treatment plants (map 3.2).

Map 3.2 Water Treatment Plants of Hiroshima City



Source: Data adapted from the National Land Numerical Information database, Ministry of Land, Infrastructure, Transport and Tourism. ©World Bank. Permission required for reuse.
Note: m^3/d = cubic meters per day.

Table 3.5 provides a basic profile of the utility.

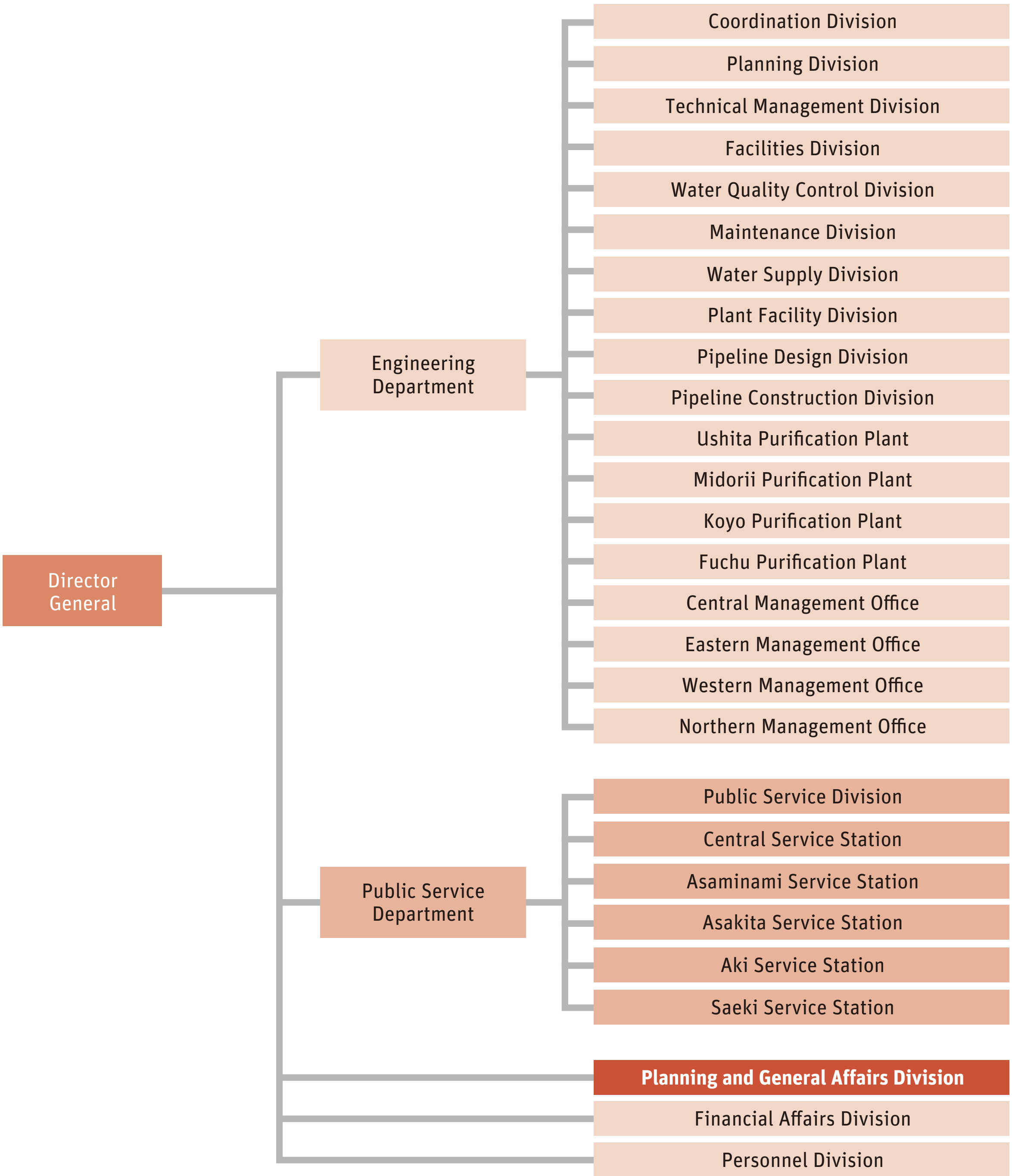
Table 3.5 Basic Profile of Hiroshima City Waterworks Bureau, 2014–15

Descriptor	Hiroshima City Waterworks Bureau
Service coverage	1.2 million or 97.6% coverage
Capacity	629,800 m^3/day[a]
Non-revenue water[b]	6.9%
Operational income	¥20.8 billion (US$183 million)
Operational expenditure	¥19.8 billion (US$174 million)
Number of staff	642
Regulator	Ministry of Health, Labour and Welfare

Source: MIC 2015.
Note: Conversion rate: US$1 = ¥113.6. m^3 = cubic meters.
a. Distribution capacity. b. “Non-revenue water” refers to the difference between the volume of water put into a water distribution system and the volume that is billed to customers.

HCWB comprises two departments and 27 divisions (figure 3.6). The Planning and General Affairs Division is mainly responsible for DRM and emergency response.

Figure 3.6 **Organizational Structure of Hiroshima City Waterworks Bureau**



Source: Based on Hiroshima City Waterworks Bureau website.

3.3.2 Disaster Risk Profile

In Hiroshima City, about 50 percent of the annual rainfall occurs from June to September. A large part of the city is situated in alluvial plains along the Ohta River, from which 90 percent of the water is extracted. The key risks to Hiroshima City from natural hazards include the following (City of Hiroshima 2015):

- Intense rains: High raw water turbidity caused by intense rains pose difficulty to stable water supply.
- Landslides: The city is topographically and geologically susceptible to landslides during intense rains. Major landslides block access to primary water facilities and damage distribution pipelines. Especially, the water supply pipelines in Asaminami District and Asakita District are susceptible to mudflows and slope failures during extreme rains because the alluvial plain is surrounded by mountains composed of granite that is easily weathered.

Because Hiroshima Prefecture has many areas with potential sediment disaster risks, the Civil Engineering Bureau of the Hiroshima prefectural government has assessed the risks based on site inspections using the method specified in Japan's Sediment Disaster Prevention Act, enacted in 2000. Some of the city's four primary WTPs and their intake stations are rated as either "yellow" or "red" landslide warning zones—meaning they are prone to sediment disasters (yellow zone) or are portions of yellow zones where particularly heavy damage and threat to human life would occur (red zone) (table 3.6).

Table 3.6 Sediment Disaster Risk of Water Treatment Plants in Hiroshima City

Water treatment plant and capacity	Sediment disaster risk
Koyo (200,000 m^3/d)	WTP: None Intake station: None
Midorii (200,000 m^3/d)	WTP: Partial yellow warning zone Intake station: None
Ushita (110,000 m^3/d)	WTP: Partial yellow warning zone Intake station: None
Fuchū[a] (27,000 m^3/d)	WTP: Partial yellow and red warning zones Intake station: Partial yellow warning zone

Source: Data adapted from the Sediment Disaster Portal of Hiroshima Prefecture, http://www.sabo.pref.hiroshima.lg.jp/portal/Top.aspx.
Note: WTP = water treatment plant. m^3/d = cubic meters per day. A "yellow" landslide warning zone is an area with a risk of sediment disaster. A "red" landslide warning zone is an area where a potential sediment disaster could destroy buildings and pose serious risk to human lives.
a. Fuchū WTP is scheduled to be decommissioned in 2019 because of an inefficient treatment process.

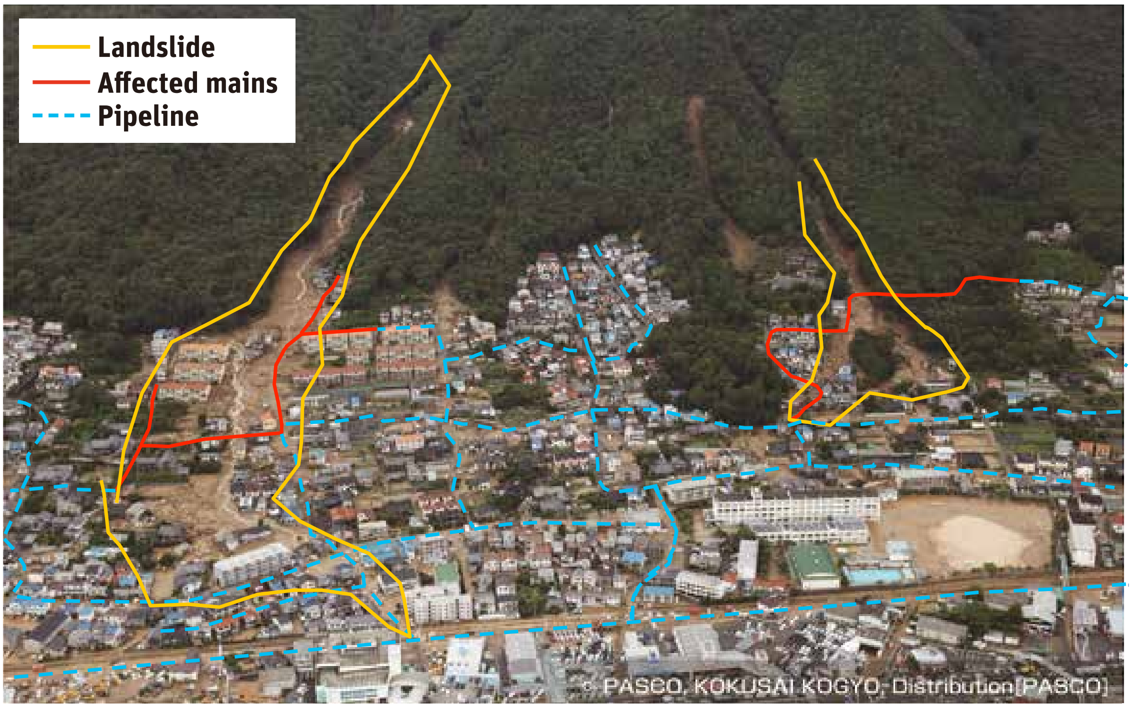
Recent Natural Disasters

In recent years, Hiroshima has experienced an increasing number of extreme precipitation events. On August 20, 2014, unexpectedly extreme rainfall induced devastating landslides that claimed the lives of 74 people, totally collapsed 179 houses, and disrupted water supply to approximately 3,500 households. During the event, the maximum hourly rainfall reached 121 millimeters, and some areas recorded 287 millimeters over a 24-hour period, the highest in history (HCWB 2014a).

Water supply pipeline damage was most severe in Asaminami District (photo 3.6). There, the landslides severely eroded road surfaces and exposed underground water distribution pipelines (photo 3.7), washing away and damaging pipelines and causing approximately 220 households to lose access to water for about 40 days until it was restored (HCWB 2014a). Also, throughout the event, the extreme rainfall caused the raw water turbidity level to reach 3,000 degrees[13] at the Koyo Water Treatment Plant, which extracts water from the Ohta River, posing a risk to water quality (Matsuoka 2016).

13 The Japanese turbidity unit is based on polystyrene latex suspension. Depending on the turbidity characteristics, 1 degree is equivalent to 0.7–0.9 NTU (Nephelometric Turbidity Unit).

Photo 3.6 Location of Damaged Water Distribution Pipelines after 2014 Landslides, Asaminami District, Hiroshima



Source: HCWB 2014a. ©Pasco Corp., Kokusai Kogyo Co. Reproduced, with permission, from Pasco Corp.; further permission required for reuse. Affected areas shown by Hiroshima City Waterworks Bureau. English translation by World Bank.

Photo 3.7 Exposed Distribution Mains in Asaminami District after 2014 Landslides in Hiroshima

Source: HCWB 2014a. ©Hiroshima City Waterworks Bureau (HCWB). Reproduced, with permission, from HCWB; further permission required for reuse.

3.3.3 Best Practices

In Japan, regulatory pressure on disaster risk management (DRM) for water and sanitation utilities is mostly focused on seismic risk mitigation and response. However, attention to extreme precipitation events is on the rise because of their increasing frequency and the associated adverse impact on water treatment due to fluctuations in raw water turbidity. Facing risks of intense rains and landslides as well as difficulties with water treatment, HCWB and Hiroshima City have taken various countermeasures in cooperation with relevant city bureaus and other utilities.

Each type of countermeasure described below pertains to one or more stages of infrastructure life cycle—systems planning, engineering design and materials, asset management, and contingency programming—as designated within brackets in the paragraph headings.

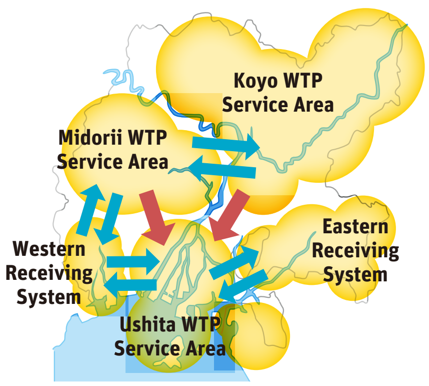
Control of High Turbidity Spikes Due to Heavy Rains [contingency programming]

Although the turbidity level during the 2014 extreme rainfall event (3,000 degrees) exceeded the highest level that HCWB had coped with before (900 degrees), operators at Koyo WTP managed to operate the plant without failure. Their success is attributed to a switch from conventional jar tests for turbidity to use of a conversion equation between turbidity and corresponding chemical dosage that HCWB had prepared in advance, learning from the experience of another city. The equation-based chemical dosage during the 2014 event enabled the Koyo WTP operators to continue operation until turbidity reached around 2,500 degrees. The operators gradually reduced the intake amount and suspended intake for five hours when turbidity was calculated to exceed 3,000 degrees, which is the maximum turbidity that can be treated by chemical coagulants (HCWB 2014a). Other success factors in controlling the turbidity increase included the support of an emergency task force made up of HCWB staff. As a lesson learned from the 2014 event, HCWB developed an internal manual for responding to extreme turbidity fluctuations.

Enhancement of Redundant Water Supply Capacity and Emergency Preparedness
[systems planning] [contingency programming]

Based on a Primary Pipeline Development Plan formulated in 2004, the utility has interconnected the primary distribution pipelines in the city center so that a partial disruption to the network will not affect water supply in larger areas (map 3.3). As of 2010, 80 percent of households in the service area can receive water from another treatment plant in case of an emergency. During the 2014 rainfall and landslide event, this interconnection allowed the Koyo WTP to suspend intake for five hours without adversely affecting water supply in the plant's service area. Also, HCWB installed emergency power generators and UPS at pumping stations to prevent service disruption during a blackout due to a natural disaster. Further, to prepare for large seismic forces, the utility has placed emergency shutoff valves at the primary reservoirs.

Map 3.3 Interconnected Backup Water Supply Networks in Hiroshima City



Source: ©Hiroshima City Waterworks Bureau (HCWB). Reproduced, with permission, from HCWB; further permission required for reuse.

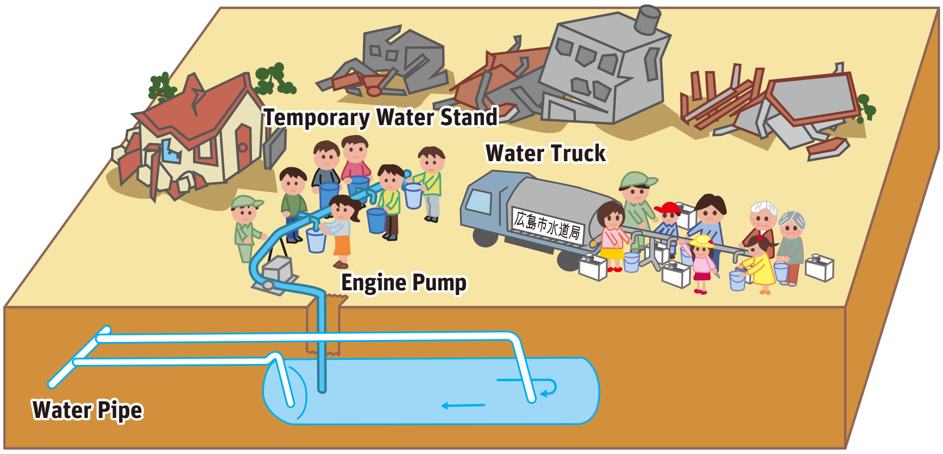
Note: WTP = water treatment plant. Blue arrows designate the existence and potential direction of interconnected pipelines for backup water supply in case of emergency. The large middle arrows extend only one way toward Ushita WTP Service Area because the water between these areas is transported via gravity flow, taking advantage of the elevation difference between the Midorii and Koyo WTPs (on high land) and the Ushita WTP (on low land). Yellow sphere-like areas designate WTP service areas. Blue lines within the map designate rivers. "Western Receiving System" and "Eastern Receiving System" represent areas where treated water is received from Hiroshima Prefectural Government, which provides wholesale water supply service to 16 municipalities including Hiroshima City.

Multiagency and Intermunicipal Cooperation for Emergency Response [contingency programming]

To secure enough drinking water in case of natural disasters, HCWB and the city's Fire Services Bureau installed underground water storage tanks at more than 36 locations across the city. The earthquake-resistant storage tanks are designed for both emergency drinking water supply and firefighting (figure 3.7). HCWB started installing these tanks in 1995 as a lesson learned from the 1995 Great Hanshin-Awaji Earthquake. During the 2014 rainfall event, the utility supplied emergency water by successfully deploying 13 water tanker trucks, distributing 4,200 water bottles, and setting up temporary water stands.

In 2012, Hiroshima City also signed a memorandum of understanding (MoU) with 20 major municipalities in Japan to provide mutual assistance for supplying a range of goods, equipment, and engineers during an emergency upon request from an affected municipality. It is of note that the MoU was not used in the 2014 event because the city was able to cope with the situation on its own.[14]

Figure 3.7 **Diagram of Underground Water Storage Tank for Emergency Drinking Water and Firefighting in Hiroshima City**



Source: ©Hiroshima City Waterworks Bureau (HCWB). Reproduced, with permission, from HCWB; further permission required for reuse.

Postdisaster City Reconstruction Vision for Resilient Water Supply Services [systems planning]

In the wake of the 2014 heavy rainfall event, Hiroshima City formulated a "Reconstruction Vision upon the Heavy Rainfall Disaster on August 20, 2014" to develop a more robust city infrastructure to minimize the disaster risks. Specifically, the vision document laid out the following actions to enhance the resilience of water supply services (City of Hiroshima 2015):

- Construct landslide barriers at high-risk spots on mountain slopes
- Design evacuation routes to the designated evacuation shelters equipped with underground water storage tanks
- Construct stormwater drainage facilities

14 HCWB, personal communication, October 17, 2017.

Water Safety Plan for Incorporating DRM into Daily Operations [contingency programming]

In response to the 2014 landslides, HCWB formulated a Water Safety Plan in December 2014, which allows for a comprehensive risk assessment and management of water quality from source to tap (HCWB 2014b). The plan identifies and includes preparedness and response measures to minimize approximately 280 potential risks that could adversely affect water quality, including odorous substances in water sources due to an increase in average temperature, an increase in turbidity at intake stations due to heavy precipitation events, and equipment malfunction at WTPs due to a natural hazard.

