MODERNIZATION OF Hydrological Services In Japan

AND LESSONS FOR DEVELOPING COUNTRIES

Foundation of River & Basin Integrated Communications, Japan (FRICS)

FRICS

THE WORLD BANK
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GFDRR
Global Facility for Disaster Reduction and Recovery

ABBREVIATIONS

ADCP	acoustic Doppler current profilers
CCTV	closed-circuit television
DRM	disaster risk management
FRICS	Foundation of River & Basin Integrated Communications, Japan
GFDRR	Global Facility for Disaster Reduction and Recovery
ICT	Information and Communications Technology
JICA	Japan International Cooperation Agency
JMA	Japan Meteorological Agency
GISTDA	Geo-Informatics and Space Technology Development Agency
MLIT	Ministry of Land, Infrastructure, Transport and Tourism
MP	multi parameter
NHK	Japan Broadcasting Corporation
SAR	synthetic aperture radar
UNESCO	United Nations Educational, Scientific and Cultural Organization

Table of Contents

1. Summary . . . 3

2. Overview of Hydrological Services in Japan . . . 7
   - 2.1 Hydrological services and river management . . . 7
   - 2.2 Flow of hydrological information . . . 7

3. Japan's Hydrological Service Development Process and Related Knowledge, Experiences, and Lessons . . . 11
   - 3.1 Relationships between disaster management development and hydrometeorological service changes . . . 11
   - 3.2 Changes in water-related disaster management in Japan and required hydrological service modernization . . . 12
   - 3.3 Lessons learned from other mega-disasters . . . 20
   - 3.4 Tools used to solve problems and achieve goals . . . 21
   - 3.5 Evolution prompted by technology development . . . 23
   - 3.6 Challenges . . . 24

4. Organizations Related to Japan's Hydrological Services and their Relationships . . . 28
   - 4.1 Changes in governmental and other organizations . . . 28
   - 4.2 Role-sharing and cooperation between the government and citizens . . . 29
   - 4.3 The involvement of the private sector . . . 30
   - 4.4 Government's relationship with mass media . . . 30
   - 4.5 Establishment of FRICS . . . 30
   - 4.6 User groups . . . 34

5. Application of Japan's Knowledge, Experience, and Lessons to International Cooperation Projects Relating to Hydrological Services . . . 36
   - 5.1 Technical cooperation projects up to the present . . . 36
   - 5.2 Lessons learned from past technical cooperation projects . . . 38
   - 5.3 Case study of disaster management in Thailand's 2011 floods . . . 39
   - 5.4 Issues for sustainable use of past project achievements . . . 41

6. How to Apply Japan's Lessons toward Hydrological Service Modernization in Developing Countries . . . 42
   - 6.1 Use a holistic approach to disaster management to promote effective cooperation among disaster management facilities. . . . 42
   - 6.2 Both the future vision and the implementation plan should be realistic and keep in mind the existing capacity of hydrological services in the country. . . . 42
   - 6.3 Uncertainties in flood forecasting should be effectively communicated. . . . 43
   - 6.4 Development of hydrological services and systems should be driven by user needs. . . . 43
   - 6.5 Hydrological services and river management should be institutionally integrated. . . . 43
   - 6.6 Long-term support is needed to ensure the sustainable operation of modernized systems. . . . 44

ANNEX 1: ANSWER SHEETS TO QUESTIONNAIRE SEEKING FEEDBACK ON TECHNICAL COOPERATION PROJECTS. . . . 46

ANNEX 2: EXAMPLES OF TECHNOLOGICAL DEVELOPMENT. . . . 54

1. Summary

Overview of hydrological services in Japan

River and basin management covers various factors, including disaster management, river water use, and conservation of the river environment. Any of these factors involves a number of intricately intertwined stakeholders who may have different needs. For example, during a flood, populations located upstream versus downstream, or on the left versus the right bank, may have different priorities to ensure safety; flood management must, therefore, take a balanced approach to safety that is based on integrated river basin management and takes all relevant perspectives into account. Over time, efforts to manage water-related disasters in Japan have led to the concept of integrated river basin management and to a mechanism allowing central management of river basins by river management authorities. These approaches were institutionalized under the revised River Law of 1964.

Integrated management of river basins requires collecting/analyzing real-time hydrological data for the whole river basin, as well as archiving/studying hydrological data for appropriate management. Japan built its system of hydrological services (and developed needed technology) in order to meet these requirements, as well as similar requirements for water use management and river environment enhancement. These attempts to promote more advanced integrated management of river basins have provided the foundation of social and economic development in Japan today. Integrated management of river basins is not only the core concept in Japan's technical cooperation with developing countries, but also part of a worldwide movement introduced in the Rhine, the Thames, and other areas where localized management was used in the past.

Based on its long experience and River Law, Japan employs a unique river management system, in which river management authorities have centralized control over rivers in the country and provide hydrological services.

River management authorities (Ministry of Land, Infrastructure and Transport, or MLIT, and prefectural governments) accurately monitor facilities for river management, develop observation networks to precisely monitor water levels and rainfall in the basin, and forecast water levels and discharge. River management authorities analyze a large amount of data and forecast floods and inundation. The collected hydrological data and forecast information are used by river management authorities themselves and also delivered to municipalities, fire and police authorities, and the Self-Defense Forces in an effort to prevent disasters from occurring, assist residents in evacuating safely, and provide emergency response quickly.

Japan's hydrological service development process and related knowledge, experiences, and lessons learned

In Japan, disaster risk management (DRM) is modernizing as a result of various influences, including socioeconomic changes, large disasters, technological breakthroughs, and other factors. The modernization has been a movement towards integrated approaches to disaster prevention (as opposed to individual or areal approaches); towards approaches that consider inundation (as opposed to those that do not); and towards approaches that account for floods exceeding designed floods (as opposed to designed floods based on historical ones). With its hydrological services integrated with river management, Japan has smoothly coped with these changes.

Japan has experienced other types of disasters besides floods, and it has incorporated knowledge, experience, and lessons from each disaster to improve its overall capacity to cope with disasters. Some of these general countermeasures are also applicable to floods: (i) To avoid fatalities, analyze how structures behave when they are hit by external forces far larger than those used in conventional structural design; (ii) to improve forecasting, carry out simulations based on data assimilation; and (iii) classify events in terms of danger levels that correspond to the actions that recipients should take.

Technological progress has improved hydrological observation, partly in response to users' needs for greater accuracy. Some technologies developed in different areas have successfully been used in hydrological observation; examples are radar technology that allows observation of the condition of raindrops over a widespread area, and information technology that has enabled in-depth analysis of voluminous data, more user-friendly interfaces, and provision of information with handheld devices.

The progress of disaster management in Japan was partly driven by the need to solve certain problems, including (i) a decline in the capacity to cope during disasters, arising from excessive expectations for DRM structures; (ii) difficulty in deciding when to order evacuation and issue advisories; and (iii) difficulty in taking responsibility for actions based on uncertain information. The modernization of hydrological services contributed to solving some of these issues.

Organizations related to Japan's hydrological services and their relationships

A significant change in governmental systems in Japan occurred in 2001, when the government decided to restructure its agencies and ministries. The Construction Ministry and the Meteorological Agency became part of the MLIT. The Cabinet Office was created to handle important government matters, including DRM, and it began to develop disaster management policies and to coordinate related agencies and ministries.

To minimize disaster damage, three components must be in place and function efficiently: public assistance (governments provide assistance before a disaster and crisis management during a disaster), self-help (people protect themselves), and mutual support (people support one another at the community level). A good example of mutual support in Japan is cooperative efforts by local residents to fight floods.

In Japan, the mass media, such as TV stations, play an important role in communicating information to the public during disasters. In an emergency, the administration and the mass media cooperate to make sure that people receive necessary disaster-related information.

The demand for hydrological information is comparably limited in normal times, and private corporations have avoided involvement in hydrological services, because they are not profitable, even if they are necessary especially during flood times. Thus when the Foundation of River & Basin Integrated Communications (FRICS) was established to provide such information, it was with funding from the government as well as organizations in the public and private sectors.

At present, hydrological information is used for operating and managing structures such as dams and water gates, monitoring unusual events during floods, and forecasting inundation. This is widely shared by local governments, which make decisions on evacuation orders and advisories; organizations that support disaster management efforts of local governments; government headquarters for disaster control, which are activated in case of large-scale disasters; organizations that operate lifeline utilities (e.g., electric power, gas) and traffic infrastructure (e.g., expressway, railway); and mass media.

Application of Japan's knowledge, experience, and lessons to international cooperation projects relating to hydrological services

In Japan, the organization that manages rivers, including construction works, provides hydrological services such as hydrological observation and flood forecasting. The institutional setup is similar in neighboring countries such as the Republic of Korea (where the relevant organization is the Ministry of Construction) and the People's Republic of China (where the organization is the Ministry of Water Resources). In many cases, if part of the budget for structural measures was instead earmarked for nonstructural measures, that would be enough to develop a flood forecasting system. In China and Korea, the flood forecasting systems were properly recognized as DRM measures and the necessary budget was provided to establish them.

On the other hand, in many developing countries, hydrological observations and analysis are carried out by organizations that do not manage rivers. In these cases, even if there is collaboration, the changing needs of management organizations that actually use the observed data may not be flexibly reflected in the observations. River management in the Philippines was under the jurisdiction of the Ministry of Public Works and Highways, and the flood forecasting project supported by the Japan International Cooperation Agency (JICA) was carried out by the Philippine Meteorological Agency (PAGASA). This arrangement might be one of the reason that flood forecasting in the Philippines was not properly budgeted, and that the forecasting system was not well maintained in the past..

Implication of Japan's experiences in modernizing hydrological services for developing countries

1. **Consider a holistic approach to disaster management to promote interactive, effective cooperation among disaster management facilities.**
   The modernization of hydrological services should be carried out with clear purpose, and with the understanding that it will enhance disaster management by providing improved hydrological information.

2. **Both the vision for the future and the specific implementation plan should be realistic and should keep in mind the existing capacity of hydrological services in the country.**
   Countries in which the economy is growing rapidly may need different sets of hydrological information at different stages of development, with the contents, accuracy, and quality of information improving over time. Institutional arrangements for hydrological services should be structured to capture and respond to such changing needs quickly and flexibly.

3. **Uncertainties in flood forecasting should be effectively communicated.**
   Forecasting of natural hazards involves uncertainties. Since structural measures alone are not sufficient to deal with all disasters, nonstructural measures such as forecasts and other types of information are particularly important for reducing damages as much as possible.

4. **Development of hydrological services and systems should be driven by user needs.**
   Information delivered through hydrological services should be user-oriented and should reflect the needs of different individuals and groups in acting and making decisions.

5. **Hydrological services and river management should be institutionally integrated.**
   Hydrological services are inseparable from water management: they do not just deal with observed data of rainfall, river water levels, and river discharge, but change their contents according to different water management issues. Therefore, institutional arrangements should seek to ensure not only data connection, but also organic links between institutions; ideally hydrological services and water management should be integrated.

6. **Long-term support is needed to ensure the sustainable operation of modernized systems.**
   Information is helpful only when it is used, and only then are any problems with it noticed. Technical cooperation should be extended beyond the stage when new hydrological services are put in place to include the stage when information is successfully delivered.

2. Overview of Hydrological Services in Japan

2.1 Hydrological services and river management

River and basin management covers various factors, including disaster management, river water use, and conservation of the river environment. Any of these factors involves a number of intricately intertwined stakeholders who may have different needs in a river basin. For example, during a flood, populations located upstream versus downstream, or on the right versus the left bank, may have different priorities for ensuring safety; flood management must therefore take a balanced approach to safety that is based on integrated river basin management and takes all relevant perspectives into account. Over time, efforts to manage water-related disasters in Japan led to the concept of integrated river basin management and to a mechanism allowing central management or river basins by river management authorities. These approaches were institutionalized under the revised River Law of 1964.

Integrated management of river basins requires collecting/analyzing real-time hydrological data for the whole river basin, as well as archiving/studying hydrological data for appropriate management. Japan built its system of hydrological services (and developed needed technology) in order to meet these requirements, as well as similar requirements for water use management and river environment enhancement. These attempts to promote more advanced integrated management of river basins have provided the foundation of social and economic development in Japan today. Integrated management of river basins is not only the core concept in Japan's technical cooperation with developing countries, but also part of a worldwide movement introduced in the Rhine, the Thames, and other areas where localized management was used in the past.

Based on its long experience and River Law, Japan employs a unique and highly effective river management system, in which river management authorities have centralized control over rivers in the country and provide hydrological services.

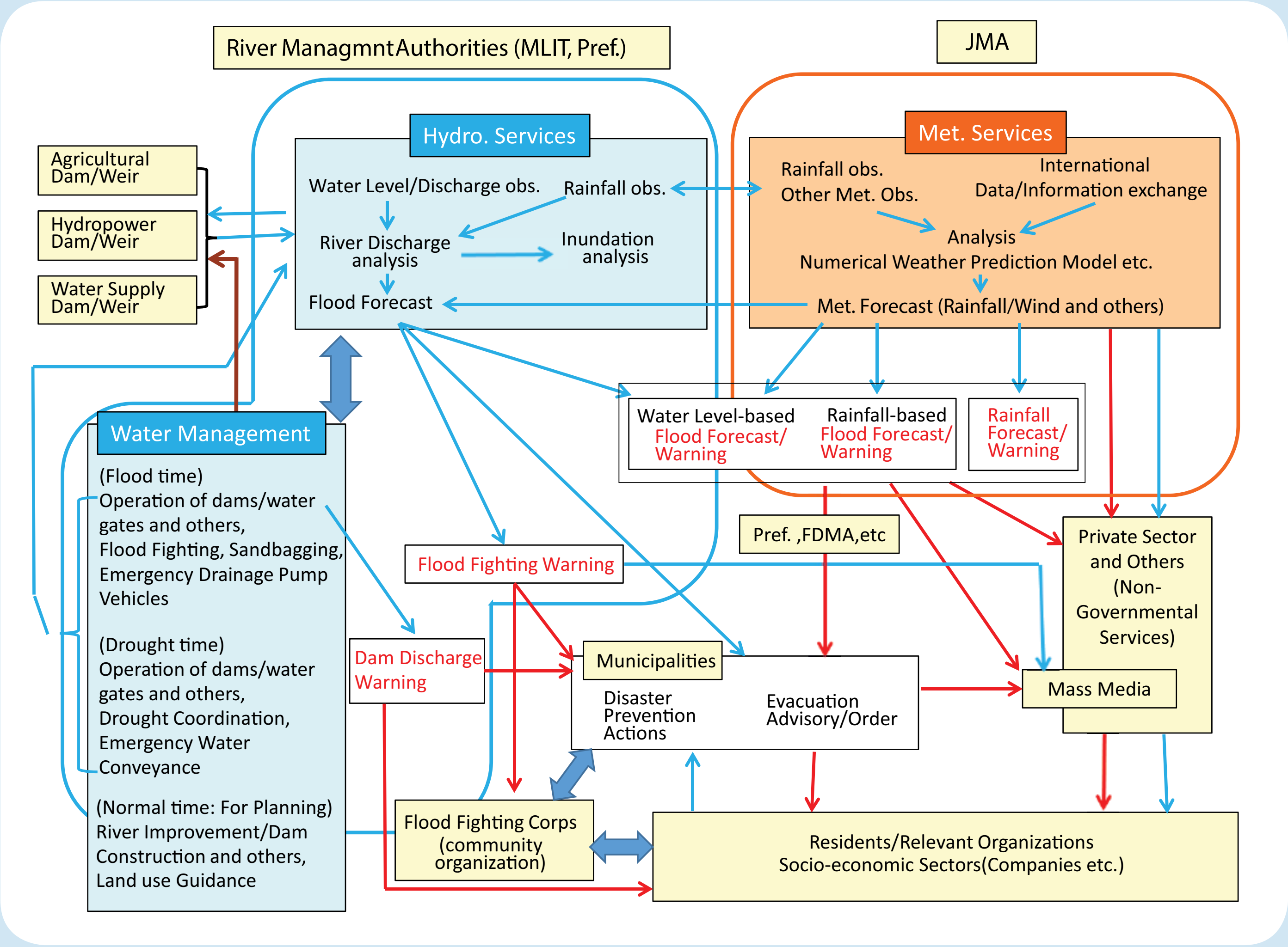
2.2 Flow of hydrological information

The flow of hydrological data collected in river basins and used in integrated water management and disaster management activities is shown in Figure 1 (see page 8).

River management authorities (MLIT, prefectural governments) accurately monitor facilities for river management and develop observation networks to precisely monitor water levels and rainfall in the basin.

Observation stations have been set up by river management authorities and are in place throughout the country (Table 1, see page 9). For river management authorities to properly manage rivers, they need to monitor and forecast discharge accurately, and their observation stations are complemented by the Japan Meteorological Agency (JMA) observation network. Radar rainfall gauging systems, which contribute to more detailed monitoring of conditions and forecasting of floods, are also being installed nationally. C-band radar now covers the entire country, and MP(multi parameter) X-band radar covers city areas. Composition of MP X-band and MP C-band radar, which will provide far more accurate observation, is now under way (Figure 2, see page 9).

Figure 1. **Overview of Hydrometeorological Services in Japan**



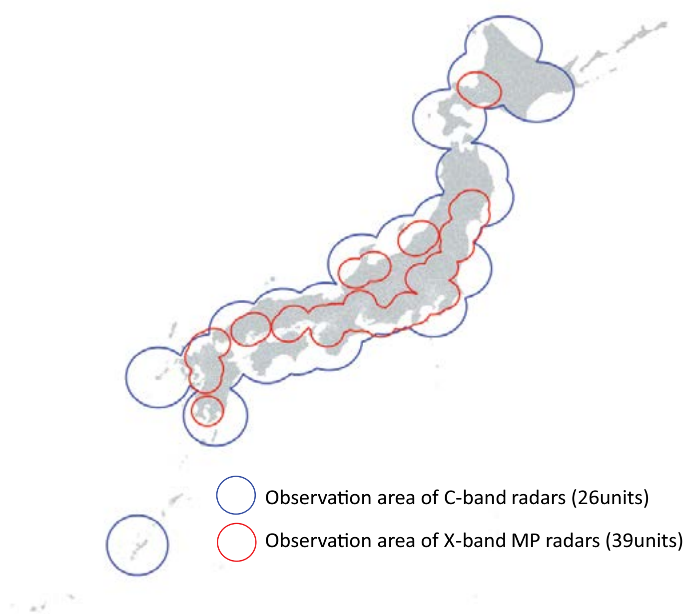
Note: In addition to channels shown here, almost all information is delivered through the website of each organization. Colors of arrows show data and analytical information (blue), order/request (brown) and forecast/warning (red).

