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

Knowledge Note 3: Designing and Implementing Urban Flood Risk Management Investments
ACKNOWLEDGEMENTS

The four-part series “Learning from Japan’s Experience in Integrated Urban Flood Risk Management: A Series of Knowledge Notes” was prepared by a World Bank team led by Jolanta Kryspin-Watson, and comprising Shoko Takemoto, Zuzaun Stanton-Geddes, Kenya Endo, and Masatsugu Takamatsu. Primary and secondary data gathering, and research, was conducted by Washington CORE and Yachiyo Engineering Co., Ltd. The four reports benefited from additional research and contributions by Jia Wen Hoe, Sayaka Yoda, Toshihiro Sonoda, Alex Keeley, Tomoki Takebayashi, Thimali Thanuja Pathirana Batuwita Pathiranage, and Chinami Yamagami; and peer review by Vivien Deparday, Keiko Saito, Ryoji Takahashi, Bontje Marie Zangerling, Srinivasa Rao Podipireddy, Dixi Mengote-Quah, Dzung Huy Nguyen, and Camilo Lombana Cordoba. The team is also grateful for the support of Mika Iwasaki, Luis Tineo, Reiko Udagawa, and Haruko Nakamatsu.

The Knowledge Notes were developed with valuable contributions and guidance from numerous Japanese professionals and experts on integrated urban flood risk management. These include Professor Hiroaki Furumai, the University of Tokyo; Arata Ichihashi, Tokyo Metropolitan Research Institute for Environmental Protection; Michiru Sasagawa, Rain City Support and People for Rainwater; Nobuyuki Tsuchiya, Japan Riverfront Research Center; Shinji Nishimura, Urban Renaissance Agency (UR); Keiji Takeda, UR; Mikio Ishiwatari, Japan International Cooperation Agency (JICA); Miki Inaoka, JICA; Tomoki Matsumura, Ministry of Land, Infrastructure, Transport and Tourism (MLIT); Akito Kinoshita, MLIT; Takjuji Nakazato; Chikao Okuda, Tokyo Metropolitan Government; Professor Takanori Fukuoka, Tokyo University of Agriculture; Yorikazu Kitae, Development Bank of Japan (DBJ); Tomohiro Ishii, Yokohama City; Minato-Mirai 21 Promotion Division, Urban Development Bureau, Yokohama City; Environmental Planning Bureau, Yokohama City; and Shoju Takemoto, Kobe City.

Editorial services were provided by Fayre Makeig and Lisa Ferraro Parmelee. Kenya Endo designed the report.

The Knowledge Notes were prepared under the auspices of the Urban Floods Community of Practice (UFCOP). UFCOP is a global knowledge initiative led by the World Bank with support from the Global Facility for Disaster Reduction and Recovery (GFDRR) and others. The Knowledge Notes were developed with the financial support of the Japan–World Bank Program for Mainstreaming Disaster Risk Management in Developing Countries, which is financed by the Government of Japan and receives technical support from the World Bank Tokyo Disaster Risk Management Hub.
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1. Summary

This Knowledge Note summarizes the experiences of and lessons learned by Japanese cities that have designed and implemented various types of urban flood risk management investments. Building on the broad principles outlined in Knowledge Note 2 of the same series, and on a review of 20 cases (detailed in an appendix) across Japan, this note focuses on five categories of investment criteria:

1) Flood management and investment objectives
2) Technical considerations
3) Urban development and finance
4) Governance and stakeholders
5) Multipurpose infrastructure

The specificities of each context inform and determine the enabling environment for investment, and also the feasibility and relevance of various mechanisms to manage flood risks.

Cities design and implement site-specific schemes to manage urban flood risks based on the type and extent of the risks assessed (discussed in Knowledge Note 1), as well as the goals and sectoral targets of their flood management plans (discussed in Knowledge Note 2). To address various types of urban flood risk (river, surface water, and storm surge floods), Japanese cities combine structural and nonstructural measures. Of structural measures, both “gray” (heavy infrastructure) and “green” (nature-based, multipurpose interventions) are being increasingly explored in Japan. Through trial and error, many cities are identifying the challenges and merits of combining structural and nonstructural as well as gray and green solutions. Such combinations often enhance the overall effectiveness of urban investments in flood management, in some cases at less cost to the public sector and other stakeholders involved.

Investing in efforts to reduce and manage urban flood risks requires cities to carefully select those measures that promise to be most effective and efficient in a given context. Cities must be able to understand and weight the strengths and weaknesses of various options, assess the range of flood management measures available, and consider the enablers needed for implementation. This can be a daunting task, given obvious limits to the information, time, and resources needed to thoroughly understand and explore the array of flood risk management options.

This note highlights the following key lessons learned from Japan’s experience in designing and implementing effective flood management investments in urban settings:

- **Consider multiple factors and criteria.** Design and implementation involve much more than technical solutions. Cities across Japan have taken a multifaceted approach that considers multiple interrelated factors including the type of flood risk, spatial and financial considerations, and implementation arrangements.

- **Design multipurpose interventions that offer multiple benefits.** Cities face an array of social, economic, and environmental challenges at once and must balance many needs and priorities beyond those related to disaster and climate risks. Finding opportunities for synergy is the most practical way to maximize the space and resources available to a city and its residents. Examples from Japan showcase various ways in which collaboration and partnerships can be effectively brokered to support multiple purposes and benefits. Cities such as Yokohama and Tokyo, for example, have achieved synergies across the goals of urban flood risk management, urban development, and environmental conservation as they work to create safe and livable urban spaces.

- **Engage the private sector and local communities.** As the number and diversity of urban flood risks increase, cities in Japan are aware of the need to engage diverse stakeholders and coordinate roles and responsibilities to most efficiently finance, implement, and expand measures to manage the risks. Many cities have explored ways to partner with and incentivize initiatives led by private developers and communities. For example, in the process of upgrading the Shibaura Wastewater Treatment Facility to enhance its stormwater and wastewater...
management capacity, the Tokyo Metropolitan Government (TMG) Bureau of Sewerage collaborated with the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) and NTT Urban Development (a private sector developer). The tools and mechanisms trialed included regulatory mechanisms, the establishment of standards and guidelines, subsidy programs, flexible urban development standards, information sharing, and awareness raising campaigns. For example, under the administrative guidance requirements (“gyosei shido” guidelines), local governments in Japan require developers to construct flood retarding basins to compensate for the expected increase volume of rainwater runoff due to development.

- **Utilize new technologies and systems.** Based on lessons from various disaster events, cities in Japan, together with research institutes and firms, have worked to advance and apply various new technologies in construction methods, materials, and management systems to enhance the effectiveness of flood management measures. For example, Hachioji Minamino City worked with the Hachioji New Town Water Circulation Conservation Systems Committee (led by academics from the University of Fukushima) to evaluate the city's hydrological cycle conservation system using the SHER model (Japan Riverfront Research Center 2007). Similarly, Setagaya Ward has collaborated with various universities and engaged communities to design, implement, and monitor green infrastructure solutions. These iterative and incremental processes of monitoring and improvement have ensured the continued relevance and effectiveness of both structural and nonstructural approaches to urban flood risk.

2. **Designing Investments for Various Types of Flood Risk**

2.1 **Factors and Criteria Considered by Cities**

In designing a site-specific effort to manage urban flood risk, various factors need to be considered to ensure successful implementation. In particular, the project's benefits (outcomes) and requirements (to create an enabling environment) must be considered in relation to planners' objectives and available resources.