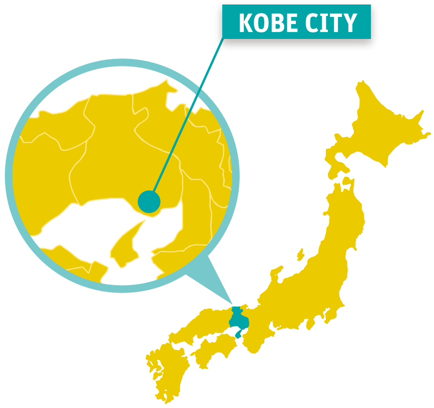
3.3.4 Lessons Learned

Seismic-resistant pipes minimize impacts of landslides [engineering design and materials]

Like all the major water supply utilities in Japan, HCWB has been increasing the use of seismic-resistant pipes after the 1995 Great Hanshin-Awaji Earthquake. Although seismic-resistant pipes were designed primarily for earthquakes, the durability of materials and special joint designs are also effective in mitigating the shocks caused by landslides.

Incorporate business continuity into water safety planning [contingency programming]

It is essential to prepare practical manuals detailing the emergency response procedures for the field engineers and regularly train staff in DRM practices to incorporate resilience measures into daily operation and maintenance activities in the context of water safety planning.



3.4 Kobe City:

Enhancing Resilience of Water Supply Services through Post-Earthquake Reconstruction

Photo 3.8 **Aerial View of Kobe City**

Source: PIXTA

The Kobe City Waterworks Bureau (KCWB) supplies water to 1.53 million residents (photo 3.8), with an NRW level of 7.4 percent as of 2014. The 1995 Hanshin-Awaji Earthquake (magnitude 7.3)[15] took the lives of 4,571 people[16] and severely damaged the infrastructure; it took approximatley 10 weeks to restore piped water supply (Ishii 2005). The utility developed and implemented a master plan comprising the following elements to achieve the recovery time objectives that they have established based on the lessons learned:

- *Seismic retrofitting of distribution pipes:* The 1995 earthquake did not affect the pipes with seismic-resistant joints. The seismic retrofitting prioritized the pipelines connected to hospitals and schools.
- *Emergency water storage system:* When the seismometers detect an earthquake, the utility's Okuhirano Control Center remotely operates emergency shutoff valves installed at 37 pairs of reservoirs. The system will shut off one of the two reservoirs for seven-day emergency use, while the other reservoir will continue distributing water to the unaffected districts and for firefighting.
- *Building of redundancy through a multifunctional transmission pipeline:* The utility has completed a 20-year project to install a 13-kilometer transmission pipeline with a diameter of 2.4 meters that can provide emergency water storage (59,000 cubic meters) through six intake points. The pipeline is connected to a distribution network, which allows the pipeline to also act as an emergency distribution pipeline.

15 "Earthquake and Tsunami Disasters in the Past." [In Japanese.] Japan Meteorological Agency website: http://www.data.jma.go.jp/svd/eqev/data/higai/higai-1995.html.

16 "Overview of Damage in 1995 Hanshin-Awaji Earthquake." [In Japanese.] Kobe City website: http://www.city.kobe.lg.jp/safety/fire/hanshinawaji/higai.html.

3.4.1 Basic Profile of Utility

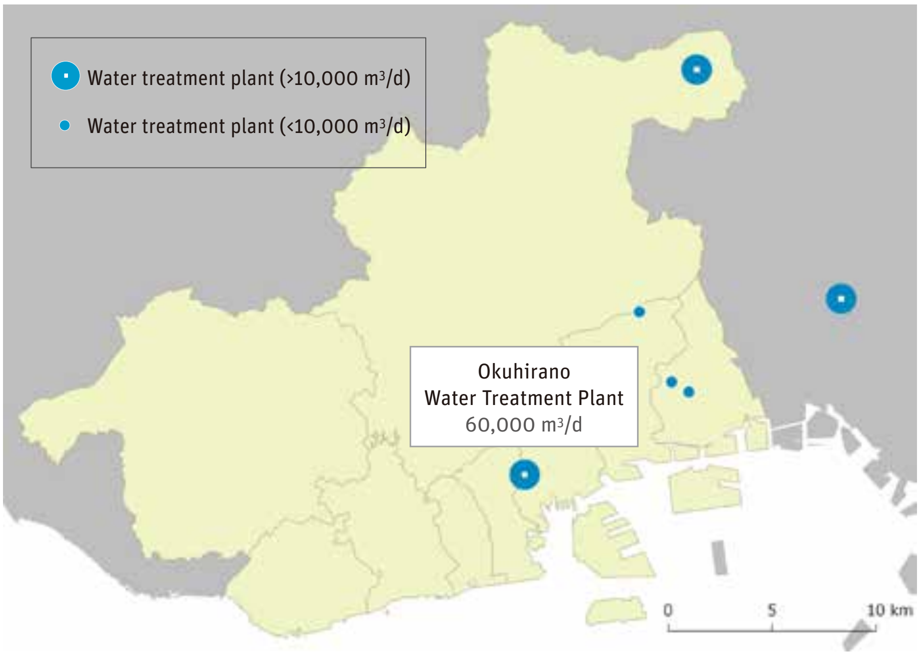
KCWB supplies water to Kobe City of Hyogo Prefecture. The utility serves 1.53 million people over 285 square kilometers of service area[17] through 0.77 million connections. As of April 2014, the utility purchased about 74 percent of its water from the Hanshin Water Supply Authority, a public water wholesaler for four municipalities including Kobe. The rest of the water comes from KCWB's own sources such as dams and rivers (23 percent) and from the Hyogo prefectural government's wholesale water supply scheme (3 percent).[18] The water extracted and purchased totals 862,000 cubic meters per day (table 3.7), of which 200,000 cubic meters is treated at the utility's six water treatment plants (map 3.4). The pipe network is 5,100 kilometers long.

Table 3.7 Basic Profile of the Kobe City Waterworks Bureau, 2014–15

Descriptor	Kobe City Waterworks Bureau
Service coverage	1.53 million population (99.8%)
Capacity	862,000 m^3/day[a]
Non-revenue water[b]	7.4%
Operational income	¥31.7 billion (US$279 million)
Operational expenditure	¥32.1 billion (US$283 million)
Number of employees	689
Regulator	Ministry of Health, Labour and Welfare

Source: MIC 2015.
Note: US$1 = ¥113.6. m^3 = cubic meters. The balance of the operational income and expenditure shows a loss because extraordinary losses were included this year due to a revision of the financial accounting system for the local public enterprises in Japan.
a. Distribution capacity.
b. "Non-revenue water" refers to the difference between the volume of water put into a water distribution system and the volume that is billed to customers.

Map 3.4 Water Treatment Plants of Kobe City Waterworks Bureau



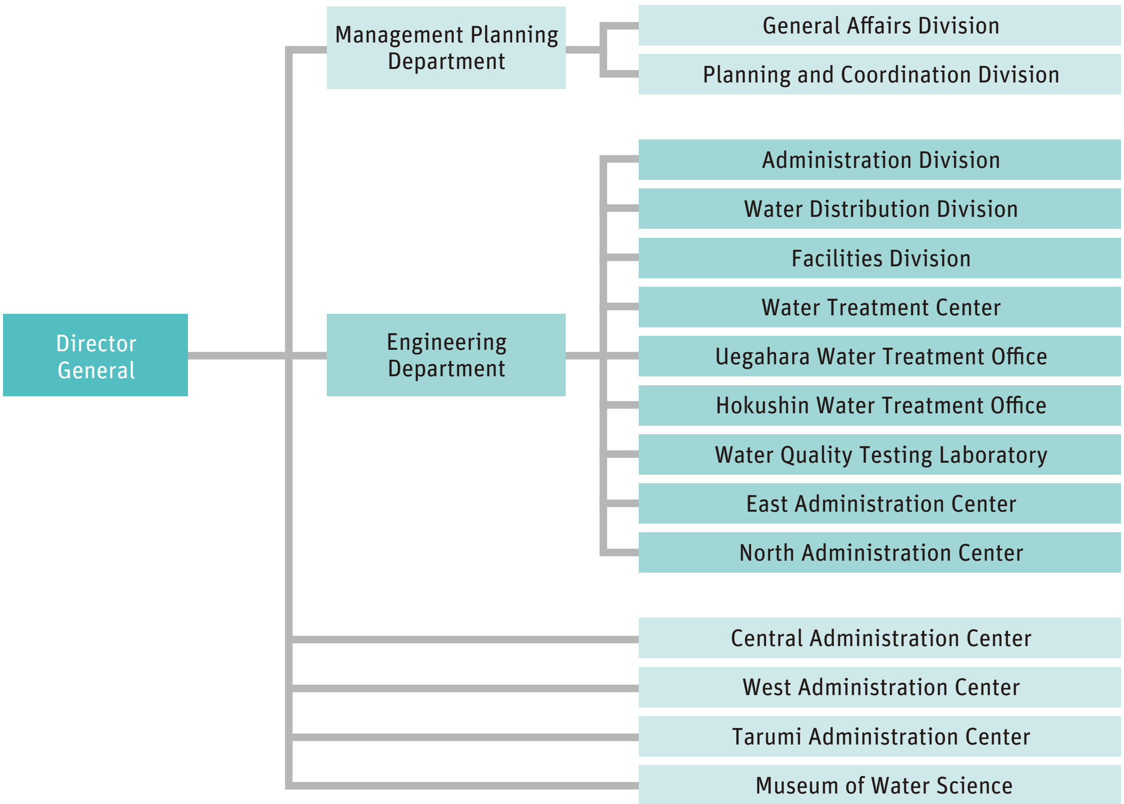
Source: Data from National Land Numerical Information database, Ministry of Land, Infrastructure, Transport and Tourism. ©World Bank. Permission required for reuse.
Note: m^3/d = cubic meters per day.

17 The administrative area of Kobe City is 557 square kilometers.

18 "Characteristics of Water Supply in Kobe." [In Japanese.] KCWB website: http://www.city.kobe.lg.jp/life/town/waterworks/water/suidou/01_01.html.

Figure 3.8 shows the utility's organizational structure. In KCWB, all the departments and centers work on DRM as well as an emergency response upon a disaster.

Figure 3.8 **Organizational Structure of Kobe City Waterworks Bureau**



Source: Based on Kobe City Waterworks Bureau website. Translation by Japan Water Research Center.

3.4.2 Disaster Risk Profile

The city covers 557 square kilometers on the southern side of Honshu, 20 kilometers north of the Awaji Island in the Seto Inland Sea. Kobe has several active faults in its vicinity, the closest being the Rokko-Awaji Island active fault zone that extends under the city. In January 1995, the active fault zone became the source of the devastating inland shallow earthquake that heavily affected the city.

Another seismic concern of note is the Nankai megathrust earthquake. Just south of Honshu is a submarine trough called the Nankai Trough, which extends about 900 kilometers offshore. Its underlying fault, the Nankai megathrust, has caused the devastating Nankai megathrust earthquakes, the last of which occurred in 1946 with a magnitude of 8.0.[19] Because the Nankai megathrust earthquake generally repeats itself every 90–200 years, the Japanese government estimates that the probability of another Nankai earthquake over the next 30 years is approximately 70 percent (Cabinet Office 2016). This earthquake could largely affect wide areas in western Japan.

19 "Earthquake and Tsunami Disasters in the Past." [In Japanese.] Japan Meteorological Agency website: http://www.data.jma.go.jp/svd/eqev/data/higai/higai-1995.html.

Recent Natural Disasters

On January 17, 1995, the Great Hanshin-Awaji Earthquake (magnitude 7.3) struck the city, claiming the lives of 4,571 people. The 1995 Great Hanshin-Awaji Earthquake extensively damaged the water supply infrastructure, including 1,757 failures along a 4,002-kilometer distribution network and requiring 89,584 repairs of 650,000 service pipes (table 3.8, photo 3.9). As a result, almost all the city's residents lost access to water. It took approximately 10 weeks for the utility to fully restore the piped supply (Ishii 2005). The total water infrastructure reconstruction cost was ¥29 billion (US$255 million).

Table 3.8 Water Infrastructure Damages in Kobe City from 1995 Great Hanshin-Awaji Earthquake

Facility type	Extent of damage	Reconstruction cost
Dam	One out of three total	¥7 billion (US$61.6 million)
Water treatment plant	Two out of seven total	—
Raw water pipe	Two locations over 43 km	—
Transmission pipe	Six locations over 260 km	—
Distribution reservoir	1 out of 119 distribution stations	¥1.9 billion (US$16.7 million)
Distribution pipe	1,757 failures over 4,002 km	¥13.5 billion (US$119 million)
Service pipe	89,584 locations over 650,000 pipelines	¥2.5 billion (US$22 million)
Other	Head office, one branch, and other offices	¥4.1 billion (US$36 million)

Source: Matsushita 2014.
Note: US$1 = ¥113.6.

Photo 3.9 Cast Iron Pipe Damaged from 1995 Hanshin-Awaji Earthquake

Source: Matsushita 2014. ©Kobe City Waterworks Bureau (KCWB). Reproduced, with permission, by KCWB; further permission required for reuse.

3.4.3 Best Practices

As an earthquake that caused some of the greatest damage to the nation's water supply infrastructure since the 1923 Great Kantō Earthquake, the 1995 Great Hanshin-Awaji Earthquake made it clear that the disaster- and WSS-related policies and measures of the Japanese government and local municipalities had much room for improvement. The 1995 earthquake triggered a series of revisions to the national legal framework as well as local ordinances. These revisions included the enactment of the 1995 Act on Special Measures for Earthquake Disaster Countermeasures and the 1995 Act on Seismic Retrofitting Promotion as well as the amendment of 1998 Act on Building Standards (Cabinet Office 2016).

Each type of countermeasure described below pertains to one or more stages of infrastructure life cycle—systems planning, engineering design and materials, asset management, and contingency programming—as designated within brackets in the paragraph headings.

Postdisaster Master Plan for Improving Disaster Resilience of Water Supply Services [systems planning]

After the 1995 earthquake, Hyogo Prefecture and Kobe City formulated a citywide postdisaster reconstruction plan. In coordination with the citywide master plan, KCWB developed a reconstruction master plan for the water supply system to increase the effectiveness of the emergency water supply and to enhance the overall system capacity so that a suspended supply can be restored much faster (KCWB 1995). KCWB established an overall recovery time objective (RTO) to restore water supply (250 liters per person per day) within 28 days postdisaster with the following progressive per capita RTOs:

- Restore 3 liters per person per day within the first three days postdisaster
- Restore 20 liters per person per day within the next seven days
- Restore 100 liters per person per day within the next 11 days

To achieve the RTOs, the utility implemented, among other measures, three major infrastructure upgrade projects (further described below): an emergency water storage system, seismic reinforcement of the distribution pipe network, and a Large-Capacity Transmission Pipeline. All of the projects were partly subsidized by the Ministry of Health, Labour and Welfare.

Emergency Water Storage System [contingency programming]

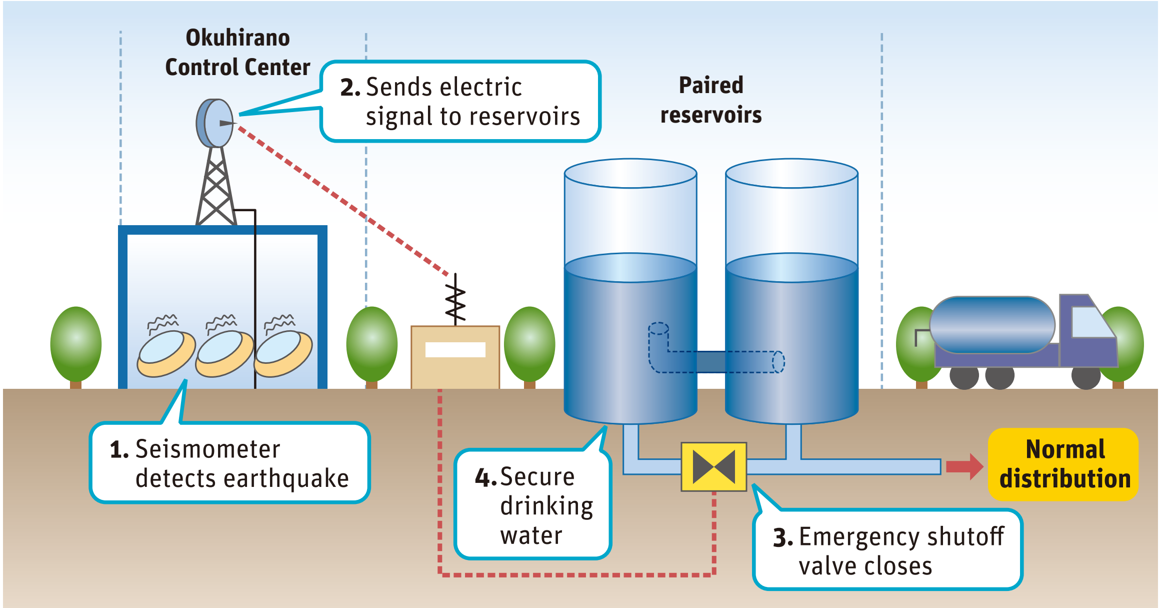
To secure enough water for emergency use, the utility has finished building an emergency water storage system at 47 sites including pumping stations and public parks. The storage system stores enough water to provide emergency water supply to all residents for seven days (three liters per day per person) postdisaster. Thirty-seven of these sites have a pair of distribution reservoirs with an emergency shutoff valve. KCWB started installing this emergency reservoir system in 1986 in response to the Ministry of Health, Labour, and Welfare (MHLW)'s policy recommendation to increase the resilience of water supply systems against disasters including earthquakes and drought (MHLW 1984). At the time of the 1995 earthquake, 21 pairs of such reservoirs had already been installed, allowing the city to secure 42,000 cubic meters of water for emergency distribution. At the sites without paired reservoirs, large water storage tanks or facilities have been constructed to serve as emergency water supply bases. In 2015, the utility completed the installation of these reservoirs and storage tanks at all 47 sites.[20] Now that all the work has been completed, every household could find at least one of these bases within a radius of 2 kilometers.

When the seismometers detect an earthquake exceeding "upper 5"[21] on the Japan Meteorological Agency's seismic intensity scale (the Great Hanshin-Awaji Earthquake reached the maximum "7" on this scale), the utility's Okuhirano Control Center automatically and remotely operates emergency shutoff valves installed at the 37 pairs of storage system reservoirs (figure 3.9). The utility extracts water from the reservoirs equipped with emergency shutoff valves using tanker trucks and opens the sites to the public so that residents can obtain water directly on their own. The reservoirs without an emergency shutoff valve would continue distributing water for the residents whose service was not disrupted and for firefighting purposes (KCWB, n.d.).

20 The exact breakdown of the 47 sites is as follows: 37 paired reservoirs with an emergency shutoff valve, 9 large water storage tanks, and 1 access point of the Large-Capacity Transmission Pipeline (discussed further below).