Table 1. The number of hydrological observation stations

	River Management Authorities	JMA	Highway Bureau
C-band Radars	26	20	
X-band MP Radars	39		
Telemetric Rain	7,533	1,303	1,176
Water Level	6,935		
Others	2,106	87	188
CCTV	9,514		12,123

Note: Data are as of March 31, 2015. Most data are updated every 5 (C-radar) or 10 (telemeter) minutes.

Figure 2. Observation area of radar used by Water and Disaster Management Bureau



River management authorities analyze a large amount of data and forecast floods and inundation, as described above.

River management authorities conduct simulations for water-level forecasting using real-time data and a runoff analysis model whose main input is basin rainfall and upstream water levels. Their inundation forecasting, on the other hand, simulates multiple flood cases by setting inundation risk points along the target river at equally spaced intervals. When an inundation actually occurs, the closest simulated case is applied to forecast the development of the inundation. Such prior simulation is usually necessary, because calculation is not instantaneous. Real-time inundation simulation is possible, however, in the case of the Tone and other large rivers floodwaters take days to expand over wide areas.

To prevent or mitigate damage due to river floods and other related events as they occur, river management authorities and flood-fighting organizations cooperate closely with many other organizations, including prefectural and other local governments, fire and police authorities, and the Self-Defense Forces. Their goals are to prevent disasters, assist residents in evacuating safely, and provide emergency response quickly. Equally critical to reducing disaster damage is the proper issuance of evacuation advisories and orders by mayors of local governments.

Forecasts of river water levels and discharges provide information directly related to those organizational efforts. The MLIT and prefectural governments, which are acknowledged as river management authorities, collect and analyze data and information on river hydrology, such as water levels and discharges, and on the condition of river structures. They forecast river water levels and discharges for over 400 rivers that have been designated for flood forecasting by means of a nationwide network built for accurate observation of rainfall over each river basin. In addition, they officially release such forecasts with JMA, coupling river flood forecasts with rainfall, typhoons, and other meteorological data and forecasts provided by the agency. River management authorities issue flood warnings and dam discharge warnings.

For more effective use of river flood forecasts during flooding, authorities should already have analyzed and planned evacuation and other relevant actions to be taken in the face of flooding, and should have informed residents of these actions through various means, such as hazard maps.

For flood forecasts to be utilized in the evacuation of every resident, information must be received quickly. An information delivery service for smartphone users, including information on flood hazard maps, is scheduled to start in 2016 as an option for individuals.

During an actual flood, river management authorities operate structures such as dams and water gates, deploy flood-fighting to prevent levee breakage, and drain inundation water using pump vehicles, even outside the river area. In times of drought, in addition to operating dams/water gates, river management authorities deploy emergency water conveyance and coordinate among water users. When normal conditions are in effect, authorities construct and maintain structures for river management, such as levees and dams, and collaborate with municipalities on land use guidance.

For all these aspects of water management conducted by river management authorities, hydrological information (including river water levels, discharge, basin rainfall, and forecasts) is indispensable.

The organizations that use hydrological information to operate facilities and execute disaster response not only cooperate with those that collect and analyze such data, but in some cases have also tailored the information to their own needs. These cases should be taken into consideration when planning the modernization of hydrological information services in developing countries.

3. Japan's Hydrological Service Development Process and Related Knowledge, Experiences, and Lessons

3.1 Relationships between disaster management development and hydrometeorological service changes

Hydrometeorological services have been evolving in Japan as an integral part of DRM along with other measures. The following provides a historical overview of the progress of Japan's hydrometeorological services.

Before the 19th century

The main purpose of disaster management before the 19th century was to protect one's own settlement. The hydrometeorological information collected and used was limited to water levels of nearby rivers and weather forecasting based on traditional knowledge.

Early 20th century

Because of conflicts of interests between upper and lower reaches and between right and left banks, river management authorities realized the need to manage river basins using an integrated approach. Hydrological observation covering the entire river system, including the main stream and its tributaries, was begun in order to plan and implement river improvements that would ensure balanced protection throughout the river basin.

1955

Flood forecasting began with the goal of avoiding or mitigating flood damage. In hydrological services, efforts were made to develop forecasting technology, implement systems to collect data needed for forecasting, and improve data accuracy by validating them with observed data. These efforts continue today.

1961

In 1959, Isewan Typhoon hit Japan and left 5,098 people dead or missing—the largest number of casualties after the Meiji era (1868-1912). The disaster led to the enactment in 1961 of the Disaster Countermeasure Basic Act, which systematically addressed issues regarding DRM and development of disaster management plans, designation of disaster risk areas, issuance of evacuation advisories and orders, disaster response, and post-disaster restoration. It also defined the roles and authority of the national and local governments, public organizations designated by the Disaster Countermeasure Basic Act, general public, and outlined financial measures. This legislation facilitated further and more systematic improvement of hydro-meteorological services.

Late 20th century

Dramatic progress in information and communication technology (ICT) made it possible to process a large quantity of data at a higher speed, which in turn enabled more accurate analysis of current conditions and more accurate forecasting. In addition, the coverage of information networks expanded, allowing many more users to gain access to information. Observation technology also advanced significantly with the installation of radar rain gauges and the use of satellite images and SAR (synthetic aperture radar) for observation.

21st century

Traditionally, hydrological data collected by observing natural phenomena were analyzed and provided to residents and relevant offices to help them take appropriate actions, such as evacuation, in the event of flooding. However, in the effort to use hydrological data more effectively in DRM, authorities have started to divide hydrological and meteorological information into several levels and provide it at stages corresponding to actions that residents should take in a given situation.

Reviewing the historical development of hydrological services in Japan should help developing counties both to assess the status of their services as they modernize, and to discuss and plan practical goals and strategies.

3.2 Changes in water-related disaster management in Japan and required hydrological service modernization

In Japan, the modernization of DRM has been influenced by various factors, including socioeconomic changes, large disasters, technological breakthroughs, among others. Historical changes in flood disasters, and the modernization of hydrological services that took place in response to them, are discussed below and summarized in Figure 3.

3.2.1 From individual/areal disaster prevention to integrated disaster prevention

In Japan, levee building to prevent flood disasters started hundreds of years ago. Before the Edo era (1603–1868), circle levees, which were usually designed to protect only the builders' own community, were very common. Over time, however, communities located upstream and downstream, or on the right and left banks, began to have conflicts over safety issues. To solve such conflicts, flood management policy was revised drastically to call for construction of continuous levees, not circle levees, on both sides of rivers to contain floodwaters within river courses and to discharge them to the sea as fast as possible.

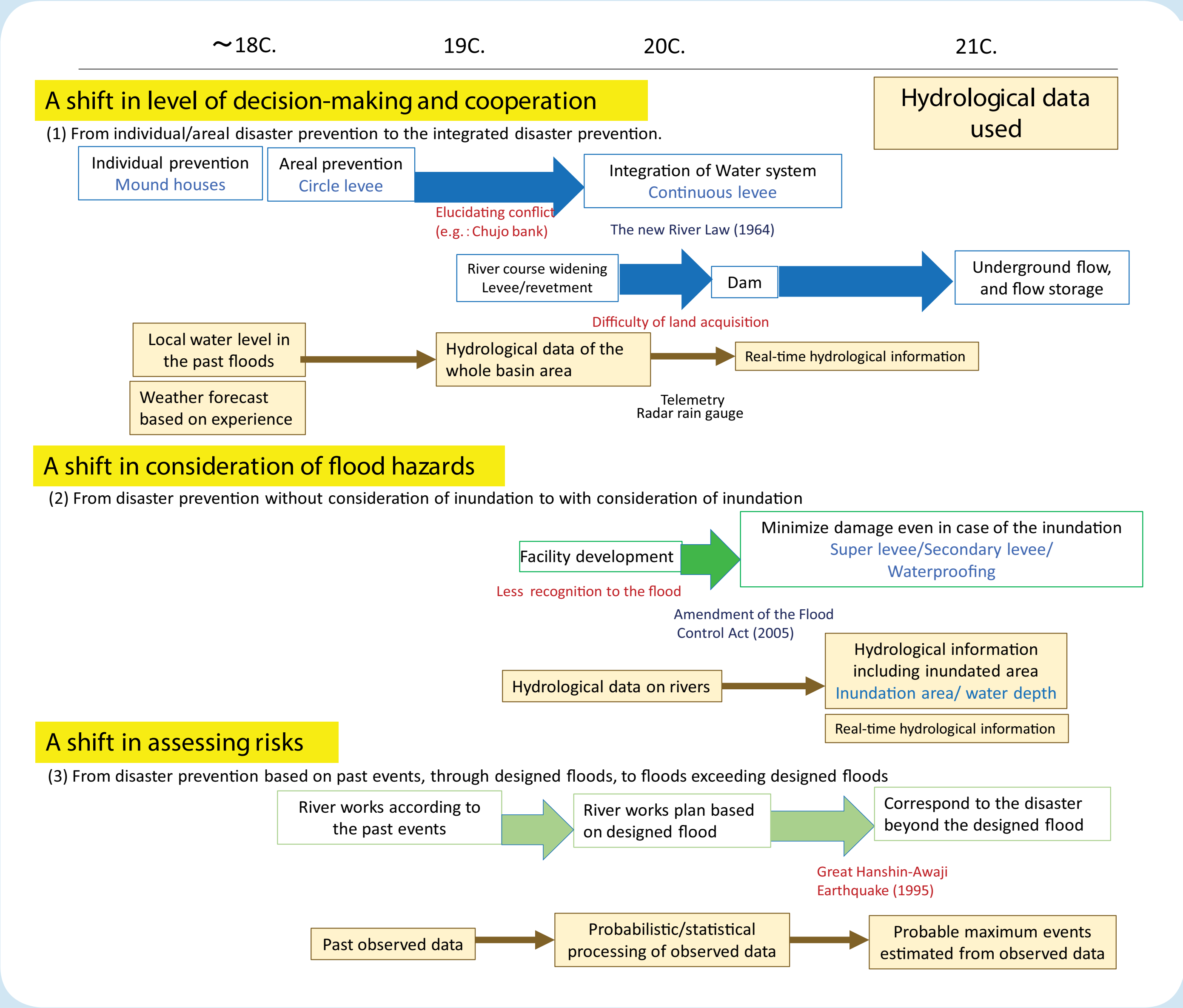
One example of such conflicts is the rehabilitation work carried out after the 1910 flood that damaged the Tokyo area. Chujo-tei, a type of levee built on the right bank of the Tone River, had long prevented the floodwaters that overflowed at the narrow section from spreading over the downstream parts of the river and inundating the upstream parts. After the flood, the local prefectural assembly and residents were divided over the rehabilitation of the Chujo-tei levee. Some local people even had a violent confrontation with the police, forcing their way into the prefectural government office. To address this conflict, the project for the Tone River was revised to widen the narrow section and build continuous levees that would allow floodwaters to flow down to the sea safely.

Integrated river basin management aims to provide each riparian community with the same level of protection against floods, and so must ensure that floodwaters are safely discharged in a channel walled by continuous levees. Meeting this objective requires that river improvement plans be designed consistently over the entire river system, including tributaries, and implemented as agreed on. In fact, the revised version of the River Law, enacted in 1964, proclaimed that integrated river basin management was the fundamental concept for high- and low-water management of rivers in Japan.

As demands for water resources increased, more dams were constructed in the upper reaches of rivers. In addition, as river improvements progressed and flood safety increased, urbanization accelerated and began to reach areas immediately along rivers, which made the acquisition of land to control floodwaters very difficult. After the Second World War, plans were developed by river management authorities (the Ministry of Construction or prefectural governments) to construct dams and retarding basins in the upper reaches to store some of the floodwaters temporarily. In response, the Specified Multipurpose Dam Act was enacted in 1957.

To develop plans based on the concept of integrated river basin management, it became necessary to collect hydrological data from the entire river basin. These plans were partly a response to rising demand for water resources, and included efforts to control

Figure 3. **Changes in water-related disaster management in Japan from the 18th century to present, and required hydrological service**



flooding and manage water resources in river basins. Since 1938, national data on rainfall and discharge have been published annually to meet demands for hydrological data. Since controlling the quantity of water is the most important factor in planning and managing dam construction and operation, observation of discharge has drawn particular attention since then.

The primary reason to modernize hydrological services in developing countries is to contribute to flood and water use management. Integrated river basin management is essential to addressing these challenges, and modernization efforts should be designed to realize this type of management.

Table 2. **Changes in prevention approaches**

Age	Approach	Implementation	Hydrological Information Used
PAST	• **Protection of houses against flood** – Raising of the house site by embankment/stone masonry – Provision of the private shelter for flood and attic in an evacuation place – Bamboo plantation around the house – Preparedness of a lifeboat in each house • **Protection of villages against flood** – Construction of circle levee around the village	By family members By the village	Water level at local levees Empirical forecast of the flood
	Conflicts of interest between upstream and downstream/left bank and right bank Example: Reconstruction of the Chujo-tei levee broken by 1910 Tokyo flood		
	• **Flood prevention by continuous levees (protection of a basin area)** – Cope with an actual flood at an initial stage	Central/local governments Regulated by the (old) River Law	Recorded values of past floods (water level, etc.)
	• **Flood protection based on integrated river basin management** – Targeting a planned flood, processed statistically	Central/local governments Regulated by the new River Law	Hydrological data during a certain period of past time (analysis is required)
	Difficulty in site acquisition for setting a wide river course, which is especially necessary in downstream city areas		
PRESENT	• **Flood control integrating the dams and reservoirs in upstream basin area** – Example: The Revised River Improvement Plan for the Tone River System in 1949	Central/local governments Specific multipurpose dam, regulated by the law	Real-time data required for dam operation (Telemeter, radar)

3.2.2 From disaster prevention without consideration of inundation to disaster prevention with consideration of inundation

In Japan, people used to regard river floods as the norm and had local coping strategies in place to deal with them. As time passed, continuous levees were built to contain floodwaters within the river course and upstream dams and retarding basins were constructed to control floodwaters.

Since building structures such as levees takes a long time, some areas may suffer serious damage before completion of improvement projects, which are developed based on occurrence probability. Moreover, even after such projects are completed, there is always a possibility that a disaster exceeding the design scale may occur. It is impossible to contain floodwaters completely within the river course, and so both structural and nonstructural measures should be in place to minimize damage when a flood actually occurs. Where river embankments are constructed of soil, for example, a flood exceeding the river's capacity could cause a breach and lead to catastrophic damage (see Figure 4), whereas super-levees with a very wide crest would not breach even during flooding and hence would minimize the damage. In addition, even under the same phenomenon of inundation, damage can be reduced if appropriate evacuation is guided. Figure 5 (see page 16) illustrates the process of reducing damage with nonstructural measures such as the provision of information.

Figure 4. Catastrophic damage resulting from a flood exceeding the capacity of a river

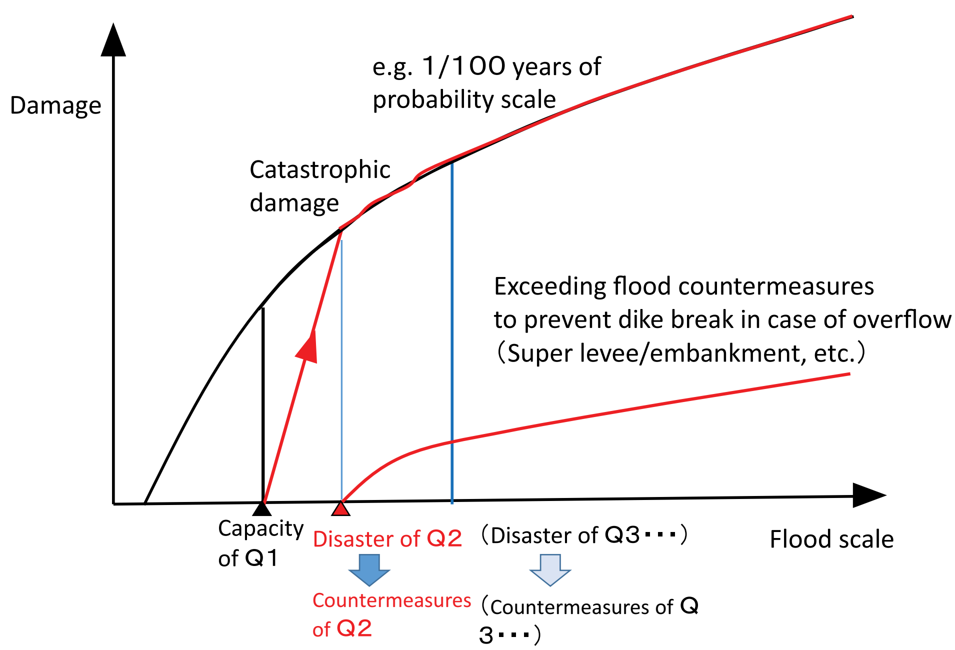
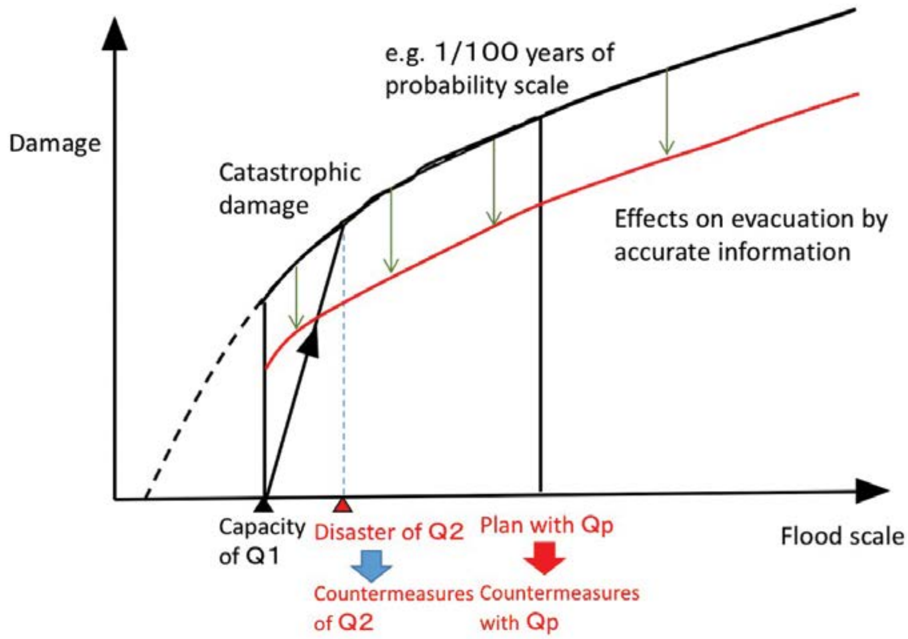


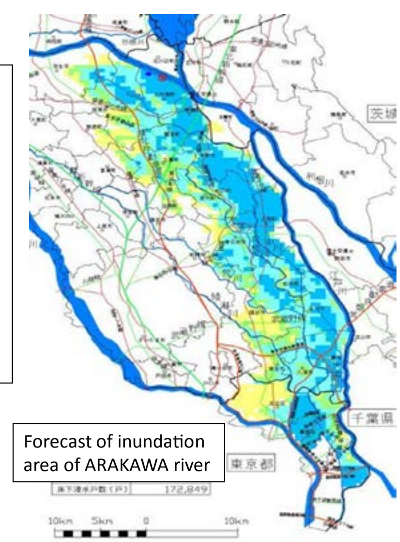
Figure 5. Process of reducing damage with nonstructural measures



These measures are disaster prevention with consideration of inundation, in which hydrological information on areas outside the river, such as expected inundation area and depth, is observed, analyzed, and delivered.