**Flood Management and Investment Objectives**

Cities may deliberate on one or a combination of approaches to managing the various types of flood risk. Selecting a measure that is suited to a site's flood risk profile (including proximity to water bodies, characteristics of the built environment, etc.) and planning and development objectives (including risk management targets laid out in city and national plans, etc.) is critical.

Investments in the management of urban **river floods** primarily aim to: (i) avoid water overflow from a river into an urban area by increasing the river's conveyance capacity (via widening or dredging) or constructing a structure (e.g., river embankment) that serves as a barrier; and (ii) temporarily store river overflow in sites away from urban centers, whether underground (in cisterns, channels, etc.) or above ground (in reservoirs, detention parks, and ponds).

Investments in managing urban **surface floods** primarily aim to manage the volume of water that enters urban drainage/sewer systems through: (i) temporarily storing stormwater in management facilities that may be underground (such as cisterns, channels, drainage pipes, culverts, etc.) or above ground (such as stormwater detention ponds, parks, and gardens); (ii) adding storage capacity to existing facilities that may be used for detention (e.g., sewerage system); (iii) harvesting rainwater in tanks within public, commercial, and community

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

2. Similar Hydrologic Element Response.
buildings; and (iv) increasing the infiltration capacity of urban surfaces through the use of green spaces, pervious pavers, infiltration trenches, and so on to reduce stormwater runoff. It must be noted that even small-scale interventions can have a large collective effect when installed throughout a city. These investments are combined with various other measures to avoid water inundating the urban areas, such as river and coastal management measures (seawalls and embankments) as well as pumping systems.

Investments in urban storm surge flood management generally aim to: (i) prevent seawater surge into urban areas by constructing barriers (e.g., seawalls or flood gates), and/or (ii) raise the ground or platform level of affected structures to avoid damages due to seawater inundation. In Japan, most storm surge flood management projects are also designed to jointly manage tsunami risks, given the vulnerability of the country’s entire coastline to seismic activity.

In general, the flood management capacity depends on the size of the infrastructure, which is often limited by the availability of financial resources and land. Flood management schemes applicable to all flood types generally aim to: (i) avoid urban development in flood-prone areas, through risk-informed land use planning and zoning; (ii) ensure that construction in flood-prone areas can withstand certain levels of flood risks, through appropriate building codes; and (iii) equip the affected population with information needed to protect their lives and livelihoods in case of flood disasters, through early warning systems, accessible evacuation centers, access to risk assessments/risk information, education, drills, efforts to raise awareness, and so on. Land use plans and zoning can go far in mitigating flood risk by deterring development in high-risk areas, thereby reducing vulnerability and asset exposure, but these interventions do not directly minimize the flood hazard itself. Similarly, building codes, early warning systems, and communication efforts can be effective in reducing losses and damages to lives and assets from flood events, but they do not directly protect developed areas from the occurrence of floods.

Urban Development and Finance: Considering Space and Cost

Given competing development pressures, the spatial and financial requirements of interventions are critical to consider. Flood management investments with a high cost and large surface footprint, such as reservoirs, detention parks, river embankments, sea walls, and ground raising are feasible options when: (i) high-value assets are located near or within the affected watershed, and a significant socioeconomic impact is expected without a large-scale investment; and (ii) an entity or group of entities can finance the high cost and coordinate complex consensus building, land acquisition, relocation, and construction processes. These tend to be in or near high-density urban centers located near large rivers and coastlines—that is, the conditions of most major cities in Japan.

Flood management investments with very high costs and a medium-sized to small surface footprint, such as underground river overflow management and stormwater facilities (e.g., cisterns, channels, drainage pipes, culverts), and the capacity expansion of sewerage systems are feasible options when: (i) very high-value assets are faced with the risk of a significant socioeconomic impact from floods; and (ii) an entity, normally from the public sector, has the capacity, authority, and access needed to develop an underground facility. These tend to be in very high-density urban centers where space above ground is limited.

Flood management investments with medium to low costs and medium-sized to small space requirements, such as storage in ponds and gardens, harvesting and reuse of rainwater, surface modification to enhance infiltration and reduce runoff, and the establishment of evacuation centers are feasible options when: (i) public and private spaces can be made available, and (ii) the level of awareness and participation of various public sector departments, the private sector, and community members is high. These tend to be located in medium-to-low-density urban areas where space above ground is available.

Technical Considerations: Positive and Negative Impacts

In addition to traditional technical surveys and feasibility-level studies, when designing a flood risk management scheme, it is important to keep in mind several technical factors, outlined as follows:

- **Flood management capacity.** Cities invest in initiatives to address existing flood risk challenges and meet citywide flood management targets. Therefore, the type of proposed investment and the extent to which it reduces flood risks (that is, its capacity to manage floods) are key considerations. For example, the high-
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As discussed in Knowledge Note 2, it is critical to consider and categorize all project stakeholders before designing an intervention. The governance framework, too, is key to an intervention’s success. Key factors are summarized as follows:

- **Policy and governance framework.** National and municipal policies and legal frameworks—such as those related to stormwater management, river management, urban development, environmental standards, disaster risk management, etc.—provide key directions and technical guidelines for the types of flood management measures that may be implemented and how they are designed in Japanese cities. At the project level, especially when responsibilities are being shared among different stakeholders, the need to establish new operational procedures and governance mechanisms becomes an important design consideration. For example, in Japan the use of collected water in a rainwater harvesting system is limited to those functions authorized by the Act to Advance the Utilization of Rainwater (MLIT 2015); these include its use in toilets and for watering plants, cleaning purposes, environmental purposes, and fire and emergency management. Knowledge Note 2 focuses on these issues.

- **Innovation and technology.** Various technological innovations are drastically changing the way city systems and inhabitants operate and interact. Today, more than ever before, planners are aware of the need to explore opportunities to integrate and adapt to these fast-changing technological contexts. Innovations in construction processes and materials, as well as technological tools that can be used to enhance stakeholder engagement, consensus building, and risk awareness and communication, are all key design considerations for cities to ensure flood management investments are relevant today and in the future.

**Governance and Stakeholders: Which Stakeholders Are Leading the Investments?**

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- **Stakeholders.** As detailed in Knowledge Note 2 (table 5), large-scale, structural interventions to manage river and storm surge flood risk are led in Japan by the national government, under the leadership of MLIT, while smaller-scale, structural and nonstructural river, surface water flood, and multihazard investments are led by municipal governments, the private sector, and communities. Area-wide structural investments that require consensus building with citizens, land realignments, and the relocation of assets or residents (such as river embankments, seawalls, ground-raising investments, some reservoirs, and detention parks) often combine flood management initiatives with urban redevelopment or environmental conservation efforts. Therefore, they are implemented through a coordinated effort between the national government (MLIT), municipal government (e.g., river, urban development, and environment departments), and private sector (e.g., housing development authorities). Partnering with community and private sector groups to design, build, finance, operate, and maintain flood risk management investments may require extensive coordination, but can significantly reduce the lifetime costs and maximize the benefits of an intervention.
o **Site-specific structural investments utilizing public space** above and below ground (such as underground river overflow and stormwater management facilities, reservoirs, detention parks, sewerage treatment plant enhancements, rainwater harvesting systems, and the enhancement of infiltration surfaces) are normally led by **municipal governments**. In recent years, **innovative ways of incentivizing private and community participation**, especially in the O&M of these facilities through private finance initiatives, are growing (showcased in Knowledge Note 4).

o **Structural investments utilizing privately owned land** (e.g., buildings, residences) above and below ground (such as detention parks, ponds, gardens, rainwater harvesting systems, and the enhancement of infiltration surfaces) are normally led by **private and community stakeholders**, often with education, awareness raising, technical support, and financial incentives provided by **municipal governments**. Through subsidy programs, the provision of technical guidelines, and the implementation of educational campaigns, public, private, and community stakeholders coordinate and collaborate to achieve the scale required for these small interventions to contribute to citywide flood management goals. Public-private partnerships, private finance initiatives, and other forms of private sector participation have been trialed to improve the efficiency of investments as well as reduce O&M costs, and share the cost burden.

o **City- or communitywide nonstructural investments** (such as land use plans, zoning and building codes, early warning systems and evacuation centers, risk assessments, drills, and efforts to raise awareness) are normally led by **municipal governments’ urban planning and development and disaster risk management departments**. Cities often collaborate with community groups, technical experts, schools, and hospitals to design and implement these initiatives. Examples from Ozu City, Ehime Prefecture, Sanjo City, and Niigata Prefecture are highlighted in **Knowledge Note 1**.