21 The exact trigger condition is the detection of gravitational acceleration exceeding 250 gal. Gal is a unit of gravitational acceleration equal to 1 centimeter per second.

Figure 3.9 Paired Emergency Water Storage System, Kobe City



Source: Matsushita 2014. ©Kobe City Waterworks Bureau (KCWB). Reproduced, with permission, from KCWB; further permission required for reuse. Adaptation and English translation by Japan Water Research Center.

Seismic Reinforcement of the Distribution Pipe Network and Other Assets [engineering design and materials]

Although the 1995 earthquake damaged more than 1,700 locations of the distribution pipe network, no damage was reported at the pipes with earthquake-resistant joints (Ishii 2005). Since the earthquake, therefore, the utility has been strengthening its efforts to improve earthquake resistance of the distribution pipelines based on certain factors including their age and ground conditions (for example, soil corrosiveness). Priority is given to pipelines connected to facilities such as hospitals and schools because emergency tap stands would be set up at these schools following a disaster for local communities. The utility has also been improving the earthquake resistance of water treatment plants and distribution reservoirs.

As of March 2015, the ratio of earthquake-resistant distribution pipes has increased from 9 percent at the time of the 1995 earthquake to 35 percent. The earthquake-resistant ratio of KCWB's primary pipelines is approximately 70 percent (Miura, Hashigami, and Konishi 2015).

Builidng Redundancy through a Multifunctional Transmission Pipeline
[systems planning] [contingency programming]

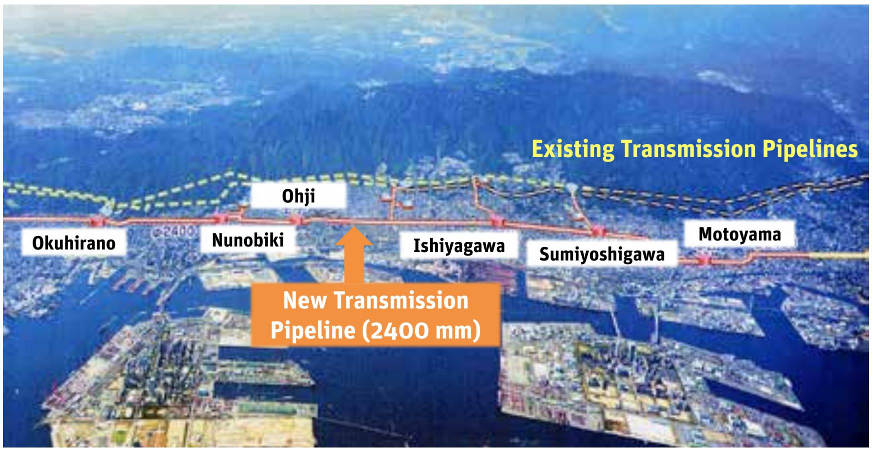
Hanshin Water Supply Authority supplies about 75 percent of the water used by Kobe. This means that reliable transportation of water from the Authority to the utility's network is critical for resilient WSS service. The 1995 earthquake caused severe traffic congestion in the central area of the city and made it difficult for the utility to mobilize tanker trunks to various locations. It also generated numerous leaks along the distribution network, prolonging the time required to resume piped supply. To enhance backup capacity, the utility installed a Large-Capacity Transmission Pipeline, a new underground water pipeline across the city's urban areas after the earthquake. With a diameter of 2.4 meters and an overall length of 12.8 kilometers, the completion of new transmission pipeline took 20 years and cost ¥37 billion (US$326 million). It now supplements the existing two transmission pipelines passing through Mt. Rokko (KCWB 2016; Kumaki 2015).

The new transmission pipeline is designed to provide multiple functions in addition to transporting treated water from the Authority based on lessons learned from the 1995 earthquake. These functions include the following:

- The new transmission pipeline can store a total of 59,000 cubic meters of water for emergency use, which amounts to a 12-day provision of three liters per person per day for all residents. The residents can obtain water from six access points (operated by KCWB staff) during an emergency (figure 3.10). Because the access points are in the central area of the city, water tanker trucks can deliver water to the city's most populated districts, shelters, general hospitals, and other primary facilities much faster than during the 1995 Great Hanshin-Awaji Earthquake.
- In case of damage to the network's upstream distribution reservoirs and primary pipelines, the transmission pipeline can be connected to the downstream portion of the network and distribute water from its storage. This would allow the utility to repair only the downstream portion of the network before resuming a piped supply, thus saving the time to fix the upstream portion (Kumaki 2015).

With the new transmission system now installed, the utility is able to operate an emergency water supply more efficiently in the urbanized area. Also, the pipeline's enhanced connectivity with the distribution network allows for a faster restoration of piped supply.

Figure 3.10 **New Transmission Pipeline with Emergency Water Storage Capacity, Kobe City**



Source: Matsushita 2014. ©Kobe City Waterworks Bureau (KCWB). Reproduced, with permission, from KCWB; further permission required for reuse. Adaptation and English translation by Japan Water Research Center.

Community-driven Emergency Water Supply [contingency programming]

Because the utility's human resources are limited, it is important that local communities are trained to secure water access by themselves. The utility has conducted routine exercises with local communities at schools and other emergency water supply bases so that they could set up the necessary equipment and obtain water on their own upon a disaster (photo 3.10). In the past, most of the emergency water supply bases were placed at distribution reservoirs and were thus off-limits to residents for security reasons. This was changed after the 1995 event. Currently, local communities can access these sites through designated entrances in case of an emergency and take out the related equipment from the storage house to set up tap stands (Yamaguchi and Hashigami 2010).

Photo 3.10 Community Drill with Utility to Set Up and Use Emergency Water Supply Equipment

Source: ©Kobe City Waterworks Bureau (KCWB). Reproduced, with permission, from KCWB; further permission required for reuse.

Regular Trainings and Mutual Support Agreements for Business Continuity Management and Planning

[contingency programming]

For a quick and efficient response and management of an emergency, the utility has developed a DRM manual and a business continuity plan (BCP). With the passage of time since the 1995 earthquake, approximately 40 percent of the utility staff members are relatively new and did not experience the disaster as utility staff (Miura, Hashigami, and Konishi 2015). To keep the staff's awareness and preparedness high, KCWB actively involves staff members in public relations campaigns as well as internal trainings, assuming various situations including pipe failures.

As part of business continuity management, KCWB has made a mutual support agreement with major water supply utilities in Sapporo, Sendai, Saitama, Chiba, Tokyo, Kawasaki, Yokohama, Sagamihara, Niigata, Shizuoka, Hamamatsu, Nagoya, Kyoto, Osaka, Sakai, Kobe, Okayama, Hiroshima, Kitakyushu, Fukuoka, and Kumamoto as described in chapter 2. In coordination with the Japan Water Works Association (JWWA), the partnering utilities dispatch emergency supplies and personnel to one another in case of an emergency. For these agreements to work efficiently, the concerned utilities conduct annual trainings and drills together. Based on these agreements, Kobe recently dispatched staff members to other municipalities several times, including after the 2011 Great East Japan Earthquake.

The utility also developed a Plan for Receiving External Support to minimize uncertainty and the time lost in arranging and hosting external support during the emergency response and recovery periods (Miura, Hashigami, and Konishi 2015).

3.4.4 Lessons Learned

Develop a WSS system master plan to meet recovery-time objectives [systems planning]

Building the disaster resilience of an overall WSS system through capital works requires time and large investments. Therefore, it is recommended that WSS utilities define recovery-time objectives (for example, restore water supply within 28 days); identify the disaster risk reduction measures required to meet the objectives; and develop a long-term WSS system master plan in close coordination with an overall city master plan.

Adopt both structural and nonstructural risk reduction measures for a resilient water supply system
[systems planning] [engineering design and materials] [contingency programming]

The primary challenge of the 1995 Hanshin-Awaji Earthquake was that it disrupted water supply in wide areas owing to a substantial number of pipe failures, prolonging the time for recovery. Service resilience is enhanced through both structural and nonstructural measures. Structural measures include an increase in the network redundancy and distribution capacity, development of an emergency water storage system, and seismic retrofitting of facilities including pipelines. Nonstructural measures include cooperation with local communities (for example, a community-driven emergency water supply); development of a DRM manual and BCP; regular DRM trainings within and outside the utility; and mutual assistance agreement with external organizations.

3.5 Kumamoto City:

Enabling Rapid Earthquake Recovery through Risk-Informed Investments and Framework Agreements on External Assistance

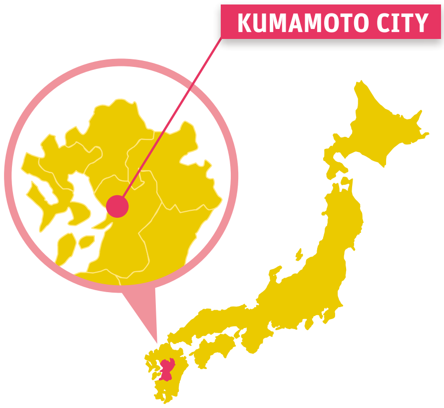


Photo 3.11 **Aerial View of Kumamoto City**

Source: ©Kumamoto City Waterworks and Sewerage Bureau (KWSB). Reproduced, with permission, from KWSB; further permission required for reuse.

Kumamoto City Waterworks and Sewerage Bureau (KWSB) provides services to about 692,000 residents (photo 3.11), with an NRW level of 10.3 percent in 2014 (table 3.9). In April 2016, two earthquakes of magnitudes 6.5 and 7.3[22] caused a loss of water access among all the residents. However, the utility restored water supply within two weeks, owing to the following measures implemented before, during, and after the disaster:

- *Seismic risk assessment and reinforcement of WSS assets:* Before the earthquakes, the utility had prioritized and implemented seismic reinforcement of pipelines, distribution reservoirs, pumping stations, and wastewater treatment plants based on a risk assessment, taking into account the pipe age, materials, soil conditions, and expected impacts in case of failure.[23]
- *Framework agreements with the private sector and mutual assistance from other utilities:* The utility commissioned the Kumamoto City Pipe Construction Cooperative (comprising 100 local companies) to identify and fix pipe failures and leakage at the onset of the response period. The Japan Waterworks Association also coordinated with the utility to deploy personnel from other utilities for emergency water supply activities and to identify pipe failures and repair works (KWSB 2016; Nakajima and Takizawa 2016).

22 “Related Information on 2014 Kumamoto Earthquake.” [In Japanese.] Japan Meteorological Agency website: http://www.jma.go.jp/jma/menu/h28_kumamoto_jishin_menu.html.

23 “About Seismic Upgrades of Water Supply Pipes.” [In Japanese.] KWSB website: http://www.kumamoto-waterworks.jp/?waterworks_article=15872.

3.5.1 Basic Profile of Utility

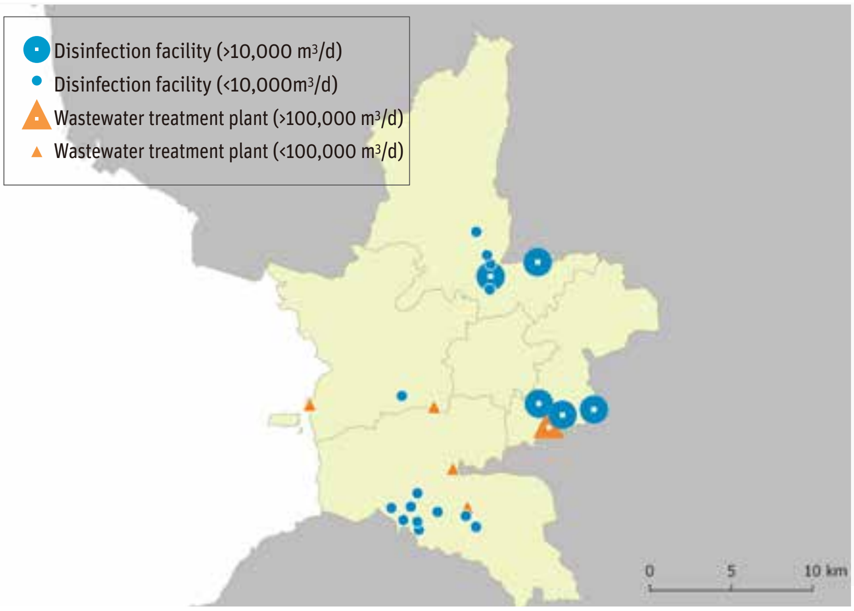
KWSB is responsible for water supply as well as sewage collection and treatment in Kumamoto City. Groundwater is the single source of water supply, and the pumped groundwater requires only chlorination at the intake wells before distribution through 3,169 kilometers of pipe networks.[24] For this reason, the utility does not have a water treatment plant (map 3.5). There are 2,545 kilometers of sewer networks that feed five sewage treatment plants. The sewerage is transported through 38 pumping stations.

Table 3.9 Basic Profile of Kumamoto City Waterworks and Sewerage Bureau, FY2014

Descriptor	Water supply service	Wastewater service
Service coverage	692,000 population (94.3%)	645,000 population (87.9%)
Capacity	316,000 m^3/day[a]	298,000 m^3/day
Non-revenue water[b]	10.3%	n.a.
Operational income	¥12.3 billion (US$108 million)	¥11.4 billion (US$100 million)
Operational expenditure	¥10 billion (US$88 million)	¥15.2 billion (US$114 million)
Number of employees	251	179
Regulator	Kumamoto Prefectural Government[c]	Ministry of Land, Infrastructure, Transport and Tourism

Source: MIC 2015.
Note: n.a. = not applicable. m^3 = cubic meters. Conversion rate: US$1 = ¥113.6.
a. Distribution capacity.
b. “Non-revenue water” refers to the difference between the volume of water put into a water distribution system and the volume that is billed to customers.
c. Under the Waterworks Act, prefectural governors—not the Minister of Health, Labour and Welfare—have the authority to approve the commencement of new water supply services if the services (a) serve equal to or fewer than 50,000 people, or (b) do not extract water from rivers or purchase water from wholesale water supply schemes that extract water from rivers (MHLW 2011).

Map 3.5 Groundwater Disinfection Facilities and Wastewater Treatment Plants of Kumamoto City

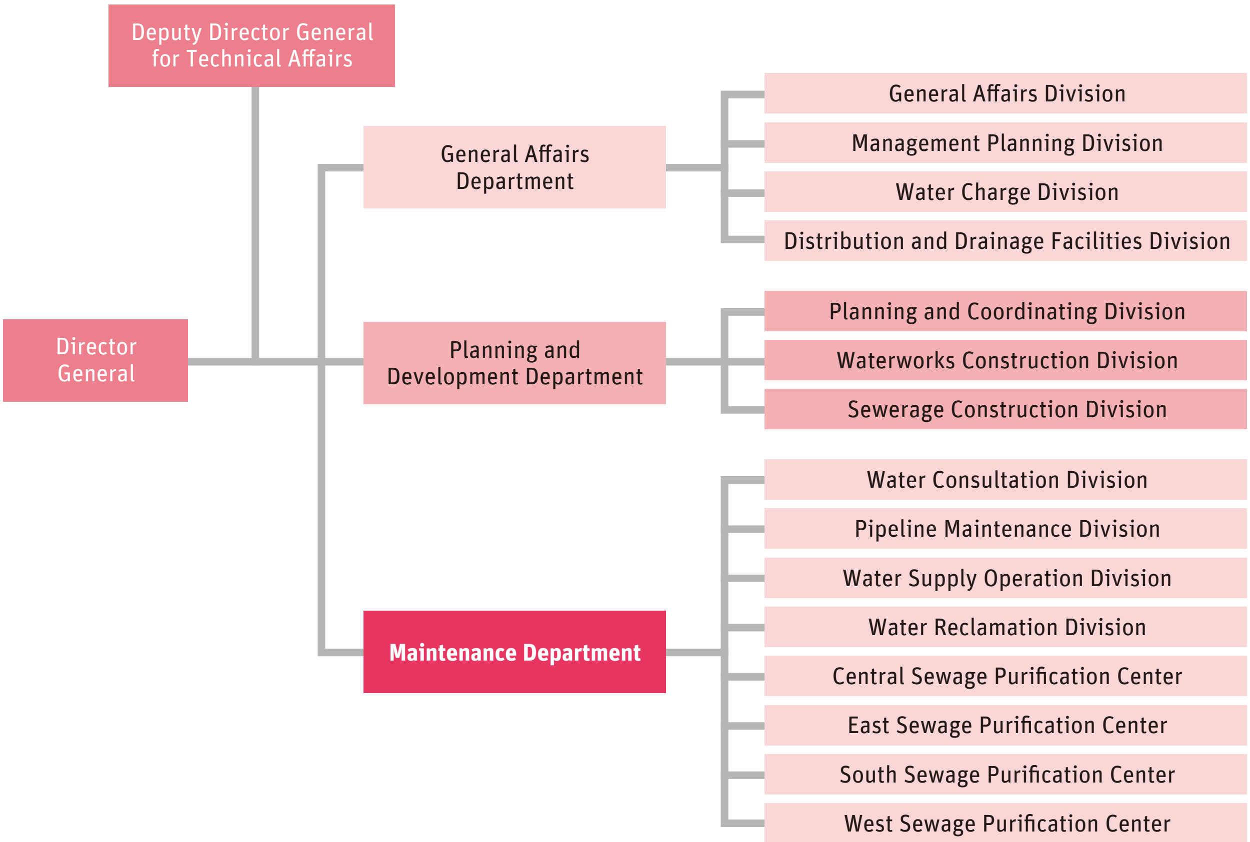


Source: Data from National Land Numerical Information database. Ministry of Land, Infrastructure, Transport and Tourism. ©World Bank. Permission required for reuse.
Note: m^3/d = cubic meters per day.

24 “How the Water Supply System Works.” [In Japanese.] KWSB website: http://www.kumamoto-waterworks.jp/?waterworks_article=1654.

KWSB has three departments (figure 3.11). The Maintenance Department is responsible for DRM and emergency response for both water supply and wastewater services.

Figure 3.11 **Organizational Structure of Kumamoto City Waterworks and Sewerage Bureau**



Source: Based on Kumamoto City Waterworks and Sewerage Bureau website.

3.5.2 Disaster Risk Profile

Kumamoto City covers 389.5 square kilometers in Kumamoto Prefecture of Kyushu island. The region has several active fault zones, including the Hinagu and Futagawa fault zones, which became the source of the devastating 2016 Kumamoto Earthquakes.

Recent Natural Disasters

In April 2016, the city was heavily affected by two large earthquakes that hit the Kumamoto region at a depth of approximately 10 kilometers over a three-day period. The first earthquake, on April 14, recorded a magnitude of 6.5 and left approximately 85,000 households without access to water as the two-thirds of the city's intake wells (69 out of 96) automatically stopped operation as meters detected a turbidity increase in the groundwater source and the emergency shutoff valves kicked in. Immediately, the utility started working to drain the affected wells, trying to resume supply as soon as possible (Nagame 2016; Nakajima 2017).