Figure 6. Forecast of inundation area and the inundation depth

The Minister of Land, Infrastructure, Transport and Tourism shall notify the relevant prefectural governors the situation of the rivers, concerning rivers within two or more prefectural areas, by indicating the water levels or flow volumes, or areas flooded by overflow and water depths therein after overflow of rivers, as well as to disseminate the above to the public, asking for cooperation of the media as necessary.
（The Flood Control Act，Article 10 Paragraph 2）



As explained, developing countries should design hydrological services to provide hydrological information on rivers and areas outside of rivers, including inundation areas.

Table 3. **Views on flood/inundation**

Age	Views on Inundation	Related Events	Specific Measures
~19 C.	*Inundation happens*	*Flood management per house/village*	*Indoor preparation of a lifeboat*
20 C. ↓	• Structural measures assuming no inundation – Flood should be controlled in a river – Inundation to be flown outside the river is not assumed	• Establishment of the new River Law	• Conventional River Development Basic Policy (Determination of the development level according to rivers.)
	• The flood cannot be contained completely	• Progress of river management • The period of time without a large-scale disaster has continued • Large-scale water-related disaster occurred frequently	
PRESENT	• Countermeasures to minimize damage are necessary, even if the disaster occurs ↓ Evolution of Floodplain risk management	• Revision of the Flood Protection Act (2005) – Regulates announcement/ dissemination about inundating area, water depth, etc. – Regulates dissemination of information on river water levels – Requires distribution of flood hazard maps	• Control of inundated water: – Maintenance of secondary levees, utilization of continuous banks, etc. • Arrangement of land use: – Arrangement of land use/building methods for geographic areas that will suffer serious damages • Reinforcement of the warning/evacuation system: – Maintenance of information collection/ transmission system, securing evacuation place/route, etc. – Evolution of hydrological information including inundation areas

3.2.3 From disaster prevention approaches based on past events, to approaches based on designed floods, and finally, based on events exceeding designed floods

There have also been changes to the process used to determine the design external force for planning of flood control structures. Determining the scale of a design external force was done to protect communities from flooding equivalent to what they had once experienced. In practice, levee heights were usually decided according to heights of past floods.

However, building levees that can withstand a flood similar to historical floods may not be a solution, because levees may breach and serious damage may result once a flood exceeds the past scale. As illustrated in Figure 7, planning and building levees in the traditional way may allow flood damage to recur, and the implementation of measures will tend to be reactive.

To avoid this problem, structural improvement plans should be developed based on a level of occurrence probability that will cope with floods larger than past events; and structures should be built and maintained according to such plans (Figure 8). Calculating a design external force based on a certain level of occurrence probability requires statistical analysis of hydrological data collected from the entire river basin, which in turn requires the accumulation of hydrological data for a long period of time. Because the basis for design external forces has shifted from past flood events to occurrence probability, archiving hydrological data has further accelerated.

These days, large-scale disasters are occurring that far exceed the scale calculated using past data. Thus, in addition to planned countermeasures based on a certain occurrence probability, the maximum probable scale is assumed, and countermeasures intended to avoid catastrophic damage in such a case are deployed in parallel.

In developing countries, where archived hydrological data are not sufficient, attempts should be made to substantiate the hydrological data required for preparing accurate plans, and to identify the "maximum probable" disaster not based on past data.

Figure 7. Tendency of implementation to be reactive

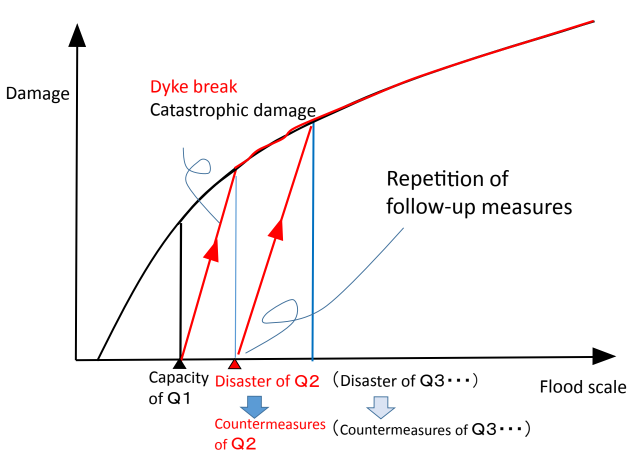


Figure 8. Structural improvement plans developed based on occurrence probability

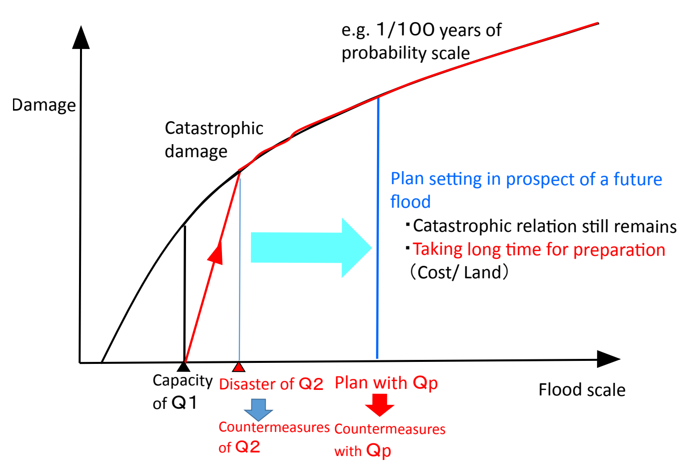


Table 4. Scale of disasters to be targeted

Age	Targeted Disasters	Related Events	Concrete/Practical Measures
PAST	Structural measures correspond to past (actual) floods; recurrence was to be prevented. **BUT** Damages would reoccur when the flooding went beyond the past records. ↓ Damage beyond conventional scale would occur. ↓ **Makeshift solution**		
↓	Formulate the scale of flood to be addressed: To be able to cope with the floods of a certain scale, if all of the rivers are controlled. **BUT** Flood occurs when the facilities were half-established. Flood beyond the planned scale occurs. ↓ **Damage would become bigger**	Establishment of the new River Law	Conventional River Development Basic Policy/Development Plan (Determination of the development scale, according to the importance of rivers) • Comprehensive flood control measures • Super-levee • Hazard map • Enhancement of evacuation information
PRESENT	**Countermeasures against the floods exceeding the designed level would be required.**	• Heavy rains without past precedent occurred frequently. • Huge earthquakes such as the Great Hanshin Earthquake, the Great East Japan Earthquake, etc., occurred.	Hydrological analysis considering inundation (expected inundation areas, depths) Revised Flood Protection Act (2015) (Countermeasures against supposed flood, inland waters, and high tide of the maximum scale [Nonstructural measures])

3.3 Lessons learned from other mega-disasters

Japan has experienced other types of disasters besides floods, and it has incorporated knowledge, experience, and lessons from each disaster to improve its overall capacity to cope with disasters. This section outlines recent mega-disasters and their impacts on water-related disaster reduction strategies.

Great earthquakes

Japan is prone to great earthquakes. Since the Meiji era alone, a dozen earthquakes have occurred in various parts of the country, claiming the lives of thousands of people: examples include Kanto (1923), Hanshin-Awaji (1995), and Great East Japan (2011).

Conventional structural design ensures structural safety and prevents serious damage even when the structure is hit by a certain level of anticipated external force ("Level 1" force). However, in the Great Hanshin-Awaji Earthquake in 1995, a large number of structures collapsed in response to tremors exceeding the scale of the anticipated external force. This event showed that to avoid fatalities, it is necessary to analyze the possible behavior of structures when they are hit by a far larger external force (i.e., "Level 2" force) than the force used for conventional structural designing ("Level 1").

This lesson has been applied to the field of flood disaster management. A typical example is the construction of "hard-to-collapse" levees, which are designed not to breach easily even during flooding. To further incorporate this concept into flood management projects, it will be necessary to figure out how to determine the scales of external forces larger than those of conventional design forces.

Great tsunamis

Since the Meiji era, Japan has on three occasions suffered catastrophic damage and extensive loss of life from great tsunamis.

The conventional approach to great tsunamis was to issue forecasts and warnings based on tsunami simulations using seismic movement. These simulations can contain significant errors. People know the existence of the errors, and are unwilling to evacuate. The Great East Japan Earthquake initiated a shift away from this conventional approach to simulation. Currently, conducting simulations based on observed data after the seismic movement are assimilated for more accurate forecasting. Such simulations include those based on changes in tidal level of the near waters around Japan. The combination of multiple types of simulation is expected to improve overall forecasting accuracy.

The same is the case in forecasting flood disasters. In addition to simulation based on rainfall forecasting, which may contain a high level of uncertainty, simulations using fact data such as observed rainfall and water levels in upper reaches—that is, data collected from phenomena very closely related to the occurrence of the flood—are now strongly encouraged.

Volcanic eruptions

Many active volcanoes exist in Japan and continue to cause damage. In 2014, Mt. Ontake in Nagano Prefecture suddenly erupted, claiming the lives of 58 hikers, the largest death toll in Japan since the Second World War.

In Japan, a volcano's danger level is quantitatively presented, but the figure is not based on the scale and extent of volcanic impact. Instead, the five levels of warning are based on how hikers and residents living nearby should act at each warning level.

This approach to classification, in which danger levels correspond to recommended actions, has also been applied to prevent damage by other types of disaster. In 2007, when the volcanic danger levels were set up, flood forecasting was also revised, and warning levels were set up that more easily translated into specific actions. Sediment disaster management also employs strategies from other areas of disaster management, such as establishing sediment disaster risk and high-risk areas, informing residents of sediment disaster risk in each area, and regulating construction and other relevant activities in risk areas.

3.4 Tools used to solve problems and achieve goals

For proper management of flood events, an integrated approach to disaster prevention and mitigation is essential: structural and nonstructural measures must work in harmony. The basic principles of disaster prevention/mitigation, applicable anywhere in the world and against any sort of disaster, are these:

1. Keep settlements out of dangerous places, so as to avoid damages even if phenomena occur (e.g., land use control, earthquake-proof building, private shelter for flood)

2. Defend assets with disaster prevention facilities, or adjust phenomena (e.g., dyke, estuary water gate, dam)

3. Escape from (or provide for rescue from) dangerous situations (e.g., evacuation, damage alleviation actions, rescue, early warning)

After the Great East Japan Earthquake in 2011, there was an emphasis on integrating effective nonstructural measures with structural measures, and on seeking how best to combine them (Figure 9).

Table 5 (see page 22) describes measures mobilized for flood prevention in Japan, including laws, systems, institutional arrangements, technologies, and budgets.

Structures for preventing inundation include improvement of river courses (embankment, dredging, etc.), dams, reservoirs, floodways, erosion control facilities, and sewerage. These are developed based on laws such as the River Law, Specified Multipurpose Dam Act, and Erosion Control Act. In order to achieve balanced facility development, with a view to integrated water resource management, the River Law stipulates that a basic policy and development plan be created for each river basin. Rivers are classified based on their importance, and the national government and local governments share the responsibility of development and management of rivers. To prevent a wide disparity in the development levels of rivers, the national government takes responsibility for the development and management of rivers' most important sections. The national government subsidizes projects executed by local governments as well.

Measures for averting/reducing damage in case of inundation include controlling the use of land at risk

Figure 9. Ideal mix of structural measures and nonstructural measures

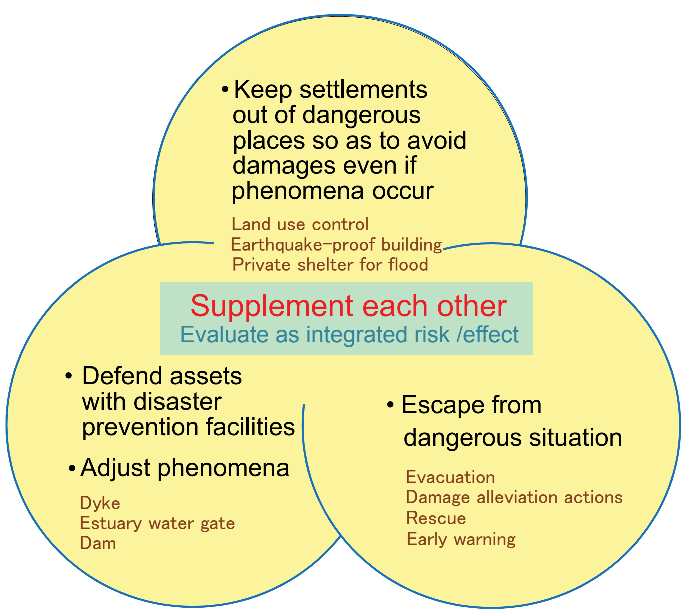


Table 5. Different tools for flood damage reduction

	Development and Maintenance of Facilities (Prevent inundation)	Regulation, Instruction (No damage in case of inundation)	Evacuation, Assets Protection Damage Alleviation Actions (Dealing with disasters)
	• Improvement of river courses (embankment, dredging, etc.) • Development of dams, reservoirs, floodways • Erosion and Sediment Control facilities, etc. • Sewerage	• Proper land use • Encouragement of flood-proof building	• Damage estimation • Establishment of warning evacuation system • Formulation/ dissemination of hazard maps • Implementation of emergency response drill • Rescue/relief • Emergency measures
Laws/Acts	• Disaster Countermeasures Basic Act • River Law • Specified Multipurpose Dam Act • Water Resources Development Organization Law • Erosion Control Act, etc.	• Disaster Countermeasures Basic Act • Building Standard Act • City Planning Act • Flood Protection Act • Sediment Disaster Prevention Act	• Disaster Countermeasures Basic Act • The Flood Protection Act (mandatory preparation/ delivery of flood hazard maps) • Disaster Relief Act
Systems	• First-class/second-class rivers (integrated water system) • Designated section for ,minister's administration • Basic policy, development plan	• Development control • Comprehensive flood management measures • Calamity danger district • Sediment disaster (special) — prone areas	• Regional Plan for Disaster Prevention
Institutions	• Ministry of Land, Infrastructure and Transport (Development Bureau/Office) • Local government (public works bureau) • Japan Water Agency	• Ministry of Land, Infrastructure and Transport • Local government (public works, urban design, architecture) • City planning council • Councils on overall flood management	• Ministry of Internal Affairs and Communications • Ministry of Land, Infrastructure and Transport • Local government (disaster prevention bureau)/ flood-fighting corps • FRICS
Technology	• Public works technology		
Budgets	• Special Account Budgets for Flood Control (National) • Local government budget	• Special Account Budgets for Flood Control (National) • Budgets for City Planning Projects • Local government budget	• Special Account Budgets for Flood Control (National) • Local government budget

of inundation and encouraging flood-proof building. In Japan, the area of controlled development is clearly identified under the City Planning Act, and disorderly development is controlled. In river basins with serious flood protection issues arising from rapid land development, a council consisting of river management authorities and local governments is organized, under which comprehensive flood management measures targeting the whole basin are taken.

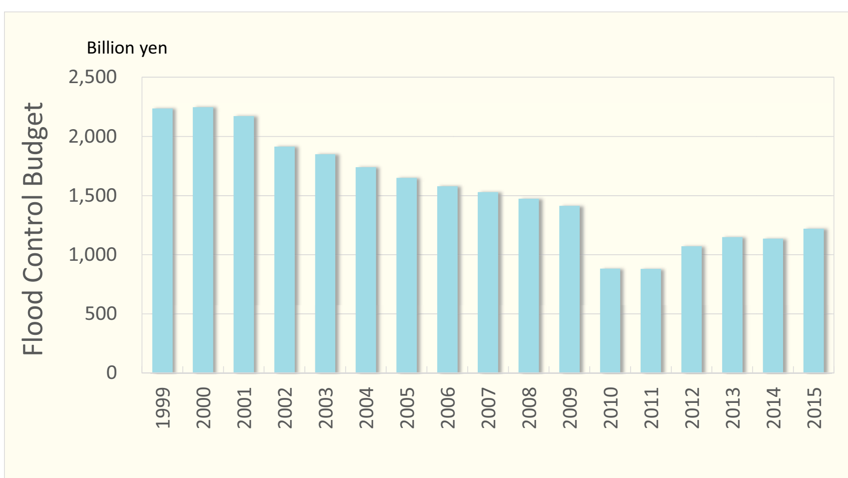
To minimize the damage in case of inundation, it is necessary to develop facilities that swiftly and reliably inform residents of disasters and evacuation plans, and that prepare and deliver flood hazard maps and disaster prevention drills (based on prior estimation of damages). There must also be emergency measures in place to deal with the rescue/relief of affected residents and support for evacuees. Mayors are responsible for securing the safety of residents, and they work together with river management authorities to reduce damage, provide hydrological services, and support efforts to deal with disasters.