### Multipurpose Infrastructure

Faced with competing development pressures and pressing priorities, cities are tasked to find creative ways to derive multiple types of benefits serving various stakeholders and purposes within a single intervention. There is a significant opportunity to harness additional benefits from proposed flood management investments (such as integrating green design elements, and engaging the public and private sectors to build, operate, and manage facilities, etc.) or to ensure that other urban initiatives (such as environmental conservation and urban development/renewal projects, public or private infrastructure or facility upgrades, etc.) also support flood management targets. Amid new research and technological advancements, structural approaches can involve both gray (hard-engineered) and green (nature-based) infrastructure.

Cities interested in advancing environmental sustainability and livability are also promoters of green infrastructure, often through collaboration with private developers and financial institutions interested in fulfilling a commitment to advance environmental, social, and governance investments. Major cities investing in green infrastructure solutions include Setagaya Ward in Tokyo, as well as Yokohama City. The public sector in general is growing increasingly more interested in green approaches to complement gray solutions, given the growing challenges of an aging infrastructure, a shrinking population, and limited human and financial resources (Development Bank of Japan 2019). For example, traditional concrete river embankments and seawalls can be combined with trees, or the height of an embankment can be reduced if complemented by other solutions such as natural wave breakers. Similarly, the size and design of storm drains, pumps, and outfalls can be redesigned with a reduced footprint when combined with nature-based infiltration systems and/or water detention facilities, such as rain gardens, etc. In Japan, efforts to utilize green infrastructure solutions for flood risk management are still at their initial stages, although nature-based solutions have deep cultural and historical roots. Experience to date shows that: (i) reservoirs, detention parks, and ponds for river floods are widely adopted (examples include Saitama Prefecture and Setagaya Ward); and (ii) the application of nature-based solutions for stormwater detention ponds, parks and gardens, rainwater harvesting systems, and enhancement of infiltration surfaces is growing in Japanese cities.

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3 For lessons learned on resilient infrastructure public-private partnerships, please see Shibuya and Sasamori (2017).
4 The Economist Intelligence Unit (EIU), for example, assesses the “livability” of cities across five dimensions: stability, health care, culture and the environment, education, and infrastructure (Ellis and Roberts 2016).
5 See Browder et al. (2019) for a discussion of how nature-based solutions can produce lower-cost and more resilient services.
Box 1: Spotlight on Structural (Gray and Green Infrastructural Measures) and Nonstructural Measures for Urban Flood Risk Management Investments

As described in Knowledge Note 2, amid increasing and diversifying risks of floods, cities are increasingly aware of the importance of integrating structural and nonstructural measures, as well as gray (hard-engineered) and green (nature-based) solutions during the design and implementation of flood risk management investments. Key strengths and weaknesses of three types of such investments are summarized below:

- **Gray infrastructure measures. Key strengths** include large flood management capacity and relatively straightforward coordination in operation and maintenance (if governance mechanisms are clarified in advance). **Key challenges** include high construction costs and potentially long construction times, as well as high operation and maintenance costs over time, which are borne mainly by the public sector. Additionally, gray infrastructure is often designed solely to manage a specific type or level of flood risk. As a result, some large-scale flood management facilities, such as underground cisterns and channels, may be used only once a year or whenever large-scale flood events strike. Built to a set design level, traditional flood mitigation facilities are unable to manage flood risks above such levels.

- **Green infrastructure measures. Key strengths** include the functions and benefits that these generate beyond flood management, with green spaces and amenities often increasing the economic, social, and environmental value of an area. This can attract and engage private and community stakeholders to play a role in the design, financing, construction, operation, and maintenance of these measures, and thus share roles and responsibilities in managing the investment. Green infrastructure may also offer more flexibility than gray infrastructure, given its higher adaptability to changing environmental conditions. Furthermore, multipurpose investments can be utilized more frequently by various stakeholders and are often valued as a public amenity that may increase the property value of surrounding land. **Key challenges** include the high level of time and effort needed for stakeholder coordination, lower flood management capacity compared with gray infrastructure measures, and the difficulty of assessing, as well as monitoring and evaluating, the actual effectiveness of these measures in managing floods and realizing other intended benefits.

- **Nonstructural measures. Key strengths** include the ability to reach a large population at a relatively low cost (i.e., through education campaigns, dissemination of hazard maps, training and drills to raise awareness, establishment of early flood warning and evacuation systems, etc.). These measures aim to equip people with the information and knowledge they need to save their own lives and prepare for disaster so as to minimize damage and loss to their assets and livelihoods, including in the case of unprecedented flood and inundation levels. **Key challenges** include limitations in the degree to which these measures can avoid or mitigate the impact of floods. Effective flood evacuation measures can save lives but their ability to avoid and reduce damage to assets and livelihoods may be limited compared with structural measures.

*Integrating Green and Gray: Creating Next Generation Infrastructure* (Browder et al. 2019) is a joint report from the World Bank and the World Resources Institute (WRI) that aims to advance the integration of green and gray infrastructure solutions on the ground, and provides further analysis on the enabling environments and lessons learned in implementing an integrated approach to flood risk management.
3. Implementing Urban Flood Risk Management Investments in Japan

Considering the above factors and criteria, Japanese cities are exploring a range of approaches and options to determine the scope, elements, and design of site-specific flood management measures, and initiate investments that are most suitable to local contexts. The planning and prioritization process is explained in Knowledge Note 2. An overview of the types of flood risk management investments common in Japan, along with specific examples from the case studies detailed in the appendix, is provided in figure 1, which spans the next several pages. While river dredging and widening, as well as the construction of dams and reservoirs upstream of vulnerable watersheds, are important elements of integrated flood management in Japan, they are not included in this Knowledge Note, which focuses on city-level interventions.⁶

⁶ A comprehensive review of structural and nonstructural measures used for integrated flood risk management globally can be found in Jha, Bloch, and Lamond (2012).
Figure 1: Types of Flood Risk Management Investments in Japanese Cities

Case 1
Reducing River Flood Risk and Promoting Urban Redevelopment: Komatsugawa High-Standard Embankment

Case 2
Reducing River and Surface Water Flood Risk by Integrating Nature-Based Solutions within an Urban Redevelopment Project: Futakotamagawa Rise and Futakotamagawa Park

Case 3
Reducing River Flood Risk by Installing Underground Overflow Management Facilities: Underground Detention Cistern beneath Loop Road No. 7

Case 4
Reducing River Flood Risk by Installing a Multipurpose Detention Park and Reservoir: Arakawa River No. 1 Detention Facility

Case 5
Reducing River and Surface Water Flood Risk through Sharing the Costs of O&M: Tetsugakudo Park Collective Housing and Myoshoji River No. 1 Detention Pond

Learning from Japan’s Experience in Integrated Urban Flood Risk Management
Case 1: Reducing River Flood Risk and Promoting Urban Redevelopment:
Komatsugawa High-Standard Embankment

Case 2: Reducing River and Surface Water Flood Risk by Integrating Nature-Based Solutions within an Urban Redevelopment Project:
Futakotamagawa Rise and Futakotamagawa Park

Case 3: Reducing River Flood Risk by Installing Underground Over/flow Management Facilities:
Underground Detention Cistern beneath Loop Road No. 7

Case 4: Reducing River Flood Risk by Installing a Multipurpose Detention Park and Reservoir:
Arakawa River No. 1 Detention Facility

Case 5: Reducing River and Surface Water Flood Risk through Sharing the Costs of O&M:
Tetsugakudo Park Collective Housing and Myoshoji River No. 1 Detention Pond

**Figure 1**, continued from previous page
Underground stormwater management facilities (cisterns, channels, drainage pipes, culverts, etc.)