This work had been proceeding for about a day and half when the second earthquake of magnitude 7.3 took place on April 16, causing a turbidity increase at all the 96 intake wells. This time, all 326,000 households lost access to water. There were 440 damages to the transmission, conveyance, and distribution pipes in addition to 2,213 damages at the service pipe (Nagame 2016; Nakajima 2017) (table 3.10). No damages were observed in the reinforced assets during the 2016 earthquakes.

Table 3.10 Overview of Pipe Damage in Kumamoto City from 2016 Kumamoto Earthquakes

Type of pipe	Damages (no.)	Share of total damage (%)
Ductile iron pipe (DIP) with seismic resistant joints	0	0
DIP without seismic resistant joint	72	16
Cast iron pipe (CIP)	37	8
Steel (unknown joint type)	109	25
Hard vinyl chloride pipe (RR long joint)	0	0
Hard vinyl chloride pipe (RR joint)	0	0
Hard vinyl chloride pipe (TS joint)	71	16
Hard vinyl chloride pipe (unknown joint type)	0	0
Polyethelene (fusion bonded joint)	0	0
Polyethelene (cold short joint)	1	0
Stainless	3	1
Interface of pipes of different material, previously repaired locations of leakage	3	1
Appurtenances (air valves, gate valves, and others)	144	33
Total	**440**	**100**

Source: KWSB 2016.

3.5.3 Best Practices

Because earthquakes are among the most damaging and frequent natural hazards in Japan, the central government actively implements regulatory measures and subsidy programs to prompt utilities to take seismic risk mitigation measures. As such, although Kumamoto City had not been heavily affected by earthquakes before 2016, the utility had already taken a range of risk reduction measures before the 2016 earthquakes.

Each type of countermeasure described below pertains to one or more stages of infrastructure life cycle—systems planning, engineering design and materials, asset management, and contingency programming—as designated within brackets in the paragraph headings.

Seismic Reinforcement of Water Supply and Sanitation Assets [engineering design and materials]

The 2016 earthquakes extensively damaged the non-seismic-resistant pipes. On April 18, the utility resumed water supply upon confirming a decrease in turbidity, but it was difficult to keep an appropriate pressure because of numerous pipe damages. In fact, the two earthquakes caused 3,597 leaks in the municipal water supply network, causing the water supply volume to increase by 50 percent beyond the usual volume (Nakajima 2017).

However, statistics show that the number of water supply pipe damage instances per kilometer in the city from the 2016 earthquake was 0.09 per kilometer. This figure is relatively small compared with 0.32 per kilometer in Kobe City and 0.07 per kilometer in Sendai City from, respectively, the 1995 Hanshin-Awaji Earthquake (magnitude 7.3) and the 2011 Great East Japan Earthquake (magnitude 9.0)[25] (Nakajima 2017). Although a simple comparison is impossible because of different conditions and intensities of these earthquakes, the comparatively lower damage to the pipelines in Kumamoto may be attributed to the city's long-term practice of replacing old and primary pipelines for improved seismic resistance as a lesson learned from 1995 and 2011 earthquakes.

For example, the utility has used earthquake-resistant pipes for all the new installations and replacements since 2005. In 2012, the utility estimated the damage to its water supply network from an earthquake of magnitude 6.5–7.2 by taking into account the pipe age, pipe material, soil conditions, corrosiveness, and expected impacts in case of failure.[26] Based on the results of analysis, the utility prioritized to replace old pipes with seismic-resistant joints. As of March 2016, 74 percent of the city's primary pipelines were earthquake-resistant,[27] and approximately 22 percent of all its pipelines were earthquake-resistant.

Seismic reinforcement has also been implemented on reservoirs, pumping stations, and wastewater treatment plants by using thick reinforced concrete. As of March 2016, approximately 93 percent of the total distribution reservoir capacity was seismic-resistant. In 2013, the utility developed a master plan to improve the seismic resilience of its sanitation services while coordinating with upper-level plans of the national and prefectural governments. The plan involved the period from 2013 to 2018 under the estimated budget of ¥3.08 billion (US$27.1 million) (KWSB, n.d.).

Repair of Leaks in Cooperation with the Private Sector and Municipalities [contingency programming]

To identify the location of and fix the damaged pipes, the utility worked together with a group of local pipe installment and maintenance companies and emergency response teams from other municipalities. Because of these efforts, the water supply was restored throughout the city on April 30, two weeks after the first earthquake occurred.

The utility has approximately 100 designated local companies to conduct pipe installation and maintenance for the city. These companies make up a network called the Kumamoto City Pipe Construction Cooperative. Approximately 30 of them are contracted to provide daily pipeline maintenance, with their staffs available 24/7 (Nakajima and Takizawa 2016). As the damage from the 2016 earthquakes focused primarily on pipelines, these companies particularly played an important role in restoring water supply by identifying and fixing pipe failures and leaks from the beginning of the response period based on their intimate knowledge about the local conditions.

In addition, the Japan Water Works Association's (JWWA) network was used immediately after the first earthquake of April 14. On April 15, 74 people from 16 municipalities arrived in the city with supplies of bottled water and participated in the utility's emergency water supply activities. As the number of water supply bases increased to 33 eventually, the number of supporting members from other utilities also increased. Personnel from other water utilities also contributed to the city's effort to identify and fix leaks. A total of 241 staff members from 19 utilities were engaged in identifying leaks from April 22 to 25, and a total of 5,216 people from 54 utilities took part in fixing them from April 26 to May 17 (KWSB 2016).

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25 "2011 Great East Japan Earthquake." [In Japanese.] Japan Meteorological Agency's website: http://www.data.jma.go.jp/svd/eqev/data/2011_03_11_tohoku/index.html.

26 "About Seismic Upgrades of Water Supply Pipes." [In Japanese.] KWSB website: http://www.kumamoto-waterworks.jp/?waterworks_article=15872.

27 Primary pipelines are defined by the utility as transmission pipes and distribution pipes of more than 350 millimeters in diameter. Transmission pipes include pipes between intake and treatment facilities as well as those between treatment facilities and distribution reservoirs.

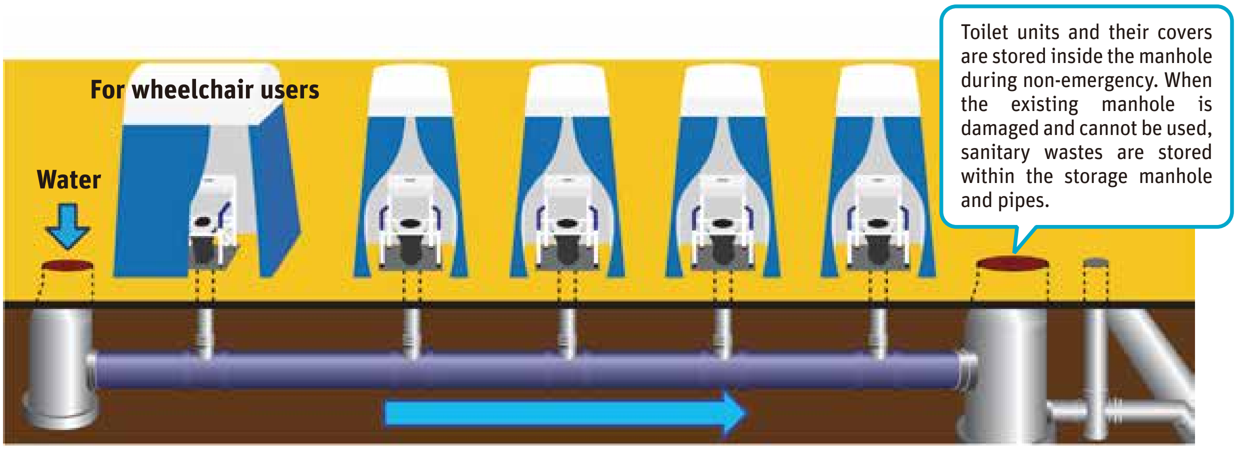
Outsourcing of Public Emergency Communication to Enable Allocation of Resources for Other Critical Emergency Response and Restoration Works [contingency programming]

After the two earthquakes, the utility received an overwhelming number of phone calls from residents and the media inquiring about related damage, water leaks, and other matters. This made it difficult for city personnel to focus on other emergency response work. Eventually, the utility decided to outsource the job and set up a hotline to receive related phone calls. The hotline helped to efficiently communicate relevant information to the residents while also reducing call abandonment. More importantly, it enabled all the utility staff to focus on the urgent tasks of addressing service disruption and restoring water supply.

Preparation of Manhole Toilets for Emergency Sanitation [contingency programming]

The 2013 master plan had an objective of installing 190 manhole toilets at 38 junior high schools. The manhole toilet system consists of toilets, toilet covers, and underground sanitation pipe connected to the public sewer system (figure 3.12). The manhole toilet is more hygienic than other types of portable toilets because sanitary waste drains directly into the sewer system instead of being stored above ground before disposal.

Figure 3.12 **Structure of Manhole Toilet System for Emergency Sanitation in Kumamoto City**



Source: KWSB, n.d. ©Kumamoto City Waterworks and Sewerage Bureau (KWSB). Reproduced, with permission, from KWSB; further permission required for reuse. English translation by Japan Water Research Center.

To make one manhole toilet system consisting of five units (one of which is designed for wheelchair users), seven new manhole structures are constructed at the school: Five manholes are used to set up toilet units above in the event of emergency. Through another manhole, water is poured (from the school's swimming pool or other nearby sources) to wash away sanitary wastes in the underground pipe. In the seventh manhole, the five toilet units and their covers are stored during nonemergency periods.

When the 2016 earthquake occurred, 20 units of manhole toilets had already been installed at four schools (photo 3.12). The utility put all the units to use for residents who evacuated to temporary shelters. Throughout the event, the utility staff members regularly maintained the system to keep it clean (KWSB, n.d.).

Photo 3.12 **Manhole Toilets Used in Kumamoto City after 2016 Earthquake**

Source: KWSB, n.d. ©Kumamoto City Waterworks and Sewerage Bureau (KWSB). Reproduced, with permission, from KWSB; further permission required for reuse.

3.5.4 Lessons Learned

Prioritize investments in building redundancy [systems planning]

KWSB extracts 65 percent of its water from the wells in the East District. Because of its close vicinity to the epicenter of the April 16, 2016 earthquake, this district was most affected and its primary pipelines (including transmission pipes) largely damaged, including the bypass piping to transfer water from the district to other areas in case of emergency. To reduce future risks from an event of similar scale, building of system redundancy needs to be reinforced by improving interconnectivity between the primary source of water and the rest of the service area.

Prepare plans and protocols to efficiently receive external assistance as part of business continuity planning [contingency programming]

As a regional leader of the JWWA's mutual aid network for water supply utilities, Kumamoto City's utility had dispatched its field engineers to other municipalities to offer help on various occasions before 2016. However, the utility had never accommodated emergency support teams from other utilities until the 2016 events. This lack of experience resulted in fragmented and inefficient management of external support because the identification of departments to coordinate various tasks with external entities had not been clarified in advance (Nakajima and Takizawa 2016). To fully take advantage of external support during emergencies, it is recommended to develop a business continuity plan including protocols for receiving or hosting external assistance.

Build emergency water supply storage systems and promote community-driven emergency water supply [contingency programming]

Supported by other utilities, the utility set up 33 emergency water supply bases throughout the city. With all the households losing access to water, however, these bases did not sufficiently meet the demand, causing long queues of residents. To address this challenge, the utility plans to install pipelines with emergency storage capacity and cooperate with communities for emergency water supply activities (Nagame 2017).

3.6 Sendai City:

Integrating Business Continuity and Asset Management after the Great East Japan Earthquake

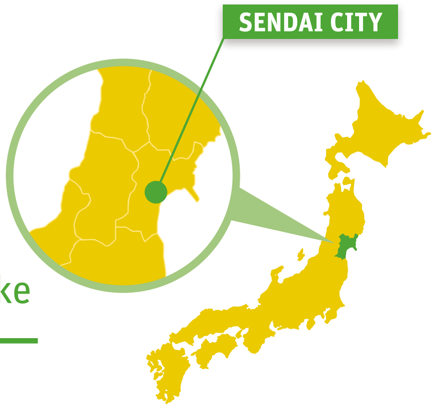


Photo 3.13 **Aerial View of Sendai City**

Source: ©Sendai City. Reproduced, with permission, from Sendai City; further permission required for reuse.

The Sendai City Waterworks Bureau (SWB) and Construction Bureau (SCB) provide services to 1.05 million residents (photo 3.13), with an NRW level of 5.8 percent in fiscal year 2014. The 2011 Great East Japan Earthquake (GEJE) of magnitude 9.0 caused up to 500,000 residents (about half of all water service users) to lose water access (SWB 2015), and the city's primary wastewater treatment plant (WwTP) was completely submerged by tsunami, reducing treatment capacity (SCB 2013). Lessons learned from GEJE include the following:

- *Building redundancy and seismic reinforcement of water supply assets:* The utility has divided the water supply distribution network into around 120 small blocks and built redundancy to increase backup capacity in addition to seismic reinforcement of assets including pipes and valves (SWB 2015). This has enabled the utility to operate the pipelines that were not physically affected by GEJE.
- *Sanitation business continuity planning:* The utility developed a disaster risk reduction plan in 2006 and was already in the process of developing a business continuity plan (BCP) when the earthquake hit. Based on the draft BCP, the utility switched to a simple, gravity-fed treatment process and opened an emergency discharge gate, which enabled it to continue treating sewage despite the reduced treatment capacity. As a result, the utility managed to prevent sewage overflows after GEJE (SCB 2015b).
- *Mutually reinforcing and integrating a sanitation BCP and an asset management (AM) system:* A geographic information system (GIS) database of assets enabled the utility to quickly identify the location and extent of pipe failures and to mobilize the relevant human resources and equipment to restore the damaged pipes. SCB plans to improve its BCP based on the results of seismic and inundation risk assessment conducted as part of the AM system. The utility will also adopt the prioritization and investment decision-making process established under the AM system for emergency repair and reconstruction works.

3.6.1 Basic Profile of Utilities

SWB is responsible for water supply services in Sendai City, Miyagi Prefecture. SWB has four primary water treatment plants (WTPs) with a total distribution capacity of about 430,000 cubic meters per day (table 3.11, map 3.6). Three-quarters of the city's water comes largely from dams, with a small amount coming from rivers. The remainder (106,000 cubic meters per day) is purchased from the Miyagi Prefectural Wholesale Water Supply. The total length of the distribution network is 3,430 kilometers.

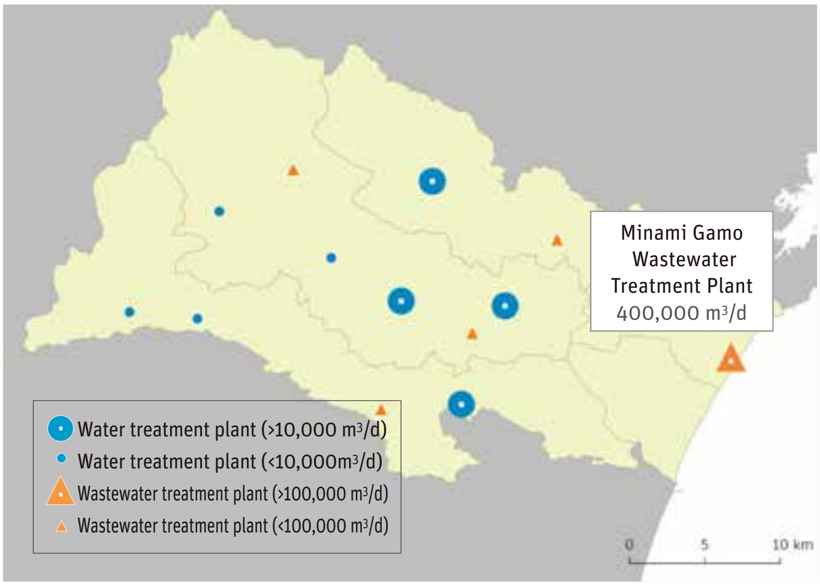
SCB is responsible for wastewater and stormwater collection, treatment, and disposal in Sendai City and has five WwTPs (table 3.11, map 3.6). Operating since 1899, SCB is the third oldest wastewater works in Japan. Approximately 70 percent of all sewage is treated at the Minami-Gamo WwTP (SCB 2013).

Table 3.11 Basic Profile of WSS Utilities in Sendai City, FY2014

Descriptor	Sendai City Waterworks Bureau (water supply)	Sendai City Construction Bureau (sewerage)
Service coverage	1.05 million people (99.6%)	1.03 million people (97.6%)
Capacity	430,000 m^3 per day[a]	490,000 m^3 per day
Non-revenue water[b]	5.8 percent	n.a.
Operational income	¥24.8 billion (US$218 million)	¥22.6 billion (US$199 million)
Operational expenditure	¥23.0 billion (US$202 million)	¥23.9 billion (US$210 million)
Number of employees	407	239
Regulator	Ministry of Health, Labour and Welfare	Ministry of Land, Infrastructure, Transport and Tourism

Source: MIC 2015.
Note: n.a. = not applicable. m^3 = cubic meters. Conversion rate: US$1 = ¥113.6.
a. Distribution capacity
b. "Non-revenue water" refers to the difference between the volume of water put into a water distribution system and the volume that is billed to customers.

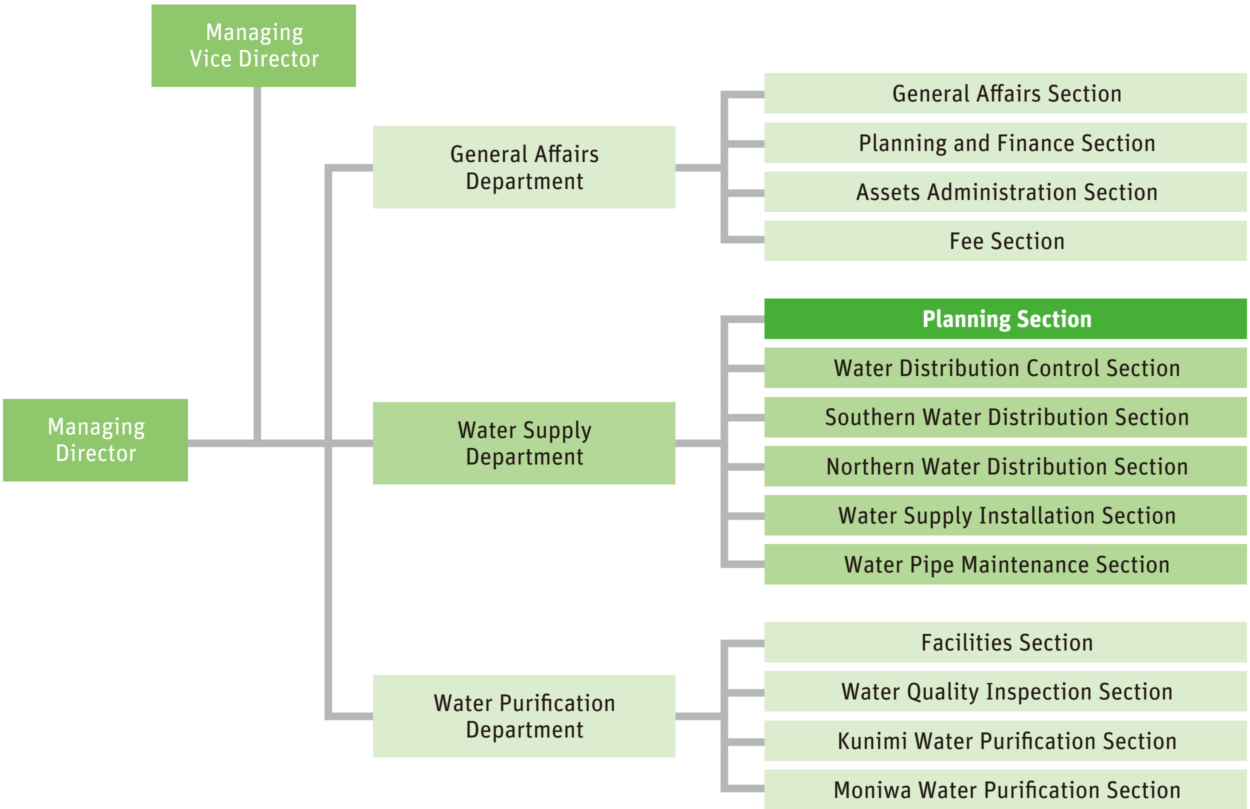
Map 3.6 Water and Wastewater Treatment Plants of Sendai City



Source: Based on National Land Numerical Information database, Ministry of Land, Infrastructure, Transport and Tourism. ©World Bank. Permission required for reuse.
Note: m^3/d = cubic meters per day.