Figure 10 shows changes in the national flood control budget, which includes hydrological services.[1] This system, in which hydrological service costs are included in the expense of flood control projects, is reasonably in line with the characteristics of hydrological services and is a practical means to ensure necessary financial resources.

3.5 Evolution prompted by technology development

Technological development in the observation of rainfall, river water levels, and flow velocity has progressed in response to users' needs for better observation accuracy and more user-friendliness. In recent years, more advanced devices using radio waves or ultrasound to observe flow velocity have been developed, such as acoustic Doppler current profilers (ADCPs), which maximize the Doppler effect of ultrasound. Other recent developments include technologies using closed-circuit television (CCTV) images to observe river surface flow velocity or using satellite images for flood forecasting.

Figure 10. Annual budget for flood risk reduction (or management) of Water and Disaster Management Bureau (billion yen)



1 It is difficult to precisely estimate the actual budget for hydrological services, as their associated costs are integrated in various budget lines.

Technologies developed in different areas have also been introduced to hydrological observation. One example is radar technology, which was originally developed for military purposes to locate airplanes. This technology has been found very useful for disaster management purposes because it is capable of observing the condition of raindrops over a widespread area. The rapid progress of information technology has also contributed to disaster management by allowing large volumes of data to be processed and transmitted at a faster rate. Advanced ICT technology has enabled in-depth analysis of voluminous data, production of more user-friendly interfaces, and provision of information with handheld devices.

A typical case in which a specific need accelerated technological development is that of X-band MP radar. In 2008, serious human damage resulted from the Toga River flood in Kobe City, which was caused by localized torrential rain. This incident evidenced the necessity of technology capable of more detailed observation in a shorter period of time complementing conventional C-band radar network, which is useful to monitor larger scale precipitation events: i.e., X-band MP radar. Today, this newly developed radar is in operation at 39 places nationwide.

See Annex 2 for other examples of technological development.

3.6 Challenges

Past flood management in Japan went through numerous successful and unsuccessful experiences while always striving for improvement. The modernization of hydrological services contributed to solving some problems.

The following section presents past issues along with solutions.

Declining coping capacity during disasters from excessive expectations for disaster prevention structures

Japan mostly consists of steep mountainous areas, with only a small percentage of the national land left habitable; thus large cities, including Tokyo, have developed in the low-lying areas downstream of large rivers, where inundation has occurred repeatedly. At present, 51% of the population and 75% of the national assets are concentrated on floodplains, which account for merely 10% of the national land. The population density of the floodplains in Japan is 1,600 persons/km2, which is much higher than that of other countries (Figure 11).

To protect people and assets from floods, the traditional focus of river management authorities was structural measures, such as construction of levees and dams. Efforts to communicate flood risks to the public were inadequate. This approach contributed to a decline in awareness of flood risks among the local residents because it gave them a false sense of safety, which resulted in an increasing number of people living in areas subject to inundation. All these trends understandably contributed to a decrease in the public's overall coping capacity in case of a large disaster (Figures 12 and 13, see page 26).

While the area of residential land experiencing inundation has decreased through river management, the amount of damage to general assets has not, because of the increase in vulnerable assets.

To address these situations, river management authorities have shifted flood management policies to provide residents with local risk information such as inundation risk areas and inundation depths.

Confusion from disaster forecasting with uncertainty

When residents face an imminent disaster, it is the municipal mayor's responsibility to issue evacuation orders and advisories in order to encourage safe and rapid evacuation, as defined by the Disaster Countermeasures Basic Act. If an evacuation advisory and order are issued prior to flooding—that is, based on flood forecasting—this may substantially reduce disaster damage. However, forecasting always entails a certain level of uncertainty, and thus disasters may not occur as forecasted. To avoid evacuation advisories and orders ending in a false alarm, they were often not issued until after

Figure 11. **Population and assets concentrated in the inundation areas in Japan**

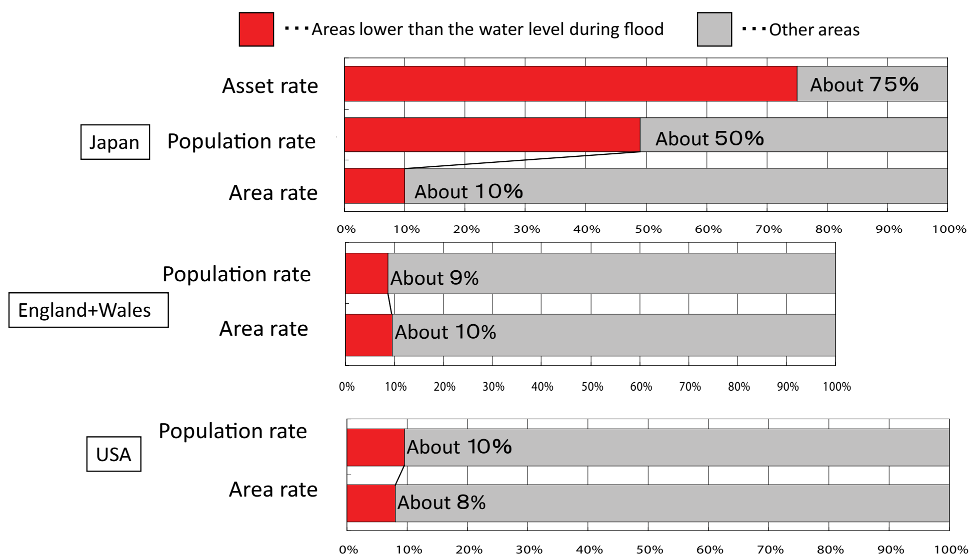


Figure 12. **Inundation area and damage amount of general assets per inundation area**

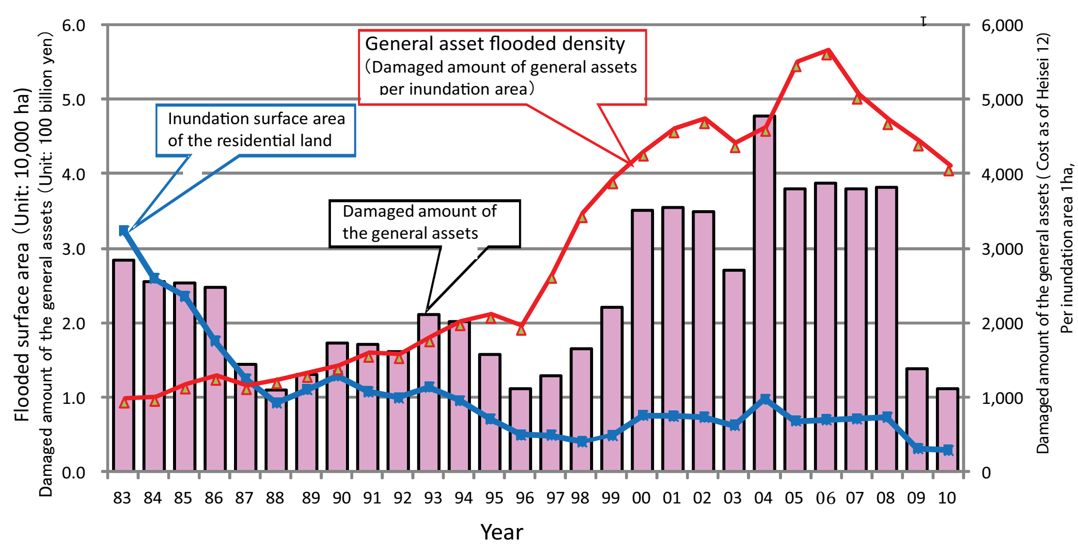
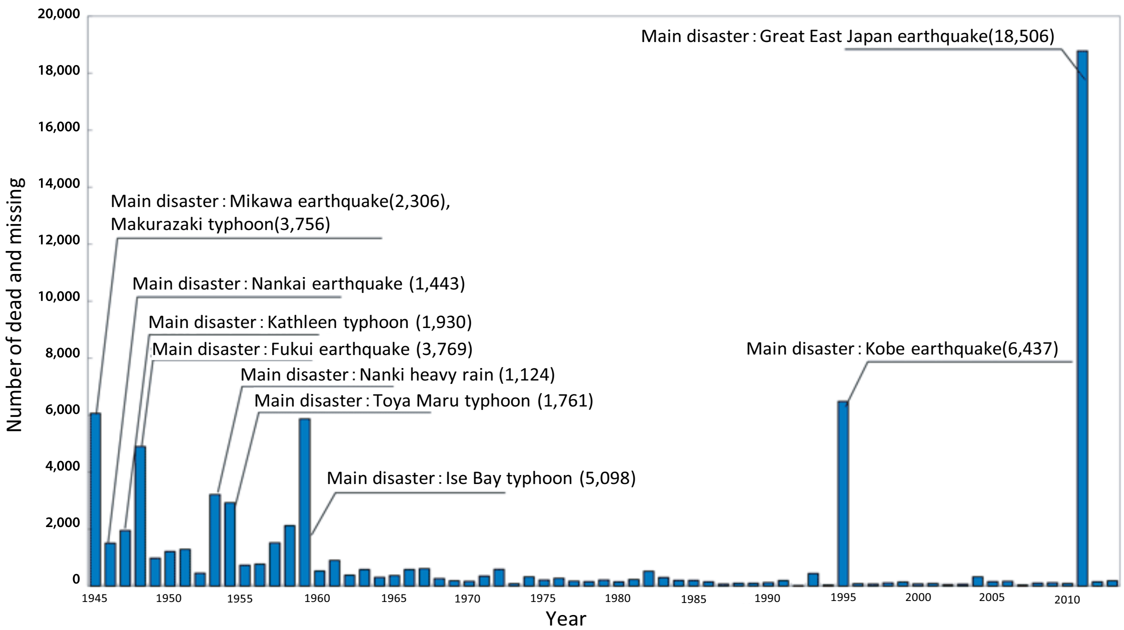


Figure 13. Number of disaster casualties in Japan



Assessment Report on Disaster Risk Reduction,2014, The Cabinet Office

a disaster had actually occurred. In fact, between 1961, when the Disaster Countermeasures Basic Act was enacted, and 2004, no evacuation advisories and orders were issued before levees breached or sediment disasters occurred.

However, for residents to understand flood risk and take appropriate evacuation action, they need to make the most use of information from flood forecasting. Acknowledging that forecasting always contains a certain level of uncertainty, river management authorities have sought to share forecasting information with local municipalities at early stages and have encouraged municipalities to use the information for disaster management. They are also working to improve how to present information containing uncertainty to residents so that it is not misunderstood.

In September 2015, record-breaking heavy rainfall hit parts of the Kanto and Tohoku regions, particularly over the upstream area of the Kinu River, which breached a part of the levee in Joso City, Ibaraki Prefecture. The flood caused serious damage, inundating about 40 km2 of land, submerging many buildings, including the Joso City Office, and leaving two dead and many injured. However, it should be noted that during the disaster, an MLIT river office in charge of the management of the Kinu River, in coordination with JMA, provided Joso City with information on flood danger and with inundation risk area maps. This was part of the effort to share and use information with careful consideration of the uncertainty it contains. As the information was not utilized by the municipal government for reducing flood damages, MLIT initiated a basic policy to rebuild a flood-disaster-conscious-society, in which administrators, the public and companies share the knowledge of and preparedness for flood risks.

Difficulty in taking responsibility for actions based on information with uncertainty

Since the construction of structures such as levees takes a long time, floods may occur during the construction. Moreover, even after structures are completed as planned, there is still a possibility of floods. Because of that, governments and citizens should understand that they need to prepare for floods to minimize damage, and in the past, river management authorities usually provided information related to flooding.

As time went by, the primary focus was shifted to structural measures such as dams and levees to prevent floods, and at the same time many lawsuits were filed by disaster victims seeking compensation for damage. As a result, river management authorities started avoiding the provision of flood information, which often seemed to create confusion about who should take responsibility for such information, and they focused their attention only on river management, where responsibilities were clearly understood.

Then, a further shift in flood management policy moved away from disaster control, which means preventing disasters from occurring completely, to disaster mitigation, which means reducing disaster damage as much as possible. After 2005, when the revision of the Flood Protection Act mandated the distribution of hazard maps, river management authorities resumed the active provision of flood information. However, more efforts are still needed to help citizens translate flood information—such as inundation risk areas and inundation depths—to appropriate evacuation actions in case of flood.

Linking flood information with disaster mitigation is also an important issue for developing countries.

Difficulty in deciding the timing of evacuation orders and advisories

Deciding when to issue an evacuation order has been a serious challenge for local governments. Not only must they confront the uncertainty often contained in forecasting information, but they are sometimes not very clear about what an evacuation order and advisory really mean. In other cases, they have little information about incoming hazards and the status of levees and other structures.

In 2004, when flood disasters occurred in many parts of Japan, the Cabinet Office developed guidelines for the preparation of a manual on making proper decisions about issuing evacuation orders and advisories, with the goal of encouraging local mayors to issue them proactively. The guidelines did not work as expected, however; mayors started issuing evacuation orders that may not have been necessary. This occurred in 2008, when Okazaki City of Aichi Prefecture issued an evacuation advisory to its entire population in response to localized torrential rain. It occurred again in 2011, when Nagoya City of the same prefecture issued an evacuation advisory to its population of more than one million people. Consequently, the public began to wonder if they really had to evacuate and to question the reliability of the orders.

Because of these situations, efforts have been made to develop easy-to-understand criteria for mayors to use in deciding when to issue evacuation orders and advisories. In addition, based on lessons learned from the 2015 Kanto-Tohoku heavy rainfall, in which hydrological information did not lead to successful evacuation of local residents, more effective methods for providing information are being sought.

4. Organizations Related to Japan's Hydrological Services and their Relationships

4.1 Changes in governmental and other organizations

Changes in governmental organizations (up to 2000)

Japan saw the modernization of governmental systems after the Meiji Restoration in 1868. The Ministry of Home Affairs was assigned responsibility for river management and flood control, and started collecting and organizing hydrological data as part of its role.

After World War II, the Home Ministry was abolished and its functions were distributed among four ministries, including the Construction Ministry, which took over the duties of river management. DRM for farmland and port facilities was assigned to the Ministry of Agriculture, Forestry and Fisheries and to the Ministry of Transport, respectively. In addition, the Ministry of Transport, the Ministry of Agriculture, JMA, the National Police Agency, the Fire Defense Agency, and the Defense Agency all had an important part in emergency response. Since several agencies and ministries were involved in DRM, the National Land Agency was given the responsibility for coordinating the effort.

Incorporation of the Meteorological Agency and the River Bureau (Establishment of MLIT)

When the governmental agencies and ministries were restructured in 2001, the River Bureau and the JMA, which had been under separate ministries since the Meiji era, were incorporated into MLIT. Long before this incorporation, however, those two agencies had issued flood forecasts jointly, and had exchanged and shared real-time hydrological and meteorological information observed by each institution. They had also kept close communication through personnel exchange. The integration has made the cooperation even closer, and it has increased opportunities for better aligning policy planning and implementation as well as jointly responding to disasters under the coordination of the Disaster Prevention Center.

Although the River Bureau and JMA seem to be conducting similar observations that could be viewed as redundant in some cases, the content of their observations is in fact different. The observations of the former mainly focus on runoff into rivers, and the data collected by the latter are primarily related to weather forecasting. For example, the radars of the River Bureau emit radio waves from high altitudes with low angles for capturing rainfall conditions near the ground; the radars of the JMA emit radio waves from low altitudes with high angles. Because of the difference in data type, the integration of data collected by each organization is not always simple, but the two institutions complement each other and work in close corporation.

Establishment of the Cabinet Office

After the major governmental restructuring in 2001, planning of important political issues in Japan—such as economic policy and disaster management policy—was to be conducted under the Prime Minister, and the Cabinet Office was established as the secretariat. With respect to disaster management policies, the minister for disaster management was assigned to the Cabinet Office, which led disaster management policy planning, and the Central Disaster Prevention Council (chaired by the Prime Minister) was to make decisions. While the Disaster Prevention Bureau of the National Land

Agency had coordinated related ministries and agencies previously, the disaster prevention section of the Cabinet Office, under the direction of the Prime Minister, now was responsible not only for coordinating related ministries and agencies, but also for planning the disaster management policies of the whole nation. These changes signaled dramatic progress in comprehensive disaster management policies based on strong coordination. Under this framework, collaboration between the River Bureau and JMA progressed, and various measures of disaster management, such as early warning information delivery on multi-hazard, advanced.

Establishment of Water and Disaster Management Bureau

In 2011, when MLIT was reorganized, the Water and Disaster Management Bureau was established by merging the Water Resources Department of Land and Water Resources Bureau, the Sewerage Works Department of City and Regional Development Bureau and the River Bureau. This integration improved coordination of various measures related to water, such as preparation of hazard maps dealing comprehensively with both floodwater from rivers and inundation caused by lack of drainage capacity in urban areas.

4.2 Role-sharing and cooperation between the government and citizens

Self-help, mutual support, and public assistance

To minimize disaster damage, three components are equally important and need to function effectively: public assistance (in which governments provide assistance before a disaster and for crisis management), self-help (in which people protect themselves), and mutual support (in which people support one another at the community level). In rescue operations, for instance, public assistance may be necessary if heavy machinery is needed, but in other cases self-help and mutual support work more effectively. During the Great Hanshin-Awaji Earthquake, for example, 85% of people were evacuated by practicing self-help and mutual support, which is much more than were rescued in governmental efforts.

The three components are also important for water-related disasters. Public assistance provides residents with hazard maps and hydrological information during disasters to encourage them to take appropriate evacuation actions. Residents are expected to practice self-help and mutual support; residents and communities receive the information, assess their own and surrounding conditions properly, and take necessary action to reduce damages.