Case 6
Reducing Surface Water Flood Risk with an Underground Stormwater Management Facility: Drainage Pipe System Improvement, Tokyo

Case 7
Reducing Surface Water Flood Risk by Installing an Underground Stormwater Management Facility with Other Public Facilities: Minamisuna Detention Pond (7a) and Hibiya Crossing Detention Pond (7b)

Case 8
Reducing Surface Water Flood Risk by Installing an Underground Stormwater Management Facility: Yokohama Station Tower and Excite Yokohama 22 District

Stormwater detention ponds, parks, and gardens

Case 9
Reducing Surface Water and River Flood Risk by Integrating a Reservoir into Large-Scale Urban Development: Koshigaya Lake Town

Case 10
Reducing Surface Water and River Flood Risk by Implementing Reservoirs, Detention Ponds, and Parks: Saitama Prefecture
Case 6: Reducing Surface Water Flood Risk with an Underground Stormwater Management Facility: Drainage Pipe System Improvement, Tokyo

Case 7: Reducing Surface Water Flood Risk by Installing an Underground Stormwater Management Facility with Other Public Facilities: Minamisuna Detention Pond (7a) and Hibiya Crossing Detention Pond (7b)

Case 8: Reducing Surface Water Flood Risk by Installing an Underground Stormwater Management Facility: Yokohama Station Tower and Excite Yokohama 22 District

Underground stormwater management facilities (cisterns, channels, drainage pipes, culverts, etc.)

Stormwater detention ponds, parks, and gardens

Case 9: Reducing Surface Water and River Flood Risk by Integrating a Reservoir into Large-Scale Urban Development: Koshigaya Lake Town

Case 10: Reducing Surface Water and River Flood Risk by Implementing Reservoirs, Detention Ponds, and Parks: Saitama Prefecture

Design event and storage capacity
- Case 6: 42,000 m³
- Case 7a: 25,000 m³
- Case 8: 170 m³

Required above-ground space
- Minimal

Cost
- Case 6: ¥6.7 billion
- Case 7a: ¥10 billion
- Case 8: ¥91.8 billion

Additional benefits
- Limited

Stakeholders
- National and local government, private developers, etc.

Storage capacity
- Case 9: 1.2 million m³
- Case 10: 100,000 m³ or under 26 million m³

Required above-ground space
- Minimal

Cost
- Case 9: ¥51.6 billion
- Case 10: ¥11.4 billion

(Annual budget in Saitama Prefecture for investments in reservoirs, detention ponds, and parks)

Additional benefits
- Urban development, recreational space, and environmental sustainability

Stakeholders
- Local government, housing developers, community, etc.

Surface water floods
- Very High: High
- High: Medium
- Medium: Low
- Low: Very Low

Figure 1, continued from previous page
Case 11
Reducing Surface Water Flood Risk by Enhancing a Sewerage Detention Facility in Collaboration with the Private Sector: Shibaura Wastewater Treatment Facility

Sewerage treatment facility improvement

Case 12
Reducing Surface Water Flood Risk through Community-Based Rainwater Harvesting Systems: Sumida Ward, Tokyo

Rainwater harvesting systems (collection systems and storage tanks installed in public, commercial, community buildings)

Case 13
Reducing Surface Water Flood Risk by Implementing a Rainwater Harvesting Tank in a Private Urban Development: Tokyo Skytree Town

Case 14
Reducing Surface Water Flood Risk by Enhancing Pervious Surfaces and Detention Ponds in a New Town Development: Hachioji Minamino City

Case 15
Reducing Surface Water Flood Risk by Enhancing Pervious Surfaces: Grand Mall Park in Yokohama City

Sewerage treatment facility improvement

Increasing surface permeability (green space, pervious pavers and infiltration trenches, etc.)
Learning from Japan’s Experience in Integrated Urban Flood Risk Management

**Case 14**
Reducing Surface Water Flood Risk by Enhancing Pervious Surfaces and Detention Ponds in a New Town Development: Hachioji Minamino City

- **Required above-ground space**: Minimal
- **Storage capacity**: 76,000 m³ storage capacity
- **Cost**: ¥256 billion (Combined cost of urban development and land readjustment projects)
- **Stakeholders**: National and local government, housing developers, etc.
- **Additional benefits**: Urban development, environmental sustainability, and DRM

**Case 15**
Reducing Surface Water Flood Risk by Enhancing Pervious Surfaces:
Grand Mall Park in Yokohama City

- **Storage capacity**
  - Public rainwater harvesting system (RHS): 9,374 m³
  - Private RHS: 14,292 m³
  - Community RHS: 283 m³
  - Household RHS: 61 m³
- **Required above-ground space**: Small household plots to 14.5 ha
- **Cost**
  - Case 12: per unit from ¥10,000–100,000 to ¥2 million–9 million
- **Stakeholders**: National and local government, housing developers, community, etc.
- **Additional benefits**: Urban redevelopment, DRM, and water consumption saving

**Case 11**
Reducing Surface Water Flood Risk by Enhancing a Sewerage Detention Facility in Collaboration with the Private Sector: Shibaura Wastewater Treatment Facility

- **Required above-ground space**: Minimal
- **Cost**: Construction: ¥20 billion
- **Stakeholders**: National and local government, housing developers, etc.
- **Additional benefits**: Urban redevelopment, environmental sustainability, and recreational space

**Case 13**
Reducing Surface Water Flood Risk by Implementing a Rainwater Harvesting Tank in a Private Urban Development: Tokyo Skytree Town

- **Storage capacity**
- **Required above-ground space**: Case 12: Small household plots to 14.5 ha
- **Cost**
  - Case 12: per unit from ¥10,000–100,000 to ¥2 million–9 million
- **Stakeholders**: National and local government, housing developers, community, etc.
- **Additional benefits**: Urban redevelopment, DRM, and water consumption saving

**Case 12**
Public rainwater harvesting system (RHS): 9,374 m³, private RHS: 14,292 m³, community RHS: 283 m³, household RHS: 61 m³

**Case 10**
Reducing Surface Water Flood Risk through Community-Based Rainwater Harvesting Systems: Sumida Ward, Tokyo

- **Required above-ground space**: Case 12: Small household plots to 14.5 ha
- **Cost**
  - Case 12: per unit from ¥10,000–100,000 to ¥2 million–9 million
- **Stakeholders**: National and local government, housing developers, community, etc.
- **Additional benefits**: Urban redevelopment, DRM, and water consumption saving

**Case 10**
Rainwater harvesting systems (collection systems and storage tanks installed in public, commercial, community buildings)

**Surface Water Floods**
Surface water floods due to insufficient drainage capacity to handle increased runoff from large coverage of impervious surfaces