Figure 3.13 shows the SWB's three-department organizational structure. Under the Water Supply Department, the Planning Section is responsible for DRM and emergency response.

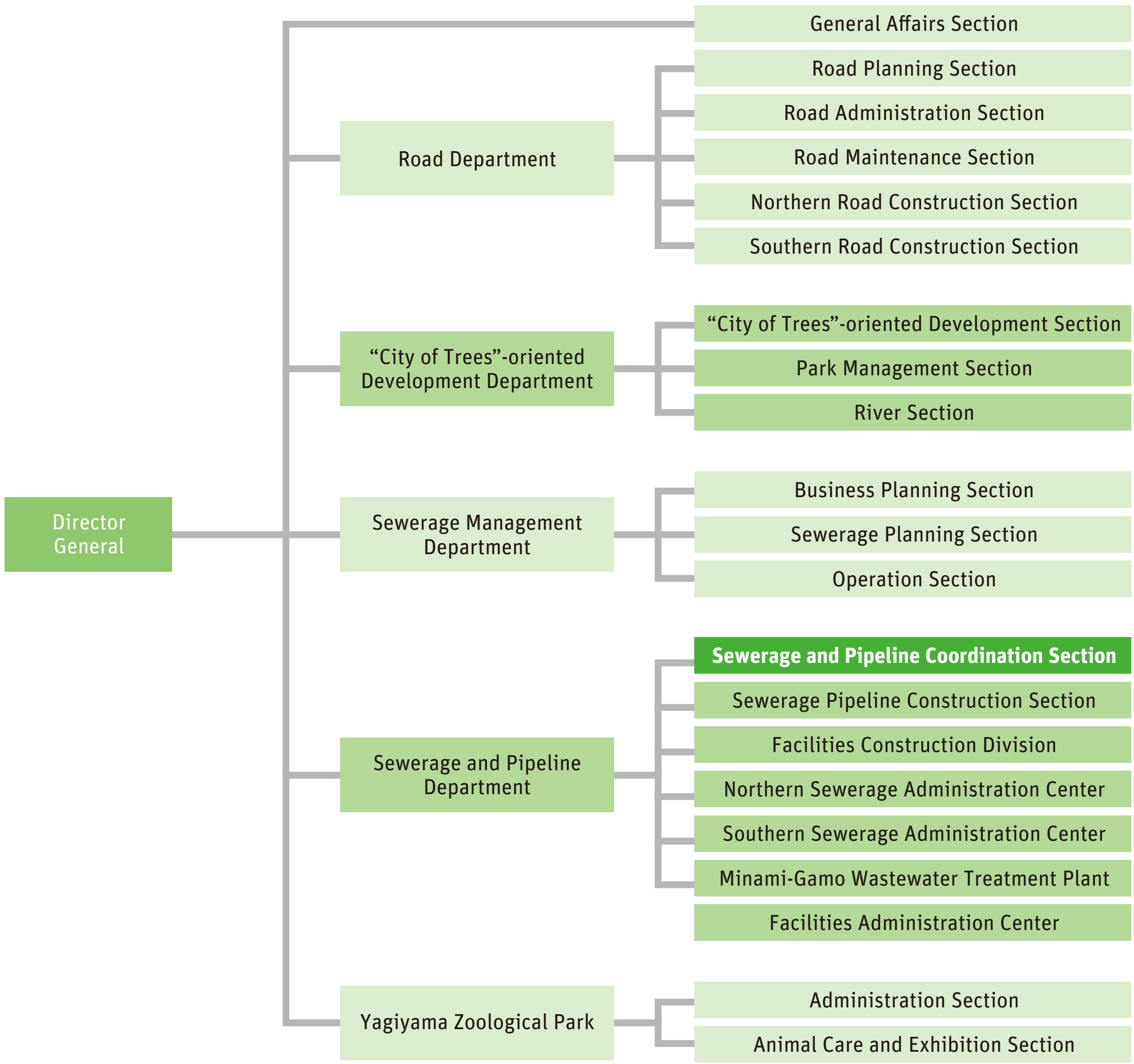
Figure 3.13 **Organizational Structure of Sendai City Waterworks Bureau**



Source: Based on Sendai City Waterworks Bureau website.

In SCB, the Sewerage and Pipeline Coordination Section is responsible for DRM and emergency response (figure 3.14).

Figure 3.14 Organizational Structure of Sendai City Construction Bureau



Source: Based on Sendai City Construction Bureau website.

3.6.2 Disaster Risk Profile

Sendai City in Miyagi Prefecture is the largest city in Tohoku region and covers about 786 square kilometers (about 304 square miles), with its coastline facing the Pacific Ocean. Sendai City has suffered periodically from Miyagi Prefecture's offshore earthquakes, which occur about every 37 years on average, with its hypocenter situated in the Japan Trench (between the Okhotsk and Pacific plates) and result in earthquake-induced tsunamis.[28] In addition, other earthquakes with hypocenters in other parts of the Japan Trench (for example, Sanriku offshore earthquake) also periodically affect Sendai City.

Recent Natural Disasters

Sendai City experienced an earthquake of magnitude 7.1 in 2005. Then on March 11, 2011, an magnitude 9.0 earthquake occurred at a depth of 24 kilometers in the Pacific Ocean. Along with the huge tsunami waves that followed, this earthquake devastated wide areas of Japan, including Miyagi Prefecture. Known as the 2011 Great East Japan Earthquake (GEJE) and Tsunami, the whole event left approximately 22,000 people dead and missing.[29]

In Sendai, 130 kilometers away from the epicenter, 904 residents lost their lives, and close to 30,000 houses totally collapsed.[30] Up to half a million people, or 230,000 households, lost access to water until SWB fully restored service on March 29, except in the severely tsunami-affected areas (SWB 2015). Because the city's water sources and treatment plants are located on elevated ground distant from the coastline, they were not affected by the tsunami. The earthquake, however, caused many pipe failures. Concrete structures of WTPs also suffered cracks, but their treatment functions were not adversely affected owing to seismic retrofitting the city had been implementing since before the event (Chiba 2012).

The damage to the sanitation services was also significant. Approximately 2 percent (102 kilometers) of all pipelines were damaged. Out of the 330 facilities (including pumping stations), 48 were affected by the earthquake and 50 by the tsunami (Suido Sangyo Shimbun 2017). In addition, the city's primary Minami-Gamo WwTP, situated along the coastline, was struck by the tsunami waves and severely damaged, which reduced treatment capacity (photo 3.14) (SCB 2013).

Photo 3.14 **Minami-Gamo Wastewater Treatment Plant, Submerged under Tsunami Waves, Sendai City, 2011**

Source: ©Sendai City Construction Bureau (SCB). Reproduced, with permission, from SCB; further permission required for reuse.

28 "Event Probability of Miyagiken-oki Earthquake," Sendai City website (accessed November 28, 2017), http://www.city.sendai.jp/kekaku/kurashi/anzen/saigaitaisaku/kanren/kakuritsu.html.

29 "Seismic Disasters in Japan after 1995" [in Japanese], Japan Meteorological Agency website (accessed November 28, 2017), http://www.data.jma.go.jp/svd/eqev/data/higai/higai1996-new.html#higai2006.

30 "Damage in the 2011 Great East Japan Earthquake" [in Japanese], Sendai City website (accessed November 28, 2017), http://www.city.sendai.jp/okyutaisaku/shise/daishinsai/higai.html.

3.6.3 Best Practices

Each type of countermeasure described below pertains to one or more stages of infrastructure life cycle—systems planning, engineering design and materials, asset management, and contingency programming—as italicized within brackets in the paragraph headings.

Water Supply

Seismic Retrofitting of Pipelines before GEJE [engineering design and materials]

SWB had retrofitted its pipeline networks by installing earthquake-resistant pipes before the GEJE hit (SWB 2015). As a result, the number of damage instances per kilometer of the water supply pipeline was relatively low (0.07 per kilometer) despite the devastating impact (SWB 2012). No damages were observed in the retrofitted assets.

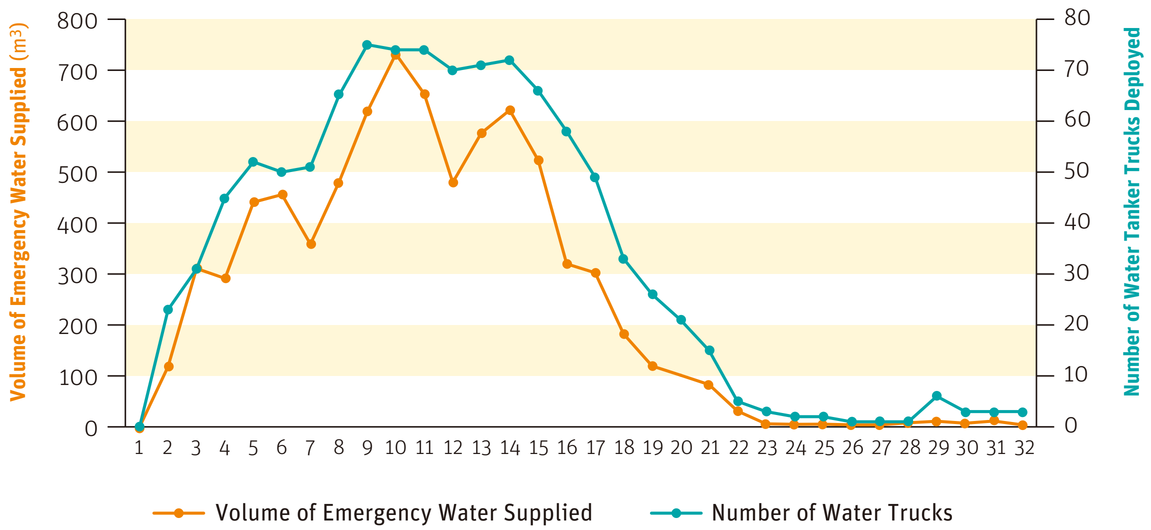
Building of Redundancy and Backup Capacity [systems planning]

Taking advantage of its multiple water sources, the city had enhanced redundancy of the water supply network by interconnecting WTPs (that use different water sources) via pipelines and increasing backup capacity so that water can be accommodated between the plants in case of an emergency. This helped minimize the seismic impact by allowing SWB to switch to the supply routes that were not affected by the earthquake, thus reducing areas that lost water service (SWB 2015). Further, the city's distribution network had been divided into 123 smaller networks or blocks to better control water flow and pressure, which also helped reduce impacts by preventing damaged blocks from affecting other blocks (SWB 2015).

Mutual Aid Agreement with Other Water Supply Utilities for Emergency Response [contingency programming]

Given the earthquake's broad impact on the city's water supply, the utility cooperated with other water supply utilities around the country for related repair works and emergency water supply operations. Per the SWB's mutual aid agreement with 18 major water supply utilities as well as other arrangements, Sendai received support from more than 60 water utilities, which dispatched emergency response teams to the city (SWB 2015). The costs of external support were borne by SWB. Because of the water tanker trucks and portable water supply equipment made available through such cooperation, the utility could conduct emergency water supply operations by mobilizing up to 75 water tanker trucks in its service area (figure 3.15).

Figure 3.15 Water Tanker Trucks and Water Supplied in Sendai after 2011 Great East Japan Earthquake and Tsunami



Source: © Sendai City Waterworks Bureau (SWB). Reproduced, with permission, from SWB; further permission required for reuse.
Note: m^3 = cubic meters.

Sanitation

Business Continuity Planning and Gravity-Fed Wastewater Treatment [contingency programming]

To allow for quick responses through emergency schemes, SCB developed a disaster management manual for sanitation services in 2006. Also, it was in the process of developing a sanitation BCP when the 2011 earthquake took place. In terms of disaster management, these preparations contributed to reducing the earthquake and tsunami's impact on the wastewater system by enabling the utility to make a swift initial response (SCB 2015b). In particular, although a sanitation BCP was not in place at the time of the GEJE, the BCP development process itself enabled individual staff members to develop a good sense of who should do what, and when, to minimize disaster impact (SCB 2013).

During the GEJE, the Minami-Gamo WwTP was completely submerged by the tsunami, and its treatment system stopped operation. As an interim restoration measure, the utility switched in a timely manner to a simpler treatment process consisting of only sedimentation and disinfection. Switching to this process required the utility to open the emergency water gate for the treated wastewater to be discharged into the ocean. This gate needed to be opened manually on-site, and staff members went to open it the day after the earthquake when there were still risks of another tsunami wave swallowing the coastal area.

Because this simple process depends solely on the force of gravity to transport wastewater from customer premises to the plant, it enabled the utility to keep receiving and treating the sewage throughout the event even though relevant pumping stations within the plant had been damaged. As a result, although its treatment capacity was reduced, the plant managed to prevent a sewage overflow in the city (SCB 2015b). Gravity-fed water flow is one of the basic principles in sanitation network design to save electricity required to transport sewage to treatment plants. But the 2011 earthquake showed that a network design based on this principle is also effective when a natural hazard affected pumping stations.

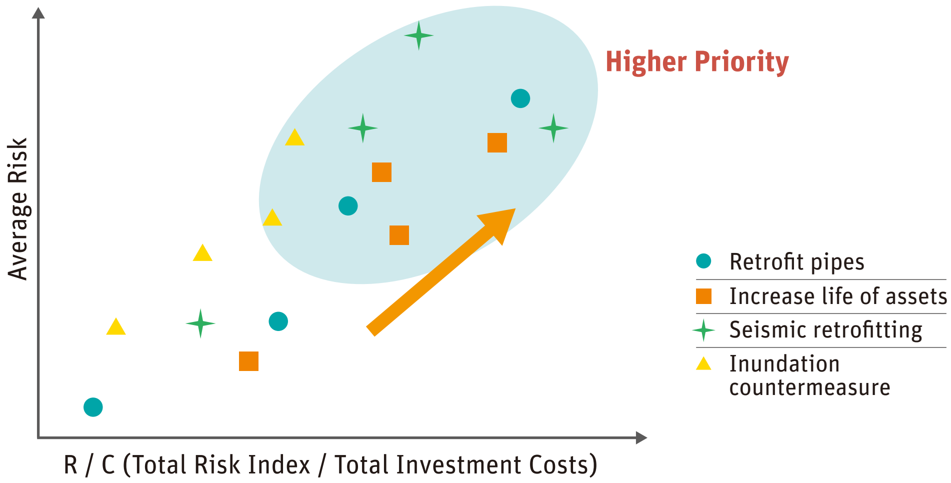
Based on lessons learned from GEJE, Sendai City's Crisis Management Department has developed a BCP for the overall emergency management at the city level. Although the Crisis Management Department and SCB share information in a timely manner during an emergency, each municipal enterprise such as SCB develops its own BCP. As a lesson learned, SCB incorporated estimates of tsunami damage and required fuel reserve in their BCP.

Robust Asset Management for Continued Service [asset management]

In 2014, SCB became the first ISO55001-certified sanitation utility in Japan. It had started developing an asset management (AM) system in 2005. The main driver was the need to increase the length of its aging pipeline (an estimated 1,980 kilometers of pipeline will have been operated for more than 50 years as of 2034, an increase from 199 kilometers as of 2014) while the municipal budget for civil works was declining. SCB developed strategies and a three-year road map for developing an AM system (Kobayashi, Tamura, and Fujiki 2016). SCB conducts a periodic internal audit to continuously improve the AM system in accordance with ISO55001. In addition, SCB established a CPD (continuing professional development) scheme for staffs to encourage human resources development for continuously improving the AM system.

SCB incorporated a risk-informed investment decision-making process into AM system by prioritizing and deciding which investments to implement based on the results of risk assessment (figure 3.16). SCB adopts four risk categories (pipeline defects, facility defects, inundation, and earthquake) and assesses risks based on probability and impacts, which are determined as per the utility's Sewerage Vision (Kobayashi, Tamura, and Fujiki 2016). The utility also estimates a renewal expenditure for the next 100 years based on the risk assessment, and determines a mid- to long-term AM plan and required construction works. Having the AM system in place enabled the utility to minimize the time required to handle customer complaints, reduce the frequency of renewals and the associated costs, and efficiently prioritize and conduct assessments based on risk-informed planning (Kobayashi, Tamura, and Fujiki 2016).

Figure 3.16 Investment Decision Making for Resilient Asset Management by Sendai City Construction Bureau



Source: ©Sendai City Construction Bureau (SCB) 2015a. Reproduced, with permission, from SCB; further permission required for reuse. English translation by World Bank

In addition, the utility developed a GIS-based asset management database to enable visualization, efficient risk estimation, and construction planning. The GIS database enabled SCB to quickly identify damaged pipes and analyze the types of damage caused by the GEJE (SCB 2013). The detailed database of its vast pipeline networks and related facilities allowed the utility to systematically visualize many of the pipe and pump failures, which in turn facilitated a quick investigation of the damaged pipes.

Mutual Aid Agreement with Utilities and Framework Agreements with Industry Associations
[contingency programming]

During the first month after the earthquake, a total of 1,630 staff members from 12 municipalities joined the visual inspections of damaged pipelines for SCB (Suido Sangyo Shimbun 2017). Even after the work was complete, they continued to be a vital part of the utility's assessment of pipeline damage and repair work. The external support was provided based on the city's mutual assistance agreement with major municipalities to accommodate a range of goods, equipment, and engineering staff during an emergency (SCB 2013).