Flood fighting in close cooperation with local communities

A good example of mutual support in Japan can be found in cooperative efforts by local residents to fight floods. When a local river floods, people cooperate in piling up sand bags to prevent inundation, warning neighbors about coming dangers, and encouraging others to evacuate.

The context for this community-based flood mitigation is the legal framework established in 1949. Municipal governments play a leading role in assisting the public in this effort, while river management authorities also support them by providing hydrological information and materials and equipment for flood fighting.

Hydrological observation by local residents

In the 1940s, when telemeter systems were still rare, MLIT (the Construction Ministry at that time) delegated hydrological observation to local residents living near an observation station. These cooperative observers helped to create a substantial archive of hydrological data by observing river water levels, as well as rainfall and groundwater, at the same time and locations every day.

The widespread use of telemeter systems gradually decreased the importance of cooperative observers in hydrological observation. While the system of cooperative observers is no longer in effect, the system was helpful in enhancing the involvement of local residents in river management.

4.3 The involvement of the private sector

The private sector has contributed a great deal to the development of observation instruments and analytical technology used in relation to hydrological data.

In Japan, imported tide gauges were used to observe river water levels. After the collapse of Japanese currency that followed the Second World War, the development of domestic automatic water-level gauges started. In 1962, under a collaboration of the public and private sector, the first domestic automatic water-level gauge (Suiken Type No.62) was finally developed and replaced the costly imported gauges. This was a milestone for the widespread use of water-level gauges that followed.

The public-private partnerships also played a large part in the dramatic progress in ICT as well as the enhancement of information systems and the development of rainfall radar (see sections 3–5).

Moreover, the public sector, research institutes, and private consulting firms have been cooperating in the development of analysis technology for hydrological data.

4.4 Government's relationship with mass media

Role of the mass media during large disasters

In Japan, the mass media (such as TV stations) plays an important role in communicating information to the public during disasters; because they are easily accessible, they offer residents a useful way to get an overall picture of the situation. In particular, the Japan Broadcasting Corporation (NHK) is the legally designated public agency for DRM and is expected to provide information in case of a disaster.

Information provision organized by the public sector is also important and is a more appropriate way to provide area-specific information; the public sector disseminates information through disaster management radio communications (outdoor publicity loudspeakers installed in neighborhoods), public relations vehicles, and the Internet. The public sector and the mass media need to closely cooperate in providing necessary information in order to encourage the public to take proper action for avoiding and reducing disaster damage.

In normal times, the mass media should be a reporting entity that is independent from the administration, and it usually has an objective attitude towards governments. In an emergency, however, those two sectors have cooperated to make sure that people receive necessary disaster-related information.

Cooperation agreement between the mass media and the public sector

The following agreements have been made to secure the cooperative relationship between the mass media and the public sector.

- Agreement on broadcasting and reporting between prefectural governments and the mass media
  This agreement is based on the Disaster Prevention Basic Act. Prefectural governors and broadcasting stations and news agencies have agreed that the governors may ask for important information (such as warnings and evacuation orders and advisories) to be broadcast and reported during disasters.

- Agreement on the provision of data and footage between MLIT, etc. and the mass media
  For the purpose of flood damage prevention and support for safe evacuation, MLIT and other relevant agencies have agreed to provide data on ground rainfall, data on water levels, radar rainfall data, and footage of rivers for broadcasting stations to use at their disposal.

4.5 Establishment of FRICS

Background of the establishment of FRICS

In the early 1980s, when public awareness of flood damage started rising and river use became frequent and diversified, the need for hydrological information grew, not only during floods and disasters but also in normal periods. In 1982, the Nagasaki flood disaster occurred (figure 14), and it was found that the damage could have been greatly reduced if residents had been provided with hydrological information. This incident further accelerated the demand for hydrological information from municipalities, the mass media and the general public during floods.

At that time, the national government also provided hydrological information to some local governments separately. However, to avoid confusion, there was an urgent need for a system that allowed information to be standardized and provided to many users.

Reluctance of the private sector to be involved in hydrological services

Meteorological information is necessary not only during disasters but also in everyday life, and it is in particularly high demand by the mass media for their daily broadcasting. In addition, people involved in agriculture or in organizing events also need meteorological information. The demand for this information is huge, constant, and from a wide variety of perspectives.

However, it is still true that the demand for hydrological information is far less in normal periods than during disasters. Power generation and agricultural facilities take, store, and use a large volume of river water, and these sectors have individual networks with river management authorities to obtain necessary information. Moreover, the river regime usually has little effect on river water intake in the case of small-scale irrigation, where the need for information on day-to-day hydrological conditions is not necessarily large. Thus few sectors have been willing to pay the cost of receiving information. In turn, private corporations have avoided involvement in hydrological services.

At present, the Foundation of River & Basin Integrated Communication (FRICS) runs a business to deliver numerical data on hydrological conditions. Although there are some cases in which weather information companies receive and process data from FRICS and deliver secondary data to users, the need for daily hydrological services at present is not large.

Figure 14. Nagasaki disaster in 1982

Establishment of FRICS

On the other hand, to meet the demand for accurate and timely information during disasters, a system needs to be designed that continues operations, including monitoring data, on a 24/7 basis. To provide information that helps to avoid and reduce disaster damage, it is important not only to provide information in a simple format but also to indicate what kind of actions are necessary given the status of a disaster. To secure human resources is another important priority; experts with practical knowledge and skill in river management and DRM are needed to handle information properly. Although national government officials recognized the significance of such institutional arrangements, creating a new agency for this role was extremely difficult, as the government of the time was working to downsize itself.

Despite these difficulties, FRICS was established, October 1, 1985, as a collaborative effort. In addition to the subsidy from the government, funding comes from both the public and private sectors: contributors include prefectures and ordinance-designated cities, the mass media such as NHK, manufacturers of devices and sensors, banks, the Japan Dam Foundation, and the Japan Civil Engineering Association.

The role of FRICS is to provide information standardized for the convenience of users, to transmit a large volume of information to numerous users (by means of its large hardware), and to monitor information 24/7, all year round. In addition, it is equipped with experts who can respond to users' needs, handle troubles appropriately, and constantly improve the system in response to various needs.

With the establishment of FRICS, the institutional arrangements were in place to facilitate delivery of quality hydrological information, mainly observed by the national government (Figures 15, 16, and 17).

Figure 15. Flow of river information

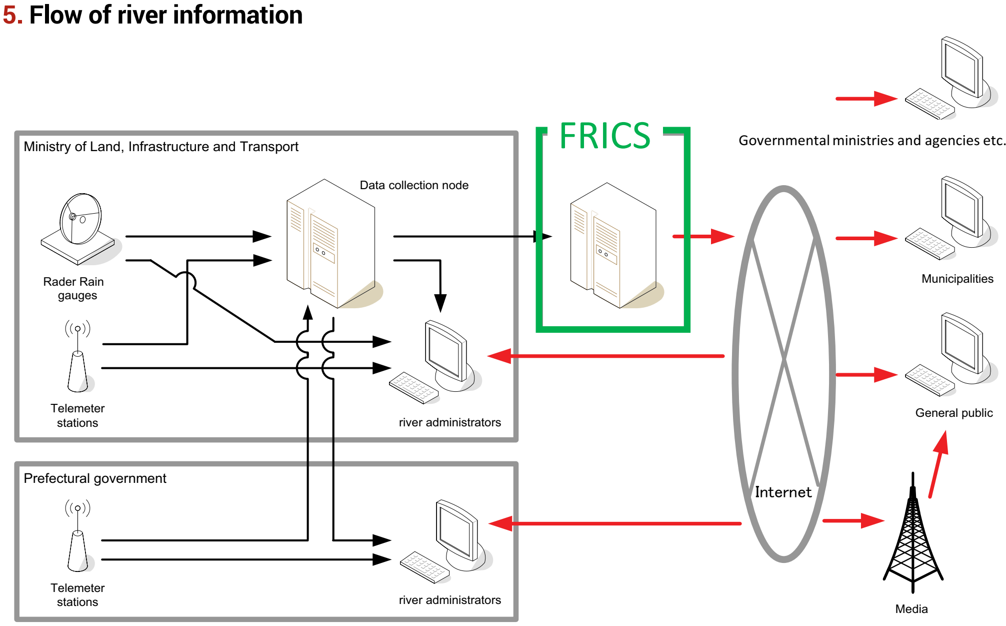


Figure 16. **Provision of river information**

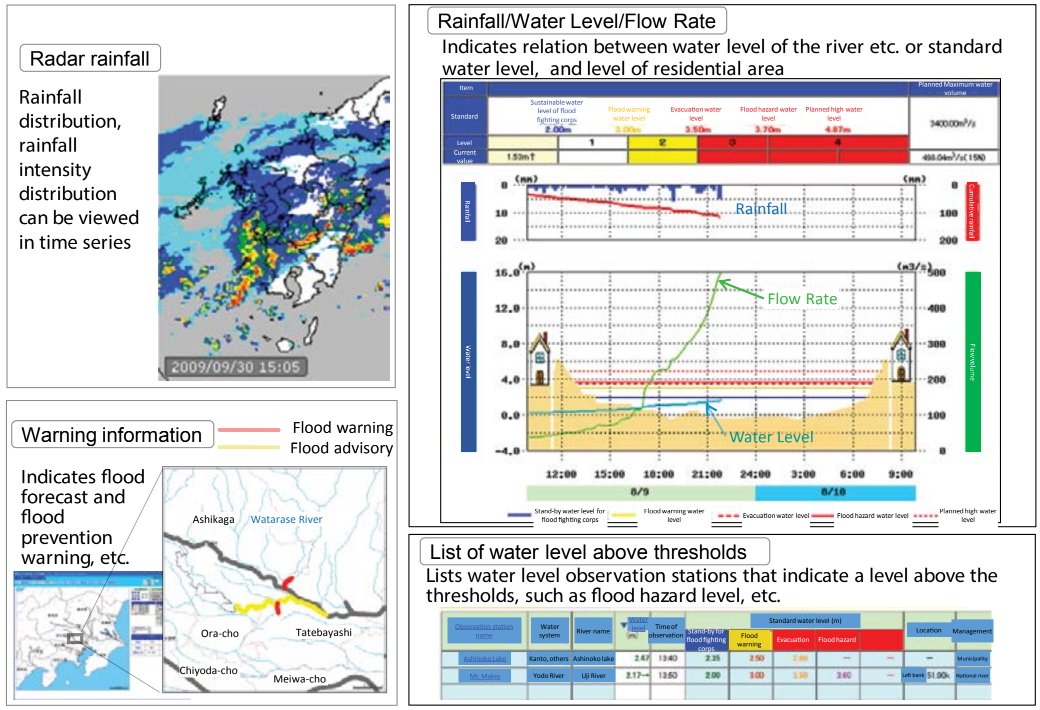
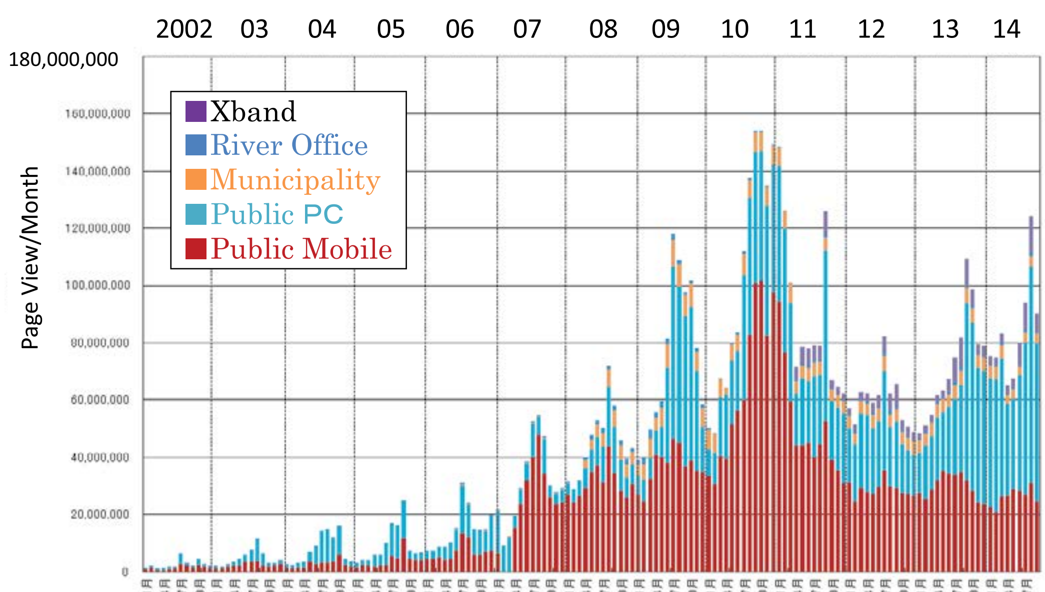


Figure 17. **Monthly accesses of river information**



Role of FRICS

In addition to providing hydrological information, FRICS conducts various projects and research and works to promote technological development using hydrological information. Specifically, it engages in the following:

- Collection, processing, analysis, and provision of river and basin information, as well as research and development to improve those activities
- Development and management of databases on hydrology and water quality
- Technological development of radar rain gauges
- Development of flood forecasting systems using hydrological data
- Development of crisis management technology using hydrological data
- Development of hazard mapping technology
- Distribution of numerical information
- Development of hydrological information systems for developing countries
- Training of interns from developing countries on hydrological information

FRICS constantly improves systems that provide hydrological information for the sake of users. In particular, the new information provision system currently under development will be capable of providing information on ground rainfall, water levels, radar rainfall, and inundation risk, as well as hazard maps and CCTV images of rivers, in a way that allows users to easily understand contents and structures. It will also realize more user-friendly operation and require no manuals. Finally, it will enable users to view all kinds of information using a smartphone. This revolutionary system has been available since April 2016.

4.6 User groups

Presently, many types of hydrological information related to DRM are widely available for the general public. However, organizations especially involved in DRM are given identification and provided with more detailed information.

The following section describes the organizations that utilize hydrological information and their purposes.

Organizations that manage rivers and structures such as dams and water gates

Information is used for operating and managing structures such as dams and water gates, monitoring unusual events during floods, and forecasting inundation.

Organizations in this category are:

- MLIT (Water and Disaster Management Bureau)
- Prefectural government (Construction Department)
- Japan Water Agency

Local governments

Local governments are responsible for securing the safety of residents: when a disaster is imminent or actually occurs, they are required to issue evacuation information (including evacuation orders and advisories), set up and manage shelters, and direct efforts to fight floods. Hydrological information is essential for local governments to make decisions on these actions.

Organizations in this category are

- Cities
- Towns
- Villages

Organizations that support disaster management efforts of local governments

In case of a disaster, prefectural governments, in cooperation with local governments, have to engage in response efforts. When a large-scale disaster occurs, the Self-Defense Force will be mobilized at the request of a prefecture or local government. The Fire Defense Agency of the Ministry of Internal Affairs and Communications (which holds jurisdiction over the firefighting efforts by prefectural and municipal governments), the National Police Agency (which oversees prefectural police), and the Self-Defense Force of the Ministry of Defense are also involved in disaster response actions; they work in cooperation with each other, using hydrological information to capture the status of a flood disaster quickly and accurately.

Organizations in this category are

- Prefectural governments
- Ministry of Internal Affairs and Communications (Fire Defense Agency)
- National Police Agency
- Ministry of Defense (Self-Defense Force)

Government headquarters for disaster control

In Japan, the government headquarters for disaster control, headed by the Prime Minister or the minister responsible for disaster control, will be activated in case of a large-scale disaster. The members are required to share hydrological information, understand the disaster situations accurately, and conduct risk management, rescue, relief, restoration, and rehabilitation immediately.

Organizations in this category are

- Central government ministries and agencies
- Japanese Red Cross Society
- Bank of Japan
- NHK
- Nippon Telegraph and Telephone Corporation

Organizations that operate lifeline utilities and traffic infrastructure

Lifeline utilities (e.g., electric power, gas) and traffic infrastructure (e.g., expressway, railway) are indispensable for people's everyday lives. Although the first priority is ensuring safety, they also should be maintained as carefully as possible to avoid interruption, and should be restored as soon as possible even when interrupted. Organizations that operate these businesses utilize hydrological information to manage facilities appropriately when a disaster is imminent or actually occurs, and to restore them when they are damaged.

Organizations in this category are

- Communications companies
- Electric power companies
- Gas companies
- Japan Post
- Japan Railways
- Airport companies
- Expressway companies

Mass Media

To encourage residents to take appropriate actions when a disaster is imminent or actually occurs, information should be delivered to as many people as possible. Currently in Japan, the mass media, such as TV, are dominant in information delivery. NHK and other broadcasting and news-reporting companies should make efforts to obtain hydrological information from authorities and provide it for the general public.

Organizations in this category are

- NHK
- Private broadcasting stations

5. Application of Japan's Knowledge, Experience, and Lessons to International Cooperation Projects Relating to Hydrological Services

5.1 Technical cooperation projects up to the present[2]

The Republic of Korea

In the Republic of Korea, the flood forecasting/warning system in the Hangang River, with a basin area of 26,200 km^2, was practically completed in 1974 with JICA's grant aid. The system received several adjustments in the operational stage thereafter. But in the system's actual operation, the consistency between the calculated estimation value and the actual measurement value was not satisfactory, and an overall and fundamental reexamination of the system and model became necessary. Responding to a request for technical cooperation from the government of the Republic of Korea in 1980, the Japanese government dispatched a flood forecasting expert in February 1981and a hydrological expert in November 1981. The technical cooperation project was carried out through actual flood forecasting/warning operations and involved (i) an overall examination on the issues and measures to improve the flood forecasting system/model for the Hangang River; (ii) an examination of specific items in the forecasting calculation model improvement; (iii) an examination of the draft comprehensive plan for the Hangang River flood forecasting/warning system, with the goal of expanding the system in the future; and (iv) deliberation about dam operation procedures and the flood forecasting calculation model improvement, as well as the low-water-flow control policy for the Hangang River (taking the completion of the Chungju Dam into consideration).