- **Very High**
- **High**
- **Medium**
- **Low**

**Figure 1**, continued from previous page
Case 19
Managing Storm Surge Flood Risk by Enhancing Seawalls and Flood Gates:
Port of Kobe

Case 20
Reducing Storm Surge Flood Risk by Raising the Ground Level:
Minato Mirai 21 District in Yokohama City
Case 19: Managing Storm Surge Flood Risk by Enhancing Seawalls and Flood Gates: Port of Kobe

- **Seawalls and gates**
- **Design event**: 1-in-100-year or 1-in-200-year storm event
- **Required above-ground space**: 59.8 km of barrier length
- **Cost**: Construction: ¥30 billion
- **Additional benefits**: Seismic resilience
- **Stakeholders**: National and local government

Case 20: Reducing Storm Surge Flood Risk by Raising the Ground Level: Minato Mirai 21 District in Yokohama City

- **Ground raising**
- **Design event**: 1-in-100-year or 1-in-200-year storm event
- **Required above-ground space**: 73.9 ha (land reclamation area)
- **Cost**: Construction: ¥2.625 trillion
- **Additional benefits**: Urban development, seismic resilience, DRM, and recreational space
- **Stakeholders**: National and local government, housing developers

*Figure 1, continued from previous page*
Risk assessment, land use plans, zoning, and building codes

Enhancing early warning systems

Improving evacuation, drills, and awareness raising

Refer to Knowledge Note 1: Box 3


Refer to Knowledge Note 1: Box 6

Disseminating Flood Risk Information—The “Timeline” Method Used by Urban Railways: Japan Railway (JR) West

Refer to Knowledge Note 1: Box 4

Neighborhood Safety Maps in Shiga Prefecture—Using Risk Assessments to Raise Awareness: Shiga Prefecture
City Hall
above second floor level
Inundation Depth;
above first floor level
above first floor level (more than 24 hours)
beneath first floor level
Primary, Secondary Evacuation Centers
Other Evacuation Centers
Hazardous Spots during Flood Events
Risk assessment, land use plans, zoning, and building codes
Enhancing early warning systems
Flood risk management capacity
Non-quantifiable
Required above-ground space
N/A due to nonstructural measure
Cost
Additional benefits
N/A due to nonstructural measures
Stakeholders
Local government
Flood risk management capacity
Non-quantifiable
Required above-ground space
Minimal
Stakeholders
Local government, community
Flood risk management capacity
Non-quantifiable
Cost
Additional benefits
N/A due to nonstructural measures
Stakeholders
Local government, community
Required above-ground space
N/A due to nonstructural measures
Flood risk management capacity
Non-quantifiable
Note: DRM = disaster risk management; ha = hectare; km = kilometer; km$^2$ = square kilometer; m$^2$ = square meter; m$^3$ = cubic meter; mm = millimeter; N/A = not applicable; O&M = operation and maintenance; ¥ = Japanese yen.
### 3.1 Managing River Flood Risk

#### River Embankments

River embankments are generally large-scale structural investments designed to protect against floods from significant river overflow, such as that due to rainfall levels with a likely frequency of once in 150 to 200 years for large rivers and once in 100 years for medium-sized rivers (NIED 2009). Given their scale, embankments require substantial financing, space, and time. Because of their high cost and complexity, in Japan, their construction is normally led by national or municipal governments, with the objective of protecting urban centers with highly concentrated populations and assets from severe economic and social damages.

Many large river embankment investments have been implemented together with urban redevelopment initiatives. For example, the Komatsugawa High-Standard Embankment (appendix, case 1) in east Tokyo was developed by MLIT to reduce significant risks of damage to lives and assets from river floods in the Tokyo Metropolitan area, as well as to provide higher ground for evacuation in the Komatsugawa District. Given its high cost (approximately ¥48.8 billion [$444 million] as of 2011) (MLIT 2011) and required land area, the embankment’s construction was implemented in conjunction with an urban redevelopment initiative led by TMG and Edogawa Ward and the Urban Renaissance Agency (UR). This example shows how large-scale, structural river management investments can leverage a multipurpose design, whereby not only flood management benefits are derived from the investments but also additional benefits such as disaster resilience and urban redevelopment.

Similarly, the redevelopment of the Futakotamagawa riverside area in western Tokyo is an initiative implemented jointly by the public sector (TMG and Setagaya Ward) and private sector partners (Tokyu Land Corporation and Tokyu Corporation). Here, a disaster-resilient and environmentally friendly commercial and residential redevelopment project was constructed alongside a high-standard embankment along the Tama River (appendix, case 2).

#### Underground River Overflow Management Facilities

Underground river overflow management facilities (cisterns, channels, etc.) are structural investments that require substantial financing and time for construction. Most are designed to manage floods likely to occur 1-in-20-year. Facilities installed in small- or medium-sized rivers in the Tokyo Metropolitan area (TMG n.d.[b], n.d.[c]) are built to withstand rainfall levels of 50–75 millimeters per hour (mm/hour).

Since they are constructed underground, the facilities do not require much land above ground for development. However, there is substantial financing, time, and coordination associated with underground construction. Because of its high cost and complexity, this construction is led by the national or municipal governments (depending on the size and designation of the river) in locations where there is an urgent need to protect highly concentrated populations and assets.

As such, investment in underground river overflow management facilities in Japan has been led by the public sector, which has made substantial efforts to reduce costs and increase flood management impacts (as discussed in Knowledge Note 2).

To achieve capacity targets as effectively as possible, cisterns and channels to detain river overflow are often constructed under public land, such as roads and parks, to save land acquisition and compensation costs. For example, TMG constructed a large-scale underground detention cistern underneath the publicly owned Loop Road No. 7, which saved significant costs and time (appendix, case 3). Furthermore, TMG often targets investments that can connect existing facilities, particularly channels, so that the overall flood management capacity can be increased by connecting separated facilities (TMG n.d.[b]).

#### River Overflow Management Facilities above Ground

River overflow management facilities located above ground (e.g., reservoirs, detention parks, and ponds) are developed near rivers at risk of overflowing. These structural, nature-based interventions have been adopted...
widely in Japan, over a long period of more than 100 years.\textsuperscript{7} Large reservoirs, normally located adjacent to large rivers, also have a large flood management capacity. The cost of construction can be extremely high depending on the size of the facility, ownership of the land (and associated cost of acquiring the land), and whether the site already functions as a natural water detention site (as this may leave less construction work for flood management functions).

Large-scale reservoirs have been developed by MLIT and managed by local government or civil society organizations. Many also function as recreational parks or environmental conservation areas, such as the Ramsar sites\textsuperscript{8} (Ministry of Environment 2018). They thus represent the significant efforts made in Japan to promote multibenefit and multipurpose designs, bringing together river and environmental departments and stakeholders in the construction and management of the facilities.

The Arakawa River No. 1 Detention Park (appendix, case 4) in Saitama City, located near Tokyo, not only stores up to 39 million cubic meters ($m^3$) of floodwater—which could protect nearby urban areas from inundation during a 1-in-200-year flood event—but also functions as a recreational facility and drinking water reservoir for residents of Saitama and Tokyo, cushioning water shortages during dry periods.

In the case of the Myoshoji River (appendix, case 5), which flows between the Shinjuku and Nakano wards in central Tokyo, local governments in partnership with TMG and UR (a housing developer) have developed a multipurpose residential development (led by UR), together with a detention pond (led by TMG) and a public park (led by the Shinjuku and Nakano wards). The total development area is approximately 11,000 square meters ($m^2$) with a water detention capacity of approximately 30,000 $m^3$. This coordinated approach has enabled the sharing of roles and responsibilities, leading to cost savings in implementation and O&M.