In addition, SCB had considerable support from industry associations with whom it had agreements to receive emergency assistance (such as engineers, materials, and damage investigation) in restoring damaged pipelines and treatment facilities (SCB 2013). To ensure swift, efficient responses during an emergency, SCB had conducted joint trainings with the associations annually (SCB 2013). The immediate arrival of the association members enabled the utility to start identifying damaged areas immediately after the earthquake.

3.6.4 Lessons Learned

Ensure seismic retrofitting of materials such as air valves and sluice valves [engineering design and materials]

In terms of seismic reinforcement of water supply infrastructure, one thing SWB had not considered before the 2011 earthquake was the seismic resistance of air valves. In the 2011 event, 47 failures were reported in water pipelines of 400 millimeters diameter or greater. While six of these failures were due to a burst pipe or pulled-off joint, the remaining 41 were due to damaged pipe appurtenances, with 39 of the 41 failures being caused by damaged air valves (Takahashi 2014). This was unexpected because the utility's primary focus had always been on a seismic upgrade of pipes. At the time of the earthquake, the earthquake resistance ratio of the city's primary pipelines was about 70 percent, which accounts for the relatively few failures of pipes or joints. On the other hand, seismic impacts on air valves had never been brought up in internal discussions and thus the air valves were left vulnerable (Takahashi 2014). Whether the damage occurs to pipes or their appurtenances, either could considerably diminish the water supply capacity. As such, this experience offers a lesson that safeguarding a water supply requires utilities to pay attention to all pipeline components, including air valves and sluice valves.

Appropriately decentralize decision making during an emergency [contingency programming]

In terms of overall disaster response and management at the time of the earthquake, SWB had a centralized decision-making system, but it did not work well during GEJE because it prohibited quick decision making on the ground. Responsiveness and appropriate decision making require reliable information—information that is difficult to obtain during emergencies because different issues arise simultaneously at different places while telecommunication networks become less reliable, and communication delays could render the same information inaccurate or irrelevant at some point. Under such circumstances, waiting for sufficient information makes it difficult to make timely decisions. In Sendai's case, delayed information processing during the initial response period led to many inquiries from affected residents as well as some inconveniences such as an unnecessary cutoff of resumed water supply due to inaccurate information (Takahashi 2014). On the other hand, experienced engineering staff in the field responded well from early on, showing substantial leadership and thus contributing much to the full restoration of water supply 18 days after the earthquake. Also, some of the staff established impromptu cooperation with local communities to boost emergency water supply efforts.

Based on these experiences, the utility reconsidered an organizational system, and decided to transfer more authority to field engineers during an emergency for quicker decision making. The updated scheme requires upper management to be responsive to the requests and needs from field engineers to facilitate their response and recovery activities in the field (Takahashi 2014).

Design topography-oriented sewer networks to continue effective treatment when pump stations are damaged from a natural hazard [engineering design and materials]

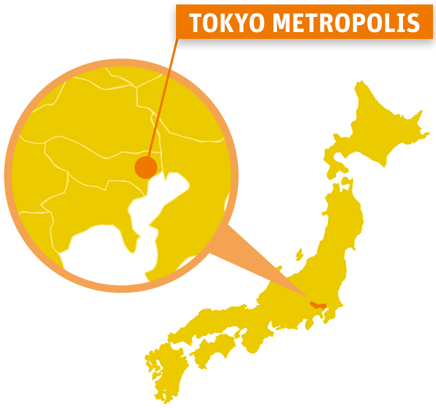
The Minami-Gamo WwTP and its gravity-fed system made the utility reappreciate the importance of designing a sanitation network by fully using a service area's topographic and geographic features because it could increase the utility's ability to continue sewerage treatment even if pumping stations get damaged upon a disaster (SCB 2013).

Mutually reinforce and integrate a BCP and asset management system [asset management] [contingency programming]

SCB plans to improve its BCP, including postdisaster emergency inspection, based on the results of seismic and inundation risk assessment conducted as part of the asset management system. The utility will also adopt the prioritization and investment decision-making process established under the asset management system for emergency repair and reconstruction works. The utility plans to improve regular inspection procedures as part of the asset management system based on the lessons learned from its pipe damage assessment during GEJE.

Regularly train the residents for community-driven emergency water supply [contingency programming]

There were areas where a shortage of utility staff made it difficult to provide emergency water supply in the immediate aftermath of the earthquake. As a lesson learned, the utility trains local communities to set up emergency tap stands at 175 schools on their own upon a disaster, without waiting for the arrival of utility personnel.



3.7 Tokyo:

Enhancing Seismic Resilience to Ensure Continuity of WSS Services for 13 Million Residents

Photo 3.15 **Aerial View of Tokyo**

Source: PIXTA

The Tokyo Metropolitan Government Bureau of Waterworks (TMBW) is the largest utility in Japan, with an NRW level of 4.1 percent as of 2014 (photo 3.15). Although Tokyo has not been significantly affected by large earthquakes since the 1923 Great Kantō Earthquake, the utility has been building resilience in the following ways, based on historical data, estimated scenarios, and lessons learned from other utilities:

- *Increasing interconnectivity between water treatment plants (WTPs) and between wastewater treatment plants (WwTPs):* The utility has interconnected the treatment plants to build a backup capacity in case some of the plants are physically affected by a natural hazard (TMBS 2016a; TMBW 2016a, 2016b).
- *Expanding emergency water supply stations:* The utility has designated various facilities (such as WTPs and parks) as emergency water supply stations within a 2-kilometer radius of any part of the city for public access (TMBW 2016b).
- *Iterative improvement of disaster risk reduciton and emergency preparedness and response:* The utility developed its first Water Supply Seismic Disaster Prevention Plan in 1973, corresponding to a Prefectural Seismic Disaster Prevention Plan. Later, in 1982, the utility separated the plan into the Earthquake Countermeasures Development Plan for risk reduction infrastructure investments and the Earthquake Emergency Response Plan, which are continuously improved. Each department and division of the utility has developed standard operating procedures and operation manuals to implement specific emergency tasks.

3.7.1 Basic Profile of Utilities

TMBW is responsible for water supply services in the 23 wards and approximately 30 municipalities of Tama District in Tokyo Metropolis. Its WTPs distribute about 4.6 million cubic meters of water daily, and its distribution network is 26,915 kilometers long (TMBW 2016c) (table 3.12, map 3.7).

Almost all the water is sourced from rivers: 78 percent from the Tone and Ara River Systems and 19 percent from the Tama River System. Until the early 1960s, TMBW was heavily dependent on the Tama River System. Later, it started developing water resources of the Tone River System to address a rapid increase in water demand associated with population and economic growth. As of March 2014, TMBW owns 6.3 million cubic meters per day of water sources (TMBW 2016d). Regarding DRM for water sources, TMBW completed Japan's first seismic upgrade of an earth-filled dam in 2002 because of concern about its seismic safety as a lesson learned from the 1995 Great Hanshin-Awaji Earthquake. The seismic upgrade was completed first for the Yamaguchi Dam and later for the Murayama Dam on Tama River in 2009.

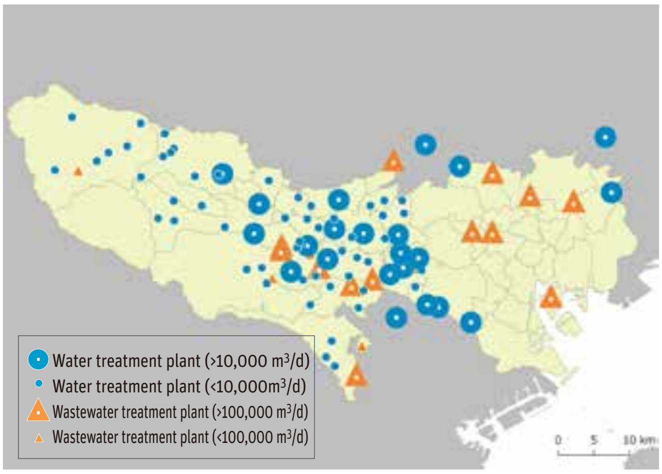
For sanitation, the Tokyo Metropolitan Government Bureau of Sewerage (TMBS) is responsible for wastewater and stormwater collection, treatment, and disposal in 23 Wards. TMBS manages over a dozen WwTPs and approximately 16,000 kilometers of wastewater pipelines (table 3.12, map 3.7). TMBS also treats wastewater for approximately 30 municipalities of Tama District in Tokyo Metropolis, with the retail services being provided by each municipality (TMBS 2016b, 2016c).

Table 3.12 Basic Profile of Utilities in Tokyo, FY 2014/15

Descriptor	Tokyo Metropolitan Government Bureau of Waterworks	Tokyo Metropolitan Government Bureau of Sewerage
Service coverage	13.09 million population (100%)	9.13 million population (99.9%)
Capacity	6.86 million m^3 per day[a]	6.34 million m^3 per day
Non-revenue water[b]	4.1%	n.a.
Operational income	¥313 billion (US$2.76 billion)	¥285 billion (US$2.51 billion)
Operational expenditure	¥281 billion (US$2.47 billion)	¥263 billion (US$2.32 billion)
Number of employees	3,603	2,124
Regulator	Ministry of Health, Labour and Welfare	Ministry of Land, Infrastructure, Transport and Tourism

Sources: MIC 2015.
Note: FY = fiscal year. WSS = water supply and sanitation. n.a. = not applicable. m^3 = cubic meters. Conversion rate: US$1 = ¥113.6.
a. Distribution capacity.
b. "Non-revenue water" refers to the difference between the volume of water put into a water distribution system and the volume that is billed to customers.

Map 3.7 Water and Wastewater Treatment Plants of Tokyo



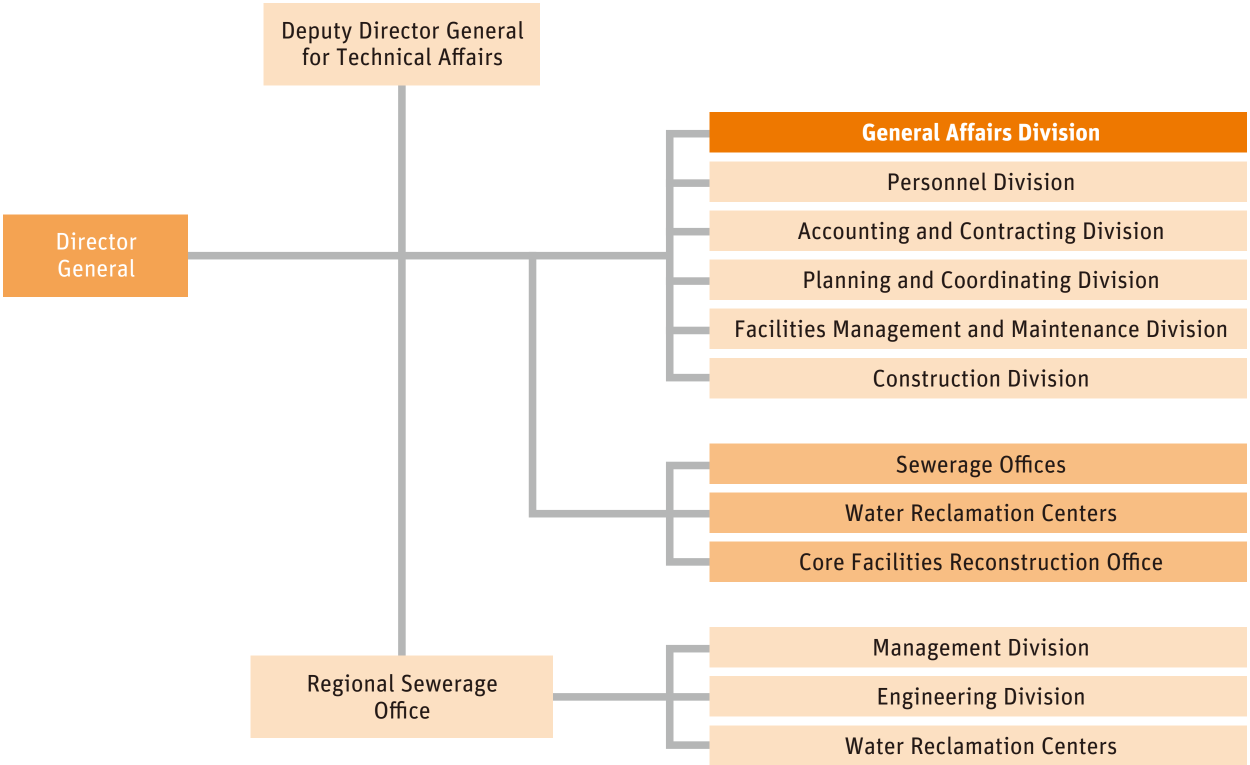
Source: Based on National Land Numerical Information database, Ministry of Land, Infrastructure, Transport and Tourism. ©World Bank. Permission required for reuse.
Note: m^3/d = cubic meters per day.

03

Tokyo

TMBW has 3,603 employees in 17 divisions, centers, or office groups (figure 3.17). The General Affairs Division is mainly responsible for DRM, while all the divisions and centers engage in emergency response upon a disaster.

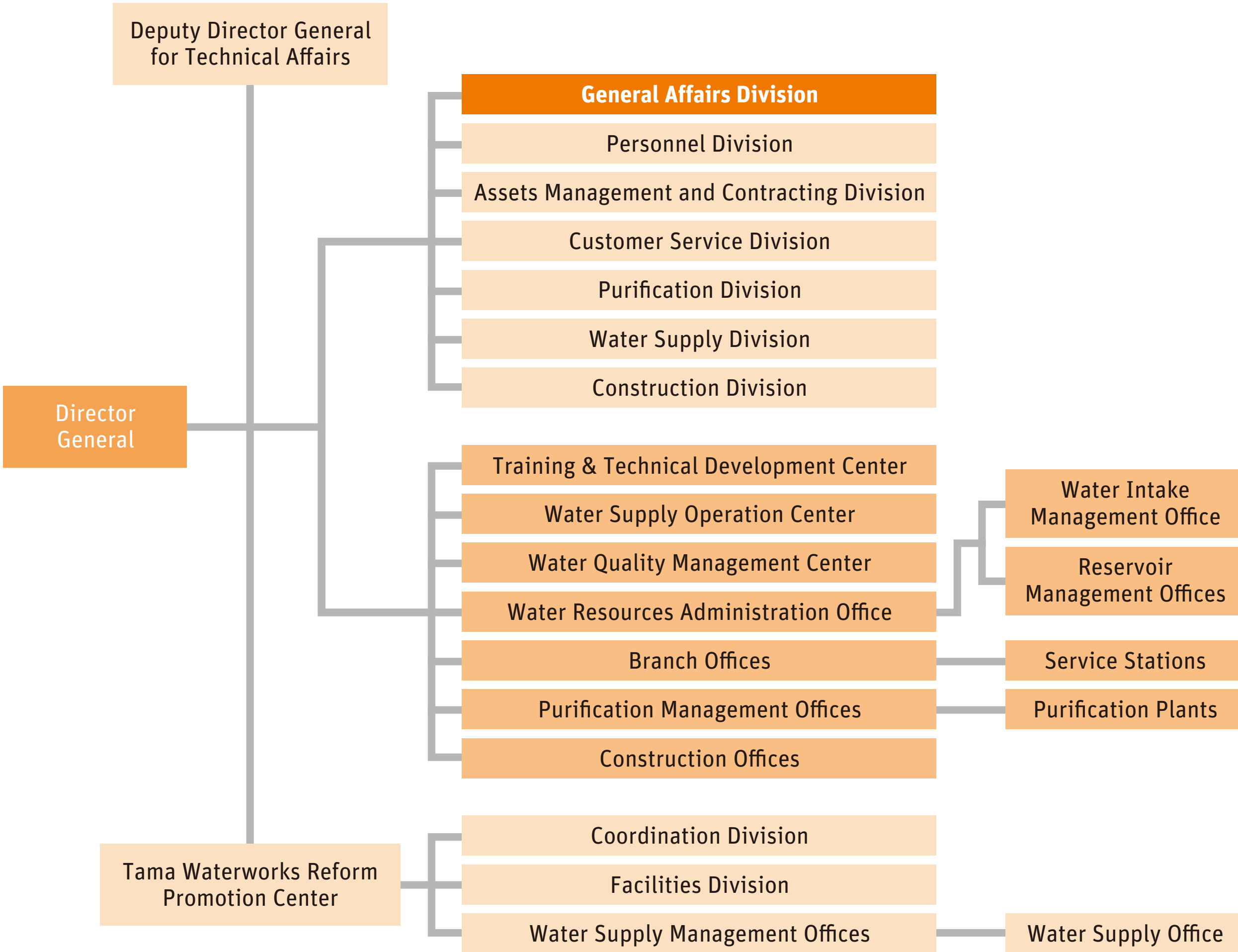
Figure 3.17 **Organizational Structure of Tokyo Metropolitan Bureau of Waterworks**



Source: Based on Tokyo Metropolitan Government Bureau of Waterworks website.

TMBS has 2,124 employees in 12 divisions, centers, or office groups (figure 3.18). In TMBS, the headquarters for emergency operation is set up under the General Affairs Division upon a large disaster.

Figure 3.18 Organizational Structure of Tokyo Metropolitan Bureau of Sewerage



Source: Based on Tokyo Metropolitan Government Bureau of Sewerage website.

3.7.2 Disaster Risk Profile

The Tokyo metropolitan area is estimated to experience an earthquake of magnitude 8.0 or greater every 200–400 years (Cabinet Office 2015). The last such earthquake occurred in 1923, known as the Great Kantō Earthquake, which left over 70,000 people dead or missing in the Tokyo metropolitan area alone in addition to many others in the surrounding prefectures (CDMC 2016).

The Japanese government estimates a 70 percent probability that an earthquake of magnitude 7.0 may directly hit the Tokyo area within the next 30 years (Cabinet Office 2015).

Recent Natural Disasters

The predecessors of TMBW and TMBS started operations in Tokyo during the 1880–90s. Since the inception of service, the utilities have experienced two earthquakes: the 1923 Great Kantō Earthquake and the 2011 Great East Japan Earthquake (GEJE). The 1923 earthquake caused a loss of water supply in the most city areas, damaging various facilities for water transmission, treatment, and distribution. Also, numerous lead service pipes were damaged by a large fire followed by the earthquake, with 64 percent of all water taps in the service area (approximately 155,000 out of 240,000) melted away (TMBW 1999). The wastewater service was also largely affected, and all the ongoing construction works were forced to close (TMBW, n.d.).

In the Tokyo metropolis, the 9.0-magnitude GEJE had a seismic intensity at the upper-5 level.[31] TMBW had a temporary service disruption to 42,000 customers in Tama District because of a blackout or an activation of emergency shutoff valves at distribution reservoirs. However, the impact was limited, and there were no large-scale water suspensions or major facility damage (Ozeki 2012).

As for wastewater service, 12 kilometers of pipelines were adversely affected by cracks and sand clogging owing to earthquake-induced soil liquefaction. WwTPs and pumping stations had also suffered some damage to the piping and building walls. However, there was no loss of functionality to the sewers and sewage treatment capabilities (Horii, n.d.).