Since 1981, the Construction Department of the Republic of Korea and the Ministry of Construction of Japan have exchanged information on river technology as part of the Japan-Korea Technical Cooperation Meeting on River and Water Resource Development. This project helped to improve Korean technology relating to flood forecasting/warning. Through capacity building and training of technical operators/engineers and relevant facility development, the country reached a level at which it can itself develop systems of flood forecasting.

The Philippines

The Pampanga River, one of the most important rivers in the Philippines, is located near the capital city of Manila and contains a large grain belt in the downstream area along a well-developed floodplain. In September 1973, with grant aid from the Japanese government, the first flood forecasting system in the Philippines was established in the Pampanga River basin. Notably, the system played a crucial role at the time of the catastrophic flood in May 1976, saving many people's lives and property from the disaster. In 1981, a general rehabilitation of the system was carried out with grant aid.

2 Technical cooperation is an all-embracing general term used to describe JICA's practical assistance to developing countries. Depending on the specific projects, technical assistance can include the dispatch of JICA experts, the training of local officials for "capacity development," or the supply of equipment or financial assistance. Technical cooperation is one of JICA's three major areas of development assistance, the others being provision of grant aid and low-cost yen loans.

Based on the success of this flood forecasting system, the government of the Philippines asked the Japanese government for a plan to expand the system into the Agno in middle Luzon, the Bicol in south Luzon, and the Cagayan in north Luzon. This expansion was completed in May 1982.

The government of the Philippines, aiming at zero disaster damage, set out to reinforce disaster mitigation organizations and to enhance the flood forecasting/warning system in the mid-term national development plan for the period 2004–2010.

In the flood forecasting/warning systems of the Pampanga River and the Agno River, major rivers in Luzon, the observation function was ineffective because the observation/monitoring apparatus had deteriorated, and because communication between the observation stations and the central monitoring center was not well-functioning. This problem was considered the cause of increasing damages.

The Philippine government requested grant aid for prompt and appropriate improvement of the system's observation/information transmission functions under the Project for Improvement Plan of Flood Forecasting and Warning System in the Pampanga and Agno River Basins. Responding to the request, in 2007–2008 the Japanese government provided funds for improving the flood forecasting and warning system, communication networks, and observation stations in the Pampanga and Agno River basins, as well as for maintaining the monitoring apparatus/equipment in the central monitoring center and in the related institutions for disaster management.

Thus 30 years after its development began, the flood forecasting/warning system of the Philippines is still not independent.

The People's Republic of China

In China, flood prevention and damage reduction are considered important issues, as flood damages have a serious influence on the national economy. This is because China's population, cultivated land, and main roads are concentrated in downstream basin areas of large rivers. However, the command and control system operated by the general headquarters of China's national institution for water disaster prevention was growing old by the 1980s, making prompt and effective response to floods difficult. In 1990, the Chinese government asked Japan, which had advanced technologies and expertise in flood forecasting, to establish an effective automatic system for water disaster prevention, and to carry out a technical cooperation project aimed at training flood forecasters.

Through this cooperation, the following outcomes were obtained:

- The "central water disaster prevention information system" constructed by this project was utilized for flood status monitoring; at a time of significant nationwide floods, including the Chang Jiang River flood (March–September 1998), it carried out automated collection, transmission, processing, and display of river information. It contributed to adequate water disaster prevention through a high-quality information system for the general headquarters of the National Command Institution for Water Disaster Prevention.[3]
- The "river information transmission system in the Zhangweinan Canal basin area" constructed by this project[4] allowed reliable transmission of river information such as rainfall, river discharge, water level, etc., even in bad weather, to the Zhangweinan Canal control bureau, and facilitated communication among respective institutions/organizations—and this—including at the time of historic flooding in August 1996. It thus contributed to adequate water disaster response by the Zhangweinan Canal control bureau.

3 According to the estimation by the Chinese, in 1998 the project's flood information and forecasting system were part of flood prevention/countermeasures that reduced China's costs by 80 billion yuan.

4 Under this project, manually operated data transmission using a wired communication line was transformed to an automated telemeter system using radio transmission.

- **The "forecast result selection system,"** which was the first practical application of this kind in China, used multiple models to solve difficult issues entailed in flood forecasting in the semi-arid region of northern China. Technologies to address similar issues in other basin areas were also transferred.

Based on the experience of this project, China is developing its flood forecasting/warning system nationally.

Pakistan

The Indus River basin of Pakistan suffers from flooding almost annually during the monsoon season (from mid-June through late September). The large-scale flood in 2010 affected about 20 million people and claimed the lives of about 2,000. Flood forecasting and warning systems, though installed in the basins of some tributaries of the Indus River, were not in place over its upper reaches or in the Kabul River basin, where much of the damage occurred during the 2010 flood. The lack of awareness about floods and crisis management was also seen as an issue for improvement.

In response, a project led by UNESCO and funded by the Japan International Cooperation Agency, entitled "Strategic Strengthening of Flood Warning and Management Capacity of Pakistan," was implemented from 2011 to 2014. It was executed as a comprehensive flood management project: it introduced flood forecasting and warning systems and hazard mapping, developed an information-sharing platform, and provided capacity development training, all as part of a collective effort involving Pakistan's national ministries and agencies, the Japan Aerospace Exploration Agency (JAXA), and the International Centre for Water Hazard and Risk Management (ICHARM). Pakistani involvement came from organizations in diverse areas ranging from nationwide disaster prevention to hydrometeorology, such as the Pakistan Meteorological Department (PMD) and the Water and Power Development Authority (WAPDA).

As a contribution to the introduction of flood forecasting and warning systems and hazard mapping, ICHARM led the development of a system called Indus-IFAS for a wide area extending from the upper to lower reaches of the Indus River. The system couples two key technologies developed by ICHARM: the Integrated Flood Analysis System (IFAS) and the Rainfall-Runoff-Inundation (RRI) model.

Capacity development training was provided through the master's program that ICHARM offers in collaboration with the National Graduate Institute for Policy Studies (GRIPS) of Japan. Six engineers in their 20s to late 30s were sent by the Pakistani government to study in this program, and they have since been in charge of the operation of Indus-IFAS. In addition, a total of 11 governmental officers participated in a 10-day training workshop in 2012 and 2013.

The quality of this project has been assured. An external evaluation committee consisting of experienced experts from home and abroad was set up and carried out academic and technological evaluation of the project. A press center was also established to provide the public with forecasting outputs and accurate hydrometeorological information. The press center remains in operation today.

Following the successful implementation of this project, Phase 2 has been initiated. This phase includes installation of Indus-IFAS for Indus' tributaries, as well as technical instruction for the Pakistani government on proper procedures for collecting local data.

5.2 Lessons learned from past technical cooperation projects

The Korean economy and Chinese economy have rapidly expanded in the past few decades, and it has been possible to secure the budget for developing and maintaining flood forecasting systems as measures for damage reduction. On the other hand, the Philippines is prone to various kinds of natural hazards, and the scale of disaster damages is large relative to its national economic power. Disasters are hindrances to economic development: economic growth in the Philippines has not been rapid. This may have been the reason that sufficient budget was not prepared for maintaining flood forecasting systems.

In Japan, the organization that manages rivers, including construction works, provides hydrologic services including hydrological observation and flood forecasting, and this arrangement also exists in the Republic of Korea (Ministry of Construction) and the People's Republic of China (Ministry of Water Resources). The flood forecasting projects described above were received by the Ministry of Construction in Korea and the Ministry of Water Resources in China. Generally speaking, nonstructural measures such as flood forecasting are relatively less costly than structural measures. In many cases, even a part of the budget necessary for the latter would be sufficient for developing a flood forecasting system. Thus flood forecasting systems were properly recognized in these countries as disaster prevention measures, and the necessary budget was secured.

On the other hand, in many developing countries, hydrological observations and analysis are carried out by organizations that do not manage rivers. In such cases, even if related organizations collaborate, the changing needs of management organizations that actually use the observed data may not be flexibly reflected in the observations. River management in the Philippines was under the jurisdiction of the Ministry of Public Works and Highways, and the aforementioned flood forecasting project was received by the Philippine Meteorological Agency. This might be one of the reasons that flood forecasting in the Philippines was not properly budgeted, and why the system was insufficiently maintained in the past. If flood forecasting had been considered an indispensable tool of DRM by the responsible authority, it is more likely to have been sustainable in terms of budget and human resources.

While the example of Pakistan is rather recent, and cannot be considered in the same bracket as the three other countries indicated above, the sustainability of the Pakistan project is expected, given that Pakistan's different national ministries and agencies are involved, and that a press center to provide the public with forecasting outputs and information is utilized by them.

How the flood forecasting system is used is of importance. Unless its social significance, such as its role in reducing damage, is clearly identified, it will be difficult to persuade the country's finance authority to secure the necessary budget.

5.3 Case study of disaster management in Thailand's 2011 floods

At the request of the Thai government (May 2012), JICA contracted with FRICS to develop a flood forecasting system, which emerged as a major need after the 2011 flood in the Chao Phraya River. A prototype was developed in September 2012. From the early stage of prototype design through its application, Thai government officials were involved in the project through workshops and technical group meetings. Officials of different government organizations, interested companies, and academics were invited to register as monitors who were allowed to access the information through the Internet.

This hydrological service system was developed from users' perspective. Prior to designing the system, multiple questionnaire surveys were conducted for a variety of respondents, including affected people, NGOs, mass media, academia, and government organizations. The system was developed to prioritize end-users' needs over the indiscriminate use of available data. Discussions were then held to determine what systems were necessary to fulfill these needs, followed by selection of data to feed into the system.

The developed system was equipped with the Runoff-Rainfall-Inundation model to forecast water levels, flow rates, and inundation areas using observed data (rainfall, water levels, discharges) and meteorological forecasting data from Thailand's Royal Irrigation Department (RID) and the Thai Meteorological Department. It was also designed to forecast highly accurate inundation areas by using LiDAR data and detailed geographic data obtained after calibrating GISTDA (Geo-Informatics and Space

Technology Development Agency) satellite images of the inundation. Meteorological, satellite, and river management agencies collaborated closely in this effort.

In addition, the overall vision of Thailand's hydrological services and the role of the project therein were defined clearly. The Basic Plan of Flood Management Information System of Thailand was formulated with the following aims:

- Collect and sort views and ideas on information systems to be constructed and operated for residents and the government, and designed to take effective action immediately before and during disasters and in the restoration stage.

- Stress the importance of understanding disaster-related information even in normal times, which will eventually lead to proper actions in case of disaster.

- Focus not on the convenience of information senders but the perceptions of information receivers, and on how to ensure that the senders provide information effectively to the receivers such as residents and government organizations.

- Understand the needs and situation of Thailand accurately, and develop practical plans in consideration of the differences in knowledge, experience, and technology between Thailand and Japan, both of which suffer from frequent natural disasters.

- Introduce effective new technologies by building on existing observation and other facilities in Thailand, as well as information collection/transfer centers, analysis systems of various organizations, and forecasting/warning systems.

- Present proposals that are not abstract but specific and ready for the Thai government to put into practice.

- Formulate plans that the Thai government can use in planning various future projects.

System operation, information utilization, and other related activities were strategically conducted to

Figure 18. Thai official happy with the updated flood management system

publicize the system in cooperation with the mass media. In some of the workshops that were held, Thai government officials, not project consultants, explained the system.

The responsibilities for the system and its operation were handed over to RID in September 2013. After the system's operation and performance were evaluated, a follow-up project was planned to achieve the following goals:

- Improve and update models, based on forecasting performance evaluations.
- Ensure effective and stable operation of the updated system.
- Improve the water management simulator and increase the understanding of operation techniques and functions.

During the follow-up workshop, system operators were given on-the-job training to learn how to operate the updated system effectively and stably. The system stopped in mid-December 2014 due to a hardware breakdown. It took eight months to find out the cause of the trouble and replace the malfunctioning parts, and another month to feed accurate observation data and restart the system. With the advice of the follow-up team, which was remotely monitoring the system, Thai operators were able to reboot the system successfully.

5.4 Issues for sustainable use of past project achievements

Information was gathered on good practices and lessons learned from past technical assistance projects for developing countries. A questionnaire was developed that asked for information about aid providers, the titles and contents of projects, projects' advantages and disadvantages (along with the reasons for each), and additional comments if any. The survey included projects implemented in Bangladesh, El Salvador, Guatemala, Kenya, Laos, Pakistan, and Central and South America. The following comments on good practices and lessons learned are taken from the questionnaire. See Annex 1 for details.

Good practices:

- G1: The type of observation device is one of the issues we need to address. Devices that are locally available and easy to maintain worked well when used in observation for forecasting and warning for evacuation.
- G2: International experts were invited to join the project team to watch the project for the technical level and overall progress.
- G3: Long-term training for capacity development was also provided with the technical assistance.

Lessons learned:

- L1: Projects should be designed not as a one-time deal but as something that will lead us to have different perspectives and plan future projects.
- L2: Some projects use knowledge and skill that are too advanced for aid recipients to understand. In such cases, it would be more effective if they were implemented with technical training for the recipients.
- L3: The type of observation device is one of the issues we need to address. Devices that are locally available and easy to maintain may be good enough for forecasting and warning for evacuation, but may not be so effective when it comes to collecting long-term data because they are not designed to collect quality-assured data.
- L4: Projects sometimes do not work as planned because of lack of preparation on the side of aid providers or because they introduce technology that has not been well-established yet.
- L5: Projects should be implemented in a way that keeps a good balance between numerical simulation and actual observation that uses it.

6. How to Apply Japan's Lessons toward Hydrological Service Modernization in Developing Countries

To apply lessons learned in Japan (described in sections 2, 3, and 4) to the modernization of hydrological services in developing countries, the following recommendations should be considered:

6.1 Use a holistic approach to disaster management to promote effective cooperation among disaster management facilities.

The basic principles of DRM and mitigation are these: (i) avoid establishing settlements in high-risk places, so that no damage will result even if a hazardous event occurs; (ii) control hazards with DRM facilities and structures; and (iii) escape (or provide rescue) from hazards or high-risk situations. These three are complementary to each other. Components of the first principle include land use control and waterproof houses; the second includes dykes, water gates, and dams; and the third includes evacuation, damage mitigation actions, and rescue. Arranging the best mix of structural and nonstructural measures is the key consideration for their integration.

To achieve the first principle, it is necessary to control the use of land where flood risk is high by providing information such as inundation risk areas and depths.

To achieve the second principle, it is necessary to operate structures such as dams and to carry out emergency measures such as sandbagging on dykes; both activities are based on hydrological information. For water-related DRM facilities and structures, proper operation and management in emergency is a prerequisite. Improper operation of dams, weirs, and water gates may result in their poor performance or can even increase damage. In particular, the use of retarding basins assumes flood damage to the area that is supposed to be compensated for afterwards. Facilities and structures should be operated with great care and coupled with adequate information management for effective performance during disasters. As structural measures increase safety against floods, they also require more information to holistically understand the conditions in rivers and other areas, the status of facility operations, and flood forecasting. This is true for two reasons: (i) during a flood, flow-controlling facilities demand more precise, careful operation; and (ii) if floodwaters exceed the capacity of facilities or levees break, the inundation area may rapidly expand.

To achieve the third principle, organizations concerned are expected to issue evacuation orders and conduct relief activities, and people are expected to make decisions about evacuation on their own. Such actions should be based on hydrologic information such as the rainfall situation, river water levels, and inundation areas and depths.

The modernization of hydrological services should be carried out with clear purpose, and with the understanding that it will enhance disaster management by providing improved hydrological information.

6.2 Both the future vision and the implementation plan should be realistic and keep in mind the existing capacity of hydrological services in the country.

Where disasters are an impediment to the economic development of a country, such as in East and Southeast Asia, a decrease in disaster risk and improved flood safety are likely to promote economic development. Some developing countries experience rapid economic growth in a short period of time. For such countries to ensure sustainable development, they may need different sets of hydrological information at different development stages, with contents, accuracy, and quality improving over time. The institutional arrangement of hydrological services should be structured to capture and respond to such changing needs quickly and flexibly.

6.3 Uncertainties in flood forecasting should be effectively communicated.

Forecast information regarding natural disasters involves uncertainties: some may originate in uncertainties of the natural phenomena, and others may be from the simulation technology. While simulation uncertainties may decrease as technology develops, those from natural phenomena are unlikely to decrease even with advanced technology.

Uncertainties involved in simulation outputs based on model calculation are a serious issue in prediction, forecasting, and warning of phenomena around the world. For this reason, Japan struggled with many problems through trial and error, including the "boy who cried wolf" issue, before implementing systems for flood forecasting and warning, debris flow disaster warning information, earthquake early warning, and volcanic eruption alert information. In fact, before 2004, no evacuation advisory or orders were issued before levees breached or sediment disasters occurred.

In 2004, the Cabinet Office developed guidelines for the preparation of a manual on making proper decisions about issuing evacuation orders and advisories, with the goal of encouraging local mayors to issue them proactively. Following the guidelines, mayors started issuing evacuation orders that may not have been necessary. Consequently, the public began to wonder if they really had to evacuate and to question the reliability of the orders.

Because of these situations, efforts have been made to develop easy-to-understand criteria to help mayors decide when to issue evacuation orders and advisories. In addition, based on lessons learned from the 2015 Kanto-Tohoku heavy rainfall, in which hydrological information did not lead to successful evacuation of local residents, more effective methods for providing information have been reviewed.

Despite a recognition in Japan that more accurate information is always desirable, few recommend withholding or not using disaster information in cases where forecasting data do not completely coincide with observed data. Most people agree to use such information; they accept the present level of accuracy in forecasting and understand that forecasting always contains some level of uncertainty. Structural measures alone cannot deal with all disasters, so to reduce damages as much as possible, nonstructural measures using forecasts and other types of information are particularly important.

6.4 Development of hydrological services and systems should be driven by user needs.

Information delivered through hydrological services should not be prepared from providers' perspective, in which information is reviewed and provided for the convenience of administrators. It should be user-oriented, reflecting the needs of different individuals and groups for actions and decisions. The preparation of user-oriented information can be divided into four stages: (i) discussion of how people should act to mitigate damage; (ii) determination of what information they need to act properly; (iii) discussion of how to obtain such information (e.g., what simulation is needed) and how it should be processed, with the discussion focused on helping people understand the information and on developing an analysis system; and (iv) selection of input and output data after considering what data are needed for such simulation and processing.