3.2 Managing Surface Water Flood Risk

Underground Stormwater Management Facilities

Similar to underground facilities for managing river overflow, underground stormwater management facilities (cisterns, channels, drainage pipes, culverts, etc.) are structural investments that require substantial financing and time for implementation. In Japan they are typically designed to manage 1-in-20-year floods, in line with MLIT and city-level stormwater management targets (as described in Knowledge Note 2).

Since the facilities are constructed underground, they do not require much space above ground, but the cost and time of underground construction is extremely high, and the stakeholder and political coordination associated with it is complex. Therefore, development of underground stormwater management facilities is usually led by municipal governments, given their responsibility for urban drainage and sewerage management in Japan. Such facilities are most often found where there is a strong need to protect highly concentrated populations and assets, supported by financing and technical guidance conducted in close coordination with the national government.

Because of the associated cost and complexity, cities in Japan have trialed various cost-saving and partnership approaches in the design and implementation of underground stormwater management facilities. In Tokyo, up to 50 mm/hour rainfall is managed through channels and pipes that tend to drain water quickly to larger rivers and the ocean. However, with a recent change in surface water flood management goals, which increased to 75 mm/hour rainfall, TMG is looking to add capacity to existing drainage facilities.\textsuperscript{9}

\textsuperscript{7} For example, the Watarase reservoir that protects the Tokyo Metropolitan Area from flooding was initiated in 1914. For more information, see http://www.watarase-kyougikai.org/history/index.html.

\textsuperscript{8} The Convention on Wetlands, called the Ramsar Convention, is an intergovernmental treaty that provides the framework for the conservation and wise use of wetlands and their resources. The convention maintains a List of Wetlands of International Importance (the Ramsar list). These Ramsar sites acquire a new national and international status. They are recognized as being of significant value not only for the country or the countries in which they are located, but for humanity as a whole. There are currently over 2,300 Ramsar sites around the world. They cover over 2.1 million square kilometers, an area larger than Mexico. For more information, see https://www.ramsar.org/about/wetlands-of-international-importance-ramsar-sites.

\textsuperscript{9} For more information, see TMG (2015).
Managing surface floods can be challenging in dense urban areas where there is significant development both above and below ground (metro, utility lines, commercial areas, etc.). **TMG has utilized innovative technologies** in the construction of its underground water detention channels: the application of the “shield method” enables channels to be constructed in dense underground spaces with high accuracy and speed but with low sound and tremor impacts to the surrounding areas (appendix, case 6).

Similarly, **TMG has added underground stormwater storage to other public facilities, to reduce costs of constructing extra facilities.** For example, in Minamisuna, TMG constructed a detention pond 20 meters below ground with a storage capacity of 25,000 m$^3$, with a public housing complex, public bicycle parking, and a park developed above ground as part of the larger urban Shinsuna Land Readjustment Project. In Hibiya, TMG, in partnership with MLIT, constructed a detention pond with a storage capacity of 3,400 m$^3$ under a common lifeline infrastructure tunnel that runs beneath a national road (appendix, case 7).

**Yokohama City has partnered with private sector developers to develop underground stormwater management facilities in conjunction with an urban redevelopment initiative at Yokohama Station.** Under MLIT’s designation of Yokohama Station and its vicinity as the first “Flood Mitigation Focus Area” in Japan, MLIT, Yokohama City, and the East Japan Railway Company (JR East, the developer) shared costs and responsibilities of installing a 170 m$^3$ underground stormwater management facility within the new Excite Yokohama 22 District development project. MLIT and Yokohama City each financed one-third of the stormwater management facility’s construction costs through subsidies, and JR East self-financed the remaining costs. All stakeholders benefited from this joint effort (appendix, case 8).

**Above-ground Stormwater Management Facilities**

Stormwater management facilities located above ground (such as detention ponds, parks, and gardens) are structural, often nature-based, measures that detain stormwater during heavy rain before it is released to drains and rivers. They are often constructed together with urban development initiatives to ensure that additional stormwater is not drained into sewerage systems due to new construction. Such facilities contribute to managing 1-in-20-year floods, in line with MLIT and city stormwater management targets (as described in **Knowledge Note 2**).

The space required depends on the size of the facility and its associated capacity. Such facilities are often designed for multiple purposes and uses; for example, to also serve as public and environmental amenities such as parks, sports fields, biotopes, biodiversity conservation sites, etc. Therefore, **various stakeholders can be engaged** in the design, financing, and O&M of interventions, creating an opportunity to **share the costs and responsibilities of flood management** with actors beyond the public sector.

**Saitama Prefecture has promoted the implementation of surface flood and river flood management measures, utilizing policy mechanisms to scale the establishment of detention ponds, parks, and gardens through both public and private efforts.** To scale private sector efforts, Saitama Prefecture took the progressive approach of **requiring all new private development projects (commercial, residential, etc.) with an area of more than 1 hectare to install detention facilities.** This builds on the administrative guidance first released by the prefecture in 1968 under the national Urban Planning Act, which was then advanced as a requirement under an ordinance enacted in 2006 (Saitama Prefecture 2018). By 2014, over 170 detention facilities with a capacity over 10,000 m$^3$ were developed through both private and public efforts in Saitama Prefecture, of which 51 were aimed to detain water to avoid overflow into rivers, and 119 were to manage additional stormwater drainage from new developments (Saitama Prefecture 2018).

For example, **Koshigaya City** in Saitama Prefecture integrated flood management measures in a new, compact, 225-hectare urban development project from 1999 to 2014. The project was led by the Urban Renaissance Agency (UR), in close collaboration with Saitama Prefecture and MLIT. A large-scale reservoir (with 1.2 million m$^3$ water detention capacity over 39.5 hectares) was established as part of the development, to manage both river and surface water floods. **Costs and responsibilities for its construction and O&M are shared** by UR, Saitama Prefecture,

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10 Lifeline infrastructure systems include interdependent and often colocated utilities (electric power, natural gas, telephone and other communication systems, water and wastewater) and transportation systems (roads and highways, rail systems, ports, and airports).

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_Learning from Japan’s Experience in Integrated Urban Flood Risk Management_
Sewerage Treatment Facility Improvements

Enhancing sewerage treatment facilities’ capacity to detain stormwater is an important urban flood management measure. It not only reduces potential inundation from overflow, but also reduces urban water pollution. Combined sewer systems, in which both rainwater and wastewater are conveyed and treated in a single channel, serve around 25 percent of the population and 13 percent of a total of 1,430 municipalities with wastewater services in Japan (JSWA 2017). Older cities with high urban densities are often served by combined systems, and as a result, during heavy rain, the discharge of untreated water is of serious concern for public health and the environment. For example, 82 percent of the central wards of Tokyo are serviced by a combined sewer system (appendix, case 16). However, the enhancement of structural sewerage treatment facilities is costly given its significant time and land requirements.

In light of these factors, several Japanese cities have set up strategic partnerships with various stakeholders to implement sewerage enhancement and upgrading efforts. For example, the Shibaura Wastewater Treatment Plant (appendix, case 11) has been responsible for sewerage water treatment in Tokyo, including the Chiyoda, Chuo, and Minato wards, since 1931. Beginning in 2012, renovation of the aging facility was undertaken in stages, with two objectives: (i) to mitigate the postflood environmental impact of the combined sewerage and drainage system, and (ii) to effectively utilize the high land value of the facility’s locations. TMG, the owner of the 11,000 m² area occupied by the Shibaura Water Treatment Plant, tendered for a private sector firm that would redevelop the area under a 30-year lease agreement, as well as renovate the water treatment plant, including constructing a combined sewer and stormwater detention facility with a capacity of 76,000 m³ under the developed land. Through the privately financed initiative, a 32-story commercial and office building (Shinagawa Season Terrace), as well as a publicly accessible park were developed, together with the upgraded wastewater treatment plant and detention facilities. TMG continues to recover the lease fee through a land-value capture mechanism, whereby the income generated through maintaining ownership and leasing 60 percent of the newly constructed building is retained by TMG. The generated income is utilized by TMG for O&M of the sewerage facility.