The limited damage from GEJE can be attributed to a wide range of antiseismic measures being taken by TMBW and TMBS to improve their resilience.

3.7.3 Best Practices

Each type of countermeasure described below pertains to one or more stages of infrastructure life cycle—policy and legislation, systems planning, engineering design and materials, asset management, and contingency programming—as designated within brackets in the paragraph headings.

Water Supply

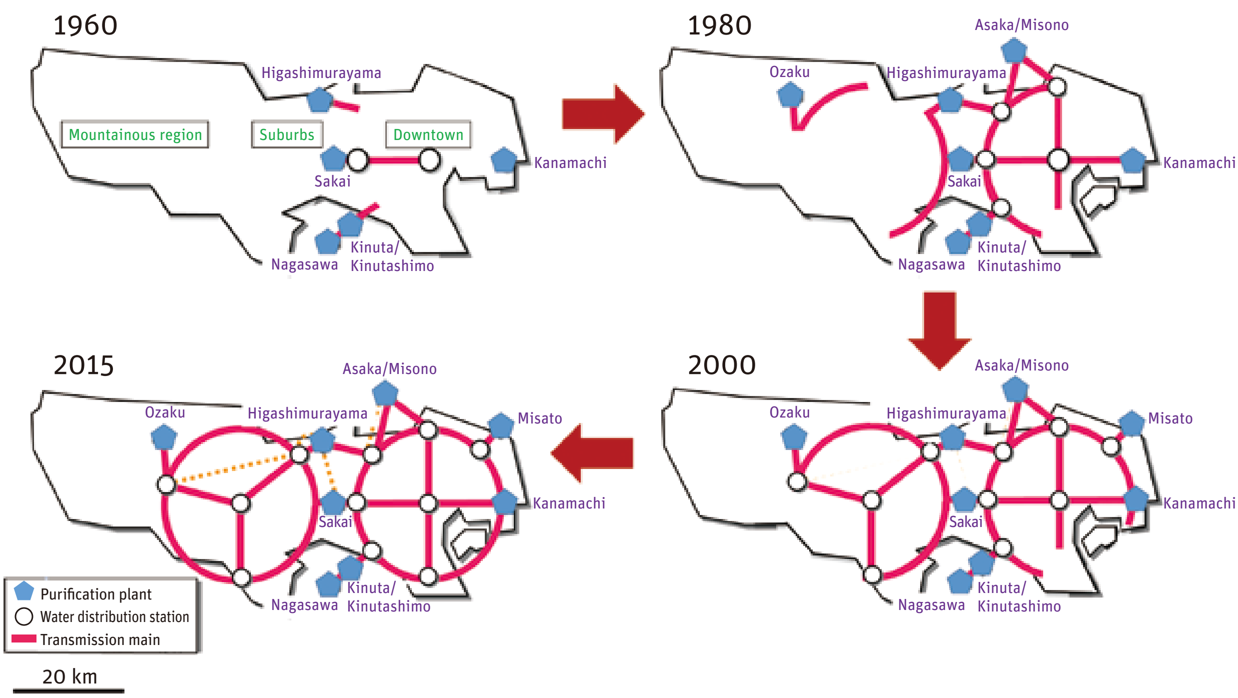
Interconnecting Water Supply Pipelines to Build a Backup Capacity [systems planning]

With installation of individual water supply facilities in good progress, TMBW set about increasing the redundancy of the transmission pipeline network in the 1960s. This was to strengthen its backup function and secure enough water even if individual facilities stop operating in emergency situations including earthquakes (figure 3.19). For the same purpose, the utility also started developing interconnectivity between the WTPs and the emergency water supply bases for residents as well as interconnectivity among the water supply bases themselves. This interconnection between various facilities is designed such that (a) different supply networks extracting from different water sources could mutually accommodate water, and (b) each water supply base could be supplied from multiple water sources (TMBW 2013, 2016b).

The increase of network redundancy in the 1960s was rather a natural step upon a rapid development of individual facilities at the time, including WTPs, water distribution stations, and transmission pipelines. The intensive system upgrade was a result of TMBW's infrastructure development plans to address fast-growing water demand in the 1960s. The infrastructure upgrade was supported by new water resources development of the Tone River System.

31 "Seismic intensity" is measured on the Japan Meteorological Agency's seismic intensity scale. Seismic intensity is the value observed at a site where a seismic intensity meter is installed, and may vary within the same city. It is a scale of 1 to 7, with 5 and 6 each divided into "lower" and "upper."

Figure 3.19 Interconnections of Water Treatment Plants with Pipelines, Tokyo, 1960–2015



Seismic Reinforcement of Pipe Joints as a Lesson Learned From the 1995 Great Hanshin-Awaji Earthquake

[engineering design and materials]

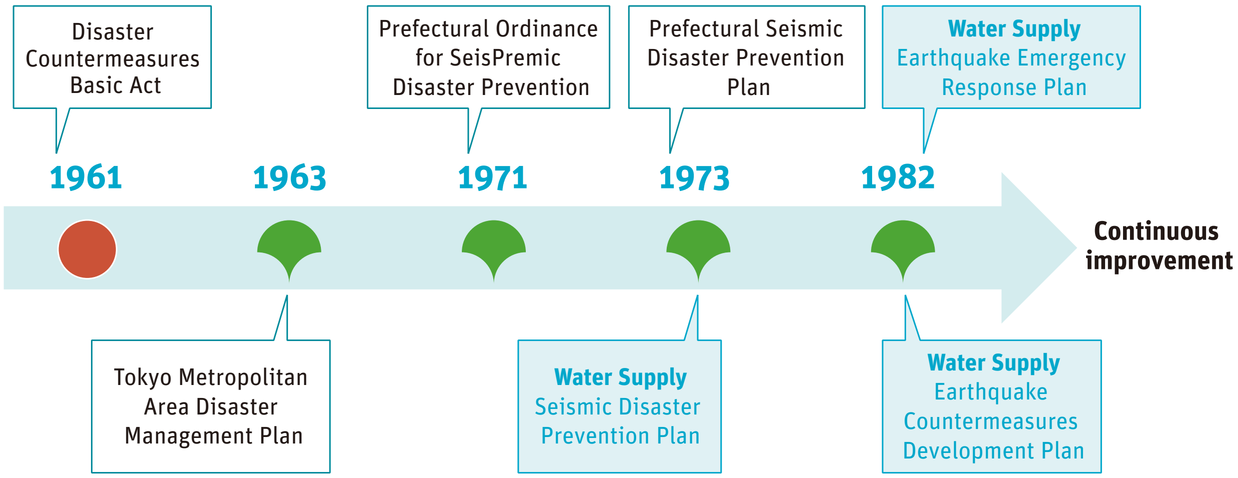
Further, to increase the seismic resistance of pipelines, the utility has adopted ductile iron pipes with seismic-resistant joints for all replacements since 1998. This replacement policy was adopted after the 1995 Great Hanshin-Awaji Earthquake, which proved the high-impact resistance of such pipes against strong earthquakes. With the seismic upgrade now in good progress for the pipelines connected to critical facilities (such as hospitals and central, ward, and municipal government buildings), the utility is shifting its priority to retrofitting pipelines for emergency evacuation sites including schools, terminal stations, emergency transportation roads, and high potential liquefaction areas (TMBW 2013).

Seismic Risk Mitigation and Emergency Preparedness and Response Planning

[policy and legislation] [contingency programming]

TMBW developed a Water Supply Seismic Disaster Prevention Plan in 1973, corresponding to a Prefectural Seismic Disaster Prevention Plan. Later, in 1982, that plan was separated into two primary plans for seismic risk mitigation and emergency response: the TMBW Earthquake Countermeasures Development Plan for risk reduction investments and the TMBW Earthquake Emergency Response Plan for emergency response (Akagawa 2016; TMG 2014). These plans were developed based on the national and prefectural legislation (figure 3.20). TMBW developed the plans to address the estimated duration of water supply suspension under four earthquake scenarios developed by the Tokyo Metropolitan Government.

Figure 3.20 Historical Development of Water Supply DRM Plans, Tokyo Metropolis



Note: DRM = disaster risk management.

The Earthquake Countermeasures Development Plan describes TMBW's mid- to long-term seismic upgrades of water supply facilities such as pipelines and WTPs as well as development of emergency water supply bases and storage tanks to enable effective emergency water supply activities. The plan is updated periodically upon completion of specific facility development objectives set for certain periods.

The Earthquake Emergency Response Plan focuses on developing an organizational system for quickly and effectively restoring water supply and securing as much emergency water supply as possible after an earthquake. TMBW establishes a disaster management information office and an emergency water supply headquarters in case one of the following occurs:

- Significant impact on the water supply expected because of an earthquake and other events
- Establishment of a Tokyo Metropolitan Government crisis management headquarters
- Seismic intensity of 6 or above

Three main activities of the plan are restoration, emergency water supply, and public relations. Like a business continuity plan, TMBW established a recovery time objective of three days for the critical metropolitan institutions and 30 days for the rest of Tokyo. TMBW stores materials and equipment required for restoring water supply in critical municipal buildings and functions. For the other areas, TMBW sets a framework in advance to prepare required materials within 10 days after a disaster.

Each department and division of the utility has developed standard operating procedures (SOP) and manuals to implement specific emergency tasks. Relevant trainings as per the Plan, SOP, and manuals are conducted regularly. The TMBW Earthquake Emergency Response Plan is updated based on changes in regulations and lessons learned from major disasters in other utilities (TMBW 2013, 2017b).

Emergency Task Force Available 24/7 and Joint Training with Other Municipalities [contingency programming]

Within the TMBW's water supply department, a division called the "emergency task force," consisting of approximately 50 utility staff members, stands by and is available 24/7 for efficient emergency responses in accordance with the abovementioned *Earthquake Emergency Response Plan*. Decision-making procedures, staffing, and emergency muster points are stipulated under the plan for different seismic intensities (5 Lower, 5 Upper, and 6 and above).

The emergency task force is divided into three groups: WTP restoration, distribution pipelines, and large-scale assets (for example, critical transmission and distribution pipelines). To conduct its work, the team has access to 2 special emergency vehicles, 2 emergency public announcement vehicles, 10 water supply vehicles, 2 valve opening/closing cars, 10 bikes for damage investigation, and other vehicles. Upon a disaster, the team is responsible for restoring—within three days from disaster onset—any affected water supplies that are impacting primary facilities and institutions in central districts. When a major pipe bursts occur in nondisaster situations, the team supports the pipe's repair and recovery and is responsible for an initial response in emergency water supply operations and related public announcements about the incident and nearby emergency water supply bases (TMBW 2016b).

The team also plays a primary role in TMBW's regular joint training program with major water supply utilities in Japan to increase the utilities' ability to provide efficient mutual support when any of them is hit by a disaster. The joint training is conducted based on TMBW's memorandum of understanding (MoU) with 20 large water supply utilities for mutual support in disasters (as further described below and in chapter 2).

Multiple Agreements with External Organizations to Enhance Emergency Response Capacity
[contingency programming]

TMBW has multiple agreements with utilities outside Tokyo, a prefecture, and the private sector to enable a prompt and smooth implementation of emergency responses and recovery activities, as follows (TMBW 2014, 2017a, 2017b):

- *Memorandum of understanding (MoU) among 21 utilities:* If a water utility is affected by a disaster and cannot respond sufficiently on its own, it can request support from other utilities under the MoU to assist with implementation of emergency response and recovery measures (as further discussed in chapter 2).
- *Ibaraki Prefecture:* When either Tokyo or Ibaraki is largely affected by a disaster and it becomes difficult to accommodate parking and overnight stays for emergency support teams from other utilities, the nonaffected party would accommodate such needs to assist in their activities. The agreement was signed in 2014 based on a lesson learned from the 2011 Great East Japan Earthquake that underlined the importance of provisional mobilization bases in which external support teams could organize aid materials sent from other parts of Japan and prepare themselves well for support activities. Ibaraki, located approximately 100 kilometers away from Tokyo, was selected as a partner because the two prefectures are well connected by transportation networks such as expressways and ports and because it is considered unlikely that both would be strongly affected simultaneously by a large earthquake (for example, a Tokyo inland earthquake).
- *Saitama Prefecture and Kawasaki City:* Tokyo Metropolis reached an agreement with Saitama Prefecture and Kawasaki City respectively to install connecting pipelines for water accommodation during an emergency. Saitama Prefecture and Tokyo connected the transmission pipelines, which can accommodate 100,000 cubic meters of water per day between the two prefectures, while the distribution pipelines between Kawasaki and Tokyo can accommodate 115,000 cubic meters of water per day between the two utilities.
- *Manufacturers:* There are agreements with various manufacturers to supply materials (such as pipes and valves) for emergency repair work.
- *General contractors:* There is an agreement with the local general contractors' association to cooperate in emergency response and recovery activities.
- *Transport companies:* There is an agreement to supply emergency vehicles.
- *Petroleum companies:* There is an agreement with the Petroleum Association of Japan for the stable supply of petroleum fuels when large-scale disasters occur.

Community-driven Emergency Water Supply [contingency programming]

In accordance with the abovementioned Earthquake Emergency Response Plan, TMBW designates WTPs, water distribution stations, and emergency storage tanks in public parks as water supply bases for residents in the event of disasters. These water supply bases are located within a 2-kilometer radius from one another so that residents could secure enough drinking water during an emergency. Also, for local communities to be able to access water immediately at these WTPs and distribution stations, TMBW has constructed a designated space at each one where residents could obtain water by themselves without waiting for the utility staff to arrive at the site (TMBW 2013). To familiarize local communities with this self-help measure, annual trainings are conducted between the utility and local communities including the setup and use of necessary equipment.

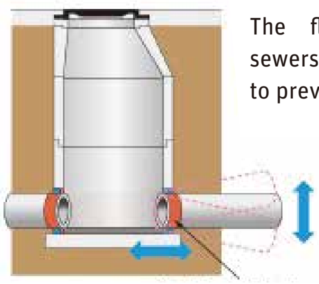
Before the 1995 Great Hanshin Earthquake, the emergency water supply bases at the WTPs and distribution stations had been separated by fences from the rest of the premises. Thus, residents would not have been allowed access for security reasons until the city staff arrived at the site. Construction of the designated spaces and proper training enable the local communities to quickly access the emergency water supply without waiting for the utility staff to arrive at the site upon a disaster. In addition, the local districts are entrusted to manage the emergency storage tanks in public parks.

Sanitation

Seismic Reinforcement of Manholes [engineering design and materials]

TMBS reinforced an interface between a manhole and sewer pipes by installing rubber rings to absorb a seismic force (figure 3.21). The interface upgrade is to prevent the manhole structures and sewer pipes from being separated from each other because of seismic forces. This measure has been prioritized for sewers connected to the toilet facilities at locations such as emergency evacuation sites, terminal stations, and government buildings (TMBS 2016a).

Figure 3.21 Reinforcement of Sewer-Manhole Joints Using Elastic Sealant



The flexible joints between sewers and manholes can bend to prevent earthquakes damege.

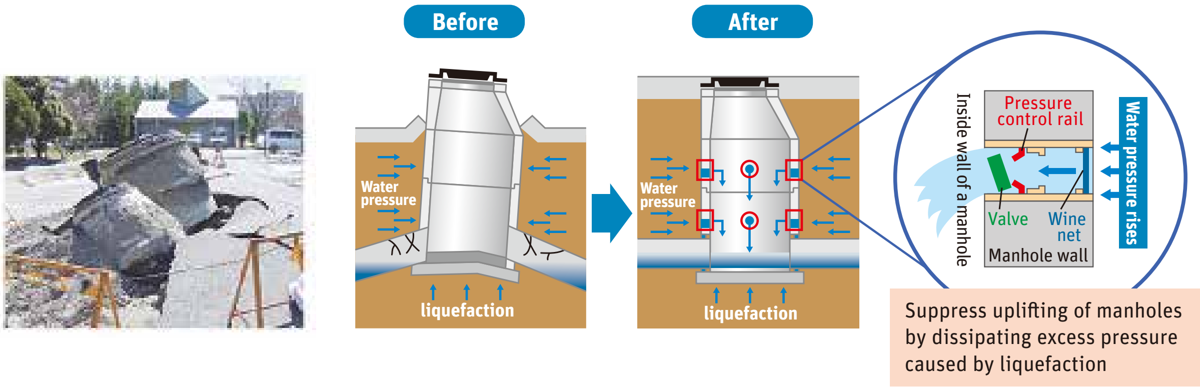
Rubber blocks absorb the earthquake impact are installed.

Trenchless seismic strengthening from inside manhole

Source: TMBS 2016a. ©Tokyo Metropolitan Bureau of Sewerage (TMBS). Reproduced, with permission, from TMBS; further permission required for reuse.

Furthermore, TMBS is taking measures to prevent flotation of manhole structures during liquefaction that could be caused by earthquakes (figure 3.22). If road surfaces get blocked or become difficult to pass by because of protruded manholes, it could adversely affect emergency transportation of relief goods, equipment, and personnel. This measure aims to prevent such hindrance to transportation, giving priority to high potential liquefaction areas where emergency transportation roads and terminal stations are situated (TMBS 2016a).

Figure 3.22 Measures to Prevent Flotation of Manhole Structures during Liquefaction



Source: TMBS 2016a. ©Tokyo Metropolitan Bureau of Sewerage (TMBS). Reproduced, with permission, from TMBS; further permission required for reuse.

Interconnecting Sewer Pipelines to Build a Backup Capacity [systems planning]

The utility has also been strengthening network redundancy between the WwTPs by connecting them via pipelines so that the plants could supplement the treatment capacity for one another in case any of them are severely affected by a natural disaster (TMBS 2016a).

3.7.4 Lessons Learned

Incorporate lessons learned from the past disasters into DRM programs
[systems planning] [contingency programming]

Learning from the past disasters is TMBW's principle for DRM, enabling continuous improvement and iterative planning to reduce seismic risks based on earthquake scenarios. A combination of structural and nonstructural measures helped minimize utility's impact from the GEJE.

Implement risk reduction investments against liquefaction associated with an earthquake to minimize impact on emergency transportation [engineering design and materials]

Based on risk assessments of potential liquefaction, TMBS has prioritized areas to implement risk reduction measures against manhole flotation caused by liquefactions so that it will minimize impacts on emergency transportation at the time of a disaster.

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04

Recommendations for Policy Makers and Utilities

04

Japan has built the resilience of its water supply and sanitation (WSS) services through an adaptive approach based on lessons learned from past natural disasters. In addition to adopting a legal and institutional framework that takes disaster risk management (DRM) into account, utilities have iteratively improved DRM measures on the ground, as discussed in chapters 2 and 3. Based on the case studies of Japanese WSS systems, this chapter presents recommendations for policy makers and utilities for each stage of infrastructure life cycle: legal and institutional frameworks, systems planning, engineering design and materials, asset management, and contingency programming.