6.5 Hydrological services and river management should be institutionally integrated.

River and basin management covers various factors, including disaster management, river water use, and conservation of the river environment. Any of these factors involves a number of intricately intertwined stakeholders who may have different needs. For example, during a flood, populations located upstream versus downstream, or on the left versus the right bank, may have different priorities to ensure safety; flood management must therefore take a balanced approach to safety that is based on integrated river basin management and takes all relevant perspectives into account. Over time, efforts to manage water-related disasters in Japan have led to the concept of integrated river basin management and to a mechanism allowing central management of river basins by authorities. These approaches were institutionalized under the revised River Law of 1964. Integrated management of river basins requires collecting/analyzing real-time hydrological data of the whole river basin, as well as archiving/studying hydrological data for appropriate management. Japan built its system of hydrological services (and developed needed technology) in order to meet these requirements, as well as similar requirements for water use management and river environment enhancement. These attempts to promote more advanced integrated management of river basins have provided the foundation of social and economic development in Japan today. Integrated management of river basins is not only the core concept of Japan's technical cooperation with developing countries, but also part of a worldwide movement—introduced in the Rhine, the Thames, and other areas where localized management was mainly used in the past.

Based on its long experience and River Law, Japan employs a unique river management system, in which river management authorities have centralized control over rivers in the country and provide hydrological services.

River management authorities (MLIT, prefectural governments) accurately monitor facilities for river management, develop observation networks to precisely monitor river water levels and rainfall in the basin, and use a large volume of observed data to accurately forecast water levels and discharge. They analyze these data to forecast floods and inundation. The collected hydrological data and forecast information are used by river management authorities themselves and also delivered to municipalities, fire and police authorities, and the Self-Defense Forces in an effort to prevent disasters from occurring, assist residents in evacuating safely, and provide emergency response quickly.

Generally speaking, nonstructural measures such as flood forecasting are less costly than structural measures. In many cases, if part of the budget for structural measures was instead earmarked for nonstructural measures, that would be enough to develop a flood forecasting system. In Japan, the hydrologic services are appropriately considered as DRM measures, and the budget is secured. In addition, since hydrological information is indispensable in allowing the government to conduct its own business, the services have been securely maintained. For these reasons, it is advisable that organizations responsible for river management also perform related observation.

Hydrological services are inseparable from water management: They do not deal just with observed data of rainfall, river water levels, or river discharge, but change their contents according to different water management issues. Therefore, institutional arrangements should seek to ensure not only data connection, but also organic links between institutions; ideally hydrological services and water management should be integrated, as has been realized in Japan.

6.6 Long-term support is needed to ensure the sustainable operation of modernized systems.

There have been many cases of technical cooperation on hydrological services in which facilities and structures are not sufficiently maintained, and expected outcomes are short-lived. Information is helpful only when it is used, and only then are any problems with it noticed. Technical cooperation should be extended beyond the stage when newly introduced hydrological services are put in place to include the stage when information is successfully delivered.

ANNEXES

Annex 1: Feedback on Technical Cooperation Projects

Answer sheets to questionnaire seeking feedback on technical cooperation projects

	A	B	C	D	E	F	G	H
Category	Country	Donor	Type of project #1	Project name/ ID# of report/ reference number	Project description	Positive feedback and reason(s)	Negative feedback and reason(s)	Any additional comments
#11	a	JICA	1	unknown	Implementation of Weather Radar System in the City of Vientiane	1. This radar system helped to understand the area of rain system. Especially it is helpful for airport operation.	1. It cannot be operated over course of 24 hours because of shortage of electricity. 2. It cannot obtain precipitation value, since Radar coefficient cannot be determined.	Regarding G2, it was better if the radar system and rain gauge were implemented at the same time. If it is so, precipitation value can be obtained
#11	b	NASA, NOAA, USGS	7 (susceptibility maps for debris flow and landslides)	unknown	Satellite derived national map updated several times per day that shows soil moisture content and identifies areas as high or low possibility of landslide/debris flow	The map provides qualitative information on areas with higher soil moisture.	1. The map is developed with a qualitative scale which is not correlated to quantitative values. 2. The map only shows areas with high relative humidity but it is not based on other data to indicate probability of landslides (e.g. flat areas are often indicated as high possibility of landslide because of high saturation, although the topography makes it impossible).	There is no personnel that can transform the product from satellite information into useful quantitative information.

Answer sheets to questionnaire seeking feedback on technical cooperation projects

	A	B	C	D	E	F	G	H
Category	Country	Donor	Type of project #1	Project name/ ID# of report/ reference number	Project description	Positive feedback and reason(s)	Negative feedback and reason(s)	Any additional comments
#11	c	JICA and others	7. Tsunami atlas	unknown	Tsunami atlas	The atlas contains several maps indicating the possible areas affected by tsunamis of different return periods.	Methodology is not clear about the calculations of maximum wave height and velocity and therefore there might be large uncertainties in run-up and inundated area calculations. Additionally, it is uncertain on which topography and bathymetry maps were used. The map should be available to the public as a downloadable version but it cannot be found on any of the Central American agencies for disaster management. The scale of the maps and resolution is not known at the moment since it cannot be digitally confirmed.	It is uncertain if the atlas is reliable since the methodology to derive them [tsunamis] cannot be verified, and it is not well described.

Answer sheets to questionnaire seeking feedback on technical cooperation projects

	A	B	C	D	E	F	G	H
Category	Country	Donor	Type of project #1	Project name/ ID# of report/ reference number	Project description	Positive feedback and reason(s)	Negative feedback and reason(s)	Any additional comments
#11	d	JICA		Project for strengthening Flood Risk Management in Lai Nullah Basin	Establishment of early warning system for Lai Nullah based on installed rain gauges and discharge gauges.	1. Installed automatic rain gauges provide basic and effective early warning for Lai Nullah catchment 2. Collaboration with local authorities and community assures effective alerts and evacuation	Detailed hazard and risk mapping of Lai Nullah catchment was not within scope of the project, resulting in continuous encroachments and development in hazardous areas	The project continues to be sustained after completion, could be replicated on other flashy / torrential catchments of the country to meet similar objectives
#12	e	UNDP - GEF	2, 3, and 4	Projet SAP-Bénin (CIRDA Regional Program)	To strengthen climate information and early warning system for resilient development in Africa. We aim to deploy 80 automatic telemetric stations for rain, river water level and marine conditions measurements, and also strengthen national institutions capacities to use the data and information for planning and implementation of quick reaction (disaster cases: flooding, drought, severe wind, coastal erosion and sea level rising) and long-term development strategy.	a. inter-agencies and inter-projects synergy upon project launching b. study missions to learn from EWS existing in others countries c. national (governmental) leadership development in early way	a. Less motivation of national staffs in charge of data collection, forecasting and warning due to less support form government b. Less management capacity demonstrated by governmental staff in charge of project management!	

Answer sheets to questionnaire seeking feedback on technical cooperation projects

	A	B	C	D	E	F	G	H
Category	Country	Donor	Type of project #1	Project name/ ID# of report/ reference number	Project description	Positive feedback and reason(s)	Negative feedback and reason(s)	Any additional comments
#12	f	World Bank	7	WKCDD/FMP	Flood mitigation program that involved several activities aimed at preserving catchment areas and reducing wash load in the river.	1. Introduction of soil conservation structures reduced wash load concentrations in the river. 2. Community participation in the projects encouraged ownership. 3. Protection of springs to help conserve river sources. 4. Income-generating activities assisted the communities.	1. Poor quality of some works due to lack of proper supervision during construction. 2. Poor accounting skills of community organizations meant a lot of funds were misused.	Lack of proper planning when deciding the projects to be implemented.
#12	f		3	Unknown	Rehabilitation of RGS stations	Most of the stations are now operational.	Manual system and data is not collected regularly. Real-time data cannot be collected.	
#12	f	JICA	7	Unknown	Construction of evacuation centers	1. Provided safe area for evacuating the community 2. Sanitary facilities provided were good.	1. Proper coordination channel not discussed. Meaning maintenance of the facility during non-flooding season is poorly done. 2. Flood hazard maps and evacuation maps require updating.	Existence of several flood coordination committees makes it difficult to manage the centers.

Answer sheets to questionnaire seeking feedback on technical cooperation projects

	A	B	C	D	E	F	G	H
Category	Country	Donor	Type of project #1	Project name/ ID# of report/ reference number	Project description	Positive feedback and reason(s)	Negative feedback and reason(s)	Any additional comments
#13 #21	g	JICA	2	Unknown	Development and implementation of rain gauge for monitoring and alert about some thresholds previously specified	1.Can be purchased from some international distributors or 2. Can be manufactured with parts which you can obtain at the local shop.	1. The first one can be very expensive. 2. The second one is not so accurate	Is very important to implement this project nowadays; we only have 40% of river with rain gauge. And also can be used for radar validation.
#13 #21	b	JICA and	4	Unknown	Implementation of measuring devices for water level and rain with very simple materials (plastic bottles, PVC pipes, simple radio networks and cell phones). The instruments are calibrated to the community's perception of floods. The instruments are connected to a volunteer's house where a light meter indicates situations.	1. After its installation in early 2010 there has been no life lost in areas where this system exists. 2. Cheap materials make it easy to replace in case of damage from floods. 3. Works with a car battery which allows enough charge to survive electricity outages during storms	1. Values are not accurate enough to keep a monitoring system. 2. It is empirical and although it has reduced loss of life during extreme events, it does not fulfill all the objectives of an early warning system according to the definition of UNISDR 3. Does not keep a history of records.	Regarding points in G, the system still needs to be improved to have a formal observation system that keeps history records.
#14	h	JICA, WB, DANIDA	8		Improvement of Meteorological Radar System, Water level observation, Hydrological gauging equipment, Water-gauging equipment, rainfall gauging stations	Help to monitor and forecast flood, rainfall, cyclone; development of national water resources database	Fragmented approach; blending of different technologies that are difficult to integrate in a model, post-project operation and maintenance. Regular updating of the system	How to integrate the data from different sources to improve the model performance.

Answer sheets to questionnaire seeking feedback on technical cooperation projects

	A	B	C	D	E	F	G	H
Category	Country	Donor	Type of project #1	Project name/ ID# of report/ reference number	Project description	Positive feedback and reason(s)	Negative feedback and reason(s)	Any additional comments
#14	b	JICA, KOIKA, Taiwan	7. Infrastructure	Unknown	Puente de la Amistad (Friendship Bridge)	Reconstruction of damaged bridge in the main access to Panajachel community	1. The project changed funding agencies several times before settling with the Korean International Cooperation Agency (KOIKA). 2. After its inauguration, during the first storm of the 2010 season the bridge collapsed once again. 3. The bridge is evidently poorly designed, as it is much narrower than the bankfull width.	The biggest issue with this project was the lack of coordination between supporting agencies.
#14	c	Inter-American Development Bank	6	Unknown	The Central American Probabilistic Risk Assessment (CAPRA) is software based on GIS to calculate risk for different hazards.	The software is supposed to be freely available online, and be user friendly. By introducing data about population, socioeconomic information and hazard it calculates risk.	1. The software has only been used with outdated proxies 2. The software is neither available nor user friendly. Commonly it is very difficult to understand. 3. When the technology has been transferred, via CDs the software is not possible to install. 4. Workshops to teach about the software have usually failed since most of the time is occupied for unsuccessful installations	To date several projects have been done using this tool although the results can only be considered as preliminary since it has been done with outdated proxies and hazard information only as exercises.

Answer sheets to questionnaire seeking feedback on technical cooperation projects

	A	B	C	D	E	F	G	H
Category	Country	Donor	Type of project #1	Project name/ ID# of report/ reference number	Project description	Positive feedback and reason(s)	Negative feedback and reason(s)	Any additional comments
#15 #22 #23	i	JICA	4 & 6	Strategic Strengthening of flood warning and management capacity of Pakistan	Development of flood warning framework, hazard mapping, model calibrations for Indus. Capacity building for flood management stakeholders in Pakistan.	1. Introduction of new flood modeling tools in Pakistan in collaboration with help of international experts 2. Capacity-building exercises at working group, mid-tier flood management stakeholders 3. Hazard mapping of Indus river using 1D/2D modeling tools	1. Not enough detailed hydrological data sets were available for ideal calibration of models 2. Direct involvement of provincial and district level stakeholders could not be ensured 3. Sustainability of project objectives could not be ensured	Data availability limitations need to be identified in developing countries. Leapfrogging technologies may be used to overcome lack of infrastructure and resources. Sustainability of project objectives needs to be ensured.
#16	g	JICA	4	Unknown	Implementation of early warning system surface elevation	Can be manufactured using parts which you can obtain at the local shop, and is useful for low-income communities.	The most vulnerable communities are also the most dangerous because of criminality, which can stop a project like this.	
#16	g	JICA	7	Unknown	Obtaining satellite images for measures of changes in morphology after a disaster by flood or debris flow	Very useful information for understanding behavior and changes in terrain.		Could be even more useful if the images can be updated after a disaster event happens.

Answer sheets to questionnaire seeking feedback on technical cooperation projects

	A	B	C	D	E	F	G	H
Category	Country	Donor	Type of project #1	Project name/ ID# of report/ reference number	Project description	Positive feedback and reason(s)	Negative feedback and reason(s)	Any additional comments
#16	j	World Bank	1, 2, 4, 6	PPCR/BRCH	Weather radar/Flood forecasting/Automatic weather station/Capacity building	Project is currently in progress. Project aims to decrease the loss of life and property due to flood through 'end to end early warning system' and enhance the capacity of flood and weather forecasting.		Project helps to upgrade the capacity of Department of Hydrology and Meteorology
#16	b	JICA	6	Unknown	Implementation of an informative museum about debris flow in a commonly affected area. The museum is based on the Kobe Earthquake Memorial Museum for disaster	1. Contains simplified information about the processes that produce a debris flow 2. Includes sections for children, with games, small drills and informative quizzes about debris flow	After implementation it is uncertain about the follow-up from local authorities since they changed some time after its opening.	Regarding point G it is important that all stakeholders follow up on projects.

A: name of country
B: name of donor
C: type of project
1. Implementation of weather radar
2. Implementation of rain gauge
3. Implementation of gauge for measuring water surface elevation
4. Implementation of early warning system for flood
5. Implementation of early warning system for debris flow
6. Capacity building
7. Other

D: Project name/Description/ID or reference
Please specify the name of project as well as ID # for future reference. If you don't know how to reference the project but you know the story, please write as unknown
E: Project Description
Please explain in as much detail as possible
F: Positive feedback
Please write your comments in terms of positive aspects of this project and explain the reasons
G: Negative feedback
Please write your comments in terms of negative aspects of this project and the reasons
*negative aspects could include insufficient outcomes
H: Any additional comments
This includes comments such as "if the project/component/implementation had been designed as follows, it would have improved xxx or it would have been better for the following purpose."

Annex 2: Technological Development Examples

Examples of hydrological services related technological development:

- Radio wave current meter
- Image processing type flowmetry
- Provision of river information by cellular phone
- X-band multi-parameter rain radar for torrential rain

Radio wave current meter

Using noncontact type radio wave current meter, flow measurement can be conducted safely and continuously even at the time of a large-scale flood with the help of recent development of technology.

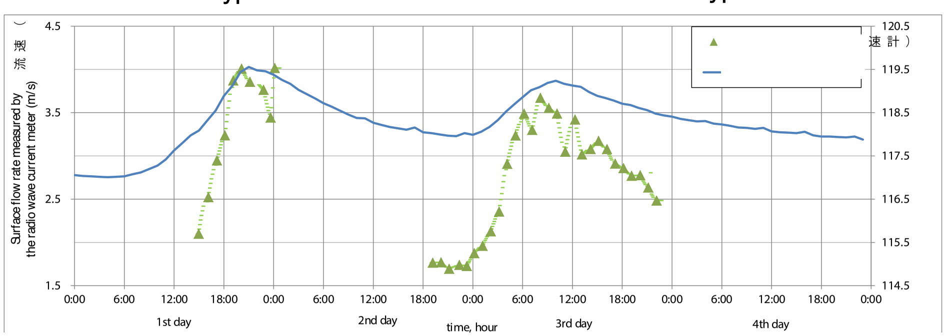
Radio wave current meter

- Using noncontact type radio wave current meter, flow measurement can be conducted safely and continuously even at the time of a large-scale flood with a help of recent development of technology.
- In the Public Works Research Institute/ICHARM, a study on advancement of the flow rate observation using this technique is proceeding now.

By emitting radio wave toward the water surface from the sensor installed on the structures such as bridges,
It can measure the surface flow rate applying Doppler shift at the time of sending/receiving of the wave.