Rainwater Harvesting Systems

Rainwater collection systems and storage tanks installed in public, commercial, and community buildings are structural measures. The storage tanks may be visible (e.g., on building rooftops) or underground. These systems may be integrated with others for the use of the collected water (e.g., pumps or piping systems to use collected water for toilets, etc.). In Japan, the 2014 Act to Advance the Utilization of Rainwater, together with the “Technical Standards for Rainwater Harvesting,” published in 2016 by the Architectural Institute of Japan Environmental Standards, were established to advance and scale rainwater harvesting systems, as well as set basic guidelines for their technical design and the use of collected water. Currently, the act limits utilization of the harvested rainwater to toilets and the watering of plants (MLIT 2015).

The capacity of stormwater management varies depending on the size of the collection and storage facilities and can range from small household systems, such as 150-liter planters that are connected from household roofs through downspouts, to tanks with total storage capacity of 2,635 m³ (Tsukahara and Okagaki 2012) installed under the Tokyo Skytree commercial development in eastern Tokyo. The costs and time required for construction and O&M also vary depending on the size of the systems.

Together with MLIT, which governs the 2014 act, city governments in Japan promote rainwater harvesting systems widely. Many local governments have installed rainwater harvesting systems in their public buildings. Others also advise (but do not require) new development projects to install facilities to manage stormwater generated on site. To support these efforts, many local governments offer subsidy programs (such as in Sumida Ward, further described in the appendix, case 12).

Rainwater harvesting systems are regarded as a major flood management measure in cities, especially in urban areas that are located inland with limited infiltration capacity, since they are more cost-effective than many other flood management measures. For example, in Sumida Ward, Tokyo, rainwater harvesting systems have been
adopted widely by public, private, and community groups, and in households, and are regarded as “urban dams.” While the rainwater harvesting capacity of each household may be small, the total contribution from household rainwater harvesting and storage systems toward reducing stormwater runoff is collectively significant. In 2008, 21 Rojisons\(^1\) were installed in Sumida Ward (Sumida Ward 2018a); by March 2018, there were 645 facilities with a capacity of 24,010 m\(^3\), equivalent to approximately 90 liters of rainwater per ward resident (Sumida Ward 2018b).

Also, in Sumida Ward, the installation of a large-scale rainwater harvesting system in Tokyo Skytree by a private developer illustrates how the private sector can catalyze innovative design. Tokyo Skytree Town was a high-profile redevelopment initiative led by the Tobu Railway Company between 2008 and 2012, to revitalize a flood-prone neighborhood in eastern Tokyo along with the construction of a new 634-meter-high broadcast tower that serves as a new landmark for Tokyo. As a key feature of the Skytree Town development, the Tobu Railway Company, the private developer, in close consultation with ward authorities, implemented progressive rainwater harvesting and utilization measures, together with various green and environmental initiatives as part of its corporate social responsibility and branding strategy. An 800 m\(^3\) rainwater harvesting tank and an 1,835 m\(^3\) underground stormwater detention cistern were established to manage not only stormwater generated on site, but also for the surrounding community. Furthermore, collected water was recycled to cool buildings and solar panels, water rooftop gardens, and flush toilets. With the installation of this system, an estimated 45 percent of water consumption was saved. Other innovative water and environmentally sensitive projects were implemented throughout the surrounding areas, including efforts led by Sumida Ward, such as a public bicycle park that combines rainwater harvesting and renewable energy features to create an attractive public green space.

Increasing the Permeability of Urban Surfaces

Enhancing the infiltration capacity of urban surfaces through their conversion into green spaces or installing pervious pavers and infiltration trenches are structural measures that aim to manage urban flood risk by minimizing the volume of drainage during heavy rain. Measures to modify the surface composition of the catchment from impervious to pervious require relatively little financial resources, time, and space. They are often implemented in conjunction with or as part of an urban redevelopment project or the maintenance and rehabilitation of roads or public spaces, and are installed so as to derive multiple benefits. Such benefits include the integration of green public and living spaces, as well as year-round functions such as heat reduction and/or drought management.

In Hachioji Minamino City, mechanisms for water circulation were key features of a 39.4 hectare town development and land readjustment project carried out by UR. The developer and the city, together with community and academic research partners, established a water circulation and restoration system to enhance and protect groundwater resources, along with other structural and nature-based flood management measures such as detention ponds. Homeowners were encouraged to install household stormwater infiltration facilities through a city-run awareness-raising campaign and subsidy program, which supported 90 percent of households’ total installation costs. Data collected on the infiltration capacity of Hachioji Minamino City between 1996 and 2013 indicate that the installation systems were highly effective in minimizing stormwater runoff during the wet season as well as mitigating drought during the dry season (appendix, case 14).

Both public and private sector efforts have been instrumental in advancing measures to enhance the infiltration capacity of Japanese cities. For example, the City of Yokohama, through its effort to renovate Grand Mall Park, a 25-meter-wide, 700-meter-long pedestrian corridor, integrated a “vertical water circulation” mechanism whereby stormwater infiltrates the pervious pavement and circulates through a system of infiltration gutters, stormwater storage macadams, and planting beds. One cubic meter of substrate (consisting of stormwater storage macadams and humus) has the capacity to hold 76 liters of water. Given the park’s location in front of the Museum of Art, it serves as an important public space. Since the space suffered from overheating during summer, the city chose to install a system that not only infiltrates stormwater to manage flooding, but also can release water moisture in the air during the dry and hot seasons, to cool the air and enhance the microclimate of the park. After the system’s installation, the air temperature of the Grand Mall Park dropped significantly (appendix, case 15).

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11 An underground, community-owned, rainwater detention facility. For more information, see appendix, case 12.
3.3 Managing Storm Surge Flood Risk

Seawalls and Gates

Seawalls and tide gates are large-scale structural measures installed along coastlines to protect people and assets from storm surge floods. Given the high seismic risks, most Japanese cities have designed seawalls and tide gates to protect against storm surge floods and tsunamis. As the risk of unforeseen natural disasters rises, including both climatic (i.e., typhoons and heavy rains) and seismic episodes, the continuous enhancement and expansion of these coastal investments is important, in terms of both infrastructure design and operation. Most seawalls and gates extend over many kilometers, thus requiring significant time and financing, and are often implemented in partnership between the city and national government stakeholders.