The objective of this chapter is to share key insights and lessons learned from Japan with low- and middle-income countries seeking to reduce their vulnerabilities in essential service provision. Some measures are capital-intensive and could be challenging to implement depending on the financial and technical capacities of countries and utilities. Therefore, it is recommended to conduct risk assessment and cost-benefit analysis to prioritize and implement financially- and technically-viable DRM practices.

4.1 Legal and Institutional Frameworks

- *Incorporate DRM into WSS regulations, including performance objectives, engineering design, operation and maintenance (O&M), emergency response, and recovery.* Reflect the changes in DRM legislation into the relevant WSS regulations (for example, design standards) and guidelines. Review and upgrade of design codes are particularly useful for countries where the WSS services are privatized and regulated through government on performance standards and codes of practices.

- *Prepare contingency funds and subsidy programs for WSS assets that are critical for building system resilience and inclusive communities.* Prepare a program to incentivize utilities to develop or upgrade the WSS facilities that are critical for building resilient and inclusive communities. For example, the eligibility criteria for financial assistance may include retrofitting of pipelines from water treatment plants to emergency operation centers, evacuation sites, and care facilities for elderly and persons with disabilities or retrofitting of pipelines beneath emergency transportation and evacuation routes.

- *Ensure there is a clear legal structure or entity responsible for coordination and enforcement of provisions for DRM in order to integrate DRM measures in utility operations management.* Designation of an emergency coordination role to an independent water or sanitation association enables quick mobilization of external assistance based on the needs of the affected utilities.

4.2 Systems Planning

- *Develop a WSS system master plan for building resilience of WSS systems in accordance with a citywide master plan.* Building the disaster resilience of an overall WSS system through capital works may require time and large investments. Therefore, it is recommended to plan investments through risk assessments, prioritize through cost-benefit analysis, and develop long-term capital investment and finance plans that are required to meet the recovery-time objectives for re-instating a safe and reliable drinking water supply. Corresponding to the risk assessments and risk reduction measures, a contingency plan will address any residual risks though preparedness and emergency response procedures.

- *Create system redundancy to increase availability and reliability of safe drinking water after disasters.* Interconnecting distribution networks at the intracity scale enables rezoning of networks to protect against disruption of water supply due to individual transmission main failure and provides capability to use multiple water resources. Centralized distribution networks should be able to decompose into autonomous systems in order to isolate disrupted segments. This will enhance the backup capacity of a pipeline network and contribute to increased network redundancy. The efforts should be part of long-term planning and should consider the regional climate and topography as well as the utilities' financial capacity for investment.

- *"Build back better" by incorporating lessons learned from natural disasters into postdisaster reconstruction plans.* Integrate measures to enhance the resilience of WSS systems into postdisaster reconstruction planning.

4.3 Engineering Designs and Materials

- *Plan and prioritize reinforcement of WSS assets based on the risk assessment for critical infrastructure.* Disaster risk assessments and critical infrastructure vulnerability assessments will identify vulnerable WSS assets and their impact of failure on a city or critical infrastructures such as hospitals, fire stations, and emergency evacuation sites. The risk assessments and proposed solutions to reduce risk and strengthen resilience provide the necessary information for cost-benefit analyses, comparative prioritization and long-term investment and emergency management planning.

- *Internalize DRM investments as part of regular maintenance works given the limited budgets.* Take the opportunity to replace aged facilities with robust designs and materials based on the results of routine inspection. Historical records prove that earthquake-resistant pipes can also absorb shocks from landslides.

- *Conduct iterative planning to optimize stormwater drainage capacity and protect against high impact of recurrent flooding.* Historical hydrometeorological data and climate change projections provide the basis for prioritizing areas that are susceptible to inundation. Review and upgrade of the flood control master plan, and the implementation of large-scale storm sewer capacity upgrades are evaluated in terms of cost and benefit (that is, risk reduction from reducing flood impacts and the recurrence of flood events). Installation of new pipelines dedicated to stormwater collection may lead to the conversion of the entire system into a separate sewer system for improved stormwater drainage capacity.

- *Design topography-oriented sewer networks to continue effective treatment when pump stations are damaged from a natural hazard.* Designing a sanitation network by fully using a service area's topographic and geographic features can save electricity and enhance continuity of sewage treatment even if pumping stations get damaged upon a disaster.

4.4 Asset Management

- *Integrate DRM into a system of improved asset management that allows for the continuous review and re-evaluation of the system performance, investment plans, financial plans, investments prioritization, and maintenance decision making.* Risk-informed asset management of existing WSS assets is key to the resilience and security of WSS services as it provides for assessment of natural hazards on the safe and reliable provision of WSS. It measures the impact of these hazards on the supply of services to affected populations and critical infrastructures such as hospitals and schools, but also accommodates the assessment of physical vulnerabilities due to material fatigue (such as age) and their impact on WSS. Incorporate a risk-informed investment decision-making process by prioritizing and deciding which investments to implement based on the results of risk assessment.

- *Integrate DRM into daily O&M to enable timely identification of vulnerable assets and implementation of preventive measures.* For example, the leakage assessment by supply zones helps to prioritize zones that require proactive water main replacement and critical emergency response preparedness. Improve regular inspection procedures based on the lessons learned from the postdisaster damage assessment.

- *Develop a geographic information system (GIS) database of assets to enable visualization, efficient risk estimation, and construction planning.* A GIS database enables utilities to quickly identify damaged pipes and mobilize the relevant human resources and equipment to investigate and restore the damaged pipes caused by a disaster.

- *Develop efficient water distribution management systems to effectively control water quality and leakage and to function as effective early warning systems that can inform emergency response needs and contingency planning.* As a means of establishing an early warning system for supply disruptions, a water utility can use a water distribution control center to monitor and remotely control water flows and pressures by operating motor valves based on an analysis of data collected from the flow meters and pressure gauges installed in water distribution pipe networks. The monitoring of abnormal supply system behavior is used as an early indication of disruption and should be used for triggering alerts and contingency planning.

4.5 Contingency Programming

- *Develop and institutionalize business continuity management (BCM) and business continuity planning (BCP) to maintain and quickly restore essential WSS services.* BCM and BCP are systematic tools to ensure that essential operational, financial, and managerial functions remain uninterrupted following natural hazard events and other emergencies. Involving the utility personnel in the development of BCM and BCP raises awareness about emergency lines of communication, roles and responsibilities, decision making under uncertainty, and the scope of emergency tasks. Conduct regular trainings and drills to exercise and improve the BCM and BCP tools annually.

- *Incorporate business continuity into water safety planning and develop an emergency operations manual for water treatment plants and headquarters operations.* In addition to an emergency preparedness and response plan or a BCP, it is essential to prepare practical manuals detailing the emergency response procedures for the field engineers. Regularly train staff in DRM practices to incorporate resilience measures into daily O&M activities in the context of water safety planning.

- *Store materials and equipment required for restoring water supply in critical municipal buildings and functions.* To minimize the associated cost, prioritize storing emergency equipment and materials required for critical municipal buildings and functions. For the other areas, set a framework agreement with the private sector in advance to prepare required materials within a certain period (such as 10 days) after a disaster. Manage an inventory of equipment and materials for emergency repair works.

- *Mutually reinforce and integrate a BCP and asset management system.* Develop a targeted emergency preparedness and response plan based on a disaster risk profile of assets identified as part of the asset management system. Adopt the prioritization and investment decision-making process established under the asset management system for emergency repair and reconstruction works.
- *Prepare mutual support agreements and framework contracts with external entities for timely emergency response and recovery.* Mutual support agreements with other utilities and framework contracts with local engineering, procurement, and construction (EPC) companies for immediate postdisaster deployment enable utilities to quickly respond and restore services given limited human resources. Mutual aids include dispatch of engineers and personnel for emergency operation and loss and damage assessment, supply of equipment and materials for repair work, and water for emergency supply. Having framework contracts with local EPC companies with an intimate knowledge of the area's water and sanitation pipe networks facilitates a prompt postdisaster response, contributing to quick identification of leakage and restoration of damaged facilities.
- *Prepare plans and protocols to efficiently receive external assistance as part of BCM and BCP.* Receiving external support from other utilities and EPC contractors requires the recipient utility to prepare related protocols and specific requests well in advance so that the external organizations can effectively and efficiently offer support without uncertainty and confusion. Examples include communication protocols, a decision-making process, types of equipment and supplies required, payment terms and conditions, and accommodation of external support staff. Without such preparation, it is often difficult for supporting organizations to effectively perform the expected activities.
- *Build early warning and emergency water storage systems to secure distribution of water via pipelines to complement emergency water tanker trucks.* Water tanker trucks are effective means for securing drinking water immediately upon a disaster. However, operation of tanker trucks is dependent on the transportation networks and may not function if the road sections are damaged or traffic congestions occur, which is normally the case especially in urban areas. In addition, tanker trucks often cannot meet the needs for nondrinking water because of the large volume of water required. Therefore, it is recommended for utilities to build emergency water supply bases (for example, distribution tanks or reservoirs) for critical customers (such as hospitals) and distribute water via pipelines to emergency water supply bases as soon as possible upon a disaster. In addition, it is recommended to install seismometers at the distribution tanks to automatically transmit an electric signal to trigger emergency shutoff valves so that water can be stored for emergency use. It is also recommended to design some of the distribution tanks without the shutoff valves so that those tanks can continue distributing water for undisrupted areas and for firefighting.
- *Train the local communities and facilitate community-driven emergency water supply.* Community-driven emergency water supply enables an efficient and timely response by mobilizing residents and allocating utilities' limited human resources for other urgent tasks. Conduct regular training and drills with local communities so that the residents can set up temporary tap stands and other necessary equipment to access water without waiting for the utility personnel to arrive.
- *Establish an emergency communication system to disseminate disaster-related information to the public in a timely manner through use of media and hotlines.* After a disaster, utilities receive an overwhelming number of phone calls and queries from the affected residents and media about the damage, leakage, and access to water. This could hinder the utilities in focusing on other critical emergency response and restoration works. It is recommended for utilities to cooperate with other municipal offices and establish a communication system in advance to handle public relations during emergency. Examples include setting up or outsourcing an emergency call center and establishing communication protocols with the media to disseminate the information to the public in a timely manner.

Annex 1

List of Major Natural Disasters and their Impacts on WSS Services since 1995

Date	Natural disaster	Impacts on Water Supply	Impacts on Sanitation
Earthquake			
January 17, 1995	Great Hanshin-Awaji Earthquake (M7.3)	1.3 million households for a maximum of 90 days	In Hyogo prefecture, eight wastewater treatment plants and 180 km of pipes were damaged. Damage costs: ¥64.2 billion (US$0.57 billion).
October 23, 2004	Niigata-ken-Chuetsu Earthquake (M6.8)	130,000 households for a maximum of 30 days (except for areas where roads became impassable)	In Niigata Prefecture, one wastewater treatment plant stopped operation, and 152 km of pipes were damaged. Damage costs: ¥20.6 billion (US$0.18 billion).
March 25, 2007	Noto Hanto Earthquake (M6.9)	13,000 households for a maximum of 13 days	15 km of pipes were damaged. Damage costs: ¥1.88 billion (US$16.5 million).
July 16, 2007	Niigata Earthquake (M6.8)	59,000 households for a maximum of 20 days	Components of a wastewater treatment plant partially damaged, and 53 km of pipes were damaged. Damage costs: were ¥6.2 billion (US$54.6 million).
June 14, 2008	Iwate-Miyagi Inland Earthquake (M7.2)	5,500 households for a maximum of 18 days (except for the evacuated areas)	–
July 24, 2008	Iwate Northern Coast Earthquake (M6.8)	1,400 households for a maximum of 12 days	–
March 11, 2011	Great East Japan Earthquake (M9.0)	2.3 million households for a maximum of 5 months (except for tsunami affected areas)	Approximately 120 wastewater treatment plants were damaged, of which 48 plants stopped operation during initial postdisaster periods. 675 km of pipes were damaged by liquefaction and other causes. Damage costs: ¥350 billion (US$3.08 billion).
November 22, 2014	Nagano Kamishiro Fault Earthqukae (M6.7)	1,300 households for a maximum of 24 days	–
April 14 & 16, 2016	Kumamoto Earthquake (M7.3)	446,000 households for a maximum of 3.5 months (except for the houses collapsed)	–
October 21, 2016	Tottori Chubu Earthquake (M6.6)	16,000 households for a maximum of 4 days	–

Date	Natural disaster	Impacts on Water Supply	Impacts on Sanitation
Hydrometeorological Disasters			
August 28–29, 2008	Inundation in Okazaki, Nagoya, and Ichinomiya City in Aichi Prefecture (maximum rainfall of 146.5 mm/h)	–	On-floor inundation: 2,669 HHs Under-floor inundation: 13,352 HHs
June 2009	Extreme rain in Chubu and Northern Kyushu Region	87,000 households for a maximum of 11 days	–
November 11, 2009	Inundation in Wakayama City (maximum rainfall of 122.5 mm/h)	–	On-floor inundation: 461 HHs Under-floor inundation: 1,819 HHs
2010	Extreme rain in Yamaguchi, Akita, and Hiroshima Prefectures and elsewhere	17,000 households for a maximum of 6 days	–
July 5, 2010	Inundation in Nerima, Itabashi, and Kita Wards in Tokyo (maximum rainfall of 69.0 mm/h)	–	On-floor inundation: 111 HHs Under-floor inundation: 110 HHs
July 6, 2010	Inundation in Koriyama City (maximum rainfall of 74.0 mm/h)	–	On-floor inundation: 62 HHs Under-floor inundation: 141 HHs
July 2011	Intense rain in Niigata and Fukushima Prefectures (maximum rainfall of 121.0 mm/hr)	50,000 households for a maximum of 68 days	–
September 2011	Tyhoon Talas in Wakayama, Mie, and Nara Prefectures	54,000 households for a maximum of 26 days (except for the evacuated areas)	–
September 2011	Tyhoon Roke in Shizuoka, Miyagi, and Nagano Prefectures and elsewhere	16,000 households for a maximum of 13 days	–
August 25, 2013	Inundation in Osaka City (maximum rainfall of 67.5 mm/h)	–	On-floor inundation: 40 HHs Under-floor inundation: 1,314 HHs
September 4, 2013	Inundation in Nagoya City (maximum rainfall of 108 mm/h)	–	On-floor inundation: 251 HHs Under-floor inundation: 4,975 HHs

Source: Based on data from the Japan Meteorological Agency, the Ministry of Health, Labour and Welfare, and the Ministry of Land, Infrastructure, Transport and Tourism.
Note: US$1 = ¥113.6. = data not available. HHs = households. WSS = water supply and sanitation. mm/h = millimeters per hour. M = magnitude (earthquake).

Annex 2

List of DRM and WSS Laws in Japan since 1949

Year	Legislation and guidelines	Objectives
	Disaster risk management	
1949	Flood Control Act	Provides for risk reduction from floods, extreme rains, tsunami, or storm surge
1951	Act on National Treasury's Sharing of Expenses for Project to Recover Public Civil Engineering Works Damaged by Disaster (MLIT)	Provides for a national financial assistance framework for a prompt recovery of disaster-affected civil engineering works including sanitation system (water supply system not included)
1961	Disaster Countermeasures Basic Act	Enacted as the primary law to address all phases of disaster risk management
1962	Act on Special Financial Assistance for Extremely Severe Disasters (aka "Extremely Severe Disasters Act")	Provides for financial assistance and measures in relation to the Disaster Countermeasures Basic Act
1964	River Act	Provides for prevention of river-related disasters due to flood, tsunami, storm surge, and so on, as well as appropriate use of rivers and maintenance of their functions
1978	Act on Special Measures Concerning Countermeasures for Large-Scale Earthquakes	Provides for the measures to be taken by the national government, local governments, companies, and other entities upon the designation of special regions that should reinforce earthquake disaster prevention measures as well as upon the issuance of related warnings
1995	Act on Special Measures for Earthquake Disaster Countermeasures	Provides for a further strengthening of earthquake disaster prevention measures
2000	Act on Promotion of Sediment Disaster Countermeasures for Sediment Disaster Prone Areas (aka "Sediment Disaster Prevention Act")	For sediment disaster-prone areas, promotes wider, more rigorous implementation of soft countermeasures such as public notification of related dangers, improvement of alert and evacuation systems, restriction of new housing development, relocation of existing houses, and so on
2003	Specified Urban River Inundation Countermeasures Act	Provides for protecting the life and property of citizens from river inundations in urban areas
2005	Ministry of Land, Infrastructure and Transport Notification No. 1291	Introduces the concept of Level 1 and Level 2 Ground Motion for sewage equipment and facilities
2011	Act on Promotion of Tsunami Countermeasures	Based on the lessons learned from the Great East Japan Earthquake, the Act aims to clarify the basic perception of tsunamis and to promote a comprehensive and effective countermeasure

Annex

Year	Legislation and guidelines	Objectives
Water supply and sanitation		
1947	Local Government Autonomy Act	Provides for the classification, organization, and management of local public entities
1952	Local Public Enterprise Act	Provides for a self-supporting accounting system of the local public enterprises including water supply utilities
1957	Waterworks Act	Issues regulations concerning earthquake resistance of water supply facilities for the first time
1957	Specified Multipurpose Dam Act	Provides for the use of multipurpose dams including water supply dams
1958	Sewerage Act	Provides for development of the sewerage system for improved public health and conservation of water quality in public water bodies
1958	Industrial Water Supply Act	Provides for the operation of industrial water supply services
1959	Sewerage Act Enforcement Order	Provides for anti-earthquake measures for wastewater drainage and treatment facilities
1968	City Planning Act	Provides items for consideration (for example, scale and shape of the urban development area, topography, buildings) when designing waterworks and sewerage works
1970	Water Pollution Control Act	Provides for the control of water pollution in public waters
1974	Notification on the National Financial Assistance Program for Disaster Affected Water Supply Facilities (MHLW)	Provides for national financial assistance for the restoration of disaster-affected water supply facilities and for the provisional installation of emergency equipment and facilities upon disasters
1993	Basic Environmental Act	Provides for the basic principles of national environmental policies including water pollution control
2000	Ministerial Ordinance for Technical Standards of Water Supply Facilities (MHLW)	Clarifies technical standards for water supply facilities
2008	Amendment of the 2000 Ministerial Ordinance for Technical Standards of Water Supply Facilities (MHLW)	Introduces the concept of Level 1 and Level 2 Ground Motion for water supply facilities
2010	Notification on the National Financial Assistance Program for Social Capital Improvement (MLIT)	Provides for the national financial assistance program for the social capital improvement and related activities carried out by municipalities

Source: Gyosei Corporation 2016; and websites of the Ministry of Land, Infrastructure, Transport and Tourism; Japan Water Works Association and Japan Sewage Works Association

Note: DRM = disaster risk management. JSWA = Japan Sewer Works Association. JWWA = Japan Water Works Association. MHLW = Ministry of Health, Labour and Welfare. MLIT = Ministry of Land, Infrastructure, Transport, and Tourism. WSS = water supply and sanitation.

World Bank DRM Hub Tokyo

The World Bank Tokyo Disaster Risk Management 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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