Portable-type radio wave current meter

Fixed-type radio wave current meter (Set plural in the transverse direction)



Observation example of the radio current meter
- It is measurable continuously for a long time.
- The left figure is an example of measuring the surface flow rate continuously by the radio wave current meter. (Average 10minutes)

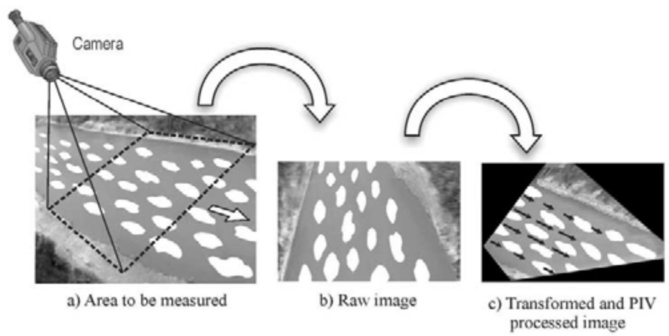
Reference：
流量観測の高度化マニュアル（高水流量観測編）
土木研究所ICHARM編
http://www.icharm.pwri.go.jp/ryukan/

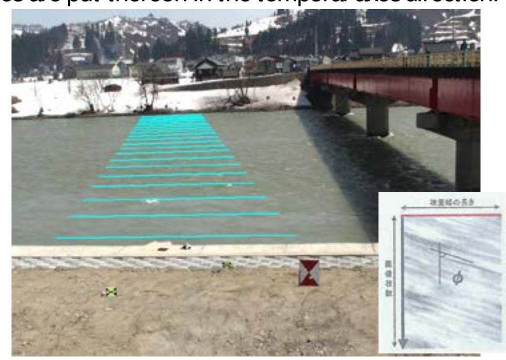
Image processing type flowmetry

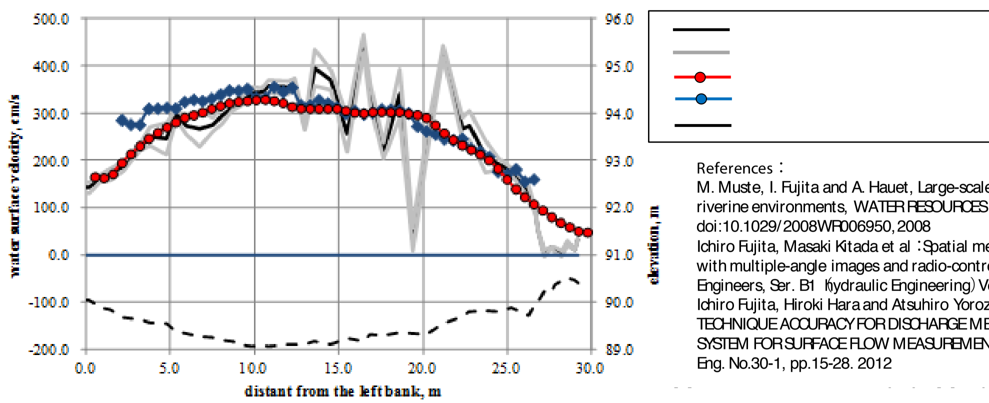
- Ø A technique to measure surface flow rate of the river, by using video images photographed with the fixed camera, has been developed.
- Ø The night observation with the far-infrared camera and the continuous observation by using CCTV camera for river management are also carried out.

The flow rate measuring methods by using video images photographed with the fixed camera are as follows:

- l Determining the light and shade patterns in a certain range drifting the water surface of the screen as particles, it is to analyze the movement amount and to compute the flow rate (LSPIV method).
- l Establishing the inspection lines so as to be along the mainstream direction, calculate the average flow rate from the inclination of the stripe pattern which appears on the time-space image when the brightness values on the inspection lines are put thereon in the temporal axes direction. (STIV method)





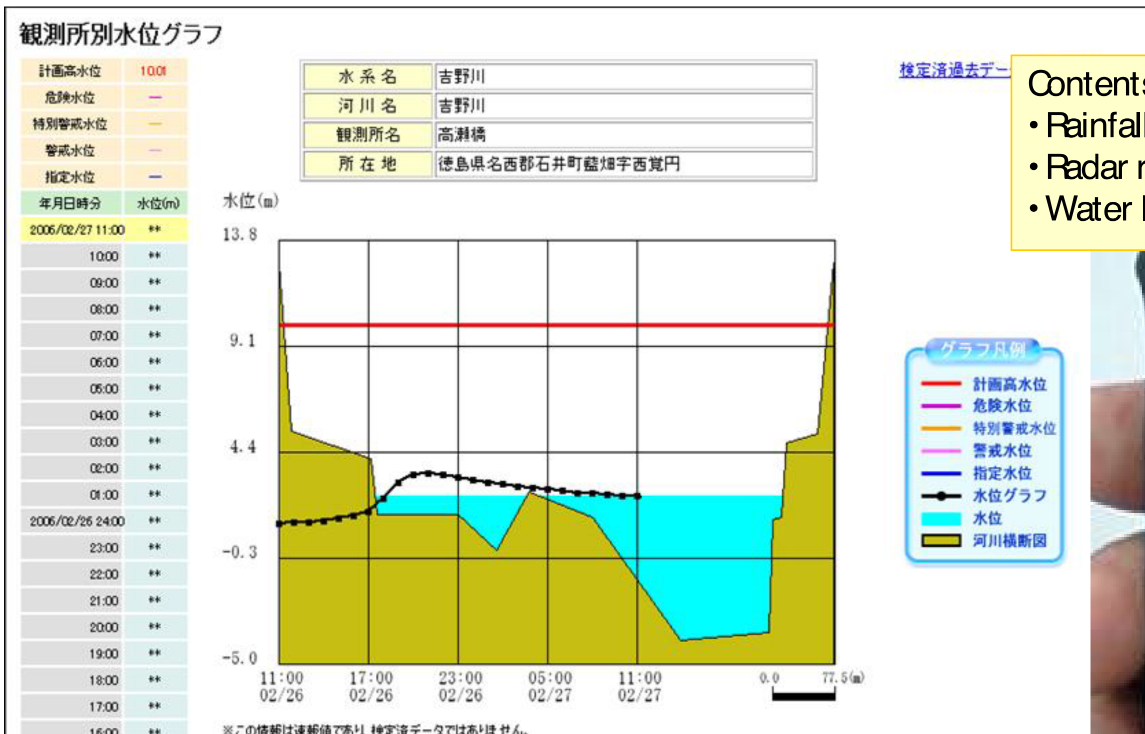


d deviation)

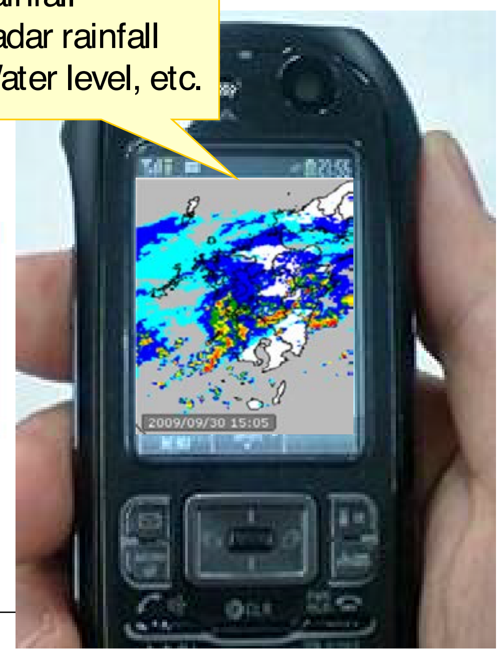
References：
M. Muste, I. Fujita and A. Hauet, Large-scale particle image velocimetry for measurements in riverine environments, WATER RESOURCES RESEARCH, VOL. 44, W00D19, doi:10.1029/2008WR006950, 2008
Ichiro Fujita, Masaki Kitada et al：Spatial measurements of snow melt flood by image analysis with multiple-angle images and radio-controlled ADCP, The Journal of Japan Society of Civil Engineers, Ser. B1（Hydraulic Engineering）Vol.70, No.4, pp.613-618, 2014.
Ichiro Fujita, Hiroki Hara and Atsuhiro Yorozuya, EVALUATION OF IMAGING TECHNIQUE ACCURACY FOR DISCHARGE MEASUREMENT AND DEVELOPMENT OF REAL TIME SYSTEM FOR SURFACE FLOW MEASUREMENT, Journal of Hydroscience and Hydraulic Eng. No.30-1, pp.15-28. 2012

Provision of river information by cellular phone

Via the internet



via the cellular phone

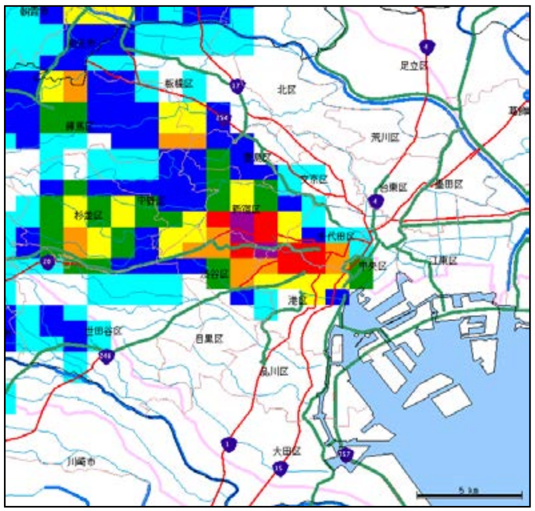


Contents:
- Rainfall
- Radar rainfall
- Water level, etc.

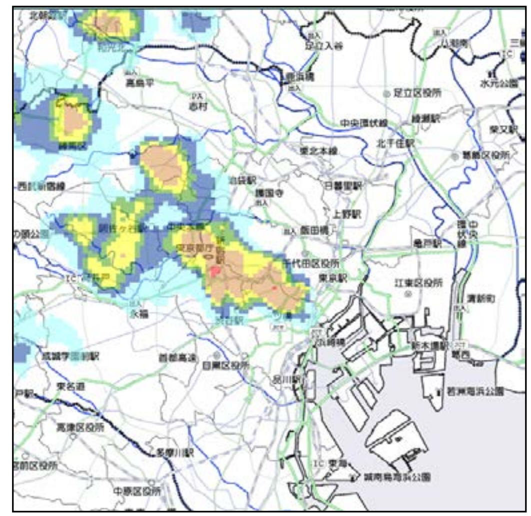
X-band multi-parameter rain radar for torrential rain

Existing radar (C-band radar)
- Min. observation area: 1 km mesh
- Observation interval: 5 minutes
- Time to end user: 5 to 10 minutes
- Obs. Radius: 120 km

X-band MP radar
- Min observation area: 250 m mesh
- Observation interval: 1 minute
- Time to end user: 1 to 2 minutes
- Obs. Radius: 60 km



High frequency (5-fold)
High resolution (16-fold)



* In contrast to C-band radar (observation radius of 120 km), which is suited for broad-area precipitation observations, with X-band radar (observation radius of 60 km), detailed and real-time observation of local heavy rain is possible though the observable area is small.

１．概要

［日本の水文サービスの概要］

河川及び流域のマネジメントには、災害対応、河川水の利用、河川環境の保全等の多様な要素が含まれているが、これらのどの要素をとりあげても、一つの流域の中に利害関係が複雑に絡み合う多くの関係者が存在している。例えば、河川の上下流や左右岸に位置する地域間で洪水時の安全性を巡る利害関係の問題があり、流域の統合管理のアプローチからバランスをとった安全レベルを持つ洪水マネジメントが不可欠である。日本が水災害対策について長年苦労してきた結果として、流域の統合管理の考えや河川管理者が流域の水を一元的に管理する仕組みが生まれ1964年の新河川法などで制度化された。

流域の統合管理を行うためには、流域全体のリアルタイムの水文データの集約と解析が必要となるほか、より的確な統合管理を行っていくための水文データの蓄積と分析も必要であり、様々な技術開発も行いながら、それに呼応した水文サービスの体制が整えられてきた。水利用や環境面も同様であり、それらも含め、その後もより高度な流域統合管理への進展が図られ、今日の日本の社会･経済の発展の礎となってきた。こうした日本の流域統合管理は、途上国への技術協力における核となっているだけでなく、以前は地域的管理が主体であったライン川やテムズ川などでも取りいれられるなど、世界的な潮流となっている。

日本では、これまでの長い経験を踏まえて、河川法には河川管理者が一元的に河川を管理し、あわせて水文サービスを実施するという、他の国にあまり類例をみない体制が明記されている。

国土交通省や都道府県などの河川管理者は、堤防やダムなど河川管理施設の状況を正確に把握するとともに、河川の水位や流域内の雨を精緻に把握する観測網を整備し、観測した膨大なデータを解析して水位・流量の的確な予測を行っている。そして、集約した水文データや予測情報を、自ら行う水マネジメントの様々な場面に用いるとともに、都道府県や市町村などの自治体、消防、警察、自衛隊など数多くの組織に提供されて、災害発生の防止、住民避難の支援、応急対策などに活用されている。

［日本の水文サービスの発展過程と知識・経験・教訓の係わり］

日本の水災害対策は、社会・経済の変化、大災害、技術革新などを契機として、近代化が進んできた。その動きは「個別あるいは地域を守る防災から、流域の統合管理に」、「氾濫を想定しない許容しない施設整備から、氾濫を含めた防災に」、「過去の災害に基づく計画洪水を対象とするものから、計画を上回る規模の災害への対応に」といった変化である。これまで、日本では、河川の管理と水文サービスが一元化されていることで、こうした流れの変化にも的確に対応することができた。

日本は、洪水災害以外にも自然災害が発生しやすい国であり、様々な種類の災害に対する考え方が相互に影響を及ぼしている。「設計に用いた外力よりも大きな外力（L2）に見舞われた場合でも致命的な事態に陥らないようにする考え方の採用」、「観測データの同化に基づく、より精度の高い予測の実施」「情報を受けとった者がとるべき行動に準拠したレベル化」といった考え方は洪水災害対策にも共通する。

水文データの観測を行う機器も、ユーザーの正確性向上のニーズに応えて技術が開発されてきた。一方、水文サービスとは異なる分野で発達した技術が、水文観測に導入されたものとしては、雨量をリアルタイムで面的に観測する技術として水文観測に取り入れられているレーダ雨量計や、IT技術の進展によって、大容量のデータを用いた詳細な解析、使い勝手のよい画面表示、携帯端末を通じた情報提供などが可能となったことがあげられる。

日本の防災対策の進展の過程で、いくつかの問題を解決してきている。例えば、「防災施設への過剰な期待による災害時の対応能力の低下」、「避難勧告・避難指示の混乱」、「不確実性を伴う情報に基づく行動に対する責任」などがある。これらのうちいくつかでは水文サービスの近代化が問題の解決に寄与している。

［日本の水文サービスに係わる組織等と水文サービス近代化］

日本政府の組織が大きく見直されたのが、2001年の中央省庁の再編である。建設省と気象庁が国土交通省の一部となり、また、新たに政府の重要事項を担う内閣府が設置されて、防災行政の政策立案や関係省庁の調整を行うなど、防災行政を実施する体制の抜本的な改善が図られた。

災害の被害を最小限度にとどめるには、行政による事前防災や危機管理といった「公助」、住民が自分自身を守る「自助」、地域社会で守る「共助」が、それぞれ十全に機能することが重要である。地域の住民は「共助」の一つの形態として、自分たちを守るための水防活動を実施している。

災害時の住民への情報伝達においては、テレビなどのマスメディアが大きな役割を担っており、法律上も災害時の情報提供に大きな役割を果たすことが期待されている。災害時には行政とマスメディアが一定の連携をして住民への伝達を図っている。

日常の水文情報に対するニーズは決して大きなものではなく、民間企業で水文サービスの実施に意欲を持つ者はなかったため、官民が連携して必要な資金を賄うことによって、財団法人河川情報センター（FRICS）が設立された。

現在、水文情報は、河川管理者によるダムや水門などの施設の操作・管理、災害発生時における異常の監視、氾濫の予測などに用いられるだけでなく、市町村が行う避難勧告や避難指示などの避難情報の発表や避難場所の設置運営などの判断基準、防災・減災活動に携わる消防・警察・自衛隊などの活動、大規模災害に設置されるに対応する政府災害対策本部、電力やガスなどのライフライン及び高速道路や鉄道などの交通インフラの適正な管理、マスメディアによる住民への周知など、様々な目的で共有されている。

［これまでの水文サービスに関する国際協力プロジェクトにおける日本の知識等の適用］

日本における水文サービスの近代化は、河川を実際に管理する者が水文観測・解析・加工・提供を行っていることで効果的に推進されてきた部分が大きい。韓国(建設部)、中国(水利部)においても同様のことが効果的近代化に繋がったと思われる。多くの場合、構造物対策に必要とされる費用の一部を洪水予測システムの構築に充てることでも、必要な規模の予算を確保できることが多い。こうして、洪水予測システムが防災対策として適正に位置づけられ、財源が確保できたものと考えられる。

一方、多くの開発途上国では、河川を管理しない組織が水文観測と解析を行っている。このような場合、関係機関の間で連携がなされたとしても、実際に観測データを使う組織の変化するニーズが観測に柔軟に反映されない。フィリピンでは、河川管理は公共事業道路省が所掌しているのに対し、JICA支援の洪水予測プロジェクトはフィリピン気象庁（PAGASA）が受け入れ機関となった。このため、フィリピン国においては、洪水予測についての適正な予算配分がされず、過去において洪水予測システムの維持管理がうまく行われなかった可能性がある。

［途上国の水文サービス近代化のための日本の教訓の活かし方］

① 防災施設と有機的かつ効果的に共同できるよう、災害のマネジメント全体で考える

水文サービスの近代化は、明確な目的をもって実施されるべきである。この意味で、水文情報の改善により災害マネジメントを進めるという視点が重要である。

② 既存の能力を念頭に、将来像と現実的な実施計画を考える

国の経済が急激に拡大するような国においては、開発段階に応じ、異なる内容、精度、品質を持った水文情報が必要になることがある。水文サービスの体制はこのような変化するニーズを迅速・柔軟に捉え、対応できるものにする必要がある。

③ 洪水予測における不確定要素の有効な伝達

自然災害に関する予測情報には不確定性が含まれている。構造物対策だけで全ての災害に対処することはできないため、出来るだけ被害を軽減するためには、予測や他のタイプの情報を使った非構造物対策が特に重要である。

④ 利用者のニーズによる水文サービスとシステムの展開

水文サービスで提供する情報は利用者優先のものとし、様々な個人・団体の行動や判断の必要性を反映すべきである。

⑤ 水文サービスと河川管理の制度的な統合

水文サービスは水マネジメントと不可分のものである。それは、単に降雨・水位・流量の観測データを取り扱うだけではなく、様々な水マネジメントの問題にあわせてその内容を変化させるものである。従って、単なるデータ連携ではなく、有機的なつながり（理想的には水文サービスとの統合）を持つ体制としていくべきである。

⑥ 近代化したシステムの持続的運用を保証するための長期的支援

情報は使われて初めて役に立ち、実際に使われるまでは問題が表面化しないことが多い。技術協力は新たに水文サービスが導入される段階に加え、情報がうまく提供される段階を含むべきである。

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The World Bank Disaster Risk Management Hub, Tokyo supports developing countries to mainstream DRM in national development planning and investment programs. As part of the Global Facility for Disaster Reduction and Recovery and in coordination with the World Bank Tokyo Office, the DRM Hub provides technical assistance grants and connects Japanese and global DRM expertise and solutions with World Bank teams and government officials. Over 37 countries have benefited from the Hub's technical assistance, knowledge, and capacity building activities. 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.