Given these high construction and O&M costs, many cities have taken an incremental approach to the development and improvement of their coastal flood management methods, and have applied innovative technology to enhance their operations. For example, as one of Japan’s major port cities facing significant risks of coastal floods, Kobe City has been implementing a storm surge protection project (costing approximately ¥30 billion, or $273 million) for more than five decades, through investing in flood management infrastructure across its 59.8-kilometer coastline. Seawalls and iron tide gates were set up in coastal areas to prevent seawater from overflowing due to storm surges. Pump stations were installed to pump seawater out from the urban areas at the time of storm surges. Nonstructural measures, such as: (i) strengthening the predisaster prevention system in areas of high flood risk by encouraging the development of business continuity plans; and (ii) enhancing early warning systems and the provision of disaster prevention information to residents and workers in coastal areas were also adopted to also ensure that preparedness and response actions are implemented in conjunction with structural measures. The city, in partnership with MLIT and academia, has regularly reviewed the strengths and weaknesses of the investments, particularly after major disaster events, such as the 2011 Great East Japan Earthquake (GEJE) and the 2018 Typhoon Jebi. After these major events, ways of addressing bottlenecks and prioritizing investments were identified. For example, learning from the experience of the GEJE, when more than 59 lives were lost or went missing as people attempted to close the tide gates, technologies to remotely operate the tide gates are being implemented. There are plans of linking the system to tsunami early warning systems that can automatically close these gates in times of disaster. After Typhoon Jebi, Kobe City planned to implement recommendations made by a technical panel, including structural measures such as ground raising and fortification of seawalls in targeted areas, to improve disaster information communication systems and the O&M of coastal embankments (appendix, case 19).

Ground Raising

Ground raising is a structural measure to protect urban areas against storm surge floods as well as tsunamis. Given its relatively large requirements for space, investment, construction time, and coordination efforts (involving complex land readjustment and relocation of preexisting structures), it is typically implemented together with urban (re)development initiatives led by city governments and large-scale private developers in Japan. Developments on raised ground serve as new economic and commercial hubs, as well as disaster risk management hubs for the surrounding areas, providing an important safe ground where critical infrastructure and utility functions as well as evacuation centers can be located to reduce disaster risks.

For example, the Minato Mirai 21 (MM21) district is a 183-hectare, master-planned urban development project in Yokohama City developed by UR in partnership with the City of Yokohama between 1983 and 2011. The project included the reclamation of a 74-hectare site, using a sand-draining method for ground stabilization, and the construction of utility tunnels under arterial roads. Disaster risks, including those of earthquakes, tsunamis, and storm surge floods, were taken into consideration in the design and implementation of the land reclamation and development process. For example, learning from the 1995 Hanshin Awaji earthquake, land improvements and measures against liquefaction were implemented. As measures against tsunamis and storm surges, revetments along the coast were constructed at a height of 2.7–3.1 meters above sea level, and residential developments were required to be developed in areas 3.1–5.0 meters above sea level in the central districts of MM21.

Despite the high costs and significant time required for the development of the MM21 district, the City of Yokohama reports significant economic benefits. Construction costs—estimated at ¥2.625 trillion ($23.9 billion) from 1983...
3.4 Managing Multihazard Risk

Together with the structural measures for urban flood risk management described above, nonstructural measures are essential in ensuring that lives and livelihoods are protected, especially under increasing risks of extreme and unprecedented disaster events. A variety of nonstructural measures have been implemented in Japanese cities to enhance flood management through a multihazard approach, by avoiding development in flood-prone areas, guiding flood-resilient construction development, and improving evacuation through improving the communication of flood risks as well as enhancing the awareness and capacity of citizens to take effective preparedness and response actions after receiving risk and warning information.

Knowledge Notes 1 and 2 elaborate on these nonstructural flood management measures. Table 1 lists the types of measures and the examples referenced in Knowledge Notes 1 and 2.

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Source: Compiled from Knowledge Notes 1 and 2.
4. Lessons Learned and Key Takeaways

Based on the case studies discussed in this Knowledge Note, several lessons and takeaways can be identified related to the various processes that inform the design and implementation of urban flood risk management investments.

Multiple factors and criteria drive the design process. Overall objectives are determined based on the types of flooding, and the target flood risk management capacity to be achieved. Spatial and financial requirements determine the type and scope of investments, which are also linked to the institutional level and type of the public entity overseeing the investments. Technical considerations, including data gathered via surveys and assessments, determine feasibility and guide the entire design process. Increasingly, schemes are designed to be multifunctional and generate multiple urban, social, and environmental benefits. Green or nature-based solutions are a case in point.

Focusing on cities, this Knowledge Note looks at the implementation of investments to manage the risk of river floods, surface floods, storm surge floods, and a combination of these types of floods. Examples across Japan illustrate efforts to engage the private sector and local communities, and the benefits of utilizing new technologies, nature-based solutions, and financing arrangements with the private sector.

- **River floods.** Common interventions in Japan to tackle river floods include river embankments, underground river overflow facilities, as well as reservoirs, detention parks, and ponds. Tokyo City’s Komatsugawa High-Standard Embankment or Futakotamagawa riverside area demonstrate how large-scale, structural river management investments can be designed to have multiple purposes and benefits. The same is true of reservoirs and detention parks, as in the cases of the Arakawa River No. 1 Detention Park and Myoshoji River. Though underground river overflow management facilities can require substantial financing and time for construction, they can be helpful where available land is scarce. Examples from Tokyo City show that cisterns and channels can be constructed under public land such as roads and parks to save land acquisition and compensation costs.

- **Surface floods.** Common interventions include cisterns, channels, drainage pipes, culverts, stormwater detention ponds, parks and gardens, sewerage treatment facilities, as well as rainwater harvesting collecting and storage systems, and surface infiltration measures. Above-ground stormwater management measures depend on the space required, and are often designed for multiple purposes and uses, with many stakeholders involved beyond the public sector. In order to scale private sector efforts to tackle surface floods, Saitama Prefecture mandates all new private development projects (commercial, residential, etc.) with an area of more than 1 hectare to install detention facilities. Enhancing the stormwater detention capacity of sewerage treatment facilities helps to mitigate urban flood risk, while reducing water pollution. To manage costs, an upgrade of the Shibaura Wastewater Treatment Plant’s stormwater detention capacity was combined with a private-financed initiative that included a 32-story commercial and office building, and a park. The lease fee, through a land-value capture mechanism, generates income used by the authorities for the O&M of the sewerage facility. Rainwater harvesting systems are widely promoted in Japan, and many local governments having installed them in public buildings. In Tokyo, both small-scale, community-led, as well as large-scale, private sector–led rainwater harvesting efforts are ongoing. The implementation of green spaces or pervious pavers and infiltration trenches can be combined with urban redevelopment or maintenance efforts to save costs. For example, the Grand Mall Park in the City of Yokohama integrated a “vertical water circulation” mechanism combined with the release of water moisture into the air, increasing infiltration capacity while cooling the air temperature of the area. A new development in Hachioji Minamino City includes a water circulation and restoration system, and a household-level campaign for the installation of stormwater infiltration facilities.
- **Storm surge floods.** A large number of Japan’s cities rely on structural protection along the country’s coastline, such as seawalls and gates, as well as ground-raising efforts. Cities such as **Kobe** invest heavily in structural solutions, and combine these with improved disaster information communication systems and improved maintenance efforts. Because ground raising can be complex due to the size, cost, time involved, and technical issues involving land readjustment and relocation, it is often implemented together with large-scale urban development initiatives led by city governments and large-scale private developers in Japan. For example, the **Minato Mirai 21** district benefited from a master-planned urban development project in **Yokohama City**, which included land reclamation, the use of the sand-drain method for ground stabilizing, and the construction of utility corridors under arterial roads. The city of **Yokohama** reports significant economic benefits after having fully recovered the investment, attracting companies and millions of annual visitors, while creating a seismic-, tsunami-, and storm-surge-resilient area within its urban center. This new evacuation hub features access to disaster-resilient land, utilities (including a decentralized heating and cooling system), ports (that can serve as logistical centers for emergency response operations), and a supply of emergency drinking water sufficient to last 500,000 people for three days (City of Yokohama n.d.).
5. References


**UFCOP**

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

**World Bank Tokyo DRM Hub**

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

**GFDRR**

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

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